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U. S. Nuclear Regulatory Commission
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Subject: McGuire Nuclear Station
Docket Nos. 50-369, 50-370

Pursuant to McGuire Technical Specifications, Appendix B, Section 3.2, please find attached the annual Lake Norman Environmental Summary Report for 1993 as required by NPDES permit NC0024392.

Questions concerning this report should be directed to Kay Crane, McGuire Regulatory Compliance at (704) 875-4306.

Very truly yours,

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LAKE NORMAN: 1993 SUMMARY

MAINTENANCE MONITORING PROGRAM

McGUIRE NUCLEAR STATION: NPDES No. NC0024392

DUKE POWER COMPANY

13339 HAGERS FERRY ROAD

HUNTERSVILLE, NORTH CAROLINA 28078

DECEMBER 1994

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EXECUTIVE SUMMARY

OPERATIONAL DATA

Both units were operational during July, August, and September, when conservation of cool water and discharge temperatures are most critical. The average monthly discharge temperature was below the permit limit for all months and use of low level intake water was not necessary for compliance with the thermal limit for McGuire Nuclear Station (MNS). This helped to conserve habitat for cool water fish in Lake Norman.

THERMAL MODELING

As in the previously submitted 316(a) demonstration report for MNS in 1985, the meteorology for 1953 still provides a worst case scenario for MNS and Marshall Steam Station (MSS) discharge temperatures. The predicted lake surface area affected by the thermal plumes from both MNS and MSS (at 100% load June-August, 90% load the rest of the year) are less than the limit established by these stations' NPDES permits (i.e., 3500 acres). This is true for both the 90°F (32.2°C) isotherm and the 5°F (2.8°C) above background temperature isotherm.

Use of the Low Level Intake (LLI) pumps has not been necessary to maintain compliance with the permitted thermal limits. In the event that LLI pumps have to be used, the predicted thermal profiles indicate that the primary temperature change would occur in the hypolimnion only during August, when these waters are usually anoxic and consequently have very low fish densities.

WATER CHEMISTRY DATA

Temporal and spatial trends in water temperature and DO data collected monthly in 1993 were similar to those observed historically. Reservoir-wide isotherm and isopleth information for 1993, coupled with heat content and hypolimnetic oxygen data, illustrated that Lake Norman exhibited thermal and oxygen dynamics characteristic of historic

conditions and similar to other Southeastern reservoirs of comparable size, depth, flow conditions, and trophic status.

Availability of suitable pelagic habitat for adult striped bass in Lake Norman in 1993 was generally similar to historic conditions. Reservoir-wide habitat elimination was observed to persist for approximately 2 months in the 1993 summer. This is somewhat longer than the duration of complete habitat elimination observed in the summer of 1992, but similar to earlier summers.

All chemical parameters measured in 1993 were within the concentration ranges previously reported for the lake during both MNS preoperational and operational years.

PHYTOPLANKTON DATA

Chlorophyll *a* concentrations at all locations during 1993 were within historical ranges and in the mesotrophic range. They were generally higher than those observed during 1987 through 1990 but were similar to those observed in 1991 and 1992.

Total phytoplankton densities and biovolumes remained similar to those observed in previous years. Phytoplankton taxonomic composition during 1993 was similar to that observed during the same months of 1992. Diatoms, green algae and cryptophytes were the most numerically abundant classes of algae observed. Diatoms and cryptophytes generally dominated the phytoplankton biovolumes in all months except August when the phytoplankton community consisted of a diverse assemblage dominated by small green algae. Dinoflagellates were sporadically dominant in terms of biovolume at some locations during all months except November. Blue-green algae were never a dominant at any location or time in 1993.

ZOOPLANKTON DATA

Total zooplankton standing crops were generally highest in May and lowest in November during 1993. Zooplankton densities, in general, were slightly higher in eplimnetic samples than in whole column samples. Total zooplankton densities at Mixing Zone locations were not significantly different from background locations during any quarter in 1993. The typical

trend of increasing zooplankton densities from downlake to uplake was observed only in November in 1993. The range of total zooplankton densities observed during 1993 was similar to the ranges observed since 1987.

Overall, rotifers dominated zooplankton standing crops in 1993, as they did in 1992, followed closely in importance by copepods. Cladocerans were dominant numerically on only one occasion in 1993. Major rotifer taxa observed in 1993 were *Keratella*, *Polyarthra* and *Synchaeta*. Copepod populations were dominated by immature forms (nauplii and cyclopoid copepodids). As in previous years, *Bosmina* was the most abundant cladoceran taxa observed at all locations. Overall, zooplankton taxonomic composition in 1993 was similar to that observed in previous years.

FISHERIES DATA

Hydroacoustic density estimates of limnetic fish in lower Lake Norman were similar to ranges observed in other areas of the reservoir. Densities were lower in the heated water plume on August 4, 1993, than in the surrounding areas,. A clumped distribution pattern is evident, with densities ranging from less than 10,000 to greater than 90,000/ha in the MNS mixing zone and in areas of the reservoir with ambient water temperatures. Surface water temperatures in the discharge area during August were 35°C. This is higher than the preferred temperatures of threadfin shad, the predominant species in the limnetic area of the reservoir (Duke Power Company 1993).

Nearly all (99.6%) of the fish collected in the purse seine in August were threadfin shad. The only other species sampled with the purse seine in lower Lake Norman was black crappie.

Dead and dying striped bass were observed during the last 2 weeks in July 1993 in the MNS mixing zone. On July 23, fourteen dead striped bass were counted in the main channel from the dam to Marker 7, approximately 6 miles above the dam and 2 miles above the confluence of Davidson Creek and the main channel. On July 30, eleven dead striped bass were counted from the dam to Marker 1A, approximately 1.5 miles above the dam. Only two of the 25 dead striped bass observed were larger than 5 pounds. Anglers fishing the area for striped bass were catching large numbers of fish less than the 20 inch size limit and returning them

to the lake. This likely contributed to the large number of dead small fish observed. Striped bass less than 5 pounds have not been reported in the literature as stressed by high summer water temperatures; however, recent research in Tennessee has shown angling mortalities of greater than 60% for striped bass caught in the summer (Phil Bettoli, personal communication).

