EXTENT OF CONTAMINATION OF A COLD-WATER STREAM BY PRIVATE DOMESTIC WASTE-DISPOSAL SYSTEMS

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ABSTRACT

EXTENT OF CONTAMINATION OF A COLD-WATER STREAM BY
PRIVATE DOMESTIC WASTE-DISPOSAL SYSTEMS

By

Dorance C. Brege

This study was an attempt to evaluate the extent of contamination of a cold-water stream by private septic systems. Fluorescein dye was flushed into nearly all of the 220 septic systems along a 20 mile stretch of the AuSable River. Visual inspection of the immediate shore line followed for a 4-5 day period. Water samples also were taken, stored, and later examined for fluorescence, and nitrate and chloride concentrations.

General surveys of invertebrate bottom fauna, oxygen fluctuations, vegetation, total phosphorus levels, and stream velocity were performed to analyze the general health of the river.

The results of this study indicate few instances of contamination from private septic systems. In only four cases was the dye actually observed and in only several instances does chemical or fluorescence analysis indicate contamination. Although the chemical load of the stream appears small, diurnal oxygen fluctuations, high water temperatures, bottom fauna, and heavy aquatic vegetation growths indicate deteriorating stream conditions.

A discussion of the extent of contamination from private septic systems and factors affecting the travel of materials from septic systems to streams is presented. Suggestions on installation of septic systems to obtain minimal contamination and suggestions to better evaluate the extent of contamination are given.

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By

Dorance C. Brege

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INTRODUCTION

Although reference has been made in surveys by Hendrickson (1966) and the Michigan Water Resources Commission (1966) on the AuSable River of the deleterious effects of effluent from the city of Grayling, Michigan, only speculation has occurred as to the magnitude of the effect of private septic systems. Thus the main objective of this study was to ascertain the possible input of materials from private domestic waste-disposal systems into the AuSable.

Due to the fact that the significance of these incoming materials is their effect in speeding eutrophication of the river; it is valuable to consider several parameters reflecting the river's general condition, due to a combination of 1) natural causes, 2) effluent from the city of Grayling, and 3) possible seepage from private septic systems. Factors considered were benthic invertebrates, diurnal fluctuations in oxygen concentration, vegetation, stream velocity, and total phosphorus levels of the stream.

The complexity of quantitatively determining the amount of contaminants entering the river is due to the large number of variables involved. Some of these are the probable low concentrations at which materials are moving, the various chemical forms involved, variations of quantity due to time and amount of use of individual septic systems, and distances involved between septic systems and the river, vertical distance between tile fields and the water table, and types of soil through which the materials must flow.

Due to this anticipated difficulty in detecting contaminating materials, it was decided that samples for chemical tests should be taken so as to have optimum probability regarding time and location for detecting contamination.

Rather than attempt to analyze for all possible forms of contaminants, indicators, materials that should be easy to detect and that are indicative of sewage wastes were selected. Those chosen were nitrate nitrogen and chlorides. Fluorescein dye also was flushed into nearly all the systems within the study area. This highly fluorescent dye was believed to be an obvious indicator of faulty systems. Its presence could be easily detected by fluorometer or by sight if present in sufficient concentration.

DESCRIPTION OF STUDY AREA

The AuSable River arises several miles north of the town of Frederic, Michigan, Section 23, T. 28 N., R. 4 W., about 15 miles upstream from the beginning of the study area, and flows through a relatively homogenous terrain throughout the study area. The river basin is shown in Figure 1.

Soils throughout most of the region are very sandy and can be described as Podzol, rubicon soil. This is a well-drained soil, with little runoff during rainstorms or spring melts. The result is a steady stream flow, the main component of which is groundwater responsible for the cold-water characteristics of the river.

Almost the entire land area within the drainage basin is forested with second growth from the lumbering of the virgin white pine forest. The watershed is almost entirely free of agriculture and industry. Except for certain areas, dwelling density is not high. In most areas dwellings are not evident, being rather sparsely located in comparison to cottage density on local lakes.

The study area extended from Pollack Bridge above Grayling to Townline Road, about 21 miles downstream. For convenience of discussion the area will be broken into

Figure 1. AuSable River Basin. From Michigan Water Resource Commission (1966).

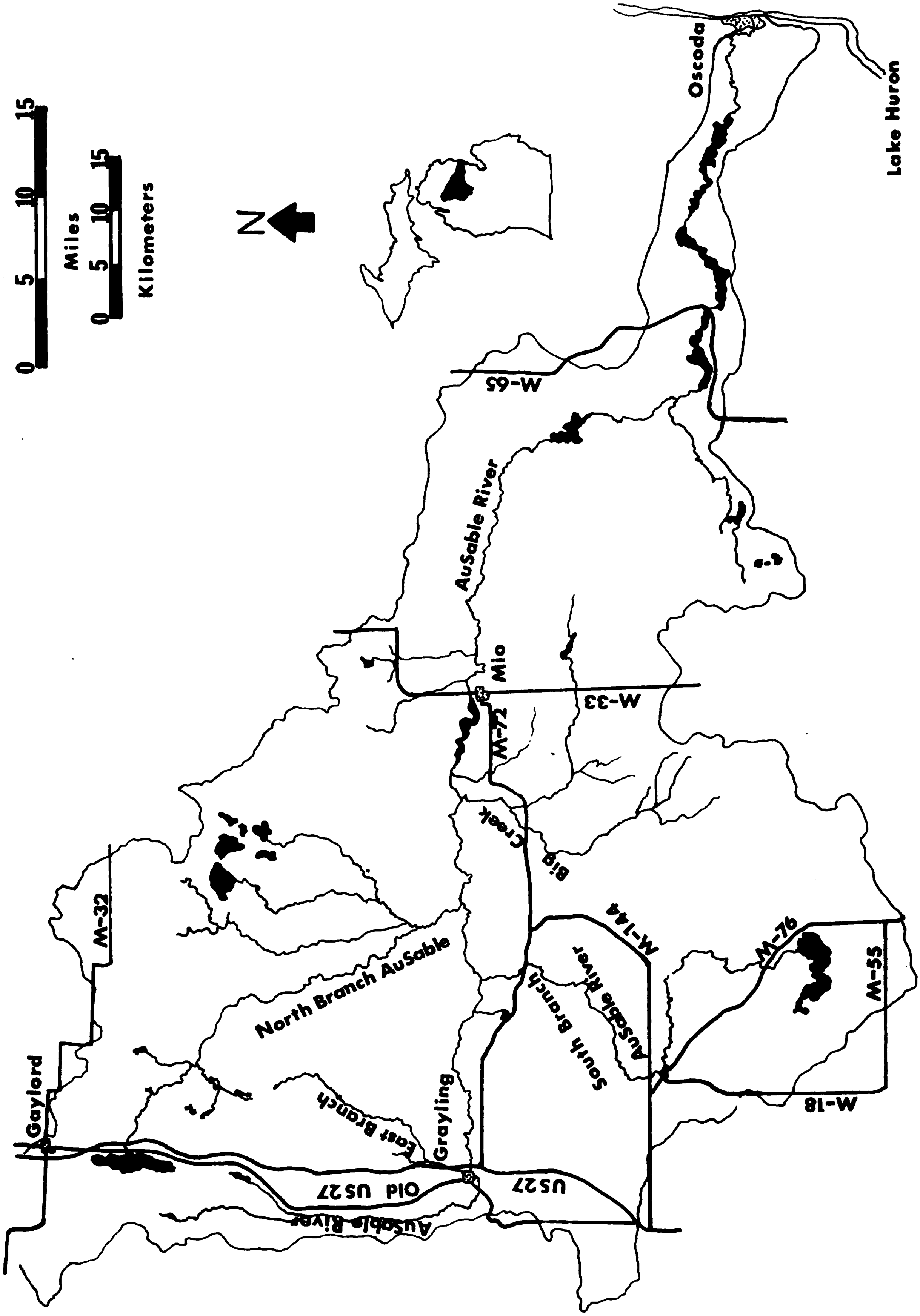

0 5 10 15
Miles
0 5 10 15
Kilometers
N
Oscoda
Lake Huron
M-65
AuSable River
Mio
M-33
M-72
Big Creek
M-144
M-76
M-55
M-18
South Branch AuSable River
North Branch AuSable
M-32
Gaylord
East Branch
Grayling
Old US27
US27
AuSable River

Figure 1

several distinct sections based on differences in bottom type, velocity, depth, vegetation types and density, and other characteristics. The limits of each section of the study are given in Figure 2. These study sections are expanded in Figures 3.1-3.4.

Section I--Section I is the area extending from Pollack Bridge 8.7 kilometers downstream to the State Street Bridge within the city of Grayling.

The stream in Section I is composed of intermittent stream and impoundment areas. The unrestricted stream is relatively shallow and predominantly sandy with virtually no gravel areas. Although current velocity is rather slow, water is cool and well oxygenated. Invertebrate life is diverse but rather sparse.

Impoundments are an important aspect of Section I, making up over one-half of the length of the area. The upstream reservoir, impounded by an old power dam, is over a mile in length. The bottom is silt filled and shallow, being less than three feet over most of the area, but becoming about 10 feet deep at the dam. Below M-72, the AuSable enters a swampy impoundment of about one-half mile in length extending into the city of Grayling. The river in this area is greatly divided, losing nearly all sense of directional flow. Large growths of waterlilies and emergent tree stumps are the dominant features of the shallow muddy flooding. Toward the eastern city limits, the width becomes restricted and depth is generally greater than 8-10 feet.

Figure 2. Study Area on the main stream of the AuSable River, sections as described in the introduction.

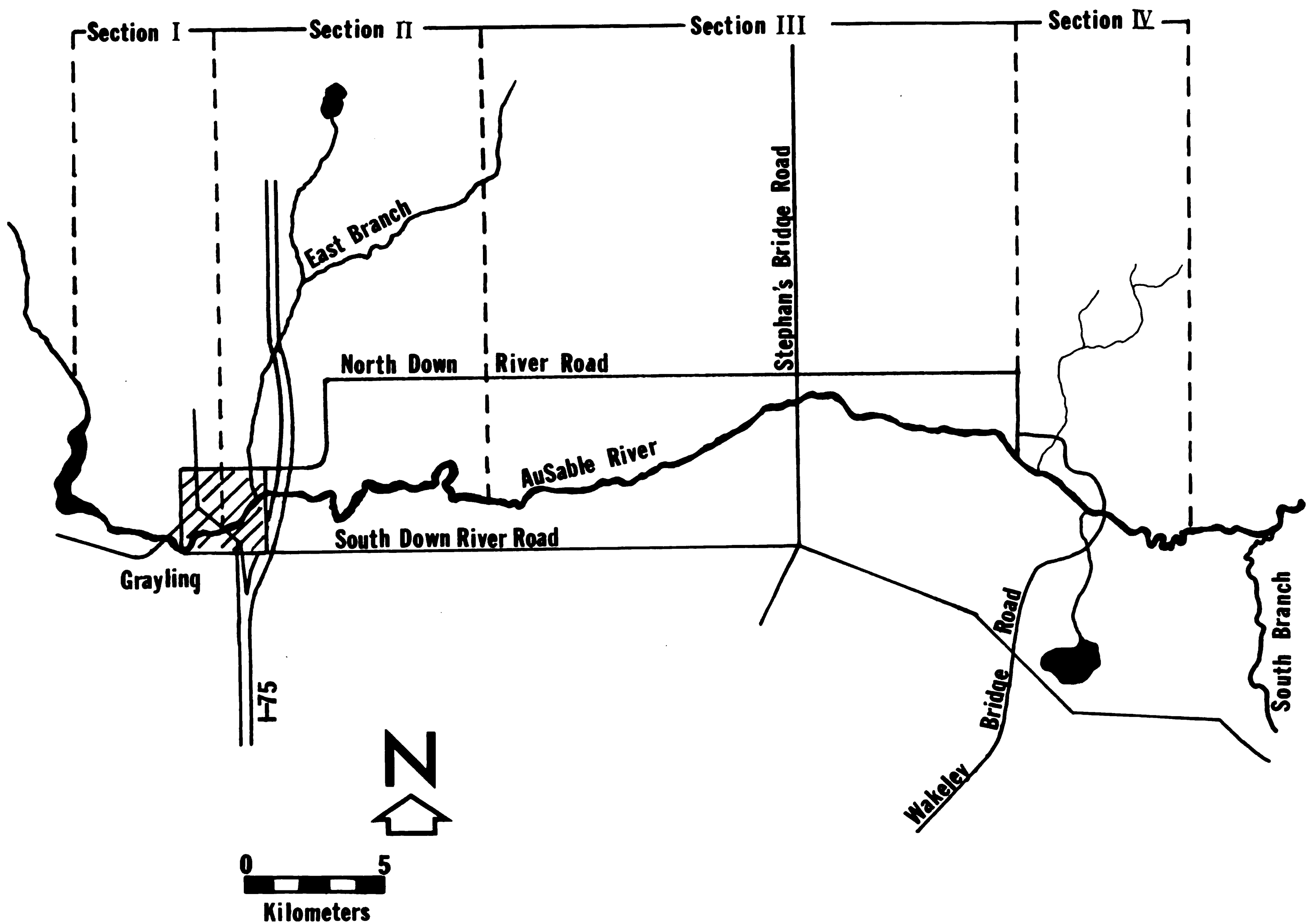

Section I
Section II
Section III
Section IV
East Branch
North Down River Road
Stephan's Bridge Road
AuSable River
South Down River Road
Grayling
I-75
Wakeley Bridge Road
South Branch
N
0
5
Kilometers

Figure 2

Figures 3.1-3.4. Sections I, II, upstream part of III, downstream part of III, and IV, respectively.

