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TO: WHOM IT MAY CONCERN

FROM: James M. Stewart
Assistant Director for Research Application

SUBJECT: Institute Report No. 73 -- "Further Characterization of the Water Quality of the New Hope and Lower Haw Rivers Including Benthic Macroinvertebrate Diversity and Trace Metal Analyses" -- by Charles M. Weiss, Thomas W. Yocum, and Jennifer E. Minogue, Department of ESE, University of North Carolina at Chapel Hill

This report presents the finding of water quality characteristics of the Lower Haw and New Hope Rivers for a period January 1971 through March 1972, with the use of 21 water quality parameters. A study is also made of the benthic macroinvertebrates of these rivers and control streams with specific relationships of their population characteristics. Metal analysis of these organisms and the waters were made. This aspect of the report will be of particular interest to scientists, agency officials and others concerned with toxic metals problems.

Recommendations include the need for increased nutrient removal to achieving higher water quality in the New Hope Lake. Specifically, the researcher cited the need to increase the nutrient removal for the treated Chapel Hill and Durham sewage effluents entering the New Hope drainage. Also, it was recommended that samples of the river bottom sediments be analyzed to determine the level of phenolic and chlorinated carbon compounds.

JMS:p

Attachment

UNC-WRRI-72-73

Further Characterization of the Water Quality of the New Hope and Lower Haw Rivers Including Benthic Macroinvertebrate Diversity and Trace Metal Analyses

by

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Various staff and students provided support for the field collections and analyses and these included the following: Mr. Tony Owen, Ms Susan Rappaport, Mr. Kenneth Teague and Ms Florence Wilson. Statistical analyses of the water quality data were provided through Dr. Ronald Helms of the Department of Biostatistics, School of Public Health.

Ms. June Foushee provided the necessary editorial assistance in organizing the report and Ms. Elizabeth Pettit effectively typed the manuscript.

Abstract

The water quality surveillance program of the New Hope and Lower Haw Rivers continued with an expanded sampling-station network. This included six new control stations draining into the Haw River between station H-1 at Saxapahaw, North Carolina, and station H-5 at the head of the upper arm of the proposed New Hope Lake. All stations were visited approximately twice monthly and reported data represents values derived from 28-31 samples from each station. Self purification along the main stem of the Haw continued to be evident. Full recovery in terms of carbonaceous pollution was essentially completed at Station H-5. The control streams were free of pollution and exhibited some dilution effect on the main river even though their flows were quite small. This was quite apparent in observations of conductivity which decreased in downstream sequence from H-1 to H-5 and H-6. In contrast, the New Hope exhibited pollution up to its junction with the Haw River.

All nonconservative parameters of water quality in the Haw showed a downstream sequence of decrease in magnitude, including total carbon, total soluble carbon, and all species of nitrogen or phosphorus. Microbiological characteristics as shown by index organisms were approximately the same in the mainstream station as in the control stream stations.

Gas chromatographic analysis of freeze concentrated samples and ether extracts of these concentrates showed no significant peaks either by use of flame ionization detectors or electron capture detectors. It appears that these waters were particularly free of phenolic and chlorinated hydrocarbon compounds.

Analysis of benthic macroinvertebrates at the station network showed that a direct relationship of several benthic parameters such as diversity index, percent pollution intolerant taxa, and number of organisms per sample were all directly related to the mean DO concentration, the mean 5-Day BOD concentration and mean total phosphorus and nitrogen concentrations. The bottom characteristics at the stations were found to be an important factor for benthic organisms. A station with a shifting coarse-sand bottom was generally poor in terms of benthic species, even though water quality characteristics might be high. However, water quality appears to be a more important limiting factor for benthic species in the New Hope drainage than in the Haw drainage.

Metal analysis on both water samples and tissues of benthic macroinvertebrates were carried out through various analytical procedures, principally atomic absorption spectroscopy. Freeze concentrated water samples from both the New Hope and Haw control streams showed that the following five metals increased in concentration in the following sequence: Hg, Cd, Pb, Cr, Zn, with the concentration of the zinc being 100 times greater than the concentration of mercury. In the main stem of the New Hope the concentration sequence was Hg, Cd, Cr, Pb, Zn. The noteworthy difference being that chromium and lead shifted positions in rank. In the Haw River the order of increase in concentration in water was Hg, Cd, Pb, Zn and Cr with the zinc and Cr concentrations being nearly the same. Metal concentrations in the macroinvertebrates followed the sequence of Cd, Pb = Hg, Cr, Zn. Differences in concentration of the various metal elements as well as age of organisms and other variables related to metabolism and growth stage made it difficult to make direct assessment of water quality based on quantities of metals found in organisms. However, gross differences in concentration in the organisms from different streams would lead to suspicion of the quality of the overlying water and thus require further investigation. Benthic macroinvertebrates do appear to provide a form of integrated screening for establishing gross differences in metal concentrations derived from overlying waters.

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Summary and Conclusions

Water quality characteristics of the Lower Haw and New Hope Rivers for the period January 1971 through March 1972, inclusive, are described with the use of some 21 water quality parameters. In addition, findings were derived from the gas chromotography of freeze concentrated samples of river waters as well as from a study of benthic macroinvertebrates of these rivers and control streams with specific relationships of their population characteristics. Metal analyses of these organisms and the waters from which the organisms were obtained have also been assembled.

Water Quality

Water quality parameters were systematically sampled at 10 stations in the New Hope drainage of which two that received no direct discharges of wastewater or inflow of waste waters from upstream sources were considered as controls. On the Haw River, six stations were sampled from Saxapahaw, N. C. (H-1) to Haywood, N. C. (H-6), below the New Hope Dam. In addition six control stations were routinely sampled, three draining from the northeast and three draining from the southwest into the Haw River between stations H-1 and H-5.

In the current period of sampling all stations were visited approximately twice monthly. The reported data represents values derived from 28-31 samples from each station. For the period of record for this report, all determinations were processed by a statistical program which provided a statement of the range of samples, the average value, median value, maximum and minimum values and standard deviation of the entire set. From the frequency distribution of values, the central 75% quartile of occurrence was derived. In addition to the statistical treatment of the data, the averaged values for the parameters which describe mass quantity were used to compute the average pounds per day transported at sampling points at or close to the gauging stations (NH-10, H-5, and H-6).

In the New Hope drainage, the key stations relevant to the proposed conservation pool of New Hope Lake are NH-5, NH-6 and NH-7 just upstream of the pool and NH-10 which will be submerged in the main pool. Stations NH-8 and NH-8A are located on small streams, White Oak and Beaver Creeks respectively, which will drain into the main body of the lake. Of particularly significance is the extent of self purification and assimilation that now takes place in the New Hope River between NH-5, NH-6, NH-7 and on to NH-10. On the average, recovery from the impact of the exertion of BOD has not been completed at NH-10 and oxygen saturation has recovered only to about 72% of saturation. However, this is quite comparable to the average value found at the control stations which was about 83%. The BOD at NH-10, 2.0 mg/l was comparable to the BOD of the two control stations, 2.0 and 1.7 mg/l. Similarly the carbon fractions, total, soluble and inorganic, are only slightly greater than those of the control stations.

Of the nitrogenous components in the water at NH-10, total nitrogen was higher than in the control streams by a factor of 3-4, but the NO_3-N concentration was 7-10 times greater than in the control waters. Phosphorus was higher by a factor of 3-6 times but this is considerably lower than what is present upstream in the vicinity of the wastewater discharges. Die off of index organisms was quite rapid with bacteriological quality at NH-7 and

NH-10 comparable to those of the control stations.

The downstream sequence of water quality changes on the Haw River (H-1 to H-5) provides a clear illustration of the capability to stabilize and assimilate the upstream wastewater discharges. Not only is assimilation clearly indicated but also the quality is comparable to the control streams flowing into the Haw River both from the northeast and southwest. The dilution effect of the control streams, even though quite small, was evident in the change in conductivity decreasing in downstream sequence from the Haw-1 to Haw-6. Since conductivity represents ions in solution and is generally considered to be a measure of conservative pollutants, this change was probably due to dilution by water of approximately one-half the conductivity of that in the main stem. This was characteristic of the control streams. At H-5 the average DO was at a saturation which was somewhat better than the saturation of the control streams where saturation was in the range of 80 to 89 percent. Residual BOD at H-5 was only about 1.5 times that of the control streams and within acceptable limits for any natural water.

All other nonconservative parameters of water quality also showed this downstream sequence of decreasing magnitude in total carbon, total soluble carbon, inorganic carbon and all species of nitrogen and phosphorus. However, by assimilation of carbonaceous materials, through the process of self-purification, mineralized nitrogen and phosphorus components were left which were approximately 2-5 times greater than found in the control streams. Index organisms at H-5 which would be the headwater station in New Hope Lake, were equivalent to numbers found in the control streams. These values apparently represent microbial characteristics of surface drainage and runoff in this area.

Organics

The collection and preparation of samples for gas chromatography were from those stations in each of the two drainages which were estimated to have the most significant location relative to possible sources of contaminating materials as well as from control locations to establish relevant background levels. Samples for gas chromatography from the New Hope were routinely collected from NH-7, just below the juncture of Morgan Creek and New Hope Creek to form New Hope River and NH-8 which served as a control for the New Hope system. On the Haw drainage, H-1 and H-5 on the main stem were sampled and H-7 from the northeast drainage and H-8 from the southwest drainage provided the control water. In all, some 42 samples were prepared by freeze concentration which resulted in an average concentration factor of 30-50X. In all samples, whether tested by direct aqueous injection or ether extraction of the freeze concentrated sample, there was no differentiation of contained material.

Although the freeze concentrated samples were highly colored, it appears from the preceding results that molecular configurations, which would be detectable by gas chromatography and either flame ionization or electron capture detector, were not present even following total concentration by factors of 300 to 500X, which includes the ether extraction concentration.

Benthic Organisms

The benthic macroinvertebrates of the New Hope and Lower Haw Rivers were described from 12 sampling stations located on both polluted and non-polluted streams of the drainage. Benthic organisms were collected in the period of February 1971 - March 1972 using rock-filled artificial substrate samplers. All collections of organisms were identified to the generic level when possible and a total of 81 different taxa were recognized. The benthic data was analyzed with reference to polluted and non-polluted portions of each river and this comparison showed the following: the polluted portions of the drainage had (1) a lower number of taxa per sample (2) a lower number of total taxa (3) a higher number of individual organisms per sample (4) a lower diversity index and (5) a lower proportion of "pollution intolerant" taxa to total taxa. These contrasts between polluted and non-polluted waters were generally less evident in the Haw River drainage than in the New Hope drainage. Comparison of water quality parameters and benthic parameters that showed a direct relationship were as follows:

Water Quality Parameter	Benthic Parameter
Mean DO concentration	Diversity index
Mean DO concentration	Percent "pollution intolerant" taxa
Mean 5-day BOD	No. of organisms per sample
Mean total phosphorus concentration	No. of organisms per sample
Mean total nitrogen concentration	No. of organisms per sample

Between the following parameters a generally inverse realtionship was found. As the water quality parameter increased the benthic parameter decreased.

Water Quality Parameter	Benthic Parameter
Mean 5-day BOD	Diversity index
Mean 5-day BOD	Percent pollution intolerant taxa

However, the bottom characteristics at the stations were found to be an important limiting factor for benthic organisms. One station in particular (H-11) had a shifting, coarse-sand bottom which yielded very few benthic species even though the water quality characteristics of this stream were similar to other control streams in the Haw drainage. It appears that water quality had distinct effects on size and species composition of benthic communities in both the Haw and New Hope drainage systems. However, the polluted main stem of the New Hope system was more noticeably different from its unpolluted tributaries than was the lower Haw from its tributaries. This was true for both water quality parameters and benthic macroinvertebrate populations. Water quality appears to be a more important limiting factor for benthic species in the New Hope drainage than in the Haw drainage.

Metals

The metals cadmium, chromium, mercury, lead, and zinc were analyzed in specific organisms of the benthic macroinvertebrate collections and in the freeze concentrated water samples. The water samples from both the New Hope and Haw control streams showed the concentration of the five metals to increase in the following sequence: Hg, Cd, Pb, Cr, Zn, with the concentration of zinc being 100 times greater than the concentration of mercury. In the New Hope main stem the concentration sequence of increasing quantity was as follows: Hg, Cd, Cr, Pb, Zn. In the Haw main stem the increasing order was Hg, Cd, Pb, Zn, Cr, with Zn and Cr levels nearly the same. The noteworthy difference was that chromium and lead had shifted positions in the rank. It appears that the high chromium levels in the Haw main river are due to industrial discharges upstream from the first sampling point, Haw-1 at Saxapahaw.

Metal concentration in the macroinvertebrates follows the sequence of Cd, Pb = Hg, Cr, Zn. Even in the cases where Cr levels in water were higher than the zinc quantities, the quantity of zinc in the organisms was higher. The highest concentration of all metals in the organisms was found in summer and early fall, possibly due to increased metabolic activity. No one organism of those examined consistently concentrated any of the five metals to a greater degree than any other. However, in all organisms the several metals examined were concentrated to a greater degree in the order noted above. Where chromium levels were unusually high in the water samples, levels of chromium in the organisms were also high indicating a relationship between concentrations in the water and the amount found in the organisms.

Due to differences in concentration of the various elements, age of organisms, season of the year and other variables related to metabolism and growth stage, it is difficult to make direct assessments of water quality based on quantities of metals found in organisms. However, if gross differences in concentration were found in organisms from different streams, the overlying water should be held suspect and investigated. It thus appears that the benthic macroinvertebrates do provide a form of integrated screening for establishing gross differences in metal concentrations derived from the overlying waters.

In neither the control streams nor polluted segments of the New Hope and Haw Rivers were any of the metals found in concentrations greater than those established by the U.S. Public Health Service Drinking Water Standards.

Conclusions

Long term trends in water quality characteristics of the lower Haw and New Hope Rivers must wait data analysis that compensates for seasonal factors. Increased mass transport appears to relate to higher flows in the current period of record since conservative parameters such as conductivity showed a marked decrease. In nearly all instances other parameters also showed a "dilution effect."

The gas chromatography of freeze concentrated samples showed a striking absence of any residues that would normally be responsive to the procedures used. This is not to say that no "exotic" materials were present, but that if they were, the quantities were below our limits of detectability.

Benthic studies demonstrated greater numbers of pollution tolerant taxa in the New Hope than lower Haw with excellent correlation of numbers found and pollution parameters such as BOD. The nature of the sediments at any station is extremely important in establishing population characteristics of a specific location and may significantly bias collections from clean waters.

Trace metal analyses of both freeze concentrated waters and benthic organisms indicated the usefulness of benthic forms for integration of the metal content of overlying waters and to serve as a screening device in water quality surveys. None of the metals assayed (Hb, Pb, Cd, Cr, and Zn)were present in the New Hope or lower Haw Rivers in concentrations which exceeded U. S. Public Health Water Quality Standards.

Recommendations

1. If New Hope Lake is to achieve its optimum use as a recreational body of water serving the population of Orange, Chatham and Wake Counties, it is essential that steps be taken to increase the extent of nutrient removal from the treated Chapel Hill and Durham sewage effluents that are now entering the New Hope drainage.
2. Although the flow in the Haw River is transporting larger quantities of polluting materials than that of the New Hope River, the much shorter residence time of this flow in New Hope Lake argues that efforts to improve treated wastewater effluents be focused on the specific Chapel Hill and Durham treatment plants.
3. The implication that the waters of the Haw and New Hope Rivers are relatively free of phenolic and chlorinated carbon compounds should be confirmed by examination of river bottom sediments for these substances to see if they might have been adsorbed onto the sediments. This might also include sediment samples upstream of Saxapahaw (Station H-1) to establish their absence from the river as one approaches the more polluted segments of the Haw River in the vicinity of Burlington and Greensboro.

INTRODUCTION

Systematic water sampling of the New Hope and lower Haw Rivers was initiated in June 1966 and continued through February 1970 by Weiss (1). This study established major differences between the water quality of the two rivers. In the Haw River, the substantial organic pollution loads were found to have undergone degradation and recovery cycles by the time the flow had reached station H-5 at the head of the arm of New Hope Lake which will form along the channel of the Haw. In contrast, the New Hope River at its junction with the Haw was still polluted. The Durham and Chapel Hill wastewater loads, which were discharged into the headwater streams of the New Hope, had not completed the cycle of degradation and recovery. At the upstream end of the conservation pool, which will form along the river channel of the New Hope, water quality parameters were indicative of excessive pollution.

The present investigation (January 1971 through March 31, 1972) continued and expanded the sampling of these two rivers to further our knowledge of the potential water quality of New Hope Lake. The construction of New Hope Dam started in December 1970, and is on schedule. The anticipated closing of the sluice gates will probably be in late 1973 or early 1974. The state of construction of the New Hope Dam on April 27, 1972 is shown in Figure 1.

The expansion of the sampling station network included sampling points on several of the small feeder streams so that the characteristics of the water draining the bordering land might be established. In addition, benthic macroinvertebrates were systematically collected to provide a measure of pollutional effects as described by their types, numbers, and diversity. Metal analyses were carried out on water samples as well as on the tissues of the benthic organisms. The organic constituents of the water were examined

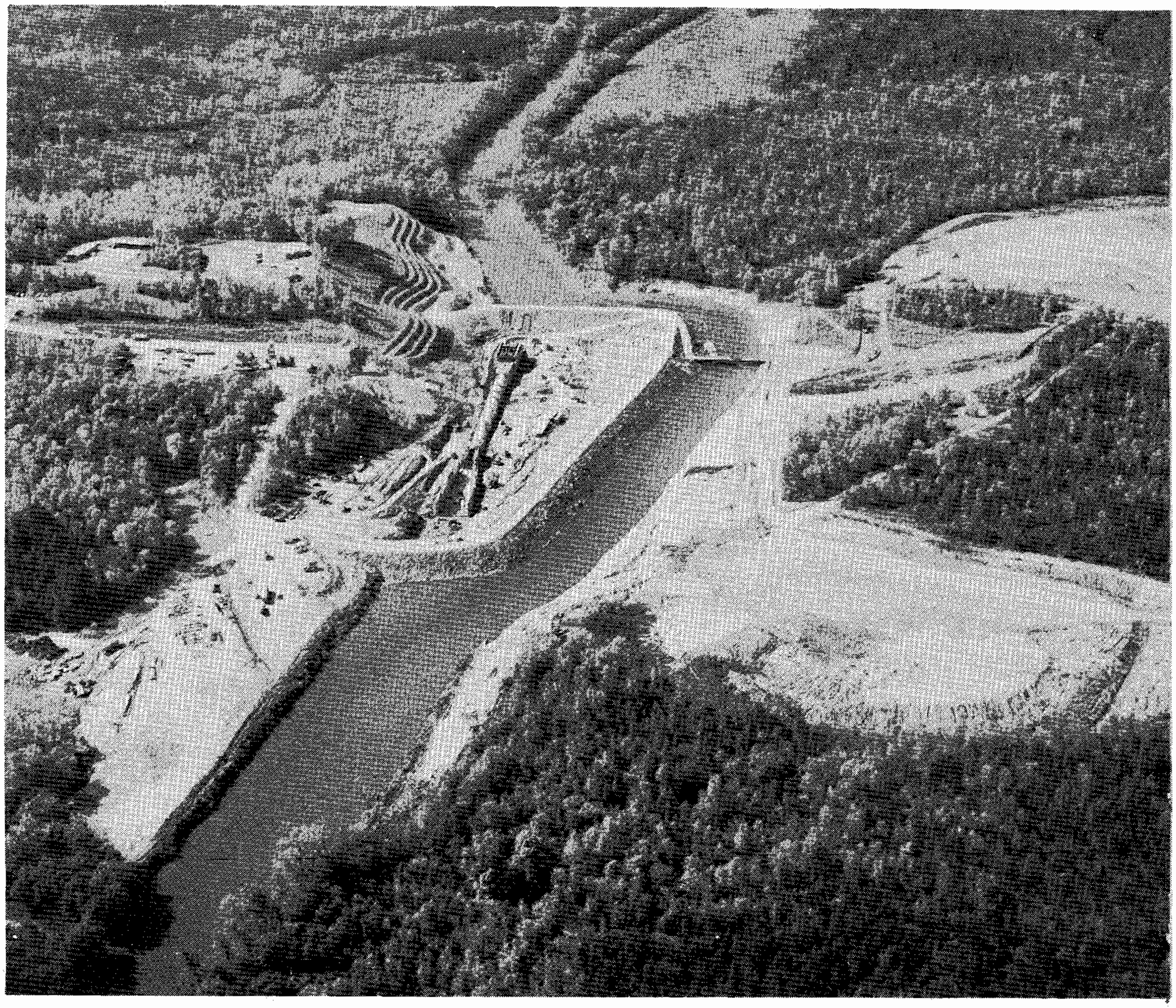


Fig. I Construction Status, New Hope Dam
April 27, 1972

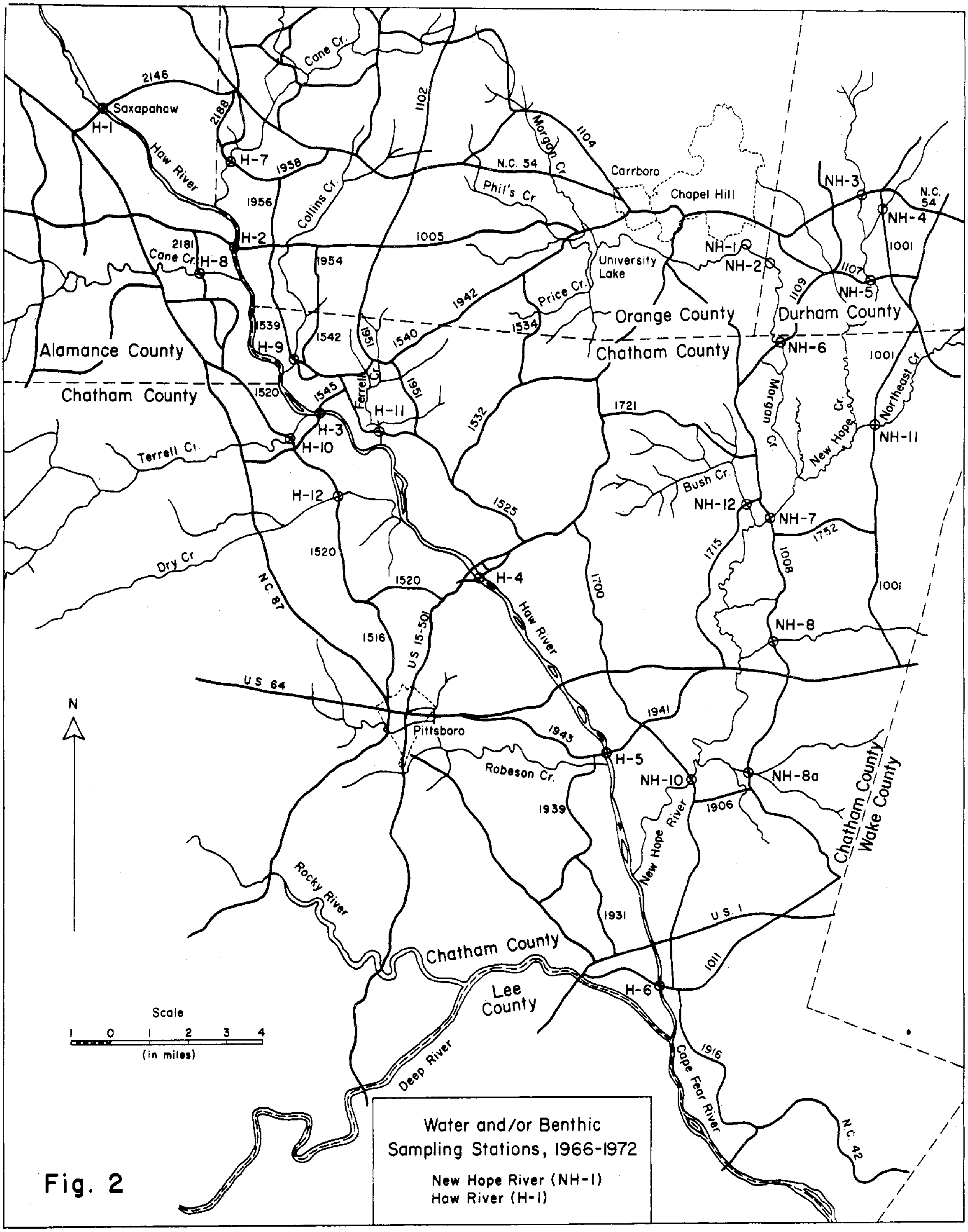
on freeze concentrated samples using flame ionization and electron capture detectors and suitable gas chromatographic columns.

Station Network

It is evident that the characteristics of water draining from land adjacent to the New Hope and lower Haw Rivers will become increasingly significant in terms of the water quality in New Hope Lake. Thus, in the current study additional "control" streams with suitable sampling points were established. They were sampled twice monthly. Figure 2 shows all the water and benthic sampling stations for the period 1966-1972. Station numbers preceded by an "H" are on the Haw and those preceded by NH are on the New Hope. A station of particular interest is NH-11 on Northeast Creek which receives drainage from the Research Triangle Area and from the primary sewage oxidation ponds operated for Durham County by the City of Durham. On both sides of the Haw River between Station H-1 at Saxapahaw and H-5 at the future headwater of one arm of New Hope Lake the Haw River flows southeasterly across Chatham County. Both to the northeast and southwest of the main river there are several small streams that flow in parallel courses to the main stem. On six of these streams, three each on the two drainages, northeast and southwest, additional control stations have been established to evaluate water quality characteristics of the land use and land forms of this area.

Analytical Procedures

The introduction of new parameters has provided additional insight into this study. Several old parameters were deleted because of the changing nature of their information and relevance to the questions of quality that are under consideration. Table 1 lists the data collected in the period



Water and/or Benthic
Sampling Stations, 1966-1972

New Hope River (NH-1)
Haw River (H-1)

Fig. 2

Table 1
Comparison of Water Quality Parameters
Used in Surveys of 1966 - 1970 and January 1971 - March 1972

	1966-1970	Jan. 1971-March 1972
Temperature °C	X	X
Residue mg/l	X	X
Turbidity, Jackson Turbidity Units	X	X
Conductivity µmhos	X	X
Dissolved Oxygen	X	X
DO % Saturation	X	X
BOD_5 mg/l	X	X
Total Carbon mg/l	-	X
Total Soluable Carbon mg/l	-	X
Inorganic Carbon mg/l	-	X
Total Nitrogen mg/l	X	X
Organic Nitrogen mg/l	X	X
NH_3-N mg/l	X	X
NO_2-N mg/l	X	-
NO_3-N mg/l	X	-
NO_2+NO_3-N mg/l	-	X
Total Phosphorus mg/l	X	X
Total Inorganic Phosphorus mg/l	X	-
PO_4-P (soluable orthophosphate)mg/l	X	X
pH	X	X
Chlorophyll Klett Units	X	X
Total Coliforms	X	X
Fecal Coliforms	-	X
Enterococci (Fecal Streptococci)	X	X

1966-70 and the present parameters for comparison. The basic physical, chemical and biological descriptions have been continued with the addition of the direct determinations of carbonaceous materials --both total, soluble, and inorganic--using a Beckman 915 total organic carbon analyzer. In the latter period there was also a change in the method of describing the nitrogenous materials. NO_2-nitrogen and NO_3-nitrogen were combined into one parameter (NO_2+NO_3-N). NO_2-N had been **present** in such consistently small amounts that continued individual determination was not justified. The particular procedure on the Technicon Autoanalyzer lends itself to ready modification to describe all oxidized nitrogenous species that are present as NO_2 or NO_3. In similar fashion the determination of total inorganic phosphorus was dropped since the determination of soluble ortho-phosphate (PO_4-P) described all inorganic forms of phosphorus that might be present. The addition of fecal coliforms for description of index organisms of recent human contamination was added to the biological descriptions. Fecal streptococci are now referred to as enterococci.

The additional analytical procedures required to describe trace organics of exotic nature or the metals that were present both in water and in animal tissue will be described in the sections in which those particular experiments are discussed.

Water Quality Characteristics

January 1971 - March 1972

General Quality Parameters

In the current period of water quality surveillance the stations on the New Hope and Haw River drainages were sampled approximately twice monthly with a total set of data reflecting values determined from 28-31 samples from each of the stations. The statistical analysis of all data collected in this period is summarized in Appendices A-1 to A-20 for the Haw River series; and B-1 to B-20 for the New Hope series. The statistical presentation that was used in the earlier report (1) on water quality of these rivers is repeated.

The period of current record, January 1971 through March 1972 introduces a slight winter bias to several water quality parameters, particularly the non-conservative characteristics whose quantities might be temperature dependent. In order that long-term trends of water quality in any river system receiving both conservative and nonconservative substances from both natural and man-made sources be established, a correction for seasonal variation is required. Such an analysis for the period of 1966-1972 is in preparation and will be reported separately (2).

The averaged values for the water quality parameters at each station sampled between January 1971 and March 1972 have been assembled in Table 2 for the New Hope drainage and Table 3 for the Haw River drainage. In these tables the stations affected directly by wastewater discharges or by upstream sources are separated from nonpolluted control stations. For those water quality sampling stations at or close to USGS gauging stations, (NH-10, H-5

Table 2

New Hope Drainage
Average Magnitude of Quality Parameter Based on 28-31 Samples
January 1971 - March 1972

Water Quality Parameter	Station	Stations Receiving Waste Water Discharges Directly or By Downstream Flow								Control Stations	
		1	2	4	5	6	7	10	11	8	8A
Temperature °C		13.5	13.7	13.1	13.4	14.0	13.3	13.5	13.4	12.9	13.1
Residue mg/l		6.0	7.9	22.0	12.0	9.1	9.9	18.2	19.6	7.1	10.3
Turbidity JT Units		27.3	27.6	55.6	42.0	31.5	40.5	48.2	59.8	24.3	38.8
Conductivity μ mhos		118	167	283	188	179	142	113	152	69	64
DO mg/l		8.8	6.7	4.2	5.0	4.9	6.5	7.9	7.1	8.9	8.5
DO % Sat.		80.5	59.7	36.5	44.5	44.1	59.1	72.6	63.7	81.1	77.0
BOD_5 mg/l		4.1	6.7	6.9	4.7	5.4	3.0	2.0	2.6	2.0	1.7
Total Carbon mg/l		13.8	23.5	36.2	22.4	22.6	18.0	16.3	21.6	13.0	13.4
Total Soluble Carbon mg/l		13.0	20.5	31.3	20.3	21.3	17.2	15.3	19.6	13.9	12.9
Inorganic Carbon mg/l		5.1	10.0	15.1	8.6	10.1	5.4	3.6	7.7	1.7	1.4
Total N mg/l		1.74	5.20	6.93	4.16	5.16	2.76	1.33	0.88	0.45	0.56
Organic N mg/l		0.30	1.01	1.15	8.74	1.13	0.44	0.31	0.40	0.33	0.32
NH_3-N mg/l		0.46	3.39	3.58	2.17	3.64	0.84	0.18	0.13	0.0	0.0
NO_2+NO_3-N mg/l		0.97	0.93	2.41	1.50	0.66	1.58	0.83	0.38	0.07	0.17
Total Phosphorus mg/l		0.38	1.66	2.79	1.41	1.49	0.98	0.60	0.47	0.10	0.23
PO_4-P mg/l		0.24	1.30	2.57	1.24	1.36	0.77	0.37	0.23	0.02	0.03
pH		6.8	6.9	6.8	6.9	7.0	6.9	6.9	6.9	7.0	6.9
Chlorophyll-klett Units		6.1	6.9	4.0	3.6	5.3	3.4	3.5	6.1	2.8	3.3
Total Coliform*		2439	14276	195	247	2447	52	37	12	13	23
Fecal Coliform*		112	1018	140	71	552	15	16	3.5	5.2	20
Enterococci*		16	89	19	8.9	27	7.5	11	6.8	14	14

*NO/100 ml ($X10^2$)

Table 3

Lower Haw River Drainage
Average Magnitude of Quality Parameter Based on 28-31 Samples
January 1971 - March 1972 (Inclusive)

Water Quality Parameter							Control Stations					
	Main Stream Stations						N.E. Watersheds			S.W. Watersheds		
Station	1	2	3	4	5	6	7	9	11	8	10	12
Temperature ^{o}C	14.8	14.5	14.7	14.8	14.8	14.7	13.3	13.4	13.0	13.7	13.9	13.8
Residue mg/l	10.7	15.2	16.5	9.5	11.9	14.9	16.8	5.2	4.7	38.1	9.8	6.5
Turbidity JT Units	41.2	43.7	42.8	36.6	38.9	47.0	48.3	26.9	24.6	43.7	39.8	23.0
Conductivity μ mhos	197	189	161	166	159	146	84	71	81	80	79	72
DO mg/l	9.2	8.2	8.7	8.9	10.1	9.0	9.4	8.8	9.3	9.1	9.3	9.6
DO % Sat.	86.7	76.7	82.0	84.7	97.0	85.5	87.4	80.8	85.4	84.5	86.8	88.9
BOD_5 mg/l	4.8	4.1	3.3	2.8	2.5	2.7	2.0	1.5	1.3	1.8	1.7	1.9
Total Carbon mg/l	21.1	20.5	19.4	17.7	17.2	17.8	11.9	12.4	12.2	12.7	13.0	11.1
Total Soluble Carbon mg/l	19.6	18.5	17.3	16.4	15.7	16.1	10.6	12.8	12.7	12.3	12.0	11.3
Inorganic Carbon mg/l	8.3	8.0	7.0	6.8	5.4	4.5	2.9	2.0	4.1	3.0	2.4	2.1
Total N mg/l	1.95	1.91	1.77	1.64	1.51	1.34	0.78	0.64	0.35	0.19	0.74	0.60
Organic N mg/l	0.45	0.43	0.40	0.33	0.37	0.30	0.23	0.28	0.17	0.22	0.24	0.20
NH_3-N mg/l	0.74	0.48	0.26	0.21	0.18	0.19	0.08	0.04	0.05	0.10	0.08	0.11
NO_2 + NO_3-N mg/l	1.00	1.20	1.11	1.09	0.96	0.85	0.52	0.32	0.13	0.50	0.43	0.35
Total P mg/l	0.66	0.68	0.63	0.52	0.48	0.45	0.10	0.07	0.06	0.10	0.09	0.06
PO_4=P mg/l	0.46	0.48	0.43	0.38	0.35	0.29	0.03	0.03	0.02	0.04	0.03	0.02
PH	7.0	7.1	7.1	7.2	7.4	7.2	7.2	7.1	7.1	7.1	7.1	7.0
Chlorophyll Klett Units	8.2	7.2	7.7	6.5	5.6	5.4	3.2	2.8	3.1	3.4	4.0	3.0
Total Coliforms *	331	340	209	71	90	72	32	14	16	77	58	19
Fecal Coliforms*	75	52	45	28	25	22	24	4.5	4.0	21	26	11
Enterococci*	5.9	14	11	8.1	11	11	19	6.5	8.0	18	22	10

*NO/100 ml ($X10^2$)

and H-6), the data were used to compute mass transport values for those water quality parameters defined by weight per unit volume. These data are assembled in Table 4 for the same period of record.

As noted, comparison of the present water quality data with that of the previous record (1) is difficult due to the relative time interval of the sample period as well as the degree of wetness or dryness of a particular year. This introduces a flow bias into long-term trends. In the present summary, basic comparisons are limited to the characteristics of the main drainage and control stations so that the information is essentially restricted to the context of the current period of sampling.

In the stream and river system of the New Hope, the key stations relevant to the proposed conservation pool of New Hope Lake are stations NH-5, NH-6 and NH-7 which are located just upstream of the conservation pool of the New Hope Lake, and NH-10 which eventually will be submerged by the filling of the lake. Stations NH-8 and NH-8A located on the small streams, White Oak and Beaver creeks respectively, will continue to drain into the main body of the lake. Station NH-11 is currently receiving effluent from primary oxidation ponds serving the Research Triangle area. Eventually, when the biological treatment plant for this area is completed, these oxidation ponds will serve as tertiary ponds. Station NH-11 has been sampled systematically over this current period of record.

Currently, self purification and assimilation of non-conservative pollutants takes place to an extended degree in the New Hope River between stations NH-5, NH-6, NH-11 and NH-7 and continuing to NH-10. On the average, recovery from the impact of the BOD load was not completed by the time river flow reached station NH-10, and although oxygen saturation recovered only to about 72 percent this was quite close to the average value found at control

Table 4

Average Mass Transport of Selected Water Quality Parameters

	New Hope and Haw River Gauged Stations January 1971 - March 1972 Pounds/Day		
	New Hope 10	Haw 5	Haw 6
Residue	40144	286654	451484
DO	19139	81614	114922
BOD	4614	25909	39381
Total Carbon	37408	143532	232641
Total Soluble Carbon	32124	105023	176153
Inorganic Carbon	2910	35574	32711
Total Nitrogen	1598	9556	12831
Organic Nitrogen	664	2570	3660
NH_3-N	253	1701	2891
NO_2+NO_3-N	681	5251	6219
Total Phosphorus	571	4016	5225
PO_4-P	280	1922	2215

stations which were about 83 percent. The residual BOD at station NH-10, 2.0 mg/1,was very close to that of the control stations NH-8 and 8A with 2.0 and 1.7 mg/1 of BOD respectively. In parallel fashion the total, soluble and inorganic carbon components were only slightly greater at station NH-10 than those of the control stations. Of the nitrogenous water quality parameters determined at station NH-10, total nitrogen was higher than in the control streams by a factor of 3-4 ; the concentration of NO_3-N was 7-10 times greater than in the control. Total phosphorus was higher by a factor of 3-6 times but at station NH-10 it was considerably lower than in the vicinity of the wastewater discharges. The die off of the index organisms in the New Hope drainage was quite rapid with bacteriological quality at station NH-7 and NH-10 directly comparable to that found at the control station.

Analysis of the downstream changes along the main stem of the Haw River provides a clear illustration of the capability of a comparatively shallow, rapidly flowing, rough bottomed river to stabilize and assimilate upstream wastewater contributions. Not only is assimilation clearly indicated in the downstream sequence but also the change in quality can be compared to that of the control streams that flow into the Haw River from both the northeast and the southwest. To illustrate this point a series of diagrams representing the main stem of the Haw River and the sampled tributaries has been prepared to show the representative water quality for both conservative and non-conservative parameters (Figures 3-23).

The dilution effect of the control streams, even though small, was particularly evident in the characteristic change in conductivity, decreasing in downstream sequence from H-1 to H-6. Since the measure of conductivity represents ions in solution and is generally considered to be a measure of conservative pollutants this change in the conductance of the Haw is

