WATER QUALITY FROM RELATIVELY UNDISTURBED FORESTED AREAS IN SOUTHERN ILLINOIS

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ABSTRACT

Stream-water quality was monitored in 86 streams in the "hill country" of southern Illinois, on a bi-weekly basis from October, 1977 to May, 1978, in order to obtain background information on the quality of water flowing from relatively undisturbed predominantly forested watersheds. Fifty-two of the streams were located in the Shawnee Hills physiographical province while thirty-four of the streams were located in the Ozark physiographical province.

Levels of suspended solids, turbidity, specific conductance, pH, nitrate-nitrogen, sodium, and potassium were determined and evaluated for each stream by province and for the southern Illinois area as a unit. Individual values for each parameter varied considerably, but values for each stream generally were relatively consistent, indicating considerable variation or difference between watersheds.

In general the average values and range of values were lower in the streams from the Shawnee Hills province than in streams located in the Ozark physiographical province.

Correlation coefficients, relating the various parameters to percent forest cover, were generally negative, but low, indicating a relatively weak tendency for concentrations to be less in the streams draining the more forested watersheds.

Overall the data indicate the relatively undisturbed, predominantly forested watersheds in southern Illinois are yielding relatively high quality water and by extrapolation,

similar regions of the Shawnee Hills and Ozark physiographical provinces should also yield relatively high quality water.

A substantial data base has been obtained which now provides background information on the quality of water emanating from relatively undisturbed, predominantly forested watersheds in southern Illinois. These data may be used as natural or baseline levels for the parameters indicated. Major increases above the values observed in this study should alert the watershed manager to the possibility that non-point pollution may be occurring. All realistic plans for the control of non-point sources of pollution from forested lands within the southern Illinois area and similar areas of the Shawnee Hills and Ozark physiographical provinces should take into account these natural or baseline levels.

WATER QUALITY FROM RELATIVELY UNDISTURBED FORESTED AREAS IN SOUTHERN ILLINOIS[1/]

The forestry profession is faced with a difficult, far-reaching problem. Public Law 92-500 mandates that forestry related non-point sources of pollution be identified, evaluated, and controlled to the extent feasible (U. S. Congress, 1972). Unfortunately, there is a paucity of data which provide an insight into the natural levels of water quality emanating from undisturbed forested conditions. As a consequence, efforts to develop realistic plans for the control of non-point sources of pollution from forested lands are frustrated. Lacking this information, there exists the danger that costly, unwanted, unworkable, ineffective restrictions may be forced upon the forestry profession, forest industry, and forest land owners.

With the above in mind, a stream water quality survey was begun in October, 1977, with the objective of obtaining background information on the quality of water flowing from relatively undisturbed, predominantly forested, watersheds in southern Illinois and, by extrapolation, from similar areas of the Shawnee Hills and Ozark physiographical provinces. The survey was restricted to the area bounded by the Shawnee National Forest within the Shawnee Hills and Ozark physiographical provinces (Fig. 1). Grab samples were obtained from 86 streams (52 in the Shawnee Hills province and 34 in the Ozark province) on a bi-weekly basis, and returned to Southern Illinois University's Forestry Department for evaluation of suspended solids, turbidity, nitrate-nitrogen, potassium, and sodium levels. Specific conductance and pH determinations were made on-site.

The watersheds ranged in size from 2.6 hectares to 7,883 hectares and varied in the percent of the watershed covered by forests from 100 percent to 11 percent (Fig. 2). Streamflow varied greatly depending on meteorological and antecedent soil moisture conditions. No attempt was made to obtain samples specifically of high or low flows. Sampling was done on a fixed time basis with the expectation that all stages of flow would be sampled during the course of the study in proportion to their normal occurrence.

1/ Study funded in part by the Illinois Institute for Environmental Quality.

