# Analysis of Pedernales River Water Quality

**Report to the Lower Colorado River Authority**

**By**

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# Executive Summary

The LCRA water quality database for the Pedernales River was analyzed to determine current conditions and whether there are significant water quality trends. Possible trends include spatial trends, in which the concentrations vary along the length of the river, and temporal trends, meaning a variation in concentrations through time at a single monitoring site.

The data were collected by the LCRA and TNRCC at four sites along the Pedernales River: RR 1320, Johnson City, RM 962, and upstream of the confluence with Falls Creek (the lower boundary of this river segment). Although the length of the monitoring period varied among the sites, the majority of the data were collected between 1984 and 1997. During this period about 7200 measurements of 24 constituents were made at the monitoring sites. A subset of these constituents was selected for detailed statistical analysis. The selected constituents include measures of oxygen content, dissolved solids, nutrients and bacteria. The constituents analyzed include:

- Dissolved Oxygen
- Specific Conductance
- Sulfate
- Chloride
- Ammonia
- Nitrate + Nitrite
- Total Kjeldahl Nitrogen
- Total Organic Carbon
- Total Phosphorus
- Fecal Coliform

Analysis of the LCRA water quality database for the Pedernales River indicates that several constituents exhibit a significant spatial trend. All of the constituents that varied

had higher concentrations upstream than down. These constituents are dissolved oxygen, chloride, sulfate, nitrate plus nitrite, and specific conductance (a measure of dissolved solids). The monitoring data are not sufficient for identifying the reasons for these changes, which may be natural, manmade, or a combination of the two.

The higher levels of dissolved solids, nitrogen, and other ionic species may be derived from groundwater inflow to the river. Groundwater often contains higher concentrations of these constituents than surface water. Elevated concentrations of these constituents also are associated with agricultural activities. Irrigation return flows have higher levels of dissolved solids and can carry nutrients derived from fertilizers as well as agricultural pesticides. Measurements of pesticide concentrations were not included in the monitoring program. Determination of the causes of the higher concentrations should be the focus of future studies, because dissolved solids, chloride, and sulfate are all listed as parameters of possible concern in the 1994 LCRA water quality assessment (LCRA, 1994). Concentrations of these constituents are currently below levels that caused them to be flagged in the 1994 report.

Temporal trends were most evident at the upstream monitoring station at RR 1320, which generally had the longest period of record. Constituents with significant temporal trends include specific conductance, chloride, and sulfate. The concentrations of each of these showed a reduction with time. The monitoring site at RM 962 showed a single parameter with a temporal trend, chloride, which also had declining concentrations. There was no significant temporal trend for any constituent at Johnson City or the Falls Creek sites. These reductions in concentration may be the result of much higher than average rainfall in 1991 and 1992. Rainfall generally has very low concentrations of these constituents, causing a dilution in groundwater, which contributes baseflow to the river, as well as in the river itself through increased surface runoff.

The water quality of the Pedernales River can be characterized as very good and supportive of all designated beneficial uses. Current concentrations of all major water quality constituents are generally below levels that would be cause for concern or result in the listing of this river segment as impaired. In addition, this data set indicates that the concentrations of the analyzed constituents at each monitoring site are relatively constant or improving. There is no immediate concern that changes in land use or other human activities threaten the water quality of the Pedernales River; however, the source of higher concentrations of dissolved solids and nutrients in the upstream reach of the river should be identified. The change from undeveloped to agricultural land use occurred many years before the beginning of any water quality monitoring programs and may be responsible for higher constituent concentrations in this portion of the watershed.

Despite the generally high quality of the Pedernales River water, eight fish kill episodes have been reported in the river, including five since 1990. Approximately half of the kills have been the result of illegal dumping of toxic substances. These episodes highlight the importance of an effective public education/outreach program. Such a program can make citizens more aware of the environmental impacts of improper disposal of waste materials. It is especially important to target owners of small businesses, which often need to dispose of significant quantities of spent solvents, lubricants, paint and other toxic materials.

The remaining fish kills were the result of wastewater treatment plant (WWTP) discharges to the Pedernales near Johnson City, resulting in low dissolved oxygen concentrations. Conventional water quality monitoring programs are not effective for identifying episodic events resulting from equipment malfunction or other causes; however, wastewater discharges may be responsible for the trend of decreasing dissolved oxygen concentrations from upstream to downstream. The number of fish kills related to wastewater discharges suggests that a review of the permit requirements and adequacy of the Johnson City WWTP should be a high priority.

# Introduction

The LCRA has been collecting periodic water quality data from a number of sites along the Colorado River and it's tributaries since the early 1980's. Geographically, the sites range from upstream of San Saba to Matagorda Bay. One of the main functions of data collection is to detect long term changes in water quality that could indicate possible causes and provide a quantitative basis for management actions. Changes in water quality may reflect the impacts of urbanization of other changes in land use patterns.

Because of the size and complexity of the data analysis required to determine current conditions and trends, a pilot study was determined to be the best way to evaluate the potential problems and time required to complete a study of the entire lower Colorado River watershed. The Pedernales River was selected as the site for initial analysis, because it was deemed representative of river system analysis, while having a much smaller data set for analysis.

The Pedernales also has been the site of five reported fish kills since 1990 that were caused primarily by illegal dumping or by wastewater treatment plant discharges. However, a general decline in water quality of this segment could have contributed to these episodes and this is an additional reason to select the Pedernales River for analysis of water quality trends.

## Scope

Sufficient water quality data for analyzing temporal and spatial trends of water quality in the Pedernales River have been collected at fours sites. From upstream to downstream, these sites are RR 1320 (Site 150), Johnson City (Site 75), RM 962 (Site 25), and just upstream of the confluence with Falls Creek (Site 15). Samples were collected between 1984 and 1997 by the LCRA and the Texas Natural Resource Conservation Commission, although the period of record varies for individual constituents. The data allow the determination of water quality changes that have occurred since 1984.

There are two primary questions addressed in this pilot study. First, does the data exhibit discernible trends through time within the given subwatershed? Second, does the data exhibit discernible trends through space along the length of the river? This study answers these questions and provides a template for further analysis of water quality data for the LCRA service area.

The constituents analyzed include:

- Dissolved Oxygen
- Specific Conductance
- Sulfate
- Chloride
- Ammonia
- Nitrate + Nitrite
- Total Kjeldahl Nitrogen
- Total Organic Carbon
- Total Phosphorus
- Fecal Coliform

# Methodology

There are numerous statistical methods for analyzing temporal and spatial trends in water quality data and their appropriateness often depends on the underlying distribution of the data. Many analyses (parametric tests) assume that the data are normally distributed; however, environmental data often does not follow this distribution. Nonparametric statistical tests are used when the distribution of the data is unknown and although they may not yield as much information, they are more robust. Consequently, many of the analyses were done with both tests, where appropriate, in order to yield the strongest results possible.

Flow rate of the Pedernales was not recorded at each location at the time of sampling. Since this is such an important parameter, average daily flow at the U.S. Geological Survey gauge at Johnson City was used to characterize conditions at the time of sampling. Although the absolute value is only correct for the Johnson City monitoring site, the numbers offer a quantitative way to differentiate between high and low flow-sampling conditions.

Many of the measurements are censored; that is, they are reported as less than or greater than some value associated with the detection limit of the method. There are numerous methods for treating censored data by assuming arbitrary values (the detection limit or zero, for instance) or by identifying the underlying distribution of the data and estimating the true value. It is far better to perform statistical analyses with the actual measured concentrations even though they fall below the instrument or method detection limit; however, laboratories rarely report results in this form. For this analysis, all censored values were assumed to have the same concentration as the detection limit.

### *Temporal Trends*

Regression analyses are commonly used to identify temporal trends in water quality data. If plots of data versus time suggest a simple linear increase or decrease over time, a linear regression of the variable against time may be fit to the data. A $t$ test may be used to test that the true slope is not different from zero. This *t* test can be misleading if seasonal cycles are present, the data are not normally distributed, and/or the data are serially correlated. In these situations, the *t* test may indicate a significant slope when the true slope actually is zero (Gilbert, 1987).

Multiple linear regression is an especially useful approach if other variables such as flow rate or temperature also affect parameter values. Since flow rate is such an important factor, especially as it relates to storm runoff and baseflow, the data at each site was first analyzed for temporal trends using multiple linear regression. The statistical software package, *Minitab for Windows: Release 12*, was used for these analyses.

For the constituents that appeared to exhibit a significant temporal trend in the multiple linear regression tests, the data also were analyzed using a nonparametric test, the Mann-Kendall test. This procedure is particularly useful since missing values are allowed and the data need not conform to any particular distribution. Also, data reported as trace or less than the detection limit can be used by assigning them a common value that is smaller than the smallest measured valued in the data set. The Mann-Kendall test can be viewed as a nonparametric test for zero slope of the linear regression (Gilbert, 1987). The test consists of a comparison of the difference of all possible pairs of values and indicates whether the values are generally increasing or decreasing, but gives no indication of the rate of change. This test is not commonly available in commercial software packages, so it was implemented as a spreadsheet.

***Spatial Trends***

Analysis of variance (ANOVA) was the statistical technique used to determine whether there are spatial trends in the water quality data (e.g., whether the mean concentrations at the sites are different). ANOVA is similar to regression in that it is used to investigate and model the relationship between a response variable and one or more independent variables. However, analysis of variance differs from regression in two ways: the independent variables are qualitative (sampling location), and no assumption is made about the nature of the relationship (i.e. the model does not include coefficients for variables). In effect, analysis of variance extends the two-sample t-test for testing the equality of two population means to a more general null hypothesis of comparing the equality of more than two means, versus them not all being equal. *Minitab for Windows: Release 12* was used for the ANOVA calculations.

For selected constituents, the data were corrected for changes in sample collection time or flow rate and then the ANOVA analysis was performed. This correction consisted of normalizing the data at each site to a consistent time or flow basis. This was accomplished by performing a linear regression against the influencing variable and calculating the average value for an arbitrary time or discharge rate. The residual error for each measurement was then added to the average value and the ANOVA test was then performed on the new data set.

# Results

## *Dissolved Oxygen*

Summary Statistics

The analysis of temporal and spatial trends in dissolved oxygen concentrations is especially difficult because of the number of factors that affect this parameter. Of particular importance is temperature, depth of sample and time of day. Samples were often collected from a series of depths at each site. There is a correlation between sample depth and oxygen deficit, with higher deficits occurring near the base of the channel. Other than samples collected at the surface, there were not a sufficient number of samples to perform a trend analysis. Consequently, only those samples collected at the surface were used to evaluate trends in the data.

The saturation concentration for dissolved oxygen was calculated for each of the samples using the Fair-Geyer expression. This expression states that:

$$C_S = \frac{5(100 - Cl)}{(T + 35)}$$

where $C_S$ is DO saturation in mg/L, $Cl$ is chlorinity in parts per thousand and $T$ is temperature in degrees Celsius. Chlorinity was taken to be zero for this analysis.

The value of the sample results was subtracted from the saturation value to determine the oxygen deficit at the time the sample was taken. A negative value for the oxygen deficit indicates that the measured value was greater than the saturation value. There are several possible physical reasons that the water could be supersaturated; consequently, these values were retained in the data set. The data was then analyzed using oxygen deficit as the parameter of interest. The site locations and summary statistics are shown in Table 1.

Trend Analysis

Analysis of all samples collected at the water surface at Falls Creek indicates a significant improvement with time in the dissolved oxygen conditions at this site (Figure 1). However, there is also a systematic trend in the time of day the samples were collected. Samples collected near the beginning of the sampling program were taken earlier in the day (Figure 2) and there is a significant correlation between time of sample collection and the oxygen deficit. The deficits are significantly higher earlier in the day when photosynthesis has not replenished dissolved oxygen in the river (Figure 3).

**Table 1 Summary Statistics for Dissolved Oxygen**

| **Parameter** | **RR 1320** | **Johnson City** | **RM 962** | **Falls Creek** |
|---|---|---|---|---|
| Period of Record | 2/84 – 10/97 | 2/84 - 10/97 | 4/84 – 10/97 | 2/84 – 5/90 |
| # of Samples | 114 | 73 | 113 | 72 |
| Average DO, mg/L | 9.19 | 9.42 | 8.62 | 8.3 |
| Median DO, mg/L | 9.00 | 9.30 | 8.59 | 8 |
| DO Std Deviation | 1.77 | 1.94 | 1.47 | 1.7 |
| Avg $O_2$ Deficit, mg/L | 0.11 | -0.20 | 0.46 | 0.74 |
| Median $O_2$ Def., mg/L | 0.24 | -0.04 | 0.48 | 0.7 |
| Deficit Std Dev | 1.09 | 1.38 | 0.79 | 1.14 |