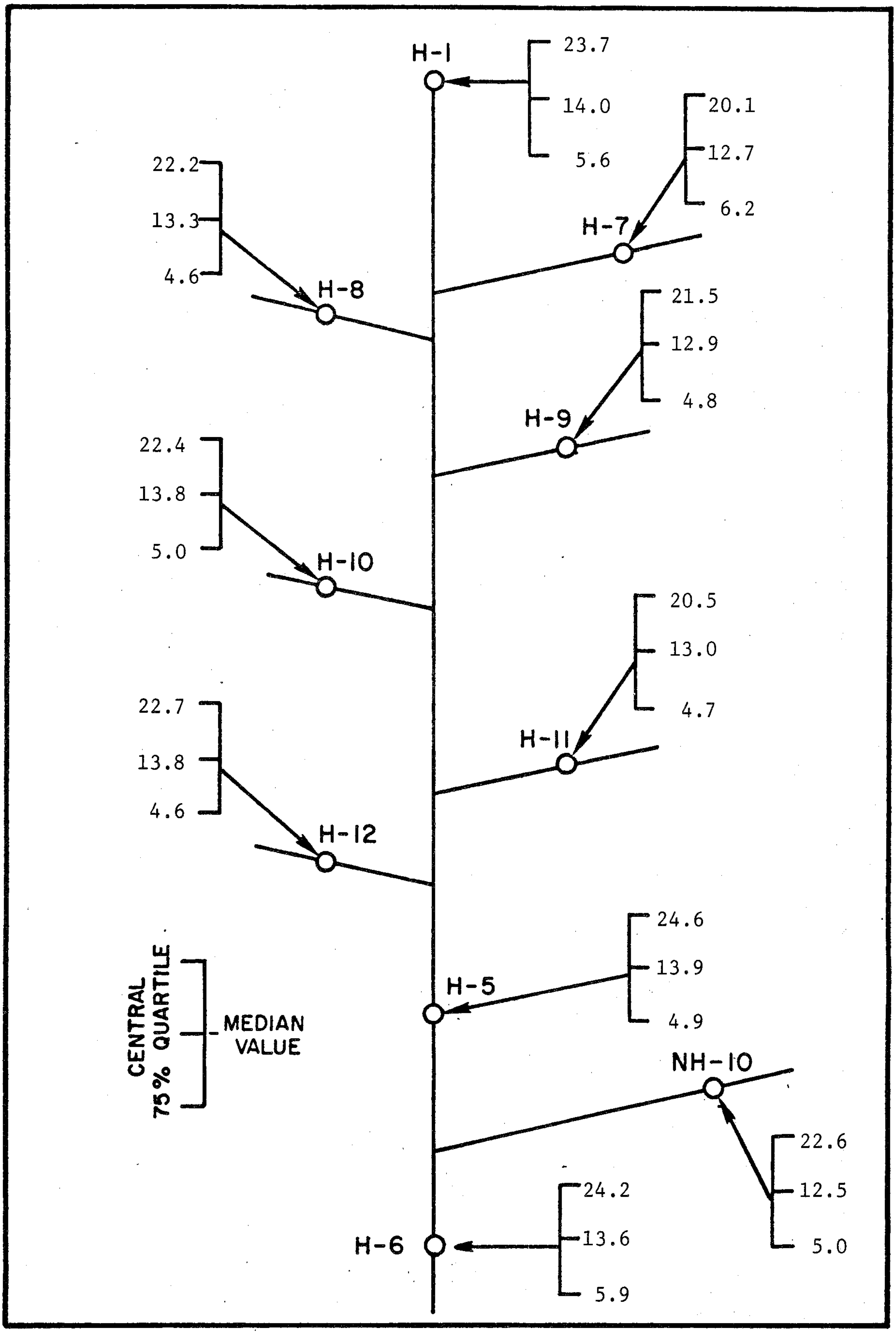


Fig. 3. Haw River stations, TEMPERATURE °C January 1971 - March 1972

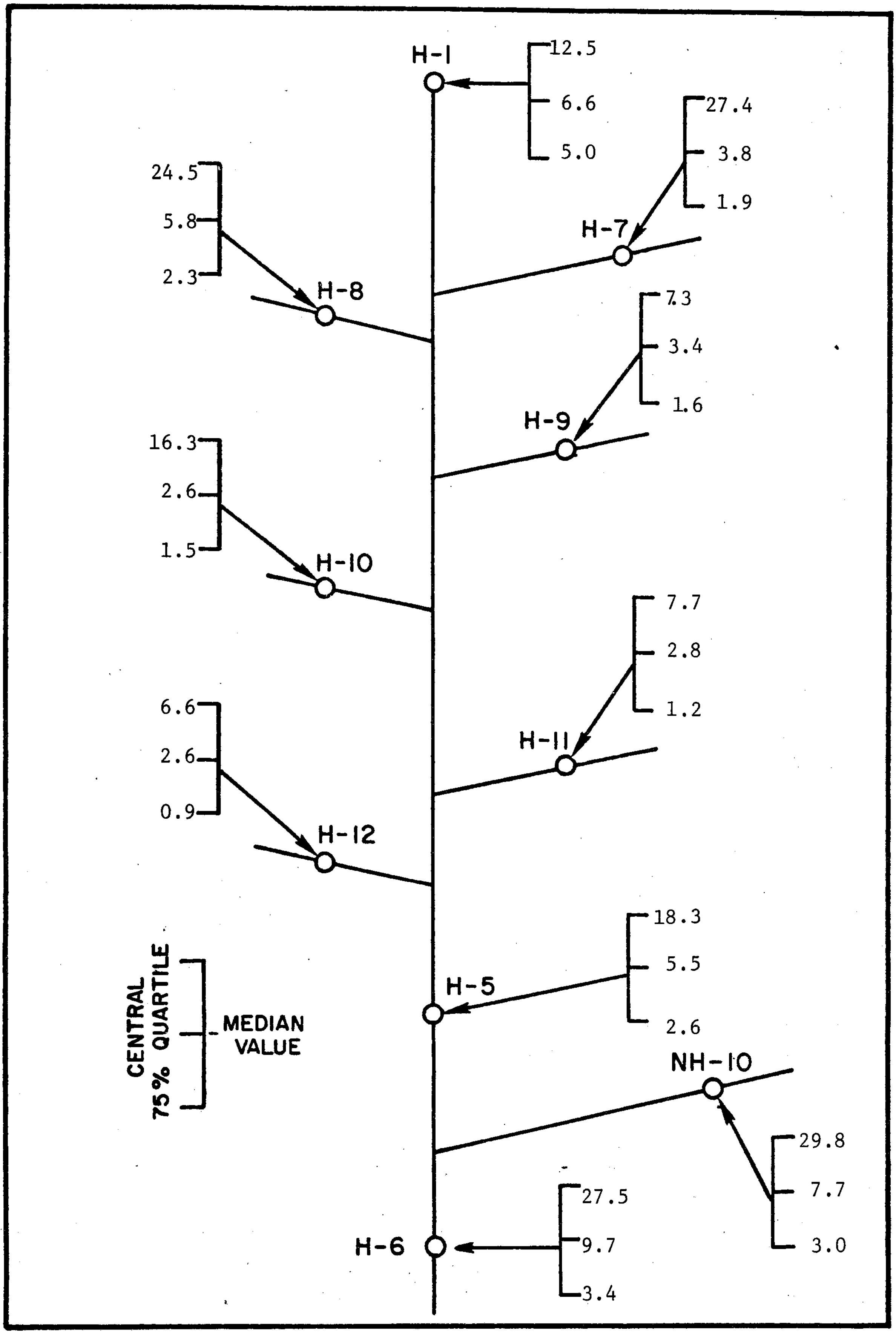


Fig. 4. Haw River stations, RESIDUE mg/1 January 1971 - March 1972

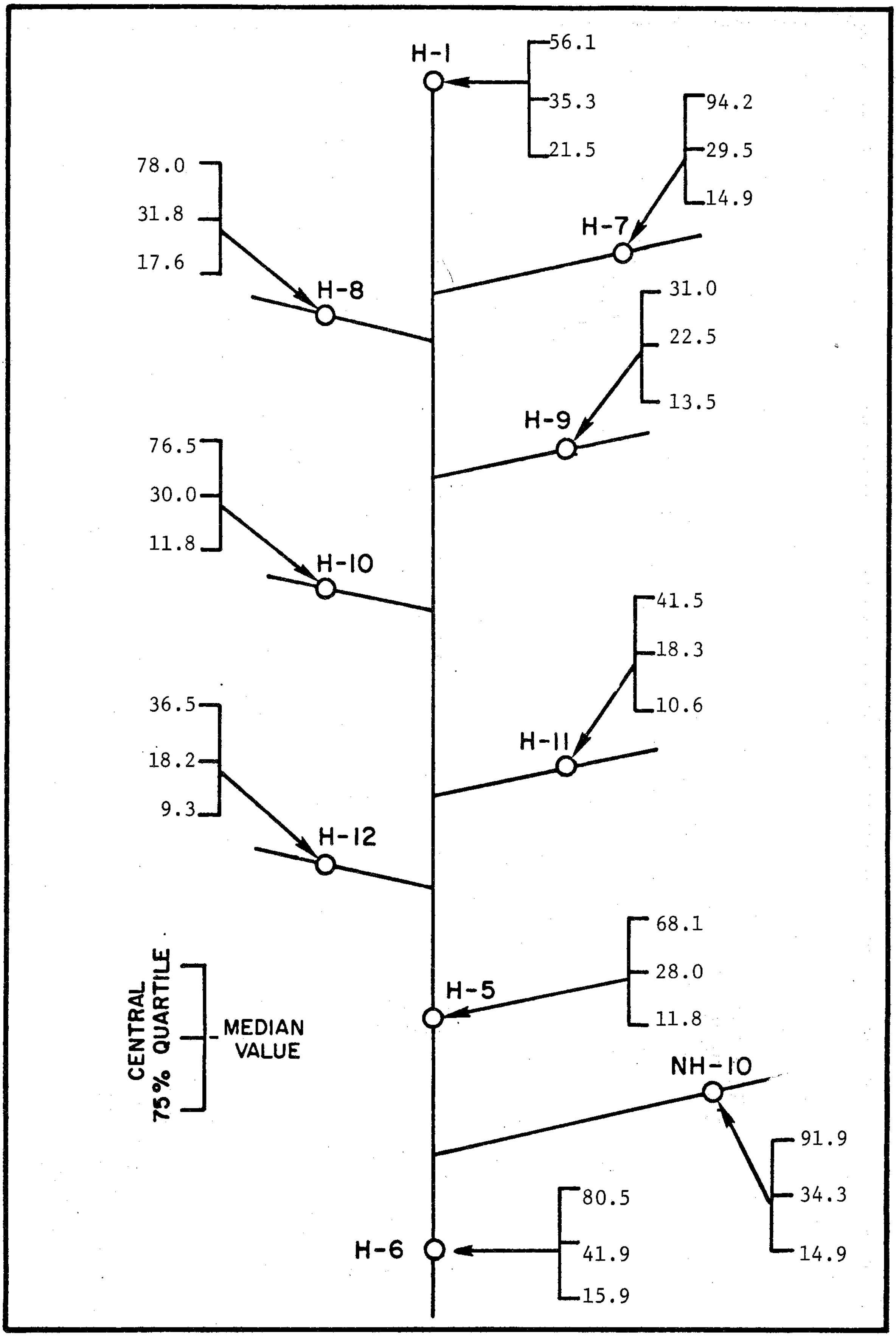


Fig. 5. Haw River stations, TURBIDITY JTU January 1971 - March 1972

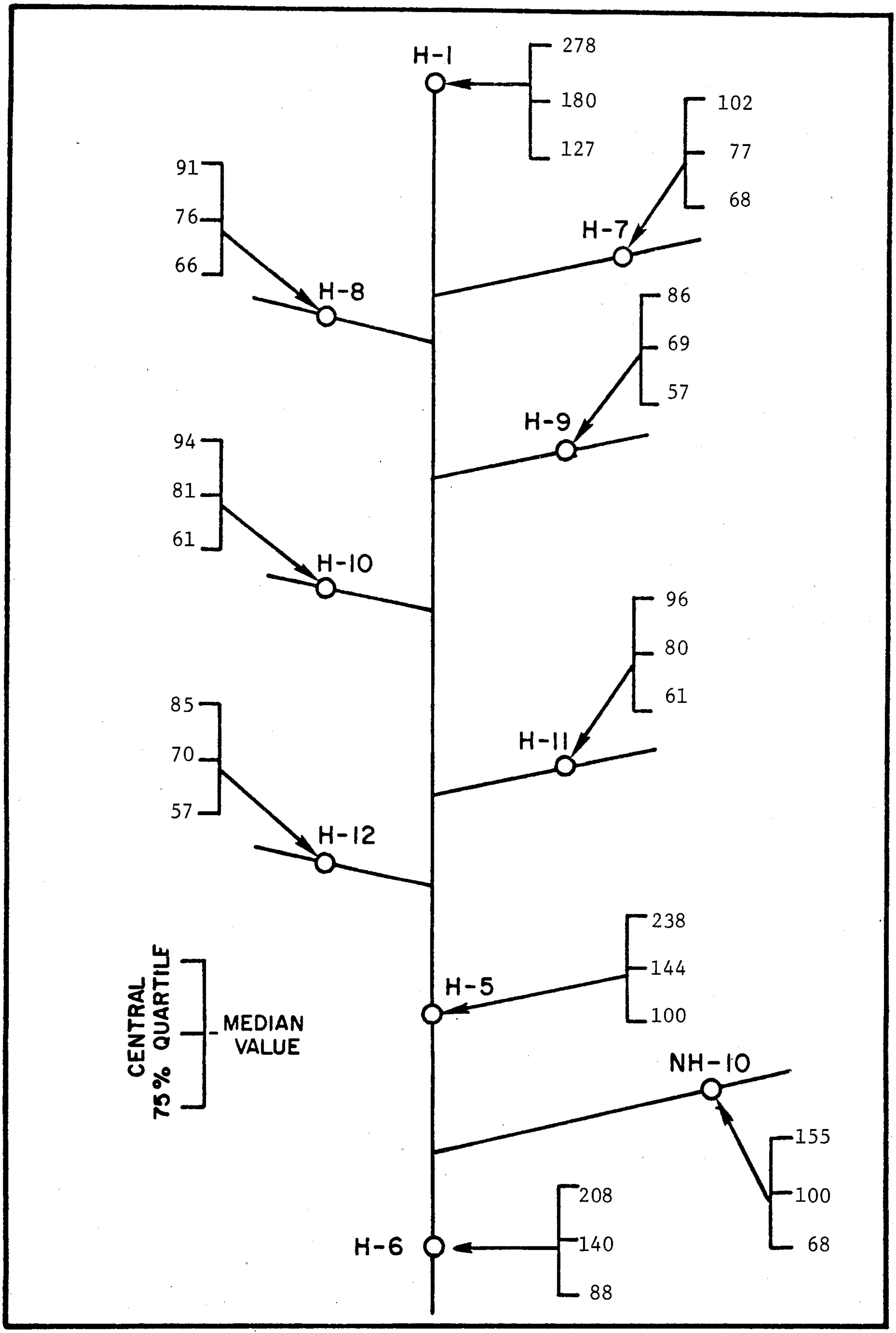


Fig. 6. Haw River stations, CONDUCTIVITY μmhos January 1971 - March 1972.

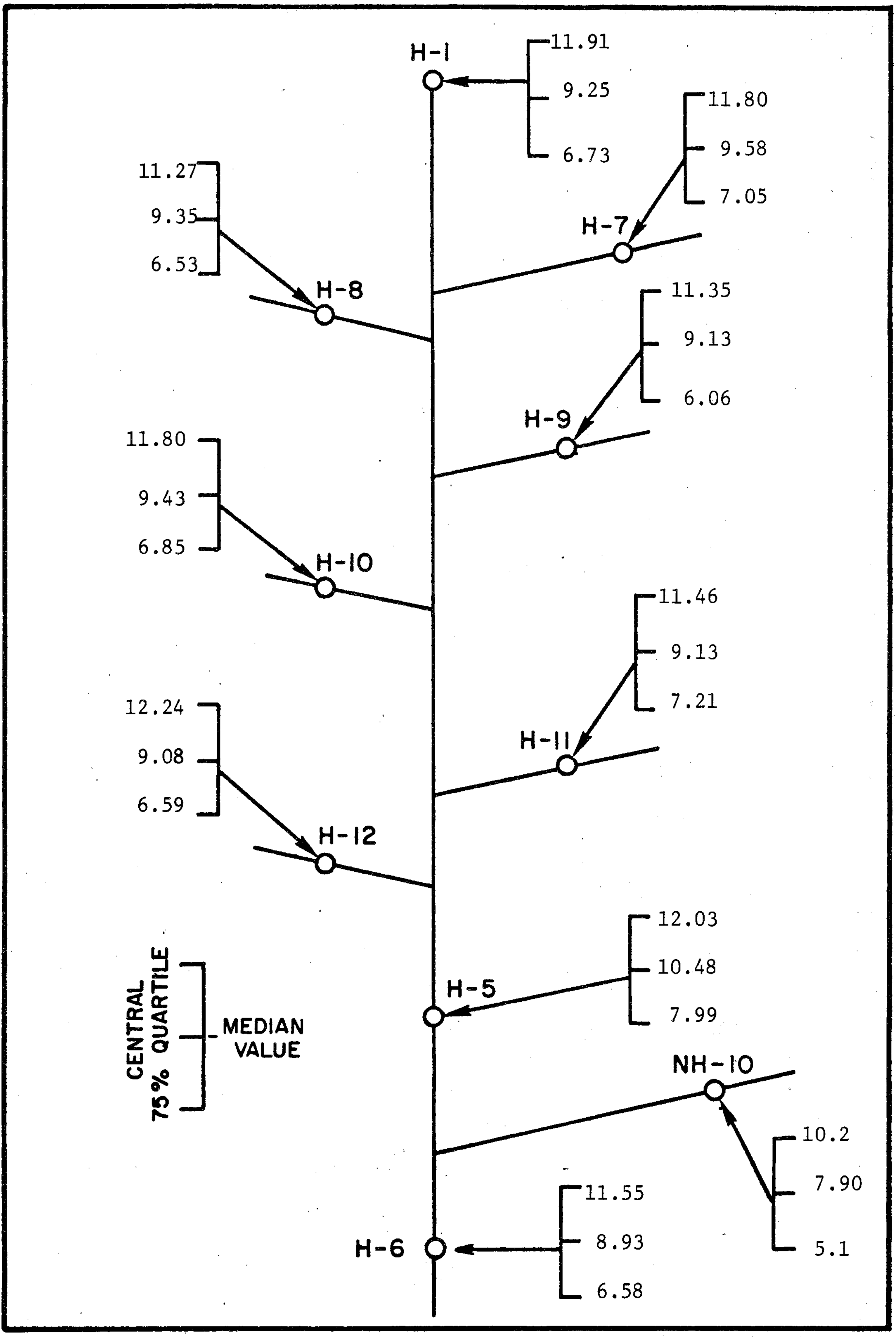


Fig. 7. Haw River stations, DISSOLVED OXYGEN mg/1 January 1971 - March 1972

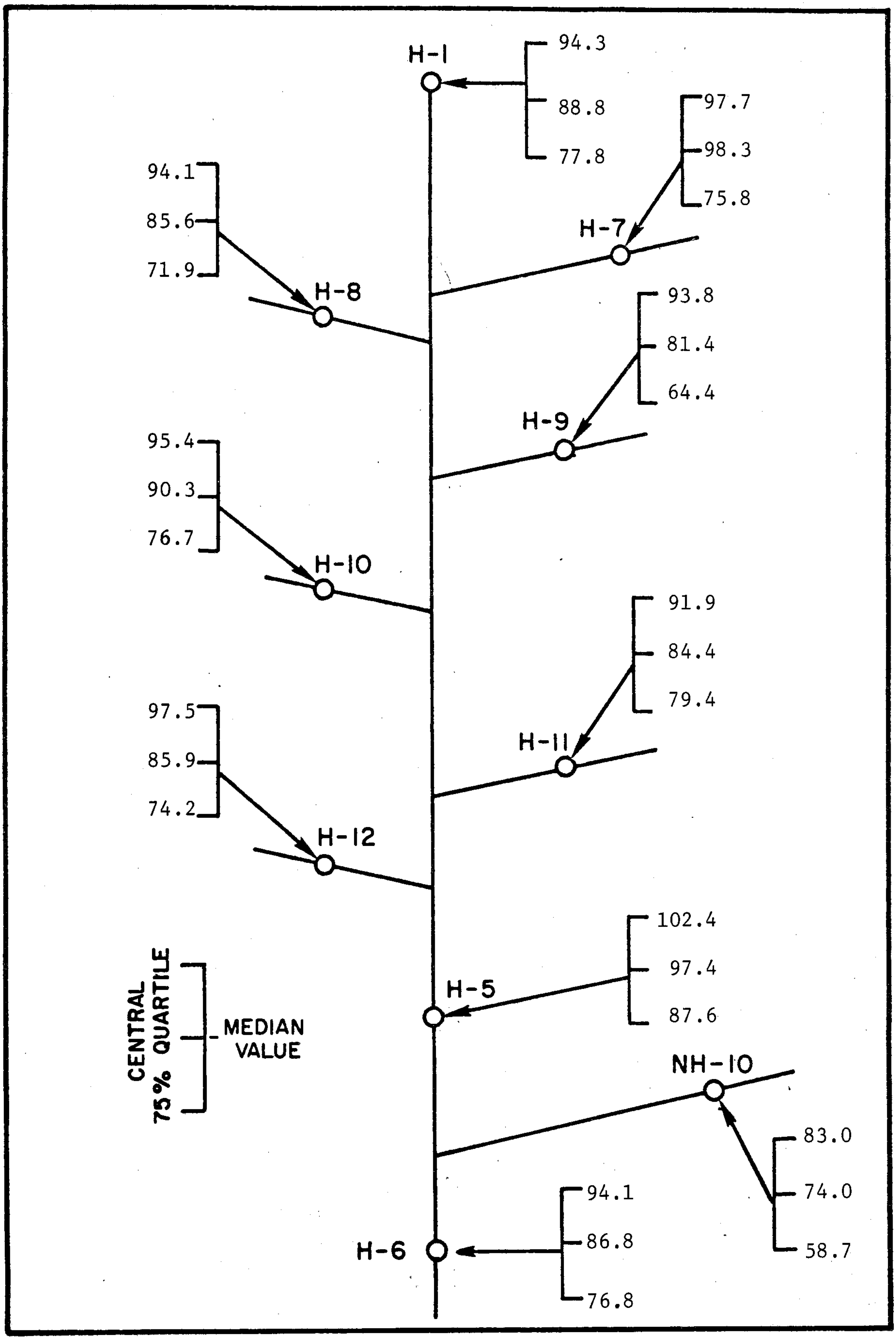


Fig. 8. Haw River stations, DO % SATURATION January 1971 - March 1972

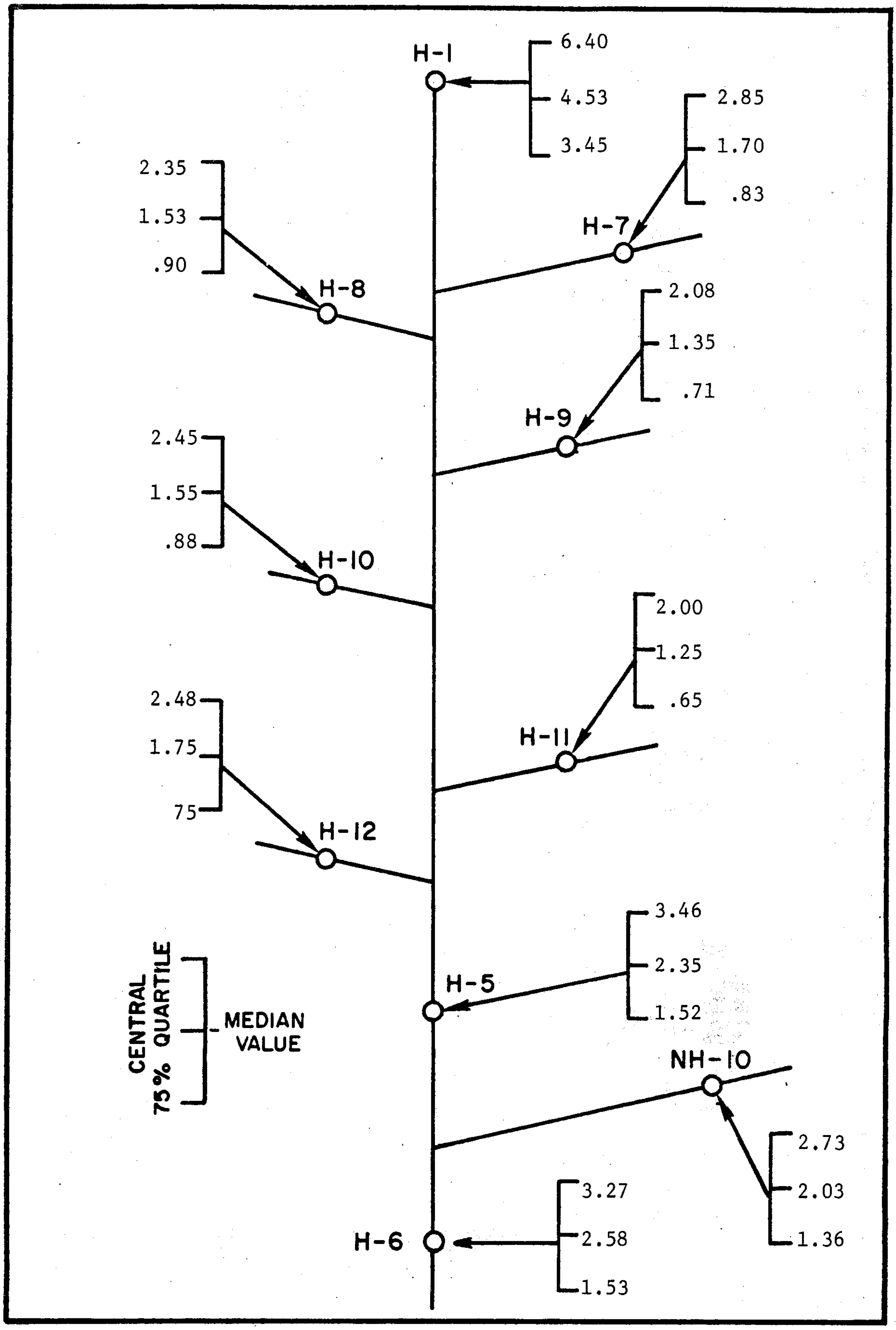


Fig. 9. Haw River stations, 5 DAY BOD mg/l January 1971 - March 1972

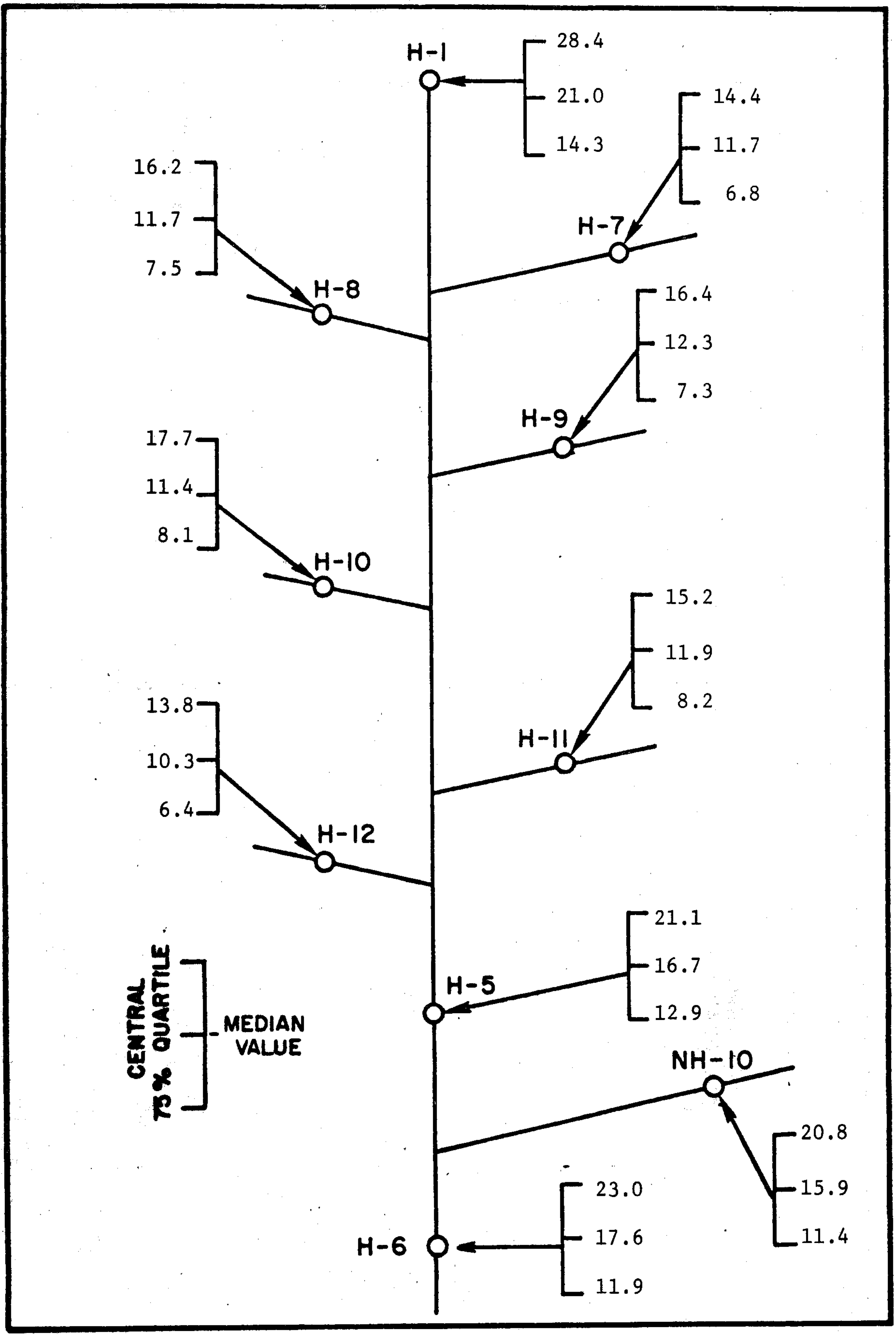


Fig. 10. Haw River stations, TOTAL CARBON mg/1 January 1971 - March 1972

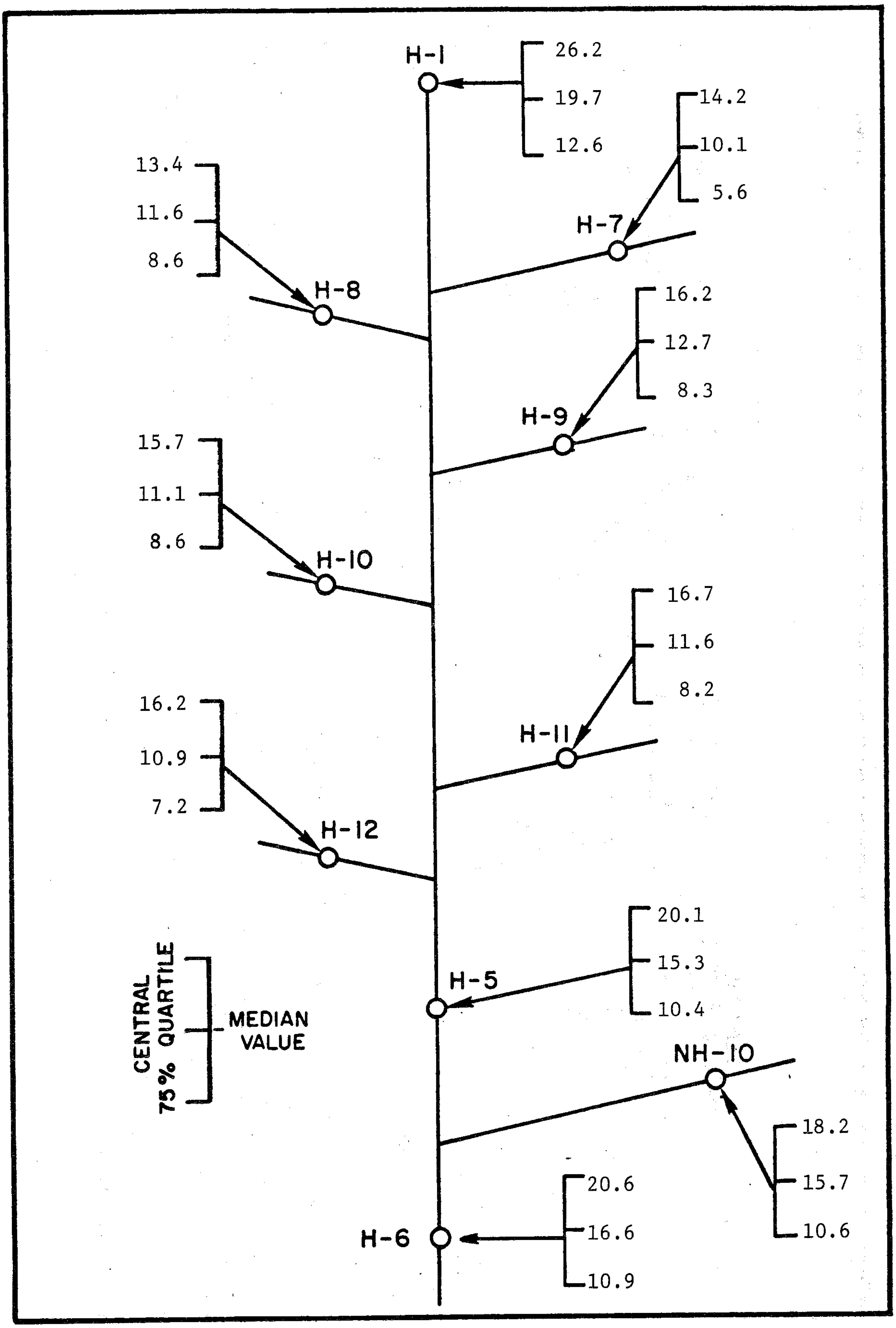


Fig. 11. Haw River stations, TOTAL SOLUBLE CARBON mg/1 January 1971 - March 1972

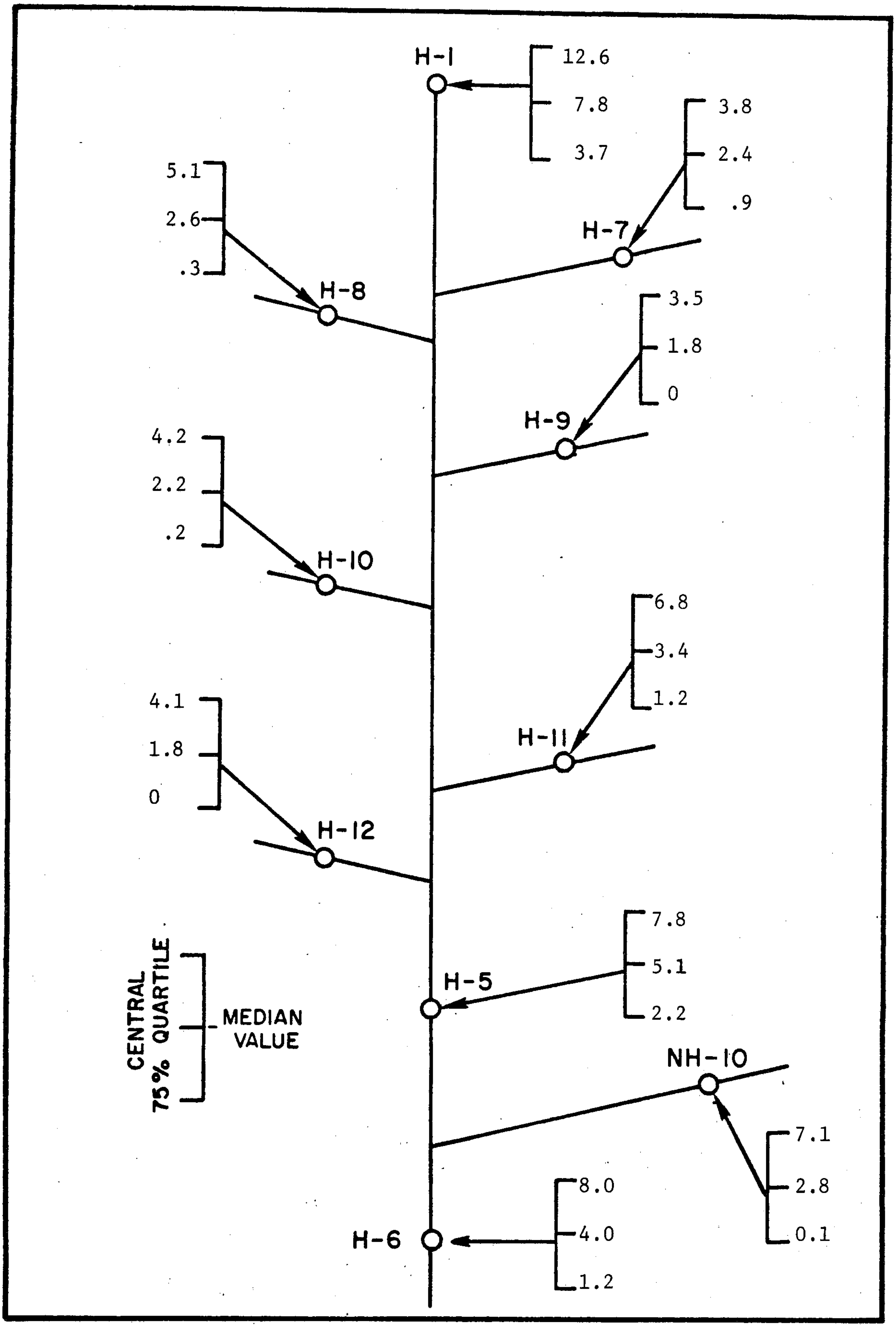


Fig. 12. Haw River stations, INORGANIC CARBON mg/1 January 1971 - March 1972

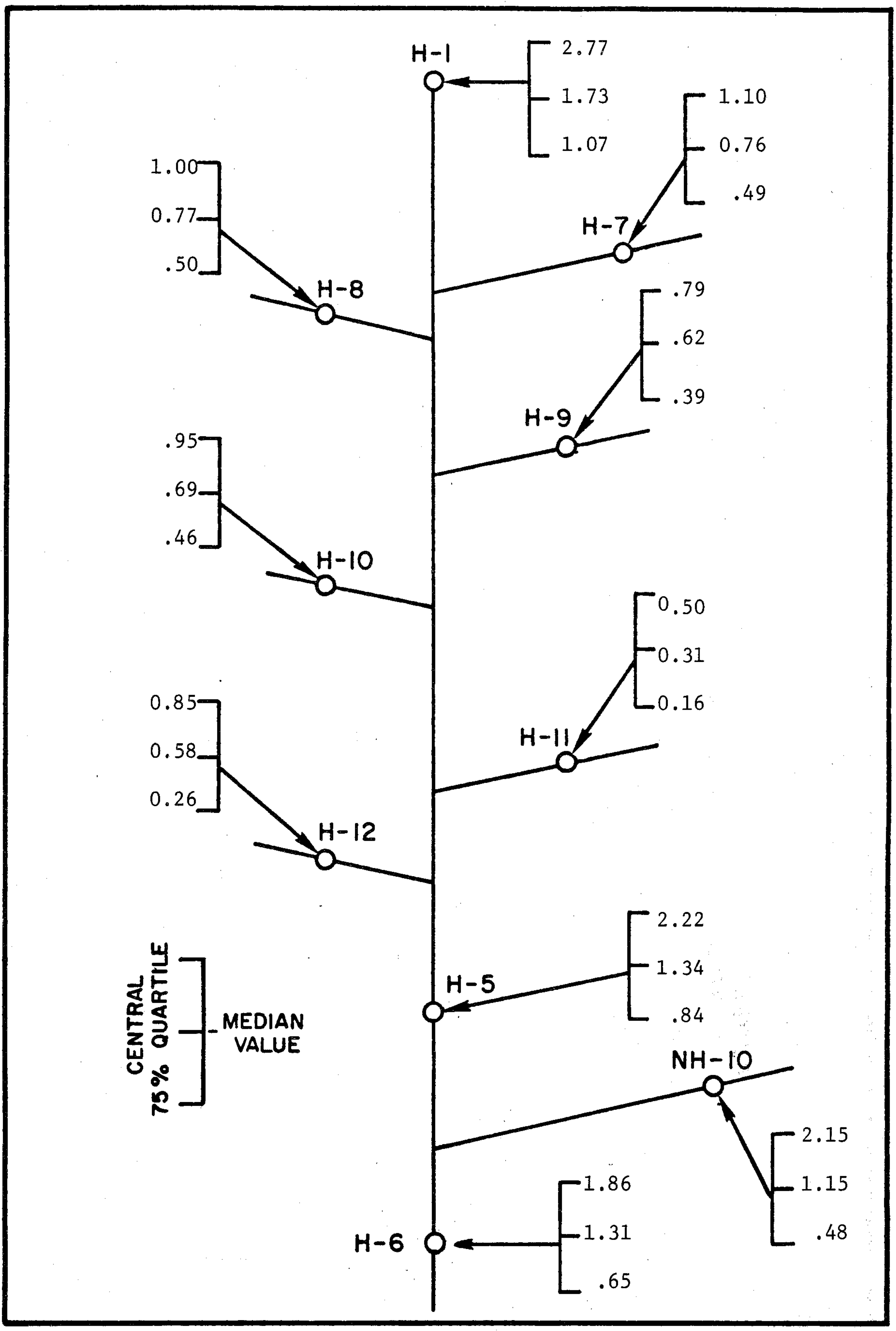


Fig. 13. Haw River stations, TOTAL NITROGEN mg/1 January 1971 - March 1972

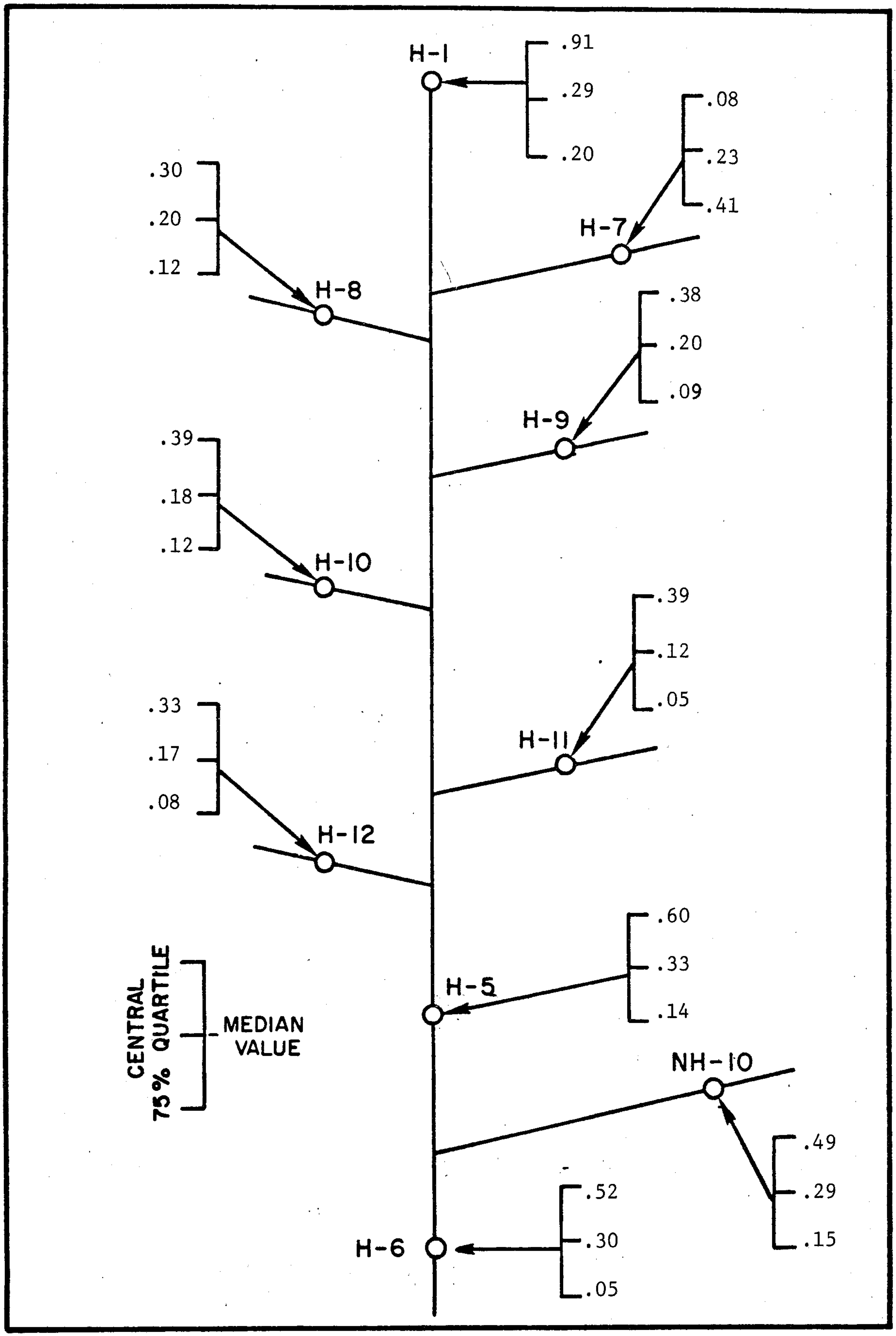


Fig. 14. Haw River stations, ORGANIC NITROGEN mg/1 January 1971 - March 1972.

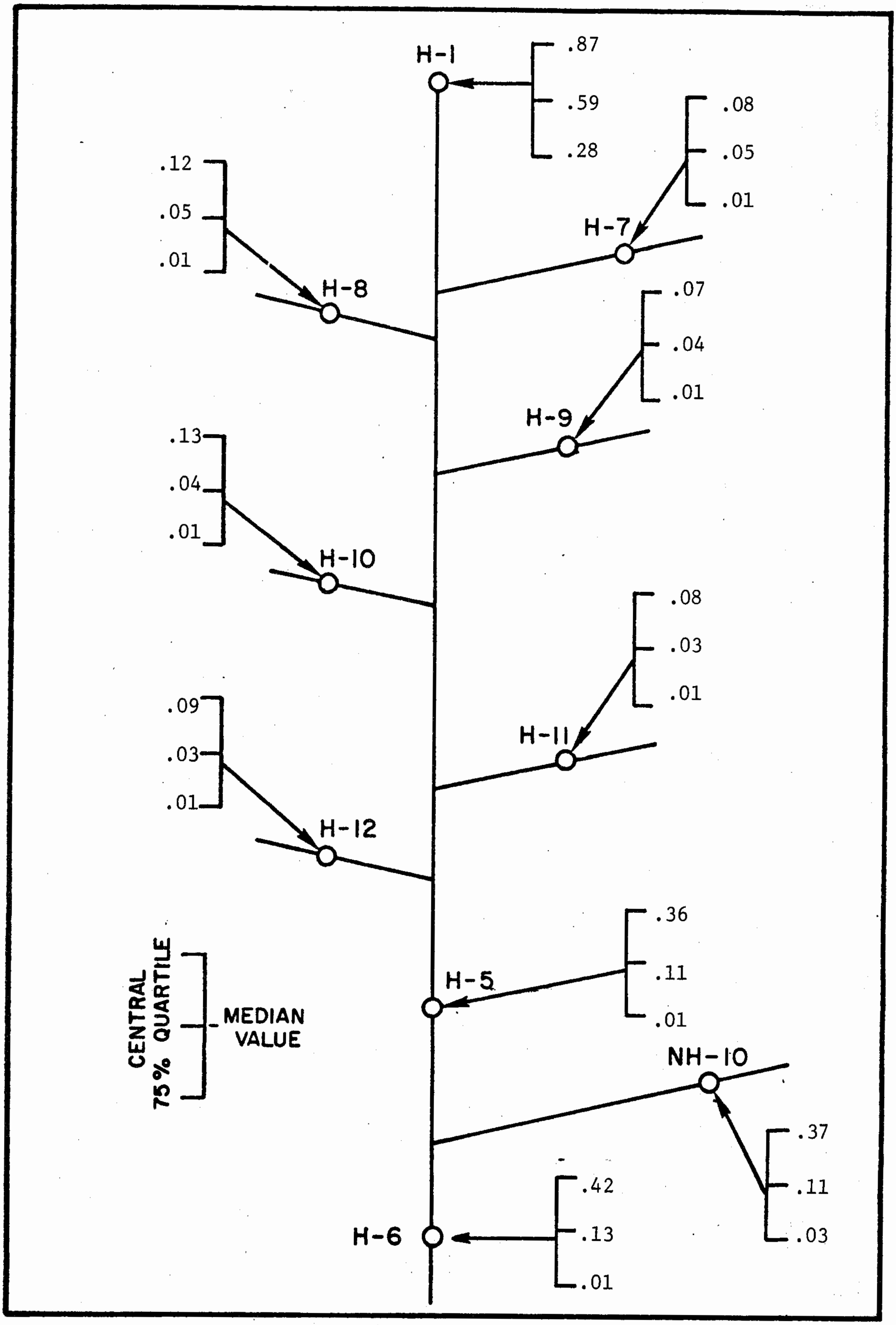


Fig. 15. Haw River stations, AMMONIA NITROGEN mg/1 January 1971 - March 1972

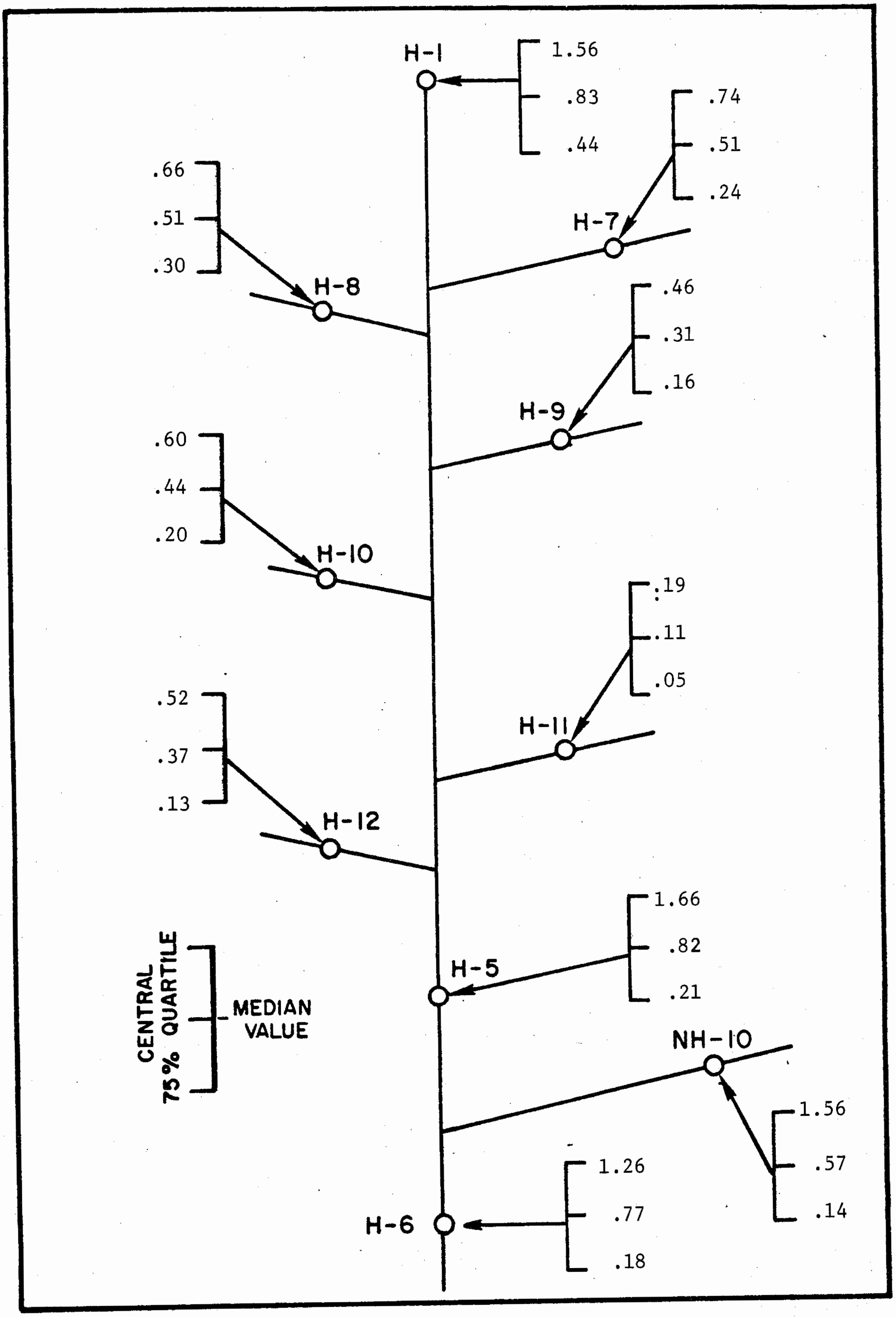


Fig. 16. Haw River stations, NITRITE AND NITRATE NITROGEN mg/1 January 1971 - March 1972