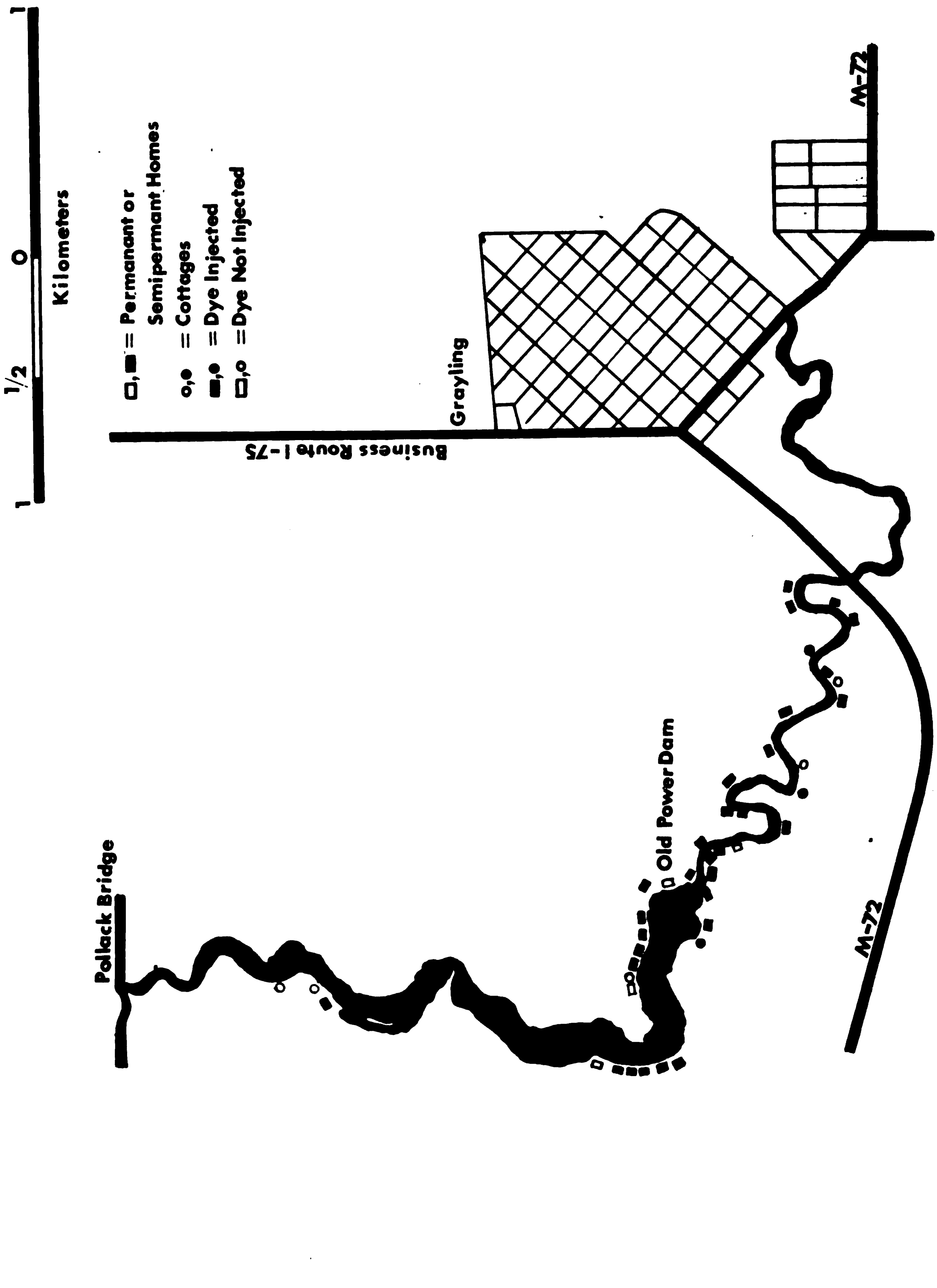


Figure 3.1 Section I

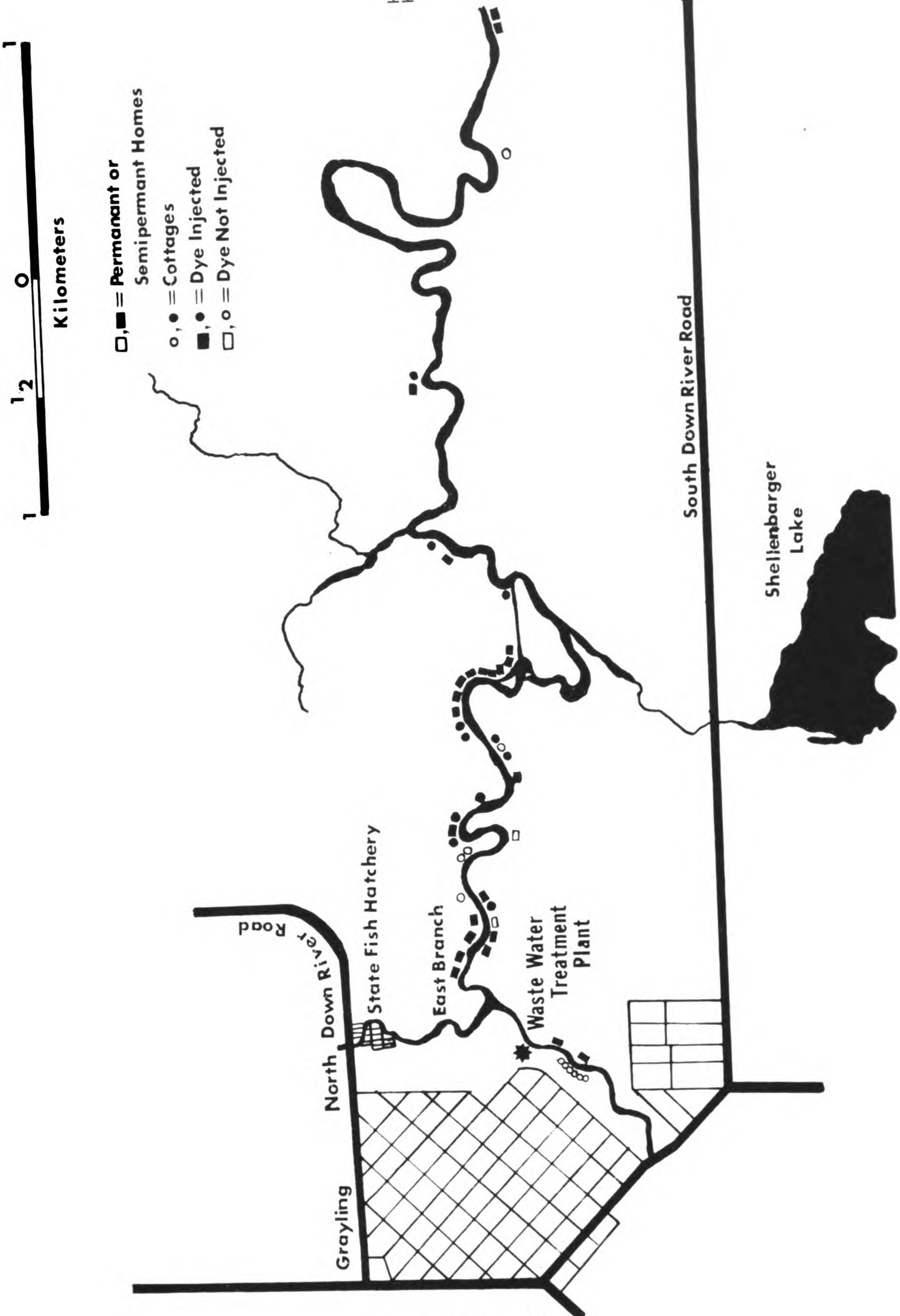
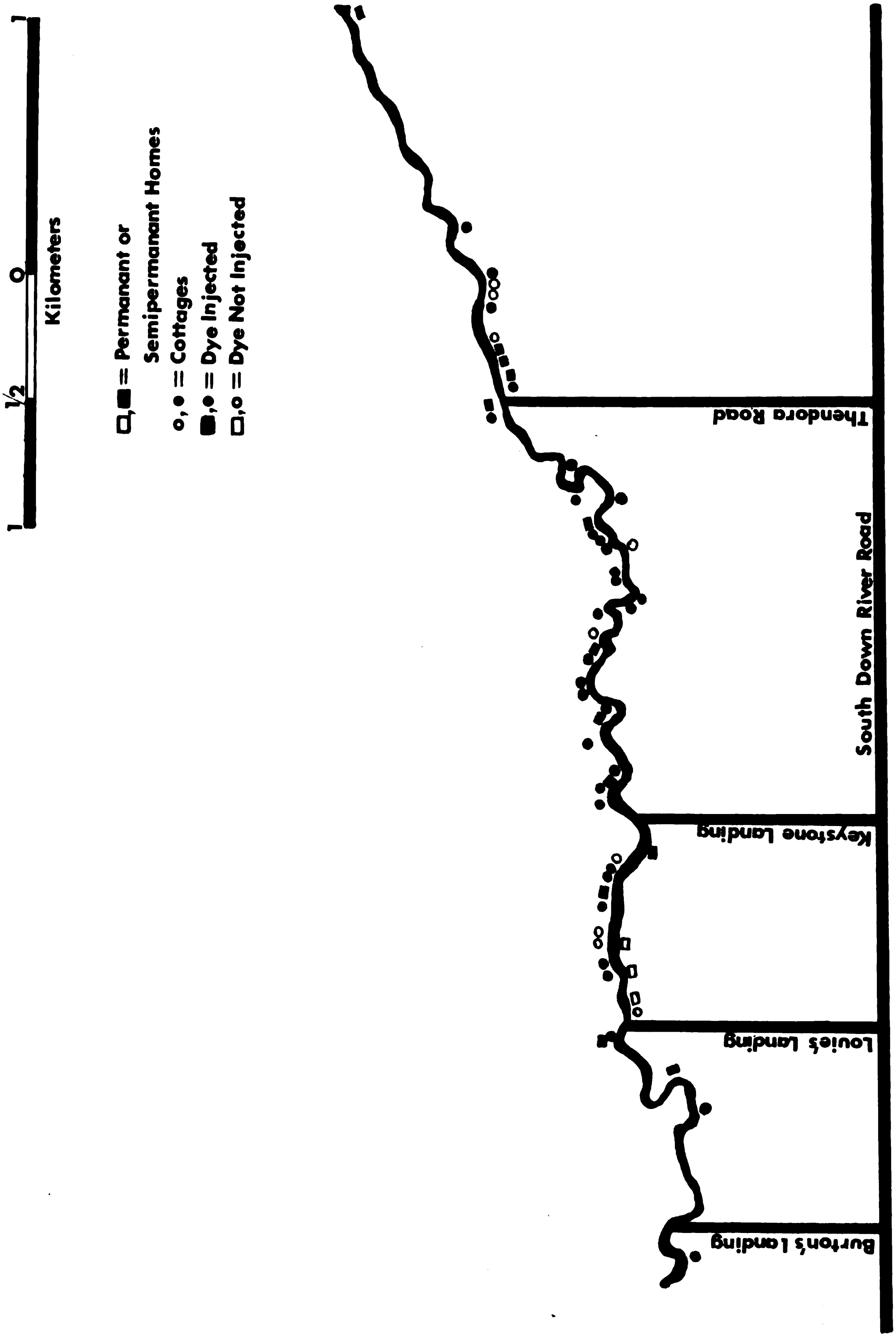


Figure 3.2 Section II



Fiqure 3.3a Upstream Part of Section III

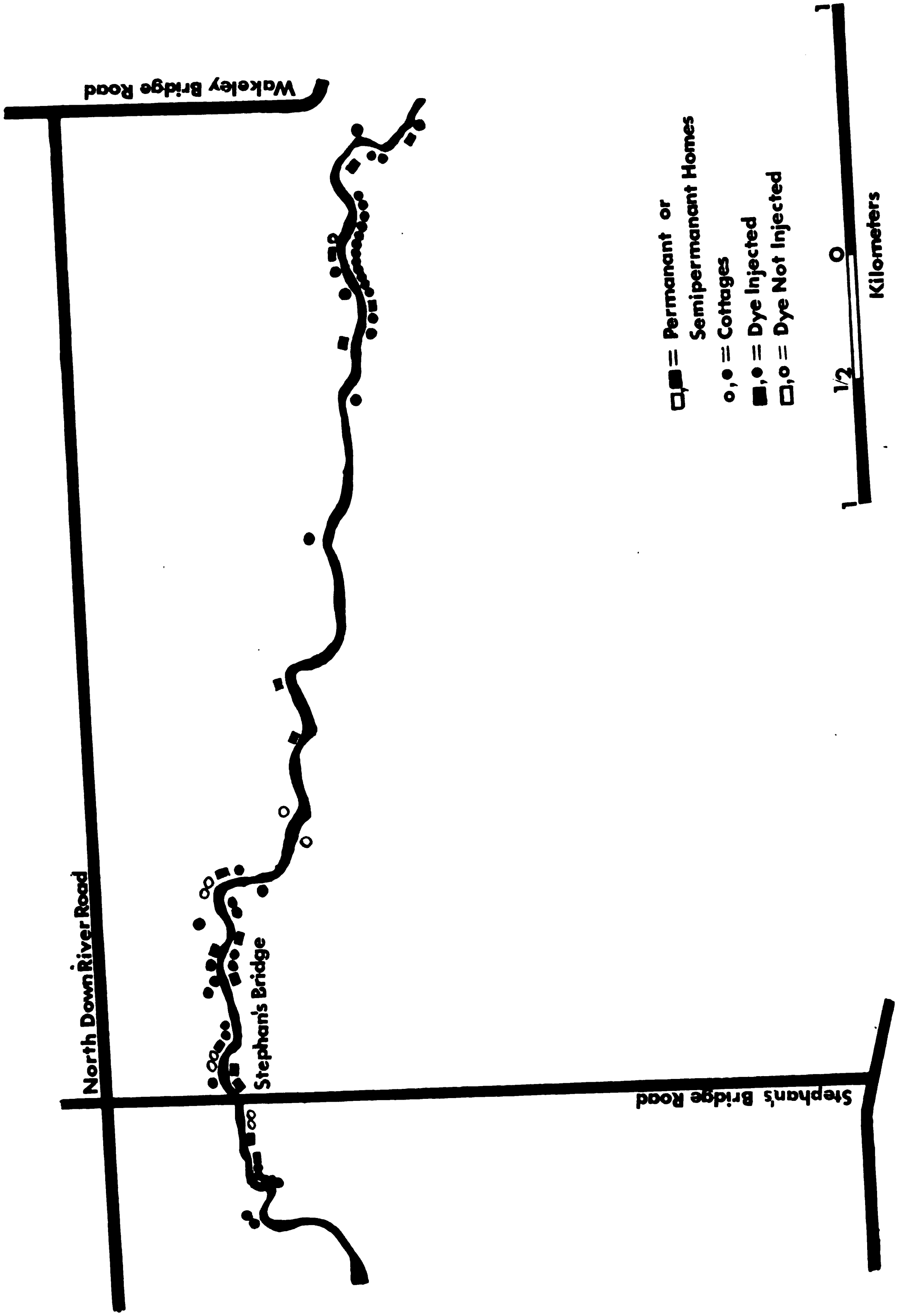


Figure 3.3b Downstream Part of Section III

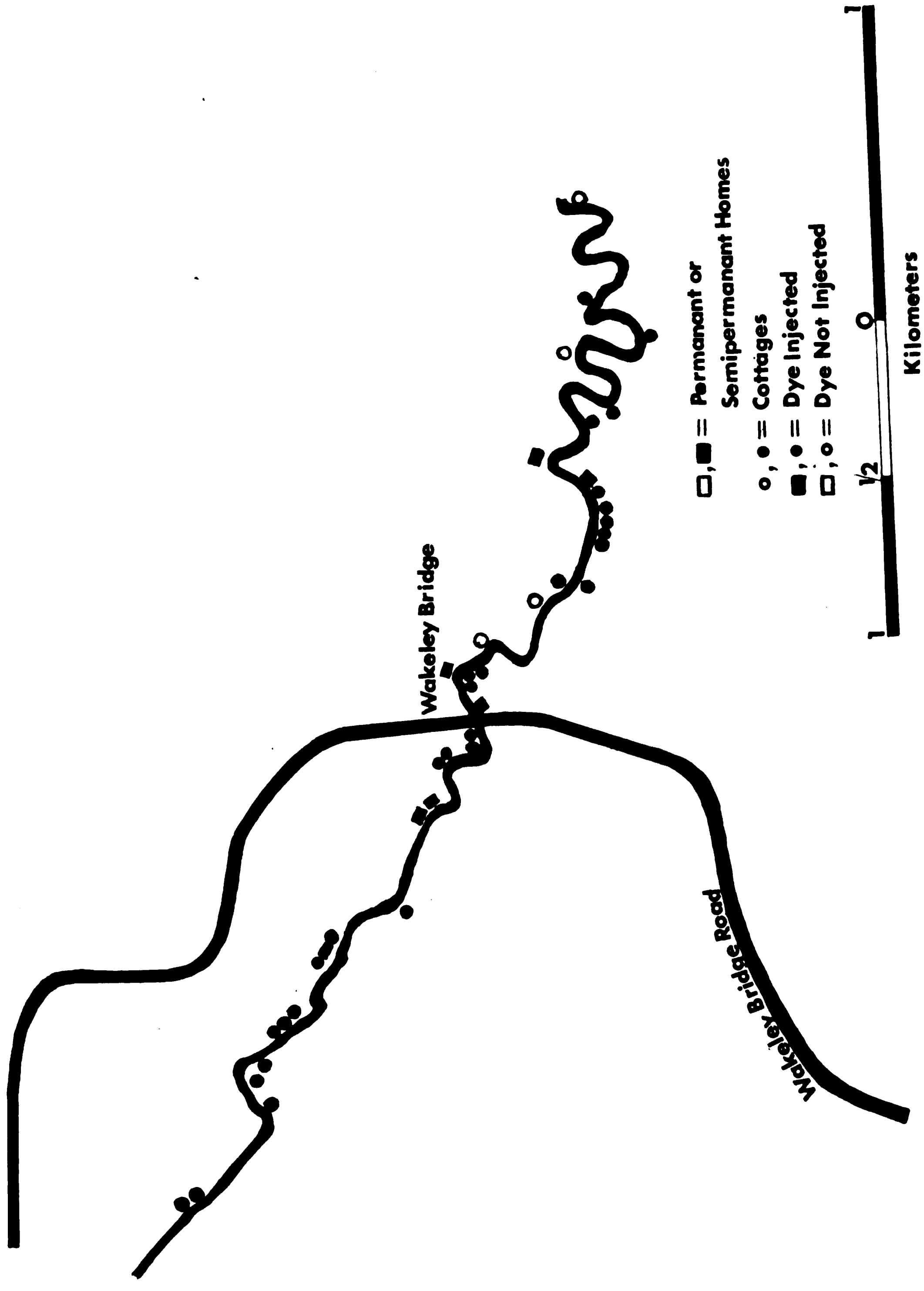


Figure 3.4 Section IV

Vegetation in the flowing stream is sparse and composed mainly of several species of potamogetons. Large beds of potamogetons are present in the impoundments. During most of the summer, a layer of green algae covered the silty bottom of the impoundments. Water was generally greenish in color with a slight fishy smell.

