316 (a) Demonstration

NEW YORK STATE
ELECTRIC & GAS
CORPORATION

Greenidge Station

T.

August 19

DISTRIBUTION LIST

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NEW YORK STATE ELECTRIC & GAS CORPORATION

BINGHAMTON, NEW YORK 13902

August 15, 1977

Gerald M. Hansler, P. E.
Regional Administrator
Region II
U. S. Environmental Protection Agency
26 Federal Plaza
New York, New York 10007

Re: Greenidge Station
NPDES Permit No. NY0001325

Dear Mr. Hansler:

Submitted herewith for your review is applicant, New York State Electric & Gas Corporation's (NYSE&G) 316(a) Demonstration for Greenidge Station. The submittal is in support of applicant's request for alternative thermal effluent limitations for Greenidge Station. The results of this Demonstration indicate that the continuation of the thermal discharge as presently operated will assure the protection and propagation of the balanced indigenous aquatic communities in the Keuka Lake Outlet and Seneca Lake near Greenidge Station.

In consideration of the results contained in the Demonstration, NYSE&G requests that the following alternative thermal effluent limitations be imposed for Greenidge Station;

1. New York State thermal limitations may be exceeded within a mixing zone in Keuka Lake Outlet. This zone encompasses the entire channel from the point of thermal discharge to the mouth of Keuka Lake Outlet.

2. New York State thermal limitations may be exceeded within a mixing zone in Seneca Lake which extends from the mouth of Keuka Lake Outlet and encompasses 230 surface acres of the lake.

Pursuant to the stipulation with the New York State Department of Environmental Conservation and the United States Environmental Protection Agency in connection with the administrative disposition of NYSE&G adjudicatory hearing request which is now in the process of being signed by all parties, NYSE&G undertook to submit this Demonstration on or before August 31, 1977.

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316 (a) Demonstration

NEW YORK STATE
ELECTRIC & GAS
CORPORATION

Greenidge Station

7

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lower incipient lethal temperature (lower lethal threshold or temperature)	- the temperature (usually the freezing point) below which an organism cannot live indefinitely, but survives for some limited period.
maximum dependable capacity	- the highest load at which a unit may be operated in a dependable and consistent fashion.
synchronous condenser	- a motor (turbine generator) that, through variation in excitation, can control the voltage, power factor and stability of transmission lines.
upper incipient lethal temperature (upper lethal threshold or temperature)	- the temperature above which an organism cannot live indefinitely but survives for some limited period.

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ABBREVIATIONS (continued)

NTU	- nephelometric turbidity unit
NWQL	- National Water Quality Laboratory
NYSBCS	- New York State Barge Canal System
NYSCD	- New York State Conservation Department
NYSDEC (DEC)	- New York State Department of Environmental Conservation
Q_O	- plant discharge
Q_R	- river flow
Q_O/Q_R	- flow ratio
RWRPB	- Regional Water Resources Planning Boards
SCPB	- Seneca County Planning Board
SCS	- Soil Conservation Service
sq ft	- square feet
sq in	- square inches
TL	- total length
USDA	- United States Department of Agriculture
USEPA (EPA)	- United States Environmental Protection Agency
USGS	- United States Geological Survey
ΔT	- change in temperature; excess-temperature
ΔT_O	- initial excess-temperature
#0 mesh	- mesh size = 571 microns or 0.571mm

SUMMARY AND CONCLUSIONS

Studies of physical, chemical and biological parameters in the Keuka Lake Outlet and Seneca Lake have demonstrated that a balanced indigenous aquatic community exists in the vicinity of Greenidge Station and that the overall effect of the thermal discharge upon this community has been negligible. Minor differences observed between ambient and discharge locations were generally attributed to natural variation in habitat. Although some localized influences of the thermal discharge were observed, the area affected was small and the overall effects are considered inconsequential. These studies demonstrate that the thermal discharge of Greenidge Station has not caused appreciable harm to the aquatic environment and that the protection and propagation of the balanced indigenous aquatic community in the Keuka Lake Outlet and Seneca Lake near the station is assured.

Station Description and Operation

Greenidge Station is a steam electric generating station, consisting of six coal-fired boilers and four turbine generators which produce a gross maximum dependable capacity of 215MW. The date of initial operation of each unit is: Unit 1, 1938; Unit 2, 1942; Unit 3, 1950; and Unit 4, 1953. All units have once-through condenser cooling. Water is withdrawn from Seneca Lake and discharged into Keuka Lake Outlet.

Greenidge Station is currently operated as a baseload facility and will probably continue this mode of operation until at least 1992. Ultimate retirement of the station, however, will depend upon the availability of more economical new generation.

Phytoplankton

The phytoplankton community in Seneca Lake near Greenidge Station during 1976 consisted of 159 taxa distributed among 79 genera. The most commonly encountered algal divisions in order of decreasing abundance, were Cyanophyta (blue-green algae), Cryptophyta (cryptomonads), Chlorophyta (green algae), Bacillariophyta (diatoms) and Chrysophyta (golden-brown algae).

The largest phytoplankton standing crop occurred in September and the smallest during December. A similar bimodal seasonal trend (peaks during both late spring and late summer) was recorded at both ambient and discharge locations. Phytoplankton density and composition were generally similar within and outside the thermal discharge area. There were no statistically significant ($P \leq 0.05$) density differences among locations which could be attributed to an effect of Greenidge Station discharge.

The effect of the Greenidge Station thermal discharge upon the balanced indigenous phytoplankton community of Seneca Lake has been negligible. No indications of accelerated growth, change in species composition, nor gross population shifts to nuisance forms were observed.

Aquatic Macrophytes

An extensive aquatic macrophyte bed composed primarily of Water Milfoil (*Myriophyllum*), occurred in Seneca Lake. The macrophyte bed extended from shoreline depths 3-4ft, lakeward to the 15-18ft depth contour. Other macrophytes identified in the study area were several species of *Potamogeton*, and *Elodea canadensis* and *Vallisneria americana*.

ategories represented a variety of habitat and environmental preferences. No endangered or threatened species were observed.

Comparisons of collections within and outside of the thermal discharge area revealed a reduction in abundance and diversity of macroinvertebrate populations due to the artificially elevated late summer temperatures. Discharge temperatures regularly reached 26-30C in August and early September. Temperatures of this magnitude were apparently above the lethal limits of most macroinvertebrates indigenous to Keuka Lake Outlet. Lethal effects are probably restricted to an area extending from the junction of the discharge canal at Keuka Lake Outlet to Seneca Lake, a distance of approximately 700ft. Repopulation of the affected area apparently occurs during periods of lower water temperatures. The reductions in overall macroinvertebrate abundance have not adversely affected fish populations foraging on macroinvertebrates in the discharge area. Large numbers of Gammarus entrained by Greenidge Station and discharged into the Keuka Lake Outlet provide a large food resource for a variety of fish species.

In conclusion, the effects of station operation were quite localized and it is doubtful that the thermal discharge has had any overall adverse effects upon the balanced indigenous macroinvertebrate community in Keuka Lake Outlet.

Fish

Adult fish were studied once monthly in March, May, June, September, October, December, February and twice in April and August. A total of 38 species of fish representing 14 families was collected. Northern hog sucker, white sucker, largemouth bass, bluegill, multiple unit plant) and general fish behavior related to temperature. The upper lethal temperatures of a limited number of species were rarely exceeded within the thermal discharge area. Temporal distributional patterns and avoidance responses of fish indicated that few fish would ever encounter any potentially lethal temperatures.

Results from this study demonstrated that the thermal discharge of Greenidge Station has not caused appreciable harm to the existing fishery; therefore, the protection and propagation of the balanced indigenous fish community is assured.

Chapter 1

Introduction

On 7 March 1975, New York State Electric & Gas Corporation (NYSE&G), Binghamton, New York requested that the Regional Administrator of the U.S. Environmental Protection Agency (EPA) impose alternative thermal limitations for Greenidge Station. This report is a 316(a) Type 3 Demonstration and has been prepared in support of our request. The report also documents the fulfillment of the biological monitoring requirements of the National Pollutant Discharge Elimination System Permit.

Greenidge Station is a coal-fired steam electric plant located on the west shore of Seneca Lake near Dresden, New York. This station presently has four Units, 1, 2, 3 and 4, in operation which have a combined maximum dependable capacity of 215MW. The dates of initial operation of these Units are 1938, 1942, 1950 and 1953, respectively.

The demonstration is based upon environmental studies conducted from March 1976 through February 1977. Plans for these studies were prepared with the advice and guidance of the U.S. Environmental Protection Agency (EPA) and New York State Department of Environmental Conservation (NYSDEC). NYSE&G met with representatives of these agencies in November and December of 1975 to develop the study plans which were subsequently submitted to the EPA and NYSDEC for approval on 30 June 1976.

Environmental studies included the investigation of phytoplankton, aquatic macrophyte, zooplankton, benthic

Chapter 2

Station Description and Operation

2.1 Description of the Station

Greenidge Station is located in Dresden, New York, on the west shore of Seneca Lake (Figure 2-1). It is a steam electric generating station, consisting of six coal-fired boilers and four turbine generators (Figure 2-2). The maximum capabilities and Units serviced by the Boilers 1-6 are as follows: Boilers 1 and 2, 110,000lbs of steam/hr, Unit 1; Boiler 3, 220,000lbs of steam/hr, Unit 2; Boilers 4 and 5, 300,000lbs of steam/hr, Unit 3; and Boiler 6, 750,000lbs of steam/hr, Unit 4. The maximum dependable capacity (gross) and date of initial operation of each unit are: Unit 1, 25MW, 1938; Unit 2, 24MW, 1942; Unit 3, 58MW, 1950; and Unit 4, 108MW, 1953. The maximum dependable capacity of Greenidge Station is 215MW.

All units have once-through condenser cooling. Water is withdrawn from Seneca Lake and is discharged into the Keuka Lake Outlet through a discharge canal. The canal, which is 900ft long, empties into the Keuka Lake Outlet 700ft upstream from Seneca Lake. The relative locations of the intake structures and discharge canal, are shown in Figure 2-2.

Units 1, 2 and 3 are serviced by two intake pipes which lie on the lake bottom. The 6ft diameter pipe extends 550ft offshore to a depth of 14ft. The 8ft diameter pipe extends 710ft offshore to a water depth of 15ft. A steel cage, consisting of 1/2in bars on 12in centers, covers each intake structure to screen out debris. The maximum current velocity at the entrance to the intake structure of the 6ft pipe is 1.1fps and is 2.1fps at the entrance of the 8ft pipe. At the shoreline, the 6ft and 8ft pipes are joined into 5ft and 6ft diameter concrete pipes, respectively, which extend to the chlorination building. At this point, they combine into a single intake tunnel which leads to the traveling screens. Trash racks, composed of 1/4in bars on 3in centers are located 7ft in front of the traveling screens.

The traveling screens consist of panels of 3/8in wire mesh and are operated automatically by a system of pressure differential controls. During the fall and spring, operation may be continuous whereas during the summer, operation is usually at intervals of two or three hours. Debris collected on the traveling screens is washed to the discharge tunnel.

A third intake pipe, which supplies water to Unit 4, is elevated on wood pilings and extends from the pumphouse to a point 650ft offshore (water depth of 11ft). The pipe opens into a 27ft x 27ft steel intake structure composed of 3/16in bars on 6in centers. The average intake velocity at the face of the intake structure is 0.2fps. There are no traveling screens for Unit 4. Reversing valves on the condenser automatically wash out any debris which might accumulate on the condenser.

The routing of the cooling water flow through the plant is shown in Figure 2-2. The maximum station flow is 293cfs (131,507gpm).

2.2 Historical and Projected Operation of the Station

Greenidge Station is currently being operated as a base-load facility. This mode of operation will probably continue until at least 1992; however, ultimate retirement of the station will depend upon the availability of more economical new generation. The station capacity factors for the last ten years are given in Table 2-1.

For the protection of the aquatic biota from abrupt temperature changes, no complete plant outages are planned, but each unit will be periodically removed from service for maintenance. Maintenance is usually scheduled to be performed during the period of February through November. The scheduled boiler maintenance normally consists of annual two-week outages for inspection and overhaul. On multiple boiler units, usually only one boiler is taken out of service at a time, allowing the turbine generator to remain in operation, but at a reduced load. An extended five-week outage for each turbine unit is scheduled every five years, but only one unit will shut down at a time. During the ten-year period ending January 1976, there were 13 unscheduled complete outages at Greenidge Station which lasted for a total of 93.4 hours. The duration of the outages ranged from 0.8 hours to 31.53 hours.

2.3 Station Operating Data

Units 1, 2 and 3 are each equipped with two circulating water pumps. Unit 4 is equipped with three pumps of which only two are operated. The third pump serves as a back-up. The combined circulating water flow for each unit is as follows: Unit 1, 44cfs

(19,749gpm); Unit 2, 44cfs (19,749gpm); Unit 3, 74cfs (33,213gpm); Unit 4, 131cfs (58,797gpm). The maximum cooling water flow for the station is 293cfs (131,507gpm).

The design temperature increases (ΔT) across the condensers for each unit under various operating conditions are given in Tables 2-2 through 2-5. The temperature rise for the station normally ranges from 3C (5.4F) to 12C (21.6F), depending upon plant load. Load factors for each unit for a typical year (1975) are summarized in Tables 2-6 through 2-9.

Tabulations of the total station heat rejected for a typical year (1975) and for typical months (February and August 1976) are provided in Tables 2-10 through 2-12. The average monthly heat rejection for the station is 509 G BTU and ranges from 389 to 619 G BTU.

Consumptive water losses at Greenidge Station are relatively small. The two principal consumptive losses are due to steam loss and ash handling. Based on data from 1966 through 1975, steam losses are estimated at 0.06cfs (27gpm). Approximately 3.30cfs (1481gpm) is used for ash handling. In addition, the consumptive water losses include the increased evaporation from the Keuka Lake Outlet and Seneca Lake due to the heated water discharge. The average annual rate of increased evaporation is approximately 1.3cfs (583gpm). The total rate of consumptive water loss for Greenidge Station is 4.66cfs (2092gpm).

2.4 Chemical Usage

A number of chemicals are presently used i: tion of Greenidge Station and then discharged with the cooling water. Chlorine, in the form of chlorine gas, two separate chlorination systems to prevent biological the condenser cooling water systems. One system serves and 3, and operates every eight hours for a 10 minute d while the other chlorinates the circulating water of Un four hours for 10 minutes. Chlorination of each system to reduce the concentration of chlorine in the receivin accordance with NPDES permit limitations, free availabl concentration averages 0.2mg/l and does not exceed a ma: 0.5mg/l in the discharge.

Other chemicals are presently released int ser cooling water discharge as part of the water treatm from the filtered water system and boiler blowdown. Th sumption and purpose of these chemicals is given in Tab total amounts of chemicals added to the feed-water and not appear in the boiler blowdown, but are consumed or different extents in the boiler, steam and condensate s

A process wastewater reclamation facility planned to comply with the requirements of the National Discharge Elimination System permit. The treated disch meet the limitations specified in this permit.

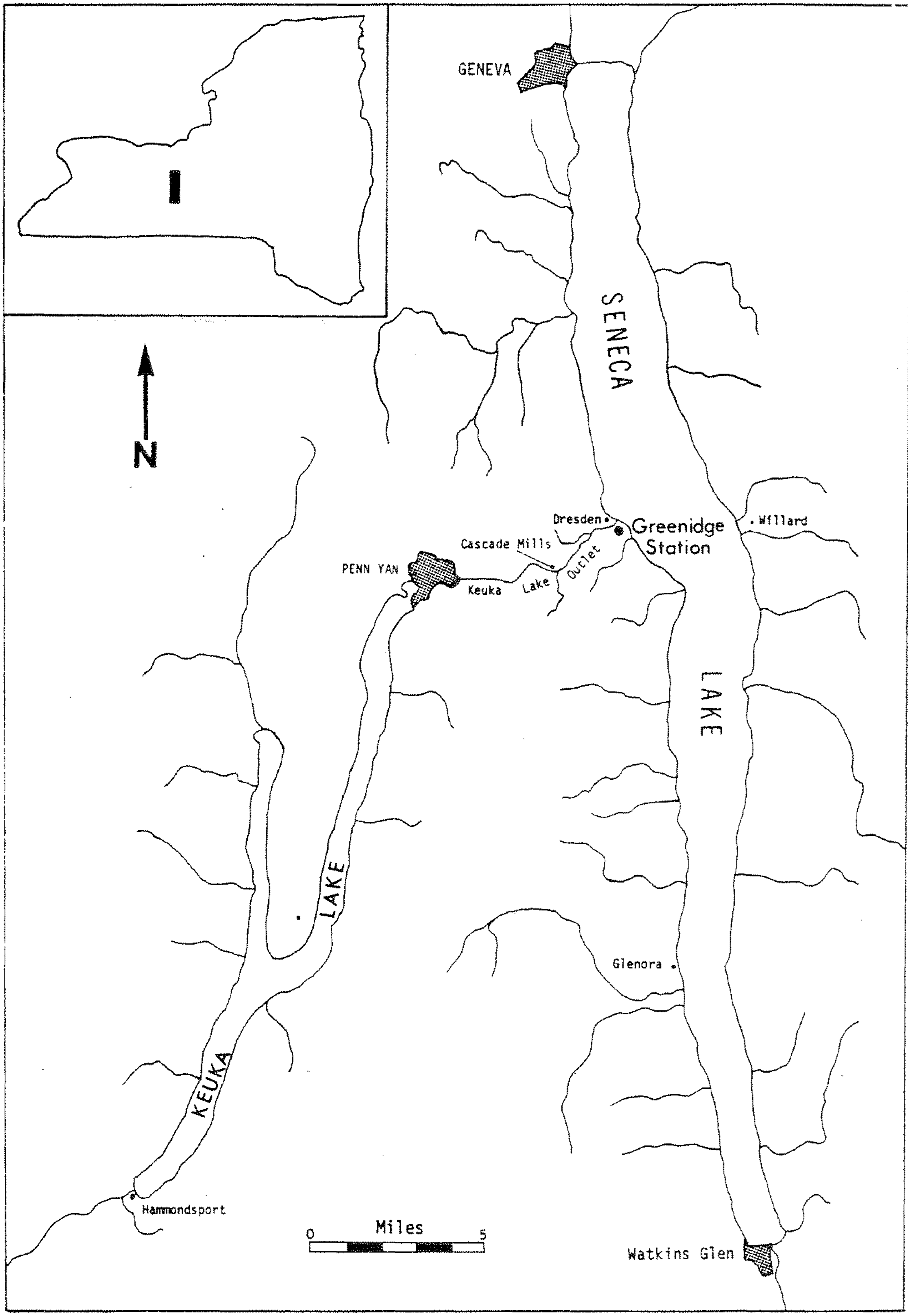

Figure 2-1. Location of Greenidge Station.

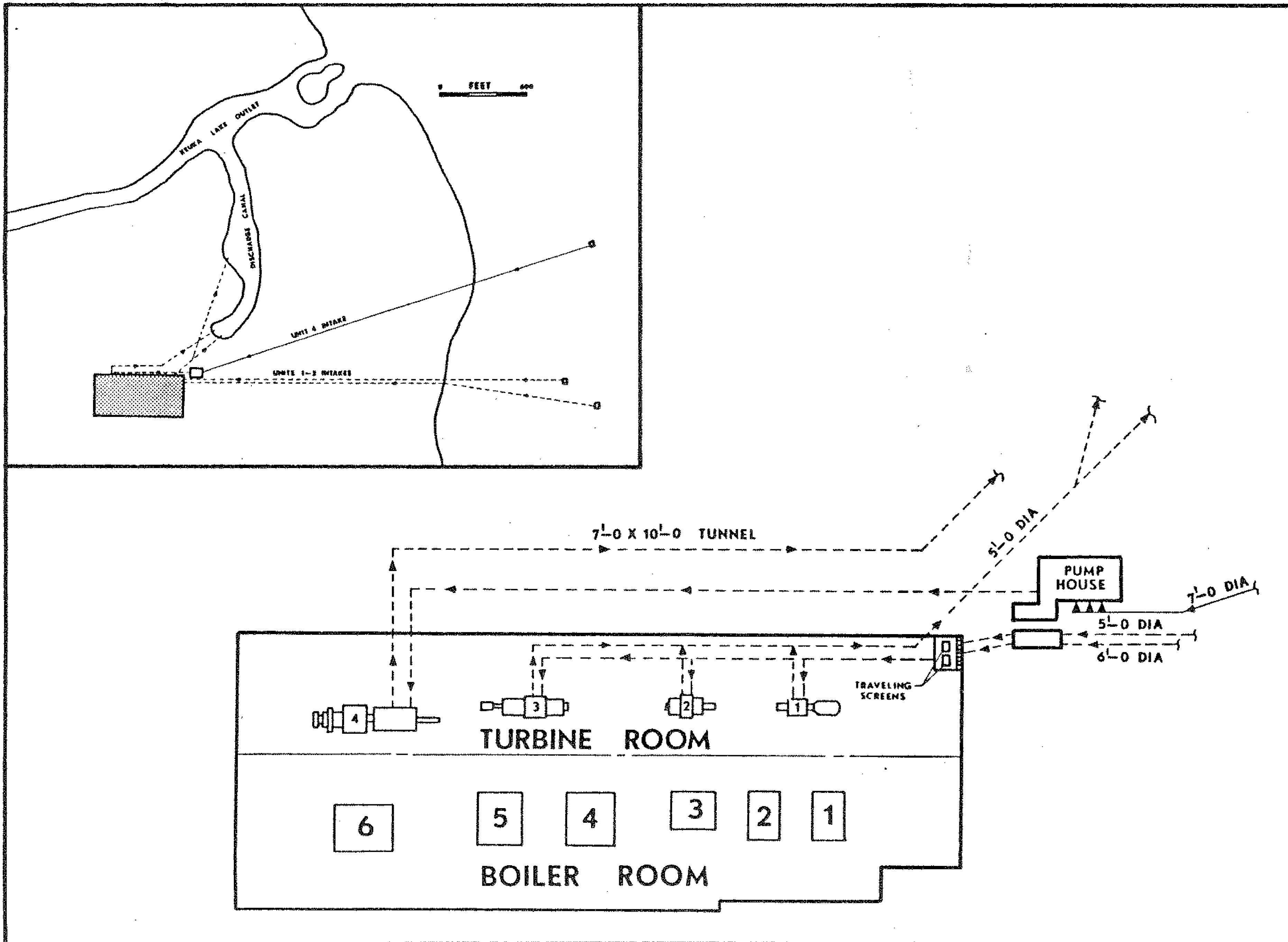

Figure 2-2. Plot plan of Greenidge Station.

Table 2-1. Greenidge Station capacity factors, 1966-1975.

Year	Capacity factor[a] (%)
1975	55
1974	66
1973	50
1972	59
1971	57
1970	51
1969	55
1968	56
1967	53
1966	52

[a]Capacity factor is calculated:

$$\text{Capacity factor (\%)} = \frac{\text{Average station generation (MW)}}{\text{Maximum dependable capacity (MW)}} \times 100$$

Where:

Average station generation (MW) =

$$\frac{(\text{Av Gen Unit 1 X Serv Hr}) + (\text{Av Gen Unit 2 X Serv Hr}) + (\text{Av Gen Unit 3 X Serv Hr}) + (\text{Av Gen Unit 4 X Serv Hr})}{\text{Number of Hours in Year}}$$

Maximum dependable capacity = 206 MW for 1966 through 1971

= 201 MW for 1972 through 1974

= 210 MW for 1975

Table 2-2. Condenser cooling water temperature rises for various loads, Greenidge Station, Unit 1.

Unit Load	Unit Load[a]	Unit Loading Time[b]		Cooling Water Flow	Condenser ΔT^{c}	
MW	%	Hours	%	cfs	Range(C)	Range(F)
<10	<40	0	0.0	44	<4.0	<7.2
10-12	40-49	1	0.1	44	4.0-4.6	7.2-8.4
13-14	50-59	3	0.4	44	5.0-5.3	9.1-9.6
15-17	60-69	59	8.3	44	5.7-6.3	10.2-11.4
18-19	70-79	254	35.6	44	6.7-7.0	12.0-12.7
20-22	80-89	370	51.8	44	7.4-8.1	13.3-14.6
23-24	90-99	27	3.8	44	8.5-8.8	15.2-15.9
25	100	0	0.0	44	9.2	16.5

[a] Calculated on the basis that 25MW = 100%.
[b] Based on October 1975 loading for Unit 1 only.
[c] Calculated on the basis of turbine heat input test data.

Table 2-3. Condenser cooling water temperature rises for various loads, Greenidge Station, Unit 2.

Unit Load	Unit Load[a]	Unit Loading Time[b]		Cooling Water Flow	Condenser ΔT[c]	
MW	%	Hours	%	cfs	Range(C)	Range(F)
<7	<40	3	0.5	44	<3.0	<5.4
7-8	40-49	0	0.0	44	3.0-3.4	5.4-6.1
9-10	50-59	2	0.3	44	3.7-4.0	6.6-7.2
11-12	60-69	14	2.2	44	4.3-4.6	7.8-8.4
13-14	70-79	95	14.9	44	5.0-5.3	9.1-9.6
15-16	80-89	431	67.9	44	5.7-6.0	10.2-10.8
17-18	90-99	90	14.2	44	6.3-6.7	11.4-12.0
19	100	0	0.0	44	7.0	12.7
20-21	-	-	-	44	7.4-7.7	13.3-13.9
22-23	-	-	-	44	8.1-8.5	14.6-15.2
24	-	-	-	44	8.8	15.9

[a] Assuming 19MW = 100% load.
[b] Based on November 1976.
[c] Calculated on the basis of turbine heat input test data.

Table 2-4. Condenser cooling water temperature rises for various loads, Greenidge Station, Unit 3.

Unit Load	Unit Load[a]	Unit Loading Time[b]		Cooling Water Flow	Condenser ΔT[c]	
MW	%	Hours	%	cfs	Range(C)	Range(F)
<23	<40	2	0.3	74	<4.6	<8.3
23-28	40-49	32	4.4	74	4.6-5.5	8.3-9.9
29-34	50-59	257	35.7	74	5.7-6.6	10.2-11.9
35-40	60-69	147	20.4	74	6.8-7.7	12.2-13.9
41-46	70-79	61	8.5	74	7.9-8.9	14.3-16.1
47-52	80-89	200	27.8	74	9.1-10.2	16.5-18.3
53-58	90-100	21	2.9	74	10.4-11.8	18.8-21.2

[a] Calculated on the basis that 58MW = 100%.
[b] Based on June 1975 loading for Unit 3 only.
[c] Calculated on the basis of turbine heat input test data.

Table 2-9. Summary of load factors[a] for 1975, Unit 4.

Unit Load (MW)	Unit Load (%)	Load Factors (%)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
<11	1-9	0.0	0.5	0.5	0.3	0.2	0.5	0.0	0.1	0.1	0.1	0.3	0.5
11-21	10-19	0.1	0.2	0.3	0.8	0.2	0.3	0.0	0.3	0.1	0.8	0.6	0.1
22-31	20-29	0.0	0.0	0.3	0.5	0.3	0.3	0.1	0.3	0.0	0.2	0.0	0.5
32-42	30-39	0.6	0.2	0.0	0.3	0.2	26.4	0.1	0.0	0.1	0.6	0.0	0.3
43-53	40-49	0.0	3.5	0.0	1.9	0.2	1.5	0.6	0.0	0.1	0.8	0.1	0.6
54-64	50-59	5.8	7.1	3.3	16.7	3.4	4.5	4.7	9.9	4.2	20.6	14.5	29.7
65-75	60-69	19.4	22.4	20.5	11.7	42.9	11.7	11.1	17.8	31.2	24.4	8.0	16.4
76-85	70-79	54.9	57.5	66.2	51.4	24.3	18.7	46.3	19.8	21.0	15.6	50.7	33.0
86-96	80-89	18.5	7.7	8.6	16.4	27.5	31.3	35.7	47.4	40.9	36.7	25.8	18.9
97-107	90-99	0.3	0.9	0.3	0.0	0.8	4.8	1.1	4.4	2.3	0.2	0.0	0.0
108	100	0.4	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0

[a] Load Factor (%) = $\frac{\text{Number of service hours at particular load}}{\text{Total number of service hours}} \times 100$

Table 2-10. Greenidge Station - total heat rejection for 1975.

MONTH	UNIT 1 GN, MWH[a]	UNIT 1 HOURS[b]	UNIT 1 HEAT REJ[c]	UNIT 2 GN, MWH	UNIT 2 HOURS	UNIT 2 HEAT REJ	UNIT 3 GN, MWH	UNIT 3 HOURS	UNIT 3 HEAT REJ	UNIT 4 GN, MWH	UNIT 4 HOURS	UNIT 4 HEAT REJ	STATION TOTAL HEAT REJ
JAN	5,875	434	47.3	6,703	516	55.9	35,335	744	233.7	53,186	675	281.7	618.6
FEB	6,692	513	63.6	5,577	429	45.9	25,202	671	166.1	43,910	572	235.9	511.5
MAR	7,999	652	66.7	7,644	635	64.2	25,568	727	170.2	28,282	360	150.4	451.5
APR	3,131	288	27.9	3,579	285	27.0	28,388	720	191.4	27,443	362	142.9	389.2
MAY	2,843	213	20.1	2,795	221	20.2	24,676	704	158.0	48,701	626	254.6	452.9
JUN	3,402	245	26.9	2,991	233	25.9	28,379	720	192.7	46,017	646	242.1	487.6
JUL	2,560	248	23.5	0[e]	0	0.0	26,758	657	182.4	56,057	677	293.4	499.3
AUG	12,126	647	94.3	0	0	0.0	29,944	744	204.1	54,995	672	292.6	591.0
SEP	12,966	650	107.2	0	0	0.0	30,767	685	207.0	54,246	666	283.7	597.9
OCT	14,223	714	120.9	0	0	0.0	32,661	738	217.8	38,296	496	200.3	539.0
NOV	5,625	275	46.7	0	0	0.0	27,412	675	186.8	50,195	632	259.3	492.8
DEC	0[d]	0	0.0	0	0	0.0	33,149	744	227.3	46,963	631	244.2	471.5
TOTAL	77,442	4,879	645.1	29,289	2,319	239.1	348,239	8,529	2,337.5	548,291	7,015	2,881.1	6,102.8

[a] GN, MWH = Gross Generator Output, Megawatt Hours.
[b] HOURS = Number of generating hours.
[c] HEAT REJ = G BTU (10^9 BTU).
[d] Unit 1 was out of service during December of 1975.
[e] Unit 2 was out of service from July through December 1975.

Table 2-11. Greenidge Station - total heat rejection for February, 1976.

DAY	UNIT 1			UNIT 2			UNIT 3			UNIT 4			STATION TOTAL
	GN, MWH[a]	HOURS[b]	HEAT REJ[c]	GN, MWH	HOURS	HEAT REJ	GN, MWH	HOURS	HEAT REJ	GN, MWH	HOURS	HEAT REJ	HEAT REJ
1	341	24	2.7	0	0	0.0	1014	24	7.0	1866	24	9.9	19.6
2	318	24	2.5	0	0	0.0	1196	24	8.3	1993	24	10.6	21.4
3	274	23	2.1	0	0	0.0	1082	24	7.5	1961	24	10.4	20.0
4	71	6	0.6	0	0	0.0	1139	24	7.9	1734	22	9.2	17.7
5	329	24	2.6	0	0	0.0	1192	24	8.3	0	0	0.0	10.9
6	318	24	2.5	0	0	0.0	1110	24	7.7	1188	16	6.3	16.5
7	321	24	2.5	0	0	0.0	1152	24	8.0	1927	24	10.3	20.8
8	308	24	2.4	0	0	0.0	1052	24	7.3	1849	24	9.8	19.5
9	334	24	2.6	0	0	0.0	1124	24	7.8	0	0	0.0	10.4
10	292	24	2.3	0	0	0.0	1186	24	8.2	0	0	0.0	10.5
11	268	24	2.1	123	11	0.9	1193	24	8.3	50	2	0.3	11.6
12	308	24	2.4	188	14	1.4	1071	24	7.4	1678	22	8.9	20.1
13	357	24	2.8	324	24	2.4	1159	24	8.0	1858	24	9.9	23.1
14	339	24	2.6	354	24	2.7	1183	24	8.2	1942	24	10.3	23.8
15	333	24	2.6	341	24	2.6	1012	24	7.0	1684	24	9.0	21.2
16	329	24	2.6	333	24	2.5	1179	24	8.2	1968	24	10.5	23.8
17	324	24	2.5	321	24	2.4	1006	24	7.0	659	9	3.5	15.4
18	301	24	2.3	344	24	2.6	887	24	6.2	1353	18	7.2	18.3
19	359	24	2.8	359	24	2.7	565	24	3.9	1821	24	9.7	19.1
20	366	24	2.8	352	24	2.7	569	24	4.0	1947	24	10.4	19.9
21	341	24	2.7	331	24	2.5	586	24	4.1	1859	24	9.9	19.2
22	330	24	2.6	260	20	2.0	882	24	6.1	1716	24	9.1	19.8
23	332	24	2.6	320	24	2.4	975	24	6.8	1697	24	9.0	20.8
24	345	24	2.7	333	24	2.5	799	24	5.5	1750	24	9.3	20.0
25	329	24	2.6	339	24	2.6	715	24	5.0	1796	24	9.6	19.8
26	314	24	2.4	348	24	2.6	859	24	6.0	1803	24	9.6	20.6
27	360	24	2.8	358	24	2.7	929	24	6.5	1996	24	10.6	22.6
28	354	24	2.8	347	24	2.6	940	24	6.5	1822	24	9.7	21.6
29	12	1	0.1	6	1	0.0	751	24	5.2	1625	24	8.6	13.9
TOTAL	8,907	654	69.6	5,681	406	42.8	28,507	696	197.9	43,542	569	231.6	541.9

[a] GN, MWH = Gross Generator Output, Megawatt Hours.
[b] HOURS = Number of generating hours.
[c] HEAT REJ = G BTU (10^9 BTU).

Table 2-12. Greenidge Station - total heat rejection for August, 1976.