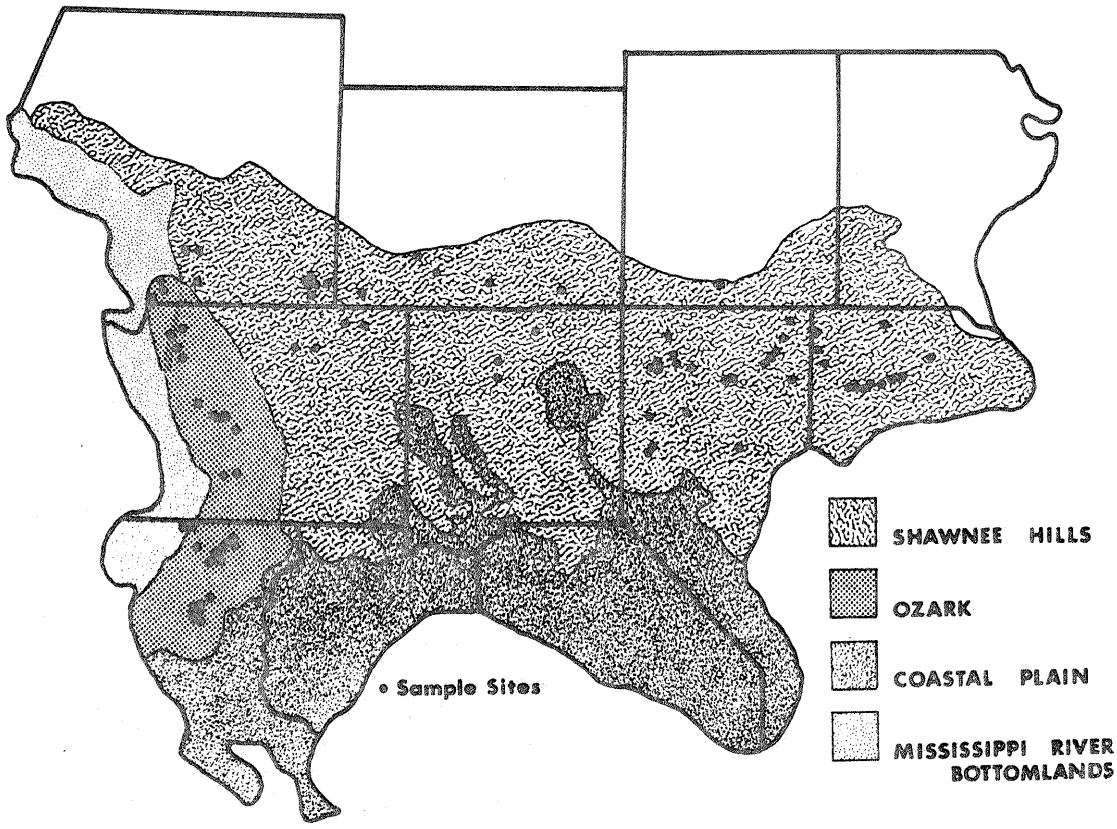

Figure 1. Sampling sites in the Shawnee Hills and Ozark physiographical provinces of southern Illinois.

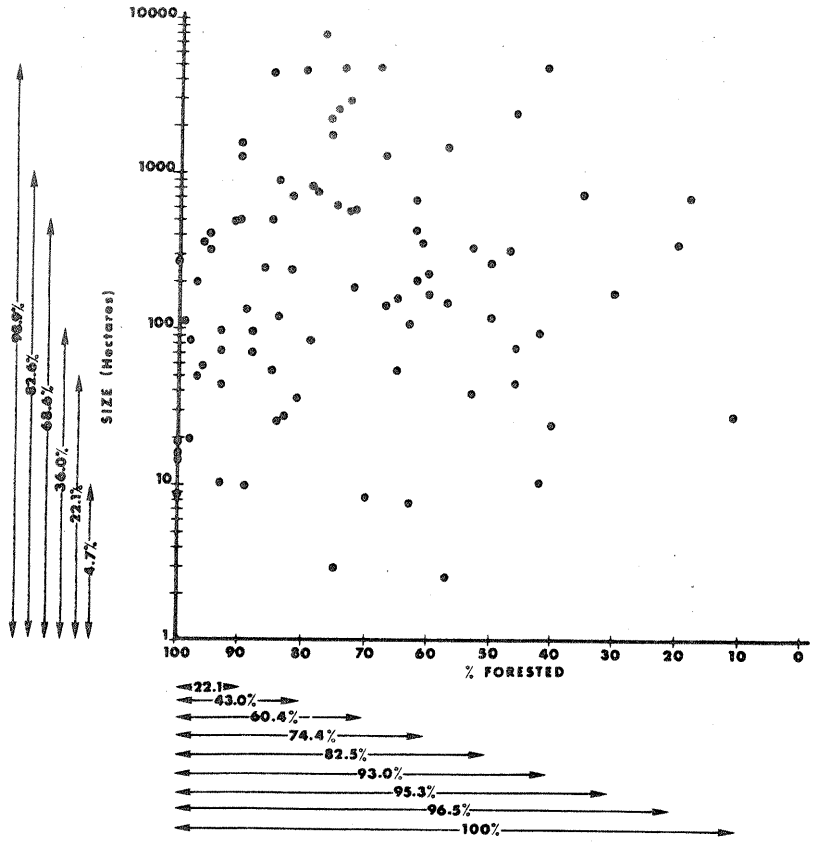

Figure 2. Relationship between watershed size and percent forest cover for the 86 watersheds evaluated.

The study area can generally be classified as "hill" country. Relief is about 200 meters. In many places, streams have eroded deep valleys with steep, unstable slopes, rock exposures and cliffs (Harris, et al., 1977). The original vegetation was mixed mesophytic forest (western phase). Most of the original forest was cut over by the early settlers and the more suitable sites placed under cultivation. However, the more recent history of the area shows that much of the area has been allowed to revert back to forested conditions and the remaining area consists predominantly of abandoned farms, pasture lands, and orchards. Relatively little of the study area is under row-crop cultivation.

The Shawnee Hills which form the backbone of southern Illinois are dominated by ridged uplands with many cliffs and deeply dissected valleys. Massive sandstones form successive ridges separated by benches underlain by shale. Silty loess generally mantles the rock with the loess gradually decreasing in an eastward direction (Harris, et al., 1977). In the Ozark hills area, the bedrock is mostly chert and siliceous limestone. Although there are few cliffs, except those bordering the Mississippi Valley and the Cache Valley on the south, the slopes are quite steep and unstable. Ridge crests are narrow. The present-day loess mantle ranges from a few centimeters to several meters deep. Many slopes are rocky due to erosion of the loess cover (Harris, et al., 1977).

