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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
U.S. Geological Survey

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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, 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 2
01098705 - HAGER POND TRIBUTARY AT MARLBOROUGH, MA (LAT 42 21 03 LONG 071 29 29)

DATE	TIME	STREAMFLOW (CFS)	SPEC. COND. (UMHOS)	PH	TEMP (DEG C)	O2 DIS (MG/L)	O2 DIS (% SAT)	N ORG (MG/L)
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)

DATE	TIME	STREAMFLOW (CFS)	SPEC. COND. (UMHOS)	PH	TEMP (DEG C)	O2 DIS (MG/L)	O2 DIS (% SAT)	N ORG (MG/L)
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)

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 12								
01098722 - GRIST MILLPOND OUTLET NEAR MARLBOROUGH, MA (LAT 42 21 26 LONG 071 28 15)								
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)								
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	NITRO-GEN, AMMONIA TOTAL (MG/L AS N)	NITRO-GEN, NITRITE TOTAL (MG/L AS N)	NITRO-GEN, NITRATE TOTAL (MG/L AS N)	NITRO-GEN, TOTAL (MG/L AS N)	PHOS-PHORUS, ORTHO, TOTAL (MG/L AS P)	PHOS-PHORUS, TOTAL (MG/L AS P)	ALGAL GROWTH POTEN-TIAL, 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)

Site 2

01098705 - HAGER POND TRIBUTARY AT MARLBOROUGH, MA (LAT 42 21 03 LONG 071 29 29)

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)
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)

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)
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)

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)
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)

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)
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[illegible]

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)	[illegible]
Site 12 — 01098722 - GRIST MILLPOND OUTLET NEAR MARLBOROUGH, MA (LAT 42 21 26 LONG 071 28 [illegible]										
AUG , 1978										
23...	31	1.9	46	12	65	19	46	58	5.6	2[illegible]
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)										
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)										
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)	CAD-MIUM TOTAL RECOV-ERABLE (UG/L AS CD)	CHRO-MIUM, TOTAL RECOV-ERABLE (UG/L AS CR)	COBALT, TOTAL RECOV-ERABLE (UG/L AS CO)	COPPER, TOTAL RECOV-ERABLE (UG/L AS CU)	IRON, TOTAL RECOV-ERABLE (UG/L AS FE)	IRON, DIS-SOLVED (UG/L AS FE)	LEAD, TOTAL RECOV-ERABLE (UG/L AS PB)	MANGA-NESE, TOTAL RECOV-ERABLE (UG/L AS MN)	MERCURY TOTAL RECOV-ERABLE (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)

Site 2

01098705 - HAGER POND TRIBUTARY AT MARLBOROUGH, MA (LAT 42 21 03 LONG 071 29 29)

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)
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)

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)
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)

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)
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)

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)
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	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 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									
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