

Synoptic Nutrient Survey of the Chester Creek Watershed

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Abstract

There have been few, if any, recent studies to document dry-weather nutrient concentrations throughout the Chester Creek watershed. The objective of this study was to conduct a synoptic nutrient survey in order to determine the effects of point source discharges on phosphorus, nitrate-nitrogen, and ammonia-nitrogen concentrations along the watershed. Nine water samples were collected on April 12, 2005 at locations above and below selected point sources and major tributaries to Chester Creek. The stream hydrograph for the period leading up to the survey was monitored by the USGS flow gage at Dutton Mill Rd. The results showed that the most significant nutrient concentrations were located at Goose Creek, which led to higher nutrient concentrations throughout the lower Chester Creek watershed. Nitrate-nitrogen was more prevalent than both ammonia-nitrogen and phosphorus. The nitrate-nitrogen concentrations may approach levels that would be a human health risk for drinking water (10 mg/L NO₃-N) during low flow periods when the dilution capacity of the stream is reduced.

General Introduction

The Chester Creek watershed covers large portions of land area in both Chester and Delaware Counties, eventually spilling into the Delaware River. The multiple industrial discharges and water treatment plants along the watershed contribute pollutants into the water. Currently, there are no synoptic studies that measure the effect these point source pollutants have on the water quality along the entire Chester Creek watershed. The objective of this lab was to conduct a synoptic nutrient survey in order to determine the effects of industrial discharges and treatment plants on phosphorus, nitrate-nitrogen, and ammonia-nitrogen concentrations along the watershed. Nine water samples were collected at key locations above and below selected industrial discharges and water treatment facilities, as well as at major tributaries to Chester Creek. Concentration, absorbance, and specific conductivity were measured for each nutrient at each of the nine locations. The results could then be compared to other watersheds in the area, such as Ridley Creek.

Historical Background

The Chester Creek watershed consists of a 67.2 square mile area located in eastern Chester County and western Delaware County. As of 1998, approximately 100,100 people live in the Chester Creek watershed contributing to 36% of the land being used for single family residents (Chester County Water Resources Agency, 2002). Another 31% of the land consists of wooded areas, while 13% is devoted to agricultural use. Chester Creek and its tributaries amount to approximately 128 miles of streams that eventually end in the Delaware River. Most of the point source pollution within the

watershed can be traced to the seven municipal treatment plants, fourteen “package” treatment plants, and twelve single residence treatment plants in the surrounding area.

Industrial discharges and treatment plant locations are summarized in Figure 1.