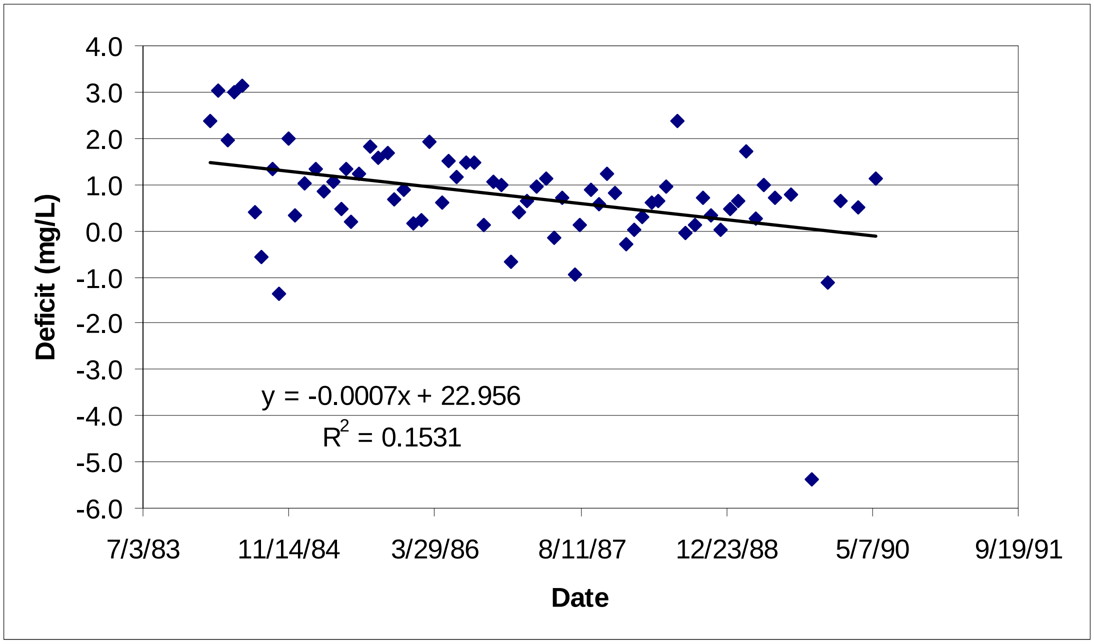


**Figure 1 Oxygen Deficit at Falls Creek**

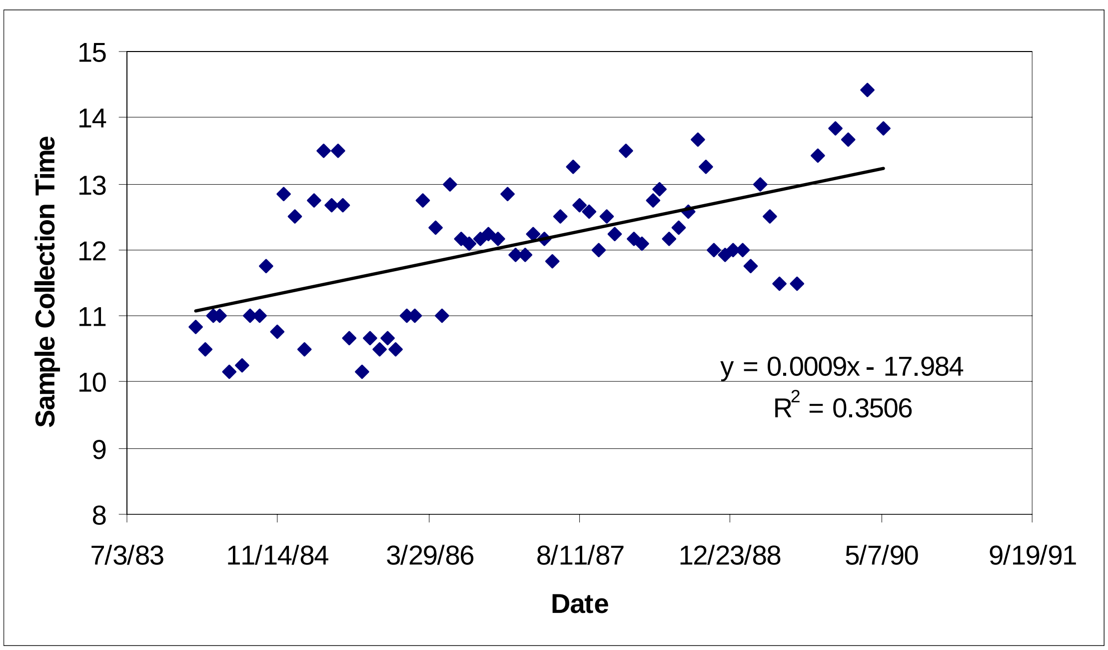


**Figure 2 Sample Collection Times at Falls Creek**

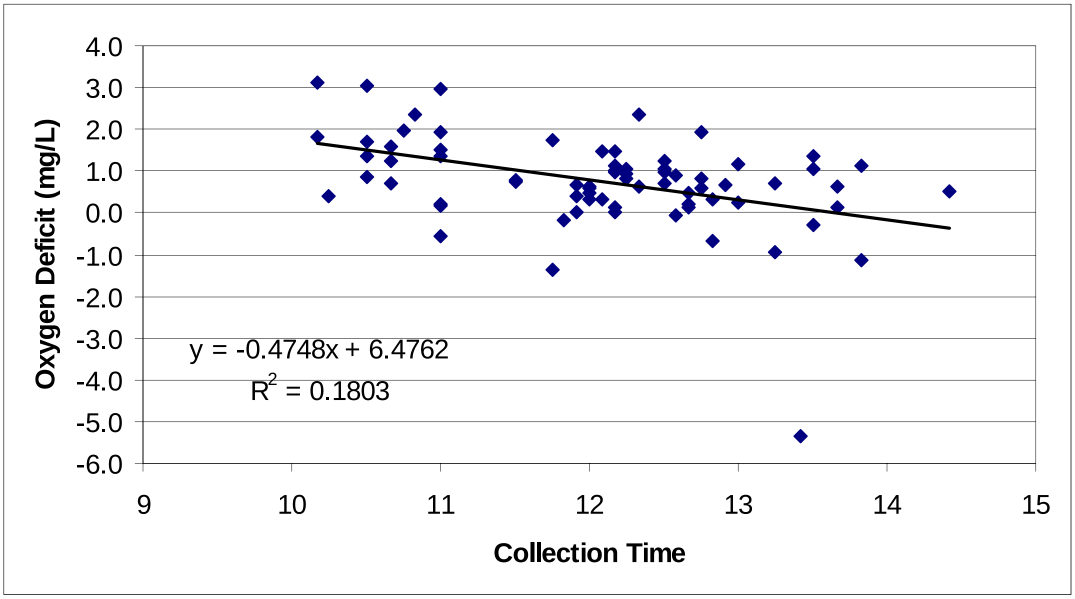


**Figure 3 Relation between Collection Time and $O_2$ Deficit**

The subtle shift in sampling protocol at this site creates such a strong signal in the data that it becomes extremely difficult to detect a correlation with land use changes or other events in the watershed. A multiple regression analysis was performed using oxygen deficit of samples collected at the surface as the dependent variable and time of day and date as the independent variables. The results are summarized in Table 11 and they indicate no significant change in oxygen deficit at the 90% confidence level.

A similar analysis was performed on the data collected at RR 1320. The sample collection at this site also changed systematically, with more recent samples collected earlier in the day. This made it appear that there was strong trend of reduced oxygen concentrations. A multiple linear regression analysis was conducted using date and time of day as the independent variables. This analysis indicated a slight trend of reduced oxygen concentrations even when time of sampling was taken into account. However, this trend was not significant at the 95% confidence level. The multiple regression statistics are shown in Table 12. The effect of season was also investigated at RR1320; however, this proved to be a completely random variable. Similar analyses were performed on the data collected at Johnson City and Hammett's Crossing. The results of the regression analyses are shown in Table 13 and Table 14. There was no significant long-term trend in oxygen deficit at either of these sites.

An ANOVA test was performed on the pooled raw data from the Pedernales, which indicated a significant spatial trend in oxygen deficit at a greater than 99% confidence level. The small difference between the mean deficits at RR 1320 and Johnson City and the mean deficits at RR 962 and Falls Creek are not significantly different. The deficits at RR 962 and Falls Creek are significantly higher than at either of the upstream stations. Table 15 contains the ANOVA statistics, while a bar graph of the average deficits is shown in Figure 4.

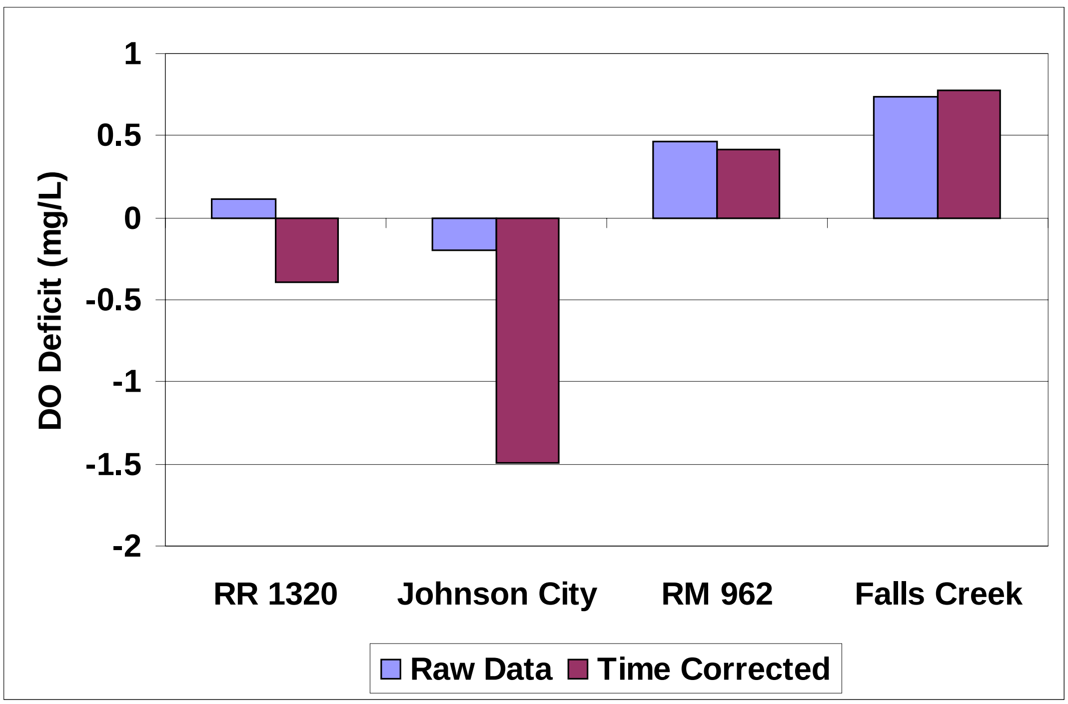


**Figure 4 Average Oxygen Deficits on the Pedernales**

The ANOVA analysis also was performed on the oxygen deficit data with a correction for sampling time. The data at each site was normalized to a common sampling time of noon. The test statistics for the normalized data shown in Table 16 indicate a more significant spatial trend than the raw data. The average value at each site based on a common sampling time is also shown in Figure 4.

Conclusions

Dissolved oxygen data from the Pedernales River collected between 1984 and 1997 indicate no significant long-term trends; however, the identification of changes in the dissolved oxygen concentrations has been hampered by systematic changes in the way the data have been collected. It is interesting to note, however, that 7 of the 8 highest oxygen deficits recorded on the Pedernales were measured during 1984. The data do indicate a trend of increasing oxygen deficit between Johnson City and the river segment boundary at Falls Creek. The dissolved oxygen conditions in the river are generally very good, even at the sites with higher deficits.

The large dissolved oxygen surplus measured at Johnson City could indicate a potential problem area. Large surpluses can be associated with algal blooms, which produce oxygen during the day via photosynthesis. Conversely, algal blooms can result in extremely low oxygen concentrations at night. Consequently, it is important to identify the reason for the high daytime readings at this site.

### ***Specific Conductivity***

Summary Statistics

The summary statistics for all the specific conductance data are shown in Table 2.

**Table 2 Summary Statistics for Specific Conductivity**

| **Parameter** | **RR 1320** | **Johnson City** | **RM 962** | **Falls Creek** |
|---|---|---|---|---|
| Period of Record | 2/84 – 10/97 | 2/84 - 10/97 | 4/84 – 10/97 | 2/84 – 5/90 |
| # of Samples | 114 | 73 | 113 | 72 |
| Average Sp. Cond | 682 | 648 | 540 | 553 |
| Median Sp. Cond | 690 | 623 | 546 | 546 |
| Std Deviation | 128 | 153 | 98 | 109 |

Trend Analysis

A temporal trend analysis was performed on the data set for each of the four monitoring sites. At two of the sites, the conductance was highly correlated with river discharge as measured at Johnson City. Consequently, a multiple linear regression was performed using date and flow as the independent variables. The regression statistics for each of the sites are shown in Table 17 through Table 20.

The regression equations indicate no significant temporal trend at Falls Creek and RM 962; however, Johnson City and RR 1320 sites both showed improvements in water quality during the monitoring period. This trend is driven mainly by very high conductance readings during the drought of 1984.

The data from Johnson City and RR 1320 were then analyzed using the Mann-Kendall test. This test confirms the downward trend in conductance at RR 1320, with a Z statistic of 2.39 indicating a probability of less than 0.008 that the trend could have occurred by chance. The analysis indicated no significant statistical relationship between date and conductance at Johnson City, where the Z statistic was 0.76 indicating a probability of 0.22 that the differences are the result of random fluctuations. A plot of the data collected at RR 1320 is shown in Figure 5.

An ANOVA test for spatial variation in conductance was conducted using the data from the four monitoring sites. The results of the test are shown in Table 21, which indicates that there is a significant spatial trend. The mean concentrations for the four sites are shown graphically in Figure 6 where the trend towards decreasing concentrations downstream is apparent.

