Statistical Comparison of Total Phosphorus Data From the FDEP and SFWMD Labs in the Period of 2000-2004

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1. Introduction

Recently, Nichols and Zhou (2004)[12] performed a comparison study of the total phosphorus (TP) data from the FDEP and SFWMD labs for various split sample studies conducted between 2000 and 2004. Here is a summary of their study (parts **a-d**):

a) Data Set. Everglades Round Robin (ERR) Study[1], USGS Round Robins[2], ENRR Split Study[3], SFWMD Performance Study[4], EVPA Splits[5], SFWMD PE Study[6], SFWMD/USCOE C111 Split samples [7].

b) Statistical Method. All data for split samples was placed into a single spread sheet and plotted verses the data from the SFWMD lab [1-7]. Linear regression models were fitted to the total phosphorus (TP) data with FDEP TP as the dependent variable and the SFWMD TP as the independent variable. The data sets were condensed by removing the low concentration samples (below 16µg/L) and removing the high concentration samples (above 200µg/L). This was done to eliminate the potential large variation in values in samples at or below the PQL, and to remove the few (10-15) high concentration samples that might have been influenced by different dilution factors. After the removal of these data points, the data was graphed and regression was performed again. The data sets were then further isolated by separating the natural samples [1,3-7] from the synthetic (prepared) samples [2,7]. These two groups were plotted and analyzed using the same method as the complete data set.

c) Main Results.

- All SFWMD vs. FDEP data sets[1-7] correlated very well and showed a very small intercept (0.0015), near 100% slope (1.002) and high correlation coefficient (R^2= 0.9976). The slope of regression between all data sets from FDEP and SFWMD was slightly increased (1.0542) after removing the very low (<0.016 mg/L) and very high (>0.2 mg/L) concentration data points.

- After separating the synthetic[2,7] samples from natural samples, the regressions between true value (TV) and TP results from FDEP and from SFWMD were calculated, respectively. The TP results of synthetic samples of FDEP and those of SFWMD were almost identical and both agreed very well with the TV .

- The slope of regression between the TP results of natural samples[1,3-7] of FDEP and those of SFWMD was slightly elevated at 1.0555. The regression between the natural sample results from FDEP and SFWMD, after removing the low (<0.016 mg/L) and high (>0.2 mg/L) concentration data points, was similar to that of all TP natural data sets .

- When the natural sample data sets were sub-grouped into two sections: 0.016-0.1 and 0.1-0.2 mg/L, the intercept (0.0014) and slope (1.005) of regression between low TP (<0.1 mg/L) data sets of FDEP and those of SFWMD indicated that the low TP results from these two labs agreed reasonably well. **However, the intercept (0.0057) and slope (1.022) of regression between high TP concentrations (0.1-0.2 mg/L) data sets of the two labs implied that TP results from FDEP were slightly higher than those from SFWMD in the 0.1-0.2 mg/L TP region. If a sample TP concentration from SFWMD lab was 0.1 mg/L, the calculated TP concentration from FDEP lab using the regression equations from low and high TP sections would be 0.1019 and 0.1079 mg/L, respectively.**

d) Methodology for TP Analysis. SFWMD[10] and the FDEP lab uses a very similar digestion [8,9] method and instrumentation, with FDEP having a slightly higher final acid concentration for samples with a TP concentration below 0.2 mg/L. From some previous studies (Zhou and Struve, 2004)[11], both final acid concentrations are within optimum concentration range for TP analysis. Zhou and Struve, (2004)[11] results) also indicated that the digestion method from both labs would recover near 100% TP from the Everglades samples even with relatively high sediment content.

Comments on Nichols and Zhou's Study and Recommendations:

1) **The FDEP and SFWMD TP data were combined from different studies. Each data pair in the data set may be taken at a different site and time. That is, the entire data set is not from the same population.**

2) **Fitting simple linear regression models is a scientifically sound way to study the relationships between FDEP TP measurements and SFWMD TP measurements. However, the regression analysis needs to be performed correctly and the fitted models needs to be interpreted carefully.**

3) **A logarithm transformation should be explored for both the FDEP TP data and the SFWMD TP data before fitting a regression model since it is well know that many environmental measurements such as TP follow a skewed (approximately log-normal?) distribution. Without the transformation, the estimated intercept and slope may be biased and not consistent. The fitted lines may not the "correct" lines.**

4) **Instead of simply interpreting the estimated coefficients, 95% confidence intervals (CI) for the intercept and slope should be constructed. If the 95% CI for the intercept contains zero, we will not reject the null hypothesis of the intercept being zero at the α =0.05 confidence level. Similarly, if the 95% CI for the slope contains one, we will not reject the null hypothesis of the slope being one at the α =0.05 confidence level.**

5) **It will be dangerous and statistically incorrect to make conclusions (such as one lab has higher or lower measurements than another) only based on a few samples. For a more thoroughly investigation of differences among labs on TP analysis (or other parameters), paired-comparison experiments need to be designed carefully and statistical analysis needs to be performed correctly for this purpose.**

In this study, we perform a statistical comparison of total phosphorus (TP) data from the FDEP and SFWMD Labs using the same data set in Nichols and Zhou (2004). Following the approach used in Nichols and Zhou (2004), TP values below the minimum detection limit (MDL) were replaced by half of the MDL and the data set is split into the following groups:

1) All TP data with 423 observations;

2) TP Data between 0.016 mg/L and 0.2 mg/L (both lab values are "0.016 mg/L or up" and below 0.2 mg/L, sample size n=165);

3) Natural TP samples with 332 observations;

4) Natural TP samples between 0.016 mg/L and 0.2 mg/L (both lab values are "0.016 mg/L or up" and below 0.2 mg/L, sample size n=97);

5) Natural TP samples between 0.016 mg/L and 0.1 mg/L (both lab values are "0.016 mg/L or up" and below 0.1 mg/L, sample size n= 70);

6) Natural TP samples between 0.1 mg/L and 0.2 mg/L (both lab values are "0.1 mg/L or up" and below 0.2 mg/L, sample size n=27);

7) TP Data 0.02 mg/L or up with n=170 observations.

Moreover, a low-level TP data comparison between FDEP and SFWMD is also carried out in this study. For this low-level comparison, TP data below 0.020 mg/L from the two labs are used.

The rest of this report is organized as follows. Section 2 reviews some basic assumptions on linear regression models and statistical inferences based on a fitted linear model. Sections 3 presents the results of our analysis, including regression models for the original TP data and for the TP data after the natural logarithm transformation. For data sets 1-7, the regression models based on the transformed TP data are recommended. For the low-level TP data comparison (TP values below 0.02 mg/L), graphical plots (histogram and Q-Q normal plot in Figure 13) show that the residuals from the regression model of original data appears closer to a normal distribution (symmetric shape of the histogram and a relatively straight line of the Q-Q normal plot). This is not surprising since we use a right-truncated data set in which the right tail of a skewed distribution is cut. For this case, we recommend using the regression model based on the untransformed TP data. Summary and conclusions in this study are given in Section 4.

2. Linear Regression.

a) Model and Assumptions.

Regression is widely used to study relationships between a response variable and a group of predictor variables. Linear regression is a special class of regression models, namely those relationships can be described by straight lines or by generalizations of straight lines to many dimensions. Regression techniques have been applied in almost every field of study, including social sciences, physical and biological sciences, business and technology, and humanities. Let $\{ y_i, i = 1, \cdots, n \}$ be the observations from a response variable, and $\{ (x_{1i}, \cdots, x_{pi}),\ \ i = 1, \cdots, n \}$ be the observations from predictors $(x_1, \cdots, x_p)$. Then a general linear regression model has the form:

$$y_i = \beta_0 + \beta_1 x_{1i} + \cdots + \beta_p x_{pi} + \varepsilon_i, \quad i = 1, \cdots, n, \tag{1}$$

where $(\beta_0,\ \beta_1, \cdots, \beta_p)$ are unknown parameters.

When only one predictor variable is available, we have the simple regression model:

$$y_i = \beta_0 + \beta_1 x_i + \varepsilon_i, \quad i = 1, \cdots, n, \tag{2}$$

where β_0 is the intercept and β_1 is the slope of the simple regression line.

In a regression model, ε_i is called the random noise (or random error) term. The most common assumptions on the random error term are:

1) $(\varepsilon_1, \cdots, \varepsilon_n)$ **are independent;**
2) $(\varepsilon_1, \cdots, \varepsilon_n)$ **are normally distributed;**
3) $(\varepsilon_1, \cdots, \varepsilon_n)$ **have mean zero and common variance** σ^2**.**

When $\{(x_{1i}, \cdots, x_{pi}; \quad y_i), \ i = 1, \cdots, n\}$ are available and the three assumption are satisfied, the unknown parameters ($\beta_0, \ \beta_1, \cdots, \beta_p$) can be estimated by the well-known least squares method (see, e.g., Weisberg, 1985[13], Chapters 1 and 2). The estimated parameters will be denoted by ($\hat{\beta}_0, \ \hat{\beta}_1, \cdots, \hat{\beta}_p$).

When either assumption 2 (normality) or assumption 3 (constant variance) or both assumptions are not valid, transformations are usually applied to the response and predictor variables, making the variables normally distributed and with constant variance (at least approximately). If the first assumption is not valid, such as time series data or spatial data, the maximum likelihood method, instead of the least squares method, should be used to estimated the unknown parameters.

b) Residual Plots for checking the three assumptions.

For a fitted regression model, residuals $(\hat{\varepsilon}_1, \cdots, \hat{\varepsilon}_n)$ can be calculated by the formula:

$$\hat{\varepsilon}_i = y_i - \hat{\beta}_0 + \hat{\beta}_1 x_{1i} + \cdots + \hat{\beta}_p x_{pi}, \quad i = 1, \cdots, n. \tag{3}$$

The following plots are usually used for graphically checking the three assumptions on the model:

- **Histogram.** Histogram of the residuals is used to describe the shape of the random error's distribution, such as skewed or not, potential outliers.

- **Q-Q Normal Plot.** This is a plot of the quantiles of the residuals against the quantile of a sample from a normal distribution. If the plot shows a straight line, the random errors have a normal distribution.

- **Residuals vs fitted values plot.** This plot can be used to check possible non-linearity relationship between the response variable and the predictors. The plot can also be used to check whether the variances of the random errors are constant or not. For example, if one part of the residuals spreads wider than other parts, variances of the random errors are not constant.

