September 5, 2017

Appendix A

Analysis of Total Phosphorus Stormwater Monitoring Information as Contained in the National Stormwater Quality Database (NSQD), Version 4.02

Contents

Introduction

The University of Alabama and the Center for Watershed Protection were awarded a U.S. Environmental Protection Agency, Office of Water 104(b)3 grant in 2001 to collect and evaluate stormwater data from a portion of NPDES (National Pollutant Discharge Elimination System) MS4 (municipal separate storm sewer system) stormwater permits. Version 3 of this database was completed under continued 104(b)3 support from the EPA, while Version 4 was completed in 2015 with support from University of Alabama, Wright Water Engineers, and Geosyntec Consultants. The general approach in data collection was to contact EPA regional offices to obtain state contacts for the MS4 data, then the individual municipalities with Phase I permits were targeted for data collection. Version 4.02 of the NSQD represents major urban area land uses, such as: residential, commercial, and open space. This monitoring data, collected over nearly a fifteen-year period from more than 250 municipalities throughout the country, was used to create the National Stormwater Quality Database (NSQD). The NSQD has several applications. For example, it can characterize national stormwater quality, provide guidance for future sampling needs, enhance local stormwater management activities in areas having limited data, and be compared to historical benchmarks. The NSQD also provides recommendations for improving the quality and management of future NPDES monitoring efforts.

Only stormwater quality outfall data are included in the NSQD, representing untreated stormwater leaving the sites. Receiving water data, source area sheetflow data, and data from locations affected by stormwater control practices are not included in the database (see the International BMP Database for stormwater performance data). Other data incorporated into the NSQD comes from various sources including; Nationwide Urban Runoff Program (NURP) (US EPA, 1983), the International Best Management Practice (BMP) Database (ASCE 2002), and specialized research projects conducted by states and by the U.S. Geological Survey Urban-Stormwater Database (Smullen and Case 2002; Driver, et al. 1985). All of the data sources were carefully reviewed (in fact, most of the effort in compiling the NSQD was spent in Quality Assurance/Quality Control (QA/QC) reviews of the data). QA/QC reviews were very important to verify the correctness of data that was added to the database. The NSQD contains extensive data for most land uses and locations for a broad range of conventional pollutants, nutrients, bacteria, heavy metals, along with some organic compounds. As an example, early lead data are included separately as a special constituent for trend analyses). The early NURP data were very helpful in filling data gaps from the upper Midwest and northeastern areas of the country, and to extend the time period of the observations.

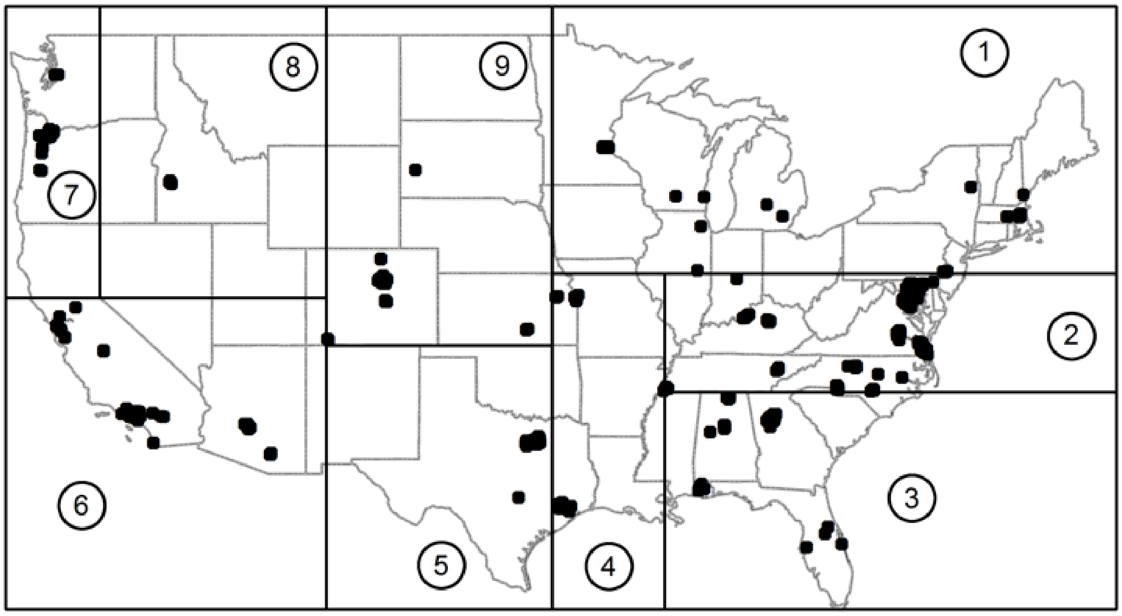
More than 9,000 stormwater monitoring events are recorded in version 4.02 of the NSQD, representing more than 600 sampling locations (median of 10 samples per site, with a maximum of 115 per site). Table 1 shows the 6 land uses, 9 EPA Rain Zones and four seasons used as data identifiers in the NSQD database. When more than one land use was present, it was considered a mixed site with the major land use noted. About 48% of the storm events stored in the database were collected in residential land use areas, followed by commercial areas with 20%, industrial areas with 13%, open space and freeways with 6% each, and institutional at 5%.

Figure 1 presents a map showing the EPA Rain Zones in the U.S., along with the locations of the communities represented in the database.

Table 1. Main Land Uses, EPA Rain Zones and Seasons Identified in the NSQD

Major Land Uses	EPA Rain Zones	Season
Commercial	Zone 1 – Great Lakes	Spring: February – April
Freeway	Zone 2 – Northeast	Summer: May – July
Industrial	Zone 3 – Southeast	Fall: August – October
Institutional	Zone 4 – Lower Mississippi Valley	Winter: November – January
Open Space	Zone 5 – Texas	
Residential	Zone 6 – Southwest	
	Zone 7 – Northwest	
	Zone 8 – California	
	Zone 9 – Rocky Mountains	

Figure 1. Sampling Locations for Data Contained in the National Stormwater Quality Database, version 4.02, by EPA Rain Zones.



The complete NSQD, version 4.02, is available as a large (7.5Mb) Excel spreadsheet at: http://www.bmpdatabase.org/nsqd.html. This website (which also contains the International BMP database) includes a new NSQD data extraction tool to explore and assess data prior to in-depth analyses. Detailed statistical analyses, site descriptions, and early versions of the database are available in a 2005 EPA final report entitled "The National Stormwater Quality Database, Version 1.1: A Compilation and Analysis of NPDES Stormwater Monitoring Information" located at: http://unix.eng.ua.edu/~rpitt/Publications/Stormwater%20Characteristics/NSQD%20EPA.pdf

Observations

There are many factors that may affect stormwater quality. These factors include, but are not limited to the following; land use, geographical region (EPA Rain Zone), and season. The NSQD includes sampling location information such as city, state, land use, drainage area, and EPA Rain Zone. The database also includes sampling information such as date, season, and rain depth, along with the concentrations for many constituents. Supplemental information available at each sampling location includes the exact sampling locations (street intersections or longitude/latitude), breakdown of land use by percentage, aerial photographs, topographic maps, information on sampling procedures, and quality control. It is important to note that the supplemental information available can vary for different sites.

Land use has an important impact on the quality of stormwater. For example, the concentrations of heavy metals are generally higher for industrial land use areas due to manufacturing processes and other activities that generate these materials. Seasons could also be a factor in the variation of nutrient concentrations in stormwater due to seasonal uses of fertilizers and seasonal leaf drop. Most studies also report lower bacteria concentrations in the winter than in the summer. Lead concentrations in stormwater also have significantly decreased since the elimination of lead in gasoline (as noted, the earlier NURP lead data were therefore not included in the main body of the NSQD).

Multivariate statistical analyses can be used to compare different constituent concentrations with land use and geographical location, along with different sampling methods. Some of the analyses used earlier versions of the NSQD when project resources enabled more extensive data analyses. For the most recent project efforts, most of our time was used to acquire additional data and to conduct needed quality control. More detailed discussions of the earlier NSQD results are found in various references, including Maestre, *et al.* (2004; 2005; 2006; 2007) and Pitt, *et al.* (2003 and 2004a/b). As noted above, metal concentrations are generally higher for industrial and commercial land uses, however EPA Rain Zone effects on pollutant concentrations appear to be important also. Lower concentrations for total dissolved solids (TDS), 5-day biochemical oxygen demand (BOD_5), and bacteria as fecal coliforms were also observed in industrial land use areas. Fecal coliform concentrations are relatively high for residential and mixed residential land uses, and nitrate concentrations are higher for the freeway land use. Open space land use areas show consistently low concentrations for the constituents examined.

Land use and geographical region analyses

Maestre and Pitt (2007) prepared a general linear model (GLM) that included the interaction effects between land use, geographical region, and season. The following discussion summarizes findings from this report which are relevant today. This analysis examined only a few of the constituents that were well represented in each category and included total suspended solids (TSS), BOD_5, chemical oxygen demand (COD), total phosphorus (TP), nitrite (NO_2)+nitrate (NO_3), total Kjeldahl nitrogen (TKN), copper (Cu), lead (Pb), and zinc (Zn).

EPA Rain Zone 8 was eliminated due to lack of data, while all four seasons were examined as they were well represented in all of the selected land uses and EPA Rain Zones. Two-way and three-way interactions were included in the model, with the results shown in Table 2. A p-value smaller than 0.05 indicates that the factor, or interaction of factors, was found to be significant at least at the 5% significance level.

The results indicated that the factors for land use, and the EPA Rain Zone, plus the interaction land use–rain zone were the most important factors used in the model. There were significant differences by EPA Rain Zone, and land use for all the constituents. None of the seasonal factors alone were significant for any constituent, except for TKN, but seasonal effects interacting with the other factors were significant for many constituents. The interaction between land uses and EPA Rain Zone is very important and must be considered when determining likely stormwater concentrations for a site.

For all the constituents except TSS, concentrations in the open space land use were lower than for the other land uses, while, samples collected at freeways and industrial sites had the highest concentrations. Total phosphorus and TKN appear to be high during the summer and low during the winter. No clear variations in concentration were observed between spring and fall. Samples collected in EPA Rain Zone 3 (the southeast) had the lowest concentrations for all the constituents. The largest concentrations were observed in EPA Rain Zone 6 (the southwest) followed by EPA Rain Zones 1 (Great Lakes and northeast) and 4 (Mississippi valley).

