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BMP IMPACTS ON WATERSHED RUNOFF, SEDIMENT, AND NUTRIENT YIELDS[1]

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ABSTRACT: To quantify the effectiveness of best management practice (BMP) implementation on runoff, sediment, and nutrient yields from a watershed, the Nomini Creek watershed and water quality monitoring project was initiated in 1985, in Westmoreland County, Virginia. The changes in nonpoint source (NPS) loadings resulting from BMPs were evaluated by comparing selected parameters from data series obtained before, during, and after periods of BMP implementation. The results indicated that the watershed-averaged curve number, sediment, and nutrient (N and P) concentrations were reduced by approximately 5, 20, and 40 percent, respectively, due to BMP implementation. The nutrient yield model developed by Frere *et al.* (1980) was applied to the water quality parameters from 175 storms, but it failed to adequately describe the observed phenomena. Seasonal changes in nutrient availability factors were not consistent with field conditions, nor were they significantly different in the pre- and post-BMP periods. An extended period of monitoring, with intensive BMP implementation over a larger portion of the watershed, is required to identify BMP effectiveness.
(KEY TERMS: best management practices; runoff; nutrient; sediment.)

INTRODUCTION

Agricultural nonpoint source (NPS) pollution is regarded as a major source of degradation of large water bodies like the Chesapeake Bay (US Environmental Protection Agency, 1983). Primary NPS pollutants of concern are those such as nutrients, pesticides, and sediment that are carried mainly by runoff from agricultural lands. These NPS pollutants may cause significant problems to aquatic environments, examples of which are well documented (e.g., Mostaghimi *et al.,* 1989a; Heatwole *et al.,* 1992). An effective method of controlling or alleviating agricultural contributions to NPS pollution is to implement Best Management Practices (BMPs) at or near the source areas (Mostaghimi *et al.,* 1989a). Agricultural BMPs may be structural or nonstructural. Structural BMPs include terracing, impoundments, and fencing, while conservation tillage and strip filters are examples of nonstructural BMPs. The effects of BMPs on reducing NPS pollutant loadings vary with type and areal extent (Heatwole *et al.,* 1992). For example, conservation tillage increases the infiltration and thus significantly reduces runoff, soil loss, and nutrient yield (Loehr *et al.,* 1979), while impoundment retards flow and reduces effluent overflow to downstream (Laflen *et al.,* 1978).

The effectiveness of BMPs has not, however, been well documented on a watershed scale, particularly for watersheds with mixed land uses (Mostaghimi *et al.,* 1989a). Most available information is based on extrapolations of existing knowledge from field data or NPS pollution model applications. Basic assumptions are that NPS pollution can be proportionally reduced if NPS loadings from critical areas that significantly contribute to pollution are controlled. It is not proven that such applications actually reduce NPS loadings from watersheds with complex land use patterns.

Unlike plot and field studies where the results from specific treatments can be directly compared to those from control conditions, the effect of BMPs on a watershed scale is not easily identifiable (Mostaghimi *et al.,* 1989a). Typically, watershed monitoring programs require a long period of data collection so that statistical comparisons between the watershed and

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water quality parameters during periods before and after BMP implementation can be made (UNESCO, 1978; Spooner *et al.*, 1985). However, there are few methods that can be used to define the changes in NPS loadings accruing from short-term BMP implementation. Such procedures are necessary to quantitatively define the effects of BMPs on a watershed scale.

In this paper, we have developed a procedure for identifying BMP effectiveness on a watershed scale. This procedure was used to evaluate the effects of BMPs on the hydrology, sediment, and nutrient yields of the Nomini Creek watershed, a 1464 ha watershed located in Westmoreland County, Virginia.

WATERSHED PARAMETERS FOR BMP EFFECTS

Several methods are available for comparing runoff, soil, and chemical losses that result from different agricultural practices. Direct comparisons are commonly used for plot studies, where the results from treated conditions and controls can be easily compared to each other (e.g. Mostaghimi *et al.*, 1989b). Direct comparisons can also be used for field-scale BMP studies when the study areas are geographically close enough so that hydrologic inputs may be considered to be the same.

Another approach is to use statistical procedures to compare parametric changes between treatments. Spooner *et al.* (1985) proposed the use of a linear relationship linking concentrations and streamflows for periods before and after BMP implementation. The slopes of the two regression lines are then compared to determine if they are significantly different. This approach is applicable when test sites are complex and direct comparisons are not possible. Unfortunately, the method requires a relatively long monitoring period to establish the minimum detectable change (MDC) level. The MDC is defined as the minimum measurable change in a water quality parameter over time that is statistically significant, and is a function of statistical tests, the number of samples taken per year, the number of monitoring years, and the variates and covariates used in the analyses (Spooner *et al.*, 1985).

The effects of BMPs' implementation on a watershed can be numerous. The BMPs may affect the hydrology, soil erosion, and transport mechanisms, as well as chemical loadings and transport processes. These effects are also closely interrelated to each other. Altering hydrologic processes may also change the sediment and chemical transport processes. Therefore, a simple regression relationship between the water quality and runoff may not sufficiently reflect the complexity of BMP effectiveness. Instead, individual transport processes should be adequately modeled using mathematical relationships, and the resulting parameters compared for different BMP implementations. The following are some of the parameters which may be considered when evaluating the effectiveness of BMPs.

Hydrology

There are several available hydrologic models that can be used to quantitatively describe the characteristics of a watershed. One such model is the Soil Conservation Service (SCS) method that may be used as a tool to define the effects of BMPs on direct runoff. In this method direct runoff from a storm event is defined as (SCS, 1973):

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)} \tag{1}$$

where Q is direct runoff (mm), P is storm rainfall (mm), and S is the storage (mm), more accurately termed the potential maximum retention. The rainfall is usually defined from a 24-hour storm. The storage is related to the curve number:

$$S = \frac{25400}{CN} - 254 \tag{2}$$

where CN is the curve number.

