CHANGES IN EFFLUENT PHOSPHORUS CONCENTRATIONS FOLLOWING IMPLEMENTATION OF THE MARYLAND PHOSPHATE DETERGENT BAN

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by

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INTRODUCTION

A recent report prepared by the Maryland Water Management Administration (Sellars et al.,1987) describes results of sewage effluent monitoring before and after implementation of the state's phosphate detergent ban in December 1985. The following table of average total phosphorus concentrations from plants without phosphorus removal facilities is derived from their analysis of effluent grab samples:

Monitoring Period	May-Oct 1985	May-Oct 1986	Difference
Grab Samples	221	230	
Plants	66	66	
Mean Effluent Total Phosphorus (ppm)			
Unweighted	5.7	3.3	2.4
Flow-Weighted	4.2	2.4	1.8

The above differences in concentration were attributed to effects of the detergent ban. Based upon these values, the report goes on to estimate impacts on phosphorus loadings to Chesapeake Bay from plants without phosphorus removal facilities and on chemical and sludge disposal costs for plants with phosphorus removal facilities.

The following report evaluates the statistical reliability of the above summary values. A variety of data reduction and screening techniques are applied to determine sensitivity of the results to analytical assumptions. Limitations in the data resulting from the grab sampling strategy are discussed. Apparent reductions in effluent phosphorus concentrations attributed to the ban are compared with previous projections (Harris and Walker,1985) and with results of similar studies conducted in other states.

DATA ANALYSIS

The plant effluent data used to develop the above summaries have been obtained from Ming-Liang Jiang, a co-author of the Sellars et al.(1987) report, in the form of hand-written tables and calculations. The information has been computerized and is tabulated in the Appendix. Average concentrations and flows are summarized by plant in Table 1.

Table 2 lists summary statistics for seasonal (May-October of each year) means derived from various averaging procedures and data sets. The eight cases involve variations in the following factors:

PLANT MEANS:
No - data averaged by year without regard to plant
Yes - data averaged by plant and year before comparing years

DATA SETS:
A - all data
B - one outlier excluded (Transcontinental Gas)
C - plants with fewer than two samples per year excluded.

FLOW WEIGHTING:
No - yearly means computed without weighting
Yes - yearly means weighted by plant mean flows

The factors have been varied to test the sensitivity of results (confidence range for mean phosphorus reduction attributed to the ban) to calculation procedures and data sets. Values presented in Table 2 generally indicate that results are sensitive to the first set of factors and insensitive to the last two.

As compiled, the data base permits consideration of three sources of variation:

(1) PLANT-TO-PLANT. These variations reflect differences in wastewater sources (domestic, industrial, institutional, etc.), conveyance systems (inflow/infiltration), and treatment processes.

(2) YEAR-TO-YEAR. These reflect random variations in wastewater characteristics at a given plant from one year to the next, as influenced by changes in the community and/or weather, as well as deterministic variations attributed to effects of the detergent ban.

(3) WITHIN YEAR. These reflect the combined influences of variations due to sampling, laboratory analysis, and true temporal variations in effluent concentration for a given plant and period. As discussed below, a portion of the within-year variation (diurnal) is not random, but systematic, and may have important implications.

The objective of the analysis is to estimate the year-to-year variation in concentration and loading attributed to the detergent ban, averaged

Table 1

Means by Plant and Year

Plant	Flow mgd	Effluent Total P (ppm) 1985	1986	85-86	Samples 1985	1986
andrews afb	0.006	8.00	3.57	4.43	1	3
ballenger ck	0.404	5.58	3.00	2.58	5	1
berlin	0.245	4.90	3.65	1.25	1	2
boones mobile hme	0.041	5.70	3.07	2.63	4	6
bowie st college	0.050	3.63	2.10	1.53	4	7
broadwater	0.295	2.90	1.60	1.30	2	3
calvert prince fred	0.116	3.60	1.97	1.63	3	3
caroline federalsbur	0.282	2.35	2.70	-0.35	2	2
cheltenham boys	0.047	5.30	3.60	1.70	1	1
crestview est	0.011	9.75	5.30	4.45	4	1
crisfield	0.775	2.90	2.07	0.83	4	3
croom romy housing	0.006	10.83	7.10	3.73	3	4
ct farms	0.002	12.50	9.00	3.50	2	2
damascus	0.459	9.07	4.77	4.30	3	6
darl nrc en cn	0.008	4.40	2.20	2.20	6	4
easton	1.550	5.64	4.03	1.61	5	3
edgemeade school	0.020	7.43	7.93	-0.50	3	3
elk neck st park	0.027	2.80	3.60	-0.80	3	2
forge heights	0.024	2.07	2.15	-0.08	3	2
frederick	4.762	6.25	7.90	-1.65	8	1
freedom	1.264	5.13	1.22	3.91	3	6
gaither manor	0.012	3.85	3.23	0.62	2	3
galena	0.030	5.90	5.50	0.40	1	2
greensboro	0.130	5.20	5.20	0.00	3	1
harve de grace	1.222	5.25	4.16	1.09	2	5
harwood s sr	0.004	1.10	0.95	0.15	4	4
holiday mobile es	0.062	5.76	3.30	2.46	7	5
jfk highway	0.016	4.90	8.75	-3.85	1	2
joppatowne	0.654	5.75	3.57	2.18	2	3
leonardstown	0.219	7.30	3.33	3.97	2	4
lyons ck mobil	0.054	4.00	1.50	2.50	4	4
manchester pk	0.016	5.90	5.15	0.75	2	2
marlboro meadows	0.296	3.70	3.30	0.40	5	3
md city	0.610	5.70	3.53	2.17	5	6
md house of corr	0.987	1.58	0.87	0.71	6	6
md manor	0.065	5.85	1.62	4.23	4	6
mifey?	0.174	8.20	5.65	2.55	3	4
montrose school	0.027	6.50	8.80	-2.30	3	1
mt carmel woods	0.012	8.35	4.65	3.70	2	2
myersville	0.048	6.64	4.00	2.64	5	1
new windsor	0.028	6.20	4.15	2.05	1	2
ocean pines	0.382	7.98	4.58	3.40	6	4
parkway	4.037	5.10	1.83	3.27	3	6
parkway inn	0.033	2.68	2.58	0.10	6	5
patapsco	34.880	3.27	1.63	1.64	3	9
patuxent mobile est	0.028	5.10	1.76	3.34	4	5
patuxent wildlife	0.016	4.53	4.20	0.33	4	6
peter pan inn	0.005	5.10	2.40	2.70	3	1
pheasant ridge	0.015	6.10	4.53	1.57	1	3
pine hill run	2.013	6.68	3.70	2.98	4	4
poolesville	0.270	8.00	2.27	5.73	1	3
potomac ht	0.179	4.80	3.65	1.15	4	2
princess anne	0.389	6.60	5.80	0.80	5	2
queen annes co	0.661	6.35	4.98	1.37	4	5
queenstown	0.058	2.25	2.73	-0.48	2	3
rock hall	0.124	1.50	1.50	0.00	2	4
rose haven	0.045	7.64	3.28	4.36	5	6
spring meadows	0.008	5.20	5.30	-0.10	2	1
summer hill	0.010	7.35	2.42	4.93	6	6
taneytown	0.225	3.60	3.67	-0.07	1	3
thurmont	0.388	7.03	5.30	1.73	8	1
trans cont gas	0.001	17.83	4.58	13.25	3	4
union bldge	0.069	4.60	3.65	0.95	1	2
waysons mobile homes	0.049	5.80	3.02	2.78	4	5
western branch	10.688	3.67	1.30	2.37	3	5
white rock	0.013	8.25	4.10	4.15	4	1