Table 2. P-Values for Main Factors And Interactions (Values Less Than 0.05 Are Traditionally Considered Significant)

Constituent	Land Use (LU)	Season (SN)	EPA Rain Zone (EPA)	LU*SN	LU*EPA	SN*EPA	LU*EPA*SN
TSS mg/L	<0.0001	0.74	<0.0001	0.017	<0.0001	0.18	<0.0001
BOD mg/L	<0.0001	0.16	<0.0001	0.0008	<0.0001	0.0011	0.22
COD mg/L	<0.0001	0.13	<0.0001	0.034	<0.0001	0.014	0.0085
TP mg/L	<0.0001	0.69	<0.0001	0.055	<0.0001	0.0004	<0.0001
NO2+NO3 mg/L	<0.0001	0.11	<0.0001	0.052	<0.0001	0.034	0.057
TKN mg/L	0.0026	0.024	<0.0001	0.99	<0.0001	<0.0001	0.17
Cu µg/L	<0.0001	0.11	<0.0001	0.62	<0.0001	0.038	0.14
Pb µg/L	<0.0001	0.76	<0.0001	0.42	<0.0001	0.28	0.012
Zn µg/L	<0.0001	0.91	<0.0001	0.94	<0.0001	0.014	<0.0001

Evaluation of Total Phosphorus Stormwater Concentrations

This data analysis focuses on total phosphorus concentrations contained in the newest version of the NSQD (version 4.02). Figure 2 is a grouped box and whisker plot (prepared using SigmaPlot 13) comparing the concentration distributions from six major land uses. The central box indicates the 25^{th}, 50^{th}, and 75^{th} percentile concentrations, while the ends of the whiskers indicate the 5^{th} and 95^{th} percentile values. The separate dots outside of the whiskers indicate values less than the 5^{th} and greater than the 95^{th} percentile values. This plot indicates that the data distributions are reasonably symmetrical and similar for each land use, with the institutional land use area generally having the lowest total phosphorus concentrations and the residential areas generally having the highest total phosphorus concentrations.

Figure 2. Box And Whisker Plots Comparing Total Phosphorus Concentrations for all Land Uses Using Data Contained in the NSQD, version 4.02.

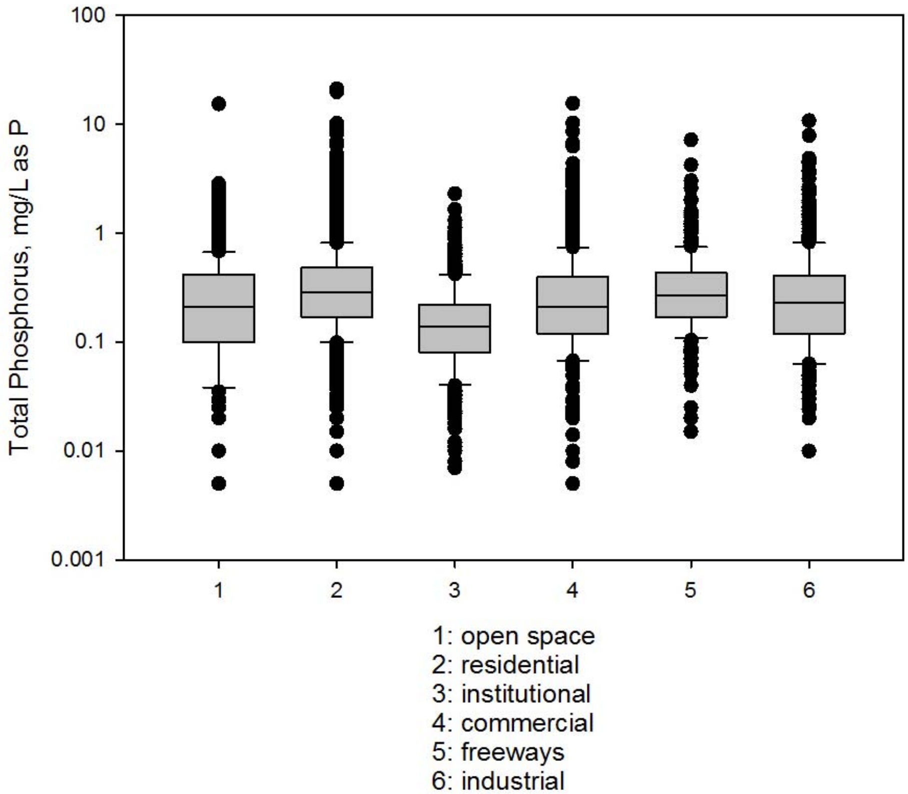


Table 3 summarizes the Kruskal-Wallis analysis (SigmaPlot 13) results comparing the total phosphorus concentrations for each land use, as shown on the above box and whisker plot. These results indicate that at least one land use is significantly different from the others ($p < 0.001$).

Table 3. All Total Phosphorus Data by Land Use using Kruskal-Wallis One Way Analysis of Variance on Ranks

Group	N	Missing	Median	25%	75%
All open space TP	446	0	0.21	0.1	0.42
All resid TP	3855	0	0.29	0.17	0.482
All instit TP	414	0	0.14	0.08	0.223
All commer TP	1599	1	0.21	0.12	0.4
All freeways TP	378	0	0.27	0.17	0.436
All indus TP	1000	0	0.23	0.12	0.41
H = 336.254 with 5 degrees of freedom. (P = <0.001)					
The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001)					

Table 4 shows the individual comparisons indicating significant differences. Most land uses are significantly different from each other, based on pairwise multiple comparison tests (Dunn's test in SigmaPlot 13). The exceptions, as shown in Table 4, are open space vs. industrial; residential vs. freeways; and freeway vs. industrial land use areas. The grouped box and whisker plots also indicate potential overlapping data for these pairs, while the others are more distinctly different.

Table 4. Probability of Significant Differences Between Land Use Pairs (Dunn's Test)

	open space	residential	institutional	commercial	freeway	industrial
open space	X	<0.001	<0.001	<0.001	<0.001	1.0
residential	<0.001	X	<0.001	<0.001	1.0	<0.001
institutional	<0.001	<0.001	X	<0.001	<0.001	<0.001
commercial	<0.001	<0.001	<0.001	X	<0.001	<0.001
Freeway	<0.001	1.0	<0.001	<0.001	X	0.017
industrial	1.0	<0.001	<0.001	1.0	0.017	X

Tables 5 through 10 summarize the observed total phosphorus concentration statistical characteristics for each land use category. The overall data distribution is shown (as plotted in the box and whisker graph), along with data distributions for each EPA Rain Zone, and for each season. Not all land uses had sufficient data in all rain zones for these summaries. The coefficients of variation (COV, the ratio of the standard deviation to the average values) are relatively large, indicating wide data spreads. However, with large numbers of data in many categories, valid statistical analyses are still possible, as shown in the following discussions, especially considering the similar distribution patterns shown on the box and whisker plots.

Table 5. NSQD, version 4.02, Open Space (OS) Total Phosphorus Concentrations (mg/L as P)

	Overall	EPA Rain Zone							Season			
	All Open Space TP as P (mg/L)	Zone 1 OS TP as P (mg/L)	Zone 2 OS TP as P (mg/L)	Zone 3 OS TP as P (mg/L)	Zone 4 OS TP as P (mg/L)	Zone 5 OS TP as P (mg/L)	Zone 6 OS TP as P (mg/L)	Zone 9 OS TP as P (mg/L)	Fall OS TP as P (mg/L)	Winter OS TP as P (mg/L)	Spring OS TP as P (mg/L)	Summer OS TP as P (mg/L)
number	446	78	103	91	18	67	75	14	106	128	93	119
average	0.363	0.290	0.319	0.471	1.135	0.373	0.149	0.506	0.378	0.371	0.263	0.421
median	0.210	0.187	0.200	0.355	0.315	0.250	0.069	0.470	0.235	0.160	0.190	0.330
minimum	0.005	0.035	0.005	0.005	0.005	0.010	0.025	0.210	0.025	0.010	0.010	0.005
maximum	15.400	2.500	2.500	2.855	15.400	2.290	2.510	1.000	2.855	15.400	1.500	2.500
standard deviation	0.813	0.361	0.361	0.460	3.566	0.413	0.313	0.260	0.469	1.385	0.264	0.404
COV	2.24	1.25	1.13	0.98	3.14	1.11	2.10	0.51	1.24	3.73	1.00	0.96

Table 6. NSQD, version 4.02, Residential Total Phosphorus Concentrations (mg/L as P)

	Overall	EPA Rain Zone									Season			
	All resid TP as P (mg/L)	Zone 1 resid TP as P (mg/L)	Zone 2 resid TP as P (mg/L)	Zone 3 resid TP as P (mg/L)	Zone 4 resid TP as P (mg/L)	Zone 5 resid TP as P (mg/L)	Zone 6 resid TP as P (mg/L)	Zone 7 resid TP as P (mg/L)	Zone 8 resid TP as P (mg/L)	Zone 9 resid TP as P (mg/L)	Fall resid TP as P (mg/L)	Winter resid TP as P (mg/L)	Spring resid TP as P (mg/L)	Summer resid TP as P (mg/L)
number	3855	551	1865	304	122	206	228	290	15	274	943	785	1091	1036
average	0.427	0.402	0.427	0.308	0.611	0.467	0.410	0.305	0.851	0.625	0.408	0.287	0.454	0.524
median	0.290	0.295	0.280	0.150	0.357	0.360	0.310	0.200	0.696	0.470	0.290	0.210	0.300	0.333
minimum	0.005	0.005	0.010	0.010	0.025	0.080	0.025	0.010	0.219	0.071	0.005	0.005	0.015	0.010
maximum	21.200	6.690	19.900	21.200	5.330	4.190	4.960	3.610	2.950	6.420	5.330	4.250	19.900	21.200
standard deviation	0.710	0.432	0.750	1.246	0.774	0.417	0.429	0.374	0.712	0.599	0.431	0.293	0.797	0.975
COV	1.66	1.08	1.76	4.04	1.27	0.89	1.05	1.22	0.84	0.96	1.06	1.02	1.75	1.86

Table 7. NSQD, version 4.02, Institutional Total Phosphorus Concentrations (mg/L as P)

	Overall	EPA Rain Zone						Season			
	All instit TP as P (mg/L)	Zone 1 instit TP as P (mg/L)	Zone 2 instit TP as P (mg/L)	Zone 3 instit TP as P (mg/L)	Zone 4 instit TP as P (mg/L)	Zone 6 instit TP as P (mg/L)	Zone 9 instit TP as P (mg/L)	Fall instit TP as P (mg/L)	Winter instit TP as P (mg/L)	Spring instit TP as P (mg/L)	Summer instit TP as P (mg/L)
number	414	13	45	175	37	49	95	65	77	75	197
average	0.197	0.167	0.237	0.116	0.112	0.303	0.308	0.198	0.175	0.237	0.190
median	0.140	0.150	0.190	0.103	0.100	0.230	0.178	0.140	0.144	0.176	0.121
minimum	0.007	0.026	0.025	0.007	0.025	0.115	0.011	0.010	0.018	0.011	0.007
maximum	2.310	0.370	0.980	0.449	0.270	1.020	2.310	1.020	0.550	0.780	2.310
standard deviation	0.219	0.093	0.194	0.077	0.064	0.191	0.355	0.185	0.118	0.194	0.263
COV	1.11	0.56	0.82	0.66	0.57	0.63	1.15	0.93	0.67	0.82	1.39