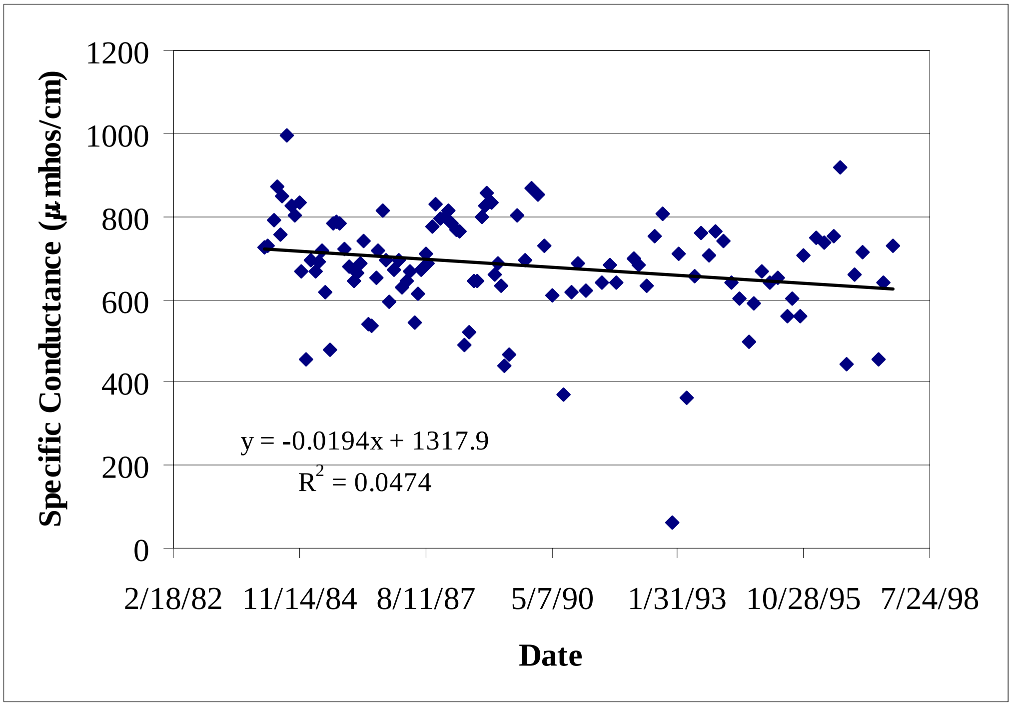


**Figure 5 Specific Conductance at RR 1320**

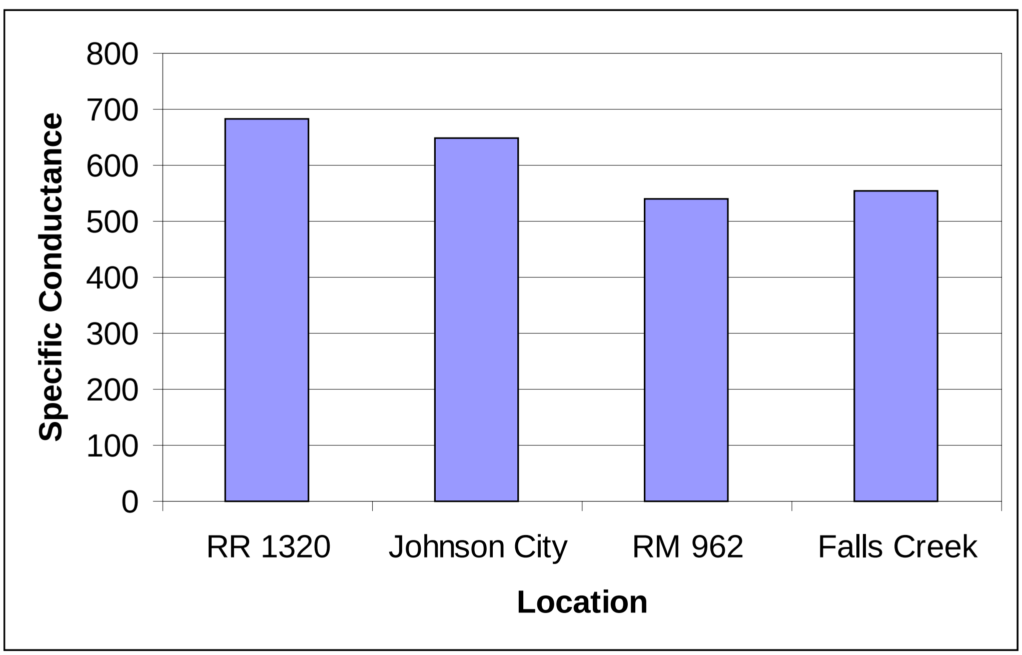


**Figure 6 Comparison of Mean Specific Conductance**

Conclusions

Conductance is clearly related to river discharge with higher readings occurring during low flow periods. This is a common relationship, since low flows are mainly created by groundwater inflows, which are generally higher in dissolved solids than storm runoff.

Only one site, RR1320, exhibited a statistically significant trend in specific conductance; however, there is a strong spatial trend in dissolved solids. The readings are highest at the upstream site and gradually decline to near the RM 962 site. This is likely the result of dilution by the dissolved solids concentrations by inflows between RR 1320 and RM 962. The high dissolved solids concentrations upstream may be the result of natural factors, but could also be due in part to human activities. High dissolved solids concentrations are often encountered in agricultural areas and can be caused by irrigation return flows. Further investigation is warranted to identify the causes, since total dissolved solids are listed as a constituent of possible concern in the LCRA Water Quality Assessment.

***Chloride***

Summary Statistics

Chloride is listed as a constituent of possible concern in the 1994 LCRA water quality assessment, which indicates that a concentration of 105 mg/L is considered a problem level. The summary data shown in Table 3 shows that the average concentrations at all four sites is well below this value.

**Table 3 Summary Statistics for Chloride**

| Parameter | RR 1320 | Johnson City | RM 962 | Falls Creek |
|---|---|---|---|---|
| Period of Record | 2/84-12/96 | 2/84-8/90 | 10/90-12/96 | 2/84 – 5/90 |
| # of Samples | 96 | 72 | 23 | 73 |
| Average (mg/L) | 66.2 | 62.5 | 37.3 | 40.7 |
| Median (mg/L) | 64.5 | 54 | 37 | 39 |
| Std Deviation | 22.8 | 32.3 | 11.2 | 20.5 |

Trend Analysis

Multiple linear regression was used initially to identify possible trends in the chloride data. The independent variables were selected as date and flow rate to account for higher salinity, which commonly is associated with low flow conditions. The regression statistics, which are shown in Table 22 through Table 25, indicate a trend of decreasing concentrations at RR 1320, Johnson City, and RM 962. The data at these sites was then subjected to the Mann-Kendall test. This test confirmed the significance of the trend at RR 1320 and RM 962, with Z statistics of 1.94 and 2.19 respectively, which corresponds to confidence levels of 0.027 and 0.014. For Johnson City, the calculated Z statistic was 0.57, which corresponds to a *P* value of 0.28. The data for RR 1320 and RM 962 are plotted in Figure 7 and Figure 8.

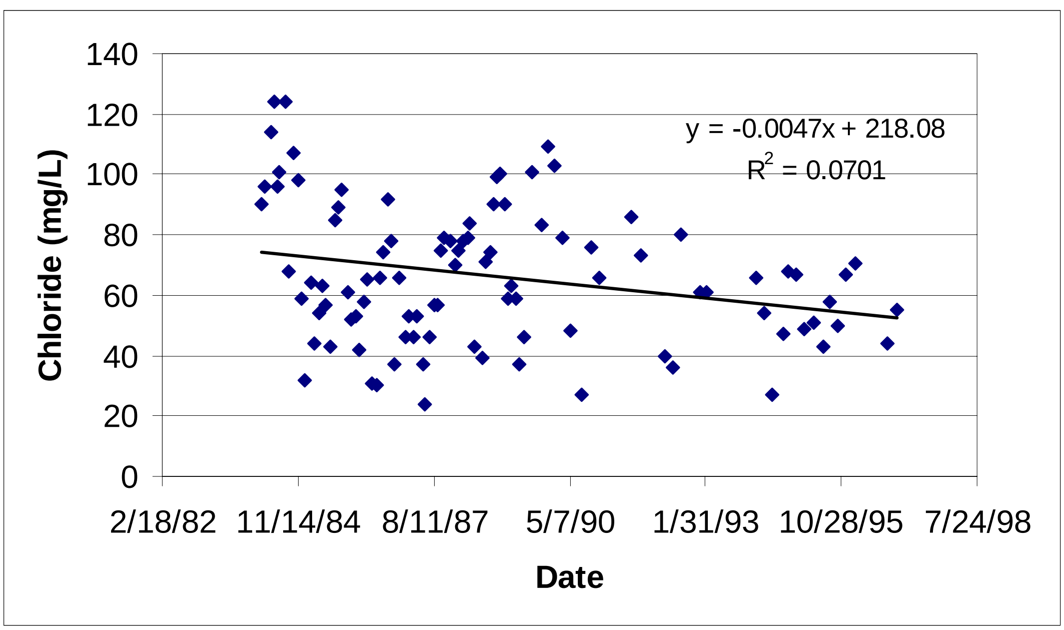


**Figure 7 Chloride Concentrations at RR 1320**

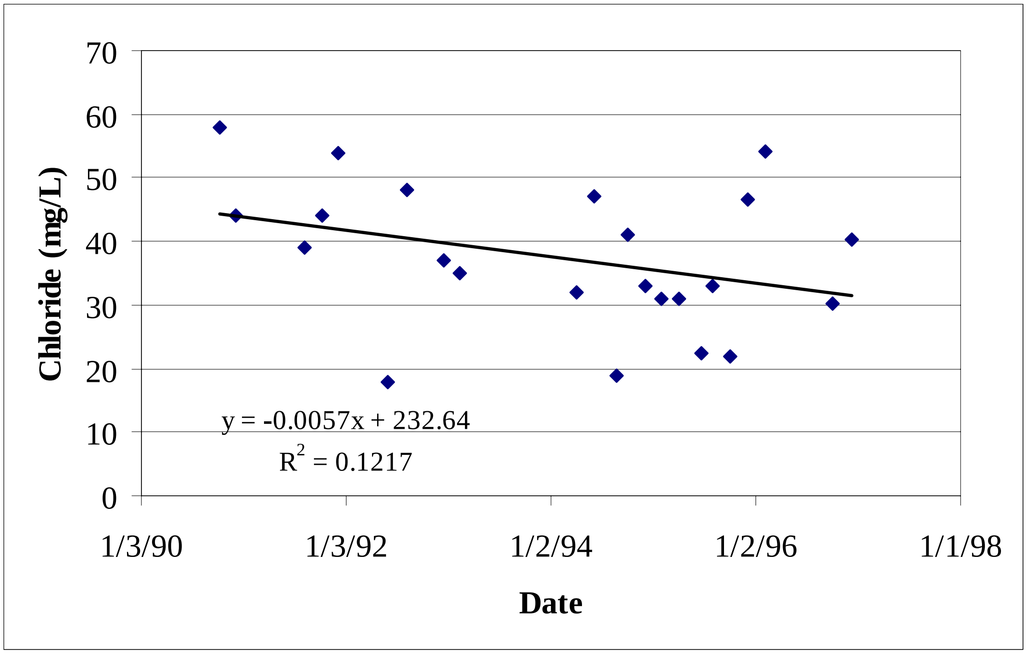


**Figure 8 Chloride Concentrations at RM 962**

An ANOVA test was performed on the pooled data from all four sites to determine whether spatial trends were present. The test statistics, which are shown in Table 26, indicate that a significant decrease in concentration occurs between Johnson City and RM 962. This decrease is evident in the graph shown in Figure 9.

Since chloride concentrations at many of the sites are significantly correlated with flow rate, the concentrations were normalized to the Pedernales median flow rate, 50 cfs. The ANOVA analysis was then performed on the normalized data. The normalized data indicate an even more statistically significant spatial trend. The averages for the normalized data set are also shown in Figure 9.

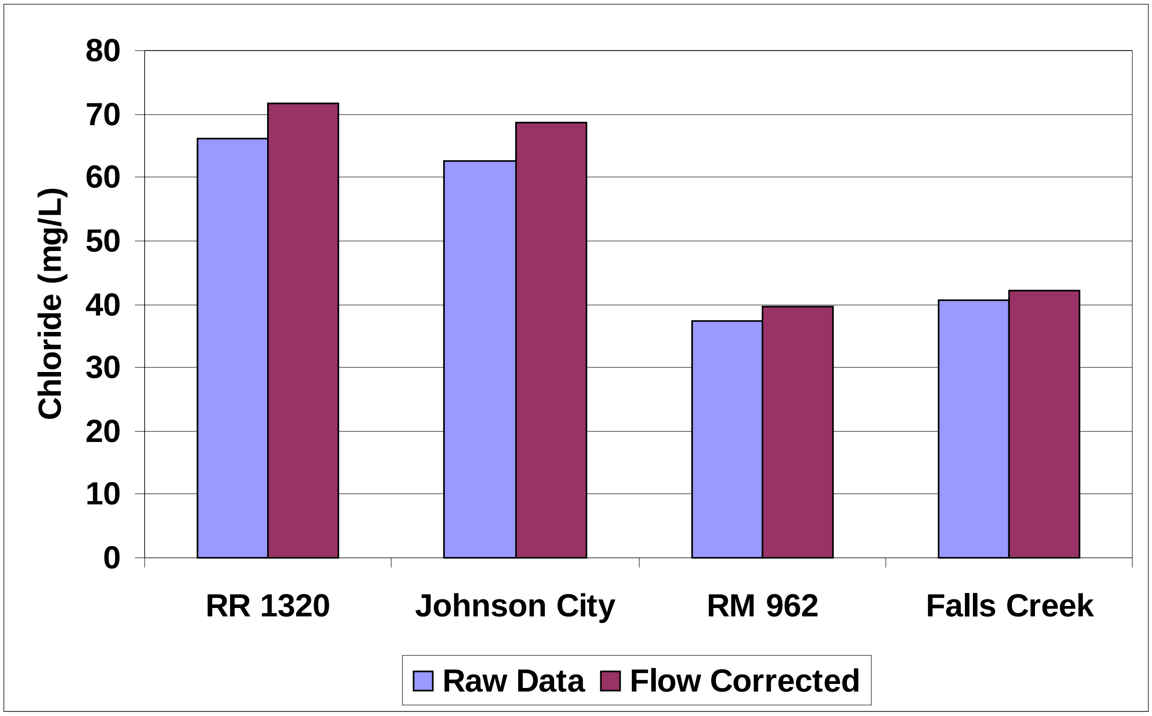


**Figure 9 Average Chloride Concentrations**

***Sulfate***

Summary Statistics

Sulfate is another constituent that the LCRA has identified of being of possible concerns because of high concentrations. The critical concentration for this constituent is 50 mg/L. The summary statistics for the four sites are shown in Table 4. The average values are much lower than the critical concentration.

