Source, Movement, and Effects of Nitrogen and Phosphorus in Three Ponds in the Headwaters of Hop Brook, Marlborough, Massachusetts

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 84-4017

Prepared in cooperation with the

COMMONWEALTH OF MASSACHUSETTS
DEPARTMENT OF ENVIRONMENTAL QUALITY ENGINEERING
DIVISION OF WATER POLLUTION CONTROL

U.S. Department of the Interior
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By John C. Briggs and William D. Silvey

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Boston, Massachusetts

1984

UNITED STATES DEPARTMENT OF THE INTERIOR

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FACTORS FOR CONVERTING INCH-POUND UNITS TO INTERNATIONAL SYSTEM OF UNITS (SI)

The following factors can be used to convert inch-pound units to International System of Units (SI).

Multiply inch-pound units	By	To obtain SI Units
	Length	
inch (in)	25.40	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
acre	0.4047	square hectometer (hm^2)
	Volume	
acre-foot (acre-ft)	1233	cubic meter (m^3)
	Volume per unit time (includes flow)	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
	Mass	
pound (lb)	0.4536	kilogram (kg)
	Specific Conductance	
micromho per centimeter at 25°C (μmho/cm at 25°C)	1.000	microsiemens per centimeter at 25°C (μS/cm at 25°C)

SOURCE, MOVEMENT, AND EFFECTS OF NITROGEN AND PHOSPHORUS IN THREE PONDS IN THE HEADWATERS OF HOP BROOK, MARLBOROUGH, MASSACHUSETTS

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ABSTRACT

The headwaters of Hop Brook near Marlborough, Massachusetts, contain a series of three in-line ponds--Hager Pond, Grist Millpond, and Carding Millpond--that receive over half of their surface-water inflow as effluent from the Marlbrorough Easterly Wastewater Treatment Plant. These ponds have a history of summer algal blooms and fish kills. Water entering these ponds contains quantities of nitrogen and phosphorus far higher than the levels known to promote excessive growth of aquatic vegetation. As the water moves through the three ponds, nitrogen levels decrease. Although some nitrogen is lost to the atmosphere by denitrification, the bulk of the nitrogen probably is retained in the pond sediments. There is a net decrease in phosphorus in the water leaving Carding Millpond compared to the water entering Hager Pond. However, during most sampling periods, the phosphorus concentration of water leaving Carding Millpond is still above the level known to cause excessive growth of aquatic vegetation in lakes. During certain summer periods, there appears to be release of some phosphorus from the sediments in Carding and Grist Millponds. No improvement in water quality of the three ponds can be expected until the concentrations of nutrients entering Hager Pond are reduced to levels that will not support excessive growth of aquatic vegetation.

INTRODUCTION

Three in-line ponds, Hager Pond, Grist Millpond, and Carding Millpond, lie in the headwaters of Hop Brook near Marlborough, Massachusetts. During the summer months, these ponds have experienced nuisance growths of algae and low dissolved-oxygen concentrations. An excessive quantity of algae is aesthetically unpleasant to area residents and causes low dissolved-oxygen concentrations with resultant fish kills. Effluent that is rich in plant nutrients has been discharged from the Marlborough Easterly Wastewater Treatment Plant into an unnamed tributary to the most upstream pond--Hager Pond--since the treatment plant was built in 1896.

The wastewater treatment plant has undergone extensive modification and expansion in an effort to improve the water quality within the ponds and to meet the needs of an expanding population. Secondary or biological treatment, including the construction of trickling filters and Imhoff tanks, was put into operation in 1946. Tertiary treatment, including the complete conversion of ammonia nitrogen to nitrate nitrogen through forced aeration, year-round removal of phosphorus, and chlorination of the final effluent, was added in phases begining in 1973, with full operation in 1975.

Waters receiving effluent from the plant have been examined by several Federal and State agencies. During 1965, the Massachusetts Department of Public Health conducted a sanitary survey of the receiving waters. From 1972 until early 1973, the USEPA (U.S. Environmental Protection Agency) included Hager Pond in the National Eutrophication Survey (U.S. Environmental Protection Agency, 1975). Also in 1973, the MDWPC (Massachusetts Division of Water Pollution Control) conducted an intensive chemical and biological study of the in-line ponds during the summer months (Massachusetts Division of Water Pollution Control, 1974).

A major concern of the MDWPC has been whether the pond system, which receives the effluent from the wastewater treatment plant, was responding to the reduced concentrations of nitrogen and phosphorus after the initiation of tertiary treatment. It was hoped that tertiary treatment would improve the water-quality conditions within the ponds.

Purpose and Scope

This report, prepared by the U.S. Geological Survey in cooperation with MDWPC, presents the results of a study, begun in 1976, of the occurrence and movement of plant nutrients within the series of ponds.

Specific objectives of the report are to: (1) Describe the sources of nitrogen and phosphorus in the system of ponds; (2) describe the movement of the nitrogen and phosphorus through the system of ponds; (3) describe the water quality of the system using algal growth potential and enumeration and identification of phytoplankton; and (4) estimate the future water-quality condition of the ponds.

Acknowledgments

Thanks are extended to the members of the Massachusetts Division of Water Pollution Control, Technical Services Branch, and to John Hartley who supervises the operation of the Marlborough Easterly Wastewater Treatment Plant for the City of Marlborough, Massachusetts, for their cooperation and assistance during the study.

DESCRIPTION OF THE STUDY AREA

The study area is located in eastern Massachusetts, about 22 miles west of Boston, in Middlesex County, and straddles the eastern corporate boundary of Marlborough. Three small ponds comprising the study area, Hager Pond, Grist Millpond, and Carding Millpond (fig. 1), lie in the headwaters of Hop Brook. The ponds drain from one to the other and into Hop Brook which is in the Merrimack River basin. The topography of the area has been modified by glaciers. Much of the area, including the bottom of the ponds, is covered by up to 28 feet of unconsolidated sands and gravels that were laid down in unnamed glacial lakes near Marlborough or as part of glacial Lake Sudbury (Nelson, 1974). Higher areas contain mostly unstratified and poorly sorted deposits of till. Bedrock underlying the study area is mostly igneous rock that ranges from quartz monzonite to quartz diorite. Principal minerals in the bedrock are quartz, perthite and microcline, plagioclase, biotite, muscovite, epidote, and hornblende (Nelson, 1975). The drainage basin generally consists of forests in higher areas and wetlands in lower areas. Relatively few homes have been built within the drainage basin, however, those present are on large lots.

As discussed later in the report, the effluent from the wastewater treatment plant constitutes 50 percent or more of the inflow to Hager Pond during much of the year. Hager Pond is about 25 acres in area, has a mean depth of 5 feet, and contains about 124 acre-feet of water (U.S. Environmental Protection Agency, 1975). Outflow from Hager Pond enters the smaller, elongated Grist Millpond, which has a surface area of about 12.5 acres. Grist Millpond drains into Carding Millpond, which is the largest of the three ponds, with a surface area of 31 acres. MDWPC (1980) reports a mean depth of 2.5 feet for Hager Pond, 2.1 feet for Grist Millpond, and 1.7 feet for Carding Millpond. From Carding Millpond, Hop Brook flows into Sterns Millpond, which was not included in the study.

A time-of-travel study, conducted by MDWPC on December 4-5, 1973 (Paul Hogan, MDWPC, written commun., 1980), determined that the leading edge of the dye used as a tracer took 6.75 hours to pass from the inlet to the outlet of Hager Pond, 19 hours to travel from the outlet of Hager Pond to the Outlet of Grist Millpond, and 22 hours from the outlet of Grist Millpond to the outlet of Carding Millpond. No measurement of streamflow was made during the time-of-travel study, however, records from Boulder Brook at East Bolton (U.S. Geological Survey, 1975 and 1980), which is about 8 miles northwest of Hager Pond, were used to estimate a discharge of 3 to 3.5 ft^3/s at the outlet of Hager Pond during the time-of-travel study.

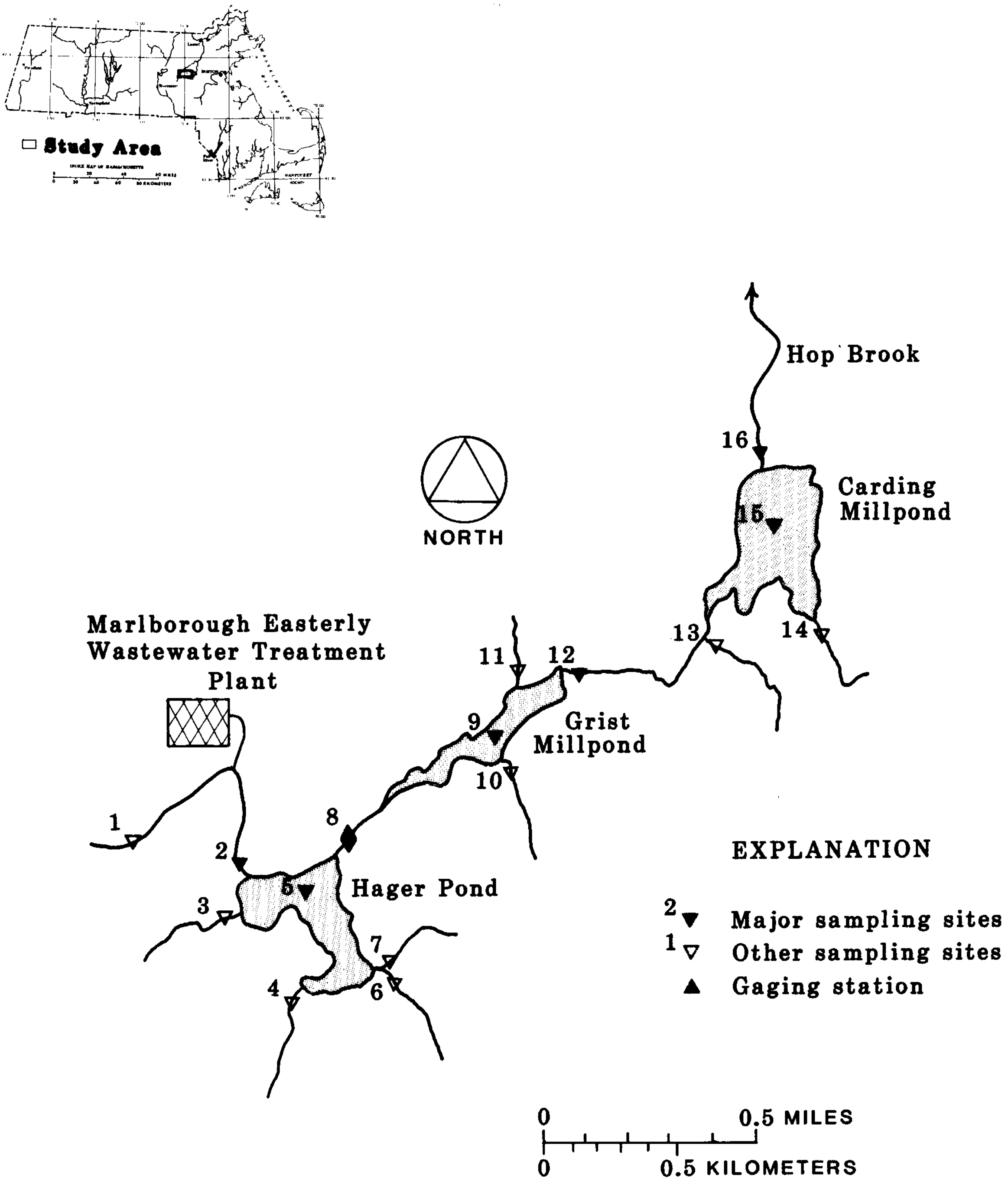

Figure 1.--Study area showing pond system, sampling sites, and wastewater treatment plant.

METHODS OF STUDY

Sampling locations are listed by site name and number in table 1 and are identified by number in figure 1. Sites were chosen to measure all surface-water inflow and outflow from the individual ponds. The seven major sampling sites had a seasonal sampling frequency which was approximately bimonthly from April through November during the study. That frequency was chosen to represent the beginning of the algal growing season, the spring maximum, the late summer period, and the fall die-off. Major sampling sites were established where there were the largest flows and on the ponds themselves. Site 2, Hager Pond tributary, which includes the effluent from the wastewater treatment plant, was sampled just upstream from where it enters Hager Pond. This tributary is the major source of water to the three-pond system. Hager Pond, site 5, was sampled midway between the major inflow, site 2, and the outflow, site 8. Grist Millpond and Carding Millpond were also sampled midway between points of major inflow and outflow (sites 9 and 15, respectively) and at their outflows (sites 12 and 16, respectively).

An additional nine sites were sampled only once at a low-flow period in November 1976. During most periods, their flows were not a significant contribution to the pond system.

Table 1.—Sampling sites in the study area

[Major sampling sites are those sampled seasonally; secondary sampling sites are those sampled once.]

Site number	Sampling site and remarks	Sampling frequency
1	Unnamed tributary to Hager Pond. Sampling point is upstream of inflow from treatment plant effluent.	November 1976, only
2	Unnamed tributary to Hager Pond. Sampling point is downstream of inflow of treatment plant effluent.	Seasonal
3	Unnamed tributary to Hager Pond.	November 1976, only
4	Unnamed tributary to Hager Pond.	November 1976, only
5	Hager Pond. Approximate center of pond.	Seasonal
6	Unnamed tributary to Hager Pond.	November 1976, only
7	Unnamed tributary to Hager Pond. No flow at time of sample collection. No sample collected.	November 1976, only
8	Hager Pond Outlet. Inflow to Grist Millpond. Streamflow gaging station.	Seasonal
9	Grist Millpond. Approximate center of pond.	Seasonal
10	Unnamed tributary to Grist Millpond.	November 1976, only
11	Unnamed tributary to Grist Millpond.	November 1976, only
12	Grist Millpond Outlet. Inflow to Carding Millpond.	Seasonal
13	Unnamed tributary to Carding Millpond.	November 1976, only
14	Unnamed tributary to Carding Millpond.	November 1976, only
15	Carding Millpond. Approximate center of pond.	Seasonal
16	Outlet of Carding Millpond. Beginning of Hop Brook.	Seasonal

Characteristics measured at the major sampling sites are shown in table 2. The tributaries to the pond system and the outflows were sampled by fluvial-sediment sampling techniques described by Guy and Norman (1970). Use of these techniques ensured that samples collected for analysis of total constituents contained a representative subsample of both the dissolved and suspended material passing through the stream cross section at the time of sampling. The term "total" applied to a measured constituent means that the sample consisted of a water-suspended sediment mixture and that the analytical method determines all the constituent in the sample. In the ponds, composite samples were collected from the water column using a weighted bottle that was raised and lowered at a constant rate of speed. The lower 1 foot of the water column was not sampled to prevent incorporating any disturbed bottom material into the sample. Collection of a composite sample of the water column was chosen rather than samples at specific depths because of the shallow depth of the three ponds.

Stream-discharge measurements were made with current meters using the techniques described by Carter and Davidian (1968). At the time of sample collection, specific conductance and pH were measured by methods described by Wood (1976), and dissolved-oxygen concentration and temperature were measured in the stream or pond with a dissolved-oxygen meter and techniques described in Skougstad and others (1979). Samples collected for laboratory analyses were preserved in the field and immediately shipped to the Geological Survey laboratory in Atlanta, Georgia, or in Albany, New York. Sample preservation and analytical methods are described in Skougstad and others (1979), Greeson and others (1977), and Greeson (1979).

Table 2.—Characteristics measured at the major sampling sites

Field determinations	Major nutrients	Biological characteristics
Discharge	Nitrogen	Algal growth potential
Water temperature	Total nitrogen	Phytoplankton, enumeration and identification of predominant genera (ponds only)
pH	Total organic nitrogen	
Specific conductance	Total ammonia nitrogen	
Dissolved oxygen	Total nitrite nitrogen	
	Total nitrate nitrogen	
	Phosphorus	
	Total phosphorus	
	Total ortosphosphate	

ADDITIONAL CONSTITUENTS MEASURED DURING THE STUDY

Common constituents:

Calcium, magnesium, sodium, potasium, silica, carbonate, bicarbonate, chloride, sulfate, hardness, and noncarbonate hardness

Trace elements:

Arsenic, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, selenium, and zinc

Organic constituents:

Polychorinated biphenyls, polychlorinated napthalenes, aldrin, chlordane, DDD, DDE, DDT, dieldrin, endosulfan, endrin, heptachlor, heptachlor epoxide, lindane, mirex, perthane, and toxaphene

All analytical determinations from samples collected during the study are given in tables 14-16. The following sections are concerned only the measured characteristics that directly influence the nuisance-algal problem in the pond system. Streamflow, nitrogen, phosphorus, phytoplankton, algal growth potential, and other measures of the trophic status of the ponds are discussed in detail. For reading ease, tables of data in the following sections list only the month in which a sample was collected; specific dates for each sample are listed in tables 14-16. During any given sampling period, all sites usually were visited within 2 consecutive days.

STREAMFLOW

A gaging station was established in January 1977 at the outlet of Hager Pond (site 8) to provide a daily record of discharge. Records of daily mean streamflow at the station are included in table 17. In addition, instantaneous streamflow measurements were made at each stream sampling site and are listed in tables 15 and 16. The measured discharges for the major sampling sites are listed in table 3.

During most sampling periods, the flow entering Hager Pond at site 2, listed in table 3, was approximately equal to the amount leaving the system at Carding Millpond outlet. During April 1977 and 1978, the smaller tributaries entering the system provided a significant amount of inflow, as much as 60 percent. These were the only sampling periods when the small tributaries were major contributors to the system.