The soils of both areas generally have developed from loessal parent material. The Hosmer-Stoy-Weir and the Grantsburg-Robbs-Wellston soil associations generally predominate in the Shawnee Hills area while the Stookey-Alford-Muren soil association generally predominates in the Ozark portion of the study area (Fehrenbacher, et al., 1967).

RESULTS AND DISCUSSION

Suspended Solids

The concentration of suspended solids in the monitored streams was quite variable--both within a given stream and between streams. Even so, the concentrations of suspended solids in the stream-water samples observed were generally quite moderate. Concentrations ranged from 0.1 to 564.3 mg/l for the 86 streams monitored (see Table 1). The average of all the individual values obtained was 10.9 mg/l with a standard error of ± 3.6 mg/l. By physiographical divisions, the streams within the Shawnee Hills province

Table 1. Means, standard errors and (ranges) of values for parameters indicated for watersheds within the Shawnee Hills and Ozark physiographical provinces.

	Shawnee Hills	Ozark	Combined
No. streams monitored	52	34	86
Suspended solids (mg/l)	6.4 ± 4.9 (0.1 - 564.3)	18.4 ± 5.0 (0.8 - 262.0)	10.9 ± 3.6 (0.1 - 564.3)
Turbidity (NTU's)	5.2 ± 0.7 (0.5 - 62.0)	9.9 ± 2.1 (0.2 - 110.0)	7.5 ± 0.9 (0.2 - 110.0)
Specific conductance (μmhos)	149 ± 13 (50 - 800)	125 ± 16 (30 - 418)	140 ± 10 (30 - 800)
pH	7.1 ± 0.1 (5.6 - 8.3)	7.1 ± 0.1 (5.5 - 8.9)	7.1 ± 0.1 (5.5 - 8.9)
Nitrate-nitrogen (ppm)	0.47 ± 0.05 (0.06 - 3.15)	0.59 ± 0.09 (0.10 - 3.00)	0.51 ± 0.05 (0.06 - 3.15)
Sodium (ppm)	6.19 ± 0.53 (0.61 - 18.83)	7.01 ± 0.61 (1.66 - 19.61)	6.51 ± 0.40 (0.61 - 19.61)
Potassium (ppm)	1.63 ± 0.11 (0.50 - 6.21)	1.81 ± 0.15 (0.55 - 6.89)	1.70 ± 0.09 (0.50 - 6.89)

produced an average suspended solid concentration of only 6.4 mg/l with a standard error of ±4.9 mg/l, while the streams within the Ozark province produced an average of 18.4 mg/l with a standard error of ±5.0 mg/l. Individual streams within the Shawnee Hills exhibited the greatest variation in suspended solids concentrations, which ranged from 0.1 to 564.3 mg/l compared to a range of 0.8 to 262.0 mg/l for the Ozark province.

The average suspended solids values for each stream monitored are presented in Figure 3. The average concentration values were plotted against percent of the area under forest cover to determine the relationship between the percent forest covering a watershed and the level of suspended solids in the stream draining the watershed. As can be seen from Figure 3, there does not appear to be a strong or clear linear relationship between the percent of forest cover and the level of suspended solids for the watersheds within the Shawnee Hills province. A slight trend can be observed in the data from the Ozark province. A similar plot of suspended solids levels against watershed size (data not shown) also failed to show a significant relationship.

Correlation coefficients presented in Table 2 show that overall, there is little or no correlation between the percent of the watershed that is forested and the concentration of suspended solids in the stream-water samples obtained from the watersheds. The same holds true for those watersheds in the Shawnee Hills province. A negative correlation coefficient of -0.375 was calculated from the data obtained from the Ozark province. This indicates there is a slight tendency for the lower concentrations of suspended solids, in the stream water, to be associated with the more forested watersheds within the Ozark province.

The implication of the suspended solids data is that overall, the amount of suspended solids in the streams draining the monitored watersheds was quite modest and that by extrapolation, relatively undisturbed, primarily forested watersheds in southern Illinois and similar areas of the Shawnee Hills and Ozark physiographical provinces are not producing substantial quantities of sediment.

