THE EFFECTS OF STREAM CHANNELIZATION ON BOTTOM DWELLING ORGANISMS

Phase I Report
"1974 Construction Season"

by

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SUMMARY

Two streams being channelized under Department contracts have been monitored since June 1974. Suspended solids, flow, rainfall and benthic population measurements have been obtained at various times for each stream. At present, all but the benthic population data have been processed.

Research will continue on the two streams monitored in 1974. In addition, at least one other stream will be monitored in 1975. Also, temperature measurements will be taken on each stream.

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BACKGROUND

Prior to 1969 the Virginia Department of Highways and Transportation gave less consideration to the location of a road from the erosion and siltation standpoint than from other location criteria. This was particularly true of the location of a road with respect to a stream. During that period, the principal criterion for locating highways was to select that corridor which would minimize cut and fill work and thus construction cost. This criterion often required that a stream be relocated in its floodplain. Such a channel change affected many hydraulic characteristics of the stream including the width, length, gradient, number of pools, and channel pattern.

Besides the changes in the hydraulic characteristics, it is now known that the stream ecology is also affected. The aquatic life in the original stream is destroyed or caused to migrate to other places in the stream because of the destruction of habitats and increased siltation levels. Aquatic plants and small immobile and very slow moving organisms are buried by the deposited silt, while the fish and other larger aquatic animals migrate up-or downstream from the area of disturbance. In the new channel higher order organisms, such as fish, are not able to survive for some time because of the new channel's instability. The lower order organisms, which act as food for fish and other higher order organisms, are unable to establish themselves.[(1)*] The return of the stream's ecology to its original state occurs only over a long period of time and at a very slow rate.

The suspended silt can affect the aquatic life in the stream and in larger bodies of water, such as lakes and ponds, for several miles downstream. C. D. Ziebell, in 1957,[(2)] determined that a gravel washing operation reduced fish food organisms in a river for a distance of $6\frac{1}{2}$ miles (10.5 kilometers) downstream. Cordone and Pennoyer, in 1960,[(3)] noted a reduction of over 75 percent in such organisms more than ten miles (16.1 kilometers) below a gravel washing plant in California.

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* Numbers in parentheses refer to entries in the list of References.

In addition to the studies of the downstream distance effects of suspended silt, the local effects have also been reported. In a study of a 3,300 foot (1 kilometer) channel change in Montana the numbers and weight of fish per acre reduced 45.8 percent and 51.1 percent, respectively, after the construction.[4] This reduction was a direct result of loss of food source removed or buried by the deposited silt and of migration. The numbers of fish per acre stayed constant for the first four years after the channel change, while the weight of fish per acre decreased slightly over the same period of time.

In a study conducted in Indiana, where stream sediment was created by a crushed limestone quarry, the researchers determined that the benthic insects for most fish below the stone quarry were much reduced.[5] With light inputs of less than 40 ppm of suspended solids a 25 percent reduction in aquatic insect population, the food source for fish, occurred. At heavier sediment loads of greater than 120 ppm a 60 percent reduction of benthic population resulted.

Two studies in Oregon showed an 85 percent reduction in the aquatic insect population from a gravel dragline operation upstream.[6,7] The turbidity of the water changed from zero to 91 ppm while the suspended solids increased from 2 ppm upstream to 103 ppm downstream.

In 1951, Wallen found that fish can tolerate high turbidities (5,000 ppm or more) for short periods of time.[8] However, he found that plant life and a good bottom fauna cannot exist with a continuous turbidity reading of 200 ppm. Since fish are dependent upon benthic forms of life, their population would decrease.

STUDY JUSTIFICATION

The need for a study such as the one reported here was suggested by a national agency in 1972. The Committee on Water Quality Criteria to the Environmental Studies Board of the National Academy of Science, National Academy of Engineering made the following statement in its report entitled "Research Needs In Water Quality Criteria 1972",[9] which was prepared in response to a request by the Environmental Protection Agency: "There is a need to investigate the consequences of eliminating food-producing riffle areas and shelter areas along the banks of streams by channelization".