In our study, a simple regression model may be used to compare the FDEP and SFWMD TP measurements. Since it is well know that many environmental measurements such as TP follow a skewed (approximately log-normal?) distribution, regression models should be fitted to the TP data after appropriate transformations. Otherwise, the estimated intercept and slope are not the best estimates (may be biased and not consistent) and their estimated standard error are not correct. In other words, the fitted lines are not the "correct" lines.

c) Model Interpretations.

After the best-fitted regression model is chosen for a study, the fitted model needs to be interpreted carefully. For example, if the SFWMD and FDEP TP data are correlated perfectly, we expect the estimated intercept will not be different from zero and the estimated slope will not be different from one. Instead of simply looking at the estimated coefficients, formal statistical tests need to be applied.

The intercept and slope in a simple regression model between the FDEP TP data and the SFWMD TP data can be tested by the following procedure:

Null Hypothesis for the Intercept: $H_0: \quad \beta_0 = 0,$ (4)

Alternative Hypothesis for the Intercept: $H_a: \quad \beta_0 \neq 0$, (5)

When the random errors are normally distributed, the test statistic $T_0 = \hat{\beta}_0 / se(\hat{\beta}_0)$ has a *t*-distribution with (n-2) degrees of freedom, where $se(\hat{\beta}_0)$ is the standard error of the estimated intercept $\hat{\beta}_0$ and *n* is the number of observations (sample size).

Similarly, we may test the hypotheses on the slope:

Null Hypothesis for the Intercept: $H_0: \quad \beta_1 = 1$, (6)

Alternative Hypothesis for the Intercept: $H_a: \quad \beta_1 \neq 1$, (7)

When the random errors are normally distributed, the test statistic $T_1 = (\hat{\beta}_1 - 1) / se(\hat{\beta}_0)$ has a *t*-distribution with (n-2) degrees of freedom, where $se(\hat{\beta}_1)$ is the standard error of the estimated intercept $\hat{\beta}_1$ and *n* is the number of observations (sample size). The p-value (also called the observed significance level) of the test can be calculated based on the T_1 value and the *t*-distribution with (n-2) degrees of freedom. If the p-value is less than a given significance level α, we reject the null hypothesis with (1-α)100% confidence. Otherwise, we will not reject the null hypothesis at this significance level.

An equivalent way of testing hypotheses on the intercept and slope is constructing confidence intervals based on the sample. For a given significance level α, a (1-α)100% confidence interval for the true intercept is

$$\hat{\beta}_0 - t(\alpha, n-2)\, se(\hat{\beta}_0) \leq \beta_0 \leq \hat{\beta}_0 + t(\alpha, n-2)\, se(\hat{\beta}_0), \tag{8}$$

where $t(\alpha, n-2)$ is the critical value of a *t*-distribution with *(n-2)* degrees of freedom and $se(\hat{\beta}_0)$ is the standard error of the estimated intercept $\hat{\beta}_0$ (see, e.g., Weisberg, 1985[13], Chapter 1). **If the 95% confidence interval of β_0 contains zero, the true intercept is not different from zero statistically at the significance level α =0.05.**

Similarly, a (1- α)100% confidence interval for the true slope can be constructed as

$$\hat{\beta}_1 - t(\alpha, n-2)\, se(\hat{\beta}_1) \le \beta_1 \le \hat{\beta}_1 + t(\alpha, n-2)\, se(\hat{\beta}_1)\,, \tag{9}$$

where $se(\hat{\beta}_1)$ is the standard error of the estimated intercept $\hat{\beta}_1$. **If the 95% confidence interval of β_1 contains one, the true slope of the regression is not different from one statistically at the significance level α =0.05.**

3. Some Results

a) All TP Data.

Table 1. Fitted Regression Models for the All TP Data Sets From FDEP and SFWMD

FDEP TP on SFWMD TP (Original Measurements)				
	Value	Std. Error	t-Value	p-Value
Intercept	0.0010	0.0003	3.5872	0.0004
SFWMD TP	1.0105	0.0024	428.5314	0.0000
R^2 = 0.9977 N = 423 95% CI for intercept: [0.00045, 0.00154] 95% CI for slope: [1.00586, 1.01513] p-value for testing slope is 1: 0.000011				
FDEP log(TP) on SFWMD log(TP) (After the Natural Logarithm Transformation)				
	Value	Std. Error	t-Value	p-Value
Intercept	-0.0233	0.0531	-0.4399	0.6602
SFWMD log(TP)	0.9870	0.0124	76.6809	0.0000
R^2 = 0.9378 N = 423 **95% CI for intercept: [-0.12762, 0.08094]** **95% CI for slope: [0.96261, 1.01130]** **p-value for testing slope is 1: 0.29281**				

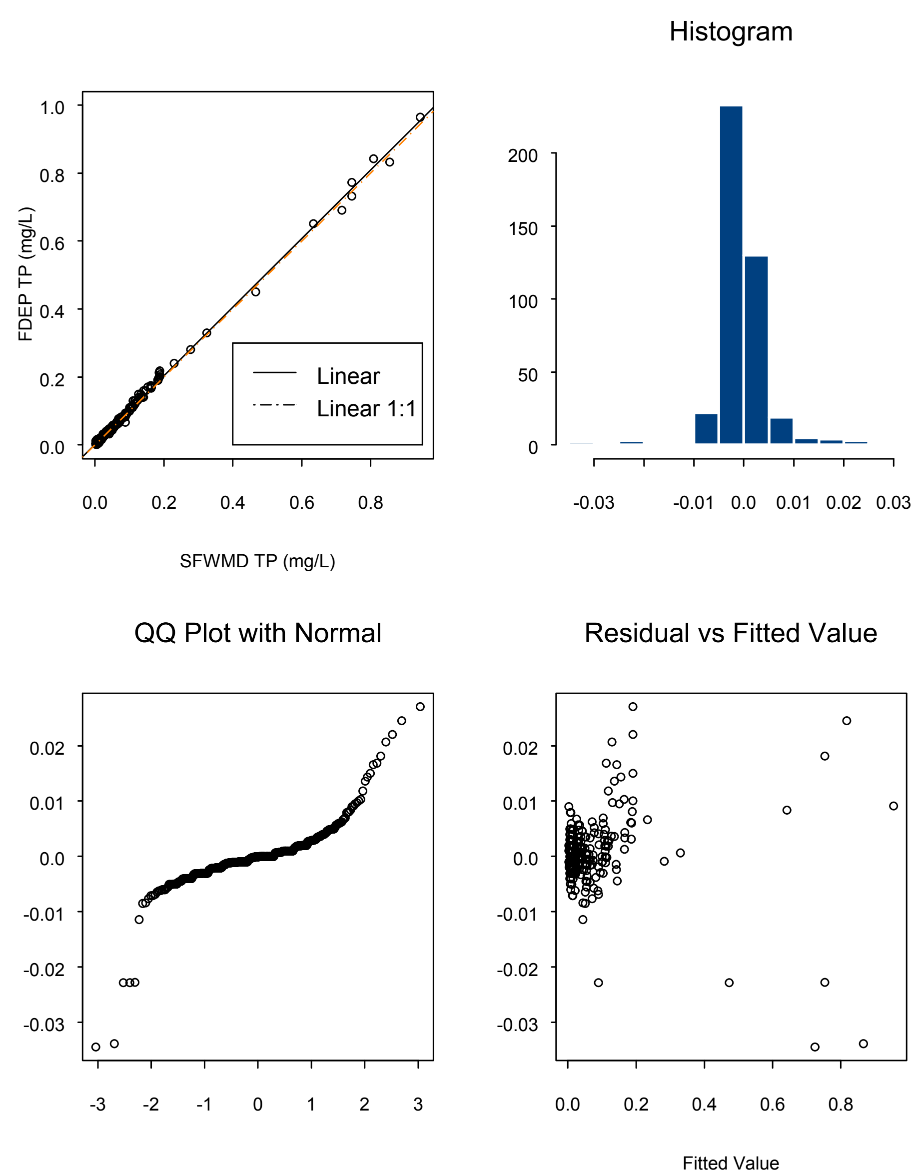
Conclusions based on the linear regression model of FDEP log(TP) on SFWMD log(TP):

- **The intercept of the regression is not different from 0 statistically since the 95% confidence interval for intercept contains 0.**

- **The slope of the regression is not different from 1 statistically since the 95% confidence interval for slope contains 1.**

Comments on plots: After the logarithm transformation, the histogram (Figure 2, top left) shows that the data are relatively symmetric, but the sample is still not perfectly normal (Figure 2, bottom right), and the variance is not constant (Figure 2, bottom left) since the data were not from the same population.

Figure 1. All TP data sets from FDEP and SFWMD (Original Measurements)



Note: the linear 1:1 line is SFWMD TP versus itself.

Figure 2. All log(TP) Data sets from FDEP and SFWMD
(After the logarithm transformation)

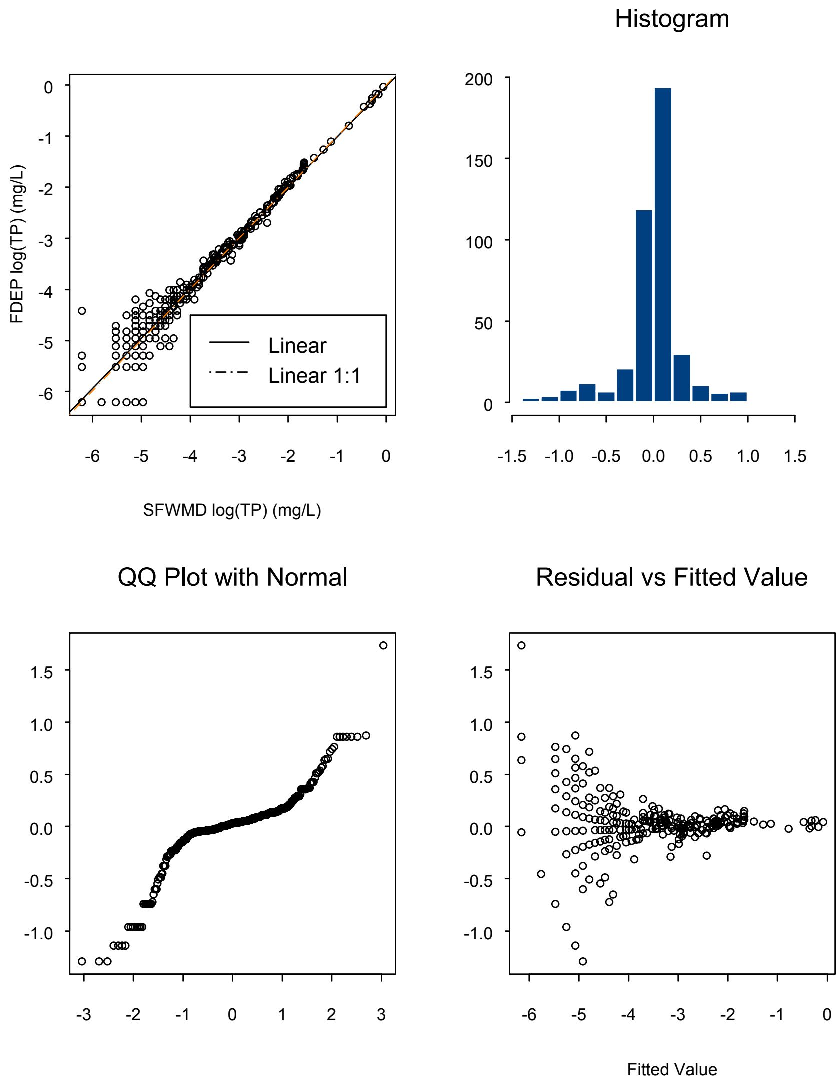


Table 2. Fitted Regression Models for the All TP Data Sets
From FDEP and SFWMD
(Values Between 0.016-0.2 mg/L)