DAY	UNIT 1			UNIT 2			UNIT 3			UNIT 4			STATION TOTAL
	GN, MWH[a]	HOURS[b]	HEAT REJ[c]	GN, MWH	HOURS	HEAT REJ	GN, MWH	HOURS	HEAT REJ	GN, MWH	HOURS	HEAT REJ	HEAT REJ
1	0	0	0.0	239	24	2.2	677	24	4.7	1617	23	8.8	15.7
2	0	0	0.0	356	24	3.3	1014	24	7.1	0	0	0.0	10.4
3	0	0	0.0	369	24	3.4	857	24	6.0	1706	24	9.3	18.7
4	50	8	0.4	370	24	3.4	837	24	5.9	1928	24	10.5	20.2
5	164	24	1.4	384	24	3.6	916	24	6.4	2128	24	11.6	23.0
6	301	24	2.5	385	24	3.6	834	24	5.8	1027	13	5.6	17.5
7	336	24	2.8	357	24	3.3	853	24	6.0	9	1	0.0	12.1
8	279	24	2.3	241	22	2.2	770	24	5.4	1692	24	9.3	19.2
9	352	24	3.0	327	24	3.0	880	24	6.2	1584	24	8.7	20.9
10	357	24	3.0	294	24	2.7	1006	24	7.0	1657	24	9.1	21.8
11	339	24	2.8	125	10	1.2	644	24	4.5	1955	24	10.7	19.2
12	358	24	3.0	8	2	0.1	643	24	4.5	1923	24	10.5	18.1
13	374	24	3.1	176	24	1.6	676	24	4.7	2016	24	11.0	20.4
14	359	24	3.0	350	24	3.2	1114	24	7.8	2020	24	11.0	25.0
15	246	24	2.1	309	24	2.9	1114	24	7.8	2014	24	11.0	23.8
16	297	24	2.5	304	24	2.8	1005	24	7.0	1646	24	9.0	21.3
17	322	24	2.7	306	24	2.8	880	24	6.2	1623	24	8.9	20.6
18	361	24	3.0	233	24	2.2	993	24	6.9	1710	24	9.4	21.5
19	360	24	3.0	108	24	1.0	1054	24	7.4	1324	17	7.2	18.6
20	361	24	3.0	105	24	1.0	661	24	4.6	0	0	0.0	8.6
21	355	24	3.0	105	24	1.0	649	24	4.5	896	13	4.9	13.4
22	353	24	3.0	101	24	0.9	667	24	4.7	1920	24	10.5	19.1
23	366	24	3.1	115	24	1.1	1034	24	7.2	1766	24	9.7	21.1
24	381	24	3.2	145	24	1.3	1114	24	7.8	0	0	0.0	12.3
25	386	24	3.2	150	24	1.4	1117	24	7.8	1913	24	10.5	22.9
26	358	24	3.0	124	24	1.1	1111	24	7.8	2120	24	11.6	23.5
27	353	24	3.0	123	24	1.1	1116	24	7.8	2092	24	11.4	23.3
28	370	24	3.1	197	24	1.8	1003	24	7.0	1991	24	10.9	22.8
29	362	24	3.0	159	24	1.5	702	24	4.9	1591	24	8.7	18.1
30	359	24	3.0	147	24	1.4	808	24	5.6	938	13	5.1	15.1
31	372	24	3.1	92	16	0.9	1004	24	7.0	254	5	1.4	12.4
TOTAL	9231	656	77.3	6804	698	63.0	27,753	744	194.0	45,060	589	246.3	580.6

[a] GN, MWH = Gross Generator Output, Megawatt Hours.
[b] HOURS = Number of generating hours.
[c] HEAT REJ = G BTU (10^9 BTU).

Table 2-13. Chemical use at Greenidge Station.

Chemical	Chemical Formula	Approximate Annual Consumption	Frequency of Use	Purpose of Use
Caustic Soda	$NaOH$	75-125lb	As required	pH control of the boiler feedwater system
Chlorine	Cl_2	16,425lb	Units 1,2,3: 3 times/day Unit 4: 4 times/day	Prevention of biological growth in condensers
Ferrous Sulfate	$FeSO_4 \cdot 7H_2O$	3500-4500lb	Continuous	Coagulant in primary water treatment system
Hydrazine	$N_2H_4 \cdot H_2O$	150-200gal	Continuous	Oxygen scavenging in the boiler feedwater system
Lime	$Ca(OH)_2$	15,000-30,000lb	Continuous	Coagulant and pH control in primary water treatment system
Morpholine	C_4H_9NO	200-250gal	Continuous	pH control of the boiler feedwater system
Muriatic Acid	$HCl+H_2O$	52gal	4 times/day	Prevents corrosion of chlorine analyzer electrodes
Phosphates Monosodium Disodium Trisodium	 NaH_2PO4 Na_2HPO4 Na_3PO_4	2500-3000lb (all 3 forms)	As required	pH control and protection against boiler scaling

Table 2-13. continued.

Chemical	Chemical Formula	Approximate Annual Consumption	Frequency of Use	Purpose of Use
Salt	NaCl	110,000-200,000lb	Continuous	Regeneration of water softeners
Sodium Sulfite	Na_2SO_3	3000-5000lb	Continuous	Oxygen scavenging in the boiler feedwater system

Chapter 3

Description of Seneca Lake and Keuka Lake Outlet

3.1 Description of Seneca Lake

Seneca Lake is located in the Oswego River drainage basin of New York. The lake is 35.2mi (56.6km) long, averages 1.9mi (3.1km) in width, and is oriented on a northwest-southeast axis (Figure 2-1). The maximum depth of Seneca Lake is approximately 618ft (188m), which is 174ft (43m) below sea level (Fliegel 1973). The lake's total surface area is 67.6sq mi (175.0sq km) and its volume is approximately 530 x 10^6 ft^3 (15 x 10^6 m^3) (Fliegel 1973).

This glacial lake is the largest of the Finger Lakes and lies in a long, narrow valley between two ridges which reach up to 900ft (274m) above sea level. The ridges are highest toward the southern end of the lake where the terrain is somewhat mountainous. The shoreline is well-developed and generally smooth, except for deltas formed by tributaries. Bedrock of the area is Devonian limestone, shale and sandstone.

The bottom of the lake drops off precipitously from the east and west shores and is relatively uniform and symmetric around the lake centerline. The northern and southern ends at Geneva and Watkins Glen, respectively, are relatively shallow with depths to about 18ft (5.5m). Depths of 500ft (152m) or more are found from 3.5mi (5.6km) north of Greenidge Station to 3.5mi (5.6km) north of Watkins Glen (NYSBCS 1968).

The drainage basin of the lake, which is a long, narrow valley, is 50mi (80km) long and 10mi (16km) wide, and covers an area of

707sq mi (1830sq km) (Fliegel 1973). This includes the area of Keuka Lake, which drains into Seneca Lake via the Keuka Lake Outlet. The amount of water which flows into the Keuka Lake Outlet is controlled by a set of gates at Penn Yan, which are operated by this municipality. The level of Keuka Lake is maintained at 712.0ft (217m) above mean sea level (msl) during the winter months and peaks to 714.5ft (217.8m) above msl during the summer. Flow of the Keuka Lake Outlet is maintained in the range of 36 to 500cfs (1 to 14m^3/s) (RWRPB 1973). The Outlet drains an area of 248sq mi (642sq km) (SCPB 1969).

Seneca Lake, which is a part of the New York State Barge Canal System, discharges into the Seneca River. The lake level is controlled by tainter gates at a dam in Waterloo, New York. The lake level is lowered in late fall and winter to increase storage capacity. The lowest level is usually 444.7ft (135.5m) above msl at Waterloo. Spring inflows then increase the lake level to its highest point of approximately 446.8ft (136.2m) above msl (RWRPB 1973).

The climate is a humid-continental type. The mean annual temperature is approximately 8.9C (48.0F) with extremes ranging from -24.4C (-12.0F) in January to 32.2C (90.0F) in July and August. Average annual total precipitation ranges from 32-36in (81-91cm) (USDA 1972). The average annual runoff in the vicinity of Seneca Lake ranges from 12-14in (31-36cm) (USDA 1972).

3.2 Keuka Lake Outlet Flow

A summary of Keuka Lake Outlet for the last 10 years (1967-1976) is presented in Figure 3-1. Data were obtained from USGS Water Resources Data reports for New York for 1967 - September 1975. Subsequent data were obtained from USGS (1977). The highest monthly average flow of 333cfs ($9.4m^3/s$) occurred in March while the minimum 86cfs ($2.4m^3/s$), occurred during September. The highest daily flow occurred in June 1972 as a result of Hurricane Agnes when the flow was 2200cfs ($62.3m^3/s$). The lowest daily flow was 12cfs ($0.3m^3/s$), which occurred in July.

3.3 Temperature

Monthly mean water temperatures of Seneca Lake for 1967-1976 were computed from daily measurements taken at the Unit 4 condenser intake of Greenidge Station (Figure 3-2). The highest average monthly temperature during this period occurred in August when the average temperature reached 23.3C (73.9F). The highest average daily temperature also occurred in August when the water temperature reached 28.3C (82.9F). Minimum temperature recorded from December through March was 1.1C (34.0F).

3.4 Bathymetry

3.4.1 Methods and Materials

Bathymetry of Seneca Lake in the vicinity of Greenidge Station was determined by measuring the water depth along transects perpendicular to the shoreline. Transects, starting from a point 1500ft (457m) north to 2000ft (610m) south of Keuka Lake Outlet, were spaced approximately 500ft (152m) apart. Also, two transects were established at 7000ft (2134m) and 7500ft (2286m) south of Keuka Lake Outlet. Water depth was measured at approximately 200ft (60m) intervals along each transect and at additional points, as necessary to define significant (>0.5m) changes in depth. Measurements were made to the point when the lake bottom drops off precipitously (approximately 2000ft [606m] offshore). Depth was measured to the nearest

0.3ft (0.1m) using a weighted sounding chain. The measurement locations were mapped with a Hewlett-Packard Model 3810A electronic distance measuring instrument which is accurate to within 0.5ft at a range of 0.5mi.

A base map of the study area which shows the plant location and configuration of the shoreline was developed from a scaled aerial photograph. In order to contour the bathymetry of the lake, the location of the measurements along with the corresponding water depths were computer plotted on the base map and the isobaths were hand contoured.

3.4.2 Results and Discussion

Results of the bathymetry survey taken on 11-12 August 1976 are shown in Figure 3-3. The water depth gradually increased from 3.3ft (1m) near the shoreline to 16.4ft (5m) at approximately 1968ft (600m) offshore. Lakeward from the 16.4ft (5m) contour, the lake bottom drops off sharply and was not defined beyond this point. In addition, two elevated areas composed of sand and gravel were also identified.

3.5 Substrate Composition

3.5.1 Methods and Materials

Bottom substrates of Seneca Lake in the vicinity of Greenidge Station were mapped on 11 and 12 August 1976. Substrates were examined by a scuba diver along nine transects perpendicular to shore at points 500, 1000, 1500ft north, and 500, 1000, 1500, 2000, 7000 and 7500ft south of Keuka Lake Outlet (Figure 3-4). Sampling points were located along each transect using a Hewlett-Packard Model 3810A electronic distance measuring instrument, which is accurate to and diversity of samples was small, the values indicated that the water in Seneca Lake is hard and contained relatively high concentrations of sodium and chlorides. These could be expected due to the underlaying strata of limestone and salt in the area. Measurements were made of temperature, dissolved oxygen, pH and turbidity on 14 occasions at locations near Greenidge Station (see Chapter 9, Table 9-1). These measurements indicated dissolved oxygen to be near 100% saturation throughout the year both within and outside the discharge area. The effect of station operation on dissolved oxygen concentrations was negligible.

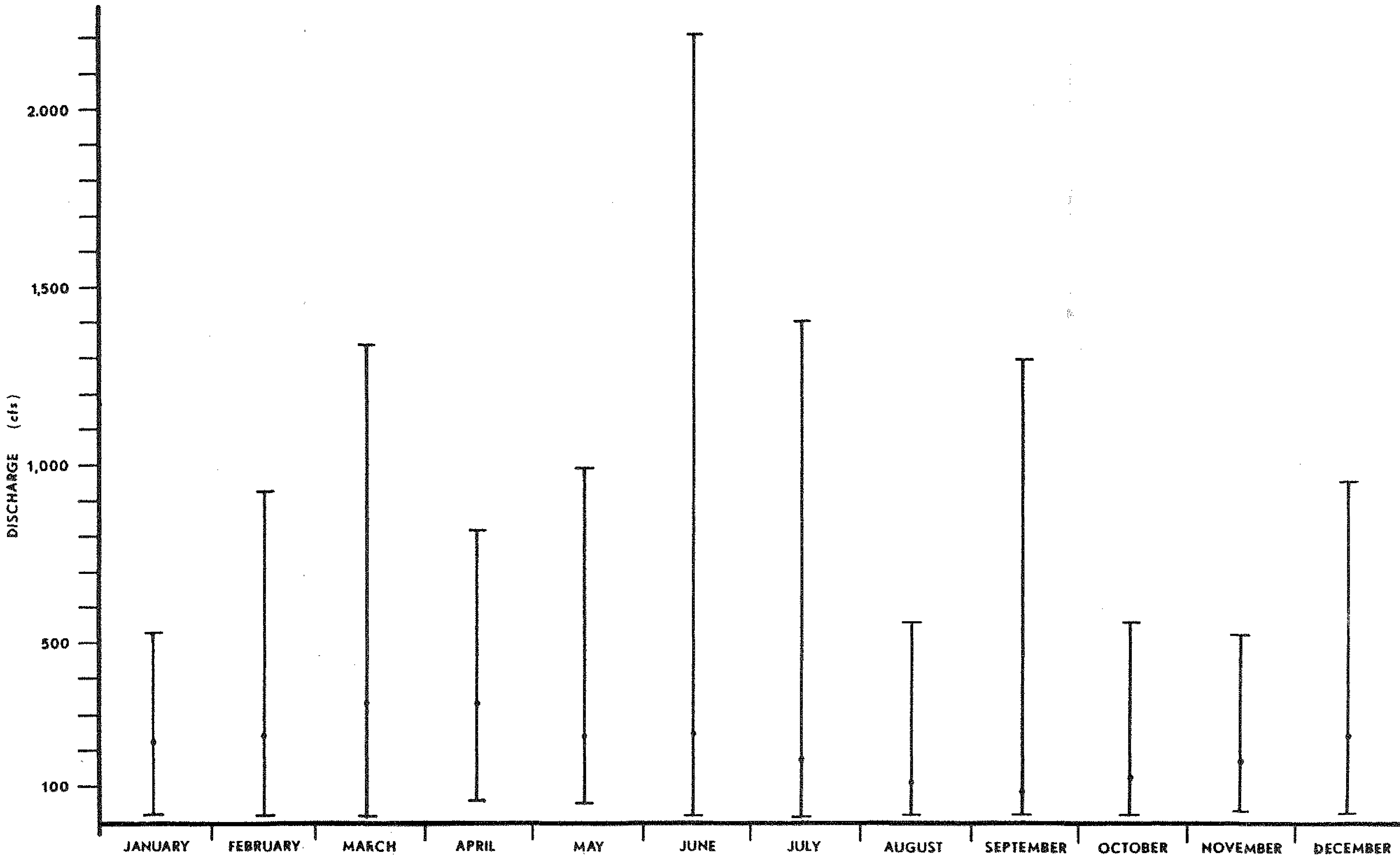

Figure 3-1. Ten-year hydrological summary for the Keuka Lake Outlet at Greenidge Station, calendar years 1967-1976. Vertical lines indicate the range in daily mean discharge. Dots on these lines indicate the mean monthly discharge.

Figure 3-1

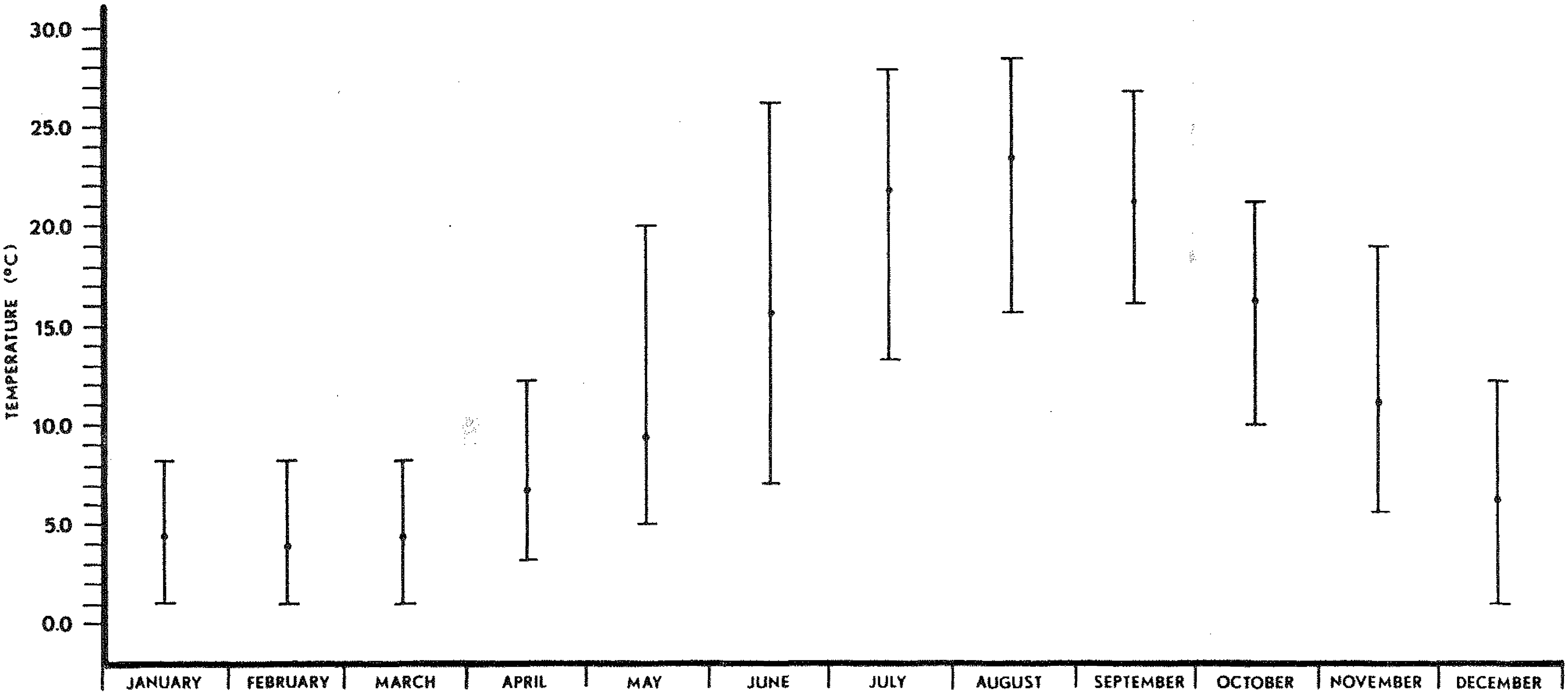

Figure 3-2. Ten-year temperature summary for Seneca Lake at Greenidge Station, calendar years 1967-1976. Vertical lines indicate the range in daily mean temperature. Dots on these lines indicate the mean monthly temperature.

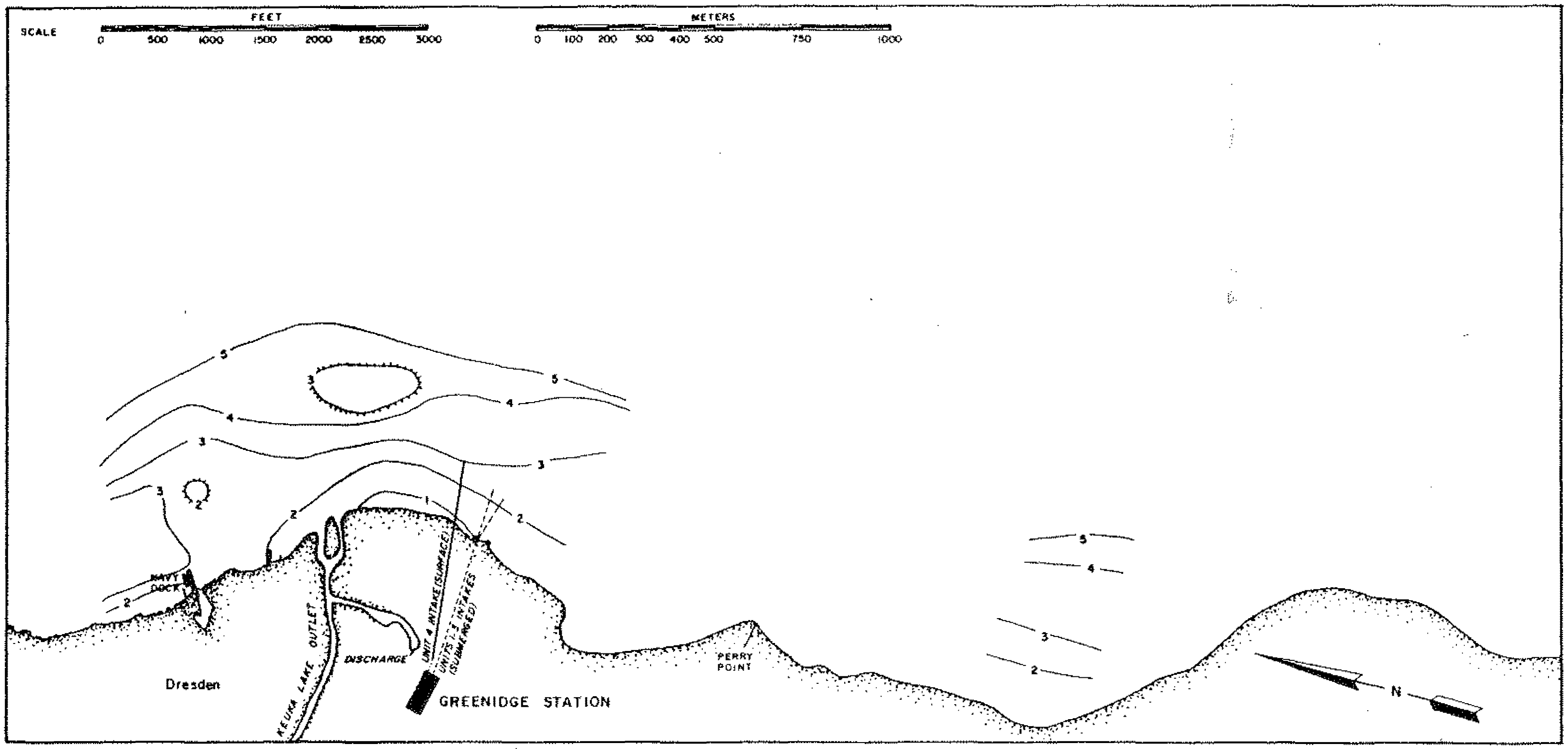

Figure 3-3. Bathymetric profile of Seneca Lake in the vicinity of Greenidge Station. Isobaths given in meters.

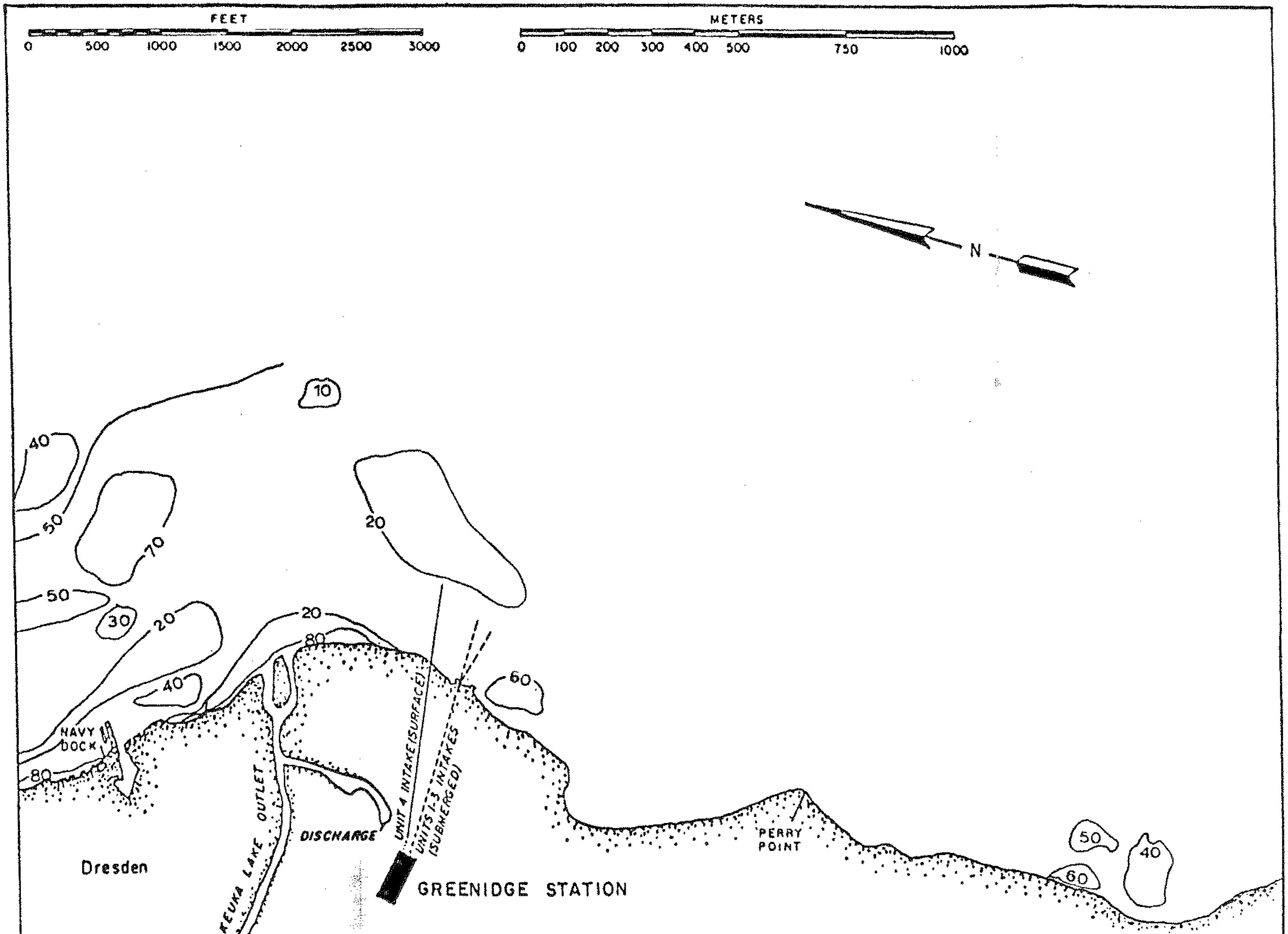

Figure 3-5. Percent occurrence of gravel (1/12 - 2-1/2in diameter).

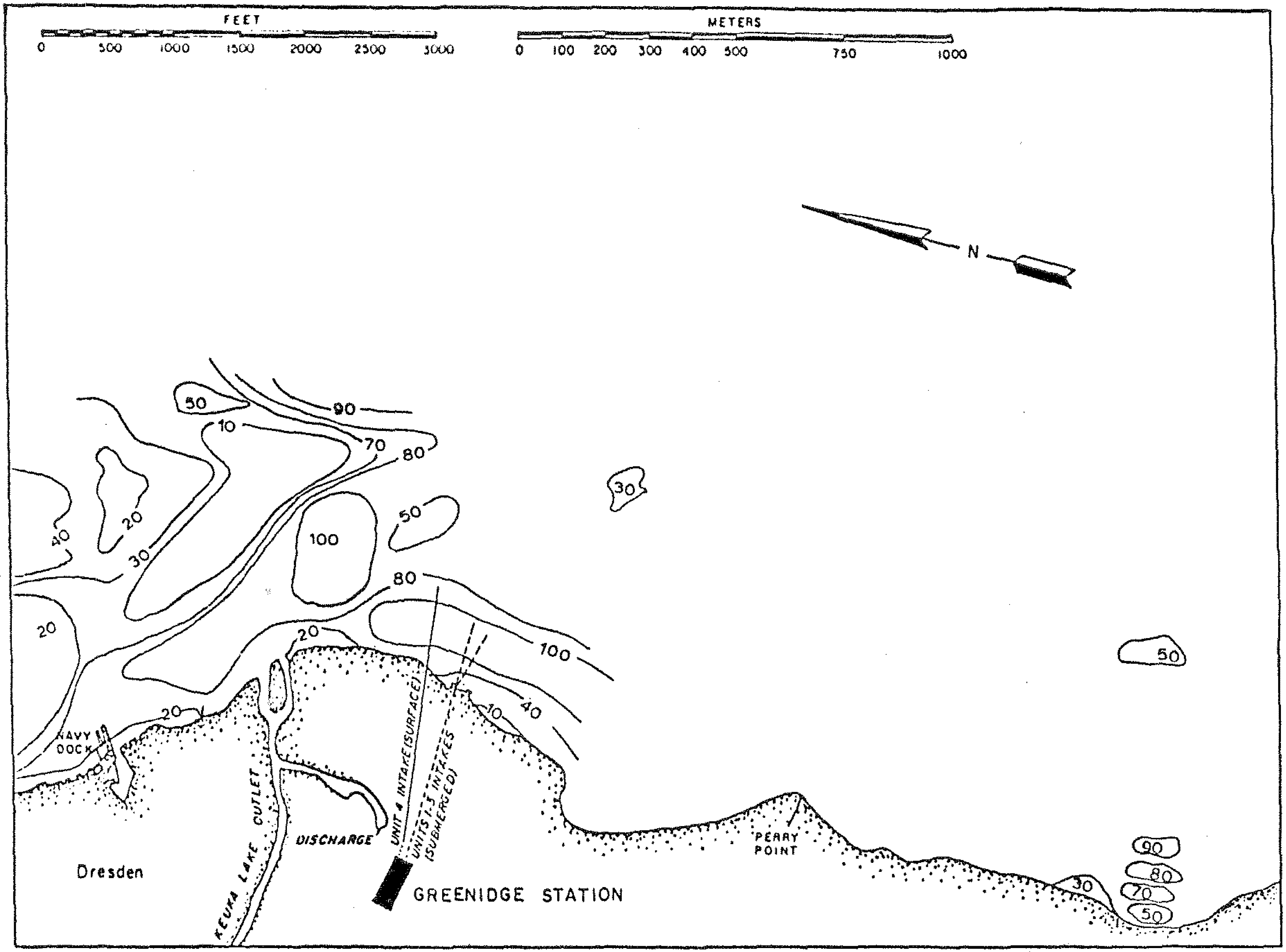

Figure 3-6. Percent occurrence of sand (.06 - 2.0mm diameter).

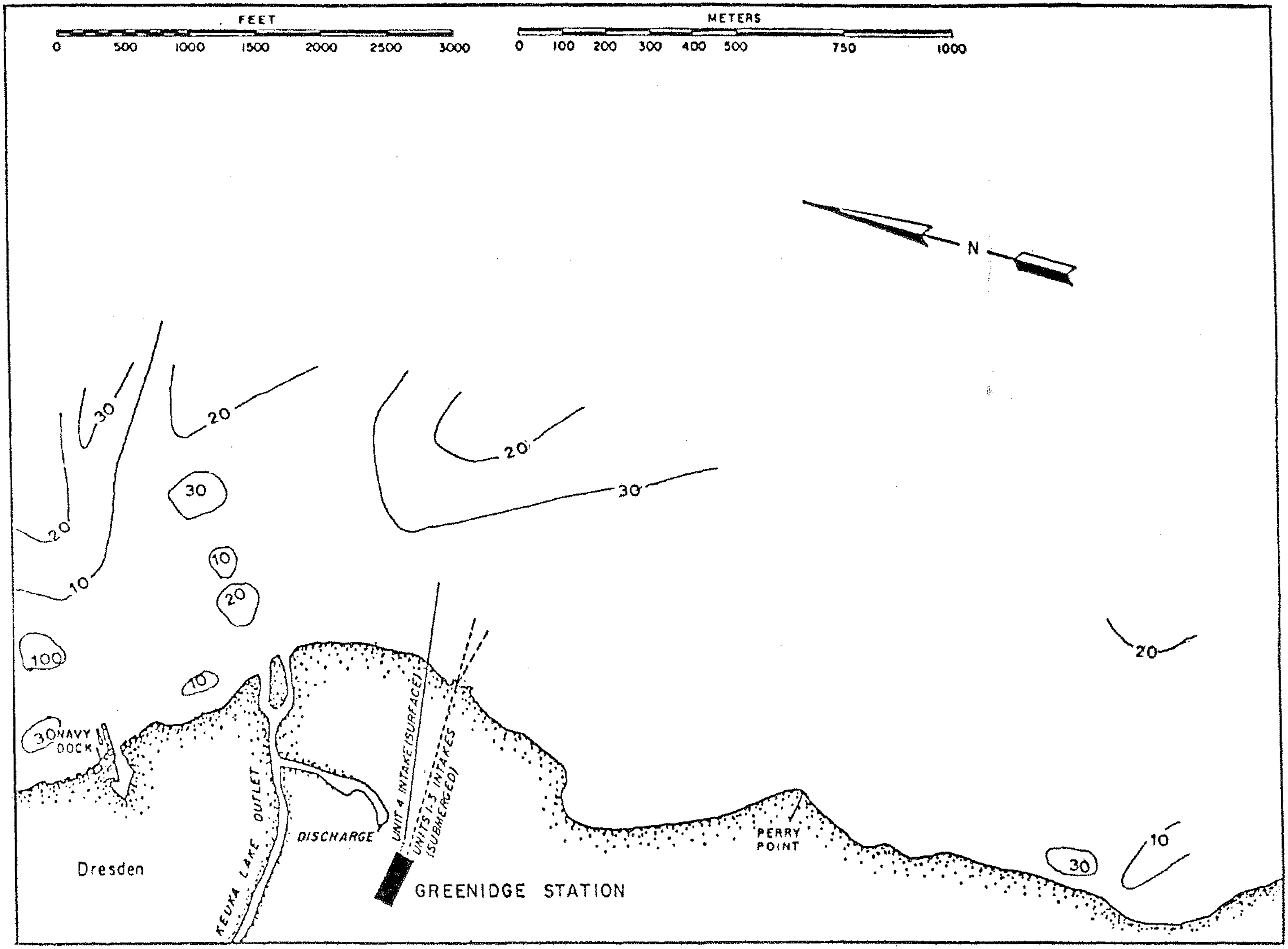

Figure 3-7. Percent occurrence of clay (<0.004mm diameter).

Table 3-1. Categories for the visual characterization of bottom substrates.