Table 2
Statistical Summary

						Effluent Total Phosphorus (ppm)			
Case	Plant Means	Data Set	Flow Wtd.	Year	N	Mean	Std. Dev.	Std. Error	T Statistic (Mean = 0)
1	No	A	No	85	223	5.68	2.98	0.32	
				86	227	3.30	1.91	0.21	
				85-86		2.38		0.38	6.22
2	No	A	Yes	85	223	4.37	2.69	0.18	
				86	227	1.88	1.81	0.12	
				85-86		2.49		0.22	11.51
3	Yes	A	No	85	66	5.69	2.69	0.33	
				86	66	3.77	1.91	0.24	
				85-86 unpaired		1.92		0.41	4.73
				85-86 paired		1.92	2.31	0.28	6.75
4	Yes	A	Yes	85	66	4.10	3.82	0.47	
				86	66	2.40	4.71	0.58	
				85-86 unpaired		1.70		0.75	2.28
				85-86 paired		1.70	2.27	0.28	6.07
5	Yes	B	No	85	65	5.50	2.23	0.28	
				86	65	3.75	1.93	0.24	
				85-86 unpaired		1.75		0.37	4.78
				85-86 paired		1.75	1.84	0.23	7.67
6	Yes	B	Yes	85	65	4.10	3.79	0.47	
				86	65	2.40	4.68	0.58	
				85-86 unpaired		1.70		0.75	2.28
				85-86 paired		1.70	2.26	0.28	6.07
7	Yes	C	No	85	45	5.21	2.46	0.37	
				86	45	3.32	1.80	0.27	
				85-86 unpaired		1.89		0.45	4.16
				85-86 paired		1.89	1.55	0.23	8.18
8	Yes	C	Yes	85	45	3.88	2.55	0.38	
				86	45	1.94	1.54	0.23	
				85-86 unpaired		1.94		0.44	4.37
				85-86 paired		1.94	1.48	0.22	8.82

Plant Means:
- No = Data Averaged by Year without Regard to Plant
- Yes = Data Averaged by Plant and Year before Comparing Years

Data Sets:
- A = All Data
- B = Screened for Outliers (Transcontinental Gas Eliminated)
- C = B + More than 1 Sample Per Station Year

Flow Wtd.:
- No = Concentration Statistics Unweighted
- Yes = Concentration Statistics Weighted by Plant Mean Flow

T Statistic Tests Whether 1985 and 1986 Means Are Significantly Different from 0. All Tests Significant at $p < .05$.

over the entire population of Maryland sewage treatment plants without phosphorus effluent limitations. During the 1985-1986 period, the total flow from these plants amounted to 112 mgd (Sellars et al.,1987), 72 mgd of which are represented in the data base analyzed here. The estimated changes are seasonal (May-October), which may differ somewhat from annual values.

The statistical procedures employed here do not consider effects of serial correlation, seasonality, or other time series behavior. Evaluation of these factors is precluded by the relatively low numbers of observations per plant-year (1-9). As demonstrated by Pallesen et al. (1985) and Booman et al. (1987), sewage influent phosphorus loadings often exhibit non-stationary behavior or "drift". Because the pre- and post-ban means are not stationary, estimation of load reductions (and confidence ranges) due to a ban by simple averaging can be risky. More sophisticated techniques, such as intervention analysis, could be applied to more intensive data sets. Non-stationary behavior may be more of a problem in analyzing data from a single treatment plant, than in analyzing data from a collection of plants. It seems unlikely that pre-ban and post-ban drifts would be strongly correlated across treatment plants. Such correlation might be introduced by variations in precipitation, although both the 1985 and 1986 sampling periods were relatively dry. Because non-random variations and non-stationary behavior are not considered, actual standard errors are probably higher than those estimated here.

The simplest approach to estimating the effects of the ban is to compare the simple averages of 1985 and 1986 data, without regard to plants or flows. This method (Case 1 in Table 2) was employed by Sellars et al. to estimate an average decrease of 2.4 ppm. Analyses of variance (ANOVA) conducted separately for each year indicate that variations among plant means are significant within each year ($p < .01$). Because of plant-to-plant variations, the samples are not independent and random. Accordingly, estimates of standard error for each year have been derived from the ANOVA results (Snedecor and Cochran,1972):

$$SE_i = (SM_i/N_i)^{.5}$$

where,

SE_i = standard error of annual mean for year i (ppm)

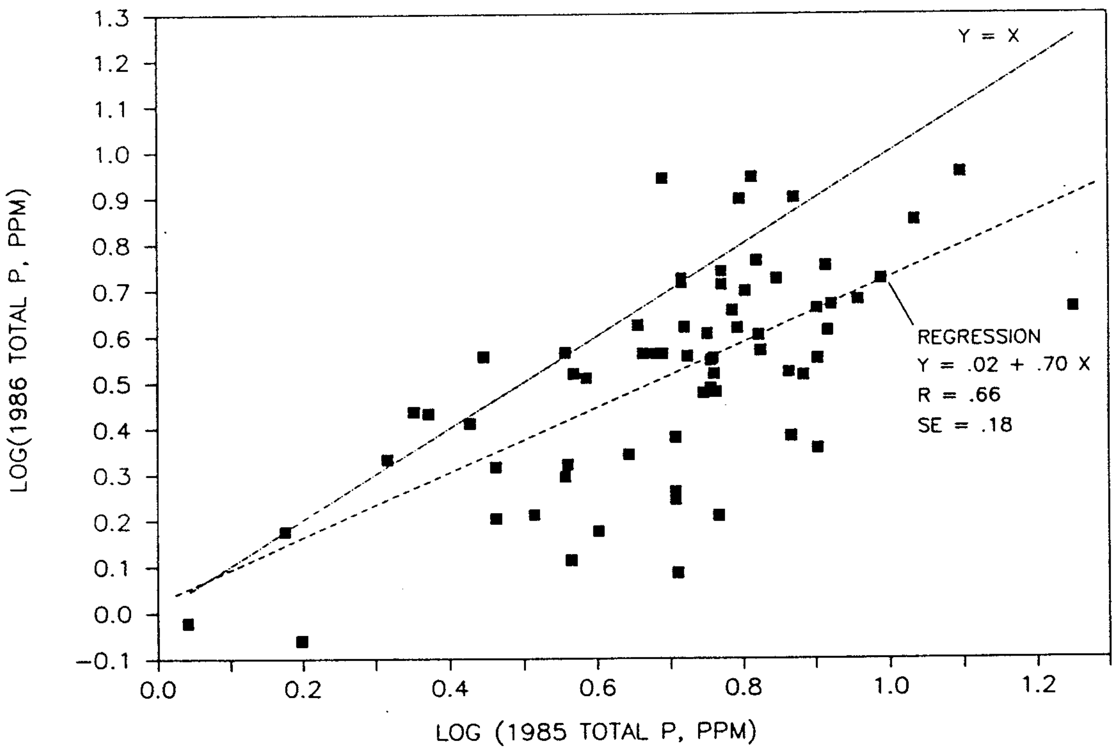
SM_i = among-plant mean square deviation for year i $(ppm)^2$

N_i = total number of samples for year i

The standard error of the difference in annual means is .38 ppm, derived from pooling the 1985 and 1986 error variances. This procedure for estimating year-to-year variations assumes that the 1985 and 1986 samples are statistically independent and that within-year variations at each plant are random.

Figure 1 plots average 1986 vs. 1985 effluent concentrations for each of the 66 sampled plants. Means have been computed from sample

Figure 1
Mean 1986 vs. Mean 1985 Effluent Phosphorus Concentrations



numbers ranging from 1 to 9 per plant per year. The correlation coefficient, 0.66, indicates that plant-to-plant variations are significant, even in the context of year-to-year variations induced by the detergent ban, other factors, and random sampling error. Mean phosphorus concentrations decreased in most of the plants, as indicated by their position relative to the line of equality (Y=X) in Figure 1.

In the presence of significant plant-to-plant variability, averaging the concentration data by year without regard to plant (Cases 1 and 2 in Table 2) is inappropriate for estimating the impacts of the ban. This is especially true, given the fact that sampling rates varied between 1985 and 1986 for most plants. For example, if a plant with relatively high phosphorus concentrations in both years was sampled once in 1985 and five times in 1986, its influence on the 1986 mean would be five times that on the 1985 mean and the resulting summary statistics (annual means for all data) would be biased.