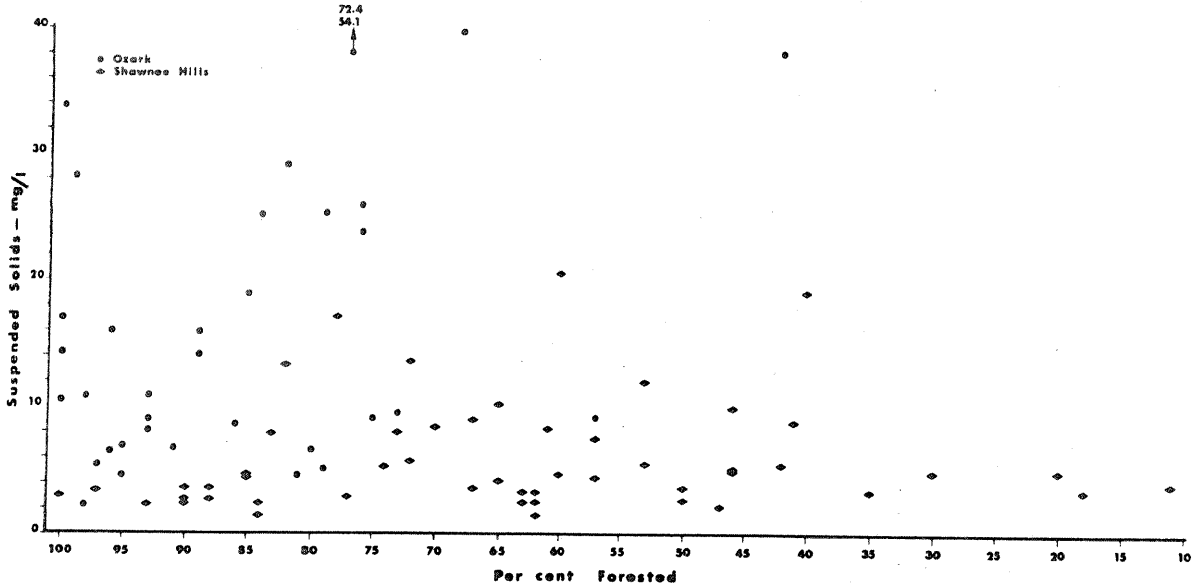

Figure 3. Mean suspended solids levels in 52 streams in the Shawnee Hills and 34 streams in the Ozark physiographical provinces of southern Illinois.

Table 2. Correlation coefficients derived from percent forested (x) and parameter means (y).

	Shawnee Hills	Ozark	Combined
Suspended solids	0.021	-0.375	0.110
Turbidity	-0.305	-0.003	0.075
Specific conductance	-0.261	-0.005	-0.236
pH	0.006	-0.080	-0.098
Nitrate-nitrogen	-0.417	-0.399	-0.293
Sodium	-0.338	-0.392	-0.264
Potassium	-0.430	-0.368	-0.313

Turbidity

The turbidity data, obtained from grab samples through the use of a laboratory model nephelometer, ranged from an overall low of 0.2 NTU's (i.e., Nephelometric Turbidity Units) to an overall high of 110.0 NTU's (see Table 1). The corresponding overall average turbidity value was 7.5 NTU's with a standard error of ±0.9 NTU's. The stream-water samples from the Shawnee Hills province generally contained slightly lower levels of turbidity than did similar samples from the Ozark province. Respective averages and ranges were 5.2 NTU's with a standard error of ±0.7 NTU's and a range of 0.5 to 62.0 NTU's for the Shawnee Hills province and an average of 9.9 NTU's with a standard error of ±2.1 NTU's and a range of 0.2 to 110.0 NTU's for the streams in the Ozark province.

The negative correlation coefficient of -0.305 for the Shawnee Hills watersheds indicates a slight tendency for lower turbidity levels to be associated with watersheds having the greater percent of forest cover and the higher turbidity values to be associated with those watersheds having the least forest cover. A plot of the data (not shown) and correlation coefficients indicated essentially no correlation between the levels of turbidity in the streams and percent forest cover on the watersheds within the Ozark province or when the data were combined to give an overall representation (see Table 2).

Specific Conductance

Individual specific conductance values ranged from a low of 30 to a high of 800 μmhos per cm (see Table 1). The overall average specific conductance value for all stream-water samples obtained from the 86 watersheds was 140 μmhos per cm with a standard error of ±10 μmhos per cm. On a physiographical province basis, the specific conductance values for the Shawnee Hills was 149 ±13 μmhos per cm with a range of 50 to 800 μmhos per cm. The values for the Ozark province were somewhat lower, averaging 125 ±16 μmhos per cm with a range of 30 to 418 μmhos per cm.

The mean values for the 86 streams are presented in Figure 4 where they are plotted against the percent of the watershed that is forest covered.