By combining Equations (1) and (2), CN can be expressed as a function of rainfall and runoff:

$$CN = \frac{25400}{5P + 10Q - \sqrt{125PQ + 100Q^2} + 254} \tag{3}$$

Storm CN from Equation (3) reflects the antecedent moisture condition (AMC) of the watershed. The effects of AMCs may be eliminated by adjusting the observed CNs for average conditions, or AMC_{II}. Based on the relationships between CNs for different AMCs, the CN for AMC_{II} (CN_{II}) may be defined from the following relationship:

$$CN_{II} = c_0 + c_1\, CN_a + c_2\, CN_a^2 + c_3\, CN_a^3 \tag{4}$$

where CN_a is the curve number for AMC_I or AMC_{III}, and c_0 , c_1, c_2 and c_3 are regression coefficients. For CN_{II} ranging from 30 to 100 (SCS, 1973), c_0, c_1, c_2 and c_3 were found to be 8.203, 1.604, -0.0083, 0.0000146 for AMC_I conditions, and -83.950, 4.161,

-0.052, 0.000289 for AMC_{III} conditions, respectively. The coefficient of determination for Equation (4) exceeded 0.99 for each of the two conditions.

Sediment Concentrations and Yields

The effects of BMPs on the sediment yields from a watershed may be characterized by using the relationships between sediment concentration, sediment yield, and discharge. The sediment concentration-discharge relationship may change when land use changes significantly modify the soil erosion processes. By comparing the relationships for the data before and after the implementation of BMPs, it may be possible to evaluate whether the BMPs implemented on a watershed contribute significantly to the reduction of sediment concentrations (Spooner *et al.*, 1985).

Another method that may be used to define the effects of BMPs on sediment yield is to compare the parametric values in a sediment yield model for pre- and post- BMP periods. As with sediment concentration, the changes in sediment yields from BMPs may be reflected in the modification of the parameters of an appropriate sediment yield model. Williams (1975) proposed a watershed sediment yield relationship of the form:

$$Y = 11.8\, Q_1\, q_p^{0.56}\, KLSCP \qquad (5)$$

where Y is storm sediment yield (Mg), Q_1 is storm runoff volume (m^3), q_p is peak runoff rate (m^3/s), and K, LS, C, and P are the USLE soil erodibility, slope, cropping and management, and erosion control practice factors, respectively.

Using the observed sediment yields, the rainfall and runoff data, and known K, LS, and P parameters, the cropping management factor C may be defined from Equation (5). The resulting C factors would reflect the change in "watershed-averaged" cropping management conditions resulting from BMP implementation.

Nutrient Concentrations and Yields

The effects of BMPs on nitrogen and phosphorus loadings may also be described using a nutrient concentration-discharge relationship and a nutrient yield model. A nutrient concentration-discharge relationship is analogous to the sediment graph, where the concentrations are plotted against discharge rates. Changes in nutrient loadings may be reflected as the variations of the slopes in the graphs.

Nutrient transport in a watershed takes place in two forms, soluble and sediment-bound. Soluble transport is a process by which nutrients in soils are dissolved into water and transported in a liquid phase. Sediment-bound transport is the process by which nutrients are washed off as sediment-bound particles. The output from soluble nutrient yield models are usually expressed in terms of a loading. Frere *et al.* (1980) used such relationships for the nitrogen and phosphorus submodels in CREAMS. Young *et al.* (1987) also adopted a similar approach in the AGNPS model. The models may be used as nutrient yield models. In the AGNPS model, the soluble nitrogen (N) yield from a storm is defined as (Young *et al.*, 1987):

$$N_s = \frac{(C_n - C_{kn})e^{-F_{N1}I} - (C_n - C_{kn})e^{-F_{N1}I - F_{N2}Q}}{C_F} + \frac{PN.Q}{ER} \qquad (6)$$

where N_s is the soluble N in runoff (kg/ha); C_n is the available soluble N contents in the soil (kg/ha); C_{kn} is the available N due to the rainfall; F_{N1} is a rate constant for downward movement of N into the soil; I is the total infiltration; F_{N2} is a rate constant for N movement into runoff; Q is the total storm runoff; C_F is a porosity factor; PN is the N contribution due to the rain; and ER is the effective rainfall. The details of each parameter are described by Young *et al.* (1987). In the AGNPS model, the relationship between C_n and the nitrogen fertilizer availability factor (FA_N) for a storm is given by:

$$C_n = (SN + FA_N)C_F \qquad (7)$$

where SN is the soluble N in the top cm of the original soil (kg/ha) and is related to the porosity (Young *et al.*, 1987). By combining Equations (6) and (7), FA_N may be defined as a function of the observed soluble nitrogen, rainfall, and runoff.

The soluble phosphorus (P) yield model is defined as (Young *et al.*, 1987):

$$P_s = \frac{(C_p - C_{kp})e^{-F_{P1}I} - (C_p - C_{kp})e^{-F_{P1}I - F_{P2}Q}}{C_F} + \frac{C_p F_{P2} Q}{C_F} \qquad (8)$$

where P_s is the soluble P in the runoff (kg/ha), C_p is the available P due to natural and fertilizer nutrient level, C_{kp} is the available P originally in the soil, F_{P1} is a rate constant for downward movement of P into the soil, and F_{P2} is a rate constant for P movement into runoff. C_p is related to the P fertilizer availability factor (FA_P) in a similar manner to C_N as described in Equation (7).

THE NOMINI CREEK WATERSHED

The Nomini Creek watershed was selected for evaluating the effectiveness of cropland BMPs on a watershed scale. It is located in Westmoreland County, Virginia (Figure 1), approximately 80 km northeast of Richmond, Virginia, and forms the upper ridge of the Nomini drainage basin that eventually drains into the Potomac River and the Chesapeake Bay. The watershed has been monitored since 1985 in an effort to evaluate the BMP effects on the quality of surface and ground water (Mostaghimi *et al.*, 1989a). Brief descriptions of the watershed characteristics and BMP implementation are given below, while detailed information on monitoring strategies are given by Mostaghimi *et al.* (1989a).

