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EPA

Use of the Black Creek Database to Analyze Techniques for Estimating Nonpoint Source Loadings From Small Watersheds

(May 1988)

FOREWORD

The U.S. Environmental Protection Agency (**USEPA**) was created because of increasing public and governmental concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment.

The Great Lakes National Program Office (**GLNPO**) of the U.S. EPA was established in Chicago, Illinois to provide specific focus on the water quality concerns of the Great Lakes. The Section 108(a) Demonstration Grant Program of the Clean Water Act (PL 92-500) is specific to the Great Lakes drainage basin and thus is administered by the Great Lakes National Program Office.

Several sediment erosion-control projects within the Great Lakes drainage basin have been funded as a result of Section 108(a). This report describes one such project supported by this Office to carry out our responsibility to improve water quality in the Great Lakes.

We hope the information and data contained herein will help planners and managers of pollution control agencies to make better decisions in carrying forward their pollution control responsibilities.

Christopher Grundler ,Director
Great Lakes National Program Office

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USE OF THE BLACK CREEK DATABASE TO ANALYZE TECHNIQUES FOR ESTIMATING NONPOINT SOURCE LOADINGS FROM SMALL WATERSHEDS

by

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INTRODUCTION

This report describes and intensive use of the database developed during the Black Creek Project to analyze various monitoring methods applied to small watersheds. It is assumed that the primary reason for monitoring in these cases is an attempt to monitor the effectiveness of various strategies for control of nonpoint source pollution. There are several reasons for desiring to conduct a monitoring program.

1. The motive may be scientific. The project may then be designed to quantify fundamental physical relationships, thereby improving understanding of the dynamics of processes such as sediment detachment and transport, nutrient leaching, etc.

2. The motive may be administrative. Monitoring may be undertaken in an effort to gain understanding of the effectiveness of management programs applied to gain control of nonpoint sources.

3. The motive may be concerned with compliance. Such a program may be primarily concerned with tracking, over time, the loadings of a substance of interest to a stream or lake.

The degree of precision necessary to accomplish the goals of a program will be determined, in large part, by the motivation. In general, the greatest sophistication in monitoring will be required if the motive is scientific. Less intensive monitoring may be necessary for tracking of program accomplishment or for establishing the effectiveness of a particular management program. However, even in these cases, it is important that the monitoring be sufficiently precise that results are not misleading.

Although this report uses the Black Creek Database, loadings reported should not, in all cases, be considered official project results, since some manipulation of data was done to create a variety of sampling scenarios. Effort has been made to make it clear which data is theoretical and which is actual in this report.

It is generally accepted that it is both difficult and expensive to conduct monitoring programs which thoroughly describe rainfall, erosion, and storm runoff in an agricultural watershed. Techniques to improve accuracy and reduce costs, are much sought after. The use of sophisticated numerical models provides one approach. Correlation of easily measured parameters with more difficult ones is another. Reducing the scope of monitoring and using sophisticated statistical techniques for analysis provides a third.

PROJECT BACKGROUND

The Black Creek Watershed Project, funded through the Great Lakes National Program Office of USEPA, was an attempt to quantify the relationships between agricultural land use and water quality. Results of this study, which was continued for 10 years, beginning in 1971, have been reported elsewhere. However, for background purposes, a brief summary is presented.

The Black Creek Watershed is a largely agricultural watershed located in Allen County, Indiana. Black Creek is a tributary of the Maumee River which in turn, flows to Lake Erie at Toledo Ohio. When the project was begun, in 1972, Lake Erie was the subject of intense concern and the Maumee River had been identified as a heavy contributor of sediment and related pollutants to the lake. Black Creek was selected as a study area because its geographic characteristics closely modeled those of the entire Maumee River Basin.

Water quality data was collected at 16 sites within Black Creek. For purposes of the analysis described in this report, only two of these sites were considered. Their characteristics, along with the characteristics of the full Black Creek Watershed, are described in Table 1.

Table 1. Study Area Characteristics

Characteristics	Black Creek Watershed	Smith-Fry Drain (Site 2)	Dreisback Drain (Site 6)
Drainage area, ha	4950	942	714
Soils (as percentage):			
Lake plan & Beach ridge	64	71	26
Glacial till	36	29	74
Land use (as percentage):			
Row crops	58	63	40
Small grain & pasture	31	26	44
Woods	6	8	4
Urban, roads, etc.	5	3	12
Number of homes:	---	28	143

Table 2 presents grand total loadings for the period 1975 through 1981. However, data for 1981 represents loadings for the first six months of the year only.