Although the river above M-72 and the old power dam is cool and well oxygenated, it generally would not be considered as good trout habitat. Only small populations of brook, brown, and rainbow trout survive, as do sculpins and darters. The majority of fish present are cyprinids. Fish populations within the impoundments are characterized by suckers, northern pike, and a few trout. Populations of trout apparently exist throughout Section I during the spring as witnessed by local fishermen.

Upstream of Business Route I-75 Bridge, several storm drainage pipes empty into the river, frequently discharging colored water. There are a large number of homes surrounding the old power dam and extending downstream to the M-72 Bridge.

Section II--Section II begins in Grayling and extends downstream 9 kilometers to Burton's Landing (Figure 2). Natural land elevation throughout most of the region is low as evidenced by Shellenbacker swamp, extending over a large area of Section II. The river seems to flow along the northern edge of this swamp. Generally the northern bank is high and very sandy, while the southern side is lower and wet.

Vegetation along the northern bank, where it is high, is mainly oak and pine while the southern bank is generally covered with tag-alders or white cedar.

The stream bottom is sandy with little gravel except for the stretch between Grayling and the I-75 Bridge. Significant features of the bottom are logs and tree branches; as well as rubbish, such as beverage containers, left from passing canoes.

Current velocity in this section is relatively slow, except for the area immediately below Grayling. Natural slope is low and some dredging has deepened the mainstream such that current velocity is quite slow in a few places.

Vegetation is represented by about equal quantities of higher aquatic plants and green algae but is not dense in comparison with downstream areas. The green algae is mainly Cladophora sp. forming long, trailing, waving masses which cling to objects jutting out from the stream bottom.

The invertebrate life present is not typical of a cold-water stream. Most forms are associated with the silty side areas of the stream or on submerged logs and aquatic vegetation, rather than in the shifting sandy bottom.

A sizeable population of brown trout appear to survive year around in the upper one-third of this section immediately below Grayling. In the remaining two-thirds, few trout were observed during summer months. More characteristic species in this area were cyprinids, yellow perch, and suckers.

A strong influence within this section is the effluent from the waste water treatment plant located on the downstream edge of Grayling. The plant discharges 0.3 million gallons per day of primary effluent which comprises roughly five percent of the average streamflow at Grayling (Michigan Water Resource Commission, 1966). A few hundred yards downstream from Grayling the main stream of the AuSable is joined by the East Branch. The volume of water from the East Branch is approximately one-half of that from the main stream and is much cooler and higher in dissolved oxygen during the summer.

There are a significant number of dwellings, mainly along the northern bank, extending from Grayling downstream to about one-half mile below the I-75 Bridge. Due to the low land elevation of the swampy area, many of the cottages and homes in the area are constructed within several feet of the water table. Dwellings are also located upon land filled areas. The proximity of several homes to the water table makes their septic systems potentially the most likely to contribute materials to the river.

Section III--Section III is differentiated distinctly from the end of Section II by a rather abrupt change in rate of flow, bottom type, and vegetation. The area extends from above Burton's Landing to beyond the end of Shaw Road. Current velocity approximately doubles that found throughout most of Section II. Bottom type, where not covered with vegetation, is almost entirely gravel or rubble with little exposed sand or clay present. Where vegetation has covered the bottom, deposited sand or silt generally covers the rubble and gravel.

The predominant vegetation form present is _Potamogeton filiformis_, but beds of _P_. _crispus_ and _Anacharis_ sp. are also significant. Algae is not noticeable in the main flow but clumps on the surface are present in quiet areas. Thick beds of _P_. _filiformis_ cover extensive sections of the streambed, while other areas remain either completely free of vegetation or contain only confined beds of vegetation surrounded by areas of rubble and gravel. _Anacharis_ sp. is generally confined to the stream edge, growing in silt deposits in slow water.

Invertebrate populations in this section are more typical of trout streams, containing a more varied selection of clean-water organisms than are present in Section II.

This and the succeeding study section can be described as good trout habitat. Overhanging cedars and other fallen trees and shrubs, with their water-penetrating sweepers, provide habitat and cover for most of the larger trout, particularly during the summer. In both of the last two sections, high sandy banks provide numerous springs, small creeks, and flowing wells that contribute a significant volume to the river. The cooling effects of this water undoubtedly plays a major role in providing the conditions for which the river is so well-known.

Dwellings on this third section of the river are mainly cottages. In several subdivided areas, cottages are closely spaced but, normally, they are rather isolated. There are major stretches containing no cottages at all or only a few that are well-concealed.

Section IV--The last study section is similar to Section III but differs significantly in surrounding soil types, depth, and vegetation.

Stream depth is generally deeper in this last section than the preceding one. Riffle areas are seldom less than two feet in depth and pools up to six or seven feet deep are common.

The vegetation coverage decreases and at the end of the study area becomes scarce in the main flow of current compared to upstream areas. In some wide slow areas thick mats of algae formed over the surface of *Anacharis* beds growing in shallow edge water.

Fish populations in this section are similar to the preceding section, with a high proportion of trout and some suckers, but the deeper pools contain whitefish which are present only on the very end of Section III.

A higher proportion of clay grades into the sandy soil from Section III and the soil becomes quite heavy toward the end of Section IV. This probably affects drainage conditions in the area; particularly toward the downstream end of the section; affecting both the operation of septic tile systems and the amount of overland flow during the rainy seasons and spring snow melts. This clay is also evident in the stream bottom with slippery patches of bare clay being common.

METHODS

Sampling Methodology

Over two-hundred dwellings within the study area resulted in a large number of samplings. This quantity put a restriction on the number of samples per individual system that could be taken. Thus in most cases only two eight-ounce water samples were collected.

To optimize the probability of detecting contaminants or injected fluorescein dye, samples were taken at a time when they would be most likely to contain dye or contaminants. The movement of nutrients to the stream is largely dependent upon the following factors: horizontal distance between tile field and the river, vertical distance between tile fields and water table, percolation and adsorption properties of soil types, and uptake of nutrients by plant roots. The amount of use of the system, presence of impermeable soil layers, presence of springs in the tile fields, and seasonal differences due to bacterial activity may also affect nutrient movement.

Although the above factors make obvious a large number of unknown variables, the following considerations were taken into account in determining time of sampling. The construction of a septic system is such that its operation is basically a displacement activity. Input of a unit volume causes overflow through the effluent conduit of an equal volume of effluent to the tile system. Depending on the volume of influent waste water put in at any one time, a variable but definite time period in the tank is required before discharge. This condition is necessary if the septic tank is to fulfill its major objective of solid settling and anaerobic fermentation. If the septic system is in continuous use, the throughput rate is high and material flushed into the tank will reach the tile fields shortly. However, if the septic system is little used, the throughput rate is low and several days may be required for material to enter and leave the tank. In an unused septic system, construction is such that material within the tank can not leave.

Time is required also for potential contaminants to travel the distance between the tile field and the river. The major route of travel here is believed to be filtration down from the tiles to the water table and then slow movement in the water table to the river. Another alternative is possible if a spring intercepts the tile field and carries the material to the surface and then rapidly to the river.

Also to be considered is that the longer materials must travel to reach the river, the more opportunity for absorption and dilution and the less chance of materials reaching the river, consequently the less chance for detection.

The final factor considered in the decision of sample timing is that the material moving through the septic tank does not act as a unit. Influent entering at one particular time is gradually displaced. Thus, fluorescein placed in the septic tank would not make a quick "one shot" flow through the system but would be displaced gradually.

In view of the above considerations, it was decided that the most appropriate time to sample would be at the latest possible date during which persons occupied the dwelling. The reasoning here was to provide the maximum amount of time for an equilibrium to be set up between the contents of the septic tank and the tile system and again between the tile field and possible entrance of a more or less steady front of material to the river. In many cases during the summer vacation period, cottages were occupied continually for several weeks. Fluorescein dye was put into the system sometime in the middle of the period and samples for analysis taken 4-5 days later. Sampling timing was the same in cases where dye was flushed into the system on a weekend or short periods of stay. However, in the cases where dye was injected into the system while no one was occupying the dwelling, sampling was delayed until some one did occupy it or until the end of the study period to sample.

The above problems of timing were not important to homes having permanent residents. It is believed that if contaminants are reaching the river from septic systems having a rather steady input, there would be an equally constant flow to the river, an equilibrium having been established.

Letters requesting permission to put fluorescein dye into individual systems were sent to all owners of dwellings within the study area as listed in the property records of Grayling Township. However, due to incomplete records, changes in addresses, and misunderstandings about the study, permission to enter buildings was difficult to obtain. Even after obtaining entrance permission, gaining entrance to the building was a very irregular, time consuming process, occurring only after finding the owner at the site of the dwelling or contacting the person in charge of the dwelling.

After gaining entrance into the building, injection of the fluorescein dye was a rather simple matter. Two teaspoons, about 15 grams, of the dye was placed into all toilets emptying into known septic tanks. The toilet was then flushed several times to insure that the dye reached the septic tank.

Visual inspection of the shoreline near the dwelling for the dye was made at least once a day for a period varying between 4 and 6 days following the date of dye input. Water samples were then taken for chemical analyses. Visual inspection continued after sampling when the opportunity occurred. This amounted to about three times a week throughout the summer.

Parameters were chosen for water chemistry analysis to be indicative of either raw sewage or varying degrees of purified sewage effluent as it travels through the soil to the stream. Also affecting the choice was the feasibility of examining the large number of samples. McGauhey (1968) gives the typical composition of medium strength raw domestic sewage to contain 100 mg. per liter chlorides but only 0.20 mg. per liter of nitrate nitrogen. Robeck, Cohen, Sayers, and Woodward (1963) measured qualities of sewage effluent after filtering through a lysimeter filled with 4 feet of sand and found the effluent to contain an average of 23 mg. per liter nitrate nitrogen and 70 mg. per liter chlorides during 219 days of operation. Thus chloride and nitrate nitrogen were chosen as indicators.

Fluorescein was the dye chosen to be used in the study largely because of the ease in obtaining it upon the short notice at which the study began. Other fluorescent dyes, notably rhodamine B, rhodamine WT, and pontacyl brilliant pink, were alternative choices for this study. These other dyes may have been more favorable to use from the standpoint of the high photochemical decay rate of fluorescein. However, this should not have seriously interfered with detectability because the dye and sampling areas were not extensively exposed to sunlight. Fluorescein dye has been used successfully to trace movement of ground water for distances up to 2500 feet using several pounds of the dye and up to 3000 yards using about 13 pounds of the dye (Thresh, Beale, and Suckling, 1949). Fluorescein is not significantly adsorbed by organic or mineral matter.

Water Chemistry

Nitrates

Nitrate determinations were made by the Brucine method as modified by Jenkins and Medsker (1964). They state that this modification is much more sensitive than the method listed in the 12th edition of Standard Methods for the Examination of Water and Wastewater, and gives highly reproducible results in the range of 0.05 to 0.8 mg per liter nitrate nitrogen. A Bausch and Lomb Spectronic 20 was used in the procedures of this method to obtain transmittancy readings.

It should be noted that although Jenkins and Medsker (1964) give limits for their nitrate nitrogen method to extend from 0.05 to 0.8 mg per liter, I have extended the method down to 0.02 mg per liter nitrate concentration. I believe that a reasonable estimate could be made to this lower level based on recovery of added nitrate nitrogen to waters from the study area having a concentration of less than 0.05 mg per liter nitrate nitrogen.

Chlorides

Chloride determinations were made by the Mohr method.

Fluorescence

Fluorescence of samples was determined by use of a Turner fluorometer. The recommendations of the 1968 Turner Manual for fluorometric procedures were followed.

The primary filters used were a combination of 2A and 47B, while the secondary filter used was a 2A-12. The general purpose lamp #110-850 was used.

Water from an upstream station, sample 52A, was arbitrarily set at a value of 20 to permit anticipated higher and lower values to be distinguished. If the fluorometer were set at 0 for this upstream sample, lower values could not be differentiated. Thus, fluorescence determinations were made on a relative scale ranging from 0 to 100.

Phosphorus

In order to establish total phosphorus levels for the study area, two series of samples, as well as a few other selected samples from dwellings suspicious of contamination, were analyzed for total phosphorus concentration by the ammonium molybdate-stannous chloride method. These samples were analyzed by a Water Quality Laboratory at Michigan State University. As samples for phosphorus were stored for several months, the procedure of acidification of samples to remove absorbed phosphorus on container walls was necessary.

Other Parameters

Oxygen and Temperature

Oxygen and temperature for diurnal curves were recorded with a Rustrak recorder, equipped with an oxygen electrode and thermistor. The oxygen electrode was standardized with a Winkler oxygen test. All oxygen readings were corrected for temperature changes.

The recorder was set up at various stream locations during August and September to determine the extent of the oxygen sag which was anticipated to be the most severe during this time period. The sensors were set at midstream so as to obtain a representative measurement for that portion of the stream.

Invertebrates

Bottom samples for examination of invertebrates were taken with a Surber bottom sampler. Bottom material was thoroughly agitated, hand scrubbing each item from the bottom and discarding it, until no further invertebrates could be found. Collected organisms were preserved in 10% formalin and later sorted in a white enamel pan and classified into families. In samples containing vegetation, plants were pulled out by the roots and pushed into the end of the Surber net before working over the bottom material. The vegetation was sorted from the invertebrates and dried as described below for vegetation samples.

Bottom samples were taken in gravel riffle areas and in similar areas covered with vegetation to compare the invertebrate life found within each of these two types of habitat. Single samples were taken at each particular combination of location and type of bottom except at Pollack Bridge where two samples from gravel riffles were pooled.

Samples were taken so environmental conditions of depth, gravel size, vegetation density, and current velocity were nearly uniform. All samples were taken during the two day period of August 27th and 28th.

Aquatic Plants

Vegetation density was defined as the total weight of vegetation including roots growing within a square foot of stream bottom. The assessment of vegetation density was made by sampling selected areas with a Surber sampler. Evenly spaced points were selected on a map of the study area and sampling was done as close as possible to the designated point. Samples were taken in the most representative area within a fifty foot section of the river, centered about the imaginary preselected line.

The Surber sampler was placed on the stream bottom of the selected area and the resulting mass of flattened vegetation was worked until only that actually growing within the square foot, metal sampler base remained there. The vegetation was then pulled out and allowed to drift back. The bottom area was worked over to remove remaining roots. Samples were then packed in plastic bags and frozen until they could be oven dried at 105°C to obtain uniform moisture conditions.

Rough estimates were made also of the total bottom area covered by vegetation thick enough so the bottom was not readily visible. Because of this definition, there can be variability in the quantity of vegetation present at different locations with the same percentage of bottom area covered.

Several visual estimates were made from canoe of conviently mapped sections of the river, each extending about several hundred feet in length. These estimates, to the nearest ten percent, were averaged, as were the estimates of the distance of each section, to produce mean values. These values were then used to calculate mean values of percentage of vegetation coverage for each study section.

Current Velocity

Current velocity was determined with a Price-Gurley current meter by placing the measuring wheel at about 0.4 of the depth of the bottom. Standard procedures were employed for conversion of meter readings to feet per second of current velocity.

