MONITORING CHANGES IN STREAM BOTTOM SEDIMENTS AND BENTHIC INVERTEBRATES

by

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(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies)

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ABSTRACT

The study was conducted to determine whether the analysis of stream bottom sediments could be used to assess sediment pollution generated by highway construction. Most of the work completed to date has involved testing and refining methods for the collection and processing of sediment and benthic invertebrates.

A transect procedure was used to characterize streambed profiles. Two devices were tested for sampling bottom sediments: a coring tube and a small grab sampler. The grab proved to be more versatile and efficient. Laboratory processing of sediments was accomplished by standard methods of drying, sieving, and weighing. The mean grain size was calculated for each sample. Organisms were collected with a Surber sampler. A combination of traditional and novel methods was used to partition the organisms from the debris in the samples. These methods included sieving, decantation, and the use of a settling tube.

The preliminary data indicated that sediment grain sizes differ spatially, but that temporal differences at specific sites are minimal. The community of invertebrates at the principal field site was characterized by low diversity. This finding suggests that the creek is moderately polluted.

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INTRODUCTION

This report is a summary of laboratory and field work, as outlined in the working plan (Pickral 1980), that has been completed prior to May 1, 1981. Much of this effort has involved the testing and refining of methods. These methods are described, and preliminary results are presented to indicate the validity of the various procedures.

All of the data and discussion concern a single field site: Meadow Creek in the vicinity of the Park Street bridge in Charlottesville, Virginia. Other streams have been investigated as possible sites for study, but none has yet been sampled extensively enough to warrant analysis. The working plan specified that stream bottom sediments and benthic invertebrates be sampled before, during, and after construction. Since construction has not been initiated at Meadow Creek, it is not possible to make temporal comparisons. It seems likely, however, that the methods developed in the early phases of the study could eventually permit such comparisons to be made.

METHODS

Field Methods

Stream Bottom Profiles

This procedure is used to determine the vertical profile of the sediment-water interface at several points on a transect across the stream. It is hypothesized that sediment derived from a highway construction site may be deposited on the bed of a nearby stream, and that this aggradation may cause detectable changes in the profile of the stream bottom. Specifically, the distance between the streambed and a fixed reference point located above the stream should decrease as aggradation proceeds.

A simple, effective method has been devised to obtain data for such profiles. Wooden surveyor's stakes are driven into the banks on opposite sides of the creek. Both stakes are notched near the top. The end of a rope is tied in the notch of one stake, and the rope is stretched across the creek to the other stake, pulled tight, and fastened in the notch. For convenience, the rope is marked at 1-ft.* intervals. A meter stick is used to determine the distance between the rope and the streambed at intervals across the stream.

There have been few problems with this method. Although the stakes are left in place between field trips, vandalism has not occurred, probably because the stakes are inconspicuous. With this method, reasonably accurate, repeatable measurements can be obtained in a few minutes. Changes in the sediment profile greater than one-half centimeter are readily detected, but changes of only a few millimeters cannot be measured reliably. Other methods, later described, can provide data concerning slight changes at the sediment surface.

Sediment Sampling

Two types of samplers were evaluated in the field. The first was a conventional coring tube 6 cm in diameter and made of clear plastic. A series of notches spaced at one-centimeter intervals were cut into the plastic to provide a vertical scale. The coring tube is pushed into the sediment to a predetermined depth (usually 10 cm). A metal plate is then placed over the bottom of the tube to prevent the loss of material as the tube is withdrawn from the sediment.

Several problems were encountered in using the coring tube. It is sometimes difficult to push the tube into the sediment, particularly if the substrate contains appreciable amounts of pebbles or cobbles. Further, the metal plate often cannot be positioned snugly at the bottom of the tube during withdrawal, with the result that sediment may be lost from the sample. Finally, the coring tube can be conveniently used only in water less than about 18 in. deep. This restriction is especially severe for winter sampling, when the water is very cold.