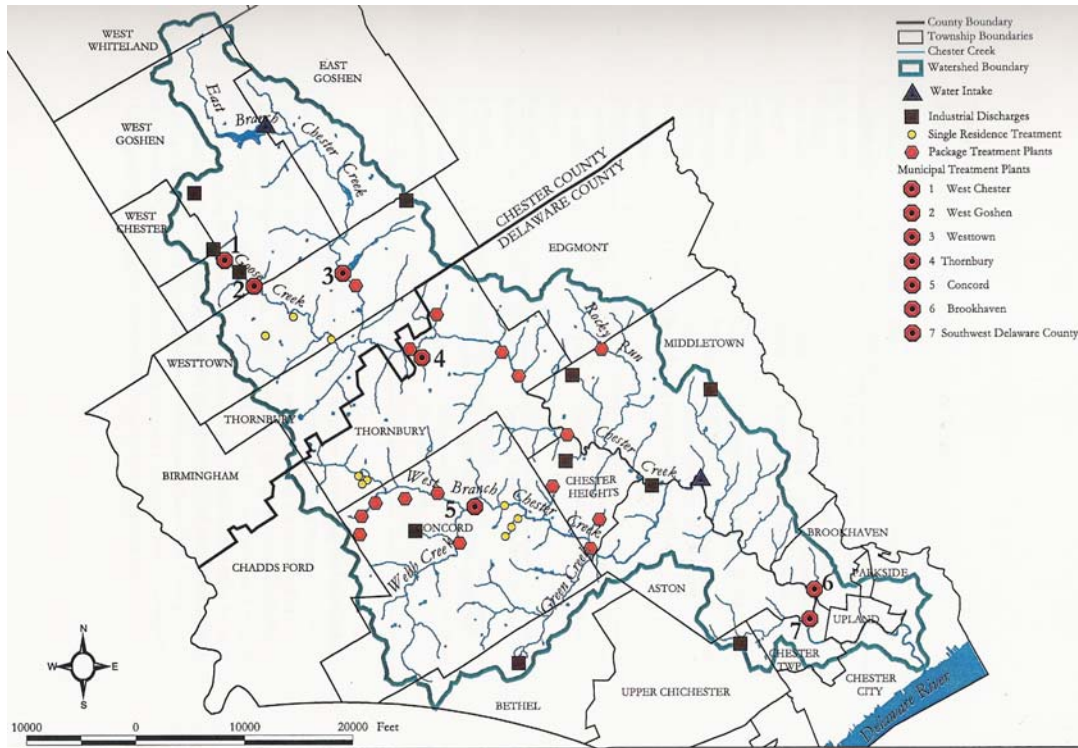


Figure 1: Point Source Discharge Locations (from Chester Creek Conservation Plan, Natural Lands Trust)

Technical Background

A watershed is the land area surrounding a body of water that contributes runoff into the body of water. The quality of water within a watershed is directly related to the condition of the surrounding land area. Large populations and industrial developments can contribute to higher amounts of pollutant contained in the water. These pollutants, consisting of bacteria, fertilizers and various other chemicals, can harm the water quality.

There are two types of pollution sources that can occur within a watershed. A point source pollutant can be traced to a single source, usually a discharge pipe such as those used by sewage treatment and industrial plants. Since the location of these pollution sources is known, they are much easier to trace and control. These discharges are closely regulated by state and federal governments to safeguard against adverse public health issues. Pollutants that mix into the soil and flow with runoff into various water sources within the watershed are referred to as non-point source pollution. These pollution sources are much harder to study and eliminate as their causes are not always easily identified.

Excessive levels of nutrients commonly found in discharged water from sewage treatment and industrial plants can over stimulate the growth of aquatic plants and algae and impact the dissolved oxygen (DO) and pH levels in the stream water due to photosynthesis and respiration. The nutrient levels found in the water not only affect aquatic life, they can also adversely impact human health through the quality of drinking water supplies.

Phosphorus stimulates algae growth, creating higher oxygen demands in water. Typical phosphorus levels usually run from 0.1 to 0.3 mg/L. Ammonia-nitrogen also stimulates algae growth and may be toxic to aquatic insects and fish, especially at elevated pH levels. Typical ammonia-nitrogen concentrations in a watershed are less than 0.5 mg/L. Nitrate-nitrogen is the end product of ammonia oxidation and may cause

human health problems at concentrations above 10 mg/L $\text{NO}_3\text{-N}$. Typical nitrate-nitrogen concentrations run from 1.5 to about 4.0 mg/L.

One method of determining nutrient concentrations in a water sample is through the use of a spectrophotometer. A spectrophotometer measures the absorbance of light at a wavelength specific to each nutrient or chemical parameter. The absorbance can then be related to the concentration of the nutrient by developing a calibration curve based on prepared samples of known concentration.

Another measure of determining the quality of a water sample is through conductivity readings. These readings measure the dissolved ion concentration in water, usually occurring in the form of salts. The higher the concentration of dissolved ions in water is, then the higher the conductivity of that water. Cleaner water will therefore have less conductivity.

Methods and Procedures

Nine sample sites were chosen based on their specific location and accessibility along the watershed. A background site was selected above all industrial discharges and treatment plants in order to provide a reference sample as to what the water was like prior to contamination from point source pollutants. Samples were also collected at major tributaries to determine the nutrient concentration entering Chester Creek. Other locations were chosen above and below specific industrial discharges and treatment plants to determine the impact they pose on the nutrient concentrations in the watershed. Figure 2 and Table 1 summarize the locations of each sampling site and major point source discharges.