FDEP TP on SFWMD TP (Original Measurements)				
	Value	Std. Error	t-Value	p-Value
Intercept	-0.0009	0.0006	-1.5177	0.1310
SFWMD TP	1.0522	0.0081	129.7687	0.0000
R^2 = 0.9904 N = 165 95% CI for intercept: [-0.00217, 0.00028] 95% CI for slope: [1.03617, 1.06819] p-value for testing slope is 1: 1.312×10^{-9}				
FDEP log(TP) on SFWMD log(TP) (After the Natural Logarithm Transformation)				
	Value	Std. Error	t-Value	p-Value
Intercept	0.0212	0.0268	0.7905	0.4304
SFWMD log(TP)	0.9959	0.0087	113.9751	0.0000
R^2 = 0.9857 N = 165 **95% CI for intercept: [-0.03171, 0.07406]** **95% CI for slope: [0.97864, 1.01318]** **p-value for testing slope is 1: 0.64042**				

Conclusions based on the linear regression model of FDEP log(TP) on SFWMD log(TP):

- **The intercept of the regression is not different from 0 statistically since the 95% confidence interval for intercept contains 0.**

- **The slope of the regression is not different from 1 statistically since the 95% confidence interval for slope contains 1.**

Comments on plots: When data are restricted to the range from 0.016 mg/L to 0.2 mg/L, the data appears to be normally distributed (Figure 4, top left and bottom right), and the variance appears to be constant (Figure 4, bottom left).

Figure 3. 0.016-0.2 mg/L TP data sets from FDEP and SFWMD (Original Measurements)

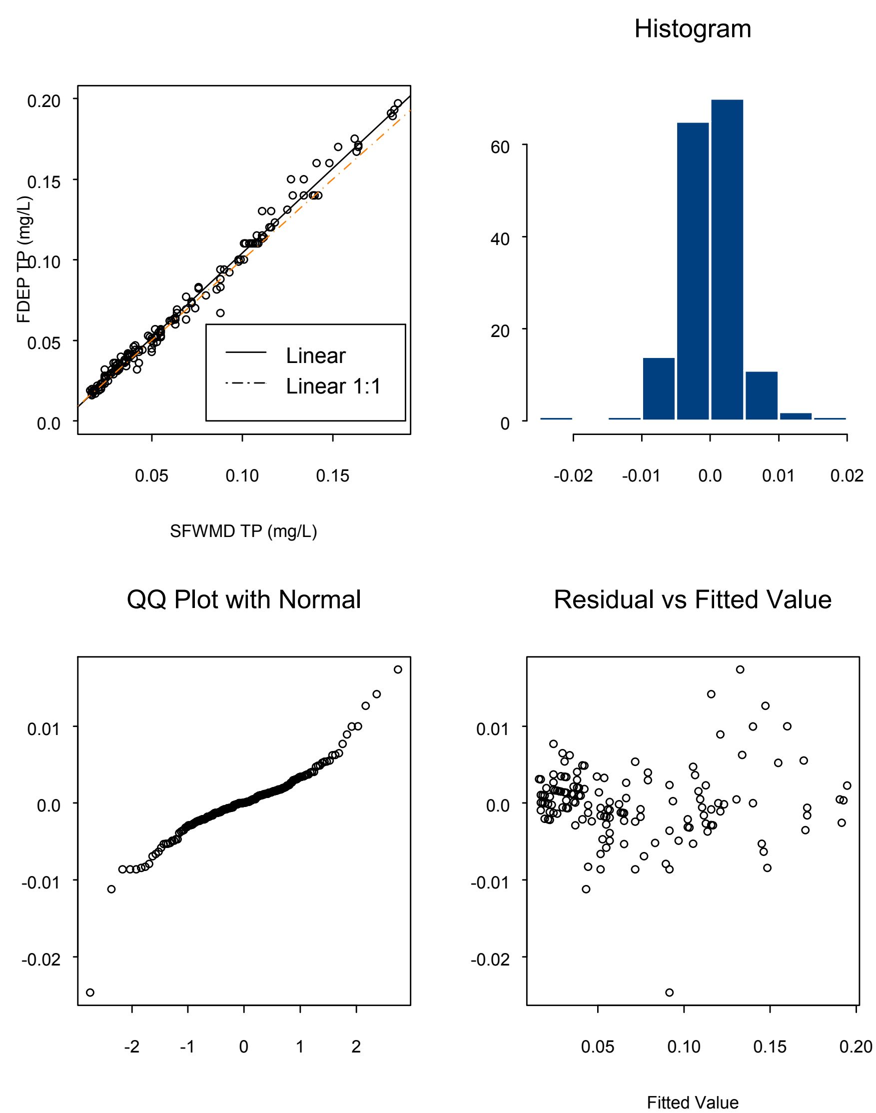
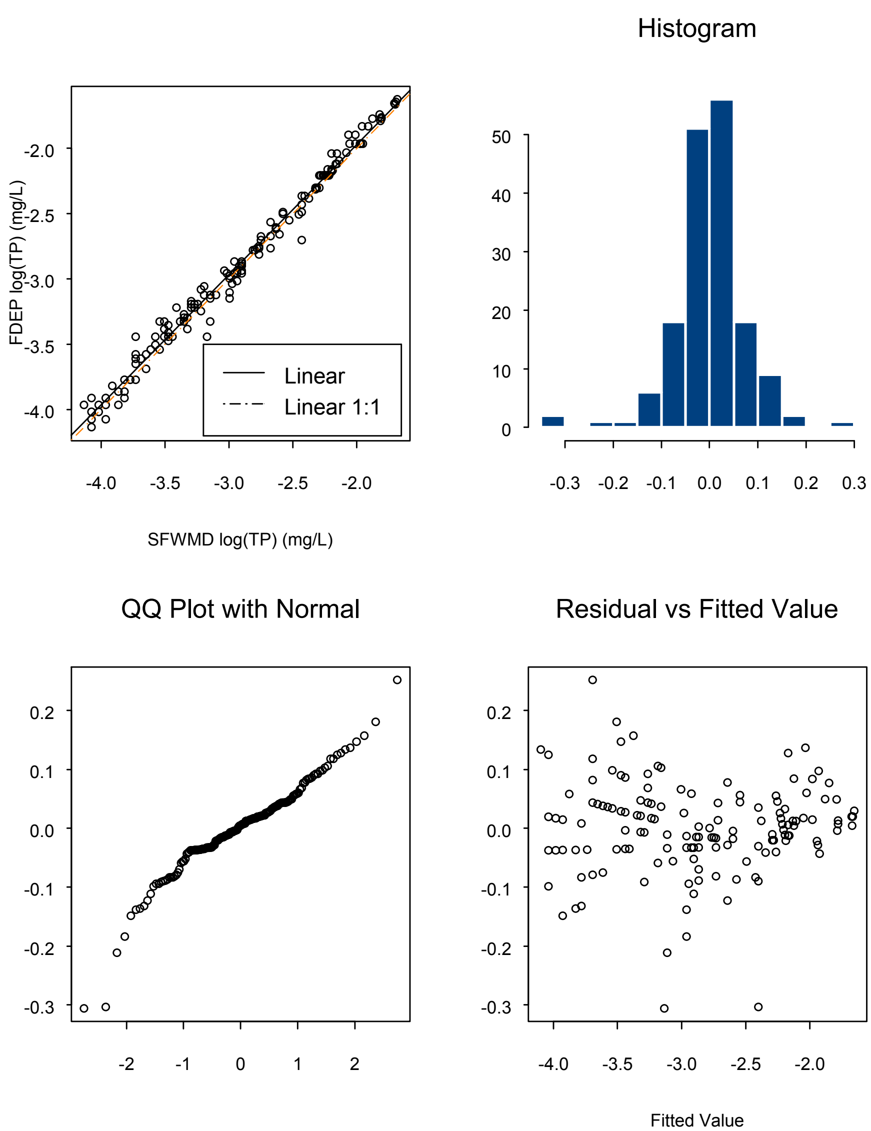


Figure 4. 0.016-0.2 mg/L log(TP) Data sets from FDEP and SFWMD (After the logarithm transformation)



b) Natural Samples.