Climate, Topography, and Soils

The watershed is located within the northern Virginia Coastal Plain. The region has a typical humid continental climate with an average annual precipitation of 101.6 cm. Of this amount, 55.9 cm (55 percent) usually falls from April through September. The watershed is predominantly agricultural and is 1464 ha in size, with 43 percent under cropland, 54 percent

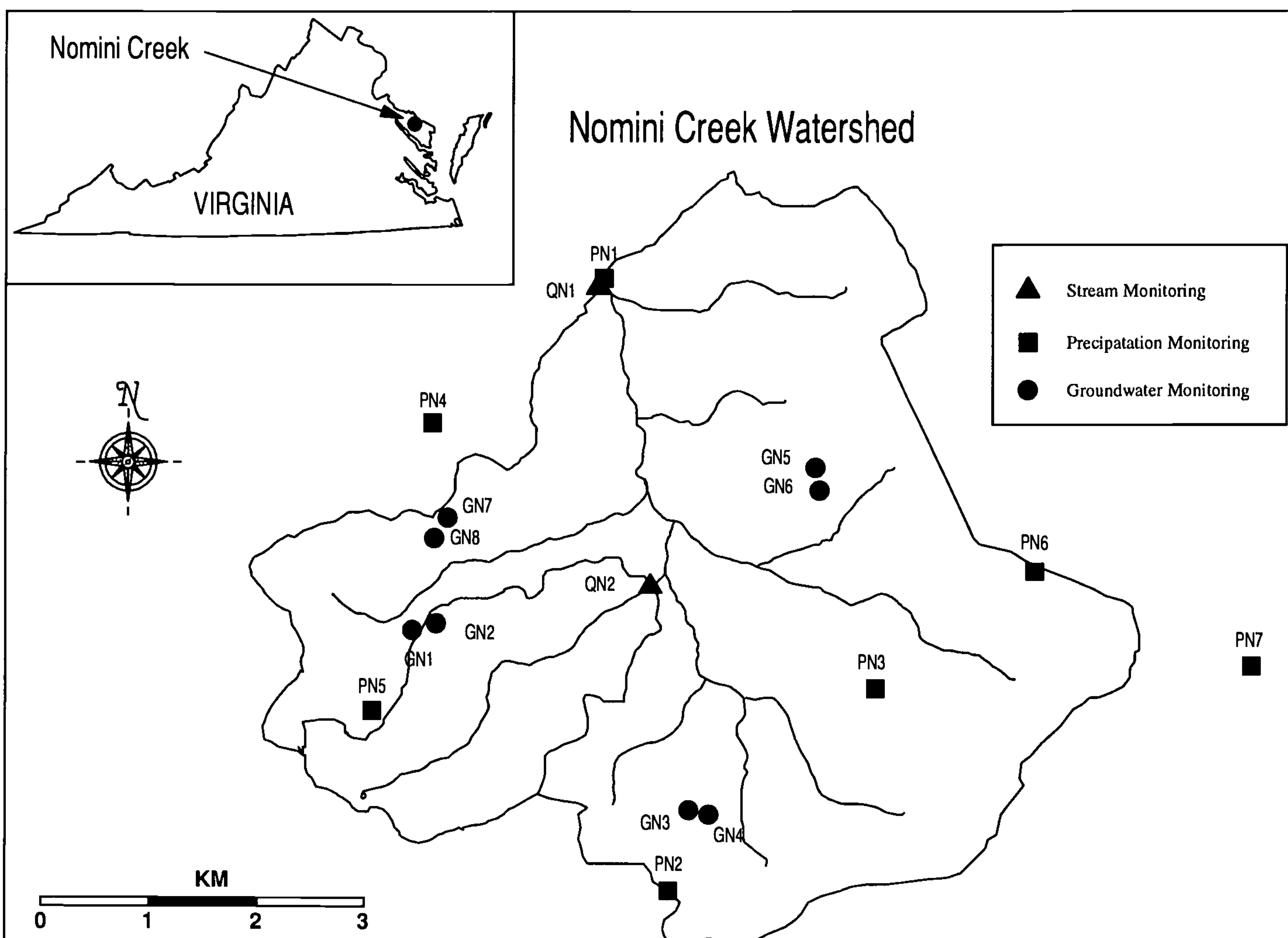

Figure 1. Location of the Nomini Creek Watershed and of the Monitoring Stations Within the Watershed.

under woodland, and 3 percent being homestead and roads. The land use percentages are somewhat typical of this region of Virginia. The watershed is a gently rolling plateau dissected by drainways. Typical slope gradients are between 0 to 6 percent, except along the streams which have steep streambanks with slopes of up to 50 percent. The average slope in the watershed is 4.3 percent. The streambanks are almost entirely forested. Major soil series on the watershed are the Suffolk and the Rumford series, which cover about 91 percent of the area. The Suffolk soils are coarse-loamy and well drained, while the Rumford soils are deep, moderately steep to steep, and well drained.

Land Use Patterns and BMP Implementation

Agricultural activities in the watershed are primarily row crops, with corn, soybeans, and small grains (wheat and barley) being the major crops. Corn followed by small grain with no-till soybeans (double crop beans) planted in small grain residue is the typical rotation in the area (Mostaghimi *et al.*, 1989a). Typical fertilizers used in the watershed are 112 kg/ha of nitrogen, 60.5 kg/ha of phosphorus, and 84 kg/ha of potassium. The state Cooperative Extension Service usually provides the recommendations on the applications, based on soil testing for nutrient management. Eighteen to 20 different land use types, based on crop and tillage practices, may be found on the watershed in a crop season. A typical example of land use patterns are shown in Figure 2, which depicts the land use condition in spring of 1991.

Since mid-1988, BMPs have been implemented by farmers under a cost-share program supported by the State of Virginia. The state supports 20 BMPs as eligible state cost-shared programs, ranging from no-till cropland to permanent vegetative cover and to animal waste control facilities. The BMPs implemented on the watershed included no-till cropland, permanent vegetative cover on critical areas, grazing land protection, diversions, and sediment retention structure. Since BMPs have been implemented after mid-1988, that year is considered as the last year of the pre-BMP periods for the watershed, and the post-BMP period initiated in 1989.

The Monitoring System

The watershed has been monitored since 1985. The specific elements of the monitoring system include basic meteorological data – physical, chemical, and biological monitoring of rain, surface water and ground water quality; and physical and chemical analyses of soils. The location of the monitoring sites in the watershed are shown in Figure 1. All the data collected from the watershed are processed and stored in the database management systems of the Department of Biological Systems Engineering, Virginia Tech. Details of the watershed monitoring system are described by Mostaghimi *et al.* (1989a). Land use has been monitored for each crop season – that is, three times a year – to investigate the usage, disturbances, and management practices which may affect changes in water quality. Parameters of concern include land use, field boundaries, land disturbances, soil amendments, and vegetation. Sources of this information include operator interviews, field surveys, ASCS and SCS records, and aerial photographs. Land use data were collected on a field by field basis, with the field boundaries being permanently fixed. The field and sub-boundaries were digitized at a 1/9 hectare resolution using routines developed by the Information System Support Laboratory (ISSL) of the Department of Biological Systems Engineering, Virginia Tech (Garland *et al.*, 1990).