Table 8. NSQD, version 4.02 Commercial Total Phosphorus Concentrations (mg/L as P)

	Overall	EPA Rain Zone									Season			
	All commercial TP as P (mg/L)	Zone 1 commer TP as P (mg/L)	Zone 2 commer TP as P (mg/L)	Zone 3 commer TP as P (mg/L)	Zone 4 commer TP as P (mg/L)	Zone 5 commer TP as P (mg/L)	Zone 6 commer TP as P (mg/L)	Zone 7 commer TP as P (mg/L)	Zone 8 commer TP as P (mg/L)	Zone 9 comer TP as P (mg/L)	Fall commer TP as P (mg/L)	Winter commer TP as P (mg/L)	Spring commer TP as P (mg/L)	Summer commer TP as P (mg/L)
number	1598	293	613	698	139	111	84	61	7	178	376	294	419	452
average	0.376	0.240	0.364	0.441	0.288	0.600	0.460	0.398	0.568	0.373	0.391	0.328	0.365	0.388
median	0.210	0.140	0.230	0.220	0.160	0.160	0.375	0.280	0.497	0.230	0.217	0.193	0.210	0.200
minimum	0.005	0.022	0.005	0.005	0.025	0.010	0.025	0.005	0.163	0.008	0.010	0.005	0.008	0.010
maximum	15.600	8.600	6.720	15.600	3.550	15.600	2.000	3.300	1.080	6.300	15.600	3.670	8.600	10.300
standard deviation	0.701	0.534	0.479	0.891	0.464	1.874	0.353	0.493	0.350	0.601	0.900	0.443	0.654	0.715
COV	1.86587	2.22	1.32	2.02	1.61	3.12	0.77	1.24	0.62	1.61	2.30	1.35	1.79	1.84

Table 9. NSQD, version 4.02, Freeways Total Phosphorus Concentrations (mg/L as P)

	Overall	EPA Rain Zone							Season			
	All freeways TP as P (mg/L)	Zone 1 free TP as P (mg/L)	Zone 2 free TP as P (mg/L)	Zone 3 free TP as P (mg/L)	Zone 5 free TP as P (mg/L)	Zone 6 free TP as P (mg/L)	Zone 7 free TP as P (mg/L)	Zone 9 free TP as P (mg/L)	Fall free TP as P (mg/L)	Winter free TP as P (mg/L)	Spring free TP as P (mg/L)	Summer free TP as P (mg/L)
number	378	3	90	14	14	211	24	22	74	151	108	45
average	0.406	0.433	0.317	0.165	0.198	0.477	0.347	0.425	0.468	0.366	0.466	0.292
median	0.270	0.410	0.240	0.125	0.125	0.298	0.280	0.315	0.365	0.250	0.250	0.260
minimum	0.015	0.353	0.020	0.071	0.020	0.015	0.110	0.100	0.015	0.025	0.020	0.070
maximum	7.191	0.537	3.030	0.459	0.750	7.191	0.900	2.600	2.600	2.600	7.191	0.910
standard deviation	0.558	0.094	0.345	0.122	0.204	0.676	0.198	0.527	0.425	0.353	0.877	0.194
COV	1.38	0.22	1.09	0.74	1.03	1.42	0.57	1.24	0.91	0.97	1.88	0.66

Table 10. NSQD, version 4.02, Industrial Total Phosphorus Concentrations (mg/L as P)

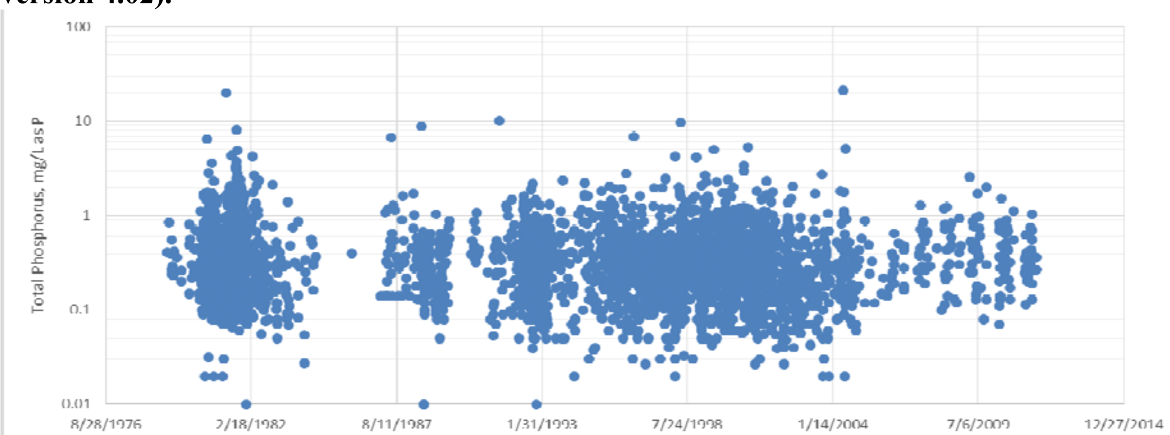
	Overall	EPA Rain Zone									Season			
	All indus TP as P (mg/L)	Zone 1 indus TP as P (mg/L)	Zone 2 indus TP as P (mg/L)	Zone 3 indus TP as P (mg/L)	Zone 4 indus TP as P (mg/L)	Zone 5 indus TP as P (mg/L)	Zone 6 indus TP as P (mg/L)	Zone 7 indus TP as P (mg/L)	Zone 8 indus TP as P (mg/L)	Zone 9 indus TP as P (mg/L)	Fall indus TP as P (mg/L)	Winter indus TP as P (mg/L)	Spring indus TP as P (mg/L)	Summer indus TP as P (mg/L)
number	1000	106	362	136	78	108	150	30	1	29	245	254	256	245
average	0.398	0.291	0.318	0.233	0.578	0.257	0.797	0.527	0.313	0.426	0.344	0.380	0.411	0.460
median	0.230	0.210	0.220	0.175	0.255	0.185	0.450	0.460		0.330	0.249	0.228	0.220	0.230
minimum	0.010	0.040	0.020	0.024	0.010	0.010	0.025	0.064		0.090	0.020	0.010	0.010	0.020
maximum	10.800	1.500	4.880	1.500	10.800	2.640	7.900	1.400		1.300	2.500	4.600	10.800	7.900
standard deviation	0.654	0.266	0.467	0.217	1.345	0.304	0.981	0.335		0.294	0.367	0.571	0.825	0.748
COV	1.640676	0.91	1.47	0.93	2.33	1.18	1.23	0.64		0.69	1.07	1.50	2.01	1.63

Trend Analyses of NSQD Residential Land Use Phosphorus Data

A time series analyses was conducted for residential total phosphorus data in the NSQD to observe any concentration trends associated with both time and rain depth. More than 3,800 total phosphorus observations are available in the NSQD, version 4.02, for residential land uses.

The Figure 3 time series plot illustrates the total phosphorus residential area concentrations by sampling data (all EPA Rain Zones and seasons combined) as contained in the NSQD (version 4.02). Stormwater nutrient concentrations, especially in residential areas, are likely affected by homeowner fertilizer use, vegetation debris, and other landscaping practices (including erosion of nutrient-rich soils). Residential area fertilizer use has likely changed over time, especially in areas having phosphate restrictions. The analysis of variance (ANOVA) on the regression coefficients (using Excel) for the very large number of observations indicated a statistically significant but very small trend ($p = 0.01$). Over a 31-year monitoring period, from 1979 to 2011, the total phosphorus concentrations decreased by about 10% (by 0.087 mg/L). Several hundred monitoring locations are included in this dataset, with most only active for short periods. It is expected that phosphorus trends may be more obvious if data were available for an individual location over many years, compared to this combined analysis of multiple locations. Similar analyses for the other land uses resulted in similar findings.

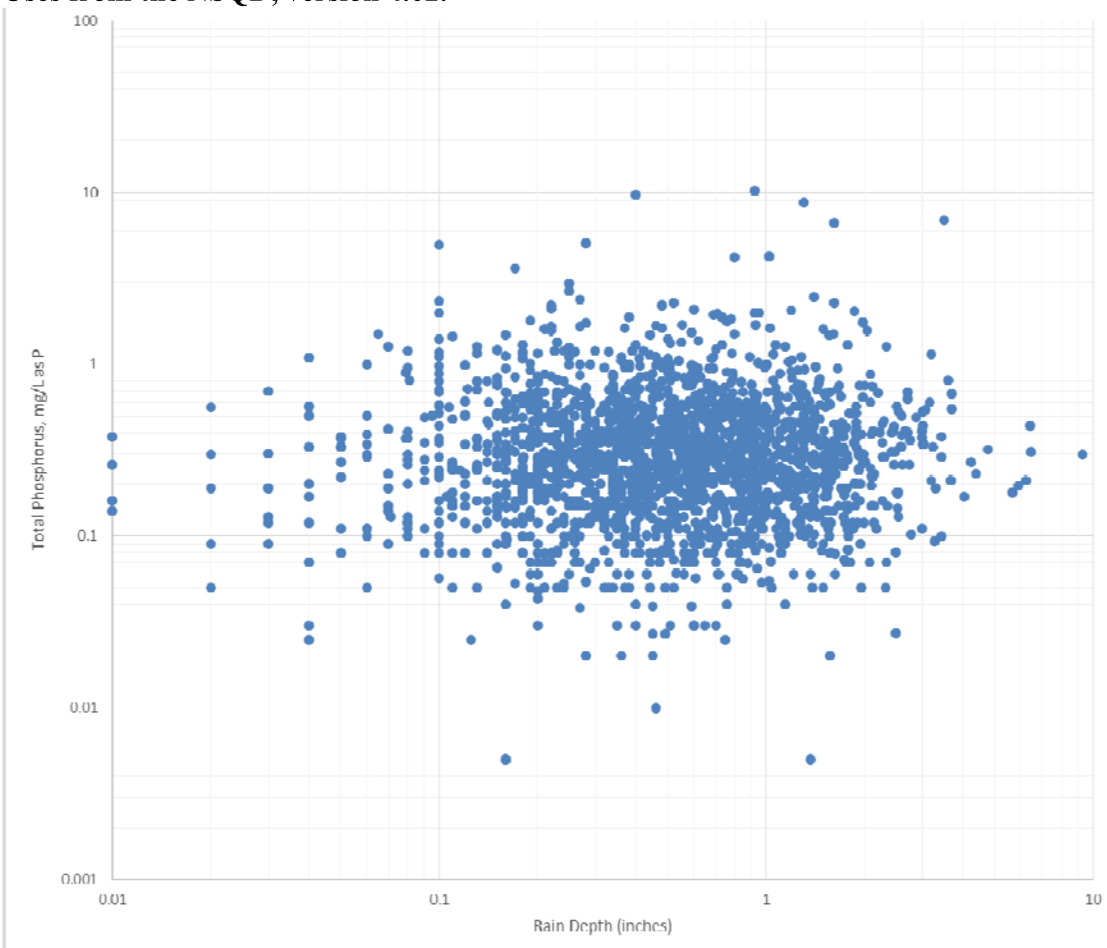
Figure 3. Time Series of Total Phosphorus Residential Area Concentrations (NSQD version 4.02).