Table 3. Fitted Regression Models for the **Natural Sample** TP Data Sets From FDEP and SFWMD

FDEP TP on SFWMD TP (Original Measurements)				
	Value	Std. Error	t-Value	p-Value
Intercept	0.00003	0.0002	0.1317	0.8953
SFWMD TP	1.0581	0.0045	234.8364	0.0000
$R^2 = 0.9941$ N = 332 95% CI for intercept: [-0.00043, 0.00049] 95% CI for slope: [1.04927, 1.06699] p-value for testing slope is 1: 0.0				

FDEP log(TP) on SFWMD log(TP) (After the Natural Logarithm Transformation)				
	Value	Std. Error	t-Value	p-Value
Intercept	-0.0244	0.0797	-0.3054	0.7602
SFWMD log(TP)	0.9867	0.0176	56.2087	0.0000
$R^2 = 0.9054$ N = 332 **95% CI for intercept: [-0.18119, 0.13249]** **95% CI for slope: [0.95220, 1.02127]** **p-value for testing slope is 1: 0.45052**				

Conclusions based on the linear regression model of FDEP log(TP) on SFWMD log(TP):

- **The intercept of the regression is not different from 0 statistically since the 95% confidence interval for intercept contains 0.**

- **The slope of the regression is not different from 1 statistically since the 95% confidence interval for slope contains 1.**

Figure 5. Natural sample TP data sets from FDEP and SFWMD (Original Measurements)

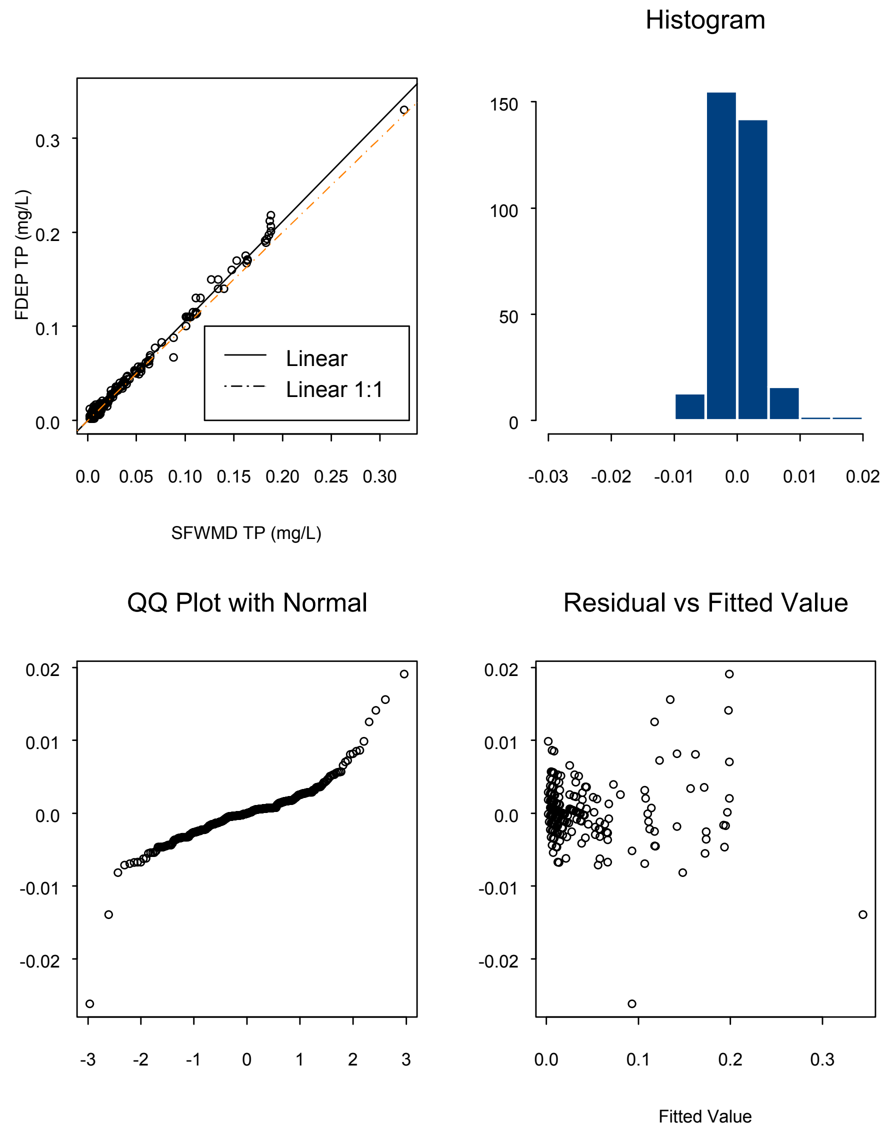


Figure 6. Natural sample log(TP) Data sets from FDEP and SFWMD (After the logarithm transformation)

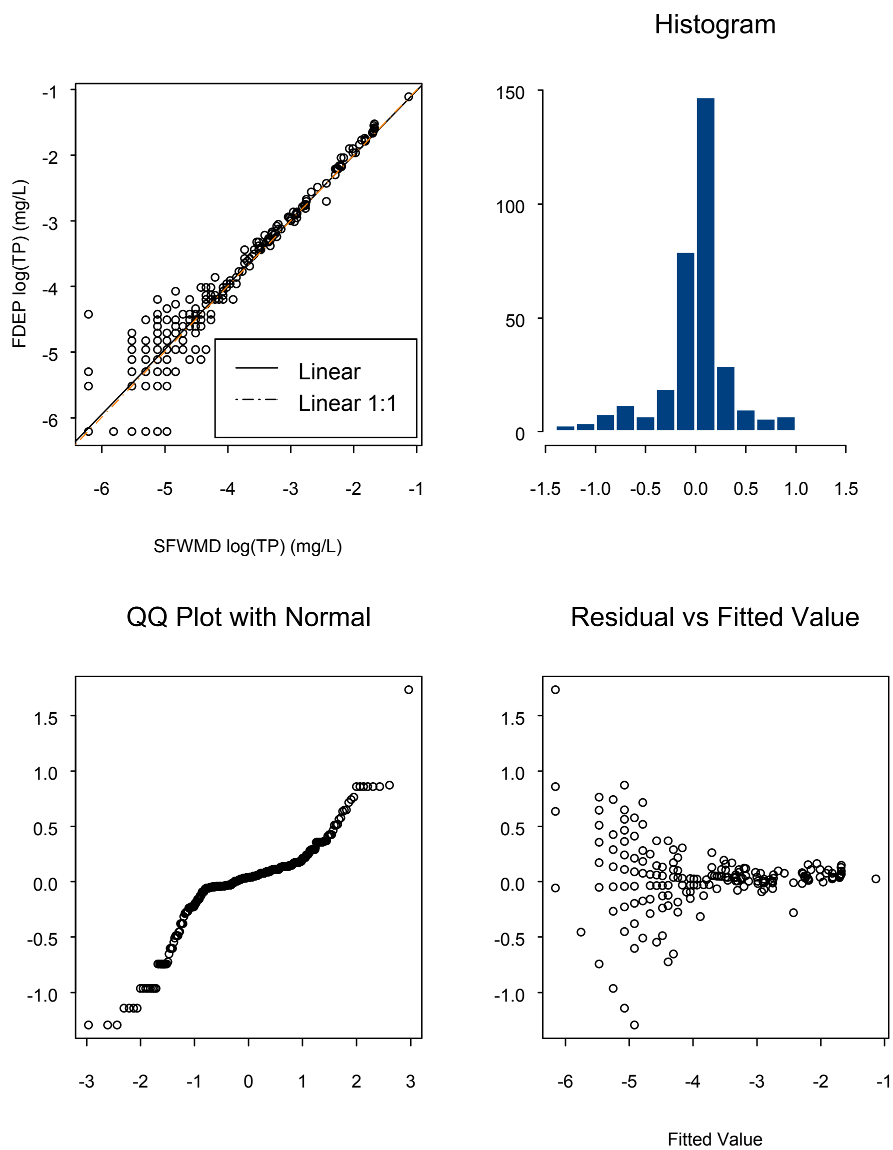


Table 4. Fitted Regression Models for the Natural Sample TP Data Sets
From FDEP and SFWMD
(Values Between 0.016-0.2 mg/L)

FDEP TP on SFWMD TP (Original Measurements)				
	Value	Std. Error	t-Value	p-Value
Intercept	-0.0002	0.0008	-0.1996	0.4304
SFWMD TP	1.0552	0.0099	106.0791	0.0000

R^2 = 0.9916
N = 97
95% CI for intercept: [-0.00176, 0.00144]
95% CI for slope: [1.03548, 1.07498]
p-value for testing slope is 1: 2.557×10^{-7}

FDEP log(TP) on SFWMD log(TP) (After the Natural Logarithm Transformation)				
	Value	Std. Error	t-Value	p-Value
Intercept	0.0421	0.0315	1.3380	0.1841
SFWMD log(TP)	0.9973	0.0103	96.4617	0.0000

R^2 = 0.9899
N = 97
95% CI for intercept: [-0.02038, 0.10464]
95% CI for slope: [0.97676, 1.01781]
p-value for testing slope is 1: 0.79365

Conclusions based on the linear regression model of FDEP log(TP) on SFWMD log(TP):

- **The intercept of the regression is not different from 0 statistically since the 95% confidence interval for intercept contains 0.**
- **The slope of the regression is not different from 1 statistically since the 95% confidence interval for slope contains 1.**

Figure 7. 0.016-0.2 mg/L TP data sets from FDEP and SFWMD
(Natural Samples; Original Measurements)

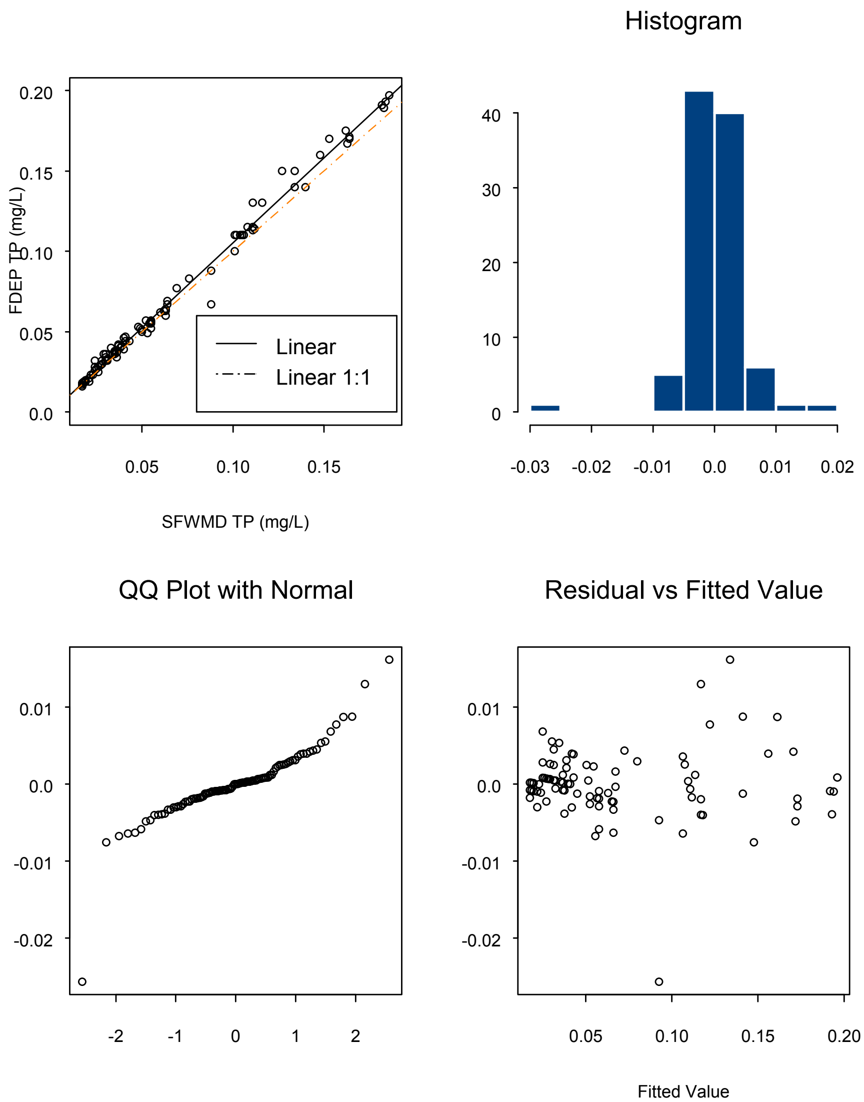


Figure 8. 0.016-0.2 mg/L log(TP) Data sets from FDEP and SFWMD (Natural Samples; After the logarithm transformation)