RESULTS

Results from General River Survey

Current Velocity

Current velocities are recorded in Table 1. As indicated, stream velocity is relatively slow in Sections I and II except in the upstream part of Section II where velocity is moderate. In the last two study sections, velocity is approximately twice as great as in the preceding sections.

As mentioned in the description of the river, this data illustrates an inherent physical quality of the river largely responsible for present conditions of the river. The current velocity of Section I is sufficient to sustain good water quality in the clean water above Grayling. However, in the downstream half of Section III, reaeration is insufficient to counteract the BOD load from the Grayling sewage treatment plant effluent. Stream flow is smooth except immediately downstream from Grayling. No rapids exist in Sections I or II. By contrast, in Sections III and IV reaeration is sufficient to purify the already partially recovered waters from upstream. Some increased aeration occurs because of the increased velocity, but rapids and riffles occurring in

Table 1. Current Velocity measured by Price-Gurley current meter at one-half midstream depth on September 10, 1968.

Station	Kilometers below Pollack Bridge	Velocity (feet per second)
Section I		
1	0.0	1.17
2	4.0	1.29
Section II		
3	8.7	1.53
4	8.9	2.23
5	9.2	2.08
6	9.5	2.23
7	10.2	2.03
8	10.4	2.69
9	11.0	1.17
10	11.9	1.60
11	12.9	1.19
12	13.6	0.43
13	14.6	1.53
14	15.5	1.47
15	16.7	1.41
16	17.7	1.29
17	18.0	1.47
Section III		
18	18.3	2.65
19	19.6	2.23
20	20.5	2.08
21	21.6	3.42
22	22.6	1.79
23	23.9	2.28
24	25.0	2.78
25	26.2	2.97
26	27.2	2.65
27	28.9	2.38
28	29.5	2.86
29	31.0	2.78
Section IV		
30	32.2	2.78
31	33.4	2.97
32	34.7	2.33
33	35.8	2.38
34	36.8	2.84

Sections III and IV probably have a much larger role in increased aeration. Also, surface turbulence in the downstream sections is probably greater than can be correlated with the current velocities present. Dense, trailing vegetation growths may not disrupt surface turbulence as much as they slow current velocity. Current velocity in Sections III and IV is also sufficient to prevent accumulations of sand from occurring in midstream except where vegetation growths occur.

Vegetation

The results of the vegetation survey are listed in Tables 2 and 3, showing density and percent of bottom coverage, respectively. As shown in these two tables, the greatest average density of vegetation in grams of oven dried material per square foot increases in each succeeding section as one proceeds downstream. However, the percentage of stream bottom covered by vegetation is greatest in Section III, about half as great in Sections II and IV and least in Section I.

It is evident also from the weights of some of the vegetation samples and from the method by which these samples were collected, that in some regions of the river extensive local coverage by thick, dense vegetation occurs. Comparative published data on quantitative vegetation densities of coldwater streams seems to be lacking in the literature. Westlake (1961) found the standing crop of *Potamogeton pectinatus* in a sewage effluent drainage channel to average 123 g dry weight/m^2 of stream surface. Owens and Edwards

Table 2. Dry weight in grams of a square foot of vegetation from the AuSable River during the fall of 1968. (To convert to square meters, multiply by 10.75.)

Sample	Kilometers below Pollack Bridge	Grams per square foot
Section I		
53	4.2	6.5
54	4.5	4.6
55	4.9	13.4
56	5.3	8.6
Average of Section I		8.3
Section II		
1	9.5	0.4
2	9.9	14.6
3	10.6	10.0
4	11.0	6.0
5	11.9	13.0
6	12.8	15.8
7	13.7	0.0
8	14.6	19.7
9	17.1	9.9
10	17.7	13.8
Average of Section II		10.3
Section III		
11	18.0	12.1
12	18.2	43.3
13	18.3	18.0
14	18.6	27.6
15	19.1	22.1
16	19.6	21.2
17	19.8	23.7
18	20.0	27.3
19	20.2	28.1
20	20.7	12.5
21	21.4	14.6
22	22.0	16.8
23	22.2	37.3
24	22.6	4.2
25	23.2	16.0
26	23.4	7.2
27	23.7	16.5
28	23.9	20.5

continued

Table 2--continued

Sample	Pilometers below Pollack Bridge	Grams per square foot
29	25.0	34.9
30	25.8	31.2
31	26.7	9.8
32	27.0	0.0
33	27.3	12.5
34	27.8	15.2
35	28.2	15.8
36	28.5	47.5
37	28.9	21.5
38	29.4	13.0
39	29.9	18.5
40	30.2	8.3
41	30.3	24.8
42	30.7	13.5
43	31.0	15.4
Average of Section III		19.8
Section IV		
44	31.5	36.2
45	31.9	53.3
46	32.3	17.8
47	32.6	17.5
48	32.8	42.6
49	33.1	18.5
50	33.4	15.1
51	33.7	8.1
52	33.9	27.1
Average of Section IV		26.2

Table 3. Mean percentage of stream bottom area covered by vegetation for the main stream of the AuSable River during the summer of 1968.

Sample	Percentage
Section I*	20
Section II	26
Section III	47
Section IV	23

*Includes only that portion extending from the Borcher Bridge, below the old power dam, to the M-72 Bridge.

(1961) measured the dry weight of macrophytes from 4 fertile but unpolluted streams in southern England. They found the average dry weight to range from 53.8 to 385.2 g/m^2 of stream surface. Although these weights are comparable to those in the present study, they are from streams that are basically more fertile. Owens and Edwards (1961) list for the rivers Test and Chess, for example, average values of 3.6 and 3.8 ppm nitrate nitrogen and 0.038 and 0.035 ppm total phosphorus, respectively. In comparison with typical cold water streams, the AuSable River seems to have an extensive growth of vegetation.

Possible causes of this growth pattern are indefinite. Certainly a major factor responsible for the quantity of growth is the enrichment of the river due to the domestic effluent from the city of Grayling and possible other causes. Possibly the chemical form of some of the organic compounds is more suitable for plant use further downstream from Grayling than at Section II closer to the point of input. Probably other ecological factors determine suitability of areas for growth. Current velocity, or some factor correlated with velocity, may be a decisive factor. This is evident as one proceeds from Section II to Section III. There is a sharp increase in current velocity, bottom material changes from sand to gravel, and an immediate increase in vegetation occurs.

Also notable is that the vast bulk of vegetation present is a single species, <u>Potamogeton filiformis</u>. Upstream from

Grayling a more varied plant community exists, composed of several species of broadleaved Potamogetons, P. filiformis, Vallisneria, sp. and Ranunculus sp. However, downstream from Grayling, P. crispus, and Anacharis sp. are only locally abundant among the continual coverage of P. filiformis.

This is perhaps the greatest single factor responsible for the present and future condition of the river. Best known of the vegetation effects are the diurnal oxygen pulses produced by oxygen production during sunlight hours and oxygen consumption during darkness. Although these pulses did not prove to be drastic in this study, in local, dense concentrations of vegetation, oxygen concentration probably was much more reduced than shown by open water measurements. This may put an environmental stress on clean-water organisms, either forcing them out of the area or preventing their development.

Another effect of vegetation is that it slows the velocity of the water filtering through it. This causes several results. First, slowing velocity and hindering mixing prevents the aeration that normally occurs. Second, decreased velocity at the base of the plants prevents the development of normally occurring swift water invertebrates. Also, water of decreased velocity is incapable of carrying its original sediment thus, deposits of sand occur in the beds of vegetation, gradually building up mounds of sediment.

With an endless enrichment of nutrients from the Grayling waste water treatment plant effluent, the quantity of vegetation may continue to increase. The decay of each annual crop adds more organic matter to the stream, filling in pools and allowing additional growth the following year. This cycle, while not yet out of control, may eventually destroy the river as it is known today.

Invertebrates

The results of invertebrate bottom samples taken in non-vegetated and vegetated areas are given in Tables 4 and 5 respectively. These results are shown graphically in Figure 4, contrasting the number of families having representatives in each sample with the sample locations. Tolerance status of families for Figure 4 are listed in Tables 4 and 5. Tolerance status is based on species tolerance status listed by Michigan Water Resources Commission (1966).

Although sampling was not extensive, a pattern for the study area is evident. At Pollack Bridge, sample 17, invertebrate density is low but representation of intolerant types is high, especially the Ephemeroptera. Inside the city of Grayling but above the entrance of the sewage treatment plant effluent, sample 1, a lack of intolerant forms is already evident. The tolerant invertebrates other than insects are present as well as the tolerant coleoptera, diptera, and hydropsychid trichoptera. Some intolerant caddis families are present.

The lack of intolerant forms found in the samples taken between the entrance of the waste water treatment plant and

Table 4. Number of invertebrates per square foot of nonvegetated bottom area for single samples taken by Surber sampler on September 27 and 28, 1968 in the AuSable River (to convert to square meters, multiply by 10.75).

Sample		17	1	2	3	5	7	8	11	13	15	18
Kilometers below Pollack Bridge		0.0	9.1	9.5	9.8	10.3	17.0	18.3	20.5	26.2	28.9	30.7
Water depth (Centimeters)		38	38	36	51	46	48	48	48	46	46	48
Bottom type		sa gr	gr	gr	gr	gr	gr	gr	gr	gr	gr	gr
Size of bottom material (cm.)		0.0-0.6	2.5-6.4	2.5-6.4	0.0-2.5	0.0-3.8	0.6-2.5	2.5-6.4	2.5-5.1	5.1-7.6	2.5-5.1	0.0-5.1
Taxa												
Turbellaris	F		17					3	6	9	4	11
Nematoda	F											
Annelida	T		3	3	8		26	1	9	5	11	7
Arthropoda												
Isopoda	F		2	11	5				2	1		3
Amphipoda	I	2	5		2		4		7	2	2	
Mollusca												
Amnicolidae	F	*			*							
Campeloma	F			7								
Ferrissia	F					10	3					1
Sphaerildae	F		5								1	
Plecoptera												
Perlidae	I											5
Perlodidae	I									3	1	8
Ephemeroptera												
Baetidae	I				1	4	4	6	9	3	1	5
Baetisidae	I	2										
Caenidae	I	3										
Ephemeridae	I											1
Ephemerellidae	I	2							2	4	4	11

Heptageniidae	I	8	8	1			2	4	12	6	3	7
Leptophebiidae	I											2
Siphtonuridae	I	2										
Tricorythidae	I	6					1		3			
Odonata												
Gomphidae	F		1									
Megaloptera												
Corydalidae	I										1	
Trichoptera												
Brachycentridae	I	1	1			1		2	1	11	46	3
Helicopsychidae	I	2										
Hydropsychidae	F	44	48	3	29	48	190	220	96	1	5	34
Leptistomatidae	I										17	
Leptoceridae	I										2	1
Philopotamidae	I		2					1				7
Psychomyidae	I		1	3	14	33	7	7	20			5
Rhyacophilidae	I							4		57	25	10
Unidentifiable												
Caddis pupae				1		1	3				6	
Lepidoptera												
Pyralidae	F											
Coleoptera												
Elmidae	F	1	19	2	11	4		8	5	14	16	46
Diptera												
Chironomidae	F	35	4	18		13	21	2	48	2	9	6
Simulidae	F				1	2	2	4		5	1	
Tipulidae	F	1	5		2	2	8	3	2			1
Empididae	F			1								
Tabanidae	F											
Rhagionidae	F	1						4			3	
TOTALS		112+	122	51	73+	118	271	271	222	116	158	182

*present, but not countable
gr = gravel
sa = sand
si = silt
I = intolerant
F = faculative
T = tolerant

Table 5. Number of invertebrates per square foot of vegetated bottom area for single samples taken by Surber sampler on September 27 and 28, 1968 in the AuSable River (to convert to square meters, multiply by 10.75).

Sample		4	6	9	10	12	14	16	19	20	21
Kilometers below Pollack Bridge		9.8	10.3	18.3	18.3	20.5	26.2	28.9	30.7	32.3	32.3
Water depth (centimeters)		51	46	48	48	48	46	46	48	48	48
Bottom type		gr sa	sa gr	sa gr	sa gr	gr sa	si gr	sa gr si	gr si	gr sa	sa gr
Begetation Weight (Grams)		14.7	15.1	19.4	3.4	10.2	12.2	11.7	11.2	----	27.3
Taxa											
Turbellaria	F			2	3	9		2	5	7	
Nematada	F					1					
Annelida	T	4		1	1	6		11	7	4	
Arthropoda											
Isopoda	F		2			14	20	2	3		2
Amphipoda	I			1	3	9	4	18		1	4
Mollusca											
Amnicolidae	F										
Campeloma	F										
Ferrussia	F						1		1		
Sphaerildae	F							2			
Insecta											
Plecoptera											
Perlidae	I										
Perlodidae	I								2	2	4
Ephemeroptera											
Baetidae	I	11	12		15	8	9			8	11
Baetescidae	I										
Caenidae	I										
Ephemeridae	I			1							

Ephemerelliade	I					5	35	52	99	16	8
Heptageniidae	I			1	1		1				
Leptophlebiidae	I								10		
Siphlonuridae	I								1		1
Tricorythidae	I						1				
Odonata											1
Gomphidae	F										
Megalaptera											
Corydalidae	I								3		
Trichoptera											
Brachycentridae	I		4		2	21	63	165	66	48	171
Helicopsychidae	I	3					1				
Hydropsychidae	F	11	26	29	55	94	2	3	10	2	1
Leptistomatidae	I						31	31		7	
Leptoceridae	I						10				3
Philopotamidae	I										
Psychomyidae	I	1	4			3					
Rhyacaphilidae	I						14	1	1	8	
Unidentifiable											
Caddis pupae		2	7			4	5				
Lepidoptera											
Pyralidae	F	1									
Coleoptera											
Elmide	F	4	1	1	6	2	7	4	14	4	
Diptera											
Chironomidae	F	101	98	31	9	65	10	14	10		7
Simulidae	F	135	190	25	2	34	2		8		13
Tipulidae	F								1		
Emphididae	F										
Tabanidae	F					1	1				
Rhagionidae	F								1	1	
TOTALS		272	343	92	82	283	220	314	243	103	229

gr = gravel
sa = sand
si = silt
I = intolerant
F = faculative
T = tolerant

Figure 4. Variation in number of families of invertebrates represented in bottom samples from vegetated and nonvegetated locations, darkened portions of bars represent families generally considered to be intolerant. (Note change in distance scale between 9 and 10.5 kilometers.)