Inorganic Components	Size or Characteristic
Bedrock or solid rock	
Boulders	Greater than 256mm (10in) in diameter
Rubble	64 to 256mm (2-1/2 to 10in) in diameter
Gravel	2 to 64mm (1/12 to 2-1/2in) in diameter
Sand	0.06 to 2.0mm in diameter; gritty texture when rubbed between fingers
Silt	0.004 to 0.06mm in diameter
Clay	Less than 0.004mm in diameter; smooth slick feeling when rubbed between fingers
Marl	Calcium carbonate; usually gray; often contains fragments of mullusc shells or *Chara*; effervesces freely with hydrochloric acid
Organic Components	**Size or Characteristic**
Detritus	Accumulated wood, sticks, and other decayed coarse plant materials
Fibrous peat	Partially decomposed plant remains; parts of plants readily distinguishable
Pulpy peat	Very finely divided plant remains; parts of plants not distinguishable; varies in color from green to brown; varies greatly in consistency - often being semi-fluid
Muck	Black; finely divided organic matter; completely decomposed

Chapter 4

Thermal Plume Characteristics

4.1 Thermal Plume Mapping

4.1.1 Methods and Materials

The three-dimensional structure of the thermal plume in the Keuka Lake Outlet and Seneca Lake was mapped on 19 March, 6 May, 1 July, 5 August, 2 September and 9 December 1976. The measurement locations during each survey were selected such that the plume configuration could be defined to the furthest areal extent of the 2C (3.6F) ΔT isotherm.

Data collected during each thermal plume mapping included:

a. Horizontal and vertical temperature distributions at several transects across the Keuka Lake Outlet and the immediate lake area;

b. Meteorological parameters including dry and wet-bulb temperatures, wind speed and direction, and cloud cover, and

c. Drogue tracking data to determine the time rate of change of temperature within the plume.

Water temperatures were measured with a Model TC-5 Montedoro-Whitney temperature measuring system which was accurate to 0.1C (0.2F). At measurement locations which were relatively deep, temperatures were measured at the surface, bottom and near mid-depth. At shallow locations, measurements were taken at 1m (3.3ft) intervals. The position of the boat at the measurement locations was determined by a shore-based Hewlett-Packard Model 3810A electronic distance measuring instrument (EDM) which is accurate to within 0.5ft (0.15m) at a range of 0.5mi (0.8km). Sufficient temperature measurements were made to enable plotting of the excess-temperature (ΔT) isotherms at intervals of 1C (1.8F).

The movements of five drogues were tracked within the plume in order to determine the time rate of temperature change. The drogues were tracked continuously from their initial placement in the discharge outlet of Greenidge Station to the furthest extent of the 2C (3.6F) ΔT isotherm in Seneca Lake (only three drogues were tracked within the discharge canal and the Keuka Lake Outlet on 19 March 1976). The drogues were made of 1/8in masonite cross vanes, 3ft wide and 1.5ft high that were attached to a 1ft diameter styrofoam float. Drogue positions were taken every 30 seconds during the first five minutes of drogue run by using a shore-based theodolite and the EDM. The drogue positions were taken once every minute after the first five minutes.

Meteorological conditions at the site were measured hourly during each plume survey. The parameters observed included the wet and dry-bulb temperatures, measured to 0.06C (0.1F) with a Bendix psychrometer, and wind speed, measured to 0.22m/s (0.5mph) with a Dwyer wind gage. In addition, the wind direction was determined from compass headings, and the cloud cover was estimated by visual observations.

A base map for the plant site was developed from a scaled aerial photograph. The locations of the survey locations along with the measured excess-temperature (ΔT) at each location were computer plotted, and the temperature-rise isotherms for each plume were hand contoured. The excess-temperatures at locations within the Keuka Lake Outlet and Seneca Lake were determined based on the measured ambient temperatures within the Keuka Lake Outlet and Seneca Lake, respectively.

The excess-temperature measured along vertical transects was also computer plotted and the isotherms were hand contoured at suitable ΔT intervals. Surface areas and maximum cross-sectional areas along the plume centerline within the 2C (3.6F) ΔT isotherms were planimetered and tabulated.

The drogue trajectory for each run was computer plotted and transferred to the base map. Plots of the drogue trajectories were overlayed on the isotherm plots, and the time-temperature relationships were determined for each trajectory. Composite time-temperature plots of all drogue runs on each date were made and an average curve was drawn through the data points to obtain the time-temperature relationship for each plume.

In order to allow comparison between time-temperature relationships measured under different operating conditions, a summary figure was plotted showing the ratio of measured excess-temperature within the plume to the initial excess-temperature ($\Delta T/\Delta T_o$) as a function of time. The time was measured starting at the point of discharge.

4.1.2 Results and Discussion

Thermal Plume Mapping

A summary of important hydraulic and thermal parameters corresponding to each survey date is presented in Table 4-1. Meteorological conditions for each survey are given in Appendix A and corresponding plant operating conditions are specified in Appendix B.

The average heat rejection rate from Greenidge Station varied between 9.6×10^8 BTU/hr (2.4×10^8 kcal/hr) on 5 August 1976 when the plant load was 74% and 3.9×10^8 BTU/hr (1.0×10^8 kcal/hr) on 19 March 1976 when the plant load was only 23%. The ambient temperature of the Keuka Lake Outlet increased from 3.1C (37.6F) in March to a maximum of 21.5C (70.7F) in July and then decreased to a minimum of 0.3C (32.5F) in December. Ambient temperature of Seneca Lake, however, steadily increased from 3.4C (38.1F) in March, reached a maximum of 18.8C (65.8F) by August, and remained at 18.8C (65.8F) during the September survey. Ambient temperature ranged from 1.5C to 4.9C (34.7F to 40.8F) during the December survey. The ambient temperature structure of Seneca Lake is indicative of the slow thermal response of large water masses to changes in climatic conditions.

The temperature patterns within the thermal plume in the Keuka Lake Outlet are shown in Figure 4-1. These patterns indicated that most of the time the ambient flow of the Keuka Lake Outlet and the thermal discharge were not completely mixed. The patterns of excess-temperature isotherms within the thermal plumes for Seneca Lake are shown in Figures 4-2 through 4-7. During the first four surveys the plume extended straight into Seneca Lake after discharge situation was found for a lakeward plume configuration, even though there was greater capacity for mixing with ambient water than with a shore-attached plume. A possible explanation for this may be found in the Keuka Lake Outlet flow rates. During the 5 August and 2 September 1976 surveys, the flow rates were small, 52cfs (1.47m^3/s) and 43cfs (1.22m /s), respectively, in comparison to the plant discharges of 293cfs (8.3m /s) and 205cfs (5.8m /s), respectively. Consequently, the excess-temperature decrease was negligible within the Keuka Lake Outlet.

The time-temperature relationship which existed on 1 July 1976 was selected as the best case since the rate of excess-temperature decrease was the most rapid of those measured. The 16 March 1976 data was not considered in selecting the best case due to the extreme low level of plant operation.

4.2 Mixing Zone Delineation for Keuka Lake Outlet

Keuka Lake Outlet in the vicinity of Greenidge Station is classified as a trout stream and, therefore, the NPDES permit thermal limitations are as follows:

a. No discharge at a temperature over 21.2C (70F) shall be permitted;

b. From June through September no discharge shall be permitted that will raise the temperature of the stream more than 1.1C (2F) over that which existed before the addition of heat of artificial origin;

c. From October through May, no discharge shall be permitted that will raise the temperature of the stream more than 2.8C (5F) over that which existed before the addition of heat of artificial origin or to a maximum of 10C (50F), whichever is less; and

d. From June through September no discharge shall be permitted that will lower the temperature of the stream more than 1.1C (2F) from that which existed immediately prior to such lowering.

The mixing zone for Keuka Lake Outlet is the area of the stream that is in noncompliance with these limitations. As shown in Figure 4-1, the entire channel of Keuka Lake Outlet from the entrance of the thermal discharge to its mouth (a distance of 700ft) is in noncompliance with the thermal limitations. Therefore, this area constitutes the mixing zone for Keuka Lake Outlet.

4.3 Mixing Zone Delineation for Seneca Lake

4.3.1 Methods and Materials

The configuration of the mixing zone in Seneca Lake (ie., area within 1.67C [3.0F] ΔT isotherm was predicted based on the following conditions: a plant discharge rate (Q_O) of 293cfs (maximum design flow rate) and a condenser temperature-rise (ΔT_O) of 8.8C (15.8F) (design ΔT for 90% load). Keuka Lake Outlet was considered to have no flow. Statistical models were used to predict the size of the mixing zone.

In order to estimate the maximum extent of the mixing zone, the data collected during the plume mapping were used to empirically determine a relationship between the excess-temperature of water discharged into Seneca Lake and the maximum extent of the resulting isotherms. Since Greenidge Station does not discharge directly into Seneca Lake, but rather into the Keuka Lake Outlet, the effects of the flow in the Outlet on this relationship had to be considered. This problem was resolved by treating the Keuka Lake Outlet as a discharge canal and considering the combined discharge of the plant and the Outlet. The discharge temperature used was the temperature that resulted from mixing the plant discharge water with the flow in the Keuka Lake Outlet. This temperature was determined by the equation:

$$T_m = \frac{Q_k T_k + Q_o T_o}{Q_T} \qquad (4.1)$$

where T_m is the temperature of the mixed water, Q_k and T_k are the flow rate and temperature of the Keuka Lake Outlet, Q_o and T_o are the flow rate and temperature of the plant discharge, and Q_T is the flow rate of the water that enters Seneca Lake (Q_k+Q_o). This procedure was the most practical way to approach the problem since the configuration of the thermal plumes was dependent upon the combined discharge of the plant and the Outlet.

Data collected during the surveys were used to determine the relationship between the maximum extent of the excess-temperature isotherms (x) and the initial temperature-rise (ΔT_o) of the water discharged into Seneca Lake. The initial temperature-rise, ΔT_m was determined by subtracting the lake ambient temperature from the actual temperature measured at the mouth of the Keuka Lake Outlet (at entry into the lake). The data were first plotted on semi-log paper as $\Delta T/\Delta T_o$ versus the maximum extent of the isotherms (Figure 4-9).

Data from March and May 1976 were not used because the flow in the Keuka Lake Outlet was so high that the data for those periods would not be useful in predicting the temperature plume that would result when there was no flow in the Outlet.

The measured thermal plume data indicated there were two distinct cases to be considered; a lakeward plume and a shore-attached plume. There were two representative examples of both types of plumes. It was assumed that the temperature decreased exponentially with distance from the Outlet; therefore, the data for the two different cases were fitted to a curve of the form

$$\frac{\Delta T}{\Delta T_o} = a\ e^{-bx} \qquad (4.2)$$

A functional relationship of this form can be readily derived from theoretical considerations (e.g., Paily and Kennedy 1975).

The coefficients a and b were calculated for both cases by using a least-squares regression technique. The coefficient of determination (r^2), which indicates how well the curve fits the data, was also calculated for each case.

The analysis indicated that the data for a lakeward plume were best parameterized by the equation

$$\frac{\Delta T}{\Delta T_o} = 0.961\ e^{-0.00202x} \qquad (4.3)$$

where x is in meters. The coefficient of determination for the analysis was $r^2 = 0.950$. The equation that best described the shore-attached plume was

$$\frac{\Delta T}{\Delta T_o} = 0.882\ e^{-0.000057x} \qquad (4.4)$$

and the coefficient of determination was $r^2 = 0.737$. Both of these curves are plotted on Figure 4-9.

Solving Equations (4.3) and (4.4) for x gives, for a lakeward plume

$$x = -19.8 - 495.0 \ln \frac{\Delta T}{\Delta T_o} \qquad (4.5)$$

and for a shore-attached plume

$$x = -221.1 - 1754.4 \ln \frac{\Delta T}{\Delta T_o} \qquad (4.6)$$

These equations were used to determine the maximum extent of the mixing zone by simply substituting the proper values for ΔT and ΔT_o.

A statistical model was also used to estimate the area within the excess-temperature isotherms of the plume that would occur under the given plant operating conditions. It was assumed that the area (A) within an isotherm was proportional to the discharge flow (Q_T). It was also assumed that the functional relationship of the temperature ratio ($\Delta T/\Delta T_o$) had a power law form. In other words, the area within the isotherm could be expressed as

$$A = a\ Q_T \left(\frac{\Delta T^b}{\Delta T_o}\right) \qquad (4.7)$$

Functional relationships of this form have been used in previous investigations of lake thermal plumes (e.g., Ashbury and Frigo 1971).

The measured thermal plume data were used to evaluate the constants a and b by using a least-squares regression technique. Only the areas measured within the 2, 3 and 4C excess-temperature isotherms were used to evaluate the constants. Again, two cases were considered; a lakeward plume and a shore-attached plume. The equation that best described the data for a lakeward plume was

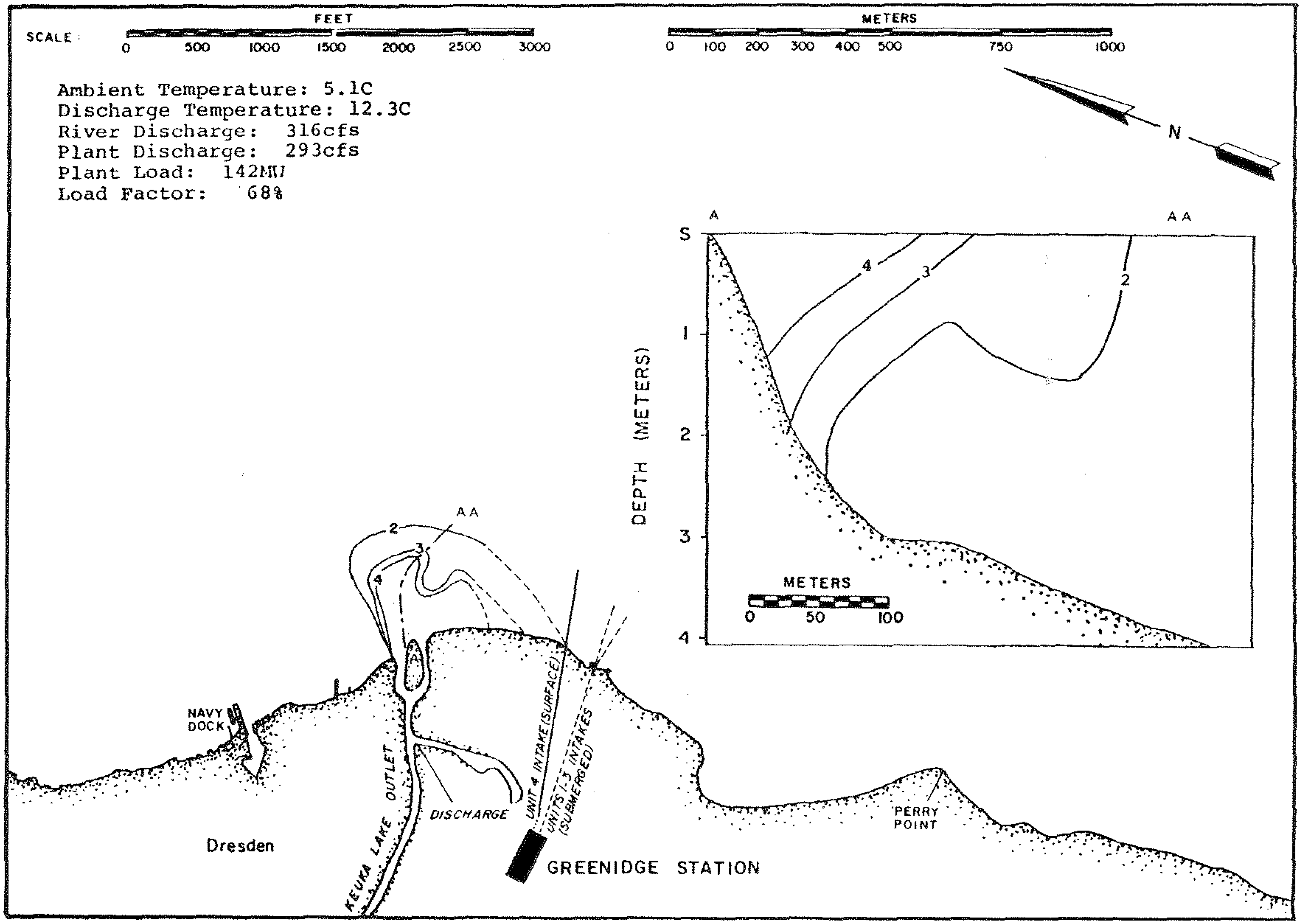

Figure 4-3. Configuration of the thermal plume in Seneca Lake on 06 May 1976. The isotherms indicate excess-temperature (ΔT) in degrees centigrade.

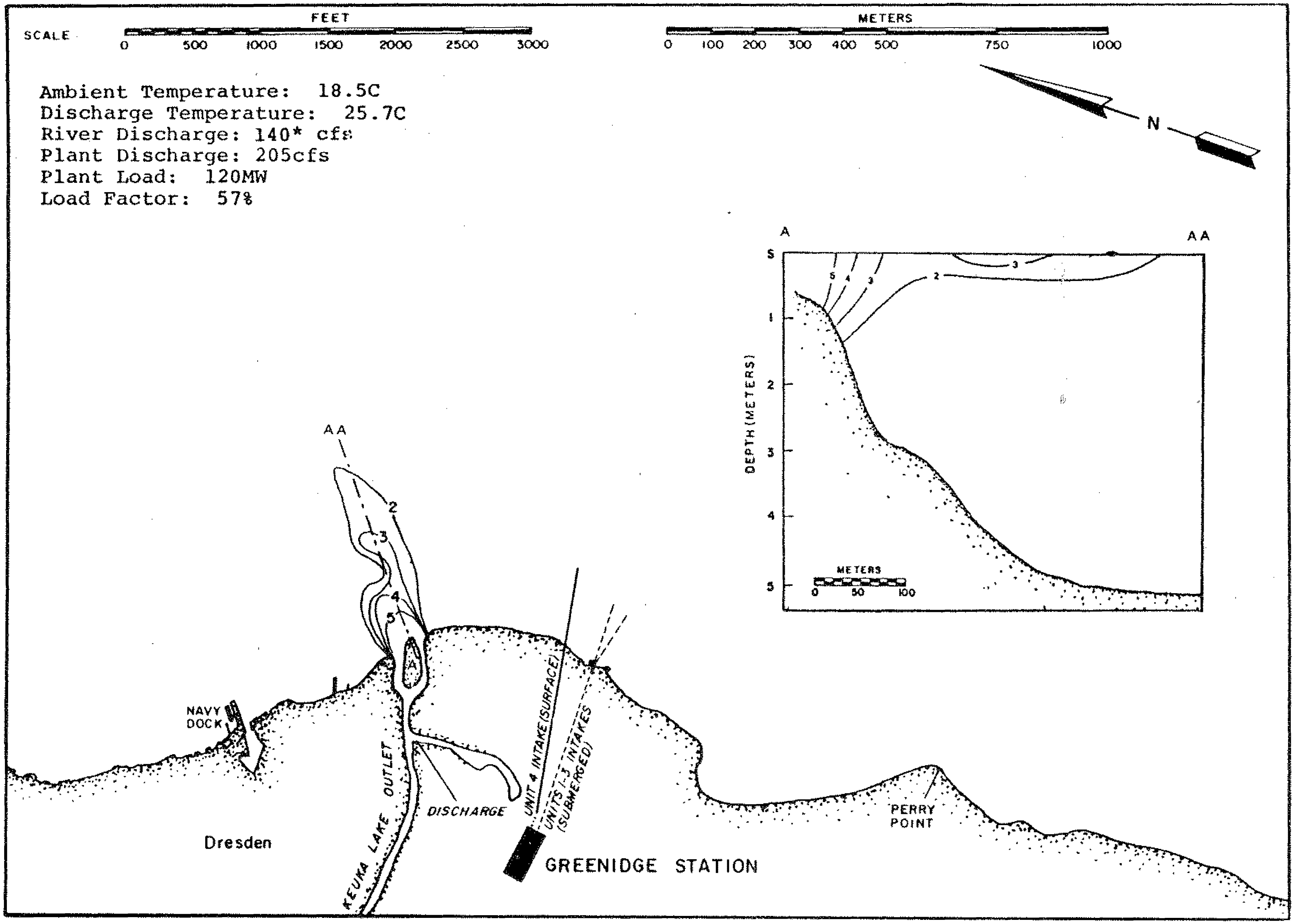

Figure 4-4. Configuration of the thermal plume in Seneca Lake on 01 July 1976. The isotherms indicate excess-temperature (ΔT) in degrees centigrade. * indicates an estimated value.

Figure 4-4

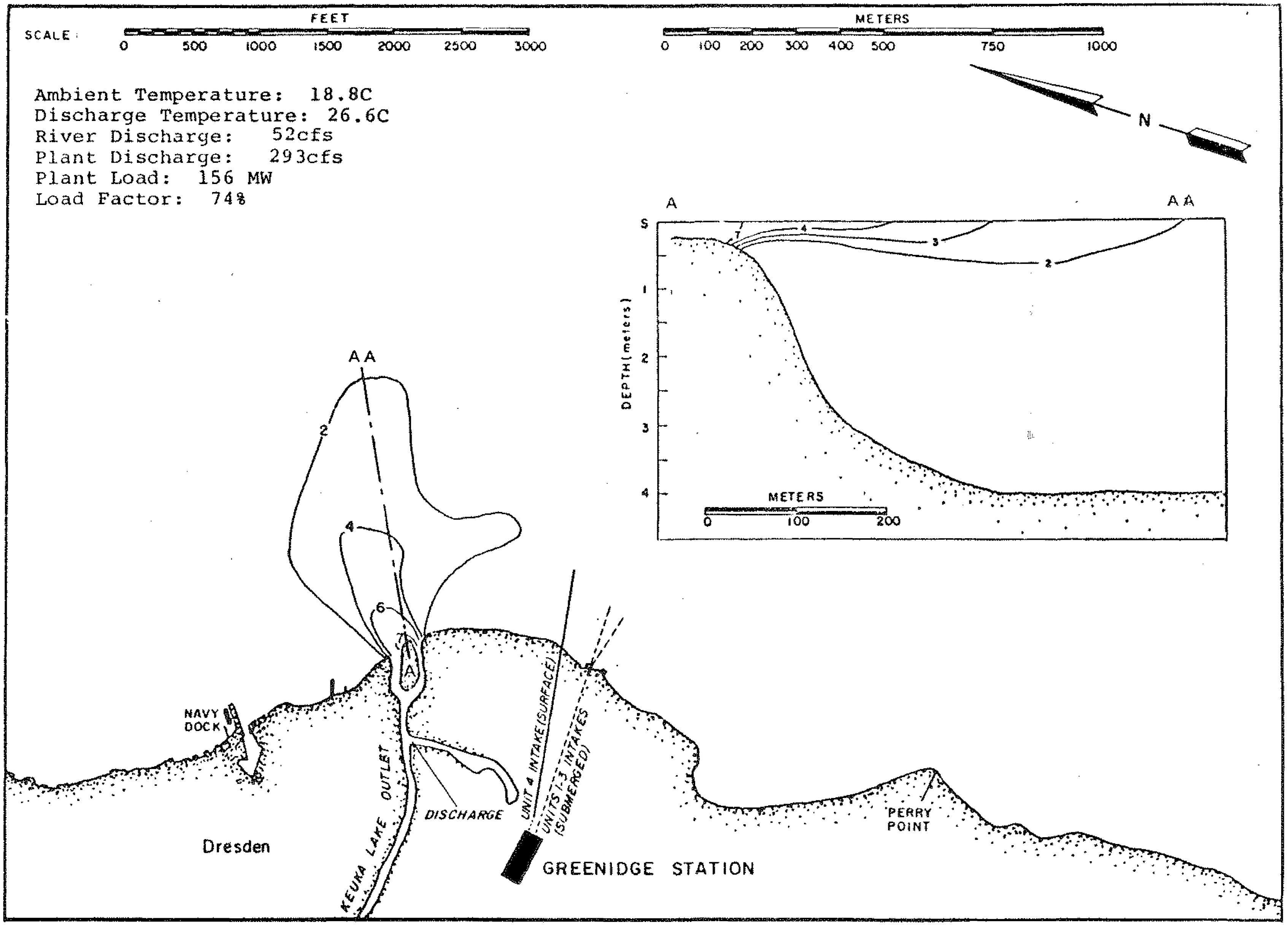

Figure 4-5. Configuration of the thermal plume in Seneca Lake on 05 August 1976. The isotherms indicate excess-temperature (ΔT) in degrees centigrade.

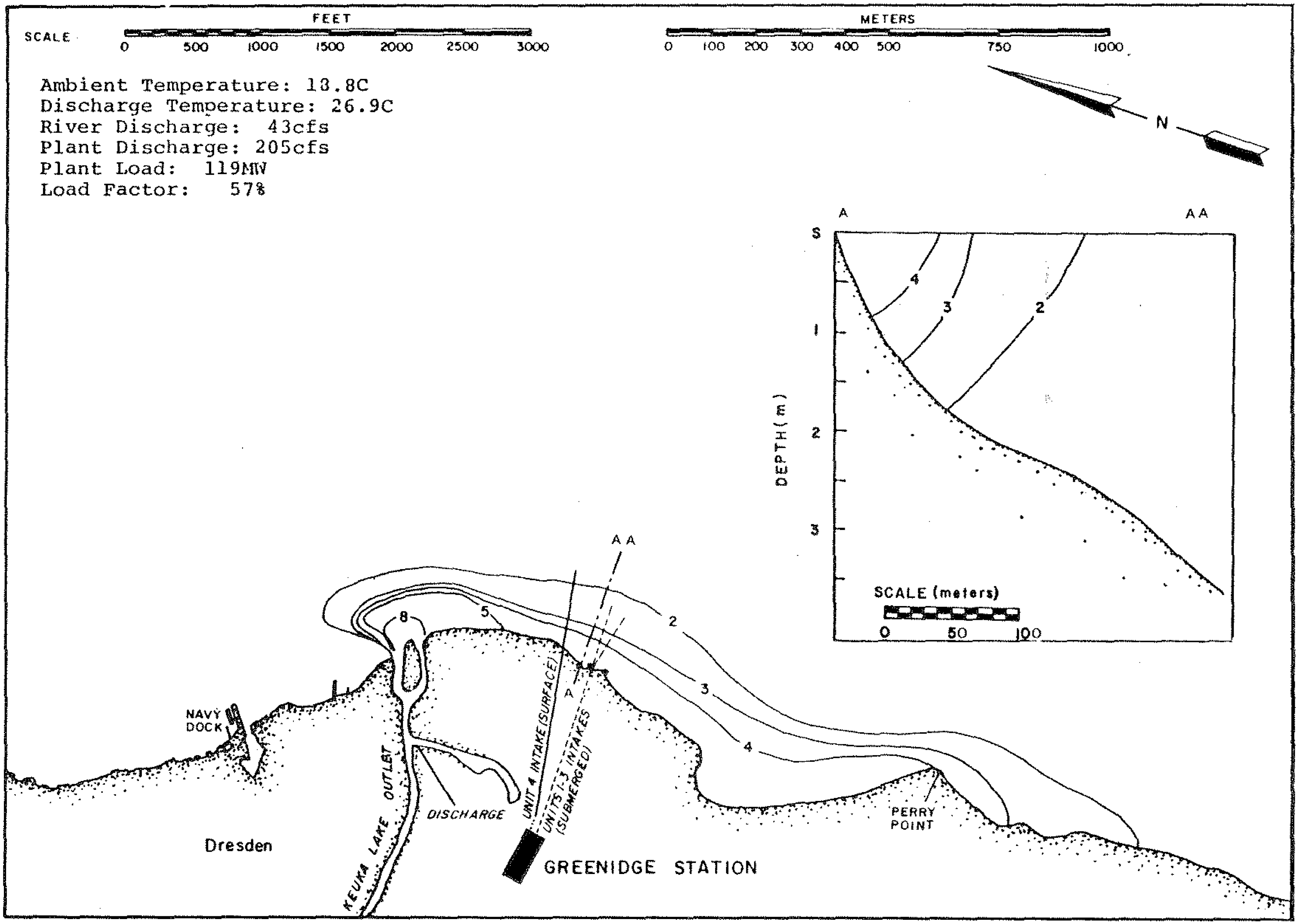

Figure 4-6. Configuration of the thermal plume in Seneca Lake on 02 September 1976. The isotherms indicate excess-temperature (ΔT) in degrees centigrade.

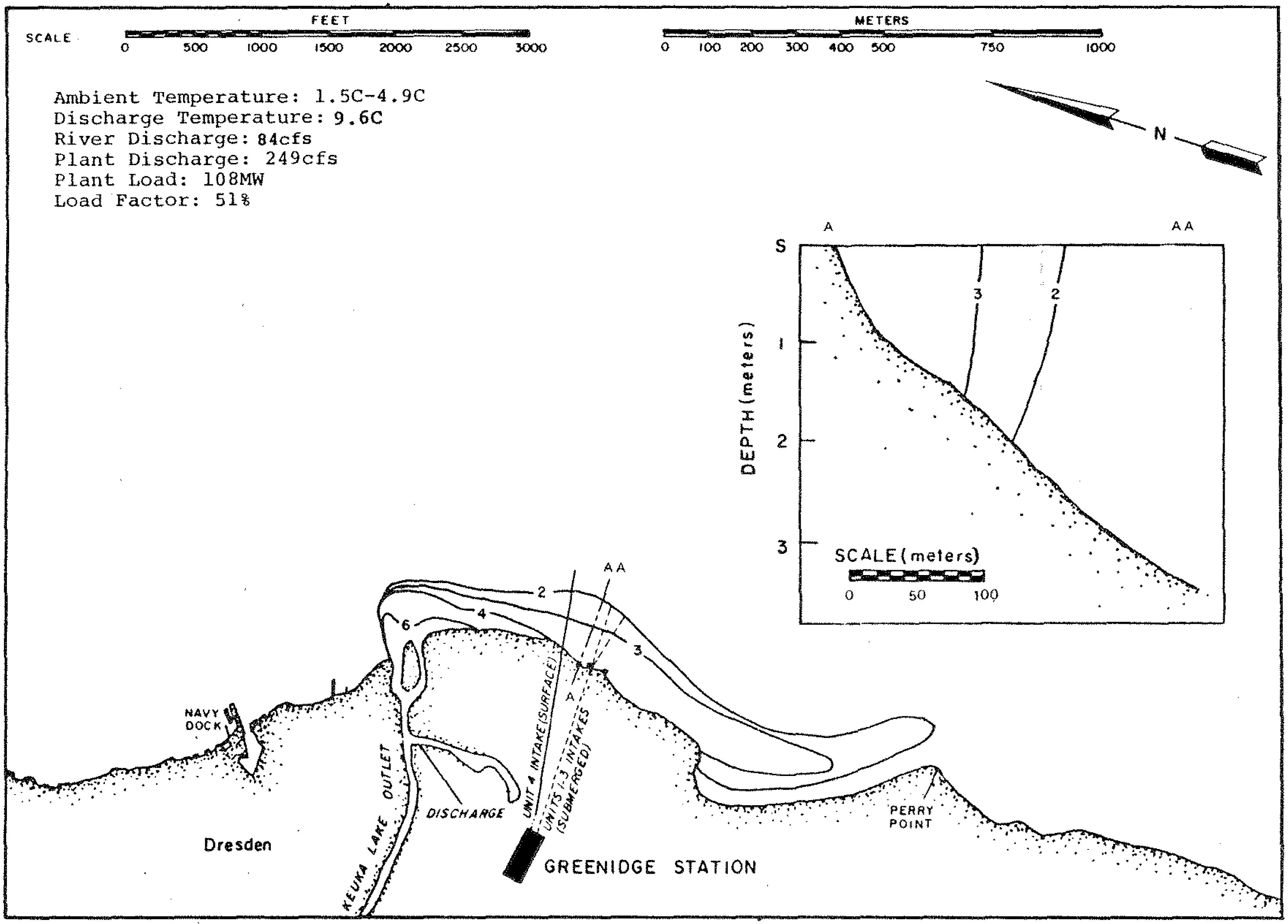

Figure 4-7. Configuration of the thermal plume in Seneca Lake on 09 December 1976. The isotherms indicate excess-temperature (ΔT) in degrees centigrade.

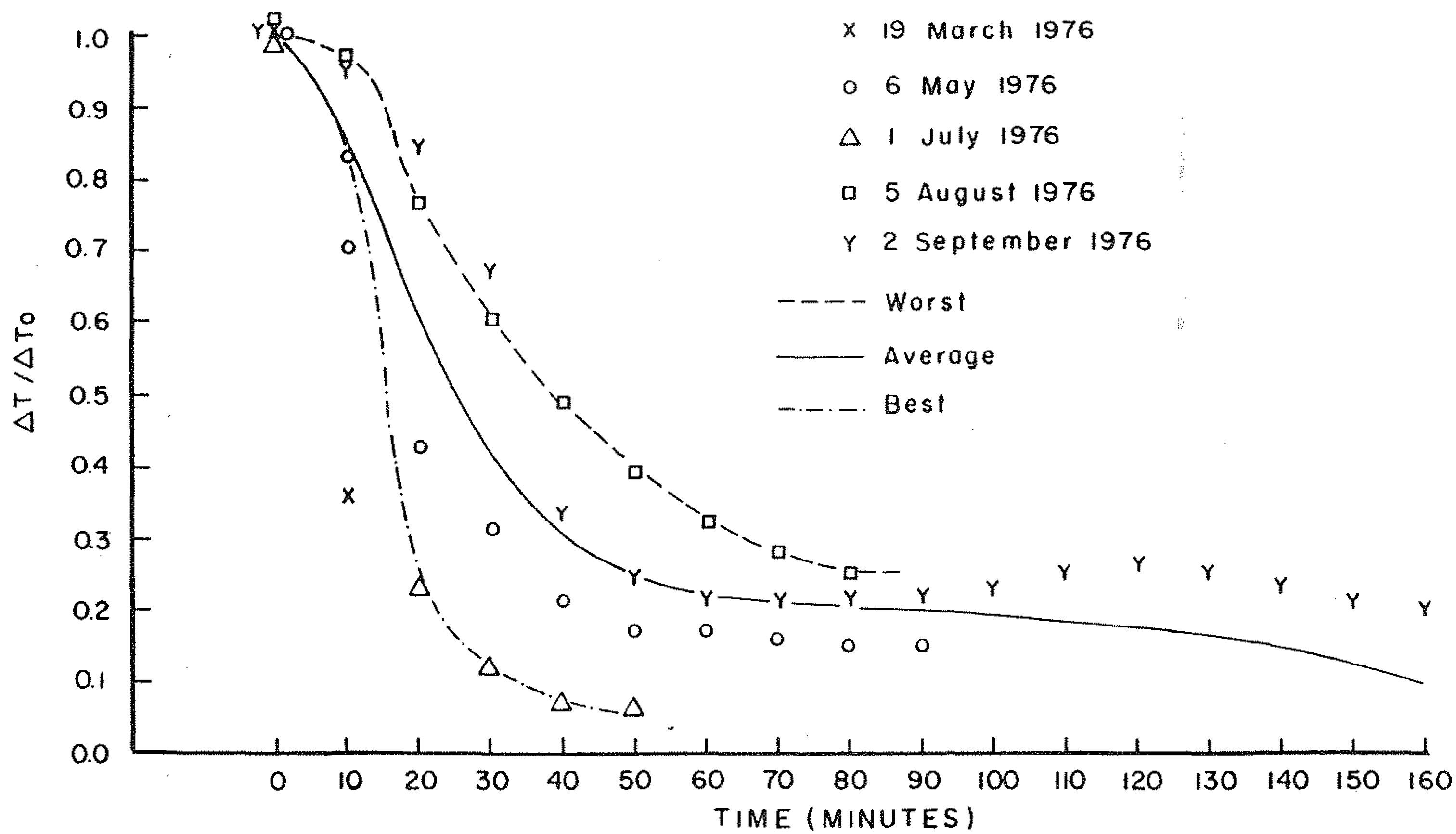

Figure 4-8. Time variations of the excess-temperature ratio ($\Delta T/\Delta T_O$) in the thermal plume measured during five surveys, 1976.