The second device tested was a small grab sampler consisting of three conjoined parts. The sampling chamber is a small metal box, open on the bottom side like a cookie cutter. A metal pole with a handle is attached to the sampling

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*See notations, page 13.

chamber. This pole is connected to a second pole such that the two can be moved like scissors. A small metal plate is fastened to the bottom of the second pole.

The grab sampler works in the following manner. The poles are first spread apart. The investigator grabs the ends of the poles, lowers the sampling chamber to the site to be sampled, pushes the chamber into the sediment, and brings the ends of the two poles together, thereby enclosing a small "brick" of sediment. The metal plate on the bottom of the second pole automatically closes off the bottom of the sampling chamber. After the device has been lifted to the surface, the chamber is opened so that the sample can be washed into a small pan and then transferred to a labeled jar for transportation to the lab.

The grab sampler has proved to be more convenient and efficient than the coring tube for sampling sediments in pools. Sampling can be accomplished more rapidly with the grab than with the tube. It is possible to use the grab sampler in depths up to 3 or 4 ft., compared to 1½ ft. for the coring tube. Sediment can be removed more quickly and completely from the grab. Further, the grab samples only the top few centimeters of the sediment, which is the portion of sediment most likely to be altered as a result of streamside construction. Consequently, the grab sampler was selected for routine use throughout the study.

Artificial Substrates

A literature search conducted by the Research Council (Pickral 1981) indicated that sediment pollution often imposes deleterious effects on stream biota by filling the voids among rocks in riffle areas. This phenomenon, referred to as embedding, apparently reduces microhabitat space for organisms, interferes with feeding and breeding activities, and leads to the emigration of invertebrates from the impacted area.

It is difficult to measure embedding in a natural stream with any degree of accuracy. Visual estimates may be of some use, but this method is not sufficient for the early detection of embedding. Therefore, another method was developed. Artificial substrates are prepared by collecting rocks of fairly uniform size (2 to 4 in. in diameter) at a local quarry. The rocks are placed in trays (12 in. x 12 in. x 2 in.), the bottom and two sides of which are constructed of treated wood. Screening (¼-in. mesh) is fastened to the back and front sides to permit stream water to enter and exit the rock-filled tray.

Three trays have been placed in a riffle area upstream from the planned construction site at Meadow Creek, and three have been placed in a downstream riffle. To date, very little sediment has accumulated among the rocks in any of the six trays. This finding coincides with the visual estimation that the natural riffles are not sites for the deposition of sand. The trays were anchored in place by putting large rocks on top of them. This procedure has the further advantage of camouflaging the trays and thereby reducing vandalism. The major drawback associated with the use of artificial substrates is their tendency to collect organic detritus and algae on the screen which faces into the current. This blanket of scum sometimes becomes sufficiently thick to obstruct the flow of water into the tray. It may be necessary periodically to clean the screen, or even to remove it.

Despite this problem, there is every indication that the artificial substrates will be suitable for measuring the degree of embedding associated with construction. The trays could be removed once or twice a month so that the trapped sediment could be collected and weighed.

Organisms

A variety of samplers have been used to collect macroinvertebrates (Pickral 1981). The Surber sampler has much to commend its use. It has been widely employed, is easily operated in shallow water by a single person, and is considered more quantitative than most of its competitors. Therefore, this sampler was chosen for the study.

Two sets of samples, from both upstream and downstream riffle areas, have been obtained at Meadow Creek. Few problems have been encountered. Rocks lying withing the sampling quadrat of the device are picked up and rubbed vigorously by hand to dislodge the adhering organisms so they can be collected in the net. Samples are preserved in formalin in the field. The author is convinced that no other sampler could give better results.

Laboratory Methods

Sediment

Samples of stream bottom sediment are first washed on a 0.063-mm sieve to remove very fine particles. Such particles are not sampled quantitatively with the grab sampler, because they can escape from the incompletely enclosed collection chamber. Further, the embedding hypothesis strongly suggests that sand, rather than silt or clay, is most responsible for reductions of organisms in streams affected by sediment pollution.