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CHAPTER 1
McGUIRE NUCLEAR STATION
OPERATIONAL DATA

INTRODUCTION

In addition to operational data for 1993, results of thermal modeling runs as requested per the NPDES permit are included in this years annual environmental summary report. This modeling was done to assess the impact of 100% load factor during the months of June, July, and August and 90% the remainder of the year.

OPERATIONAL DATA FOR 1993

Both units were operational during July, August, and September, when conservation of cool water and discharge temperatures are most critical (Table 1-1). During these months the thermal limit for MNS increases from a monthly average of 95^{O}F to 99^{O}F. The average monthly discharge temperature was 94.1^{O}F (34.5^{O}C) for July, 91.9^{O}F (33.3^{O}C) for August, and 83.8^{O}F (28.8^{O}C) for September 1993. Use of low level intake water was not necessary for compliance with the thermal limit for MNS. This helped to conserve habitat for cool water fish in Lake Norman. The volume of cool water in Lake Norman is tracked throughout the year to ensure that an adequate volume is available to comply with both the Nuclear Regulatory Commission Technical Specification requirements and the NPDES monthly discharge water temperature limit.

THERMAL MODELING RESULTS

Based on a request made by the North Carolina Department of Environmental Management (NCDEM), Duke Power has completed additional modeling analyses of the thermal regime in Lake Norman resulting from operations at McGuire Nuclear Station (MNS) and Marshall Steam Station (MSS). Specifically, NCDEM requested that Duke "remodel and assess the impact of 100% load factor during the months of June-August and 90% for the remainder of the year."

The model set-up for this additional analysis is basically the same as it was for the June 1985 316(a) demonstration report (Duke Power Company 1985). Please refer to that report for a description of the model, the assumptions made, validation of the model, and predictive results assuming a year-round 90% load factor for both MNS and MSS.

Meteorology

In order to demonstrate worst case conditions, it was necessary to determine which year produced meteorological conditions such that maximum discharge temperatures at MNS and MSS would result. Meteorological records from the Charlotte Airport (approximately 17 miles from MNS and 25 miles from MSS) were obtained for years 1951 through 1993. By running this entire period of meteorological data through the thermal model (set in predictive mode), 1953 produced the highest June-August discharge temperatures, as shown in Table 1-2. (Note that this was also the case for the 316(a) demonstration report submitted in 1985.) Therefore, 1953 meteorological data was used to obtain the model results discussed in the following section.

Results and Discussion

For the 1953 predictive model run, the load (or capacity) factor was 100% for June-August and 90% the remainder of the year. Tables 1-3 through 1-6 provide the model results for both MNS and MSS for the June-August period when both stations were operating at 100%. Note that results for the months having a capacity factor of 90% are given in the 316(a) demonstration report (Duke Power Company 1985).

Table 1-3 provides Condenser Cooling Water (CCW) data for both MNS and MSS. Although this data is fairly self-explanatory, the discharge temperature and CCW usage at

MNS warrant further discussion. The thermal model (when run in a predictive mode) will not let monthly average discharge temperatures at MNS exceed 37.2°C (99.0°F). To accomplish this, the Low Level Intake pumps (LLI) at MNS are judiciously used to bring cool water from the bottom of Lake Norman to the surface so it can be mixed with the warmer water brought in by the Upper Level Intake pumps (ULI) located near the surface of Lake Norman. In doing this, the overall temperature of the intake water at MNS is reduced enough to keep the station's discharge temperature in compliance with its 37.2°C (99.0°F) monthly average discharge limit during the summer months. Refer to the MNS 316(a) demonstration report (Duke Power Company 1985) for a description and drawings of the LLI and ULI pumping structures.

For the June-August period, LLI water requirements for the 1953 predictive run were 0 cfs, 108 cfs, and 173 cfs, respectively (Table 1-3). This amount of flow is very small when compared to the overall station CCW requirements of 4580 cfs. Thus, the majority of CCW water used for the 1953 worst case scenario comes from the surface waters of Lake Norman and only a small amount from the cooler bottom layers. This is reflected in the predicted thermal profiles for June, July, and August (Figure 1-1). For the vast majority of years, the model predicts that the LLI pumps will not have to operate to comply with the stations NPDES discharge temperature limit, even with capacity factors of 100% during the summer months. This has also been the experience of station personnel since the 37.2°C (99.0°F) monthly average discharge limit was granted. Use of the LLI pumps has not been necessary to maintain compliance with the permitted thermal limits. In the event that LLI pumps have to be used, the predicted thermal profiles indicate that the primary temperature change would occur in the hypolimnion during only August, when these waters are usually anoxic and consequently have very low fish densities (See Chapters 2 and 5)

Table 1-4 provides the hydrological and meteorological parameters used for the 1953 predictive model run. Note that the river flow values are simulated Cowans Ford Hydro discharge flow rates. Also, the meteorological data was obtained from the Charlotte Airport.

The lake surface area and shore-line affected by the 90°F (32.2°C) isotherm resulting from predicted thermal discharges from MNS and MSS are given in Table 1-5. The largest 90°F (32.2°C) isotherm from MNS occurred during July (1897 acres, or approximately 7% of Lake Norman's total surface area). For MSS, the largest 90°F (32.2°C) isotherm occurred during August (336 acres, or approximately 1% of Lake Norman's total surface area). Note that neither of these isotherm acreages are greater than the limits established in these stations' NPDES permits (i.e., 3500 acres). Maximum shore-line affected by the 90°F (32.2°C) isotherm is 25 km (16 mi), or 3% of the total shore-line for MNS and 3 km (2 mi), or approximately 0.05% of the total shore-line for MSS.