Trend Analysis

Multiple linear regression, with date and flow as the independent variables, was used to identify temporal trends at each site. The regression statistics are shown in Table 28 through Table 31. According to the regression analysis, the only site with a significant temporal trend in RR 1320. The data from this site was also tested for significance using the Mann-Kendall test. The Z statistic was 2.59, which corresponds to a *P* value of 0.005, confirming the temporal trend. The data from RR 1320 is shown in Figure 10.

**Table 4 Summary Statistics for Sulfate**

| Parameter | RR 1320 | Johnson City | RM 962 | Falls Creek |
|---|---|---|---|---|
| Period of Record | 2/84-12/96 | 2/84-8/90 | 10/90-12/96 | 2/84 – 5/90 |
| # of Samples | 95 | 72 | 23 | 73 |
| Average (mg/L) | 32.2 | 36.6 | 26.0 | 27.4 |
| Median (mg/L) | 33 | 33 | 26 | 27 |
| Std Deviation | 8.6 | 28.0 | 6.4 | 11.2 |

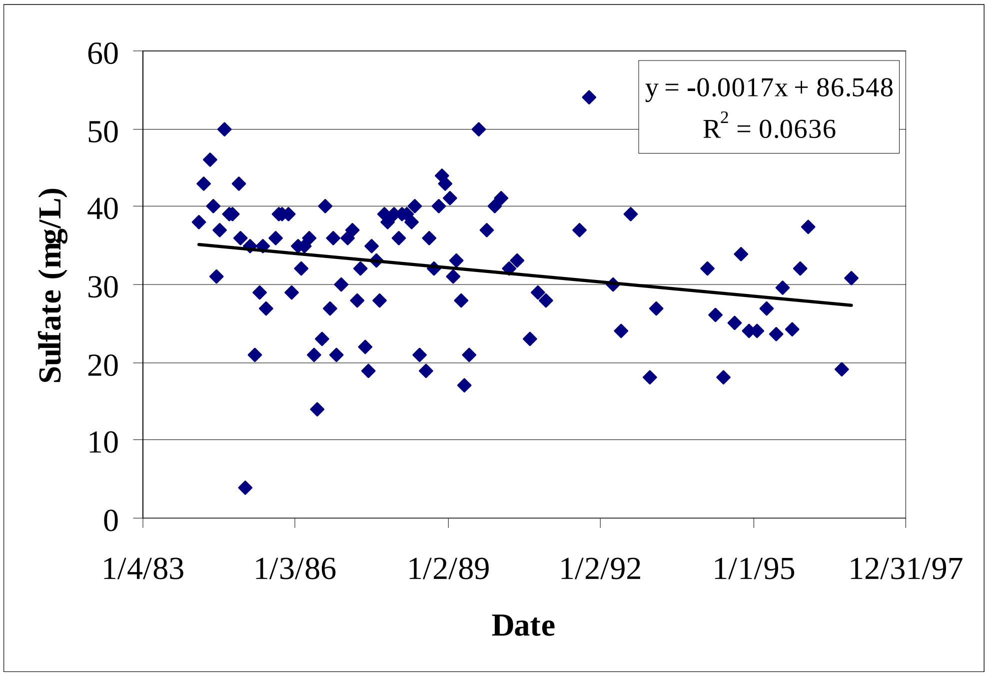


**Figure 10 Sulfate Concentrations at RR 1320**

The ANOVA analysis was then used to determine whether there were significant differences among the sites. The ANOVA statistics are shown in Table 32 and they indicate that the concentrations at Johnson City are significantly higher than at the two downstream monitoring stations. The concentrations at RR 1320 are also higher than the downstream sites; however, the difference is not significant. The average concentrations at the sites are shown in Figure 11.

The ANOVA analysis was also performed with data normalized to the median flow rate of 50 cfs. This data set also had a significant spatial variation, which had a higher degree of confidence than the raw data. The average values for the normalized data are also presented in Figure 10.

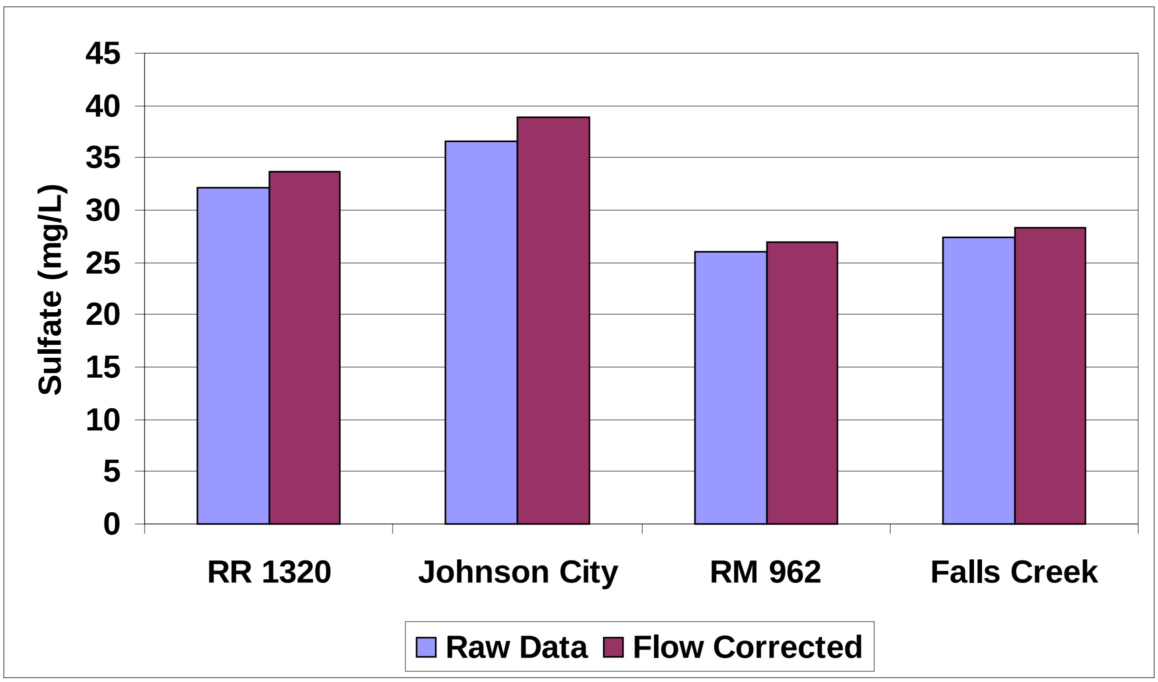


**Figure 11 Average Sulfate Concentrations**

### *Nitrate plus Nitrite*

<u>Summary Statistics</u>

Nutrients are listed as a constituent of concern in the LCRA 1994 Water Quality Assessment and the nitrogen concentrations are relatively high compared to many surface water bodies. The average concentrations and other summary statistics for the four monitoring sites are shown in Table 5. The average values are much higher than the median values compared to other constituents indicating that the underlying distribution is skewed.

**Table 5 Summary Statistics for Nitrate plus Nitrite**

| Parameter | RR 1320 | Johnson City | RM 962 | Falls Creek |
|---|---|---|---|---|
| Period of Record | 2/84-10/95 | 2/84-8/90 | 10/90-12/96 | 2/84 – 5/90 |
| # of Samples | 92 | 72 | 13 | 73 |
| Average (mg/L) | 0.36 | 0.28 | 0.21 | 0.19 |
| Median (mg/L) | 0.18 | 0.095 | 0.16 | 0.08 |
| Std Deviation | 0.43 | 0.32 | 0.23 | 0.21 |

<u>Trend Analysis</u>

Multiple linear regression, using flow and date as the independent variables, was used to test for a temporal trend at each of the monitoring sites. The regression statistics for each of the sites are shown in Table 34 through Table 37. The only site with a statistically significant trend was RR 1320, which showed a decrease in concentration through time. The data at this site was then analyzed using the Mann-Kendall test. The calculated Z statistic was 1.19, which corresponds to a *P* value of 0.117 and indicates that the trend is not statistically significant.

An ANOVA analysis was performed on the data to determine whether there were differences among the sites and the results are shown in Table 38. The analysis indicated a significant difference at the 0.009 confidence level. A plot of the average concentration at each site is shown in Figure 12 and the trend to decreasing concentrations downstream is readily apparent.

This reduction in concentration could be the result of uptake of the nutrients in the river or dilution by inflows with lower nitrogen concentrations. The fact that specific conductance shows this same trend suggests that the reduction is due primarily to dilution. The higher concentrations upstream could be caused by naturally high levels of nitrogen in groundwater contributing baseflow to the river, use of fertilizers in agricultural areas, or discharge from wastewater treatment plants.

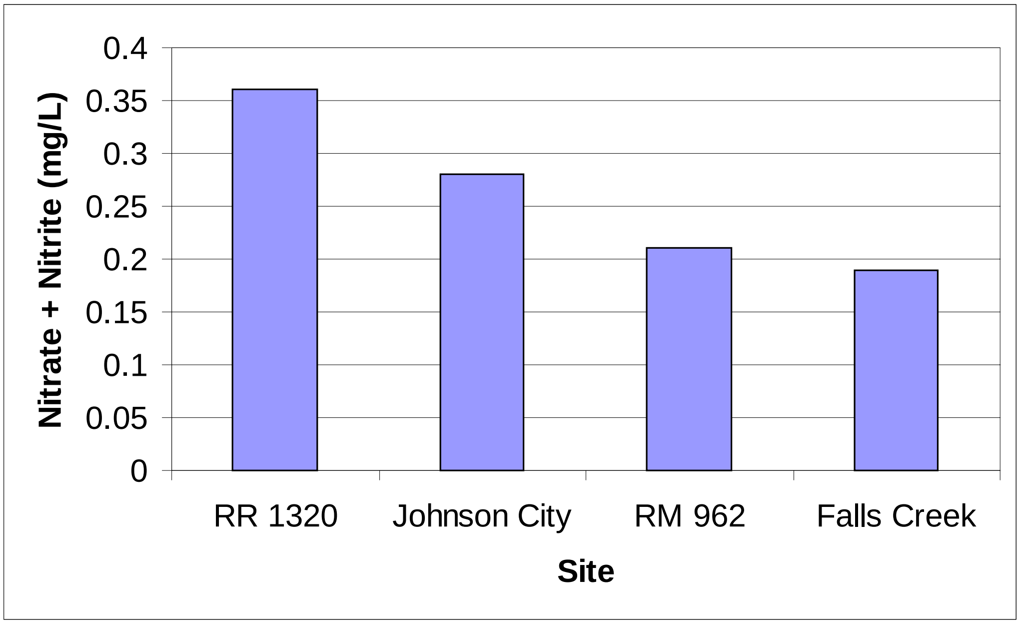


**Figure 12 Average Nitrate plus Nitrite Concentrations**

***Total Kjeldahl Nitrogen***

<u>Summary Statistics</u>

Another important for of nitrogen is total Kjeldahl nitrogen (TKN), which includes ammonia plus organic nitrogen. The summary statistics for each of the sites is shown in Table 6.

<u>Trend Analysis</u>

Multiple linear regression, using flow and date as the independent variables, was used to test for a temporal trend at each of the monitoring sites. The regression statistics for each of the sites are shown in Table 39 through Table 42. The regression analysis indicates that the only significant trend occurs at Johnson City, where the concentrations are decreasing with time (Figure 13). The data from Johnson City were then examined with the Mann-Kendall test. The Z statistic for this test was 1.61, which corresponds to a P value of 0.054, and indicates that the slope is not statistically significant at the 95% confidence level.

**Table 6 Summary Statistics for Total Kjeldahl Nitrogen**

| Parameter | RR 1320 | Johnson City | RM 962 | Falls Creek |
|---|---|---|---|---|
| Period of Record | 2/84-12/96 | 2/84-8/90 | 10/90-12/96 | 2/84 – 5/90 |
| # of Samples | 96 | 72 | 23 | 73 |
| Average (mg/L) | 0.58 | 0.69 | 0.53 | 0.73 |
| Median (mg/L) | 0.49 | 0.535 | 0.277 | 0.54 |
| Std Deviation | 0.44 | 0.50 | 0.75 | 0.79 |

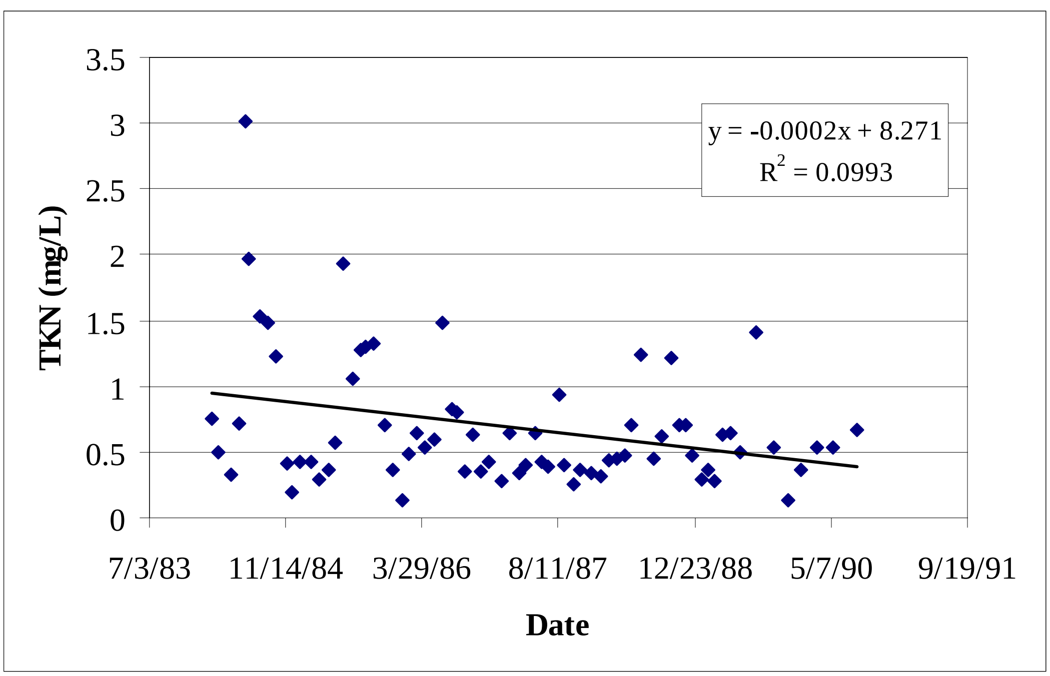


**Figure 13 Total Kjeldahl Nitrogen at Johnson City**

An ANOVA test was conducted on the TKN data and the results are shown in Table 43. Although there is a general trend towards decreasing concentrations in the downstream direction, the differences are not statistically significant (P = 0.354).