In the summer of 1973, the Research Council conducted a study on the erosion and sediment control procedures and problems of the Virginia Department of Highways and Transportation. The study involved a survey of the Department's erosion-siltation control program and developed 29 recommendations.

Several of the recommendations involved the minimization of channel changes, the location of roads away from live streams, and the rehabilitation of streams that have undergone channel changes.[10]

In addition to the concern shown in that study for activities in live streams and the effects of channelization, the Virginia Commission of Game and Inland Fisheries sent a letter to the Virginia Department of Highways and Transportation on April 16, 1974, stating their tentative policy positions regarding stream channelization. In essence, the 11 positions stated that stream channelization should be avoided if at all possible, and that when channelization is necessary the new channel should be designed and constructed according to their guidelines.

OBJECTIVES OF THE STUDY

The following objectives were stated in the working plan for this study.[11]

1. Determine the percentages reductions in various benthic populations as a result of stream channelization.
2. Determine the downstream extent of the reduction of the benthic populations.
3. Determine the recovery time for the stream's ecology after the channelization.
4. Determine the relationship of turbidity and/or suspended solids to the benthic insect population reductions.

INVESTIGATIVE APPROACH

Two streams proposed for channelization by the Department were selected to be studied in 1974. One was located in the Valley and Ridge physiographic area of Virginia, while the other was located in the Piedmont area. Figure 1 shows the location of the sampling stations with respect to the channelization work and the relocated highway, Route 254 near Staunton, Virginia, for the Valley and Ridge project. The sampling stations were located on Meadow Run, which traversed the construction. At stations 1, 2, 4, and 5 flow measurements were obtained at various intervals of time from the first of June to the middle of October. In addition, suspended solids and benthic populations were determined at all five stations over this same period of time.