After this preliminary washing, the sediment is placed in a large evaporating dish and put into a drying oven (105°C) for at least two days. The sampler is then introduced onto a 4.0-mm sieve, beneath which are nested sieves of 2.0, 1.0, 0.5, 0.25, 0.125, and 0.063 mm mesh size. A mechanical shaker is used to sieve the sample for 5 minutes.

The seven individual size fractions are removed from the respective sieves and transferred to tared aluminum weighing dishes. Weights are recorded to the nearest 0.01 gram. The data obtained are processed to obtain the total weight of sediment in the sample, the percent composition of each size class, the cumulative percentages, and the mean grain size of the entire sample, calculated by the equation

$$\bar{X} = \frac{\Sigma_i (w_i d_i)}{\Sigma\ w_i} ,$$

where

$\bar{X}$ = mean grain size (mm),

w_i = weight of i_{th} size fraction (g), and

d_i = midpoint in i_{th} size class (mm).

Representative subsamples of each size fraction were introduced into a muffle furnace and fired at 600°C for 30 minutes. The loss of weight on ignition was very small compared to the total weight of the sample. This finding indicates that organic detritus accounts for little of the total sediment weight. Thus, the entire dry weight of the samples can be regarded as inorganic sediment. No further analysis with the muffle furnace is considered necessary.

There have been no difficulties associated with the laboratory analysis of sediment samples. The methods employed have been widely used by other investigators with good results.

Organisms

The material collected with the Surber sampler consists of a mixture of sand, organic detritus, and macroinvertebrates. The macroinvertebrates must be sorted from the associated debris before they can be identified and counted. This sorting process can be very time consuming. Therefore, efforts were made to develop methods to expedite sorting.

First, the total sample is washed on a coarse sieve (2.0 mm mesh). The small volume of material retained on the sieve is placed in an enamel pan and visually inspected. Organisms are removed with forceps and stored in ethyl alcohol. This step requires only a few minutes per sample.

Second, the material that passes through the 2.0-mm sieve is transferred to a 0.5-mm sieve and washed again. Debris passing through this sieve is discarded, because macroinvertebrates are defined as organisms which will not pass through such a sieve. This secondary sieving substantially reduces the volume of debris to be sorted. Material smaller than 2.0 mm and larger than 0.5 mm is washed into a jar. The jar is agitated, and the lightweight, slow-settling fraction containing organisms and detritus is decanted onto a fine sieve; the heavier sand grains remain in the decanting jar. After the process has been repeated several times, virtually all of the organisms and detritus have been separated from the sand. This separation greatly facilitates the subsequent sorting of organisms from debris.

Some samples initially contain high volumes of sand. Since decantation would be very time consuming, another method was devised for these samples. The doubly-sieved sample is introduced into the top of a 1-m settling tube filled with water. Sand grains, which are heavier than the other particles, quickly sink to the bottom of the tube where they are permitted to exit the tube through a large stopcock. The slower settling organisms and detritus are retained on a fine sieve placed beneath the stopcock. Separation efficiencies achieved by this method exceed 99%.

The mixture of invertebrates and detritus that remains after the preliminary sorting procedures outlined above is examined under a dissecting microscope. Individual organisms are removed with fine forceps and stored in ethyl alcohol for later identification. Standard toxonomic references are used to facilitate this work.

PRELIMINARY RESULTS

Sediments

Table 1 provides data on the mean grain size of sediments collected from Meadow Creek on three sampling dates. The mean grain size is a statistic, previously defined, which summarizes the relative frequencies of the individual size classes which constitute the total sediment sample. Seven size fractions were determined by sieve analysis for samples from Meadow Creek. The mean grain size affords a single number to characterize the texture of the entire sample.