Table 2. Annual Loadings Sites 2 and 6

Site 2

Parameter	75	76	77	78	79	80	81*
Inorg.P (kg/ha)	.12	.07	.20	.21	.24	.20	.08
Ammonium (kg/ha)	1.24	.58	.79	.77	.97	.65	.35
Inorg. N (kg/ha)	15.98	5.51	16.99	9.74	21.61	13.43	7.11
Rainfall (cm)	104.84	65.95	98.22	81.18	79.86	88.3	46.8
Runoff (cu Dm)	249	116	203	185	231	155	70
Sediment N (kg/ha)	29.45	4.64	6.72	6.15	5.72	9.06	5.1
Sediment P (kg/ha)	5.19	1.08	1.9	.71	1.0	2.94	1.05
Sol. Org. N (kg/ha)	1.57	.46	.54	1.22	1.22	1.79	.14
Sol. Org. P (kg/ha)	.08	.04	.07	.09	.07	.03	.03
Sus. Sol (kg/ha)	2138	652	513	427	646	669	210

Site 6

Inorg.P (kg/ha)	.42	.51	.47	.73	.88	.3	.20
Ammonium (kg/ha)	1.57	.82	1.12	2.96	1.93	.59	.34
Inorg. N (kg/ha)	9.52	2.44	10.75	6.81	7.86	4.67	5.5
Rainfall (cm)	106	69.2	95.7	81.3	80.7	82.6	44.7
Runoff (cu Dm)	165	72	138	159	152	68	68
Sediment N (kg/ha)	18.6	2.274	5.05	8.24	7.78	8.25	9.28
Sediment P (kg/ha)	3.69	.67	2.11	.92	1.46	2.50	2.47
Sol. Org. N (kg/ha)	2.16	.37	1.09	3.39	2.27	.84	.19
Sol. Org. P (kg/ha)	.11	.03	.1	.34	.10	.05	.05
Sus. Sol (kg/ha)	3411	388	525	660	630	408	298

*Half Year Totals Only

A detailed discussion of some of the important relationships between sediment, runoff, and various nutrients, is contained in EPA-905/9-81-003. Logically, the strongest relationships were established between sediment and sediment-bound nutrients. Relationships between more easily measured parameters such as runoff and various nutrients were higher for solubles than for particulates.

DATA MANAGEMENT AND COLLECTION

Water quality samples were collected both as grab samples and through automated samplers. An attempt was made to place the automated sampler operation under the real-time control of a computer located in the Agricultural Engineering Department at Purdue University. From time to time, comparisons were made between loadings as estimated from grab samples and loadings as estimated from the records collected from the automated stations.

PS-69 samplers furnished the basis for most automated sample collections on the Black Creek itself and on the two primary sub-watersheds studied. In addition, an automated sampler was installed on a tile line to collect data on the erosion potential from tile drainage systems. Special battery-powered sampling stations were installed on the eight best management practice watersheds.

The Black Creek Project relied heavily on computer storage and manipulation of data files. Data management falls naturally into two primary areas: (1) data verification and entry; and (2) data retrieval for analysis. Complete descriptions of the data management system at Purdue are included in EPA-905/9-77-007-B and EPA-905/9-81-003.

Briefly, data verification and entry for the bulk of Black Creek water quality data followed this scheme:

1. Water stage and rain guage charts were converted to machine readable form and entered into digital computer files.

2. Rainfall data, available as accumulated inches of rainfall, were converted into rates in cm/hr. Areal rainfall was calculated as the weighted average of the rainfall data on an area basis between adjacent sites.

3. Rainfall data, water stage data and water quality data were stored by year and site number.

4. Grab sample data was verified for entry errors and corrections made; then the data was sorted by time, date, and site number.

5. Grab sample and pump sample data was checked for errors and omissions. Errors included unrealistic dates and times, unreadable characters, abnormally high values, and unrealistic valued for nutrient components.

6. Base estimates were made for missing data or erroneous water quality parameters.

7. Errors due to faulty analysis were corrected according to the following scheme:

Let soluble N = Nitrate + Ammonium, if Nitrate + Ammonium > soluble N
Let total N = soluble N if soluble N > total N
Let soluble P = inorganic P, if inorganic P > soluble P
Let total P = soluble P, if soluble P > total P

In order to make retrieval and analysis of data more convenient, the master files, created in accordance with the scheme outlined above, were converted into an event-orientated format. The data files, as outlined above, contain data on physical and chemical water quality, stage, and rainfall. Each of the new files contains data for one site, with the records stored in chronological order.