DATA ANALYSES, RESULTS AND DISCUSSIONS

Direct Runoff Estimations

The streamflow data from the Nomini Creek watershed indicate that the average seasonal values of runoff to rainfall ratios vary from 15 to 27 percent for the monitoring station at the watershed outlet, designated as QN1 in Figure 2. The data also revealed that significant portions of runoff occurred in the form of baseflow. Two different data sets were used in this study. One is the direct runoff data, and the other is the sediment and nutrient concentration data.The direct runoff data resulting from individual storm events were used to define storm CNs and storm sediment and nutrient yields. The CNs were determined by directly substituting the precipitation and runoff depths into Equation (3). The resulting CNs were then adjusted to AMC_{II} conditions, based on the antecedent moisture conditions for each event. The concentration data were used to develop concentration-discharge relationships.

Direct runoff was separated from baseflow for evaluation of BMP effectiveness on watershed hydrology, sediment, and nutrient yields. Direct runoff was initially estimated by using the constant slope method and the master depletion curve (MDC) method (McCuen, 1989). Since the results of these two methods were very similar, only the constant slope method

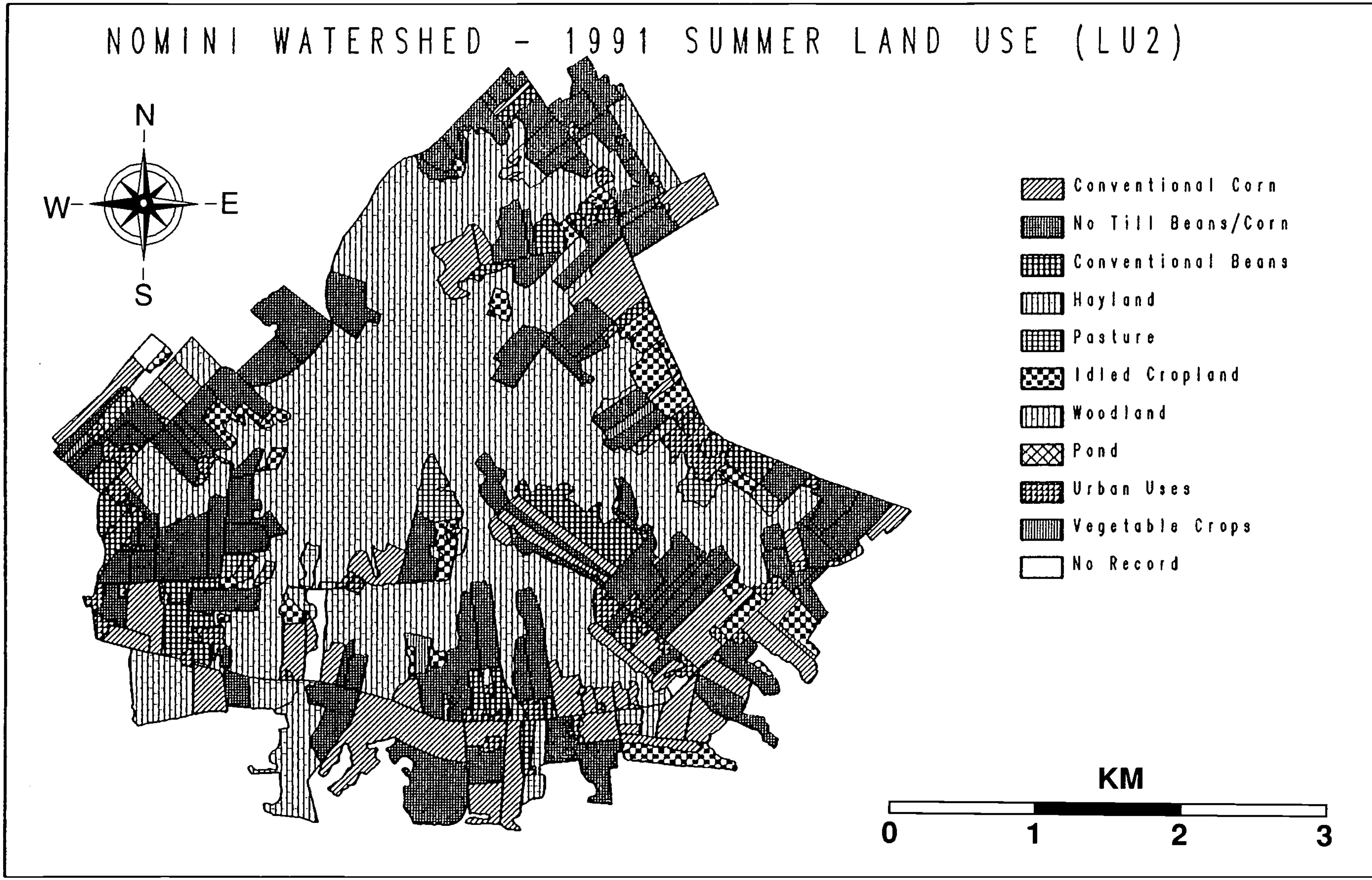

Figure 2. Landuse Patterns at the Nomini Creek Watershed (Summer, 1991).

was used in consequent analyses. This method assumes that daily baseflow is equal to the average of daily runoff prior to and after a storm event, and is a standard procedure being used by many researchers (SCS, 1973). The storm sediment and nutrient yields for direct runoff were also calculated by subtracting the yields for baseflow from the total yield. The total sediment and nutrient yields were defined by integrating discharges and concentrations over the volume of runoff, while the baseflow yields were evaluated from the baseflow rates multiplied by the average flow concentration. The average concentration was obtained by averaging the concentrations before and after a storm event.

Results from direct runoff estimation procedures were divided into two groups, based on year of occurrence. The storm data from 1987 and 1988 were considered as the pre-BMP series, while the data collected since 1989 were treated as the post-BMP series. There were some BMPs implemented during 1988, but this took place in the latter part of that year. There may be some time lags between BMP installation time and when the actual effects could be seen, which may justify the inclusion of the 1988 data in the pre-BMP series. A total of 175 storm events were used in the ensuing analyses, 73 of which (42 percent) were for the pre-BMP period.