Table 3.—Instantaneous streamflow, in cubic feet per second, at the major sampling sites

Date	Site name and number[1]						
	Tributary to Hager Pond (2)	Hager Pond (5)	Hager Pond Outlet (8)	Grist Millpond (9)	Grist Millpond Outlet (12)	Carding Millpond (15)	Carding Millpond Outlet (16)
1976							
November	4.9	—	2.8	—	4.2	—	4.6
1977							
April	17	—	19	—	31	—	29
June	5.1	—	4.2	—	5.4	—	5.2
August	3.9	—	3.0	—	3.2	—	2.7
October	6.5	—	5.5	—	3.7	—	12
1978							
April	11	—	14	—	22	—	27
June	5.8	—	4.8	—	5.2	—	6.0
July	4.1	—	3.3	—	3.1	—	2.6
August	4.9	—	2.3	—	3.6	—	2.8
November	4.1	—	5.1	—	3.4	—	3.6

[1] See figure 1 for site locations.

The wastewater treatment plant contributes a significant amount of the inflow to the system. Figure 2 illustrates the significance of this contribution. Selected daily average streamflows from the gaging station at Hager Pond Outlet (site 8) are plotted against the daily average percentage of treatment plant effluent in the streamflow at Hager Pond Outlet. Daily average flows of effluent were obtained from the treatment plant operators. Monthly average flows are (table 17). Figure 2 shows that, at flows of about 9 ft^3/s or less from Hager Pond, 50 percent or more of the flow is from the wastewater treatment plant. At flows as low as 2 to 3 ft^3/s, 90 percent or more of the flow is contributed by the plant. During the 1977 and 1978 calendar years, the annual mean discharge at site 8 was 7.3 ft^3/s and 6.3 ft^3/s, respectively. The monthly mean discharge for the summer months, shown in table 17, was considerably less than the annual mean discharge with a low of 2.6 ft^3/s in September 1978.

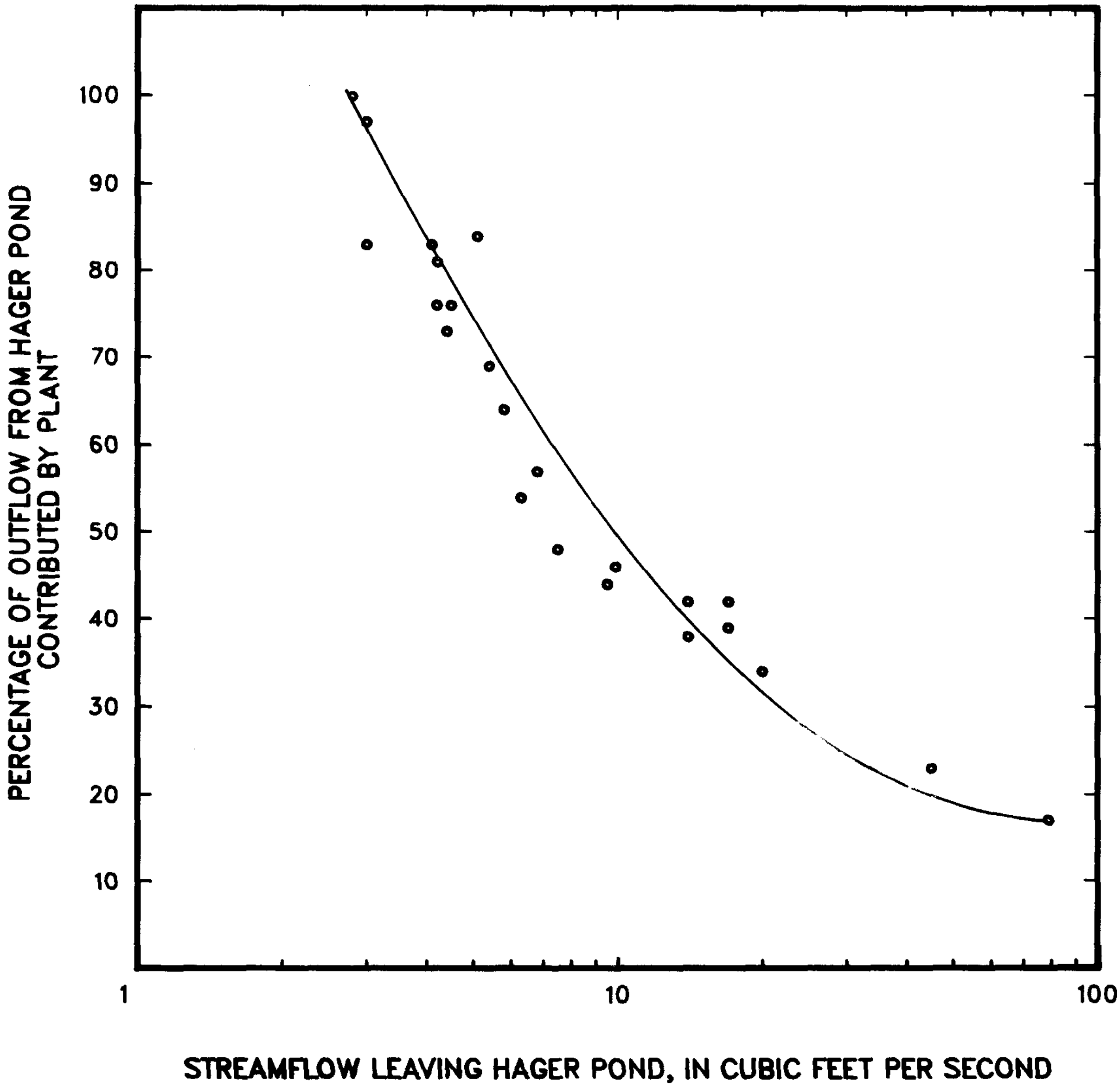

Figure 2.-- Percentage of contribution of wastewater treatment plant effluent to the flow from Hager Pond.

Storage and release of water from the ponds and the large inflow from the wastewater treatment plant helps explain most variations in flow between sites, such as shown in table 3 for the August 1978 sampling period. Flows for the four major streamflow sites (sites 2, 8, 12, and 16) were 4.9, 2.3, 3.6 and 2.8 ft^3/s, respectively. Flow from the wastewater treatment plant varied from 0.2 to 3.5 ft^3/s over the same sampling period. During wet periods, the daily average flow from the wastewater treatment plant was higher, in some instances exceeding 13 ft^3/s. This variation in flow from the treatment plant, coupled with the natural cycles of storage and release of each pond, evapotranspiration, and traveltimes through each pond, could account for the variations in streamflows at the time of sampling.

Losses of pond water to evapotranspiration, evaporation from water surfaces, and transpiration from the plants and trees in or adjacent to the water bodies, could be a significant fraction of the water moving within the ponds during the summer months. Frimpter (1981) shows evapotranspiration at Hyannis, Mass., as high as 5 inches per month during the summer. Using evapotranspiration of 3.5 inches per month as an example, the flow at the Carding Millpond outlet could be reduced by 0.5 ft^3/s. During a particularly dry and hot period, this loss would be higher.

WATER QUALITY

Nitrogen

Different forms of nitrogen were included for analysis in this study (table 2). "Total" in all cases refers to the samples which have not been filtered and are, therefore, composed of both dissolved and suspended particulate material. As mentioned previously, these samples were collected using suspended-sediment sampling techniques to ensure that the sample was representative of both the dissolved and particulate material present in the stream or pond.

The most common nitrogen forms found in water are nitrate, nitrite, ammonia, and organic nitrogen. Organic nitrogen is nitrogen which is included within complex carbon-containing molecules formed by plants and animals. Waste material from plants and animals, as well as their remains after death, are decomposed by bacterial action releasing nitrogen compounds. Organic compounds containing nitrogen are further broken down by bacteria into ammonia. Ammonia is converted by bacteria to nitrite and then into nitrate in the presence of oxygen. This biological conversion of organic and inorganic nitrogen compounds from a reduced state to a more oxidized state is termed "nitrification." Nitrification occurs only when there is a supply of oxygen available.

All forms of nitrogen may enter a lake or pond from a number of sources. These include atmospheric deposition, fixation of elemental nitrogen from the atmosphere by blue-green algae, release of nitrogen from the bottom sediments, input from ground water, and input from the tributaries which enter the pond system. Sources of nitrogen in the waters of tributaries can be either natural, such as leaf material, or man-induced such as agricultural fertilizers or wastewater treatment plant effluents.

The water leaving the pond system can remove nitrogen as either dissolved material or suspended particulate material, such as algae. Nitrogen also may be incorporated into floating and emergent plants in the shallow areas of the ponds. This nitrogen can be released back to the water when the plant dies and decomposes. Nitrogen can be moved from the water column to the bottom sediments by being sorbed to bottom materials or by being incorporated in the bottom sediments when algae or other plant material settles to the pond bottom. However, part of the organic matter on the bottom of shallow ponds may be decomposed and released back into the water. Nitrogen also may be removed by denitrification which proceeds most rapidly under low oxygen conditions and high water temperatures. As dissolved-oxygen levels decrease and approach zero, certain types of bacteria can use the oxygen in the nitrate and nitrite ions as a source of oxygen and, in the process, convert the ions into nitrogen gas. Nitrogen gas can then be lost to the atmosphere or be used by blue-green algae before reaching the atmosphere.

The process of gain and loss of nitrogen within a pond system, as well as the transformation of the forms of nitrogen, is termed the nitrogen cycle. A more complete discussion of the cycle as it applies to aquatic ecosystems is given by Wetzel (1975, chapter 11).

Organic Nitrogen

The values for organic nitrogen at the major sampling sites are listed in table 4. Site 2, which includes the effluent from the wastewater treatment plant, shows a considerable variation in the concentrations of organic nitrogen, which ranged from 0.10 to 2.0 mg/L (milligrams per liter). These concentrations are low for waters containing effluent from a wastewater treatment plant and reflect the treatment process used by the plant to oxidize the organic nitrogen to the nitrate form. For most sampling periods, organic nitrogen remained at about the same concentration throughout the pond system or increased slightly in Carding Millpond and in the water leaving that pond. Blue-green algae, which will be discussed later, were found to predominate in Carding Millpond in the late summer and early fall period, replacing green algae which were dominant earlier. These algae have the ability to "fix" elemental nitrogen; that is, to convert elemental nitrogen into a form usable by the algae as a nutrient source. This adds nitrogen to the system, part of it as organic nitrogen bound up in the algal cell. As the blue-green algae grow, they secrete dissolved organic compounds containing nitrogen. The increase in organic nitrogen seen in Carding Millpond and the outflow from the pond may have been the result of nitrogen fixation by the blue-green algae and release of nitrogen compounds from the decaying remains of green algae.

Table 4.—Concentrations of total organic nitrogen as N, in milligrams per liter, at the major sampling sites

Date	Site name and number[1]						
	Tributary to Hager Pond (2)	Hager Pond (5)	Hager Pond Outlet (8)	Grist Millpond (9)	Grist Millpond Outlet (12)	Carding Millpond (15)	Carding Millpond Outlet (16)
1976							
November	0.90	—	1.2	—	—	—	1.5
1977							
April	1.2	1.2	.93	0.98	0.99	0.92	.95
June	2.0	1.2	1.3	.97	1.3	1.7	2.0
August	.10	1.5	2.2	1.9	1.4	1.8	2.1
October	1.2	1.3	1.2	1.4	1.2	1.9	1.8
1978							
April	.86	.59	.53	.53	.41	.47	.28
June	.40	2.0	1.9	1.4	1.7	1.8	.80
July	1.9	1.8	2.2	2.4	2.8	3.1	2.7
August	1.2	3.1	2.4	3.0	1.6	3.0	2.8
November	1.5	1.8	1.7	2.1	1.8	2.2	2.7

[1] See figure 1 for site locations.

Ammonia Nitrogen

Total ammonia nitrogen concentrations in the pond system are shown in table 5. Amounts of ammonia nitrogen entering Hager Pond at site 2 ranged from 0.29 to 0.88 mg/L, while concentrations in Hager Pond ranged from 0.15 to 1.1 mg/L. Ammonia nitrogen concentrations generally decreased when bacteria converted ammonia to nitrite as the water moved through the pond system.

Table 5.--Concentrations of total ammonia nitrogen as N, in milligrams per liter, at the major sampling sites

[Values marked with an asterisk exceed criterion of 0.02 mg/L of un-ionized ammonia nitrogen established for the protection of freshwater aquatic life (U.S. Environmental Protection Agency, 1976).]

Date	Site name and number[1]						
	Tributary to Hager Pond (2)	Hager Pond (5)	Hager Pond Outlet (8)	Grist Millpond (9)	Grist Millpond Outlet (12)	Carding Millpond (15)	Carding Millpond Outlet (16)
1976							
November	0.50	—	0.34	—	—	—	0.17
1977							
April	.63	0.44	.57	0.32	0.21	0.08	.15
June	.71	.60	.51	.53	.24	*.36	*.48
August	.31	*.15	*.14	*.21	*.20	.02	.74
October	.47	.75	.66	.33	.18	*.14	.12
1978							
April	.74	.71	.47	.35	.33	.24	.24
June	.52	*.33	*.14	*.38	*.49	*.54	*.50
July	.88	*1.1	*1.5	*.33	*.40	.01	*.05
August	.29	*.95	*.62	*.07	*.42	*.23	*.23
November	.87	.50	.41	.31	.30	*.18	*.23

[1]See figure 1 for site locations.

Although the concentrations of ammonia seem to be low compared to that of nitrate (discussed in a later section of the report), the ammonia concentrations are sufficiently high to cause problems for susceptible fish species living in the lakes. U.S. Environmental Protection Agency (1976) lists a criterion of 0.02 mg/L un-ionized ammonia for protection of freshwater aquatic life. Ammonia dissolved in water forms a chemical equilibrium between un-ionized ammonia (NH_3) and ionized ammonia (NH_4^+). The concentrations shown in table 5 are for both the ionized and the un-ionized forms. The toxicity of ammonia in freshwater systems is attributed to the un-ionized species. Because the equilibrium between ionized and un-ionized ammonia is dependent on pH and temperature, the total ammonia nitrogen value, which was reported, must be mathematically converted to an un-ionized ammonia value. The periods during which the 0.02 criterion was exceeded are shown in table 5.

Nitrite Nitrogen

Concentrations of nitrite nitrogen, which may result from the oxidation of ammonia nitrogen by *Nitrosomonas* bacteria, are shown in table 6. Concentrations of nitrite nitrogen entering the system at site 2 are low; most samples contained less than 0.03 mg/L. During sampling periods in the early spring and late fall, when the pH was near 7, nitrite nitrogen concentrations remained less than 0.1 mg/L throughout the pond system. However, during the summer periods, active algal growth produced an increase in pH to well above 8. Concentrations of nitrite nitrogen may increase during these periods because the bacteria, *Nitrobacter*, which is primarily responsible for oxidizing nitrite to nitrate, is less tolerant of high pH than the bacteria oxidizing ammonia to nitrite. This may have allowed a small accumulation of nitrite in the system. Compared to the concentrations of nitrate nitrogen, however, nitrite nitrogen concentrations remained low at all times.

Table 6.--Concentrations of total nitrite nitrogen as N, in milligrams per liter, at the major sampling sites

Date	Site name and number[1]						
	Tributary to Hager Pond (2)	Hager Pond (5)	Hager Pond Outlet (8)	Grist Millpond (9)	Grist Millpond Outlet (12)	Carding Millpond (15)	Carding Millpond Outlet (16)
1976							
November	0.01	—	0.09	—	—	—	0.09
1977							
April	.01	0.03	.04	0.03	0.02	0.01	.03
June	.02	.08	.10	.13	.12	.10	.11
August	.01	.29	.29	.36	.37	.03	.08
October	.01	.11	.11	.20	.15	.12	.10
1978							
April	.02	.04	.03	.03	.02	.02	.02
June	.12	.12	.12	.15	.17	.18	.16
July	.17	.30	.32	.28	.25	<.01	.01
August	.06	.13	.16	.23	.17	<.01	<.01
November	.01	.06	.07	.12	.12	.13	.12

[1]See figure 1 for site locations.

Nitrate Nitrogen

The predominant form of nitrogen within the pond system is nitrate nitrogen (NO_3^-). At least 80 percent or more of the nitrogen in the water entering the pond system at site 2 is in the form of nitrate. Nitrate levels (table 7) were high compared to many standards and criteria for the water entering the pond system and remained high through Hager Pond and Grist Millpond. U.S. Environmental Protection Agency (1976) specifies 10 mg/L as the maximum allowable concentration of nitrate nitrogen for drinking-water supplies to provide protection for infants, who are susceptible to methemoglobinemia from ingestion of waters with high nitrate concentrations. Estimates of maximum nitrate concentrations that will not lead to nuisance growths of algae and other aquatic plants are variable. The U.S. Council on Environmental Quality (1975) assigned a maximum concentration of 0.6 mg/L of nitrate nitrogen as a "benchmark" level for aquatic life protection, suggesting that higher levels are indicative of undesirable eutrophication. Other criteria for nitrate nitrogen established by various States to limit eutrophication range from 0.10 mg/L in pristine waters to 3 mg/L in less-sensitive waters. A study of 365 sampling points on major rivers within the United States showed that nitrate nitrogen levels were below 1.0 mg/L at 85 percent of the sites and below 0.5 mg/L at 65 percent of the sites (Briggs and Ficke, 1978).

Table 7.—Concentrations of total nitrate nitrogen as N, in milligrams per liter, at the major sampling sites

Date	Site name and number[1]						
	Tributary to Hager Pond (2)	Hager Pond (5)	Hager Pond Outlet (8)	Grist Millpond (9)	Grist Millpond Outlet (12)	Carding Millpond (15)	Carding Millpond Outlet (16)
1976							
November	18	—	15	—	—	—	7.6
1977							
April	5.7	4.0	5.4	3.7	2.1	1.3	2.3
June	21	13	14	9.9	9.9	5.6	4.8
August	16	9.5	9.7	5.4	4.7	.13	.27
October	16	11	9.9	8.8	8.2	5.4	4.9
1978							
April	6.8	4.8	2.8	2.5	2.3	1.8	1.7
June	18	9.7	9.4	5.6	5.5	2.0	1.8
July	14	5.1	5.3	1.8	1.7	.01	.10
August	4.2	6.1	5.8	1.1	1.0	.01	.14
November	18	16	16	14	14	7.8	7.5

[1]See figure 1 for site locations.