The Figure 4 scatterplot compares the residential area total phosphorus concentrations plotted against the rain depths associated with these same monitored events. Typical assumptions about stormwater concentrations and rains include: larger rains produce greater erosion and delivery of contaminants, but that the larger discharge volumes tend to dilute the runoff, resulting in lower overall concentration values. It is also sometimes assumed that smaller rains are associated with “first-flush” higher concentrations. These assumptions imply that larger concentrations are associated with smaller rains rather than larger rains.

During this 31 year period of time, the rains ranged from 0.01 to 9.28 inches, with an average rain depth of 0.72 inches (and a median depth of 0.52 inches). The rains represented in this analysis therefore include a broad range, with most events of intermediate rain depths. The ANOVA on the regression analysis (using Excel) for these data pairs indicated no significant relationship or trend of total phosphorus with changes in rain depth, even with more than 2,100 data pairs (p = 0.53).

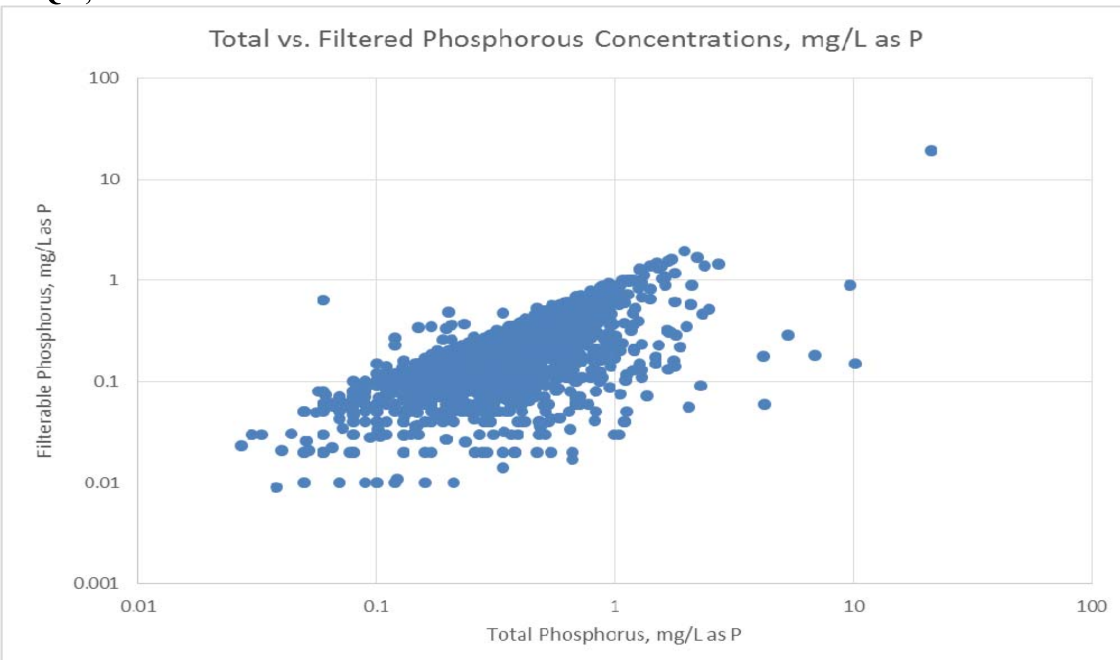
Figure 4. Total Phosphorus Concentrations vs. Rain Depth for All Residential Land Uses from the NSQD, version 4.02.



Figures 5 and 6 and Table 11 compare the total phosphorus concentrations with concurrent filterable phosphorus concentrations (material passing through a nominal 0.45 µm membrane filter, which can include a variety of pollutant forms, including colloids and organic complexes; not all of the filterable material are in "dissolved" or ionic forms) for the residential land use area data for all locations and seasons in the NSQD, version 4.02. The filterable phosphorus portion of the total phosphorus concentration is usually much more difficult to remove using conventional stormwater management practices (which usually rely on sedimentation or filtering). It is also readily available for aquatic plant growth and more likely to cause eutrophication problems. The smaller the filterable fraction (and larger the particulate-bound fraction), the greater removal usually occurs with conventional stormwater control practices. The filterable fraction usually needs to be treated using chemical (coagulation/precipitation, ion exchange, or sorption) or biological (nutrient uptake) processes. Infiltration can also reduce phosphorus surface water discharges by capturing the phosphorus in surface soils during infiltration, as long as groundwater contamination potential is low.

The Figure 5 scatterplot of total vs. filterable phosphorus concentrations indicate that the largest ratio approaches 1 (the apparent upper line of observations along the 1:1 slope), but most are below this upper limit (a few data observations indicate filterable concentrations larger than the total concentrations reflecting minor, but common, processing and analysis errors).

Figure 5. Scatterplot of Total vs. Filterable Phosphorus From Residential Land Uses in NSQD, version 4.02.



The above scatterplot of total vs. filterable phosphorus concentrations resulted in a very significant regression relationship between these variables ($p < 0.001$) with a slope term (the overall average ratio of filterable to total phosphorus) of 0.53. This is in good agreement with the usually assumed filterable fraction of about 50%. Table 11 summarizes the total and filterable concentrations, and their ratio for the NSQD, version 4.02, residential area observations. The median and the average ratios are both 0.57 when examining the available 1,468 data pairs.

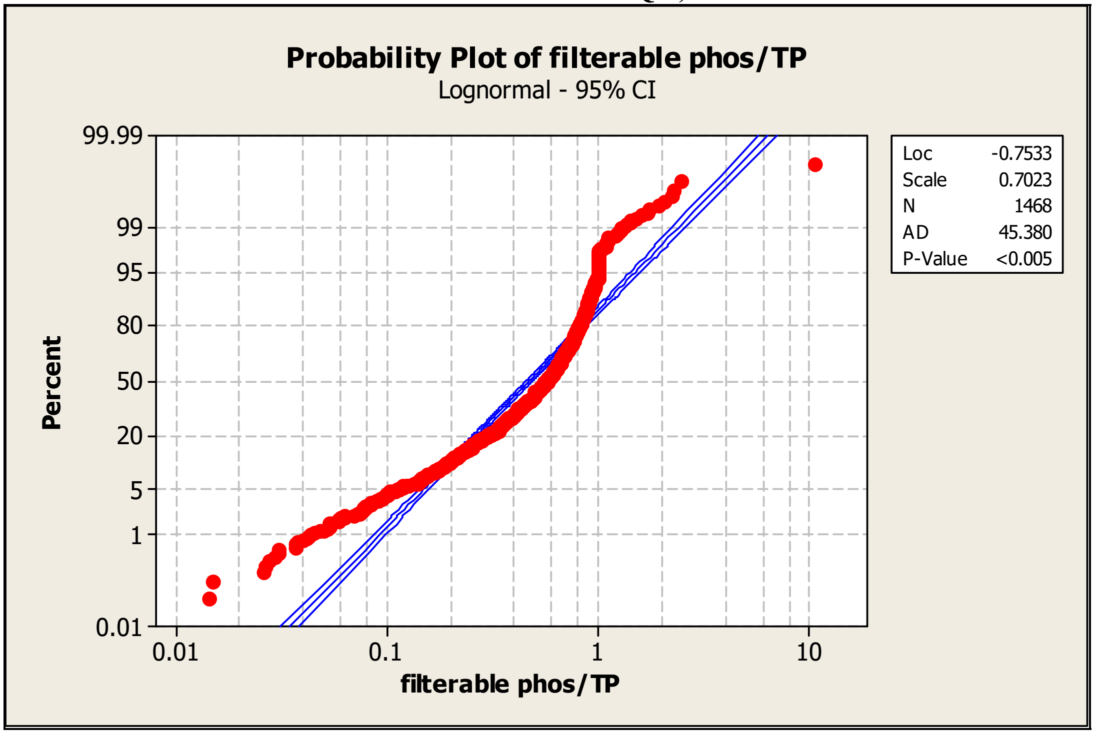
Table 11. Total and Filterable Phosphorus Concentrations at NSQD, version 4.02, Residential Land Use Areas

	Total Phosphorous (mg/L as P)	Filterable Phosphorous (mg/L as P)	Ratio of Filterable to Total Phosphorus
Number	1,468	1,468	1,468
Average	0.46	0.23	0.57
Median	0.33	0.16	0.57
Minimum	0.03	0.01	0.01
Maximum	21.2	19.3	10.7
Standard deviation	0.77	0.54	0.39
COV	1.68	2.34	0.69

Figure 6 is a log-normal probability plot (using Minitab 16) of the calculated filterable to total phosphorus ratios for these data, visually showing the spread of these data ratios. About

2% of the filterable concentrations were greater than the total concentrations (these are the data points in the scatterplot that are above the 1:1 slope), reflecting typical data variations associated with sample processing and analyses.

Figure 6. Log-Normal Probability Plot of Filterable to Total Phosphorus Concentrations from Residential Areas in the NSQD, version 4.02.



Total Phosphorus Concentration Relationships by Geographical Area and by Season for All Land Uses in the NSQD, version 4.02

More detailed geographical area and seasonal analyses were conducted focusing on residential area total phosphorus concentrations only, due to their large number of observations compared to the other land uses. The Figure 7 box and whisker plot for the different EPA rain zones shows reasonably symmetrical and similar distributions for all geographical area groups, but with larger differences between the areas. The Kruskal-Wallis analyses on Table 12 indicated at least one of the areas was significantly different from the others ($p < 0.001$).

Figure 7. Box and Whisker Plots for NSQD, version 4.02, Residential Total Phosphorus Concentrations by Geographical Location.