***Ammonia***

Summary Statistics

Ammonia can be toxic to aquatic life at low concentrations and therefore is a critical water quality parameter.  The high dissolved oxygen concentrations in the Pedernales are oxidize the ammonia to nitrate, reducing the concentration of ammonia.  The average concentrations and other summary statistics are shown in Table 7.

**Table 7 Summary Statistics for Ammonia**

| **Parameter** | **RR 1320** | **Johnson City** | **RM 962** | **Falls Creek** |
|---|---|---|---|---|
| Period of Record | 2/84-12/96 | 2/84-8/90 | 10/90-12/96 | 2/84 – 5/90 |
| # of Samples | 94 | 72 | 23 | 73 |
| Average (mg/L) | 0.054 | 0.070 | 0.058 | 0.069 |
| Median (mg/L) | 0.02 | 0.035 | 0.04 | 0.03 |
| Std Deviation | 0.10 | 0.117 | 0.062 | 0.097 |

Trend Analysis

Multiple linear regression, with flow and date as the independent variables, was used to detect the presence of temporal trends.  The regression statistics shown in Table 44 through Table 47 indicated no significant trend at any of the sites.

An ANOVA analysis was used to detect differences in ammonia concentrations among the sites.  The ANOVA statistics, which are shown in Table 48, indicate no significant differences in concentration.

### ***Total Phosphorus***

<u>Summary Statistics</u>

The summary statistics for phosphorus are shown in Table 8 and they indicated low median concentrations at all monitoring sites.

**Table 8 Summary Statistics for Total Phosphorus**

| Parameter | RR 1320 | Johnson City | RM 962 | Falls Creek |
|---|---|---|---|---|
| Period of Record | 2/84-12/96 | 2/84-8/90 | 10/90-12/96 | 2/84 – 5/90 |
| # of Samples | 96 | 72 | 23 | 73 |
| Average (mg/L) | 0.046 | 0.148 | 0.071 | 0.033 |
| Median (mg/L) | 0.02 | 0.05 | 0.03 | 0.02 |
| Std Deviation | 0.08 | 0.61 | 0.141 | 0.035 |

<u>Trend Analysis</u>

Multiple linear regression, using flow and date as the variables indicated a significant trend only at Johnson City. The regression statistics for this analysis are shown in Table 49 through Table 52. The Mann-Kendall test was performed on the data from Johnson City to confirm the trend. The value of the Z statistic was 0.81, which corresponds to a P value of 0.209, indicating no significant trend.

### ***Total Organic Carbon***

<u>Summary Statistics</u>

The summary statistics shown in Table 9 demonstrate the relatively low concentrations of Total Organic Carbon (TOC) present in the Pedernales River.

**Table 9 Summary Statistics for Total Organic Carbon**

| Parameter | RR 1320 | Johnson City | RM 962 | Falls Creek |
|---|---|---|---|---|
| Period of Record | 2/84-12/96 | 2/84-8/90 | 10/90-12/96 | 2/84 – 5/90 |
| # of Samples | 96 | 72 | 23 | 73 |
| Average (mg/L) | 3.69 | 4.02 | 3.12 | 3.29 |
| Median (mg/L) | 3 | 3 | 3 | 3 |
| Std Deviation | 1.81 | 2.40 | 1.34 | 1.51 |

Trend Analysis

Multiple linear regression, using date and flow as the independent variables, indicates that the only statistically significant temporal occurs at Johnson City. The statistics for the linear regression test are shown in Table 54 through Table 57. The data were analyzed with the Mann-Kendall test to confirm the trend. The Z statistic for this test was 1.01, which corresponds to a P value of 0.156, indicating that the slope is not significant.

The ANOVA analysis indicated no significant differences in concentration among the stations. The ANOVA statistics are shown in Table 58.

### *Fecal Coliform*

Summary Statistics

The summary statistics for the fecal coliform data at the four monitoring sites are shown in Table 10. The large difference between the average and median values for all the sites indicates that the underlying distribution is not normal. Consequently, the median is a better representation of the normal conditions in the river than the average value. All of the median values are well below standards for contact recreation.

**Table 10 Summary Statistics for Fecal Coliform Data**

| Parameter | RR 1320 | Johnson City | RM 962 | Falls Creek |
|---|---|---|---|---|
| Period of Record | 2/84-12/96 | 2/84-8/90 | 10/90-12/96 | 2/84 – 5/90 |
| # of Samples | 96 | 72 | 23 | 73 |
| Average Count/100 ml | 280 | 332 | 311 | 328 |
| Median Count/100 ml | 43 | 75 | 36 | 16 |
| Std Deviation | 680 | 1190 | 803 | 1698 |

Trend Analysis

Multiple linear regression was used to identify significant temporal trends in the water quality data. The independent variables were time and flow rate. Flow rate was selected to try to distinguish between conditions of baseflow and storm runoff; however, flow was not statistically significant at any of the sites. The regression analysis indicated that there was no temporal trend at any of the sites. The regression statistics for fecal coliform at the four sites are shown in Table 59 through Table 62.

ANOVA test for difference in Fecal Coliform means for all sites on the Pedernales indicate no statistically significant spatial trend. The ANOVA statistics are shown in Table 63.

## Conclusions and Recommendations

The LCRA water quality sampling program for the Pedernales River has focused primarily on the quality of ambient, baseflow conditions. Of the 264 samples collected and analyzed for Fecal coliform and other common constituents, only 18 (7%) were collected during peak flow conditions caused by stormwater runoff. The current sampling program is best suited for identifying long term changes in water quality caused by continuous point source discharges and by significant changes in groundwater quality.

Reduction in groundwater quality resulting from land use changes would have to be widespread or very severe to cause statistically significant changes in the quality of the Pedernales and other rivers in the LCRA service area. In general, agricultural land uses have a greater impact on groundwater quality than urban land uses. Consequently, one would expect the most commonly identified impacts to be associated with agricultural activities and be reflected in higher concentrations of dissolved solids and nutrients. Urbanization of a watershed generally affects the water quality of the river during ambient conditions by increased discharges from wastewater treatment facilities. These discharges are often associated with a reduction in dissolved oxygen concentrations. Urbanization also can result in reduction of baseflow because the increased impervious cover prevents rainfall from infiltrating; however, the urban area would have to cover a large portion of the watershed for the changes to be obvious.

Analysis of the LCRA water quality database for the Pedernales River indicates that several constituents exhibit a significant spatial trend. All of the constituents that varied had higher concentrations upstream than down. These constituents are dissolved oxygen, chloride, sulfate, nitrate plus nitrite, and specific conductance. The monitoring data are not sufficient for identifying the reasons for these changes, which may be natural, manmade, or a combination of the two.

The higher levels of dissolved solids, nitrogen, and other ionic species may be derived from groundwater inflow to the river. Groundwater often contains higher concentrations of these constituents than surface water. Elevated concentrations of these constituents also are associated with agricultural activities. Irrigation return flows have higher levels of dissolved solids and can carry nutrients derived from fertilizers as well as agricultural pesticides. Measurements of pesticide concentrations were not included in the monitoring program. Determination of the causes of the higher concentrations should be the focus of future studies, because dissolved solids, chloride, and sulfate are all listed as parameters of possible concern in the 1994 LCRA water quality assessment (LCRA, 1994). Concentrations of these constituents are currently below levels that caused them to be flagged in the 1994 report.

Temporal trends were most evident at the upstream monitoring station at RR 1320, which generally had the longest period of record. Constituents with significant temporal trends include specific conductance, chloride, and sulfate. The concentrations of each of these showed a reduction with time. The monitoring site at RM 962 showed a single parameter with a temporal trend, chloride, which also had declining concentrations. There was no significant temporal trend for any constituent at the Johnson City and Falls Creek sites. These reductions in concentration may be the result of much higher than average rainfall in 1991 and 1992. Rainfall generally has very low concentrations of these constituents, causing a dilution in groundwater, which contributes baseflow to the river, as well as in the river itself through increased surface runoff.

The water quality of the Pedernales River can be characterized as very good and supportive of all designated beneficial uses. Current concentrations of all monitored water quality constituents are generally below levels that would be cause for concern or result in the listing of this river segment as impaired. In addition, this data set indicates that the concentrations of the analyzed constituents at each monitoring site are relatively constant or improving. There is no immediate concern that changes in land use or other human activities threaten the water quality of the Pedernales River; however, the source of higher concentrations of dissolved solids and nutrients in the upstream reach of the river should be identified. The change from undeveloped to agricultural land use occurred many years before the beginning of any water quality monitoring programs and may be responsible for higher constituent concentrations in this portion of the watershed.

A consistent sampling protocol is required to reduce the noise inherent in the dissolved oxygen and other environmental data. For dissolved oxygen, important variables in the sampling program are collection time and sampling depth. In order to avoid a situation where sampling time changes systematically during the monitoring period or where sampling times differ systematically between monitoring stations, collection times should be randomized.

Despite the generally high quality of the Pedernales River water, eight fish kill episodes have been reported in the river, including five since 1990. Approximately half of the kills have been the result of illegal dumping of toxic substances. These episodes highlight the importance of an effective public education/outreach program. Such a program can make citizens more aware of the environmental impacts of improper disposal of waste materials. It is especially important to target owners of small businesses, which often need to dispose of significant quantities of spent solvents, lubricants, paint and other toxic materials.

The remaining fish kills were the result of wastewater treatment plant (WWTP) discharges to the Pedernales near Johnson City, resulting in low dissolved oxygen concentrations. Conventional water quality monitoring programs are not effective for identifying episodic events resulting from equipment malfunction or other causes and samples collected within a few weeks of the events did not have particularly low dissolved oxygen concentrations. Wastewater discharges may be a factor in the trend of decreasing dissolved oxygen concentrations from upstream to downstream. The number of fish kills related to wastewater discharges suggests that a review of the permit requirements and adequacy of the Johnson City WWTP should be a high priority.

# Bibliography


Gilbert, R.O., 1987, *Statistical Methods for Environmental Pollution Monitoring*, Van Nostrand Reinhold Company, New York.

LCRA, 1994, *1994 Water Quality Assessment of the Colorado River Basin*.

Minitab Inc, 1998, *Minitab for Windows: Release 12*, State College, PA.

# Appendix A

## Table 11 Regression Statistics for Oxygen Deficit at Falls Creek

| Predictor | Coef | StDev | T | P |
|---|---|---|---|---|
| Constant | 16.981 | 6.635 | 2.56 | 0.013 |
| DATE | -0.0003847 | 0.0002371 | -1.62 | 0.109 |
| Time | -0.3322 | 0.1484 | -2.24 | 0.028 |

S = 1.027 R-Sq = 21.0% R-Sq(adj) = 18.8%

Analysis of Variance

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Regression | 2 | 19.415 | 9.708 | 9.20 | 0.000 |
| Residual Error | 69 | 72.836 | 1.056 | | |
| Total | 71 | 92.252 | | | |

| Source | DF | Seq SS |
|---|---|---|
| DATE | 1 | 14.125 |
| Time | 1 | 5.290 |

## Table 12 Regression Statistics for Oxygen Deficit at RR 1320

| **Predictor** | **Coef** | **StDev** | **T** | **P** |
|---|---|---|---|---|
| Constant | 0.018 | 2.725 | 0.01 | 0.995 |
| DATE | 0.00012079 | 0.00006925 | 1.74 | 0.084 |
| time | -0.34966 | 0.08567 | -4.08 | 0.000 |
| Season | -0.04620 | 0.08257 | -0.56 | 0.577 |

S = 0.9904 R-Sq = 20.3% R-Sq(adj) = 18.1%

**Analysis of Variance**

| **Source** | **DF** | **SS** | **MS** | **F** | **P** |
|---|---|---|---|---|---|
| Regression | 3 | 27.1926 | 9.0642 | 9.24 | 0.000 |
| Residual Error | 109 | 106.9077 | 0.9808 | | |
| Total | 112 | 134.1003 | | | |

| **Source** | **DF** | **Seq SS** |
|---|---|---|
| DATE | 1 | 10.5199 |
| Time | 1 | 16.3656 |
| Season | 1 | 0.3071 |

**Table 13 Regression Statistics for Oxygen Deficit at Johnson City**

| Predictor | Coef | StDev | T | P |
|---|---|---|---|---|
| Constant | 7.917 | 6.192 | 1.28 | 0.205 |
| DATE | -0.0000683 | 0.0001923 | -0.36 | 0.724 |
| Time_(d) | -0.6022 | 0.1711 | -3.52 | 0.001 |

S = 1.289    R-Sq = 15.6%    R-Sq(adj) = 13.2%

Analysis of Variance

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Regression | 2 | 21.445 | 10.722 | 6.45 | 0.003 |
| Residual Error | 70 | 116.351 | 1.662 | | |
| Total | 72 | 137.796 | | | |

| Source | DF | Seq SS |
|---|---|---|
| DATE | 1 | 0.850 |
| Time_(d) | 1 | 20.595 |

**Table 14 Regression Statistics for Oxygen Deficit at Hammett's Crossing**

| Predictor | Coef | StDev | T | P |
|---|---|---|---|---|
| Constant | 0.307 | 2.384 | 0.13 | 0.898 |
| DATE | 0.00004533 | 0.00006302 | 0.72 | 0.474 |
| Time_d | -0.11427 | 0.03820 | -2.99 | 0.003 |