The lake surface area and shore-line affected by the 5°F (2.8°C) above background temperature isotherm resulting from predicted thermal discharges from MNS and MSS are given in Table 1-6. The largest area affected by MNS occurred during August (2100 acres, or approximately 7% of Lake Norman's total surface area). For MSS, the largest area also occurred during August (579 acres, or approximately 2% of Lake Norman's total surface area). Note that neither of these isotherm acreages are greater than the limits established in these stations' NPDES permits (i.e., 3500 acres). Maximum shore-line affected by the 5°F (2.8°C) above background isotherm is 27 km (17 mi),or 3% of the total shore-line for MNS and 9 km (6 mi), or approximately 1% of the total shore-line for MSS.

SUMMARY

1. The meteorology for 1953 still provides a worst case scenario for MNS and MSS discharge temperatures. Note that 1953 meteorological data was also used to predict worst case conditions in the 1985 MNS 316(a) demonstration report.
2. Use of the LLI pumps have not been necessary to maintain compliance with the current permitted thermal limits. In the event that LLI pumps has to be used, the predicted thermal profiles indicate that the primary temperature change would occur in the hypolimnion only during August, when these waters are usually anoxic and consequently have very low fish densities.
3. The predicted lake surface area affected by the thermal plumes from both MNS and MSS (at 100% load June-August, 90% load the rest of the year) are less than the limit established by these stations' NPDES permits (i.e., 3500 acres). This is true for both the 90°F (32.2°C) isotherm and the 5°F (2.8°C) above background temperature isotherm.

LITERATURE CITED

Duke Power Company. 1985. McGuire Nuclear Station, 316(a) Demonstration. Duke Power Company, Charlotte, NC.

Table 1-1. **Average monthly capacity factors (%) calculated from daily unit capacity factors [Net Generation (Mwe per unit day) x 100 / 24 h per day x 1129 mw per unit] and monthly average discharge water temperatures for McGuire Nuclear Station during 1993**

Month	CAPACITY FACTOR (%)			TEMPERATURE	
	Unit 1 Average	Unit 2 Average	Station Average	Monthly Average °F	°C
January	101.0	101.9	101.4	67.0	19.4
February	101.90	89.0	95.4	65.1	18.4
March	35.2	94.9	65.1	61.3	16.3
April	0	101.8	50.7	69.3	20.7
May	0	98.1	48.7	75.0	23.9
June	38.2	78.0	58.1	84.0	28.9
July	96.6	0	47.9	94.1	34.5
August	65.2	0	32.0	91.9	33.3
September	0	34.2	16.5	83.8	28.8
October	40.3	49.2	44.8	76.8	24.9
November	95.3	100.1	97.7	75.5	24.2
December	100.6	82.8	91.7	69.6	20.9

Table 1-2: Predicted MNS discharge temperatures (MNS and MSS capacity factors = 100% June, July, and August; 90% the remainder of the year).

YR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JUN-AUG AVG
1951	72.5	71.5	74.8	77.4	84.1	91.2	98.0	99.0	94.1	86.9	77.3	73.7	96.1
1952	73.9	74.5	74.9	77.7	83.7	96.0	99.0	98.7	92.1	84.2	76.7	74.4	97.9
1953	73.7	74.2	74.9	78.7	86.7	97.0	98.9	98.6	93.4	86.1	75.1	73.5	98.2
1954	71.1	73.9	75.7	79.3	82.7	90.9	98.1	99.0	94.1	86.5	75.9	71.4	96.0
1955	71.2	71.2	75.1	80.1	85.8	91.3	98.3	97.8	92.0	84.4	76.4	71.7	95.8
1956	68.3	74.4	74.9	77.1	84.0	91.7	98.0	98.3	91.1	82.2	77.4	74.8	96.0
1957	73.2	74.4	74.8	77.9	85.1	92.9	98.3	96.5	92.3	80.9	75.6	74.7	95.9
1958	68.3	69.2	74.1	77.1	83.2	92.6	97.8	98.5	91.6	83.5	77.2	71.3	96.3
1959	69.7	73.3	74.3	78.9	86.0	92.4	96.3	98.5	91.5	85.9	76.8	73.6	95.7
1960	72.2	71.6	68.6	77.9	82.6	93.0	97.3	96.8	91.8	85.5	75.7	71.9	95.7
1961	70.2	70.6	75.1	75.2	81.8	90.8	96.1	96.5	92.2	84.3	79.2	74.3	94.5
1962	70.2	72.6	74.3	77.5	86.7	93.4	95.7	95.3	91.2	84.8	74.8	69.7	94.8
1963	68.6	67.9	74.1	80.4	83.7	91.2	95.0	97.1	90.6	83.7	76.7	70.8	94.4
1964	69.0	70.0	73.3	77.8	84.1	92.7	95.3	95.4	90.5	81.5	78.0	74.8	94.5
1965	72.2	72.6	73.7	78.7	87.7	92.8	96.0	96.8	92.5	83.2	76.4	74.2	95.2
1966	70.1	69.8	74.0	77.1	84.0	91.4	97.1	96.0	91.6	83.1	77.0	72.7	94.8
1967	70.7	71.0	74.3	80.4	81.5	89.5	95.3	96.0	88.8	83.1	76.2	74.8	93.6
1968	68.3	70.0	73.5	79.4	83.5	90.9	97.2	98.5	90.8	84.8	76.8	71.9	95.5
1969	68.7	71.3	72.1	79.0	84.6	92.7	98.5	96.4	90.9	83.6	76.0	70.4	95.9
1970	67.0	71.3	75.2	78.2	85.5	91.8	95.8	95.6	93.1	84.9	77.4	74.4	94.4
1971	69.8	68.9	74.5	77.4	82.7	91.4	95.9	95.1	92.4	86.1	78.8	74.7	94.1
1972	74.5	70.1	75.5	77.6	82.1	88.3	94.8	95.1	90.5	81.5	77.0	73.6	92.7
1973	70.7	69.4	74.6	76.4	81.3	92.0	96.6	96.3	92.9	84.9	75.9	72.8	95.0
1974	74.8	74.6	75.5	77.8	83.7	90.9	94.5	94.5	89.0	81.0	76.9	71.2	93.3
1975	73.2	74.7	74.5	77.1	85.9	92.1	94.6	98.1	92.2	84.9	79.0	73.6	94.9
1976	68.9	74.0	75.4	78.7	82.3	89.1	94.7	94.7	88.9	82.6	74.7	70.8	92.8
1977	65.0	68.3	75.5	79.5	83.8	91.8	98.5	97.4	93.9	82.6	77.3	73.2	95.9
1978	68.1	66.8	72.2	79.6	82.1	94.0	98.2	98.9	95.0	83.1	79.0	74.2	97.0
1979	68.2	67.0	75.0	79.9	84.3	90.6	94.4	96.9	91.2	82.1	77.5	73.8	94.0
1980	70.7	69.4	73.1	78.9	82.9	92.1	97.9	98.5	95.5	83.4	76.4	72.5	96.2
1981	66.6	70.6	74.7	79.2	82.1	94.2	97.0	94.9	90.9	81.4	75.7	70.9	95.4
1982	67.2	72.4	74.7	77.4	84.9	93.6	98.8	98.2	90.9	83.9	76.7	74.9	96.9
1983	69.9	72.0	75.2	76.5	82.3	89.4	96.8	98.1	93.6	83.0	76.0	72.9	94.8
1984	67.4	72.4	73.6	76.1	81.7	90.6	95.4	95.9	90.5	84.9	78.3	74.8	94.0
1985	69.6	69.0	75.2	78.8	85.6	93.3	96.6	96.3	92.0	85.7	79.8	73.7	95.4
1986	68.3	71.8	74.2	79.8	84.9	94.6	99.0	98.0	91.7	87.0	78.4	74.6	97.2
1987	70.4	70.9	74.0	77.2	83.0	92.6	98.9	98.9	93.8	81.8	76.0	74.1	96.8
1988	67.7	71.5	75.2	79.4	83.9	91.3	96.3	98.7	90.9	81.8	75.2	73.3	95.4
1989	73.7	74.2	74.9	78.0	82.3	92.8	96.7	96.1	91.6	83.5	78.1	69.6	95.2
1990	71.9	75.9	75.2	77.8	84.9	92.7	97.7	98.0	94.2	86.2	77.7	75.0	96.1
1991	73.5	73.8	76.4	80.1	85.6	92.8	98.3	97.1	93.6	84.3	76.6	74.7	96.1
1992	72.1	74.1	76.1	78.7	80.4	86.9	97.0	95.4	92.8	81.9	77.6	73.4	93.1
1993	73.0	71.9	73.1	77.0	82.5	93.0	99.0	98.2	94.7	83.3	76.3	73.1	96.7