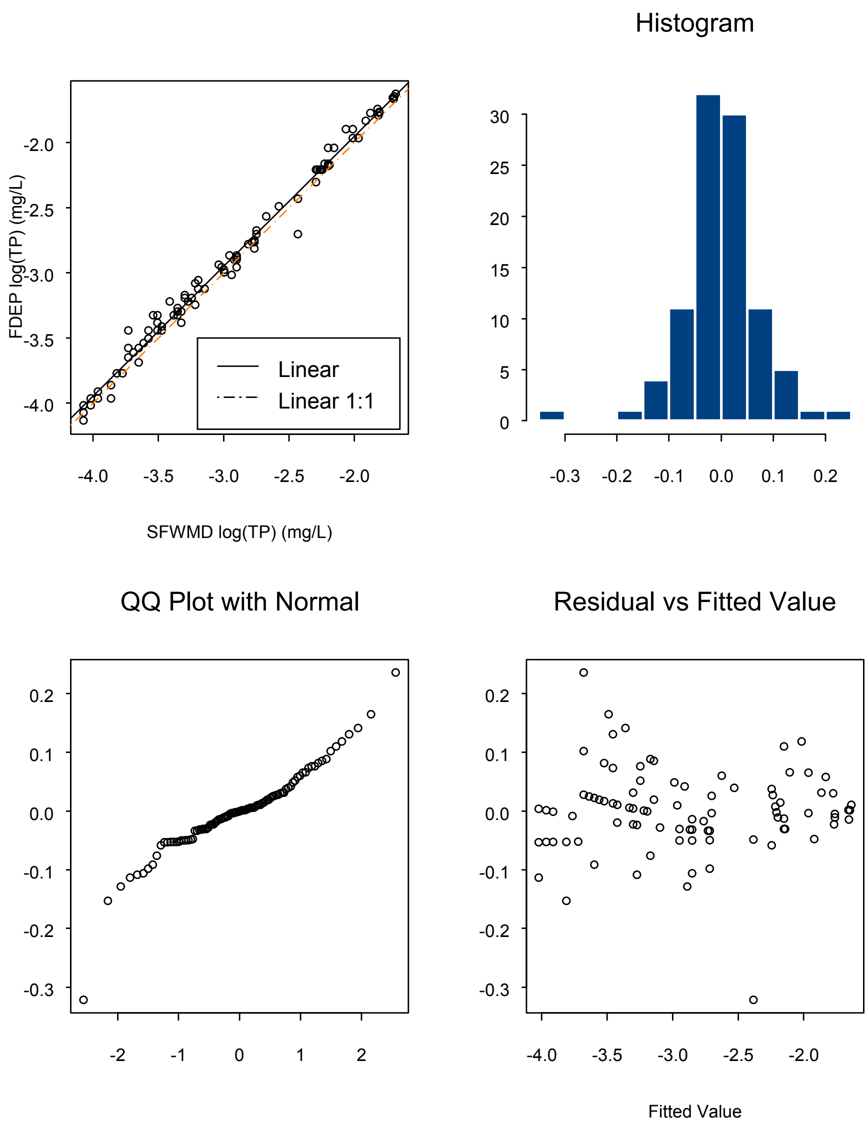


Table 5. Fitted Regression Models for the **Natural Sample** TP Data Sets
From FDEP and SFWMD (0.016-0.1 mg/L)

FDEP TP on SFWMD TP (Original Measurements)				
	Value	Std. Error	t-Value	p-Value
Intercept	0.0034	0.0011	3.0735	0.0030
SFWMD TP	0.9551	0.0257	37.2199	0.0000
R^2 = 0.9532 N = 70 95% CI for intercept: [0.00119, 0.00562] 95% CI for slope: [0.90388, 1.00629] p-value for testing slope is 1: 0.08458				
FDEP log(TP) on SFWMD log(TP) (After the Natural Logarithm Transformation)				
	Value	Std. Error	t-Value	p-Value
Intercept	-0.0655	0.0716	-0.9149	0.3635
SFWMD log(TP)	0.9663	0.0214	45.2447	0.0000
R^2 = 0.9678 N = 70 **95% CI for intercept: [-0.20840, 0.07737]** **95% CI for slope: [0.92370, 1.00893]** **p-value for testing slope is 1: 0.11939**				

Conclusions based on the linear regression model of FDEP log(TP) on SFWMD log(TP):

- **The intercept of the regression is not different from 0 statistically since the 95% confidence interval for intercept contains 0.**

- **The slope of the regression is not different from 1 statistically since the 95% confidence interval for slope contains 1.**

Figure 9. 0.016-0.1 (mg/L) TP data sets from FDEP and SFWMD (Natural Samples; Original Measurements)

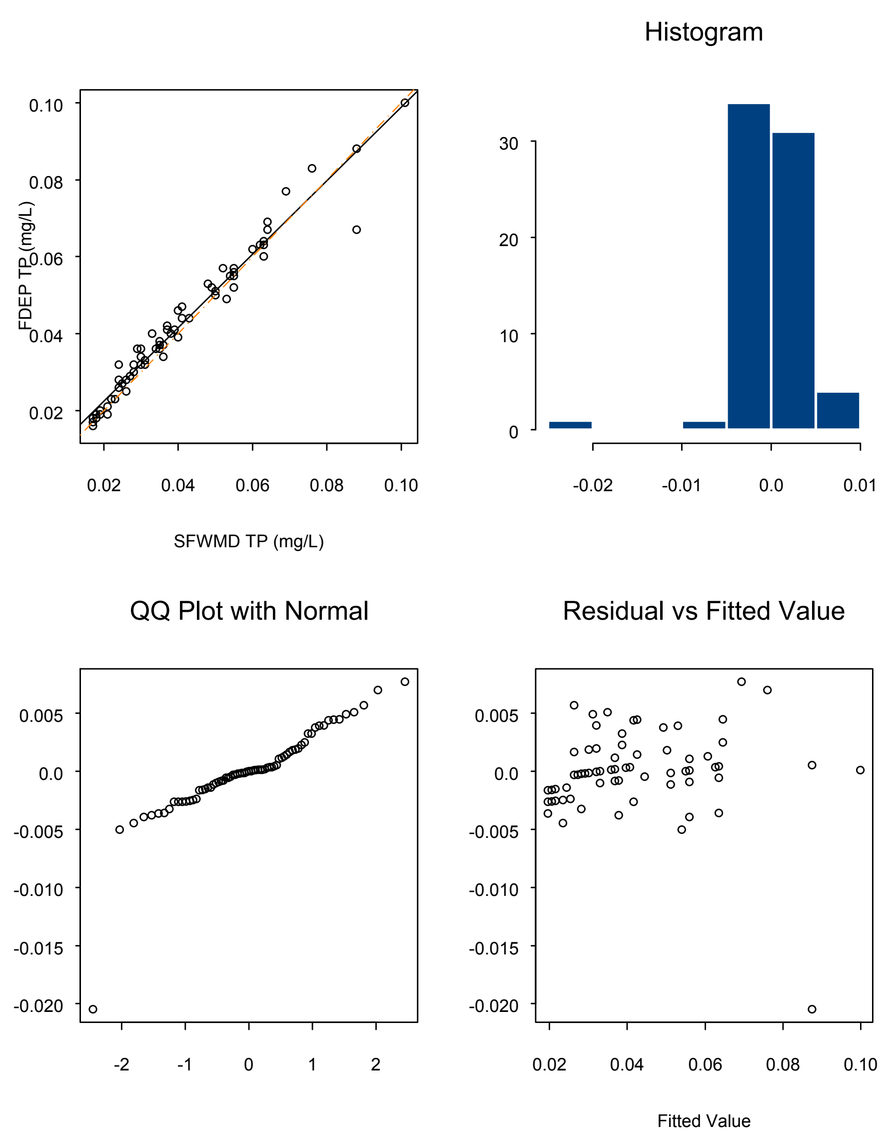


Figure 10. Natural sample log(TP) Data sets from FDEP and SFWMD (After the logarithm transformation)