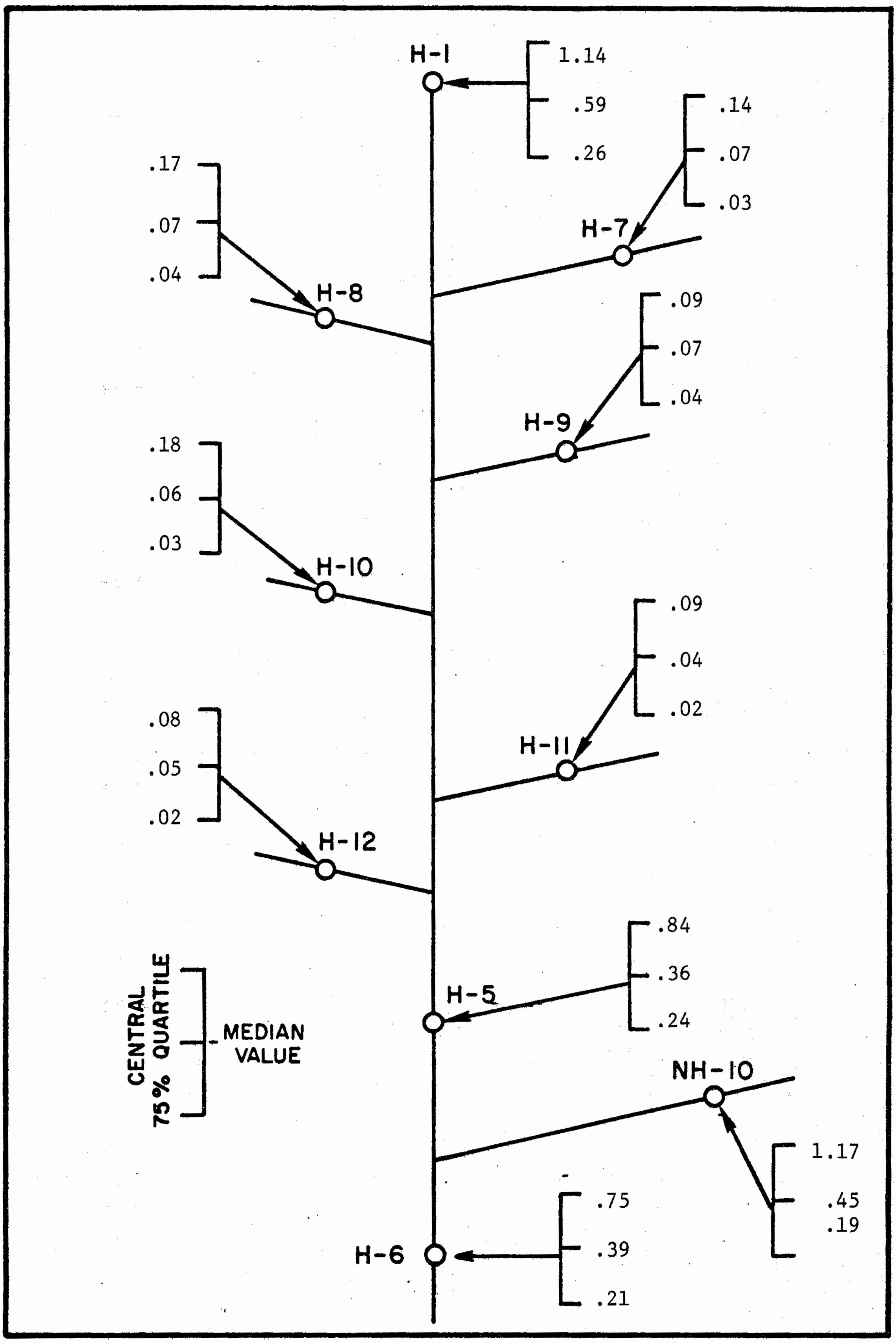


Fig. 17. Haw River stations, TOTAL PHOSPHORUS mg/1 January 1971-March 1972

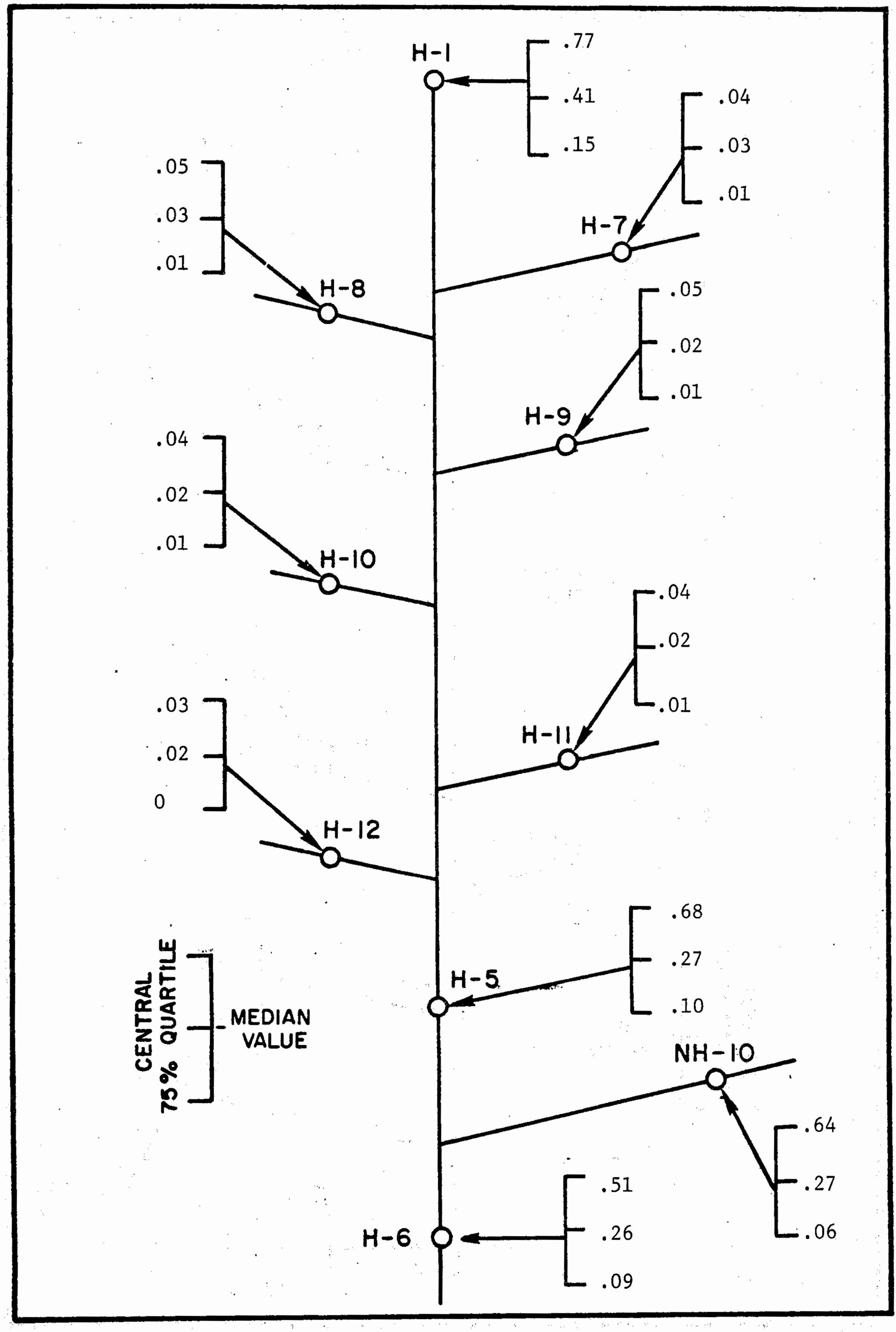


Fig. 18. Haw River stations, ORTHOPHOSPHATE-P mg/l January 1971-March 1972

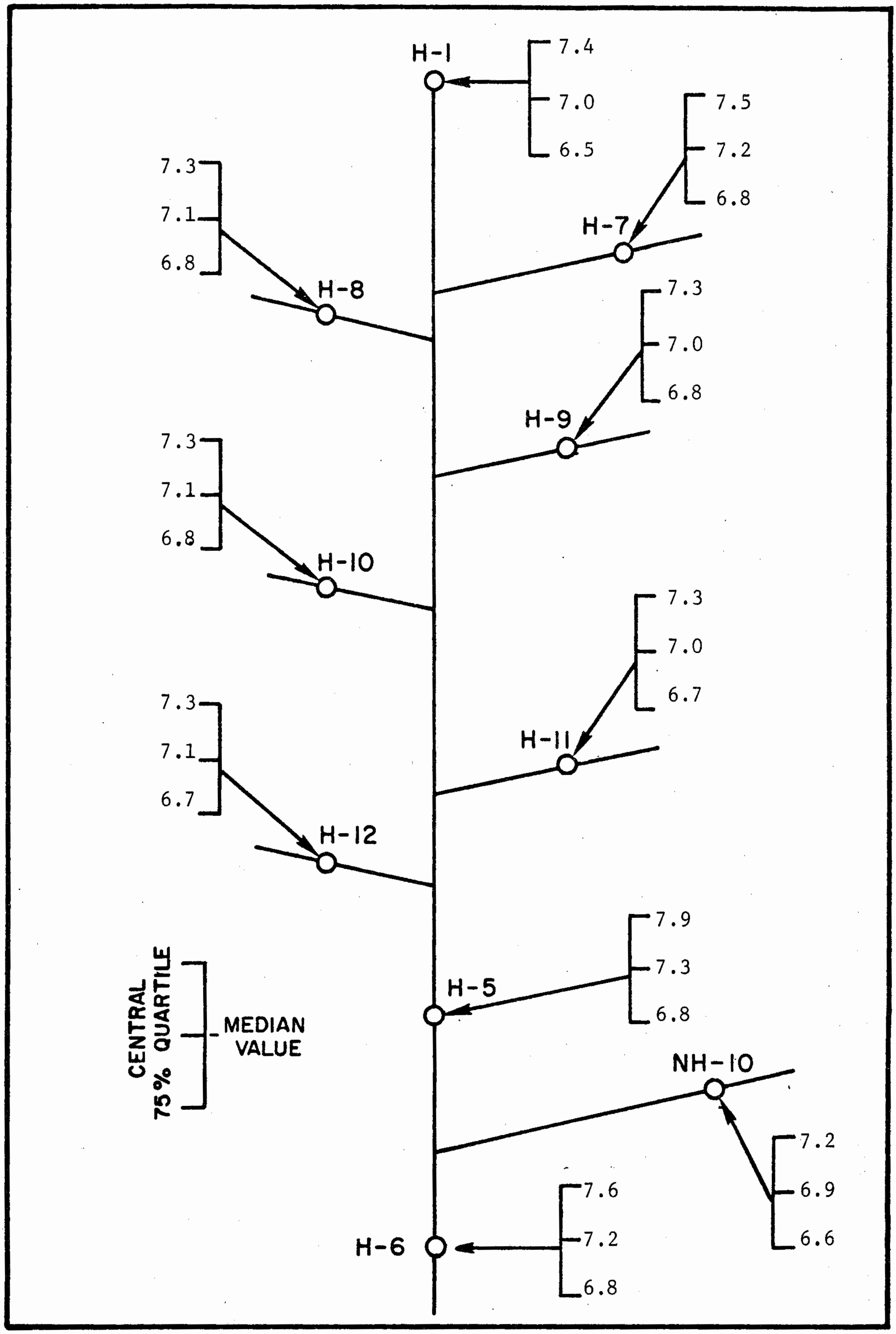


Fig. 19. Haw River stations, pH January 1971 - March 1972

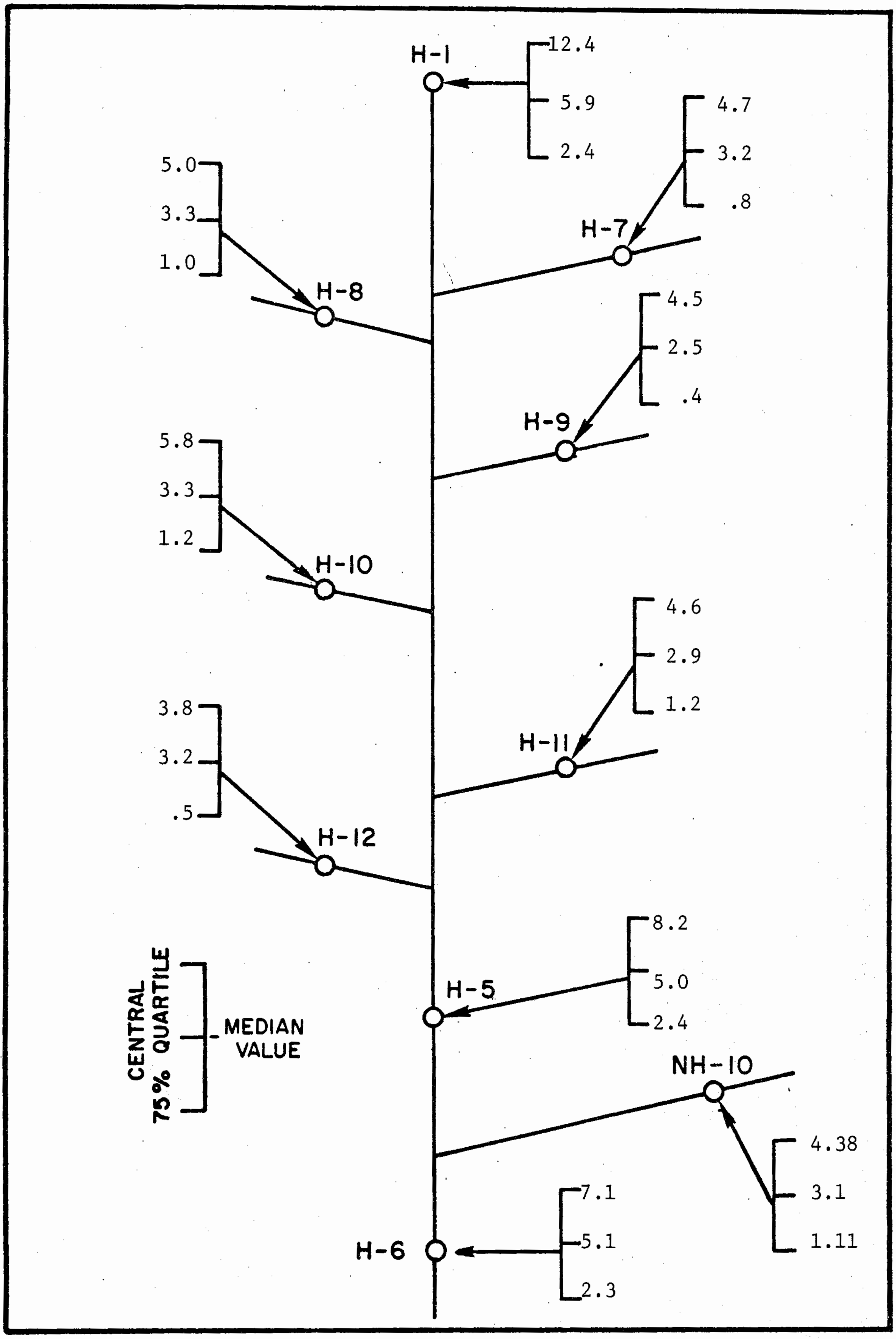


Fig. 20. Haw River stations, CHLOROPHYLL - KLETT UNITS, January 1971-March 1972

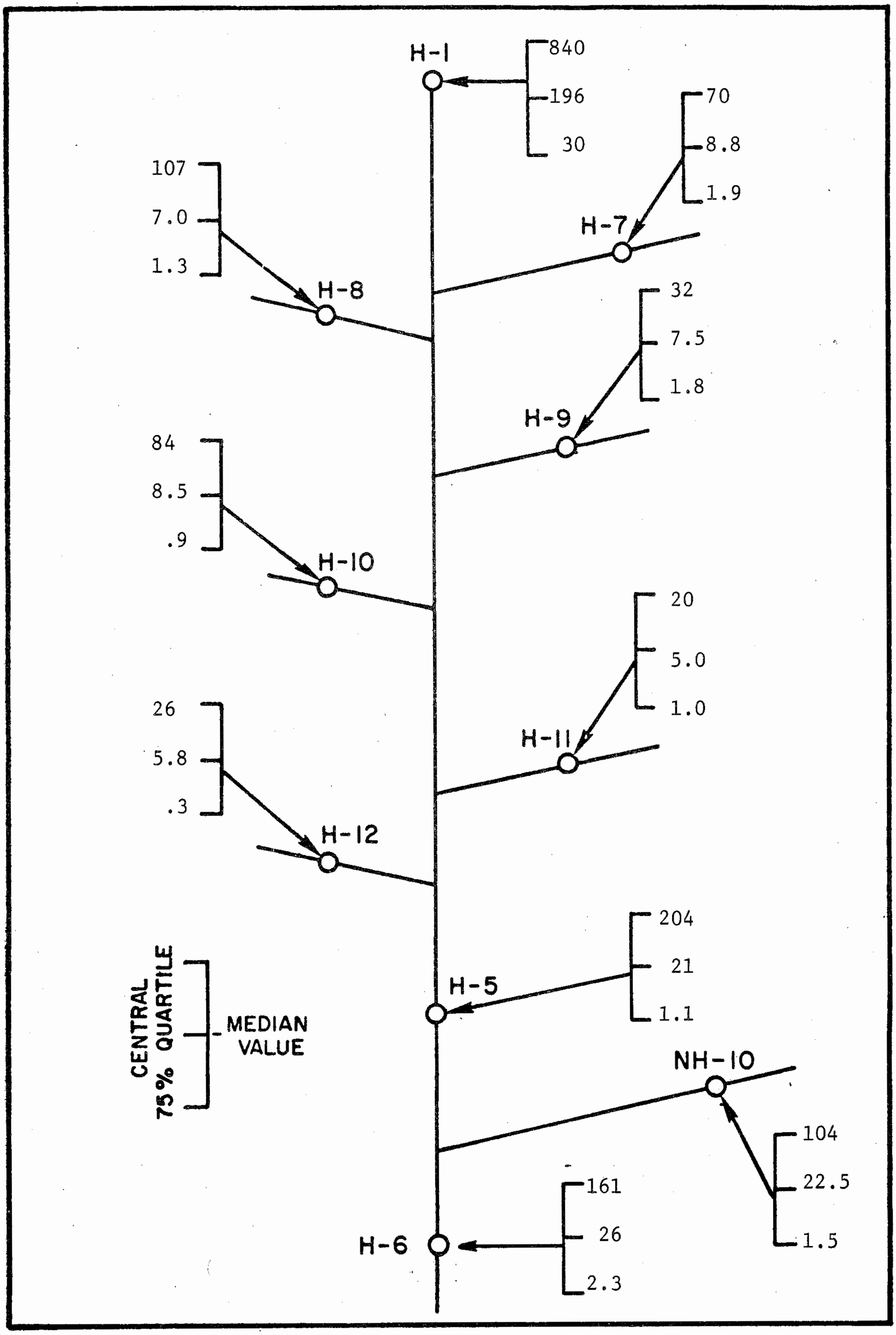


Fig. 21. Haw River stations, TOTAL COLIFORMS No./100 ml (x10^2)
January 1971 - March 1972

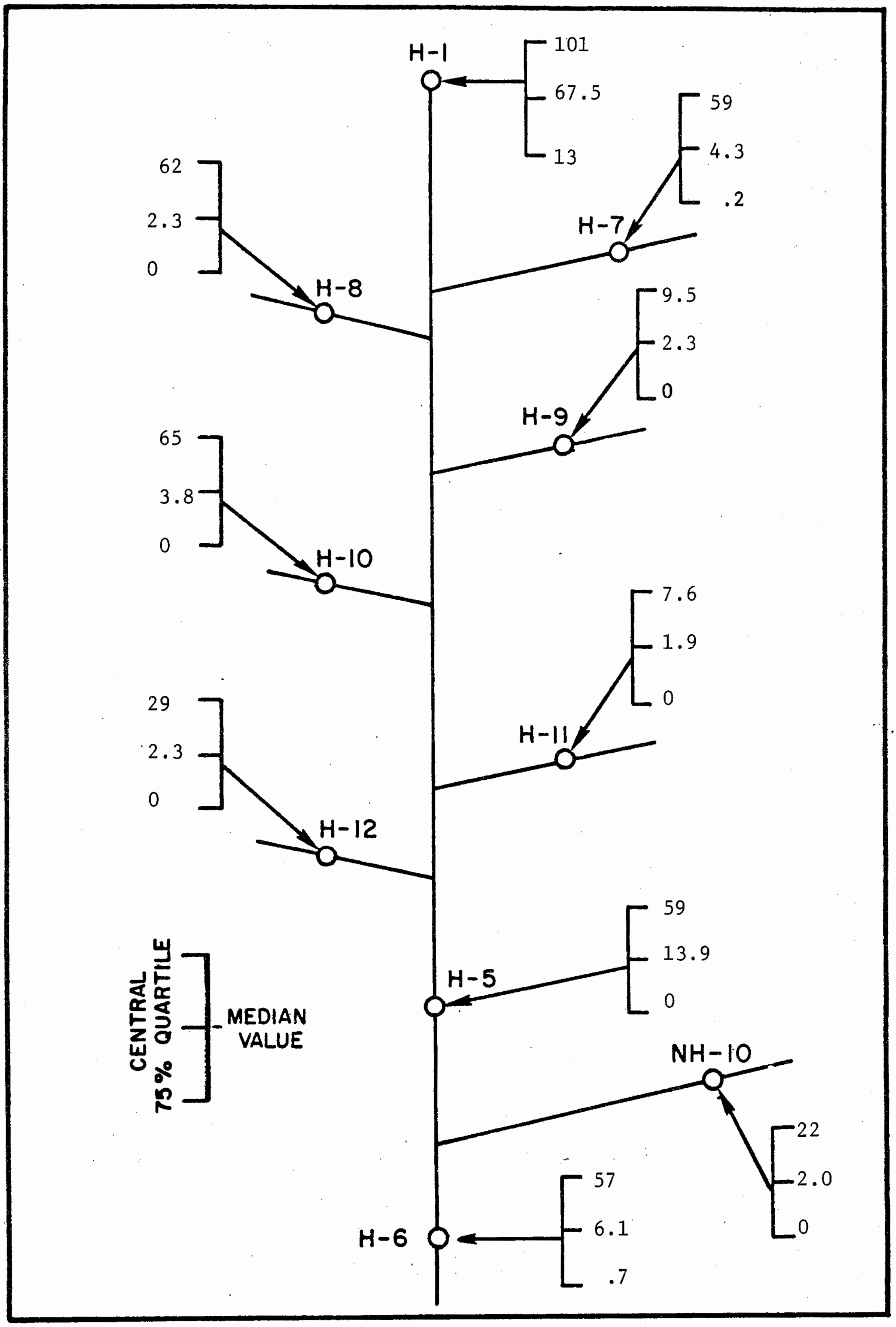


Fig. 22. Haw River stations, FECAL COLIFORMS No./100 ml (x10^2)
January 1971 - March 1972

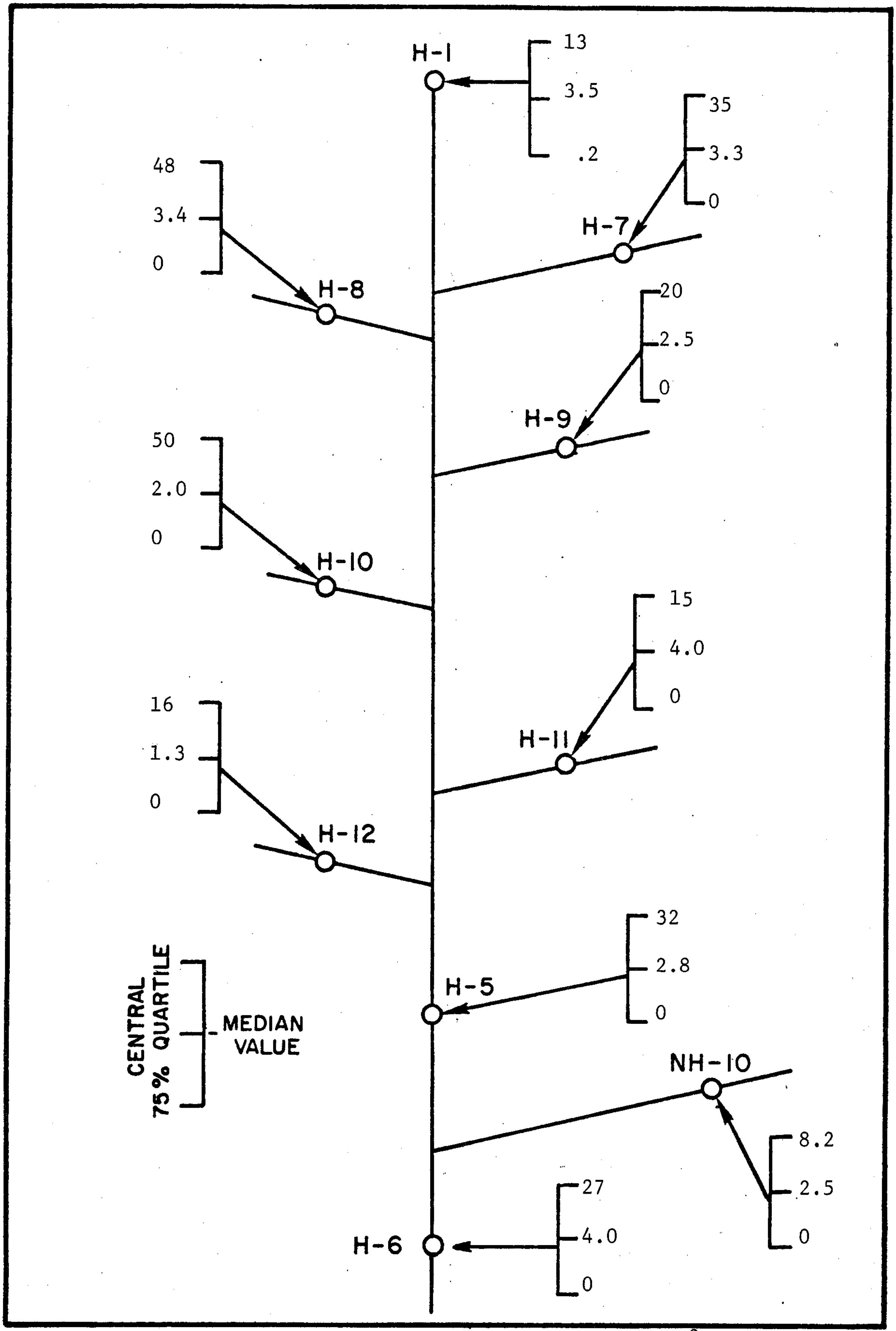


Fig. 23. Haw River stations, ENTEROCOCCI No./100 ml $(x10^2)$
January 1971 - March 1972

probably due to dilution by water with an ion concentration which was more characteristic of the control streams.

At station H-5 dissolved oxygen was on the average at 100 percent saturation. This was even better than the saturation values for the control streams where the average saturation was in the range of 80-89 percent. The residual BOD at H-5 was only about 1.5 times greater than that found in the control streams and well within acceptable limits for any natural water.

All other nonconservative water quality parameters also changed in downstream sequence, decreasing in magnitude. These included total carbon, total soluble carbon, inorganic carbon, and the several species of nitrogen and phosphorus. Although there was an assimilation of carbonaceous materials through the process of stream self purification, the mineralization of nitrogen and phosphorus species resulted in concentrations approximately two to five times greater than found in the control streams. Biological index organisms at station H-5 were equivalent to the numbers found in the control streams. These values apparently represent the microbial characteristics of surface drainage and runoff in this area.

Long term trends in water quality characteristics of the Lower Haw and New Hope Rivers may be indicated by an analysis of existing data that provides for compensation of seasonal factors and variations in flow. There has been assembled in Table 5 a list of several conservative and nonconservative pollutants that provide a comparison of the sample period 1966-1970 and 1971-1972. As indicated from the data of Table 4, increased mass transport appears to be related to higher flows in the current period of record. This is indicated on the basis that conservative parameters such as conductivity show a marked increase. In all other instances the other parameters also show the "dilution effect."

Table 5
Two Periods of Record
Comparison of Average Values of Water Quality Parameters, New Hope and Lower Haw Rivers

	NH-10		H-5	
	1966-1970	1971-1972	1966-1970	1971-1972
Residue mg/l	30	18.2	27.6	11.9
Turbidity JTU	36.4	48.2	28.7	38.9
Conductivity µmhos	164	113	290	159
DO mg/l	6.5	7.9	10.8	10.1
DO % Sat	60.6	72.6	98.3	97.0
BOD_5 mg/l	1.7	2.0	2.8	2.5
Total N mg/l	2.0	1.3	2.2	1.5
Org N mg/l	0.74	0.31	1.07	0.37
NH_3N mg/l	0.35	0.18	0.36	0.18
NO_2 + NO_3-N mg/l	0.93	0.83	0.87	0.96
Total -P mg/l	1.01	0.60	0.85	0.48
PO_4 -P mg/l	0.80	0.37	0.74	0.35
pH	7.1	6.9	7.7	7.4
Chlorophyll-klett Units	4.6	3.5	9.4	5.6
Total Coliform	11	22.5	12	20
Enterococci*	1.3	2.5	0.8	2.8

*NO/100 ml ($X10^2$) median values

For this period of record, the water quality of the lower Haw and New Hope drainages does not appear to have changed significantly either for the better or worse from that previously reported. The quality of the Haw River at station H-5 continues to indicate that the water is of acceptable quality for the lake to be impounded by the New Hope Dam. The quality of the water in the New Hope River, does not appear to have improved, particularly at the stations at the head of the proposed conservation pool. Improvement is essential for providing water of acceptable quality for the upper reaches of the New Hope arm of New Hope Lake.

Organic Characteristics of Freeze Concentrated Samples

The transport nature of water lends itself to the movement of materials from the land and into water courses. Many synthetic organics are introduced into the aquatic environment. Some are of high toxicity as well as low solubility. Describing these residues which may have entered streams either from agricultural applications or through wastewater discharges is essential for proper definition of water quality. These procedures quite often require detection methods and analytical procedures of a high order of refinement. For this study samples were collected approximately monthly from both "polluted" and "control" stations in both the Haw and New Hope drainages. These included NH-7, NH-8, H-1, H-5, and H-8. On each sampling date 18 liters of water were brought to the laboratory where through a process of freeze concentration the original volume was reduced to a final volume ranging from 0.4 to 0.6 liters, a concentration factor of 24 to 45 times. The final concentrate of approximately 500 ml. was stored in a dark cold room at a temperature of 2-3^{o}C. In addition to direct analysis by gas chromatography of the concentrated water samples, concentrates were extracted with diethyl ether or hexane for further chromatographic analysis.

The following experimental parameters were utilized in the gas chromatographic analyses performed:

Three microliter aliquots of freeze-concentrated water samples were injected directly onto the following column of the system parameters listed.

Instrument: Perkin-Elmer Model 900 gas chromatograph

Detector: Flame Ionization

Column: 5 ft. x 1/8 in. O.D. stainless steel containing poropak QS

Column Temperature: 170°C isothermal

Carrier Nitrogen Flow Rate: 35 cc/min.

Phenol was used as an internal standard and represented a retention time of 10.4 min. Maximum sensitivity, assuming recovery of 80%, would be 0.1 ppm for phenol.

The above procedure was repeated on an alternate column of 14% FFAP on Anakrom A at the same temperature and flow rates. Phenol was again used as an internal standard and represented a retention time of 11.9 min. Maximum sensitivity for phenol would be 0.1 ppm.

Ten milliliter aliquots of the freeze-concentrated water samples (adjusted to pH 2.0 by addition of orthophosphoric acid) were extracted with 3 ml of diethyl ether by shaking in a stoppered test tube. Three microliters of the organic extract were injected.

Instrument: Perkin-Elmer Model 900

Detector: Flame Ionization

Column: 5 ft. x 1/8 in. O.D. stainless steel containing 10% DC-200 on Chromosorb W-AW, 80/100 mesh

Column Temperatures: 100°C isothermal

200°C isothermal

Carrier Nitrogen Flow Rate: 35 cc/min.

Phenol was used as a standard, with a retention time of 14.7 min, and indicating a sensitivity for phenol of 0.05 ppm.

Ten milliliter aliquots of the freeze-concentrated water samples were extracted with 3 ml of nanograde hexane by shaking in a stoppered test tube. Organic extracts were dried with sodium sulfate. Two microliter volumes of the extracted samples and an extracted distilled water blank were injected on the column.

Instrument: Perkin-Elmer Model 900

Detector: Electron Capture (^{63}Nickel)

Column: 6 ft. x 1/4 in. glass containing 5% SE-30 on acid-washed Chromosorb W, 60/80 mesh.

Column Temperature: 180°C

Carrier Nitrogen Flow Rate: 60 cc/min.

Sensitivity: 0.2 ng of p,p'-DDE produced 50% full-scale deflection.

P,P'-DDE was used as a standard with retention time of 10.6 min. (3). No peaks were resolved, including those which would have represented retention times corresponding to 25 chlorobiphenyl compounds as reported by Zitko (3). The minimum detectable limit was estimated to be 0.1 ppb of p,p'-DDE, assuming 80% recovery of the residue from the freeze concentration and hexane extraction steps.

Although both systems that were used for examination of either the concentrated water samples injected directly or through a second chemical extraction were systems of high sensitivity, no significant peaks measurable above background were detected. The implication is that in these water samples materials that would respond to these detection systems were not present. The agricultural activities of the lands through which feeder streams drain might be singularly free of materials detectable by these two systems as well as industrial wastewaters that have been discharged from upstream communities. Since both rivers carry significantly high sediment loads at times of rain and high runoff and since many of these compounds are absorbed onto sediments it could be that these materials have been removed through these processes of absorption and sedimentation. Regardless of the degree and process of removal, it is apparent that soluble organic residues of phenolic or chlorinated nature are not present in any significant quantity in the main water course of the Haw and New Hope or in the feeder streams that have been sampled.

Recent investigations on the nature of organic compounds in surface waters (4, 5, and 6) have shown that techniques used in the above analyses for the samples from the Haw and New Hope will at least indicate the presence of materials at very low concentrations on the order of parts per billion. The lack of identification of chlorinated compounds which are readily detectable by electron capture gas chromotography may be particularly indicative of removal by absorption processes on sediments. The fluctuating sediment loads of the two rivers and their interaction with organics is a possibility that needs to be considered in establishing a reason for the absence of residues of persistent hydrocarbons in the samples collected in the past period and analyzed by these sensitive procedures.

Benthic Macroinvertebrates in the New Hope and Lower Haw Rivers

Introduction

The purpose of this phase of the overall study is to describe the benthic macroinvertebrate communities at several points along the main streams and tributaries of the lower Haw and New Hope Rivers. It is expected that the benthic populations of these streams are influenced by water quality and other ecological factors and that the species and their number will be indicative of long term conditons.

Weiss (1) has reported the water quality characteristics at six of the stream stations being considered in this report. These earlier findings, based on four years of data collection (1966-1970), showed that the main stream of the Haw was highly nutrient-enriched but had near normal dissolved oxygen resources at the point where it will be impounded by the New Hope Dam. The main stream of the New Hope, while containing very similar concentrations of nutrients and oxygen demanding materials, was found to have below-normal dissolved oxygen resources. Two smaller, unpolluted tributaries of the New Hope had considerably lower concentrations of nutrients and oxygen demanding materials, and dissolved oxygen concentrations intermediate between those found on the mainstreams of the New Hope and Haw Rivers.

The long-term sampling has continued and been expanded to include a number of the unpolluted tributary streams of the lower Haw system. As noted in Tables 2 and 3, the conditions of the main streams of each river and the two control tributaries of the New Hope are similar to previously reported conditions. The tributary streams along the lower Haw system, however, contain comparatively low concentrations of nutrients and oxygen demanding materials and normal dissolved oxygen resources, indicative of clean, unpolluted water.

Other investigators (6, 7) have described the water quality characteristics and the biota of the upper Haw River (above Saxapahaw, N.C.). They noted decreased oxygen resources and reduced numbers of "pollution sensitive" bottom organisms present at several stations along the upper Haw and its tributaries. These streams receive heavy industrial and municipal wastewater loads from the cities of Greensboro, Burlington, and Graham, N. C.

There have been many investigations on the macroinvertebrate populations of streams and rivers. The running water (lotic) habitat is favorable to the development of a very diverse and dynamic population of macroinvertebrates, including insects, crustaceans, flat worms, round worms, segmented worms, snails, clams, and freshwater sponges (8). Of these, the immature forms of insects are usually the dominant group (9). Benthic organisms are very important as food for fish (10, 11, 12). Smith (13) has stated that a good trout stream should be about half pools and half riffles, showing the complementary roles of two habitats. Riffles are the sites for production of food while pools furnish necessary shelter. Needham and Needham (14) attribute the greater abundance and diversity of bottom organisms in riffles to the greater stability of the bottom and the great variety of macrohabitats or niches to be found there.

A high diversity of organisms results in a stable community due to the increased complexity of the trophic structure of the community (15). When the aquatic community is exposed to some form of stress, such as extreme temperatures, reduced oxygen concentration, or extreme hydrogen ion concentrations, some members of the community will be eliminated, thus reducing the diversity and stability of the community.

Measures of the diversity of stream macroinvertebrate communities have been used to give some indication of the extent to which the stream is under an environmental stress. The simplest measure of diversity is the number of taxa (kinds) of organisms collected in the stream. Since the number of taxa collected will depend in part upon the number and size of the samples taken, it is usually desirable to express diversity as some function of both the number of taxa and the number of organisms collected. Margalef (16) proposed using the formula: $d=\frac{s-1}{\ln N}$ where $\underline{s}$ is the number of species and $\underline{N}$ is the number of individuals. This "diversity index" is easy to use and has been reported to be a useful tool for interpreting benthic macroinvertebrate data in streams receiving organic wastes (17).

Different species of aquatic organisms have differing degrees of tolerance to the low dissolved oxygen concentration and other stresses imposed by polluted water (18, 19). Numerous attempts have been made to find a universal "indicator organism" whose presence or absence positively establishes the stream in which it was found as either polluted or not polluted. Since the distribution of any species is also regulated by many factors other than the degree of pollution in the water, such attempts have largely been abandoned.

Certain groups of organisms have, however, been shown to be more prevalent in either a polluted or an unpolluted environment. Most organisms adapted to life in polluted water can also be found in unpolluted water. Because of this, Gaufin and Tarzwell (20) suggested that it is more revealing to identify organisms which require clean water and note their absence in polluted waters.

While the limiting effects of pollution have received a great deal of attention, other physical parameters have been found to be equally important. Hora (21) concluded that the flow rate of the current is the primary factor influencing the aquatic community. It affects the type of substrate, the dissolved gases, and the quantity of available food. Pate (22) emphasized the importance of both bottom type and stream width in the productivity of streams, showing that smaller streams are much richer in bottom organisms than are larger streams. Many investigators have found that areas of streams with a rubble substrate are much more productive than areas with a sand substrate (12, 22, 23, 24, 25).

In attempting to evaluate the extent to which pollution is affecting the benthic community in a stream, it is evident that one must take into account the multitude of other factors which also affect these organisms.

Methods and Materials

The streams under study included the main stem and four of the tributary streams of the Haw River from Saxapahaw, N.C. downstream to just below the point where Route U.S. 64 crosses the Haw, a distance of approximately 23 river miles, and the main stem and some tributaries of the New Hope River from just below Chapel Hill and Durham, N.C., to the confluence of this stream with the Haw River. Sampling sites (Fig.2) were chosen because they were representative of these portions of the rivers and were readily accessible.

Stations H-1 and H-5 are on the Haw River itself. Control stations H-7, H-8, H-11, and H-12 are each located on smaller tributary streams which receive no municipal or industrial wastes, but whose flows are made up of runoff from farm and woodland. In the New Hope drainage, stations NH-5, NH-7, and NH-11 are located on streams which carry heavy loads of treated domestic wastes from the town of Chapel Hill and the city of Durham. The treatment plants of these communities are located on headwater streams and the discharge volume from the plants for most of the year exceeds the volume of the receiving creek. Control stations NH-8, NH-8A, and NH-12 are smaller streams whose flow is made up solely from runoff from farmland and woodland, with no known significant waste discharges. (Appendix C provides a detailed description of each benthic sampling station.)

The period of sampling was from February, 1971, to March, 1972. It was thought that at least one complete year of observation was desirable to establish existing conditions in the streams.

Artificial substrate samplers of the type described by Mason et al. (26) were used exclusively at all stations. This sampler consists of a cylindrical chrome-plated wire chicken barbeque basket of dimensions 11" long X 7" diameter (28 cm X 18 cm) filled with about 19 lbs. (8.2 kg.) of fist-sized granite rock. One sampler was placed on the bottom of each sampling station. At each station where conditions permitted, placement was made in an area of riffles rather than pools, and some effort was made to make their presence as inconspicuous as possible. Neither of these criteria was always satisfied, resulting in some baskets being placed in slower moving water, and some baskets being lost or damaged. Periods during which the streams were swollen due to heavy rains often made the samplers impossible to recover at the desired intervals. Likewise, samplers were occasionally left "high and dry" by reduced flows during the dry summer months even though all the streams studied are permanent streams.

Each sampler was allowed to remain in the stream for a period of approximately 6-8 weeks, at the end of which it was removed from the water, organisms which had colonized in it removed, and the sampler returned to the stream for another exposure period. The removal of the accumulated macroinvertebrates was accomplished by shaking and scraping each rock in a bucket of water, in a manner similar to that employed when operating a Surber-type bottom sampler. The organisms were then concentrated by pouring the bucket of water and organisms through a No. 40 mesh (420 openings/in.) sieve. The contents of the sieve were then sorted in a white enamel pan and the organisms preserved in 70 percent ethanol solution. Each sample was then taken back to the laboratory and the organisms identified to the generic level when possible.

Results and Discussion

A total of 61 benthic samples were collected from 12 stations, 35 samples from the Haw system and 26 from the New Hope. Each station was sampled at least four times, some as many as seven times. Figure 24 provides the approximate dates of sampling for each station.

Table 6 is a summary of the biological (benthic) and water quality data discussed in this report, including values for each station and average values for control and main streams in each system. It should be noted here, as well as in the figures which follow, that no water quality measurements were made at station NH-12. This stream is believed to be unpolluted since it traverses only farm and forested land. It is encouraging to note, however, that the benthic data compiled at this station are very similar to those for stations NH-8 and NH-8A, which are known to be unpolluted and which are similar in respect to bottom type, flow rate, and size. These stations have the following benthic characteristics when compared to stations NH-5, NH-7, and NH-11: relatively high number of taxa per sample, high number of total taxa collected, low numbers of individuals per sample, high diversity index, and high proportion of "pollution

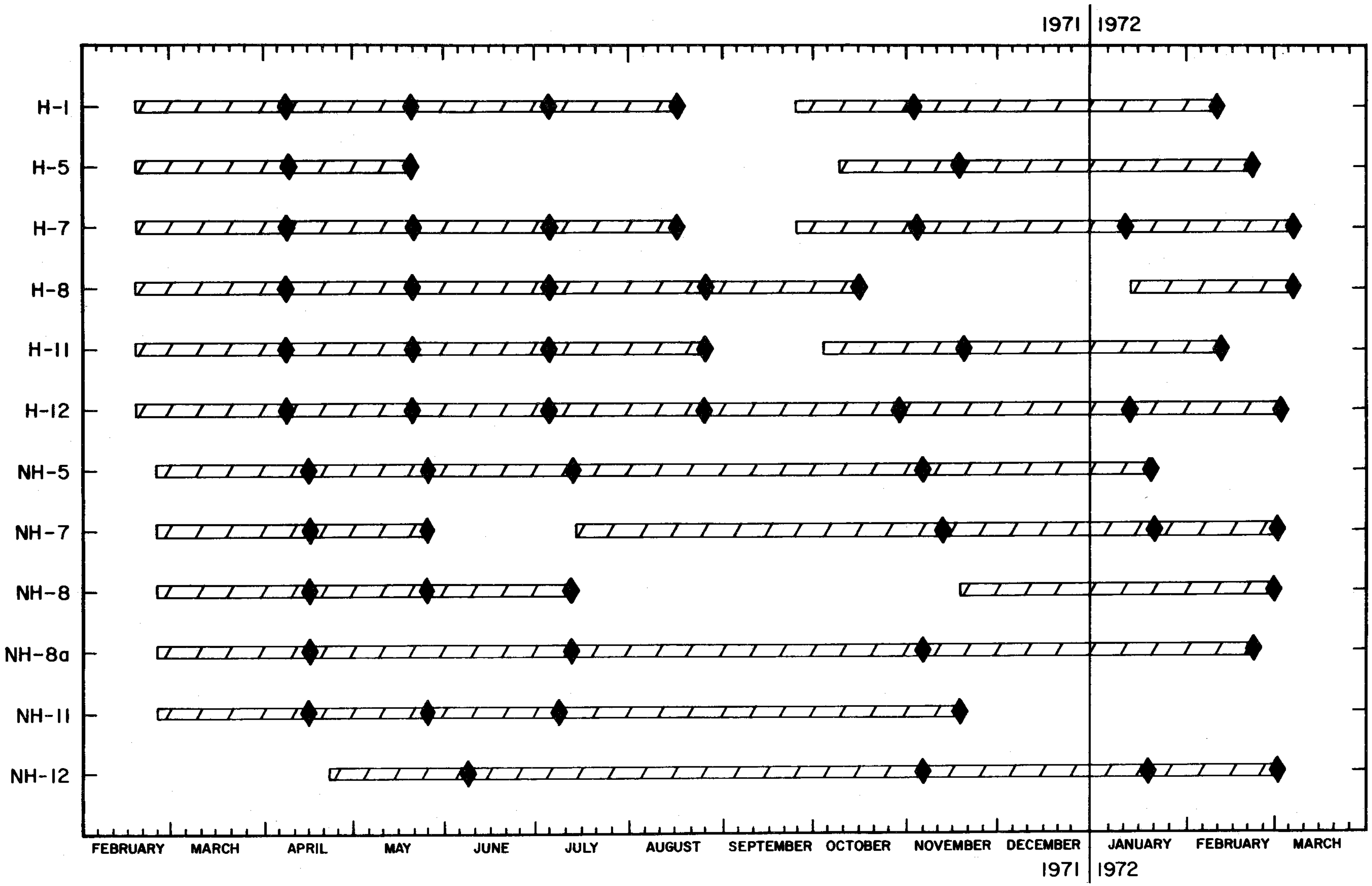


Figure 24. Exposure periods and collection dates for samplers at each station.