Nitrate nitrogen concentrations in the water entering the pond system were high in comparison to the criteria and examples given above. As explained earlier, the tributary entering Hager Pond at site 2 provided most of the water to the pond system, especially during the drier periods of the year. Even in wet periods, the tributary still accounted for half of the water flowing through the pond system. Because there was no other significant source of water to the system, the nitrate nitrogen concentrations, entering at site 2, were not diluted. Nitrate nitrogen concentrations did decrease as the water moved through the pond system; concentrations were as low as 0.01 mg/L by the time the water reached Carding Millpond.

Total Nitrogen

Total nitrogen (table 8) is the sum of organic nitrogen, ammonia nitrogen, nitrite nitrogen, and nitrate nitrogen. Concentrations of nitrogen in the water leaving Carding Millpond were substantially lower than concentrations in Hager Pond or in the tributary entering Hager Pond. Table 9 shows loads of nitrogen, in pounds per day, entering Hager Pond, moving between ponds, and leaving Carding Millpond. The data in table 9 also show that for all sampling periods, there was net nitrogen removal from the pond waters when comparing site 2 with site 16. Figure 3 shows the amount removed during the study. A larger portion of the nitrogen was removed from the water during the summer months. Total nitrogen entering Hager Pond during the sampling periods of June, July, and August 1978 ranged from 153 to 594 pounds per day. Nitrogen leaving Carding Millpond during the same period ranged from 39 to 107 pounds per day.

Table 8.—Concentrations of total nitrogen as N, in milligrams per liter, at the major sampling sites

Date	Site name and number[1]						
	Tributary to Hager Pond (2)	Hager Pond (5)	Hager Pond Outlet (8)	Grist Millpond (9)	Grist Millpond Outlet (12)	Carding Millpond (15)	Carding Millpond Outlet (16)
1976							
November	19	—	17	—	—	—	9.4
1977							
April	7.5	5.6	6.9	5.0	3.3	2.3	3.4
June	24	15	16	12	12	7.8	7.4
August	16	11	12	7.9	6.7	2.0	3.2
October	18	13	12	11	9.7	7.5	6.9
1978							
April	8.4	6.1	3.8	3.4	3.0	2.5	2.2
June	19	12	12	7.5	7.9	4.5	3.3
July	17	8.3	9.3	4.8	5.1	3.1	2.8
August	5.8	10	9.0	4.4	3.2	3.2	3.1
November	20	18	18	16	16	10	11

[1] See figure 1 for site locations.

Table 9.—Total nitrogen loads as N, in pounds per day, at the major sampling sites

Date	Tributary to Hager Pond (2)	Hager Pond (5)	Hager Pond Outlet (8)	Grist Millpond (9)	Grist Millpond Outlet (12)	Carding Millpond (15)	Carding Millpond Outlet (16)
	Site name and number[1]						
1976							
November	502	—	257	—	—	—	233
1977							
April	688	—	707	—	552	—	531
June	660	—	362	—	350	—	208
August	337	—	194	—	116	—	47
October	631	—	356	—	194	—	447
1978							
April	498	—	287	—	356	—	320
June	594	—	310	—	222	—	107
July	376	—	166	—	85	—	39
August	153	—	112	—	62	—	47
November	442	—	495	—	293	—	214

[1] See figure 1 for site locations.

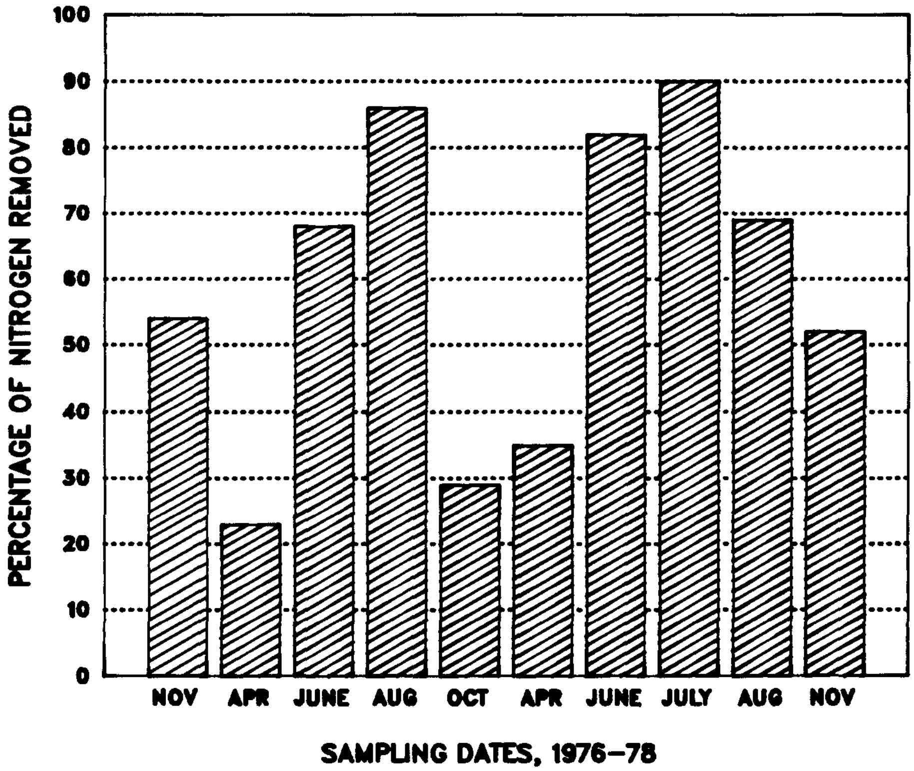

Figure 3.—Percentage of total nitrogen removed from the water column during transit through the ponds

Nitrogen is removed from the water column by two pathways—sedimentation and denitrification. Sedimentation occurs when organic material is incorporated into the bottom sediments. As the abundant algae and other aquatic plants die, their remains may sink to the bottom of the pond. If the material accumulates faster than it can be released, there will be a net loss of nitrogen into the bottom sediments. Nitrogen can be released back to the water column by a number of mechanisms, such as by decomposition of organic materials on the bottom, by rooted aquatic plants absorbing nutrients from the bottom sediments, and by disturbance of the bottom sediments by burrowing aquatic organisms.

Denitrification is the process by which nitrate is converted to elemental nitrogen gas. When the dissolved-oxygen concentration is zero or near zero, many bacteria are able to use nitrate as a source of oxygen to oxidize organic substances. Nitrate is converted to nitrogen gas which can be released to the atmosphere, thereby losing it from the system. The ponds in this study are particularly well adapted to denitrification. The ponds are shallow with an average depth of 5 feet or less. Jones and Simon (1981) found that the rate of denitrification and production of nitrogen gas was significantly faster in shallow water bodies (5 feet) compared to deep lakes. Dissolved-oxygen measurements in the pond indicated that the upper part of the water column had abundant oxygen during daylight hours. In the bottom 1 foot of the water column, the dissolved-oxygen concentration approached zero. Unlike deeper lakes, which will stratify during the summer with little mixing between the upper and the lower layers of water, the three ponds of this system are mixed by wind and wave action throughout the summer season. Fresh supplies of nitrate were available to the bottom sediments, and the bottom layer of water and could be used to oxidize the abundant organic material.

Rates of sedimentation and denitrification were not measured during the study; however, some estimate of the relative rates of the two can be made. Jones and Simon (1981) report that their literature review shows denitrification rates reported to be in the range of 0.8 to 6.0 millimoles per square meter per day (0.01 to 0.08 grams per square meter per day). The higher rates were in the more eutrophic water bodies. Applying the higher rate to the three ponds gives potential nitrogen removal rates of 19 pounds per day in Hager Pond, 9 pounds per day in Grist Millpond, and 23 pounds per day in Carding Millpond. Using the values shown in table 9, the average decrease in nitrogen load was 163 pounds per day in Hager Pond, 77 pounds per day in Grist Millpond, and 29 pounds per day in Carding Millpond. Comparison of the actual nitrogen removed from the water in the ponds and the calculated maximum nitrogen loss by denitrification, suggests that much of the nitrogen remains in the sediments of the ponds.

Phosphorus

Phosphorus data are reported as total phosphorus as P and total orthophosphate phosphorus as P. Total phosphorus includes all forms of phosphorus, such as soluble orthophosphate, soluble hydrolyzable phosphorus, soluble organic phosphorus, collodial material, and both inorganic and organic suspended materials. A large proportion of the phosphorus in the water column of a lake usually is bound organically as organic phosphates in the cellular material of the algae, vascular plants, and bacteria living in the water and sorbed or associated with inorganic and organic particulate matter. The previous discussion of nitrogen pointed out that there were several forms of inorganic nitrogen of importance to the aquatic plants of the pond system. Phosphorus, in contrast, has only one significant inorganic species, orthophosphate, which is readily available as a plant nutrient. Other species of phosphorus are in forms which are not available as nutrients to aquatic plants. These other species are important because they may be converted into orthophosphate and then may be available for plant growth.

Orthophosphate Phosphorus

Concentrations of orthophosphate phosphorus measured within the pond system are shown in table 10. Concentrations of orthophosphate phosphorus generally were highest at site 2 and decreased in Hager Pond and the other two ponds. Soluble orthophosphate is the form most available to the algae and bacteria as a nutrient source. Cycling of orthophosphate into particulate forms and then back to a soluble form can occur quickly. For example, orthophosphate can be taken up by algae, converted to organic phosphorus, and then excreted by the algae as a waste product. When algae die, their remains rapidly break down releasing soluble phosphate.

Table 10.—Concentrations of total orthophosphate phosphorus as P, in milligrams per liter, at the major sampling sites

Date	Site name and number[1]						
	Tributary to Hager Pond (2)	Hager Pond (5)	Hager Pond Outlet (8)	Grist Millpond (9)	Grist Millpond Outlet (12)	Carding Millpond (15)	Carding Millpond Outlet (16)
1976							
November	0.21	—	0.17	—	—	—	0.16
1977							
April	.08	0.03	.07	0.05	0.03	0.02	.03
June	1.2	.16	.20	.11	.12	.13	.14
August	.80	.19	.20	.12	.11	.11	.24
October	.46	.14	.12	.09	.06	.06	.08
1978							
April	.14	.10	.05	.06	.05	.04	.04
June	.34	.26	.18	.21	.25	.23	.25
July	.10	.26	.22	.29	.25	.31	.27
August	.30	.28	.25	.14	.23	.31	.35
November	.42	.49	.38	.37	.31	.12	.12

[1] See figure 1 for site locations.

Total Phosphorus

Concentrations of total phosphorus within the pond system are shown in table 11. Total phosphorus is generally regarded as the measurement most critical in determining availability of phosphorus for algal and bacterial growth. U.S. Environmental Protection Agency (1976) discusses a proposed criterion designed to prevent or control nuisance aquatic-plant growth. This criterion proposes that total phosphorus levels not exceed 0.05 mg/L for any stream at the point where it enters a lake or reservoir or not exceed 0.025 mg/L within the lake or reservoir. USEPA uses the term "total phosphates" which is equivalent to the use by the Survey of the term "total phosphorus." The concentrations shown in table 11 are higher than the proposed criterion by an order of magnitude or more. Within the ponds, phosphorus was abundant at all sites. The total phosphorus concentrations were far in excess of the proposed criterion for prevention of nuisance aquatic-plant growth.

Table 11.—Concentrations of total phosphorus as P, in milligrams per liter, at the major sampling sites

Date	Site name and number[1]						
	Tributary to Hager Pond (2)	Hager Pond (5)	Hager Pond Outlet (8)	Grist Millpond (9)	Grist Millpond Outlet (12)	Carding Millpond (15)	Carding Millpond Outlet (16)
1976							
November	0.66	—	0.44	—	—	—	0.31
1977							
April	.34	0.22	.22	0.12	0.16	0.14	.16
June	3.0	.54	.51	.26	.23	.29	.33
August	2.1	.51	.44	.38	.26	.36	.54
October	1.7	.63	.46	.40	.26	.34	.33
1978							
April	.43	.29	.16	.16	.15	.10	.10
June	.58	.55	.48	.38	.45	.38	.36
July	.49	.47	.47	.54	.56	.53	.46
August	.76	.60	.34	.45	.34	.66	.60
November	.79	.70	.60	.45	.41	.24	.31

[1] See figure 1 for site locations.

Another way of expressing the amount of phosphorus which will cause undesirable aquatic growth within a lake is the annual phosphorus loading to the lake. Certain factors affect the amount of phosphorus loading that a lake may receive and yet still maintain a phosphorus level which will not cause excessive aquatic-plant growth. These factors include the surface area of the lake, the depth, and the amount of water entering the lake. From assessment of data on numerous lakes, R. A. Vollenweider developed the following equation (as expressed in Hammer and Mac Kichan, 1981):

$$P = \frac{L/q}{1+(z/q)^{0.5}} = \frac{Lt/z}{1+(t)^{0.5}} \qquad (1)$$

where P = phosphorus concentrations in lake water, in grams per cubic meter
L = annual phosphorus loading, in grams per square meter per year
q = annual hydraulic loading, in meters per year, or mean depth/retention time (z/t)
z = mean depth, in meters
t = water renewal time (theoretical water-filling time), in years, or mean depth/hydraulic loading (z/q)

From the examination of data from a number of studies, the commonly accepted (Hammer and Mac Kichan, 1981) critical phosphorus concentration is 10 mg/m^3 (milligrams per cubic meter) or 0.01 mg/L at the end of the spring overturn. At this level or lower, lakes had no excessive algal growth during the growing season. Observed phosphorus levels greater than 20 mg/m^3 (0.02 mg/L) at the spring overturn produce eutrophic conditions. To determine what phosphorous loading is required to produce these phosphorous levels in a lake, equation 1 can be rearranged to:

$$L_c = P_c q \left[1 + \left(\frac{z}{q}\right)^{0.5}\right] = \frac{P_c z}{t}\left[1 + (t)^{0.5}\right] \qquad (2)$$

where L_c = critical annual phosphorus loading, in grams per square meter
P_c = critical phosphorus concentrations at spring overturn, in grams per cubic meter
q = annual hydraulic loading, in meters per year
z = mean depth, in meters
t = water renewal time, in years

From equation 2, critical annual phosphorus loadings for the three ponds in this study may be calculated for the two levels of phosphorus concentrations. Results of these calculations for the 2 calendar years of the study are:

Site	Year	Observed annual phosphorus loading, in grams per square meter	Critical annual phosphorus loading, P_c = 10 mg/m^3, in grams per square meter	Critical annual phosphorus loading, P_c = 20 mg/m^3, in grams per square meter
Hager Pond	1977	115	0.71	1.42
	1978	34	.62	1.23
Grist Millpond	1977	53	1.37	2.74
	1978	45	1.19	2.38
Carding Millpond	1977	12	.57	1.14
	1978	17	.57	1.14

Observed annual phosphorus loading was determined using the average total phosphorus values for each calendar year. The observed phosphorus loadings to Hager Pond, Grist Millpond, and Carding Millpond exceed by over an order of magnitude the values of phosphorus loading that would be expected to cause massive aquatic growth. However, results calculated from the use of equation 2 should be used with some caution in this study. Equations 1 and 2 were developed using data from lakes which were deeper and had a longer water renewal time than Hager Pond, Grist Millpond, and Carding Millpond.

Phosphorus commonly is lost from the water column to the bottom sediments as an inorganic form by processes such as: Phosphorus sorbed onto clays and ferric hydroxide precipitate; phosphorus coprecipitated with iron, manganese, and carbonates; or phosphorus precipitated as apatite or ferric phosphate ($FePO^4$). When dissolved oxygen is available, phosphorous also can be removed from the water column by sorption onto suspended sediment particles such as clays. These sediments can settle and be incorporated into the bottom materials of the pond. Holdren and Armstrong (1980) found that the composition of the bottom sediment is an important factor in the retention of phosphorus. Noncalcarious sediments, those which contain little calcium carbonate, have a higher sorption capacity than do sediments with significant calcium carbonate. The geology of the study area indicates that the sediments in the ponds should be noncalcarious. Neither the bedrock nor the glacial material overlaying the bedrock contain significant quantities of calcium carbonate.

Most of the total phosphorus loss from the water column occurs in Hager Pond with lesser amounts as the water moves through the other two ponds. For each major stream-sampling site, table 12 shows the total phosphorus load, in pounds per day, transported during each sampling period. Phosphorus loads usually decreased by half or more from entering to the system at site 2 to exiting the system at Carding Millpond outlet, site 16.

Table 12.—Total phosphorus loads as P, in pounds per day, at the major sampling sites

Date	Site name and number[1]						
	Tributary to Hager Pond (2)	Hager Pond (5)	Hager Pond Outlet (8)	Grist Millpond (9)	Grist Millpond Outlet (12)	Carding Millpond (15)	Carding Millpond Outlet (16)
1976							
November	17	—	6.6	—	—	—	7.7
1977							
April	31	—	23	—	27	—	25
June	83	—	11	—	6.7	—	9.3
August	44	—	7.1	—	4.5	—	7.9
October	60	—	13	—	5.2	—	21
1978							
April	26	—	12	—	18	—	15
June	18	—	12	—	13	—	12
July	11	—	8.4	—	9.4	—	6.5
August	20	—	4.2	—	6.6	—	9.1
November	17	—	16	—	7.5	—	6.0

[1]See figure 1 for site locations.

Phosphorus can be released in large quantities from the bottom sediments if the sediments become anoxic. This release occurs in several ways, including iron being reduced from the ferric to the ferrous form which is more soluble. Any phosphorus which has sorbed or coprecipitated with the iron will be released to the water when the iron compounds dissolve. Phosphorus sorbed to other materials will also be desorbed under these conditions. However, when the top layer of sediments contains 1 to 2 mg/L of oxygen (Wetzel, 1975), phosphorus is not released from the sediments even though the water contained in the deeper sediments may be totally devoid of dissolved oxygen.