Figure 2: Sampling Site Locations

Table 1: Summary and Significance of Sampling Sites

Site	Location	Collection Time	Description	Distance from Delaware River (mi)	Significance
1	East Branch Chester Creek	3:10 pm	Westtown Bridge (Westtown Rd)	1.9*	-Background sample
2	Goose Creek	2:45 pm	Goose Creek Grill on Rt. 926	17.57	-Below 2 industrial discharges -Below 2 municipal treatment plants
3	Chester Creek	3:30 pm	Locksley Bridge	14.56	-Above 2 package treatment plants -Above 1 municipal treatment plant
4	Chester Creek	3:45 pm	Creek Road Bridge (Glen Mills)	13.33	-Below 2 package treatment plants -Below 1 municipal treatment plant
5	Rocky Run	4:00 pm	Valley Road Bridge (Rocky Run Trail)	10.46	-Major tributary input
6	Chester Creek	4:25 pm	Lenni Road	9.35	-Between Rocky Run and West Branch tributaries
7	West Branch Chester Creek	4:40 pm	Mount Road	8.82	-Tributary input -Below a package treatment plant
8	Chester Creek	4:45 pm	Mount and Pennel Road	7.69	-Above 2 municipal water treatment plants
9	Chester Creek	5:00 pm	Dutton Mill Road	5.27	-Below 2 municipal water treatment plants. -Location of USGS flow gage.
*from confluence with Goose Creek					

Each sample was collected from the middle of the stream. Before the sample was collected in a plastic bottle, each bottle was flushed twice with the stream water from that location. One bottle was filled with de-ionized water in the field to be consistent with the other nine samples. This bottle was established as the field blank. The time and location number were recorded on each bottle, and the bottles were placed in a cooler for the duration of the field work. Photographs were taken at each sampling site location. The samples were stored in a refrigerator overnight. Testing was conducted within a 24 hour period the following day.

A spectrophotometer (Hach DR4000) was used to determine nutrient concentrations and absorbency by measuring the wavelength of the color of the sample after it had been mixed with a reagent. The corresponding program for each nutrient was entered into the spectrophotometer before testing. Twelve samples were tested for each nutrient. Nine from the various stream locations, a field blank, a zero blank (consisting of pure de-ionized water from the lab) and a duplication of stream location #3. Calibration curves were run for each nutrient and are contained in the Appendix of this report.

To test for ammonia-nitrogen, test tubes were obtained which already contained 3 mL of de-ionized water (Hach Low Range Ammonia Nitrogen Test-N- Tube method). Another 2 mL of sample were placed into each test tube. An ammonia salicylate reagent was added to the sample which was then shaken for a minute. A second reagent (ammonia cyanurate) was then added and shaken. A twenty minute reaction time was

expected, after which a color change indicated the ammonia concentration, with a darker shade of green indicating higher concentration. The test tubes were then placed in the spectrophotometer, where concentration and absorbance were determined.

To test for phosphorus, test tubes were obtained which already contained 4 mL of de-ionized water (Hach Total Reactive Phosphorus Test-N Tube method).. Another 5 mL of sample were placed into each test tube. These were then used to zero the spectrophotometer before each reading. After zeroing, a reagent was added to each test tube and shaken for two minutes. The test tubes were placed back in the machine and readings of concentration and absorbance were taken.

Vials were limited, so samples were prepared for nitrate testing as the experiment was being conducted (Hach Nitra-Ver 5 Nitrate method). Ten milliliters of each sample were pipetted into each vial. Then a nitrate reagent pillow was added to each sample individually. The vials were capped and shaken to ensure even mixing of the reagent with the sample water. The vials were allowed ten minutes for the reagent to react with the nitrate in the water samples. The water turned yellow as it reacted. Two additional glass vials were used to test each specimen in the spectrophotometer. The first vial was filled with 10 mL of the sample water. This vial was used to zero the spectrophotometer for that sample before testing. The sample vial that had been combined with the reagent was then poured into the second vial. After a zero had been established using the unmixed sample in the first vial, the second vial was tested in the spectrophotometer. Readings for absorbance and concentration were recorded. This process was repeated for all samples, including the field blank, zero blank, and a duplication of sample number three. Specific conductivity readings were taken at another time by the supervising professor.

The total inorganic nitrogen concentration was calculated for each of the sample sites using Equation 1. The corresponding nitrogen-phosphorus ratio was then calculated via Equation 2. The limiting nutrient was based on the Redfield Ratio (16 moles N/ 1 mole P, or approximately 7 g N/1 g P). Information from the USGS flow gage located at Dutton Mill was used via Equation 3 to calculate the mass load per day for each of the three nutrients at that location.