Hydrologic Analysis

The CNs calculated from the rainfall and runoff data for storm events varied from 60 to 92. Figure 3 displays the relationships between storm rainfall and the CNs adjusted for AMC_{II}. The CNs were higher for small storms than for large ones. The average CN decreases curvilinearly with rainfall amount, which may be an indication that the watershed consists of subareas having different hydrologic soil complexes.

Figure 3 also shows a comparison of the relationships between rainfall and observed CNs for the pre- and post-BMP data series. Mean CNs for the pre-BMP series ranged from 68 to 96, decreasing

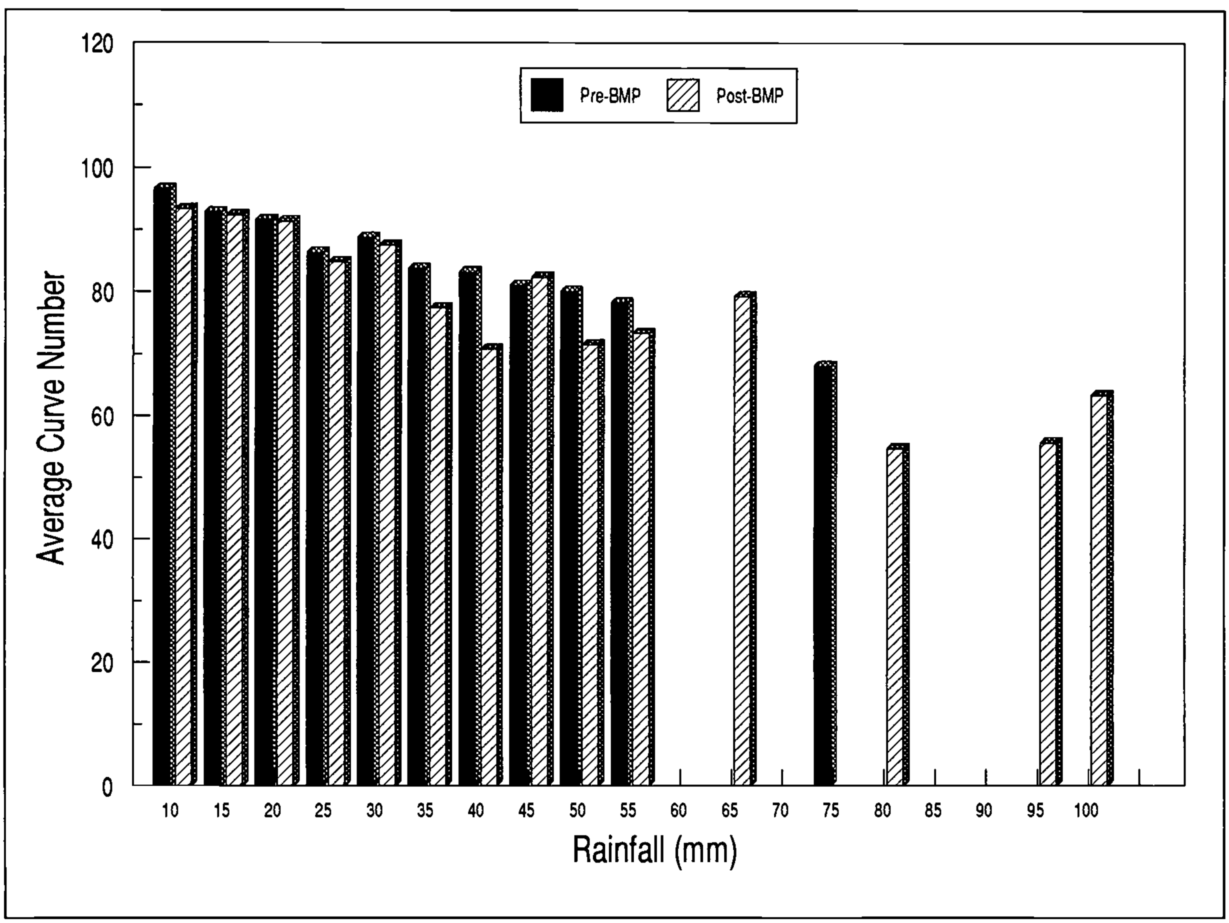

Figure 3. Variations of Watershed-Averaged Curve Number with Storms for the Pre- and Post-BMP Periods.

nonlinearly with increasing rainfall. Similar patterns were observed for the post-BMP data, with the CNs ranging from 55 to 93. When the mean pre-BMP CNs for each rainfall group was compared to the corresponding quantity for the post-BMP data, it was found that the watershed CNs decreased by approximately 5 percent for the same rainfall amounts. Statistical analyses using the one way ANOVA procedure also show that the difference in the overall means of the pre-BMP and post-BMP data series is significant at the 0.05 level (p-value = 0.0001).

The changes in storm CNs resulting from the implementation of BMPs may be partially due to no-till practices on some croplands within the watershed. At one particular time, approximately 110 ha were converted to no-till practices, which is only 16 percent of the cropland, and less than 10 percent of the total area. The reduction in CNs due to crop residues is often considered to be approximately ten percent (Rawls *et al.*, 1980). Since BMPs were only implemented on 10 percent of the watershed, it seems reasonable to expect a one percent reduction in CN. The 5 percent change actually observed may indicate that either the CN changes are higher than the predicted value but within the same order of magnitude, or that the BMPs were implemented on areas which have an inordinately high influence on the hydrologic behavior of the watershed.

Sediment Concentrations and Yields

A comparison of the average discharge-sediment concentration relationships for the pre- and post-BMP periods is presented in Figure 4. This comparison indicates that the sediment concentrations vary considerably with discharge rates, but no definite trends were found. A comparison of the mean concentrations of the two data sets for each rainfall group revealed that sediment concentrations decreased by an average of 20 percent due to BMP implementation (Table 1). When compared across the rainfall groups