A standard report macro was created to provide the following information:

1. Total transport, in kilograms and kilograms per hectare, of suspended solids, ammonia, nitrate, soluble organic and sediment-bound nitrogen, and inorganic, soluble organic, and sediment-bound phosphorus passing the site during the specified time period.

2. Flow weighted concentration, in milligrams per liter, for these parameters.

3. Flow characteristics, including peak and mean flow rates, volume of runoff, total runoff, and total rainfall for the period.

4. Statistical analysis of the concentrations, including: maximum, minumum, mean, median, and standard deviations.

This report can be varied by the user. It can be generated for any site, and for any specified period of time. In addition, the user can request linear interpolation throughout the analysis.

At the end of the project, a tremendous amount of data had been collected. However, standard methods of data analysis did not yield satisfactory results. The data generated on the project was, as suspected, highly variable, and did not always provide purely linear relationships. A measure of the variability is indicated in Table 3.

Table 3. Means and Standard Deviations for Various Parameters Sites Two and Six

Site 6 (Dreisback Drain)

	Inorg P (g)	NH4 (g)	Rainfall (cm)	Runoff (cu m)	Sed N (g)	Sed P (g)	Sus. Sol (g)
1975							
M	.03	.13	.01	195	1.5	.31	287
SD	.42	.50	.09	993	16.4	3.1	4914
1976							
M	.04	.07	.007	81	.22	.05	31
SD	.18	.28	.099	410	3.02	.72	486
1977							
M	.04	.09	.01	157	.41	.17	42
SD	.17	.48	.06	661	4.1	1.3	310
1978							
M	.06	.24	.009	181	.67	.07	53
SD	.34	1.6	.05	838	5.8	.54	430
1979							
M	.07	.15	.009	172	.63	.12	51
SD	.33	.73	.05	595	3.7	.65	249
1980							
M	.02	.05	.009	77	.67	.20	33
SD	.13	.27	.07	415	9.7	3.2	419
1981							
M	.03	.06	.01	155	1.5	.39	48
SD	.21	.36	.06	955	15.6	4.1	401

Site 2 (Smith - Fry Drain)

	Inorg P (g)	NH4 (g)	Rainfall (cm)	Runoff (cu m)	Sed N (g)	Sed P (g)	Sus. Sol (g)
1975							
M	.01	.13	.01	295	3.3	.58	238
SD	.08	.65	.09	1493	43	7.1	3608
1976							
M	.01	.06	.007	131	.49	.11	69
SD	.04	.28	.04	625	4.04	1.1	679
1977							
M	.02	.08	.01	231	.57	.2	54
SD	.11	.45	.07	914	5.1	1.8	416
1978							
M	.02	.08	.009	210	.7	.07	45
SD	.12	.41	.05	854	7.0	.55	282
1979							
M	.03	.10	.009	272	.6	.11	69
SD	.15	.45	.05	974	3.8	.8	312
1980							
M	.02	.06	.009	175	.97	.31	45
SD	.1	.31	.06	742	10.9	2.8	283
1981							
M	.02	.08	.01	160	1.09	.23	45
SD	.09	.48	.07	593	9.8	1.9	283

As can be seen from Table 3., standard deviations were, in most cases, several times the mean values of selected parameters.

One important result sought in this project was to apply a correlation model to project results. The goal was to correlate parameters which are relatively easy to measure, such as runoff or rainfall with parameters which are more difficult or costly to measure, such as dissolved materials or particulate matter. Table 4 provides some results of this analysis. Based on the number of samples analyzed, a correlation coefficient of .8 would be required to establish statistical significance. Table 4 reports correlations between rainfall in the watershed and the measured loadings of various parameters by year. When correlation of rainfall proved to be not significant, it was suggested that some attention should be paid to the response time of the watershed. Therefore, additional correlations were calculated attempting to relate the parameter with rainfall which had been occurring one, two or three hours earlier. Although this technique improved the correlations, none were statistically significant.