Equation 1. $TIN = NH_3N + NO_3N$

Where: TIN = Total Inorganic Nitrogen (mg/L)

NH₃N = Ammonia Nitrogen Concentration (mg/L)

NO₃N = Nitrate Nitrogen Concentration (mg/L)

Equation 2. $TIN / P = \frac{TIN}{P}$

Where: TIN/P = nitrogen-phosphorus ratio

TIN = total inorganic nitrogen (mg/L)

P = phosphorus concentration (mg/L)

Equation 3. $M = [Q \times C] \times 5.4$

Where: M = mass load per day

Q = USGS flow rate at Dutton Mill (cfs)

C = specific nutrient concentration (mg/L)

After all the data and calculations were completed for each location, nutrient concentrations were classified as low, typical, and high. The nitrogen-phosphorus ratio

was then used to determine which nutrient was limiting. Conclusions were then drawn accordingly based on nutrient concentrations and ratios at each location.

Results and Discussion

The concentration, absorbance, and specific conductivity lab results for each of the nutrients tested are shown in Table 2. The nitrogen-phosphorus ratios for each sampling site are summarized in Table 3.

Table 2: Lab Results for Nutrients

Bottle No.	PO₄-P (mg/L)	PO₄ Absorb.	NH₃-N (mg/L)	NH₃-N Absorb.	NO₃-N (mg/L)	NO₃-N Absorb.	Spec. Cond. (umho/S)
1	0.03	0.018	0.070	0.044	1.6	0.043	418
2	0.84	0.463	1.436	0.895	6.0	0.148	574
3	0.35	0.196	0.715	0.446	3.3	0.087	440
4	0.31	0.170	0.577	0.360	3.4	0.090	411
5	0.05	0.026	0.037	0.023	1.4	0.039	368
6	0.22	0.122	0.198	0.123	2.4	0.064	376
7	0.14	0.080	0.000	0.000	3.7	0.096	297
8	0.20	0.108	0.125	0.078	3.5	0.091	358
9	0.16	0.092	0.034	0.021	4.2	0.108	356
Field Blank	0.03	0.018	0.094	0.059	0.8	0.023	-
Zero Blank	0.02	0.015	0.000	0.000	0.7	0.019	-
Dup. (#3)	0.36	0.196	0.692	0.432	3.7	0.096	-

Table 3: Nitrogen-Phosphorus Ratios for Sampling Sites

Sample Site	TIN	PO ₄	TIN/P	Limiting?
1	1.7	0.03	55.67	PO ₄
2	7.4	0.84	8.85	PO ₄
3	4.0	0.35	11.47	PO ₄
3 (Dup)	4.4	0.36	12.20	PO ₄
4	4.0	0.31	12.83	PO ₄
5	1.4	0.05	28.74	PO ₄
6	2.6	0.22	11.81	PO ₄
7	3.7	0.14	26.43	PO ₄
8	3.6	0.2	18.13	PO ₄
9	4.2	0.16	26.46	PO ₄

Table 4 summarizes nutrient level classifications at each sampling site location (see Technical Background for information on typical nutrient levels).

Table 4: Nutrient Concentration Classifications

Sample Site	PO ₄	NH ₃ -N	NO ₃ -N
1	Low	Low	Typical
2	High	High	High
3	High	High	Typical
3(Dup)	High	High	Typical
4	High	High	Typical
5	Low	Low	Low
6	Typical	Typical	Typical
7	Typical	Low	Typical
8	Typical	Typical	Typical
9	Typical	Low	Typical

The mass load per day at Dutton Mill for each of the three nutrients is summarized in Table 5.

Table 5: Mass Load at Dutton Mill

Nutrient	Concentration (mg/L)	Mass Load (lb/day)
PO4	0.16	150
NH3-N	0.034	32
NO3-N	4.2	3900
*Dutton Mill USGS Flow rate (4/12/05) = 174 cfs		

The results from the lab testing showed a general trend in which nitrate-nitrogen was more prevalent than either of the other two nutrients. As expected, our background samples (#1 Westtown and #5 Rocky Run) contained the lowest overall nutrient concentrations; however, ammonia was still lower in the sample of the West Branch Chester Cr (#7). Phosphorus and ammonia-nitrogen concentrations generally decreased moving downstream through the watershed, while nitrate-nitrogen decreased initially, but then began to increase again closer to the Delaware River. Specific conductivity generally decreased moving downstream. From the results in Table 3, phosphorus was the limiting nutrient at each of the nine sampling sites

The mass load per day at the Dutton Mill sampling site located near a USGS flow gage was highest for nitrate-nitrogen. Ammonia-nitrogen and phosphorus mass loads per day were much lower than the nitrate load..