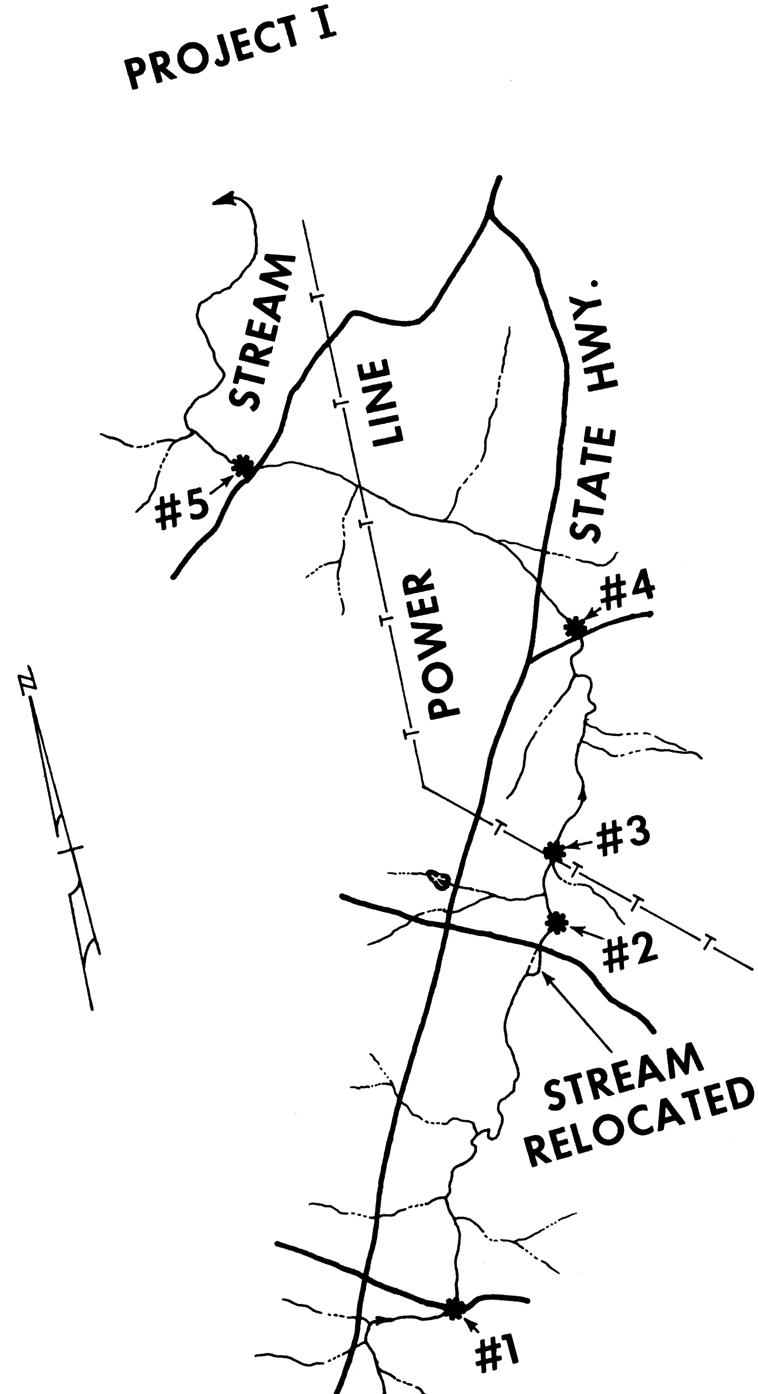

Figure 1. Meadow Run — Route 254 site.

The plans for the Route 254 construction called for the contractor to construct a four-barrel box culvert in the dry, or completely out of the stream. Then approximately 600 feet (182.9 meters) of new channel would be excavated to intercept the old channel. At some time during the construction the upward end of the new channel would be excavated and the stream changed over.

Figure 2 shows the Piedmont project and the sampling stations selected. The sampling stations were located on Moores Creek near Route 29 south of Charlottesville. Approximately 500 feet (152.4 meters) above station 3 a small channel feeding the main stream was proposed to be relocated. However, the disturbance and silt load created by this channelization was only minor compared to the total disturbance from just below station 1 to just above station 5. In this project the effect of the overall stream disturbance, which is also important to the Department, is being determined rather than the effect of the small channelization project initially proposed for study.

The flow of Moores Creek was determined at stations 1, 3, 4, and 5, and suspended solids and benthic populations were determined at the six stations.

Sampling stations were selected on both projects to determine the effects of the stream disturbances on the bottom fauna at various distances downstream (objective 2). In addition, station 1 on each project was located to determine the background levels of benthic populations and suspended solids. This sampling station would then provide data to allow a determination of the percentage reduction of various benthic populations downstream (objective 1). Also the change in suspended solids due to the construction can be determined with the background suspended solids determination at station 1.

To determine the benthic populations present at the different stations, sets of a modified Hester-Dendy, multi-plate artificial substrate (Figure 3) were placed in the streams around the first of June. Figure 3 shows two different substrates. The smaller substrate has one square foot (0.3 meter) of exposed surface to which the bottom fauna may attach. In order to obtain a statistically sound sample the small substrate was replaced with the five square foot (1.5 meters) device shown at the top in Figure 3. If a pool of water at a station was not large enough to hold the large substrate, then five of the small devices were placed in different pools in the station area.

Every two weeks a set of substrates (five from Meadow Run and six from Moores Creek) was removed from each stream. Each set was left in the stream for six weeks. The substrates were transported to the laboratory, where the benthic populations and other debris were cleaned from them and stored in individual jars with a 3 percent solution of formaldehyde. The benthic organisms were sorted from the solution and classified into their genera. After classification the organisms were separated into one of three categories: sensitive, intermediate, and tolerant. As suggested by the category names, the sensitive organisms can tolerate little polluants or silt, while the tolerant are very hardy. The intermediates fall between these two.