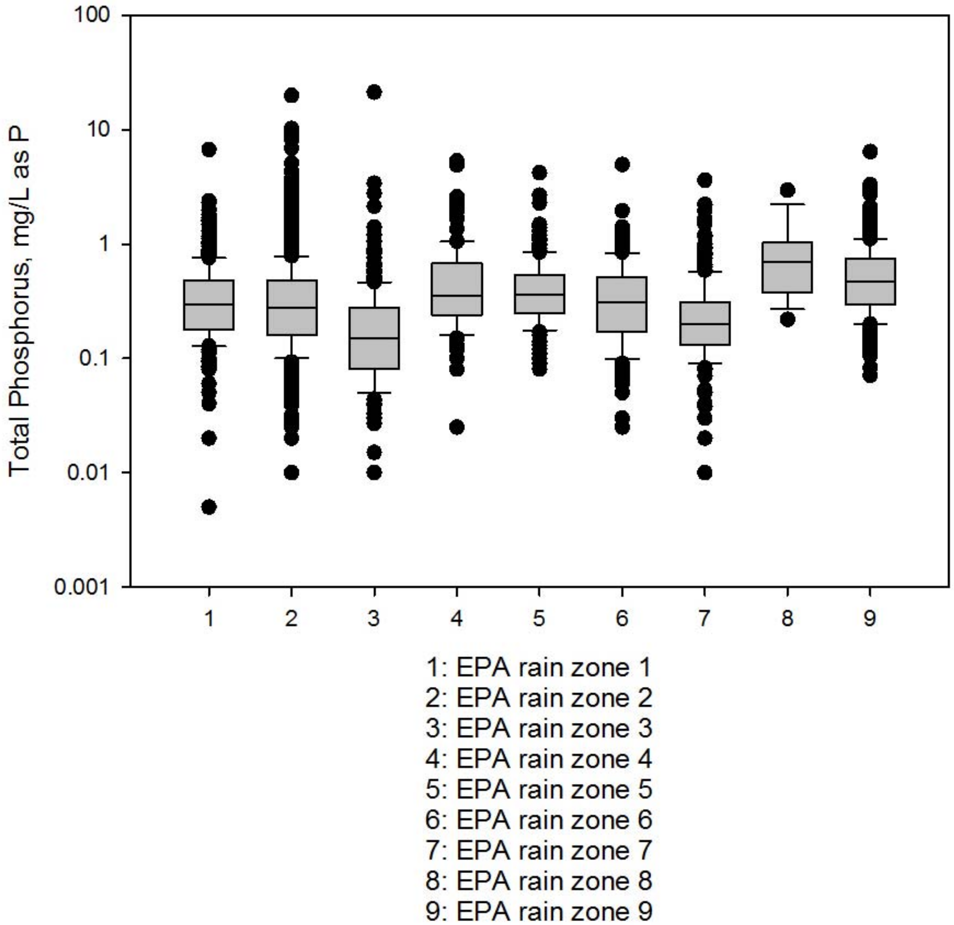


Table 12. Residential Area TP Data by EPA Rain Zone using Kruskal-Wallis One Way Analysis of Variance on Ranks

Group	N	Missing	Median	25%	75%
Z1 res TP	551	0	0.30	0.18	0.48
Z2 res TP	1865	0	0.28	0.16	0.48
Z3 res TP	304	0	0.15	0.08	0.28
Z4 res TP	122	0	0.36	0.24	0.68
Z5 res TP	206	0	0.36	0.25	0.54
Z6 res TP	228	0	0.31	0.17	0.52
Z7 res TP	290	0	0.2	0.13	0.31
Z8 res TP	15	0	0.70	0.38	1.03
Z9 res TP	274	0	0.47	0.30	0.75
H = 356.756 with 8 degrees of freedom. (P = <0.001)					
The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001)					

These analyses also indicated significant differences between most of the EPA rain zone areas, as indicated on the Dunn's multi-pairwise Table 13.

Table 13. Dunn's Multi-Pairwise Comparisons between all EPA Rain Zones for Residential Total Phosphorus Concentrations

	1	2	3	4	5	6	7	8	9
1	X	1.0	<0.001	0.035	0.004	1.0	<0.001	0.013	<0.001
2	1.0	X	<0.001	0.001	<0.001	1.0	<0.001	0.005	<0.001
3	<0.001	<0.001	X	<0.001	<0.001	<0.001	0.063	<0.001	<0.001
4	0.035	0.001	<0.001	X	1.0	0.20	<0.001	0.99	0.61
5	0.004	<0.001	<0.001	1.0	X	0.068	<0.001	0.77	0.11
6	1.0	1.0	<0.001	0.20	0.068	X	<0.001	0.022	<0.001
7	<0.001	<0.001	0.063	<0.001	<0.001	<0.007	X	<0.001	<0.001
8	0.013	0.005	<0.001	0.99	0.77	0.022	<0.001	X	1.0
9	<0.001	<0.001	<0.001	0.61	0.11	<0.001	<0.001	1.0	X

Potential significant data overlaps may occur for EPA Rain Zones 1, 2, and 6; 3 and 7; and 4, 5, 8, and 9, resulting in three geographical groups for residential areas.

The Figure 8 box and whisker plot and Tables 14 and 15 show the same residential land use data separated by season (all geographical areas combined). The Kruskal-Wallis analyses indicated that at least one season is significantly different from the others ($p < 0.001$).

Figure 8. Box and Whisker Plot of NSQD, version 4.02, Total Phosphorus Residential Area Concentrations Grouped by Season.

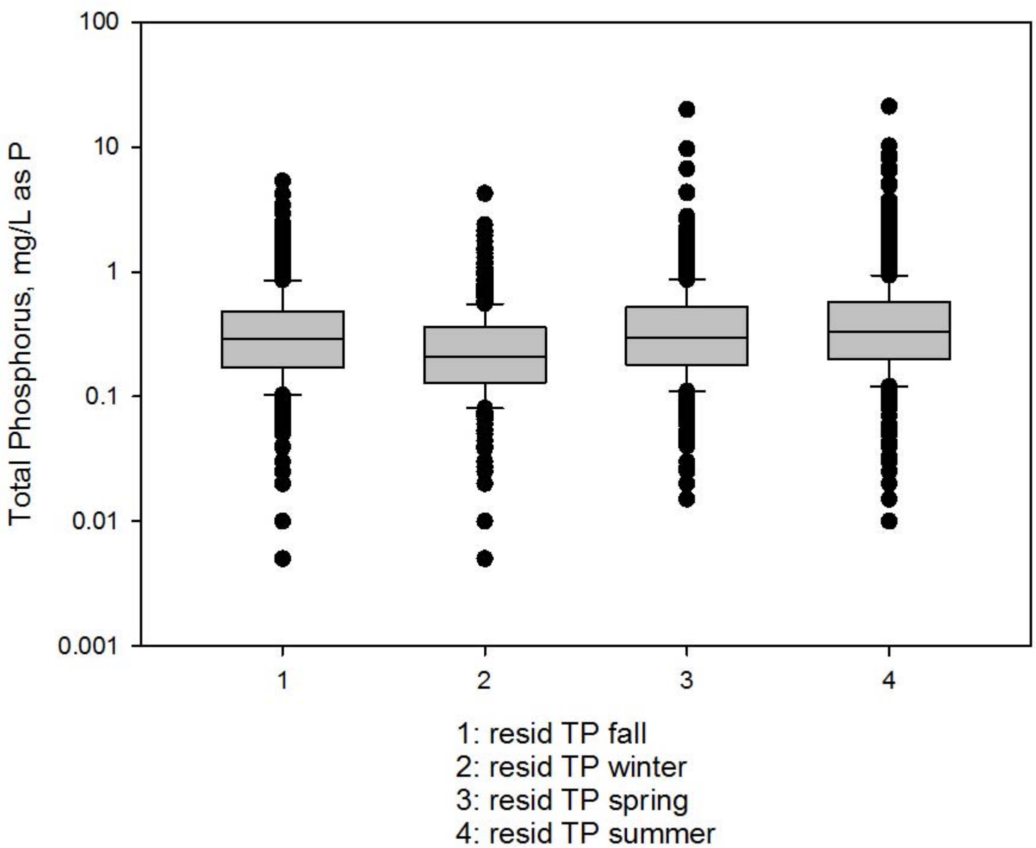


Table 14. Residential Area TP Data by Season using Kruskal-Wallis One Way Analysis of Variance on Ranks

Group	N	Missing	Median	25%	75%
resid TP fall	943	0	0.29	0.17	0.48
resid TP winter	785	0	0.21	0.13	0.36
resid TP spring	1091	0	0.30	0.18	0.52
resid TP summer	1036	0	0.33	0.20	0.57
H = 149.709 with 3 degrees of freedom. (P = <0.001)					
The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001)					

The Dunn's pair-wise comparisons of all of the NSQD residential land use total phosphorus data indicate that the winter season had the lowest total phosphorus concentrations, summer had the highest concentrations, and fall and spring had intermediate concentrations.

Table 15. Dunn's Pair-Wise Comparisons of Residential Total Phosphorus Concentrations by Season

	fall	winter	spring	summer
fall	X	<0.001	1.0	<0.001
winter	<0.001	X	<0.001	<0.001
spring	1.0	<0.001	X	0.017
summer	<0.001	<0.001	0.017	X

EPA Rain Zone 1 Total Phosphorus Analyses

The following analyses examine EPA Rain Zone 1 total phosphorus concentrations for all land uses by season. The prior analyses indicated that geographical area, land use, and season all affect the likely total phosphorus concentrations for an area. These data are from 69 locations in 8 states, and total 1,019 observations. Samples were collected between 1979 and 2003, covering a period of about 24 years. Tables 16 through 23 list the station names by state and the amount of total phosphorus data available from each in EPA Rain Zone 1.

Table 16. Illinois Monitoring Locations in EPA Rain Zone 1, NSQD, version 4.02

Illinois Station Name	First event	Last event	# of events	# stations in state	# events in state	first event in state	last event in state
Lake_Ellyn_1_Inflow_Lake_Ellyn	4/3/1980	6/8/1981	18	1	18	4/3/1980	6/8/1981

Table 17. Indiana Monitoring Locations in EPA Rain Zone 1, NSQD, version 4.02

Indiana Station Name	First event	Last event	# of events	# stations in state	# events in state	first event in state	last event in state
Basin_C1_control	7/17/1999	12/5/2003	12				
Basin_C2_test	7/17/1999	12/5/2003	12				
Basin_I1_control	7/17/1999	12/5/2003	11				
Basin_I2_test	7/17/1999	12/5/2003	11				
Basin_C3	10/8/1999	12/5/2003	10				
Basin_R1_control	10/8/1999	10/14/2003	9				
Basin_R2_test	10/8/1999	10/14/2003	9	7	74	7/17/1999	12/5/2003

Table 18. Massachusetts Monitoring Locations in EPA Rain Zone 1, NSQD, version 4.02

Massachusetts Station Name	First event	Last event	# of events	# stations in state	# events in state	first event in state	last event in state
P4_Anna_St_Fitzgerald_Brook	6/16/1980	9/26/1980	6				
P5_Convent_Tributary to Coal Mine Brook	6/20/1980	8/11/1980	8				
P1_Jordan_Pond_Inlet	6/29/1980	9/18/1980	8				
P2_Rt_9_Belmont_St	7/17/1980	9/18/1980	5				
P3_Locust_St_Tributary to Belmont St	7/17/1980	9/26/1980	6				
Addison Wesley	4/4/1981	8/5/1981	5				
Hemlock Road	4/14/1981	8/5/1981	5				
Brighton_25E037	4/11/1992	6/24/1992	3				
Charlestown_29J212	4/11/1992	8/14/1992	3				
Dorchester_8J102	4/11/1992	6/24/1992	3				
Hyde_Park_2F120	4/17/1992	6/24/1992	3				
West_Roxebury_13D077_078	4/17/1992	3/18/1998	15				
Beaver Brook	3/28/2000	9/28/2003	11				
Brookdale Street	3/28/2000	9/28/2003	12				
Camp Street	3/28/2000	9/28/2003	11				
Middle Brook	3/28/2000	9/28/2003	11				
New Bond Street	3/28/2000	9/28/2003	11				
Olean Street	3/28/2000	9/28/2003	12				
Park Ave and Maywood St	3/28/2000	9/28/2003	12				
Mount_Vernon_26K099	6/2/2001	7/17/2001	3				
Wesley_G_Ross_6G108	9/25/2001	9/25/2001	1				
27K397_Mount_Vernon_St_Charlestown	3/3/2002	4/28/2002	3				
5F208_HydeParkAve_Hyde_Park	4/11/2003	10/26/2002	11	23	168	6/16/1980	9/28/2003