Given significant plant-to-plant variations, a more appropriate procedure is to average the data by plant and year first and then average across plant means within each year. This method filters out the effects of plant-to-plant variations on the difference in annual means. The procedure also permits pairing of plant means; confidence limits for the average 85/86 difference across all plants can be calculated from the distribution of the 85/86 differences for the individual plants. Pairing in this way reduces the standard error of the resulting summary statistic and increases the power of the analysis for detecting significant differences (Snedecor and Cochran,1972).

Results using this suggested calculation method are listed in Table 2 (Cases 2-8). Approximate 95% confidence range (mean + 2 standard errors) for the annual means and differences in annual means are shown in Figure 2. A general insensitivity of results to variations in data set and flow weighting is apparent. Estimates of mean reductions attributed to the ban range from 1.70 to 1.94 ppm for Cases 2-8 and standard errors (paired tests) range from .22 to .28 ppm. The reductions are similar to that computed by Sellars et al.(1987) based upon flow-weighted plant means (Case 4).

Flow-weighting seems appropriate for the purpose of estimating impacts on effluent loadings. Results are insensitive to flow weighting, however. Figure 3 plots the difference in annual means (1985-1986) vs. the logarithm of plant flow. Concentration change is not significantly related to plant flow. The general insensitivity to flow weighting reflects the fact that the observed concentration reduction for the plant with the highest flow (Patapsco, 35 mgd, vs. .001-10.7 mgd for others) was similar to the average reduction for all plants (1.9 ppm).

As shown in Figure 3, one plant, Transcontinental Gas, had a significantly greater reduction in mean concentration (13.3 ppm), as compared with the other plants in the data set. This plant also had the smallest mean flow of those sampled (.001 mgd). Cases 5-6 in Table 2 indicate that results are insensitive to exclusion of this outlier, particularly when statistics are flow-weighted. Eliminating data from

Figure 2
Confidence Ranges for Annual Means and Reductions in Annual Mean Derived from Cases 3-8 in Table 2

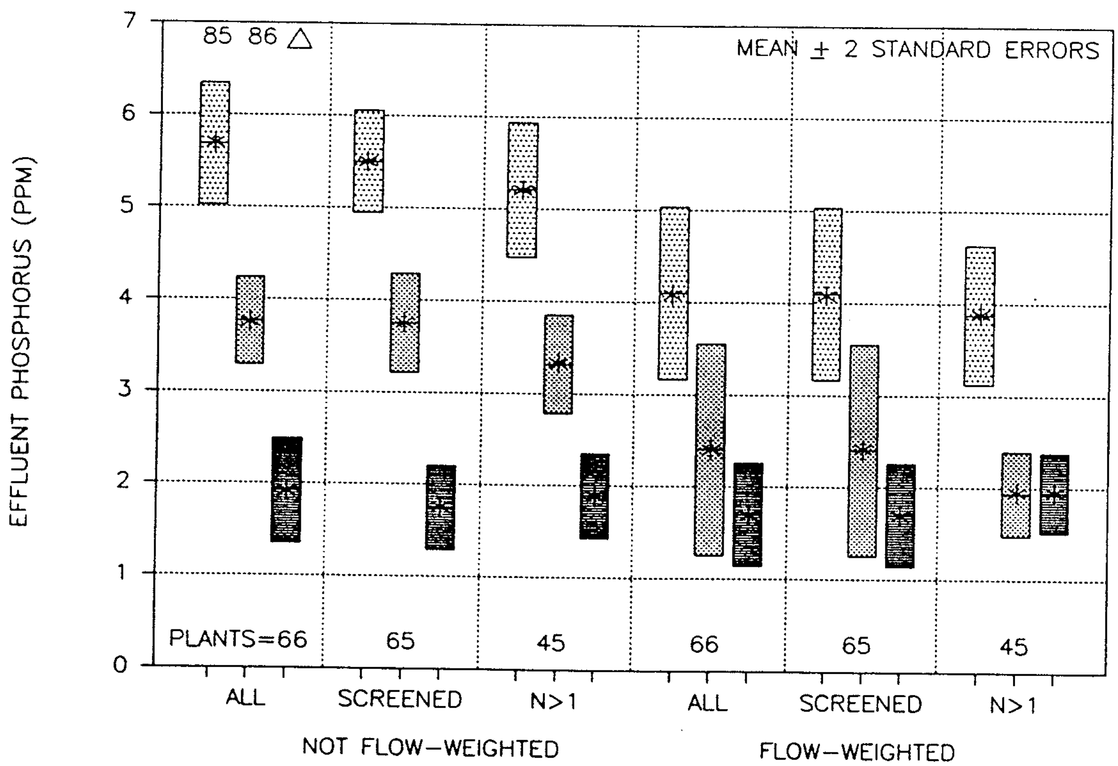
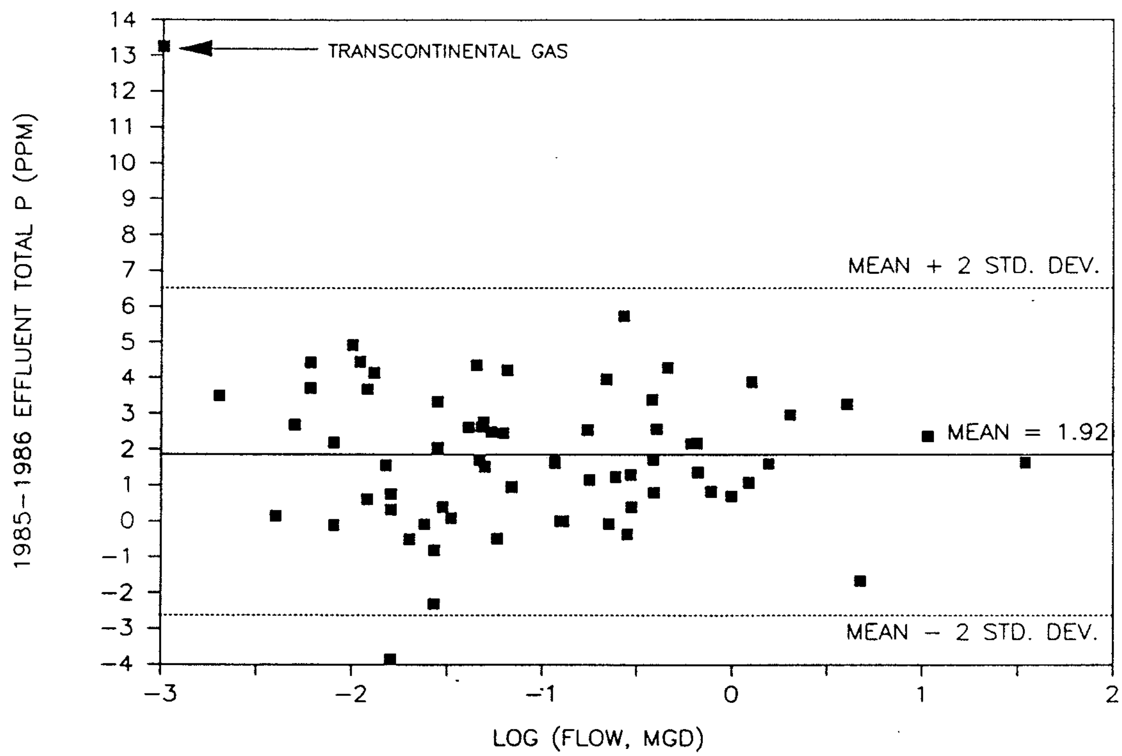


Figure 3
Reduction in Mean Annual Phosphorus Concentration vs. Plant Flow



plants which were sampled only once per year in either 1985 or 1986 likewise has little influence on the results (Cases 7-8).

Additional insights can be derived from frequency distribution plots in Figures 4-7, based upon yearly mean effluent concentrations from 66 plants. Incremental and cumulative frequency distributions of mean effluent concentrations are shown in Figures 4 and 5, respectively. Frequency distributions of mean concentration differences (1985-1986) and ratios (1986/1985) are shown in Figures 6 and 7, respectively. The difference in concentration (Figure 6) has a square-shaped distribution, with approximately 80% of the values falling between 0 and 5 ppm.