The increased temperature of both the water and sediments during the summer season increases the microbial activity within the sediments. The top layer of oxygenated sediments becomes thiner which increases the ability of the phosphorus to be released from the deeper anoxic sediments especially by bioturbation—the activity of benthic organisms on the top sediment layer. Holdren and Armstrong (1980) found that the presence of tubificids and actively emerging chironomid larvae in the sediments significantly increased the phosphorus release from lake sediments in shallow water areas. However, no information was collected on benthic organism of the three ponds during this study.

Aquatic plants, which are rooted in the bottom sediments and emerge above the water surface, are abundant in Carding Millpond and are present in lesser amounts in the other two ponds. Phosphorus from the sediments is available to the root system of these plants which then can release phosphorus into the water as waste products or as the end result of the decay of the dead plant material. Because of the abundance of these plants, their contribution of phosphorus may be significant but may not be observable in the data because of the much larger amount of phosphorus entering the ponds at site 2.

Comparison of the total phosphorus loads during the summer months between sites 8 and 12 and between sites 12 and 16 indicates that there may have been a net release of phosphorus from the sediments of Grist Millpond and, in particular, Carding Millpond. This release was apparent in 1977 during June, August, and October for Carding Millpond. The data in table 12 show that for all sampling periods, however, there was phosphorus removal from the water in the pond system when comparing the inflow at site 2 with the outflow from the pond system at site 16.

Biological Characteristics

Phytoplankton

Samples were collected from the three ponds for counts of phytoplankton cell numbers and identification to the genus level. Complete results from each sample are included in table 16. During the study period, green algae were always the predominant group found in Hager Pond and Grist Millpond. This group included *Pediastrum*, *Scenedesmus*, and *Chlorella*. Carding Millpond also had these as predominant groups during the spring and late fall periods, but during the summer and early fall, the blue-green alga, *Anacystis*, was predominant. *Anacystis* has the capability of fixing atmospheric nitrogen into a form capable of being used by that alga as a nutrient source, whereas green algae do not. Predominance of *Anacystis* in Carding Millpond came at times when the nitrate concentration was low, but when abundant phosphorus was available for growth. This indicates that during summer months, sufficient nitrogen may have been removed to make nitrogen the limiting nutrient for green algae in Carding Millpond. Both Hager Pond and Grist Millpond had sufficient supplies of nitrate nitrogen available for green algae to grow and predominate.

Algal Growth Potential

Algal growth potential is the maximum algal mass, as dry weight, that can be produced in a water sample under the standard laboratory conditions. The green alga, *Selenastrum capricornatum*, used as the test organism, is tolerant of a wide variety of water-quality conditions. The algal growth determined using *S. capricornatum* correlates well with algal growth potential determined with species indigenous to waters within various regions of the United States (Maloney and others, 1972). In the procedure used for this study, the sample was filtered through a 0.45-micrometer membrane filter at the time of collection to remove all particulate matter and algal and bacterial cells. Only dissolved nutrients passed through the filter. The sample was innoculated with the test organism and kept under controlled temperature and light conditions. By removing the existing algae from the sample, the algal growth potential provides an estimate of the additional algal growth that could be produced with the available dissolved nutrients.

Table 13 shows the algal growth potential determined at the major sampling sites. High algal growth potential at site 2 is to be expected because the site is immediately downstream from the wastewater treatment plant, a major source of nutrients. There was insufficient contact time from the point the effluent entered the stream to the sampling point for algal growth to take place, therefore, dissolved nutrients were not incorporated into the algal cells. As the water moved through the pond system, dissolved nutrients were incorporated into algal cells or otherwise removed from the water column. When the sample was filtered to remove the particulate material in the water, the resulting algal growth potentials were lower for the downstream sites.

Table 13.—Algal growth potential as dry weight of algal mass, in milligrams per liter, at the major sampling sites

Date	Site name and number[1]						
	Tributary to Hager Pond (2)	Hager Pond (5)	Hager Pond Outlet (8)	Grist Millpond (9)	Grist Millpond Outlet (12)	Carding Millpond (15)	Carding Millpond Outlet (16)
1976							
November	58	105	96	96	96	82	82
1977							
April	24	27	22	26	19	22	26
June	20	57	89	84	26	71	47
August	251	23	40	16	35	—	15
October	126	61	59	50	46	49	29
1978							
April	13	14	—	15	10	10	12
June	126	77	85	77	86	42	85
July	—	—	—	—	—	—	—
August	113	64	84	64	48	6.1	9.9
November	—	—	—	—	—	—	—

[1]See figure 1 for site locations.

Algal growth potentials measured at the major sampling sites within the pond system were high even though the values were somewhat lower at the downstream end of the system. Miller and others (1974) compared the known trophic state of 23 United States lakes with results from algal growth potential tests. They defined four productivity classes based on the algal growth potential measured in those lakes: (1) Low productivity (0.00-0.10 mg/L); (2) moderate productivity (0.11-0.80 mg/L); (3) moderately high productivity (0.81-6.00 mg/L); and (4) high productivity (6.10-20.00 mg/L). Table 13 shows that, for all samples, algal growth potential was in or above the high productivity class. The values were 6.1 mg/L and greater, with the highest, 251 mg/L, measured at site 2. Miller and others (1974) found that, of the 23 lakes in their study, all those with moderately high and high productivity were classified by other measurements as eutrophic.

ALTERNATIVES FOR WATER QUALITY IN THE POND SYSTEM

An objective of this study was to estimate future water-quality conditions of the pond system. One possibility is straightforward--if the concentrations of nitrogen and phosphorus found during the study continue to enter the pond system, no improvement can be expected in the water-quality conditions. Concentrations of nitrogen and phosphorus entering Hager Pond far exceed levels known to produce undesirable growths of aquatic vegetation. The nuisance growth of algae and other aquatic plants during the summer months and the wide variations in dissolved-oxygen concentration and pH can be expected to continue in all three ponds.

For the water quality of the pond system to improve, concentrations of phosphorus entering the pond must be reduced by an order of magnitude or more. It is beyond the scope of this report to discuss the engineering and economic feasibility of treating the water that enters Hager Pond so that phosphorus loads are sufficiently low to prevent the growth of excessive aquatic plants.

Diversion of the wastewater treatment plant effluent to another stream basin has been suggested as a way of reducing the phosphorus loads to the pond system (Warren Kimball, MDWPC, written commun., 1982). This action would significantly reduce the flow of water through the pond system. Effluent from the wastewater treatment plant accounted for most of the flow during the late summer and early fall and accounted for about 55 percent of the total flow during the study period. This reduced flow could prolong the recovery period of the ponds.

Assuming that a way can be found to reduce adequately the phosphorus loading to the pond system, the water quality of ponds would be expected to improve. How quickly the water quality improved would depend on many factors, including the quantity and quality of the inflow to the ponds, the amount of phosphorus in the sediment and interstitial water of the sediment, the phosphorus release rate from the sediment, and the phosphorus sedimentation rate. A mathematical model that incorporates these factors to predict the recovery of an eutrophic lake was developed by Bingham and Feng (1980), based on earlier work by Snow and DiGiamo (1976). This model was developed for Lake Warner in North Hadley, Massachusetts, which has certain similarities to the ponds in this study: Lake Warner and the ponds in this study received effluent from a wastewater treatment plant, are shallow lakes (5 feet average depth), and have a short hydraulic retention time. Significant differences between Lake Warner and the ponds in this study are that concentrations of phosphorus at the start of Lake Warner's recovery are much lower (0.09 mg/L), and effluent from the wastewater treatment plant contributes a much smaller fraction of the total inflow to Lake Warner.

In order to apply the Bingham and Feng model to Hager Pond, Grist Millpond, and Carding Millpond, a decision must be made on how the nutrient concentrations of the inflow to the ponds will be reduced and to what level. This will affect the concentration of nutrients and the volume of inflow. Additional data must be collected from the ponds including the phosphorus concentrations of the interstitial water and the total phosphorus concentration in the sediment. Because the phosphorus load entering Hager Pond has been significantly higher, the phosphorus release rate coefficient and the phosphorus sedimentation coefficient probably should be determined in situ for these ponds rather than using the values determined by Snow and DiGiamo (1976) for Lake Warner.

SUMMARY

The headwaters of Hop Brook near Marlborough, Mass., contain three in-line ponds—Hager Pond, Grist Millpond, and Carding Millpond. Throughout much of the year the Marlborough Easterly Wastewater Treatment Plant contributes a significant amount of the inflow to Hager Pond. During the summer months, when flows are as low as 2 to 3 ft^3/s, 90 percent or more of the flow is contributed by the plant.

The bulk of the nitrogen entering Hager Pond is in the form of nitrate nitrogen. Nitrate levels, in water entering Hager pond, were high compared to standards and criteria set to avoid nuisance growth of aquatic plants, ranging from 4.2 to 18 mg/L. Nitrate nitrogen concentrations decreased as the water moved through the pond system; concentrations were a low as 0.01 mg/L in Carding Millpond, the most downstream pond. Total nitrogen concentrations decreased in the water as the it moved through the ponds. Part was probably removed by denitrification but much of the nitrogen was incorporated into the bottom sediments of ponds.

Concentrations of total phosphorus entering Hager Pond ranged from 0.08 to 1.2 mg/L; well above the USEPA suggested maximum level of 0.05 mg/L for waters entering a lake. Total phosphorus levels remained high throughout the pond system with concentrations of phosphorus leaving Carding Millpond ranging from 0.03 to 0.35 mg/L. A comparion of the inflow to Hager Pond with the outflow from Carding Millpond, indicates there was phosphorus removal from the water at each sampling period. During the summer months there may be a net release of phosphorus from the bottom sediments of Grist Millpond and Carding Millpond. The observed phosphorus loadings to the three ponds exceed by over an order of magnitude the values of phosphorus loading that would be expected to cause nuisance growths of aquatic plants.

Blue-green algae, found in Carding Millpond during the summer months, along with the low nitrate concentrations, indicate that nitrogen may be the limiting nutrient for green algae in Carding Millpond. Both Hager Pond and Grist Millpond had sufficient supplies of nitrate nitrogen available for green algae to grow and predominate. Algal growth potential tests at all sites indicated a high productivity.

As long as concentrations of nitrogen and phosphorus found during the study continue to enter the pond system, no improvement can be expected in the existing water-quality conditions. Concentrations of nitrogen and phosphorus entering Hager Pond exceed levels known to produce undesirable growths of aquatic vegetation. The nuisance growth of algae and other aquatic plants during the summer months and the wide variations in dissolved-oxygen concentrations and pH can be expected to continue in all three ponds.

Table 14.--Chemical and physical data for major sampling sites

DATE	TIME	STREAM-FLOW, INSTAN-TANEOUS (CFS)	SPE-CIFIC CON-DUCT-ANCE (UMHOS)	PH (UNITS)	TEMPER-ATURE (DEG C)	OXYGEN, DIS-SOLVED (MG/L)	OXYGEN, DIS-SOLVED (PER-CENT SATUR-ATION)	NITRO-GEN, ORGANIC TOTAL (MG/L AS N)
Site 2								
01098705 - HAGER POND TRIBUTARY AT MARLBOROUGH, MA (LAT 42 21 03 LONG 071 29 29)								
NOV , 1976								
01...	1030	4.9	620	6.2	13.0	10.1	95	.90
APR , 1977								
05...	0800	17	420	6.7	7.5	7.8	65	1.2
JUN								
15...	0730	5.1	710	6.8	18.0	7.7	81	2.0
AUG								
10...	1100	3.9	597	7.2	22.2	8.5	97	.10
OCT								
12...	0900	6.5	740	7.3	16.0	9.2	92	1.2
APR , 1978								
04...	0930	11	460	6.5	6.5	11.4	93	.86
JUN								
21...	1430	5.8	570	6.9	20.5	7.6	84	.40
JUL								
26...	0745	4.1	600	6.6	19.0	6.2	66	1.9
AUG								
23...	1015	4.9	590	6.9	21.5	7.9	89	1.2
NOV								
21...	0730	4.1	540	6.4	10.0	10.5	93	1.5
Site 5								
01098709 - HAGER POND AT MARLBOROUGH, MA (LAT 42 20 57 LONG 071 29 14)								
NOV , 1976								
02...	1030	--	440	7.7	5.5	13.5	107	--
APR , 1977								
05...	1300	--	440	7.2	8.5	9.9	84	1.2
JUN								
14...	0930	--	580	7.3	20.0	8.3	91	1.2
AUG								
11...	0900	--	550	9.9	25.0	16.2	193	1.5
OCT								
13...	0830	--	575	7.0	13.0	11.2	106	1.3
APR , 1978								
05...	0830	--	360	6.7	6.5	12.0	97	.59
JUN								
22...	0815	--	525	9.3	22.5	14.2	162	2.0
JUL								
26...	0830	--	540	8.7	24.0	7.2	84	1.8
AUG								
22...	1045	--	425	9.3	25.0	>20.0	239	3.1
NOV								
21...	0900	--	535	7.1	7.5	11.9	99	1.8

Table 14.--Chemical and physical data for major sampling sites (continued)

DATE	TIME	STREAM-FLOW, INSTAN-TANEOUS (CFS)	SPE-CIFIC CON-DUCT-ANCE (UMHOS)	PH (UNITS)	TEMPER-ATURE (DEG C)	OXYGEN, DIS-SOLVED (MG/L)	OXYGEN, DIS-SOLVED (PER-CENT SATUR-ATION)	NITRO-GEN, ORGANIC TOTAL (MG/L AS N)
Site 8								
01098710 - HAGER POND OUTLET AT MARLBOROUGH, MA (LAT 42 21 06 LONG 071 29 11)								
NOV , 1976								
03...	1030	2.8	910	7.4	6.5	12.2	99	1.2
APR , 1977								
05...	1100	19	450	7.2	8.5	8.6	73	.93
JUN								
15...	1100	4.2	570	7.8	21.0	7.8	87	1.3
AUG								
10...	1330	3.0	575	9.9	27.2	10.7	133	2.2
OCT								
12...	1100	5.5	575	6.8	13.5	10.4	99	1.2
APR , 1978								
04...	1145	14	260	6.6	5.0	12.7	99	.53
JUN								
22...	1430	4.8	525	9.3	24.5	11.3	134	1.9
JUL								
26...	0915	3.3	540	8.4	24.5	7.4	88	2.2
AUG								
23...	1200	2.3	475	9.3	25.0	10.6	126	2.4
NOV								
22...	0930	5.1	525	7.4	6.0	12.0	96	1.7
Site 9								
01098712 - GRIST MILLPOND NEAR MARLBOROUGH, MA (LAT 42 21 17 LONG 071 28 51)								
NOV , 1976								
02...	1430	--	580	7.2	6.5	12.8	104	--
APR , 1977								
05...	1345	--	360	7.1	8.5	9.2	78	.98
JUN								
14...	1130	--	545	7.2	21.0	7.4	82	.97
AUG								
11...	1045	--	560	9.7	25.5	17.0	205	1.9
OCT								
13...	1145	--	535	7.1	12.0	9.2	85	1.4
APR , 1978								
05...	1100	--	275	6.5	7.0	12.0	99	.53
JUN								
22...	1030	--	485	9.2	24.0	13.6	159	1.4
JUL								
26...	1030	--	515	9.2	24.5	10.4	123	2.4
AUG								
22...	1330	--	475	9.8	28.0	>20.0	253	3.0
NOV								
21...	1030	--	515	8.1	5.5	12.2	97	2.1

Table 14.--Chemical and physical data for major sampling sites (continued)

Site 12

01098722 - GRIST MILLPOND OUTLET NEAR MARLBOROUGH, MA (LAT 42 21 26 LONG 071 28 15)

DATE	TIME	STREAM-FLOW, INSTAN-TANEOUS (CFS)	SPE-CIFIC CON-DUCT-ANCE (UMHOS)	PH (UNITS)	TEMPER-ATURE (DEG C)	OXYGEN, DIS-SOLVED (MG/L)	OXYGEN, DIS-SOLVED (PER-CENT SATUR-ATION)	NITRO-GEN, ORGANIC TOTAL (MG/L AS N)
NOV , 1976								
03...	1300	4.2	600	7.5	6.0	12.2	98	--
APR , 1977								
05...	1445	31	350	7.2	7.5	9.3	77	.99
JUN								
15...	1400	5.4	530	7.5	22.5	6.3	72	1.3
AUG								
12...	0930	3.2	515	9.9	25.5	7.1	86	1.4
OCT								
12...	1430	3.7	510	7.5	13.5	10.0	95	1.2
APR , 1978								
04...	1315	22	245	6.5	5.0	13.1	102	.41
JUN								
23...	0815	5.2	515	8.9	21.5	6.0	67	1.7
JUL								
26...	1115	3.1	500	8.4	25.0	5.6	67	2.8
AUG								
23...	1400	3.6	445	9.2	25.5	6.1	73	1.6
NOV								
21...	1445	3.4	520	8.1	5.5	12.3	97	1.8

Site 15

01098730 - CARDING MILLPOND NEAR MARLBOROUGH, MA (LAT 42 21 42 LONG 071 27 57)

DATE	TIME	STREAM-FLOW, INSTAN-TANEOUS (CFS)	SPE-CIFIC CON-DUCT-ANCE (UMHOS)	PH (UNITS)	TEMPER-ATURE (DEG C)	OXYGEN, DIS-SOLVED (MG/L)	OXYGEN, DIS-SOLVED (PER-CENT SATUR-ATION)	NITRO-GEN, ORGANIC TOTAL (MG/L AS N)
NOV , 1976								
03...	0800	--	530	8.6	5.5	13.8	109	--
APR , 1977								
05...	1530	--	310	7.4	8.5	10.0	85	.92
JUN								
14...	1330	--	425	9.1	23.0	12.4	143	1.7
AUG								
11...	1430	--	560	9.9	29.5	19.9	258	1.8
OCT								
13...	1500	--	455	9.4	13.0	17.4	164	1.9
APR , 1978								
05...	1345	--	193	6.3	6.0	11.9	95	.47
JUN								
22...	1315	--	435	8.9	25.5	10.2	123	1.8
JUL								
26...	1315	--	550	10.2	25.5	>20.0	241	3.1
AUG								
22...	1600	--	435	9.6	29.0	>20.0	257	3.0
NOV								
21...	1145	--	515	10.2	6.0	19.7	158	2.2