Table 19. Michigan Monitoring Locations in EPA Rain Zone 1, NSQD, version 4.02

Michigan Station Name	First event	Last event	# of events	# stations in state	# events in state	first event in state	last event in state
PITAARETBNNINLT Pitt AA RB N PNI	6/29/1979	5/10/1981	13				
Pittsfield_Retention_Basin_1_in_Pittsfield_Retent	6/30/1979	10/24/1980	7				
GCO_MI006_Waverly_Hills	4/3/1980	10/17/1981	35				
MI1001_Grand_River	4/3/1980	11/19/1981	22				
Upsized_Pipe_1_Inlet_MI008_Grace_St_N_Inlet	4/3/1980	11/19/1981	40				
MI1002_Industrial_Drain	5/30/1980	10/19/1981	18				
Traver_Creek_Detention_Basin_1_in_Traver_Crk_Retention	4/11/1981	6/13/1981	5	7	140	6/29/1979	11/19/1981

Table 20. Minnesota Monitoring Locations in EPA Rain Zone 1, NSQD, version 4.02

Minnesota Station Name	First event	Last event	# of events	# stations in state	# events in state	first event in state	last event in state
Carver_Ravine_Wetland_Detention_Facility_01_in_Carver_Ravine	4/26/1988	4/4/1989	19				
Carver_Ravine_Wetland_Detention_Facility_03_out_Carver_Ravine	5/8/1988	4/4/1989	9				
Site1_Harriet_Pkwy_44th_St	1/30/2001	10/4/2002	14				
Site5a_Snelling_ave_S_and_E_24th_St	3/9/2001	10/8/2002	24				
Site2_Luella_St_at_Orange_ave	3/15/2001	10/7/2002	13				
Site3_Vandalia_St_350_ft_S_of_Capp_Rd	3/15/2001	10/7/2002	13				
Site4_Charles_ave_Mackubin_to_Arundel_St	3/15/2001	10/7/2002	11				
Charles Ave	5/6/2001	11/12/2001	9				
E_Harriet_Pkwy_W44_St	5/6/2001	10/13/2001	10				
Luella St Orange Ave	5/6/2001	10/13/2001	9				
E_29_St_31_Ave_S	5/20/2001	11/12/2001	10				
Vandalia St	5/20/2001	11/12/2001	10	12	151	4/26/1988	10/8/2002

Table 21. New Hampshire Monitoring Locations in EPA Rain Zone 1, NSQD, version 4.02

New Hampshire Station Name	First event	Last event	# of events	# stations in state	# events in state	first event in state	last event in state
1_PKG_Shop_n_Save_Parking_Lot	7/29/1980	10/6/1981	27	1	27	7/29/1980	10/6/1981

Table 22. New York Monitoring Locations in EPA Rain Zone 1, NSQD, version 4.02

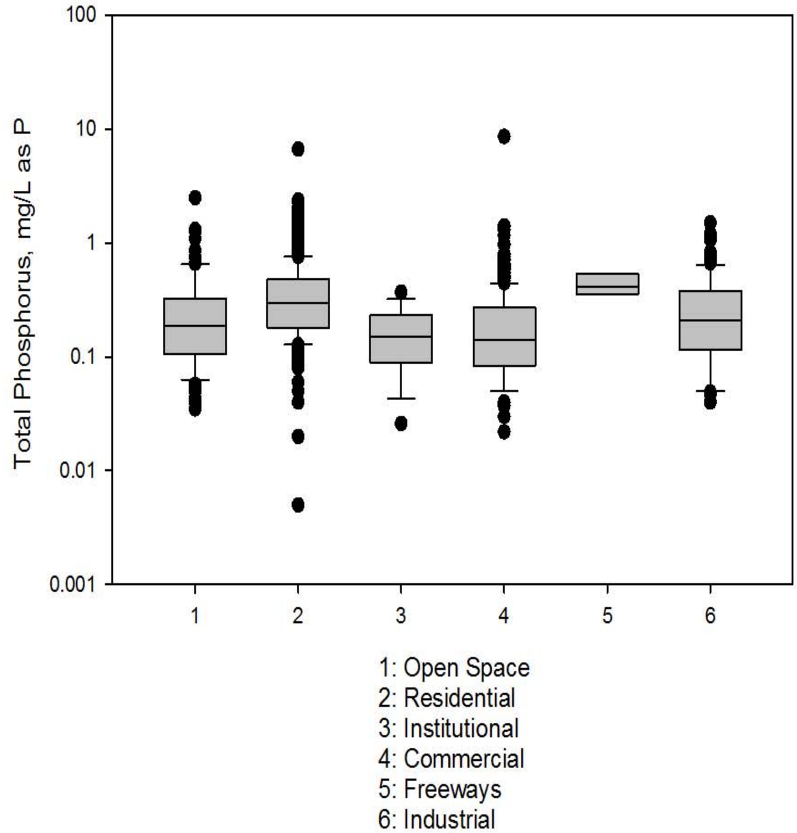
New York Station Name	First event	Last event	# of events	# stations in state	# events in state	first event in state	last event in state
Cedar Lane Storm Sewer	9/2/1980	11/20/1981	32				
Sherriff's Dock SS	9/2/1980	11/20/1981	33				
NY_1021_Unqua_Influent	9/18/1980	7/20/1981	8				
NY1031_Carlls_River_Street_Sweeping	11/17/1980	10/25/1982	24	4	97	9/2/1980	10/25/1982

Table 23. Wisconsin Monitoring Locations in EPA Rain Zone 1, NSQD, version 4.02

Wisconsin Station Name	First event	Last event	# of events	# stations in state	# events in state	first event in state	last event in state
Wood Center	3/14/1980	10/17/1981	47				
Post Office Capital Court South	4/3/1980	10/17/1981	60				
Rustler Capital Court North	4/4/1980	10/17/1981	37				
State Fair	5/28/1980	10/17/1981	28				
N Hastings	6/2/1980	7/25/1981	24				
N_Burbank_633	6/6/1980	10/17/1981	45				
Lincoln Creek	4/4/1981	10/6/1981	23				
Wet_Pond_Monroe_St_I1	2/28/1987	4/5/1988	30				
Harper Road	6/17/1993	11/12/1993	7				
Lakeland Ave	6/17/1993	4/12/1994	6				
Observatory Dr	6/17/1993	8/12/1994	8				
Syene Road	6/17/1993	9/22/1994	15				
West Towne	6/17/1993	5/14/1994	7				
Annamark Road	10/8/1993	5/14/1994	7	14	344	3/14/1980	9/22/1994

The first analyses compared the different land uses in EPA Rain Zone 1, as shown on Figure 9 box and whisker plots and Tables 24 and 25 multivariate analyses.

Figure 9. Box and Whisker Plots of NSQD, version 4.02, Total Phosphorus EPA Rain Zone 1 Concentrations Grouped by Land Use (Significant Land Use Groupings).



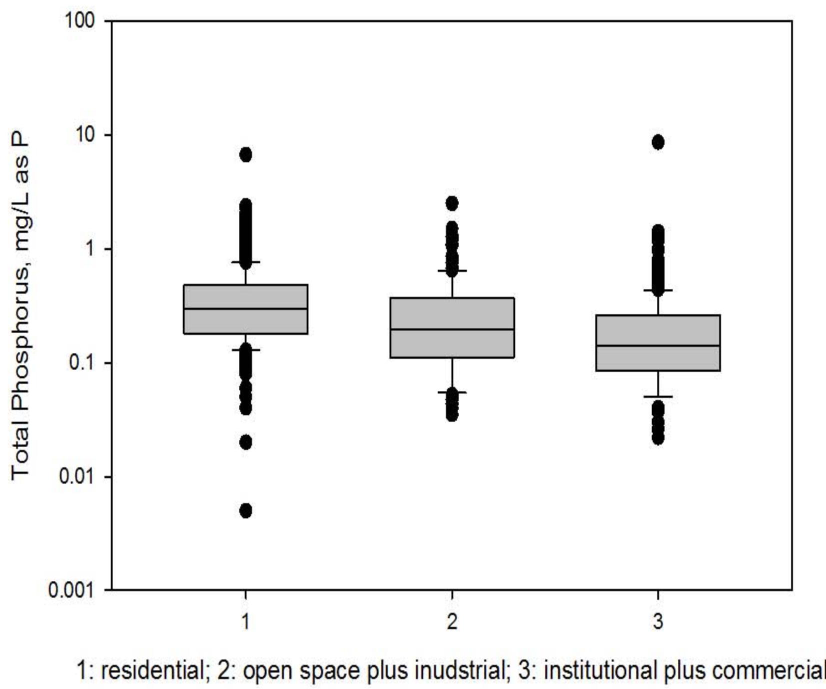


Table 24. Kruskal-Wallis One Way Analysis of Variance on Ranks

Group	N	Missing	Median	25%	75%
Z1 TP OS	78	0	0.19	0.11	0.33
Z1 TP Res	551	0	0.30	0.18	0.48
Z1 TP instit	13	0	0.15	0.090	0.24
Z1 TP commer	293	0	0.14	0.083	0.27
Z1 TP free	3	0	0.41	0.35	0.54
Z1 TP indus	106	0	0.21	0.12	0.38
H = 146.660 with 5 degrees of freedom. (P = <0.001)					
The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001)					

The Kruskal-Wallis tests indicated that at least one land use were different from the others. Therefore, multiple pairwise comparisons (Dunn's test) were used, as summarized in Table 25 of p values for all pairs.