Table 1-3: MNS and MSS Operating Conditions for 1953 Predictive Run.

MO / YR	McGUIRE NUCLEAR STATION						MARSHALL STEAM STATION				
	Total CCW cfs	LLI CCW cfs	CCW ΔT °C (°F)	Capacity Factor (%)	Intake Temp °C (°F)	Discharge Temp °C (°F)	CCW Flow cms (cfs)	CCW ΔT °C (°F)	Capacity Factor (%)	Intake Temp °C (°F)	Discharge Temp °C (°F)
Jun / 1953	4580	0	9.0 (16.2)	100	27.0 (80.6)	36.0 (96.8)	51 (1784)	11.2 (20.1)	100	17.7 (63.9)	28.9 (84.0)
Jul / 1953	4580	108	9.1 (16.3)	100	28.2 (82.7)	37.2 (99.0)	59 (2068)	9.6 (17.3)	100	22.9 (73.3)	32.6 (90.6)
Aug/ 1953	4580	173	9.1 (16.4)	100	27.8 (82.1)	36.9 (98.5)	64 (2264)	8.8 (15.8)	100	26.4 (79.6)	35.2 (95.4)

Table 1-4: Hydrological and Meteorological Parameters for 1953 Predictive Run.

MO / YR	HYDROLOGICAL			METEOROLOGICAL				
	Background Temp °C (°F)	Water Surface Elevation m (ft)	River Flow cms (cfs)	Dry Bulb °C (°F)	Dew Point °C (°F)	Cloud Cover (%)	Solar Radiation LY/Day	Wind Speed at height = 26 m m/s (mph)
Jun / 1953	28.2 (82.8)	230.1 (755.0)	42 (1472)	24.6 (76.3)	18.6 (65.5)	60	511.0	2.19 (4.9)
Jul / 1953	29.6 (85.2)	229.4 (752.5)	36 (1256)	26.3 (79.4)	19.1 (66.4)	60	513.2	2.15 (4.8)
Aug/ 1953	29.2 (84.5)	230.1 (755.0)	36 (1274)	25.2 (77.3)	18.1 (64.5)	40	486.1	1.83 (4.1)

Table 1-5: 90°F (32.2°C) Isotherms for MNS and MSS for 1953 Predictive Run.

90°F (32.2°C) ISOTHERM												
	McGUIRE NUCLEAR STATION				MARSHALL STEAM STATION				TOTAL OF BOTH PLANTS			
MO / YR	Surface Area Ha (ac)	Lake[1] Surface %	Shore-line km (mi)	Lake[2] Shore %	Surface Area Ha (ac)	Lake[1] Surface %	Shore-line km (mi)	Lake[2] Shore %	Surface Area Ha (ac)	Lake[1] Surface %	Shore-line km (mi)	Lake[2] Shore %
Jun/ 1953	400 (990)	3	17 (11)	2	0 (0)	0	0 (0)	0	400 (990)	3	17 (11)	2
Jul/ 1953	768 (1897)	7	25 (16)	3	6 (14)	0	0 (0)	0	774 (1911)	7	25 (16)	3
Au/ 1953	625 (1545)	5	22 (14)	3	136 (336)	1	3 (2)	0	761 (1881)	6	25 (16)	3

Table 1-6: 5°F (2.8°C) Above Background Temperature Isotherm for MNS and MSS 1953 Predictive Run.