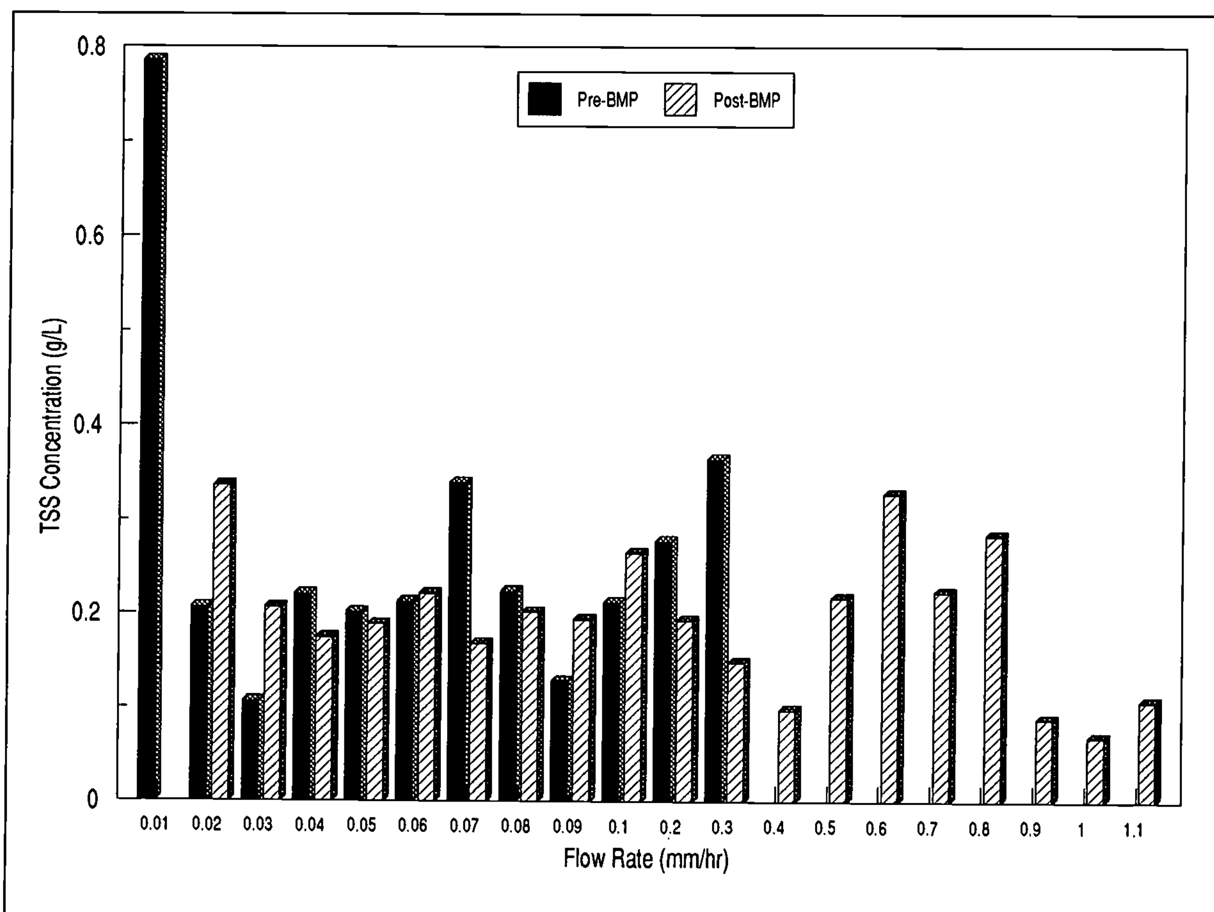

Figure 4. Variations of the Mean Concentrations of Sediment (TSS) with Discharge Rates for the Pre- and Post-BMP Periods.

TABLE 1. Comparisons of Sediment and Nutrient Concentrations for the Pre-BMP and Post-BMP Series for Various Levels of Peak Runoff Rate.

Runoff Rates (m^3/s)	Number of Samples			Total Suspended Solids (mg/L)		
	Pre	Post	Pre/Post	Pre	Post	Pre/Post
<0.03	0	1	0	–	228	–
0.03-0.05	216	342	0.63	166	161	0.97
0.05-0.08	48	102	0.47	256	187	0.73
0.08-0.10	19	69	0.28	163	202	1.24
0.10-0.13	8	41	0.2	234	230	0.98
0.13-0.15	6	26	0.23	334	146	0.44
>0.15	1	121	0.01	364	160	0.45
Sum	**298**	**701**	**0.43**			
Mean				**186**	**172**	**0.80**

Runoff Rates (m^3/s)	Total Kjeldahl Nitrogen (mg/L)			Total Phosphorus (mg/L)		
	Pre	Post	Pre/Post	Pre	Post	Pre/Post
<0.03	–	4.26	–	–	0.31	–
0.03-0.05	4.94	2.59	0.52	0.78	0.52	0.66
0.05-0.08	4.38	2.19	0.5	1.02	0.55	0.54
0.08-0.10	5.32	3.47	0.65	1.22	0.43	0.35
0.10-0.13	5.75	2.92	0.51	0.63	0.77	1.22
0.13-0.15	4.43	2.9	0.65	0.62	0.36	0.59
>0.15	5.09	2.49	0.49	0.73	0.59	0.81
Mean	**4.89**	**2.64**	**0.55**	**0.84**	**0.53**	**0.64**

using the ANOVA procedure, the pre-BMP and post-BMP sediment concentrations were significantly different (p-value = 0.0013). The reduction in sediment concentration may be partially due to the conservation tillage practices implemented on the watershed; such practices have been found effective for controlling soil losses from single fields, and these results may be an indication that these BMPs can also be effective on a watershed having complex land use patterns.

Nutrient Concentrations and Yields

Figures 5 and 6 show the variations of total Kjeldahl nitrogen (TKN) and total phosphorus (TP) concentrations versus discharge rate for the pre- and post-BMP data sets, respectively. Figure 5 shows that the mean concentrations of TKN do not always increase with runoff rates. However, the values for the post-BMP series were consistently lower than those for the pre-BMP series, by an average of 42 percent. Such sharp decreases in TKN concentrations are partly due to the reduction in CNs and sediment concentration, in addition to the direct impacts of BMPs on the nutrient loadings.

Figure 6 shows that the mean concentration of TP was also reduced by approximately 35 percent since the BMPs have been implemented. Maximum TP concentration during the pre-BMP periods was about 18 mg/L, while the corresponding value in the post-BMP series was 9 mg/L. Reductions in CNs and sediment concentrations may have played significant roles in reducing the chemical concentrations.