Table 25. Pairwise p Values for EPA Rain Zone 1 Total Phosphorus Concentrations by Land Use Groups

	open space	residential	institutional	commercial	freeways	industrial
open space	X	<0.001	1.0	0.76	0.59	1.0
residential	<0.001	X	0.015	<0.001	1.0	<0.001
institutional	1.0	0.015	X	1.0	0.23	1.0
commercial	0.76	<0.001	1.0	X	0.18	0.015
freeways	0.59	1.0	0.23	0.18	X	0.95
industrial	1.0	<0.001	1.0	0.015	0.95	X

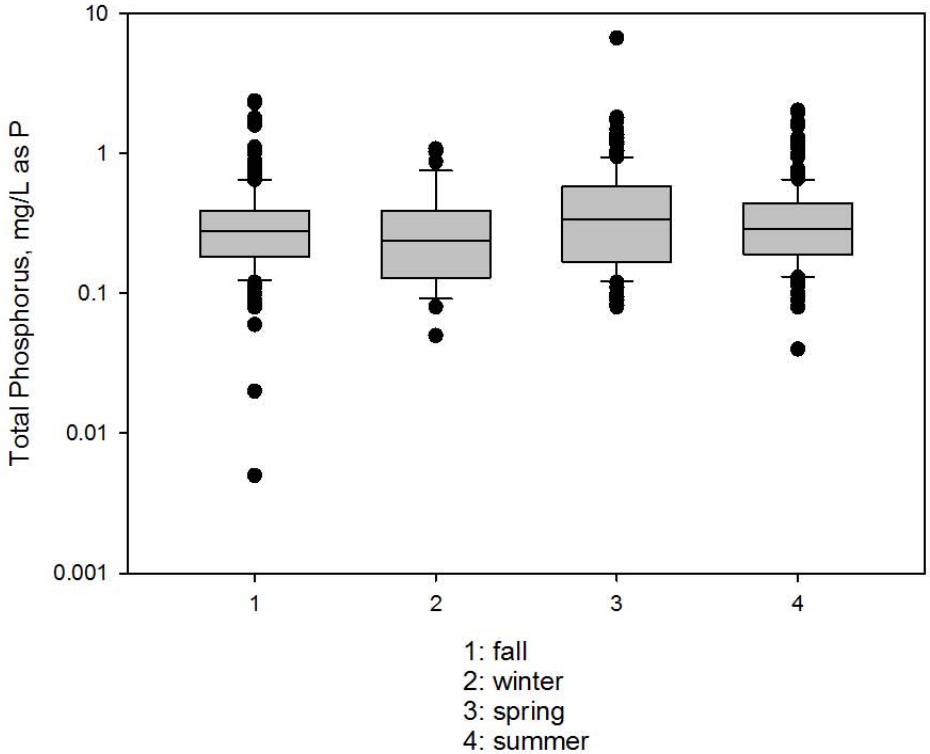
Very few data were available for freeways, so they were not included in the final groupings. The significant land use groupings of EPA Rain Zone 1 total phosphorus data were therefore further evaluated for seasonal effects:

- Residential land uses
- Open space plus industrial land uses
- Institutional plus commercial land uses

It is possible that the last two groups could be further combined, leaving residential areas as the only separate land use for this area. The box and whisker plot for these three combined categories are also shown above with the plots for the individual groups.

The following analyses examine these three groups by season. The first is for the residential group of total phosphorus observations shown on Figure 10 and Tables 26 and 27.

Figure 10. Box And Whisker Plots of NSQD, version 4.02, EPA Rain Zone 1 Residential Land Use Total Phosphorus Concentrations Grouped by Season.



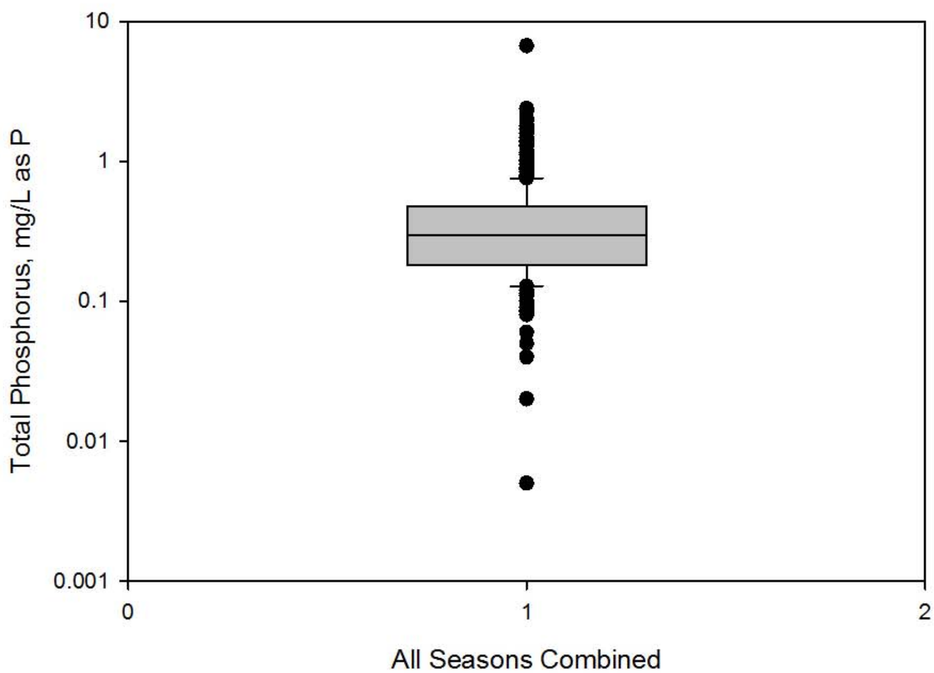


Table 26. EPA Rain Zone 1 Residential Area Total Phosphorus Comparisons using the Kruskal-Wallis One Way Analysis of Variance on Ranks Test

Group	N	Missing	Median	25%	75%
Z1 res fall TP	164	0	0.89	0.14	0.99
Z1 res winter TP	38	0	0.24	0.13	0.32
Z1 res spring TP	142	0	0.49	0.78	0.95
Z1 res summer TP	207	0	0.29	0.19	0.44
H = 7.920 with 3 degrees of freedom. (P = 0.048)					
The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = 0.048)					

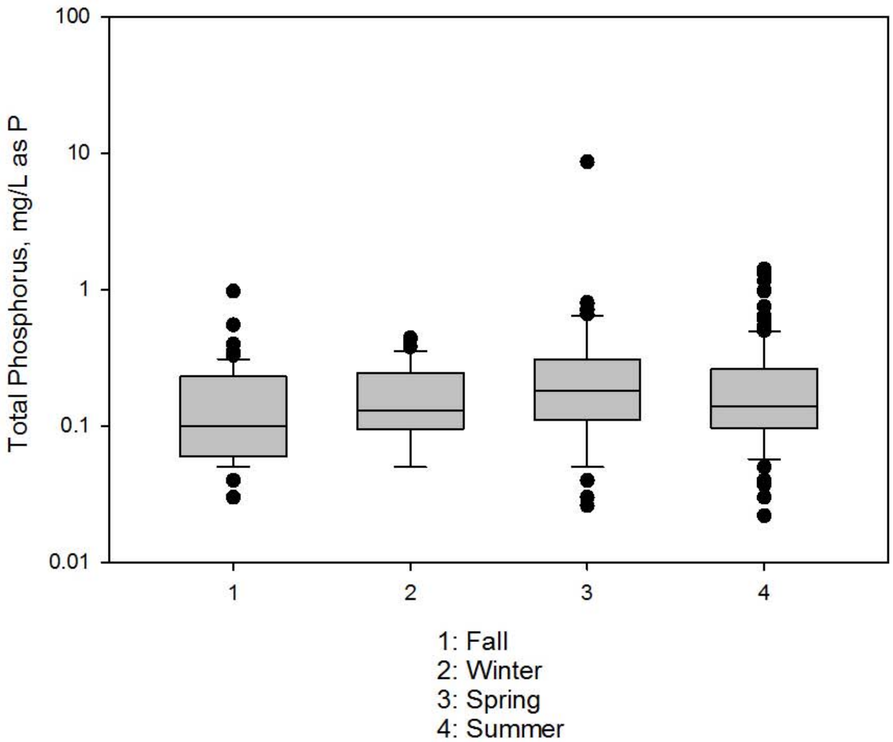
Table 27. Pairwise p Values for EPA Rain Zone 1 Total Phosphorus Concentrations by Season Groups for Residential Land Use Areas

	Fall	Winter	Spring	Summer
Fall	X	1.0	0.19	1.0
Winter	1.0	X	0.10	1.0
Spring	0.19	0.10	X	0.41
Summer	1.0	1.0	0.41	X

Although the Kruskal-Wallis test indicates that at least one season was significantly different from the others (p = 0.048), the pairwise tests were not able to identify any significant differences. Therefore, the residential land use total phosphorus values in this region were not separated by seasonal difference.

The following analyses shown on Figure 11 and Tables 28 through 30 examine the combined group of institutional plus commercial land use total phosphorus data.

Figure 11. Box And Whisker Plots of NSQD, version 4.02, EPA Rain Zone 1 Institutional Plus Commercial Land Use Total Phosphorus Concentrations Grouped by Season.



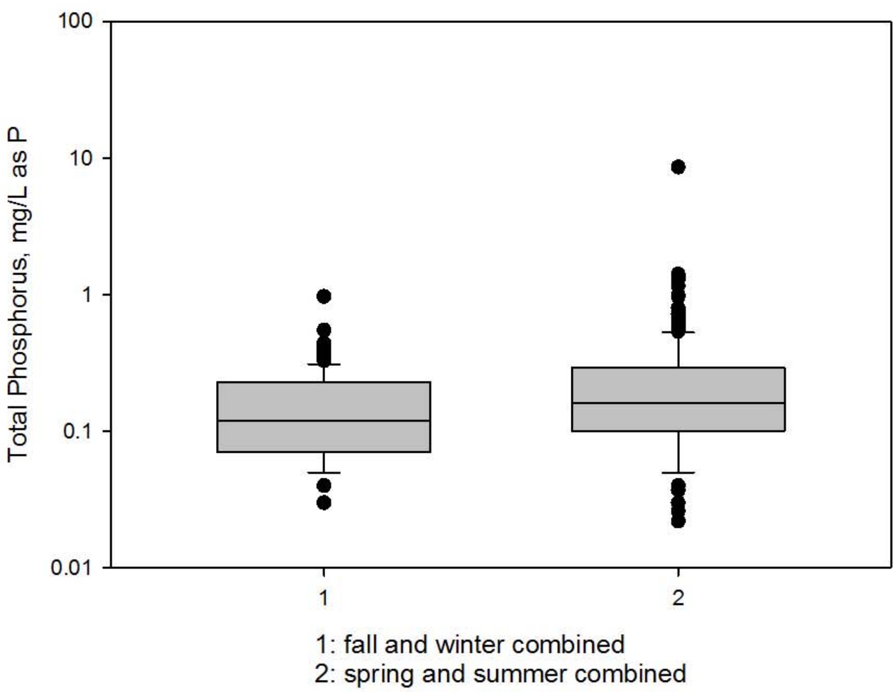


Table 28. EPA Rain Zone 1 Institutional plus Commercial Area Total Phosphorus Comparisons using the Kruskal-Wallis One Way Analysis of Variance on Ranks Test by Seasons

Group	N	Missing	Median	25%	75%
Z1 fall inst commer TP	79	0	0.1	0.06	0.23
Z1 winter inst commer TP	33	0	0.13	0.095	0.45
Z1 spring inst commer TP	68	0	0.18	0.11	0.31
Z1 summer inst commer TP	126	0	0.14	0.078	0.23
H = 12.164 with 3 degrees of freedom. (P = 0.007)					
The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = 0.007)					