5°F (2.8°C) ABOVE BACKGROUND TEMPERATURE ISOTHERM												
	McGUIRE NUCLEAR STATION				MARSHALL STEAM STATION				TOTAL OF BOTH PLANTS			
MO / YR	Surface Area Ha (ac)	Lake[1] Surface %	Shore-line km (mi)	Lake[2] Shore %	Surface Area Ha (ac)	Lake[1] Surface %	Shore-line km (mi)	Lake[2] Shore %	Surface Area Ha (ac)	Lake[1] Surface %	Shore-line km (mi)	Lake[2] Shore %
Jun/ 1953	797 (1969)	7	25 (16)	3	0 (0)	0	0 (0)	0	797 (1969)	7	25 (16)	3
Jul/ 1953	768 (1897)	7	25 (16)	3	6 (14)	0	0 (0)	0	774 (1911)	7	25 (16)	3
Au/ 1953	850 (2100)	7	27 (17)	3	234 (579)	2	9 (6)	1	1084 (2679)	9	36 (22)	4

1. Lake surface areas (based on monthly water surface elevations): June 11780 Ha (29100 ac); July 11030 Ha (27250 ac); August 11780 Ha (29100 ac).

2. Based on total shoreline mileage of 840 km (522 mi).

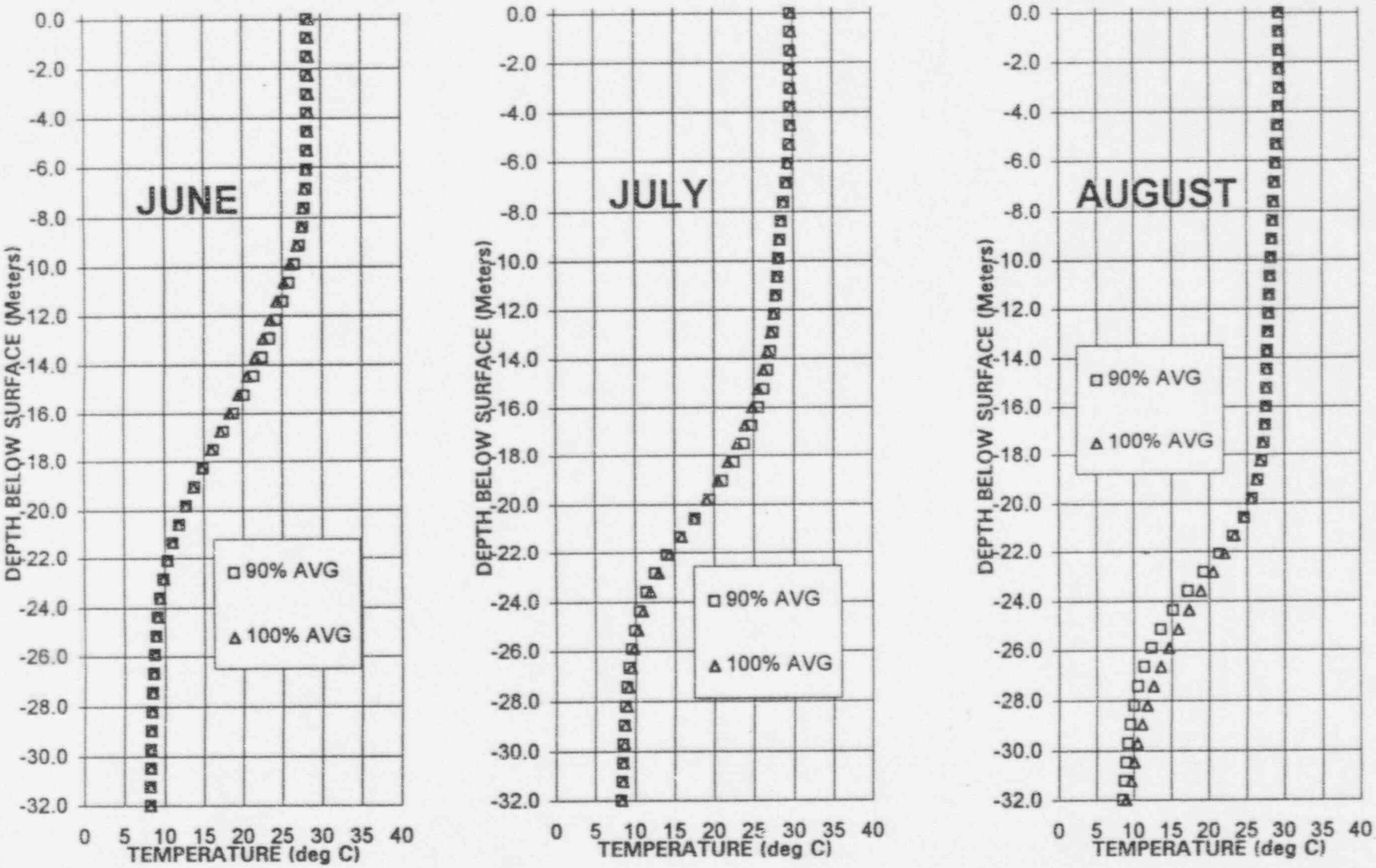

Figure 1-1. Predicted average temperature profile comparisons for capacity factors of 90% and 100% at both MNS and MSS.

CHAPTER 2
WATER CHEMISTRY

INTRODUCTION

The objectives of the water chemistry portion of the McGuire Nuclear Station (MNS) NPDES Maintenance Monitoring Program are to:

1) maintain continuity in Lake Norman's chemical data base so as to allow detection of any significant station-induced and/or natural change in the physicochemical structure of the lake; and
2) compare, where appropriate, these physicochemical data to similar data in other hydropower reservoirs and cooling impoundments in the Southeast.

This year's report focuses primarily on 1992 and 1993. Where appropriate, reference to pre-1992 data will be made by citing reports previously submitted to the North Carolina Department of Environment, Health, and Natural Resources (NCDEHNR).