Conclusions

A synoptic nutrient survey was conducted at nine locations along the Chester Creek watershed in order to determine the effects of point source discharges on phosphorus, nitrate-nitrogen, and ammonia-nitrogen concentrations in the water. Nine sampling sites were chosen based on accessibility, relevance to selected industrial discharges and wastewater treatment facilities, and at major tributaries to Chester Creek. A spectrophotometer was used to determine nutrient concentrations at each location and conclusions were drawn accordingly.

The results from the lab testing on each of the sampling sites indicated several general trends. As expected, background sites yielded much lower nutrient concentrations than impacted sites, with the East Branch Chester Cr at Westtown and Rocky Run background samples having the lowest overall nutrient concentrations. The West Branch sample site had a much higher nitrate-nitrogen concentration than both the East Branch and Rocky Run due to its location downstream of a treatment plant. The sample site with the highest overall nutrient concentrations was Goose Creek, located directly below two industrial discharges and two municipal treatment plants. Moving downstream through Chester Creek, nutrient concentrations generally decreased, moving from high to high to typical levels. This indicates that Goose Creek had the greatest overall impact on the nutrient concentrations throughout the entire watershed.

From the calculations of the nitrogen-phosphorus ratios, phosphorus was the limiting reactant at all the sampling sites. The calculated mass load per day at the Dutton Mill USGS flow gage was significantly higher for nitrate-nitrogen than either phosphorus or ammonia-nitrogen. Nitrate-nitrogen was the most prevalent nutrient throughout the watershed. The nitrate-nitrogen concentration at Goose Creek was 6 mg/L, indicating a potential health hazard due to toxicity to human health at 10 mg/L.

In summer months, when flow rates are lower, nutrient concentrations would be even higher, reaching potentially dangerous levels at Goose Creek. It would be beneficial to closely monitor the discharges and treatment plants at Goose Creek to ensure that nutrient concentrations do not reach dangerous levels.

References

Chester County Water Resources Agency (2002), Chester Creek Watershed Action Plan.

Hach DR 4000 Methods Manual.

Natural Lands Trust, Chester Creek Conservation Plan.

Tremblay, Michelle. What is a Watershed? New Hampshire Lakes Association. 4/15/05

<<http://www.nhlakes.org/edbrochures/whatisawatershed.htm>>

Appendix

Sample Calculations

- Calculating total inorganic nitrogen concentrations (Equation 1):

$$TIN = NH_3N + NO_3N = 1.436 + 6.0 = 7.4$$

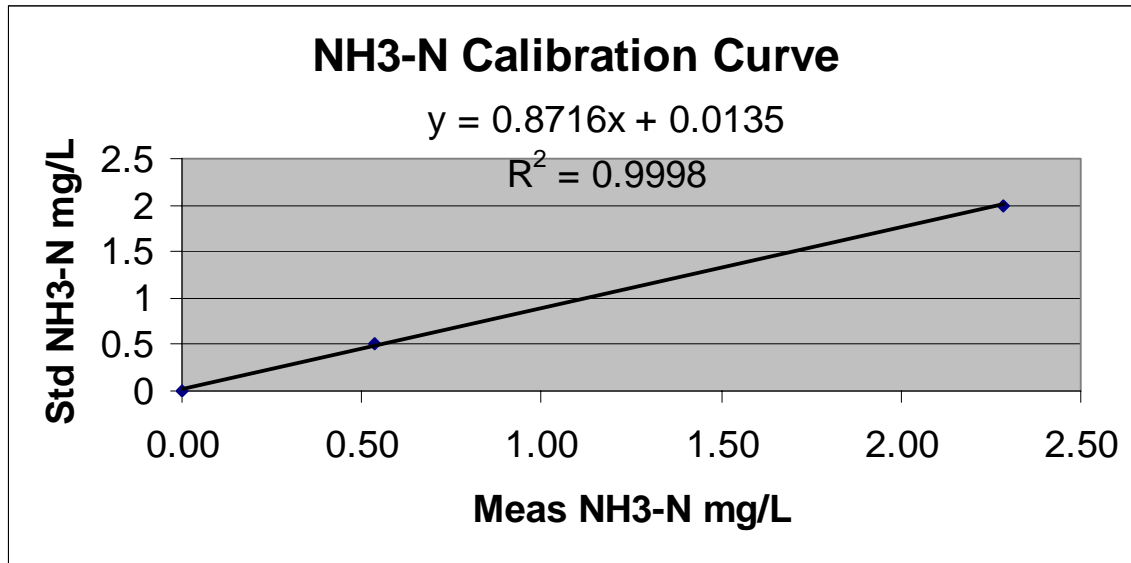
- Calculating nitrogen-phosphorus ratio (Equation 2):