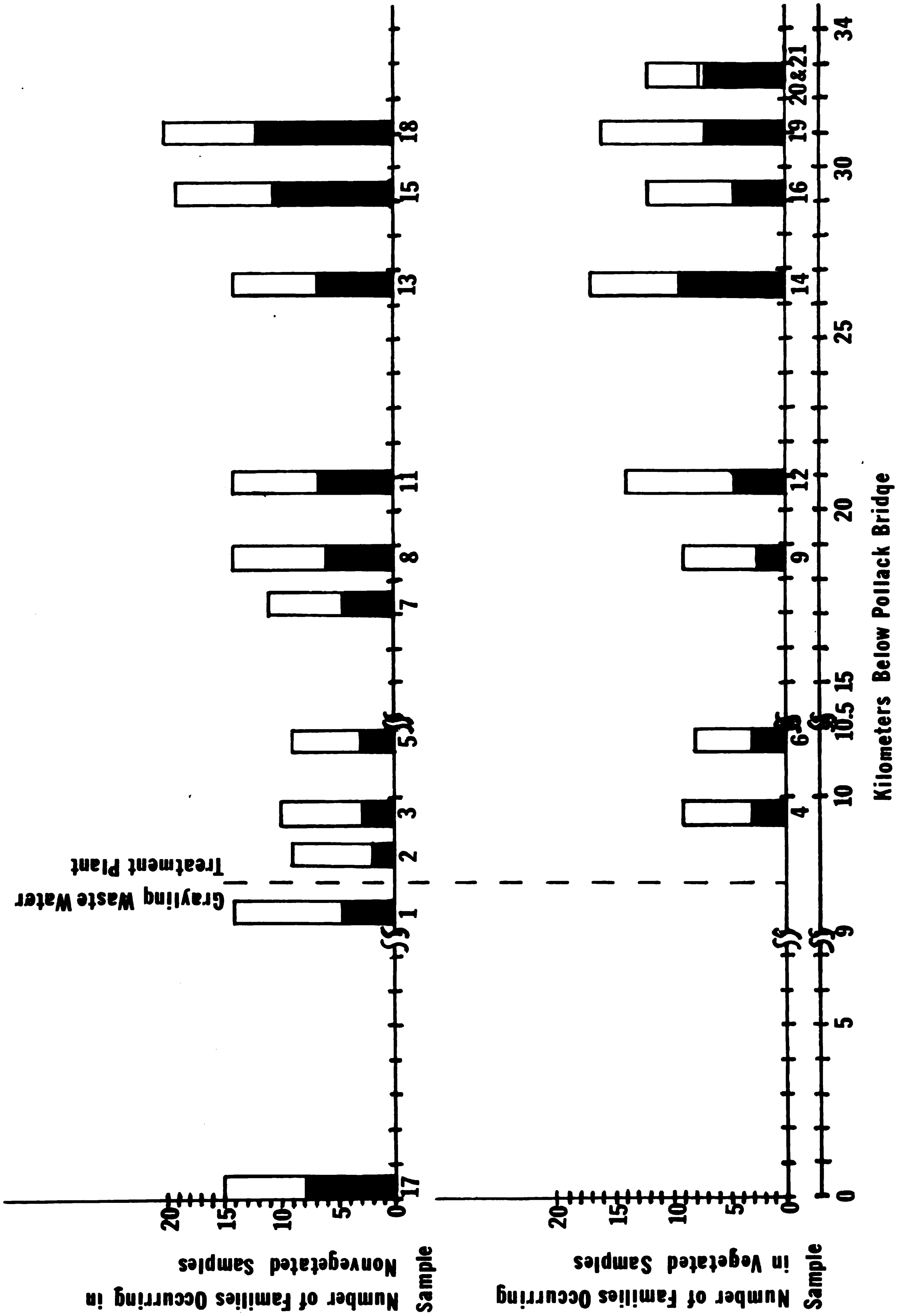

Number of Families Occurring in Nonvegetated Samples
Number of Families Occurring in Vegetated Samples
Sample
Grayling Waste Water Treatment Plant
Kilometers Below Pollack Bridge

Figure 4

Burton's Landing, samples 2 to 7 illustrate the more harsh conditions of low dissolved oxygen and warm water in this area. Only a few families of caddis flies and sparse populations of several families of mayflies are present. The more tolerant dipterans and coleoptera are well represented.

The series of samples extending from Burton's Landing to Sayer's cottage samples 8 to 21, in the middle of Section IV illustrate the improved water quality of the last two sections of the study area. Good representation of nearly all types of invertebrates, especially intolerant forms, occurs within this region. The presence of two families of stoneflies in the last few samples typifies a degree of water quality that is not reached anywhere upstream within the study area.

It is noteworthy that although the number of intolerant families present varies with location, the number of tolerant and faculative families remains quite constant throughout the study area.

A comparison of the populations of invertebrates found within the two types of samples shows the vegetated samples to generally contain larger populations made up of more limited types than found in nonvegetated samples, both with respect to total number of families present and numbers of individual per families. Vegetated samples taken in the same location as nonvegetated samples also contained fewer numbers of intolerant families. Populations in vegetated samples were composed mainly of organisms clinging to or attached to the current swept vegetation. Usually the substrate within these vegetated samples was choked with sand or silt, preventing the more typical organisms associated with the gravel bottom from occurring there. Notable large groups from these samples were the families Ephemerellidae, Brachycentridae, Chironomidae, and Simulidae. In comparison with vegetated samples, samples from gravel areas generally contained moderate populations of many types except for the caddis family hydropsychidae which was abundant in several samples.

A probable explanation for the observed low numbers of organisms present is the date of collection. During late September, many forms would only be present as eggs or very small larvae which would be difficult to detect.

Oxygen and Temperature Fluctuations

Diurnal curves for oxygen concentration and temperature are located in Figure 5. Curves are presented to show dissolved oxygen concentration, dissolved oxygen saturation levels, and temperature.

At the upstream end of the study area, a rather typical natural diurnal curve occurs with high dissolved oxygen during the entire cycle. However, below Grayling, Allison's and Harland's residences, dissolved oxygen is constantly low, never reaching saturation; while temperature reaches the

Figure 5. Diurnal oxygen and temperature fluctuations for locations and dates as listed. Dissolved oxygen concentration is shown as a solid line (——), dissolved oxygen saturation as a dotted line (...), temperature as a dashed line (---).

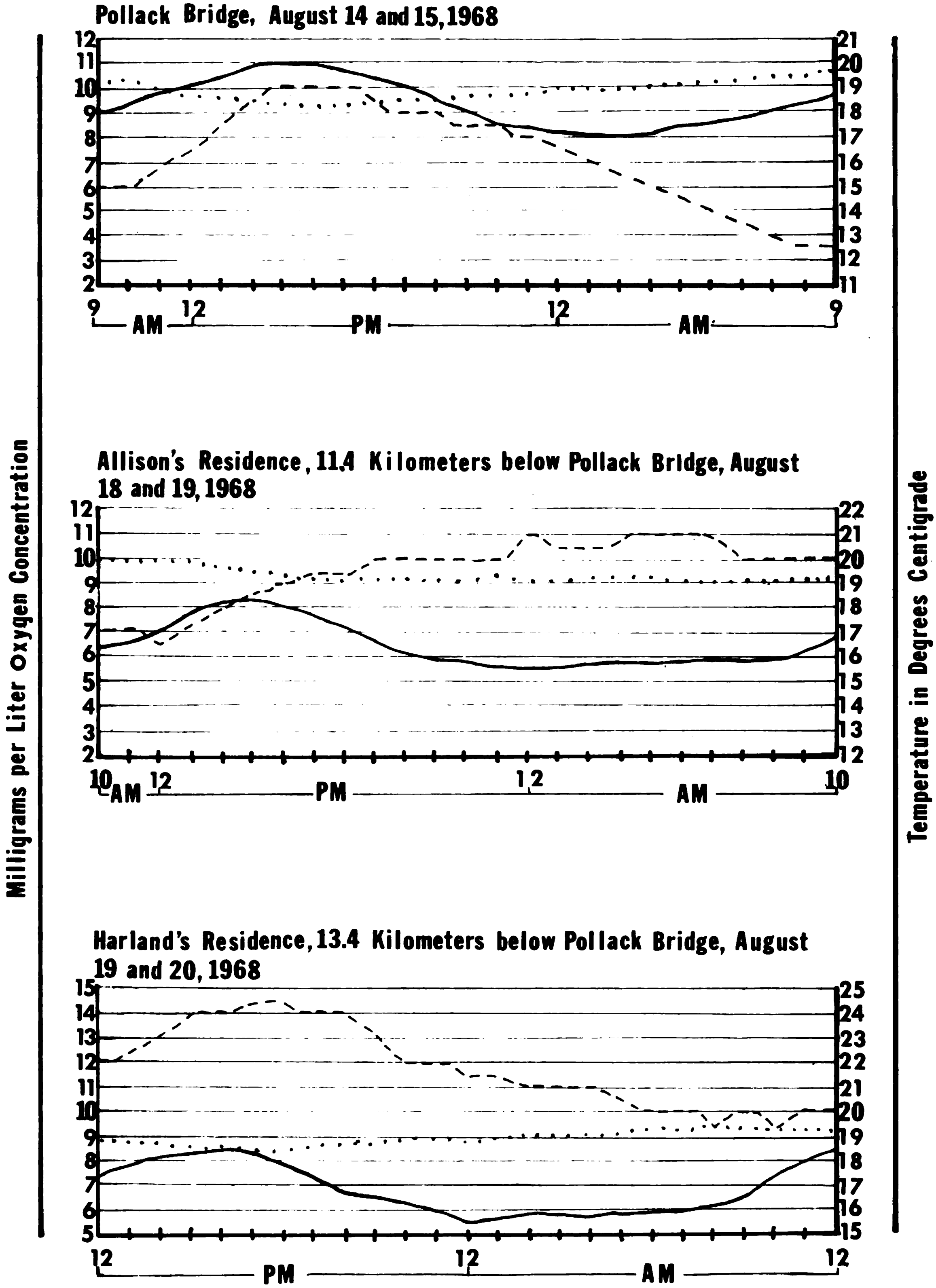


Figure 5 continued

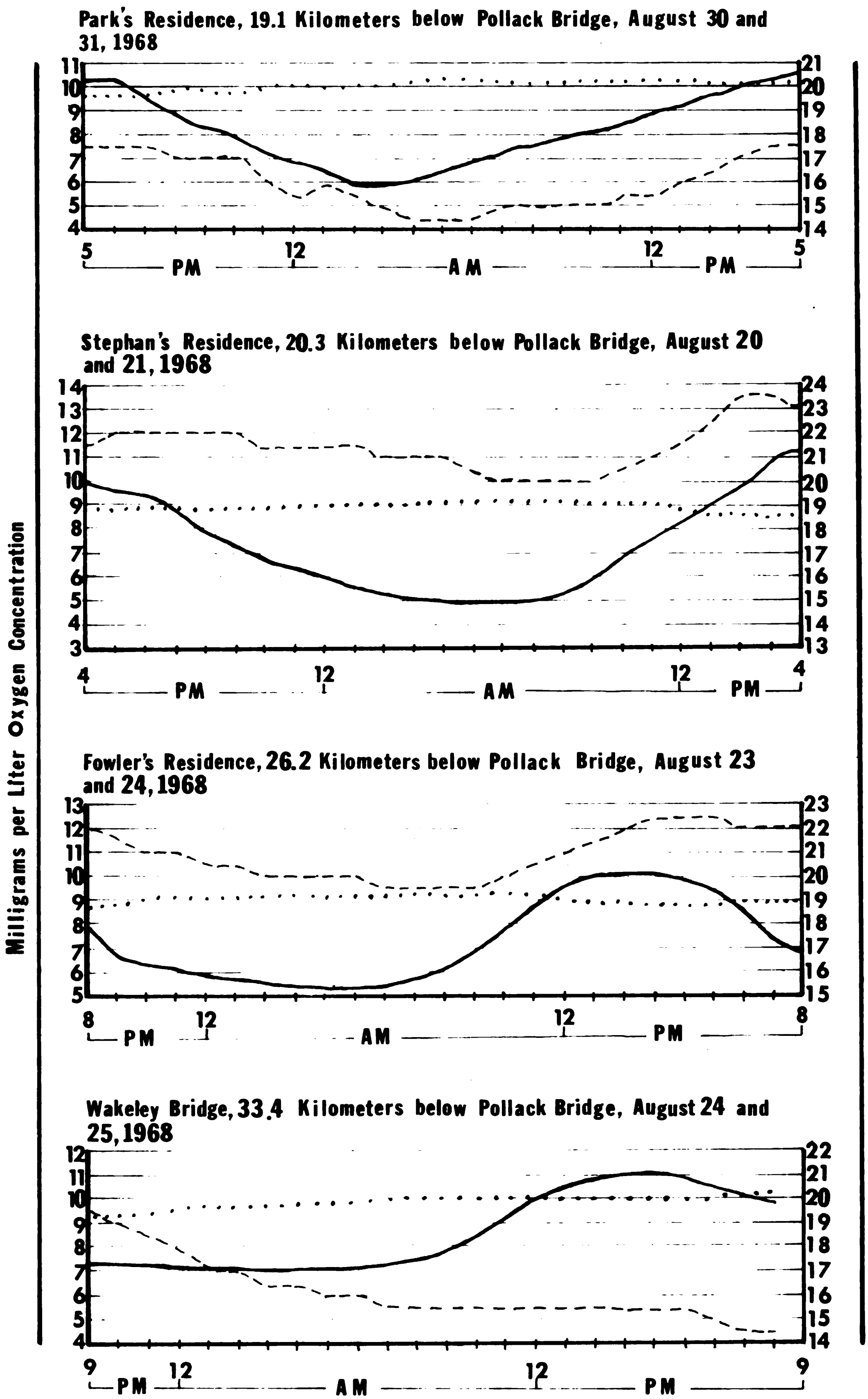


Figure 5 continued

upper limits for species normally designated as cold water types. In reaching Section III, Park's, Stephan's, and Fowler's residences, oxygen values show a greater fluctuation, becoming supersaturated in late afternoon and dropping to 6 mg/liter and less before daybreak. In Section IV, this variation becomes less distinct, with the low oxygen values of Section III disappearing.

It is believed that the above oxygen results reflects the vegetation, pollution level, and water temperature present within each area of the river. At Pollack Bridge, temperature is moderate and vegetation sparse. Thus oxygen concentration is high. Below Grayling, low vegetation density and high organic load does not allow oxygen concentrations to reach saturation. Farther downstream increasing current velocity and vegetation density react to produce a wide fluctuation in oxygen concentration, with perhaps the stream turbulence preventing extremely low oxygen concentrations. In Section IV, current velocity and entering ground water and tributaries play a dominant role. Although vegetation is dense, increased amounts of air-water exchange and cool water prevents the results of Section III.

The Michigan Water Resource Commission (1966) recorded similar diurnal oxygen and temperature curves with an important exception. They reported large oxygen fluctuations immediately below Grayling, Allison's and Harland's residences, with supersaturation during afternoon and low oxygen concentration at night. They also reported large aquatic plant growths between Grayling and these areas, which were not observed during this study.

Phosphorus

Total phosphorus concentrations for the Main Stream for several stations of the East Branch, and for several sample sites downstream from dwellings suspicious of contamination are listed in Table 6. Figure 9 graphically shows the series of phosphorus samples.

Upstream from the entrance of effluent from the Grayling waste water treatment plant, total phosphorus concentration of the Main Stream is very low, but rises below the sewage treatment plant. This higher level quickly drops off to a relatively stable level throughout the study area. The stream vegetation may be responsible for the apparent rapid loss of total phosphorus.

Results from Individual Septic Systems

Actual totals of chemical results and fluorescence of samples, as well as adjusted chemical and fluorescence results are listed in an Appendix. Adjusted results are the actual values of the dwelling samples minus the average of samples taken within that section of the river for that data. Due to differences of the stream in time and area, actual results are more difficult to analyze. Samples not taken directly from the river were considered separately

Table 6. Total phosphorus concentrations for two series from the Main Stream, two East Branch samples, and several selected samples from dwellings.

Location	Kilometers below Pollack Bridge	Collection Date	Milligrams per liter total Phosphate
Pollack Bridge	0.0	Sept. 23, 1968	0.01
200 ft. above S.T.P.*	9.1	Sept. 28, 1968	0.01
500 ft. below S.T.P.*	9.2	Sept. 28, 1968	0.08
1,000 ft. below S.T.P.*	9.5	March 19, 1969	0.26
Above East Bramch	9.5	Sept. 23, 1968	0.28
Haugh's Residence	9.9	Sept. 13, 1968	0.09
Above Madsen's Residence	10.4	July 18, 1968	0.03
Madsen's Residence	10.4	July 18, 1968	0.03
Above Allison's Residence	11.4	Sept. 28, 1968	0.03
Olson's Residence	11.5	July 18, 1968	0.03
Burton's Landing	18.3	Sept. 23, 1968	0.03
Burton's Landing	18.3	Sept. 28, 1968	0.03
Keystone Landing	20.5	Sept. 23, 1968	0.07
Keystone Landing	20.5	Sept. 28, 1968	0.03
Above Evan's Residence	27.1	Sept. 28, 1968	0.06
Wakely Bridge	33.6	Sept. 28, 1968	0.03
Osborne's Residence	34.5	Aug. 15, 1968	0.06
Townline Road	36.8	Sept. 23, 1968	0.03
East Branch, above hatchery	----	March 19, 1969	0.06
East Branch, above hatchery	----	March 19, 1969	0.05

*S.T.P. = Grayling Sewage Treatment Plant.

separately within their section and date of collection in determining adjusted values.