In interpreting the frequency distribution plots, it is important to consider that they are based upon **estimates** of mean values derived from limited data. The variability is attributed to sampling error in estimating the period means from limited data, random period-to-period variations, as well as deterministic effects of the detergent ban.

The frequency distributions of yearly means (Figure 4) are skewed towards high values. This has some bearing on interpretation of the computed standard errors and confidence limits, which assume that the underlying distributions are normal. This skewness is not likely to have a major effect on the comparisons of means based upon t-tests, since the skewness does not appear to be large and the distribution shapes are similar (Montgomery and Loftis,1987). Skewness is reduced when the paired differences in means are examined (Figure 6), particularly when one outlier (Transcontinental Gas) is eliminated.

The following statistics summarize the apparent impacts of the ban on effluent phosphorus levels. Cases 3 and 4 are used for this purpose because Transcontinental Gas is clearly an outlier (Figure 3), and restricting sampling frequencies (Cases 7 and 8) did not substantially reduce standard errors of estimate:

Effluent Total Phosphorus (ppm)
Mean (Standard Error)

	Unweighted	Flow-Weighted
PRE-BAN	5.5 (.28)	4.1 (.47)
POST-BAN	3.7 (.24)	2.4 (.58)
REDUCTION	1.8 (.23)	1.7 (.28)

The analysis supports the reduction estimated by Sellars et al.(1987), based upon flow-weighted means (1.8 ppm), subject to inherent data limitations discussed below.

CONSEQUENCES OF GRAB SAMPLING

The grab-sampling strategy is an important limitation in the data set and its summary statistics. Despite the relatively large number of samples, a sampling strategy which does not account for diurnal or weekly variations may introduce certain biases when used to estimate changes in annual or seasonal loadings caused by a detergent ban.