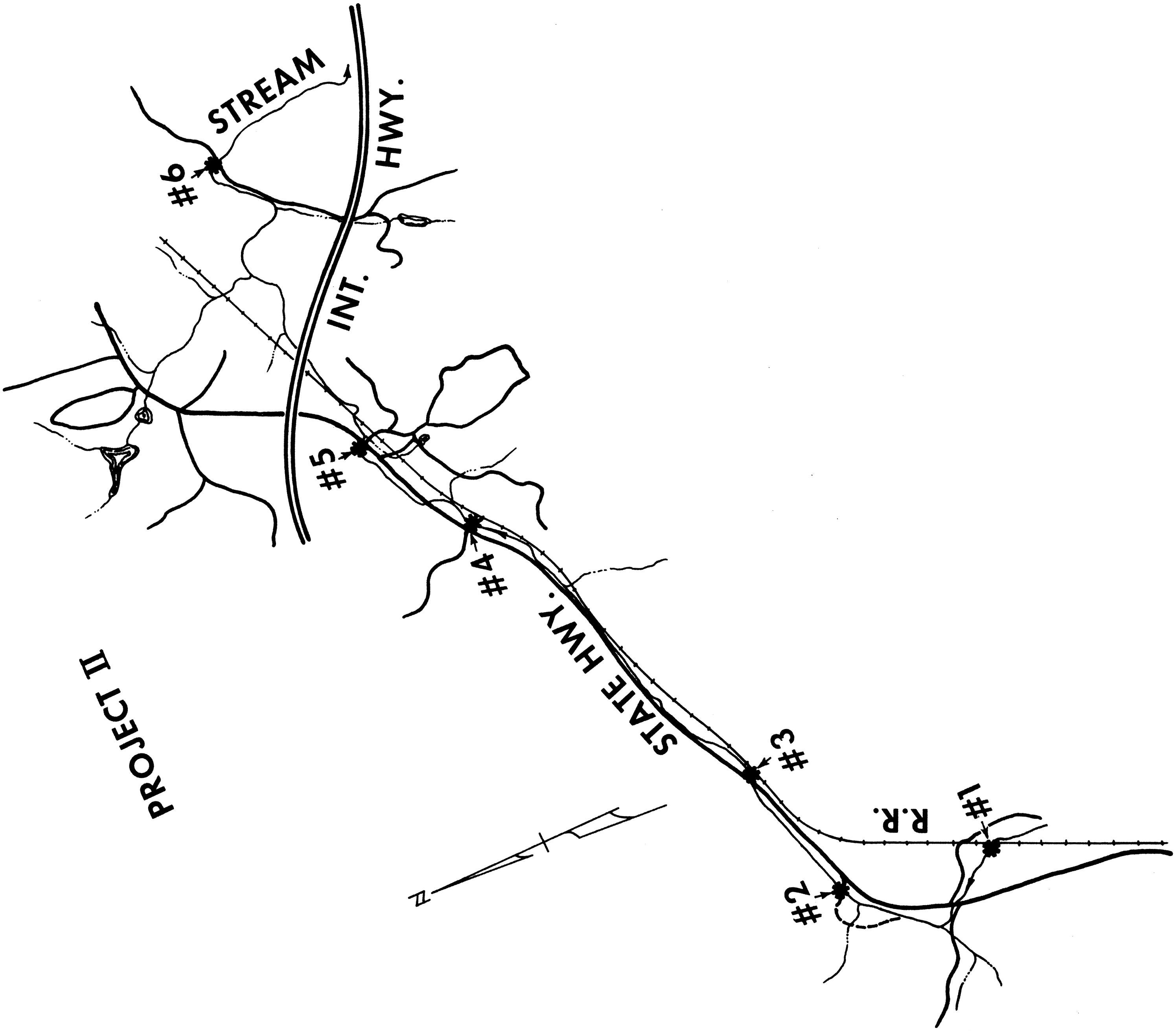

Figure 2. Moores Creek — Route 29.