Figures 6, 7, and 8 are graphs showing frequency of adjusted results occurring within designated ranges. As evident from these graphs few sample results occur within a range that could be considered deviate enough from zero to be indicative of contamination. Belief is that if no samples are from sites of contamination, that would cause higher values of parameters, subtraction of the average of all values, which should be nearly equal for a short distance and time, would produce adjusted values of zero or near zero. Samples from sites of contamination would produce high positive adjusted values. Due to the fact that sampling was preformed in such a way to include any incoming water which might include contaminants, these samples would be low in parameter values relative to control samples and dwelling samples which included little incoming dilute water. Such samples would be expected to have negative adjusted values. Control samples, taken in midstream where contaminants or pure ground water from the stream edge would have little effect on parameter magnitude, were clustered about zero.

The small number of samples indicated as being suspicious of contamination in the Appendix, and the graphs in Figures 6, 7, and 8, do not indicate the dwelling located along the study area of the river to be a major source of contamination. Further reasoning behind this statement will be taken up in the discussion.

Figure 6. Distribution of adjusted relative fluorescence values for control samples and samples from dwellings.

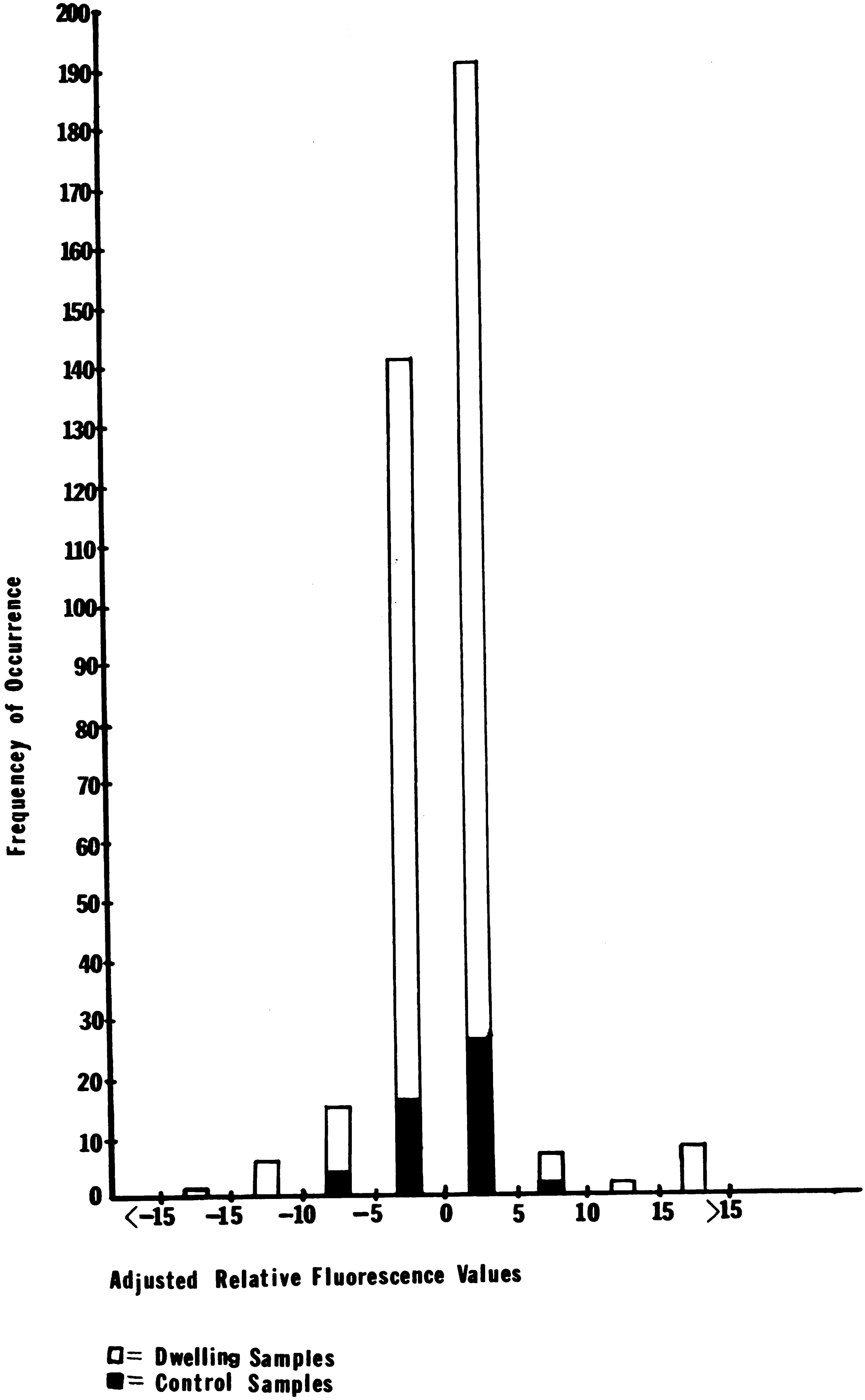

200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
Frequencey of Occurrence
<-15
-15
-10
-5
0
5
10
15
>15
Adjusted Relative Fluorescence Values
= Dwelling Samples
= Control Samples

Figure 6

Figure 7. Distribution of adjusted chloride values (in milligrams per liter) for control samples and samples from dwellings.

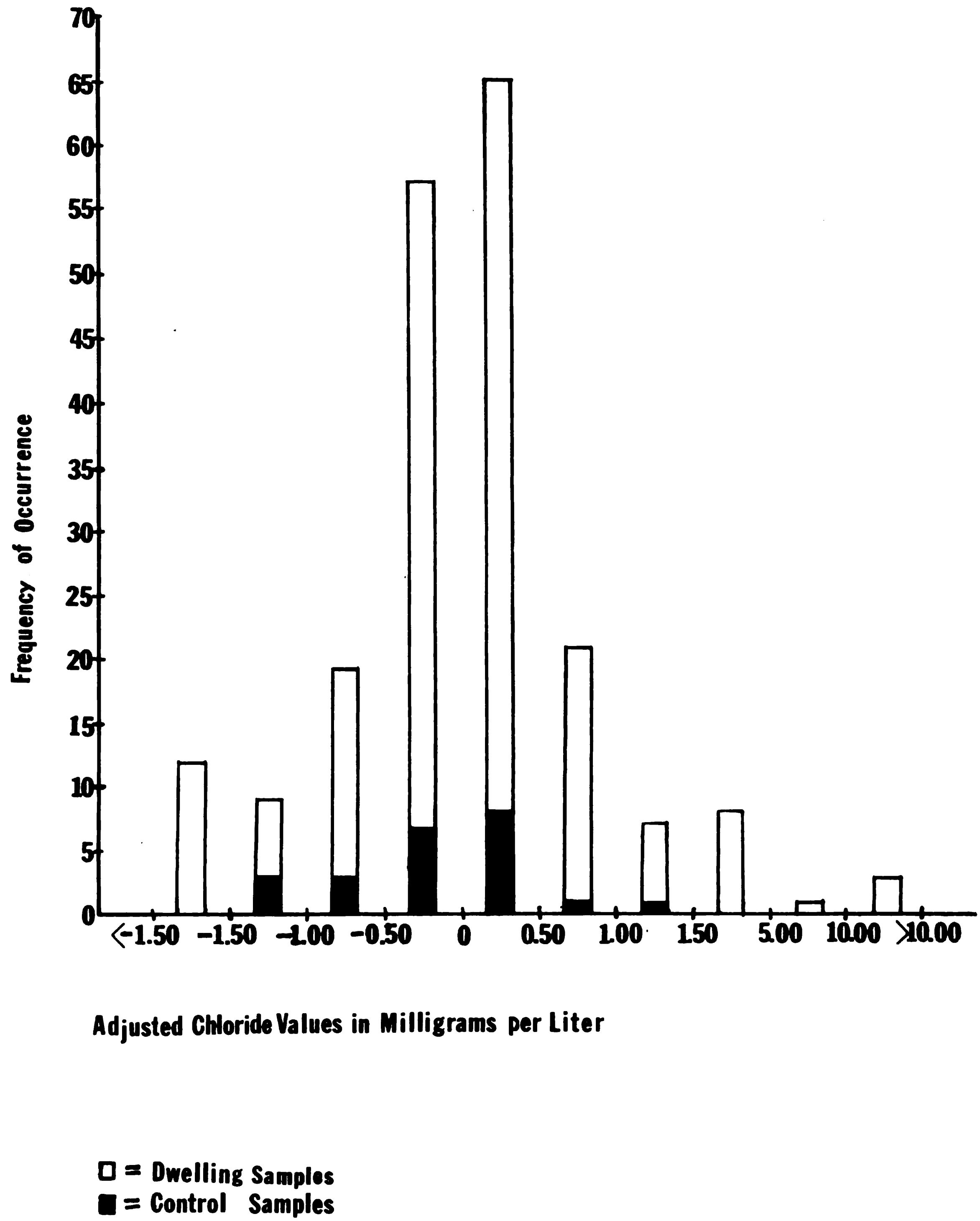

70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
Frequency of Occurrence
<-1.50 -1.50 -1.00 -0.50 0 0.50 1.00 1.50 5.00 10.00 >10.00
Adjusted Chloride Values in Milligrams per Liter
= Dwelling Samples
= Control Samples

Figure 7

Figure 8. Distribution of adjusted nitrate nitrogen values (in micrograms per liter) for control samples and samples from dwellings.

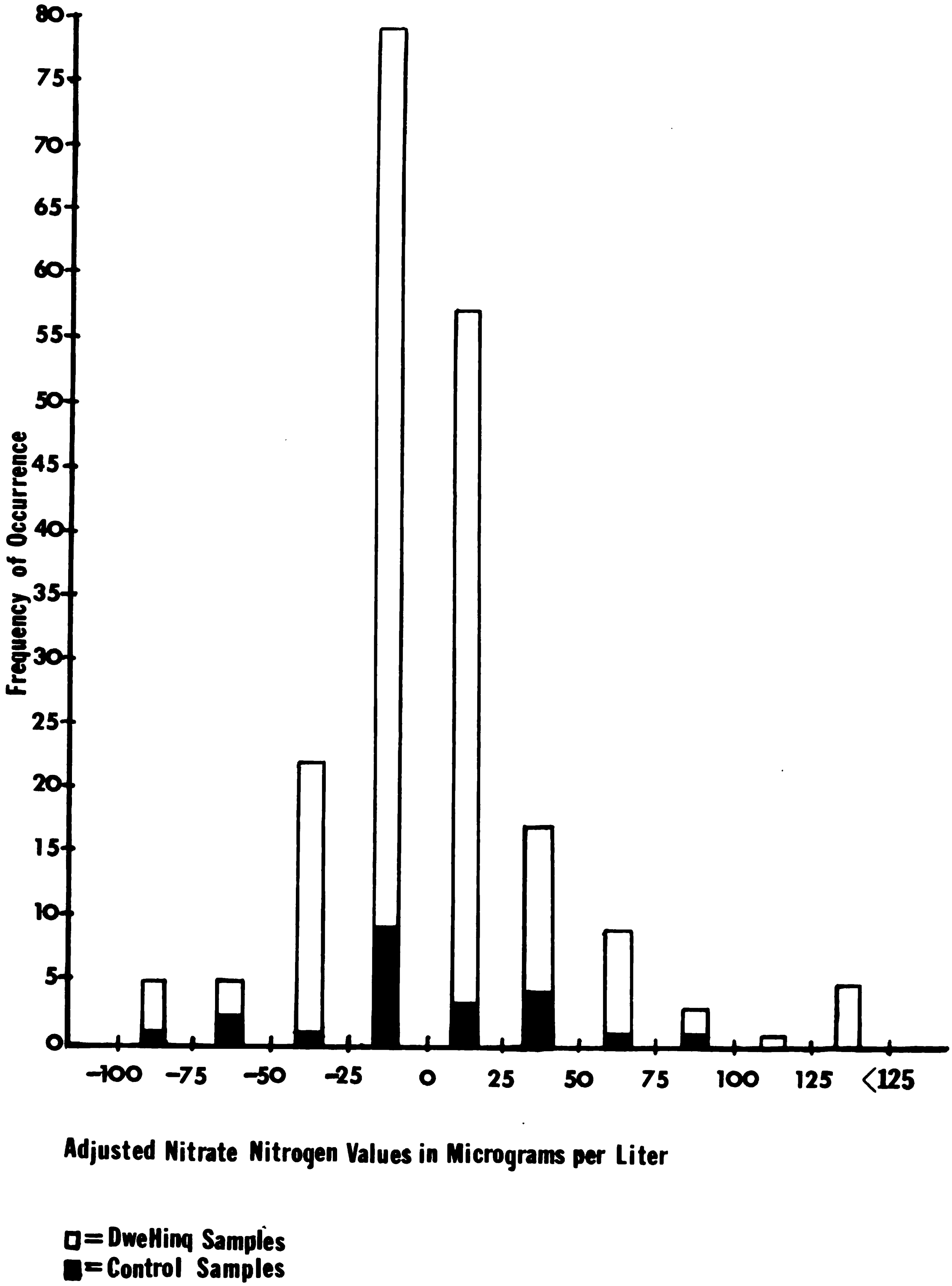

Frequency of Occurrence
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-100 -75 -50 -25 0 25 50 75 100 125 <125
Adjusted Nitrate Nitrogen Values in Micrograms per Liter
= Dwelling Samples
= Control Samples

Figure 8

No statistical tests were made to distinguish dwelling samples as being indicative of contamination, nor could any rightfully be made because of the number of samples taken per dwelling. Samples considered as being indicative of contamination were determined by considering the magnitude and variation of the adjusted values, particularly the control and upstream values. Those adjusted results being several times greater than the range of the majority of results were indicated as being suspicious.

Figure 9 is a plot of total phosphorus, chloride, nitrate nitrogen, and fluorescence levels of control samples taken over the range of the study area. These graphs give the general levels that the various parameters occupied during the time of the study. Due to the few samples plotted and differences of parameter levels with time, the graphs appear erratic. However, general patterns are evident. Total phosphorus, nitrate nitrogen, and chloride concentrations are low. Total phosphorus and nitrate nitrogen concentrations temporarily increase below Grayling. Chlorides and fluorescence show no strong pattern. Although increases in parameter levels downstream could possibly be due to additions of materials from some source such as private septic systems, this may be due only to small sample size or sampling in areas where incoming dilution waters caused samples to be less concentrated.

Figure 9. Variation in total phosphorus, chloride, nitrate nitrogen and fluorescence with location as shown by selected control samples.