TABLE 6

Summary of Benthic and Related Water Quality Data

	Average No. Per Sample			Total	% of Total Taxa	Average Concentration mg/l			
Station	Taxa 1	Individuals 2	Diversity Index 3	Number 4	Pollution Intolerant 5	DO 6	BOD_5 7	Total-P 8	Total-N 9
H-1	7.5	198.2	1.30	19	32%	9.02	4.76	0.68	1.96
H-5	15.5	221.0	2.72	32	33%	9.90	2.57	0.49	1.52
H-7	11.7	67.7	2.61	34	38%	9.25	2.16	0.10	0.80
H-8	12.8	154.6	2.21	39	54%	8.91	1.77	0.11	0.83
H-11	4.2	10.0	1.55	16	56%	9.15	1.31	0.06	0.38
H-12	12.0	85.6	2.50	35	54%	9.07	1.75	0.06	0.58
Average H-1,5	10.7	207.3	1.86	26	33%	9.46	3.66	0.59	1.74
Average H-7,8, 11,12	10.6	82.0	2.27	31	51%	9.10	1.75	0.08	0.65
NH-5	8.2	149.4	1.46	15	7%	4.69	4.76	1.43	4.29
NH-7	9.8	313.6	1.53	18	22%	5.97	3.18	1.08	3.11
NH-8	7.5	39.8	1.85	22	41%	8.51	2.05	0.10	0.46
NH-8A	9.0	37.0	2.28	25	44%	8.31	1.69	0.16	0.56
NH-11	8.5	78.8	1.79	20	40%	6.60	2.67	0.49	0.88

TABLE 6

Continued

Station	Average No. Per Sample			Total	% of Total Taxa	Average Concentration mg/1			
	Taxa 1	Individuals 2	Diversity Index 3	Number 4	Pollution Intolerant 5	DO 6	BOD_5 7	Total-P 8	Total-N 9
NH-12	11.3	44.3	2.87	28	50%	--	---	----	----
Average NH-5, 7,11	8.9	187.9	1.58	18	23%	5.72	3.51	1.00	2.76
Average NH-8, 8A, 12	9.3	40.3	2.33	25	45%	8.41	1.87	0.13	0.51

intolerant" taxa. These same contrasts are generally evident in the Haw system when comparing main stream and control stream stations, but to a lesser degree. The water quality data for the Haw system is likewise less different between main stream and control stream stations. These results indicate the value of benthic data for assessing water quality in streams.

From all stations eighty-one taxa were identified, including eight orders of insects, plus crustaceans, molluscs, segmented worms, flat worms, and fresh water sponges. Appendix D provides the list of taxa and the stations at which each was collected. It can be seen that a few taxa were very common, occurring at every station, and several taxa were found to occur at almost all stations. By far the majority of taxa identified, however, were relatively rare, each occurring at only a few stations.

Stations in the Haw River system had, on the average, more total taxa per station than did stations in the New Hope system (Appendix D). This may be due, in part, to the fact that more samples were collected from the Haw system. It is thought, however, that general differences in bottom type, current velocity, and pollution load between the two systems may have been important factors. The streams sampled in the Haw system are, in general, faster moving, less polluted, and have more stable bottoms (rubble) than those of the New Hope which have sandy bottoms. Each of these factors is more favorable for benthic diversity in the Haw system than in the New Hope system.

The main streams of both the New Hope and the Haw contain fewer taxa per station than did their respective tributaries. It may be noted that station H-11, an unpolluted control stream, had an unusually low number of taxa. The stream bottom at this station is made up almost completely of coarse sand, which presents an unstable habitat for bottom organisms (23,25).

The bottom type at this station is in contrast to that of the other three control stations in the Haw system. For this reason, two calculations were made for the control streams in the Haw. One includes H-11, while the other excludes H-11. The differences between the main stream of the Haw and the tributaries are seen to be more pronounced when the anomalous H-11 is excluded. The two main differences between the main stream and the "control" streams of each system are size (volume of flow) and degree of pollution. The larger streams may naturally tend to be poorer in benthic organisms (22). It can be seen (Table 6), however, that station H-1 (BOD_5=4.76) had far fewer taxa than did H-5 (BOD_5=2.57), and that stations NH-5 (BOD_5=4.76), NH-7 (BOD_5=3.18), and NH-11 (BOD_5=2.67) showed the same general inverse relationship between five-day BOD and total number of taxa collected. The bottom types at H-1 and H-5 are both rubble, while those at NH-5, NH-7, and NH-11 are all stable mixtures of clay, sand, and rubble. These results tend to give support to the idea that the degree of pollution rather than stream size or bottom type is the most important difference between each main stream and its unpolluted tributaries.

The number of taxa collected per sample for each sampling period is shown in Table 7. Values ranged from no taxa at station H-11 in April, 1971, to 24 taxa at station H-8, also in April, 1971. The average for each station over the whole year of sampling also shows that the control stations of the Haw (minus H-11) usually had more taxa per sample than did the main river stations. The same trend can be seen for the New Hope system.

The bottom line of Table 7 shows the mean number of taxa per sample for each sampling period. It can be seen that there were generally fewer taxa collected during the summer than during the winter. These results may be explained by the fact that most insects whose immature stages are spent in

TABLE 7

Number of Taxa per Sample for All Stations by Month of Collection

	1971					1972		
Station	April	May	July	Aug.	Nov.	Jan.	Feb.	Yearly
H-1	7	7	8	9	7	--	7	7.5
H-5	13	13	--	--	21	--	15	15.5
H-7	14	9	12	10	8	13	16	11.7
H-8	24	12	7	12	6	--	16	12.8
H-11	0	7	5	5	4	--	--	4.2
H-12	14	8	14	7	11	15	15	12.0
Monthly Average	12.0	9.3	9.2	8.6	9.5	14.0	13.8	

Haw Overall Average = 10.6
Main Haw Average (1,5) = 10.7
Control Haw Average (7,8,11,12) = 10.6
Control Haw Average (minus H-11)=(12.2)

Station	April	May	July	Aug.	Nov.	Jan.	Feb.	Yearly
NH-5	7	9	8	--	9	8	--	8.2
NH-7	11	7	--	--	10	9	12	9.8
NH-8	9	8	7	--	--	--	6	7.5
NH-8A	9	--	7	--	13	--	7	9.0
NH-11	6	8	8	--	12	--	--	8.5
NH-12	--	12	--	--	6	17	10	11.3
Monthly Average	8.4	8.8	7.5	--	10.0	11.3	8.8	

New Hope Overall Average = 9.0
Main New Hope (5,7,11) Average = 8.9
Control New Hope (8, 8A, 12) Average = 9.3

the water emerge as adults during the spring and summer months. Adult stages of mayflies, stoneflies, dragonflies, caddisflies, two-winged flies, months, alderflies, and some beetles are non-aquatic and will not, of course, be collected by sampling the benthic community (14, 27, 28).

Table 8 shows the number of individual organisms per sample for each sampling period. Values ranged from no organisms at station H-11 in April, 1971, to 431 organisms at station H-1 in November, 1971. It is evident that the main stream stations in each system had generally far greater numbers of individuals per sample than did the control stations. Such a tendency in moderately polluted streams has been reported by many investigators. An abnormally high benthic productivity is considered to be one of the best indicators or organic pollution (29, 30).

In Figure 25 the mean number of benthic organisms per sample is related to mean dissolved oxygen. It indicates that the number of benthic individuals at the New Hope stations is inversely related to the DO concentration. No such specific relationship can be seen, however, for the Haw system, or for the systems combined.

Figure 26 shows the average number of individuals per sample plotted against mean five-day BOD. Figure 27 is analogous to Figure 26 except that number of individuals is plotted against mean total phosphorous concentration. Figure 28 is similar to Figures 26 and 27, with number of individuals per sample plotted against mean total nitrogen concentration. One may note general trends in Figures 26, 27, and 28 toward higher numbers with greater enrichment. Here again, however, the trends are more well-defined in the New Hope system than in the Haw.

Table 9 shows the diversity index per sample for each sampling period. The index used is that proposed by Margalef (16): $d=\frac{s-1}{\ln N}$ where $\underline{s}$ is the

TABLE 8

Number of Individuals per Sample for all Stations by Month of Collection

	1971					1972		
Station	April	May	July	Aug.	Nov.	Jan.	Feb.	Yearly
H-1	68	85	155	164	431	---	286	198.2
H-5	131	147	---	---	423	---	183	221.0
H-7	92	66	70	40	53	78	75	67.7
H-8	294	114	265	78	106	---	71	154.6
H-11	0	20	20	6	4	---	---	10.0
H-12	57	95	134	34	62	130	87	85.6
Monthly Average	107.0	87.8	100.8	64.4	179.8	104.0	140.4	

Total Haw = 3983
Average Overall Haw = 113.8
Main Haw Average (1, 5) = 207.3
Control Haw Average (7, 8, 11, 12) = 82.0
Control Haw Average (minus H-11) = (100.0)

Station	April	May	July	Aug.	Nov.	Jan.	Feb.	Yearly
NH-5	70	124	173	---	206	174	---	149.4
NH-7	318	259	---	---	343	268	380	313.6
NH-8	28	68	20	---	---	---	43	39.8
NH-8A	45	---	31	---	59	---	13	37.0
NH-11	90	58	29	---	138	---	---	78.8
NH-12	---	26	---	---	10	103	38	44.3
Monthly Average	110.2	107.0	63.3		151.2	181.6	118.5	

Total New Hope = 2932
Average Overall New Hope = 112.8
Main New Hope Average (5, 7, 11)= 187.9
Control New Hope Average (8, 8A, 12) = 40.3

TABLE 9

Diversity Index per Sample for all Stations by Month of Collection $\left(d = \frac{S-1}{\ln N}\right)$

	1971					1972		
Station	**April**	**May**	**July**	**Aug.**	**Nov.**	**Jan.**	**Feb.**	**Yearly**
H-1	1.42	1.35	1.39	1.57	0.99	1.06	---	1.30
H-5	2.47	2.40	---	---	3.31	---	2.69	2.72
H-7	3.10	2.15	2.59	2.44	1.76	2.75	3.48	2.61
H-8	2.72	2.32	1.08	2.53	1.07	---	3.52	2.21
H-11	No org.	2.00	1.34	2.23	2.17	---	---	1.55
H-12	3.21	1.54	2.65	1.70	2.42	2.87	3.13	2.50
Monthly Average	2.15	1.96	1.81	2.09	1.95	2.23	3.21	

Overall Haw Average = 2.15
Main Haw (1, 5) Average = 1.86
Control Haw (7, 8, 11, 12) Average = 2.27
Control Haw (minus H-11) Average = (2.45)

	1971					1972		
Station	**April**	**May**	**July**	**Aug.**	**Nov.**	**Jan.**	**Feb.**	**Yearly**
NH-5	1.41	1.67	1.36	---	1.50	1.36	---	1.46
NH-7	1.74	1.08	---	---	1.54	1.43	1.85	1.53
NH-8	2.40	1.66	2.00	---	---	---	1.33	1.85
NH-8A	2.10	---	1.75	---	2.94	---	2.34	2.28
NH-11	1.11	1.72	2.08	---	2.23	---	---	1.79
NH-12	---	3.37	---	---	2.17	3.46	2.47	2.87
Monthly Average	1.75	1.90	1.80	---	2.08	2.08	2.00	

Overall New Hope Average = 1.92
Main New Hope (5, 7, 11) Average = 1.58
Control New Hope (8, 8A, 12) Average = 2.33

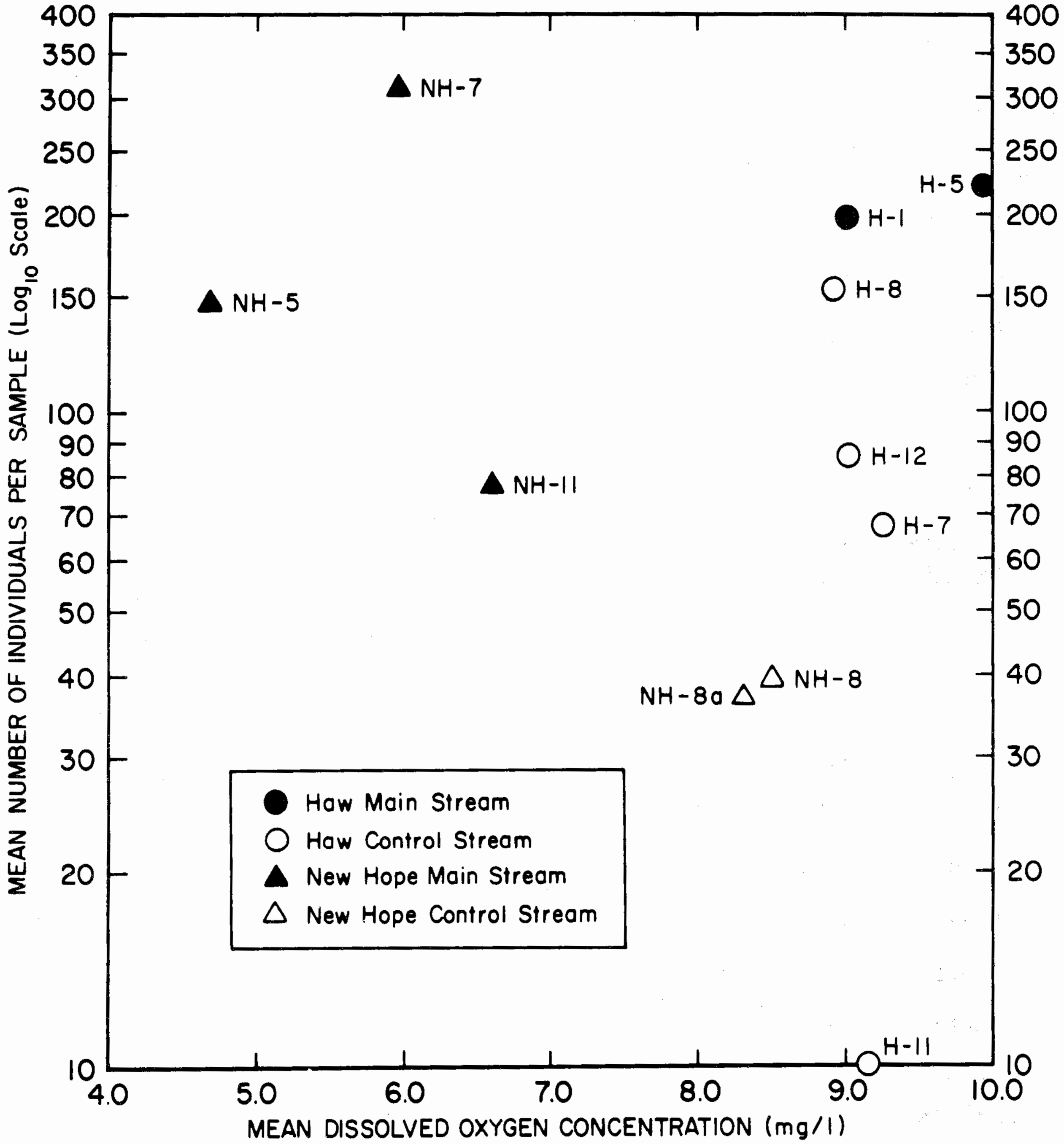


Figure 25. Mean Number of Individuals per Sample as related to Mean D.O. Concentration.

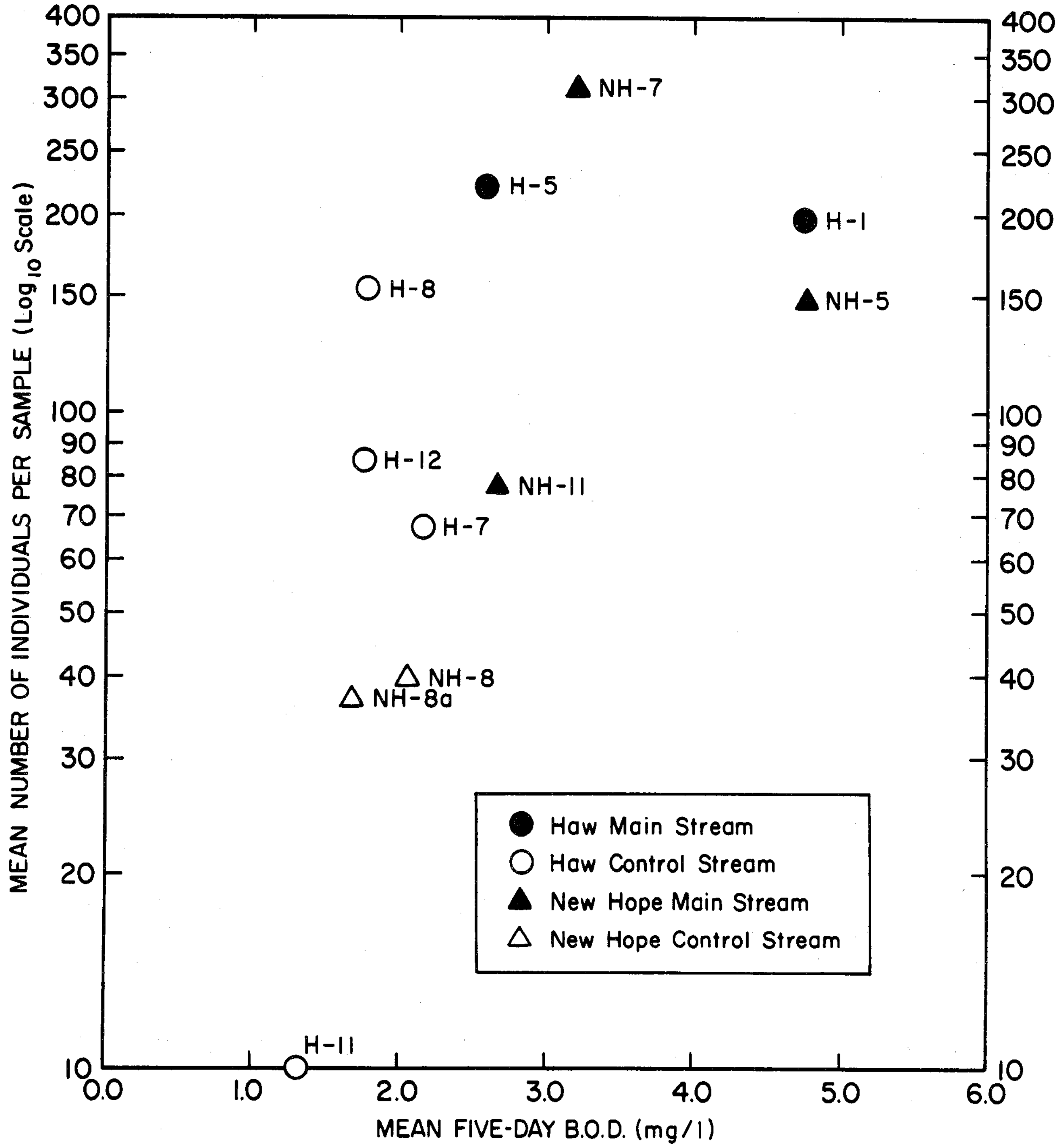


Figure 26. Mean Number of Individuals per Sample as related to Mean Five Day B.O.D.

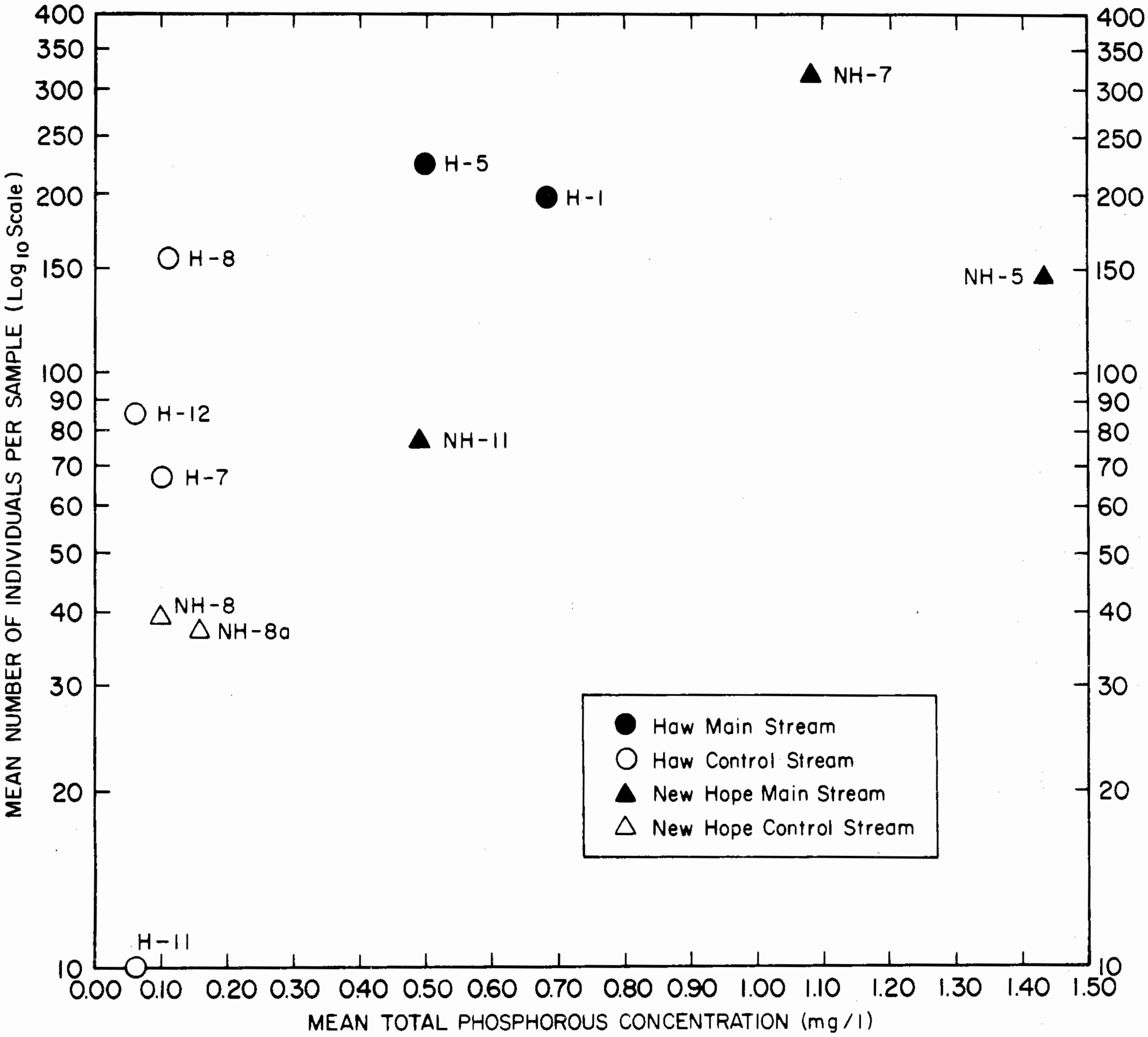


Figure 27. Mean Number of Individuals per Sample as related to Mean Total Phosphorous Concentration.

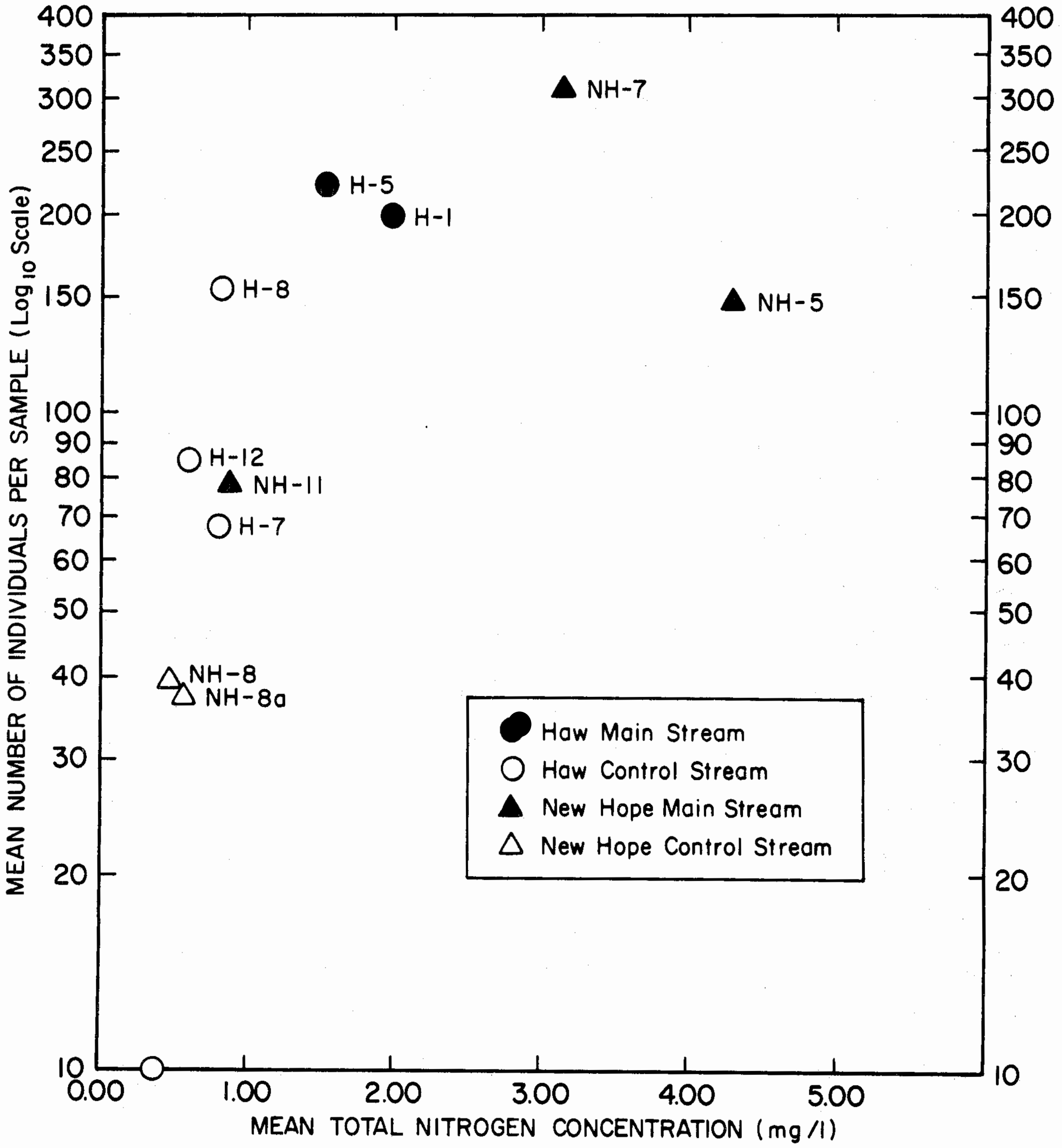


Figure 28. Mean Number of Individuals per Sample as related to Mean Total Nitrogen Concentration.

number of taxa per sample and N is the number of individuals per sample. Values ranged from 0 (no organisms) at station H-11 in April, 1971, to 3.52 at station H-8 in February, 1972. The control streams in both system have generally higher average diversity indices than the main streams. It should be pointed out, however, that station H-5 (main stream) had the second highest average index of any station sampled (2.72), surpassed only by station NH-12 (control) with a value of 2.87.

Figure 29 is a plot of mean diversity index versus mean dissolved oxygen concentration for each station. There appears to be a direct relationship between these two factors, especially evident in the New Hope system, where there was much more varied oxygen concentrations among the stations. The comparatively great variation in diversity among the Haw stations cannot, it seems, be attributed to differences in mean dissolved oxygen concentration. While mean diversity index values range from 1.30 to 2.72, mean dissolved oxygen concentrations range only from 8.91 to 9.90 mg/l. In fact, the lowest single value for any water sample taken in the Haw system from February 18, 1971, to February 23, 1972, was 4.8 mg/l, which is not low enough to make one expect any drastic damage to benthic organisms. Ellis (31) set a value of 5 mg/l dissolved oxygen as the minimum concentration favorable for support of a mixed warm-water fish population and its food organisms. The Aquatic Life Advisory Committee of ORSANCO (32) recommended maintaining an absolute minimum of 3 mg/l, with no less than 5 mg/l during at least 16 hours of any 24-hour period in order to sustain well-rounded warm-water fish population.

Figure 30 is a plot of mean diversity index versus mean five-day BOD for each station. There seems to be an inverse relationship between these two variables, especially for stations with mean BOD greater than about 2.5 mg/l.

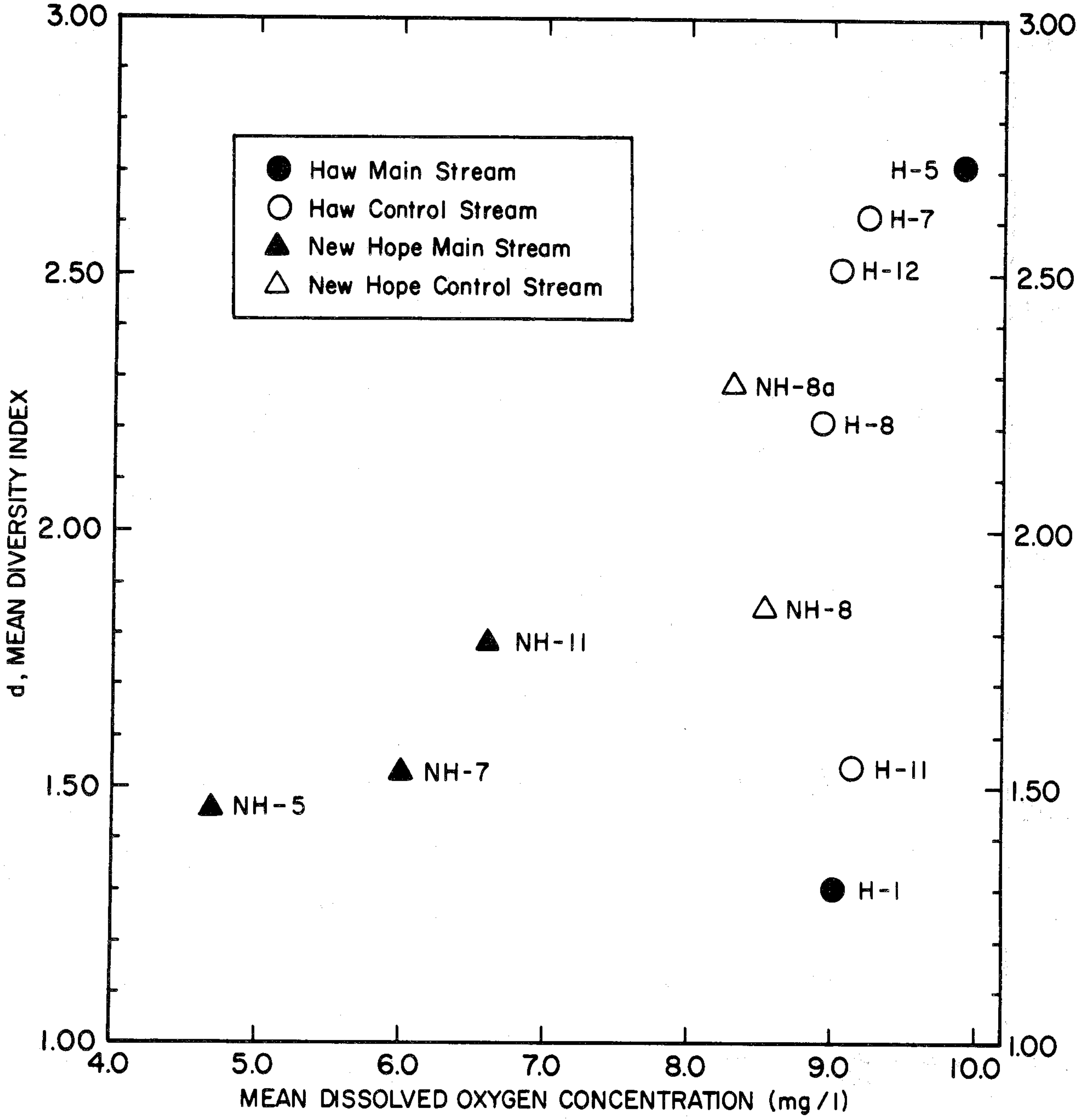


Figure 29. Mean Diversity Index $\left[d=\frac{S-1}{\ln N}\right]$ as related to Mean D.O. Concentration

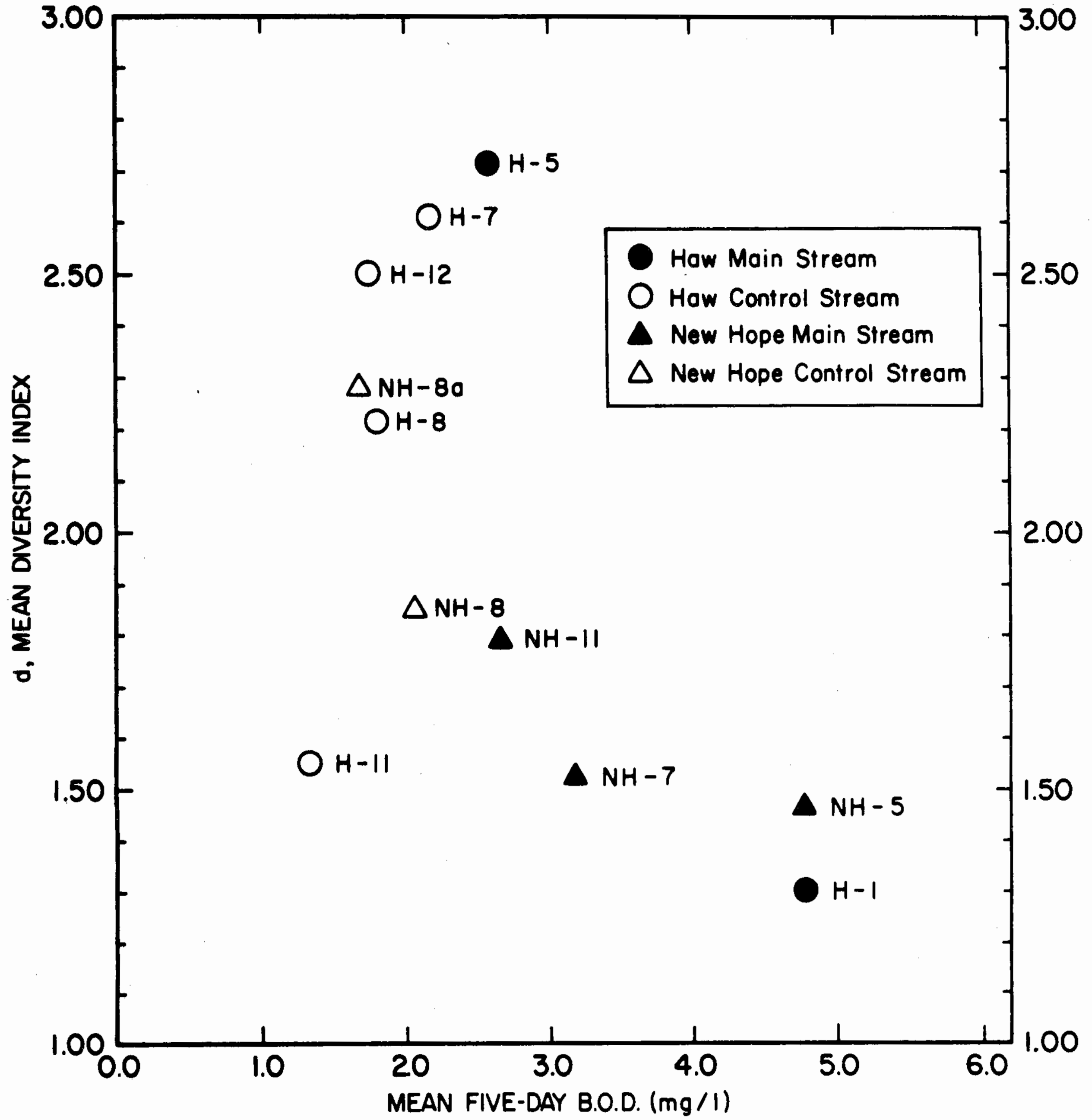


Figure 30. Mean Diversity Index $\left[d=\frac{S-1}{\ln N}\right]$ as related to Mean Five-Day B.O.D.

Bartsch and Ingram (33) summarized studies done on the effect of pollution on stream life and stated that caddisflies, mayflies, stoneflies, hellgrammites, and gillbreathing snails are all types of benthic organisms which are usually found only in clean water. Studies by Gaufin and Tarzwell (34) found these same general groups to be intolerant of organic pollution, but with a few exceptions. On the basis of their studies they recommend that the following organisms should not be considered strictly pollution intolerant: caddisflies of the family Hydropsychidae, mayflies of the genera Stenonema and Callibaetis and stoneflies of the genus Allocapnia. Beetles of the family Elmidae were found strictly in well-oxygenated water.

Following the general guidelines mentioned above, certain taxa collected during this sampling period were classified for the purpose of this report as "pollution intolerant," with no attempt being made to further subdivide the remaining taxa. In Appendix C each taxon classified as "pollution intolerant" is designated by an asterisk. The proportion of all taxa collected which were members of the "pollution intolerant" subset is shown on the bottom line of Appendix C and in column 4 of Table 6.

In both Haw and New Hope systems, the proportion of clean water taxa to total taxa is generally much higher in the control streams than in the main streams. The relationship between mean dissolved oxygen concentration and proportion of "pollution intolerant" taxa is shown in Figure 31. A direct relationship between these two variables appears to exist for the New Hope stations, but is not apparent for the Haw stations. The linearity of the realtionship seems strongest at mean dissolved oxygen values lower than about 7 mg/l. On the basis of these results, it might be theorized that dissolved oxygen is limiting in this lower range while some other ecological factor is limiting at higher dissolved oxygen concentrations. The data

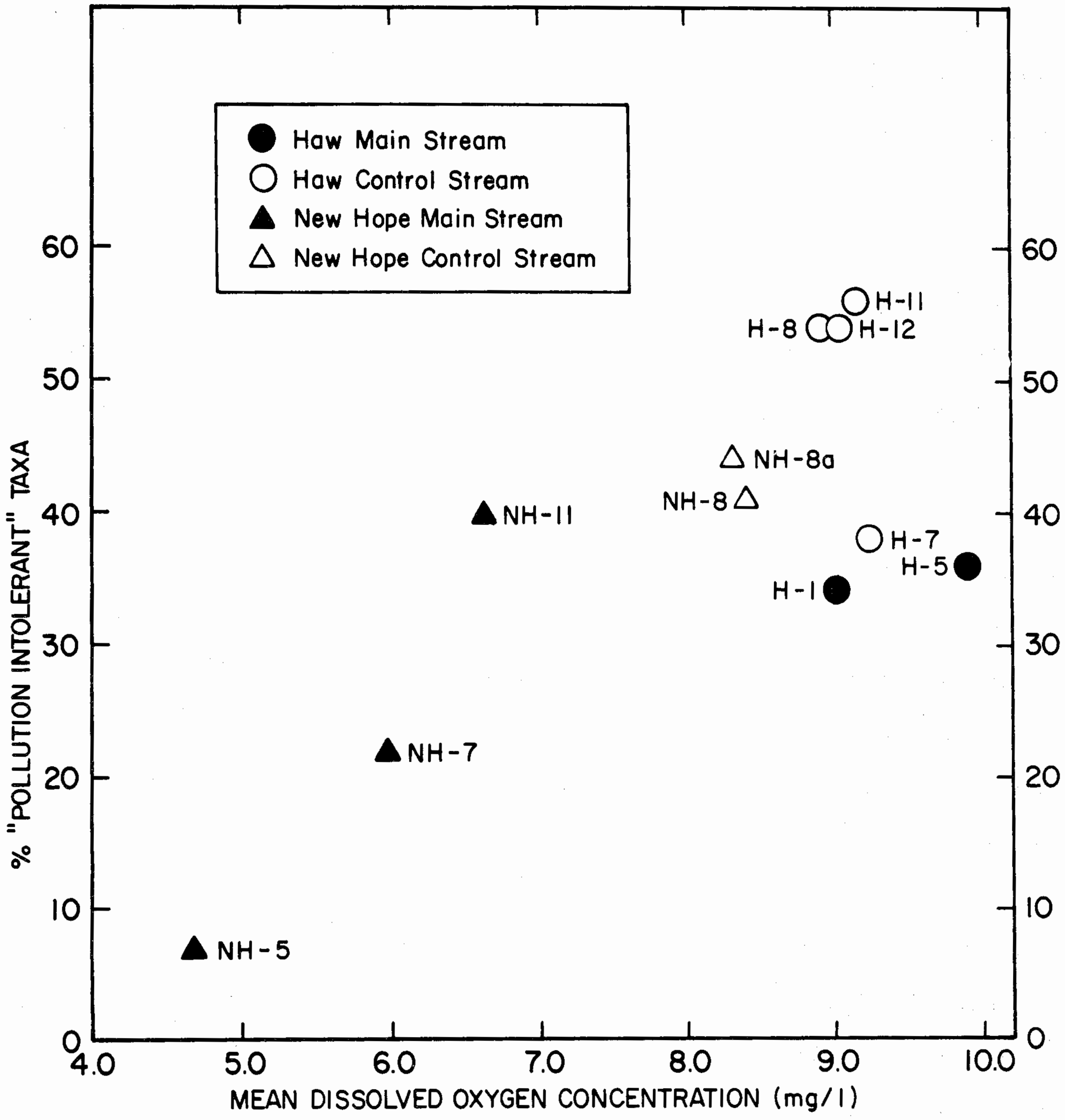


Figure 31. Percent "Pollution Intolerant" Taxa as related to Mean D.O. Concentration.

available here does not justify strong a case for this theory.

Figure 32 shows the relationship of the proportion of "pollution intolerant" taxa to mean five-day BOD at each station. The distribution of this graph appears to show a general inverse relationship between the two variables. As before, the trend is more clearly evident at the New Hope stations than at the Haw stations. But this might be because high BOD values were seldom found at the Haw stations.

Summary and Conclusions

Analysis of the benthic data has shown that the polluted main stem of each river had the following characteristics when compared to its unpolluted tributaries: (1) lower number of taxa per sample (2) lower number of total taxa collected (3) higher number of individual organisms per sample (4) lower diversity index (5) lower proportion of "pollution intolerant" taxa to total taxa. These contrasts are generally less evident in the Haw River system than in the New Hope system.