Table 14.--Chemical and physical data for major sampling sites (continued)

DATE	TIME	STREAM-FLOW, INSTAN-TANEOUS (CFS)	SPE-CIFIC CON-DUCT-ANCE (UMHOS)	PH (UNITS)	TEMPER-ATURE (DEG C)	OXYGEN, DIS-SOLVED (MG/L)	OXYGEN, DIS-SOLVED (PER-CENT SATUR-ATION)	NITRO-GEN, ORGANIC TOTAL (MG/L AS N)
				Site 16				
				01098733 - HOP BROOK NEAR MARLBOROUGH, MA (LAT 42 22 02 LONG 071 28 01)				
NOV , 1976								
04...	1130	4.6	500	8.2	7.0	11.7	96	1.5
APR , 1977								
05...	1615	29	310	7.2	8.0	9.2	78	.95
JUN								
16...	0800	5.2	435	8.7	20.0	6.7	73	2.0
AUG								
12...	1030	2.7	455	9.6	25.5	5.1	61	2.1
OCT								
12...	1530	12	445	8.4	14.5	11.8	115	1.8
APR , 1978								
04...	1500	27	188	6.6	5.0	12.8	100	.28
JUN								
23...	0945	6.0	450	7.4	20.5	3.7	41	.80
JUL								
26...	1445	2.6	485	9.8	27.0	7.0	87	2.7
AUG								
23...	1615	2.8	415	9.0	25.5	5.5	66	2.8
NOV								
21...	1330	3.6	510	9.8	6.5	13.5	110	2.7

Table 14.--Chemical and physical data for major sampling sites (continued)

DATE	NITROGEN, AMMONIA TOTAL (MG/L AS N)	NITROGEN, NITRITE TOTAL (MG/L AS N)	NITROGEN, NITRATE TOTAL (MG/L AS N)	NITROGEN, TOTAL (MG/L AS N)	PHOSPHORUS, ORTHO, TOTAL (MG/L AS P)	PHOSPHORUS, TOTAL (MG/L AS P)	ALGAL GROWTH POTENTIAL, BOTTLE TEST (MG/L)
			Site 2				
	01098705 - HAGER POND TRIBUTARY AT MARLBOROUGH, MA (LAT 42 21 03 LONG 071 29 29)						
NOV , 1976							
01...	.500	.010	18	19	.210	.660	58
APR , 1977							
05...	.630	.010	5.7	7.5	.080	.340	24
JUN							
15...	.710	.020	21	24	1.20	3.00	20
AUG							
10...	.310	<.010	16	16	.800	2.10	251
OCT							
12...	.470	.010	16	18	.460	1.70	126
APR , 1978							
04...	.740	.020	6.8	8.4	.140	.430	13
JUN							
21...	.520	.120	18	19	.340	.580	126
JUL							
26...	.880	.170	14	17	.100	.490	--
AUG							
23...	.290	.060	4.2	5.8	.300	.760	113
NOV							
21...	.870	.010	18	20	.420	.790	--
			Site 5				
	01098709 - HAGER POND AT MARLBOROUGH, MA (LAT 42 20 57 LONG 071 29 14)						
NOV , 1976							
02...	--	--	--	--	--	--	105
APR , 1977							
05...	.440	.030	4.0	5.6	.030	.220	27
JUN							
14...	.600	.080	13	15	.160	.540	57
AUG							
11...	.150	.290	9.5	11	.190	.510	23
OCT							
13...	.750	.110	11	13	.140	.630	61
APR , 1978							
05...	.710	.040	4.8	6.1	.100	.290	14
JUN							
22...	.330	.120	9.7	12	.260	.550	77
JUL							
26...	1.10	.300	5.1	8.3	.260	.470	--
AUG							
22...	.950	.130	6.1	10	.280	.600	64
NOV							
21...	.500	.060	16	18	.490	.700	--

Table 14.--Chemical and physical data for major sampling sites (continued)

DATE	NITROGEN, AMMONIA TOTAL (MG/L AS N)	NITROGEN, NITRITE TOTAL (MG/L AS N)	NITROGEN, NITRATE TOTAL (MG/L AS N)	NITROGEN, TOTAL (MG/L AS N)	PHOSPHORUS, ORTHO, TOTAL (MG/L AS P)	PHOSPHORUS, TOTAL (MG/L AS P)	ALGAL GROWTH POTENTIAL, BOTTLE TEST (MG/L)
Site 8							
01098710 - HAGER POND OUTLET AT MARLBOROUGH, MA (LAT 42 21 06 LONG 071 29 11)							
NOV , 1976							
03...	.340	.090	15	17	.170	.440	96
APR , 1977							
05...	.570	.040	5.4	6.9	.070	.220	22
JUN							
15...	.510	.100	14	16	.200	.510	89
AUG							
10...	.140	.290	9.7	12	.200	.440	40
OCT							
12...	.660	.110	9.9	12	.120	.460	59
APR , 1978							
04...	.470	.030	2.8	3.8	.050	.160	--
JUN							
22...	.140	.120	9.4	12	.180	.480	85
JUL							
26...	1.50	.320	5.3	9.3	.220	.470	--
AUG							
23...	.620	.160	5.8	9.0	.250	.340	84
NOV							
22...	.410	.070	16	18	.380	.600	--
Site 9							
01098712 - GRIST MILLPOND NEAR MARLBOROUGH, MA (LAT 42 21 17 LONG 071 28 51)							
NOV , 1976							
02...	--	--	--	--	--	--	96
APR , 1977							
05...	.320	.030	3.7	5.0	.050	.120	26
JUN							
14...	.530	.130	9.9	12	.110	.260	84
AUG							
11...	.210	.360	5.4	7.9	.120	.380	16
OCT							
13...	.330	.200	8.8	11	.090	.400	50
APR , 1978							
05...	.350	.030	2.5	3.4	.060	.160	15
JUN							
22...	.380	.150	5.6	7.5	.210	.380	77
JUL							
26...	.330	.280	1.8	4.8	.290	.540	--
AUG							
22...	.070	.230	1.1	4.4	.140	.450	64
NOV							
21...	.310	.120	14	16	.370	.450	--

Table 14.--Chemical and physical data for major sampling sites (continued)

DATE	NITROGEN, AMMONIA TOTAL (MG/L AS N)	NITROGEN, NITRITE TOTAL (MG/L AS N)	NITROGEN, NITRATE TOTAL (MG/L AS N)	NITROGEN, TOTAL (MG/L AS N)	PHOSPHORUS, ORTHO, TOTAL (MG/L AS P)	PHOSPHORUS, TOTAL (MG/L AS P)	ALGAL GROWTH POTENTIAL, BOTTLE TEST (MG/L)
Site 12							
01098722 - GRIST MILLPOND OUTLET NEAR MARLBOROUGH, MA (LAT 42 21 26 LONG 071 28 15)							
NOV , 1976							
03...	--	--	--	--	--	--	96
APR , 1977							
05...	.210	.020	2.1	3.3	.030	.160	19
JUN							
15...	.240	.120	9.9	12	.120	.230	26
AUG							
12...	.200	.370	4.7	6.7	.110	.260	35
OCT							
12...	.180	.150	8.2	9.7	.060	.260	46
APR , 1978							
04...	.330	.020	2.3	3.0	.050	.150	10
JUN							
23...	.490	.170	5.5	7.9	.250	.450	86
JUL							
26...	.400	.250	1.7	5.1	.250	.560	--
AUG							
23...	.420	.170	1.0	3.2	.230	.340	48
NOV							
21...	.300	.120	14	16	.310	.410	--
Site 15							
01098730 - CARDING MILLPOND NEAR MARLBOROUGH, MA (LAT 42 21 42 LONG 071 27 57)							
NOV , 1976							
03...	--	--	--	--	--	--	82
APR , 1977							
05...	.080	.010	1.3	2.3	.020	.140	22
JUN							
14...	.360	.100	5.6	7.8	.130	.290	71
AUG							
11...	.020	.030	.13	2.0	.110	.360	--
OCT							
13...	.140	.120	5.4	7.5	.060	.340	49
APR , 1978							
05...	.240	.020	1.8	2.5	.040	.100	10
JUN							
22...	.540	.180	2.0	4.5	.230	.380	42
JUL							
26...	.010	<.010	.01	3.1	.310	.530	--
AUG							
22...	.230	<.010	.01	3.2	.310	.660	6.1
NOV							
21...	.180	.130	7.8	10	.120	.240	--

Table 14.--Chemical and physical data for major sampling sites (continued)

DATE	NITROGEN, AMMONIA TOTAL (MG/L AS N)	NITROGEN, NITRITE TOTAL (MG/L AS N)	NITROGEN, NITRATE TOTAL (MG/L AS N)	NITROGEN, TOTAL (MG/L AS N)	PHOSPHORUS, ORTHO, TOTAL (MG/L AS P)	PHOSPHORUS, TOTAL (MG/L AS P)	ALGAL GROWTH POTENTIAL, BOTTLE TEST (MG/L)
Site 16 01098733 - HOP BROOK NEAR MARLBOROUGH, MA (LAT 42 22 02 LONG 071 28 01)							
NOV , 1976							
04...	.170	.090	7.6	9.4	.160	.310	82
APR , 1977							
05...	.150	.030	2.3	3.4	.030	.160	26
JUN							
16...	.480	.110	4.8	7.4	.140	.330	47
AUG							
12...	.740	.080	.27	3.2	.240	.540	15
OCT							
12...	.120	.100	4.9	6.9	.080	.330	29
APR , 1978							
04...	.240	.020	1.7	2.2	.040	.100	12
JUN							
23...	.500	.160	1.8	3.3	.250	.360	85
JUL							
26...	.050	.010	.10	2.8	.270	.460	--
AUG							
23...	.230	<.010	.14	3.1	.350	.600	9.9
NOV							
21...	.230	.120	7.5	11	.120	.310	--

Table 14.--Chemical and physical data for major sampling sites (continued)

DATE	CALCIUM DIS-SOLVED (MG/L AS CA)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG)	SODIUM, DIS-SOLVED (MG/L AS NA)	POTAS-SIUM, DIS-SOLVED (MG/L AS K)	BICAR-BONATE FET-FLD (MG/L AS HCO3)	CAR-BON-ATE FET-FLD (MG/L AS CO3)	SULFATE DIS-SOLVED (MG/L AS SO4)	CHLO-RIDE DIS-SOLVED (MG/L AS CL)	SILICA, DIS-SOLVED (MG/L AS SIO2)	SOLIDS, SUM OF CON-STIT-UENTS, DIS-SOLVED (MG/L)
Site 2 01098705 - HAGER POND TRIBUTARY AT MARLBOROUGH, MA (LAT 42 21 03 LONG 071 29 29)										
AUG , 1978										
23...	53	3.5	46	12	80	0	59	65	9.6	288
NOV										
21...	42	3.4	62	11	23	0	58	76	9.8	274
Site 5 01098709 - HAGER POND AT MARLBOROUGH, MA (LAT 42 20 57 LONG 071 29 14)										
NOV , 1976										
02...	--	--	--	--	--	--	--	--	--	--
OCT , 1977										
13...	--	--	--	--	--	--	--	--	--	--
JUN , 1978										
22...	30	3.7	60	8.4	70	6	28	74	6.8	252
AUG										
22...	37	2.5	46	12	69	7	53	59	7.7	258
NOV										
21...	41	3.2	46	11	34	0	58	60	8.5	245
Site 8 01098710 - HAGER POND OUTLET AT MARLBOROUGH, MA (LAT 42 21 06 LONG 071 29 11)										
AUG , 1978										
23...	41	2.6	47	12	59	21	52	58	7.8	271
NOV										
22...	40	3.4	45	11	34	0	59	59	8.3	242
Site 9 01098712 - GRIST MILLPOND NEAR MARLBOROUGH, MA (LAT 42 21 17 LONG 071 28 51)										
NOV , 1976										
02...	--	--	--	--	--	--	--	--	--	--
OCT , 1977										
13...	--	--	--	--	--	--	--	--	--	--
JUN , 1978										
22...	28	3.5	55	7.3	78	0	34	69	6.2	242
AUG										
22...	35	2.2	47	10	48	36	48	59	6.9	268
NOV										
21...	39	3.2	45	10	37	0	59	58	7.9	240

Table 14.--Chemical and physical data for major sampling sites (continue

DATE	CALCIUM DIS- SOLVED (MG/L AS CA)	MAGNE- SIUM, DIS- SOLVED (MG/L AS MG)	SODIUM, DIS- SOLVED (MG/L AS NA)	POTAS- SIUM, DIS- SOLVED (MG/L AS K)	BICAR- BONATE FET-FLD (MG/L AS HCO3)	CAR- BON- ATE FET-FLD (MG/L AS CO3)	SULFATE DIS- SOLVED (MG/L AS SO4)	CHLO- RIDE DIS- SOLVED (MG/L AS CL)	SILICA, DIS- SOLVED (MG/L AS SIO2)	S S U SO (M

Site 12

01098722 - GRIST MILLPOND OUTLET NEAR MARLBOROUGH, MA (LAT 42 21 26 LONG 071 28

DATE	CA	MG	NA	K	HCO3	CO3	SO4	CL	SIO2	
AUG , 1978										
23...	31	1.9	46	12	65	19	46	58	5.6	2
NOV										
21...	38	3.5	44	10	38	0	57	57	7.8	2[illegible]

Site 15

01098730 - CARDING MILLPOND NEAR MARLBOROUGH, MA (LAT 42 21 42 LONG 071 27 57)

DATE	CA	MG	NA	K	HCO3	CO3	SO4	CL	SIO2	
NOV , 1976										
03...	--	--	--	--	--	--	--	--	--	--
OCT , 1977										
13...	--	--	--	--	--	--	--	--	--	--
JUN , 1978										
22...	26	3.3	48	6.8	80	5	30	61	6.3	226
AUG										
22...	28	2.2	49	10	61	30	33	58	6.5	247
NOV										
21...	41	3.5	45	10	0	1	63	61	6.6	237

Site 16

01098733 - HOP BROOK NEAR MARLBOROUGH, MA (LAT 42 22 02 LONG 071 28 01)

DATE	CA	MG	NA	K	HCO3	CO3	SO4	CL	SIO2	
AUG , 1978										
23...	30	2.4	48	10	93	0	33	58	6.5	234
NOV										
21...	40	3.7	45	10	46	17	63	60	7.2	269

Table 14.--Chemical and physical data for major sampling sites (continued)

DATE	ARSENIC TOTAL (UG/L AS AS)	CADMIUM TOTAL RECOVERABLE (UG/L AS CD)	CHROMIUM, TOTAL RECOVERABLE (UG/L AS CR)	COBALT, TOTAL RECOVERABLE (UG/L AS CO)	COPPER, TOTAL RECOVERABLE (UG/L AS CU)	IRON, TOTAL RECOVERABLE (UG/L AS FE)	IRON, DISSOLVED (UG/L AS FE)	LEAD, TOTAL RECOVERABLE (UG/L AS PB)	MANGANESE, TOTAL RECOVERABLE (UG/L AS MN)	MERCURY TOTAL RECOVERABLE (UG/L AS HG)
Site 2										
01098705 - HAGER POND TRIBUTARY AT MARLBOROUGH, MA (LAT 42 21 03 LONG 071 29 29)										
AUG , 1978										
23...	1	--	--	--	--	--	20	--	--	<.5
NOV										
21...	2	2	<20	--	12	1700	520	45	310	<.5
Site 5										
01098709 - HAGER POND AT MARLBOROUGH, MA (LAT 42 20 57 LONG 071 29 14)										
NOV , 1976										
02...	--	--	--	--	--	--	--	--	--	--
OCT , 1977										
13...	2	ND	<20	ND	<20	490	--	7	170	<.5
JUN , 1978										
22...	1	2	<20	4	8	800	120	8	150	.5
AUG										
22...	1	--	--	--	--	--	20	--	--	<.5
NOV										
21...	1	<2	<20	--	12	800	140	12	170	<.5
Site 8										
01098710 - HAGER POND OUTLET AT MARLBOROUGH, MA (LAT 42 21 06 LONG 071 29 11)										
AUG , 1978										
23...	1	--	--	--	--	--	20	--	--	<.5
NOV										
22...	1	4	<20	--	11	710	20	25	140	<.5
SITE 9										
01098712 - GRIST MILLPOND NEAR MARLBOROUGH, MA (LAT 42 21 17 LONG 071 28 51)										
NOV , 1976										
02...	--	--	--	--	--	--	--	--	--	--
OCT , 1977										
13...	3	ND	<20	ND	8	440	--	5	160	<.5
JUN , 1978										
22...	1	--	--	--	--	--	180	--	--	.5
AUG										
22...	2	--	--	--	--	--	<10	--	--	<.5
NOV										
21...	1	<2	<20	--	8	410	50	14	100	<.5

Table 14.--Chemical and physical data for major sampling sites (continued)