S = 0.7344    R-Sq = 15.7%    R-Sq(adj) = 14.2%

Analysis of Variance

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Regression | 2 | 11.0656 | 5.5328 | 10.26 | 0.000 |
| Residual Error | 110 | 59.3270 | 0.5393 | | |
| Total | 112 | 70.3927 | | | |

| Source | DF | Seq SS |
|---|---|---|
| DATE | 1 | 6.2402 |
| Time_d | 1 | 4.8254 |

**Table 15 ANOVA Statistics for Oxygen Deficit**

```
Source     DF        SS        MS        F        P
Factor      3     43.96     14.65    10.07    0.000
Error     372    541.44      1.46
Total     375    585.40
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ----------+---------+---------+-----
-
Falls Cr   73     0.741     1.140                    (-----*----)
RM 962    114     0.546     1.237                 (----*---)
Johnson    74    -0.202     1.383  (-----*----)
RR 1320   115     0.108     1.089          (---*----)
                                   ----------+---------+---------+-----
-
Pooled StDev =    1.206                    0.00      0.50      1.00
```

**Table 16 ANOVA Statistics for DO Corrected for Time**

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      3   236.463    78.821    79.92    0.000
Error     367   361.956     0.986
Total     370   598.418
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  --+---------+---------+---------+---
-
1320noon  113   -0.3900    0.9918               (-*-)
johnoon    73   -1.4900    1.2724   (-*--)
962noon   113    0.4200    0.7295                         (-*--)
fcnoon     72    0.7800    1.0320                             (--*--)
                                   --+---------+---------+---------+---
-


Pooled StDev =   0.9931           -1.60     -0.80     -0.00      0.80
```

**Table 17 Regression Statistics for Specific Conductance at Falls Creek**

| Predictor | Coef | StDev | T | P |
|---|---|---|---|---|
| Constant | 383.0 | 642.3 | 0.60 | 0.553 |
| DATE | 0.00556 | 0.02021 | 0.28 | 0.784 |
| Flow (cf | -0.03527 | 0.02589 | -1.36 | 0.178 |

S = 108.6 R-Sq = 2.7% R-Sq(adj) = 0.0%

Analysis of Variance

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Regression | 2 | 22461 | 11231 | 0.95 | 0.391 |
| Residual Error | 69 | 813739 | 11793 | | |
| Total | 71 | 836200 | | | |

| Source | DF | Seq SS |
|---|---|---|
| DATE | 1 | 583 |
| Flow (cf | 1 | 21878 |

**Table 18 Regression Statistics for Specific Conductance at Johnson City**

The regression equation is

CONDUCTANCE (UMHOS/CM @ 25C) = 2102 - 0.0446 DATE - 0.240 Flow (cfs)

| Predictor | Coef | StDev | T | P |
|---|---|---|---|---|
| Constant | 2101.7 | 680.9 | 3.09 | 0.003 |
| DATE | -0.04465 | 0.02135 | -2.09 | 0.040 |
| Flow (cf | -0.24019 | 0.08798 | -2.73 | 0.008 |

S = 143.8 R-Sq = 14.1% R-Sq(adj) = 11.6%

Analysis of Variance

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Regression | 2 | 237438 | 118719 | 5.74 | 0.005 |
| Residual Error | 70 | 1446592 | 20666 | | |
| Total | 72 | 1684030 | | | |

| Source | DF | Seq SS |
|---|---|---|
| DATE | 1 | 83408 |
| Flow (cf | 1 | 154031 |

**Table 19 Regression Statistics for Specific Conductance at Hammett's Crossing**

| Predictor | Coef | StDev | T | P |
|---|---|---|---|---|
| Constant | 493.6 | 217.3 | 2.27 | 0.025 |
| DATE | 0.001824 | 0.006636 | 0.27 | 0.784 |
| Flow (cf | -0.07132 | 0.03288 | -2.17 | 0.032 |

S = 97.03 R-Sq = 4.1% R-Sq(adj) = 2.4%

Analysis of Variance

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Regression | 2 | 44381 | 22190 | 2.36 | 0.100 |
| Residual Error | 109 | 1026228 | 9415 | | |
| Total | 111 | 1070608 | | | |

| Source | DF | Seq SS |
|---|---|---|
| DATE | 1 | 87 |
| Flow (cf | 1 | 44294 |

**Table 20 Regression Statistics for Specific Conductance at RR 1320**

| Predictor | Coef | StDev | T | P |
|---|---|---|---|---|
| Constant | 1361.1 | 268.1 | 5.08 | 0.000 |
| DATE | -0.020420 | 0.008190 | -2.49 | 0.014 |
| Flow (cf | -0.04861 | 0.04700 | -1.03 | 0.303 |

S = 123.4 R-Sq = 6.8% R-Sq(adj) = 5.1%

Analysis of Variance

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Regression | 2 | 121217 | 60608 | 3.98 | 0.021 |
| Residual Error | 110 | 1673716 | 15216 | | |
| Total | 112 | 1794933 | | | |

| Source | DF | Seq SS |
|---|---|---|
| DATE | 1 | 104944 |
| Flow (cf | 1 | 16273 |

**Table 21 ANOVA Statistics for Specific Conductance**

```
Source     DF        SS        MS        F        P
Factor      3   1483597    494532    33.32    0.000
Error     368   5461561     14841
Total     371   6945158
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ----+---------+---------+---------+-
-
RR 1320   114     682.1     127.8                        (---*--)
Johnson    73     647.8     152.9                 (----*----)
RM 962    113     539.9      98.8  (---*---)
Falls C    72     553.0     108.5   (----*----)
                                   ----+---------+---------+---------+-
-
Pooled StDev =    121.8              540       600       660       720
```

**Table 22 Regression Statistics for Chloride at RR 1320**

```
The regression equation is
CHLORIDE (MG/L AS CL) = 229 - 0.00473 DATE - 0.0659 FLOW

Predictor        Coef       StDev          T        P
Constant       228.55       46.73       4.89    0.000
DATE        -0.004730    0.001438      -3.29    0.001
FLOW        -0.065859    0.009561      -6.89    0.000

S = 18.10       R-Sq = 38.4%     R-Sq(adj) = 37.1%

Analysis of Variance

Source            DF          SS          MS         F        P
Regression         2     19001.9      9501.0     29.02    0.000
Residual Error    93     30451.7       327.4
Total             95     49453.6

Source       DF      Seq SS
DATE          1      3465.0
FLOW          1     15536.9
```

**Table 23 Regression Statistics for Chloride at Johnson City**

```
The regression equation is
```

CHLORIDE (MG/L AS CL) = 444 - 0.0117 DATE - 0.0765 FLOW

| Predictor | Coef | StDev | T | P |
|---|---|---|---|---|
| Constant | 444.3 | 162.1 | 2.74 | 0.008 |
| DATE | -0.011685 | 0.005095 | -2.29 | 0.025 |
| FLOW | -0.07649 | 0.01722 | -4.44 | 0.000 |

S = 28.10       R-Sq = 26.7%     R-Sq(adj) = 24.5%

Analysis of Variance

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Regression | 2 | 19817.9 | 9909.0 | 12.55 | 0.000 |
| Residual Error | 69 | 54488.1 | 789.7 | | |
| Total | 71 | 74306.0 | | | |

| Source | DF | Seq SS |
|---|---|---|
| DATE | 1 | 4241.9 |
| FLOW | 1 | 15576.0 |

**Table 24 Regression Statistics for Chloride at RM 962**

The regression equation is
CHLORIDE (MG/L AS CL) = 272 - 0.00670 DATE - 0.0372 FLOW

| Predictor | Coef | StDev | T | P |
|---|---|---|---|---|
| Constant | 271.87 | 96.90 | 2.81 | 0.011 |
| DATE | -0.006700 | 0.002814 | -2.38 | 0.027 |
| FLOW | -0.03722 | 0.01189 | -3.13 | 0.005 |

S = 9.021       R-Sq = 41.1%     R-Sq(adj) = 35.2%

Analysis of Variance

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Regression | 2 | 1134.01 | 567.00 | 6.97 | 0.005 |
| Residual Error | 20 | 1627.52 | 81.38 | | |
| Total | 22 | 2761.53 | | | |

| Source | DF | Seq SS |
|---|---|---|
| DATE | 1 | 336.18 |
| FLOW | 1 | 797.83 |

**Table 25 Regression Statistics for Chloride at Falls Creek**

The regression equation is

CHLORIDE (MG/L AS CL) = - 35 + 0.00244 DATE - 0.0109 FLOW

| Predictor | Coef | StDev | T | P |
|---|---|---|---|---|
| Constant | -34.9 | 117.4 | -0.30 | 0.767 |
| DATE | 0.002444 | 0.003696 | 0.66 | 0.511 |
| FLOW | -0.010858 | 0.004771 | -2.28 | 0.026 |

S = 20.01       R-Sq = 7.3%      R-Sq(adj) = 4.7%

Analysis of Variance

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Regression | 2 | 2207.6 | 1103.8 | 2.76 | 0.070 |
| Residual Error | 70 | 28033.0 | 400.5 | | |
| Total | 72 | 30240.6 | | | |

| Source | DF | Seq SS |
|---|---|---|
| DATE | 1 | 133.1 |
| FLOW | 1 | 2074.5 |

**Table 26 ANOVA Statistics for Chloride**

Analysis of Variance for CHLORIDE

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| STATION | 3 | 38190 | 12730 | 21.11 | 0.000 |
| Error | 260 | 156762 | 603 | | |
| Total | 263 | 194952 | | | |

```
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level        N      Mean     StDev --------+---------+---------+--------
 15         73     40.70     20.49        (----*----)
 50         23     37.37     11.20  (-------*--------)
 75         72     62.51     32.35                        (----*----)
150         96     66.26     22.82                            (---*---)
                                   --------+---------+---------+--------
Pooled StDev =     24.55                  36        48        60
```

**Table 27 ANOVA Statistics for Chloride Normalized for Flow**

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      3     49378     16459    34.87    0.000
Error     264    124602       472
Total     267    173980
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ---+---------+---------+---------+--
-
150        97     71.70     18.92                               (---*--
75      _  73     68.66     28.74                            (---*---)
50         24     41.20      9.74  (------*-------)
15         74     42.70     19.79      (----*---)
                                   ---+---------+---------+---------+--
-
Pooled StDev =    21.73              36        48        60        72
```

**Table 28 Regression Statistics for Sulfate at RR 1320**

```
The regression equation is
SULFATE (MG/L AS SO4) = 89.7 - 0.00169 DATE - 0.0189 FLOW

95 cases used 1 cases contain missing values

Predictor        Coef       StDev          T        P
Constant        89.74       19.50       4.60    0.000
DATE       -0.0016945   0.0005998      -2.83    0.006
FLOW        -0.018911    0.003970      -4.76    0.000

S = 7.511       R-Sq = 24.9%     R-Sq(adj) = 23.3%

Analysis of Variance

Source            DF          SS          MS         F        P
Regression         2     1720.20      860.10     15.24    0.000
Residual Error    92     5190.71       56.42
Total             94     6910.91

Source       DF       Seq SS
DATE          1       439.68
FLOW          1      1280.52
```

**Table 29 Regression Statistics for Sulfate at Johnson City**

```
The regression equation is
SULFATE (MG/L AS SO4) = - 153 + 0.00607 DATE - 0.0283 FLOW

Predictor         Coef       StDev          T        P
Constant        -152.9       158.9      -0.96    0.339
DATE          0.006073    0.004993       1.22    0.228
FLOW          -0.02833     0.01688      -1.68    0.098

S = 27.54       R-Sq = 5.8%      R-Sq(adj) = 3.1%

Analysis of Variance

Source            DF          SS          MS         F        P
Regression         2      3242.6      1621.3      2.14    0.126
Residual Error    69     52330.3       758.4
Total             71     55572.9

Source       DF      Seq SS
DATE          1      1105.1
FLOW          1      2137.5
```

**Table 30 Regression Statistics for Sulfate at RM 962**

```
The regression equation is
SULFATE (MG/L AS SO4) = 101 - 0.00214 DATE - 0.0155 FLOW

Predictor         Coef       StDev          T        P
Constant        101.16       64.59       1.57    0.133
DATE         -0.002136    0.001876      -1.14    0.268
FLOW         -0.015491    0.007921      -1.96    0.065

S = 6.012       R-Sq = 18.9%     R-Sq(adj) = 10.8%

Analysis of Variance

Source            DF          SS          MS         F        P
Regression         2      168.76       84.38      2.33    0.123
Residual Error    20      722.94       36.15
Total             22      891.70

Source       DF      Seq SS
DATE          1       30.52
FLOW          1      138.23
```

**Table 31 Regression Statistics for Sulfate at Falls Creek**

The regression equation is
SULFATE (MG/L AS SO4) = 51.7 - 0.00072 DATE - 0.00653 FLOW

| Predictor | Coef | StDev | T | P |
|---|---|---|---|---|
| Constant | 51.66 | 63.75 | 0.81 | 0.420 |
| DATE | -0.000725 | 0.002006 | -0.36 | 0.719 |
| FLOW | -0.006533 | 0.002590 | -2.52 | 0.014 |

S = 10.86 R-Sq = 8.6% R-Sq(adj) = 6.0%

Analysis of Variance

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Regression | 2 | 775.4 | 387.7 | 3.29 | 0.043 |
| Residual Error | 70 | 8260.1 | 118.0 | | |
| Total | 72 | 9035.5 | | | |

| Source | DF | Seq SS |
|---|---|---|
| DATE | 1 | 24.5 |
| FLOW | 1 | 750.8 |

**Table 32 ANOVA Statistics for Sulfate**

Analysis of Variance for SULFATE

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| STATION | 3 | 3863 | 1288 | 4.61 | 0.004 |
| Error | 259 | 72411 | 280 | | |
| Total | 262 | 76274 | | | |

```
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ---------+---------+---------+-------
 15        73     27.40     11.20          (------*-----)
 50        23     25.99      6.37   (----------*-----------)
 75        72     36.63     27.98                        (-----*------)
150        95     32.19      8.57                 (-----*----)
                                   ---------+---------+---------+-------
Pooled StDev =    16.72                  24.0      30.0      36.0
* NOTE * N missing = 1
```