It was found that there seems to be a generally direct relationship between the following water quality and benthic parameters:

Water Quality Parameter	Benthic Parameter
mean DO concentration	diversity index
mean DO concentration	% "pollution intolerant" taxa
mean BOD_5	no. of organisms / sample
mean total P conc.	no. of organisms/sample
mean total N conc.	no. of organisms/sample

A generally inverse realtionship was found between the following parameters:

Water Quality Parameter	Benthic Parameter
mean BOD_5	diversity index
mean BOD_5	% "pollution intolerant" taxa

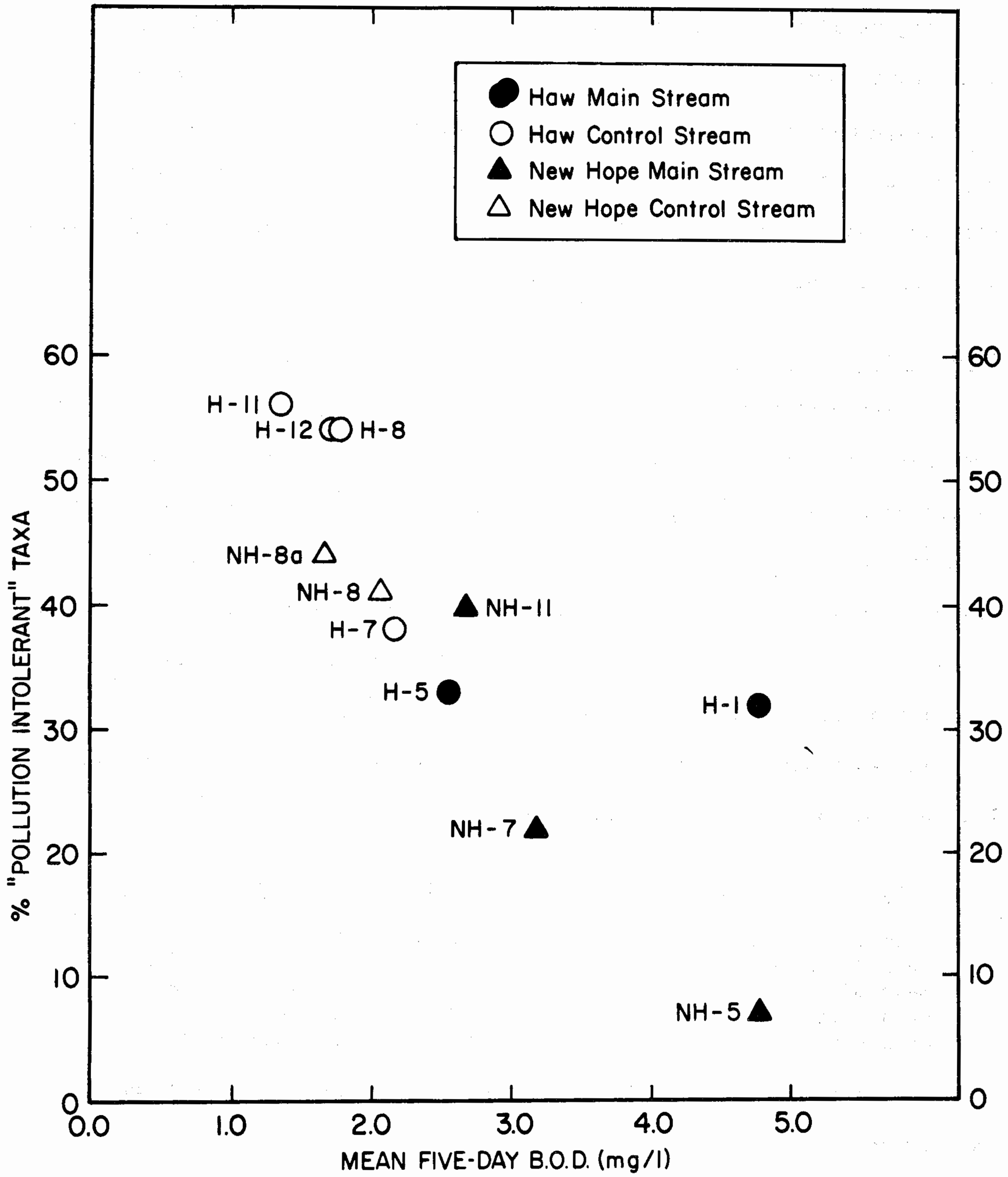


Figure 32. Percent "Pollution Intolerant" Taxa as related to Mean Five-Day B.O.D.

It was noted, however, that bottom type can be an important limiting factor for benthic organisms. One station in particular (H-11) which had a shifting, coarse sand bottom yielded very few bottom organisms even though the water quality characteristics of this stream were very similar to the other control streams in the Haw drainage system.

It appears that water quality has some discernible effects on the size and species composition of the benthic communities in both the Haw and New Hope drainage systems. The polluted main stem of the New Hope is, however, more noticeably different from its unpolluted tributaries than is the Haw from its respective tributaries. This is true with respect to both water quality parameters and benthic macroinvertebrate population parameters. These results indicate that water quality is a more important limiting factor for benthic macroinvertebrates at the New Hope stations that at the stations of the Haw system.

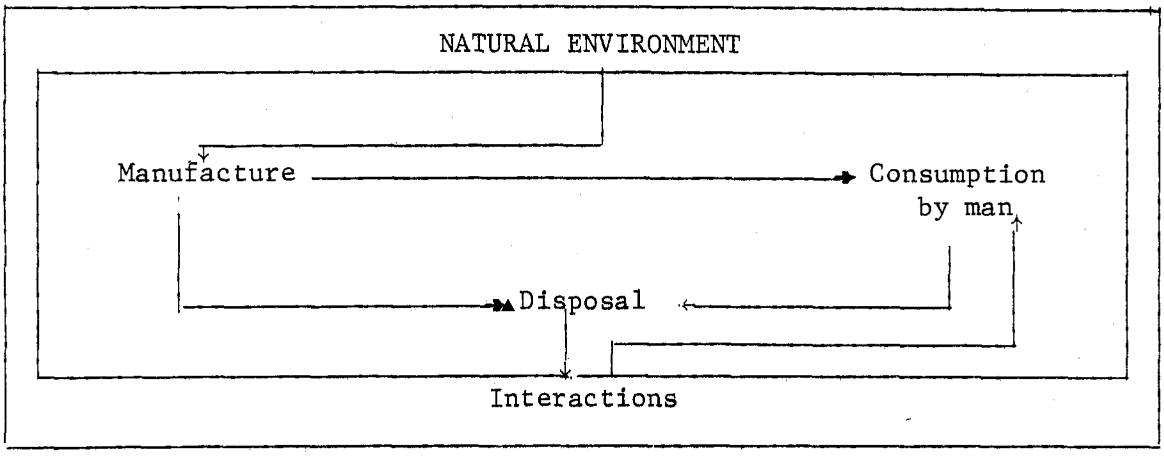
Heavy Metals in the Macroinvertebrates and Waters of the New Hope and Lower Haw Rivers

Introduction

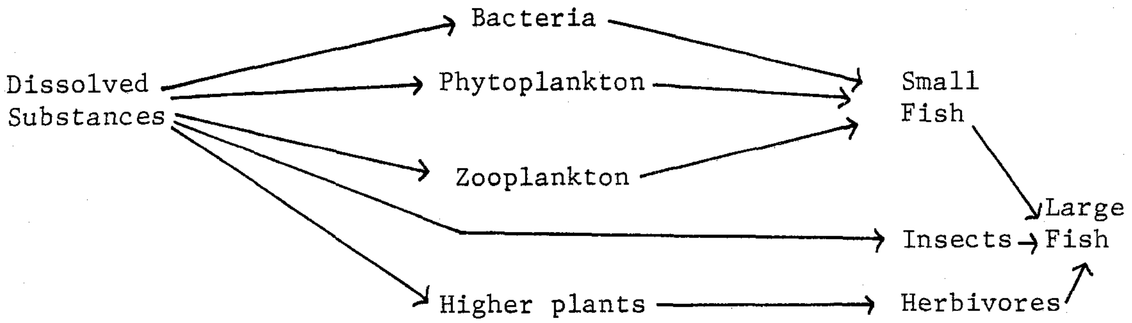
Much concern has been expressed in recent years over the increasing concentrations of heavy metals in our environment. Serious environmental and health effects have been indicated in many metals now currently in use. Japan and Sweden have had serious problems with mercury contamination of the aquatic environment which resulted in 45 deaths in Japan (35) and a decline in the wildlife populations and contamination of fish in Sweden (36).

Heavy metals are used not only in the elemental state but also in a myriad of compounds. Effluents from the mining and manufacturing processes often contain metallic contaminants. Exposure can occur through use of the finished product and further environmental contamination occurs after disposal. Incineration releases metals into the atmosphere in various forms which are then washed into waterways by rainfall. Manufacture and consumption result in the release of metals to the environment. Biological metabolism can change the form of the substance and also can result in a new exposure for man. The movement of toxic substances from the environment to man and through the aquatic food chains is shown in the following diagrams.

Movement of toxic Substances from the Environment to Man (37).



The higher trophic levels contain higher amounts of the toxic material as the metals are concentrated in the food chains. Thus, although the concentrations in water may not be harmful, the ability of organisms which live in the aquatic environment to concentrate metals may ultimately pass on harmful amounts to man.



Flow of materials through an aquatic food chain (38).

Metals, unlike synthetic organic compounds, have always been present in the environment, and organisms have evolved in their presence. Whereas many organic compounds are degraded, even though slowly in some cases, metals are not and are always available although their form may change unless removed from the ecosystem by either natural or artificial means. The toxicity of various metals varies widely and the form they take also determines their relative toxicity. The danger to the ecosystem depends on both the concentration and the chemical form. Effects on a particular organism are a function of age, health, metabolic system, stresses and other factors so that it is difficult if not impossible to extrapolate results to man. Much more data is needed to assess the total problem with respect not only to man but to the entire ecosystem.

Trace metals enter the aquatic environment from natural sources such as erosion of soils and rocks as well as from man-made sources. Krauskopf (39) studied factors that could control the concentration of trace metals in sea water. He concluded that sea water was no where near saturated with trace elements even in places of extreme temperature and pH. Amounts of Zn, Hg, Cu, Pb, and Cr could be controlled in part by the precipitation of sulphides in a locally reducing environment. This was probably not a major factor and it did not control some metals. Adsorption could control some of the metals. Manganese dioxide and hydrated ferric oxide serve as efficient adsorbents. Biological control played a major role in the control of some metals but data were incomplete at that time. It is this biological uptake that we are concerned with at this time.

Organisms take up from the water and from their diet those elements required for maintenance, growth, and reproduction. The proportion of the various elements required for maintenance are different from the proportions that exist in the environment and this results in different concentrations of elements within the organism. These elements may be obtained by organisms above the algae in the food chain from the water directly and/or by ingestion. Since the requirements for elements are different in different kinds of organisms, the fluxes of the various elements are variable at different trophic levels. The elements accumulated by organisms are not always independent of one another and elements of similar chemical properties tend to be taken up together with some alteration in the proportion that exists in the environment (40).

Living cells are able to take up elements from a solution againat a concentration gradient. Several generalizations can be made based on data for marine algae and plankton (41). All elements are concentrated to various degrees except sodium and chlorine. For cations, the order of affinity for living matter is tetravalent and trivalent elements > divalent transition metals > divalent group II-A metals > univalent group I metals. However the order or concentration factor is not readily correlated with the order of stability of complexes formed with organic ligands. Heavier elements are taken up more readily than light ones, perhaps due to their greater polarizability. For anions, the order of affinity is nitrate > trivalent anions > divalent anions > univalent anions. Comparable concentration of elements takes place for freshwater organisms.

Invertebrates can be divided into two groups: those with permeable skins (molluscs, annelids) and those without (crustacea). Marine organisms with permeable skins have blood similar to sea water. Gills of those with impermeable skins are permeable to salts and water. Fresh water organisms take up ions by mouth and through the skin and lose ions through diffusion and the excretion of urine. The blood is less similar to sea water but still has higher ion concentrations than the surrounding medium (41).

There are thus two general processes involved in the uptake of trace elements from the aquatic environment. First, direct transfer of ionic species or dissolved substances from the water to the organism (such factors as biological specificity of the ion, mass of the ion, charge, radius, and oxidation-reduction potential may play a part as well as the relative availability of the element) and secondly, ingestion of particulate matter (42).

Brooks and Rumsby (43) suggested that accumulation could occur by ingestion of elements via preconcentration in food material, the complexing of metals by coordinate linkages with appropriate organic molecules, and the incorporation of metals into physiological systems. Adsorption of particulate matter on the gills is another method. Table 10 indicates the variability of uptake among elements and species.

Several controlled environment studies have been performed on shellfish, especially oysters, and some generalities have been made. Pringle and his coworkers (44) came to several conclusions. There is a species difference in the uptake and concentration of a given metal. The environmental concentration level to which various species may be subjected will result in different uptake rates (ppm per kg per day) as well as concentration levels attained depending on the duration of exposure. The temperature, salinities, dissolved oxygen, pumping rates, and physiological conditions are all closely related to the uptake and concentration level obtained for any given metal with all species. Higher temperature causes increased uptake and this implies a seasonal variation. The apparent toxicity of any metal for a given species determines not only the uptake and concentration but also the duration of the experiment. Each metal accumulates more in certain anatomical areas; for example, lead accumulates most in the digestive gland of the oyster. Trace metals become chemically and structurally incorporated into the tissue of the various organs. They may take one of three forms: metal chelates of smaller organic molecules, structural incorporation into

TABLE 10

Enrichment Factors for Trace Elements in Shellfish Compared with the Levels in the Marine Environment (43)

Element	Scallop	Oyster	Mussel
Ag	2,300	18,700	330
Cd	2,260,000	318,000	100,000
Cr	200,000	60,000	320,000
Cu	3,000	13,700	3,000
Fe	291,500	68,200	196,000
Mn	55,500	4,000	13,500
Mo	90	30	60
Ni	12,000	4,000	14,000
Pb	5,300	3,300	4,000
V	4,500	1,500	2,500
Zn	28,000	110,300	9,100

macromolecules, or inorganic incorporation into the shell matrix. Removal or depletion depends on the reversal of the incorporation process. Temperature and initial concentration also affects the depletion rate. Selectivity among molluscan species depends upon the metals available in the environment, the chemical and physical properties, the kind and numbers of ligands available for chelation, transport and storage, and stability of the complex formed.

Schuster and Pringle (45) noted that the environmental levels of metals cannot be accurately determined on the basis of the levels in shellfish. In another study (46), three trends in shell growth were noted. Cadmium exposed oysters did not develop as much new shell as non-exposed oysters. Considerable growth occurred in the Zn, Cu, and Cr exposed samples. Copper exposed samples exhibited the most growth. They also noted that body color, mantle edge, pigmentation and general body appearance were also affected by the accumulation of trace metals.

Phelps (47) studied the partitioning of elements within a benthic community. The qualitative and quantitative structure of the community had a direct effect on the distribution of the elements throughout the community.

Many select deposit feeders (polychaetes) feed within a restricted area at the sediment-water interface and this source of nutrition is the most recently settled particulate materials. Non-select deposit feeders, omnivores, and carnivores move freely through the upper layers of the sediments and feed upon sediments, living organisms and detritus. Metals concentrations are highest in those most dependent on sediment as a source of nutriment--that is, select deposit feeders have the highest concentration and carnivores the lowest and those highest in the food chain seem to be lowest in concentration. Organisms feeding upon the most recently settled particulate materials are exposed to readily available sources whereas those feeding below the water-sediment interface do not, due to the fact that the metals are removed from biological availability. However this may be just the opposite for Zn. In any event, these organisms concentrate a considerable amount of zinc which can be transferred through fish to man.

The study was continued (48) and it was found that copper was enhanced in organisms living in close proximity to the land mass. It seemed to be more available in sedimentary interstitial water and in older and more compact sediments. The sediment-water interface acts as a settling board for particulate materials including concentration of stable elements. It also acts as a membrane below which some elements may undergo chemical and physical transformation which makes them more or less available for biological systems. The interface may have no relationship with the physical-chemical state of the element or its relative biological abundance.

Changes in the taxonomic composition of faunal groups did not seem to influence the elemental composition of the group. Feeding types seemed to play the major role. There also seemed to be no temperature influence on the elemental composition of the benthic groups.

Mathis and Cummings (49) studied the distribution of metals in bottom sediments, water, clams, tubificid annelids, and fishes in the Middle Illinois River. They found that bottom dwelling animals reflected the concentrations of the metals in the sediments more closely than did the fishes. Non-carnivorous fishes had higher concentrations of Cu, Ni, Fe, Cr, and Zn when compared to carnivorous fishes. They concluded that the metals did not concentrate along successive trophic levels since the carnivorous fishes exhibited the lowest concentrations.

The present study is concerned with the concentration of various toxic heavy metals in insect larvae present in freshwater streams in North Carolina. These organisms serve as food for larger animals in the streams and thus act as intermediates in the food chain.

The design of the study called for a comparison between streams which receive industrial and municipal effluents (polluted) and those which do not (non-polluted). Since the polluted streams generally also receive heavy organic loads, it would be difficult to determine whether any change in diversity was due to the sublethal concentrations of heavy metals or to the organic loading.

Water sampling and benthic collections were from the stations shown in Figure 2. Two water samples were taken every two weeks from March 1971 through February 1972 alternating between the New Hope and the Haw sampling stations. On each date one polluted station and one control station were sampled. NH-8, 8A, and 12 and H-7 through 12 inclusive are control stations since they receive no direct pollution except land runoff. Concentrations of various metals were compared in organisms and waters from the different rivers and their tributary control streams to determine if there was any significant difference.

Materials and Methods

Water samples were collected in a plastic bucket and the water was transferred to a Nalgene 20 liter polyethylene jerrican for storage at 2.0°C. Eighteen liters of the raw water were freeze-concentrated by a method suggested by Malo and Baker (50) using a VirTis freeze-concentrator with a six-liter tank. Three six-liter aliquots were concentrated and combined and were then concentrated to the final volume. The concentrated samples were stored in screw-top polyethylene bottles at 2.0°C.

Both raw and concentrated water samples were analyzed by the method outlined by the Water Quality Office of the Environmental Protection Agency (51).

All glassware used was borosilicate glass and was washed with 7-X detergent, rinsed with distilled water, then rinsed with 1:1 nitric acid, and finally rinsed with distilled water. All chemicals used in the preparation and analyses of the samples were reagent grade or better.

To prepare dissolved constituents for analysis, an aliquot was filtered through a 0.45 membrane filter. The volume was recorded and the filtrate was acidified with 1:1 nitric acid (3 ml per liter) and stored in a polyethylene bottle.

To prepare total metals samples, the sample was not filtered. A representative aliquot was transferred to a 250 ml Griffin beaker and 3 ml of concentrated nitric acid were added. The beaker was placed uncovered on a steam bath and evaporated to dryness. Another 3 ml of nitric acid were added, the beaker was covered with a watch glass, and the sample was heated for several hours. The watch glass was removed and the acid was allowed to evaporate. The beaker was cooled and 2 ml of concentrated hydrochloric acid were added. The beaker was warmed to dissolve the material and the volume of the sample was adjusted to 25 ml. The samples were stored in polyethylene bottles.

All analyses were performed using a Perkin-Elmer 303 atomic absorption spectrophotometer. For those elements analyzed by atomic absorption (Cd, Cr, Pb, Zn), a three slot burner was used and standard conditions were employed (52). Mercury was analyzed only for total metal. The flameless atomic absorption technique (UV absorption by elemental mercury vapor) was used to determine mercury (51).

Representative specimens of the macroinvertebrates that were collected for diversity studies were identified and preserved in 70 percent ethyl alcohol. For analysis, the samples were placed on weighed filter paper in a buchner funnel and excess alcohol was removed by vacuum filtration. The sample and filter paper were weighed to determine the wet weight. The samples were dried in an oven at 105°C overnight, and were then placed in weighed 1 oz screw-top polyethylene bottles, crushed with a glass stirring rod, and reweighed to determine the dry weight.

The macroinvertebrate samples were digested using a variation of the method of Adrian (53). Two ml of concentrated nitric acid and one ml of concentrated perchloric acid were added to each polyethylene sample bottle and the top was replaced tightly. The samples were allowed to digest at room temperature overnight and the following day were heated at 70°C in a water bath for several hours. When digestion was complete the volume was adjusted to 10 ml with distilled water. The biological samples were analyzed for metals by the same methods as the water samples.

Results and Discussion

Water

Water samples from the Haw and New Hope Rivers and their tributaries were analyzed for five heavy metals (Tables 11, 12 and 13). All analyses were performed on samples which were freeze-concentrated. All values were corrected to the raw water concentration.

Table 11 summarizes mean levels found in the Haw and New Hope main stem and control (tributary) streams during the year March 1971 to February 1972. Cadmium levels were the same in all streams. Mercury and lead exhibited

TABLE 11

Means of Total Metal Concentrations* in Water of the New Hope and Haw River Systems
March 1971 - February 1972

Metal ppb	New Hope River		Haw River	
	Main Stem	Control Streams	Main Stem	Control Streams
No. of Samples	11	8	10	10
Cd	0.5	0.5(7)+	0.7(9)	0.7
Cr	34.1(8)	1.7(7)	3.4(9)	2.3(9)
Hg	0.10	0.07	0.08	0.05
Pb	2.2	1.6	3.8	1.1
Zn	21.0(9)	13.4(7)	6.6	6.8

*Freeze concentrated water analyses corrected to raw water concentrations.
+Number of samples used to calculate the mean.

TABLE 12

Variation in Concentrations of Metals in New Hope River Water at Stations NH-7 and NH-8
March 1971 - February 1972++

	Cd ppb			Cr ppb			Hg ppb	Pb ppb			Zn ppb		
	*t	d	s	t	d	s	t	t	d	s	t	d	s
Mean	0.7	0.4	0.3	3.4	0.6	2.8	0.07	3.8	-	3.8	6.6	1.4	5.2
NH-7 Range	0.3- 9.0	+nd- 0.8	nd- 0.8	1.5- 4.8	nd- 2.2	1.5- 4.6	0.03- 0.14	nd- 13.1	nd	nd- 13.1	4.4 9.4	nd- 5.9	nd- 9.0
No. of Samples	9	9	9	9	9	9	10	10	10	10	10	10	10
Mean	0.7	0.4	0.3	2.3	0.2	2.1	0.05	1.1	-	1.1	6.8	2.2	4.6
NH-8 Range	0.2- 2.1	nd- 1.6	nd- 0.7	1.0 5.8	nd- 0.7	0.4- 5.8	0.01- 0.08	nd- 4.2	nd	nd- 4.2	0.7 18.4	nd- 7.9	0.5- 9.3
No. of Samples	10	10	10	9	9	9	10	10	10	10	10	10	10

*Total, dissolved, suspended

+Not detectable

++Freeze concentrated water analyses corrected to raw water concentrations.

TABLE 13

Variation in Concentrations of Metals in Haw River Water at Stations H-1, H-5, H-7 and H-8
March 1971 - February 1972++

		Cd ppb			Cr ppb			Hg ppb	Pb ppb			Zn ppb		
		*t	d	s	t	d	s	t	t	d	s	t	d	s
	Mean	0.5	0.4	0.1	43.7	22.4	21.3	0.08	2.4	-	2.4	21.8	13.5	8.3
H-1	Range	0.3-0.8	+nd-0.8	nd-0.4	15.9-74.2	1.7-41.9	2.8-36.1	0.04-0.10	nd-5.6	nd	nd-5.6	10.2-29.0	8.1-24.1	2.1-14.3
No. of Samples		5	5	5	6	6	6	6	6	6	6	6	6	6
	Mean	0.4	0.2	0.2	18.1 **(0.9)	3.1 (nd)	15.0 (0.9)	0.12	1.9	-	1.9	19.3 (3.4)	9.6 (2.4)	9.7 (1.0)
H-5	Range	0.1-0.6	nd-0.4	0.1-0.3	16.2-21.3 (0.7-1.1)	1.8-4.1 (nd)	12.1-17.9 (0.7-1.1)	0.03-0.30	nd-4.1	nd	nd-4.1	15.6-21.7 (2.5-4.4)	8.5-11.3 (0.4-4.4)	7.1-12.7 (nd-2.1)
No. of Samples		4	4	4	3 (2)	3 (2)	3 (2)	5	5	5	5	3 (2)	3 (2)	3 (2)
	Mean	0.6	0.3	0.3	1.9	0.1	1.8	0.07	1.6	-	1.6	15.0	3.8	11.2
H-7	Range	0.2-0.8	nd-0.7	nd-0.4	1.1-2.8	nd-0.6	1.1-2.8	0.03-0.15	nd-4.3	nd	nd-4.3	1.7-40.6	nd-13.8	1.7-32.5
No. of Samples		6	6	6	4	4	4	6	6	6	6	6	6	6

TABLE 13

Continued

		Cd ppb			Cr ppb			Hg ppb	Pb ppb			Zn ppb		
		t	d	s	t	d	s	t	t	d	s	t	d	s
	Mean	0.2	nd	0.2	1.1	0.1	1.0	0.07	1.7	0.7	1.0	3.7	0.1	3.6
H-8	Range	0.2	nd	0.2	1.1- 1.2	nd- 0.2	0.9- 1.2	0.05- 0.09	1.7- 1.8	nd- 1.5	0.2- 1.8	3.7	0.1	3.6
No. of Samples		1	1	1	2	2	2	2	2	2	2	1	1	1

*Total, dissolved, suspended
+Not detectable
++Freeze concentrated water analyses corrected to raw water concentrations.
**Samples divided into two series due to large range over the time period.

slightly higher levels in the main stems than in the control streams. Zinc levels were much higher in the Haw main stem than the Haw control stream but levels were similar in the New Hope system and were lower than concentrations in the Haw. Chromium exhibited the greatest difference between the main stem and control stream. This is in agreement with high levels being discharged from the Haw River Sanitary District treatment plant (7).

Appendix E presents the original data. It was felt a more realistic value for a yearly average would be obtained if exceptionally high or low values were excluded. High values could be due to slugs discharged from outfalls while low values could be due to dilution by rainfall. Those values which were not detectable were assumed to be zero for calculation of the mean. However, the limits of detectability vary with the element and the degree of freeze-concentration; i. e., those samples which were more highly concentrated would have a lower limit of detection in terms of the raw water. Thus one must be cautious and consider the freeze-concentration factor. Detection limits for the metals analyzed are as follows:

Limits of Detection
Atomic Absorption Spectroscopy

Element	Limit of Detection
Cd	0.004 μg/ml
Cr	0.01 μg/ml
Hg	0.05 μg
Pb	0.03 μg/ml
Zn	0.002 μg/ml

Tables 12 and 13 show the mean total, dissolved, and suspended concentrations of the various metals at the different stations of the New Hope and Haw River systems respectively. Only total mercury was determined due to the time involved for each analysis. Suspended concentrations of chromium, lead, and zinc were higher than dissolved concentrations with a few exceptions. Cadmium was more erratic in its distribution. As raw water is freeze-concentrated, precipitates to which ions can adsorb form. This results in lower concentrations of metals in the water. This cannot be considered a true reflection of the proportions to be encountered in the raw waters since these precipitates would not otherwise be present, and thus the amount of adsorption depends on the level of freeze-concentration.

Figures 33 through 35 diagram the seasonal variations of the means of the various metals in the main stem and control streams. Cadmium showed in July 1971 a marked increase in the Haw and New Hope main stems and the Haw controls. The average for the remainder of the year was just below 1.0 ppb (μg/l). Figure 34 shows clearly that the Haw main stem had higher concentrations of chromium than the control or the New Hope system. An anomalous reading was encountered in September when the concentrations in both the control streams and main stem of the Haw was approximately 75 ppb compared to less than 5 ppb for the remainder of the year. Contamination of the samples taken that day could account for the high values.

Figure 33 shows that there was not much difference in the mercury levels throughout the year. Note that the concentration scale is expanded for ease of plotting and that small differences are accentuated.

Lead as diagrammed in Figure 34 also showed little variation except for one high value on the main stem of the New Hope river in September. Again this could have been due to contamination or perhaps a sudden discharge from an upstream outfall.

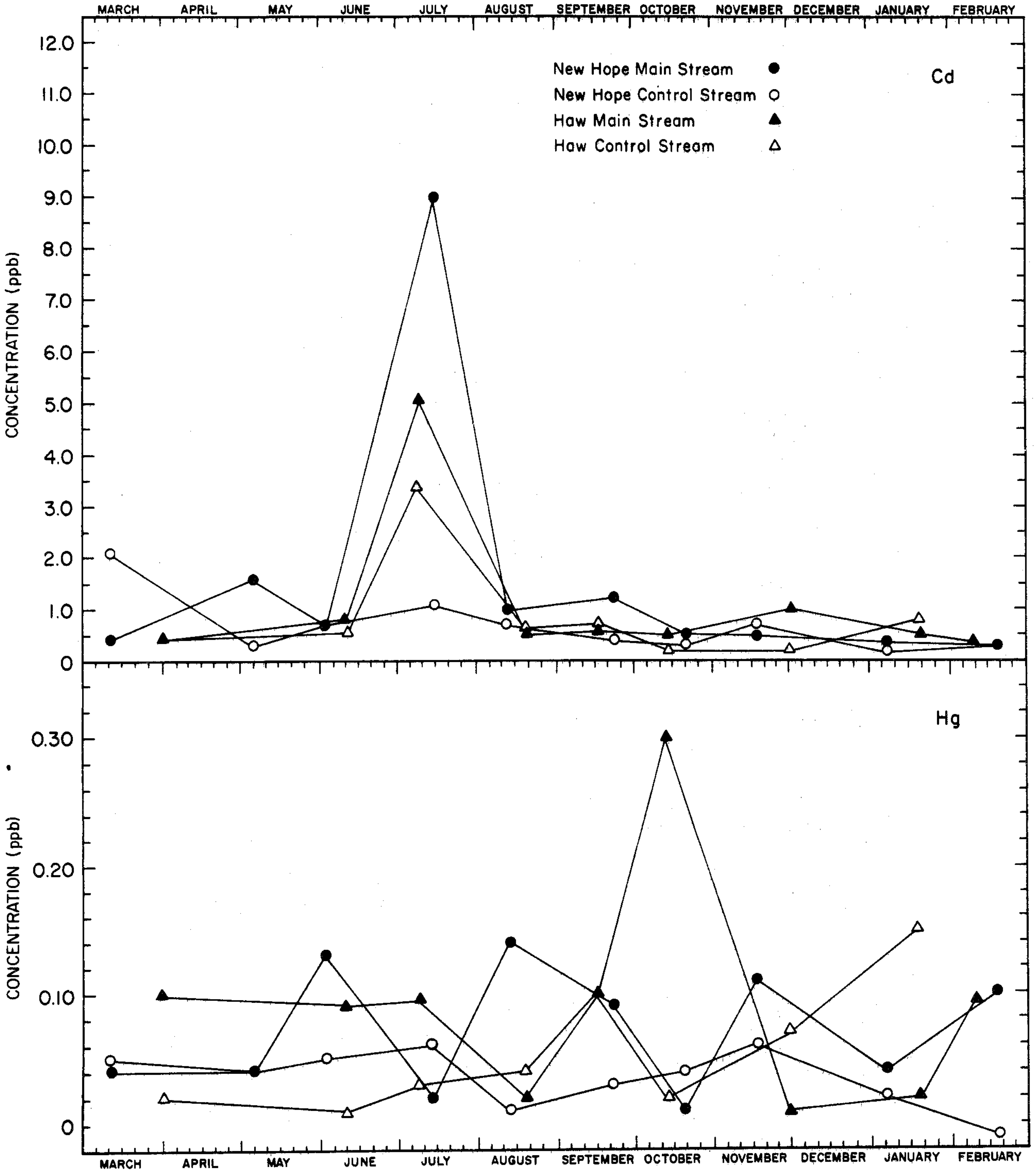


Figure 33 Mean monthly variation of cadmium and mercury concentrations in the water of the New Hope and Lower Haw River drainages, March 1971 to February 1972.

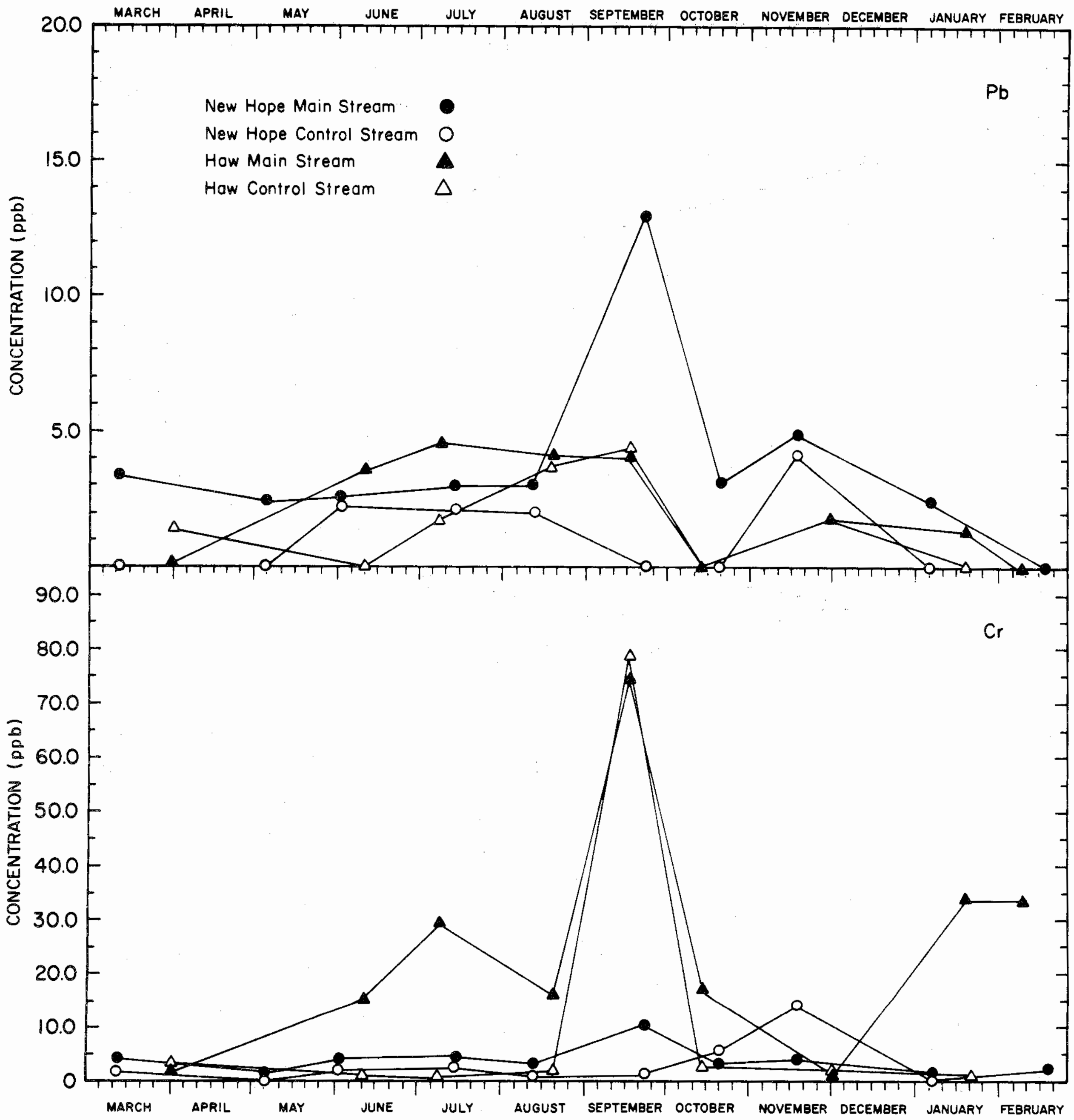


Figure 34 Mean monthly variation of lead and chromium concentrations in the water of the New Hope and Lower Haw River drainages, March 1971 to February 1972.

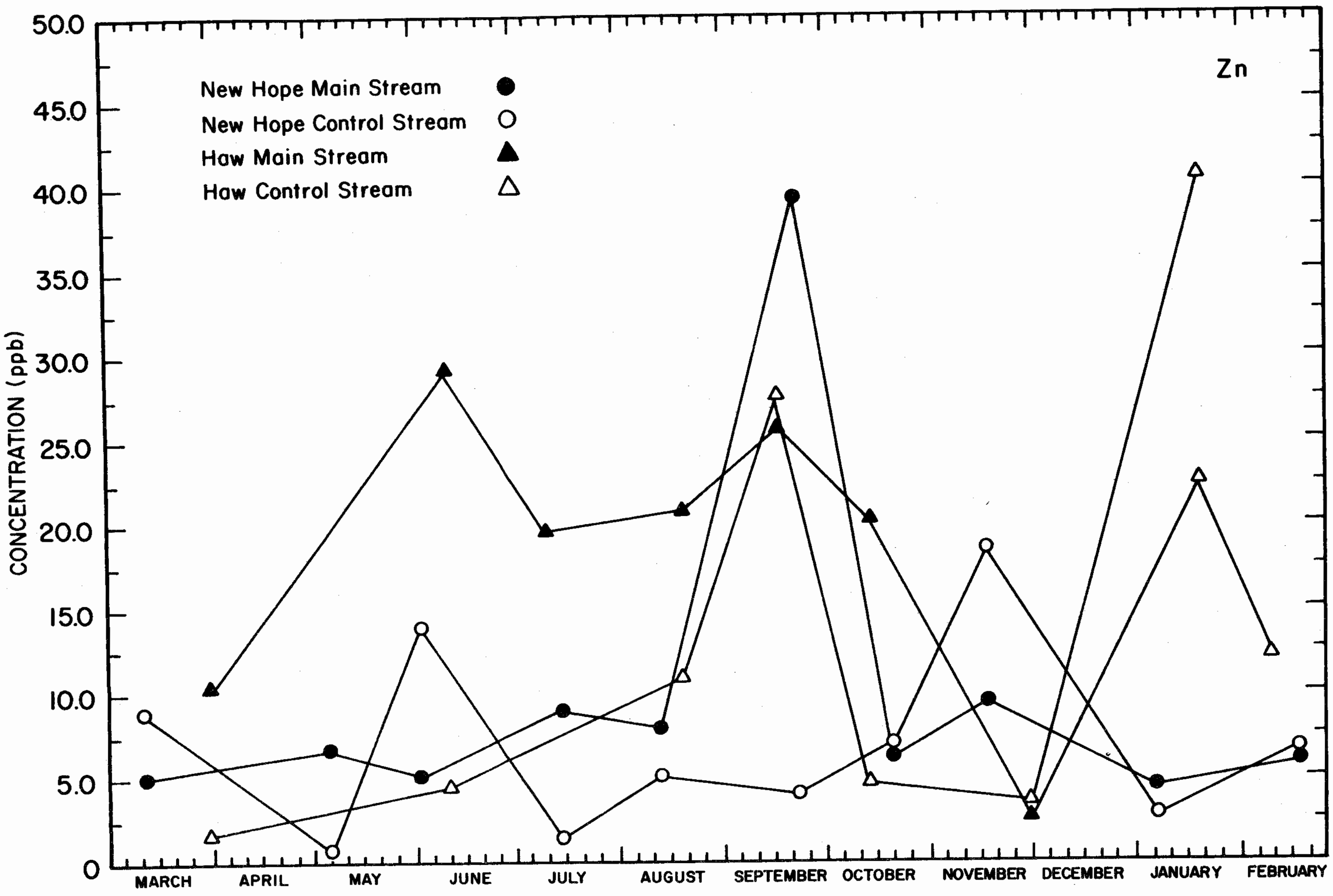


Figure 35 Mean monthly variation of zinc concentrations in the water of the New Hope and Lower Haw River drainages, March 1971 to February 1972.

Figures 35 indicates that zinc had a greater monthly variation than the other metals which were studied. High readings were found in all streams but the trend indicates that the concentration was highest in September.

Thus, it is concluded that there appears to be a trend towards higher concentrations of the metals from mid-summer to early fall which follows the seasonal decrease in runoff.

Macroinvertebrates

Samples of freshwater benthic macroinvertebrates were taken from the New Hope and Haw main stems and their tributary streasm as described earlier in this report. Samples from the tributaries would serve as controls to set a baseline for comparison of the five metals in the main stems which receive municipal and industrial discharges. The samples were sorted and analyzed by orders to determine if there was any difference in the degree of concentration among the various types of organisms.

Appendix F tabulates the data by river and station. The listings do not include every type of organism found at each station since those orders too few in number to analyze were excluded. Values reported as not detectable were considered as zero in the calculation of the mean but since each sample was a different weight and each element has a different sensitivity, the limits of detection varied from sample to sample. Therefore caution must be exercised in interpreting the data.

Figures 36 through 39 diagram the concentrations of the five metals in each order in the main stem and control streams. It can be noted that all the orders were not found in both the main stem and the controls and comparisons will be made with this in mind.