DATE	ARSENIC TOTAL (UG/L AS AS)	CADMIUM TOTAL RECOVERABLE (UG/L AS CD)	CHROMIUM, TOTAL RECOVERABLE (UG/L AS CR)	COBALT, TOTAL RECOVERABLE (UG/L AS CO)	COPPER, TOTAL RECOVERABLE (UG/L AS CU)	IRON, TOTAL RECOVERABLE (UG/L AS FE)	IRON, DISSOLVED (UG/L AS FE)	LEAD, TOTAL RECOVERABLE (UG/L AS PB)	MANGANESE, TOTAL RECOVERABLE (UG/L AS MN)	MERCURY TOTAL RECOVERABLE (UG/L AS HG)
Site 12 01098722 - GRIST MILLPOND OUTLET NEAR MARLBOROUGH, MA (LAT 42 21 26 LONG 071 28 15)										
AUG , 1978										
23...	1	--	--	--	--	--	<10	--	--	<.5
NOV										
21...	1	3	<20	--	7	400	<10	22	90	<.5
Site 15 01098730 - CARDING MILLPOND NEAR MARLBOROUGH, MA (LAT 42 21 42 LONG 071 27 57)										
NOV , 1976										
03...	--	--	--	--	--	--	--	--	--	--
OCT , 1977										
13...	3	ND	20	<2	7	290	--	9	60	<.5
JUN , 1978										
22...	1	--	--	--	--	--	100	--	--	.5
AUG										
22...	2	--	--	--	--	--	<10	--	--	<.5
NOV										
21...	1	<2	<20	--	6	150	30	11	30	<.5
Site 16 01098733 - HOP BROOK NEAR MARLBOROUGH, MA (LAT 42 22 02 LONG 071 28 01)										
AUG , 1978										
23...	2	--	--	--	--	--	60	--	--	<.5
NOV										
21...	--	--	--	--	--	--	40	--	--	--

Table 14.--Chemical and physical data for major sampling sites (continued)

DATE	SELE-NIUM, TOTAL (UG/L AS SE)	ZINC, TOTAL RECOV-ERABLE (UG/L AS ZN)	PCB, TOTAL (UG/L)	NAPH-THA-LENES, POLY-CHLOR. TOTAL (UG/L)	ALDRIN, TOTAL (UG/L)	CHLOR-DANE, TOTAL (UG/L)	DDD, TOTAL (UG/L)	DDE, TOTAL (UG/L)	DDT, TOTAL (UG/L)
Site 2									
01098705 - HAGER POND TRIBUTARY AT MARLBOROUGH, MA (LAT 42 21 03 LONG 071 29 29)									
AUG , 1978									
23...	<1	--	.00	.00	.00	.00	.00	.00	.00
NOV									
21...	<1	40	.00	.00	.00	.00	.00	.00	.00
Site 5									
01098709 - HAGER POND AT MARLBOROUGH, MA (LAT 42 20 57 LONG 071 29 14)									
NOV , 1976									
02...	--	--	.00	.00	.00	.00	.00	.00	.00
OCT , 1977									
13...	<1	30	.00	.00	.00	.00	.00	.00	.00
JUN , 1978									
22...	<1	<20	.00	.00	.00	.00	.00	.00	.00
AUG									
22...	<1	--	.00	.00	.00	.00	.00	.00	.00
NOV									
21...	<1	20	.00	.00	.00	.00	.00	.00	.00
Site 8									
01098710 - HAGER POND OUTLET AT MARLBOROUGH, MA (LAT 42 21 06 LONG 071 29 11)									
AUG , 1978									
23...	<1	--	.00	.00	.00	.00	.00	.00	.00
NOV									
22...	<1	40	.00	.00	.00	.00	.00	.00	.00
Site 9									
01098712 - GRIST MILLPOND NEAR MARLBOROUGH, MA (LAT 42 21 17 LONG 071 28 51)									
NOV , 1976									
02...	--	--	.00	.00	.00	<.10	.01	.01	.00
OCT , 1977									
13...	<1	20	.00	.00	.00	.00	.00	.00	.00
JUN , 1978									
22...	<1	--	.00	.00	.00	.00	.00	.00	.00
AUG									
22...	<1	--	.00	.00	.00	.00	.00	.00	.00
NOV									
21...	<1	50	.00	.00	.00	.00	.00	.00	.00

Table 14.--Chemical and physical data for major sampling sites (continued)

DATE	SELENIUM, TOTAL (UG/L AS SE)	ZINC, TOTAL RECOVERABLE (UG/L AS ZN)	PCB, TOTAL (UG/L)	NAPHTHALENES, POLYCHLOR. TOTAL (UG/L)	ALDRIN, TOTAL (UG/L)	CHLORDANE, TOTAL (UG/L)	DDD, TOTAL (UG/L)	DDE, TOTAL (UG/L)	DDT, TOTAL (UG/L)
Site 12									
01098722 - GRIST MILLPOND OUTLET NEAR MARLBOROUGH, MA (LAT 42 21 26 LONG 071 28 15)									
AUG , 1978									
23...	<1	--	.00	.00	.00	.00	.00	.00	.00
NOV									
21...	<1	20	.00	.00	.00	.00	.00	.00	.00
Site 15									
01098730 - CARDING MILLPOND NEAR MARLBOROUGH, MA (LAT 42 21 42 LONG 071 27 57)									
NOV , 1976									
03...	--	--	.00	.00	.00	.00	.00	.00	.00
OCT , 1977									
13...	<1	20	.00	.00	.00	.00	.00	.00	.00
JUN , 1978									
22...	<1	--	.00	.00	.00	.00	.00	.00	.00
AUG									
22...	<1	--	.00	.00	.00	.00	.00	.00	.00
NOV									
21...	<1	<20	.00	.00	.00	.00	.00	.00	.00
Site 16									
01098733 - HOP BROOK NEAR MARLBOROUGH, MA (LAT 42 22 02 LONG 071 28 01)									
AUG , 1978									
23...	<1	--	.00	.00	.00	.00	.00	.00	.00
NOV									
21...	--	--	.00	.00	.00	.00	.00	.00	.00

Table 14.--Chemical and physical data for major sampling sites (continued)

DATE	DI-ELDRIN TOTAL (UG/L)	ENDO-SULFAN, TOTAL (UG/L)	ENDRIN, TOTAL (UG/L)	HEPTA-CHLOR, TOTAL (UG/L)	HEPTA-CHLOR EPOXIDE TOTAL (UG/L)	LINDANE TOTAL (UG/L)	MIREX, TOTAL (UG/L)	PER-THANE TOTAL (UG/L)	TOX-APHENE, TOTAL (UG/L)
Site 2									
01098705 - HAGER POND TRIBUTARY AT MARLBOROUGH, MA (LAT 42 21 03 LONG 071 29 29)									
AUG , 1978									
23...	.00	.00	.00	.00	.00	.00	.00	--	.00
NOV									
21...	.00	.00	.00	.00	.00	.00	--	.00	.00
Site 5									
01098709 - HAGER POND AT MARLBOROUGH, MA (LAT 42 20 57 LONG 071 29 14)									
NOV , 1976									
02...	.00	--	.00	.00	.00	.00	--	--	.00
OCT , 1977									
13...	.00	.00	.00	.00	.00	.00	--	--	.00
JUN , 1978									
22...	.00	.00	.00	.00	.00	.00	.00	--	.00
AUG									
22...	.00	.00	.00	.00	.00	.00	.00	--	.00
NOV									
21...	.00	.00	.00	.00	.00	.00	--	.00	.00
Site 8									
01098710 - HAGER POND OUTLET AT MARLBOROUGH, MA (LAT 42 21 06 LONG 071 29 11)									
AUG , 1978									
23...	.00	.00	.00	.00	.00	.00	.00	--	.00
NOV									
22...	.00	.00	.00	.00	.00	.00	--	.00	.00
Site 9									
01098712 - GRIST MILLPOND NEAR MARLBOROUGH, MA (LAT 42 21 17 LONG 071 28 51)									
NOV , 1976									
02...	.00	--	.00	.00	.00	.00	--	--	.00
OCT , 1977									
13...	.00	.00	.00	.00	.00	.00	--	--	.00
JUN , 1978									
22...	.00	.00	.00	.00	.00	.00	.00	--	.00
AUG									
22...	.00	.00	.00	.00	.00	.00	.00	--	.00
NOV									
21...	.00	.00	.00	.00	.00	.00	--	.00	.00

Table 14.--Chemical and physical data for major sampling sites (continued)

DATE	DI-ELDRIN TOTAL (UG/L)	ENDO-SULFAN, TOTAL (UG/L)	ENDRIN, TOTAL (UG/L)	HEPTA-CHLOR, TOTAL (UG/L)	HEPTA-CHLOR EPOXIDE TOTAL (UG/L)	LINDANE TOTAL (UG/L)	MIREX, TOTAL (UG/L)	PER-THANE TOTAL (UG/L)	TOX-APHENE, TOTAL (UG/L)
Site 12									
01098722 - GRIST MILLPOND OUTLET NEAR MARLBOROUGH, MA (LAT 42 21 26 LONG 071 28 15)									
AUG , 1978									
23...	.00	.00	.00	.00	.00	.00	.00	--	.00
NOV									
21...	.00	.00	.00	.00	.00	.00	--	.00	.00
Site 15									
01098730 - CARDING MILLPOND NEAR MARLBOROUGH, MA (LAT 42 21 42 LONG 071 27 57)									
NOV , 1976									
03...	.00	--	.00	.00	.00	.00	--	--	.00
OCT , 1977									
13...	.00	.00	.00	.00	.00	.00	--	--	.00
JUN , 1978									
22...	.00	.00	.00	.00	.00	.00	.00	--	.00
AUG									
22...	.00	.00	.00	.00	.00	.00	.00	--	.00
NOV									
21...	.00	.00	.00	.00	.00	.00	--	.00	.00
Site 16									
01098733 - HOP BROOK NEAR MARLBOROUGH, MA (LAT 42 22 02 LONG 071 28 01)									
AUG , 1978									
23...	.00	.00	.00	.00	.00	.00	.00	--	.00
NOV									
21...	.00	.00	.00	.00	.00	.00	--	.00	.00

Table 15.--Chemical and physical data for other sampling sites

DATE	TIME	STREAMFLOW, INSTANTANEOUS (CFS)	SPECIFIC CONDUCTANCE (UMHOS)	PH (UNITS)	TEMPERATURE (DEG C)	OXYGEN, DISSOLVED (MG/L)	OXYGEN, DISSOLVED (PERCENT SATURATION)	NITROGEN, ORGANIC TOTAL (MG/L AS N)
Site 1 01098704 - HAGER POND TRIBUTARY AT MARLBOROUGH, MA (LAT 42 21 07 LONG 071 29 43)								
NOV 1976								
01...	0830	.13	290	6.6	6.5	10.6	86	.18
Site 3 01098706 - HAGER POND TRIBUTARY AT MARLBOROUGH, MA (LAT 42 20 57 LONG 071 29 30)								
NOV, 1976								
01...	1300	.28	73	5.8	7.0	8.9	73	.40
Site 4 01098707 - HAGER POND TRIBUTARY AT MARLBOROUGH, MA (LAT 42 20 30 LONG 071 29 20)								
NOV , 1976								
01...	1430	.09	68	6.1	6.5	10.3	84	.32
Site 6 01098708 - HAGER POND TRIBUTARY AT MARLBOROUGH, MA (LAT 42 20 48 LONG 071 29 03)								
NOV , 1976								
02...	1300	.12	90	5.9	7.0	12.3	101	.16
Site 10 01098714 - GRIST MILLPOND TRIBUTARY NEAR MARLBOROUGH, MA (LAT 42 21 16 LONG 071 28 44)								
NOV , 1976								
03...	0930	.18	146	6.4	4.0	12.4	94	.19
Site 11 01098718 - GRIST MILLPOND TRIBUTARY NEAR MARLBOROUGH, MA (LAT 42 21 27 LONG 071 28 42)								
NOV , 1976								
03...	1215	.03	200	5.9	7.5	5.8	48	1.3
Site 13 01098725 - CARDING MILLPOND TRIBUTARY NEAR MARLBOROUGH, MA (LAT 42 21 24 LONG 071 28 00)								
NOV , 1976								
03...	1430	.05	210	6.0	6.5	7.8	63	.24
Site 14 01098728 - CARDING MILLPOND TRIBUTARY NEAR MARLBOROUGH, MA (LAT 42 21 26 LONG 071 27 48)								
NOV 4, 1976								
04...	0830	.09	154	6.1	6.0	8.5	68	.19

Table 15.--Chemical and physical data for other sampling sites (continued)

DATE	NITROGEN, AMMONIA TOTAL (MG/L AS N)	NITROGEN, NITRITE TOTAL (MG/L AS N)	NITROGEN, NITRATE TOTAL (MG/L AS N)	NITROGEN, TOTAL (MG/L AS N)	PHOSPHORUS, ORTHO, TOTAL (MG/L AS P)	PHOSPHORUS, TOTAL (MG/L AS P)	ALGAL GROWTH POTENTIAL, BOTTLE TEST (MG/L)
Site 1 01098704 - HAGER POND TRIBUTARY AT MARLBOROUGH, MA (LAT 42 21 07 LONG 071 29 43)							
NOV , 1976							
01...	.070	.010	.39	.65	.010	.020	--
Site 3 01098706 - HAGER POND TRIBUTARY AT MARLBOROUGH, MA (LAT 42 20 57 LONG 071 29 30)							
NOV , 1976							
01...	.030	.010	.02	.46	.010	.030	2.9
Site 4 01098707 - HAGER POND TRIBUTARY AT MARLBOROUGH, MA (LAT 42 20 30 LONG 071 29 20)							
NOV , 1976							
01...	.010	.010	.02	.36	.020	.030	1.1
Site 6 01098708 - HAGER POND TRIBUTARY AT MARLBOROUGH, MA (LAT 42 20 48 LONG 071 29 03)							
NOV , 1976							
02...	.020	.010	.01	.20	.020	.020	.4
Site 10 01098714 - GRIST MILLPOND TRIBUTARY NEAR MARLBOROUGH, MA (LAT 42 21 16 LONG 071 28 44)							
NOV , 1976							
03...	.010	.010	.00	.21	.010	.020	.5
Site 11 01098718 - GRIST MILLPOND TRIBUTARY NEAR MARLBOROUGH, MA (LAT 42 21 27 LONG 071 28 42)							
NOV , 1976							
03...	.260	.010	.04	1.7	.010	.200	.8
Site 13 01098725 - CARDING MILLPOND TRIBUTARY NEAR MARLBOROUGH, MA (LAT 42 21 24 LONG 071 28 00)							
NOV , 1976							
03...	.010	.010	.02	.28	.010	.030	2.3
Site 14 01098728 - CARDING MILLPOND TRIBUTARY NEAR MARLBOROUGH, MA (LAT 42 21 26 LONG 071 27 48)							
NOV , 1976							
04...	.010	.010	.00	.21	.010	.030	.5

Table 16.--Phytoplankton data for all sampling sites

Site 2
01098705 HAGER POND TRIBUTARY AT MARLBOROUGH, MA

PHYTOPLANKTON ANALYSES, AUGUST 1978 TO NOVEMBER 1978

DATE	AUG 23,78		NOV 21,78	
TIME	1015		0730	
TOTAL CELLS/ML	480		980	
ORGANISM	CELLS /ML	PER- CENT	CELLS /ML	PER- CENT
CHRYSOPHYTA				
.BACILLARIOPHYCEAE				
..CENTRALES				
...COSCINODISCACEAE				
....COSCINODISCUS	--	-	14	1
..PENNALES				
...ACHNANTHACEAE				
....ACHNANTHES	16	3	--	-
...GOMPHONEMATACEAE				
....GOMPHONEMA	11	2	--	-
...NAVICULACEAE				
....NAVICULA	16	3	14	1
...NITZSCHIACEAE				
....NITZSCHIA	110#	22	--	-
CYANOPHYTA (BLUE-GREEN ALGAE)				
.CYANOPHYCEAE				
..HORMOGONALES				
...OSCILLATORIACEAE				
....OSCILLATORIA	320#	67	920#	94
EUGLENOPHYTA (EUGLENOIDS)				
.EUGLENOPHYCEAE				
..EUGLENALES				
...EUGLENACEAE				
....EUGLENA	5	1	29	3

NOTE: # - DOMINANT ORGANISM; EQUAL TO OR GREATER THAN 15 PERCENT
* - OBSERVED ORGANISM, MAY NOT HAVE BEEN COUNTED; LESS THAN 1/2 PERCENT

Table 16.--Phytoplankton data for all sampling sites (continued)

Site 5
01098709 HAGER POND AT MARLBOROUGH, MA

PHYTOPLANKTON ANALYSES, NOVEMBER 1976 TO NOVEMBER 1978

DATE	NOV 2,76		JUN 14,77		AUG 11,77		OCT 13,77	
TIME	1030		0930		0900		0830	
TOTAL CELLS/ML	150000		16000		46000		41000	
ORGANISM	CELLS /ML	PER- CENT	CELLS /ML	PER- CENT	CELLS /ML	PER- CENT	CELLS /ML	PER- CENT
CHLOROPHYTA (GREEN ALGAE)								
.CHLOROPHYCEAE	--	-	2300	14	--	-	--	-
..CHLOROCOCCALES								
...HYDRODICTYACEAE								
....PEDIASTRUM	--	-	2100	13	23000#	51	25000#	59
...MICRACTINIACEAE								
....GOLENKINIA	*	0	--	-	7800#	17	2600	6
....MICRACTINIUM	--	-	530	3	--	-	--	-
...OOCYSTACEAE								
....ANKISTRODESMUS	--	-	*	0	--	-	--	-
....CHLORELLA	88000#	60	--	-	--	-	--	-
....KIRCHNERIELLA	--	-	600	4	--	-	--	-
....OOCYSTIS	--	-	270	2	380	1	--	-
....TETRAEDRON	--	-	--	-	--	-	*	0
...SCENEDESMACEAE								
....SCENEDESMUS	57000#	39	8200#	50	14000#	31	12000#	29
..TETRASPORALES								
...PALMELLACEAE								
....GLOEOCYSTIS	--	-	--	-	--	-	--	-
..VOLVOCALES								
...CHLAMYDOMONADACEAE								
....CHLAMYDOMONAS	960	1	*	0	--	-	340	1
..ZYGNEMATALES								
...DESMIDIACEAE								
....STAURASTRUM	--	-	--	-	--	-	--	-
CHRYSOPHYTA								
.BACILLARIOPHYCEAE								
..CENTRALES								
...COSCINODISCACEAE								
....CYCLOTELLA	--	-	*	0	--	-	--	-
..PENNALES								
...ACHNANTHACEAE								
....ACHNANTHES	--	-	*	0	--	-	--	-
...FRAGILARIACEAE								
....FRAGILARIA	--	-	--	-	--	-	340	1
...NAVICULACEAE								
....GYROSIGMA	--	-	--	-	--	-	*	0
....NAVICULA	--	-	--	-	--	-	--	-
...NITZSCHIACEAE								
....NITZSCHIA	*	0	870	5	--	-	250	1
...SURIRELLACEAE								
....SURIRELLA	*	0	--	-	--	-	--	-
CRYPTOPHYTA (CRYPTOMONADS)								
.CRYPTOPHYCEAE								
..CRYPTOMONADALES								
...CRYPTOCHRYSIDACEAE								
....CHROOMONAS	--	-	--	-	*	0	--	-
...CRYPTOMONADACEAE								
....CRYPTOMONAS	--	-	*	0	--	-	*	0
CYANOPHYTA (BLUE-GREEN ALGAE)								
.CYANOPHYCEAE								
..CHROOCOCCALES								
...CHROOCOCCACEAE								
....ANACYSTIS	--	-	1200	7	--	-	850	2
..HORMOGONALES								
...RIVULARIACEAE								
....RAPHIDIOPSIS	--	-	--	-	--	-	--	-