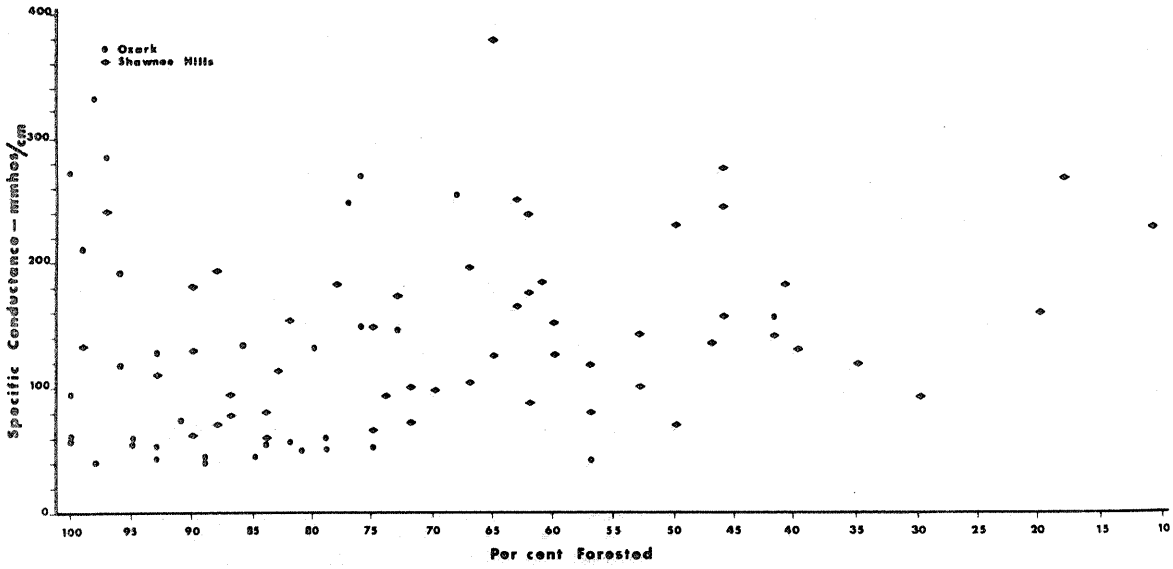

Figure 4. Mean specific conductance levels in 52 streams in the Shawnee Hills and 34 streams in the Ozark physiographical provinces of southern Illinois.

Correlation coefficients presented in Table 2 indicate that a slight general trend exists for the watersheds having the greater percentage of forest cover to have the lower specific conductance values. However, the correlation coefficient values are low indicating that the relationship is not strong.

In essence, the specific conductance data indicate that the ionic activity in the stream-water samples was relatively low and by implication that the nutrient load is moderate to low. The data and low correlation coefficients indicate that while there is a general tendency for the water draining the more forested watersheds in southern Illinois to contain less nutrients, the overall nutrient loss from relatively undisturbed watersheds in the area is relatively low. The data indicate that slightly greater nutrient losses are taking place from the watersheds in the Shawnee Hills physiographical province than are taking place from watersheds in the Ozark province.

pH

Individual pH values ranged from pH 5.5 to 8.9 (see Table 1) with extreme values being isolated cases. Most values ranged from pH 6.0 to 8.0. Overall averages for stream-water samples obtained from the 52 Shawnee Hills watersheds and the 34 Ozark watersheds were 7.1 pH units with a standard error of ± 0.1 pH units as calculated using a straight arithmetic mean procedure.

Correlation coefficients (see Table 2) were very low. No correlation between pH levels in the stream and percent of forest cover can be made.

Mean pH values for the 86 watersheds are presented in Figure 5.

The pH data can be interpreted as meaning that the streams draining relatively undisturbed watersheds in southern Illinois generally have pH values between 6.0 and 8.0 and that stream-water pH values are not necessarily related to the extent of forest cover present on the watershed.

Nitrate-nitrogen

A plot of the mean nitrate-nitrogen concentrations in the streams draining watersheds in the Shawnee Hills and

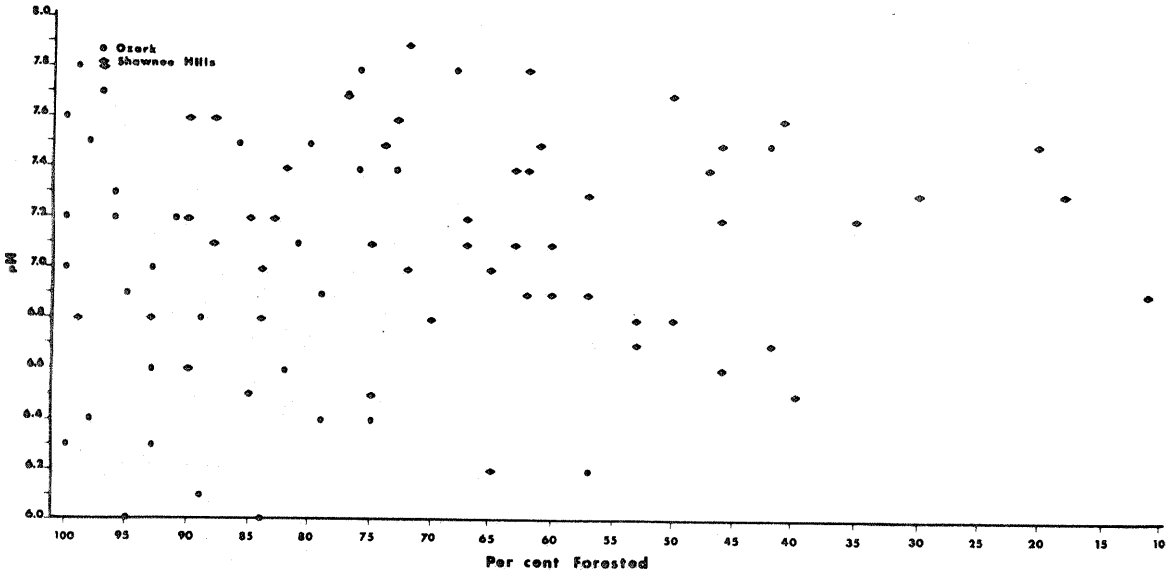

Figure 5. Mean pH levels in 52 streams in the Shawnee Hills and 34 streams in the Ozark physiographical provinces of southern Illinois.