Figure 4
Incremental Frequency Distributions - Plant Means 1985 and 1986

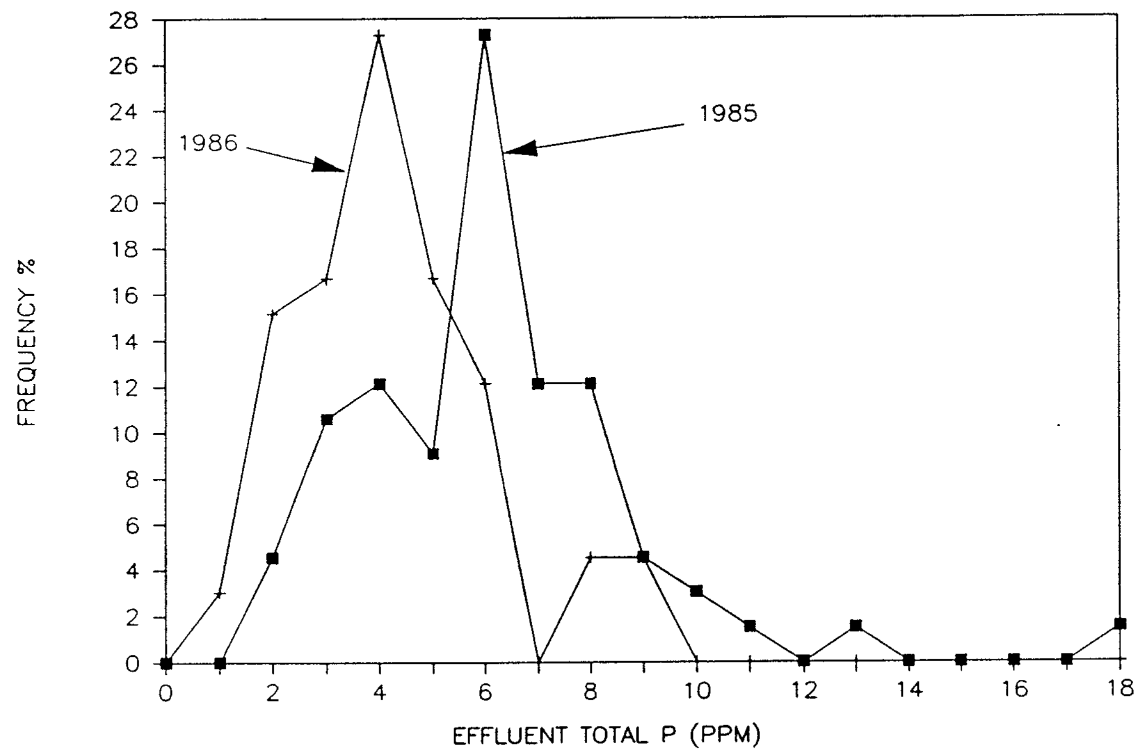


Figure 5
Cumulative Frequency Distributions - Plant Means 1985 and 1986

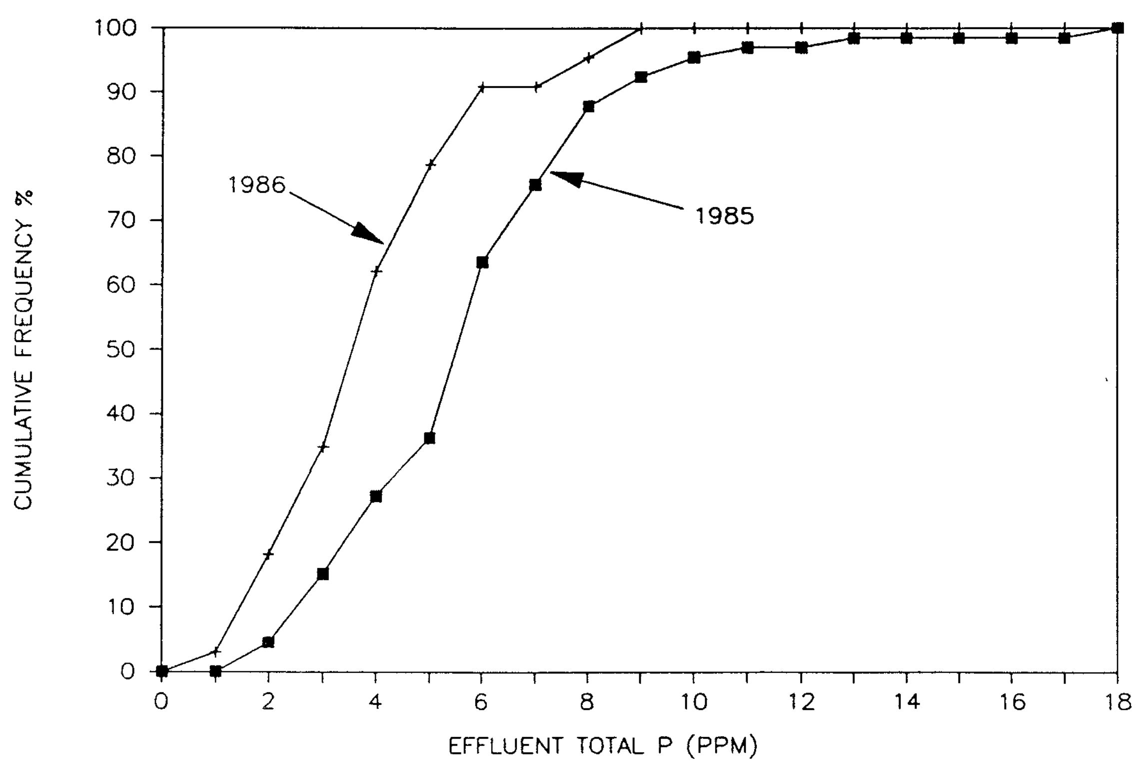


Figure 6
Frequency Distribution - Difference in Annual Means

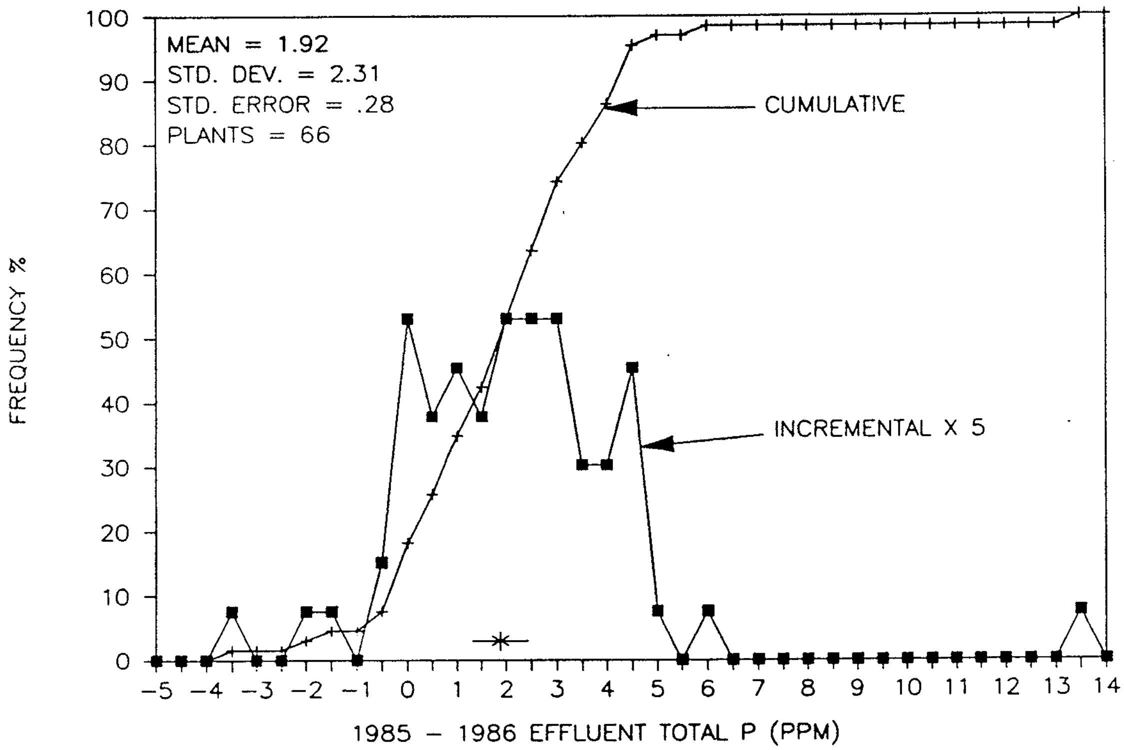
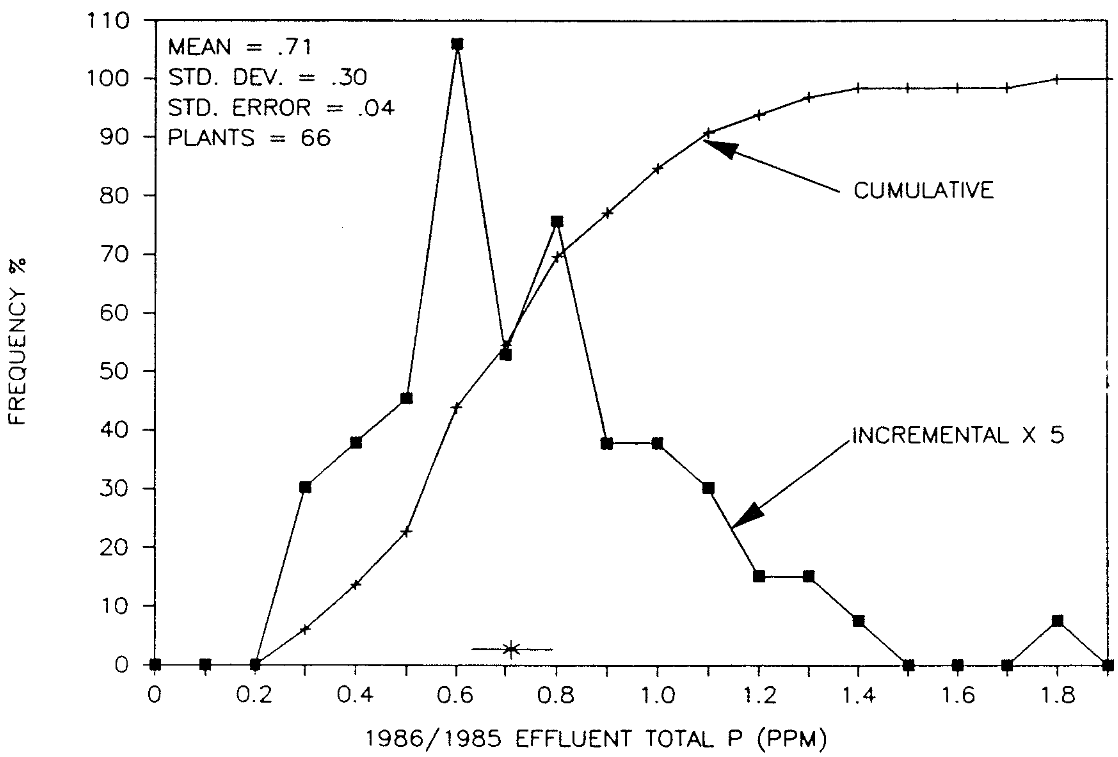


Figure 7
Frequency Distribution - Ratio of Annual Means



It seems reasonable that systematic diurnal or weekly variations in the phosphorus concentrations of sewage effluents would exist because of diurnal variations in domestic and commercial activities. One hypothetical scenario leading to biases in the above concentration differences (1.7-1.8 ppm) would result from a sampling strategy which, on the average, takes grab samples at a time-of-day or day-of-week when laundry activities (and, therefore, detergent-derived phosphorus) are above the weekly, flow-weighted average. It seems likely that grab samples would be taken during the day and on weekdays, a time schedule which may coincide with maximum laundry activity.

Significant diurnal variations in wastewater phosphorus concentration attributed to detergent use were documented by Shannon (1975) in a study of a .043 mgd treatment facility serving a Canadian military barracks and married quarters area. Figure 8 plots average diurnal variations in influent phosphorus concentration measured during three, three-week-long periods:

(1) "BASELINE": all consumers using detergents of free choice, subject to maximum phosphorus content of 8.7%;

(2) "HIGH-P": all consumers using detergent containing 12.1% phosphorus; and

(3) "NTA": all consumers using detergent formulated with Nitrilotriacetic Acid.

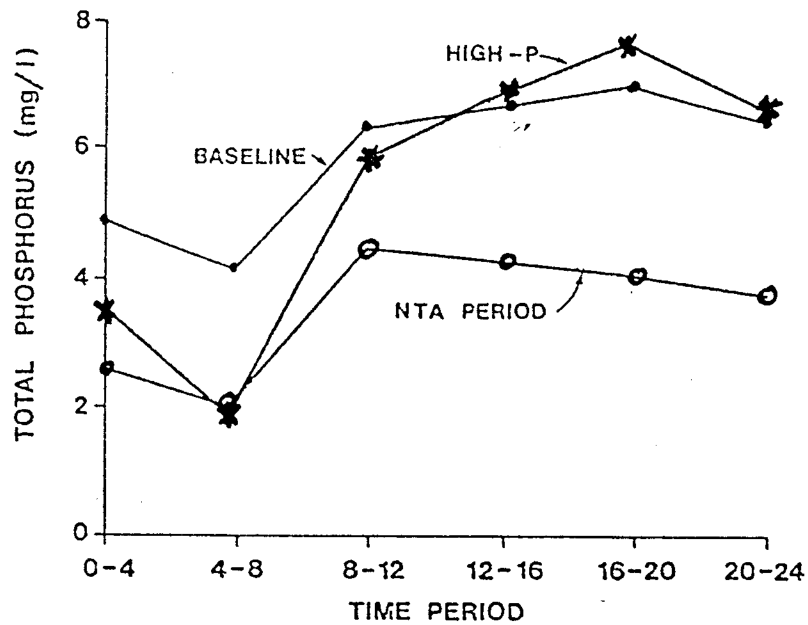
It is apparent from Figure 8 that changes in detergent formulation influence diurnal variations in phosphorus concentration. Differences between the HIGH-P and NTA periods were most pronounced during the afternoon and evening (12-16, 16-20, 20-24 hrs) and least pronounced during the early morning (0-4, 4-8 hrs).