The results of the ANOVA procedure when applied to TKN and TP concentrations indicate that the pre-BMP data series is significantly different from the post-BMP series (p-values of 0.032 and 0.007 for TKN and TP, respectively). The results support the earlier discussions that the BMPs have significantly reduced the nutrient losses from the watershed. The storm nutrient availability factors were computed using Equations (6) and (8) for soluble N and P yields, respectively. The results were grouped based on the data series for different months and are summarized in Table 2. As indicated in this table, the average monthly nutrient availability factor ranges from –34 to 40 kg/ha for FA_N, and from –5 to 11 kg/ha for FA_P. The negative values indicate that the fertilizer availability factors were less than the average levels available in the top centimeter of typical soils and soluble N concentration in rain, reflecting that the watershed acted like a sink. For soluble TKN, the availability factor (FA_N) was reduced by approximately 52 percent following the BMP implementation. The reduction rate in FA_N is similar to the 46 percent reduction rate

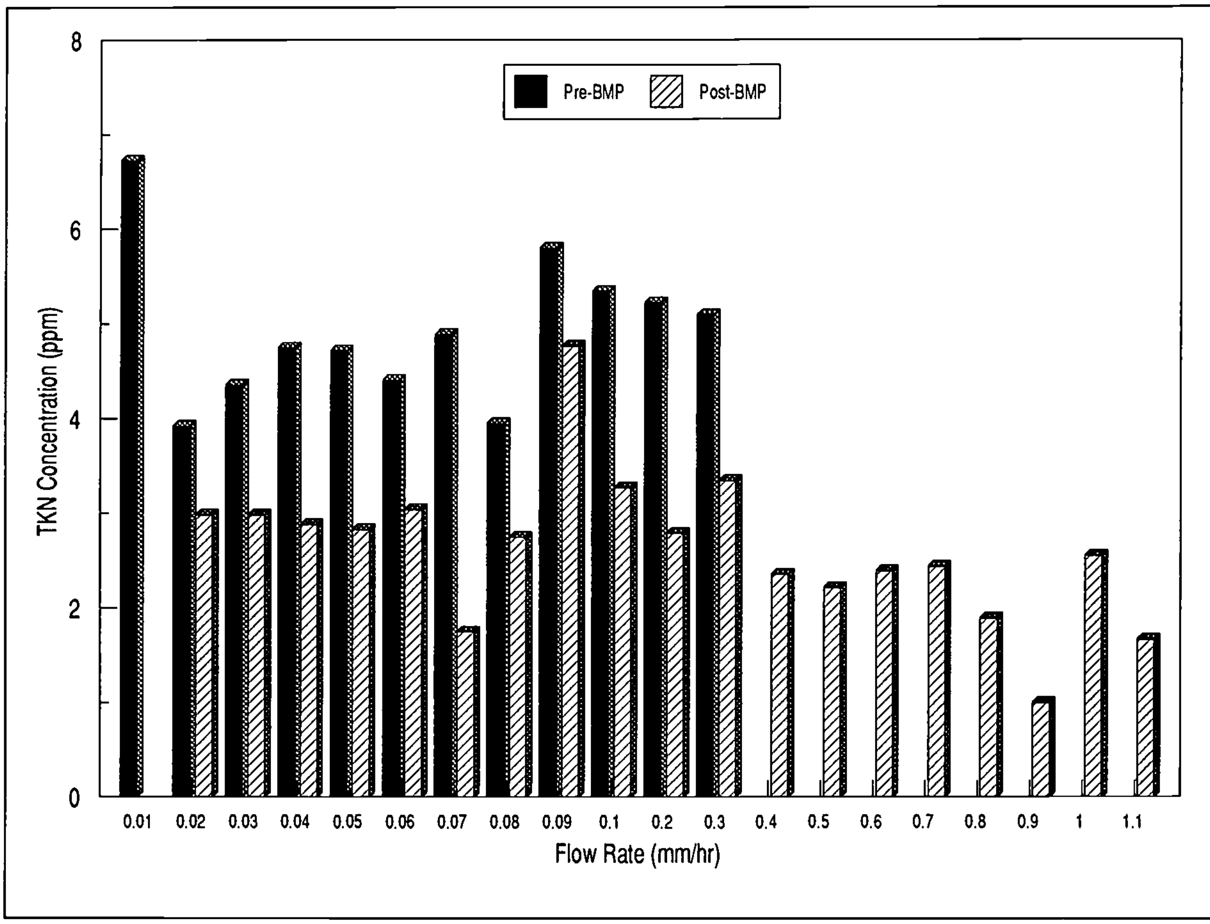

Figure 5. Variations of the Mean Concentrations of Total Kjeldahl Nitrogen (TKN) with Discharge Rates for the Pre- and Post-BMP Periods.

for the TKN concentrations. However, FA_P for the post-BMP period increased by approximately 45 percent as compared to the pre-BMP period (Table 2). These results sharply contradict the earlier finding in the TP concentration-discharge relationships, suggesting that the model may not adequately describe the nutrient loadings. No attempts were made to evaluate the applicability of the models to the watershed, since the fertilizer availability may vary significantly during a crop season.

The monthly fluctuations of the fertilizer availability factors on the watershed are noteworthy. They were higher during dormant seasons compared to growing seasons (Table 2). This result apparently contradicts the fact that the fertilizer availability factors are high immediately after application, and is partly due to the failure of the model to adequately describe the watershed conditions. Further studies may be needed to develop a nutrient model that can realistically define the nutrient yields from watersheds having complex land use patterns.

As was discussed earlier, the effectiveness of BMPs on the runoff, sediment, and nutrient yields in a watershed may not be easily identified. Due to the complex nature of natural processes, longer periods of water quantity and water quality monitoring are required. Improved methods of comparing the results from different BMPs should be explored until statistically significant reductions in NPS pollution loadings from a watershed can be verified. However, methods similar to those discussed in this paper may be applied when limited data are available.