One of the important assumptions of this study has been that mean grain size data can be used to detect and quantify changes in stream bottom sediments caused by erosion from highway construction projects. Because construction has not begun at the Park Street bridge, it has not been possible directly to test this assumption. However, the preliminary data exhibit characteristic spatial and temporal variations which deserve comment.

First, it is obvious that sediment texture varies within sampling stations. For example, nine samples were collected at a station upstream from the bridge on February 9. Three samples were obtained from the left side of the creek, three from the middle, and three from the right side (with respect to an observer facing downstream). The samples taken from the right side all had mean grain sizes greater than 2.0 mm, while samples from the middle and right substations had values close to 1.0 mm. That is, the sediment on the right side was coarser than the sediment at the other two substations. This difference reflects the fact that the current is swifter on the right side; thus, fine particles are less likely to be deposited there. Similar textural asymmetries were evident at the upstream station on the other two dates. Nonparametric statistical tests (Mann-Whitney procedure) indicated that the differences were significant at the $P = 0.05$ level. Similarly, sediment in the middle of the downstream station was significantly coarser than sediment on the right side on all three dates. Samples were not collected on the left side of that station because the water was too deep.

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Table 1

Mean Grain Sizes (mm) of Sediment at Meadow Creek

Upstream

Location		Feb. 9	Mar. 31	Apr. 7
Left	1	0.70	0.74	1.10
	2	1.20	0.91	0.87
	3	1.21	1.24	1.18
Middle	1	0.96	1.10	0.90
	2	0.75	0.91	1.22
	3	0.91	1.16	0.85
Right	1	2.20	2.02	1.90
	2	2.14	1.97	2.28
	3	2.23	2.31	2.15

Downstream

Location		Feb. 9	Mar. 31	Apr. 7
Middle	1	2.92	2.83	2.39
	2	2.33	3.21	2.65
	3	3.90	2.72	2.86
Right	1	0.46	0.60	0.48
	2	0.52	0.58	0.62
	3	0.47	0.49	0.63

Temporal comparisons showed that the mean grain size varied remarkably little at individual substations between sampling dates. Consequently, the differences in sediment texture across the creek persisted from date to date. A large storm might alter the bottom texture at the respective sampling stations, but the small storms which occurred during the study had little effect. In other words, the grain size of the sediment appears to be a conservative property for a small, well-defined area of the creek bottom.

Organisms

Macroinvertebrates were sampled in Meadow Creek on the same dates that sediment was collected. The preliminary results of the monitoring can be stated succinctly. Chironomid larvae were the only organisms found anywhere in the creek in appreciable numbers. Approximately equal numbers (usually 5 to 12 per square foot) occurred at all sampling locations. Thus, the macro-invertebrate community in the creek can be said to exhibit a very low diversity. This finding suggests that the creek is moderately polluted, perhaps by sewage. It is not immediately apparent what effect sediment pollution from highway construction might have on the creek. It should be noted, however, that suspended solid levels in Meadow Creek are already high after storm events.

SUMMARY

These results indicate that the texture of stream bottom sediments varies in a characteristic manner across the stream, but that textural properties at a given location remain constant over appreciable intervals of time. It would be possible to sample the same sites during construction to determine whether fine material derived from the project alters the mean grain size at the selected sampling points, and whether the numbers and diversity of benthic invertebrates change concurrently. The methods developed during the study for the collection and analysis of sediments and organisms could permit such monitoring to be accomplished.

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REFERENCES

Pickral, J. C. 1980. Working Plan - "Monitoring Changes in Stream Bottom Sediments and Benthic Invertebrates". VHTRC 81 WP-5. Virginia Highway & Transportation Research Council, Charlottesville, Virginia.

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NOTATIONS

S. I. Equivalents of English Units

1 inch = 0.025 m

1 foot = 0.305 m

1 square foot = 0.093 m^2

English Equivalents of S. I. Units

1 mm = 0.039 in

1 centimeter = 0.394 in

1 gram = 0.002 lb

Degrees Celsius = 5/9 (F^o - 32^o)