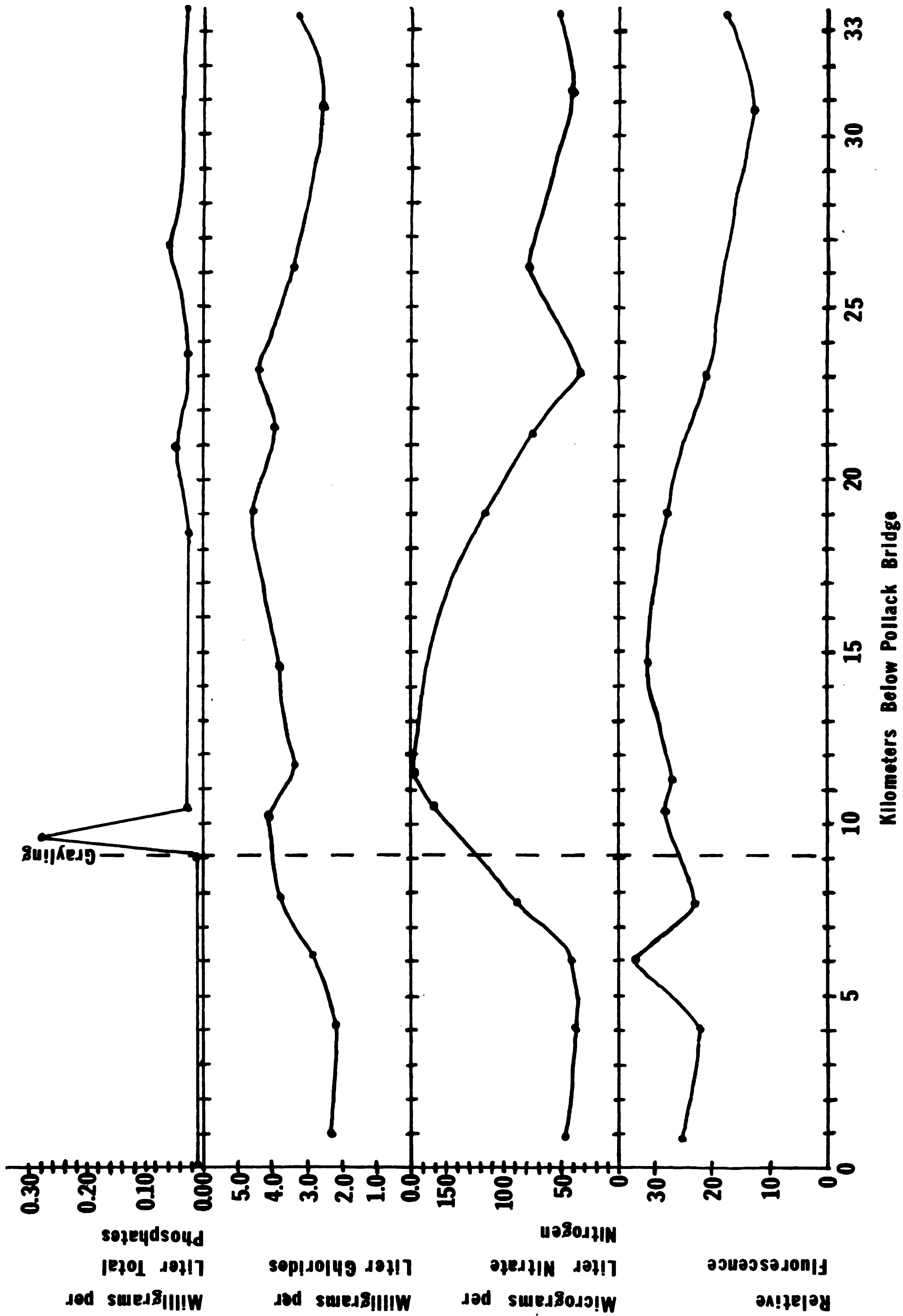

Milligrams per Liter Total Phosphates
0.30 0.20 0.10 0.00
Milligrams per Liter Chlorides
5.0 4.0 3.0 2.0 1.0 0.0
Micrograms per Liter Nitrate Nitrogen
150 100 50 0
Relative Fluorescence
30 20 10 0
Grayling
0 5 10 15 20 25 30 33
Kilometers Below Pollack Bridge

Figure 9

DISCUSSION

Detectability

A discussion of the factors influencing the detectability of contaminants is necessary to help evaluate the results of the study.

The lower limit of a fluorescein solution that was readily visible was of the magnitude of one part per million concentration. With a fluorometer, concentrations on the order of one part per billion could be distinguished. Considering that the quantity of dye injected was approximately 15 grams per system, this quantity had a potential capacity to produce 15,000 liters of visibly fluorescent water and 15,000,000 liters of fluorescent water detectable by fluorometer. Assuming that sampling was preformed at a time so as to intercept the dye, and since not much dye was observed or suspected in fluorescence readings, this requires material from septic systems to be considerably diluted.

Dilution of contaminants is an important factor to consider. The possibility exists that nutrients are reaching the river in concentrations that are below the sensitivity of the tests used to detect them. This is particularly true in the case of chlorides, which should not be transformed, readily absorbed, or taken up by plant roots. Chlorides will eventually reach the stream. Since these were detected in only several cases, probabilities are that this material is moving at dilute concentrations.

Samples to be analyzed for nitrate nitrogen had to be stored for several months before analysis. Although stored at near freezing temperatures, changes in nitrate concentrations probably did occur. Jenkins (1967) showed that nitrate concentration for estuarine water of similarly stored samples increased slightly over about a month period. Personal observations on samples collected in March of 1969 and followed closely showed nitrate concentration to decrease. However, the relatively low nitrate nitrogen results of this study are not in disagreement with those from the Michigan Water Resources Commission (1966) or Hendrickson (1966).

Another factor involved here is the matter of timing the sample collection. Determining the amount of time required for materials to travel to the stream is very important in sampling potential contaminants or dye at their maximum concentrations.

Sources of contamination other than domestic waste may interfere with the results of the study. Fertilizers from lawns may result in high nitrate readings. Some synthetic detergent products are strongly fluorescent and the entrance of these materials from kitchen sink drains may interfere with fluorometer tests for fluorescein (Turner Fluorometry Reviews, 1968). Although these substances are just as serious pollutants as is domestic waste, they are not the particular effort of this study and may bias results.

Factors Influencing the Degree of Contamination

I do not believe the private septic system of dwellings within the study area to be a major contribution of nutrients to the AuSable River. This conclusion is based upon the results of the study and the following factors: the number of systems and amount of use they receive, distance and elevation from the river, the transformation and absorption of materials in and near the tile fields, and the uptake of nutrients by plant roots.

Reference to the Appendix shows that in only four cases was dye actually observed and in only several other instances were samples designated as being suspicious. These cases were probably the result of faulty systems where material made a relatively direct flow to the river from some point in the tile field and are not representative of the majority of septic systems.

According to study records, there are approximately 220 dwellings on the nearly 20 miles of stream bank located within the study area. These can be subdivided into 68 permanent homes, 25 "half-year" homes, and 127 cottages.

Allowing 52 weeks of residence for permanent homes, 26 weeks for "half-year" homes and 4 weeks for cottages with an average of 4 persons per dwelling, this amounts to 18,776 weeks spent by people within the study area serviced by private domestic waste treatment facilities. This is about 15 percent of the amount of time spent by people in the city of Grayling as recorded in the Michigan Water Resources Commission Report (1966). Assuming that the quantity of domestic waste is roughly proportional to the length of time at the location, then even if the entire amount of waste from private systems went directly into the river, the effect would be small relative to the primary effluent from Grayling's municipal waste water treatment plant. However, there is considerable evidence available to indicate that septic tank effluent undergoes gross changes in composition while traveling through the soil.

After materials leave the anaerobic conditions of the septic tank they enter the aerobic conditions of the tile field. Here the reduced products of the septic tank become oxidized. Robeck, Cohen, Sayers, and Woodward (1962) showed that allowing 5 gal. of domestic sewage to flow daily through four feet of sand in a lysimeter simulating conditions below a septic system tile field, substantially lowered the BOD and total phosphorous levels of the effluent and converted organic and ammonia nitrogen to nitrates. After several months of using this experimental apparatus, they found populations of microflora associated with organic breakdown in the lysimeter soil.

Jansson (1958) postulated an internal mineralization-immobilization nitrogen cycle. He states that heterotrophic microflora convert organic matter into microbial cells to the extent that the energy-nitrogen ratio of the organic additive will allow. The rest of the organic matter is converted to a surplus inorganic nitrogen pool. In the case of sewage sludge, which is rich in nitrogen, the nitrogen supply is sufficient to meet the needs of the microbial demands for cell synthesis and provide a net mineralization of nitrate and ammonium compounds available for higher plant use or denitrification. Jansson (1958) further states that after mineralization occurs, forming nitrate or ammonium products, losses of these inorganic nitrogen forms may occur due to evaporation, leaching, and denitrification.

A small amount of evaporation of ammonia may occur from the top layer of alkaline soils when organic materials high in nitrogen are added.

The nitrate pool of soil is quite liable to losses when the soil is not occupied by plants. As nitrate ions are practically not adsorbed by soil colloids, losses occur as soon as leaching begins.

Denitrification is a typically anaerobic process requiring either alternating aerobic and anaerobic conditions or continuous semi-aerobic conditions. He states that losses of nitrogen readily occur through denitrification in natural soils.

Ellis and Erickson (1969) studied phosphorus adsorption ability of various Michigan soils. They state that the phosphorus adsorption capacity of calcium phosphate in pounds per acre for a three foot profile to be 1,699, 1,818, and 2,106 for three soils from the study area, Grayling Sand, Roseland Sand, and Rubicon Sand respectively. Similar results were obtained for sodium phosphate. They also state that soils have the ability to recover their adsorptive capacity after a period of rest. Three months after saturation, all but one of the sixteen soils studied had recovered at least 50 percent of its absorptive capacity. They calculate that a septic tank system serving a permanent residence of four would require 8,101 cubic feet of soil between the tile field and water table to prevent phosphorus concentration leaving the field drainage system from reaching 0.5 ppm after 10 years. This calculation makes the following other assumptions. Total phosphorus content of the 200 gal per day discharge is 20 mg/liter. The phosphorus is all soluble orthophosphate, no phosphorus is removed in the septic tank, and the soil will recover its adsorptive capacity only once, and the tile line is placed in the C horizon. The calculation is made using a Rubicon Sand, with similar phosphorus adsorption capacity to soils within the study area and thus the calculation applies fairly well to dwellings within the study area. It should be noted that all figures applying to the soil and other septic system qualities mentioned are minimum values, and it is likely that a lesser load is put on the system and that a greater quantity of phosphorus can be adsorbed than stated. In a permanent residence it is likely that absorptive capacity is recovered more than once. Some phosphorus is removed in the septic tank. If the tile lines are placed in the B rather than C horizon, only 5,144 cubic feet of soil are needed. Also it is evident that in systems with limited use, phosphorus adsorption recovery may prevent the soil in the system from ever reaching saturation.

There are several dwellings with septic systems located near the water table or close to the river; particularly the group of homes located just below Grayling. However, most dwellings are situated far back from the river horizontally and elevated rather high vertically. Few dwelling owners when questioned claimed to have septic systems that were closer than 100 feet to the river. Many systems were several hundred feet from the river. Also in the majority of cases land elevation where dwellings were located were at least five feet above the stream surface and in some instances elevation is probably greater than twenty feet. This distance factor allows time for good oxidation and contact volume for adsorption of products from the tile field to the water table where the primary degradation of septic tank products occurs. Some degradation may also occur in the distance material travels from the point of intersection of the water table to the stream.

Another factor of possible great importance in the movement of nutrients through the soil is the abundance of vegetation covering the banks of the stream. Probably of greatest importance here are trees as opposed to annuals, which send roots not only to the water table but are known also to grow roots to the tile field. The United States Department of Health, Education, and Welfare manual of septic-tank practice (1967) states that this phenomena has been used to some degree of success in aiding the disposal of sewage effluent in tight clay soils where evaporation is limited. It also states that this factor may be of importance in northern resort areas during the summer. Nitrogen forms from the tile field may be either ammonia or nitrates, both of which could be utilized by plants. Other oxidized forms of nutrients such as phosphates are probably available for plant uptake. Also if oxidized nutrients are moving at low concentrations through at least 100 feet of stream bank covered with vegetation, plant roots will probably absorb much of the material before it is able to reach the river.

Suggestions on Improvements of the Stream

The Michigan Water Resources Commission Report of 1966 suggests several improvements in the stream. These are to

remove the dams causing the large, shallow bodies of water above Grayling and to remove the effects of the sewage plant effluent from the city of Grayling. In the long run the fulfillment of these two suggestions will lower water temperatures and retard eutrophication of the stream. However, the fact should be stated that fulfillment of these suggestions will not restore the lower water quality of the downstream half of Section II to the quality of water found in Sections III and IV. There are certain inherent qualities of this area documented in this study that naturally bias the quality of this water to be low. The shallow, sand bottomed stream of low velocity simply is not capable of supporting the large populations of cold-water life found downstream.

Another suggestion is to provide for closer supervision of installation of private septic systems. The minimum requirements should be those suggested by Hendrickson (1966). Tile fields should be at least three feet above the water table and a minimum horizontal distance of 50 feet from the river or springs and seepage areas. The large number of springs located along certain stretches of the river present a difficult problem in the present location of some septic systems which may be 50 or 100 feet from the river but only several feet from a small brook or spring running directly into the river.

An effort should also be made to distribute septic tank effluent in the tile field such that it spreads over a large area and thus contacts a large volume of unsaturated subsoil. The size of effective absorption fields of septic systems located near streams should be based on the ability of subsoils to adsorb nutrients rather than solely on the current standards of permeability of soils.[1]

Suggestions for Further Studies

In order to examine the extent of contamination in cases of properly installed septic systems more thoroughly, the following suggestions would be useful in a further study. Consider only several dwellings, representative of homes and cottages along the river. These dwellings should be picked so that complete cooperation is obtained with the owner and locations of septic tanks and drainage fields are known. In the case of cottages, where use is seasonal, closely monitor the fluorescence, nitrate, and chloride levels by taking several samples per day before and after putting the fluorescein into the septic system at the beginning of the period of use. Also, monitor several areas where contamination from private systems is unlikely, to compare with the results obtained from nearby areas containing tile fields of permanent homes.

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[1]Personal communication with Dr. Boyd Ellis, Associate Professor of Soil Science at Michigan State University.

CONCLUSIONS

1) As indicated in the description of the river, I would consider Sections III and IV of the study area to be of relatively good water quality. Sections I and II are of lesser water quality, with the downstream half of Section II being notably degraded. The above is most clearly shown by the invertebrate life present in each section and also by other aspects discussed. The chemical load of the stream is relatively light, except below Grayling where they temporarily increase. Vegetation in the stream is a significant factor, greatly affecting dissolved oxygen, bottom type, and current velocity. This subsequently affects life forms and eutrophication of the stream.

2) I am convinced that I was able to detect only cases of contamination where most of the material was channeled through a relatively small area, rather directly to the river. This obviously included defective systems from which sewage material entered the stream relatively unchanged, but also may have included cases in which sewage materials filtered through several feet of soil before reaching the stream. The results of this study show these cases to be relatively few.

3) I also believe that if domestic wastes or products of waste do reach the river from properly installed septic systems, they must travel in relatively low concentrations due to the proportionally large volume of ground water they must encounter in their movement. This would provide opportunity for transformation of reduced septic tank products to oxidized forms, adsorption of some materials, particularly phosphorous, and absorption of materials by plant roots.

Due to the position of most dwellings relative to the river, situated both well elevated and far back from the river, and due to the small amount of use most of the septic systems receive, I believe that in most cases, contamination from these systems is negligible. Only in the case of permanent homes located close to the water table is contamination suspected but could not be shown.

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LITERATURE CITED

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APPENDIX

APPENDIX

Actual and Adjusted Fluorescence, Nitrate, and Chloride Results for Samples Taken from the AuSable River During the Summer and Fall of 1968.