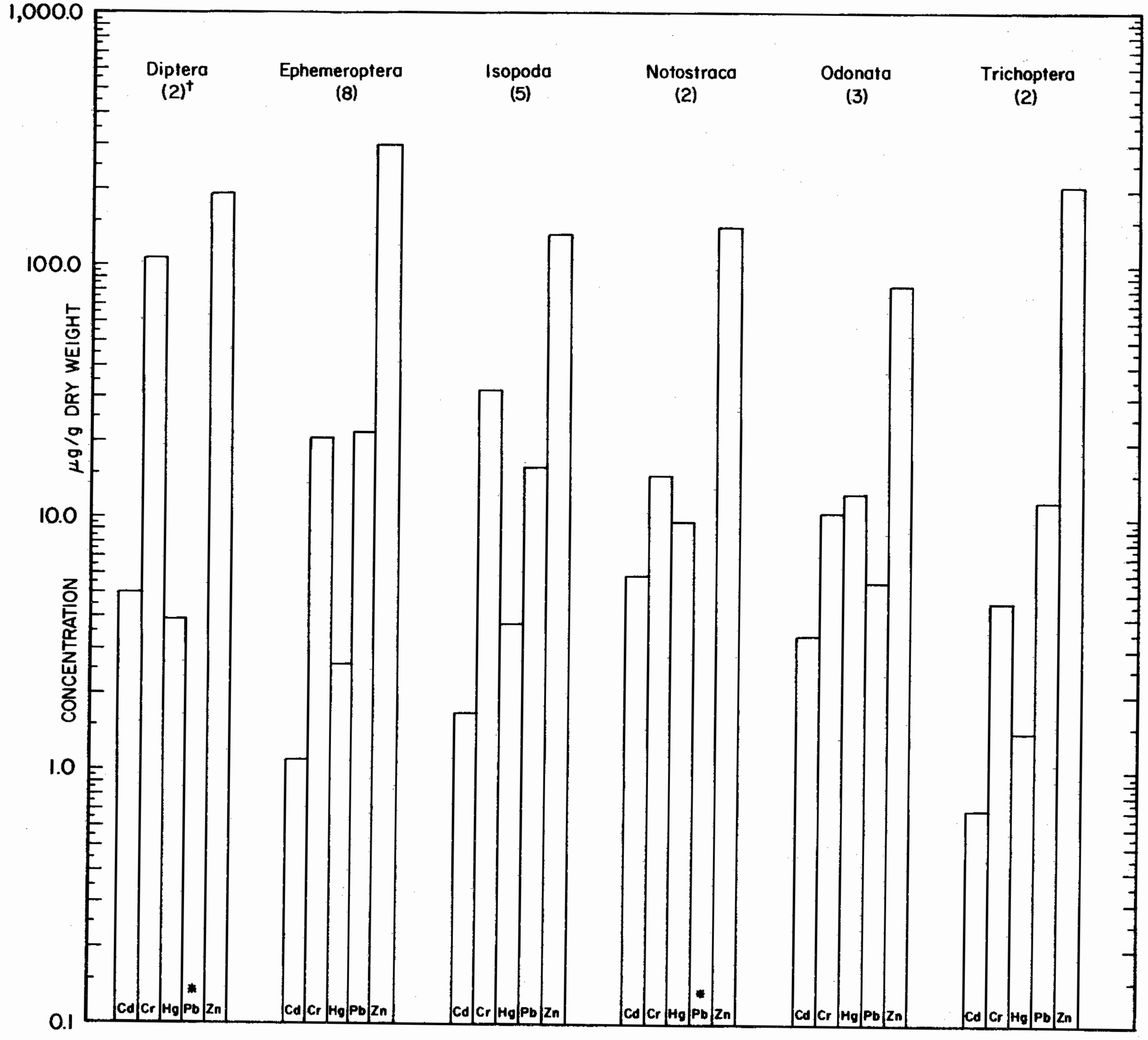


Figure 36 Mean concentrations of cadmium, chromium, mercury, lead, and zinc in benthic macroinvertebrates from the New Hope main stem.
* Not detectable + Number of samples

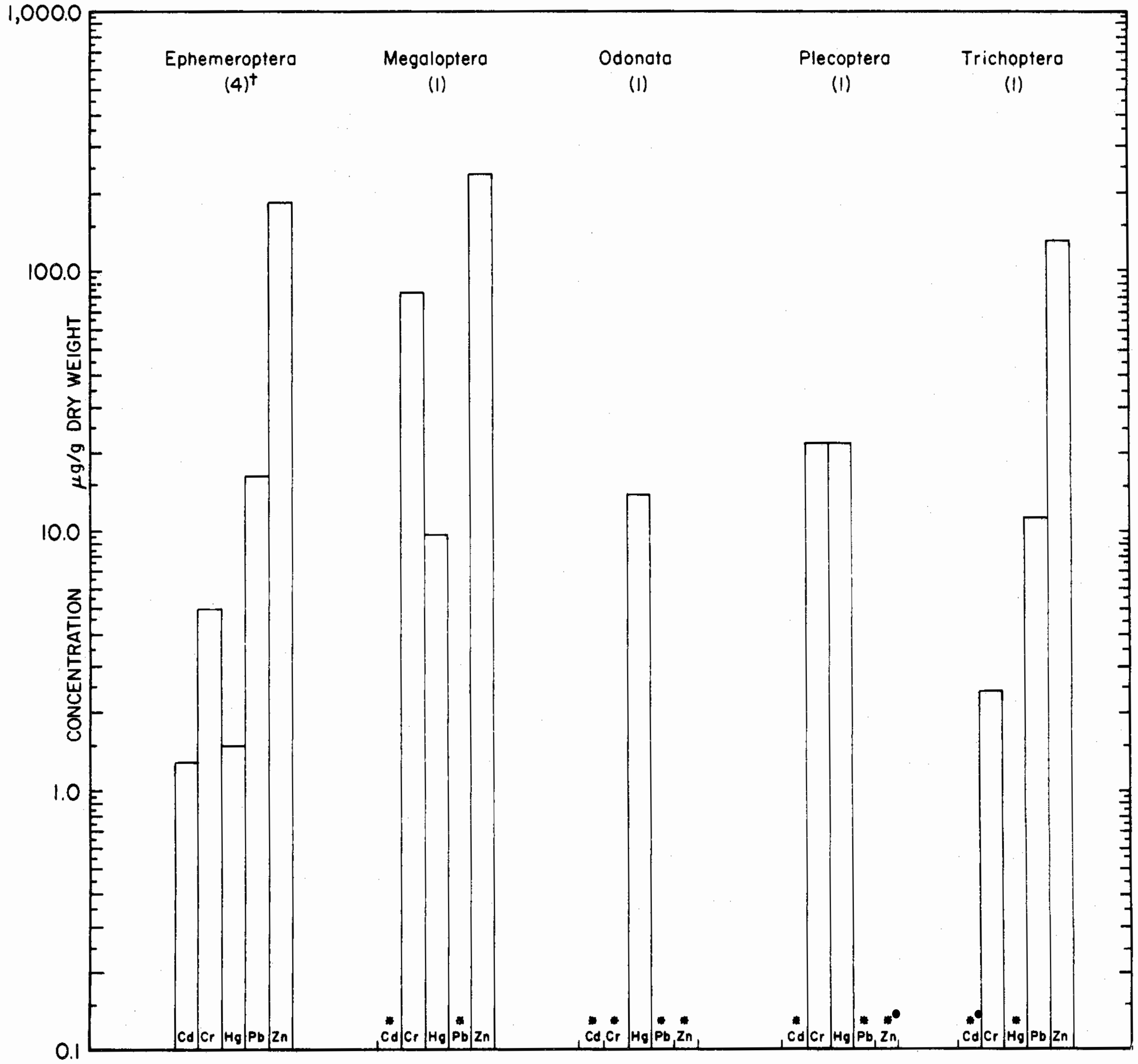


Figure 37 Mean concentrations of cadmium, chromium, mercury, lead, and zinc in benthic macroinvertebrates from the New Hope control streams.
* Not detectable + Number of samples

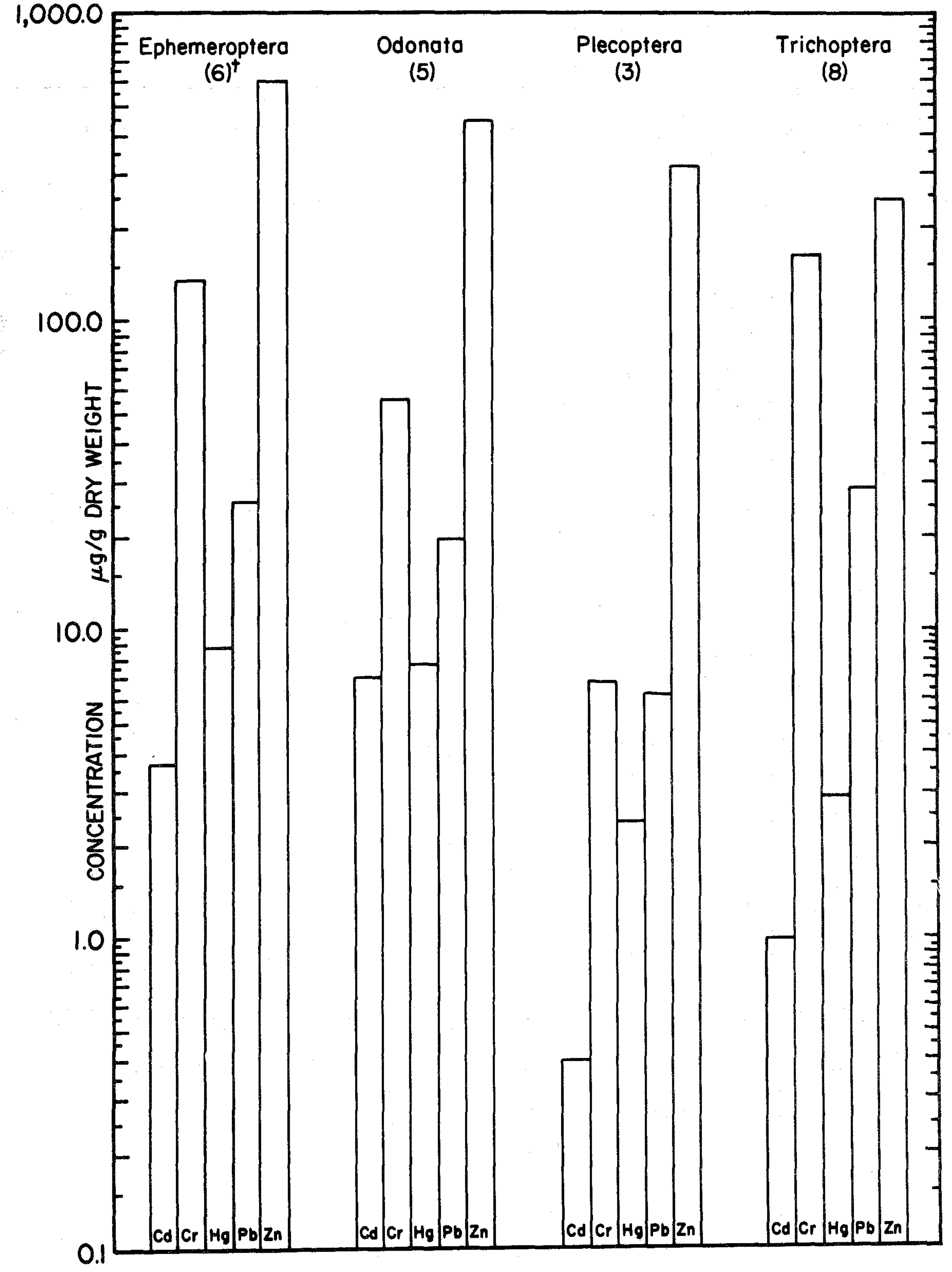


Figure 38 Mean concentrations of cadmium, chromium, mercury, lead, and zinc in benthic macroinvertebrates from the Lower Haw main stem.
+ Number of samples

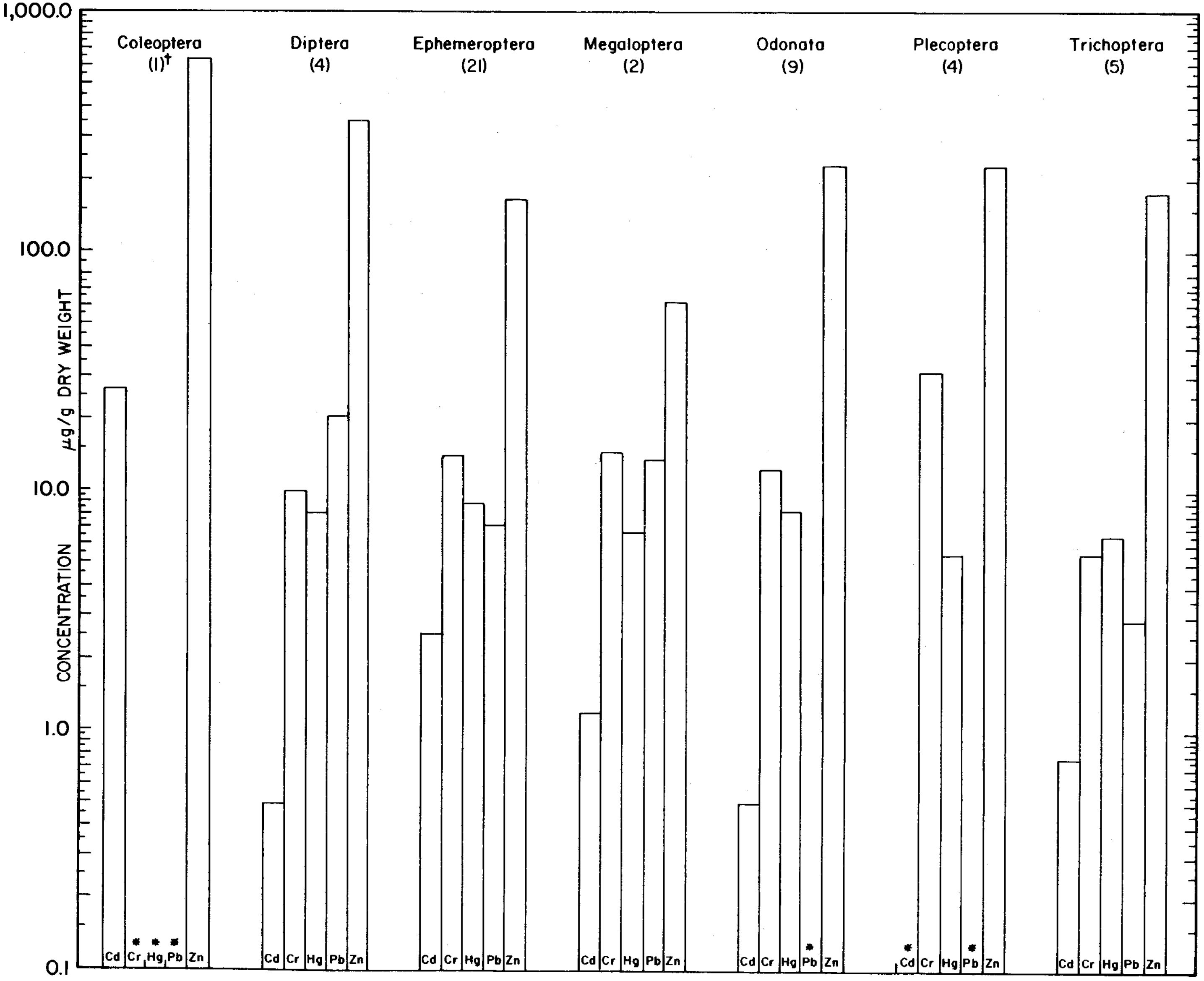


Figure 39 Mean concentrations of cadmium, chromium, mercury, lead, and zinc in benthic macroinvertebrates in the Lower Haw control streams.
* Not detectable + Number of samples

Ephemeroptera, Odonata, and Trichoptera were the only orders found in both the main stem and control streams in the New Hope series. In the specimens from these orders cadmium appears to be found in the lowest concentrations. Lead and mercury were also low. Chromium was usually intermediate and zinc had the highest concentration with two exceptions.

Cadmium did not appear to have a strict order of affinity among the organisms in the New Hope streams although the Trichoptera were usually lower than the other orders. Ephemeroptera concentrated more chromium than either Trichoptera or Odonata in both the main stem and controls but it did not have the highest concentration of all orders present. For mercury in both the main stem and control streams, the order of affinity was Trichoptera < Ephemeroptera < Odonata. Lead and zinc showed similar orders of affinity in the main stem and controls with Odonata < Trichoptera < Ephemeroptera.

Four orders were common to both the main stem and the control streams of the Haw system: Ephemeroptera, Odonata, Plecoptera, and Trichoptera. Most notable was the similar order of affinities for the main stem samples analyzed for chromium, mercury and zinc: Trichoptera < Plecoptera < Odonata < Ephemeroptera. The degrees of concentration of various elements for the different orders otherwise were erratic as was the case in the New Hope system.

It can thus be concluded that there was no one organism that consistently concentrated metals to a greater degree than any other. However different metals were consistently concentrated to a greater degree in all organisms. This will be discussed more fully later.

Figures 40 and 41 accentuate the differences in concentration in the same four orders (Ephemeroptera, Odonata, Trichoptera, and Plecoptera) at the

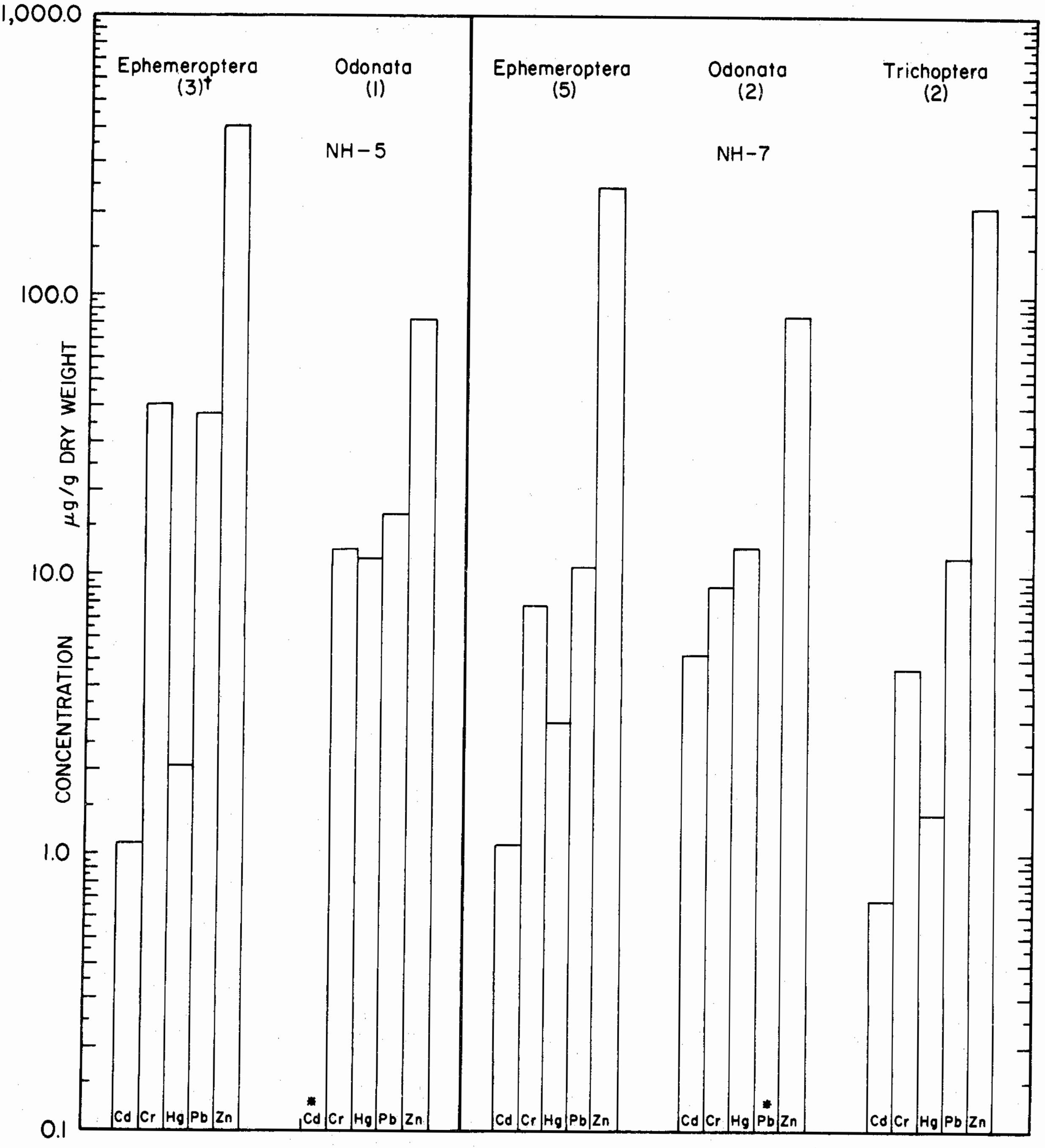


Figure 40 Mean concentrations of cadmium, chromium, mercury, lead, and zinc in benthic macroinvertebrates collected at New Hope main stem stations NH-5 and NH-7.

* Not detectable + Number of samples

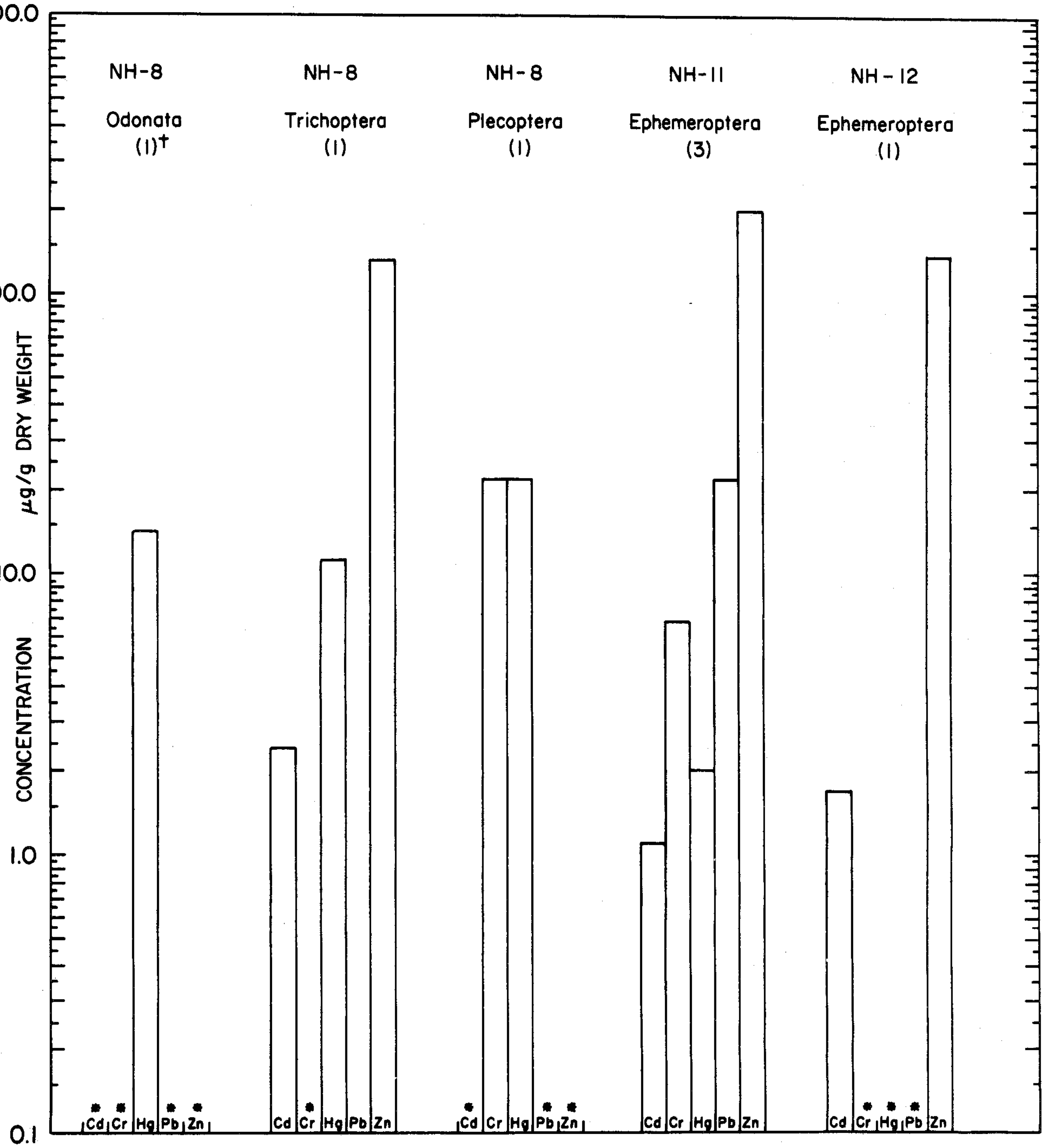


Figure 41 Mean concentrations of cadmium, chromium, mercury, lead, and zinc in benthic macroinvertebrates collected at New Hope control stations NH-8, NH-11, and NH-12.
* Not detectable + Number of samples

various New Hope sampling stations. Ephemeroptera exhibited the highest zinc concentrations throughout the series but there was little difference between the main stem and control streams except for high chromium concentrations at NH-5. Trichoptera also showed little difference between main stem and control. No conclusions are drawn from Odonata due to the small sample size.

Figures 42 and 43 diagram the Haw River system. It is immediately apparent that chromium was found at much higher concentrations at the Haw main stations 1 and 5 than in the control stations 7, 8, and 12. Lead also was higher at the main stem stations. Zinc had very little variation and mercury and cadmium do not appear to have been consistently high or low at any station.

Figures 44 through 46 present the concentrations for one element averaged over all the organisms over the yearly cycle in the New Hope and Haw River systems. For cadmium, the New Hope main stem and control streams showed little variation throughout the year while the Haw system had a much more erratic cycle. The chromium curve showed that the concentration of chromium in the Haw main stem was consistently higher than the Haw controls and the New Hope system throughout the year. Mercury concentrations were steady in the controls and main stem of the New Hope but inconsistent behavior was found in the Haw system. Lead concentrations were higher in the New Hope main stem organisms than the controls but the Haw river did not show such a definite trend. The zinc curve highlights the fact that the main stems of both rivers had higher zinc levels in the organisms than did the controls throughout the year. The levels remain fairly constant in all but the Haw main stem, but more data would be necessary during the fall months to determine the trend in the Haw main stem.

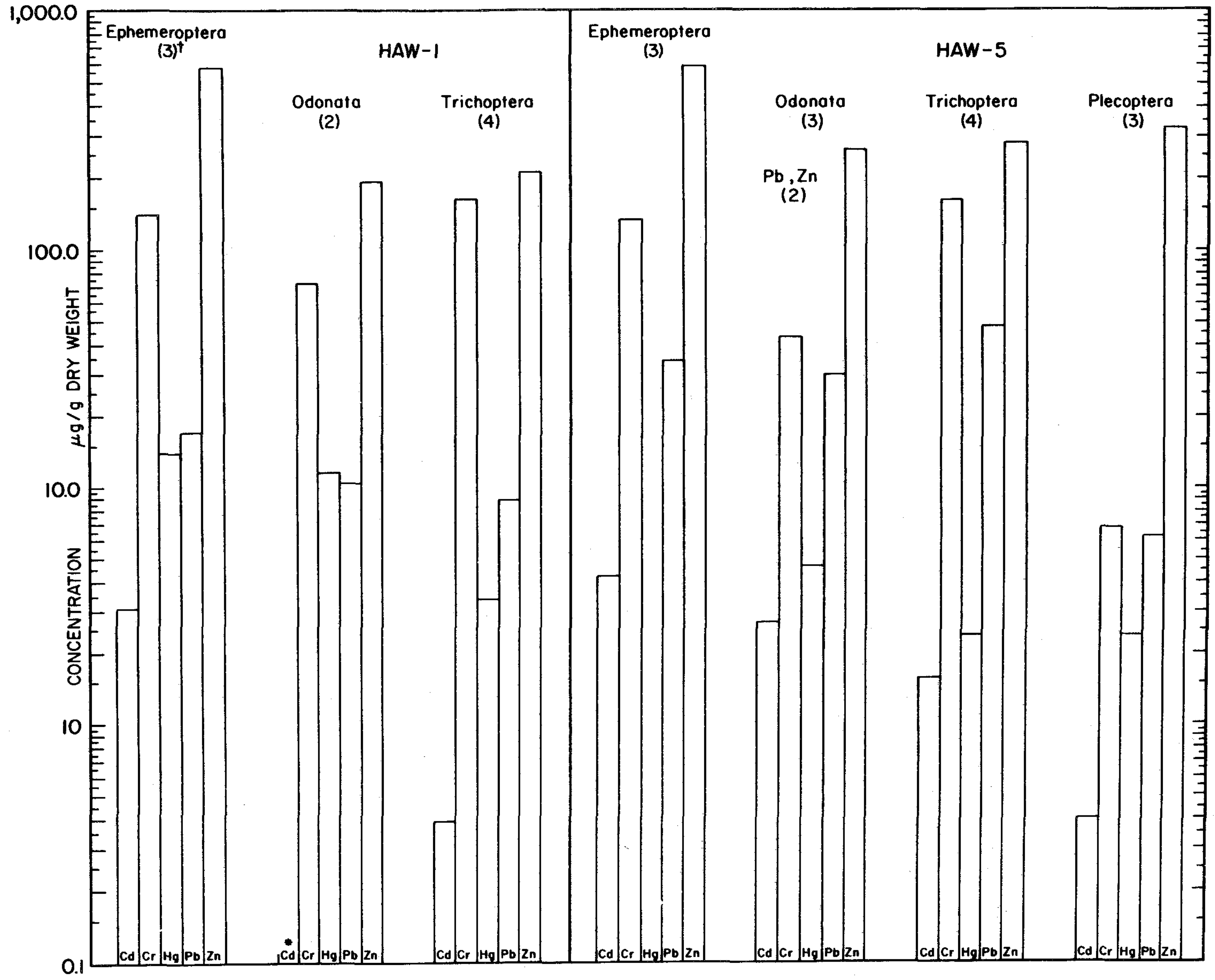


Figure 42 Mean concentrations of cadmium, chromium, mercury, lead, and zinc in benthic macroinvertebrates collected at Haw main stem stations H-1 and H-5.

* Not detectable + Number of samples

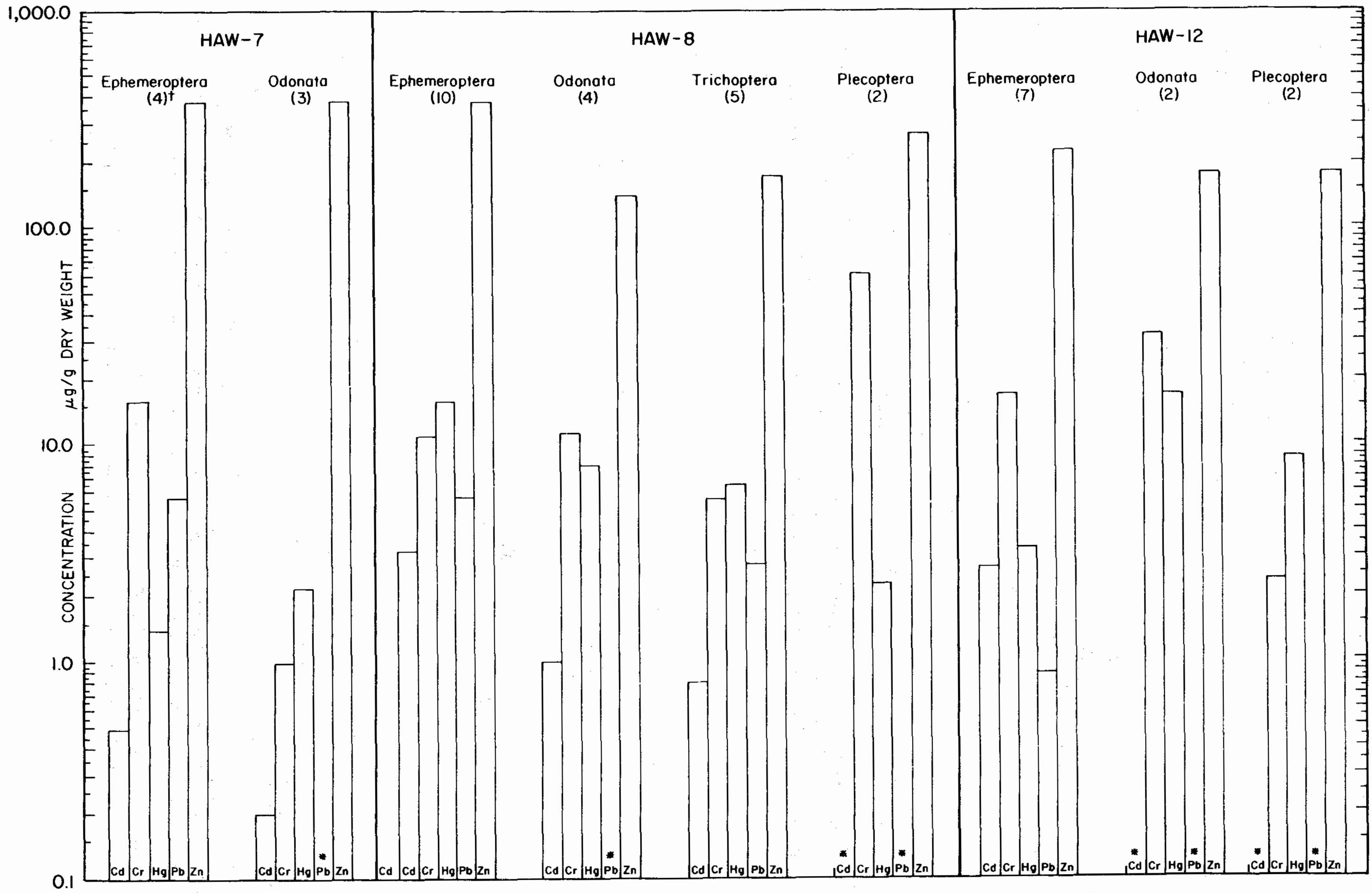


Figure 43 Mean concentrations of cadmium, chromium, mercury, lead, and zinc in benthic macroinvertebrates collected at Haw control stations H-7, H-8, and H-12.
* Not detectable + Number of samples

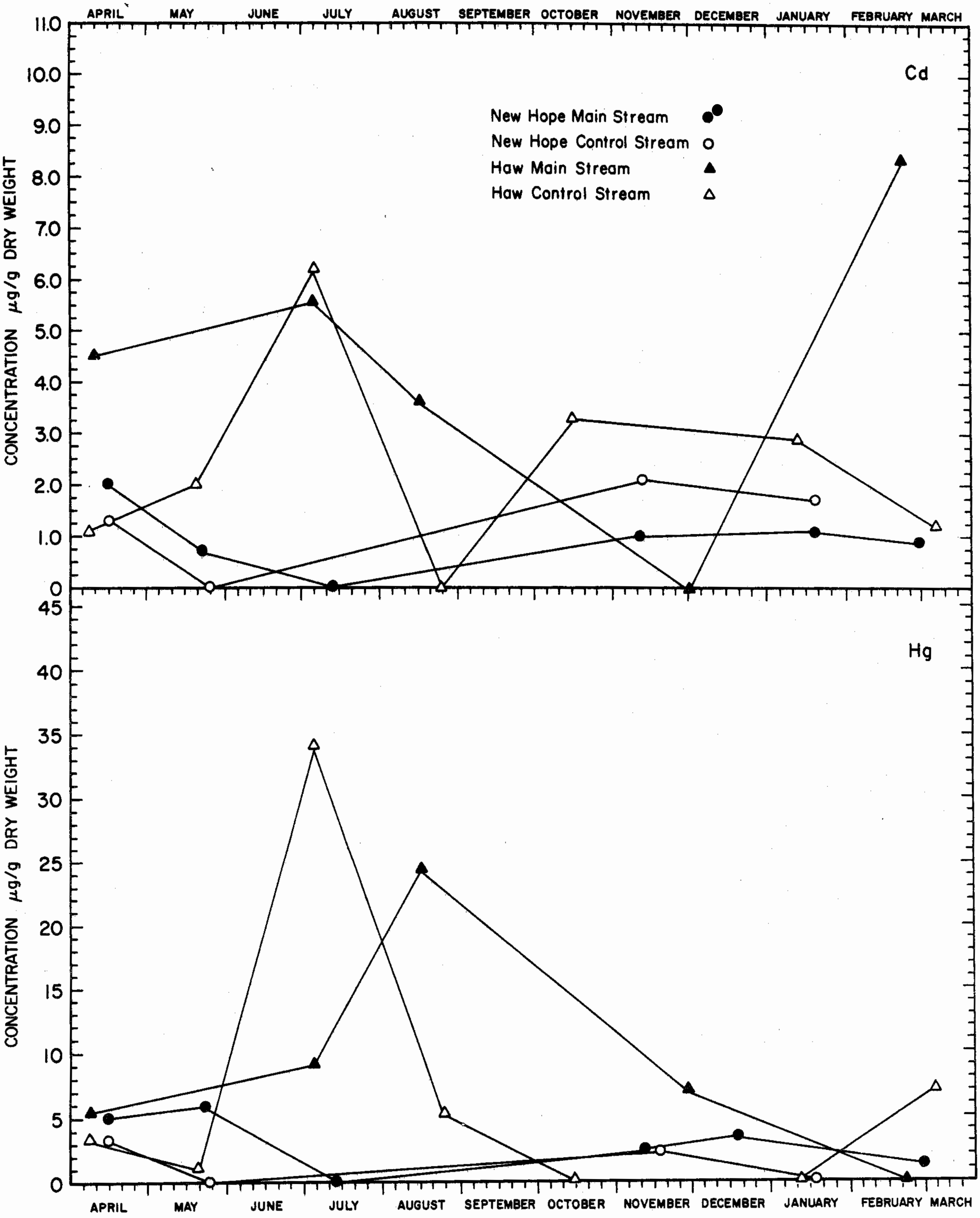


Figure 44 Mean monthly variation of cadmium and mercury concentrations in Ephemeroptera from the New Hope and Lower Haw River drainages, April 1971 to March 1972.

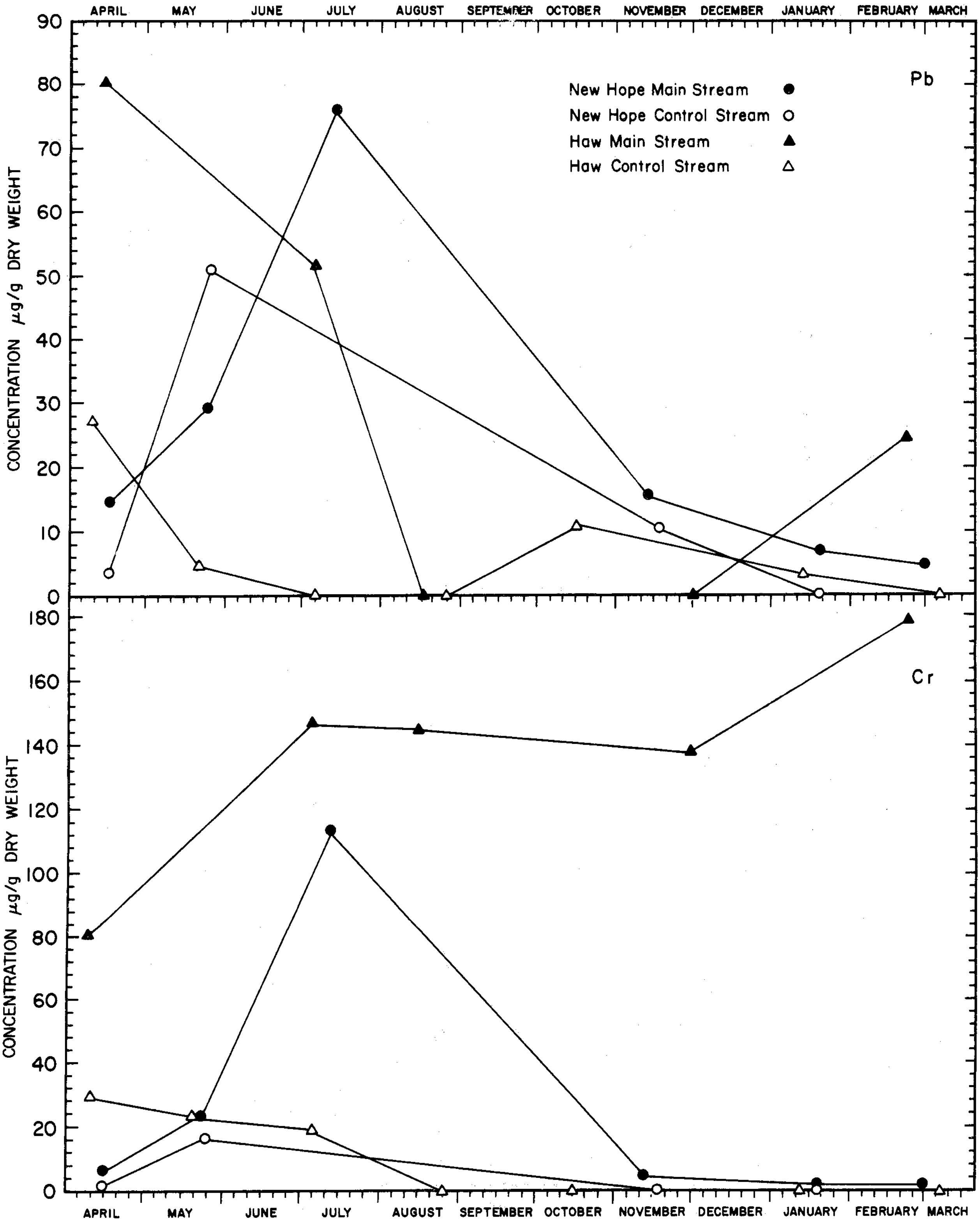


Figure 45 Mean monthly variation of lead and chromium concentrations in Ephemeroptera from the New Hope and Lower Haw River drainages, April 1971 to March 1972.

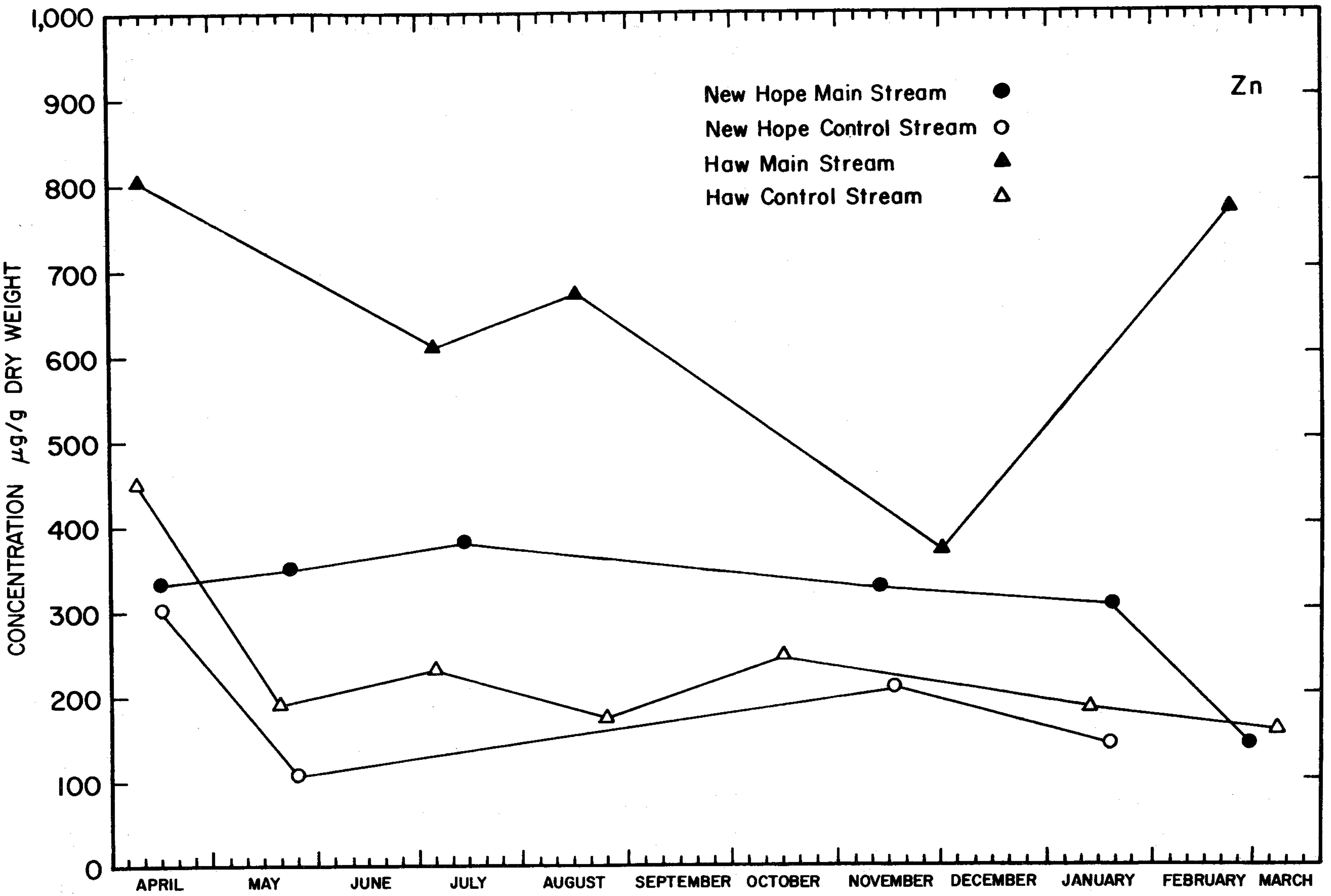


Figure 46 Mean monthly variation of zinc concentrations in Ephemeroptera from the New Hope and Lower Haw River drainages, April 1971 to March 1972.

To emphasize the fact that the organisms contain concentrations of heavy metals to a much higher degree than the surrounding water, Figures 47 through 51 were constructed. The organisms common to the main stems and controls of both river systems were used for ease of comparison. Levels of cadmium in the main stem and control streams were similar, but organisms in the main stem contained slightly higher levels. Chromium levels were much higher in the Haw main stem and the organisms corresponded except for the Plecoptera. Mercury appears to have had the greatest degree of concentration over the levels in the water but there was little difference in levels in the main stem and control organisms. The difference in lead concentrations appears to have been greater in the Haw River system although differences in the water levels were greater between the New Hope main stem and controls. More data is needed to draw conclusions. Zinc water levels were similar and this was reflected in similar concentrations among the organisms although in all cases the main stem streams were slightly higher in both the water and the organisms.

Conclusions

Several conclusions may be drawn on the basis of the data collected.

1. In the New Hope and Haw control streams, the concentration of the five metals was found to increase in the following sequence: Hg < Cd < Pb < Cr < Zn, the concentration of zinc being 100 times greater than the concentration of mercury.

In the New Hope main stem, the sequence followed the order Hg<Cd<Cr<Pb<Zn. In the Haw main stem the increasing order was Hg<Cd<Pb<Zn<Cr with the Zn and Cr levels being nearly the same. High chromium levels in the Haw main stem were due to industrial discharges

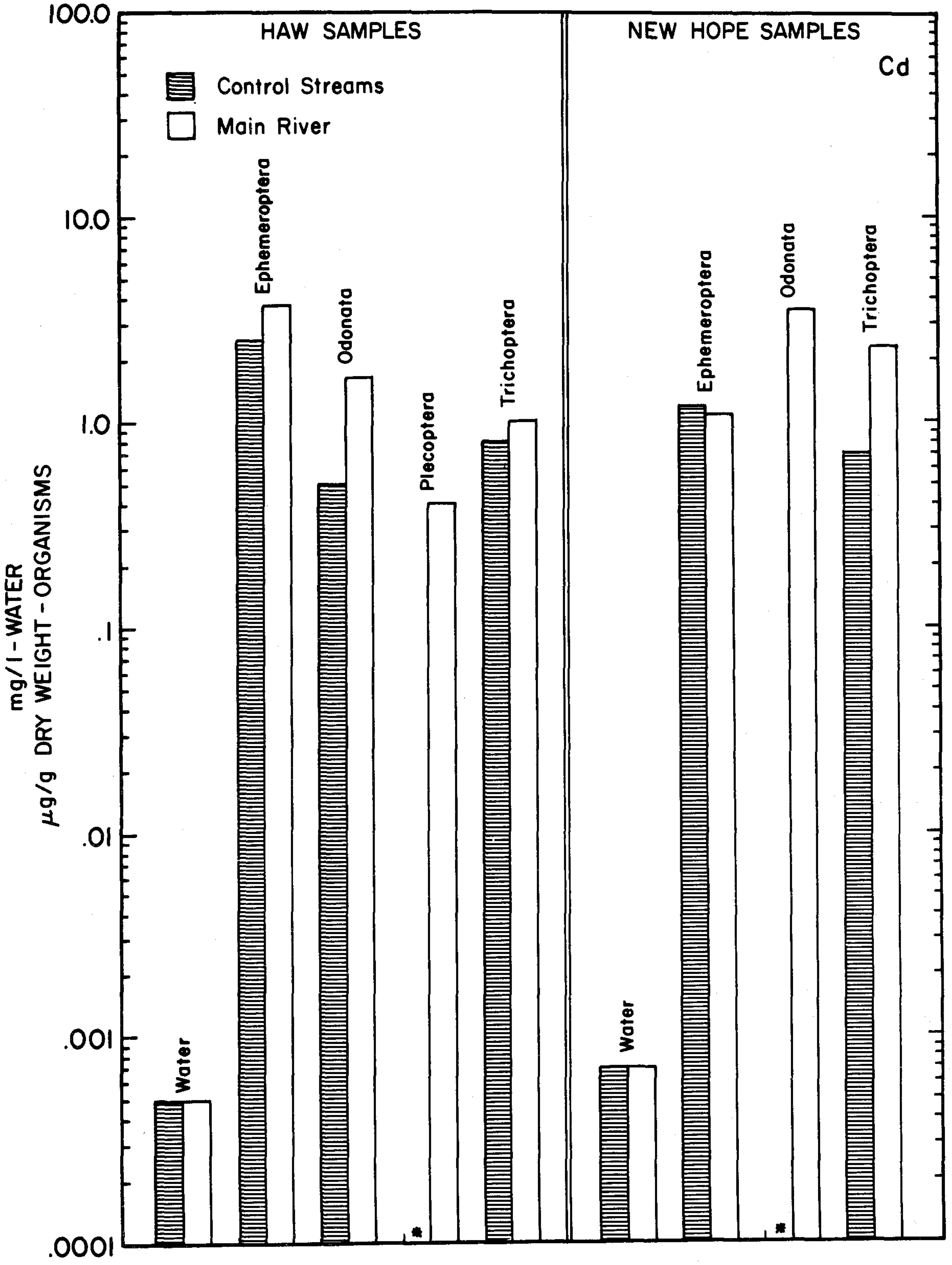


Figure 47 Mean concentrations of cadmium in water and benthic macroinvertebrates from the New Hope and Lower Haw River drainages.