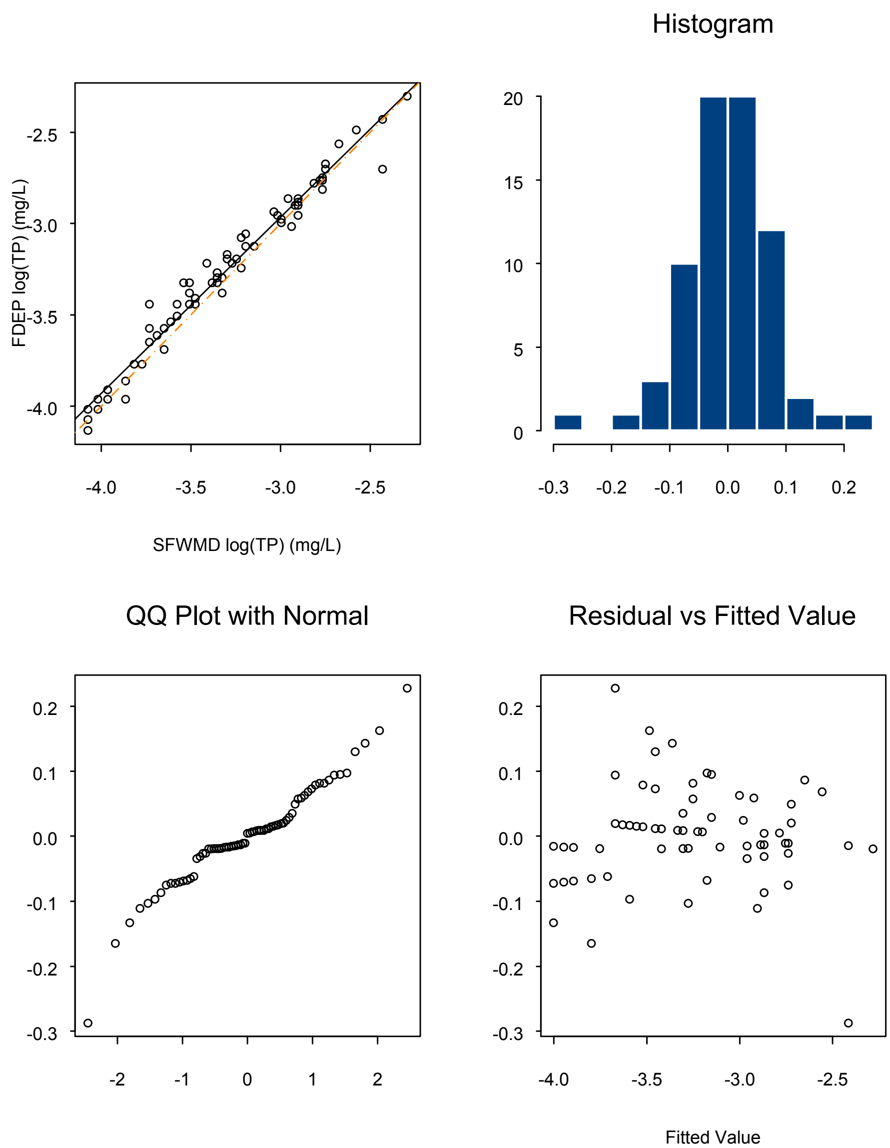


Table 6. Fitted Regression Models for the **Natural Sample** TP Data Sets
From FDEP and SFWMD (0.10-0.20 mg/L)

FDEP TP on SFWMD TP (Original Measurements)				
	Value	Std. Error	t-Value	p-Value
Intercept	0.0037	0.0052	0.7126	0.4827
SFWMD TP	1.0339	0.0380	27.2167	0.0000
R^2 = 0.9674 N = 27 95% CI for intercept: [-0.00702, 0.01445] 95% CI for slope: [0.95569, 1.11217] p-value for testing slope is 1: 0.38028				

FDEP log(TP) on SFWMD log(TP) (After the Natural Logarithm Transformation)				
	Value	Std. Error	t-Value	p-Value
Intercept	0.0349	0.0794	0.4399	0.6638
SFWMD log(TP)	0.9878	0.0388	25.4463	0.0000
R^2 = 0.9628 N = 27 **95% CI for intercept: [-0.12858, 0.19842]** **95% CI for slope: [0.90783, 1.06772]** **p-value for testing slope is 1: 0.75545**				

Conclusions based on the linear regression model of FDEP log(TP) on SFWMD log(TP):

- **The intercept of the regression is not different from 0 statistically since the 95% confidence interval for intercept contains 0.**

- **The slope of the regression is not different from 1 statistically since the 95% confidence interval for slope contains 1.**

Figure 11. 0.1-0.2 mg/L TP data sets from FDEP and SFWMD (Natural Samples; Original Measurements)

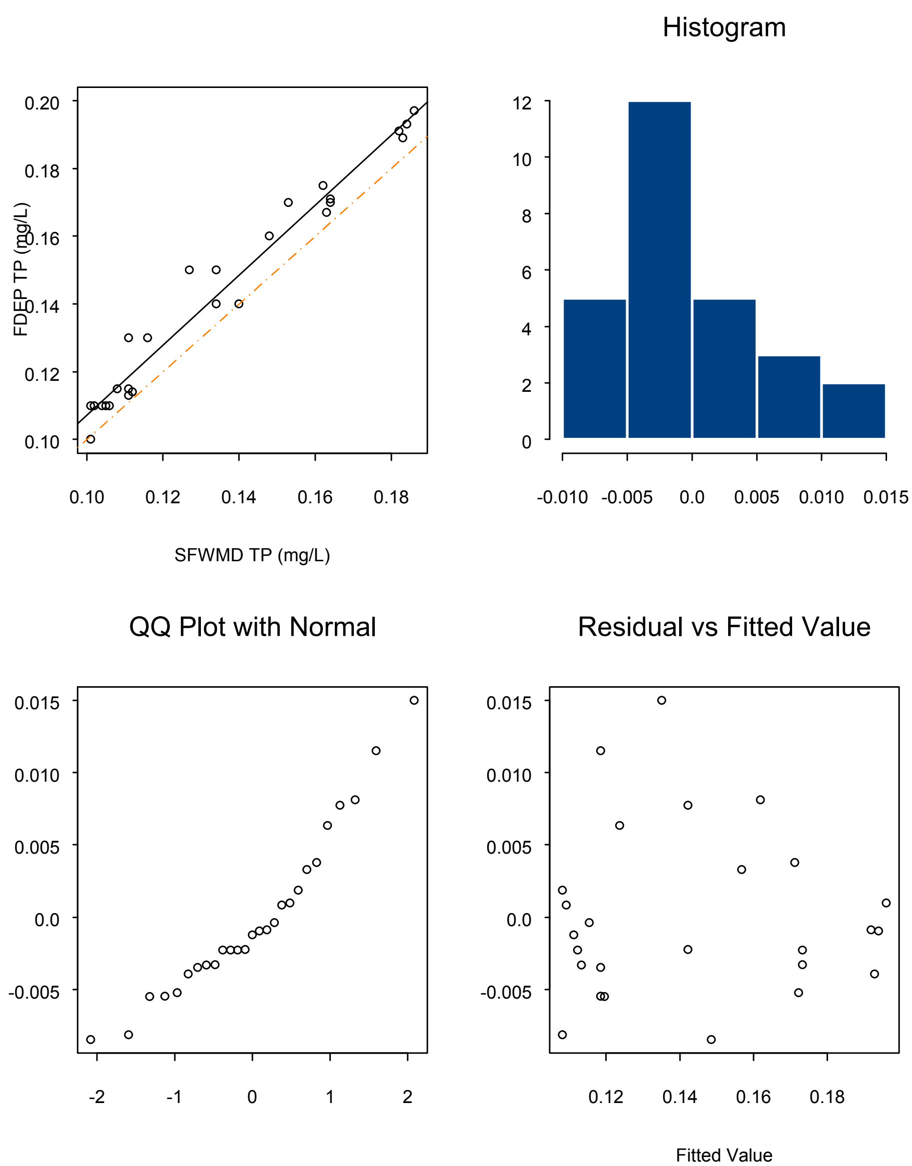


Figure 12. Natural sample log(TP) Data sets from FDEP and SFWMD
(After the logarithm transformation)

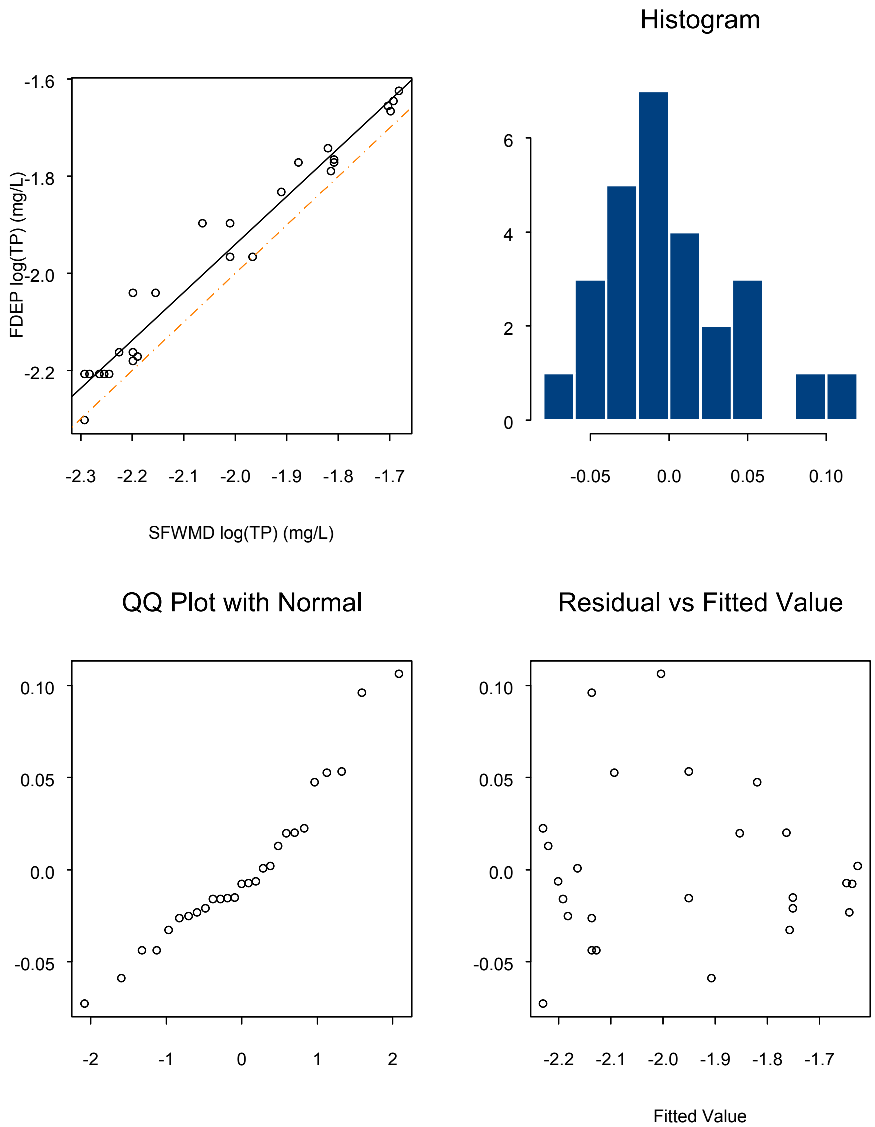


Table 7. Fitted Regression Models for the TP Data Sets
From FDEP and SFWMD
(Both lab TP values are less than 0.020 mg/L)

FDEP TP on SFWMD TP (Original Measurements)				
	Value	Std. Error	t-Value	p-Value
Intercept	0.0010	0.0003	2.9823	0.0031
SFWMD TP	0.9339	0.0383	24.4100	0.0000

R^2 = 0.7036
N = 253
95% CI for intercept: [0.000338, 0.00165]
95% CI for slope: [0.85858, 1.00929]
p-value for testing slope is 1: 0.0854

FDEP log(TP) on SFWMD log(TP) (After the Natural Logarithm Transformation)				
	Value	Std. Error	t-Value	p-Value
Intercept	-0.7132	0.2529	-2.8195	0.0052
SFWMD log(TP)	0.8516	0.0505	16.8775	0.0000

R^2 = 0.5316
N = 253
95% CI for intercept: [-1.21132, -0.21501]
95% CI for slope: [0.75223, 0.95098]
p-value for testing slope is 1: 0.00358

Comments on the regression: Since the TP data are right truncated at the 0.020 mg/L level, residuals from the regression model for the original data appear closer to a normal distribution than the residuals from the regression model for the transformed data (histogram and Q-Q normal plots in Figure 13 and Figure 14). For this right truncated data set, I suggest using the regression model for the original data.