Table 4. Correlation of Loadings With Rainfall

	Rainfall	Lagged Rainfall 1 Hour	Lagged Rainfall 2 Hours	Lagged Rainfall 3 Hours
1975 - Site 2				
Inorg. P.	.13	.23	.34	.36
NH4	.13	.17	.24	.29
NO3 + NO2	.13	.17	.23	.28
Sediment N	.23	.36	.43	.37
Sediment P	.23	.32	.39	.40
Sol. Org. N	.15	.22	.28	.27
Sol. Org. P	.17	.25	.32	.35
Sus. Solids	.29	.48	.53	.41
1976 - Site 6				
Inorg. P.	.05	.07	.11	.13
NH4	.07	.11	.15	.16
NO3 + NO2	.08	.13	.16	.18
Sediment N	.04	.09	.19	.26
Sediment P	.04	.09	.18	.26
Sol. Org. N	.08	.10	.14	.15
Sol. Org. P	.06	.10	.15	.18
Sus. Solids	.03	.08	.19	.26
1976 - Site 2				
Inorg. P.	.08	.12	.14	.15
NH4	.09	.12	.15	.17
NO3 + NO2	.10	.14	.17	.19
Sediment N	.13	.16	.20	.21
Sediment P	.11	.14	.17	.20
Sol. Org. N	.07	.09	.12	.14
Sol. Org. P	.09	.13	.16	.17
Sus. Solids	.07	.11	.14	.15
1975 - Site 6				
Inorg. P.	.01	.01	.02	.05
NH4	.02	.04	.08	.13
NO3 + NO2	.04	.06	.11	.19
Sediment N	.04	.04	.17	.18
Sediment P	.04	.04	.12	.24
Sol. Org. N	.04	.04	.11	.22
Sol. Org. P	.04	.04	.09	.17
Sus. Solids	.03	.03	.07	.21
1976 - Site 20				
Inorg. P.	.00	.00	.01	.03
NH4	.10	.10	.11	.11
NO3 + NO2	.07	.09	.11	.14
Sediment N	.07	.09	.11	.13
Sediment P	.09	.11	.15	.17
Sol. Org. N	.06	.08	.11	.14
Sol. Org. P	.09	.11	.17	.18
Sus. Solids	.09	.11	.16	.16

MODELING APPROACH

In order to analyze the often confusing data collected during the project, a detailed computer based model, ANSWERS, was developed. This model was then validated using elements of the Black Creek data set. Validation is the process of determining the accuracy with which a mathematically based model describes the behavior of phenomena which it purports to characterize. For environmentally related models, this generally means collecting data concerning model input variables and observed responses for field conditions which the model should be capable of characterizing and then comparing this data with predicted values. At best, this process can only be rather crudely accomplished on a watershed scale for comprehensive, distributed parameter models such as ANSWERS. This crudeness results from the impracticality of measuring all of the input data associated with spatially non-uniform variables.

Models of complex phenomena such as nonpoint source pollution frequently rely on the availability of a period of gaged data from the target watershed to determine the most suitable model coefficients to be used on that watershed. This process is known as model calibration. It usually results in a substantial improvement in the accuracy with which that model can predict events, for the gaged watershed, not used in the calibration analysis, i.e. it improves validation comparisons. Unfortunately, the number of situations for which adequate data is available to calibrate a comprehensive model is very limited. Furthermore, use of historical calibration data can severely limit the accuracy of such models for predicting potential future behavior if proposed treatments interact substantially with processes being predicted, but not prevalent when calibration data were collected.

Basically, models are useful for two different kinds of applications: magnitude prediction and cause-effect evaluations. Of course, applications requiring cause-effect information must be able to predict magnitudes, but they require a model with more stringent requirements than a purely predictive application.

The most widely used predictive model structure employs statistical correlation techniques. Statistically based models represent a cost-effective approach to estimating future trends in processes that are too complex to characterize by known physical equations or for which the cost of such characterization is not consistent with the intended use for the results. A major limitation of such models is that they cannot be reliably used for inverse applications, e.g. in a planning mode to infer that a desired change in level of the dependent variable can be accomplished by changing the level of the independent variables by the amount indicated by the correlation relationship. It is well known that between 1920 and 1975, the magnitude of the Dow-

Jones stock average and the distance above the floor of the most popular hemline for women's dress was strongly correlated. However, it would not be correct to assert that raising the hemline of women's dresses would cause the stock market to rise.

In contrast to correlation models, cause-effect models must be built using relationships whose dependent and independent variables are known to be interrelated directly by physical principles. Usually, practical models are constructed by combining relationships which are known to exist between various components of complex processes, i.e. by combining several cause-effect relationships for individual sub-processes.