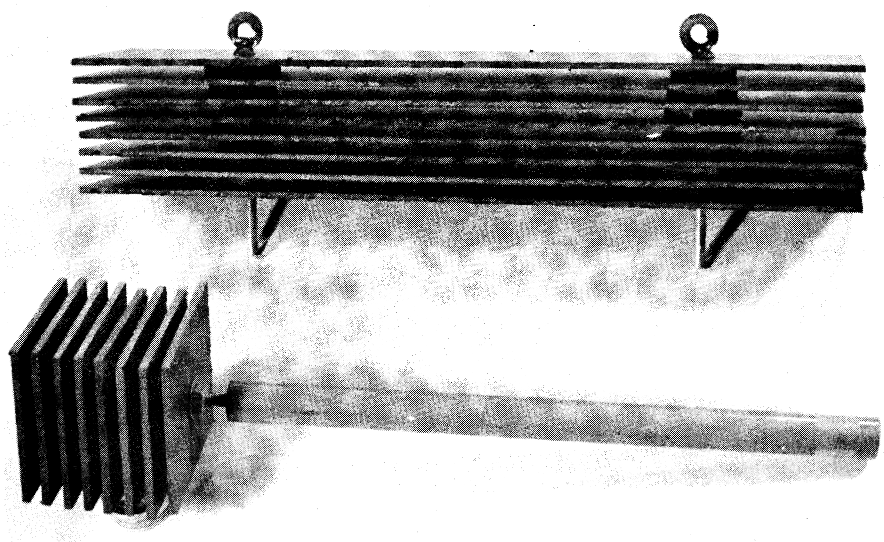

Figure 3. Hester-Dendy multi-plate artificial substrates.

In addition to suspended solids, flow, and benthic populations rainfall data were obtained from the nearest State Water Control Board recording station. With these data the amount of rainfall can be related to the amount of suspended solids and flow on each project. Rainfall data for the Meadow Run — Route 254 project were obtained from the Staunton Sewage Treatment Plant, while the McCormick Road Observatory in Charlottesville provided the data for the Moores Creek — Route 29 project.

RESULTS

At present, the data obtained during the summer and fall of 1974 are being processed. Suspended solids, rainfall, and flow results have been obtained, but the classification of all the benthic samples will not be completed for several months.

Table 1 shows the suspended solids and flow results for the Meadow Run — Route 254 project. The average suspended solids for ambient conditions after channelization decreased at every station from the results obtained before channelization. This trend of before and after channelization effects also held true for all stations except station 2, which is located approximately 100 feet (30.5 meters) downstream from the end of the channelization work, when a 0.1-inch (0.25 cm.) storm event occurred. The increase of 12 ppm at station 2 for this small storm event is understandable, since the new channel is unstable.

Table 1

Meadow Run — Route 254

Average Measurements Before Channelization	Stations 1	2	3	4	5
Suspended solids (ppm) - ambient	13	19	22	29	25
Suspended solids (ppm) -0.1-inch (0.25 cm.) storm event	33	21	21	19	35
Flow (cfs-m^3/sec) - ambient	4 (141.3)			16 (565.0)	19 (671.0)
Flow (cfs-m^3/sec) - 0.1-inch (0.25 cm.) storm event	5 (176.6)			30 (1059.4)	34 (1200.7)
After Channelization					
Suspended solids (ppm) - ambient	11	9	12	17	19
Suspended solids (ppm) - 0.1-inch (0.25 cm.) storm event	22	33	17	15	24
Flow (cfs-m^3/sec) - ambient	5 (176.6)	9 (317.8)		18 (635.7)	21 (741.6)
Flow (cfs-m^3/sec) - 0.1-inch (0.25 cm.) storm event	5 (176.6)	11 (388.5)		20 (706.3)	25 (882.9)

Table 1 also shows the flow results before and after channelization. Station 2 yielded no flow results until the stream was relocated through the new box culvert. The ambient average flows before and after channelization are very similar. However, stations 4 and 5 show a decrease in flow after channelization for 0.1-inch (0.25 cm.) storm events. Although no definite trends are evident, this occurrence, if validated by further results, would be contrary to present beliefs of environmentalists.