Table 4-2. Configuration of 2C ΔT isotherm within the thermal plumes during March, May, July, August, September and December 1976.

Date	Downstream Distance[a] (ft)	Maximum Width (ft)	Surface Area (acres)	Maximum Cross-Sectional area[a] (acres)
19 March	520	180	1.5	0.02
06 May	1100	1250[b]	22.4	0.09
01 July	1450	436	9.2	0.04
05 August	2050	1746	40.8	0.03
02 September	5820	798	71.5	0.07
09 December	4400	450	40.6	0.05

[a] Along plume centerline.
[b] Estimated.

Chapter 5

Phytoplankton

5.1 Methods and Materials

Three replicate water samples for phytoplankton analyses were collected from one foot below the water surface at ambient Locations A-1 and A-2, and at discharge Locations P-1 and P-2 (Figure 5-1). Whole water samples were collected with a Kemmerer water sampler on 10 June, 15 July, 5 and 19 August, 9 and 24 September, 6 October and 17 December 1976. Each replicate sample was placed in a 1.9 liter polyethylene bottle and immediately preserved at the time of collection with 60ml of "M^3" fixative (Meyer 1971).

Prior to analysis the individual samples were thoroughly shaken and an appropriate aliquot (ie., 10, 25 or 50ml) of the water sample was settled for approximately 15hrs in a Zeiss settling chamber.

Enumeration and identification of the algal components was undertaken utilizing a Zeiss phase contrast inverted microscope at 400 or 1000X magnification. The same preparatory and analytical procedures were used for all samples from all locations. A sample of medium density was chosen among the locations so that the volume of water settled yielded an approximate count of 500 reporting units. The area of the counting chamber analyzed remained constant regardless of the sampling location. This technique is necessary to insure that; a) a sufficient number of organisms was examined to characterize the population; and, b) that the sample sizes were equal so that the only variable being statistically tested was the density of organisms.

Phytoplankton density was reported in units per milliliter. A unit for filamentous algal forms was standardized at 100μm lengths (ie. 100μm filament length equals 1 unit). Colonial forms were enumerated as four-cell units, except for Aphanocapsa, Aphanothece and Microcystis, which were reported in 50 cell units (ie., 50 cells equals 1 counting unit). All other forms were counted as a single cell or diatom frustule unit. All identifications were made to the lowest positive taxonomic level (genus or species) utilizing the taxonomic keys indicated in Table 5-1.

Density and percentage composition was calculated for each taxon and major group. Species diversity was calculated for each sample and cumulatively for each sampling location using Shannon's formula (Shannon 1948) with log base 2.

A non-parametric statistical test (Kruskal-Wallis analysis of variance) was applied to the monthly phytoplankton data to test for significant differences ($P \leq 0.05$) in the numbers of individuals of total phytoplankton, major divisions and dominant taxa (species that made up 5% or more of the mean total phytoplankton). If a significant P value resulted from the Kruskal-Wallis test, a multiple comparison procedure was employed to identify the specific differences among locations.

5.2 Results and Discussion

5.2.1 Community Structure and Seasonal Fluctuations

Phytoplankton collections near Greenidge Station during this investigation comprised 159 taxa distributed among 79 genera and seven divisions: Cyanophyta (blue-green algae), Cryptophyta (cryptomonads), Chlorophyta (green algae), Bacillariophyta (diatoms), Chrysophyta (golden-brown algae), Pyrrhophyta (dinoflagellates), and Euglenophyta (euglenoid flagellates) (Table 5-1).

Mean total phytoplankton densities ranged from 681 units/ml at discharge Location P-2 in December to 19,476 units/ml at ambient Location A-2 on 9 September (Table 5-3). Phytoplankton populations fluctuated seasonally among sampling locations and similar seasonal trends in abundance were exhibited at all locations. Two major peaks in phytoplankton density generally occurred at all locations, one in the late spring (10 June) and the other in the late summer (9 September) (Table 5-3 and Figure 5-2). The late summer peak was greater than that in late spring. This seasonal pattern was a typical bimodal cycle and comparable to the bimodal periodicity documented for the phytoplankton populations in Lake Michigan by Damann (1960); Stoermer and Kopzynoka (1967); Everhart and Rasgus (1974); Mayhew and Barber (1974); Barber and Redmond (1975); and Festin (1975 and 1976).

Twelve taxa composed the majority of the phytoplankton community and were considered dominant. Each dominant taxon constituted at least 5% of the total phytoplankton community at one location during one or more collection period (Table 5-4).

Significant differences in total phytoplankton densities were observed among locations on 10 June and 19 August, despite the similar seasonal cycle exhibited by all locations. Mean total phytoplankton populations were significantly ($P \leq 0.05$) more abundant at ambient Location A-2 than at discharge Location P-2 on 10 June. This was mainly due to the significant differences in densities of the golden-brown algae (A-2>P-2) (Table 5-5). Mean total phytoplankton densities were also significantly greater at ambient Location A-1 than at discharge Location P-2 on 19 August. This was mainly a result of the significant differences in densities of Chlamydomonas sp. (A-1>P-2) (Tables 5-4 and 5-5). These significant differences in populations among locations were not consistent in all months; therefore, they probably were attributable to natural spatial variability and reflect a variability of natural environmental conditions.

5.2.2 Spatial and Temporal Distribution of Major Taxa

Blue-green algae (Cyanophyta) was the most abundant division of the phytoplankton community. Mean total densities of blue-green algae ranged from 148 units/ml at discharge Location P-1 in June to 17,557 units/ml at ambient Location A-2 on 9 September (Table 5-3). This group constituted more than 31% of the total phytoplankton community in all sampling periods except June when blue-green algae accounted for only 2% to 14% of the total phytoplankton at each location (Table 5-3). This smaller percent occurrence of blue-greens was, in part, due to golden-brown algae and diatoms which occurred in greater densities than in all other sampling periods.

A total of 17 blue-green taxa belonging to 10 genera were identified from all locations. The most abundant taxa were

Coelosphaerium naegelianum and Gomphosphaeria lacustris (Table 5-4). The variations in the total blue-green algal densities were generally reflective of the variations in densities of Coelosphaerium naegelianum (Tables 5-3 and 5-4). This taxon is a relatively small euplanktonic coccoid form which reportedly occurs abundantly in late summer or autumn in nitrogenous hard water lakes with adequate carbon dioxide (Prescott 1962; Hutchinson 1967). The largest single assemblage (17,497 units/ml) of this taxon occurred at ambient Location A-2 on 9 September and the smallest assemblage (122 units/ml) at discharge Location P-1 on 10 June (Table 5-4).

The only statistically significant differences in densities of total Cyanophyta and Coelosphaerium naegelianum among locations were recorded in June. Densities of both components were significantly greater at ambient Location A-2 than at discharge Location P-1 (Table 5-5). These differences were inconsistent between discharge and ambient locations; therefore, they probably were a result of natural spatial variability.

The cryptomonads (Cryptophyta) were the second most abundant group of phytoplankton and contributed no more than 49% of the total density. The mean total density of this group ranged from 13 units/ml to 610 units/ml (Table 5-3). Three species belonging to two genera were identified. Rhodomonas minuta var. nannoplanctica and Cryptomonas ovata were the most predominant taxa (Table 5-4). In June Rhodomonas minuta var. nannoplanctica was significantly more abundant at discharge Location P-1 than at ambient location A-1 (Table 5-5). This was probably attributable to natural spatial variability.

Green algae (Chlorophyta), composed mainly of coccoid forms, was the third most abundant and the second most diverse algal division, comprising 54 taxa belonging to 30 genera (Table 5-1). The taxa most frequently encountered in the order of decreasing abundance were Coelastrum reticulatum, Chlamydomonas sp., Dichtyosphaerium pulchellum and Selenastrum minutum. All green algae encountered during the investigation were euplanktonic (Hynes 1970), eurytopic-chlorococcal plankton (Hutchinson 1967) and are known to thrive and flourish in organically enriched habitats (Palmer 1971). Green algae reached peak abundances in early September at all locations. This was a normal seasonal cycle as greens usually are most abundant during the seasonally warmest water temperatures (McCombie 1953; Hutchinson 1967). There were some statistically significant differences in densities of Chlorophyta (e.g., Chlamydomonas sp. and Coelastrum reticulatum), among locations on 19 August (Table 5-5). However, these differences were not indicative of any consistent location/taxon correlation.

Diatoms (Bacillariophyta) were the most diverse division with a total of 66 taxa belonging to 21 genera. This group contributed <1 to 35% of the mean total phytoplankton population with densities ranging from 5 units/ml to 3270 units/ml (Table 5-3). The most frequently encountered pennate diatom, Fragilaria crotonensis, dominated the diatom peaks (Table 5-4) in the late spring (10 June) and early fall (21 September). This taxon has been reported to be abundant in various nearshore regions of Lake Michigan (Stoermer and Yang 1969; Everhart and Rasgus 1974;

Festin 1975; Industrial BIO-TEST Labs, Inc.; NALCO 1976a and 1976b). Diatoms were significantly more abundant at ambient Location A-1 than at ambient Location A-2 on 9 September (Table 5-5). *Asterionella formosa* was significantly more abundant at ambient Location A-2 than at ambient Location A-1 in June (Table 5-5).

The golden-brown algae (Chrysophyta) were represented by 12 taxa belonging to 8 genera. This algal group displayed a bimodal periodicity. Two peaks were recorded for this group; one major late spring (10 June) peak and a minor late summer (9 September) peak (Table 5-3). *Chrysidalis peritaphrena* and *Dinobryon divergens* were the most frequently encountered golden-brown algae (Table 5-4). The high densities of *Chrysidalis peritaphrena* at all locations in June were responsible for the late spring peak in total phytoplankton abundance that occurred during this month (Tables 5-3 and 5-4). Chrysophyta was significantly more abundant at ambient Location A-2 than at discharge Location P-1 and P-2 on 10 June. This was a result of the significantly greater density of *Chrysidalis peritaphrena* at ambient Location A-2 than at discharge locations P-1 and P-2. *Dinobryon divergens* was significantly more abundant at discharge Location P-2 than at ambient Location A-1 on 10 June. These differences probably were attributable to natural spatial variations as there were no detectable consistent patterns of statistical differences.

Divisions of Pyrrhophyta (dinoflagellates) and Euglenophyta (euglenoid flagellates) were represented by very few taxa and appeared only in small numbers. None of these groups ever made up more than 5% of the mean phytoplankton density at any location. Little importance can be attributed to their appearance in the phytoplankton community of the study area.

Mean species diversity and evenness for phytoplankton ranged from 0.59 to 2.41 and 0.18 to 0.70, respectively (Table 5-6). Generally, the lowest evenness and diversity values were recorded on 9 September at all locations. This reflected the numerical dominance of Coelospherium naegelianum (a blue-green alga) which accounted for 86% to 90% of the phytoplankton during this month.

The highest diversity and evenness values at all locations were recorded on 5 August and indicated a homogeneous distribution of densities among species (ie., no single dominant taxon).

Phytoplankton densities and percentage composition of the communities were similar at both plume and ambient locations. There were no significant ($P \leq 0.05$) density differences among locations which could be attributed to the operation of Greenidge Station.

5.3 Conclusions

The effect of thermal enrichment on the phytoplankton community of receiving waters has been studied by many investigators and found to be physically manifested in several ways. The effects, which vary with specific locations and conditions, may take the form of increased algal growth, changes in species composition, gross population shifts from diatoms to green algae to blue-green algae (Patrick 1974) or a large decrease in the mid-summer populations resulting from depression of photosynthesis

(Coutant 1970). Comparisons of ambient and discharge communities in Seneca Lake found no indication of these effects.

Phytoplankton community structure and the seasonal periodicity of algal divisions was generally similar within and outside of the thermal discharge area. There were some significant ($P \leq 0.05$) differences between ambient and discharge locations in densities of some taxa; however, these differences were not consistent among locations and were not indicative of thermal effects.

In conclusion, the operation of Greenidge Station did not appear to have had any adverse effect upon the balanced community of phytoplankton that exists in the vicinity of the station.

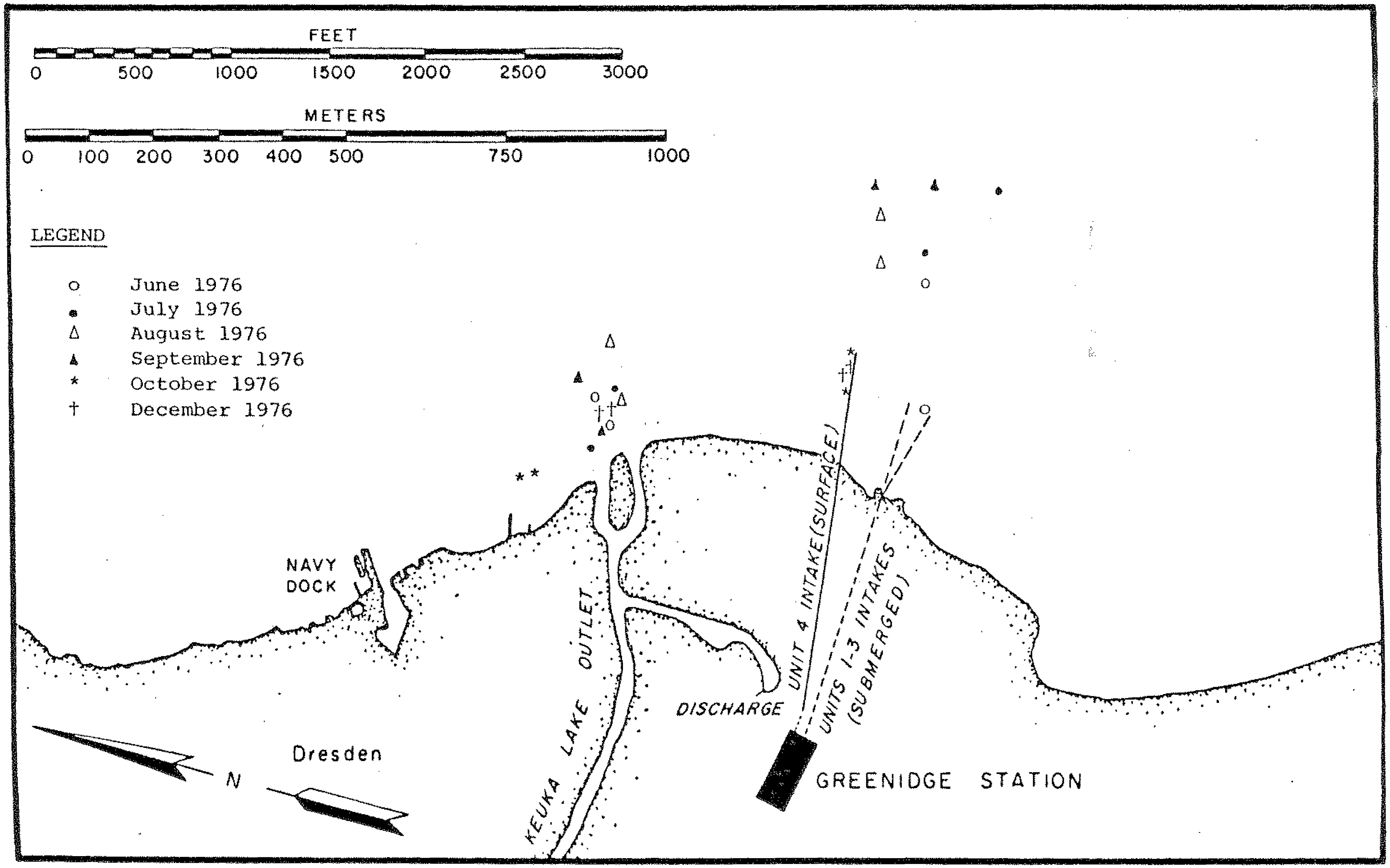

Figure 5-1. Collection locations for phytoplankton. All sampling points indicated directly offshore of Keuka Lake Outlet represent Locations P-1 and P-2. Those sampling points indicated near and offshore from the Unit 4 intake represent Locations A-1 and A-2.

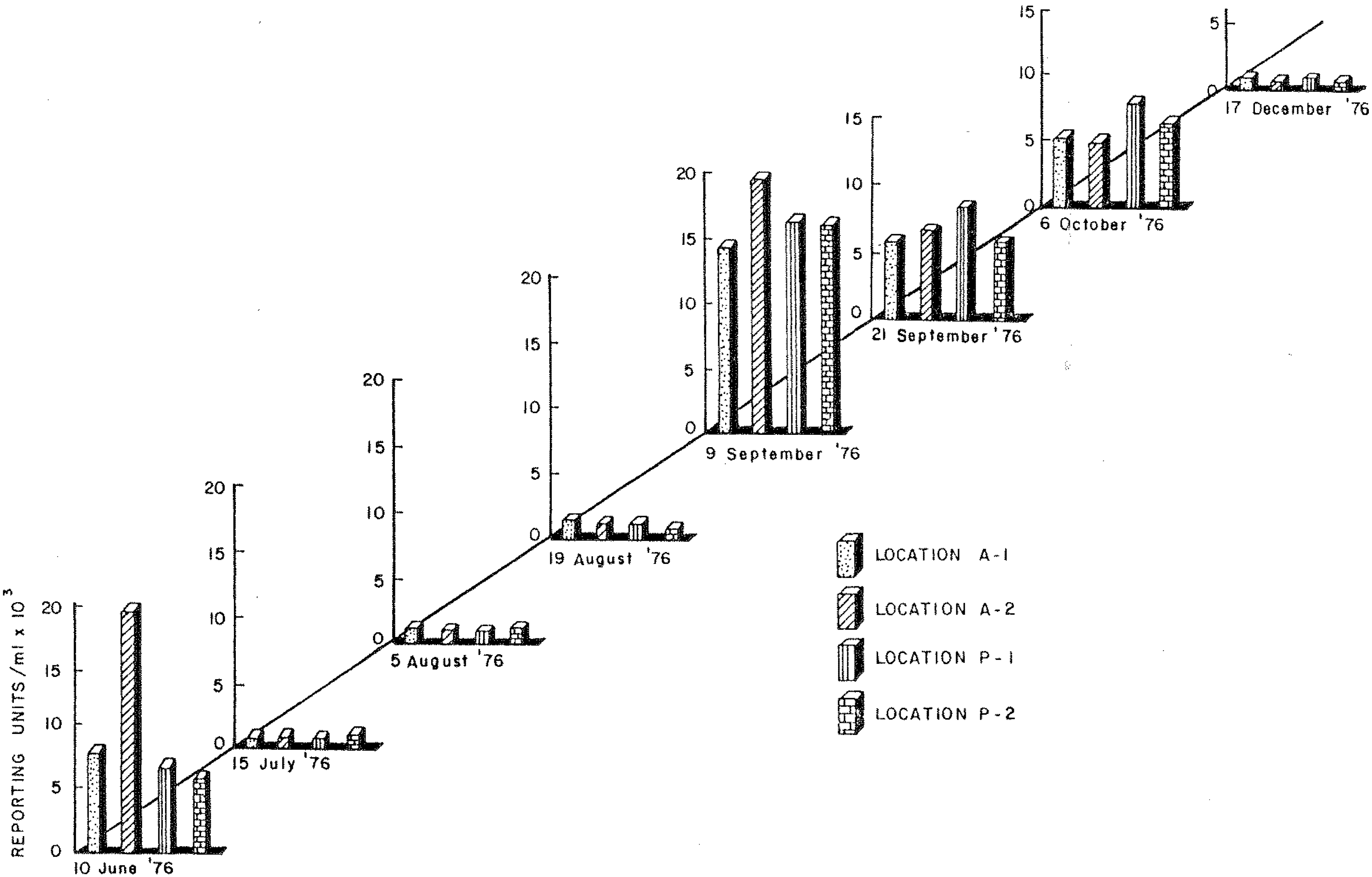

Figure 5-2. Phytoplankton abundance from 10 June through 17 December 1976.

Table 5-1. Taxonomic inventory of phytoplankton collected from 10 June through 21 December 1976. Numbers in parentheses refer to taxonomic references listed in Table 5-2.

Bacillariophyta Centrales
- Cyclotella Kuetzing
  - bodanica Eulenstein v. bodanica (3)
  - comta (Ehrenberg) Kuetzing v. comta (3)
  - meneghiniana Kuetzing v. meneghiniana (3)
  - michiganiana Skvortzow v. michiganiana (16)
- Melosira Agardh
  - ambigua (Grunow) Mueller v. ambigua (9), (8)
  - distans (Ehrenberg) Keutzing v. distans (9), (8)
  - islandica O. Mueller v. islandica (9), (8)
  - italica (Ehrenberg) Kuetzing italica (9), (8)
- Microsiphona Weber
  - potamos Weber v. potamos (17), (18)
- Rhizosolenia Ehrenberg
  - eriensis Smith v. eriensis (3), (9)
- Stephanodiscus Ehrenberg
  - astraea (Ehrenberg) Grunow v. astraea (3), (9)
  - invisitatus Hohn and Hellerman v. invisitatus (4)
  - minutus Grunow ex Cleve and Moller v. minutus (3)
  - tenuis Hustedt v. tenuis (3)
  - unidentified sp.

Bacillariophyta Pennales
- Achnanthes Bory
  - exigua Grunow v. exigua (2), (9)
  - lanceolata (Brebisson) Grunow v. lanceolata (2), (9)
  - unidentified sp.
- Amphora Ehrenberg
  - ovalis (Kuetzing) Kuetzing v. ovalis (1)
  - ovalis v. pediculus (Kuetzing) Van Heurck (1)
  - perpusilla Grunow v. perpusilla (1)
- Asterionella Hassall
  - formosa Hassall v. formosa (2)
- Caloneis Cleve
  - bacillum (Grunow) Cleve v. bacillum (2)
- Cocconeis Ehrenberg
  - pediculus Ehrenberg v. pediculus (2)
  - placentula v. euglypta (Ehrenberg) Cleve (2)
- Cylindrotheca Rabenhorst
  - gracilis (Brebisson) Grunow v. gracilis (9)
- Cymbella Agardh
  - affinis Kuetzing v. affinis
  - minuta Hilse ex Rabh. v. minuta (1)
  - minuta v. silesiaca (Bleisch ex Rabenhorst) Reimer (1)
  - muelleri v. ventricosa (1)
  - prostrata (Berkley) Cleve v. prostrata (1)
  - unidentified sp.

Table 5-1. continued.

Bacillariophyta Pennales (continued)
- Diatoma Bory
  - tenue v. flongatum Lyngbye (2)
  - vulgare Bory v. vulgare (2)
- Fragilaria Lyngbye
  - capucina Desmazieres v. capucina (2)
  - construens (Ehrenberg) Grunow v. construens (2)
  - crotonensis Kitton v. crotonensis (2)
  - intermedia Grunow v. intermedia (2)
  - vaucheriae (Kuetzing) Petersen v. vaucheriae (2)
- Gomphonema Agardh
  - olivaceum (Lyngbye) Kuetzing v. olivaceum (2)
- Navicula Bory
  - anglica Ralfs v. anglica (2)
  - cryptocephala Kuetzing v. cryptocephala (2)
  - exigua Gregory ex Grunow v. exigua (2)
  - menisculus Schumann v. menisculus (9)
  - salinarum v. intermedia (Grunow) Cleve (2)
  - tripunctata (Mueller) Bory v. tripunctata (2)
  - vaucheriae Petersen v. vaucheriae (2)
  - unidentified sp.
- Nitzschia Hassall
  - acicularis (Kuetzing) Smith v. acicularis (9)
  - actinastroides (Lemmermann) Van Goor v. actinastroides (7)
  - agnewii Cholnoky v. agnewii (11)
  - bacata Hustedt v. bacata (3)
  - capitellata Hustedt v. capitellata (9)
  - diserta Hudstedt v. diserta (3)
  - dissipata (Kuetzing) Grunow v. dissipata (9)
  - frustulum (Kuetzing) Grunow v. frustulum (9)
  - palea (Kuetzing) Smith v. palea (9)
  - unidentified sp.
- Rhoicosphenia Grunow
  - curvata (Kuetzing) Grunow ex Rabenhorst v. curvata (2), (9)
- Surirella Turpin
  - angusta Kuetzing v. angusta (9)
  - ovata Kuetzing v. ovata (9)
- Synedra Ehrenberg
  - delicatissima Smith v. delicatissima (2)
  - filiformis Grunow v. filiformis (2)
  - radians Kuetzing v. radians (2)
  - ulna (Nitzsch) Ehrenberg v. ulna (2)
- Tabellaria Ehrenberg
  - flocculosa (Roth) Kuetzing v. flocculosa (2)

Chlorophyta non-filamentous
- Ankistrodesmus Corda
  - falcatus (Corda) Ralfs (19)

Table 5-1. continued.

Chlorophyta non-filamentous (continued)
- *falcatus* v. *mirabilis* (West and West) West (19)
- *spiralis* (Turner) Lemmermann (19)

Bohlinia Lemmermann
- *echidna* (Bohlin) Lemmermann (20)

Carteria Diesing (19)
- unidentified sp.

Chlamydomonas Ehrenberg (19)
- unidentified sp.

Closteriopsis Lemmermann
- *longissima* Lemmermann (19)
- *longissima* v. *tropica* West and West (19)

Closterium Corda (19)
- unidentified sp.

Coelastrum Naegeli in Kuetzing
- *cambricum* Archer (19)
- *microporum* Naegeli in Braun (19)
- *reticulatum* (Dangeard) Senn (19)
- *sphaericum* Naegeli

Cosmarium Corda (19)
- unidentified sp.

Crucigenia Morren
- *irregularis* Wille (19)
- *quadrata* Morren (19)

Dictyosphaerium Naegeli (19), (20)
- *pulchellum* Wood

Elakotothrix Wille
- *viridis* (Snow) Printz (19), (20)

Franceia Lemmermann
- *ovalis* (France) Lemmermann (19), (20)

Golenkinia Chodat
- *radiata* (Chodat) Wille (19), (21)

Lagerheimia (de Toni) Chodat
- *ciliata* (Lagerheim) Chodat (19), (22)
- *citriformis* (Snow) Smith (19)
- *longiseta* (Lemmermann) Printz (19), (20)

Micractinium Fresenius
- *pusillum* Fresenius (19), (20), (22)

Nephrocytium Naegeli
- *agardhianum* Naegeli (19), (20)

Oocystis Naegeli in Braun
- *borgei* Snow (19), (20), (22)
- *gloeocystiformis* Borge (19)
- *pusilla* Hansgirg (19)
- *solitaria* Wittrock in Wittrock and Nordstedt (19)

Pandorina Bory
- *morum* (Mueller) Bory (20), (19), (22)

Pediastrum Meyen
- *boryanum* (Turpin) Meneghini (19)
- *duplex* Meyen (19), (20)

Table 5-1. continued.

Chlorophyta non-filamentous (continued)
- Platymonas West
  - elliptica Smith (20)
- Scenedesmus Meyen
  - abundans (Kirschner) Chodat (19)
  - arcuatus Lemmermann (19)
  - bijuga (Turpin) Lagerheim (19)
  - denticulatus Lagerheim (19)
  - dimorphus (Turpin) Keutzing (19)
  - incrassatulus Bohlin (19)
  - longispina Chodat (19)
  - longus Meyen (19)
  - opoliensis Richter (19)
  - quadricauda (Turpin) Brebisson (19)
  - serratus (Corda) Bohlin (19)
- Schizochlamys Braun in Keutzing
  - gelatinosa Braun in Kuetzing (19)
- Schroederia Lemmermann
  - setigera (Schroeder) Lemmermann (19)
- Selenastrum Reinsch
  - minutum (Naegeli) Collins (19)
- Sphaerocystis Chodat
  - schroeteri Chodat (19), (20)
- Staurastrum Meyen (19)
  - unidentified sp.
- Tetraedron Kuetzing (19)
  - minimum (Braun) Hansgirg
- Tetraspora Link
  - gelatinosa (Vaucher) Desvaux (19)
  - lamellosa Prescott (19)
- Tetrastrum Chodat
  - staurogeniaeforme (Schroeder) Limmermann (19), (20)
- Treubaria Bernard
  - setigerum (Archer) Smith (19)

Chrysophyta
- Chrysidalis Schiller
  - peritaphrena Schiller (23)
- Chrysochromulina
  - unidentified sp. (23)
- Chrysosphaerella Lauterborn
  - longispina Lauterborn (19)
- Dinobryon Ehrenberg
  - divergens Imhof (19), (22), (25)
  - pediforme (Lemmermann) Steinecke (22), (25)
  - sociale Ehrenberg (19), (22), (25)

Table 5-1. continued.

Chrysophyta (continued)
- Mallomonas Perty
  - caudata Iwanoff (19), (23)
  - producta (Zacharias) Iwanoff (19), (23)
  - pseudocoronata Prescott (19), (23)
- Rhizochrysis Pascher
  - limnetica Smith (19), (23)
- Salpingoeca J. Clark
  - frequentissima (Zacharias) Lemmermann (23)
- Stipitococcus West and West
  - urceolatus West and West (19)

Cyanophyta non-filamentous
- Aphanocapsa Naegeli
  - delicatissima West and West (19)
- Aphanothece
  - microscopica Naegeli (19)
  - nidulans P. Richter (19)
- Chroococcus Naegeli
  - limneticus Lemmermann (19)
  - prescottii Drouet and Daily in Drouet (19)
- Coelosphaerium Naegeli
  - naegelianum Unger (19), (20)
- Gomphosphaeria Kuetzing
  - aponina Kuetzing (19), (20)
  - lacustris Chodat (19), (20)
- Microcystis Kuetzing
  - incerta Lemmermann (19)

Cyanophyta filamentous
- Anebaena Bory
  - flos-aguae (Lyngbye) Brebisson in de Brebisson and Godey (19)
  - spiroides Klebahn (19)
  - unidentified sp.
- Aphanizomenon Morren
  - flos-aguae (Linnaeus) Ralfs (19)
- Lyngbya Agardh
  - contorta Lemmermann (19)
  - unidentified sp.
- Oscillatoria Vaucher (19)
  - limnetica Lemmermann (19)
  - unidentified sp.

Euglenophyta
- Euglena Ehrenberg
  - acus v. rigida Huebner (19)
  - unidentified sp.
- Trachelomonas Ehrenberg (19)
  - unidentified sp.

Table 5-1. continued.

Pyrrhophyta
- *Ceratium* Schrank
  - *hirundinella* (Mueller) Dujardin (19)
- *Glenodinium* (Ehrenberg) Stein
  - *quadridens* (Stein) Schiller (19)
- *Peridinium* Ehrenberg (19)
  - unidentified sp.

Cryptophyta
- *Cryptomonas* Ehrenberg
  - *marssonii* Skuja (19), (21), (24)
  - *ovata* Ehrenberg (19), (21), (24)
- *Rhodomonas* Karsten (19), (21), (24)
  - *minuta* v. *nannoplanctica* Skuja (24)

Table 5-2. Summary of taxonomic references utilized in identification of phytoplankton listed in Table 5-1.

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Table 5-4. Mean density[a] and percent composition of dominant[b] phytoplankton taxa collected from June through December 1976.

DATE & TAXA	A-1 Units/ml	A-1 %	A-2 Units/ml	A-2 %	P-1 Units/ml	P-1 %	P-2 Units/ml	P-2 %
10 June 1976								
Bacillariophyta								
Pennales								
Fragilaria crotonensis	592	8	1111	6	181	3	425	7
Asterionella formosa	401	5	1405	7	666	10	797	14
Chrysophyta								
Chrysidalis peritaphrena	5417	69	11481	60	3894	59	2534	44
Dinobryon divergens	57	0.7	397	2	296	4	713	12
Cyanophyta								
Coelosphaerium naegelianum	539	7	2536	13	122	2	449	8
Cryptophyta								
Rhodomonas minuta var. *nannoplanctica*	129	2	340	2	594	9	253	4
Total phytoplankton	7803		19240		6611		5829	
15 July 1976								
Bacillariophyta								
Pennales								
Fragilaria crotonensis	0	0	52	5	14	2	96	9
Chlorophyta								
Selenastrum minutum	155	19	168	17	7	0.9	24	2
Chryptophyta								
Rhodomonas minuta var. *nannoplanctica*	256	32	168	17	377	44	477	45
Cyanophyta								
Coelosphaerium naegelianum	306	38	374	39	274	32	312	29
Gomphosphaeria lacustris	0	0	0	0	48	5	0	0
Total phytoplankton	814		970		855		1061	
5 August 1976								
Cyanophyta								
Coelosphaerium naegelianum	494	39	440	36	390	37	412	33
Cryptophyta								
Rhodomonas minuta var. *nannoplanctica*	283	22	316	26	330	31	425	34
Cryptomonas ovata	170	14	176	15	128	12	145	12
Total phytoplankton	1262		1219		1055		1252	
19 August 1976								
Chlorophyta								
Chlamydomonas sp.	119	8	90	7	69	5	-	-
Coelastrum reticulatum	-	-	87	7	180	13	85	9

Table 5-4. continued.

DATA & TAXA	Sampling Locations A-1 Units/ml	%	A-2 Units/ml	%	P-1 Units/ml	%	P-2 Units/ml	%
Dichtyosphaerium pulchellum	-	-	-	-	68	5	80	9
Cyanophyta Coelosphaerium naegelianum	825	56	782	59	748	55	527	56
Cryptophyta Rhodomonas minuta var. nannoplanctica	-	-	68	5	-	-	-	-
Total phytoplankton	1477		1323		1348		934	
9 September 1976								
Cyanophyta Coelosphaerium naegelianum	12170	86	17497	90	14153	88	13911	87
Total phytoplankton	14235		19476		16085		15941	
21 September 1976								
Bacillariophyta Fragilaria crotonensis	707	12	561	8	629	8	503	9
Cyanophyta Coelesphaerium naeglianum	4573	77	5605	83	7155	85	4898	85
Total phytoplankton	5956		6783		8442		5796	
6 October 1976								
Cyanophyta Coelosphaerium naegelianum	4413	85	3996	80	7012	90	5632	90
Total phytoplankton	5225		4973		7797		6288	
17 December 1976								
Bacillariophyta Fragilaria crotonensis	71	9	46	6	9	10	43	6
Cyanophyta Coelosphaerium naegelianum	503	66	607	74	648	66	526	77
Cryptophyta Rhodomonas minuta var. nannoplankton	62	8	63	8	64	7	0	0
Total phytoplankton	820		758		979		681	

[a] Values are based on the mean of three replicate samples.
[b] Taxa composing 5% or more of total phytoplankton.
[c] No individuals collected

Table 5-5. continued.