SUMMARY AND CONCLUSIONS

In an effort to evaluate the effectiveness of BMP implementation on a watershed scale on the NPS pollution losses, the data from the Nomini Creek watershed were analyzed. The hydrology and water quality of the watershed have been monitored since 1986, and

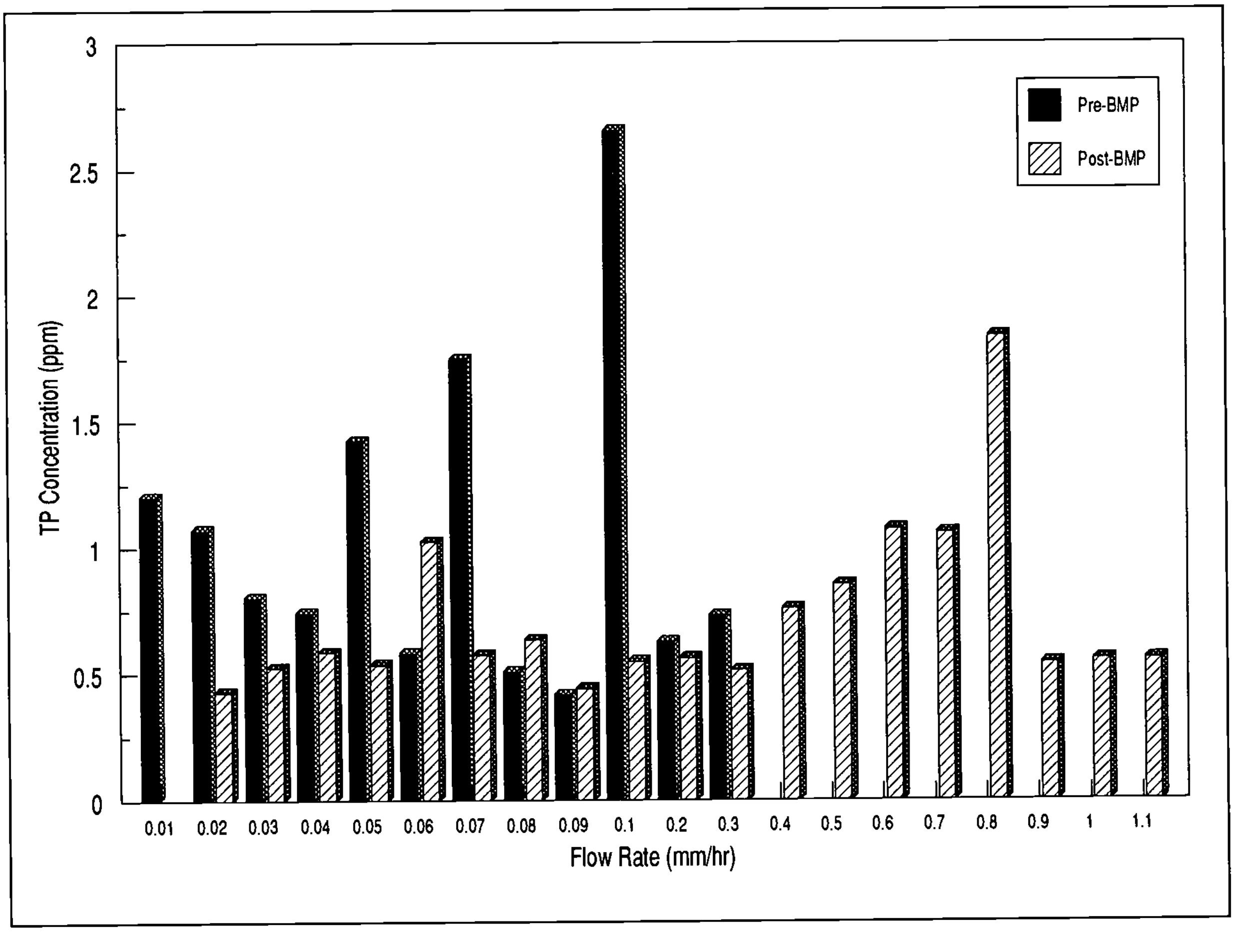

Figure 6. Variations of the Mean Concentrations of the Total Phosphorus (TP) with Discharge Rates for the Pre- and Post-BMP Periods.

TABLE 2. Comparisons of the Monthly Average Fertilizer Availability Factors for Young *et al.* (1985) Nutrient Yield Model.

	Nitrogen Availability Factor (FA_N)			Phosphorus Availability Factor (FA_P)		
Month	**Pre-BMP**	**Post-BMP**	**Pre/Post**	**Pre-BMP**	**Post-BMP**	**Pre/Post**
January	13.6	17.4	1.3	0.3	–	–
February	17.9	11.9	0.7	0.4	–0.3	–
March	11.7	10.6	0.9	0.7	0.1	0.1
April	15.7	10.7	0.7	1.1	–0.1	–
May	18.2	–24	–	0.9	–5.4	–
June	6.7	–33.8	–	0.5	11.1	22.2
July	40.2	–8.3	–	2	2.2	1.1
August	6.1	4.9	0.8	–0.4	0.5	–
September	6.5	18	2.8	0	0.1	–
October	4.4	2.9	0.7	0.4	2.2	5.5
November	18.9	19.6	1	0.9	0.5	0.6
December	9.4	57.9	6.2	0.9	0	–

BMPs have been implemented since June, 1988. The data for the pre- and post- BMP implementation periods were compared in an effort to determine if the BMPs have affected the hydrology, sediment, and nutrient yields. Several models were used to compare BMP effectiveness in reducing runoff quantities and nutrient losses.

The results from this study may be summarized as follows:

1. Watershed models using runoff, sediment, and nutrient yield data from single storm events are required to objectively compare the effects of BMPs on NPS loadings from a watershed. By separating the direct runoff components of sediment and nutrient yield, the direct effect of NPS pollution from croplands can be evaluated.

2. BMPs, as have been implemented on the Nomini Creek watershed, have significantly affected rainfall-runoff relationships based on the computed curve numbers for individual storms. The average storm CN was reduced by approximately 5 percent following the BMPs implementation.

3. Sediment concentration graphs for pre- and post- BMP periods are significantly different from each other. Average sediment concentrations were decreased by approximately 20 percent as a result of BMP implementation.

4. The sediment model for single storms used in this study failed to depict the variations of sediment yields from the watershed. A different model may be needed to compare the changes in sediment yields between the pre- and post- BMP periods.

5. Nutrient concentrations were found to be significantly reduced after BMP implementation. TKN and TP concentrations were reduced by approximately 42 percent and 35 percent, respectively. The results may be partly due to the reduction in curve numbers resulting from hydrological modifications due to BMP implementation.

6. The nitrogen and phosphorus availability factors for a watershed nutrient loading model showed erratic seasonal variations and failed to adequately reflect the nutrient yields from single storms. A different nutrient model is required, which would identify the effects of BMPs on a watershed scale from short monitoring periods.

7. The areal extent of BMPs implemented could be a factor in the detection of significant reductions in pollutant loadings from the Nomini Creek watershed. Great variations in NPS loadings with storms indicate the necessity of longer monitoring periods.

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