Table 29. Pairwise p Values for EPA Rain Zone 1 Total Phosphorus Concentrations by Season Groups for Institutional plus Commercial Land Use Areas

	Fall	Winter	Spring	Summer
Fall	X	1.0	0.005	0.082
Winter	1.0	X	0.68	1.0
Spring	0.005	0.68	X	1.0
Summer	0.082	1.0	1.0	X

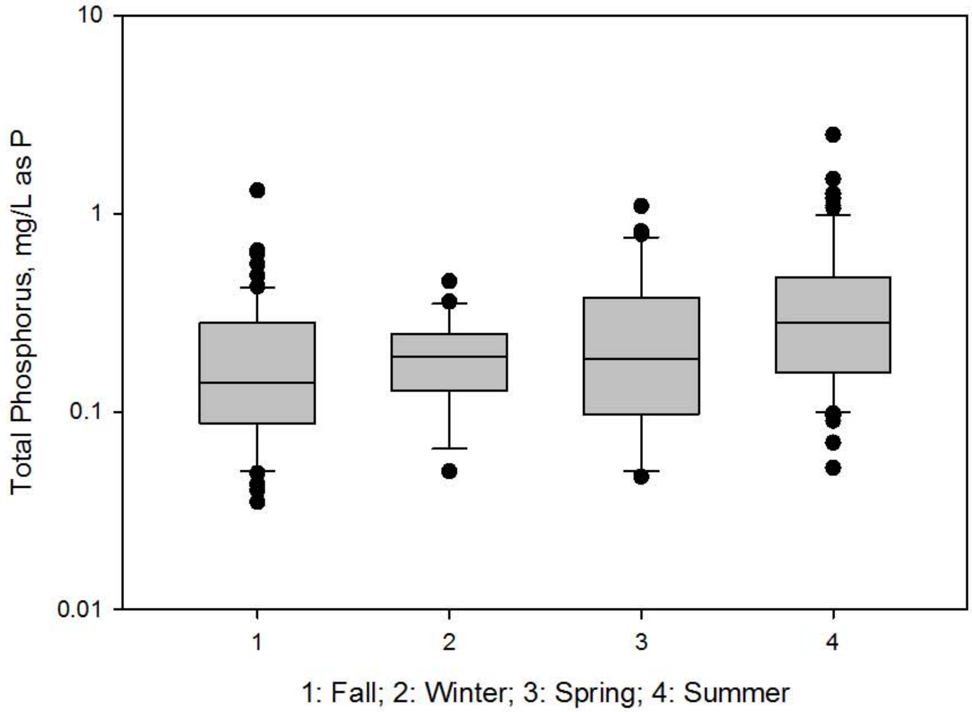
The Kruskal-Wallis test indicated that at least one season was different from the others. The obvious differences shown are between spring and fall and possibly fall and summer. Further analyses investigated the seasons by grouping fall with winter and spring with summer, as also shown on the preceding box and whisker plot. As shown by the Mann-Whitney test (SigmaPlot 13), these two groups were significantly different, with the summer-spring group having larger total phosphorus concentrations compared to the winter-fall group.

Table 30. Mann-Whitney Rank Sum Test Comparing Institutional plus Commercial Total Phosphorus Values for Fall and Winter vs. Summer and Spring Seasonal Groups

Group	N	Missing	Median	25%	75%
Z1 fall win inst commer TP	112	0	0.12	0.07	0.23
Z1 spring summ inst commer TP	194	0	0.16	0.1	0.22
Mann-Whitney U Statistic= 8602.500					
T = 14930.500 n(small)= 112 n(big)= 194 (P = 0.002)					
The difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference (P = 0.002)					

The total phosphorus concentrations in the combined open space plus industrial land use group was also evaluated as shown on Figure 12 and Tables 31 through 33.

Figure 12. Box And Whisker Plots of NSQD, version 4.02, EPA Rain Zone 1 Open Space Plus Industrial Land Use Total Phosphorus Concentrations Grouped by Season.



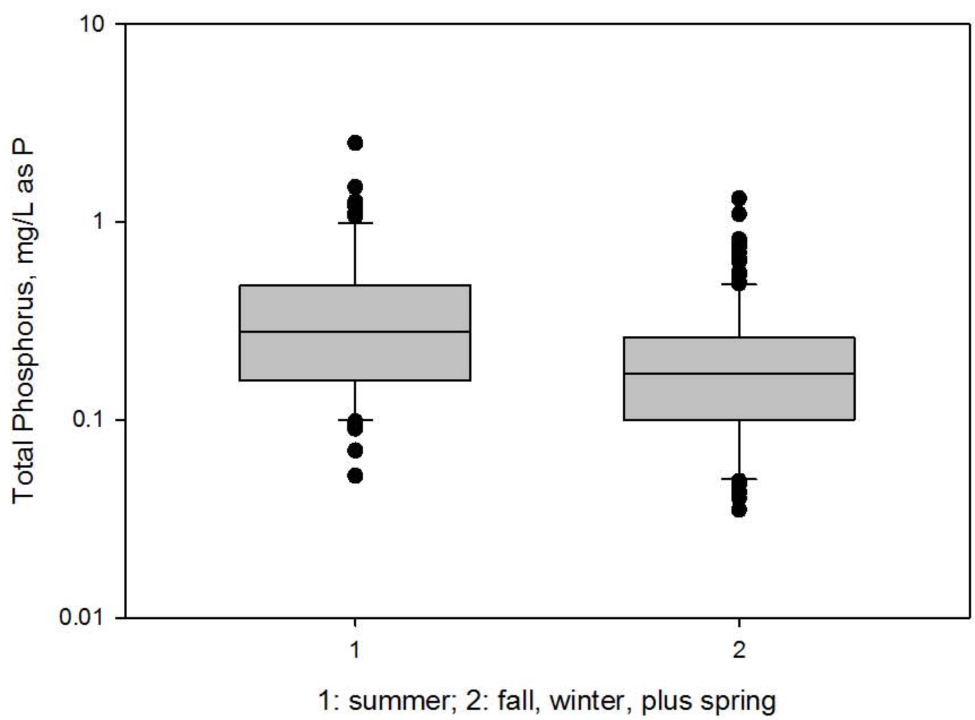


Table 31. Open Space and Industrial Land Use Seasonal Analyses using the Kruskal-Wallis One Way Analysis of Variance on Ranks Test

Group	N	Missing	Median	25%	75%
ZI fall opnspc indus TP	63	0	0.14	0.087	0.28
ZI winter opnspc indus TP	22	0	0.89	0.38	0.58
ZI spring opnspc indus TP	36	0	0.95	0.097	0.89
Z1 summer opnspc indus TP	63	0	0.28	0.67	0.48
H = 19.639 with 3 degrees of freedom. (P = <0.001)					
The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001)					
To isolate the group or groups that differ from the others use a multiple comparison procedure.					

The Kruskal Wallis test indicated that at least one seasonal data set was significantly different from the others. Table 32 shows all pairwise comparisons for these data.

Table 32. Pairwise p Values for EPA Rain Zone 1 Total Phosphorus Concentrations by Season Groups for Open Space plus Industrial Land Use Areas

	Fall	Winter	Spring	Summer
Fall	X	1.0	1.0	<0.001
Winter	1.0	X	1.0	0.19
Spring	1.0	1.0	X	0.01
Summer	<0.001	0.19	0.01	X

The major differences were between the fall and summer seasons, while the summer and spring seasons also indicated significant differences in total phosphorus concentrations, with the summer concentrations appearing to be larger than the other groups on the grouped box and whisker plot and the fall period being the lowest. Therefore, these data were grouped with fall, winter, and spring all combined, with summer left separate, as shown on the above plot. The Mann-Whitney analysis on Table 33 shows that these two data groups are significantly different (p<0.001), with the summer having the highest total phosphorus concentrations compared to the other group of remaining seasons.

Table 33. Mann-Whitney Rank Sum Test Comparing Open Space plus Industrial Total Phosphorus Values for Summer vs. Fall, Winter and Spring Seasonal Groups

Group	N	Missing	Median	25%	75%
Z1 op spc indus summer TP	63	0	0.28	0.67	0.48
Z1 opspc indus fall wint sprin	121	0	0.17	0.1	0.26
Mann-Whitney U Statistic= 2330.500					
T = 7308.500 n(small)= 63 n(big)= 121 (P = <0.001)					
The difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference (P = <0.001)					

Conclusions

EPA Rain Zone, the interaction between EPA Rain Zone and land use, and land use alone, were all statistically significant when examining variations in stormwater pollutant concentrations. However, based on the analyses, season alone is not a significant factor. Yet, the interaction between season and EPA Rain Zone is significant for all the standard pollutants, except for TSS and total lead. For land use categories, the variability between sampling locations is greater than between land uses, which justifies the need to examine many sampling sites at one geographical area.

Detailed analyses examined total phosphorus concentrations contained in the NSQD, version 4.02. These analyses indicate that total phosphorus concentrations varied by geographical location (as reflected by the EPA Rain Zone), land use, and season. An example analysis was therefore conducted focusing only on the total phosphorus concentrations observed in the EPA Rain Zone 1 (the northeast and upper Midwest areas of the U.S.). About 1,020 observations for total phosphorus were available for this area from 69 locations in eight states (IL, IN, MA, MI, MN, NH, NY, and WI), with data collected from June 1970 through December 2003. Trend analyses of the residential area total phosphorus data did show a significant, but very small, decrease in total phosphorus concentrations with time during this sampling period. Less than a 10% decrease was found during this 34 year period. There were no significant trends in total phosphorus residential concentrations according to rain depth. Analyses of the filterable fraction of the total residential area phosphorus concentrations indicated that about 50 to 60% of the total phosphorus was in filterable forms.

Nonparametric multivariate analyses identified six separate data groupings for total phosphorus stormwater concentrations in this area. Table 34 summarizes these groups and the corresponding total phosphorus concentrations.

Table 34. Total Phosphorus Concentrations for Different Land Uses and Seasonal Data Groups for EPA Rain Zone 1 (upper Midwest and Northeast U.S.)

	Residential Land Uses		Institutional and Commercial Land Uses		Open Space and Industrial Land Uses	
	Fall and Winter	Spring and Summer	Fall and Winter	Spring and Summer	Summer	Fall, Winter, and Spring
Number of Observations	202	349	112	194	63	121
Average	0.37	0.42	0.16	0.28	0.42	0.23
Median	0.28	0.31	0.12	0.16	0.28	0.17
Minimum	0.005	0.04	0.03	0.022	0.052	0.035
Maximum	2.4	6.7	0.97	8.6	2.5	1.3
Standard Deviation	0.35	0.47	0.13	0.65	0.41	0.21
COV	0.95	1.12	0.81	2.29	0.99	0.94

Therefore, these concentrations (and uncertainties) can be used to predict stormwater total phosphorus concentrations in this region of the U.S., depending on land use and season.

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