METHODS AND MATERIALS

The complete water chemistry monitoring program, including specific variables, locations, depths, and frequencies is outlined in Table 2-1. Sampling locations are identified in Figure 2-1, whereas specific chemical methodologies, along with the appropriate references are presented in Table 2-2. Data were analyzed using two approaches, both of which were consistent with earlier studies (Duke Power Company 1985, 1987, 1988a, 1989, 1990, 1991, 1992, 1993). The first method involved partitioning the reservoir into mixing, background, and discharge zones, and making comparisons among zones and years. In this report, the discharge includes only Location 4; the mixing zone encompasses Locations 1 and 5; the background zone includes Locations 8, 11, and 15. The second approach emphasized a much broader lake-wide investigation and encompassed the plotting of monthly isotherms and isopleths, and summer-time striped bass habitat. Several quantitative calculations were also performed. These included the calculation of the areal hypolimnetic oxygen deficit (AHOD), maximum whole-water column and hypolimnion heat content, mean epilimnion and hypolimnion heating rates over the stratified period, and the Birgean heat budget.

RESULTS AND DISCUSSION

Precipitation Amount

Precipitation in the vicinity of MNS measured about 46 inches in 1993, compared to 49 inches in 1992 (Figure 2-2.). The wettest month of 1993 was March in which 8.65 inches of precipitation fell.

Temperature and Dissolved Oxygen

Water temperatures measured in 1993 illustrated similar temporal and spatial trends in the background and mixing zones (Figures 2-3, 2-4). Water temperatures in the winter and spring of 1993 were generally equal to or cooler throughout the water column as compared to 1992 in both zones (Figure 2-3, 2-4). The only exception to this occurred in February when epilimnion temperatures in the mixing zone were 2 to 5°C (3.6 to 9.0°F) warmer than the background zone. Both zones exhibited slightly warmer epilimnion and metalimnion temperatures in the summer of 1993 than in 1992 with the greatest between year differences (3 to 5°C or 5.4 to 9.0°F) measured in July and September. Fall temperatures were similar throughout the reservoir in 1992 and 1993. Despite some seasonal and spatial variability in temperature data between 1992 and 1993, the 1993 temperatures were well within the historic range (Duke Power Company 1985, 1989, 1991, 1993). Temperature data at the discharge location in 1993 were generally similar to or slightly cooler than measured in 1992 (Figure 2-5) and historically (Duke Power Company 1985, 1987, 1988a, 1989, 1990, 1991, 1992, 1993). The warmest temperature at the discharge location in 1993 occurred in August and measured 35.3°C (95.5°F), slightly less than the historic maximum of 36.3°C (97.3°F) measured in August, 1991 (Duke Power Company 1992).

Seasonal and spatial patterns of DO in 1993 were reflective of the patterns exhibited for temperature, i. e., generally similar in both the mixing and background zones (Figures 2-6 and 2-7). Winter and spring DO values generally ranged from about 0.2 to 2.0 mg/l higher throughout the water column in both zones in 1993 than in 1992, and were well within the historic range (Duke Power Company 1985, 1987, 1988a, 1989, 1990, 1991, 1992, 1993). Summer DO values in 1993 were generally lower throughout the water column in both the mixing and background zones than observed in 1992, but within the historic range (Duke Power Company 1985, 1987, 1988a, 1989, 1990, 1991, 1992, 1993). These lower values in 1993 may be related, at least partially, to the warmer water temperatures in 1993 which would decrease oxygen solubility and increase microbial respiration (Wetzel 1975). Fall DO values were generally similar between the two years. Some differences were observed in November but these data are probably a reflection of meteorological differences influencing the rate of water column cooling and reoxygenation. Interannual differences in DO are common in Southeastern reservoirs, particularly during the stratified period, and can reflect yearly differences in hydrological, meteorological, and limnological forcing variables (Cole and Hannon 1985; Petts1984).

The seasonal pattern of DO in 1993 at the discharge location was similar to that measured historically, with the highest values observed during the winter and lowest observed in the summer and early-fall (Figure 2-5). Generally, DO values in 1993 were either equal to or slightly less than in 1992, but within the historic range (Duke Power Company 1985, 1987, 1988a, 1989, 1990, 1991, 1992, 1993). The lowest DO concentration measured at the discharge location in 1993 (4.1 mg/l) occurred in August and was slightly lower than the August, 1992, low of 5.0 mg/l (Figure 2-5).

Reservoir-wide Temperature and Dissolved Oxygen

The monthly reservoir-wide temperature and dissolved oxygen data for 1993 are presented in Figures 2-8 and 2-9. For the most part, the temporal and spatial distributional patterns of both temperature and dissolved oxygen are similar to other cooling impoundments and hydropower reservoirs in the Southeast (Cole and Hannon 1985; Petts 1984). During the winter cooling and mixing period, vertical rather than horizontal homogeneity in temperature predominated, with the shallower uplake 'riverine' zone exhibiting slightly cooler temperatures than the deeper downlake 'lacustrine' zone (Figure 2-8). These longitudinal

differences in temperatures were clearly illustrated in January and February. The principal factors influencing this gradient in Lake Norman are thermal discharges from MSS and MNS, morphometric (depth) differences within the reservoir, and surface water inputs from the upper reaches of the reservoir.

The heating period in Lake Norman generally begins in March, as more heat is gained at the water's surface than is lost at night. During the initial stages of the heating period, buoyancy forces "smooth out" the horizontal differences in temperature, thereby reducing temperature differences between up-reservoir and down-reservoir locations. Due to the vertical instability of the water column during this period, temperature increases are observed at all depths. These points are illustrated by contrasting the January and February temperature data with the March and April data (Figure 2-8). As solar radiation and air temperatures increase, heating occurs at a greater rate in the upper waters than in the mid or bottom waters due to differential thermal absorption and vertical density differences (Wetzel 1975, Ford 1985). Eventually, differential heating at the surface leads to the formation of the classical epilimnion, metalimnion, and hypolimnion zones. These zones are clearly depicted in the July, 1993 data (Figure 2-8).