$$TIN / P = \frac{TIN}{P} = \frac{7.4}{0.84} = 8.85$$

- Calculating mass load per day (Equation 3):

$$M = [Q \times C] \times 5.4 = [174 \times .16] \times 5.4 = 150 \text{ lb/day}$$

Ammonia-Nitrogen Calibration Curve



NH3-N Calibration Curve

Meas	Abs	Std Conc
2.28	1.424	2
0.54	0.336	0.5
0.00	0	0

SUMMARY OUTPUT

<i>Regression Statistics</i>	
Multiple R	0.999882486
R Square	0.999764985
Adjusted R	0.99952997
Standard E	0.022565433
Observatio	3

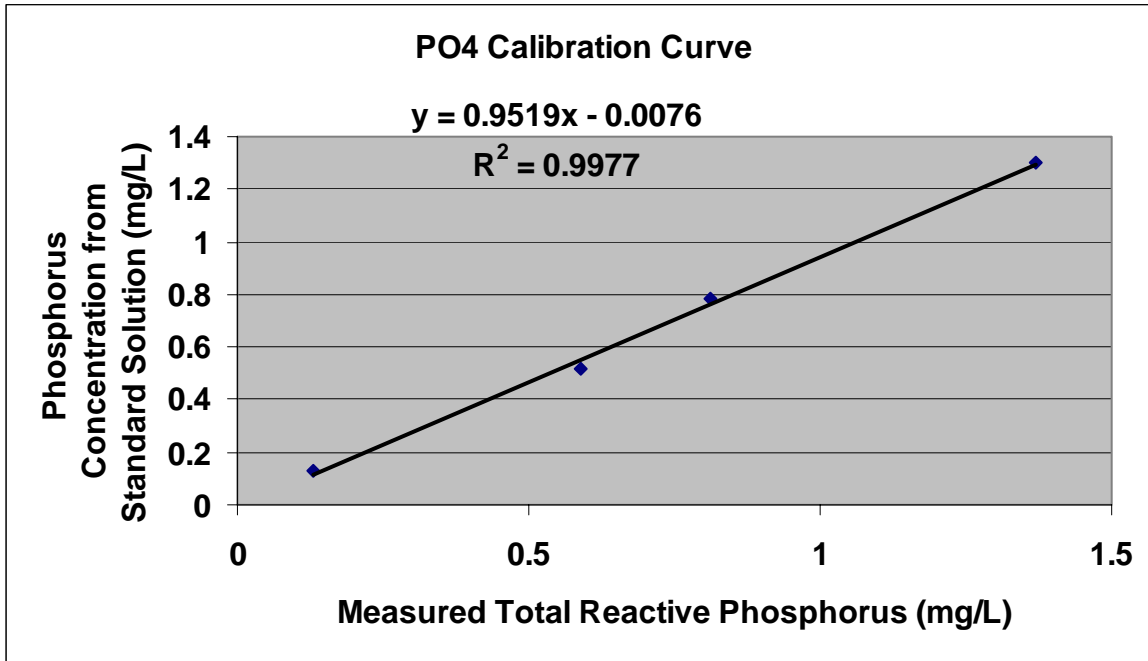
MSE= 0.000509
 mean error= 0.023

ANOVA

	df	SS	MS	F	Significance F
Regressor	1	2.166157468	2.16615747	4254.051	0.009759886
Residual	1	0.000509199	0.0005092		
Total	2	2.166666667			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	0.013470622	0.018103622	0.74408439	0.592752	-0.216556715	0.24349796
X Variable	0.871576234	0.013363002	65.223085	0.00976	0.701783919	1.04136855