**Table 33 ANOVA Statistics for Sulfate Normalized for Flow**

Analysis of Variance

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Factor | 3 | 4621 | 1540 | 5.85 | 0.001 |

```
Error      259     68138       263
Total      262     72759
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level        N      Mean     StDev  ------+---------+---------+---------
+
150    _    95     33.70      7.75                  (----*-----)
75     _    72     38.89     27.44                          (-----*----
50          23     27.60      5.92   (----------*----------)
15          73     28.60     10.72         (------*-----)
                                   ------+---------+---------+---------
+
Pooled StDev =    16.22               24.0      30.0      36.0      42.0
```

**Table 34 Regression Statistics for Nitrate plus Nitrite at RR 1320**

```
The regression equation is
NITRITE PLUS NITRATE, TOTAL 1 D = 2.79 -0.000077 DATE +0.000511 FLOW

91 cases used 5 cases contain missing values

Predictor        Coef       StDev          T        P
Constant        2.787       1.236       2.25    0.027
DATE      -0.00007706  0.00003825      -2.01    0.047
FLOW        0.0005113   0.0002224       2.30    0.024

S = 0.4189      R-Sq = 9.3%      R-Sq(adj) = 7.2%

Analysis of Variance

Source            DF          SS          MS         F        P
Regression         2      1.5787      0.7893      4.50    0.014
Residual Error    88     15.4414      0.1755
Total             90     17.0201

Source       DF      Seq SS
DATE          1      0.6514
FLOW          1      0.9273
```

**Table 35 Regression Statistics for Nitrate plus Nitrite at Johnson City**

```
The regression equation is
```

NITRITE PLUS NITRATE, TOTAL 1 D = 0.37 -0.000005 DATE +0.000490 FLOW

| Predictor | Coef | StDev | T | P |
|---|---|---|---|---|
| Constant | 0.374 | 1.766 | 0.21 | 0.833 |
| DATE | -0.00000501 | 0.00005549 | -0.09 | 0.928 |
| FLOW | 0.0004897 | 0.0001876 | 2.61 | 0.011 |

S = 0.3061      R-Sq = 9.0%      R-Sq(adj) = 6.4%

Analysis of Variance

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Regression | 2 | 0.63893 | 0.31946 | 3.41 | 0.039 |
| Residual Error | 69 | 6.46367 | 0.09368 | | |
| Total | 71 | 7.10260 | | | |

| Source | DF | Seq SS |
|---|---|---|
| DATE | 1 | 0.00054 |
| FLOW | 1 | 0.63839 |

**Table 36 Regression Statistics for Nitrate plus Nitrite at RM 962**

The regression equation is
NITRITE PLUS NITRATE, TOTAL 1 D = - 5.19 +0.000159 DATE - 0.00076 FLOW

13 cases used 10 cases contain missing values

| Predictor | Coef | StDev | T | P |
|---|---|---|---|---|
| Constant | -5.187 | 4.018 | -1.29 | 0.226 |
| DATE | 0.0001586 | 0.0001176 | 1.35 | 0.207 |
| FLOW | -0.000763 | 0.001267 | -0.60 | 0.561 |

S = 0.2317      R-Sq = 15.5%     R-Sq(adj) = 0.0%

Analysis of Variance

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Regression | 2 | 0.09828 | 0.04914 | 0.92 | 0.431 |
| Residual Error | 10 | 0.53671 | 0.05367 | | |
| Total | 12 | 0.63499 | | | |

| Source | DF | Seq SS |
|---|---|---|
| DATE | 1 | 0.07885 |
| FLOW | 1 | 0.01943 |

**Table 37 Regression Statistics for Nitrate plus Nitrite at Falls Creek**

The regression equation is
NITRITE PLUS NITRATE, TOTAL 1 D = - 0.07 +0.000008 DATE +0.000090 FLOW

| Predictor | Coef | StDev | T | P |
|---|---|---|---|---|
| Constant | -0.066 | 1.192 | -0.06 | 0.956 |
| DATE | 0.00000751 | 0.00003752 | 0.20 | 0.842 |
| FLOW | 0.00009006 | 0.00004844 | 1.86 | 0.067 |

S = 0.2032 R-Sq = 4.8% R-Sq(adj) = 2.1%

Analysis of Variance

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Regression | 2 | 0.14571 | 0.07285 | 1.76 | 0.179 |
| Residual Error | 70 | 2.88967 | 0.04128 | | |
| Total | 72 | 3.03538 | | | |

| Source | DF | Seq SS |
|---|---|---|
| DATE | 1 | 0.00301 |
| FLOW | 1 | 0.14270 |

**Table 38 ANOVA Statistics for Nitrate plus Nitrite**

Analysis of Variance for NITRITE + NITRATE

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| STATION | 3 | 1.348 | 0.449 | 3.96 | 0.009 |
| Error | 245 | 27.793 | 0.113 | | |
| Total | 248 | 29.141 | | | |

```
                                     Individual 95% CIs For Mean
                                     Based on Pooled StDev
Level        N      Mean     StDev   --------+---------+---------+-------
-
 15         73    0.1895    0.2053          (------*-----)
 50         13    0.2149    0.2300    (--------------*--------------)
 75         72    0.2783    0.3163                  (-----*------)
150         91    0.3674    0.4349                          (-----*----)
                                     --------+---------+---------+-------
-
Pooled StDev =   0.3368                    0.12      0.24      0.36
* NOTE * N missing = 15
```

**Table 39 Regression Statistics for TKN at RR 1320**

The regression equation is
NITROGEN, KJELDAHL, TOTAL, (MG/ = 1.00 -0.000013 DATE +0.000147 FLOW

95 cases used 1 cases contain missing values

| Predictor | Coef | StDev | T | P |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| Constant | 0.995 | 1.163 | 0.86 | 0.394 |
| DATE | -0.00001310 | 0.00003584 | -0.37 | 0.716 |
| FLOW | 0.0001470 | 0.0002316 | 0.63 | 0.527 |

S = 0.4382 R-Sq = 0.6% R-Sq(adj) = 0.0%

Analysis of Variance

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Regression | 2 | 0.1028 | 0.0514 | 0.27 | 0.766 |
| Residual Error | 92 | 17.6633 | 0.1920 | | |
| Total | 94 | 17.7661 | | | |

| Source | DF | Seq SS |
|---|---|---|
| DATE | 1 | 0.0255 |
| FLOW | 1 | 0.0773 |

**Table 40 Regression Statistics for TKN at Johnson City**

The regression equation is
NITROGEN, KJELDAHL, TOTAL, (MG/ = 8.31 -0.000238 DATE -0.000518 FLOW

| Predictor | Coef | StDev | T | P |
|---|---|---|---|---|
| Constant | 8.312 | 2.687 | 3.09 | 0.003 |
| DATE | -0.00023752 | 0.00008445 | -2.81 | 0.006 |
| FLOW | -0.0005184 | 0.0002854 | -1.82 | 0.074 |

S = 0.4657 R-Sq = 14.0% R-Sq(adj) = 11.5%

Analysis of Variance

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Regression | 2 | 2.4437 | 1.2219 | 5.63 | 0.005 |
| Residual Error | 69 | 14.9671 | 0.2169 | | |
| Total | 71 | 17.4108 | | | |

| Source | DF | Seq SS |
|---|---|---|
| DATE | 1 | 1.7282 |
| FLOW | 1 | 0.7155 |

**Table 41 Regression Statistics for TKN at RM 962**

The regression equation is
NITROGEN, KJELDAHL, TOTAL, (MG/ = - 9.77 +0.000302 DATE - 0.00025 FLOW

21 cases used 2 cases contain missing values

| Predictor | Coef | StDev | T | P |
|---|---|---|---|---|
| Constant | -9.765 | 9.506 | -1.03 | 0.318 |
| DATE | 0.0003024 | 0.0002771 | 1.09 | 0.289 |
| FLOW | -0.000252 | 0.001046 | -0.24 | 0.812 |

S = 0.7903      R-Sq = 6.7%      R-Sq(adj) = 0.0%

Analysis of Variance

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Regression | 2 | 0.8065 | 0.4032 | 0.65 | 0.536 |
| Residual Error | 18 | 11.2432 | 0.6246 | | |
| Total | 20 | 12.0497 | | | |

| Source | DF | Seq SS |
|---|---|---|
| DATE | 1 | 0.7703 |
| FLOW | 1 | 0.0362 |

**Table 42 Regression Statistics for TKN at Falls Creek**

The regression equation is
NITROGEN, KJELDAHL, TOTAL, (MG/ = 7.45 -0.000210 DATE -0.000112 FLOW

72 cases used 1 cases contain missing values

| Predictor | Coef | StDev | T | P |
|---|---|---|---|---|
| Constant | 7.445 | 4.660 | 1.60 | 0.115 |
| DATE | -0.0002102 | 0.0001466 | -1.43 | 0.156 |
| FLOW | -0.0001119 | 0.0001882 | -0.59 | 0.554 |

S = 0.7891      R-Sq = 3.5%      R-Sq(adj) = 0.7%

Analysis of Variance

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Regression | 2 | 1.5390 | 0.7695 | 1.24 | 0.297 |
| Residual Error | 69 | 42.9598 | 0.6226 | | |
| Total | 71 | 44.4988 | | | |

| Source | DF | Seq SS |
|---|---|---|
| DATE | 1 | 1.3188 |
| FLOW | 1 | 0.2203 |

**Table 43 ANOVA Statistics for TKN**

```
Analysis of Variance for NITROGEN TKN
Source     DF        SS        MS        F        P
STATION     3     1.172     0.391     1.09    0.354
Error     256    91.725     0.358
Total     259    92.898
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -+---------+---------+---------+-----
 15        72    0.7417    0.7917                    (-------*--------)
 50        21    0.5678    0.7762  (--------------*---------------)
 75        72    0.6879    0.4952                (--------*--------)
150        95    0.5905    0.4347            (-------*------)
                                   -+---------+---------+---------+-----
Pooled StDev =   0.5986           0.32      0.48      0.64      0.80
* NOTE * N missing = 4
```

**Table 44 Regression Statistics for Ammonia at RR 1320**

```
The regression equation is
NITROGEN, AMMONIA, TOTAL (MG/L = - 0.192 +0.000008 DATE +0.000078 FLOW

78 cases used 18 cases contain missing values

Predictor        Coef       StDev          T        P
Constant      -0.1921      0.2863      -0.67    0.504
DATE       0.00000756  0.00000877       0.86    0.392
FLOW       0.00007808  0.00006656       1.17    0.244

S = 0.1035      R-Sq = 2.6%      R-Sq(adj) = 0.0%

Analysis of Variance

Source            DF          SS          MS         F        P
Regression         2     0.02153     0.01076      1.01    0.371
Residual Error    75     0.80314     0.01071
Total             77     0.82467

Source       DF      Seq SS
DATE          1     0.00679
FLOW          1     0.01474
```

**Table 45 Regression Statistics for Ammonia at Johnson City**

```
The regression equation is
```

```
NITROGEN, AMMONIA, TOTAL (MG/L = 1.19 -0.000035 DATE -0.000055 FLOW

62 cases used 10 cases contain missing values

Predictor        Coef       StDev          T        P
Constant       1.1876      0.7517       1.58    0.119
DATE      -0.00003457  0.00002359      -1.47    0.148
FLOW      -0.00005512  0.00007728      -0.71    0.478

S = 0.1227      R-Sq = 4.3%      R-Sq(adj) = 1.1%

Analysis of Variance

Source            DF          SS          MS         F        P
Regression         2     0.04001     0.02001      1.33    0.272
Residual Error    59     0.88756     0.01504
Total             61     0.92757

Source       DF      Seq SS
DATE          1     0.03236
FLOW          1     0.00765
```

**Table 46 Regression Statistics for Ammonia at RM 962**

```
The regression equation is
NITROGEN, AMMONIA, TOTAL (MG/L = - 0.048 +0.000004 DATE -0.000080 FLOW

21 cases used 2 cases contain missing values

Predictor        Coef       StDev          T        P
Constant      -0.0482      0.8562      -0.06    0.956
DATE       0.00000351  0.00002475       0.14    0.889
FLOW      -0.00008036  0.00008899      -0.90    0.378

S = 0.06511     R-Sq = 5.0%      R-Sq(adj) = 0.0%

Analysis of Variance

Source            DF          SS          MS         F        P
Regression         2    0.004045    0.002023      0.48    0.628
Residual Error    18    0.076306    0.004239
Total             20    0.080351

Source       DF      Seq SS
DATE          1    0.000588
FLOW          1    0.003457
```

**Table 47 Regression Statistics for Ammonia at Falls Creek**

The regression equation is
NITROGEN, AMMONIA, TOTAL (MG/L = - 0.428 +0.000016 DATE -0.000026 FLOW

| Predictor | Coef | StDev | T | P |
|---|---|---|---|---|
| Constant | -0.4279 | 0.5710 | -0.75 | 0.456 |
| DATE | 0.00001579 | 0.00001797 | 0.88 | 0.382 |
| FLOW | -0.00002633 | 0.00002320 | -1.13 | 0.260 |

S = 0.09731     R-Sq = 2.8%      R-Sq(adj) = 0.0%

Analysis of Variance

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Regression | 2 | 0.018826 | 0.009413 | 0.99 | 0.375 |
| Residual Error | 70 | 0.662806 | 0.009469 | | |
| Total | 72 | 0.681633 | | | |

| Source | DF | Seq SS |
|---|---|---|
| DATE | 1 | 0.006632 |
| FLOW | 1 | 0.012194 |

**Table 48 ANOVA Statistics for Ammonia**

```
Analysis of Variance for Ammonia
Source     DF        SS        MS        F        P
STATION     3    0.0235    0.0078     0.69    0.562
Error     213    2.4370    0.0114
Total     216    2.4605
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -----+---------+---------+---------
+-
 15        56    0.0870    0.1048                 (--------*--------)
 50        21    0.0630    0.0634   (--------------*--------------)
 75        62    0.0794    0.1233               (-------*--------)
150        78    0.0628    0.1035          (-------*-------)
                                   -----+---------+---------+---------
+-
Pooled StDev =   0.1070               0.030     0.060     0.090
0.120
* NOTE * N missing = 47
```