In contrast to most natural lakes, but not unlike many reservoirs in the Southeast, a distinct thermocline within the metalimnion was not observed in Lake Norman in 1993 and is consistent with that observed in previous years (Duke Power Company 1992, 1993). Rather, the metalimnion was more or less continuous with respect to vertical density differences within the lower water column, and even showed signs of merging with the hypolimnion, as illustrated in the August data (Figure 2-8).

Cooling of the water column began in early September as illustrated by decreases in surface temperatures compared to August data. Concurrent with decreases in surface temperatures was an increase in the depth of the epilimnion (caused by convective mixing) and a disruption of the horizontal homogeneity in epilimnion temperatures (caused by reservoir-wide differential heating and cooling, and advective inputs from upstream). Continuation of these differential vertical and horizontal processes led to even more pronounced thermal differences within the reservoir. For example, by October the uplake riverine zone had already 'turned over', while the downlake lacustrine zone was still strongly stratified. Not until early November was Lake Norman completely mixed vertically throughout the

reservoir. Morphometric, and in particular, depth differences throughout the longitudinal reaches of the reservoir, coupled with seasonal variability in the volume and density of upstream inputs are major contributors to these horizontal gradients of heating and cooling in reservoirs (Ford 1986; Imberger 1987 ; Petts 1984).

Distributional patterns of dissolved oxygen in 1993 were similar to but not identical to temperature (Figure 2-9). Generally, dissolved oxygen concentrations were greatest during the winter cooling and mixing period when biological respiration was at a minimum and atmospheric reaeration was at a maximum. The highest reservoir-wide mean concentration of dissolved oxygen (11.6 mg/l) occurred in March when the reservoir exhibited a mean temperature of 8.7°C or 47.7°F (Figure 2-8). Unlike the thermal regime, no major longitudinal differences existed in dissolved oxygen within the reservoir during the winter. Not until the lake became stratified, thereby isolating the metalimnion and hypolimnion from atmospheric reaeration and vertical water mass exchanges, were uplake-to-downlake gradients in dissolved oxygen observed. Longitudinal gradients in metalimnetic and hypolimnetic dissolved oxygen in 1993 were first observed in May. Differential dissolved oxygen depletion and eventual anoxia were first observed in the transitional zone (Locations 15 through 62) where hypolimnetic volume is small, water column and sediment organic matter high, and advective mixing minimal. This longitudinal and progressive display of oxygen depletion has been reported for many southern U.S. impoundments (Hannon et. al., 1979; Cole and Hannon 1985; Petts 1984). By August, the complete hypolimnion throughout the reservoir below elevation 219 m was anoxic. This represents approximately 22% of the entire volume of the lake at full pond. Complete hypolimnetic deoxygenation (below the thermocline) in natural lakes is indicative of the net effect of cultural eutrophication (Wetzel 1975). Alternatively, the occurrence of hypoxia in reservoirs is influenced by a combination of hydrologic, hydraulic, morphometric and limnological factors (Cole and Hannon 1985; Petts 1984; Ruane 1989).

Reaeration of the water column started in September concomitantly with the cooling and mixing of the reservoir. Decreasing air temperatures cooled the surface waters resulting in a convective deepening, aided by wind-induced mixing, of the epilimnion. As the oxygenated epilimnion eroded progressively deeper into the water column, the width of the anoxic zone decreased. Longitudinal differences in reaeration were also observed and apparently were related to differential mixing caused by MNS and MSS, and upstream advective inputs from

Lookout Shoals Hydroelectric Facility. Reaeration of the reservoir was essentially complete by early November, except for the bottom waters in the downlake "lacustrine" zone.

Table 2-3 presents some common quantitative limnological calculations for the thermal environment in Lake Norman. Few comparable calculations exist in the literature for reservoirs, but these data are generally within the "ballpark" of those presented by Hutchinson (1957) for natural lakes at similar latitudes throughout the world.

Table 2-4 presents the 1993 AHOD for Lake Norman compared to similar estimates for 18 TVA reservoirs. The data illustrate that Lake Norman exhibits an AHOD that is similar to other Southeastern reservoirs of comparable depth, chlorophyll a status, and secchi depth.

Striped Bass Habitat

Suitable pelagic habitat for adult striped bass, defined as that layer of water with temperatures ≤ 26 C and DO levels ≥ 2.0 mg/l, was found lake-wide from October 1992 through June 1993. Beginning in late June, habitat reduction proceeded rapidly throughout the reservoir both as a result of deepening of the 26°C isotherm and metalimnetic and hypolimnetic deoxygenation (Figure 2-10). Complete habitat elimination occurred sometime in mid-July and persisted until mid-September, or about 2 months. Refugia for adult striped bass were recorded during this period but these areas were of limited size and restricted to the uplake, riverine sections of the reservoir just below the Lookout Shoals Hydroelectric facility. Physicochemical habitat was observed to expand appreciably in late September, primarily as a result of epilimnion cooling, and in response to changing meteorological conditions The temporal and spatial pattern of striped bass habitat expansion and reduction observed in 1993 was similar to that previously reported in Lake Norman and many other Southeastern reservoirs (Coutant 1985, Matthews 1985; DPC 1992, DPC 1993). The duration of complete habitat elimination in 1993 was greater than observed in 1992 but well within the historic range.

Turbidity and Specific Conductance

Surface turbidity values were low at the MNS discharge, mixing zone, and mid-lake background locations during 1992 and 1993, ranging from 2-6 NTUs (Table 2-5). Bottom turbidity values were also low over the two-year period, ranging form 1-10 NYUs (Table 2-5). These values were well within the range (Duke Power Company 1989, 1990, 1991, 1992).