ANSWERS is a model developed using a cause-effect structure. ANSWERS was designed to simulate the behavior of agricultural watersheds during and immediately after a rainfall event. Its primary purpose is for planning and evaluations. The model is designed as a "distributed parameter" rather than a more common "lumped parameter" model. The fundamental hypothesis of the model is as follows:

> At every point within a watershed, functional relationships exist between water flow rates and those hydrologic parameters which govern them, i.e. Rainfall intensity, infiltration, topography, soil type, etc. Furthermore, these flow rates can be utilized in conjunction with appropriate component relationships as the basis for modeling other transport-related phenomenon such as soil erosion and chemical movement within that watershed.

In practice, the points are expanded to become watershed elements in which the hydrologic parameters are assumed to be uniform.

The process described by the model is as follows:

(1) Rainfall begins

(2) The amount of rainfall exceeds the ability of the crop canopy to intercept and store it.

(3) Rainfall reaches the soil surface and infiltration begins.

(4) The amount of moisture reaching the soil surface exceeds the infiltration rate. Water collects in surface storage.

(5) Runoff begins.

(6) Subsurface drainage begins.

(7) A steady state is reached in which the infiltration rate equals the subsurface drainage rate.

(8) Rainfall ends.

(9) Surface drainage ends.

(10) Infiltration ends.

(11) Subsurface drainage ends.

The Black Creek database was used t validate and to a lesser extent calibrate ANSWERS. It was on the basis of the model that the project concluded that application of Black Creek land treatment would have resulted in a 25 percent reduction in phosphorus loadings to Lake Erie.

OTHER USES OF DATABASE

If it is desired to estimate the mean within 30 percent, and the total variation involved represents that associated with measurement and trivial effects so that the standard deviation - about 20 percent of the mean, it can be shown that 25 samples would guarantee an estimate of the mean within 30 percent of the value of the mean at the 95 percent confidence level.

As has been noted, for most of the parameters measured in the Black Creek project, standard deviations were often found to be several times the mean, so that the number of samples required to estimate the mean was much larger, calculations show the following number of required, randomly collected samples to estimate the mean within 30 percent for two parameters measured in the Black Creek Project, suspended solids and dissolved nitrogen (nitrate + nitrite). Results are presented in Table 5.

Table 5. Number of Samples Needed to Estimate the mean of two parameters measured in Black Creek Watershed

Year	Parameter	Number of Samples Needed
1975	Suspended Solids	9046
1976	Suspended Solids	4254
1977	Suspended Solids	2532
1978	Suspended Solids	1675
1979	Suspended Solids	872
1980	Suspended Solids	3170
1981	Suspended Solids	1687

Cont. Table 5.

Year	Parameter	Number of Samples Needed
1975	Nitrate & Nitrite	750
1976	Nitrate & Nitrite	1125
1977	Nitrate & Nitrite	721
1978	Nitrate & Nitrite	860
1979	Nitrate & Nitrite	777
1980	Nitrate & Nitrite	891
1981	Nitrate & Nitrite	929

A year contains 365*24 - 8,760 hours, so that, in looking at the sample requirements, usually hourly samples would have been sufficient to estimate the mean of these parameters within 30 percent.

It was possible, through computer techniques to create a virtual watershed record, producing an hour by hour datapoint for each parameter measured in the Black Creek Project. This was done by summing samples which were collected more frequently than one hour and partitioning values in which the period between samples was greater than one hour. The result of this analysis was a record which, while not necessarily an accurate reflection of the Black Creek data, was a record of plausible monitoring results which the same statistical characteristics of a data set collected through monitoring.

After consultation with data specialists monitoring the conduct of target watersheds under the Rural Clean Water Program, it was determined that this data set could be used to analyze the potential error of monitoring in the following situations:

(1) Samples collected daily

(2) Samples collected weekly

(3) Daily Composite Samples

(4) Weekly Composite Samples

The errors produced by these sampling schemes are reported in the following tables.

Table 6 presents the results for phosphorus at sites 2 and 6.