**Table 49 Regression Statistics for Total Phosphorus at RR 1320**

The regression equation is
PHOSPHORUS, TOTAL, WET METHOD ( = - 0.250 +0.000009 DATE +0.000031 FLOW

| Predictor | Coef | StDev | T | P |
|---|---|---|---|---|
| Constant | -0.2504 | 0.2083 | -1.20 | 0.233 |
| DATE | 0.00000902 | 0.00000641 | 1.41 | 0.163 |
| FLOW | 0.00003072 | 0.00004263 | 0.72 | 0.473 |

S = 0.08067 R-Sq = 2.6% R-Sq(adj) = 0.5%

Analysis of Variance

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Regression | 2 | 0.016202 | 0.008101 | 1.24 | 0.293 |
| Residual Error | 93 | 0.605264 | 0.006508 | | |
| Total | 95 | 0.621465 | | | |

| Source | DF | Seq SS |
|---|---|---|
| DATE | 1 | 0.012822 |
| FLOW | 1 | 0.003380 |

**Table 50 Regression Statistics for Total Phosphorus at Johnson City**

The regression equation is
PHOSPHORUS, TOTAL, WET METHOD ( = 7.23 -0.000221 DATE -0.000349 FLOW

| Predictor | Coef | StDev | T | P |
|---|---|---|---|---|
| Constant | 7.228 | 3.449 | 2.10 | 0.040 |
| DATE | -0.0002211 | 0.0001084 | -2.04 | 0.045 |
| FLOW | -0.0003493 | 0.0003663 | -0.95 | 0.344 |

S = 0.5978 R-Sq = 6.9% R-Sq(adj) = 4.2%

Analysis of Variance

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Regression | 2 | 1.8197 | 0.9099 | 2.55 | 0.086 |
| Residual Error | 69 | 24.6560 | 0.3573 | | |
| Total | 71 | 26.4757 | | | |

| Source | DF | Seq SS |
|---|---|---|
| DATE | 1 | 1.4948 |
| FLOW | 1 | 0.3249 |

**Table 51 Regression Statistics for Total Phosphorus at RM 962**

The regression equation is
PHOSPHORUS, TOTAL, WET METHOD ( = 0.20 -0.000004 DATE +0.000116 FLOW

| Predictor | Coef | StDev | T | P |
|---|---|---|---|---|
| Constant | 0.204 | 1.579 | 0.13 | 0.899 |
| DATE | -0.00000424 | 0.00004587 | -0.09 | 0.927 |
| FLOW | 0.0001161 | 0.0001937 | 0.60 | 0.556 |

S = 0.1470      R-Sq = 1.9%      R-Sq(adj) = 0.0%

Analysis of Variance

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Regression | 2 | 0.00834 | 0.00417 | 0.19 | 0.826 |
| Residual Error | 20 | 0.43226 | 0.02161 | | |
| Total | 22 | 0.44060 | | | |

| Source | DF | Seq SS |
|---|---|---|
| DATE | 1 | 0.00057 |
| FLOW | 1 | 0.00777 |

**Table 52 Regression Statistics for Total Phosphorus at Falls Creek**

The regression equation is
PHOSPHORUS, TOTAL, WET METHOD ( = 0.202 -0.000005 DATE -0.000002 FLOW

| Predictor | Coef | StDev | T | P |
|---|---|---|---|---|
| Constant | 0.2022 | 0.2087 | 0.97 | 0.336 |
| DATE | -0.00000530 | 0.00000657 | -0.81 | 0.422 |
| FLOW | -0.00000189 | 0.00000848 | -0.22 | 0.824 |

S = 0.03556      R-Sq = 1.0%      R-Sq(adj) = 0.0%

Analysis of Variance

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Regression | 2 | 0.000905 | 0.000453 | 0.36 | 0.700 |
| Residual Error | 70 | 0.088539 | 0.001265 | | |
| Total | 72 | 0.089444 | | | |

| Source | DF | Seq SS |
|---|---|---|
| DATE | 1 | 0.000842 |
| FLOW | 1 | 0.000063 |

**Table 53 ANOVA Statistics for Total Phosphorus**

```
Analysis of Variance for TOTAL PHOSPHOROUS
Source     DF        SS        MS        F        P
STATION     3     0.589     0.196     1.85    0.139
Error     260    27.627     0.106
Total     263    28.216
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  --------+---------+---------+--------
 15        73    0.0334    0.0352     (--------*---------)
 50        23    0.0714    0.1415  (----------------*----------------)
 75        72    0.1482    0.6107                   (---------*--------)
150        96    0.0466    0.0809        (-------*-------)
                                   --------+---------+---------+--------
Pooled StDev =   0.3260                 0.000     0.080     0.160
```

**Table 54 Regression Statistics for TOC at RR 1320**

The regression equation is
CARBON, TOTAL ORGANIC (MG/L AS = 10.3 -0.000203 DATE -0.000140 FLOW

95 cases used 1 cases contain missing values

| Predictor | Coef | StDev | T | P |
|---|---|---|---|---|
| Constant | 10.329 | 4.682 | 2.21 | 0.030 |
| DATE | -0.0002030 | 0.0001440 | -1.41 | 0.162 |
| FLOW | -0.0001405 | 0.0009498 | -0.15 | 0.883 |

S = 1.794   R-Sq = 2.1%   R-Sq(adj) = 0.0%

Analysis of Variance

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Regression | 2 | 6.459 | 3.230 | 1.00 | 0.371 |
| Residual Error | 92 | 296.254 | 3.220 | | |
| Total | 94 | 302.713 | | | |

| Source | DF | Seq SS |
|---|---|---|
| DATE | 1 | 6.389 |
| FLOW | 1 | 0.070 |

**Table 55 Regression Statistics for TOC at Johnson City**

The regression equation is
CARBON, TOTAL ORGANIC (MG/L AS = 39.6 - 0.00111 DATE - 0.00131 FLOW

| Predictor | Coef | StDev | T | P |
|---|---|---|---|---|
| Constant | 39.63 | 13.28 | 2.98 | 0.004 |
| DATE | -0.0011138 | 0.0004173 | -2.67 | 0.009 |
| FLOW | -0.001305 | 0.001410 | -0.93 | 0.358 |

S = 2.301 R-Sq = 10.4% R-Sq(adj) = 7.8%

Analysis of Variance

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Regression | 2 | 42.418 | 21.209 | 4.00 | 0.023 |
| Residual Error | 69 | 365.407 | 5.296 | | |
| Total | 71 | 407.824 | | | |

| Source | DF | Seq SS |
|---|---|---|
| DATE | 1 | 37.881 |
| FLOW | 1 | 4.537 |

**Table 56 Regression Statistics for TOC at RM 962**

The regression equation is
CARBON, TOTAL ORGANIC (MG/L AS = - 19.6 +0.000658 DATE + 0.00108 FLOW

| Predictor | Coef | StDev | T | P |
|---|---|---|---|---|
| Constant | -19.60 | 14.20 | -1.38 | 0.183 |
| DATE | 0.0006577 | 0.0004124 | 1.59 | 0.126 |
| FLOW | 0.001077 | 0.001742 | 0.62 | 0.543 |

S = 1.322 R-Sq = 12.0% R-Sq(adj) = 3.2%

Analysis of Variance

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Regression | 2 | 4.777 | 2.389 | 1.37 | 0.278 |
| Residual Error | 20 | 34.942 | 1.747 | | |
| Total | 22 | 39.719 | | | |

| Source | DF | Seq SS |
|---|---|---|
| DATE | 1 | 4.110 |
| FLOW | 1 | 0.668 |

**Table 57 Regression Statistics for TOC at Falls Creek**

The regression equation is
CARBON, TOTAL ORGANIC (MG/L AS = 17.7 -0.000454 DATE +0.000122 FLOW

| Predictor | Coef | StDev | T | P |
|---|---|---|---|---|
| Constant | 17.704 | 8.792 | 2.01 | 0.048 |
| DATE | -0.0004543 | 0.0002767 | -1.64 | 0.105 |
| FLOW | 0.0001225 | 0.0003572 | 0.34 | 0.733 |

S = 1.498 R-Sq = 3.8% R-Sq(adj) = 1.1%

Analysis of Variance

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Regression | 2 | 6.230 | 3.115 | 1.39 | 0.256 |
| Residual Error | 70 | 157.121 | 2.245 | | |
| Total | 72 | 163.351 | | | |

| Source | DF | Seq SS |
|---|---|---|
| DATE | 1 | 5.966 |
| FLOW | 1 | 0.264 |

**Table 58 ANOVA Statistics for Total Organic Carbon**

Analysis of Variance for Total Organic Carbon

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| STATION | 3 | 26.22 | 8.74 | 2.48 | 0.062 |
| Error | 259 | 913.61 | 3.53 | | |
| Total | 262 | 939.83 | | | |

```
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level        N      Mean     StDev  -+---------+---------+---------+----
-
 15         73     3.289     1.506           (------*------)
 50         23     3.122     1.344  (------------*------------)
 75         72     4.022     2.397                     (------*------)
150         95     3.717     1.795                 (-----*-----)
                                    -+---------+---------+---------+----
-
Pooled StDev =     1.878           2.40      3.00      3.60      4.20
* NOTE * N missing = 1
```

**Table 59 Multiple Regression Statistics for Fecal Coliform at RR 1320**

The regression equation is
FECAL COLIFORM,MEMBR FILTER,M-F = 1774 - 0.0483 DATE + 0.540 FLOW

95 cases used 1 cases contain missing values

| Predictor | Coef | StDev | T | P |
|---|---|---|---|---|
| Constant | 1774 | 1750 | 1.01 | 0.313 |
| DATE | -0.04831 | 0.05388 | -0.90 | 0.372 |
| FLOW | 0.5397 | 0.3579 | 1.51 | 0.135 |

S = 675.8        R-Sq = 3.2%        R-Sq(adj) = 1.1%

Analysis of Variance

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Regression | 2 | 1405229 | 702615 | 1.54 | 0.220 |
| Residual Error | 92 | 42013081 | 456664 | | |
| Total | 94 | 43418311 | | | |

| Source | DF | Seq SS |
|---|---|---|
| DATE | 1 | 366726 |
| FLOW | 1 | 1038503 |

**Table 60 Multiple Regression Statistics for Fecal Coliform at Johnson City**

The regression equation is
FECAL COLIFORM,MEMBR FILTER,M-F = 6320 - 0.194 DATE + 1.31 FLOW

| Predictor | Coef | StDev | T | P |
|---|---|---|---|---|
| Constant | 6320 | 6768 | 0.93 | 0.354 |
| DATE | -0.1936 | 0.2127 | -0.91 | 0.366 |
| FLOW | 1.3077 | 0.7189 | 1.82 | 0.073 |

S = 1173        R-Sq = 5.6%        R-Sq(adj) = 2.9%

Analysis of Variance

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Regression | 2 | 5667955 | 2833978 | 2.06 | 0.135 |
| Residual Error | 69 | 94937923 | 1375912 | | |
| Total | 71 | 100605879 | | | |

| Source | DF | Seq SS |
|---|---|---|
| DATE | 1 | 1115080 |
| FLOW | 1 | 4552875 |

**Table 61 Multiple Regression Statistics for Fecal Coliform at RM 962**

The regression equation is
FECAL COLIFORM,MEMBR FILTER,M-F = 5317 - 0.150 DATE + 1.46 FLOW

22 cases used 1 cases contain missing values

| Predictor | Coef | StDev | T | P |
|---|---|---|---|---|
| Constant | 5317 | 9222 | 0.58 | 0.571 |
| DATE | -0.1504 | 0.2673 | -0.56 | 0.580 |
| FLOW | 1.461 | 1.055 | 1.38 | 0.182 |

S = 792.4 R-Sq = 11.8% R-Sq(adj) = 2.6%

Analysis of Variance

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Regression | 2 | 1601635 | 800817 | 1.28 | 0.302 |
| Residual Error | 19 | 11928952 | 627840 | | |
| Total | 21 | 13530587 | | | |

| Source | DF | Seq SS |
|---|---|---|
| DATE | 1 | 398784 |
| FLOW | 1 | 1202850 |

**Table 62 Multiple Regression Statistics for Fecal Coliform at Falls Creek**

The regression equation is
FECAL COLIFORM,MEMBR FILTER,M-F = 3589 - 0.106 DATE + 0.598 FLOW

71 cases used 2 cases contain missing values

| Predictor | Coef | StDev | T | P |
|---|---|---|---|---|
| Constant | 3589 | 10037 | 0.36 | 0.722 |
| DATE | -0.1063 | 0.3158 | -0.34 | 0.737 |
| FLOW | 0.5984 | 0.4040 | 1.48 | 0.143 |

S = 1694 R-Sq = 3.2% R-Sq(adj) = 0.4%

Analysis of Variance

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Regression | 2 | 6518103 | 3259051 | 1.14 | 0.327 |
| Residual Error | 68 | 195198893 | 2870572 | | |
| Total | 70 | 201716996 | | | |

| Source | DF | Seq SS |
|---|---|---|
| DATE | 1 | 221718 |
| FLOW | 1 | 6296384 |

## Table 63 ANOVA Statistics for Fecal Coliform

```
Source     DF         SS        MS        F        P
STATION     3     144190     48063     0.03    0.992
Error     255  359167039   1408498
Total     258  359311229
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N       Mean     StDev  -------+---------+---------+--------
-
 15        70        328      1709          (--------*--------)
 50        22        311       803   (---------------*---------------)
 75        72        332      1190          (--------*--------)
150        95        280       680         (-------*-------)
                                    -------+---------+---------+--------
-
Pooled StDev =      1187                  0       300       600
* NOTE * N missing = 5
```