The following table compares influent phosphorus concentrations estimated from midday grab sampling (12-16 hrs in Figure 8) with values derived from continuous, flow-weighted composite sampling for each time period:

	Influent Total Phosphorus (ppm) Continuous	Midday Grab	Bias(%)
BASELINE	5.0	6.7	34%
HIGH-P	5.3	7.0	32%
NTA	3.6	4.4	22%
BASELINE - NTA	1.4	2.3	64%
HIGH-P - NTA	1.7	2.6	53%

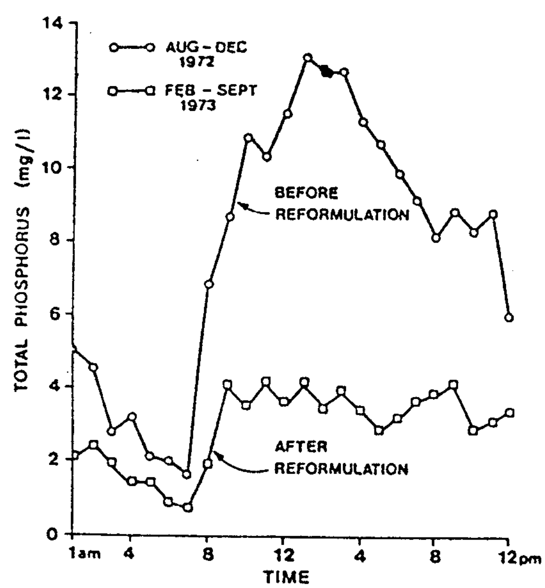
As a consequence of systematic diurnal variations, midday grab sampling significantly overestimates average influent concentrations and effects of changes in detergent formulation.

Figure 8
Diurnal Variation of Influent Total Phosphorus Concentration
Canadian Forces Station Gloucester
Shannon (1975)



Diurnal variation of total phosphorus in raw wastewater.

Figure 9
Diurnal Variation of Influent Total Phosphorus Concentration
Canadian Forces Base Uplands
Stepko and Shannon (1974), Shannon (1975)



Diurnal variation of total phosphorus in raw wastewater at Canadian Forces Base Uplands.

Figure 9 shows diurnal variations in wastewater phosphorus concentrations monitored at another military base by Stepko and Shannon(1974). Values are shown for two periods:

(1) "BEFORE REFORMULATION": all detergents < 8.7% phosphorus;

(2) "AFTER REFORMULATION": all detergents < 2.2% phosphorus;

The diurnal variations detected under this longterm study were more pronounced than those shown in Figure 8. Effects of changes in detergent formulation were greatest during midday (approaching 9 mg/l) and smallest during the early morning (1 mg/l). The absolute magnitudes of these 1974 figures do not necessarily apply to Maryland in 1985-1986 because of unregulated reductions in detergent phosphate content between 1974 and 1985. The diurnal patterns, however, reflect consumer habits which are more likely to be general. Because of storage in the treatment plant, diurnal variations in effluent concentrations may be less pronounced than those shown in Figures 8 and 9.

It is apparent that diurnal variations are important to consider in monitoring wastewater phosphorus levels, particularly if one is attempting to measure changes in daily, seasonal, or annual loadings attributed to a detergent ban. Possible biases introduced by the grab sampling strategy cannot be removed by data analysis and should be considered in interpreting the results. Unless the grab sampling strategy was truly random (over 24-hour period and 7-day week), the statistical summaries presented above probably over-estimate the impacts of the detergent ban on flow-weighted-mean effluent concentrations.

INTERPRETATIONS

In a previous report, reductions in average effluent phosphorus concentration resulting from the ban were projected to range from .75 to 2.1 ppm (Harris and Walker, 1985). Based upon the grab-sample data analyzed above, the observed reduction averaged 1.7 ppm, with a 95% confidence range of 1.1 to 2.3 ppm. Considering that the grab-sample data likely over-estimate the concentration reduction because they do not reflect diurnal variations, the observed reductions appear to be consistent with the projections. The range can be compared with the average 1.5 ppm reduction in influent phosphorus concentrations reported following detergent bans in Michigan and Wisconsin (Hartig and Horvath,1982; Schuettpelz, et al.,1982; Sonzogni and Heidtke,1986); the reduction in effluent concentrations in these states was probably less than 1.5 ppm because of phosphorus removal in the treatment facilities.

Estimates of loading reductions to Chesapeake Bay can be developed by multiplying the average concentration reduction by the total flow from treatment plants without phosphorus limits. Sellars et al.(1987) estimated the total flow at 112 mgd in 1986. Applied to the 1.1-2.3 ppm confidence range for concentration, the load reduction would range from 1,028 to 2,148 lbs/day. Planned implementation of phosphorus controls at major plants in 1987 will reduce the untreated effluent volume by approximately 65 mgd, or 58%. As described by Harris and Walker (1985), the water quality benefits of these reductions must be considered in relation to the total loadings to the Bay (on the order of 30,000 lbs/day) and to the fact that eutrophication is limited more by nitrogen than by phosphorus throughout most of the Bay, especially during summer.

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APPENDIX
Effluent Data Listings

MARYLAND EFFLUENT PHOSPHORUS DATA 1

PLANT	FLOW	YEAR	TOTAL P
andrews afb	0.006	85	8.0
andrews afb	0.006	86	3.5
andrews afb	0.006	86	3.5
andrews afb	0.006	86	3.7
ballenger ck	0.404	85	0.3
ballenger ck	0.404	85	5.4
ballenger ck	0.404	85	6.7
ballenger ck	0.404	85	7.5
ballenger ck	0.404	85	8.0
ballenger ck	0.404	86	3.0
berlin	0.245	85	4.9
berlin	0.245	86	3.5
berlin	0.245	86	3.8
boones mobile hme	0.041	85	4.4
boones mobile hme	0.041	85	5.5
boones mobile hme	0.041	85	6.2
boones mobile hme	0.041	85	6.7
boones mobile hme	0.041	86	2.0
boones mobile hme	0.041	86	2.7
boones mobile hme	0.041	86	2.8
boones mobile hme	0.041	86	3.1
boones mobile hme	0.041	86	3.5
boones mobile hme	0.041	86	4.3
bowie st college	0.050	85	1.2
bowie st college	0.050	85	3.8
bowie st college	0.050	85	4.2
bowie st college	0.050	85	5.3
bowie st college	0.050	86	1.1
bowie st college	0.050	86	1.8
bowie st college	0.050	86	2.1
bowie st college	0.050	86	2.1
bowie st college	0.050	86	2.1
bowie st college	0.050	86	2.7
bowie st college	0.050	86	2.8
broadwater	0.295	85	2.7
broadwater	0.295	85	3.1
broadwater	0.295	86	0.6
broadwater	0.295	86	1.6
broadwater	0.295	86	2.6
calvert prince fred	0.116	85	2.3
calvert prince fred	0.116	85	3.8
calvert prince fred	0.116	85	4.7
calvert prince fred	0.116	86	0.6
calvert prince fred	0.116	86	2.2
calvert prince fred	0.116	86	3.1
caroline federalsbu	0.282	85	2.0
caroline federalsbu	0.282	85	2.7