Ozark provinces is presented in Figure 6. Means, standard errors, and ranges are presented in Table 1, while the correlation coefficients are presented in Table 2.

In general, nitrate-nitrogen levels were quite low with individual sample values ranging from a low of 0.06 ppm up to a high of 3.15 ppm. The overall average was 0.51 ppm with a standard error of ±0.05 ppm (see Table 1). Average nitrate-nitrogen levels in samples obtained from the Shawnee Hills and Ozark provinces' watersheds were quite similar, being 0.47 ±0.05 ppm for the Shawnee Hills and 0.59 ±0.09 ppm for the Ozark watersheds.

Correlation coefficients (see Table 2), while of the order of -0.3 to -0.4, were consistently negative indicating a tendency for higher nitrate-nitrogen levels to be found in stream-water samples obtained from those watersheds with a smaller percentage of forest cover. Lowest nitrate-nitrogen levels were associated with the higher percentage of forest cover.

The implication of the nitrate-nitrogen data is that the more forested watersheds in southern Illinois produce stream-water with lower levels of nitrate-nitrogen than do the less forested watersheds. By extrapolation, one may generally assume that similar areas throughout the Shawnee Hills and Ozark physiographical provinces should respond similarly.

Sodium

Sodium concentrations, in general, showed a fairly consistently close distribution around an average of about 4.5 to 5.0 ppm for those watersheds containing greater than 77% forest cover (see Figure 7). For watersheds with forest cover less than 77%, the dispersion of means and individual values increased substantially. Overall individual sodium levels ranged from a low of 0.61 ppm to a high of 19.61 ppm. The corresponding overall average of all the samples observed was 6.51 ppm with a standard error of 0.40 ppm (see Table 1). The representative means, standard errors, and ranges are 6.19 ±0.53 ppm (0.61 to 18.83 ppm) for the Shawnee Hills province watersheds and 7.01 ±0.61 ppm (1.66 to 19.61 ppm) for watersheds in the Ozark province.

The levels of sodium observed were substantially higher than what was expected. Suspecting possible analytical or

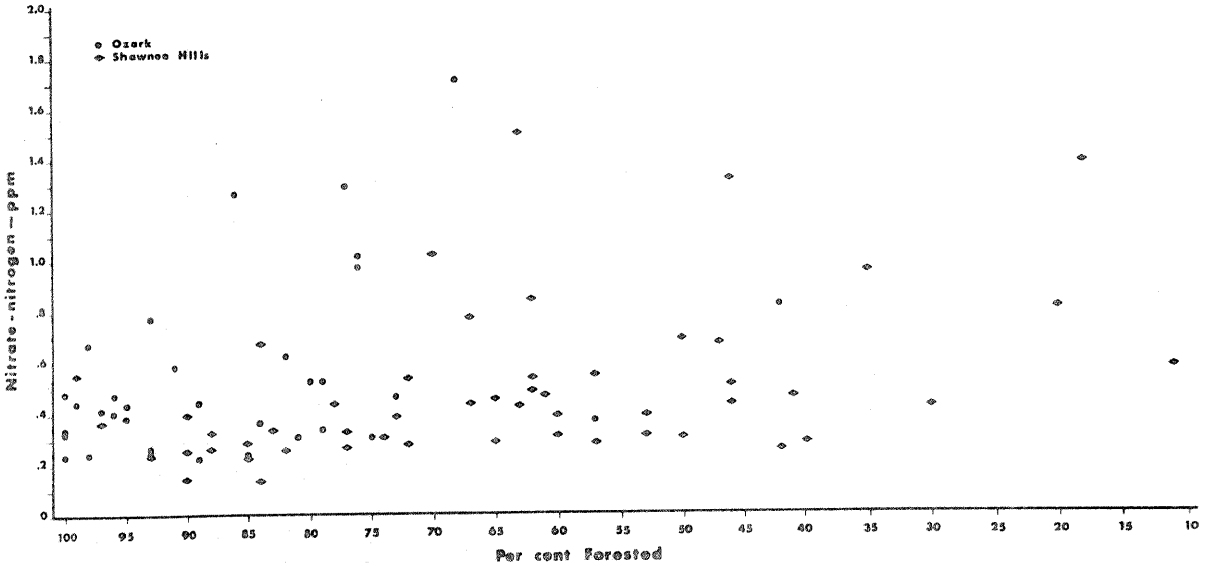

Figure 6. Mean nitrate-nitrogen levels in 52 streams in the Shawnee Hills and 34 streams in the Ozark physiographical provinces of southern Illinois.