Conclusions: based on the linear regression model of FDEP TP on SFWMD TP:

- **The intercept of the regression is different from 0 statistically since the 95% confidence interval for intercept does not contain 0.**
- **The slope of the regression is not different from 1 statistically since the 95% confidence interval for slope contains 1.**

Figure 13. Less than 0.020 (mg/L) TP data sets from FDEP and SFWMD (Original Measurements)

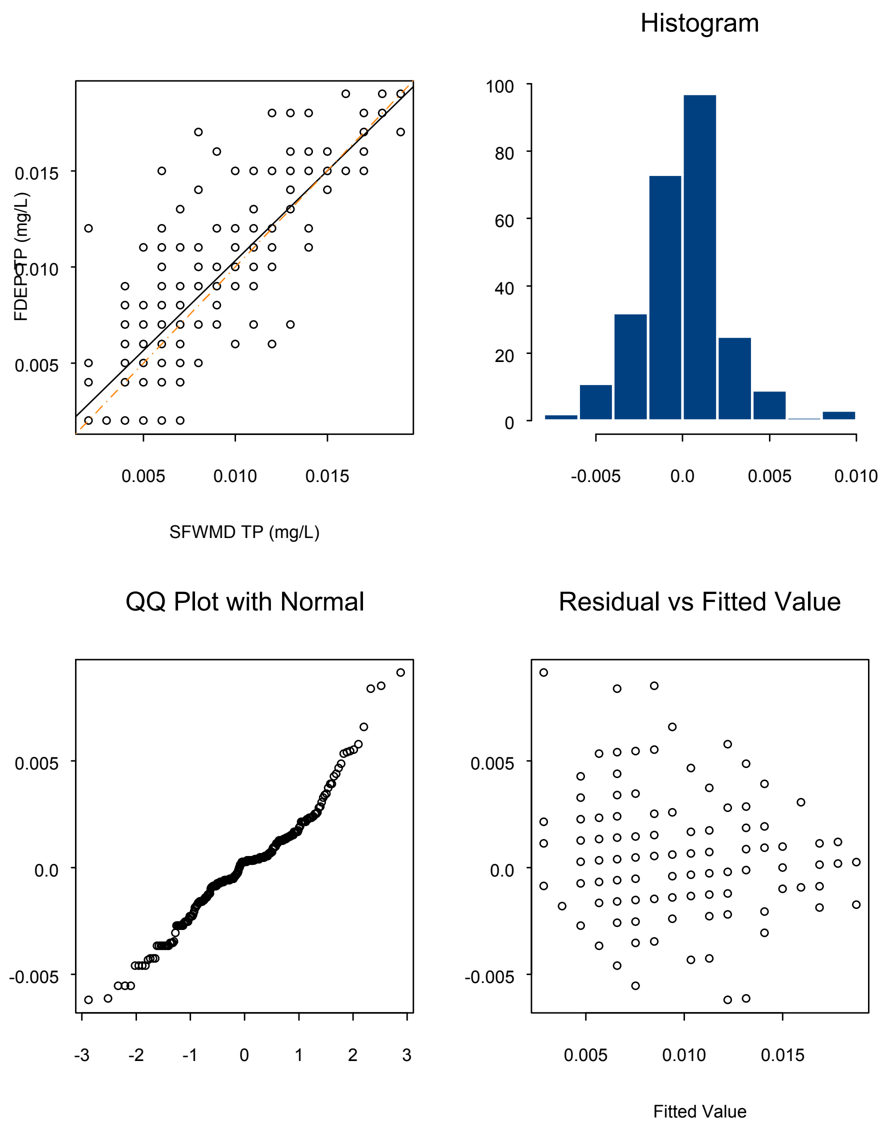


Figure 14. log(TP) Data sets from FDEP and SFWMD
(After the Natural logarithm transformation)

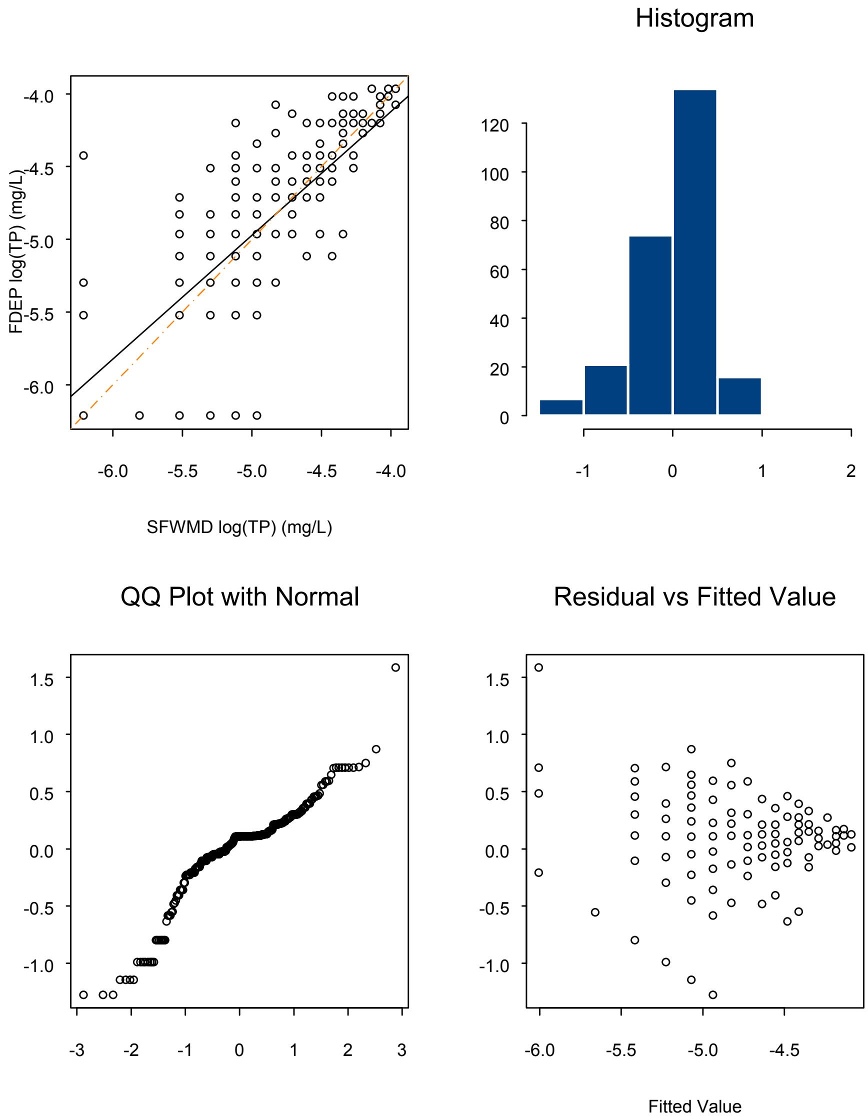


Table 8. Fitted Regression Models for the TP Data Sets
From FDEP and SFWMD (0.020 mg/L and up)

FDEP TP on SFWMD TP (Original Measurements)				
	Value	Std. Error	t-Value	p-Value
Intercept	0.0022	0.0007	3.0756	0.0025
SFWMD TP	1.0070	0.0039	261.3189	0.0000
R^2 = 0.9976 N = 170 95% CI for intercept: [0.000855, 0.003660] 95% CI for slope: [0.999374, 1.01448] p-value for testing slope is 1: 0.071996				

FDEP log(TP) on SFWMD log(TP) (After the Natural Logarithm Transformation)				
	Value	Std. Error	t-Value	p-Value
Intercept	0.0129	0.0208	0.6237	0.5537
SFWMD log(TP)	0.9921	0.0072	137.2718	0.0000
R^2 = 0.9912 N = 170 **95% CI for intercept: [-0.02803, 0.05393]** **95% CI for slope: [0.97781, 1.00634]** **p-value for testing slope is 1: 0.27432**				

Conclusions based on the linear regression model of FDEP log(TP) on SFWMD log(TP):

- **The intercept of the regression is not different from 0 statistically since the 95% confidence interval for intercept contains 0.**

- **The slope of the regression is not different from 1 statistically since the 95% confidence interval for intercept contains 1.**

Figure 15. 0.020 (mg/L) and Up TP data sets
from FDEP and SFWMD (Original Measurements)