Date/Taxa	Probability	Multiple Comparison Differences
Coelosphaerium naegelianum	0.215	
Pyrrhophyta	0.329	
Total Phytoplankton	0.192	
19 August 1976		
Bacillariophyta	0.042	NS
Chlorophyta	0.042	P-1>P-2
Chlamydomonas sp.	0.023	A-1>P-2
Coelastrum reticulatum	0.034	P-1>A-1
Dichtyosphaerium pulchellum	0.037	NS
Cryptophyta	0.029	NS
Rhodomonas minuta var. *nannoplanctica*	0.028	NS
Cyanophyta	0.049	NS
Coelosphaerium naegelianum	0.061	
Pyrrhophyta	0.039	NS
Total phytoplankton	0.033	A-1>P-2
9 September 1976		
Bacillariophyta	0.029	A-1>A-2
Chlorophyta	0.319	
Chrysophyta	0.729	
Cryptophyta	0.282	
Cyanophyta	0.270	
Coelosphaerium naegelianum	0.270	
Pyrrhophyta	0.060	
Total phytoplankton	0.313	
21 September 1976		
Bacillariphyta	0.101	
Fragilaria crotonensis	0.376	
Chlorophyta	0.065	
Chrysophyta	0.025	NS
Cryptophyta	0.047	
Cyanophyta	0.113	
Coelosphaerium naegelianum	0.113	
Total phytoplankton	0.086	

Table 5-5. continued.

Date/Taxa	Probability	Multiple Comparison Differences
6 October 1976		
Bacillariophyta	0.691	
Chlorophyta	0.040	NS
Chrysophyta	0.095	
Cyanophyta	0.092	
Coelosphaerium naegelianum	0.092	
Pyrrhophyta	0.021	NS
Cryptophyta	0.125	
Total phytoplankton	0.099	
17 December 1976		
Bacillariophyta	0.068	
Fragilaria crotonensis	0.200	
Chlorophyta	0.480	
Chrysophyta	0.181	
Cryptophyta	0.099	
Rhodomonas minuta var. *nannoplanctica*	0.099	
Cyanophyta	0.502	
Coelosphaerium naegelianum	0.536	
Pyrrhophyta	0.334	
Total phytoplankton	0.135	

[a] Not statistically significant.
[b] Blank space denotes Probability is greater than 0.05; therefore, Tukey's multiple comparison was not run.

Table 5-6. Density (units/ml), total number of taxa, diversity and evenness indices for phytoplankton collected from June through December 1976.

Data	Location	Mean[a] Total Density	Mean[a] Number of Species	Diversity[b]	Evenness
10 June 1976	A-1	7803	21	1.265	0.413
	A-2	19240	22	1.538	0.498
	P-1	6611	25	1.607	0.499
	P-2	5829	31	2.409	0.703
15 July 1976	A-1	814	22	1.615	0.526
	A-2	970	21	1.665	0.551
	P-1	855	29	1.672	0.499
	P-2	1061	27	1.617	0.491
5 August 1976	A-1	1262	29	1.980	0.590
	A-2	1219	28	1.960	0.588
	P-1	1055	26	1.789	0.550
	P-2	1252	30	1.893	0.560
19 August 1976	A-1	1477	30	1.953	0.574
	A-2	1323	24	1.788	0.562
	P-1	1348	28	1.786	0.536
	P-2	934	32	1.913	0.555
9 September 1976	A-1	14235	29	0.780	0.232
	A-2	19476	27	0.587	0.178
	P-1	16085	26	0.671	0.207
	P-2	15941	29	0.705	0.209
21 September 1976	A-1	5955	29	1.041	0.303
	A-2	6783	24	0.838	0.264
	P-1	8442	29	0.758	0.226
	P-2	5796	20	0.722	0.243
6 October 1976	A-1	5225	28	0.914	0.273
	A-2	4973	24	1.021	0.321
	P-1	7797	30	0.625	0.185
	P-2	6288	19	0.586	0.201
17 December 1976	A-1	820	21	1.177	0.389
	A-2	758	19	1.413	0.477
	P-1	979	21	1.405	0.462
	P-2	681	21	1.117	0.369

[a] Values are based on the mean of three replicate samples.
[b] Shannon (1948).

Chapter 6

Aquatic Macrophytes

6.1 Methods and Materials

Aquatic macrophytes in Seneca Lake near Greenidge Station were sampled concurrent with substrate sampling (Section 3.5). on 11 and 12 August 1976. Substrata were examined by a scuba diver for macrophytes along nine transects, perpendicular to shore at points 500, 1000, 1500ft north and 500, 1000, 1500, 2000, 7000 and 7500ft south of Keuka Lake Outlet (Figure 6-1). A 1 x 3ft metal frame was placed on the lake bottom to delineate the sampling area at a series of locations along each transect. Sampling locations on each transect were located using a Hewlett-Packard Model 3810A electronic distance measuring instrument which is accurate to within 0.5ft at a range of 0.5mi. The scuba diver conducted an in-situ visual examination of the 3sq ft area within the frame for macrophytes at each location. The density of macrophyte growth was categorized as either sparse, moderate or dense. The term sparse denoted when growth was seldom observed; moderate when the growth covered approximately half the sampling area; and dense when the growth was continuous within the grid. Any macrophyte beds observed between locations or transects were also examined and recorded. Macrophytes were identified in the field when practical and were dried in a plant press and mounted for laboratory examination when field identifications were not possible. Taxonomic keys used for the identifications were Britton and Brown (1913), Fassett (1957), Gleason and Cronquist (1963) and Winterringer and Lopinot (1966).

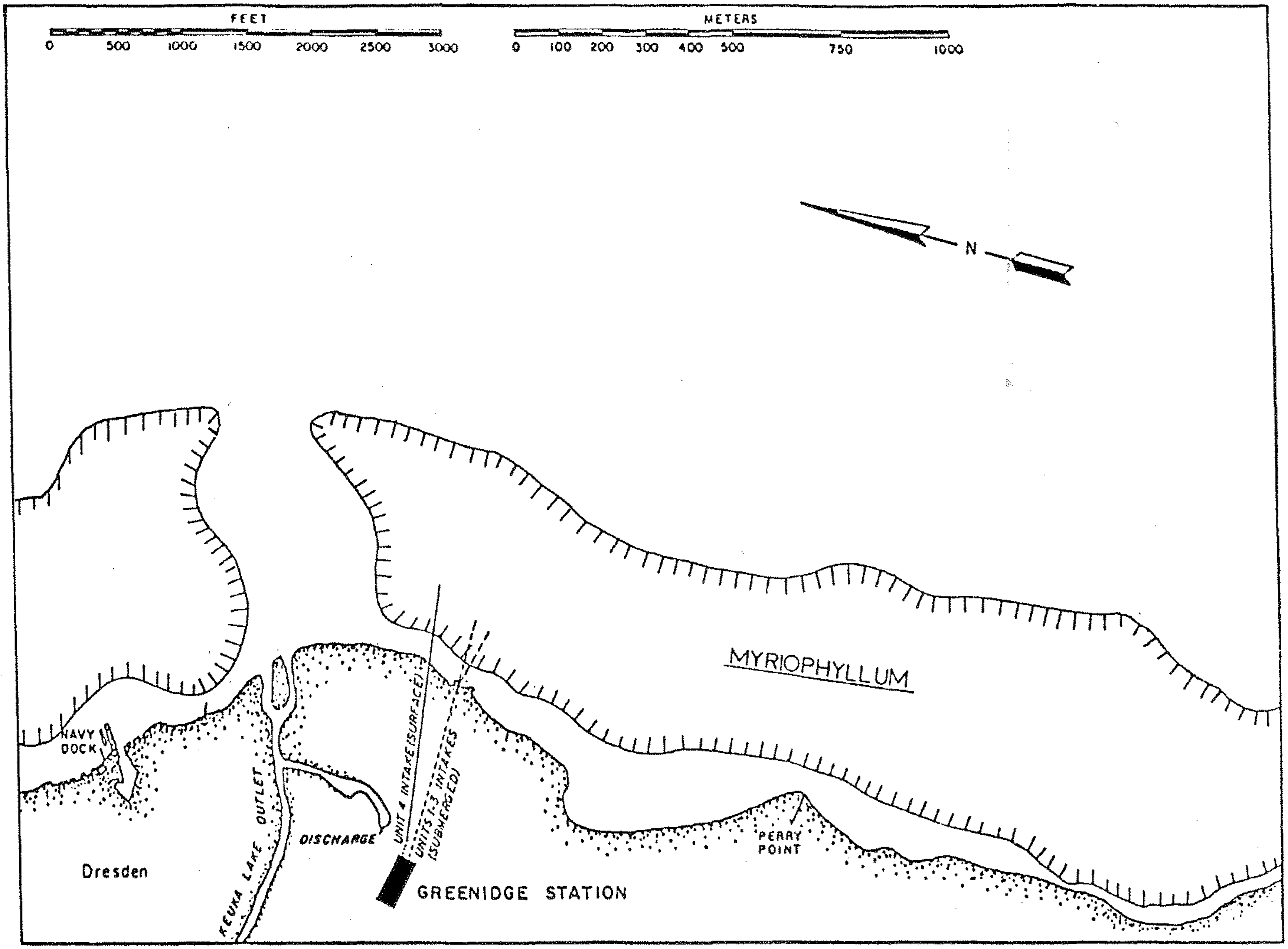

Figure 6-2. Distribution of aquatic macrophyte beds in Seneca Lake, August 1976.

Table 7-5. Population density and percent occurrence of dominant and subdominant zooplankton collected on 5 August 1976.

Taxon	Location A-1		Location A-2		Location P-1		Location P-2	
	Mean No./m^3	% Occurrence	Mean No./m^3	% Occurrence	Mean No./m^3	% Occurrence	Mean No./m^3	% Occurrence
nauplii	12432	27	45252	32	10098	31	12153	27
cyclopoid copepodites	12139	27	32174	23	6062	19	5915	13
Bosmina longirostris	5181	11	17217	12	8073	25	9820	22
Keratella spp.	2004	4	8953	6	1270	4	3229	7
Ploesoma spp.	29	<1	–[a]	–	29	<1	29	<1
Polyarthra spp.	4697	10	14957	11	3538	11	5959	13
Synchaeta spp.	88	<1	37	<1	66	<1	125	<1
Trichocerca spp.	8234	18	20740	15	2642	8	7721	17
Total Copepoda	25346	55	78262	55	16357	51	18279	40
Total Cladocera	5181	11	17221	12	8073	25	9820	21
Total Rotifera	15132	33	44724	31	7633	23	17194	37
Total Zooplankton	45659		140207		32063		45293	

[a] No individuals collected.

Table 7-3. Summary of species diversity[a] for zooplankton from Locations A-1, A-2, P-1 and P-2, 10 June through 17 December 1976.

	H'	J	S	N	H' Max	H' Min	R
<u>10 June 1976</u>							
Location A-1	0.8473	0.2450	11	3811954.	3.4595	0.0001	0.7551
Location A-2	0.6970	0.2015	11	2114961.	3.4595	0.0002	0.7986
Location P-1	0.7988	0.2159	13	1580433.	3.7005	0.0002	0.7842
Location P-2	0.6441	0.1939	10	2567385.	3.3220	0.0001	0.8062
<u>15 July 1976</u>							
Location A-1	1.9253	0.4928	15	271052.	3.9069	0.0011	0.5074
Location A-2	1.7676	0.4777	13	187824.	3.7005	0.0013	0.5226
Location P-1	1.9251	0.4710	17	272327.	4.0875	0.0012	0.5292
Location P-2	1.8700	0.4787	15	354552.	3.9069	0.0008	0.5215
<u>5 August 1976</u>							
Location A-1	2.0174	0.5452	13	61682.	3.7005	0.0034	0.4553
Location A-2	2.0120	0.5613	12	187260.	3.5850	0.0012	0.4390
Location P-1	1.8702	0.5217	12	47579.	3.5850	0.0040	0.4789
Location P-2	2.0287	0.5864	11	81504.	3.4595	0.0022	0.4140
<u>9 September 1976</u>							
Location A-1	1.7356	0.4162	18	742140.	4.1700	0.0005	0.5839
Location A-2	1.5954	0.4312	13	762612.	3.7005	0.0004	0.5690
Location P-1	1.1091	0.2773	16	118380.	4.0000	0.0024	0.7232
Location P-2	2.1847	0.4765	24	57320.	4.5850	0.0069	0.5244
<u>6 October 1976</u>							
Location A-1	1.6797	0.4686	12	17012.	3.5850	0.0101	0.5330
Location A-2	1.8096	0.4632	15	93618.	3.9069	0.0027	0.5373
Location P-1	2.1034	0.5146	17	31175.	4.0875	0.0084	0.4865
Location P-2	2.0490	0.4665	21	43540.	4.3924	0.0077	0.5345
<u>17 December 1976</u>							
Location A-1	2.3531	0.6023	15	19970.	3.9069	0.0111	0.3989
Location A-2	2.3484	0.6551	12	23343.	3.5850	0.0075	0.3457
Location P-1	2.1420	0.5975	12	17697.	3.5850	0.0097	0.4036
Location P-2	2.2080	0.5800	14	30353.	3.8074	0.0070	0.4209

[a] Based on Shannon (1948), using log base 2.
H' = Species diversity.
J = Evenness.
S = Total number of species.
N = Total number of organisms.
R = Redundancy.

Table 7-1. Taxonomic inventory of zooplankton collected from 10 June through 17 December 1976, with notes on the relative abundance of each taxon.

Taxa	10 Jun	15 Jul	5 Aug	9 Sep	6 Oct	17 Dec
Copepoda						
nauplii	R	SD	D	SD	SD	SD
Calanoid copepodites	R	R	R	R	R	R
cyclopoid copepodites	R	SD	D	SD	SD	SD
Cyclops bicuspidatus thomasi	VR	R	R	VR	VR	R
Cyclops vernalis	-	R	VR	VR	-	-
Diaptomus oregonensis	-	-	-	VR	-	R
Diaptomus sicilis	-	-	-	-	-	R
Diaptomus siciloides	VR	VR	VR	VR	-	-
Eucyclops agilis	-	-	-	VR	VR	-
Tropocyclops prasinus mexicanus	VR	R	R	R	SD	VR
Cladocera						
Acroperus harpae	-	-	-	VR	VR	-
Alona guttata	-	VR	-	VR	-	-
Alona quadranglaris	-	-	-	-	VR	-
Anchistropus minor	-	-	-	VR	-	-
Bosmina longirostris	R	SD	D	D	R	SD
Ceriodaphnia lacustris	-	-	VR	-	R	-
Ceriodaphnia quadrangula	-	-	-	R	-	-
Chydorus sphaericus	R	VR	-	VR	VR	VR
Daphnia retrocurva	-	-	-	R	-	-
Disparalona rostrata	-	-	-	-	VR	-
Holopedium gibberum	-	-	-	VR	-	-
Polyphemus pediculus	-	-	-	-	VR	-
Rotifera						
Asplanchna spp.	-	R	R	-	VR	-
bdelloid Rotifera	R	R	R	R	VR	-
Brachionus spp.	VR	-	-	-	-	-
Cephalodella spp.	VR	VR	-	R	VR	-
Collotheca spp.	-	-	-	VR	VR	-
Conochiloides spp.	VR	-	-	-	-	-
Conochilus spp.	R	R	R	R	VR	-
Dicranophorus spp.	VR	-	-	VR	-	-
Encentrum spp.	-	-	R	R	-	-
Euchlanis spp.	-	VR	-	-	VR	-
Filinia spp.	R	R	VR	R	R	VR
Kellicottia spp.	R	R	-	R	VR	SD
Keratella spp.	D	D	SD	D	D	D
Lecane spp.	-	-	-	R	VR	-
Monostyla spp.	-	-	-	VR	VR	-
Notholca spp.	R	-	-	VR	VR	VR
Ploesoma spp.	-	D	R	R	VR	-
Polyarthra spp.	SD	SD	SD	SD	SD	SD
Pompholyx spp.	-	-	-	R	-	-
Synchaeta spp.	SD	R	R	R	SD	SD
Testudinella spp.	-	-	-	R	R	VR
Trichocerca spp.	-	R	D	R	R	VR
Trichotria spp.	VR	-	-	-	-	VR

[a] D = Dominant - 15% or more of the total zooplankton
SD = Sub-dominant - 3-14% of the total zooplankton.
R = Rare - Less than 3% of the total zooplankton.
- = Species did not occur in the samples.
VR = Very Rare - Occasional or solitary individuals.

littoral. Some genera such as Notholca, Trichocerca and Brachionus contain more species which are littoral rather than planktonic. Conochilus is a free living form in Seneca Lake, although it is often colonial elsewhere. Several genera such as Asplanchna, Keratella, Synchaeta and Polyarthra are true plankters which may be found in all regions of a lake during the periods of maximum abundance. The rotifers have not been extensively studied in North America; however, they are generally more abundant than Crustacea in the zooplankton community (Bricker et al. 1975; Schar et al. 1975).

7.4 Conclusion

The Seneca Lake zooplankton community is typical of large temperate lakes. The seasonal fluctuations in abundance and sequential dominance of the zooplankton community by rotifer and copepod taxa are typical of large oligotrophic lakes. All evidence indicated that the balanced indigenous zooplankton community that exists in Seneca Lake near Greenidge Station was not affected. station operation.

Known lethal temperature limits of zooplankton are presented in Table 7-10. Seneca Lake discharge temperatures seldom approached lethal limits for the zooplankters found except for Cyclops vernalis in September when a surface temperature of 27.25C was recorded (1.65C below the lethal limit).

Thermal tolerance studies on Lake Michigan zooplankton (Cyclops bicuspidatus thomasi and Diaptomus spp.) revealed the elevated temperatures of condenser passage approached tolerance limits only when ambient lake temperatures of 20C or more existed (Krueger 1975). Maximum discharge temperatures observed during this study (Chapter 4) were below lethal limits for all organisms found.

Zooplankton abundance in large lakes, such as Seneca Lake, generally exhibits large fluctuations between summer and winter. During winter the community consists of long-lived species such as copepods, many of which reproduce in the winter. The crustacean community is usually dominated at that time by diaptomid adults and cyclopoid copepodites. A recent study (Schar et al. 1975) revealed that Rotifera are also abundant in the winter and usually account for 50% or more of the zooplankton, as was found in Seneca Lake. The life cycle of rotifers is short with a succession from one taxon to another over a period of a few months, as evidenced in this study. The short-lived species such as Cladocera and Rotifera usually become extremely abundant as water temperature and phytoplankton abundance increase in the summer. The net increase in zooplankton populations during the summer often exceeds the winter populations. Numbers decline slowly in the fall and winter as the short-lived species begin to produce resistant over-wintering eggs.

and cyclopoid copepodites (5 to 10%), remained subdominant as in the previous month. Species diversity and redundancy values changed little from the previous month because the same taxa were dominant or subdominant in the same ratios as the previous month (Table 7-3).

Densities for December total zooplankton decreased from the previous month and ranged from 7220 organisms/m^3 (Location P-1) to 12,415 organisms/m^3 (Location P-2) (Table 7-8). Total Copepoda (24 to 33%) and total Cladocera (7 to 22%) increased in relative abundance due to the subdominance of nauplii (6 to 21%), cyclopoid copepodites (8 to 11%) and *Bosmina longirostris* (8 to 23%). Rotiferan relative abundance decreased from October to December. *Kellicottia* (2 to 5%), *Polyarthra* (3 to 6%) and *Synchaeta* (7 to 22%) remained subdominant whereas *Keratella* (26 to 44%) remained dominant. Species diversity and redundancy values changed little from the previous month (Table 7-3).

7.3 Discussion

Although significant differences in abundance occurred between sampling locations in all months (Table 7-9), no consistent pattern was apparent which could have been a result of operation of Greenidge Station. In June, two contradictory patterns of difference occurred. Population densities of many taxa at Location P-2 were significantly greater than at some or all other locations. Densities at Location P-1, however, were often significantly less than at other locations. Discharge Locations P-1 and P-2 were positioned in close proximity to each other and should have exhibited a similar statistical trend. The lack of statistical similarity while all other taxa were either rare or very rare. Species diversity values in June were less than 1.0 due to large population densities of the three rotifer taxa, Keratella, Polyarthra and Synchaeta (Table 7-3).

Total zooplankton densities for July were less than June densities and ranged from 68,511 (Location A-2) to 125,862 organisms/m^3 (Location P-2). This reduction in population between months reflected a decline in the density of Keratella, Synchaeta and Polyarthra (Table 7-4). Total Rotifera, again dominated the community, ranging from 76 to 85% of the total zooplankton; however, Keratella (32 to 43%) and Ploesoma (26 to 43%) dominated the zooplankton community. Subdominant taxa included Polyarthra (3 to 4%), nauplii (3 to 8%), cyclopoid copepodites (2 to 4%) and Bosmina longirostris (5 to 11%). Larger species diversity values for the July data were the result of densities being more evenly distributed between two dominant and several subdominant taxa in conjunction with a larger number of taxa being present and a lesser total density (Table 7-3).

Total zooplankton densities in August ranged from 32,063 (Location P-1) to 140,207 organisms/m^3 (Location A-2) and again exhibited a net decline from the previous month (Table 7-5). Dominance shifted from the rotifers to juvenile copepods with other Cladocera and Rotifera also being important. Nauplii (27 to 32%) and cyclopoid copepodites (13 to 27%), two immature copepod forms, were the dominant zooplankton taxa, while Bosmina longirostris (11 to 25%) was the dominant cladoceran. Trichocerca (8 to 18%)

preserved with 4% buffered formalin containing several drops of a common detergent to reduce surface tension, thereby reducing clumping of organisms.

Preceding analysis, each sample was concentrated or diluted, depending on the density of zooplankters and/or debris in the sample. A subsample was withdrawn from one replicate of each location. The subsample was scanned to determine the approximate density of organisms in each selected replicate. The replicate with the lowest density was used to determine an appropriate subsample volume. An appropriate subsample volume containing an approximate total of 300 organisms was selected.

Each sample was thoroughly mixed and a random subsample of the volume determined above was placed in a Borgorov counting chamber. All microcrustacea and rotifers present in the subsample were identified and enumerated under 10-70X magnification using a dissection microscope. Any organism which could not be identified was removed from the chamber, mounted on a slide and examined at higher magnification using a compound microscope. Two subsequent subsamples of similar volume to the first subsample were counted in the same manner. A fourth larger subsample was examined for subdominant taxa, ie., taxa occurring at a rate of less than 50 individuals in the first three subsamples. A fifth subsample was examined for rare taxa (taxa occurring at a rate of less than 50 individuals in the first four subsamples). By examining five subsamples per sample, at least 10% of the total sample volume was examined.

Table 7-6. Population density and percent occurrence of dominant and subdominant zooplankton collected on 9 September 1976.

Taxon	Location A-1		Location A-2		Location P-1		Location P-2	
	Mean No./m^3	% Occurrence	Mean No./m^3	% Occurrence	Mean No./m^3	% Occurrence	Mean No./m^3	% Occurrence
nauplii	34992	12	33231	11	1003	2	1035	5
cyclopoid copepodites	19434	6	21606	7	467	1	216	1
Bosmina longirostris	60649	20	103919	34	3024	7	1052	5
Kellicottia spp.	1409	0	-	-	-	-	-	-
Keratella spp.	150008	50	125760	41	32511	79	12043	59
Ploesoma spp.	2063	1	2516	1	634	2	712	3
Polyarthra spp.	12914	4	8455	3	533	1	633	3
Syncharta spp.	5544	2	2097	1	954	2	1359	7
Trichocerca spp.	8228	3	5837	2	945	2	474	2
Total Copepoda	56759	18	56373	18	1553	3	1343	6
Total Cladocera	61781	20	104381	33	3137	7	1116	5
Total Rotifera	183557	60	148497	48	36252	88	17915	87
Total Zooplankton	302097		309251		40942		20374	

Table 7-8. Population density and percent occurrence of dominant and subdominant zooplankton collected on 17 December 1976.

Taxa	Location A-1		Location A-2		Location P-1		Location P-2	
	Mean No./m^3	% Occurrence	Mean No./m^3	% Occurrence	Mean No./m^3	% Occurrence	Mean No./m^3	% Occurrence
nauplii	1977	21	2096	19	559	8	806	6
cyclopoid copepodites	718	8	889	8	683	9	1426	11
Bosmina longirostris	731	8	1048	10	1189	16	2800	23
Kellicottia spp.	449	5	489	4	145	2	317	3
Keratella spp.	2492	26	3100	28	3153	44	4738	38
Ploesoma spp	-	-	-	-	-	-	-	-
Ployarthra spp.	541	6	586	5	295	4	352	3
Synchaeta spp.	2043	22	2083	19	550	8	920	7
Trichocerca spp.	9	0	-	-	-	-	-	-
Total Copepoda	3180	33	3495	32	1796	24	3126	25
Total Cladocera	731	7	1048	9	1189	16	2822	22
Total Rotifera	5590	58	6341	58	4235	58	6467	52
Total Zooplankton	9501		10884		7220		12415	

using a compound microscope. All organisms were identified to the lowest practical taxon, usually genus or species.

Biomass determinations (dry weights and ash-free dry weights) were made for the most abundant taxa of macroinvertebrates. Procedures used for measurement of dry and ash-free dry weights followed that of ASTM (1970).

References utilized in the identification and classification of macroinvertebrates are given in Table 8-2. Identification of Lumbriculidae and Naididae was based upon external characteristics. Some Tubificidae were identified by the characteristic shape and configuration of somatic chaetae (at all stages of maturity), and others were recognized by internal organs present only at sexual maturity. Specimens which were sexually immature and could not be identified were divided into two groups: unidentifiable immatures with capilliform chaetae and unidentifiable immatures without capilliform chaetae.

Species diversity indices for each sample and mean diversity for each sampling station were calculated according to Brillouin (1956) where:

$$H = \frac{1}{N} \log \left(\frac{N!}{n_1!n_2!\ldots n_s!} \right)$$

and where n_i is the number of individuals in the i^{th} species ($i = 1,\ldots,s$) and N is the total number of all species.

8.2 Results

8.2.1 Description of Habitats

Ambient Location K-2 was established in the Keuka Lake Outlet 1500ft upstream of the Greenidge Station discharge canal

(Figure 8-1). A riffle habitat characterized by depths seasonally ranging from 1-3ft and coarse gravel substrates was sampled at K-2. Location K-3 was in a similar riffle area within Keuka Lake Outlet; however, it was 300ft downstream of the discharge canal within the thermal discharge area. Water depths ranged from 1-3ft during the study and the substrates samples varied from a mixture of equal fractions of rubble and gravel in June to almost exclusively gravel (80-90%) in September and December. Location DC-1 was established within the Greenidge Station discharge canal. Water depth ranged from 1-4ft and bottom materials were 60-80% gravel throughout the study. Current velocities were estimated at 1-2ft/sec at all three collection locations.

8.2.2 Species Composition

A total of 66 taxa were identified in the collections from June, September and December 1976 (Tables 8-1 and 8-2). Diverse assemblages of oligochaetes (aquatic worms), ephemeropterans (may-flies), elmids (riffle beetles) and chironomids (midges) occurred in the vicinity of Greenidge Station. Individuals identified among each of these taxonomic categories have been reported from a variety of habitats throughout North America. No endangered or threatened species (USDI 1976) were recorded through the duration of this study.

8.2.3 Composition and Abundance of Benthic Macroinvertebrates, June

Macroinvertebrate communities differed greatly among the three collection locations in June (Table 8-3). Macroinvertebrates totaled only 250 organisms/m^2 at ambient Location K-2. This sparse macroinvertebrate community was predominated by the naidid Nais bretscheri, the mayfly Baetis, the midges Cricotopus spp. and Diamesa and blackflies (Simuliidae). In contrast, a total of 449 organisms/m^2 dominated by a slightly different macroinvertebrate association was observed at the discharge Location K-3. Over two-thirds of the community was composed of the midges Cricotopus spp., Orthocladius and Diamesa. Nais bretscheri, the amphipod Gammarus fasciatus and blackflies accounted for 7.2%, 4.1% and 3.6% of the total, respectively.

The greatest population densities were collected in the discharge canal at Location DC-1. Macroinvertebrates, which totaled 968 organisms/m^2, were composed almost exclusively of amphipods (Crangonyx and G. fasciatus) and midges (Cricotopus spp.).

September

In September, ambient Location K-2 harbored a macroinvertebrate community different from either discharge location (Table 8-4). A total of 283 organisms/m^2 was collected at K-2. The midge Rheotanytarsus was the single most abundant taxa (175/m^2) composing 61.9% of the community. Several other midge genera, the riffle beetle Stenelmis, the mayfly Baetis and the amphipod G. fasciatus constituted most of the remainder of the community.

Large population densities of G. fasciatus were observed at both discharge locations. This species was associated with only a few representatives of other forms. G. fasciatus, which totaled 183 and 356 organisms/m^2 at Location K-3 and DC-1, respectively, composed 90-95% of the community.

December

Macroinvertebrate populations totaled 230 organisms/m^2 at Location K-2 in December (Table 8-5). The stonefly Allocapnia and simuliids (blackflies) numerically accounted for over half of the community. Several taxa of naidids, caddisflies and midges constituted most of the remaining macroinvertebrate community. In contrast, stoneflies, blackflies, naidids and midges were absent and/or sparse in the discharge locations. A total of only 59 organisms/m^2 was collected at Location K-3. Sparse populations ($<20/m^2$) of nematodes, G. fasciatus, Cheumatopsyche and Stenelmis were the major macroinvertebrate components. In the discharge canal, Location DC-1 contained 207 organisms/m^2. Rhabdocoels (flatworms) totaled 177/m^2 85.3% of the community. Very small numbers of Hydra, two oligochaetes, a polychaete and three amphipod species accounted for the balance of the community.

Results of macroinvertebrate biomass analyses for June, September and December are given in Appendix C.

8.3 Discussion

8.3.1 Effects of Station Operation on the Macroinvertebrate Community

Prior to the discussion of the macroinvertebrate data it must be pointed out that on 11 June 1976 (one day following macroinvertebrate sampling) the NYDEC conducted experimental sampling for sea lamprey ammocoetes (C. Creech, personal communication, NYDEC, Cortland, N.Y., 4 April 1977). The lampricide, Bayer 73, in granular form, was broadcast over the south channel of Keuka Lake Outlet at a point approximately 450ft above its confluence with Seneca Lake. The resultant concentration of the lampricide was unknown. This experimental program may have encompassed the area of Location K-3. The lampricide was not considered as a factor in the analysis of macroinvertebrate results for two reasons; 1) concentrations considered lethal to the macroinvertebrates (Rye and King 1976) indigenous to Keuka Lake Outlet are considerably higher than that probably used to sample the ammocoete larvae, and 2) community structure was similar in subsequent collection periods between Location K-3 and Location DC-1 which was not treated with Bayer 73.

Artificially elevated water temperatures may alter macroinvertebrate community structure through a variety of mechanisms. The most direct effect of thermal discharges may be the elimination of certain organisms by exceeding their thermal (reproductive or lethal) limits. Less direct, but equally important effects may be the alteration of emergence patterns of aquatic insects and increased or decreased reproductive capacity of macroinvertebrates.

With the exception of temperature, the physical habitat was similar between locations in all three sampling months; therefore, variations in community structure due to habitat differences were probably minimal. Most, if not all, lethal and sublethal effects of the elevated temperatures should be readily discernible by comparing community structure (in terms of composition, abundance and diversity) between ambient and discharge collections.

River beds of rubble-gravel materials sustaining substantial flow are usually typified by low overall abundance and large diversity of macroinvertebrates (Hynes 1963). Location K-2 in the

Keuka Lake Outlet harbored a typical riffle fauna. Throughout the collection year, abundance of macroinvertebrates was consistently small, ranging from 230 to 283 organisms/m^2 (Tables 8-3 through 8-5). Similarly, mean diversity indices exhibited a narrow range (1.25-1.64) of variability (Table 8-6). The community comprised a variety of naidids, mayflies, stoneflies, caddisflies and midges. The ambient community in Keuka Lake Outlet, therefore, appeared quite stable in terms of overall abundance and diversity. Species composition and the relative abundance of macroinvertebrates exhibited seasonal variability probably indicating normal life cycle fluctuations (e.g., insect emergence).

Community structure was less stable in the thermal discharge. Distinct differences between the ambient locations and discharge locations occurred in respect to overall abundance, composition and diversity from June through December. Water temperatures during June collections were 20.5C at discharge Locations K-3 and DC-1 and 20.0C at ambient Location K-2 (Table 8-7). Total numbers of macroinvertebrates were larger in the discharge locales than at ambient Location K-2 during June. Naidids, amphipods and chironomids were the predominant macroinvertebrates collected. Mean diversity values were 1.93 and 1.61 at Locations K-3 and DC-1, respectively (Table 8-6). The minor differences in composition, abundance and diversity in June may have reflected natural variability in the habitats that were sampled; therefore, it was apparent that large numbers of individuals distributed among a variety of macroinvertebrate types were indigenous to discharge areas in early summer.

Maximum discharge temperatures occurred in late August and early September. Temperatures regularly reached 26-30C and occasionally 33C (NYSE&G 1977). Following the summer temperature maxima, reductions in the abundance and diversity of macroinvertebrates occurred at Locations K-3 and DC-1 (Tables 8-4 and 8-6). On 9 September, over 90% of the community was represented by a single species, Gammarus fasciatus. Oligochaetes, insects and mollusks were absent and/or sparse. December collections also revealed a scarcity of macroinvertebrates in both discharge locales.

The large populations of G. fasciatus in the discharge canal and Keuka Lake Outlet discharge locations were probably not indigenous. Large numbers of the species occurred in the lake and subsequently passed through the station in cooling waters from the lake and were discharged into Keuka Lake Outlet (NYSE&G 1977a). The dense populations of Gammarus provided a large food resource for fish as was proven by stomach analyses of many fish (Table 9-34).