Table 2 shows the average suspended solids and range of suspended solids determined on the day the stream was diverted through the new channel. Station 1 results were not affected by the diversion since the new channel was constructed just above station 2. Stations 4 and 5, on the average, were lower in suspended solids this day by 16 and 8 ppm, respectively, than determined under ambient conditions for other days before channelization. However, for stations 2 and 3 the average suspended solids levels increased 106 and 33 ppm, respectively, over the average ambient levels before channelization. More important is the fact that during the day suspended solids levels exceeded the ambient levels at stations 2 and 3 by as much as 515 and 125 ppm, respectively,

Table 2

Suspended Solids on Day of Channelization

	Stations 1	2	3	4	5
Average (ppm)	10	125	55	13	17
Range (ppm)	9-11	19-534	8-147	8-29	9-30

If the Environmental Protection Agency sets their suspended solids limit at 80 ppm above the ambient conditions, the Department would be exceeding this limit if a sample was taken at this high suspended solids time. However, the Department seems to be able to obtain this limit after the channel's initial flushing out period. For a 0.6-inch (1.5 cm.) storm event the suspended solids level increased only 19 ppm over the ambient condition before channelization at station 2. For 1.1-inch (2.8 cm.) storm event the suspended solids level exceeded the ambient level by 25 ppm, which is well within 80 ppm above ambient.

Table 3 shows the results obtained on the Moores Creek project. The average ambient suspended solids for stations 1 through 4 were essentially the same. However, between stations 1 and 2 a small stream feeds into Moores Creek and this caused dilution of the suspended solids determined at station 2.

Table 3

Moores Creek — Route 29

Measurements	Stations 1	2	3	4	5	6
Ambient						
Average Suspended Solids (ppm)	30	32	27	35	15	4
Range of Suspended Solids (ppm)	5-57	7-108	3-69	1-162	2-71	0-8
Flow (cfs-m^3/sec)	1 (35.3)		5 (176.6)	12 (423.8)	4 (141.3)	
During three 0.7-inch (1.8 cm.) Storm Events→1"						
Average Suspended Solids (ppm)	118	202	267	133	99	83
Range of Suspended Solids (ppm)	68-184	102-363	62-601	52-216	52-147	67-99
Flow (cfs-m^3/sec)	2 (70.6)		7 (247.2)	18 (635.7)	8 (282.5)	

During the five months of study on Moores Creek construction of a two-barrel box culvert approximately 100 feet (30.5 meters) above station 3 was conducted. This construction accounted for the high suspended solids value of 69 ppm and other similar values at station 3.

The high value of 108 ppm of suspended solids at station 2 was due to the filling of waste material by the contractor up to and into the stream between stations 1 and 2. The filling process, which occurred mostly in the month of July, also accounted for the high suspended solids value of 363 ppm during one of the 0.7-inch (1.8 cm.) storm events. During this same storm event, 601 ppm of suspended solids was determined at station 3 due mostly to the construction of the box culvert above this station. Table 3 shows that the average suspended solids during a 0.7-inch (1.8 cm.) storm event increased 88, 170, and 240 ppm at stations 1, 2, and 3, respectively, although the flow did not increase but 1 and 2 cfs (35.3 and 70.6 m^3/sec) above ambient at stations 1 and 3, respectively. At stations 4 and 5 the flow increased more over ambient than at stations 1 and 3, but the suspended solids decreased considerably with distance past station 3. The suspended solids above ambient level were 98, 84, and 79 ppm at stations 4, 5, and 6, respectively.