Table 6. Errors in Daily vs Weekly Sampling Schemes
for Dissolved phosphorus, sites 2 and 6

	Percent Error			
	Site 2		Site 6	
Year	Daily	Weekly	Daily	Weekly
1975	7.4	24.5	18.3	27.2
1976	11.9	14.6	4.9	0.6
1977	7.3	64.1	9.3	39.3
1978	1.9	41.5	10.1	43.9
1979	11.6	62.3	2.8	3.5
1980	10.3	28.8	4.9	44.5
Average	8.4	39.4	8.4	26.5

Table 7. Errors in Daily vs Weekly Sampling Schemes
for suspended solids, sites 2 and 6

	Percent Error			
	Site 2		Site 6	
Year	Daily	Weekly	Daily	Weekly
1975	53.7	84.9	39.5	83.7
1976	21.5	27.5	25.9	191.7
1977	11.9	21.9	1.8	30.3
1978	18.1	5.0	34.4	58.7
1979	1.6	39.9	0.1	107.0
1980	32.4	15.1	49.9	41.7
Average	23.2	32.4	25.2	85.5

Table 8 Presents information for composite sampling schemes at sites 2 and 6 for dissolved phosphorus.

Table 8. Daily and Weekly Composite Samples
Dissolved Phosphorus, Sites 2 and 6

	Percent Error			
	Site 2		Site 6	
Year	Daily	Weekly	Daily	Weekly
1975	13.9	66.1	19.0	77.6
1976	12.7	7.3	3.5	39.8
1977	.5	15.4	7.8	9.9
1978	8.8	34.7	7.8	16.5
1979	2.9	29.2	6.8	41.1
1980	13.9	79.5	21.2	85.4
Average	8.7	38.7	11.1	45.1

Table 9 Presents information for composite sampling schemes at sites 2 and 6 for suspended solids.

Table 9. Daily and Weekly Composite Samples
Suspended Solids, sites 2 and 6

	Percent Error			
	Site 2		Site 6	
Year	Daily	Weekly	Daily	Weekly
1975	15.7	91.8	28.1	89.5
1976	14.9	33.5	29.7	16.7
1977	2.7	32.6	14.5	17.5
1978	13.1	41.2	19.9	21.7
1979	8.6	17.5	6.5	41.0
1980	30.0	82.6	28.1	93.6
Average	14.1	49.8	21.1	46.

Average results are summarized in Table 10.

Table 10. Comparison of Sampling Schemes

	Percent Error			
	Site 2		Site 6	
Parameter	Daily	Weekly	Daily	Weekly
Phosphorus	8.4	39.4	8.4	26.5
Suspended Solids	23.2	32.4	25.2	85.5
Phosphorus	8.7	38.7	11.1	45.1
Suspended Solids	14.1	49.8	21.1	46.6

CONCLUSIONS

If one has as a criteria, measuring of certain parameters within 30 percent of the mean, these results indicate that daily samples will generally accomplish this, although in years where some significant portion of total loadings occur in one or two major storm events, results will not be satisfactory with a regular daily monitoring scheme.

In the watersheds analyzed here, weekly samples will not, in general, produce results within 30 percent of the mean.

Compositing of samples offers more improvement for suspended materials than for dissolved materials, although in no case did the compositing scheme employed in this project improve results sufficiently.

As would be expected, greater errors were introduced when sampling frequence was reduced for dissolved materials than for suspended materials.

It should be emphasized that the results reported here are for annual loadings only and do not necessarily reflect results sufficient to draw cause and effect conclusions. Also, it should be pointed out that the effect of compositing would be expected to be better when the watershed being considered was larger than considered here.

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15. SUPPLEMENTARY NOTES

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16. ABSTRACT

This report describes an intensive use of the database developed during the the Black Creek Project to analyze various monitoring methods applied to small watersheds. It is assumed that the primary reason for monitoring in these cases is an attempt to monitor the effectiveness of various strategies for control of non-point source pollution.

Water quality data was collected at 16 sites within Black Creek. For purposes of the analysis described in this report, only two of these sites were considered. Sites 2 and 6.

Although this report uses the Black Creek Database, loadings reported should not, in all cases, be considered official project results, since some manipulation of data was done to create a variety of sampling scenarios. Effort has been made to make it clear which data is theoretical and which is actual in this report.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Database Statistics Rainfall Measurements Runoff Water Quality Nutrients	Sediment Erosion Loadings Watershed		

18. DISTRIBUTION STATEMENT Document available to the public through National Technical Information Service, NTIS, Springfield, VA 22161	19. SECURITY CLASS *(This Report)* None 20. SECURITY CLASS *(This page)* None	21. NO. OF PAGES 24 22. PRICE

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