Maximum summer discharge temperatures appear to have substantially reduced the macroinvertebrate communities in portions of Keuka Lake Outlet. Coutant (1962) in an investigation of the Delaware River riffle fauna, proposed that "there is a tolerance limit close to 90F [32C] for a normal population structure with extensive loss in numbers and diversity of organisms accompanying further rise." Table 8-8 lists available data on the tolerance of macroinvertebrates to temperature. Although few of the taxa listed occurred in Keuka Lake Outlet, it is apparent that most macroinvertebrates closely allied to those collected in Keuka Lake Outlet are intolerant to temperatures of the magnitude reached in Greenidge Station discharge locations in late summer. This lethal effect is probably restricted to an area extending from the junction of the discharge canal at Keuka Lake Outlet to Seneca Lake, a distance of approximately 700ft. Repopulation of the affected area apparently occurs during periods of low water temperature as illustrated by the substantial macroinvertebrate populations reported in June.

8.4 Conclusion

The thermal discharge has altered the composition and reduced the abundance and diversity of benthic macroinvertebrates in the discharge area of Keuka Lake Outlet during the summer. However, the effects of station generation were quite localized and it is doubtful that the thermal discharge has had any overall adverse effects upon the balanced indigenous macroinvertebrate community in Keuka Lake Outlet.

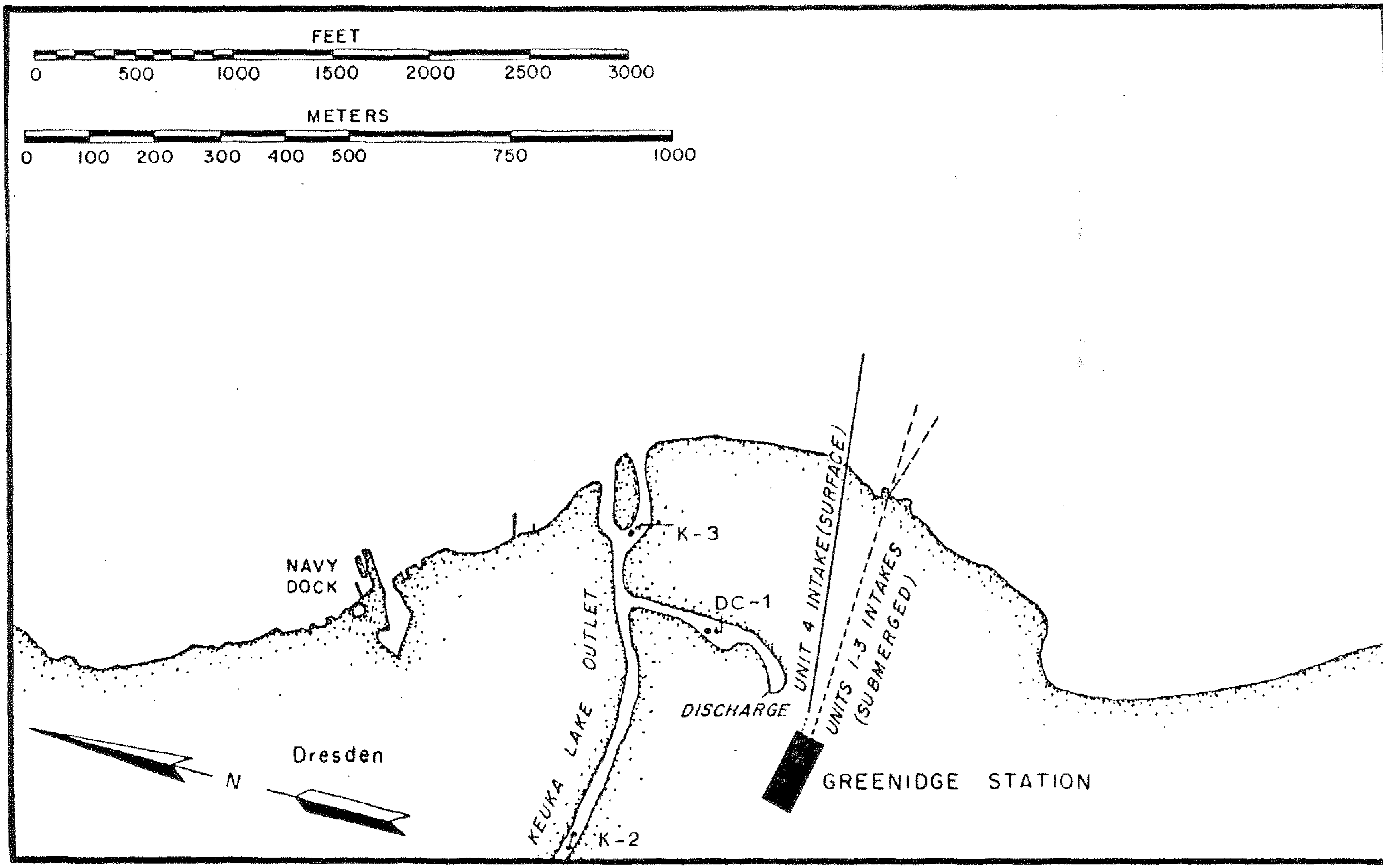

Figure 8-1. Collection locations for benthic macroinvertebrates.

Table 8-1. Taxonomic inventory of macroinvertebrates collected on 10 June, 9 September and 9 December 1976. Numbers in parentheses indicate taxonomic references listed in Table 8-2.

Porifera
- *Spongilla fragilis* (6)

Cnidaria
- *Hydra* sp. (6)

Platyhelminthes
- Tricladida (6)
- Rhabdocoela (15)

Nematoda (6)

Annelida
- Enchytraeidae (2)
- Naididae (19, 20)
  - *Chaetogaster diaphanus*
  - *Nais barbata*
  - *N. behningi*
  - *N. bretscheri*
  - *N. communis*
  - *N. elinguis*
  - *N. variabilis*
  - *Ophidonais serpentina*
  - *Paranais frici*
  - *Slavina appendiculata*
- Tubificidae (2)
  - *Aulodrilus limnobius*
  - *Branchiura sowerbyi*
- Unidentified immature forms: (2)
  - with capilliform chaetae
  - without capilliform chaetae
- Lumbriculidae (2)
- Sabellidae
  - *Manayunkia speciosa* (8)

Arthropoda
- Ostracoda (6)
- Amphipoda (1, 15)
  - *Crangonyx* sp.
  - *Gammarus fasciatus*
  - *G. pseudolimneaus*
  - *Hyallela azteca*
- Isopoda
  - *Asellus* sp. (22)
- Decapoda
  - *Orconectes* sp. (14)

Ephemeroptera
- Ephemeridae (5)
  - *Ephemera* sp.
- Heptageniidae (17)
  - *Stenonema fuscum*
  - *S. ithaca*
  - *S. terminatum*

Table 8-1 . continued.

Leptophlebiidae (5)
Plecoptera (9)
Perlidae
Perlesta placida
Capniidae
Allocapnia sp.
Trichoptera
Psychomyiidae (7, 18)
Polycentropus sp.
Hydropsychidae (18)
Cheumatopsyche sp.
Hydropsyche sp.
Coleoptera
Elmidae (3)
Dubiraphia sp.
Stenelmis sp.
Diptera
Simuliidae (16)
Chironomidae (10)
Chironominae
Cryptochironomus sp.
Dicrotendipes sp.
Polypedilum (s.s.) *scalaenum* type
Rheotanytarsus sp.
Tanytarsus sp.
Tanypodinae
Thienemannimyia group
Orthocladiinae
Cricotopus bicinctus (12)
Cricotopus (*isocladius*) (12)
Cricotopus sp.
Diplocladius sp.
Eukiefferiella sp.
Microcricotopus sp.
Orthocladius sp.
Psectrocladius sp.
Trissocladius sp.
Diamesinae
Diamesa sp.
Ceratopogonidae (16)
Empididae (16)
Mollusca
Gastropoda (11, 21)
Amnicola sp.
Goniobasis sp.
Physa sp.
Pelecypoda (4)
Pisidium sp.

Table 8-6 . Mean monthly diversity[a] values for benthic macroinvertebrate collections on 10 June, 9 September and 9 December 1976.

Date	Location	Replicate	Number of Taxa	Diversity	Evenness
10 June	K-2	a	16	1.75	0.72
		b	14	1.74	0.88
		c	6	0.99	0.67
		$\bar{x}$	12	1.49	0.76
	K-3	a	13	1.96	0.89
		b	14	1.91	0.87
		c	19	1.91	0.73
		$\bar{x}$	15	1.93	0.83
	DC-1	a	16	1.71	0.65
		b	13	1.49	0.64
		c	13	1.63	0.71
		$\bar{x}$	14	1.61	0.67
9 September	K-2	a	6	0.92	0.72
		b	12	1.51	0.73
		c	15	1.31	0.56
		$\bar{x}$	11	1.25	0.67
	K-3	a	2	0.20	0.34
		b	2	0.09	0.13
		c	6	0.63	0.39
		$\bar{x}$	3	0.30	0.29
	DC-1	a	1	0.00	0.00
		b	4	0.47	0.42
		c	6	0.20	0.12
		$\bar{x}$	4	0.22	0.18
9 December	K-2	a	19	2.00	0.82
		b	9	1.43	0.78
		c	10	1.48	0.80
		$\bar{x}$	13	1.64	0.80
	K-3	a	5	1.09	0.92
		b	7	1.35	0.93
		c	3	0.60	1.00
		$\bar{x}$	5	1.01	0.95
	DC-1	a	2	0.11	0.18
		b	6	0.63	0.39
		c	4	0.47	0.49
		$\bar{x}$	4	0.40	0.35

[a] Diversity indices are mean values of three replicate samples calculated according to Brillouin (1956).

Chapter 9

Fish

9.1 Methods and Materials

9.1.1 Adult Fish

Adult fish were collected near Greenidge Station at Locations K-S, DC-1, K-3 and K-1 (Figure 9-1). Fish were collected by electroshocking, hoop-netting, fyke netting, gill netting and seining. Locations DC-1 and K-3 were within the area of the thermal discharge, whereas Location K-1 was an area of ambient conditions. Location K-S was generally not within the influence of the thermal discharge. Adult fish were sampled on 19 March, 7 April, 22 April, 6 May, 10 June, 5 August, 19 August, 21-24 September, 6 October, 9 December and 28 February. Throughout the work, care was taken to minimize stress on all fish captured and to return them to the water alive. Large rough fish, such as carp, were held in separate tubs of water from game fish in order to reduce stress on the latter. Fish were returned to the water in an expedient manner as soon as field processing had been completed at a location.

Fish were collected with a boat-mounted boom electroshocker with pulsating direct current during each sampling period. Electroshocking was conducted after dark for a 30min period covering 400ft of shoreline at Locations K-S, DC-1 and K-3. Electroshocking was attempted in the Keuka Lake Outlet near Location K-1 on 19 March and 7 April. On both dates, sampling was ineffective and was prematurely terminated due to adverse conditions. No subsequent attempts were made to electroshock Location K-1.

Hoop nets were set and fished overnight at Locations DC-1, K-3 and K-1 in March, April, May, October and December and at Locations DC-1 and K-3 in February. The nets were 2-1/2ft in diameter (3/4in bar mesh) with two 6ft long wings. A Maine styled fyke net of 1/2in bar mesh with two 25ft x 4ft wings and a 100ft x 4ft lead was fished overnight at Location K-S in March, April, May, October, December and February and at Location K-1 in February.

Gill nets were set perpendicular to the shoreline at Transects S-2, S-3 and S-4 in September (Figure 9-2). The gill nets were set on the bottom for a 24hr period at three dpeth ranges on each transect. On 21 September, gill nets were set offshore on the slope of each transect extending lakeward where the depth range at S-2 was from 18 to 100ft, S-3 was from 18 to 115ft, and S-4 was from 30 to 78ft. The gill nets set on 22 September were situated on the shelf extending shoreward from the slope on each transect. These gill nets were set at depths ranging from 13 to 18ft (S-2), 14 to 18ft (S-3) and 14 to 25ft (S-4). On 23 September, the near shore gill nets were set at depths ranging from 7 to 13ft (S-2), 7 to 10ft (S-3) and 6 to 8ft (S-4). The gill nets were 300ft x 6ft, and constructed of 25ft panels of 1/2, 1, 1-1/2, 2, 2-1/2 and 3-1/2in (bar measure), monofilament mesh. The panels of the gill nets were aligned according to increasing mesh size with the sequence being repeated to make up the 300ft. The gill nets were set with the 1/2in panel of the first sequence towards the shore.

On 28 February three gill nets were set parallel to the shoreline in the proximity of Transect S-2 at Locations A, B and C

(Figure 9-2). The gill nets were set on the bottom and fished overnight. Location A was situated in 14 to 18ft of water and Locations B and C were in 7-9ft of water. These nets were each 360ft x 6ft and constructed of 90ft panels of 1 and 3-1/2in (bar measure) and a 180ft panel of 2in (bar measure), monofilament mesh.

On 22-23 September, back pack electroshocking was conducted at five locations in the Keuka Lake Outlet. The sampling locations were approximately 4000, 7000, 7500, 11,500 and 12,000ft upstream from the mouth of the Keuka Lake Outlet. At each sampling location, 200ft of the stream was electroshocked using a Coffelt Model BP-1C, 115 volt, D.C. back pack electroshocker.

Two seine hauls were made at Location DC-1, K-S, K-3 and K-1 on each date electroshocking was conducted. Locations DC-1, K-S and K-3 were seined after dark, except in September. Location K-1 was seined during the daylight hours throughout the study. A 30ft x 6 ft bag seine of 1/8in bar mesh was used to collect fish at Location K-S on all dates, Location K-3 on 19 March and 7 April, and Location DC-1 on 7 April. Due to physical constraints all remaining samples were collected with a 15ft x 6ft straight seine.

All fish collected by electroshocking, gill netting, fyke netting ahd hoop netting were identified to species using appropriate taxonomic keys (Koelz 1929; Eddy 1957; Bailey 1970, and Hubbs and Lagler 1970), enumerated, weighed (grams fresh weight) and measured in total length (mm). Seine samples were preserved in 10% formalin and returned to the laboratory for identification and enumeration. Incidence of parasitism, disease and any abnormal external conditions were noted.

Scale samples were taken from as many as 30 representative individuals of each species collected (except minnows) on each date. Impressions of selected scales from each sample were made on soft cellulose acetate slides. The scale impressions were enlarged through the use of a microprojector. Scales were aged based on each annuli representing a year of completed growth.

Food habits of fish representing three trophic levels were determined. Stomachs, with contents, from 102 individuals representing three species were collected and preserved during electroshocking collections. Stomach contents were identified to major taxonomic groups, and the dry weight of these groups was determined. Composition by dry weight was calculated for the stomach contents of each fish species examined.

Condition factors (K_{TL}) were calculated for all fish weighed and measured in the field. Condition factors were calculated using the formula:

$$K_{TL} = \frac{W \times 10^5}{L^3}$$

where W = fresh weight in grams and L = total length in millimeters.

9.1.2 Larval Fish

For the purposes of this investigation, larval fish were defined as any fish not possessing a full compliment of adult characteristics (ie., all fins, spines, and/or rays ossified and fully developed).

Samples for larval fish were collected during the day twice monthly from March through September and once in October, at Transects S-1, S-2, S-3 and S-4 (Figure 9-2). During each sampling period two samples were collected at each transect, using a 1m diameter conical ring net of #0 Nitex mesh (.571mm aperture), equipped with a General Oceanics model 2030 flow meter. In March, April and May the samples were taken by towing the net (one immediately subsurface, the other at mid-depth) lakeward for approximately 1000ft starting from a point where the water depth was about 6ft. Beginning in June both samples were taken immediately subsurface because extensive growths of aquatic macrophytes prevented the mid-depth tow. The larval fish were identified to the lowest practical taxon using Fish (1932), Norden (1961), Mansueti and Hardy (1967), May and Gasaway (1967), Meyer (1970), Lippson and Moran (1974) and Chambers et al. (1976). The density of each taxon was calculated (No./1000m^3).

9.1.3 Physical-Chemical Measurements

Water temperatures and dissolved oxygen concentrations were measured during each sampling date using a Hydrolab model TDO-2. Turbidity and pH samples were taken 1m below the surface at Location S-4 during each sampling period. Turbidity values were determined using a Hach model 2100A Turbidimeter. Values for pH were determined using a Sargent-Welch pH meter model PBX.

9.2 Results

9.2.1 Adult Fish

Description of Habitats

The collection locations selected within the study area were generally comparable in habitat with the exception of current velocity and substrates. High current velocities were characteristic of Location K-1 and portions of K-3, whereas Locations DC-1 and electroshocking and yellow perch collected by gill nets are presented in Tables 9-29 through 9-33. Northern hog suckers were represented by age groups II and III; white suckers, age groups I through IV; largemouth bass, age groups I through VI; bluegill, age groups III through VI and yellow perch, age groups I and III through IX.

Stomach analysis data from selected fish species are given in Table 9-34. Fish and amphipods were the major food items identified.

Incidence of ectoparasites, disease and physical abnormalities occurred in less than 3% of the individuals of each fish species collected. Lymphocystis was present for over 2% of the white suckers examined. Incidence of ectoparasites or disease was not observed on largemouth bass and alewives. Lernia was occasionally observed on bluegills.

Sport fishing activity was observed to occur from March through October in the vicinity of Greenidge Station. Visual observations, which were recorded on each collection date, indicated that the greatest intensity of sport fishing was in the spring and summer.

9.2.2 Larval Fish

A total of 3136 larval fish representing 10 taxa was collected throughout the study (Table 9-35). Rainbow smelt was the most abundant species collected, composing 97.1% of the collection, with all larvae collected in April and May. The greatest number of rainbow smelt larvae was collected at Locations S-2 and S-4 in May. Alewives were the second most abundant larval fish and were collected from July through September with the largest number taken in August at Location S-2. One unidentifiable coregonid larvae was collected in both March and April. Unidentifiable catostomid larvae were collected in April and May and carp larvae were observed in July and August.

Temperature, dissolved oxygen, pH and turbidity were measured in conjunction with larval fish sampling (Table 9-36). Dissolved oxygen concentrations were at or near saturation levels on each collection date and would not have a limiting influence on fish of any life stage throughout the study (Tables 9-1 and 9-36).

9.3 Discussion

9.3.1 Life History of Principal Species

Northern Hog Sucker

Northern hog suckers generally inhabit riffle and pool areas of clear shallow rivers with rock substrata and are relatively intolerant of waters with heavy domestic or industrial pollution (Scott and Crossman 1973). During the fall, adults may move downstream to deeper waters where they remain during the winter (Trautman 1957). In early spring when water temperatures rise to 4-5C, northern hog suckers begin to migrate upstream to riffle and boulder areas and spawn in April or May in New York (Wright and Allen 1913). Spawning usually occurs in riffles or along the edges of pools and is initiated at a temperature of approximately 15.6C (Scott and Crossman 1973). The substrate and swift water of Keuka Outlet probably provides suitable habitat for northern hog sucker spawning. A lesser number of northern hog sucker was collected in March and April than during subsequent sampling periods.

The maximum age of northern hog suckers is approximately 10-11 years. Males normally attain sexual maturity at two to three years and females at three years (Scott and Crossman 1973). Northern hog suckers collected in August were age group II and III fish, the majority of which were probably mature (Table 9-29). Individuals collected near Greenidge Station exhibited a greater growth in length than comparable age groups reported from Catatouk Creek and the Genesee River, New York (Raney and Lachner 1946).

The diet of the northern hog sucker is primarily insect larvae, crustaceans and vegetation. Feeding is accomplished by scraping rocks and overturning stones with the mouth and head to consume uncovered invertebrates (Scott and Crossman 1973).

White Sucker

White suckers migrate upstream in the spring, usually from April to early June (Stewart 1926; Raney and Webster 1942), to spawn in areas of gravel substrate, frequently below dams (Scott and Crossman 1973). Migration and spawning occurs primarily at dusk and throughout the night (Trautman 1957). Suitable habitat is available in the Keuka Lake Outlet for white sucker spawning. Optimum water temperature for spawning is 10.5C (Webster 1941) and spawning has been observed to occur over a range of water temperatures from 5.5 to 23C, with an optimum range of 10C to 20C (Trautman 1957). Many of the white suckers collected on 28 February 1977 were in a ripe and running condition. This suggests that the thermal discharge may have accelerated the spawning period. Although it is not known if early spawning is detrimental, and since the area and number of fish items found in stomachs of largemouth bass collected near Greenidge Station (Table 9-34).

Bluegill

Bluegill inhabit shallow weedy areas of lakes and slow flowing areas of small rivers and creeks (Scott and Crossman 1973). Spawning in New York occurs in late spring or early summer, usually in May or June (Wright and Allen 1913). Temperatures at spawning range from 17C (Stevenson, et al. 1969) to 32.2C (Clugston 1966). Males prepare nests or shallow depressions on a firm substrate of gravel, sand or mud (Breder and Rosen 1966). Suitable substrate is available for bluegill spawning in the lower portion of the Keuka Lake Outlet and in the shallows of Seneca Lake (Section 3.5). The *Lepomis* sp. larvae collected in August at Locations S-1 and S-3 (Table 9-35) may have been bluegill. Optimal temperatures for egg hatching range from 22.2 to 23.9C (Banner and VanArman 1973). Average time for hatching is 3-5 days (Scott and Crossman 1973).

Maximum age of bluegills is approximately 8-10 years (Scott and Crossman 1973) with sexual maturity attained at 2 to 3 years of age by males and 3 to 4 years by females. Bluegill collected in June ranged from age group III to VI (Table 9-32) indicating that most were probably sexually mature. The growth in length of bluegills collected in June was greater than that reported for bluegill from lakes in Michigan (Beckman 1946) and Wisconsin (Snow 1969).

The food of bluegill is generally considered to be insects, crustaceans and plant materials (Keast and Webb 1966). The most common food item identified in the stomachs of bluegills during the study was amphipods (Table 9-34). Other major food items were plant material, earthworms and terrestrial insects.

Yellow Perch

Yellow perch commonly inhabit both lakes and rivers and prefer clear waters with moderate vegetation and bottom types of muck, sand and gravel (Trautman 1957; Scott and Crossman 1973).

Female yellow perch require four to five months of cold water temperatures (below 4C) to ensure egg maturation. Spawning usually takes place during April or May on a sand, gravel or rubble bottom or on vegetation (Herman et al. 1964). Adults move into the shallows of lakes, and sometimes into tributaries to spawn (Scott and Crossman 1973). In New York, yellow perch spawn at water temperatures ranging from 6.7 to 12.8C (Breder and Rosen 1966; Brown 1974). A temperature of 11.9C has been established as an optimum spawning temperature (Jones et al. 1973). Eggs are deposited encased in long gelatinous ribbons which become attached to the substrate (Herman et al. 1964). An average of 27 days of incubation is required at water temperatures ranging from 8.5 to 12C (Mansueti 1964). In the vicinity of Greenidge Station, suitable spawning habitat is available in the near shore areas of Seneca Lake. A few larval yellow perch were collected in June at Location S-1 (Table 9-35) indicating spawning did occur within the study area.

Yellow perch mature at three to four years of age, with males usually maturing a year earlier than females (Hile and Jobes 1942; Scott and Crossman 1973). Age groups I, and III through IX were collected during September, with age groups III and IV predominant (Table 9-33). The average total length of all age groups was generally greater than those reported for comparable northern latitudes (Laarman 1963; Scott and Crossman 1973).

Food habits of yellow perch change with size of the fish, season and food availability. Zooplankton, immature insects, larger invertebrates and fish are frequently included in the diets of yellow perch (Tharratt 1959; Siefert 1972; Ney and Smith 1975; and Noble 1975).

Alewife

Alewives inhabit deep water areas of lakes during the winter (Wells 1968) and move into nearshore areas and streams to spawn in early summer. Rothschild (1966) observed alewives at inshore areas of Cayuga Lake as early as 15 May. He reported that alewives were attracted to the warm water areas at the mouths of streams at earlier dates than at other inshore areas. Many alewives migrated up these streams to spawn (Rothschild 1966). Active spawning occurred at both stream and inshore areas of Cayuga Lake from mid-June to mid-August. During the present study, large numbers of alewives were observed and collected moving upstream at Location K-1 in June (Table 9-23). In July and August alewife larvae were collected in Seneca Lake (Table 9-35), and were most abundant at Location S-2 which was situated off of the mouth of the Keuka Lake Outlet. It was apparent that alewives spawned in the vicinity of Greenidge Station. The most intensive spawning activity was observed in portions of the Keuka Lake Outlet upstream from the discharge canal.

Alewives in freshwater have a maximum life span of six or seven years (Brown 1972). In Cayuga Lake, both sexes are usually sexually mature at 2 years of life (Rothschild 1966).

Alewives are generally planktivorous, both as young and adults (Scott and Crossman 1973). In freshwater, principal food items are copepods, cladocerans, mysids and ostracods (Norden 1968; Scott and Crossman 1973).

9.3.2 Effects of the Thermal Discharge

Temperature is one of the major environmental influences affecting fish. Behavioral and physiological responses of fish may be altered due to artificially elevated temperatures. These reponses may include alterations of migration patterns, avoidance and/or attraction of fish to various temperature regimes, death of fish resulting from excess heat or cold shock. The primary objective of this study was to evaluate any possible effects of the Greenidge Station thermal discharge upon the Keuka Lake Outlet and Seneca Lake fishery.

Fish Migration

The configuration of the thermal plume at Greenidge Station is not expected to adversely affect upstream migration of fish in the Keuka Lake Outlet. During the spring and early summer (March, May and July), when the most active movement of migratory species such as rainbow trout, white sucker, northern hog sucker, rainbow smelt and alewife would be expected to occur, the confluence of the discharge plume and ambient waters of the Keuka Lake Outlet did not completely intermix (Figure 4-1). Therefore, a zone of passage (ambient water) along the north bank of Keuka Lake Outlet was available for migrating species. In addition, discharge temperatures in spring were relatively low, and should not impede the upstream migration of trout, suckers, alewives and rainbow smelt.

Generally, the average flow (cfs) of the Keuka Lake Outlet is greatest from March through May when spring spawning fish migrate up the Outlet (Figure 3-1). The increased flow during this period assured that a zone of passage (ambient water) would be available for these spring run spawners. The high flow of the Outlet during the spring restricts or confines the thermal plume along the south bank of the Outlet directly below the discharge canal with little mixing occurring (Figure 4-1).

Successful migrations of rainbow and brown trout up the Keuka Lake Outlet, beyond the Greenidge Station discharge have been documented in a recent creel census (B. Abraham, personal communication on 17 March 1977, New York State Department of Environmental Conservation, Avon). In addition, young-of-the-year (Age 0+) rainbow trout were collected during a fisheries survey of the Keuka Lake Outlet in 1976 (B. Abraham, personal communication on 17 March 1977). This indicated migration and successful spawning of rainbow trout in the Keuka Lake Outlet; however, the magnitude of this spawning run and degree of successful reproduction was unknown. In addition, large numbers of alewives successfully passed the thermal discharge during their migration up Keuka Lake Outlet on 10 June (Table 9-23).

Avoidance-Attraction

The reaction of fish in the presence of a heated effluent is varied, as elevated temperatures may attract fish, repel them or have no influence. In general, a greater number of fish were collected at Location DC-1 in the discharge canal in the spring (March through May) and winter (December through February) than at other locations (Table 9-37). The total catch of fish at Location K-3 showed a general increase from March through June, a reduction in August and October and an increase in December and February (Table 9-37). The numbers of fish collected at Location K-S were small on nearly every sampling date and no seasonal trends were discernible (Table 9-37).

These temporal variations in abundance may reflect a tendency for some fish to be attracted to the discharge area in spring and intermediate temperatures in summer and fall. The data may also indicate a tendency of fish to avoid the warmest temperatures which were present at DC-1 in summer and fall. Upper avoidance temperatures for the most commonly collected species in the vicinity of Greenidge Station are shown in Table 9-38. Approximate upper avoidance temperatures of northern hog sucker and rainbow trout were exceeded at some of the thermal discharge locations during the August sampling (Table 9-1). Of the 63 northern hog suckers collected in August, only 5 were collected at Location DC-1 (Table 9-37), which may indicate some avoidance to the immediate vicinity of the thermal discharge. There were no rainbow trout collected at the sampling locations during the summer collection dates. It is expected that adult rainbow trout inhabit the cooler, deeper portions of Seneca Lake during the warm summer months (Scott and Crossman 1973).

Indications of attraction to the thermal discharge in the spring was evident for white sucker, bluegill and largemouth bass

(Table 9-37). A summary of temperature preference data for frequently collected fish is presented in Table 9-39. Temperature preference data indicate that different species may be attracted to elevated discharge temperatures with periods of attraction varying between species. In spring, temperatures noted at discharge locations, especially DC-1, more closely approached preference temperatures of white sucker, bluegill and largemouth bass than did ambient locations. However, it was possible that these fish were attracted to Location DC-1 for reasons not temperature related such as current velocity and habitat availability.

The growth of fish for each age group examined did not appear to vary between ambient and discharge locations. Fish collected at discharge locations had similar condition factors to those collected at ambient locations. There were no differences in incidence of disease, parasitism or physical abnormalities between fish collected at discharge and ambient locations.

Temperature preferences should be conservatively interpreted for several reasons. Residence time in a thermal plume may be limited for an individual fish or species. Results of recent studies at Point Beach Plant on Lake Michigan indicated that residence time of tagged and recaptured fish in the thermal plume was relatively short (Romberg et al. 1973). Consequently, the impact of movement into and out of an area of heated influence would be of less significance. Other factors which may also mask the influence of the thermal plume are daily and seasonal movements of fish from deep water to shallow water and vice versa. These movements may be in response to reproductive cycles, temperature cycles and food availability which may vary even among different sizes and ages of a particular species (Muench 1974). Therefore, temperature alone may not be the primary controlling factor of fish distribution in a thermal discharge area.

Possible Lethal Effects of Elevated Temperature

Lethal effects may occur when fish are exposed to rapid increases in temperature or prolonged exposure to temperatures above tolerance limits. Even though upper temperature tolerances (CTM and TL_{50}) for some species may be occasionally exceeded in the Greenidge Station discharge (Tables 9-40 and 9-41), there appears to be little danger of fish mortalities. Avoidance temperatures are usually considerably lower than upper temperature tolerance and fish should be repelled by high discharge temperatures before lethal temperatures are encountered. Spigarelli (1975) reported that maximum densities of fish in thermal discharges occurred at intermediate temperatures rather than at high temperatures; thus fish should inhabit areas farther from the point of discharge as temperatures approach upper tolerance limits. The temporal distributional patterns and avoidance responses suggested that fish avoided potentially lethal temperatures near Greenidge Station. Fish have the ability to leave discharge areas when lethal temperatures are approached and inhabit areas of preferred temperature (Spigarelli 1975). No white sucker or bluegill, and only one largemouth bass were collected at Location DC-1 on 19 August indicating they may have avoided potentially harmful temperatures. Some species, such as rainbow trout and rainbow smelt, which might be adversely affected by high summer discharge temperatures, would not be expected to inhabit inshore areas during this time of the year.

Possible Lethal Effects of Cold Shock

Cold shock may occur when fish attracted to a discharge during the winter become acclimated to the elevated temperatures and develop a lower lethal temperature which is higher than the ambient temperature. In the case of a complete station shutdown, these fish would be subjected to rapid decreases in temperature to the ambient level and may suffer cold shock.

Fish seldom become acclimated to maximum discharge temperatures, but tend to orient themselves in temperatures intermediate between discharge maxima and ambient conditions (Spigarelli 1975). Under these conditions, the drop in temperature that fish would be exposed to in the event of a complete station shutdown would be greatly reduced and probably not sufficient to result in mortalities. Furthermore, a complete shutdown is highly unlikely to occur at Greenidge Station, as it is a baseload, multiple unit plant (Section 2.2).

9.4 Conclusions

It has been demonstrated that a balanced indigenous fish community is present in the Keuka Lake Outlet and Seneca Lake within the vicinity of Greenidge Station. The growth and general condition of principal species was examined and found to be similar or slightly greater than those reported for other areas of the state, and were not different for fish collected within or outside of the thermal discharge area. Spawning periods and migrations, except for white sucker, were not affected by plant operation. Apparently the spawning period of the white sucker was accelerated by the thermal discharge, but this is not expected to adversely affect the population.

Although a few fish species are attracted to the thermal discharge during the spring and winter and may have avoided it during the summer thermal maxima, no adverse community alterations or fish mortalities were detected or expected to occur.

Results from the study demonstrate that the thermal discharge of Greenidge Station has not caused appreciable harm to the existing Seneca Lake fishery; therefore, the protection and propagation of the balanced indigenous fish community is assured.

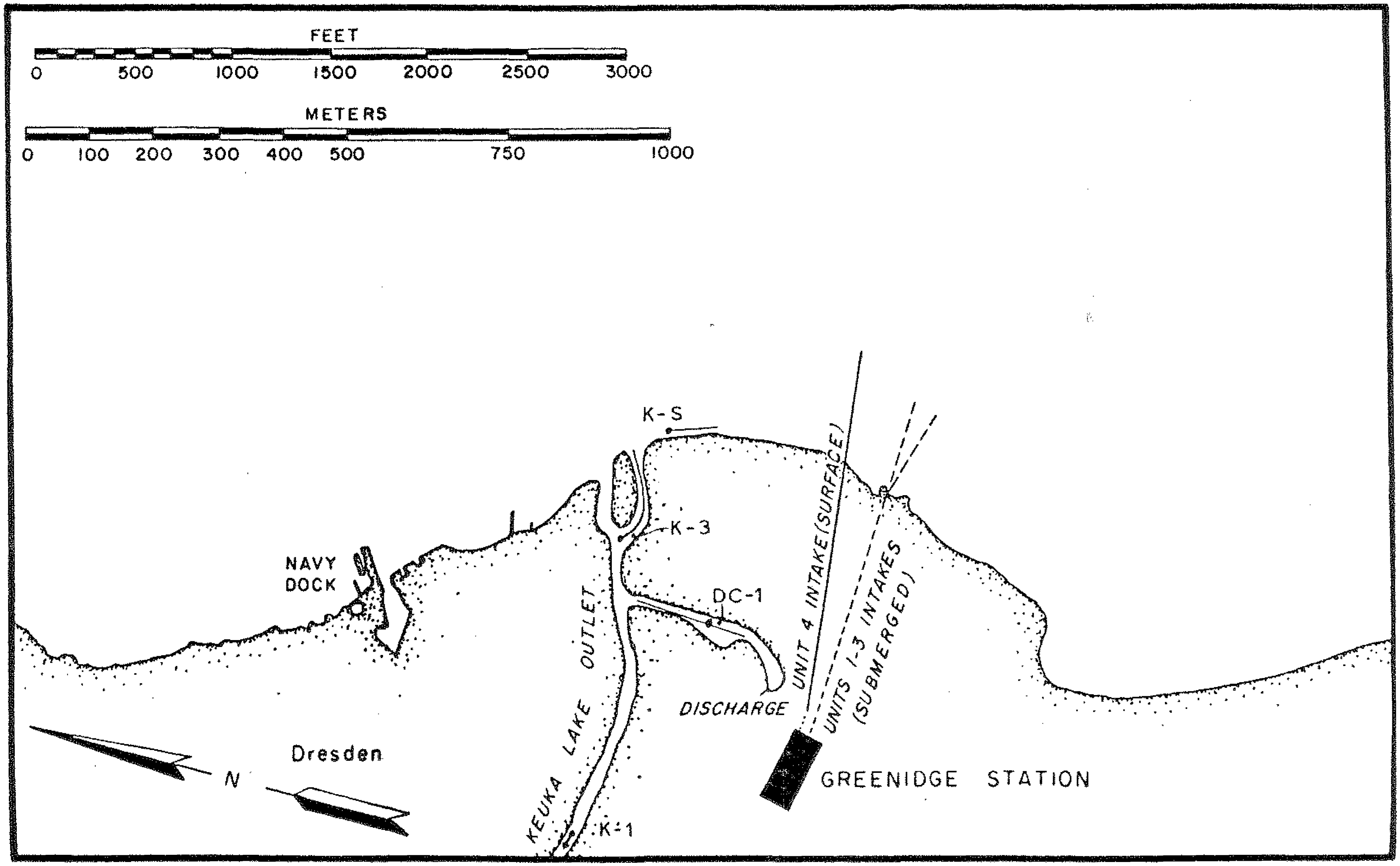

Figure 9-1. Adult fish collection locations (electroshocking, seining and hoop-netting).