	Relative Fluorescence				Micrograms per liter Nitrate Nitrogen		Milligrams per liter Chloride	
Sample	Actual		Adjusted		Actual	Adjusted	Actual	Adjusted
175U	33	33.5	0	.5	74	-14	2.70	-0.10
176	32.5	32.5	-.5	-.5	106	19	2.45	-0.35
177	33	33	0	0	82	-6	3.25	0.45
159C	25.5	23.5	2.5	.5	36	5	2.10	0.20
52C	20	16	2	-2	30	0	2.30	0.70
53	20	23	2	5	40	10	2.10	0.50
158	23.5	23.5	.5	.5	20	-11	2.10	0.20
54	17	9	-1	-9	50	20	1.00	-0.60
157	23.5	26	.5	3	50	19	1.80	-0.10
55	17	11.5	-1	-7.5	20	-10	1.00	-0.60
149	23	22.5	0	-.5	40	9	2.15	0.25
150	27.5	25	4.5	2	20	-11	2.00	0.10
151	24	24.5	1	1.5	20	-11	1.90	0.00
58	18	21	0	3	20	-10	1.70	0.10
57	17	21	-1	3	20	-10	1.45	-0.15
56	20.5	18	2.5	0	30	0	1.75	0.15
156	24	24	1	1	53	22	2.00	0.10
155	24.5	22.5	1.5	-.5	30	-1	2.10	0.20
154	25	23	2	0	30	-1	2.10	0.20
152	29	24.5	6	1.5	20	-11	1.65	-0.25

D = Dye observed; U = Sample taken upstream from dwelling; C = Control sample taken in midstream; S = Sample considered suspicious of contamination; T = sample not taken directly from the stream proper.

continued

APPENDIX--Continued

Sample	Relative Fluorescence Actual		Relative Fluorescence Adjusted		Micrograms per liter Nitrate Nitrogen Actual	Micrograms per liter Nitrate Nitrogen Adjusted	Milligrams per liter Chloride Actual	Milligrams per liter Chloride Adjusted
153	19.5	23	-3.5	0	20	-11	1.25	-0.65
223	28	--	4	--	37	-29	1.55	-0.10
224	12.5	--	-11.5	--	72	15	2.00	0.35
98	21	20.5	-2	-2.5	40	60	2.15	-0.20
97	24.5	20.5	1.5	-2.5	48	9	2.00	-0.35
99C	20.5	22.5	-2.5	-0.5	35	-4	2.15	-0.20
104	15	14.5	0	-.5	36	5	3.25	0.90
222	--	--	--	--	47	-10	1.35	-0.30
221	31.5	--	7.5	--	97	40	2.50	0.85
220	29	--	5	--	49	-8	2.30	0.65
96	21.5	27	-1.5	4	30	-9	2.20	-0.15
95	27	23.5	4	.5	47	8	4.40	2.05
94	22.5	23	-.5	0	36	-3	1.70	-0.65
76	39.5	37.5	5.5	3.5	61	7	4.55	0.95
77	37	24	3	1	45	-9	1.95	-0.40
225	24	--	0	--	40	-17	1.25	-0.40
226ST	16.5	--	-7.5	--	252	195	0.70	-0.95
75	33.5	33.5	-.5	-.5	60	6	3.65	0.05
74	37.5	38.5	3.5	4.5	37	-17	3.15	-0.45
73C	32.5	33	-1.5	-1	40	-14	2.55	-1.05
72	31.5	33	-2.5	-1	59	5	3.30	-0.30
71	32.5	34	-1.5	0	66	12	4.00	0.40
70	33	35	-1	1	52	-2	3.75	0.15
69	36	33.5	3	-.5	57	3	3.80	0.20
68	33.5	34	-.5	0	53	-1	3.80	0.20
141C	33.5	34	2.5	3	66	-73	3.40	-1.25
140	34	33	3	2	104	-33	7.95	3.30
178	19.5	19.5	-.5	-.5	166	11	5.30	1.25

continued

APPENDIX--Continued

Sample	Relative Fluorescence				Micrograms per liter Nitrate Nitrogen		Milligrams per liter Chloride	
	Actual		Adjusted		Actual	Adjusted	Actual	Adjusted
124C	12.5	12.5	-8.5	-8.5	123	26	4.15	0.35
125	22.5	24	1.5	3	143	46	2.55	-1.25
126	18	18	-3.0	-3.0	155	58	3.70	-0.10
142	30	30	-1	-1	233	96	5.30	0.65
143	32.5	30	1.5	-1	182	45	4.70	0.05
144	28.5	30	-2.5	-1	290	153	4.40	-0.25
145	31.5	31.5	.5	.5	182	45	5.45	0.80
127	19.5	--	-2.5	--	95	-2	2.55	-1.25
128	22	16.5	1	-4.5	122	25	9.35	5.55
112	9.5	17	-5.5	2	205	46	9.00	4.05
113	17	18	2	3	112	-47	4.60	-0.35
179	9	--	-11	--	66	-85	4.85	0.80
82C	28	30	7	9	167	97	2.55	-0.45
1U	26.5	27	.5	1	155	27	5.50	1.30
2S	40	34.5	14	8.5	278	150	6.55	2.35
180TS	8.5	--	-11.5	--	230	79	21.60	17.55
181	21	21	1	1	183	32	4.20	0.15
83	23	23.5	2	2.5	22	-48	2.70	-0.30
84	22	22	1	1	134	64	4.45	1.45
182	21.5	21.5	1.5	1.5	99	52	4.20	0.15
3U	27	26.5	1	.5	170	42	3.30	-0.90
4S	42	21.5	16	-4.5	148	20	5.05	0.85
183	21	21.5	1	1.5	250	99	4.30	0.25
134	21.5	21.5	.5	.5	20	-77	4.20	0.40
135	21.5	11	.5	-10.0	45	-52	1.65	-2.15
136	22	9	1	-12	30	-67	2.55	-1.25
133	21.5	22.5	.5	1.5	157	60	4.25	0.45
132	22	21.5	1	.5	121	24	4.35	0.55
184	20	22.5	0	2.5	127	-24	4.25	0.20

continued

APPENDIX--Continued

Sample	Relative Fluorescence Actual		Relative Fluorescence Adjusted		Micrograms per liter Nitrate Nitrogen Actual	Micrograms per liter Nitrate Nitrogen Adjusted	Milligrams per liter Chloride Actual	Milligrams per liter Chloride Adjusted
185	23	22.5	3	2.5	210	59	4.50	0.45
186	22.5	22.5	2.5	2.5	72	-79	4.25	0.20
131	41	21.5	2.0	.5	115	18	4.20	0.40
187	21	--	1	--	125	-26	4.65	0.60
130	22	21.5	1	.5	20	-77	3.95	0.15
146C	31	31	0	0	41	-96	3.75	-0.90
147	29	30	-2	-1	66	-71	3.15	-1.50
188	23.5	21.5	3.5	1.5	141	-10	4.15	0.10
111	18	18	0	0	20	-24	3.75	0.00
110	17	19.5	-1	1.5	67	23	3.70	-0.05
189	23	21.5	3	1.5	101	36	3.60	-0.45
67	15.5	17	1.5	3	30	2	3.40	0.50
85	21.5	27	.5	6	137	67	3.75	0.75
190	18.5	18.5	-1.5	-1.5	111	46	3.75	-0.30
109	17	16	2	1	30	-1	3.80	1.45
191	19.5	18.5	-.5	-1.5	47	-18	3.60	-0.45
5U	30	26	4	0	113	61	4.60	0.40
6	27.5	26	1.5	0	85	33	3.20	-1.00
148	24	--	-7	--	71	-66	2.90	-1.75
192	18.5	18	-1.5	-2	66	1	3.75	-0.30
193	20.5	21.5	.5	1.5	30	-35	3.60	-0.45
114	14.5	16.5	-.5	1.5	30	-8	3.25	-0.20
194	18.5	19.5	-1.5	-.5	51	-14	4.10	0.05
86	22	21.5	1	.5	25	-45	3.10	0.10
195	22.5	21	2.5	1	60	-5	3.55	-0.50
115	15	15	0	0	20	18	3.00	-0.45
102T	8	10	-7	-5	0	-31	0.00	-2.35

continued

APPENDIX--Continued

Sample	Relative Fluorescence				Micrograms per liter Nitrate Nitrogen		Milligrams per liter Chloride	
	Actual		Adjusted		Actual	Adjusted	Actual	Adjusted
103	16	19	1	3	20	-11	0.85	-1.50
101	16.5	21.5	1.5	6.5	37	6	3.15	0.80
7U	24	26	-2	0	115	-13	3.75	-0.45
8	24	23.5	-2	-2.5	67	-61	3.40	-0.80
196	19	20	-1	0	30	-35	3.95	-0.10
9U	24	23.5	-2	-2.5	70	-58	3.55	-0.65
10	25	25	-1	-1	104	-24	3.55	-0.65
197	20.5	21	.5	1	72	7	3.95	-0.10
13U	21.5	22	2.5	3	50	-2	3.95	-0.25
14	22.5	18.5	3.5	-.5	67	12	4.65	0.45
198	20	20	0	0	96	31	3.20	-0.85
199	20	19.5	0	-.5	39	-26	3.65	-0.40
88	22.5	20	1.5	-1	30	-40	3.10	0.10
200	19.5	--	.5	--	111	46	3.50	-0.55
18U	20.5	19.5	1.5	.5	20	-32	4.55	0.35
19	16	19	-3	0	20	-32	3.45	-0.75
15U	23	21.5	4	2.5	50	-2	4.50	0.30
16	19	22.5	0	3.5	31	-21	3.90	-0.30
17	21.5	--	2.5	--	35	-17	3.50	-0.70
201	21.5	24	1.5	4	20	-45	4.00	-0.05
100	17	16.5	2	1.5	81	50	3.40	1.05
89	18	16.5	-3	-4.5	69	-1	3.00	0.00
202	15	14.5	-1	-1.5	105	44	3.45	-0.60
203	16	16	0	0	30	-31	4.35	1.10
204	17	17.5	1	1.5	65	4	4.50	1.25
165	29.5	35.5	6.5	12.5	57	26	3.85	0.55
166	19	--	-4	--	25	-6	0.00	-3.30
205S	18.5	--	2.5	--	63	-2	32.35	29.10

continued

APPENDIX--Continued

Sample	Relative Fluorescence				Micrograms per liter Nitrate Nitrogen		Milligrams per liter Chloride	
	Actual		Adjusted		Actual	Adjusted	Actual	Adjusted
206	18	--	2	--	35	-26	4.80	1.55
207	20.5	--	4.5	--	90	29	4.90	1.65
117	16	17.5	1	2.5	20	-14	5.20	1.75
208T	18	18	2	2	20	-41	0.00	-3.25
209	14	14	-2	-2	41	-20	3.40	0.15
174	19	--	0	--	25	-7	3.15	0.05
173	19	--	0	--	39	7	3.95	0.85
172	18.5	--	-.5	--	28	-4	1.05	-2.05
171	18.5	--	-.5	--	30	-2	3.10	0.00
170	18.5	--	-.5	--	20	-12	3.95	0.85
169	18.5	--	-.5	--	48	16	3.45	0.35
11U	21.5	22	-4.5	-4	108	-20	3.95	-0.25
12	21	21	-5	-5	121	-7	3.90	-0.30
20U	18	15	-1	-4	50	-2	2.80	-1.40
21S	10.5	12	-8.5	-7	166	114	6.50	2.30
210	14	12	-2	-4	48	-13	1.10	-2.15
90	17	17	-4	-4	44	-26	2.85	-0.15
40	15.5	18.5	.5	3.5	53	17	3.50	0.25
39	13	16	-2	1	53	17	3.40	0.15
38T	6	6	-9	-9	40	4	0.00	-0.55
37	13.5	11	-1.5	-4	28	-8	3.55	0.30
25T	23	22.5	4	3.5	30	5	0.00	-0.10
26T	8	9	1	2	20	-5	0.00	-0.10
211	16.5	--	.5	--	38	-23	3.55	0.30
212	15	--	-1	--	115	54	3.10	-0.15
213	15.5	16	-.5	0	69	8	3.50	0.25
214	16	17	0	1	20	-41	3.35	0.10

continued

APPENDIX--Continued

Sample	Relative Fluorescence Actual		Relative Fluorescence Adjusted		Micrograms per liter Nitrate Nitrogen Actual	Micrograms per liter Nitrate Nitrogen Adjusted	Milligrams per liter Chloride Actual	Milligrams per liter Chloride Adjusted
104	15	14.5	0	-.5	36	5	3.25	0.90
215	16	15	0	-1	81	20	2.95	-0.30
234	14.5	--	-3.5	--	50	2	1.50	-1.10
160	14	14	-9	-9	20	-11	2.05	-1.25
27T	7	7	0	0	20	-5	0.00	-0.10
28T	7	7	0	0	20	-5	0.00	-0.10
216	14	15	-2	-1	72	11	2.65	-0.90
29U	10	12.5	-9	-6.5	50	--	3.05	0.35
30	15	15	-4	-4	30	5	2.95	0.25
59T	6	5	-8	-9	20	-8	1.55	-1.35
217T	6	15.5	-9	-5	120	59	3.10	-0.15
31T	6	6	-1	-1	0	-25	0.60	0.50
32T	2.5	6.5	-4.5	-.5	0	-25	0.00	-0.10
41S	13.5	11.5	-1.5	-3.5	59	23	16.25	13.00
42T	5	9	-2	2	30	-6	1.05	-2.20
43	13	15	-2	0	20	-16	3.15	-0.10
44	16	16	1	1	40	4	3.50	0.25
60	11	12.5	-3	-1.5	20	-8	2.30	-0.60
61	12.5	13	-1.5	-1	20	-8	3.25	0.35
62	13	13	-1	-1	20	-8	3.50	0.60
63	12	12.5	-2	1.5	40	12	3.60	0.70
64	13	14.5	-1	.5	48	20	3.10	0.20
33U	14	14	-5	-5	30	5	2.05	-0.65
34DS	36	35.5	17	16.5	1490	1465	2.30	-0.40
91T	6.5	5.5	-14.5	-15.5	0	-70	1.45	-1.55
123	19.5	20	-.5	0	57	0	3.40	0.00
66	14.5	13	.5	-1	25	-3	2.95	0.05

continued

APPENDIX--Continued

Sample	Relative Fluorescence Actual		Relative Fluorescence Adjusted		Micrograms per liter Nitrate Nitrogen Actual	Micrograms per liter Nitrate Nitrogen Adjusted	Milligrams per liter Chloride Actual	Milligrams per liter Chloride Adjusted
105	14.5	--	-.5	--	0	-31	0.00	-2.35
106	14.5	12.5	-.5	-2.5	37	6	2.85	0.50
167T	18.5	19	-4.5	-4	20	-11	3.50	0.20
168	19	25	-4	2	42	11	3.35	0.05
231	16	--	-2	--	20	-28	2.20	-0.40
232	19	--	1	--	30	-18	2.80	0.20
233	20	--	2	--	66	18	2.75	0.15
78	22	19.5	3	.5	39	-5	3.85	0.15
79	9	19	-10	0	20	-24	3.00	-0.70
92	24	25.5	3	4.5	20	-50	2.80	-0.20
119	16	15	1	0	40	2	3.40	-0.05
120	14.5	--	-.5	--	45	7	3.10	-0.35
121	15.5	16	.5	1	20	-18	4.35	0.90
122	10	20	-5	5	20	-18	4.35	0.90
230	14.5	--	-3.5	--	60	12	3.15	0.55
229	17.5	--	-.5	--			2.60	0.00
118T	11.5	10	-3.5	-5	103	65	0.00	-3.45
228	19.0	--	1	--	79	31	2.95	0.35
164	19.5	20	-3.5	-3	25	-6	3.10	-0.20
218	17.5	18	1.5	2	25	-36	3.35	0.10
22U	20	18.5	1	-.5	50	-2	4.40	0.20
23	20.5	14.5	1.5	-4.5	30	-22	3.70	-0.50
35U	14	19.5	5	.5	53	28	3.00	0.30
36	15	19.5	4	.5	20	-5	2.70	0.00
163	20	18	-3	-5	40	9	3.00	-0.30
51	17.5	17	2.5	2	20	-16	3.00	-0.25

continued

APPENDIX--Continued

Sample	Relative Fluorescence				Micrograms per liter Nitrate Nitrogen		Milligrams per liter Chloride	
	Actual		Adjusted		Actual	Adjusted	Actual	Adjusted
49	16	18.5	1	3.5	28	-8	3.15	-0.10
48	18.5	14.5	3.5	-.5	30	-6	2.80	-0.45
50C	14.5	15.5	-.5	.5	30	-6	2.75	-0.50
65DS	33.5	29.5	19.5	15.5	320	292	2.80	-0.10
108	12.5	13	-2.5	-2	47	16	3.05	-0.30
45D	17	18.5	2	3.5	22	-14	3.10	-0.15
47	20.5	17.5	5.5	2.5	60	24	3.05	-0.20
46	3.5	17.5	-11.5	2.5	33	-3	3.15	-0.10
162	24.5	--	1.5	--	31	0	3.10	-0.20
80DS	100	100	81	81	65	21	4.90	1.20
81	23	22	4	3	53	9	3.05	-0.65
107	12.5	14.5	-2.5	-.5	20	-11	3.25	0.00
161S	20	--	-3	--	22	-9	7.65	4.35
227	20	--	2	--	30	-18	3.10	0.50