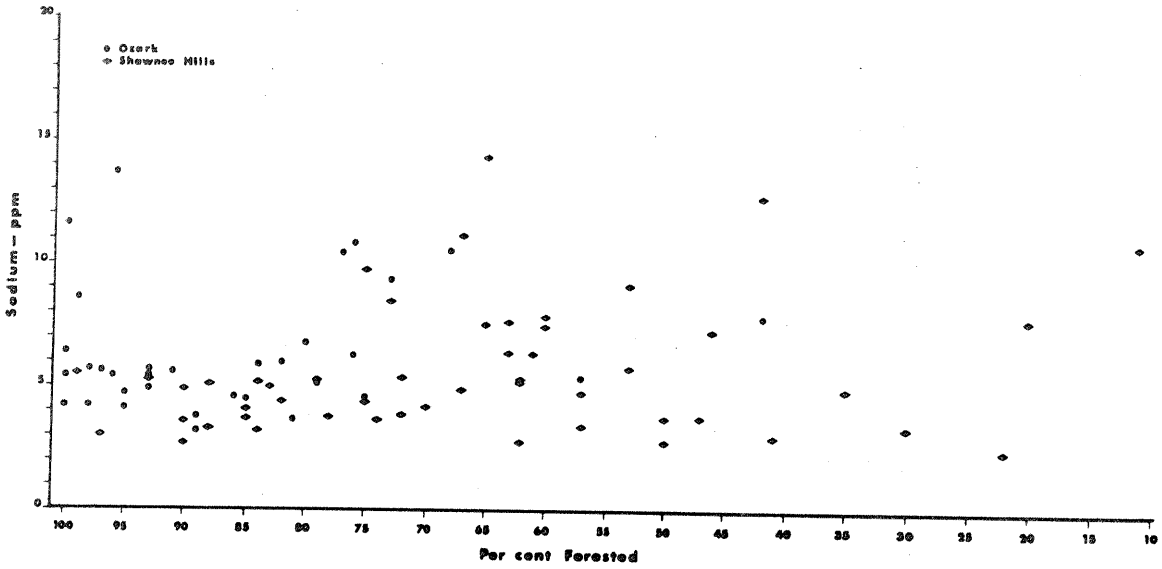

Figure 7. Mean sodium levels in 52 streams in the Shawnee Hills and 34 streams in the Ozark physiographical provinces of southern Illinois.

procedural error, we reanalyzed a large number of the samples exhibiting high values and found the high values to be correct. Further reinforcing the fact that analytical or procedural error or contamination was not responsible for the high values observed is the fact that samples from the same watershed, collected and run at different times, gave relatively consistent high values while similar samples obtained from other watersheds on the same day and run with the same instrument set up consistently produced relatively low sodium concentrations.

Inquiry made to the Geology Department produced information that there are numerous salt springs scattered throughout southern Illinois produced by upward leakage of salty water from the Illinois basin and that drainage from many local strip mines has quite high sodium levels due to the release of cognate brine water from the uncovered shale. We hypothesize that the high sodium levels come from as yet unidentified salt seepage into the watersheds exhibiting high sodium levels. We hope to be able to provide a more definitive analysis with further research which will include an evaluation of the chloride content of the stream-water.

The correlation coefficients for sodium all came up negative, being -0.338, -0.392, and -0.264 for the Shawnee Hills, Ozark, and combined data, respectively (see Table 2). This indicates a trend (as can be seen from Figure 7) for lower values of sodium in our stream-water samples to be associated with greater percent of forest cover in the watershed and conversely, the higher stream-water levels of sodium to be associated with those watersheds having less forest cover.

The implication of the sodium data is difficult to assess. The data indicate that sodium levels in some of the streams of southern Illinois may naturally be relatively high. The negative correlation coefficients appear to indicate that the forest cover is causing a reduction in sodium levels in the streams draining the more forested watersheds. However, if our hypothesis is correct that the sodium is in fact coming from salt seepage, then the relationship is purely coincidental as the presence or absence of a forest cover would do little to influence the occurrence of salt seepage. Even here a possible tenuous relationship may be proposed in that it is well known that different cover types have different evapotranspiration water usages. Relatively mature hardwoods withdraw more

water from the soil than do most agricultural crops or pasture plants. Thus the increased soil moisture content may enhance salt seepage under certain conditions.

Potassium

Mean potassium values for the 86 streams monitored are presented in Figure 8. Average values, standard errors, and ranges are presented in Table 1. Correlation coefficients, which were negative, are presented in Table 2.

The overall range in potassium levels in the streams of the Shawnee Hills and Ozark provinces within southern Illinois ranged from a low of 0.50 ppm up to a high of 6.89 ppm. Values for the two provinces were quite similar.

The data indicate that potassium levels in the streams of southern Illinois are moderately low and that there appears to be a relationship between the amount of forest cover and the level of potassium in the stream--with the watersheds having the greater percentage of forest cover generally having the lower concentration of potassium in the streams flowing therefrom.

General

The generally negative correlation coefficients for all the parameters (see Table 2) indicate that for the 86 streams monitored in southern Illinois, there is a tendency for lower values of the parameters measured to be associated with greater percentage of forest cover on a watershed. The implication of this is that the more forested watersheds are somehow responsible for maintaining a higher quality of water in the streams draining therefrom than are the watersheds with less percentages of forest cover. This may result from nutrient uptake and/or the effect of the forest on leaching, runoff, erosion, and sediment transport within the watershed.

The objectives of the study have been fulfilled. A substantial data base has been obtained which now may provide background information on the quality of water emanating from relatively undisturbed, predominantly forested watersheds in southern Illinois.