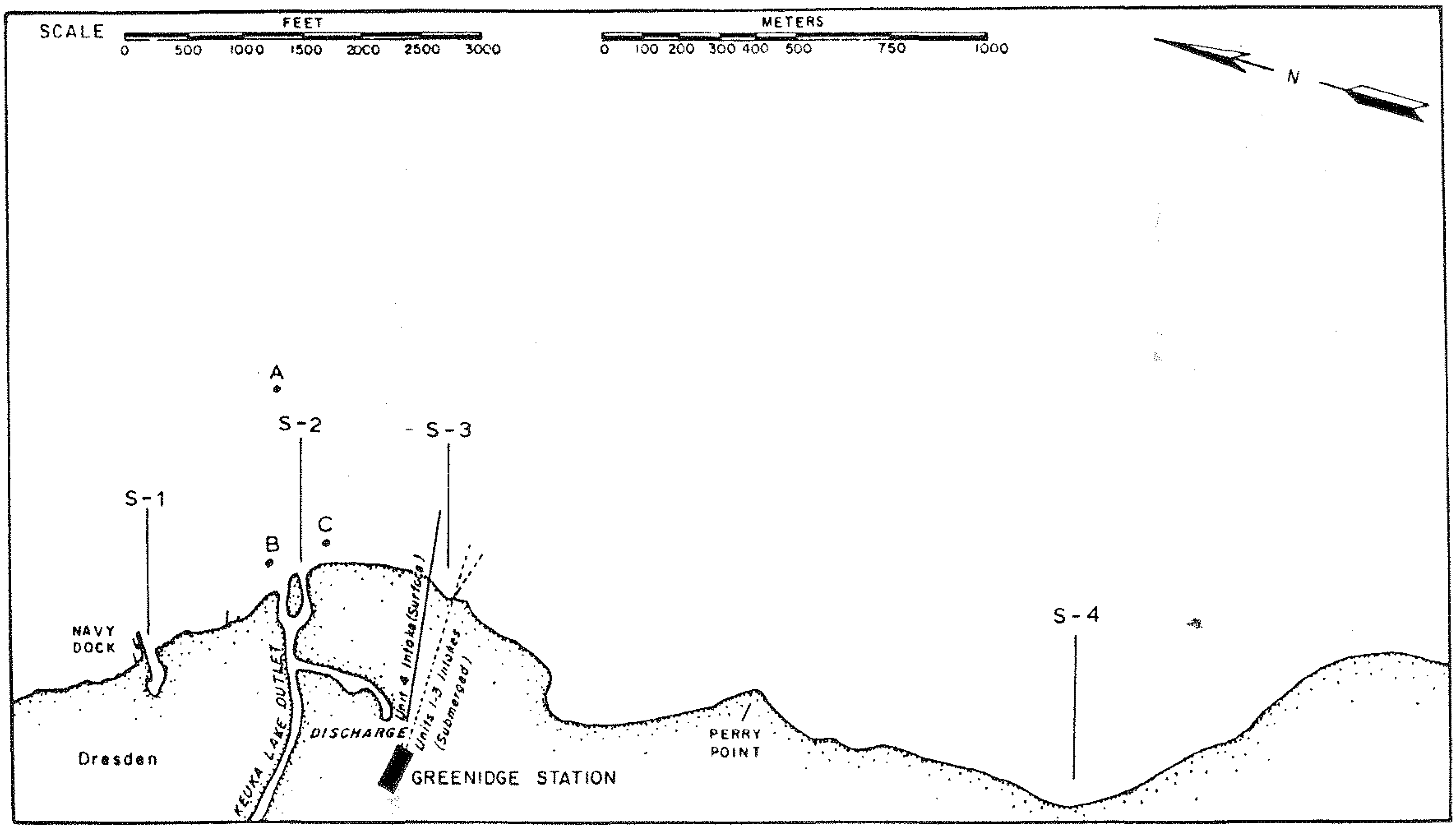

Figure 9-2. Larval fish collection transects and gill netting locations.

Table 9-1. Water temperature, dissolved oxygen, pH and turbidity values, measured during adult fish sampling, for each location, March 1976 through February 1977.

	19 March				7 April				22 April			
Location	Temp. (C)	D.O. (mg/l)	pH	Turb. (NTU)	Temp. (C)	D.O. (mg/l)	pH	Turb. (NTU)	Temp. (C)	D.O. (mg/l)	pH	Turb. (NTU)
DC-1	8.5	9.0	8.2	2.4	14.8	11.0	-[a]	6.4	13.8	15.0	-	2.8
K-1	4.0	8.9	8.4	15.5	6.1	11.4	-	6.6	10.3	14.6	-	1.8
K-3	6.8	9.6	8.2	16.0	10.5	11.0	-	6.6	13.0	15.0	-	1.6
K-S	4.0	10.1	8.2	17.4	5.4	12.7	8.0	3.8	8.0	14.2	7.6	2.8

	6 May				10 June				5 August			
Location	Temp. (C)	D.O. (mg/l)	pH	Turb. (NTU)	Temp. (C)	D.O. (mg/l)	pH	Turb. (NTU)	Temp. (C)	D.O. (mg/l)	pH	Turb. (NTU)
DC-1	12.5	-	-	2.1	19.8	7.4	-	0.6	26.3	5.8	-	3.3
K-1	11.2	-	-	1.6	20.0	10.3	-	1.5	25.7	8.3	-	3.3
K-3	11.5	-	-	1.6	19.9	10.4	-	1.5	25.8	8.2	-	3.3
K-S	9.0	-	7.6	1.4	14.0	14.2	7.9	0.6	20.7	8.4	8.4	3.3

	19 August				6 October				9 December			
Location	Temp. (C)	D.O. (mg/l)	pH	Turb. (NTU)	Temp. (C)	D.O. (mg/l)	pH	Turb. (NTU)	Temp. (C)	D.O. (mg/l)	pH	Turb. (NTU)
DC-1	27.8	9.3	-	2.5	24.0	-	-	-	8.8	14.3	-	-
K-1	24.5	9.2	-	2.5	24.0	-	-	-	0.3	16.6	-	-
K-3	26.1	9.4	-	2.5	23.8	-	-	-	8.4	13.9	-	-
K-S	25.6	9.8	8.2	2.5	18.0	-	7.9	1.8	4.9	14.5	7.1	4.5

	28 February			
Location	Temp. (C)	D.O. (mg/l)	pH	Turb. (NTU)
DC-1	10.0	12.4	-	-
K-1	1.3	13.8	-	-
K-3	10.5	13.0	-	-
K-S	4.1	13.1	7.9	1.8

[a] pH and turbidity measured only at Location K-S; data missing on dissolved oxygen values was due to instrument malfunction.

Table 9-2. Taxonomic inventory of fishes collected from March 1976 through February 1977.

Family and Scientific Name	Common Name
Petromyzontidae (lampreys)	
Petromyzon marinus	Sea lamprey
Clupeidae (herrings)	
Alosa pseudoharengus	Alewife
Salmonidae (trouts)	
Coregonus sp.	_[a]
Salmo gairdneri	Rainbow trout
Salmo trutta	Brown trout
Salvelinus namaycush	Lake trout
Osmeridae (smelts)	
Osmerus mordax	Rainbow smelt
Esocidae (pikes)	
Esox a. vermiculatus	Grass pickerel
Esox lucius	Northern pike
Esox niger	Chain pickerel
Cyprinidae (minnow and carp)	
Campostoma anomalum	Stoneroller
Cyprinus carpio	Carp
Notemigonus crysoleucas	Golden shiner
Notropis atherinoides	Emerald shiner
Notropis cornutus	Common shiner
Notropis heterolepis	Blacknose shiner
Notropis hudsonius	Spottail shiner
Notropis spilopterus	Spotfin shiner
Notropis volucellus	Mimic shiner
Pimephales notatus	Bluntnose minnow
Rhinichthys cataractae	Longnose dace
Semotilus atromaculatus	Creek Chub
Catostomidae (sucker)	
Catostomus commersoni	White sucker
Hypentelium nigricans	Northern hog sucker
Ictaluridae (freshwater catfishes)	
Ictalurus melas	Black bullhead
Ictalurus nebulosus	Brown bullhead
Noturus insignis	Margined madtom

Table 9-2. continued

Family and Scientific Name	Common Name
Percopsidae (trout-perches)	
Percopsis omiscomaycus	Trout-perch
Cyprinodontidae (killifishes)	
Fundulus diaphanus	Banded Killifish
Gasterosteidae (sticklebacks)	
Culaea inconstans	Brook Stickleback
Centrarchidae (sunfishes)	
Ambloplites rupestris	Rock bass
Lepomis gibbosus	Pumpkinseed
Lepomis macrochirus	Bluegill
Micropterus dolomieui	Smallmouth bass
Micropterus salmoides	Largemouth bass
Percidae (perches)	
Etheostoma olmstedi	Tessellated darter
Perca flavescens	Yellow perch
Cottidae (sculpins)	
Cottus cognatus	Slimy sculpin

[a] Larval fish identified as *Coregonus* sp.

Table 9-3. Number and percent of catch of fish collected by electroshocking, March 1976 through February 1977.

Species	Sampling Locations: K-S No.	K-S Percent of Catch	DC-1 No.	DC-1 Percent of Catch	K-3 No.	K-3 Percent of Catch	K-1[a] No.	K-1[a] Percent of Catch	Total Number of Fish Collected	Total Percent of Catch
Sea lamprey	1	1.3	-[b]	-	-	-	-	-	1	0.1
Alewife	10	12.7	-	-	2	0.4	-	-	12	1.3
Rainbow trout	1	1.3	1	0.3	3	0.7	-	-	5	0.5
Brown trout	-	-	-	-	6	1.3	-	-	6	0.7
Rainbow smelt	-	-	-	-	5	1.1	2	40.0	7	0.8
Northern pike	3	3.8	-	-	7	1.5	-	-	10	1.1
Grass pickerel	-	-	1	0.3	1	0.2	-	-	2	0.2
Chain pickerel	2	2.5	9	2.4	7	1.5	-	-	18	2.0
Carp	6	7.5	6	1.6	12	2.6	-	-	24	2.6
Spottail shiner	1	1.3	-	-	5	1.1	-	-	6	0.7
White sucker	5	6.3	114	30.5	78	17.1	3	60.0	200	21.9
Northern hog sucker	36	45.6	60	16.0	104	22.8	-	-	200	21.9
Black bullhead	1	1.3	-	-	7	1.5	-	-	8	0.9
Brown bullhead	-	-	8	2.1	12	2.6	-	-	20	2.2
Rock bass	3	3.8	6	1.6	4	0.9	-	-	13	1.4
Pumpkinseed	6	7.5	9	2.4	42	9.2	-	-	57	6.2
Bluegill	1	1.3	45	12.0	57	12.5	-	-	103	11.2
Smallmouth bass	1	1.3	11	2.9	29	6.4	-	-	41	4.5
Largemouth bass	-	-	102	27.2	75	16.4	-	-	177	19.4
Yellow perch	2	2.5	2	0.5	-	-	-	-	4	0.4
Total No. of Fishes	79		374		456		5		914	
Total No. of Species	15		13		18		2		20	

[a] Location sampled in March and April.
[b] No fish collected.

Table 9-4. Number and percent of catch of fish collected by electroshocking on 19 March 1976.

Species	K-S No.	K-S Percent of Catch	DC-1 No.	DC-1 Percent of Catch	K-3 No.	K-3 Percent of Catch	K-1 No.	K-1 Percent of Catch	Total Number of Fish Collected	Total Percent of Catch
Rainbow trout	-[a]	-	1	3.8	-	-	-	-	1	2.6
Chain pickerel	-	-	1	3.8	1	12.5	-	-	2	5.3
Spottail shiner	1	33.3	-	-	-	-	-	-	1	2.6
White sucker	-	-	12	46.1	3	37.5	1	100.0	16	42.1
Northern hog sucker	2	66.6	3	11.5	2	25.0	-	-	7	18.4
Bluegill	-	-	1	3.8	-	-	-	-	1	2.6
Largemouth bass	-	-	8	30.8	2	25.0	-	-	10	26.3
Total No. of Fishes	3		26		8		1		38	
Total No. of Species	2		6		4		1		7	

[a] No fish collected.

Table 9-5. Number and percent of catch of fish collected by electroshocking on 7 April 1976.

Species	Sampling Locations: K-S No.	K-S Percent of Catch	DC-1 No.	DC-1 Percent of Catch	K-3 No.	K-3 Percent of Catch	K-1 No.	K-1 Percent of Catch	Total Number of Fish Collected	Total Percent of Catch
Rainbow smelt	-[a]	-	-	-	3	10.3	2	50.0	5	5.9
Chain pickerel	-	-	3	5.8	-	-	-	-	3	3.5
Spottail shiner	-	-	-	-	5	17.2	-	-	5	5.9
White sucker	-	-	18	34.6	1	3.4	2	50.0	21	24.7
Northern hog sucker	-	-	2	3.8	9	31.0	-	-	11	12.9
Bluegill	-	-	3	5.8	-	-	-	-	3	3.5
Smallmouth bass	-	-	2	3.8	3	10.3	-	-	5	5.9
Largemouth bass	-	-	24	46.2	8	27.6	-	-	32	37.6
Total No. of Fishes	-		52		29		4		85	
Total No. of Species	-		6		6		2		8	

[a] No fish collected.

Table 9-7. Number and percent of catch of fish collected by electroshocking on 5 May 1976.

Species	Sampling Locations K-S No.	K-S Percent of Catch	DC-1 No.	DC-1 Percent of Catch	K-3 No.	K-3 Percent of Catch	Total Number of Fish Collected	Total Percent of Catch
Rainbow trout	–[a]	–	–	–	2	4.2	2	1.9
Rainbow smelt	–	–	–	–	1	2.1	1	0.9
Grass pickerel	–	–	1	1.7	–	–	1	0.9
Chain pickerel	–	–	1	1.7	1	2.1	2	1.9
Carp	–	–	3	5.3	1	2.1	4	3.8
White sucker	1	100.0	16	28.1	3	6.2	20	18.9
Northern hog sucker	–	–	2	3.7	17	35.4	19	17.9
Rock bass	–	–	–	–	1	2.1	1	0.9
Pumpkinseed	–	–	2	3.5	2	4.2	4	3.8
Bluegill	–	–	6	10.5	2	4.2	8	7.5
Smallmouth bass	–	–	1	1.7	–	–	1	0.9
Largemouth bass	–	–	25	43.8	18	37.4	43	40.6
Total No. of Fishes	1		57		48		106	
Total No. of Species	1		9		10		12	

[a] No fish collected.

Table 9-8. Number and percent of catch of fish collected by electroshocking on 10 June 1976.

Species	Sampling Locations: K-S No.	K-S Percent of Catch	DC-1 No.	DC-1 Percent of Catch	K-3 No.	K-3 Percent of Catch	Number of Fish Collected	Total Percent of Catch
Alewife	8	57.1	-[a]	-	2	1.9	10	6.2
Brown trout	-	-	-	-	1	0.9	1	0.6
Northern pike	2	14.3	-	-	-	-	2	1.2
Chain pickerel	2	14.3	-	-	1	0.9	3	1.9
Carp	1	7.1	1	2.6	3	2.8	5	3.1
White sucker	-	-	1	2.6	3	2.8	4	2.5
Northern hog sucker	-	-	-	-	21	19.6	21	13.1
Brown bullhead	-	-	3	7.6	5	4.7	8	5.0
Rock bass	1	7.1	-	-	1	0.9	2	1.2
Pumpkinseed	-	-	6	15.4	33	30.8	39	24.4
Bluegill	-	-	16	41.0	12	11.2	28	17.5
Smallmouth bass	-	-	1	2.6	6	5.6	7	4.4
Largemouth bass	-	-	11	28.2	19	17.8	30	18.8
Total No. of Fishes	14		39		107		160	
Total No. of Species	5		7		12		13	

[a] No fish collected.

Table 9-10. Number and percent of catch of fish collected by electroshocking on 19 August 1976.

Species	K-S No.	K-S Percent of Catch	DC-1 No.	DC-1 Percent of Catch	K-3 No.	K-3 Percent of Catch	Total Number of Fish Collected	Total Percent of Catch
Alewife	1	3.4	–[a]	–	–	–	1	1.1
Grass pickerel	–	–	–	–	1	1.8	1	1.1
Carp	–	–	–	–	4	7.0	4	4.3
White sucker	2	6.9	–	–	–	–	2	2.2
Northern hog sucker	18	62.1	5	83.3	16	28.1	39	42.4
Black bullhead	1	3.4	–	–	6	10.5	7	7.6
Rock bass	1	3.4	–	–	–	–	1	1.1
Pumpkinseed	3	10.3	–	–	1	1.8	4	4.3
Bluegill	–	–	–	–	10	17.5	10	10.9
Smallmouth bass	1	3.4	–	–	11	19.3	12	13.0
Largemouth bass	–	–	1	16.7	8	14.0	9	9.8
Yellow perch	2	6.9	–	–	–	–	2	2.2
Total No. of Fishes	29		6		57		92	
Total No. of Species	8		2		8		12	

[a] No fish collected.

Table 9-11. Number and percent of catch of fish collected by electroshocking on 6 October 1976.

	Sampling Locations							
	K-S		DC-1		K-3		Total Number of Fish Collected	Total Percent of Catch
Species	No.	Percent of Catch	No.	Percent of Catch	No.	Percent of Catch		
Alewife	1	20.0	-[a]	-	-	-	1	1.4
Chain pickerel	-	-	1	5.6	-	-	1	1.4
Carp	-	-	-	-	2	4.3	2	2.9
Northern hog sucker	4	80.0	2	11.1	5	10.9	11	15.9
Brown bullhead	-	-	-	-	7	15.2	7	10.2
Bluegill	-	-	6	33.3	27	58.7	33	47.8
Smallmouth bass	-	-	6	33.3	1	2.2	7	10.2
Largemouth bass	-	-	3	16.7	4	8.7	7	10.2
Total No. of Fishes	5		18		46		69	
Total No. of Species	2		5		6		8	

[a] No fish collected.

Table 9-13. Number and percent of catch of fish collected by electroshocking on 28 February 1977.

Species	Sampling Locations: K-S No.	K-S Percent of Catch	DC-1 No.	DC-1 Percent of Catch	K-3 No.	K-3 Percent of Catch	Total Number of Fish Collected	Total Percent of Catch
Sea lamprey	1	33.3	–[a]	–	–	–	1	0.8
Rainbow trout	1	33.3	–	–	–	–	1	0.8
Brown trout	–	–	–	–	5	7.0	5	3.8
Chain pickerel	–	–	1	1.7	2	2.8	3	2.2
Carp	1	33.3	–	–	–	–	1	0.8
White sucker	–	–	39	67.2	53	74.6	92	69.7
Northern hog sucker	–	–	16	27.6	10	14.1	26	19.7
Rock bass	–	–	2	3.4	1	1.4	3	2.2
Total No of Fishes	3		58		71		132	
Total No of Species	3		4		5		8	

[a] No fish collected.

Table 9-14. Number and percent of catch of fish collected by hoop and fyke netting, March and April 1976.

	Sampling Locations									
	K-S		DC-1		K-3		K-1		Total Number of Fish Collected	Total Percent of Catch
Species	No.	Percent of Catch	No.	Percent of Catch	No.	Percent of Catch	No.	Percent of Catch		
Sea lamprey	–[a]	–	–	–	–	–	1	10.0	1	2.7
Rainbow smelt	5	33.3	–	–	4	100.0	1	10.0	10	27.0
Chain pickerel	–	–	–	–	–	–	1	10.0	1	2.7
Golden shiner	1	6.7	–	–	–	–	–	–	1	2.7
Spottail shiner	2	13.3	–	–	–	–	–	–	2	5.4
White sucker	–	–	–	–	–	–	2	20.0	2	5.4
Northern hog sucker	4	26.7	–	–	–	–	–	–	4	10.8
Pumpkinseed	3	20.0	3	37.5	–	–	–	–	6	16.2
Bluegill	–	–	5	62.5	–	–	4	40.0	9	24.3
Yellow perch	–	–	–	–	–	–	1	10.0	1	2.7
Total No. of Fishes	15		8		4		10		37	
Total No. of Species	5		2		1		6		10	

[a] No fish collected.

Table 9-15. Number and percent of catch of fish collected by gill netting, 21-24 September 1976.

	Sampling Locations													
	Near Shore[d]				Shelf[b]				Slope[c]				Total Number of Fish Collected	Total Percent of Catch
	S-2	S-3	S-4		S-2	S-3	S-4		S-2	S-3	S-4			
Species	No.	No.	No.	Percent of Catch	No.	No.	No.	Percent of Catch	No.	No.	No.	Percent of Catch		
Alewife	–[d]	–	8	8.7	65	24	93	56.3	76	24	–	39.7	290	43.5
Lake trout	–	–	–	–	–	–	–	–	3	6	2	4.4	11	1.6
Rainbow smelt	–	–	–	–	–	–	–	–	4	35	–	15.5	39	5.8
Northern pike	–	1	1	2.2	2	1	–	0.9	–	–	–	–	5	0.7
Chain pickerel	1	4	2	7.6	1	–	2	0.9	–	–	–	–	10	1.5
Carp	5	11	–	17.4	–	–	–	–	–	1	1	0.8	18	2.7
Golden shiner	–	–	–	–	6	–	–	1.9	–	–	–	–	6	0.9
Spottail shiner	9	–	–	9.7	–	7	–	2.2	6	1	–	2.8	23	3.4
White sucker	2	2	4	8.7	3	4	–	2.2	4	2	19	9.9	40	6.0
Northern hog sucker	2	–	–	2.2	–	–	–	–	–	–	–	–	2	0.3
Brown bullhead	14	1	–	16.3	7	–	1	2.5	–	–	–	–	23	3.1
Trout-perch	–	–	–	–	–	1	–	0.3	1	–	–	0.4	2	0.3
Rock bass	–	–	–	–	1	3	–	1.2	2	2	4	3.1	12	1.8
Pumpkinseed	4	1	1	6.5	9	1	–	3.1	–	–	–	–	16	2.1
Bluegill	1	1	–	2.2	3	–	–	0.9	–	–	–	–	5	0.7
Smallmouth bass	–	–	–	–	4	4	–	2.5	4	1	6	4.4	19	2.8
Largemouth bass	–	1	–	1.1	1	–	1	0.6	–	–	–	–	3	0.4
Yellow perch	9	6	1	17.4	52	11	16	24.5	15	7	26	19.0	143	21.4
Total No. of Fishes	47	28	17		154	56	113		115	79	58		667	
Total No. of Species	9	9	6		12	9	5		9	9	6		18	

[a] From the point when the water depth was 6 ft, extending Lakeward (10-15 ft).
[b] From the beginning of the slope (18-25 ft), extending shoreward (8-15 ft).
[c] From the beginning of the slope (18-25 ft), extending lakeward (78-115 ft).
[d] No fish collected.

Table 9-16. Number and percent of catch of fish collected by gill netting at Locations A, B and C near Transect S-2 on 28 February 1977.

Species	Sampling Locations A	B	C	Total Number of Fish Collected	Total Percent of Catch
Northern pike	1	-[a]	-	1	10
Chain pickerel	-	1	2	3	30
Northern hog sucker	-	2	1	3	30
Yellow perch	2	1	-	3	30
Total No. of Fishes	3	4	3	10	
Total No. of Species	2	3	2	4	

[a] No fish collected.

Table 9-17. Number and percent of catch of fish collected by back pack electroshocking in Keuka Lake Outlet, 22-23 September 1976.

	Sampling Locations										Total	
	4000 ft		7000 ft		7500 ft		11500 ft		12000 ft		Number	Total
Species	No.	Percent of Catch	No.	Percent of Catch	No.	Percent of Catch	No.	Percent of Catch	No.	Percent of Catch	of Fish Collected	Percent of Catch
Stoneroller	2	5.9	-[b]	-	20	23.0	16	25.8	63	46.0	101	29.9
Common shiner	-	-	4	22.2	19	21.8	3	4.8	33	24.1	59	17.4
Blacknose shiner	1	2.9	-	-	-	-	-	-	1	0.7	2	0.6
Spottail shiner	1	2.9	-	-	-	-	-	-	-	-	1	0.3
Longnose dace	10	29.4	-	-	10	11.5	34	54.8	6	4.3	60	17.8
Creek chub	8	23.5	-	-	3	3.4	-	-	2	1.5	13	3.8
White sucker	4	11.8	7	38.9	6	6.9	4	6.5	13	9.5	34	10.1
Northern hog sucker	8	23.5	6	33.3	23	26.4	3	4.8	13	9.5	53	15.7
Margined madtom	-	-	-	-	3	3.4	2	3.2	4	2.9	9	2.6
Bluegill	-	-	-	-	3	3.4	-	-	-	-	3	0.9
Smallmouth bass	-	-	1	5.6	-	-	-	-	2	1.5	3	0.9
Total No. of Fishes	34		18		87		62		137		338	
Total No. of Species	7		4		8		6		9		11	

[a] Distance (ft) upstream from the mouth of Keuka Lake Outlet.
[b] No fish collected.

Table 9-18. Number and percent of catch of fish collected by seining at each location, March 1976 through February 1977.

Species	Locations K-S	Locations DC-1	Locations K-3	Locations K-1	Total Number of Fish Collected	Total Percent of Catch
Alewife	-	-	-	1451	1451	57.2
Rainbow smelt	7	-	24	-	31	1.2
Grass pickerel	-	-	2	-	2	0.1
Chain pickerel	-	3	-	-	3	0.1
Stoneroller	1	-	2	21	24	0.9
Emerald shiner	-	-	4	-	4	0.1
Common shiner	1	-	2	30	33	1.3
Blacknose shiner	1	-	7	6	14	0.5
Spottail shiner	34	2	4	7	47	1.8
Spotfin shiner	413	1	285	26	725	28.6
Mimic shiner	-	-	30	-	30	1.2
Bluntnose minnow	2	-	1	-	3	0.1
Longnose dace	-	-	-	8	8	0.3
Creek chub	-	-	-	9	9	0.3
White sucker	-	3	1	10	14	0.5
Northern hog sucker	1	-	20	27	48	1.9
Banded killifish	1	-	4	-	5	0.2
Brook stickleback	1	-	-	-	1	<0.1
Rock bass	1	-	-	-	1	<0.1
Pumpkinseed	-	5	1	-	6	0.2
Bluegill	2	10	6	4	22	0.9
Smallmouth bass	3	1	-	-	4	0.1
Largemouth bass	-	11	10	2	23	0.9
Tessellated darter	9	5	8	7	29	1.1
Slimy sculpin	1	-	-	-	1	<0.1
Total No. of Fishes	478	41	411	1608	2538	
Total No. of Species	15	9	17	13	25	

[a] No fish collected.

Table 9-19. Number and percent of catch of fish collected by seining on 19 March 1976.

Species	Sampling Locations K-S No.	K-S Percent of Catch	DC-1[a] No.	DC-1[a] Percent of Catch	K-3 No.	K-3 Percent of Catch	K-1[a] No.	K-1[a] Percent of Catch	Total Number of Fish Collected	Total Percent of Catch
Rainbow smelt	-	-			1	33.3			1	10.0
Grass pickerel	-	-			2	66.7			2	20.0
Spotfin shiner	7	100.0			-	-			7	70.0
Total No. of Fishes	7				3				10	
Total No. of Species	1				2				3	

[a] Location not sampled due to high current velocity

Table 9-20. Number and percent of catch of fish collected by seining on 7 April 1976.

Species	K-S No.	K-S Percent of Catch	DC-1 No.	DC-1 Percent of Catch	K-3 No.	K-3 Percent of Catch	K-1[a] No.	K-1[a] Percent of Catch	Total Number of Fish Collected	Total Percent of Catch
Rainbow smelt	4	14.8	-[b]	-	22	10.1			26	10.4
Stoneroller	-	-	-	-	1	0.5			1	0.4
Blacknose shiner	-	-	-	-	7	3.2			7	2.8
Spotfin shiner	22	81.5	-	-	167	76.6			189	75.6
Bluntnose minnow	-	-	-	-	1	0.5			1	0.4
White sucker	-	-	2	40.0	-	-			2	0.8
Northern hog sucker	1	3.7	-	-	8	3.6			9	3.6
Banded killifish	-	-	-	-	3	1.4			3	1.2
Pumpkinseed	-	-	2	40.0	-	-			2	0.8
Bluegill	-	-	-	-	1	0.5			1	0.4
Largemouth bass	-	-	1	20.0	4	1.8			5	2.0
Tessellated darter	-	-	-	-	4	1.8			4	1.6
Total No. of Fishes	27		5		218				250	
Total No. of Species	3		3		10				12	

[a] Location not sampled due to high current velocity.
[b] No fish collected.

Table 9-21. Number and percent of catch of fish collected by seining on 22 April 1976.

Species	K-S No.	K-S Percent of Catch	DC-1 No.	DC-1 Percent of Catch	K-3 No.	K-3 Percent of Catch	K-1 No.	K-1 Percent of Catch	Total Number of Fish Collected	Total Percent of Catch
Rainbow smelt	3	0.8	–[a]	–	–	–	–	–	3	0.7
Stoneroller	1	0.3	–	–	–	–	1	2.9	2	0.5
Common shiner	–	–	–	–	–	–	30	88.2	30	7.3
Emerald shiner	–	–	–	–	1	14.3	–	–	1	0.2
Spottail shiner	6	1.6	–	–	2	28.6	2	5.9	10	2.4
Spotfin shiner	350	95.9	–	–	–	–	–	–	350	84.7
White sucker	–	–	1	14.3	–	–	1	2.9	2	0.5
Banded killifish	–	–	–	–	1	14.3	–	–	1	0.2
Pumpkinseed	–	–	1	14.3	–	–	–	–	1	0.2
Bluegill	–	–	2	28.6	–	–	–	–	2	0.5
Largemouth bass	–	–	3	42.8	3	42.8	–	–	6	1.5
Tessellated darter	5	1.4	–	–	–	–	–	–	5	1.2
Total No. of Fishes	365		7		7		34		413	
Total No. of Species	5		4		4		4		12	

[a] No fish collected.

Table 9-22. Number and percent of catch of fish collected by seining on 6 May 1976.

Species	Sampling Locations								Total Number of Fish Collected	Total Percent of Catch
	K-S		DC-1		K-3		K-1			
	No.	Percent of Catch	No.	Percent of Catch	No.	Percent of Catch	No.	Percent of Catch		
Rainbow smelt	–[a]	–	–	–	1	4.2	–	–	1	1.7
Blacknose shiner	1	3.2	–	–	–	–	–	–	1	1.7
Spottail shiner	–	–	–	–	2	8.3	–	–	2	3.4
Spotfin shiner	28	90.3	–	–	16	66.7	–	–	44	75.9
Banded killifish	1	3.2	–	–	–	–	–	–	1	1.7
Northern hog sucker	–	–	–	–	4	16.6	–	–	4	6.9
Largemouth bass	–	–	1	100.0	1	4.2	–	–	2	3.4
Tessellated darter	–	–	–	–	–	–	2	100.0	2	3.4
Slimy sculpin	1	3.2	–	–	–	–	–	–	1	1.7
Total No. of Fishes	31		1		24		2		58	
Total No. of Species	4		1		5		1		9	

[a] No fish collected.

Table 9-23. Number and percent of catch of fish collected by seining on 10 June 1976.

Species	K-S No.	K-S Percent of Catch	DC-1 No.	DC-1 Percent of Catch	K-3 No.	K-3 Percent of Catch	K-1 No.	K-1 Percent of Catch	Total Number of Fish Collected	Total Percent of Catch
Alewife	–[a]	–	–	–	–	–	1451	99.4	1451	97.3
Chain pickerel	–	–	2	25.0	–	–	–	–	2	0.1
Stoneroller	–	–	–	–	1	6.2	–	–	1	0.1
Common shiner	1	12.5	–	–	2	12.5	–	–	3	0.2
Spotfin shiner	1	12.5	–	–	4	25.0	–	–	5	0.3
Mimic shiner	–	–	–	–	1	6.2	–	–	1	0.1
Bluntnose minnow	1	12.5	–	–	–	–	–	–	1	0.1
White sucker	–	–	–	–	–	–	1	0.1	1	0.1
Northern hog sucker	–	–	–	–	4	25.0	1	0.1	5	0.3
Brook stickleback	1	12.5	–	–	–	–	–	–	1	0.1
Rock bass	1	12.5	–	–	–	–	–	–	1	0.1
Pumpkinseed	–	–	2	25.0	1	6.2			3	0.2
Bluegill	2	25.0	4	50.0	2	12.5	4	0.3	12	0.8
Largemouth bass	–	–	–	–	–	–	2	0.1	2	0.1
Tessellated darter	1	12.5	–	–	1	6.2	–	–	2	0.1
Total No. of Fishes	8		8		16		1459		1491	
Total No. of Species	7		3		8		5		15	

[a] No fish collected.