NOTE: # - DOMINANT ORGANISM; EQUAL TO OR GREATER THAN 15 PERCENT
* - OBSERVED ORGANISM, MAY NOT HAVE BEEN COUNTED; LESS THAN 1/2 PERCENT

Table 16.--Phytoplankton data for all sampling sites (continued)

Site 5
01098709 HAGER POND AT MARLBOROUGH, MA

PHYTOPLANKTON ANALYSES, NOVEMBER 1976 TO NOVEMBER 1978

DATE	JUN 22,78		AUG 22,78		NOV 21,78	
TIME	0815		1045		0900	
TOTAL CELLS/ML	95000		17000		93000	
ORGANISM	CELLS /ML	PER-CENT	CELLS /ML	PER-CENT	CELLS /ML	PER-CENT
CHLOROPHYTA (GREEN ALGAE)						
.CHLOROPHYCEAE	--	-	--	-	--	-
..CHLOROCOCCALES						
...HYDRODICTYACEAE						
....PEDIASTRUM	62000#	65	3100#	18	--	-
...MICRACTINIACEAE						
....GOLENKINIA	--	-	--	-	--	-
....MICRACTINIUM	--	-	--	-	--	-
...OOCYSTACEAE						
....ANKISTRODESMUS	--	-	--	-	--	-
....CHLORELLA	--	-	--	-	--	-
....KIRCHNERIELLA	--	-	--	-	--	-
....OOCYSTIS	4500	5	--	-	--	-
....TETRAEDRON	--	-	--	-	--	-
...SCENEDESMACEAE						
....SCENEDESMUS	25000#	26	8500#	50	90000#	97
..TETRASPORALES						
...PALMELLACEAE						
....GLOEOCYSTIS	2800	3	--	-	--	-
..VOLVOCALES						
...CHLAMYDOMONADACEAE						
....CHLAMYDOMONAS	--	-	230	1	--	-
..ZYGNEMATALES						
...DESMIDIACEAE						
....STAURASTRUM	--	-	--	-	2700	3
CHRYSOPHYTA						
.BACILLARIOPHYCEAE						
..CENTRALES						
...COSCINODISCACEAE						
....CYCLOTELLA	780	1	--	-	--	-
..PENNALES						
...ACHNANTHACEAE						
....ACHNANTHES	--	-	--	-	--	-
...FRAGILARIACEAE						
....FRAGILARIA	--	-	--	-	--	-
...NAVICULACEAE						
....GYROSIGMA	--	-	--	-	--	-
....NAVICULA	*	0	--	-	--	-
...NITZSCHIACEAE						
....NITZSCHIA	560	1	--	-	--	-
...SURIRELLACEAE						
....SURIRELLA	--	-	--	-	--	-
CRYPTOPHYTA (CRYPTOMONADS)						
.CRYPTOPHYCEAE						
..CRYPTOMONADALES						
...CRYPTOCHRYSIDACEAE						
....CHROOMONAS	--	-	5000#	29	--	-
...CRYPTOMONADACEAE						
....CRYPTOMONAS	--	-	--	-	--	-
CYANOPHYTA (BLUE-GREEN ALGAE)						
.CYANOPHYCEAE						
..CHROOCOCCALES						
...CHROOCOCCACEAE						
....ANACYSTIS	--	-	--	-	--	-
..HORMOGONALES						
...RIVULARIACEAE						
....RAPHIDIOPSIS	--	-	230	1	--	-

NOTE: # - DOMINANT ORGANISM; EQUAL TO OR GREATER THAN 15 PERCENT
* - OBSERVED ORGANISM, MAY NOT HAVE BEEN COUNTED; LESS THAN 1/2 PERCENT

Table 16.--Phytoplankton data for all sampling sites (continued)

Site 8
01098710 HAGER POND OUTLET AT MARLBOROUGH, MA

PHYTOPLANKTON ANALYSES, AUGUST 1978 TO NOVEMBER 1978

DATE	AUG 23,78		NOV 22,78	
TIME	1200		0930	
TOTAL CELLS/ML	12000		88000	
ORGANISM	CELLS /ML	PER- CENT	CELLS /ML	PER- CENT
CHLOROPHYTA (GREEN ALGAE)				
.CHLOROPHYCEAE				
..CHLOROCOCCALES				
...CHARACIACEAE				
....SCHROEDERIA	87	1	--	-
...HYDRODICTYACEAE				
....PEDIASTRUM	1500	12	6900	8
...SCENEDESMACEAE				
....SCENEDESMUS	8900#	72	77000#	88
..ZYGNEMATALES				
...DESMIDIACEAE				
....STAURASTRUM	--	-	3900	4
CHRYSOPHYTA				
.BACILLARIOPHYCEAE				
..PENNALES				
...NAVICULACEAE				
....NAVICULA	*	0	--	-
CRYPTOPHYTA (CRYPTOMONADS)				
.CRYPTOPHYCEAE				
..CRYPTOMONADALES				
...CRYPTOCHRYSIDACEAE				
....CHROOMONAS	1100	9	--	-
CYANOPHYTA (BLUE-GREEN ALGAE)				
.CYANOPHYCEAE				
..CHROOCOCCALES				
...CHROOCOCCACEAE				
....ANACYSTIS	650	5	--	-

NOTE: # - DOMINANT ORGANISM; EQUAL TO OR GREATER THAN 15 PERCENT
* - OBSERVED ORGANISM, MAY NOT HAVE BEEN COUNTED; LESS THAN 1/2 PERCENT

Table 16.--Phytoplankton data for all sampling sites (continued)

Site 9
01098712 GRIST MILLPOND NEAR MARLBOROUGH, MA

PHYTOPLANKTON ANALYSES, NOVEMBER 1976 TO NOVEMBER 1978

DATE	NOV 2,76		JUN 14,77		AUG 11,77		OCT 13,77	
TIME	1430		1130		1045		1145	
TOTAL CELLS/ML	140000		13000		85000		46000	
ORGANISM	CELLS /ML	PER- CENT	CELLS /ML	PER- CENT	CELLS /ML	PER- CENT	CELLS /ML	PER- CENT
CHLOROPHYTA (GREEN ALGAE)								
.CHLOROPHYCEAE								
..CHLOROCOCCALES								
...COELASTRACEAE								
....COELASTRUM	--	-	*	0	--	-	--	-
...HYDRODICTYACEAE								
....PEDIASTRUM	--	-	1600	12	45000#	53	31000#	67
...MICRACTINIACEAE								
....GOLENKINIA	*	0	*	0	13000#	15	4000	9
....MICRACTINIUM	890	1	180	1	--	-	--	-
...OOCYSTACEAE								
....ANKISTRODESMUS	--	-	*	0	--	-	--	-
....CHLORELLA	40000#	29	--	-	--	-	--	-
....OOCYSTIS	--	-	89	1	--	-	--	-
....SELENASTRUM	--	-	*	0	--	-	--	-
....TETRAEDRON	--	-	130	1	--	-	--	-
...SCENEDESMACEAE								
....SCENEDESMUS	89000#	64	9200#	68	27000#	32	9500#	21
..VOLVOCALES								
...CHLAMYDOMONADACEAE								
....CHLAMYDOMONAS	*	0	--	-	--	-	--	-
...VOLVOCACEAE								
....PANDORINA	--	-	*	0	--	-	--	-
..ZYGNEMATALES								
...DESMIDIACEAE								
....STAURASTRUM	--	-	*	0	--	-	--	-
CHRYSOPHYTA								
.BACILLARIOPHYCEAE								
..CENTRALES								
...COSCINODISCACEAE								
....CYCLOTELLA	*	0	--	-	--	-	--	-
..PENNALES								
...ACHNANTHACEAE								
....ACHNANTHES	*	0	--	-	--	-	--	-
...CYMBELLACEAE								
....AMPHORA	*	0	--	-	--	-	--	-
...EUNOTIACEAE								
....EUNOTIA	1800	1	--	-	--	-	--	-
...FRAGILARIACEAE								
....FRAGILARIA	1300	1	220	2	--	-	--	-
....SYNEDRA	*	0	--	-	--	-	--	-
...GOMPHONEMATACEAE								
....GOMPHONEMA	*	0	--	-	--	-	--	-
...MERIDIONACEAE								
....MERIDION	*	0	--	-	--	-	--	-
...NAVICULACEAE								
....NAVICULA	*	0	*	0	--	-	--	-
....PINNULARIA	*	0	--	-	--	-	--	-
...NITZSCHIACEAE								
....NITZSCHIA	890	1	650	5	*	0	260	1
.CHRYSOPHYCEAE								
..CHRYSOMONADALES								
...OCHROMONADACEAE								
....OCHROMONAS	--	-	89	1	--	-	--	-
.XANTHOPHYCEAE								
..RHIZOCHLORIDALES								
...STIPITOCOCCACEAE								
....STIPITOCOCCUS	--	-	--	-	--	-	260	1
CRYPTOPHYTA (CRYPTOMONADS)								
.CRYPTOPHYCEAE								
..CRYPTOMONADALES								
...CRYPTOMONADACEAE								
....CRYPTOMONAS	--	-	160	1	--	-	*	0
CYANOPHYTA (BLUE-GREEN ALGAE)								
.CYANOPHYCEAE								
..CHROOCOCCALES								
...CHROOCOCCACEAE								
....ANACYSTIS	--	-	800	6	--	-	970	2
..HORMOGONALES								
...OSCILLATORIACEAE								
....OSCILLATORIA	--	-	240	2	--	-	*	0
EUGLENOPHYTA (EUGLENOIDS)								
.EUGLENOPHYCEAE								
..EUGLENALES								
...EUGLENACEAE								
....TRACHELOMONAS	*	0	--	-	--	-	*	0

NOTE: # - DOMINANT ORGANISM; EQUAL TO OR GREATER THAN 15 PERCENT
* - OBSERVED ORGANISM, MAY NOT HAVE BEEN COUNTED; LESS THAN 1/2 PERCENT

Table 16.--Phytoplankton data for all sampling sites (continued)

Site 9
01098712 GRIST MILLPOND NEAR MARLBOROUGH, MA

PHYTOPLANKTON ANALYSES, NOVEMBER 1976 TO NOVEMBER 1978

DATE	JUN 22,78		AUG 22,78		NOV 21,78	
TIME	1030		1330		1030	
TOTAL CELLS/ML	14000		84000		120000	
ORGANISM	CELLS /ML	PER- CENT	CELLS /ML	PER- CENT	CELLS /ML	PER- CENT
CHLOROPHYTA (GREEN ALGAE)						
.CHLOROPHYCEAE						
..CHLOROCOCCALES						
...COELASTRACEAE						
....COELASTRUM	--	-	--	-	--	-
...HYDRODICTYACEAE						
....PEDIASTRUM	9700#	71	4700	6	--	-
...MICRACTINIACEAE						
....GOLENKINIA	--	-	670	1	--	-
....MICRACTINIUM	--	-	--	-	--	-
...OOCYSTACEAE						
....ANKISTRODESMUS	--	-	--	-	--	-
....CHLORELLA	--	-	--	-	--	-
....OOCYSTIS	--	-	--	-	--	-
....SELENASTRUM	--	-	--	-	--	-
....TETRAEDRON	--	-	--	-	--	-
...SCENEDESMACEAE						
....SCENEDESMUS	3800#	28	78000#	93	110000#	98
..VOLVOCALES						
...CHLAMYDOMONADACEAE						
....CHLAMYDOMONAS	--	-	*	0	--	-
...VOLVOCACEAE						
....PANDORINA	--	-	--	-	--	-
..ZYGNEMATALES						
...DESMIDIACEAE						
....STAURASTRUM	--	-	--	-	2200	2
CHRYSOPHYTA						
.BACILLARIOPHYCEAE						
..CENTRALES						
...COSCINODISCACEAE						
....CYCLOTELLA	--	-	*	0	--	-
..PENNALES						
...ACHNANTHACEAE						
....ACHNANTHES	--	-	--	-	--	-
...CYMBELLACEAE						
....AMPHORA	--	-	--	-	--	-
...EUNOTIACEAE						
....EUNOTIA	--	-	--	-	--	-
...FRAGILARIACEAE						
....FRAGILARIA	--	-	--	-	--	-
....SYNEDRA	--	-	--	-	--	-
...GOMPHONEMATACEAE						
....GOMPHONEMA	--	-	--	-	--	-
...MERIDIONACEAE						
....MERIDION	--	-	--	-	--	-
...NAVICULACEAE						
....NAVICULA	--	-	*	0	--	-
....PINNULARIA	--	-	--	-	--	-
...NITZSCHIACEAE						
....NITZSCHIA	*	0	*	0	--	-
.CHRYSOPHYCEAE						
..CHRYSOMONADALES						
...OCHROMONADACEAE						
....OCHROMONAS	--	-	--	-	--	-
.XANTHOPHYCEAE						
..RHIZOCHLORIDALES						
...STIPITOCOCCACEAE						
....STIPITOCOCCUS	--	-	--	-	--	-
CRYPTOPHYTA (CRYPTOMONADS)						
.CRYPTOPHYCEAE						
..CRYPTOMONADALES						
...CRYPTOMONADACEAE						
....CRYPTOMONAS	--	-	--	-	--	-
CYANOPHYTA (BLUE-GREEN ALGAE)						
.CYANOPHYCEAE						
..CHROOCOCCALES						
...CHROOCOCCACEAE						
....ANACYSTIS	--	-	--	-	--	-
..HORMOGONALES						
...OSCILLATORIACEAE						
....OSCILLATORIA	--	-	--	-	--	-
EUGLENOPHYTA (EUGLENOIDS)						
.EUGLENOPHYCEAE						
..EUGLENALES						
...EUGLENACEAE						
....TRACHELOMONAS	--	-	--	-	--	-

NOTE: # - DOMINANT ORGANISM; EQUAL TO OR GREATER THAN 15 PERCENT
* - OBSERVED ORGANISM, MAY NOT HAVE BEEN COUNTED; LESS THAN 1/2 PERCENT

Table 16.--Phytoplankton data for all sampling sites (continued)

Site 12
01098722 GRIST MILLPOND OUTLET NEAR MARLBOROUGH, MA

PHYTOPLANKTON ANALYSES, AUGUST 1978 TO NOVEMBER 1978

DATE	AUG 23,78		NOV 21,78	
TIME	1400		1445	
TOTAL CELLS/ML	41000		100000	
ORGANISM	CELLS /ML	PER- CENT	CELLS /ML	PER- CENT
CHLOROPHYTA (GREEN ALGAE)				
.CHLOROPHYCEAE				
..CHLOROCOCCALES				
...SCENEDESMACEAE				
....SCENEDESMUS	41000#	100	94000#	92
..VOLVOCALES				
...CHLAMYDOMONADACEAE				
....CHLAMYDOMONAS	--	-	690	1
CHRYSOPHYTA				
.BACILLARIOPHYCEAE				
..CENTRALES				
...COSCINODISCACEAE				
....CYCLOTELLA	--	-	*	0
..PENNALES				
...NITZSCHIACEAE				
....NITZSCHIA	--	-	*	0
CYANOPHYTA (BLUE-GREEN ALGAE)				
.CYANOPHYCEAE				
..CHROOCOCCALES				
...CHROOCOCCACEAE				
....ANACYSTIS	--	-	6900	7

NOTE: # - DOMINANT ORGANISM; EQUAL TO OR GREATER THAN 15 PERCENT
* - OBSERVED ORGANISM, MAY NOT HAVE BEEN COUNTED; LESS THAN 1/2 PERCENT

Table 16.--Phytoplankton data for all sampling sites (continued)