Phosphorus Calibration Curve



Total Reactive Phosphorus

Calibration Check

Meas P mg/L P	STD P mg/L P
1.37	1.3
0.81	0.78
0.59	0.52
0.13	0.13

SUMMARY OUTPUT

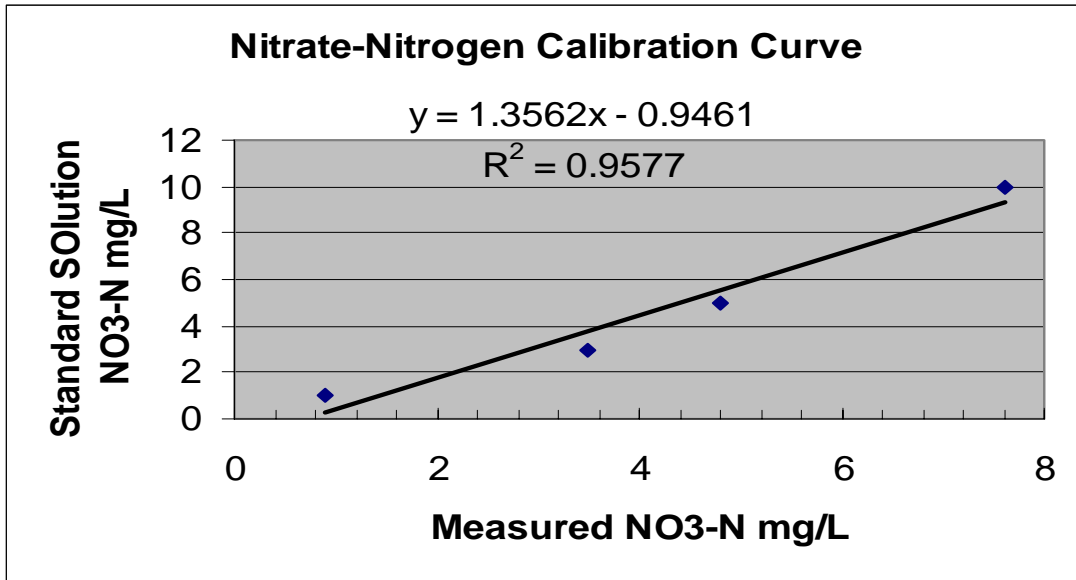
<i>Regression Statistics</i>	
Multiple R	0.998867259
R Square	0.997735802 MSE = 0.000818
Adjusted R Sq	0.996603703
Standard Error	0.028599183 mean error = 0.028599 (so mean error in P = 0.028 mg/L P)
Observations	4

ANOVA

	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	1	0.720839173	0.720839	881.3149	0.00113274
Residual	2	0.001635827	0.000818		
Total	3	0.722475			

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
Intercept	-0.00763985	0.027293091	-0.279919	0.805834	-0.12507262	0.109792926
X Variable 1	0.951917033	0.032065169	29.68695	0.001133	0.81395165	1.089882416

Nitrate-Nitrogen Calibration Curve



Meas NO ₃ -N mg/L	Standard Solution NO ₃ -N mg/L N
7.6	10
4.8	5
3.5	3
0.9	1

SUMMARY OUTPUT

<i>Regression Statistics</i>	
Multiple R	0.978616654
R Square	0.957690556
Adjusted R Squar	0.936535833
Standard Error	0.972971644
Observations	4

Mean Square Error = 0.9467
 mean error = 0.97 mg/L NO₃-N

ANOVA

	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	1	42.85665236	42.8566524	45.2707696	0.021383346
Residual	2	1.893347639	0.94667382		
Total	3	44.75			

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
Intercept	-0.946137339	0.976410638	-0.96899532	0.4347697	-5.147296159	3.2550215
X Variable 1	1.356223176	0.201568295	6.72835564	0.02138335	0.488944196	2.2235022