Table 9-24. Number and percent of catch of fish by seining on 5 August 1976.

Species	K-S No.	K-S Percent of Catch	DC-1 No.	DC-1 Percent of Catch	K-3 No.	K-3 Percent of Catch	K-1 No.	K-1 Percent of Catch	Total Number of Fish Collected	Total Percent of Catch
Chain pickerel	–[a]	–	1	10.0	–	–	–	–	1	1.0
Blacknose shiner	–	–	–	–	–	–	2	40.0	2	1.9
Spottail shiner	26	74.3	–	–	–	–	–	–	26	24.8
Spotfin shiner	5	14.3	–	–	36	65.4	–	–	41	39.0
Mimic shiner	–	–	–	–	11	20.0	–	–	11	10.5
White sucker	–	–	–	–	1	1.8	2	40.0	3	2.8
Northern hog sucker	–	–	–	–	3	5.5	–	–	3	2.8
Bluegill	–	–	3	30.0	–	–	–	–	3	2.8
Smallmouth bass	3	8.6	–	–	–	–	–	–	3	2.8
Largemouth bass	–	–	6	60.0	1	1.8	–	–	7	6.7
Tessellated darter	1	2.8	–	–	3	5.5	1	20.0	5	4.8
Total No. of Fishes	35		10		55		5		105	
Total No. of Species	4		3		6		3		11	

[a] No fish collected.

Table 9-25. Number and percent of catch of fish collected by seining on 19 August 1976.

	Sampling Locations									
	K-S		DC-1		K-3		K-1		Total Number of Fish Collected	Total Percent of Catch
Species	No.	Percent of Catch	No.	Percent of Catch	No.	Percent of Catch	No.	Percent of Catch		
Stoneroller	-[a]	-	-	-	-	-	20	27.8	20	14.3
Blacknose shiner	-	-	-	-	-	-	4	5.6	4	2.9
Spottail shiner	-	-	-	-	-	-	5	6.9	5	3.6
Spotfin shiner	-	-	-	-	49	72.0	-	-	49	35.0
Mimic shiner	-	-	-	-	18	26.5	-	-	18	12.8
Longnose dace	-	-	-	-	-	-	8	11.1	8	5.7
Creek chub	-	-	-	-	-	-	9	12.5	9	6.4
White sucker	-	-	-	-	-	-	6	8.3	6	4.3
Northern hog sucker	-	-	-	-	1	1.5	16	22.2	17	12.1
Tessellated darter	-	-	-	-	-	-	4	5.6	4	2.9
Total No. of Fishes	-		-		68		72		140	
Total No. of Species	-		-		3		8		10	

[a] No fish collected.

Table 9-27. Number and percent of catch of fish collected by seining on 9 December 1976.

Species	Sampling Locations: K-S No.	K-S Percent of Catch	DC-1 No.	DC-1 Percent of Catch	K-3 No.	K-3 Percent of Catch	K-1 No.	K-1 Percent of Catch	Total Number of Fish Collected	Total Percent of Catch
Emerald shiner	-[a]	-	-	-	3	100.0	-	-	3	27.3
Spottail shiner	2	100.0	2	100.0	-	-	-	-	4	36.3
Northern hog sucker	-	-	-	-	-	-	4	100.0	4	36.3
Total No. of Fishes	2		2		3		4		11	
Total No. of Species	1		1		1		1		3	

[a] No fish collected.

Table 9-28. Number and percent of catch of fish collected by seining on 28 February 1977.

Species	Sampling Locations: K-S No.	K-S Percent of Catch	DC-1 No.	DC-1 Percent of Catch	K-3 No.	K-3 Percent of Catch	K-1 No.	K-1 Percent of Catch	Total Number of Fish Collected	Total Percent of Catch
Spotfin shiner	-[a]	-	1	20.0	5	100.0	-	-	6	40
Northern hog sucker	-	-	-	-	-	-	5	100.0	5	33
Tessellated darter	-	-	4	80.0	-	-	-	-	4	27
Total No. of Fishes	-	-	5		5		5		15	
Total No. of Species	-	-	2		1		1		3	

[a] No fish collected.

Table 9-29. Age, size and mean condition factors for northern hog sucker collected by electroshocking, August 1976.

Age Group	Number	Total Length (mm) Mean	Total Length (mm) Range	Weight (g) Mean	Weight (g) Range	Mean K-Factor	Percent Occurrence
II	7	209.4	180-237	114.3	70.0-150.0	1.22	14.6
III	41	264.3	174-345	234.3	90.0-555.0	1.21	85.4

Table 9-30. Age, size and mean condition factors for white sucker collected by electroshocking, August and December 1976.

Age Group	Number	Total Length (mm)		Weight (g)		Mean K-Factor	Percent Occurrence
		Mean	Range	Mean	Range		
I	6	218.0	165-242	111.7	55-145	1.04	17.1
II	18	285.1	165-356	259.2	50-465	1.05	51.4
III	9	314.6	191-368	380.0	95-540	1.17	25.7
IV	2	382.0	360-404	680.0	500-860	1.19	5.7

Table 9-31. Age, size and mean condition factors for largemouth bass collected by electroshocking, April 1976.

Age Group	Number	Total Length (mm)		Weight (g)		Mean K-Factor	Percent Occurrence
		Mean	Range	Mean	Range		
I	34	152.1	104-181	52.7	14-85	1.42	48.6
II	9	194.0	171-252	119.4	80-265	1.55	12.9
III	8	253.9	190-283	283.8	110-400	1.65	11.4
IV	13	329.2	260-385	638.5	310-960	1.73	18.6
V	5	398.8	360-422	1185.0	820-1450	1.84	7.1
VI	1	440.0	NA[a]	1675.0	NA	1.97	1.4

[a] Not applicable.

Table 9-34. Stomach contents of fish collected from March through December 1976.

Species	Total Length Range (mm)	Stomachs Examined: With Food	Empty	% Empty	Food Items	Monthly Percentage Composition by Dry Weight: 19 Mar	7 Apr	22 Apr	6 May	10 Jun	5 Aug	19 Aug	6 Oct	9 Dec
White sucker	165-541	16	17	51.5	Sideswimmers (Amphipoda)	100.0	0.0	0.0	23.2	100.0	97.5	100.0	0.0	84.0
					Midges (Chironomidae)	0.0	0.0	0.0	30.1	0.0	0.0	0.0	0.0	0.0
					Caddisflies (Hydropsychidae)	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0
					Unrecognizable	0.0	0.0	100.0	45.9	0.0	2.5	0.0	0.0	16.0
Bluegill	130-205	27	4	12.9	Plant Fragments	0.0	0.0	0.0	0.0	56.6	0.0	0.0	0.0	0.0
					Earthworms (Lumbricidae)	0.0	13.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
					Sideswimmers (Amphipoda)	0.0	86.4	100.0	94.5	5.6	100.0	100.0	91.2	0.0
					Midges (Chironomidae)	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
					Sow bugs (Isopoda)	0.0	0.0	0.0	2.8	0.0	0.0	0.0	0.0	0.0
					Snails	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0
					Terrestrial insects (unrecognizable)	0.0	0.0	0.0	1.6	32.2	0.0	0.0	0.3	0.0
					Bryozoa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.5	0.0
Largemouth bass	150-421	30	8	21.0	Fish (unrecognizable)	0.0	0.0	39.6	0.0	0.0	0.0	100.0	95.0	0.0
					Fish (largemouth bass)	0.0	10.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
					Fish (alewife)	0.0	0.0	0.0	0.0	97.9	0.0	0.0	0.0	0.0
					Fish (rainbow smelt)	0.0	89.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
					Crayfish	0.0	0.0	8.5	0.0	0.0	0.0	0.0	5.0	0.0
					Sow bugs (Isopoda)	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
					Sideswimmers (Amphipoda)	100.0	0.1	51.7	100.0	2.1	100.0	0.0	<0.1	0.0

Table 9-37. continued.

Species	5 August			19 August			6 October			9 December			28 Feburary			Total Number of Fish Collected
	DC-1	K-3	K-S	DC-1	K-3	K-S	DC-1	K-3	K-S	DC-1	K-3	K-S	DC-1	K-3	K-S	
Sea lamprey	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Alewife	-	-	-	-	-	1	-	-	1	-	-	-	-	-	-	12
Rainbow trout	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	5
Brown trout	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	6
Rainbow smelt	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5
Northern pike	-	7	1	-	-	-	-	-	-	-	-	-	-	-	-	10
Grass pickerel	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	2
Chain pickerel	-	-	-	-	-	-	1	-	-	-	-	-	1	2	-	18
Carp	-	-	1	-	4	-	-	2	-	-	-	-	-	-	1	24
Spottail shiner	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6
White sucker	-	1	2	-	-	2	-	-	-	17	13	-	39	53	-	197
Northern hog sucker	-	13	11	5	16	18	2	5	4	30	9	-	16	10	-	200
Black bullhead	-	1	-	-	6	1	-	-	-	-	-	-	-	-	-	8
Brown bullhead	-	-	-	-	-	-	-	7	-	4	-	-	-	-	-	20
Rock bass	-	-	1	-	-	1	-	-	-	1	1	-	2	1	-	13
Pumpkinseed	-	6	2	-	1	3	-	-	-	1	-	-	-	-	-	57
Bluegill	2	1	1	-	10	-	6	27	-	1	3	-	-	-	-	103
Smallmouth bass	-	7	-	-	11	1	6	1	-	-	1	-	-	-	-	41
Largemouth bass	-	2	-	1	8	-	3	4	-	-	1	-	-	-	-	177
Yellow perch	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	4
Total No. of Fishes	2	38	19	6	57	29	18	46	5	54	29	-	58	71	3	909
Total No. of Species	1	8	7	2	8	8	5	6	2	6	7	-	4	5	3	20

[a] Thermal plume locations.
[b] Ambient locations.
[c] No fish collected.

Table 9-38. Summary of upper avoidance temperatures of some fish common to Keuka Lake Outlet and Seneca Lake.

Species	Acclimation Temperature (C)	Upper Avoidance Temperature (C)	Source
Alewife	25	30	Raney 1971
Rainbow trout	5	20.5	Otto, et al. 1975
	10	21.5	
	15	23.5	
	20	24.5	
Rainbow smelt	5	10.5	Otto, et al. 1975
	10	16.0	
White sucker (Larvae)	-	31.2	McCormick, et al. 1974
Northern hog sucker	-	≈25.2[a]	Gammon 1973
Largemouth bass			
(Juvenile)	25	30.6-32.8	Meldrin and Gift 1971
(Adult)	-	30	Clugston 1973
Yellow perch	5	26	Otto, et al. 1975
	10	30	
	15	31	
	20	31	
	25	33	

[a] Based on field observation.

Table 9-39. Summary of the temperature preferenda of some fish common to Keuka Lake Outlet and Seneca Lake.

Species	Acclimation Temperature (C)	Preferred Temperature (C)	Final Preferred Temperature (C)	Source
Rainbow trout	6	10.0-11.7	11.6	Cherry, et al. 1975
	9	12.5-13.4	12.6	
	12	14.4-15.1	14.4	
	15	16.2-16.9	16.9	
	18	17.9-18.7	18.1	
	21	19.7-20.6	20.1	
	24	21.4-22.5	22.0	
White sucker	14.0	10.4	-[a]	Reutter & Herdendorf 1975
	19.0	23.4	-	
Pumpkinseed	Spring	23.8	-	Reutter & Herdendorf 1975
	Summer	27.7	-	
Bluegill (Adult)	-	32.3	-	Ferguson 1958
(Juvenile)	-	-	30.3	Neill & Magnuson 1974
Largemouth bass				
(Adult)	-	26.6-27.7	-	Ferguson 1958
(Juvenile)	-	30.0-32.2	-	
Yellow perch	8.0	18.6	-	Ferguson 1958
	10.0	19.3	-	
	15.0	23.0	-	
	20.0	23.1	-	
	25.0	24.5	-	
	30.0	26.7	-	

[a] No data available.

Table 9-40. Summary of critical thermal maxima (CTM) of some fish common to Keuka Lake Outlet and Seneca Lake.

Species	Acclimation Temperature (C)	CTM (C)	Source
Alewife (Adult)	5	24.7	Otto, et al. 1975
	10	28.7	
	15	29.9	
	20	31.9	
	25	32.8	
(Young of year)	5	24.7	
	10	26.7	
	15	29.5	
	20	31.9	
	25	34.3	
	30	36.7	
Rainbow trout (Yearling)	5	27.9	Otto, et al. 1975
	10	28.4	
	15	29.7	
	20	31.1	
Rainbow smelt	5	23.5	Otto, et al. 1975
	10	24.4	
	1.1	23.5	Reutter and Herdendorf 1975
	6	24.9	
White sucker	5	27.8	Otto, et al. 1975
	10	28.7	
	15	30.5	
	20	32.9	
Largemouth bass	0.9	18.0	Reutter and Herdendorf 1975
Yellow perch (Adult)	5	26.6	Otto, et al. 1975
	10	29.3	
	15	31.6	
	20	33.8	
	25	35.4	
(Young of year)	5	27.5	
	10	28.6	
	15	30.3	
	20	32.6	
	25	35.1	

Table 9-41. Summary of the upper (U) and lower (L) temperature tolerance limits (TL_{50}) of some fish common to Keuka Lake Outlet and Seneca Lake.

Species	Acclimation Temperature (C)	Tolerance Limit (TL_{50}) Extreme	Tolerance Limit (TL_{50}) Temperature (C)	Source
Rainbow trout	5	U	23.4	Otto 1975
	10	U	24.7	
	15	U	25.7	
	20	U	25.7	
	5	L	<1.0	Otto 1974
	10	L	<1.0	
	15	L	2.0	
	20	L	4.0	
White sucker	5	U	26.3	Brett 1956
	10	U	27.7	
	15	U	29.3	
	20	U	29.3	
		L	2.5	
	25	U	29.3	
		L	6.0	
(Newly-hatched)	8.9	U	29.0	McCormick, et al. 1974
	15.2	U	31.1	
	21.1	U	31.5	
		L	<2.9	
(Swim-up larvae)	10.0	U	28.5	
	15.8	U	30.7	
	21.1	U	32.0	
		L	3.1	
Pumpkinseed	18	U	28.0	Black 1953
	24	U	30.2	
	21.1	U	38.9	Trembley 1961:
Bluegill	15	U	30.7	Hart 1952
	20	U	31.5	
	15	L	2.5	
	20	L	5.0	
	25	L	7.5	
(Juvenile)	12.1	U	28.5	Banner and VanArman 1973
		L	3.2	
	19.0	U	33.0	
		L	4.7	
	26.0	U	36.4	
		L	8.2	
Largemouth bass	7.2	U	30.6	Trembley 1961
	20	U	31.8-32.5	Hart 1952
	22-23	U	32.2	Hathaway 1927
	30	U	36.4	Hart 1952
Yellow perch	5	U	21.3	Brett 1956
	10	U	25.0	
		L	1.1	
	15	U	27.0	
	25	U	29.0	
		L	3.7	
	5	U	22.2	Otto, et al. 1975
	10	U	24.7	
	15	U	27.7	
	20	U	29.8	
	25	U	31.2	

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APPENDIX A

Meteorological conditions and river discharge during the thermal plume surveys.

Table A-1. Meteorological conditions and stream discharge[a] during the thermal plume survey on 19 March 1976.

Time (EST)	Wind Speed (mph)	Wind Direction	Air Temperature Dry Bulb (C)	Air Temperature Wet Bulb (C)	Relative Humidity (%)	Cloud Cover (T)
1045	5-6	SW	8.9	6.7	73	100
1115	6-8	WSW	10.6	6.7	56	100
1200	0.7	SWS	11.1	10.0	86	100
1230	0-3	SW	15.6	10.0	48	100
1340	4-6	W	17.2	11.1	46	75

[a] Keuka Lake Outlet discharge = 572cfs (USGS 1977).

Table A-2. Meteorological conditions and stream discharge[a] during the thermal plume survey on 6 May 1976.

Time (EDST)	Wind Speed (mph)	Wind Direction	Air Temperature Dry Bulb (C)	Air Temperature Wet Bulb (C)	Relative Humidity (%)	Cloud Cover (%)
1052	4	NW	17.3	15.0	84	0
1205	4	N	10.8	10.0	91	100
1307	5	N	11.1	10.0	90	100
1340	4	NE	9.7	8.9	90	100
1440	3	N	9.7	9.2	94	100
1714	3	N	8.6	7.8	90	100
1814	1-2	N	7.2	6.9	96	100

[a] Keuka Lake Outlet discharge = 316cfs (USGS 1977).

Table A-3. Meteorological conditions and stream discharge[a] during the thermal plume survey on 1 July 1976.

Time (EDST)	Wind		Air Temperature		Relative Humidity (%)	Cloud Cover (%)
	Speed (mph)	Direction	Dry Bulb (C)	Wet Bulb (C)		
1118	7	SW	25.0	19.3	59	20
1204	6	SWS	22.9	18.4	80	30
1302	5	SW	25.0	21.1	83	75
1402	Calm	-[b]	22.7	18.5	69	100
1503	4-6	SWS	22.8	18.3	65	100
1558	1-3	SW	22.1	18.3	69	100

[a] Keuka Lake Outlet discharge ≈ 140cfs (estimated).
[b] Not applicable.

Table A-4. Meteorological conditions and stream discharge[a] during the thermal plume survey on 5 August 1976.

Time (EDST)	Wind Speed (mph)	Wind Direction	Air Temperature Dry Bulb (C)	Air Temperature Wet Bulb (C)	Relative Humidity (%)	Cloud Cover (%)
1000	2-4	S	23.9	18.9	79	20
1100	2-6	S	27.2	20.6	76	20
1200	0-4	S	27.8	20.6	74	50
1300	2-10	SW	28.9	20.6	71	50
1400	0-7	SW	27.8	20.6	74	80

[a] Keuka Lake Outlet discharge = 52cfs (USGS 1977).

Table A-5. Meteorological conditions and stream discharge[a] during the thermal plume survey on 2 September 1976.

Time (EDST)	Wind		Air Temperature		Relative Humidity (%)	Cloud Cover (%)
	Speed (mph)	Direction	Dry Bulb (C)	Wet Bulb (C)		
1000	15-20	NE	16.7	14.4	84	100
1045	8-10	NE	18.3	15.0	70	70
1200	5-9	NE	22.2	17.8	65	40
1400	10	NE	25.3	17.8	47	30
1610	8-10	NE	23.9	15.6	41	10
1700	10-14	NE	23.9	15.6	41	5
1818	8-14	NE	21.7	15.6	53	0

[a] Keuka Lake Outlet discharge = 43cfs (USGS 1977).

Table A-6. Meteorological conditions and stream discharge[a] during the thermal plume survey on 9 December 1976.

Time (EST)	Wind		Air Temperature		Relative Humidity (%)	Cloud Cover (%)
	Speed (mph)	Direction	Dry Bulb (C)	Wet Bulb (C)		
1030	Calm	-[b]	-5.0	-	-	85
1205	7	NE	-5.6	-	-	100
1255	3	NE	-5.0	-	-	100
1445	8	ENE	-5.8	-	-	95
1545	4	E	-6.7	-	-	60

[a] Keuka Lake Outlet discharge = 84cfs (USGS 1977).
[b] Not applicable.

APPENDIX B

Station operating data during the thermal plume surveys.

Table B-1. Station operating data[a] during the thermal plume survey on 19 March 1976.

Time (EST)	Unit No.	Temperature Intake (C)	Temperature Discharge (C)	ΔT[b] (C)	Discharge Flow Rate[c] (cfs)	Total Plant Heat Rejection Rate (10^9 BTU/hr)
1000	1	3.3	7.2	3.9	44	0.39
	2	3.3	11.1	7.8	44	
	3	5.0	11.1	6.1	74	
	4	a	a	0	131	
1100	1	3.3	7.2	3.9	44	0.39
	2	3.3	11.1	7.7	44	
	3	5.0	11.1	6.1	74	
	4	a	a	0	131	
1200	1	3.3	7.2	3.9	44	0.39
	2	3.3	11.1	7.8	44	
	3	5.0	11.1	6.1	74	
	4	a	a	0	131	
1300	1	3.3	7.8	4.5	44	0.39
	2	3.9	11.1	7.2	44	
	3	5.0	11.1	6.1	74	
	4	a	a	0	131	
1400	1	3.3	7.8	4.5	44	0.41
	2	3.9	11.1	7.2	44	
	3	5.0	11.7	6.7	74	
	4	a	a	0	131	
1500	1	3.9	7.8	3.9	44	0.40
	2	4.4	11.7	7.2	44	
	3	5.0	11.7	6.7	74	
	4	a	a	0	131	
1600	1	3.9	7.8	3.9	44	0.38
	2	4.4	11.7	7.2	44	
	3	5.6	11.7	6.1	74	
	4	a	a	0	131	

[a] Unit 4 not operational; operating data for Units 1, 2, and 3 supplied by Station personnel.
[b] Plant ΔT measured at the discharge outlet = 5.1C.
[c] Total plant discharge rate = 162cfs.

Table B-2. Station operating data[a] during the thermal plume survey on 6 May 1976.

Time (EDST)	Unit No.	Temperature Intake (C)	Temperature Discharge (C)	Temperature ΔT[b] (C)	Discharge Flow Rate[c] (cfs)	Total Plant Heat Rejection Rate (10^9 BTU/hr)
1000	1	6.1	12.8	6.7	44	0.77
	2	6.1	13.9	7.8	44	
	3	7.8	13.3	5.5	74	
	4	8.3	15.0	6.7	131	
1100	1	6.1	13.3	7.2	44	0.73
	2	6.7	14.4	7.7	44	
	3	7.8	11.7	3.9	74	
	4	7.8	14.4	6.6	131	
1200	1	6.7	13.3	6.6	44	0.70
	2	6.7	14.4	7.7	44	
	3	7.8	11.1	3.3	74	
	4	7.8	14.4	6.6	131	
1300	1	6.1	12.8	6.7	44	0.74
	2	6.7	13.9	7.2	44	
	3	8.3	11.1	2.8	74	
	4	9.4	17.2	7.8	131	
1400	1	7.8	14.4	6.6	44	0.70
	2	8.3	15.6	7.3	44	
	3	8.9	11.1	2.2	74	
	4	9.4	16.7	7.3	131	
1500	1	7.8	14.4	6.6	44	0.81
	2	8.3	15.6	7.3	44	
	3	9.4	15.6	6.2	74	
	4	8.9	16.1	7.2	131	
1600	1	6.7	13.3	6.6	44	0.82
	2	6.7	14.4	7.7	44	
	3	6.7	12.0	6.1	74	
	4	6.7	13.9	7.2	131	
1700	1	6.7	13.3	6.6	44	0.80
	2	6.7	14.4	7.7	44	
	3	6.7	12.2	5.5	74	
	4	6.7	13.9	7.2	131	
1800	1	6.7	13.3	6.6	44	0.85
	2	6.7	14.4	7.7	44	
	3	6.7	12.8	6.1	74	
	4	7.2	15.0	7.8	131	

Table B-2. continued.

Time (EDST)	Unit No.	Temperature Intake (C)	Temperature Discharge (C)	ΔT[b] (C)	Discharge Flow Rate[c] (cfs)	Total Plant Heat Rejection Rate (10^9 BTU/hr)
1900	1	6.7	13.9	7.2	44	0.86
	2	6.7	14.4	7.7	44	
	3	6.7	12.8	6.1	74	
	4	7.2	15.0	7.8	131	

[a] Station operating data supplied by Station personnel.
[b] Plant ΔT measured at the discharge outlet = 8.1C
[c] Total plant discharge rate = 293cfs.

Table B-3. Station operating data[a] during the thermal plume survey on 1 July 1976.

Time (EDST)	Unit No.	Temperature Intake (C)	Temperature Discharge (C)	ΔT[b] (C)	Discharge Flow Rate[c] (cfs)	Total Plant Heat Rejection Rate (10^9 BTU/hr)
0900	1	-[d]	-	-	-	0.68
	2	18.9	26.7	7.8	44	
	3	20.6	26.7	6.1	74	
	4	20.6	27.1	6.7	131	
1000	1	-	-	-	-	0.84
	2	18.9	26.7	7.8	44	
	3	20.6	31.7	11.1	74	
	4	20.0	26.7	6.7	131	
1100	1	-	-	-	-	0.84
	2	18.9	26.7	7.8	44	
	3	20.6	31.7	11.1	74	
	4	20.0	26.7	6.7	131	
1200	1	-	-	-	-	0.85
	2	18.9	26.7	7.8	44	
	3	20.6	31.7	11.1	74	
	4	20.0	27.2	7.2	131	
1300	1	-	-	-	-	0.57
	2	-	-	-	-	
	3	21.7	30.0	8.3	74	
	4	21.1	27.2	6.1	131	
1400	1	-	-	-	-	0.68
	2	-	-	-	-	
	3	21.1	31.1	10.0	74	
	4	20.0	27.2	7.2	131	
1500	1	16.1	22.2	6.1	44	0.79
	2	-	-	-	-	
	3	19.4	29.4	10.0	74	
	4	20.0	27.2	7.2	131	
1600	1	16.7	22.8	6.1	44	0.76
	2	-	-	-	-	
	3	18.9	27.8	8.9	74	
	4	20.0	27.2	7.2	131	

[a] Station operating data supplied by Station personnel.
[b] Plant ΔT measured at the discharge outlet = 8.2C.
[c] Total plant discharge rate = 249cfs.
[d] Unit not in operation.

Table B-4. Station operating data[a] during the thermal plume survey on 5 August 1976.

Time (EDST)	Unit No.	Temperature: Intake (C)	Temperature: Discharge (C)	Temperature: ΔT^b (C)	Discharge Flow Rate[c] (cfs)	Total Plant Heat Rejection Rate (10^9 BTU/hr)
0400	1	20.0	23.9	3.9	44	0.89
	2	20.0	28.3	8.3	44	
	3	20.0	26.7	6.7	74	
	4	19.4	28.3	8.9	131	
0500	1	20.0	23.3	3.3	44	0.88
	2	20.0	28.3	8.3	44	
	3	20.0	26.7	6.7	74	
	4	19.4	28.3	8.9	131	
0600	1	20.0	23.3	3.3	44	0.89
	2	20.0	28.9	8.9	44	
	3	20.0	26.7	6.7	74	
	4	19.4	28.3	8.9	131	
0700	1	20.0	23.9	3.9	44	0.95
	2	20.0	28.9	8.9	44	
	3	20.0	27.2	7.2	74	
	4	19.4	28.9	9.5	131	
0800	1	19.4	23.3	3.9	44	0.99
	2	19.4	28.3	8.9	44	
	3	19.4	27.2	7.8	74	
	4	18.9	28.9	10.0	131	
0900	1	19.4	23.3	3.9	44	1.02
	2	19.4	28.9	9.5	44	
	3	19.4	27.2	7.8	74	
	4	18.9	29.4	10.5	131	
1000	1	19.4	23.3	3.9	44	1.00
	2	19.4	28.9	9.5	44	
	3	19.4	27.2	7.8	74	
	4	18.9	28.9	10.0	131	
1100	1	19.4	23.3	3.9	44	0.99
	2	19.4	28.3	8.9	44	
	3	19.4	27.2	7.8	74	
	4	18.9	28.9	10.0	131	
1200	1	19.4	23.3	3.9	44	0.99
	2	19.4	28.3	8.9	44	
	3	19.4	27.2	7.8	74	
	4	18.9	28.9	10.0	131	

Table B-4. continued.

Time (EDST)	Unit No.	Temperature Intake (C)	Temperature Discharge (C)	ΔT[b] (C)	Discharge Flow Rate[c] (cfs)	Total Plant Heat Rejection Rate (10^9 BTU/hr)
1300	1	19.4	22.8	3.4	44	0.99
	2	19.4	28.9	9.5	44	
	3	19.4	27.2	7.8	74	
	4	18.9	28.9	10.0	131	
1400	1	19.4	23.3	3.9	44	0.99
	2	19.4	28.3	8.9	44	
	3	19.4	27.2	7.8	74	
	4	18.9	28.9	10.0	131	
1500	1	19.4	22.8	3.4	44	0.98
	2	19.4	28.3	8.9	44	
	3	19.4	27.2	7.8	74	
	4	18.9	28.9	10.0	131	
1600	1	19.4	22.8	3.4	44	0.97
	2	19.4	28.3	8.9	44	
	3	19.4	26.7	7.3	74	
	4	18.9	28.9	10.0	131	
1700	1	19.4	22.8	3.4	44	0.87
	2	19.4	27.8	8.4	44	
	3	19.4	27.2	7.8	74	
	4	1.9	28.9	10.0	131	
1800	1	19.4	22.8	3.4	44	0.97
	2	19.4	27.8	8.4	44	
	3	19.4	26.1	6.7	74	
	4	18.3	28.9	10.6	131	

[a] Station operating data supplied by Station personnel.
[b] Plant ΔT measured at the discharge outlet = 7.4C.
[c] Total plant discharge rate = 293cfs.

Table B-5. Station operating data[a] during the thermal plume survey on 2 September 1976.

Time (EDST)	Unit No.	Temperature Intake (C)	Temperature Discharge (C)	ΔT[b] (C)	Discharge Flow Rate[c] (cfs)	Total Plant Heat Rejection Rate (10^9 BTU/hr)
0800	3	20.0	27.2	7.2	74	0.62
	4	20.6	28.3	7.7	131	
0900	3	20.0	25.6	5.6	74	0.58
	4	20.0	27.8	7.8	131	
1000	3	20.0	26.7	6.7	74	0.61
	4	20.0	27.8	7.8	131	
1100	3	20.0	26.7	6.7	74	0.61
	4	10.0	27.8	7.8	131	
1200	3	20.0	26.7	6.7	74	0.61
	4	20.0	27.8	7.8	131	
1300	3	20.0	26.7	6.7	74	0.61
	4	20.0	27.8	7.8	131	
1400	3	20.0	26.7	6.7	74	0.61
	4	20.0	27.8	7.8	131	
1500	3	20.0	26.7	6.7	74	0.61
	4	20.0	27.8	7.8	131	
1600	3	20.6	27.2	6.6	74	0.61
	4	20.6	28.3	7.7	131	
1700	3	20.6	27.2	6.6	74	0.61
	4	20.6	28.3	7.7	131	
1800	3	20.6	27.2	6.6	74	0.61
	4	20.6	28.3	7.7	131	
1900	3	20.6	27.2	6.6	74	0.61
	4	20.6	28.3	7.7	131	

[a] Station operating data supplied by Station personnel.
[b] Plant ΔT measured at the discharge outlet = 7.2C.
[c] Total plant discharge rate = 205cfs.

Table B-6. Station operating data[a] during the thermal plume survey on 9 December 1976.

Time (EST)	Unit[b] No.	Temperature Intake (C)	Temperature Discharge (C)	ΔT[c] (C)	Discharge Flow Rate[d] (cfs)	Total Plant Heat Rejection Rate (10^9 BTU/hr)
0700	1	3.3	6.7	3.4	44	0.69
	3	3.9	11.1	7.2	74	
	4	4.4	12.2	7.8	131	
0800	1	4.4	7.8	3.4	44	0.69
	3	3.9	11.1	7.2	74	
	4	4.4	12.2	7.8	131	
0900	1	4.4	7.2	2.8	44	0.60
	3	3.9	10.6	6.7	74	
	4	4.4	11.1	6.7	131	
1000	1	3.9	6.7	2.8	44	0.63
	3	3.3	10.0	6.7	74	
	4	3.9	11.1	7.2	131	
1100	1	3.9	6.7	2.8	44	0.60
	3	3.3	10.0	6.7	74	
	4	4.4	11.1	6.7	131	
1200	1	3.9	3.9	0.0	44	0.55
	3	3.3	10.0	6.7	74	
	4	4.4	11.1	6.7	131	
1300	1	3.9	3.9	0.0	44	0.60
	3	1.7	10.0	8.3	74	
	4	4.4	11.1	6.7	131	
1400	1	3.9	3.9	0.0	44	0.55
	3	3.3	10.0	6.7	74	
	4	5.6	12.2	6.6	131	
1500	1	3.9	3.9	0.0	44	0.55
	3	3.3	10.0	6.7	74	
	4	5.6	12.2	6.6	131	
1600	1	3.9	3.9	0.0	44	0.57
	3	2.8	10.0	7.2	74	
	4	5.0	11.7	6.7	131	

B-6. continued.

Time (EST)	Unit[b] No.	Temperature Intake (C)	Temperature Discharge (C)	ΔT[c] (C)	Discharge Flow Rate[d] (cfs)	Total Pleat Heat Rejection Rate (10^9 BTU/hr)
1700	1	3.9	3.9	0.0	44	0.54
	3	2.8	10.0	7.2	74	
	4	5.0	11.1	6.1	131	

[a] Station operating data supplied by Station personnel.
[b] Unit 2 not in operation.
[c] Plant ΔT measured at the discharge outlet = 10.3C
[d] Total plant discharge rate = 249cfs.

APPENDIX C

Abundance and ash-free dry weight of predominant macroinvertebrate taxa.

Table C-1. Abundance and ash-free dry weight of predominant macroinvertebrate taxa at Location K-2, Location K-3 and Location DC-1, 10 June 1976.

Taxa	Location K-2		Location K-3		Location DC-1	
	No./m^2	Ash-free dry wt gm/m^2	No./m^2	Ash-free dry wt gm/m^2	No./m^2	Ash-free dry wt gm/m^2
Gammarus sp.	–[a]	–	6	0.0012	–	–
Amphipoda	–	–	–	–	122	0.0006
Ephemeroptera	–	–	12	ND[b]	–	–
Plecoptera	–	–	–	–	6	ND
Chironomidae	43	ND	122	0.0267	335	0.0049
Simuliidae	6	0.0037	6	ND	–	–
Elmidae	6	0.0055	–	–	–	–
Goniobasis sp.	–	–	6	0.3459	–	–
Miscellaneous	55	0.1222	–	–	12	ND

[a] No organisms collected.
[b] Not determined because value was below detectability limits.

Table C-2. Abundance and ash-free dry weight of predominant macroinvertebrate taxa at Location K-2, Location K-3 and Location DC-1, 9 September 1976.

Taxa	Location K-2		Location K-3		Location DC-1	
	No./m^2	Ash-free dry wt gm/m^2	No./m^2	Ash-free dry wt gm/m^2	No./m^2	Ash-free dry wt gm/m^2
Amphipoda	–[a]	–	12	ND[b]	604	0.1293
Ephemeroptera	24	0.0067	–	–	–	–
Trichoptera	6	0.0043	–	–	24	0.0079
Elmidae	24	0.0037	6	0.0018	–	–
Chironomidae	268	0.0104	–	–	–	–

[a] No organisms collected.
[b] Not determined becasue value was below detectability limits.