Site 15
01098730 CARDING MILLPOND NEAR MARLBOROUGH, MA

PHYTOPLANKTON ANALYSES, NOVEMBER 1976 TO NOVEMBER 1978

DATE	NOV 3,76		AUG 11,77		OCT 13,77		JUN 22,78		AUG 22,78		NOV 21,78	
TIME	0800		1430		1500		1315		1600		1145	
TOTAL CELLS/ML	100000		130000		220000		8900		65000		120000	
ORGANISM	CELLS /ML	PER-CENT	CELLS /ML	PER-CENT	CELLS /ML	PER-CENT	CELLS /ML	PER-CENT	CELLS /ML	PER-CENT	CELLS /ML	PER-CENT
CHLOROPHYTA (GREEN ALGAE)												
.CHLOROPHYCEAE												
..CHLOROCOCCALES												
...HYDRODICTYACEAE												
....PEDIASTRUM	--	-	8300	6	150000#	71	2200#	25	3600	5	--	-
...MICRACTINIACEAE												
....GOLENKINIA	*	0	*	0	14000	6	--	-	360	1	--	-
...OOCYSTACEAE												
....ANKISTRODESMUS	--	-	*	0	--	-	--	-	--	-	--	-
....CHLORELLA	18000#	17	--	-	--	-	--	-	--	-	--	-
....CHODATELLA	--	-	--	-	--	-	--	-	--	-	*	0
....TETRAEDRON	*	0	--	-	*	0	--	-	--	-	--	-
...SCENEDESMACEAE												
....SCENEDESMUS	81000#	79	3600	3	32000	15	6700#	75	7500	11	100000#	84
..TETRASPORALES												
...PALMELLACEAE												
....SPHAEROCYSTIS	--	-	--	-	--	-	--	-	4300	7	--	-
..VOLVOCALES												
...CHLAMYDOMONADACEAE												
....CHLAMYDOMONAS	1600	2	*	0	*	0	--	-	--	-	*	0
...VOLVOCACEAE												
....PANDORINA	--	-	--	-	--	-	--	-	--	-	19000#	16
CHRYSOPHYTA												
.BACILLARIOPHYCEAE												
..PENNALES												
...FRAGILARIACEAE												
....SYNEDRA	*	0	--	-	--	-	--	-	--	-	--	-
...NITZSCHIACEAE												
....NITZSCHIA	--	-	*	0	*	0	--	-	--	-	--	-
.XANTHOPHYCEAE												
..RHIZOCHLORIDALES												
...STIPITOCOCCACEAE												
....STIPITOCOCCUS	--	-	--	-	*	0	--	-	--	-	--	-
CRYPTOPHYTA (CRYPTOMONADS)												
.CRYPTOPHYCEAE												
..CRYPTOMONADALES												
...CRYPTOMONADACEAE												
....CRYPTOMONAS	--	-	--	-	*	0	--	-	--	-	--	-
CYANOPHYTA (BLUE-GREEN ALGAE)												
.CYANOPHYCEAE												
..CHROOCOCCALES												
...CHROOCOCCACEAE												
....ANACYSTIS	1600	2	120000#	90	16000	7	--	-	50000#	76	--	-

NOTE: # - DOMINANT ORGANISM; EQUAL TO OR GREATER THAN 15 PERCENT
* - OBSERVED ORGANISM, MAY NOT HAVE BEEN COUNTED; LESS THAN 1/2 PERCENT

Table 16.--Phytoplankton data for all sampling sites (continued)

Site 16
01098733 HOP BROOK NEAR MARLBOROUGH, MA

PHYTOPLANKTON ANALYSES, AUGUST 1978 TO NOVEMBER 1978

DATE	AUG 23,78		NOV 21,78	
TIME	1615		1330	
TOTAL CELLS/ML	61000		150000	
ORGANISM	CELLS /ML	PER- CENT	CELLS /ML	PER- CENT
CHLOROPHYTA (GREEN ALGAE)				
.CHLOROPHYCEAE				
..CHLOROCOCCALES				
...HYDRODICTYACEAE				
....PEDIASTRUM	--	-	1000	1
...OOCYSTACEAE				
....CHODATELLA	--	-	*	0
...SCENEDESMACEAE				
....SCENEDESMUS	14000#	23	130000#	85
..TETRASPORALES				
...PALMELLACEAE				
....SPHAEROCYSTIS	4000	7	--	-
..VOLVOCALES				
...CHLAMYDOMONADACEAE				
....CHLAMYDOMONAS	*	0	--	-
...VOLVOCACEAE				
....PANDORINA	--	-	20000	13
CHRYSOPHYTA				
.BACILLARIOPHYCEAE				
..CENTRALES				
...COSCINODISCACEAE				
....CYCLOTELLA	*	0	*	0
..PENNALES				
...NAVICULACEAE				
....NAVICULA	*	0	--	-
...NITZSCHIACEAE				
....NITZSCHIA	*	0	--	-
CYANOPHYTA (BLUE-GREEN ALGAE)				
.CYANOPHYCEAE				
..CHROOCOCCALES				
...CHROOCOCCACEAE				
....ANACYSTIS	42000#	69	--	-

NOTE: # - DOMINANT ORGANISM; EQUAL TO OR GREATER THAN 15 PERCENT
* - OBSERVED ORGANISM, MAY NOT HAVE BEEN COUNTED; LESS THAN 1/2 PERCENT

Table 17.--Streamflow data for site 8, Hager Pond Outlet near Marlborough

01098710 HAGER POND OUTLET AT MARLBOROUGH, MA

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1976 TO SEPTEMBER 1977
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1				3.7	4.8	12	14	10	4.1	4.1	2.8	2.3
2				3.6	4.4	11	13	9.8	4.1	3.6	6.1	2.1
3				3.5	4.4	10	13	9.4	4.1	3.2	5.4	2.1
4				3.4	4.4	10	11	9.3	4.1	2.8	4.5	1.9
5				3.3	4.4	14	17	9.3	4.1	3.0	3.5	1.7
6				3.3	4.4	17	17	9.3	4.1	3.0	3.0	1.5
7				3.6	4.4	14	14	9.0	4.5	2.8	2.7	1.5
8				4.4	4.4	13	13	8.8	5.4	2.6	2.8	1.5
9				3.8	4.4	13	12	10	5.4	3.0	2.9	1.5
10				5.1	4.4	15	12	17	5.5	3.0	3.0	1.7
11				7.5	4.4	16	11	18	6.3	3.1	3.0	1.9
12				6.6	4.4	16	11	17	6.9	3.3	2.9	1.9
13				5.8	4.4	17	9.9	15	6.9	3.8	3.0	1.9
14				5.1	5.1	17	9.5	13	6.3	4.3	3.0	1.7
15				5.1	5.1	19	9.2	12	4.1	4.5	2.8	1.7
16				4.8	5.1	17	9.0	11	3.7	4.5	2.8	1.7
17				4.8	5.1	15	8.8	11	3.5	4.0	2.8	1.9
18				4.8	5.1	15	8.4	11	3.5	3.5	2.6	2.1
19				4.4	5.1	15	8.5	9.5	3.8	3.2	2.3	2.6
20				4.4	5.1	14	9.1	8.8	3.8	2.9	2.6	3.8
21				4.1	5.1	14	9.4	8.0	3.7	3.2	2.6	5.8
22				3.8	5.1	16	9.6	7.4	3.5	3.4	2.3	4.1
23				3.6	5.1	31	11	6.8	3.3	3.1	2.3	3.3
24				4.1	4.8	20	18	6.6	3.1	2.9	2.3	3.0
25				4.1	11	17	21	6.6	3.1	2.7	2.6	3.0
26				4.1	12	16	16	6.2	3.5	3.5	2.6	5.1
27				4.1	12	17	13	5.6	4.1	3.3	2.6	10
28				4.1	12	16	12	5.4	4.3	2.8	2.6	7.2
29				4.8	---	16	11	5.2	4.5	2.5	2.6	5.8
30				4.8	---	17	10	4.4	4.5	2.2	2.6	4.4
31				4.8	---	15	---	4.1	---	2.0	2.6	---
TOTAL				137.4	160.4	485	361.4	294.5	131.8	99.8	92.2	90.7
MEAN				4.43	5.73	15.6	12.0	9.50	4.39	3.22	2.97	3.02
MAX				7.5	12	31	21	18	6.9	4.5	6.1	10
MIN				3.3	4.4	10	8.4	4.1	3.1	2.0	2.3	1.5
(*)				4.00	4.32	7.22	5.52	4.75	3.09	2.52	2.64	2.86

* Diversion, in cubic feet per second, from city of Marlborough Easterly sewage treatment plant to unnamed tributary to Hager Pond. Records furnished by Marlborough Department of Public Works.

Table 17.--Streamflow data for site 8, Hager Pond Outlet near Marlborough (continued)

01098710 HAGER POND OUTLET AT MARLBOROUGH, MA

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1977 TO SEPTEMBER 1978
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	4.8	5.4	13	9.3	11	5.8	17	7.0	5.6	3.8	2.8	2.6
2	6.6	5.4	14	9.3	11	5.8	18	6.9	5.2	3.7	2.9	2.6
3	6.3	5.4	12	9.3	10	5.8	16	6.9	5.4	3.6	3.0	2.6
4	5.4	5.4	11	8.8	9.5	5.8	14	6.9	5.6	3.7	3.0	2.6
5	4.8	5.4	11	8.5	8.8	5.8	14	6.9	5.4	4.1	3.0	2.6
6	4.8	5.4	11	8.2	8.8	5.8	14	7.2	5.0	4.1	3.9	2.6
7	4.4	5.4	10	8.0	10	5.6	14	7.2	4.7	4.1	5.2	2.6
8	4.1	8.0	9.5	7.7	8.8	5.4	13	6.9	5.2	3.8	12	2.6
9	5.1	20	9.3	22	8.2	5.4	12	6.1	5.4	3.6	9.2	2.3
10	7.2	13	9.3	18	8.0	5.4	12	6.6	5.0	3.6	6.5	2.3
11	6.6	12	8.8	12	7.7	5.4	11	6.1	4.5	3.6	5.3	2.4
12	5.8	10	8.5	11	7.5	5.8	11	5.8	4.2	3.8	4.6	2.8
13	4.8	9.3	8.2	9.8	7.5	7.0	11	5.8	4.1	3.8	4.3	2.8
14	4.8	9.0	8.0	11	6.9	7.6	10	5.8	4.1	3.8	4.1	2.8
15	4.8	8.8	11	10	6.9	10	9.2	8.5	4.1	4.2	4.1	2.8
16	6.1	8.5	12	9.3	6.6	11	9.0	11	4.1	5.4	3.9	2.8
17	12	8.2	11	8.8	6.6	10	8.6	12	4.1	5.4	3.8	2.8
18	11	9.5	9.8	9.3	6.3	9.0	8.4	9.5	4.1	5.4	3.7	2.8
19	9.0	9.0	9.5	9.8	6.3	8.5	8.4	9.0	4.3	4.8	3.6	2.8
20	8.8	8.2	9.5	9.3	6.3	9.0	12	8.7	6.1	4.3	3.1	2.8
21	10	8.0	12	9.3	6.3	10	11	8.5	6.1	3.8	3.0	2.8
22	9.0	8.0	20	7.7	6.3	18	10	8.3	5.6	3.5	3.0	2.8
23	7.7	8.0	15	7.5	6.3	19	8.8	7.6	5.1	3.2	3.0	2.6
24	6.9	8.0	13	7.5	6.4	19	8.3	7.4	4.9	3.0	2.9	2.6
25	6.6	7.7	12	8.0	6.1	17	8.2	8.2	4.4	2.8	2.8	2.6
26	6.6	8.8	13	31	5.8	15	8.0	8.2	4.4	2.8	2.8	2.6
27	6.6	9.8	12	30	5.8	19	8.0	8.0	4.4	2.8	2.8	2.6
28	6.3	9.0	11	20	5.8	25	7.6	7.4	4.1	3.0	2.8	2.6
29	6.1	8.5	11	16	---	22	7.5	7.2	3.8	2.9	2.8	2.6
30	5.4	8.2	9.8	14	---	20	7.3	6.4	3.8	2.8	2.6	2.6
31	5.4	---	9.8	12	---	18	---	6.0	---	2.7	2.6	---
TOTAL	203.8	255.3	345.0	372.4	211.5	341.9	327.3	234.0	142.8	115.9	123.1	79.4
MEAN	6.57	8.51	11.1	12.0	7.55	11.0	10.9	7.55	4.76	3.74	3.97	2.65
MAX	12	20	20	31	11	25	18	12	6.1	5.4	12	2.8
MIN	4.1	5.4	8.0	7.5	5.8	5.4	7.3	5.8	3.8	2.7	2.6	2.3
(*)	4.10	4.55	5.40	5.26	3.85	5.52	5.31	3.89	3.22	2.75	2.94	2.82

CAL YR 1977 TOTAL 2657.3 MEAN 7.28 MAX 31 MIN 1.5
WTR YR 1978 TOTAL 2752.4 MEAN 7.54 MAX 31 MIN 2.3

* Diversion, in cubic feet per second, from city of Marlborough Easterly sewage treatment plant to unnamed tributary to Hager Pond. Records furnished by Marlborough Department of Public Works.

Table 17.--Streamflow data for site 8, Hager Pond Outlet near Marlborough (continued)

01098710 HAGER POND OUTLET AT MARLBOROUGH, MA

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1978 TO SEPTEMBER 1979
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	2.6	3.0	4.1	5.1	16	8.6	8.2	9.0	9.9	4.5	4.3	5.6
2	2.6	3.3	3.8	8.0	14	9.0	8.6	8.2	9.5	4.5	4.2	5.2
3	2.6	3.3	3.6	13	13	10	11	7.8	8.6	4.5	4.2	4.9
4	2.6	3.3	3.6	11	12	11	11	7.4	8.2	4.2	5.5	4.8
5	2.6	3.3	4.1	8.8	12	13	12	7.0	8.2	4.2	5.5	4.7
6	5.8	3.0	4.1	8.0	11	17	12	6.6	8.2	4.2	5.5	4.7
7	6.3	3.0	3.8	7.5	9.9	20	11	6.6	8.2	4.2	5.5	6.2
8	4.4	3.3	3.8	15	9.5	18	14	6.6	8.2	4.2	5.2	5.3
9	3.3	3.3	5.1	16	9.5	16	14	5.9	7.8	3.6	4.8	5.0
10	2.6	3.3	7.7	11	9.5	14	18	14	7.4	3.1	5.2	4.7
11	2.3	3.3	5.8	10	9.0	17	14	12	7.0	3.1	6.2	4.4
12	3.0	3.8	5.1	9.3	8.2	17	11	7.8	7.0	3.1	13	4.4
13	3.3	5.8	4.1	8.7	7.8	15	10	7.4	6.6	3.3	24	4.4
14	3.6	4.4	3.8	15	7.4	12	9.9	7.4	6.2	3.3	17	4.4
15	4.1	3.6	3.8	14	7.0	9.0	9.9	7.0	5.9	3.5	12	4.8
16	3.8	3.6	3.6	11	7.0	9.0	9.9	7.0	5.5	6.0	9.5	4.3
17	3.6	3.3	3.8	10	6.6	9.0	9.9	6.8	5.2	7.5	7.8	4.2
18	3.0	3.8	3.8	9.9	6.2	9.9	9.5	6.6	4.8	6.3	7.4	4.2
19	2.8	3.8	3.8	9.2	5.9	9.9	9.0	6.6	4.8	5.2	7.0	4.2
20	2.8	3.6	3.8	8.8	5.2	9.9	8.6	7.0	4.8	4.7	7.0	3.9
21	2.6	3.6	4.4	18	5.2	9.9	8.2	7.8	4.5	4.5	6.6	3.6
22	2.6	3.3	5.1	26	5.2	9.9	8.2	7.8	4.5	4.3	5.9	5.9
23	2.8	3.3	5.1	16	5.2	9.9	7.4	7.8	4.5	4.1	5.2	7.0
24	2.8	3.3	5.1	13	11	8.6	7.4	9.0	4.2	3.8	5.0	5.5
25	2.6	3.3	6.1	79	19	9.5	7.4	21	4.2	4.0	4.8	4.8
26	2.3	3.3	6.6	45	14	11	7.4	21	4.5	4.2	5.6	4.5
27	3.0	3.3	6.1	28	10	10	15	16	4.5	6.0	6.5	4.5
28	3.6	3.0	4.4	23	8.6	9.5	17	13	4.2	5.4	7.5	4.2
29	3.3	3.0	4.4	20	---	7.4	13	12	4.5	5.0	7.4	5.9
30	3.3	3.8	4.1	18	---	6.6	10	12	4.5	4.7	7.0	7.4
31	3.0	---	4.1	17	---	8.2	---	11	---	4.5	6.4	---
TOTAL	99.6	104.3	140.6	512.3	264.9	354.8	322.5	293.1	186.1	137.7	228.7	147.6
MEAN	3.21	3.48	4.54	16.5	9.46	11.4	10.8	9.45	6.20	4.44	7.38	4.92
MAX	6.3	5.8	7.7	79	19	20	18	21	9.9	7.5	24	7.4
MIN	2.3	3.0	3.6	5.1	5.2	6.6	7.4	5.9	4.2	3.1	4.2	3.6
(*)	3.70	3.59	4.04	6.48	4.60	5.52	5.14	4.56	3.74	3.12	3.77	3.43

CAL YR 1978 TOTAL 2292.8 MEAN 6.28 MAX 31 MIN 2.3
WTR YR 1979 TOTAL 2792.2 MEAN 7.65 MAX 79 MIN 2.3

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1979 TO SEPTEMBER 1980
MEAN VALUES

DAY	OCT	NOV	DAY	OCT	NOV
1	7.4	7.0	21	6.6	---
2	7.4	7.0	22	7.4	---
3	8.2	16	23	7.4	---
4	11	18	24	7.4	---
5	10	13	25	7.0	---
6	9.0	9.9	26	6.6	---
7	8.6	---	27	6.6	---
8	8.6	---	28	6.6	---
9	8.2	---	29	6.6	---
10	7.8	---	30	7.0	---
			31	7.0	---
11	8.6	---			
12	9.0	---	TOTAL	248.7	---
13	11	---	MEAN	8.02	---
14	10	---	MAX	11	---
15	9.5	---	MIN	6.6	
			(*)	4.32	4.89
16	8.6	---			
17	7.8	---			
18	7.4	---			
19	7.4	---			
20	7.0	---			

* Diversion, in cubic feet per second, from city of Marlborough Easterly sewage treatment plant to unnamed tributary to Hager Pond. Records furnished by Marlborough Department of Public Works.

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