* Not detectable

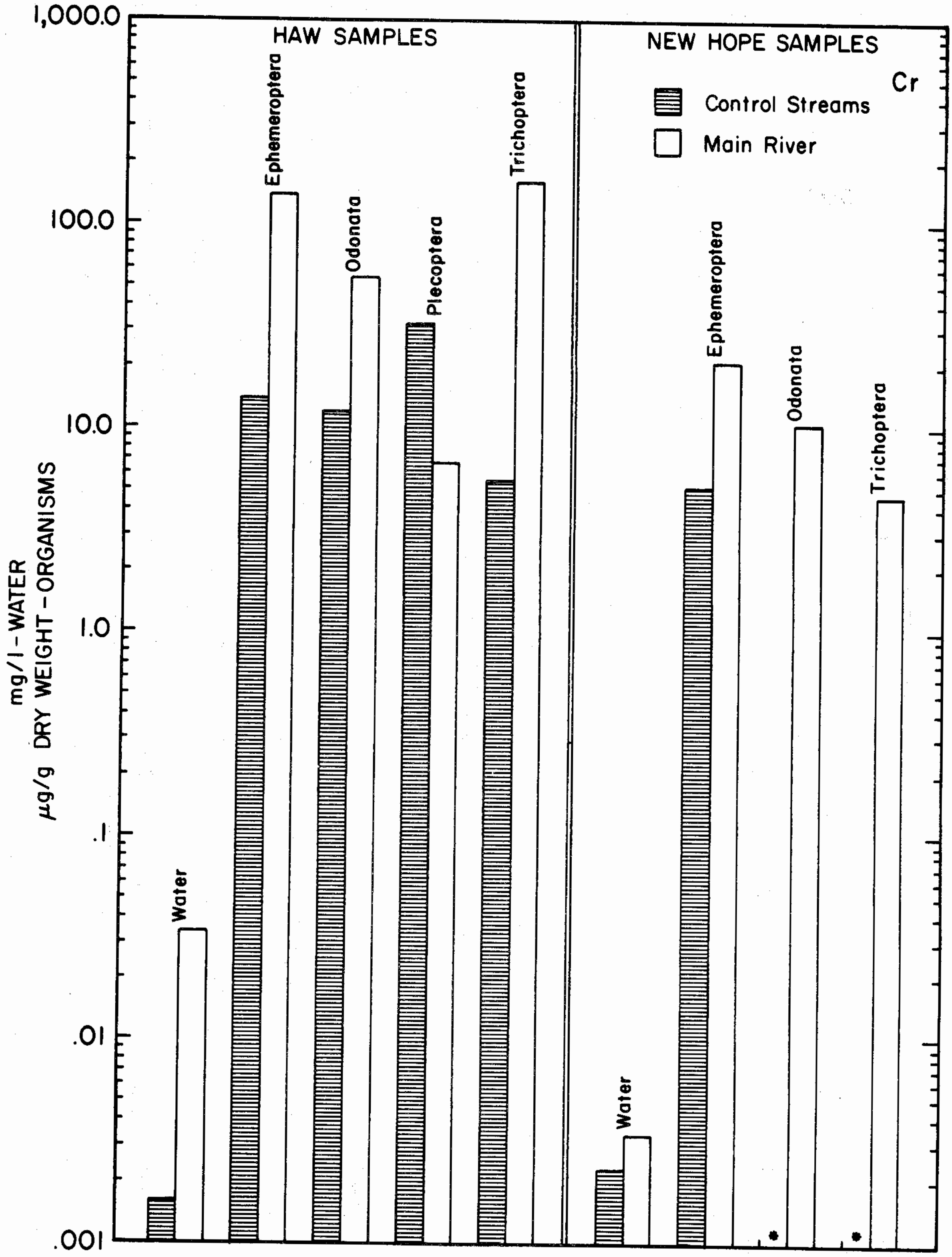


Figure 48 Mean concentrations of chromium in water and benthic macroinvertebrates from the New Hope and Lower Haw River drainages.

* Not detectable

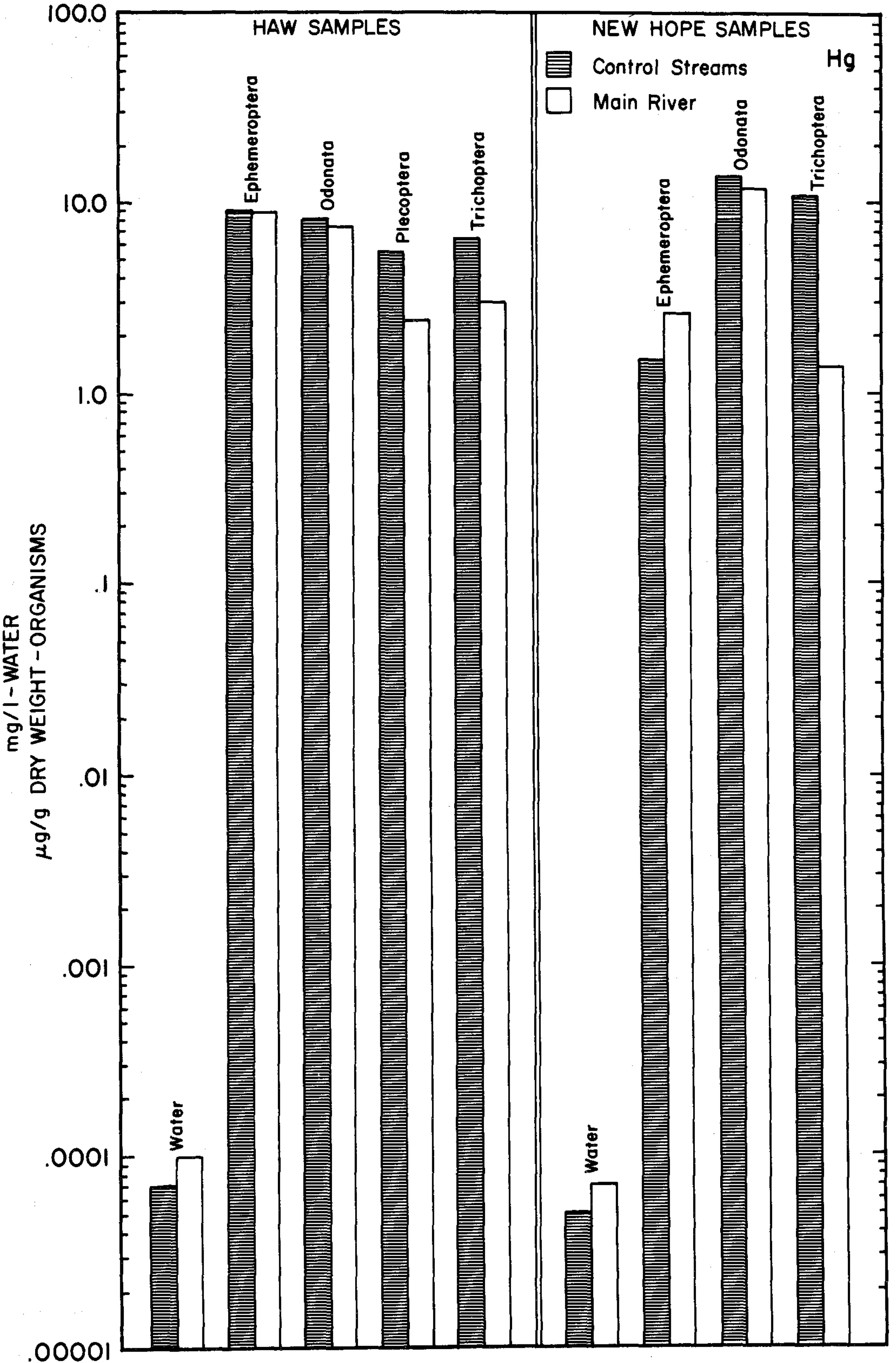


Figure 49 Mean concentrations of mercury in water and benthic macroinvertebrates from the New Hope and Lower Haw River drainages.

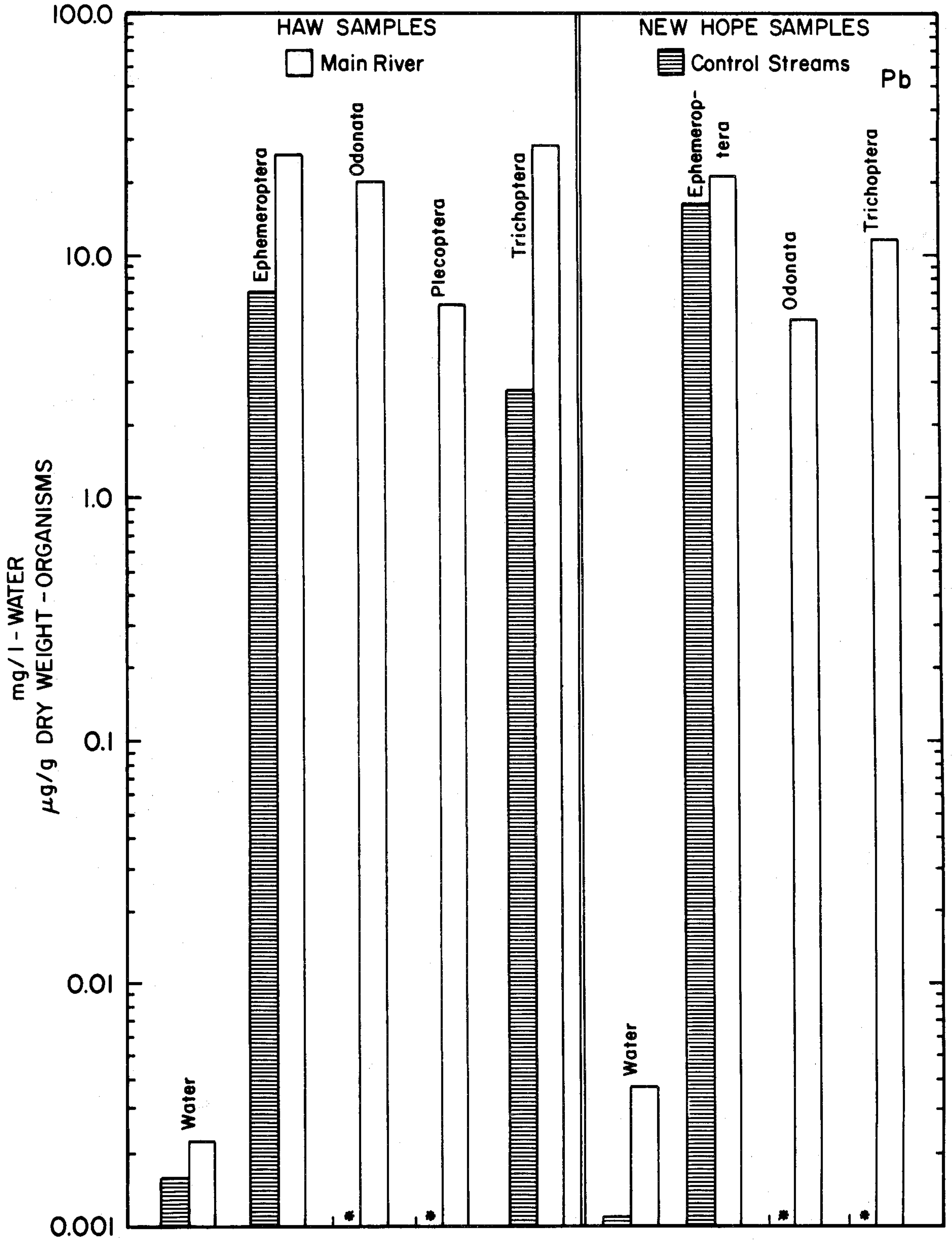


Figure 50 Mean concentrations of lead in water and benthic macroinvertebrates from the New Hope and Lower Haw River drainages.
* Not detectable

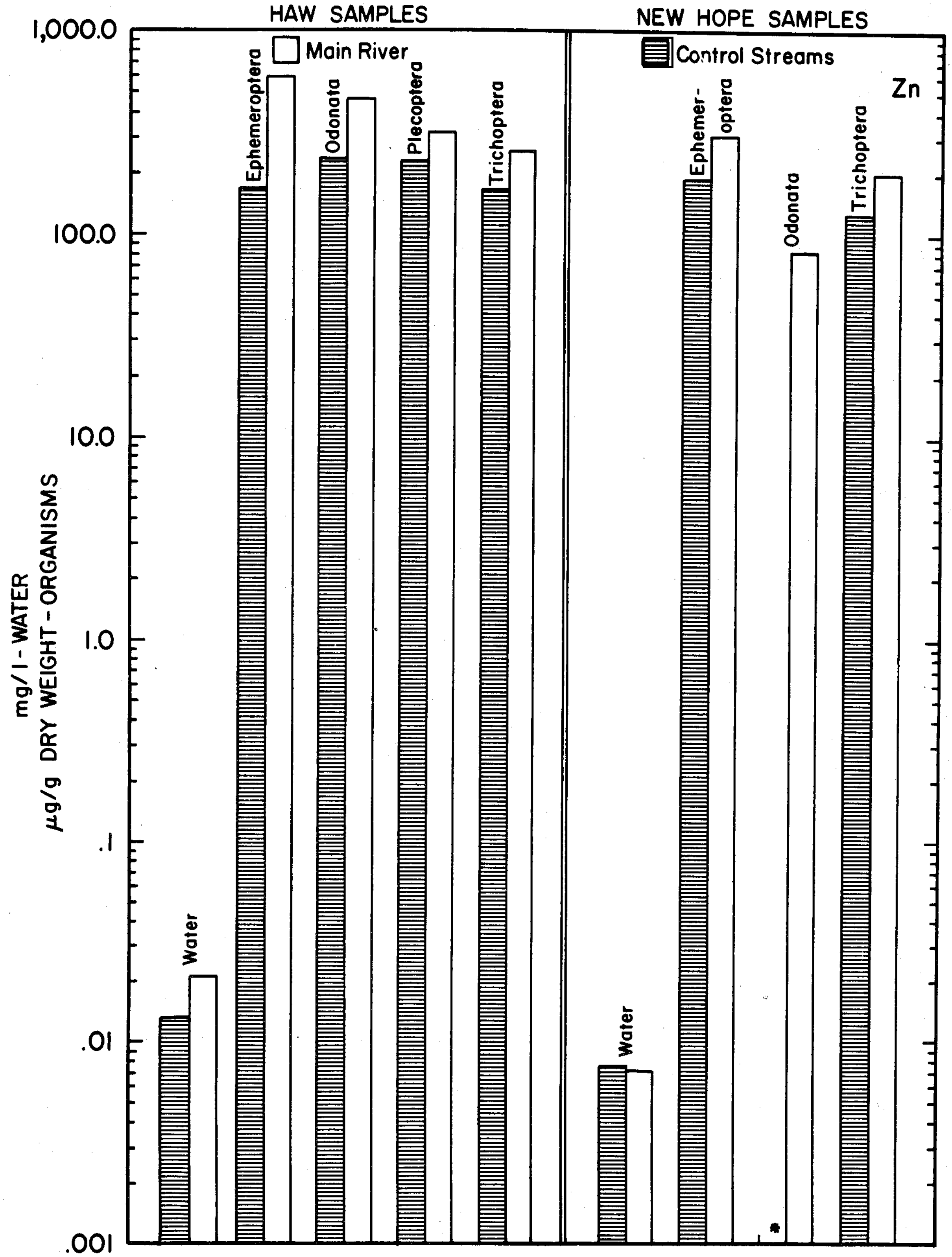


Figure 51 Mean concentrations of zinc in water and benthic macroinvertebrates from the New Hope and Lower Haw River drainages.
* Not detectable

upstream from the first sampling point, station H-1 at Saxapahaw.

2. Levels of metal concentration in general for all of the macroinvertebrates followed the sequence of Cd<Pb = Hg<Cr<Zn. Even in the instances in which Cr levels in water were higher than the Zn concentrations, the levels of Zn in the organisms were higher.

3. As shown in Table 11 all metals were found in lower concentrations than those required by the U.S. Public Health Service Drinking Water standards. U.S. Public Health Drinking Water Standards for metals are as follows:

Cd - 0.01 mg/1
Cr - 0.05 mg/1
Pb - 0.05 mg/1
Zn - 5.0 mg/1

The standard for mercury has been proposed as 0.5μg/1.

4. Highest levels of all metals in the organisms were found in the summer and early fall, probably due to increased metabolic rates.

5. No one organism of those studied consistently concentrated any of the five metals to a greater degree than any other. However, the different metals were concentrated to a greater degree in all organisms in the order given above.

6. In the case in which chromium levels were high in the water samples, levels in the organisms were also high indicating a correlation between concentrations in the water and the amount found in the organisms. However, it would be difficult to make a direct assessment of water quality based on levels found in the organisms due to differences in degrees of concentration for the various elements, age of the organisms, season of the year, and other

such variables. Nevertheless if gross differences in concentration were found in organisms from different streams, the water should be held suspect and investigated.

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Glossary

Ammonia nitrogen (NH_3-N): Nitrogen in the reduced state as ammonia.

Benthic macroinvertebrates: Organisms that are on, in, or associated with the bottom of a stream in some stage of their life cycle. Insect larvae form a large component of this population.

BOD: Biochemical oxygen demand. A statement of the quantity of organic matter present as shown by the oxygen consumed by the activity of bacteria utilizing the organic matter as a food substrate.

Chlorophyll: The green photosynthetic pigment contained in plants. It is extracted with 95% acetone from the particulate substances (including algae) following filtration through a 0.45 micron membrane filter. The quantitative value is determined by the light absorbance of the extractant at 640 mμ with a Klett photometer.

Coleoptera: Beetles.

Conductivity: The electrical conductivity of water. Essentially it measures the total ions in solution. It is reported as the reciprocal of resistance, (micro mhos/cm at 25°C).

Diptera: Flies, gnats, midges, crane flies, and mosquitoes.

Electron capture detector: By detecting the loss of current, the amount and electron affinity of the organic components in a carrier gas can be determined. This detector is particularly sensitive to halogenated compounds.

Enterococci: Streptococci bacteria associated with human fecal discharges.

Glossary (cont.)

Ephemeroptera: May flies.

Fecal coliforms: Bacteria of recent human fecal origin.

Flame ionization detector: Detects the change in electrical current flow through hydrogen flame due to passage of organic materials which can be detected at very low concentrations. It is used in conjunction with specific chromatographic columns and is useful for the detection of hydrocarbons.

Freeze concentration: The slow freezing of agitated water to form ice. This concentrates both organic and ionic chemical species since the formation of an ice crystal excludes the "contaminants."

Gas chromatography: A procedure utilizing the phenomenon of variable movement along different substrates to separate mixtures of organic materials. The mixture to be separated is carried in a gas phase and forced under pressure through the chromatographic column. As they emerge from the column, the separated materials are detected using devices such as the flame ionization and electron capture detectors.

Inorganic carbon: The materials in water solution which, upon being raised to a temperature of $300^{\circ}C$, give off CO_2 (as in the breakdown of carbonates). The resulting total CO_2 is determined on the infrared spectrophotometer.

Isopoda: Sow bugs.

Lotic: A term used to describe running water habitats.

Megaloptera: Alderflies, dobsonflies and fishflies.

Glossary (cont.)

Nitrite + nitrate nitrogen (NO_2+NO_3-N): The sum of NO_2 and NO_3 nitrogen, both oxidized states being reported together since the former is generally present in very small quantities in surface waters.

Notostraca: Tadpole shrimp.

Odonata: Dragon flies, damsel flies.

Organic nitrogen: Nitrogen associated with organic materials and released by the strong digestion in the kjeldahl procedure.

Orthophosphate phosphorus (PO_4-P): The oxidized state of phosphorus reported as PO_4-P.

Part per billion: 1 micro g/kg, (one microgram per kilogram).

Part per million: 1 mg/kg.

pH: pH is the logarithm of the reciprocal of the hydrogen ion concentration in moles per liter. The numerical value defines the acidity or alkalinity of the liquid. A pH of 7 is neutral.

Plecoptera: Stone flies.

Residue: In water, the suspended particulate material (both organic and inorganic) which is removable by filtration. The dried weight of the filtered material is reported as residue.

Total carbon: The total quantity of carbonaceous materials in water as determined by volatilization at 900°C. The CO_2 generated is measured on an infrared spectrophotometer. Total carbon includes both organic and inorganic carbon materials.

Total coliforms: Bacterial growth counts from sample water after collection on a membrane filter using ludo broth. This describes enteric organisms of recent fecal origin as well as from other sources.

Glossary (cont.)

Total nitrogen: The summation of all nitrogen determinations including the kjeldahl, ammonia and $NO_2 + NO_3$ nitrogen.

Total phosphorus (Total P): The total quantity of phosphorus found in the sample following perchlorate digestion under the temperature and pressure conditions of the autoclave.

Total soluble carbon: The components of the carbonaceous material which pass through a 0.45 micron membrane filter. They are determined in the same manner as total carbon.

Trichoptera: Caddis flies.

Trophic structures: The interrelationship of organisms (both plant and animal) through which energy passes from the primary level by conversion of solar energy, up through the highest and most complex forms found in a particular community.

Turbidity: The suspended particulate material (both organic and inorganic) which reduces the clarity of water. It is reported in Jackson turbidity units.

APPENDIX A

Water Quality Characteristics, New Hope River Stations
January 1 Through March 1972

Appendix A-1

Water Quality Characteristics
New Hope River Stations
January 1971 - March 1972

TEMPERATURE C°

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
1	28	25.5	-1.0	13.5	12.5	7.31	5.8 - 22.6
2	27	26.0	0.0	13.7	12.9	7.28	5.4 - 22.7
4	28	25.0	1.0	13.1	12.8	6.82	5.3 - 21.0
5	28	26.0	0.0	13.4	13.0	7.26	4.5 - 22.1
6	28	25.0	1.0	14.0	14.5	7.15	6.3 - 23.0
7	30	26.0	1.0	13.3	12.3	7.50	4.8 - 23.1
8	30	26.0	0.0	12.9	11.5	7.16	5.4 - 22.6
8A	30	26.0	0.0	13.1	11.5	7.16	5.7 - 22.2
10	30	26.0	1.0	13.5	12.5	7.42	5.0 - 22.6
11	28	25.0	1.0	13.4	12.3	7.24	4.3 - 22.6

Appendix A-2

Water Quality Characteristics
New Hope River Stations
January 1971 - March 1972

RESIDUE mg/l

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
1	29	26.0	0.9	6.0	4.3	5.9	1.7 - 11.8
2	28	24.5	1.7	7.9	5.5	5.7	2.9 - 12.4
4	29	109.3	3.0	22.0	14.4	24.2	5.5 - 32.9
5	29	35.3	1.8	12.0	10.3	8.2	4.1 - 20.6
6	29	37.9	1.8	9.1	6.5	7.6	3.7 - 13.4
7	31	32.0	1.1	9.9	6.8	7.8	3.0 - 18.1
8	28	32.3	0.8	7.1	4.7	6.7	2.6 - 11.0
8A	31	33.9	0.3	10.3	6.6	8.8	3.4 - 22.2
10	29	187.0	1.0	18.2	7.7	34.3	3.0 - 29.8
11	28	76.6	2.8	19.6	14.3	16.3	7.2 - 30.8
				RESIDUE lbs/day			
10	29	277214	437	40144	7343	73308	1075-79647

Appendix A-3

Water Quality Characteristics
New Hope River Stations
January 1971 - March 1972

TURBIDITY
JTU

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
1	29	85	8	27.3	17.3	21.2	8.0 - 43.0
2	28	73	8	27.6	22.0	17.6	9.5 - 42.5
4	29	140	13	55.6	42.3	36.3	42.5 - 20.9
5	29	140	13	42.0	34.6	29.3	16.3 - 70.0
6	29	110	11	31.5	21.0	25.8	11.53- 59.0
7	31	100	12	40.5	31.0	26.9	15.3 - 74.3
8	30	100	10	24.3	17.2	19.3	11.8 - 36.4
8A	31	160	12	38.8	24.5	36.6	13.4 - 80.5
10	31	200	12	48.2	34.3	40.9	14.9 - 91.9
11	29	160	16	59.8	44.5	35.9	22.7 - 97.5

Appendix A-4

Water Quality Characteristics
New Hope River Stations
January 1971 - March 1972

CONDUCTIVITY micromhos

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
1	27	235	74	118	102	43	80 - 155
2	26	340	86	167	163	60	98 - 231
4	27	480	108	283	263	99	181 - 412
5	27	340	72	188	174	65	124 - 243
6	27	375	78	179	168	74	90 - 239
7	29	240	69	142	138	46	80 - 182
8	28	96	44	69	69	12	56 - 83
8A	29	87	7	64	66	16	52 - 78
10	29	213	51	113	100	41	68 - 155
11	27	270	67	152	148	49	91 - 211

Appendix A-5

Water Quality Characteristics
New Hope River Stations
January 1971 - March 1972

DISSOLVED OXYGEN mg/1

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
1	29	12.80	4.60	8.81	8.73	2.52	5.2 - 11.4
2	28	11.60	1.30	6.66	6.85	3.28	1.6 - 10.4
4	29	10.70	0.50	4.17	3.03	2.94	1.2 - 8.1
5	28	10.80	1.60	5.00	3.70	2.83	2.1 - 8.5
6	29	11.30	1.30	4.88	3.89	2.89	1.9 - 8.7
7	31	12.40	2.50	6.53	6.00	2.73	2.9 - 9.2
8	31	13.00	5.00	8.86	9.23	2.24	5.8 - 11.2
8A	31	13.00	0.70	8.48	9.13	2.90	4.5 - 11.3
10	31	11.80	4.70	7.87	7.90	2.21	5.1 - 10.2
11	29	12.50	2.20	7.07	7.55	3.34	2.8 - 10.8

DISSOLVED OXYGEN lbs/day

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
10	31	170246	661	19139	5953	33713	1315-46513

Appendix A-6

Water Quality Characteristics
New Hope River Stations
January 1971 - March 1972

DISSOLVED OXYGEN Percent Saturation

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
1	27	100.0	52.9	80.5	83.6	13.3	58.2 - 92.6
2	27	89.7	13.8	59.7	66.6	24.7	19.0 - 84.7
4	28	79.3	5.3	36.5	31.5	21.6	12.1 - 65.0
5	27	81.7	18.4	44.5	36.3	19.1	23.7 - 69.6
6	28	83.7	15.3	44.1	41.4	20.9	19.9 - 73.5
7	30	89.9	27.2	59.1	63.5	16.9	33.8 - 73.3
8	30	96.1	53.2	81.1	83.2	10.9	64.7 - 90.5
8A	30	100.8	8.2	77.0	82.9	19.4	52.3 - 90.1
10	30	91.7	50.0	72.6	74.0	11.1	58.7 - 83.0
11	28	92.6	23.4	63.7	73.5	22.4	31.4 - 85.1

Appendix A-7

Water Quality Characteristics
New Hope River Stations
January 1971 - March 1972

5-DAY BOD mg/1

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
1	28	6.80	1.7	4.09	3.85	1.35	2.45 - 5.78
2	27	15.00	0.0	6.66	6.89	3.81	0.45 -10.12
4	28	14.80	0.0	6.91	7.10	4.00	1.10 -10.55
5	28	10.20	0.0	4.65	4.40	2.47	1.85 - 6.85
6	28	11.40	0.0	5.40	5.65	2.77	1.95 - 7.70
7	29	5.50	0.0	3.05	3.19	1.15	1.65 - 3.98
8	28	5.80	0.8	1.99	1.60	1.14	1.13 - 2.68
8A	29	3.30	1.0	1.71	1.51	0.64	1.07 - 2.48
10	29	3.00	0.8	2.05	2.03	0.56	1.36 - 2.73
11	28	5.50	0.0	2.58	2.55	1.16	1.18 - 3.85

5-DAY BOD lbs/day

10	29	28625	194	4614	1299	7126	383-9706

Appendix A-8

Water Quality Characteristics
New Hope River Stations
January 1971 - March 1972

TOTAL CARBON mg/1

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
1	29	23	7	13.8	13.3	4.0	7.9 - 17.4
2	28	48	10	23.5	21.5	8.2	14.5 - 32.5
4	29	62	18	36.2	37.0	10.7	22.2 - 44.5
5	29	38	11	22.4	21.3	6.4	14.8 - 28.7
6	29	39	10	22.6	21.8	7.8	12.6 - 31.7
7	31	32	8	18.0	17.9	4.2	13.4 - 21.1
8	30	27	1	13.0	12.8	5.3	7.4 - 17.7
8A	31	27	1	13.4	12.6	5.5	6.0 - 20.1
10	31	29	4	16.3	15.9	4.8	11.4 - 20.8
11	29	37	6	21.6	22.1	7.3	11.6 - 28.2

TOTAL CARBON lbs/day

10	31	250560	1555	37408	10899	62435	4167-86332

Appendix A-9

Water Quality Characteristics
New Hope River Stations
January 1971 - March 1972

TOTAL SOLUBLE CARBON mg/l

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
1	29	21	8	13.0	12.7	3.3	8.5 - 16.5
2	27	36	9	20.5	18.4	7.2	13.4 - 30.9
4	29	52	18	31.3	30.0	9.2	20.3 - 40.9
5	28	32	12	20.3	19.5	5.3	13.8 - 26.0
6	29	52	11	21.3	18.9	9.3	12.4 - 29.6
7	31	27	12	17.2	17.0	4.0	12.5 - 20.3
8	30	37	8	13.9	13.3	5.8	8.4 - 19.1
8A	31	36	7	12.9	11.4	5.7	7.6 - 16.1
10	31	22	10	15.3	15.7	3.3	10.6 - 18.7
11	29	29	12	19.6	19.8	4.9	13.2 - 24.7

TOTAL SOLUBLE CARBON lbs/day

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
10	31	195858	2419	32124	10286	50077	4020-78702

Appendix A-10

Water Quality Characteristics
New Hope River Stations
January 1971 - March 1972

INORGANIC CARBON mg/1

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
1	29	16	0.0	5.1	4.4	3.7	1.2 - 9.4
2	28	28	1.0	10.0	9.0	6.5	2.5 - 16.5
4	29	29	5.0	15.1	14.6	6.6	5.9 - 22.1
5	29	22	1.0	8.6	8.0	4.6	2.6 - 12.4
6	29	29	2.0	10.1	8.3	6.9	2.3 - 17.8
7	31	19	1.0	5.4	4.9	3.8	1.0 - 8.4
8	30	13	0.0	1.7	0.7	2.9	0.0 - 4.2
8A	31	12	0.0	1.4	0.7	2.5	0.0 - 2.4
10	31	16	0.0	3.6	2.8	3.6	0.1 - 7.1
11	29	21	0.0	7.7	7.3	5.1	1.6 - 13.4

INORGANIC CARBON lbs/day

10	31	15066	0.0	2910	2024	3038	269-4964

Appendix A-11

Water Quality Characteristics
New Hope River Stations
January 1971 - March 1972

TOTAL NITROGEN mg/1

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
1	27	9.15	0.43	1.74	1.02	1.81	.67 - 3.13
2	27	14.20	1.20	5.20	4.73	3.04	2.07 - 8.94
4	27	18.90	1.55	6.92	5.59	4.75	2.29 - 13.13
5	27	10.10	0.99	4.16	3.99	2.27	1.56 - 6.62
6	27	14.4	1.00	5.16	4.63	3.34	1.43 - 9.01
7	30	12.15	0.42	2.76	2.17	2.37	.66 - 4.79
8	29	1.21	0.21	0.45	0.41	0.21	.23 - .65
8A	30	1.10	0.28	0.56	0.51	0.20	.33 - .74
10	30	3.55	0.30	1.33	1.15	0.87	.48 - 2.15
11	28	2.30	0.37	0.88	0.78	0.44	.49 - 1.16
		TOTAL NITROGEN lbs/day					
10	30	6780	151	1598	891	1680	415-3124

Appendix A-12

Water Quality Characteristics
New Hope River Stations
January 1971 - March 1972

ORGANIC NITROGEN mg/1

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
1	28	0.68	0.02	0.30	0.29	0.20	.08 - .59
2	27	3.50	0.00	1.01	0.88	0.81	.22 -1.77
4	27	4.70	0.05	1.15	0.81	1.13	.18 -2.28
5	25	1.80	0.00	0.74	0.66	0.45	.21 -1.14
6	25	3.90	0.00	1.13	0.74	1.04	.19 -2.51
7	27	0.96	0.00	0.44	0.40	0.28	.10 - .85
8	28	1.18	0.12	0.33	0.30	0.20	.17 - .45
8A	30	0.98	0.06	0.32	0.30	0.19	.13 - .48
10	29	0.66	0.01	0.31	0.29	0.16	.15 - .49
11	27	1.55	0.10	0.40	0.38	0.27	.17 - .54

ORGANIC NITROGEN lbs/day

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
10	29	3465	27	664	162	1004	57 - 2185

Appendix A-13

Water Quality Characteristics
New Hope River Stations
January 1971 - March 1972

AMMONIA NITROGEN mg/l
(NH_3-N)

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
1	29	1.90	0.02	0.46	0.32	0.44	.11 - .92
2	28	8.70	0.54	3.39	3.09	2.10	1.05 -5.80
4	28	13.80	0.45	3.58	3.05	2.99	.91 -6.68
5	28	7.80	0.24	2.17	1.63	1.79	.71 -3.55
6	29	12.80	0.44	3.64	2.98	2.91	.52 -5.99
7	31	2.70	0.02	0.84	0.59	0.70	.14 -1.68
8	29	0.25	0.01	0.04	0.03	0.05	.01 - .07
8A	31	0.30	0.01	0.06	0.04	0.06	.01 - .10
10	31	0.51	0.02	0.18	0.11	0.15	.03 - .37
11	28	0.40	0.01	0.13	0.11	0.09	.03 - .22

AMMONIA NITROGEN lbs/day

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
10	31	1264	6	253	152	312	13 - 516

Appendix A-14

Water Quality Characteristics
New Hope River Stations
January 1971 - March 1972

NITRITE-NITRATE NITROGEN mg/l
($NO_2 + NO_3$ -N)

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
1	28	8.30	0.13	0.97	0.40	1.58	.27 - 1.73
2	28	8.10	0.17	0.93	0.48	1.47	.29 - 1.43
4	29	13.40	0.40	2.41	1.46	2.68	.53 - 4.69
5	28	5.00	0.39	1.50	1.21	1.04	.62 - 2.18
6	29	3.10	0.03	0.66	0.49	0.62	.19 - 1.09
7	31	9.00	0.02	1.58	1.09	1.76	.23 - 2.89
8	30	0.30	0.01	0.07	0.07	0.06	.01 - .10
8A	31	0.36	0.02	0.17	0.16	0.09	.07 - .27
10	31	3.05	0.03	0.83	0.57	0.79	.14 - 1.56
11	29	1.16	0.03	0.38	0.30	0.28	.12 - .57
NITRITE NITRATE NITROGEN							
10	31	3013	15	681	536	621	13 - 516

Appendix A-15

Water Quality Characteristics
New Hope River Stations
January 1971 - March 1972

TOTAL PHOSPHORUS mg/1

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
1	29	1.31	0.09	0.38	0.24	0.32	.12 - .73
2	27	4.60	0.20	1.66	1.40	1.07	.48 - 2.82
4	26	6.50	0.24	2.79	2.39	1.83	.98 - 5.30
5	28	2.95	0.12	1.41	1.23	0.87	.37 - 2.52
6	27	4.40	0.15	1.49	1.12	1.09	.36 - 2.76
7	30	3.40	0.12	0.98	0.71	0.85	.24 - 2.11
8	30	0.80	0.01	0.10	0.06	0.14	.03 - .13
8A	31	2.62	0.04	0.23	0.10	0.51	.06 - .16
10	31	2.55	0.12	0.60	0.45	0.51	.19 - 1.17
11	29	1.19	0.09	0.47	0.33	0.33	.16 - .96

TOTAL PHOSPHORUS lbs/day

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
10	31	1987	83	572	354	481	179-987

Appendix A-16

Water Quality Characteristics
New Hope River Stations
January 1971 - March 1972

ORTHOPHOSPHATE mg/l

$(PO_4^{=} -P)$

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
1	29	1.00	0.02	0.24	0.14	0.24	.04 - .46
2	28	4.25	0.07	1.30	1.13	0.97	.28 - 2.42
4	29	9.20	0.30	2.57	1.71	2.19	.62 - 5.34
5	28	4.45	0.11	1.24	0.94	0.95	.33 - 2.28
6	29	5.00	0.06	1.36	0.97	1.22	.19 - 2.22
7	31	3.30	0.05	0.77	0.47	0.77	.09 - 1.64
8	30	0.10	0.01	0.02	0.02	0.02	.01 - .03
8A	31	0.06	0.01	0.03	0.03	0.01	.01 - .04
10	31	1.73	0.02	0.37	0.27	0.38	.06 - .64
11	29	0.70	0.01	0.23	0.14	0.21	.04 - .53

ORTHOPHOSPHATE lbs/day

10	31	753	21	280	243	184	101-524

Appendix A-17

Water Quality Characteristics
New Hope River Stations
January 1971 - March 1972

pH

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
1	29	7.4	6.3	6.8	6.6	0.4	6.3 - 7.2
2	28	7.3	6.4	6.9	6.8	0.3	6.5 - 7.2
4	29	7.3	6.5	6.8	6.9	0.3	6.5 - 7.1
5	29	7.2	6.6	6.9	6.9	0.2	6.6 - 7.1
6	29	7.4	6.6	7.0	7.0	0.2	6.7 - 7.2
7	31	7.3	6.5	6.9	6.9	0.2	6.5 - 7.1
8	31	7.9	6.2	7.0	6.9	0.3	6.6 - 7.2
8A	31	7.3	6.1	6.9	6.9	0.3	6.4 - 7.1
10	31	7.2	6.4	6.9	6.9	0.2	6.5 - 7.1
11	29	7.4	6.4	6.9	6.9	0.2	6.6 - 7.2

Appendix A-18

Water Quality Characteristics
New Hope River Stations
January 1971 - March 1972

CHLOROPHYLL - KLETT UNITS

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
1	29	13.0	2.0	6.1	5.9	3.1	2.16 - 9.37
2	28	30.0	1.0	6.9	5.3	5.5	2.38 - 10.50
4	29	15.0	0.0	4.0	3.8	2.5	1.54 - 4.79
5	29	12.0	0.0	3.6	3.1	2.3	1.11 - 4.87
6	29	21.0	1.0	5.3	4.6	3.8	1.66 - 7.68
7	31	10.0	0.0	3.4	3.1	2.0	.96 - 5.06
8	29	7.0	0.0	2.8	2.7	1.5	.81 - 3.73
8A	31	7.0	0.0	3.3	3.0	1.6	.52 - 4.78
10	31	11.0	1.0	3.5	3.1	2.2	1.11 - 4.38
11	29	32.0	2.0	6.1	4.9	5.6	2.00 - 8.38

Appendix A-19

Water Quality Characteristics
New Hope River Stations
January 1971 - March 1972

TOTAL COLIFORMS No/100 ml (x 10^2)

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
1	22	19800	0.0	2438.6	770.0	4488.5	18 - 5439
2	21	51000	3.0	14276.3	6700.0	14953.6	1263-32625
4	22	2000	0.0	195.3	49.0	424.6	4.8-239
5	22	2000	0.0	246.5	79.5	460.2	1.8-503
6	21	8000	12.0	2446.8	1968.8	2420.8	181 -6113
7	24	136	0.0	52.3	45.0	43.5	4.0-102
8	22	100	0.0	12.8	3.5	23.7	0.0- 26
8A	23	140	2.0	22.6	8.1	31.5	2.5- 44
10	24	120	1.0	36.5	22.5	39.6	1.5-104
11	22	76	0.0	12.4	7.5	16.8	.4- 22

Appendix A-20

Water Quality Characteristics
New Hope River Stations
January 1971 - March 1972

FECAL COLIFORMS No/100 ml (x 10^2)

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
1	22	360	0.0	112.3	95.0	102.9	4.5 - 220
2	21	5700	50.0	1018.1	490	1528.9	94 - 1969
4	22	1800	0.0	139.8	5.0	391.7	0.0 - 192
5	22	430	0.0	71.3	14.0	112.4	0.0 - 185
6	21	6000	7.0	552.4	195.0	1277.1	39 - 804
7	24	80	0.0	15.2	4.5	22.1	0.0 - 48
8	22	38	0.0	5.2	1.5	10.5	0.0 - 5.8
8A	23	224	0.0	20.4	4.1	47.8	0.0 - 39
10	24	165	0.0	16.0	2.0	34.4	0.0 - 22
11	22	24	0.0	3.5	1.2	5.7	0.0 - 9.2

Appendix A-21

Water Quality Characteristics
New Hope River Stations
January 1971 - March 1972

ENTEROCOCCI No/100 ml (x 10^2)

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
1	22	50	0.0	16.4	12.8	14.3	1.1 - 33
2	21	320	6	88.9	59.8	87.1	14 - 190
4	22	105	0.0	19.1	2.0	33.1	0.0 - 58
5	22	69	0.0	8.9	1.2	17.4	0.0 - 18
6	21	95	0.0	26.6	19.3	26.7	1.6 - 52
7	24	99	0.0	7.5	0.8	20.3	0.0 - 13
8	22	144	0.0	14.2	1.3	33.9	0.0 - 25
8A	23	91	0.0	14.4	2.3	26.6	.1 - 44
10	24	80	0.0	11.4	2.5	22.2	0.0 - 31
11	22	67	0.0	6.8	1.9	15.3	0.0 - 8.2

APPENDIX B

Water Quality Characteristics, Haw River Stations
January 1 Through March 1972

Appendix B-1

Water Quality Characteristics
Haw River Stations
January 1971 - March 1972

TEMPERATURE ^{o}C

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
1	29	26.5	3.5	14.8	14.0	7.26	5.6 - 23.7
2	29	26.0	2.0	14.5	13.9	7.43	4.6 - 23.2
3	29	26.5	2.0	14.7	14.4	7.54	4.8 - 23.7
4	29	27.0	2.0	14.8	14.4	7.53	4.8 - 24.2
5	31	26.0	3.0	14.8	13.9	7.62	4.9 - 24.6
6	31	26.5	2.0	14.7	13.6	7.7	5.9 - 24.2
7	29	24.0	4.0	13.3	12.7	5.91	6.2 - 20.1
8	29	24.5	3.0	13.7	13.3	6.64	4.6 - 22.2
9	29	24.5	3.0	13.4	12.9	6.52	4.8 - 21.5
10	29	24.0	4.0	13.9	13.8	6.55	5.0 - 22.4
11	29	23.0	2.5	13.0	13.0	6.30	4.7 - 20.5
12	29	24.5	3.0	13.8	13.8	6.89	4.6 - 22.7

Appendix B-2

Water Quality Characteristics
Haw River Stations
January 1971 - March 1972

RESIDUE mg/1

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
1	25	68.8	2.9	10.7	6.6	12.9	5.0 - 12.5
2	25	174.2	3.4	15.2	6.4	33.6	4.0 - 17.0
3	25	143.4	2.4	16.5	7.2	31.1	3.9 - 16.1
4	25	81.4	2.1	9.5	5.8	15.4	2.8 - 12.0
5	27	93.4	2.1	11.9	5.5	18.6	2.6 - 18.3
6	27	92.4	2.2	14.9	9.7	17.7	3.4 - 27.5
7	25	225.0	1.3	16.8	3.8	44.5	1.9 - 27.4
8	25	732.9	2.2	38.1	5.8	145.1	2.3 - 24.5
9	25	22.6	1.2	5.2	3.4	5.2	1.6 - 7.3
10	25	72.5	1.3	9.8	2.6	17.8	1.5 - 16.3
11	25	28.6	1.1	4.7	2.8	5.8	1.2 - 7.7
12	25	86.3	0.4	6.5	2.6	16.8	.9 - 6.6

RESIDUE lbs/day

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
5	27	6304494	7190	286654	31888	---	9072-129932
6	27	8482314	10692	451484	93924	---	14428-377845

Appendix B-3

Water Quality Characteristics
Haw River Stations
January 1971 - March 1972

TURBIDITY

JTU

Station	No. Sample	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
1	29	145	12.0	41.2	35.3	25.5	21.5 - 56.1
2	29	210	7.0	43.7	33.5	42.2	13.3 - 64.2
3	29	190	8.0	42.8	34.8	39.2	14.1 - 61.8
4	29	150	10.0	36.6	30.1	28.0	12.6 - 56.7
5	31	150	7.0	38.9	28.0	32.7	11.8 - 68.1
6	31	140	10.0	47.0	41.9	30.1	15.9 - 80.5
7	29	200	10.0	48.3	29.5	47.9	14.9 - 94.2
8	29	140	12.0	43.7	31.8	32.7	17.6 - 78.0
9	28	90	9.0	26.9	22.5	16.5	13.5 - 36.0
10	28	160	11.0	39.8	30.0	35.5	11.8 - 76.5
11	28	73	8.4	24.6	18.3	15.7	10.6 - 41.5
12	28	63	6.0	23.0	18.2	14.2	9.3 - 36.5

Appendix B-4

Water Quality Characteristics
Haw River Stations
January 1971 - March 1972

CONDUCTIVITY micromhos

Station	No. Sample	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
1	28	365	90	197	180	75	127 - 278
2	28	390	42	189	175	81	108 - 259
3	28	370	41	161	154	75	80 - 232
4	28	315	89	166	153	58	109 - 238
5	30	305	90	159	144	58	100 - 238
6	30	270	43	146	140	54	88 - 208
7	28	155	45	84	77	25	68 - 102
8	28	138	62	80	76	15	66 - 91
9	28	124	27	71	69	17	57 - 86
10	28	132	33	79	81	18	61 - 94
11	28	128	33	81	80	21	61 - 96
12	28	120	48	72	70	14	57 - 85

Appendix B-5

Water Quality Characteristics
Haw River Stations
January 1971 - March 1972

DISSOLVED OXYGEN

mg/1

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
1	29	13.00	4.80	9.18	9.25	2.18	6.73 - 11.91
2	29	12.50	4.10	8.25	8.43	2.45	5.16 - 11.17
3	29	12.60	5.40	8.71	8.70	2.11	5.98 - 11.45
4	29	12.60	6.10	8.94	8.65	1.94	6.53 - 11.37
5	31	13.00	7.10	10.14	10.48	1.72	7.99 - 12.03
6	31	12.60	5.30	9.05	8.93	2.09	6.58 - 11.55
7	29	12.80	6.50	9.45	9.58	1.97	7.05 - 11.80
8	29	12.60	6.00	9.09	9.35	2.06	6.53 - 11.27
9	29	12.60	5.10	8.81	9.13	2.21	6.06 - 11.35
10	29	13.40	3.50	9.29	9.43	2.24	6.85 - 11.80
11	29	12.90	6.60	9.30	9.13	1.82	7.21 - 11.46
12	29	20.10	5.70	9.59	9.08	3.02	6.59 - 12.24