MARYLAND EFFLUENT PHOSPHORUS DATA 2

PLANT	FLOW	YEAR	TOTAL P
caroline federalsbu	0.282	86	2.2
caroline federalsbu	0.282	86	3.2
cheltenham boys	0.047	85	5.3
cheltenham boys	0.047	86	3.6
crestview est	0.011	85	8.6
crestview est	0.011	85	9.5
crestview est	0.011	85	9.5
crestview est	0.011	85	11.4
crestview est	0.011	86	5.3
crisfield	0.775	85	0.8
crisfield	0.775	85	2.9
crisfield	0.775	85	3.5
crisfield	0.775	85	4.4
crisfield	0.775	86	1.9
crisfield	0.775	86	2.1
crisfield	0.775	86	2.2
croom romy housing	0.006	85	10.7
croom romy housing	0.006	85	10.8
croom romy housing	0.006	85	11.0
croom romy housing	0.006	86	5.9
croom romy housing	0.006	86	5.9
croom romy housing	0.006	86	6.6
croom romy housing	0.006	86	10.0
ct farms	0.002	85	12.5
ct farms	0.002	85	12.5
ct farms	0.002	86	7.0
ct farms	0.002	86	11.0
damascus	0.459	85	8.8
damascus	0.459	85	8.8
damascus	0.459	85	9.6
damascus	0.459	86	3.4
damascus	0.459	86	3.8
damascus	0.459	86	4.9
damascus	0.459	86	5.0
damascus	0.459	86	5.3
damascus	0.459	86	6.2
darl nrc en cn	0.008	85	2.5
darl nrc en cn	0.008	85	3.6
darl nrc en cn	0.008	85	4.3
darl nrc en cn	0.008	85	4.6
darl nrc en cn	0.008	85	5.6
darl nrc en cn	0.008	85	5.8
darl nrc en cn	0.008	86	1.1
darl nrc en cn	0.008	86	1.5
darl nrc en cn	0.008	86	2.5
darl nrc en cn	0.008	86	3.8

MARYLAND EFFLUENT PHOSPHORUS DATA 3

PLANT	FLOW	YEAR	TOTAL P
easton	1.550	85	4.3
easton	1.550	85	4.6
easton	1.550	85	5.9
easton	1.550	85	6.5
easton	1.550	85	6.9
easton	1.550	86	3.4
easton	1.550	86	4.2
easton	1.550	86	4.5
edgemeade school	0.020	85	5.7
edgemeade school	0.020	85	7.7
edgemeade school	0.020	85	8.9
edgemeade school	0.020	86	6.3
edgemeade school	0.020	86	8.5
edgemeade school	0.020	86	9.0
elk neck st park	0.027	85	1.5
elk neck st park	0.027	85	2.8
elk neck st park	0.027	85	4.1
elk neck st park	0.027	86	1.7
elk neck st park	0.027	86	5.5
forge heights	0.024	85	0.9
forge heights	0.024	85	1.3
forge heights	0.024	85	4.0
forge heights	0.024	86	1.5
forge heights	0.024	86	2.8
frederick	4.762	85	5.1
frederick	4.762	85	5.2
frederick	4.762	85	5.2
frederick	4.762	85	5.3
frederick	4.762	85	5.8
frederick	4.762	85	6.4
frederick	4.762	85	7.8
frederick	4.762	85	9.2
frederick	4.762	86	7.9
freedom	1.264	85	4.5
freedom	1.264	85	5.1
freedom	1.264	85	5.8
freedom	1.264	86	0.5
freedom	1.264	86	0.8
freedom	1.264	86	0.8
freedom	1.264	86	1.2
freedom	1.264	86	1.9
freedom	1.264	86	2.1
gaither manor	0.012	85	1.0
gaither manor	0.012	85	6.7
gaither manor	0.012	86	2.4
gaither manor	0.012	86	2.5
gaither manor	0.012	86	4.8

MARYLAND EFFLUENT PHOSPHORUS DATA 4

PLANT	FLOW	YEAR	TOTAL P
galena	0.030	85	5.9
galena	0.030	86	5.1
galena	0.030	86	5.9
greensboro	0.130	85	4.4
greensboro	0.130	85	4.8
greensboro	0.130	85	6.4
greensboro	0.130	86	5.2
harve de grace	1.222	85	4.7
harve de grace	1.222	85	5.8
harve de grace	1.222	86	3.1
harve de grace	1.222	86	3.8
harve de grace	1.222	86	3.9
harve de grace	1.222	86	4.3
harve de grace	1.222	86	5.7
harwood s sr	0.004	85	0.4
harwood s sr	0.004	85	1.0
harwood s sr	0.004	85	1.4
harwood s sr	0.004	85	1.6
harwood s sr	0.004	86	0.5
harwood s sr	0.004	86	0.8
harwood s sr	0.004	86	0.8
harwood s sr	0.004	86	1.7
holiday mobile es	0.062	85	4.8
holiday mobile es	0.062	85	5.0
holiday mobile es	0.062	85	5.3
holiday mobile es	0.062	85	5.5
holiday mobile es	0.062	85	5.6
holiday mobile es	0.062	85	7.0
holiday mobile es	0.062	85	7.1
holiday mobile es	0.062	86	3.2
holiday mobile es	0.062	86	3.2
holiday mobile es	0.062	86	3.2
holiday mobile es	0.062	86	3.3
holiday mobile es	0.062	86	3.6
jfk highway	0.016	85	4.9
jfk highway	0.016	86	8.7
jfk highway	0.016	86	8.8
joppatowne	0.654	85	5.0
joppatowne	0.654	85	6.5
joppatowne	0.654	86	3.5
joppatowne	0.654	86	3.5
joppatowne	0.654	86	3.7
leonardstown	0.219	85	5.7
leonardstown	0.219	85	8.9
leonardstown	0.219	86	1.7
leonardstown	0.219	86	3.2
leonardstown	0.219	86	3.8

MARYLAND EFFLUENT PHOSPHORUS DATA 5

PLANT	FLOW	YEAR	TOTAL P
leonardstown	0.219	86	4.6
lyons ck mobil	0.054	85	2.5
lyons ck mobil	0.054	85	4.0
lyons ck mobil	0.054	85	4.7
lyons ck mobil	0.054	85	4.8
lyons ck mobil	0.054	86	1.4
lyons ck mobil	0.054	86	1.4
lyons ck mobil	0.054	86	1.5
lyons ck mobil	0.054	86	1.7
manchester pk	0.016	85	4.7
manchester pk	0.016	85	7.1
manchester pk	0.016	86	4.7
manchester pk	0.016	86	5.6
marlboro meadows	0.296	85	0.9
marlboro meadows	0.296	85	1.1
marlboro meadows	0.296	85	1.2
marlboro meadows	0.296	85	3.3
marlboro meadows	0.296	85	12.0
marlboro meadows	0.296	86	1.6
marlboro meadows	0.296	86	3.5
marlboro meadows	0.296	86	4.8
md city	0.610	85	2.9
md city	0.610	85	3.6
md city	0.610	85	5.3
md city	0.610	85	8.3
md city	0.610	85	8.4
md city	0.610	86	1.8
md city	0.610	86	3.2
md city	0.610	86	3.4
md city	0.610	86	4.2
md city	0.610	86	4.2
md city	0.610	86	4.4
md house of corr	0.987	85	0.5
md house of corr	0.987	85	0.7
md house of corr	0.987	85	0.9
md house of corr	0.987	85	1.5
md house of corr	0.987	85	2.6
md house of corr	0.987	85	3.3
md house of corr	0.987	86	0.6
md house of corr	0.987	86	0.7
md house of corr	0.987	86	0.7
md house of corr	0.987	86	0.9
md house of corr	0.987	86	1.0
md house of corr	0.987	86	1.3
md manor	0.065	85	4.3
md manor	0.065	85	5.9
md manor	0.065	85	6.4
md manor	0.065	85	6.8

MARYLAND EFFLUENT PHOSPHORUS DATA 6

PLANT	FLOW	YEAR	TOTAL P
md manor	0.065	86	1.1
md manor	0.065	86	1.1
md manor	0.065	86	1.2
md manor	0.065	86	1.3
md manor	0.065	86	1.9
md manor	0.065	86	3.1
mifey?	0.174	85	8.2
mifey?	0.174	85	8.2
mifey?	0.174	85	8.2
mifey?	0.174	86	5.2
mifey?	0.174	86	5.6
mifey?	0.174	86	5.8
mifey?	0.174	86	6.0
montrose school	0.027	85	3.4
montrose school	0.027	85	7.4
montrose school	0.027	85	8.7
montrose school	0.027	86	8.8
mt carmel woods	0.012	85	7.9
mt carmel woods	0.012	85	8.8
mt carmel woods	0.012	86	4.5
mt carmel woods	0.012	86	4.8
myersville	0.048	85	6.2
myersville	0.048	85	6.2
myersville	0.048	85	6.3
myersville	0.048	85	6.9
myersville	0.048	85	7.6
myersville	0.048	86	4.0
new windsor	0.028	85	6.2
new windsor	0.028	86	3.8
new windsor	0.028	86	4.5
ocean pines	0.382	85	3.7
ocean pines	0.382	85	5.9
ocean pines	0.382	85	8.0
ocean pines	0.382	85	8.1
ocean pines	0.382	85	10.7
ocean pines	0.382	85	11.5
ocean pines	0.382	86	2.5
ocean pines	0.382	86	4.2
ocean pines	0.382	86	5.4
ocean pines	0.382	86	6.2
parkway	4.037	85	2.5
parkway	4.037	85	3.9
parkway	4.037	85	8.9
parkway	4.037	86	0.8
parkway	4.037	86	1.5
parkway	4.037	86	1.9
parkway	4.037	86	2.2