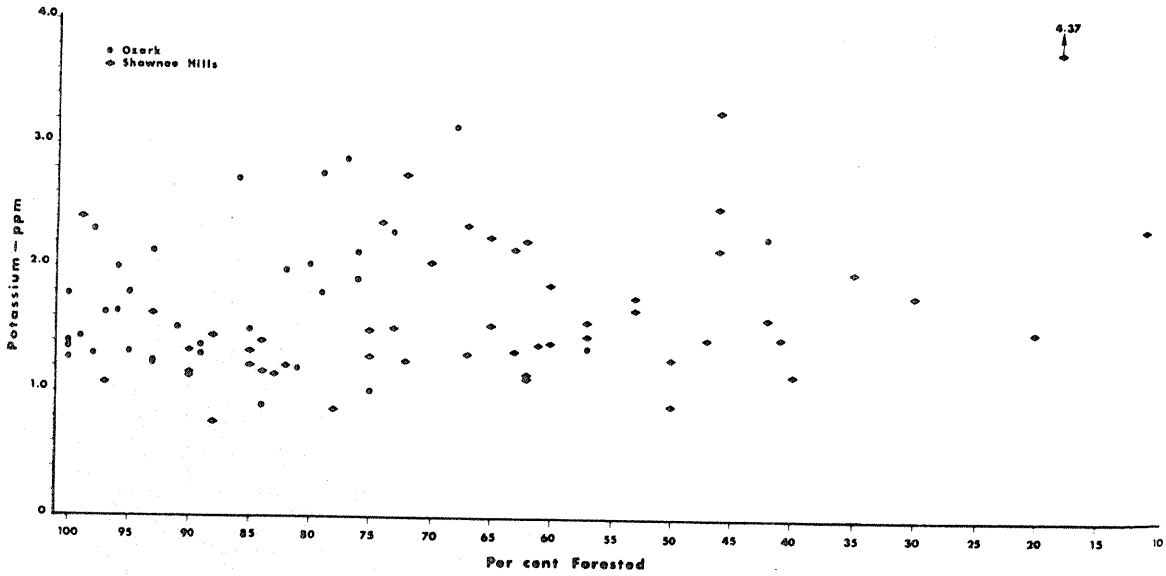

Figure 8. Mean potassium levels in 52 streams in the Shawnee Hills and 34 streams in the Ozark physiographical provinces of southern Illinois.

SUMMARY AND CONCLUSIONS

Approximately 1,000 grab samples were obtained from 86 streams in the Shawnee Hills and Ozark physiographical provinces of southern Illinois between October, 1977 and May, 1978. These samples were evaluated for levels of suspended solids, turbidity, nitrate-nitrogen, sodium and potassium. Levels of specific conductance and pH were determined on-site whenever grab samples were obtained.

Levels of the various parameters varied considerably, within relatively narrow ranges, between streams. Values for individual streams, while exhibiting some variation, generally were relatively consistent. In general the average values and range of values were lower in the streams draining watersheds in the Shawnee Hills province than were similar values for streams draining watersheds located in the Ozark physiographical province. Overall, the data indicated considerable variability between watersheds.

Levels of suspended solids, turbidity, specific conductance, pH, nitrate-nitrogen, and potassium were only moderate to low and well within Public Health standards for drinking water. Numerous streams exhibited rather high sodium levels which are assumed to be associated with seepage of salt water into the watersheds.

A general tendency existed for lower levels, of the parameters evaluated, to be correlated to the greater percentage of the watershed covered by forest. Conversely, higher levels of the parameters and hence somewhat poorer quality water were found to be associated with those watersheds having the least forest cover. These relationships were more pronounced in the Ozark province than in the Shawnee Hills physiographical province.

One can conclude, from evaluating the data obtained in this study, that: 1) relatively undisturbed, mostly forested watersheds in the Shawnee Hills and Ozark physiographical provinces of southern Illinois are yielding relatively high quality water, and 2) the less forest covered, or more disturbed, the watershed, the poorer the quality of water draining therefrom. By extrapolation, one may assume that similar watersheds throughout the Shawnee Hills and Ozark physiographical provinces should yield similar quality waters.

The data provided through this study should be of use in

the identification and evaluation of non-point sources of pollution which may be related to forestry or other activities within the area. These data may be used as natural or baseline levels for the parameters indicated. Major increases above the values observed in this study should alert the watershed manager to the possibility that non-point pollution may be occurring. All realistic plans for the control of non-point sources of pollution from forested lands within the southern Illinois area and similar areas of the Shawnee Hills and Ozark physiographical provinces should take into account these natural or baseline levels.

LITERATURE CITED

Fehrenbacher, J. B., G. O. Walker, and H. L. Wascher. 1967. Soils of Illinois. Bull. 725, U. of Ill. Agr. Exp. Sta., August. 47 pp.

Harris, Stanley E., Jr., C. William Horrell, and Daniel Irwin. 1977. Exploring the Land and Rocks of Southern Illinois. A Geological Guide. Southern Ill. Univ. Press, Carbondale and Edwardsville. 240 pp.

U. S. Congress. 1972. An Act to Amend the Federal Water Pollution Control Act. Public Law 92-500. 92nd Congress, S. 2770. Oct. 18. 89 pp.