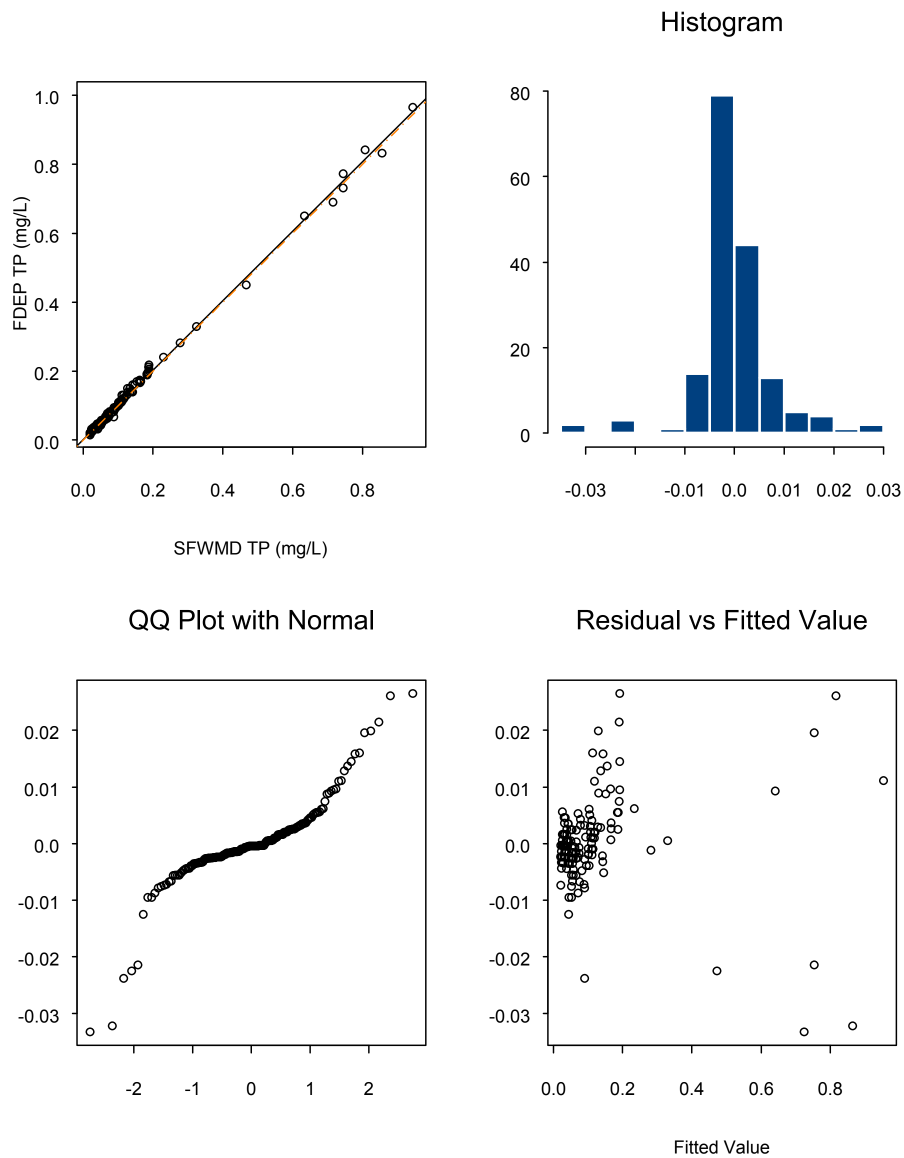
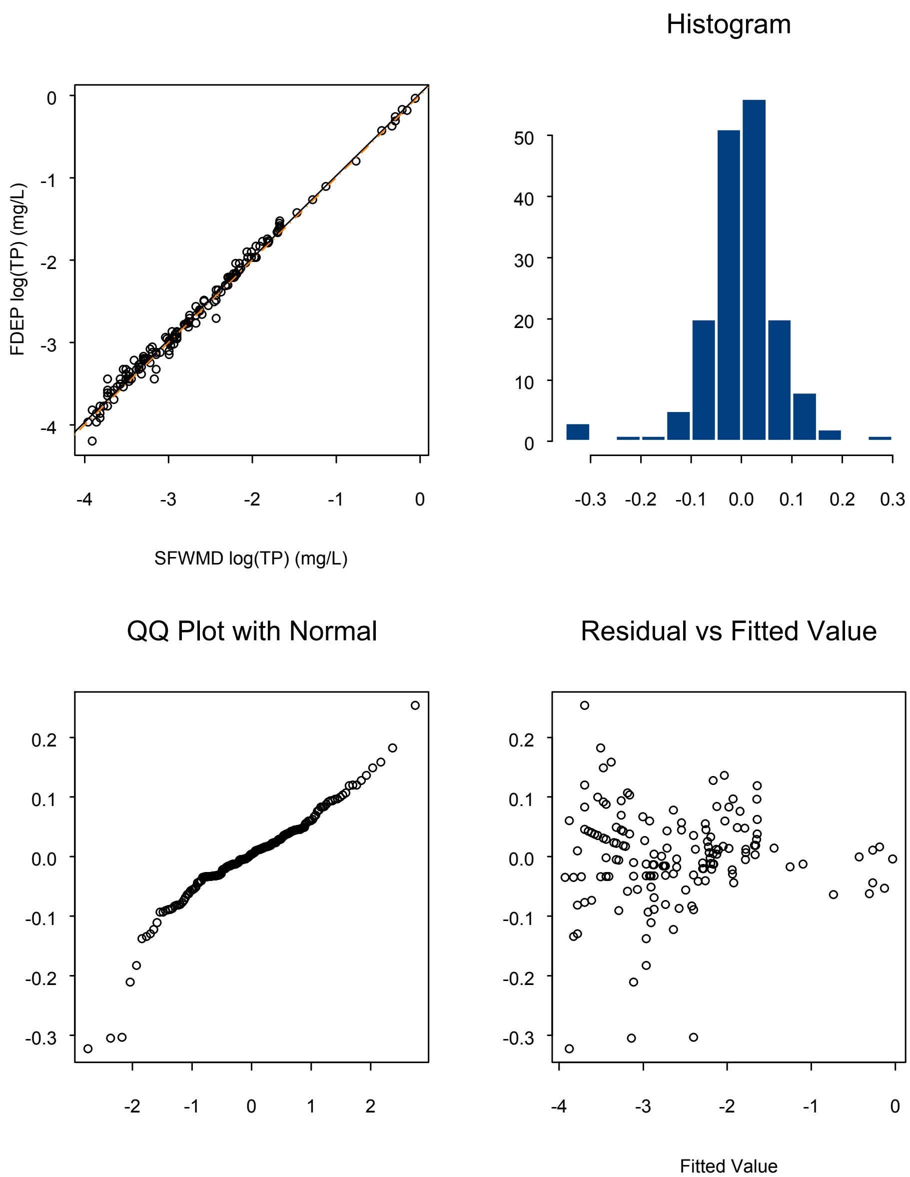


Figure 16. log(TP) Data sets from FDEP and SFWMD
(After the Natural logarithm transformation)



4. Summary of the Comparison.

Based on the results in Section 3, we have the following conclusions:

a). The TP data from FDEP and SFWMD were split into the following seven groups:

8) All TP data with 423 observations (Results in Table 1, Figures 1 and 2);

9) TP Data between 0.016 mg/L and 0.2 mg/L (both lab values are "0.016 mg/L or up" and below 0.2 mg/L, sample size *n*=165. Results in Table 2, Figures 3 and 4);

10) Natural TP samples with 332 observations (Results in Table 3, Figures 5 and 6);

11) Natural TP samples between 0.016 mg/L and 0.2 mg/L (both lab values are "0.016 mg/L or up" and below 0.2 mg/L, sample size *n*=97. Results in Table 4, Figures 7 and 8);

12) Natural TP samples between 0.016 mg/L and 0.1 mg/L (both lab values are "0.016 mg/L or up" and below 0.1 mg/L, sample size *n*= 70. Results in Table 5, Figures 9 and 10);

13) Natural TP samples between 0.1 mg/L and 0.2 mg/L (both lab values are "0.1 mg/L or up" and below 0.2 mg/L, sample size *n*=27, Results in Table 6, Figures 11 and 12);

14) TP Data 0.02 mg/L or up with *n*=170 observations (Results in Table 8, Figures 15 and 16).

After the natural logarithm transformation on the TP data, simple linear regression models were fitted to the seven data sets for the purpose of assessing the correlation between FDEP TP measurements and SFWMD TP measurements.

The 95% confidence intervals for the intercept and the slope based on the fitted regression models were constructed. The intercepts of the seven regression models are all not different from 0 statistically since the 95% confidence intervals for the intercepts contains 0. The slopes of the seven regression models are all not different from 1 statistically since the 95% confidence interval for the slopes contains 1.

b). For a low-level comparison, we used the TP data below 0.02 mg/L. In this case, the TP data were right truncated at the 0.020 mg/L level. In other words, the right tail of the right-skewed distribution was cut. Comparing the histograms and Q-Q normal plots in Figures 13 and 14, we see that the residuals from the regression model for the original data appear to be closer to a normal distribution than the residuals from the regression model for the transformed data. Therefore, for this right truncated data set I suggest using the regression model for the original data**.** The results are listed in Table 7.

Based on the linear regression model of FDEP TP on SFWMD TP (Table 7), the 95% confidence intervals for the intercept and slope are [0.000338, 0.00165] and [0.85858, 1.00929], respectively.

The intercept of the regression is slightly above 0 since the 95% confidence interval for the intercept does not contain 0. Notice that the lower limit of the interval is only 0.0003, which is much lower than the minimum detection limit (0.004). This difference is negligible in practice.

The slope of the regression is not different from 1 statistically since the 95% confidence interval for slope contains 1.

c). Based on the results listed in a) and b), we conclude that the differences between FDEP TP measurements and SFWMD TP measurements in this TP data set are not significant statistically.

5. References

1. ERR – Everglades Round Robin Studies
ERR #9 – February 2001; ERR #10 – October 2001
ERR #11 – February 2002; ERR #12 – November 2002
ERR #13 – March 2003; ERR #14 – October 2003

2. USGS Round Robin Studies
March 2000; October 2000
April 2001; September 2001
March 2002; September 2002; March 2003

3. ENRR SS Studies –Everglades Nutrient Removal Split Sample Studies
June 10, 2002; September 16, 2002
December 9, 2002; March 17, 2003
June 9, 2003; September 15, 2003
December 22, 2003

4. SFWMD Performance Studies
October 30, 2002; August 25, 2003

5. EVPA Splits – Everglades Protection Area Split Sample Studies
March 2003; June 2003; September 2003; December 2003

6. SFWMD PE Studies – SFWMD Performance Evaluations
August 2003; December 2003

7. SFWMD/USCOE C111 Split Samples
June 5, 2000 – December 9, 2003

8. FDEP. 2002. Determination of Low Level Total Phosphorus in Water using the Alpkem Segmented Flow Analyzer - Modified RFA (EPA Method 365.1). NU-005-2.6.

9. FDEP. 2003. Low Level TP Autoclave Sample Preparation (EPA Method 365.1). NU-049-3.7.

10. SFWMD. 2004. Standard Operating Procedure for the Determination of Total Phosphorus. 3100.1-3.0.

11. Zhou, M. and D. Struve. 2004. Optimal conditions for the determination of total phosphorus concentration in water. Submitted to Wat. Res.

12. Nichols, J. and Zhou, M. (2004). TPO_4 Data Evaluation 2000-2004. South Florida Water Management District Technical Report.

13. Weisberg S. (1985). *Applied Linear Regression, Second Edition*. John Wiley & Sons.