DISSOLVED OXYGEN lbs/day

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
5	31	749250	7983	81614	55588	130336	13873-106709
6	31	1000620	8940	114922	73394	177336	15040-152755

Appendix B-6

Water Quality Characteristics
Haw River Stations
January 1971 - March 1972

DISSOLVED OXYGEN Percent Saturation

Station	No. Sample	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
1	29	101.7	58.5	86.7	88.8	8.8	77.8 - 94.3
2	29	93.8	50.0	76.7	79.2	12.0	61.5 - 89.8
3	29	97.7	62.1	82.0	83.5	9.3	69.3 - 91.7
4	29	96.2	72.9	84.7	84.8	6.3	77.3 - 92.8
5	31	122.2	84.5	97.0	97.4	7.1	87.6 -102.4
6	31	97.6	60.9	85.5	86.8	8.7	76.8 - 94.1
7	29	100.0	70.7	87.4	89.3	8.6	75.8 - 97.7
8	29	98.2	70.2	84.5	85.6	8.8	71.9 - 94.1
9	29	96.2	58.6	80.8	81.4	10.7	64.4 - 93.8
10	29	102.3	39.8	86.8	90.3	12.7	76.7 - 95.4
11	29	96.6	73.4	85.4	84.4	5.7	79.4 - 91.9
12	29	177.9	60.0	88.9	85.9	19.8	74.2 - 97.5

Appendix B-7

Water Quality Characteristics
Haw River Stations
January 1971 - March 1972

5 DAY BOD mg/1

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
1	28	7.60	2.7	4.78	4.53	1.22	3.45 - 6.40
2	28	7.80	2.2	4.13	3.75	1.50	2.75 - 6.10
3	28	7.10	0.0	3.33	3.10	1.36	2.15 - 4.75
4	28	5.40	1.4	2.76	2.65	0.96	1.72 - 3.65
5	27	5.10	0.9	2.51	2.35	1.00	1.52 - 3.46
6	29	4.20	1.3	2.57	2.58	0.75	1.53 - 3.27
7	28	6.70	0.5	2.04	1.70	1.48	.83 - 2.85
8	28	6.50	0.6	1.75	1.53	1.11	.90 - 2.35
9	28	5.30	0.5	1.49	1.35	0.93	.71 - 2.08
10	28	3.40	0.0	1.67	1.55	0.74	.88 - 2.45
11	28	3.10	0.4	1.34	1.25	0.66	.65 - 2.00
12	28	6.40	0.4	1.86	1.75	1.21	.75 - 2.48

5 DAY B. O. D. lbs/day

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
5	27	344250	1725	25909	12312	64510	3509-27940
6	29	385560	1625	39381	18630	72039	5950-56602

Appendix B-8

Water Quality Characteristics
Haw River Stations
January 1971 - March 1972

TOTAL CARBON mg/l

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
1	29	32	13	21.1	21.0	5.4	14.3 - 28.4
2	29	33	12	20.5	20.3	5.2	13.6 - 25.7
3	29	31	12	19.4	18.6	4.9	13.4 - 25.7
4	29	25	12	17.7	16.8	3.6	12.9 - 21.8
5	31	24	11	17.2	16.7	3.6	12.9 - 21.1
6	31	27	11	17.8	17.6	4.3	11.9 - 23.0
7	29	33	6	11.9	11.7	5.5	6.8 - 14.4
8	29	39	6	12.7	11.7	5.9	7.5 - 16.2
9	29	22	4	12.4	12.3	4.2	7.3 - 16.4
10	29	26	6	13.0	11.4	4.7	8.1 - 17.7
11	29	21	7	12.2	11.9	3.1	8.2 - 15.2
12	29	30	4	11.1	10.3	4.9	6.4 - 13.8

TOTAL CARBON lbs/day

5	31	1552499	17107	143532	85171	270419	26006-172341
6	31	2111399	23220	232641	112185	390244	38244-300078

Appendix B-9

Water Quality Characteristics
Haw River Stations
January 1971 - March 1972

TOTAL SOLUBLE CARBON mg/1

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
1	29	30	10	19.6	19.7	5.2	12.6 - 26.2
2	29	29	12	18.5	19.0	4.4	12.6 - 22.4
3	29	27	10	17.3	17.3	4.2	11.6 - 22.4
4	29	23	10	16.4	16.3	3.4	11.6 - 20.2
5	31	23	10	15.7	15.3	3.7	10.4 - 20.1
6	31	22	9	16.1	16.6	3.7	10.9 - 20.6
7	29	18	5	10.6	10.1	3.4	5.6 - 14.2
8	29	37	6	12.3	11.6	5.4	8.6 - 13.4
9	29	18	6	12.8	12.7	3.2	8.3 - 16.2
10	29	21	5	12.0	11.1	3.4	8.6 - 15.7
11	29	26	3	12.7	11.6	4.7	8.2 - 16.7
12	29	23	4	11.3	10.9	4.1	7.2 - 16.2

TOTAL SOLUBLE CARBON lbs/ day

5	31	675000	16157	105023	78079	117617	27688-152253
6	31	1009800	25542	176153	106798	204760	33627-275562

Appendix B-10

Water Quality Characteristics
Haw River Stations
January 1971 - March 1972

INORGANIC CARBON mg/1

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
1	29	14	3	8.3	7.8	3.5	3.7 - 12.6
2	29	16	3	8.0	7.3	3.6	3.3 - 11.7
3	29	14	3	7.0	6.7	3.0	3.2 - 10.2
4	29	15	2	6.8	6.7	3.2	2.8 - 10.1
5	31	11	2	5.4	5.1	2.5	2.2 - 7.8
6	31	12	0.0	4.5	4.0	2.8	1.2 - 8.0
7	29	11	0.0	2.9	2.4	2.0	.9 - 3.8
8	29	11	0.0	3.0	2.6	2.3	.3 - 5.1
9	29	5	0.0	2.0	1.8	1.4	0.0 - 3.5
10	29	6	0.0	2.4	2.2	1.6	.2 - 4.2
11	29	9	0.0	4.1	3.4	2.4	1.2 - 6.8
12	29	5	0.0	2.1	1.8	1.7	0.0 - 4.1

INORGANIC CARBON lbs/day

5	31	202500	1901	35574	23902	38039	9828-56835
6	31	131220	0.0	32711	29268	25648	9127-48330

Appendix B-11

Water Quality Characteristics
Haw River Stations
January 1971 - March 1972

TOTAL NITROGEN mg/1

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
1	26	4.33	0.73	1.95	1.73	0.91	1.07 - 2.77
2	28	5.26	0.79	1.91	1.73	0.97	.98 - 2.68
3	28	3.71	0.79	1.77	1.59	0.78	.95 - 2.90
4	29	4.06	0.66	1.64	1.46	0.77	.82 - 2.52
5	31	3.26	0.54	1.51	1.34	0.69	.84 - 2.22
6	31	3.23	0.49	1.34	1.31	0.60	.65 - 1.86
7	28	1.30	0.31	0.78	0.76	0.26	.49 - 1.10
8	29	2.36	0.32	0.82	0.77	0.36	.50 - 1.00
9	29	1.85	0.22	0.64	0.62	0.30	.39 - .79
10	28	1.76	0.21	0.74	0.69	0.30	.46 - .95
11	29	0.85	0.12	0.35	0.31	0.19	.16 - .50
12	29	1.13	0.17	0.60	0.58	0.26	.26 - .85

TOTAL NITROGEN lbs/day

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
5	31	54675	513	9556	7416	9732	2549-13633
6	31	86292	2551	12831	9725	14976	2975-18068

Appendix B-12

Water Quality Characteristics
Haw River Stations
January 1971 - March 1972

ORGANIC NITROGEN mg/1

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
1	25	1.35	0.02	0.45	0.29	0.36	.20 - .91
2	27	1.07	0.04	0.43	0.36	0.29	.10 - .80
3	27	1.01	0.00	0.40	0.34	0.27	.08 - .72
4	28	0.83	0.00	0.33	0.34	0.20	.09 - .54
5	30	1.00	0.05	0.37	0.33	0.23	.14 - .60
6	30	0.61	0.00	0.30	0.30	0.17	.05 - .52
7	28	0.48	0.05	0.23	0.23	0.13	.08 - .41
8	29	0.48	0.06	0.22	0.20	0.09	.12 - .30
9	29	1.50	0.06	0.28	0.20	0.27	.09 - .38
10	28	0.59	0.07	0.24	0.18	0.13	.12 - .39
11	29	0.45	0.01	0.17	0.12	0.14	.05 - .39
12	28	0.63	0.06	0.20	0.17	0.13	.08 - .33

ORGANIC NITROGEN lbs/day

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
5	30	19575	186	2570	1403	3660	464-3779
6	30	37638	0.0	3660	1742	6947	331-6571

Appendix B-13

Water Quality Characteristics
Haw River Stations
January 1971 - March 1972

AMMONIA NITROGEN mg/1

(NH_3-N)

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
1	28	5.00	0.21	0.74	0.59	0.87	.28 - .87
2	28	3.40	0.02	0.48	0.37	0.62	.05 - .65
3	28	0.74	0.01	0.26	0.24	0.20	.04 - .49
4	28	0.78	0.01	0.21	0.16	0.20	.02 - .46
5	30	0.90	0.01	0.18	0.11	0.20	.01 - .36
6	30	0.70	0.01	0.19	0.13	0.19	.01 - .42
7	29	0.85	0.01	0.08	0.05	0.15	.01 - .08
8	29	1.02	0.01	0.10	0.05	0.18	.01 - .12
9	29	0.11	0.01	0.04	0.04	0.03	.01 - .07
10	29	0.72	0.01	0.08	0.04	0.14	.01 - .13
11	29	0.15	0.01	0.05	0.03	0.04	.01 - .08
12	29	1.70	0.01	0.11	0.03	0.31	.01 - .09

AMMONIA NITROGEN lbs/day

5	30	20925	23	1701	319	3852	43-2792
6	30	31212	32	2891	863	5849	57-5039

Appendix B-14

Water Quality Characteristics
Haw River Stations
January 1971 - March 1972

NITRITE-NITRATE NITROGEN mg/l

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
1	29	2.70	0.12	1.0	0.83	0.66	.44 - 1.56
2	29	4.50	0.16	1.16	1.04	0.88	.47 - 1.92
3	29	2.60	0.19	1.11	1.00	0.68	.42 - 1.89
4	29	3.40	0.16	1.09	0.91	0.71	.44 - 1.92
5	31	2.20	0.14	0.96	0.82	0.57	.21 - 1.66
6	31	2.70	0.07	0.85	0.77	0.58	.18 - 1.26
7	29	1.12	0.19	0.52	0.51	0.21	.24 - .74
8	29	1.05	0.14	0.50	0.51	0.18	.30 - .66
9	29	0.68	0.10	0.32	0.31	0.13	.16 - .46
10	29	0.86	0.03	0.43	0.44	0.19	.20 - .60
11	29	0.56	0.02	0.13	0.11	0.10	.05 - .19
12	29	0.73	0.02	0.35	0.37	0.18	.13 - .52

NITRITE NITRATE NITROGEN lbs/day

5	31	14345	133	5251	4549	3757	1502-9941
6	31	17442	677	6219	5917	4284	1895-10064

Appendix B-15

Water Quality Characteristics
Haw River Stations
January 1971 - March 1972

TOTAL PHOSPHORUS mg/1

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
1	29	1.70	0.22	0.66	0.59	0.37	.26 - 1.14
2	29	1.80	0.24	0.68	0.64	0.37	.26 - 1.08
3	29	1.60	0.20	0.63	0.46	0.37	.25 - 1.04
4	29	1.06	0.19	0.52	0.45	0.27	.23 - .83
5	31	0.95	0.20	0.48	0.36	0.24	.24 - .84
6	31	1.13	0.20	0.45	0.39	0.24	.21 - .75
7	29	0.45	0.03	0.10	0.07	0.09	.03 - .14
8	27	0.41	0.03	0.10	0.07	0.09	.04 - .17
9	29	0.20	0.04	0.07	0.07	0.03	.04 - .09
10	29	0.29	0.03	0.09	0.06	0.07	.03 - .18
11	28	0.32	0.02	0.06	0.04	0.06	.02 - .09
12	29	0.23	0.03	0.06	0.05	0.04	.02 - .08

TOTAL PHOSPHORUS lbs/day

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
5	31	48600	209	4016	2010	8499	819-5182
6	31	59670	778	5225	2914	10362	1008-7182

Appendix B-16

Water Quality Characteristics
Haw River Stations
January 1971 - March 1972

ORTHOPHOSPHATE mg/1

Station No.	Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
1	29	1.50	0.05	0.46	0.41	0.31	.15 - .77
2	29	1.60	0.09	0.48	0.43	0.33	.15 - .79
3	29	1.40	0.06	0.43	0.34	0.31	.13 - .85
4	29	1.00	0.07	0.38	0.31	0.25	.12 - .69
5	31	0.90	0.02	0.35	0.27	0.24	.10 - .68
6	31	0.80	0.07	0.29	0.26	0.20	.09 - .51
7	29	0.06	0.01	0.03	0.03	0.01	.01 - .04
8	29	0.17	0.01	0.04	0.03	0.03	.01 - .05
9	29	0.07	0.01	0.03	0.02	0.02	.01 - .05
10	29	0.08	0.01	0.03	0.02	0.02	.01 - .04
11	29	0.06	0.01	0.02	0.02	0.01	.01 - .04
12	29	0.05	0.01	0.02	0.02	0.01	.00 - .03

ORTHOPHOSPHATE lbs/day

Station No.	Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
5	31	6736	62	1922	1461	1653	586-3289
6	31	7436	608	2215	1776	1672	798-3164

Appendix B-17

Water Quality Characteristics
Haw River Stations
January 1971 - March 1972

pH

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
1	29	7.6	6.4	7.0	7.0	0.38	6.5 - 7.4
2	29	7.7	6.5	7.1	7.1	0.33	6.7 - 7.4
3	29	7.6	6.6	7.1	7.1	0.32	6.7 - 7.5
4	29	7.6	6.7	7.2	7.2	0.29	6.7 - 7.5
5	31	8.3	6.4	7.4	7.3	0.46	6.8 - 7.9
6	31	8.0	6.6	7.2	7.2	0.33	6.8 - 7.6
7	29	7.8	6.7	7.2	7.2	0.27	6.8 - 7.5
8	29	7.7	6.7	7.1	7.1	0.24	6.8 - 7.3
9	29	7.6	6.7	7.1	7.0	0.21	6.8 - 7.3
10	29	7.5	6.7	7.1	7.1	0.22	6.8 - 7.3
11	29	7.4	6.6	7.1	7.0	0.21	6.7 - 7.3
12	28	7.5	6.4	7.0	7.1	0.23	6.7 - 7.3

Appendix B-18

Water Quality Characteristics
Haw River Stations
January 1971 - March 1972

CHLOROPHYLL - KLETT UNITS

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
1	29	30.0	2.0	8.2	5.9	6.5	2.4 - 12.4
2	29	20.0	2.0	7.2	6.7	3.9	2.9 - 9.9
3	29	15.0	0.0	7.7	7.0	4.0	2.8 - 13.2
4	29	22.0	0.0	6.5	5.9	4.1	2.3 - 9.7
5	30	15.0	1.0	5.6	5.0	3.1	2.4 - 8.2
6	31	14.0	1.0	5.4	5.1	2.8	2.3 - 7.1
7	29	7.0	0.0	3.2	3.2	1.8	.8 - 4.7
8	27	7.0	1.0	3.4	3.3	1.7	1.0 - 5.0
9	28	8.0	0.0	2.8	2.5	1.8	.4 - 4.5
10	29	16.0	0.0	4.0	3.3	3.0	1.2 - 5.8
11	29	8.0	0.0	3.1	2.9	1.6	1.2 - 4.6
12	29	8.0	0.0	3.0	3.2	1.6	.5 - 3.8

Appendix B-19

Water Quality Characteristics
Haw River Stations
January 1971 - March 1972

TOTAL COLIFORMS No/100 ml (x 10^2)

Station No.	Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
1	22	1020	0.0	331	196	332	30 - 840
2	23	1400	6.0	340	225	346	24 - 640
3	23	930	3.0	209	108	257	9.4 - 576
4	21	630	0.0	71	21	141	4.4 - 135
5	25	650	0.0	91	21	148	1.1 - 204
6	25	450	0.0	72	26	106	2.3 - 161
7	23	200	0.0	32	8.8	48	1.9 - 70
8	22	1050	0.0	78	7.0	223	1.3 - 107
9	22	55	0.0	15	7.5	16	1.8 - 32
10	22	720	0.0	58	8.5	155	.9 - 84
11	23	200	1.0	17	5.0	41	1.0 - 20
12	23	200	0.0	20	5.8	42	.3 - 26

Appendix B-20

Water Quality Characteristics
Haw River Stations
January 1971 - March 1972

FECAL COLIFORMS No/100 ml (x 10^2)

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
1	22	370	0.0	74.9	67.5	76.6	13 - 101
2	23	200	0.0	51.7	27.8	57.8	4.8 - 102
3	23	160	0.0	45.2	26.0	50.2	3.8 - 119
4	21	110	0.0	28.1	13.5	35.4	.6 - 74
5	25	130	0.0	24.8	13.9	33.0	0.0 - 59
6	25	121	0.0	22.3	6.1	30.6	.7 - 57
7	23	200	0.0	23.8	4.3	47.9	.2 - 59
8	23	200	0.0	20.8	2.3	45.1	0.0 - 62
9	22	25	0.0	4.5	2.3	6.1	0.0 - 9.5
10	22	200	0.0	25.8	3.8	49.7	0.0 - 65
11	23	25	0.0	4.0	1.9	6.0	0.0 - 7.6
12	23	60	0.0	11.2	2.3	18.4	0.0 - 29

Appendix B-21

Water Quality Characteristics
Haw River Stations
January 1971 - March 1972

ENTEROCOCCI No/100 ml $(\times 10^2)$

Station	No. Samples	Max.	Min.	Average	Median	S.D.	Central 75% Quartile
1	22	24	0.0	5.9	3.5	6.4	.2 - 13
2	23	150	0.0	13.7	3.1	31.7	.2 - 22
3	23	82	0.0	11.2	4.3	19.7	0.0 - 22
4	21	42	0.0	8.1	3.0	12.4	0.0 - 19
5	25	78	0.0	11.2	2.8	20.6	0.0 - 32
6	25	65	0.0	10.9	4.0	16.2	0.0 - 27
7	23	200	0.0	18.5	3.3	42.3	0.0 - 35
8	23	200	0.0	18.4	3.4	43.0	0.0 - 48
9	22	29	0.0	6.5	2.5	9.2	0.0 - 20
10	22	200	0.0	21.9	2.0	44.8	0.0 - 50
11	23	47	0.0	8.0	4.0	12.0	0.0 - 15
12	23	108	0.0	10.3	1.3	22.9	0.0 - 16

APPENDIX C

DESCRIPTION OF BENTHIC SAMPLING STATIONS

H-1	Located at bridge on Alamance County Rt. 2146 crossing Haw River at Saxapahaw, N.C. Portion of river sampled is approximately 125 ft. wide; average depth approximately 3 ft., with alternating riffles and pools. Stream has stable mixed bottom composed mostly of boulders, rubble, and gravel.
H-5	Located at bridge on Chatham County Rt. 1943 crossing Haw River, about 2 miles downstream from U.S. 64. River is approximately 300 ft. wide; average depth approximately 4 ft., with alternating riffles and pools, the latter most common. Stream has stable mixed bottom composed mostly of boulders, rubble, and gravel.
H-7	Located at bridge on Orange County Rt. 1958 crossing Cane Creek (east), about 1.5 miles downstream from N.C. 54. Stream is approximately 35 ft. wide; average depth approximately 2 ft., with alternating riffles and pools. Stream has stable mixed bottom, composed mostly of boulders, rubble, gravel, and coarse sand.
H-8	Located at bridge on Alamance County Rt. 2180 crossing Cane Creek (west), about 1 mile downstream from N.C. 87. Stream is approximately 25 ft. wide; average depth approximately 2 ft., with alternating riffles and pools. Stream has stable mixed bottom composed mostly of boulders, rubble, gravel, and coarse sand.
H-11	Located at bridge on Chatham County Rt. 1525 crossing Ferrell Creek, about 4 miles north of Bynum, N.C. Stream is approximately 20 ft. wide; average depth approximately 2 ft., with riffles and pools, the latter most common. Stream has unstable, shifting bottom composed mostly of coarse sand.
H-12	Located at bridge on Chatham County Rt. 1520 crossing Dry Creek, about 2 miles downstream from N.C. 87. Stream is approximately 20 ft. wide; average depth approximately 1 1/2-2 ft, with alternating riffles and pools. Stream has stable mixed bottom composed mostly of boulders, rubble, and gravel.
NH-5	Located at bridge on Orange County Rt. 1107 crossing New Hope Creek, about 2 miles downstream from N.C. 54. Stream is approximately 30 ft. wide; average depth approximately 2 1/2-3 ft No significant riffles; almost uniformly slow current. Stream has stable bottom composed mostly of clay mud with a few boulders.

Appendix C (continued)

NH-7	Located at bridge on Chatham County Rt. 1008 crossing New Hope River at Farrington, N.C. River is approximately 60 ft. wide; average depth approximately 3 1/2 ft. More area in pools than in riffles. Stream has stable mixed bottom composed mostly of boulders, rubble, and clay mud.
NH-8	Located at bridge on Chatham County Rt. 1008 crossing Whiteoak Creek, about 1 mile north of U.S. 64. Stream is approximately 15 ft. wide; average depth approximately 2 ft., mostly pools rather than riffles. Stream has somewhat unstable bottom composed mostly of coarse sand and boulders.
NH-8A	Located at bridge on Chatham County Rt. 1008 crossing Beaver Creek, about 2.5 miles south of U.S. 64. Stream is approximately 20 ft. wide; average depth approximately 2 1/2-3 ft. No significant riffles; mostly slow current. Stream has somewhat unstable bottom composed mostly of coarse sand, clay mud, and boulders.
NH-11	Located at bridge on Chatham County Rt. 1001 corssing Northeast Creek, about 6 miles north of U.S. 64. Stream is approximately 25 ft. wide; average depth approximately 3-3 1/2 ft. Uniformly slow current; no no riffles. Stream has stable bottom composed mostly of clay mud and coarse sand.
NH-12	Located at bridge on Chatham County Rt. 1715 crossing Bush Creek just west of Farrington, N.C. Stream is approximately 15 ft. wide; average depth approximately 1 1/2 ft.; mostly pools rather than riffles. Stream has somewhat unstable bottom composed mostly of coarse sand and clay mud.

APPENDIX D

List of Taxa and Station Where Collected Between 8 April 71 and 6 March 72

	Haw						New Hope					
Station	1	5	7	8	11	12	5	7	8	8A	11	12
Phylum *Arthropoda*												
Class *Insecta*												
Order *Ephemeroptera* (mayflies)												
Family *Heptageniidae*												
Genus *Stenonema*	x	x	x	x	x	x	x	x	x	x	x	x
*Genus Cinygma						x						
Family *Bactidae*												
*Genus *Baetis*	x			x	x	x		x				x
*Genus *Pseudocloeon*				x	x	x			x	x		
*Genus *Isonychia*		x	x	x		x						
*Genus *Ephemerella*	x	x	x	x		x				x	x	x
*Genus *Paraleptophlebia*				x	x				x	x		x
*Genus *Leptophlebia*											x	
*Genus *Caenis*						x						
Family *Ephemeridae*												
*Genus *Hexagenia*											x	
Order *Diptera* (2-winged flies)												
Family *Tendipedidae* (midges)	x	x	x	x	x	x	x	x	x	x	x	x
Family *Simulidae* (black flies)	x	x		x		x						x
Family *Ceratopogonidae* (biting midges)											x	
Family *Tipulidae* (crane flies)												
Genus *Tipula*			x	x		x			x	x		
Order *Plecoptera* (stoneflies)												
Family *Perlidae*												
*Genus *Acroneuria*		x			x	x						
*Genus *Perlesta*			x	x	x	x			x	x		x
Family *Perlodidae*												
*Genus *Isogenus*				x		x				x	x	x
*Genus *Isoperla*	x			x		x		x	x	x		x
Family Nemouridae												
*Genus *Nemoura*				x		x			x	x		

*"Pollution intolerant" taxon

Appendix D (continued)

	Haw						New Hope					
	1	5	7	8	11	12	5	7	8	8A	11	12
Family _Nemouridae_ (con't)												
*Genus _Taeniopteryx_	x		x			x		x		x		x
*Genus _Brachyptera_				x		x						
*Genus _Leuctra_						x			x			x
Genus _Allocapnia_									x			
Order _Coleoptera_ (beetles)												
*Family _Elmidae_	x	x	x	x	x	x				x	x	x
*Family _Dryopidae_			x	x		x						x
Family _Dytiscidae_		x	x			x	x					
*Family _Psephenidae_						x						
Family _Gyrinidae_			x	x	x				x			
Family _Hydrophilidae_	x											x
Family _Chrysomelidae_		x										
Order _Trichoptera_ (caddisflies)												
Family _Hydropsychidae_	x	x	x	x		x		x	x	x		x
*Family _Philopotamidae_				x								
*Family _Psychomyiidae_	x		x	x	x	x					x	
*Family _Limnephilidae_			x	x							x	
*Family _Phyrganeidae_												x
*Family _Rhyacophilidae_				x					x			
*Family _Calamoceratidae_			x									
*Family _Hydroptilidae_									x			
*Family _Leptoceridae_				x								
Order _Megaloptera_ (alderflies, dobsonflies)												
Family _Sialidae_												
*Genus _Sialis_		x	x		x		x		x	x	x	x
Family _Corydalidae_												
*Genus _Corydalus_				x								
*Genus _Nigronia_				x								
Order _Hemiptera_ (true bugs)												
Family _Corixidae_										x		
Family _Dipsocoridae_						x						

Appendix D (continued)

	Haw						New Hope					
	1	5	7	8	11	12	5	7	8	8A	11	12
Order *Odonata* (dragonflies, damselflies)												
Sub-Order *Anisoptera* (dragonflies)												
Family *Gomphidae*												
Genus *Gomphus*		x	x									
Genus *Hagenius*				x								
Genus *Lanthus*						x						
Genus *Dromogomphus*		x										
Family *Libelullidae*												
Genus *Erythemis*			x									
Genus *Epicordulia*				x								
Genus *Tetragoneuria*			x									
Genus *Somatochlora*				x					x			x
Genus Libellula		x										
Genus *Neurocordulia*		x		x								
Family *Aeshnidae*												
Genus *Pachydiplax*							x					
Genus *Aeshna*		x		x		x			x			x
Genus *Boyeria*			x		x	x	x					
Genus *Gomphaeschna*				x								
Genus *Oplonaeschna*				x								
Sub-Order *Zygoptera* (damselflies)												
Family *Agrionidae*												
Genus *Agrion*			x					x				
Genus *Hetaerina*		x										
Family *Coenagrionidae*												
Genus *Argia*	x	x	x				x	x		x		
Genus *Hyponeura*	x	x	x	x							x	
Genus *Enallagma*		x									x	
Order *Lepidoptera*												
*Family *Pyralidae* (aquatic moths)		x										

Appendix D

	Haw						New Hope					
	1	5	7	8	11	12	5	7	8	8A	11	12
Class *Crustacea*												
Order *Isopoda*												
Family *Asellidae*												
Genus *Asellus* (sowbugs)		x	x	x			x	x	x	x		x
Order *Amphipoda*												
Family *Talitridae*												
Genus *Hyalella* (scuds)	x	x	x			x	x	x		x	x	x
Order *Decapoda*												
Family												
Genus *Cambarus* (crayfish)	x	x	x	x	x	x	x	x	x	x	x	x
Phylum *Annelida* (segmented worms)												
Class *Oligochaeta* (aquatic earthworms)		x	x	x	x		x	x	x	x		x
Class *Hirudinea* (leeches)	x		x			x		x		x	x	
Phylum *Platyhelminthes*												
Class *Turbellaria* (flatworms)	x		x			x	x	x	x	x	x	x
Phylum *Porifera* (sponges)												
*Family *Spongillidae* (freshwater sponges)		x		x								
Phylum *Mollusca*												
Class *Gastropoda* (snails)												
Order *Pulmonata* (lung breathers)												
Family *Physidae*												
Genus *Physa*	x	x	x	x			x	x	x	x	x	x
Family *Lymnaeidae*												
Genus *Lymnaea*												x
Family *Planorbidae*												
Genus *Gyraulus*	x	x	x		x	x	x	x			x	
Order *Ctenobranchiata* (gill breathers)												
Family *Valvatidae*												
*Genus *Valvata*		x						x	x			
Family *Viviparidae*												
*Genus *Campeloma*						x						x
*Genus Geniobasis		x	x									
Family *Amnicolidae*												
*Genus *Bithinia*		x	x		x							
*Genus *Gillia*		x										x

*"Pollution intolerant" taxon

Appendix D (continued)

	Haw						New Hope					
	1	5	7	8	11	12	5	7	8	8A	11	12
Class Pelecypoda (clams) Family Sphaeriidae (fingernail clams)		x	x	x		x	x	x		x	x	

	Haw						New Hope					
Station	1	5	7	8	11	12	5	7	8	8A	11	12
TOTAL TAXA =	19	33	34	39	16	35	15	18	22	25	20	28
*TAXA =	6	11	13	21	9	19	1	4	9	11	8	14
%*TAXA =	32%	33%	38%	54%	56%	54%	7%	22%	41%	44%	40%	50%

Total Taxa
Per Station:

Main Haw (1,5)	26.0
Control Haw (7, 8, 11, 12)	31.0
Control Haw (minus H-11)	(36.0)
Main New Hope (5, 7, 11)	17.6
Control New Hope (8, 8A, 12)	25.0

APPENDIX E

Concentration of Metals in the New Hope River and Tributaries
March 1971 - February 1972*

		Cd ppb			Cr ppb			Hg ppb	Pb ppb			Zn ppb		
Sample No.	Date	t**	d	s	t	d	s	t	t	d	s	t	d	s
New Hope-7														
112	3-11-71	0.4	0.3	0.1	4.3	0.5	3.8	0.06	3.3	-	3.3	5.0	-	5.0
116	5-5-71	1.6	0.8	0.8	1.6	-	1.6	0.06	2.4	-	2.4	6.7	-	6.7
118	6-2-71	0.7	-	0.7	4.6	-	4.6	0.13	2.6	-	2.6	5.1	-	5.1
121	7-14-71	9.0$^+$	3.6$^+$	5.4$^+$	4.8	2.2	2.6	0.04	3.0	-	3.0	9.0	-	9.0
123	8-12-71	1.1	0.6	0.5	3.6	0.8	2.8	0.14	3.0	-	3.0	7.9	-	7.9
126	9-22-71	1.2	0.6	0.6	10.8$^+$	0.7$^+$	10.1$^+$	0.09	13.1	-	13.1	39.3$^+$	-$^+$	39.3$^+$
128	10-20-71	0.5	0.5	-	3.7	0.8	2.9	0.03	3.1	-	3.1	6.2	-	6.2
130	11-17-71	0.5	0.5	-	4.4	1.5	2.9	0.08	4.9	-	4.9	9.4	4.9	4.5
132	1-6-72	0.3	0.3	-	1.5	-	1.5	0.06	2.4	-	2.4	4.4	1.8	2.6
135	2-18-72	0.3	0.3	-	2.1	-	2.1	0.10	-	-	-	5.9	5.9	-
New Hope-8														
112	3-11-71	2.1	1.6	0.5	2.0	0.2	1.8	0.07	-	-	-	8.9	2.2	6.7
116	5-5-71	0.3	-	0.3	1.4	-	1.4	0.06	-	-	-	0.7	-	0.7
118	6-2-72	0.7	-	0.7	2.3	-	2.3	0.07	2.3	-	2.3	13.9	4.6	9.3
121	7-14-71	1.1	0.7	0.4	3.1	0.7	2.4	0.08	2.1	-	2.1	1.4	-	1.4
123	8-12-71	0.7	0.7	-	1.0	0.6	0.4	0.03	2.0	-	2.0	5.0	1.0	4.0
126	9-22-71	0.4	0.4	-	1.6	-	1.6	0.05	-	-	-	4.0	-	4.0
128	10-20-71	0.3	0.3	-	5.8	-	5.8	0.06	-	-	-	7.0	2.9	4.1
130	11-17-71	0.7	0.6	0.1	19.3$^+$	4.8$^+$	14.5$^+$	0.07	4.2	-	4.2	18.4	7.9	10.5
132	1-6-72	0.2	-	0.2	1.0	-	1.0	0.04	-	-	-	2.7	1.7	1.0
135	2-18-72	0.3	0.2	0.1	2.9	-	2.9	0.01	-	-	-	6.4	1.4	5.0

*Freeze-concentrated water analyses corrected to raw water concentrations.

$^+$Not included in averages in Table 3.

**Total, dissolved, and suspended concentrations.

APPENDIX E

Concentration of Metals in the Haw River and Tributaries
April 1971 - February 1972*

		Cd ppb			Cr ppb			Hg ppb	Pb ppb			Zn ppb		
Sample No.	Date	t**	d	s	t	d	s	t	t	d	s	t	d	s
Haw-1														
113	4-1-71	0.4	-	0.4	1.4[+]	-[+]	1.4[+]	0.10	-	-	-	10,2	8.1	2.1
118	6-10-71	0.8	0.8	-	15.9	1.7	14.2	0.09	3.6	-	3.6	29.0	24.1	4.9
120	7-8-71	5.9[+]	5.2[+]	0.7[+]	37.7	16.8	20.9	0.10	5.6	-	5.6	23.7	16.8	6.9
125	9-16-71	0.6	0.6	-	74.2	41.9	32.3	0.10	4.0	-	4.0	25.8	12.9	12.9
133	1-19-72	0.5	0.4	0.1	34.1	31.3	2.8	0.04	1.4	-	1.4	22.5	8.2	14.3
134	2-9-72	0.3	0.3	-	56.5	20.4	36.1	0.05	-	-	-	19.6	10.9	8.7
Haw-5														
120	7-8-71	4.3[+]	3.9[+]	0.4[+]	21.3	3.4	17.9	0.09	3.6	-	3.6	15.6	8.5	7.1
123	8-19-71	0.6	0.4	0.2	16.2	4.1	12.1	0.04	4.1	-	4.1	20.7	11.3	9.4
127	10-13-71	0.5	0.3	0.2	16.9	1.8	15.1	0.30	-	-	-	21.7	9.0	12.7
130	12-1-71	0.1	-	0.1	1.1	-	1.1	0.03	1.8	-	1.8	2.5	0.4	2.1
134	2-9-72	0.3	-	0.3	0.7	-	0.7	0.14	-	-	-	4.4	4.4	-
Haw-7														
113	4-1-71	0.4	-	0.4	1.4	-	1.4	0.04	1.4	-	1.4	1.7	-	1.7
118	6-10-71	0.6	0.6	-	1.1	-	1.1	0.03	-	-	-	4.3	-	4.3
123	8-19-71	0.6	0.2	0.4	2.6	0.6	2.0	0.06	3.8	-	3.8	10.8	-	10.8
125	9-16-71	0.7	0.7	-	79.3[+]	44.8[+]	34.5[+]	0.10	4.3	-	4.3	27.6	13.8	13.8
127	10-13-71	0.2	-	0.2	2.8	-	2.8	0.04	-	-	-	4.7	0.8	3.9
133	1-19-72	0.8	0.5	0.3	1.5	-	1.5	0.15	-	-	-	40.6	8.1	32.5
Haw-8														
120	7-8-71	3.4[+]	0.8[+]	2.6[+]	1.1	0.2	0.9	0.05	1.7	1.5	0.2	4.6[+]	29.0[+]	-
130	12-1-71	0.2	-	0.2	1.2	-	1.2	0.09	1.8	-	1.8	3.7	0.1	3.6

[+] Not included in averages in Table 4.

*Freeze-concentrated water corrected to raw water concentrations

**Total, dissolved, and suspended concentrations.

APPENDIX F

Concentration of Metals in Benthic Macroinvertebrates

New Hope Drainage

Main Stem

Station 5	Date Collected	Cd ppm*	Cr ppm	Hg ppm	Pb ppm	Zn ppm
Diptera	5-25-71	---	46.9	7.8	---	391
	7-13-71	10.2	163	---	---	---
Ephemeroptera	7-13-71	---	114	---	75.9	380
	11-5-71	---	5.2	2.6	26.1	387
	1-9-72	3.2	5.5	3.7	13.7	447
Isopoda	4-15-71	2.0	6.8	12.1	60.5	202
	5-25-71	---	81.8	---	---	91
	7-13-71	3.5	62.5	---	---	---
	11-5-71	---	---	4.6	---	221
	1-19-72	2.9	8.6	2.3	17.9	158
Odonata	5-25-71	---	12.3	11.3	16.5	82
Average		2.0	46.0	4.0	19.1	214
Range		nd-10.2	nd-163	nd-12.1	nd-75.9	nd-447
Station 7						
Ephemeroptera	4-15-71	2.0	6.8	4.9	14.6	331
	5-23-71	0.7	24.9	5.8	29.2	351
	11-12-71	2.1	5.2	2.5	5.2	262
	1-20-72	---	---	0.7	---	159
	3-1-72	0.9	2.2	1.0	5.0	142

*µg/g dry weight

APPENDIX F

New Hope Drainage
Main Stem
Continued

Station 7	Date Collected	Cd ppm*	Cr ppm	Hg ppm	Pb ppm	Zn ppm
Notostraca	4-15-71	10.1	7.5	12.6	---	251
	5-23-71	1.7	22.2	6.8	---	34
Odonata	4-15-71	10.5	---	14.0	---	70
	5-23-71	---	18.7	11.7	---	99
Trichoptera	11-12-71	1.4	7.4	1.8	13.8	249
	1-20-72	---	1.9	1.1	9.4	166
Average		2.7	8.8	5.7	7.0	192
Range		nd-10.5	nd-24.9	0.7-14.0	nd-29.2	34-351
Main Stem Average		2.3	27.4	4.8	13.0	203
Main Stem Range		nd-10.5	nd-163	nd-14.0	nd-75.9	nd-447

*µg/g dry weight

APPENDIX F

Concentrations of Metals in Organisms

New Hope Drainage

Control Streams

Station 8	Date Collected	Cd ppm*	Cr ppm	Hg ppm	Pb ppm	Zn ppm
Odonata	4-15-71	---	---	14.2	---	---
Trichoptera	2-29-72	2.4	---	11.2	---	131
Average		1.2	---	12.7	---	66
Range		nd-2.4	nd	11.2-14.2	nd	nd-131
Station 8A						
Megaloptera	7-13-71	---	84.3	9.6	---	241
Plecoptera	4-15-71	---	22.1	22.1	---	---
Average		---	53.2	15.8	---	120
Range		nd	22.1-84.3	9.6-22.1	nd	nd-241
Station 11						
Ephemeroptera	4-15-71	1.3	3.4	3.4	3.8	305
	5-25-71	---	16.9	---	50.8	102
	11-17-71	2.1	---	2.5	10.5	210
Average		1.1	6.8	2.0	21.7	206
Range		nd-2.1	nd-16.9	nd-3.4	3.8-50.8	102-305

*µg/g dry weight

APPENDIX F

New Hope Drainage
Control Streams
Continued

Station 12	Date Collected	Cd ppm*	Cr ppm	Hg ppm	Pb ppm	Zn ppm
Ephemeroptera	1-18-72	1.7	---	---	---	140
Control Average		0.9	15.8	7.9	8.1	141
Control Range		nd-2.4	nd-84.3	nd-22.1	nd-50.8	nd-305

*µg/g dry weight

APPENDIX F

Concentration of Metals in Organisms
Haw Drainage

Main Stem

Station 1	Date Collected	Cd ppm*	Cr ppm	Hg ppm	Pb ppm	Zn ppm
Ephemeroptera	7-5-71	5.6	148	9.2	51.9	611
	8-16-71	3.6	145	24.2	---	676
	11-3-71	---	129	8.5	---	479
Odonata	8-16-71	---	84	18.1	---	181
	11-3-71	---	60	5.4	21.5	209
Trichoptera	5-20-71	1.6	87	---	---	125
	8-16-71	---	126	12.0	---	229
	11-3-71	---	209	0.4	23.4	309
	2-11-72	---	237	1.2	11.9	207
Average		1.2	136	8.8	12.1	336
Range		nd-5.6	60-237	nd-24.2	nd-51.9	125-676
Station 5						
Ephemeroptera	4-8-71	4.5	81	5.4	80.7	807
	11-18-71	---	147	5.3	---	253
	2-22-72	8.4	179	---	24.0	767
Odonata	4-8-71	1.4	40	3.6	10.0	328
	4-8-71	4.4	44	10.4	696	1391
	5-20-71	2.5	48	---	50.2	201
Plecoptera	5-20-71	---	10	2.9	12.1	241
	11-18-71	---	---	2.3	---	484
	2-22-72	1.3	11	2.0	6.7	256

*µg/g dry weight

APPENDIX F

Concentration of Metals in Organisms
Haw Drainage
Main Stem
Continued

Station 5	Date Collected	Cd ppm*	Cr ppm	Hg ppm	Pb ppm	Zn ppm
Trichoptera	4-8-71	2.3	132	5.7	56.8	250
	5-20-71	1.3	84	3.2	52.5	262
	11-18-71	---	201	0.6	57.1	336
	2-22-72	2.9	237	---	29.3	293
Average		2.2	93	3.2	31.6	373
Range		nd-8.4	nd-237	nd-10.4	nd-80.7	201-807
Main Stem Average		1.8	111	5.5	23.2	357
Main Stem Range		nd-8.4	nd-237	nd-24.2	nd-80.7	125-807

*µg/g dry weight

APPENDIX F

Concentration of Metals in Organisms
Haw Drainage

Control Streams

Station 7	Date Collected	Cd ppm*	Cr ppm	Hg ppm	Pb ppm	Zn ppm
Diptera	4-8-71	0.8	9.2	1.8	46.1	184
	3-6-72	---	---	13.3	25.8	161
Ephemeroptera	4-8-71	---	17.2	---	---	776
	5-20-71	1.1	6.8	5.7	22.7	635
	7-5-71	---	40.5	---	---	---
	3-6-72	0.9	---	---	---	126
Odonata	4-8-71	---	2.8	3.4	---	900
	8-16-71	---	---	3.2	---	246
	1-12-72	0.3	---	---	---	13
Average		0.3	8.5	3.0	10.5	338
Range		nd-1.1	nd-40.5	nd-13.3	nd-46.1	nd-900
Station 8						
Coleoptera	7-5-71	26.6	---	no sample	---	628
Diptera	4-8-71	1.1	8.6	8.6	10.8	711
	4-8-71	---	22.3	9.3	---	372
Ephemeroptera	4-8-71	2.3	28.0	---	93.5	187
	4-8-71	2.0	24.1	4.8	16.1	201
	5-20-71	---	47.9	---	---	---
	5-20-71	2.9	11.5	---	---	115
	7-5-71	12.9	---	48.4	---	419

*µg/g dry weight

APPENDIX F

Concentration of Metals in Organisms
Haw Drainage
Control Streams
Continued

Station 8	Date Collected	Cd ppm*	Cr ppm	Hg ppm	Pb ppm	Zn ppm
Ephemeroptera	7-5-71	6.1	---	73.2	---	195
	8-25-71	---	---	5.2	---	175
	10-15-71	3.3	---	---	11.0	243
	3-6-72	1.3	---	---	---	140
	3-6-72	1.6	---	28.7	---	264
Megaloptera	4-8-71	---	14.4	13.4	26.9	126
	5-20-71	2.4	14.2	---	---	---
Odonata	4-8-71	3.8	---	23.0	---	115
	4-8-71	---	13.4	8.9	---	312
	5-20-71	---	16.8	---	---	153
	7-5-71	---	15.4	---	---	---
Plecoptera	4-8-71	---	20.4	4.6	---	544
	5-20-71	---	102	---	---	---
Trichoptera	4-8-71	1.0	16.3	5.1	6.1	244
	5-20-71	---	11.5	---	---	102
	7-5-71	1.7	---	24.9	---	159
	8-25-71	---	---	2.3	---	200
	10-15-71	1.5	---	---	7.7	153
Average		2.7	14.1	10.4	6.6	221
Range		nd-26.6	nd-102	nd-48.4	nd-93.5	nd-711

*µg/g dry weight

APPENDIX F

Concentration of Metals in Organisms
Haw Drainage
Control Streams
Continued

Station 12	Date Collected	Cd ppm*	Cr ppm	Hg ppm	Pb ppm	Zn ppm
Ephemeroptera	4-8-71	---	48.6	8.3	---	625
	5-20-71	1.6	8.2	---	---	198
	5-20-71	4.2	29.7	---	---	---
	7-5-71	6.0	36.0	15.0	---	299
	1-12-72	1.9	---	---	6.4	116
	1-12-72	3.9	---	---	---	253
	3-2-72	1.0	---	---	---	98
Odonata	5-20-71	---	11.9	---	---	89
	7-15-71	---	52.0	34.9	---	262
Plecoptera	5-20-71	---	4.8	---	---	127
	8-25-71	---	---	17.5	---	234
Average		1.7	17.4	6.9	0.6	209
Range		nd-6.0	nd-48.6	nd-34.9	nd-6.4	nd-625
Control Average		2.0	13.8	8.1	5.9	241
Control Range		nd-26.6	nd-102	nd-48.4	nd-93.5	nd-900

*μg/g dry weight