As shown by this project with the runoff silt-laden water into a stream from a fill up to its stream bank and disturbances in the stream, large amounts of suspended solids were still present several miles downstream. Station 6 is located 1½ miles (2414 meters) downstream from the end of construction and the suspended solids level was just at the EPA proposed limit of 80 ppm.

RESEARCH FOR 1975

Suspended solids, flow, rainfall, and benthic population measurements will be determined on both of these construction projects from March through November 1975. After the 1974 benthic population results are obtained, the number of stations for each project may be decreased in 1975 if the data justifies such action. Otherwise the same number of stations and locations will be repeated this construction season.

In addition, stream temperature measurements will be taken on the Meadow Run — Route 254 project to determine the effects the new channel has on the water temperature. The guidelines sent to the Department on April 16, 1974, by the Virginia Commission of Game and Inland Fisheries suggest ways to construct necessary channel changes to keep the stream temperature from increasing from ambient due to the channelization. With the increase in temperature from shallower water and fewer shrubs and trees around the new channel than the old channel, less aquatic life will be present. This occurrence is due to the lack of dissolved oxygen from the increased temperature. In a study in Utah it was shown that 50 percent of the mayfly larva died after 96 hours of exposure to 11.7°C [12] higher temperature than their normal living conditions.

A channelization project near I-64 at Lexington will be added to the study this year. The proposed project will be conducted on the Maury River and background data will be obtained during the summer of 1975. The study approach will be similar to that for the present two projects.

OBSERVATIONS AND RECOMMENDATIONS

Although the analysis of the benthic populations is incomplete at this time, the following observations and recommendations can be made from the data analyzed thus far.

Observations

1. Construction activities next to a stream or in a stream must be eliminated or kept to a minimum when unavoidable. From Table 3 it is seen that suspended solids levels can reach 162 ppm just below stream activity when no precipitation is occurring. For 0.7-inch (1.8 cm.) storm events the level of suspended solids can reach 601 ppm which is 574 ppm over the average suspended solids during ambient conditions at this station. If the 80 ppm of suspended solids over the ambient value criterion is enforced by the EPA, then the Department will well exceed the limit.

Most of the suspended solids were contributed by the box culvert construction in the stream and the runoff entering the stream from a waste area spilling into the stream.

2. Channelization guidelines suggested by the Fish Division of the Commission of Game and Inland Fisheries should be followed by the Department. At present the Department has agreed to use the guidelines sent to the Environmental Quality Division by the Commission. Even though the guidelines are being used by the Department, it is felt that the need for them should be reemphasized in light of the suspended solids results obtained on the Meadow Run — Route 254 project. In Tables 1 and 2 it is shown that the construction of a box culvert in the dry affected only the suspended solids levels at the downstream stations on the day the new channel was opened. The suspended solids levels under ambient conditions on other days showed a decrease after channelization from the levels before channelization at each station.

Recommendations

1. It is recommended that the use of straw bale dams in live streams be discontinued. A straw bale dam installed in the old channel of the Meadow Run — Route 254 project was monitored on the day the stream was diverted. The dam backed the stream up but did not burst during the day. Suspended solids measurements taken above and below the dam indicated only a 1 to 4

ppm reduction in suspended solids through the straw bales. Prior to these measurements it was felt that once a soil particle reached a stream its removal was almost impossible.

2. It is recommended that the use of log dams in streams be discontinued. Experience has shown that during storm events most straw or log dams wash out due to the force of water backed behind them. A log dam was installed by the contractor on the Meadow Run-Route 254 project. This dam provided another opportunity to monitor one of the common stream barriers used by the Department. On this project it was found that the suspended solids load below the log dam was higher than the suspended solids load above the dam. Under high suspended solids loads the increase was as much as 400 ppm, while low suspended solids loads increased the load by only 8 ppm.

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