MARYLAND EFFLUENT PHOSPHORUS DATA 7

PLANT	FLOW	YEAR	TOTAL P
parkway	4.037	86	2.3
parkway	4.037	86	2.3
parkway inn	0.033	85	1.1
parkway inn	0.033	85	1.9
parkway inn	0.033	85	2.2
parkway inn	0.033	85	2.8
parkway inn	0.033	85	3.8
parkway inn	0.033	85	4.3
parkway inn	0.033	86	1.1
parkway inn	0.033	86	1.4
parkway inn	0.033	86	1.7
parkway inn	0.033	86	3.1
parkway inn	0.033	86	5.6
patapsco	34.880	85	2.4
patapsco	34.880	85	3.6
patapsco	34.880	85	3.8
patapsco	34.880	86	0.8
patapsco	34.880	86	1.2
patapsco	34.880	86	1.2
patapsco	34.880	86	1.4
patapsco	34.880	86	1.5
patapsco	34.880	86	1.5
patapsco	34.880	86	2.1
patapsco	34.880	86	2.3
patapsco	34.880	86	2.7
patuxent mobile est	0.028	85	4.2
patuxent mobile est	0.028	85	4.7
patuxent mobile est	0.028	85	5.7
patuxent mobile est	0.028	85	5.8
patuxent mobile est	0.028	86	1.0
patuxent mobile est	0.028	86	1.1
patuxent mobile est	0.028	86	1.7
patuxent mobile est	0.028	86	2.4
patuxent mobile est	0.028	86	2.6
patuxent wildlife	0.016	85	3.0
patuxent wildlife	0.016	85	3.3
patuxent wildlife	0.016	85	4.4
patuxent wildlife	0.016	85	7.4
patuxent wildlife	0.016	86	2.9
patuxent wildlife	0.016	86	3.8
patuxent wildlife	0.016	86	4.0
patuxent wildlife	0.016	86	4.4
patuxent wildlife	0.016	86	4.9
patuxent wildlife	0.016	86	5.2
peter pan inn	0.005	85	3.9
peter pan inn	0.005	85	4.6
peter pan inn	0.005	85	6.8
peter pan inn	0.005	86	2.4

MARYLAND EFFLUENT PHOSPHORUS DATA 8

PLANT	FLOW	YEAR	TOTAL P
pheasant ridge	0.015	85	6.1
pheasant ridge	0.015	86	3.8
pheasant ridge	0.015	86	4.1
pheasant ridge	0.015	86	5.7
pine hill run	2.013	85	6.0
pine hill run	2.013	85	6.4
pine hill run	2.013	85	6.5
pine hill run	2.013	85	7.8
pine hill run	2.013	86	3.4
pine hill run	2.013	86	3.7
pine hill run	2.013	86	3.8
pine hill run	2.013	86	3.9
poolesville	0.270	85	8.0
poolesville	0.270	86	1.6
poolesville	0.270	86	1.9
poolesville	0.270	86	3.3
potomac ht	0.179	85	3.8
potomac ht	0.179	85	4.5
potomac ht	0.179	85	5.2
potomac ht	0.179	85	5.7
potomac ht	0.179	86	3.1
potomac ht	0.179	86	4.2
princess anne	0.389	85	2.1
princess anne	0.389	85	5.9
princess anne	0.389	85	6.0
princess anne	0.389	85	7.5
princess anne	0.389	85	11.5
princess anne	0.389	86	5.5
princess anne	0.389	86	6.1
queen annes co	0.661	85	5.2
queen annes co	0.661	85	6.4
queen annes co	0.661	85	6.7
queen annes co	0.661	85	7.1
queen annes co	0.661	86	4.0
queen annes co	0.661	86	5.0
queen annes co	0.661	86	5.0
queen annes co	0.661	86	5.3
queen annes co	0.661	86	5.6
queenstown	0.058	85	1.9
queenstown	0.058	85	2.6
queenstown	0.058	86	1.8
queenstown	0.058	86	2.2
queenstown	0.058	86	4.2
rock hall	0.124	85	0.2
rock hall	0.124	85	2.8
rock hall	0.124	86	1.4
rock hall	0.124	86	1.4

MARYLAND EFFLUENT PHOSPHORUS DATA 9

PLANT	FLOW	YEAR	TOTAL P
rock hall	0.124	86	1.5
rock hall	0.124	86	1.7
rose haven	0.045	85	4.1
rose haven	0.045	85	7.0
rose haven	0.045	85	8.0
rose haven	0.045	85	8.6
rose haven	0.045	85	10.5
rose haven	0.045	86	1.8
rose haven	0.045	86	1.9
rose haven	0.045	86	3.2
rose haven	0.045	86	3.6
rose haven	0.045	86	4.2
rose haven	0.045	86	5.0
spring meadows	0.008	85	2.2
spring meadows	0.008	85	8.2
spring meadows	0.008	86	5.3
summer hill	0.010	85	4.7
summer hill	0.010	85	5.1
summer hill	0.010	85	7.6
summer hill	0.010	85	8.8
summer hill	0.010	85	8.8
summer hill	0.010	85	9.1
summer hill	0.010	86	0.8
summer hill	0.010	86	1.7
summer hill	0.010	86	1.8
summer hill	0.010	86	2.5
summer hill	0.010	86	2.9
summer hill	0.010	86	4.8
taneytown	0.225	85	3.6
taneytown	0.225	86	2.9
taneytown	0.225	86	3.7
taneytown	0.225	86	4.4
thurmont	0.388	85	5.6
thurmont	0.388	85	5.6
thurmont	0.388	85	6.7
thurmont	0.388	85	6.7
thurmont	0.388	85	7.5
thurmont	0.388	85	7.5
thurmont	0.388	85	8.1
thurmont	0.388	85	8.5
thurmont	0.388	86	5.3
trans cont gas	0.001	85	14.2
trans cont gas	0.001	85	18.5
trans cont gas	0.001	85	20.8
trans cont gas	0.001	86	3.8
trans cont gas	0.001	86	4.2
trans cont gas	0.001	86	4.3
trans cont gas	0.001	86	6.0

MARYLAND EFFLUENT PHOSPHORUS DATA 10

PLANT	FLOW	YEAR	TOTAL P
union bldge	0.069	85	4.6
union bldge	0.069	86	2.8
union bldge	0.069	86	4.5
waysons mobile home	0.049	85	4.7
waysons mobile home	0.049	85	5.9
waysons mobile home	0.049	85	6.1
waysons mobile home	0.049	85	6.5
waysons mobile home	0.049	86	2.7
waysons mobile home	0.049	86	2.7
waysons mobile home	0.049	86	2.9
waysons mobile home	0.049	86	2.9
waysons mobile home	0.049	86	3.9
western branch	10.688	85	3.0
western branch	10.688	85	3.9
western branch	10.688	85	4.1
western branch	10.688	86	1.1
western branch	10.688	86	1.1
western branch	10.688	86	1.4
western branch	10.688	86	1.4
western branch	10.688	86	1.5
white rock	0.013	85	7.8
white rock	0.013	85	8.0
white rock	0.013	85	8.1
white rock	0.013	85	9.1
white rock	0.013	86	4.1