Specific conductance in Lake Norman in 1993 ranged from 51 to 88 umho/cm and was similar to that observed in 1992 (Table 2-5) and historically (Duke Power Company 1989,1992). Specific conductance in surface and bottom waters was generally similar throughout the year except in late fall at several of the deeper locations when bottom waters averaged about 20-40 umhos/cm higher than surface values. These increases in conductance were undoubtedly related to the release of soluble iron and manganese from the lake bottom under anoxic conditions (Table 2-5).

pH and Alkalinity

During 1993, pH and alkalinity values were similar among MNS discharge, mixing, and mid-lake-lake background zones (Table 2-5); they were also similar to values measured in 1992 (Table 2-5) and historically (DPC 1989,1992). Individual pH values in 1993 ranged from 6.1 to 6.9, whereas alkalinity ranged from 10.6 to 23.8 mg-$CaC0^{3}$/l.

Major Cations and Anions

The concentrations (mg/l) of major ionic species in the MNS discharge, mixing, and mid-lake background zones are provided in Table 2-5. The overall ionic composition of Lake Norman during 1993 was similar to that reported for 1992 (Table 2-5) and previously (Duke Power Company 1989,1992). Lake-wide, the major cations were sodium, calcium, magnesium, and potassium; major anions were bicarbonate, sulfate, and chloride.

Nutrients

Nutrient concentrations in the discharge, mixing, and mid-lake background zones of Lake Norman are provided in Table 2-5. Overall, nitrogen and phosphorus levels in 1993 were similar to those measured in 1992 and historically (Duke Power Company 1989, 1990, 1991, 1992); they are also characteristic of the lake's oligo-mesotrophic status (Rodriguez 1982). Ammonia nitrogen concentrations increased in bottom waters in each of the three zones during the summer and fall, concurrent with the development of anoxic conditions. Total and soluble phosphorus concentrations in 1993 were similar to values recorded in 1992 and historically (Duke Power Company 1989, 1990, 1991, 1992 , 1993).

Metals

Metal concentrations in the discharge, mixing, and mid-lake background zones of Lake Norman for 1993 were similar to that measured in 1992 (Table 2-5) and historically (DPC 1989, 1990, 1991, 1992, 1993). Iron concentrations near the surface were generally low (≤ 0.1 mg/l) during 1992 and 1993, whereas iron levels near the bottom were slightly higher during the stratified period, particularly in early fall. Similarly, manganese concentrations in the surface and bottom waters were generally low (≤ 0.1 mg/l) in both 1992 and 1993, except during the summer and fall when bottom waters approached or became anoxic (Table 2-5). Manganese concentrations near the bottom rose above the NC water quality standard (0.5 mg/l) at various locations throughout the lake in summer and fall of both years, and is characteristic of historic conditions (Duke Power Company 1989,1990,1991, 1992, 1993). Heavy metal concentrations in Lake Norman never approached NC water quality standards, and there were no consistent appreciable differences between 1992 and 1993.

FUTURE STUDIES

No changes are planned for the Water Chemistry portion of the Lake Norman maintenance monitoring program during 1994.

SUMMARY

Temporal and spatial trends in water temperature and DO data collected monthly in 1993 were similar to those observed historically. Temperature and DO data collected in 1993 were within the range of previously measured values.

Reservoir-wide isotherm and isopleth information for 1993, coupled with heat content and hypolimnetic oxygen data, illustrated that Lake Norman exhibited thermal and oxygen dynamics characteristic of historic conditions and similar to other Southeastern reservoirs of comparable size, depth, flow conditions, and trophic status.

Availability of suitable pelagic habitat for adult striped bass in Lake Norman in 1993 was generally similar to historic conditions. Reservoir-wide habitat elimination was observed to persist for approximately 2 months in 1993. This is somewhat longer than the duration of complete habitat elimination observed in 1992, but similar to that in earlier years.

All chemical parameters measured in 1993 were within the concentration ranges previously reported for the lake during both MNS preoperational and operational years. As has been observed historically, manganese concentrations in the bottom waters in the summer and fall of 1993 often exceeded the NC water quality standard.

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Table 2-1. Water chemistry program for the McGuire Nuclear Station NPDES long-term maintenance monitoring on Lake Norman.

McGUIRE NPDES SAMPLING PROGRAM
Sample Collection Schedule for 1993

PARAMETERS	LOCATIONS	1.0	2.0	4.0	5.0	8.0	9.5	11.0	13.0	14.0	15.0	15.9	62.0	69.0	72.0	80.0	16.0
	DEPTH (m)	33	33	5	20	32	23	27	21	10	23	23	15	7	5	4	3
	SAM CODE							IN-SITU ANALYSIS									
Temperature	Hydrolab																
Dissolved Oxygen	Hydrolab																
pH	Hydrolab																
Conductivity	Hydrolab																
								NUTRIENT ANALYSES									
Ammonia	AA-Nut	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Nitrate+Nitrite	AA-Nut	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Orthophosphate	AA-Nut	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Total Phosphorus	AA-TP,DG-P	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Silica	AA-Nut	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Cl	AA-Nut	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
TKN	AA-TKN	S/T,B												S/T,B			
								ELEMENTAL ANALYSES									
Aluminum	ICP-24		S/T,B	S/T		Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Calcium	ICP-24	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Iron	ICP-24	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Magnesium	ICP-24	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Manganese	ICP-24	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Potassium	306-K	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Sodium	ICP-24	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Zinc	ICP-24	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Cadminum	HGA-CD		S/T,B	S/T		S/T,B	S/T,B			S/T		S/T,B					S/T
Copper	HGA-CU		S/T,B	S/T		S/T,B	S/T,B			S/T		S/T,B					S/T
Lead	HGA-PB		S/T,B	S/T		S/T,B	S/T,B			S/T		S/T,B					S/T
								ADDITIONAL ANALYSES									
Alkalinity	T-ALKT	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Turbidity	F-TURB	Q/T,B	Q/T,B	Q/T	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T,B	Q/T		Q/T,B		Q/T,B			S/T
Sulfate	UV_SO4		S/T,B	S/T		S/T,B				S/T		S/T,B					S/T
Total Solids	S-TSE		S/T,B	S/T		S/T,B				S/T		S/T,B					S/T
Total Suspended Solid	S-TSSE		S/T,B	3/T		S/T,B				S/T		S/T,B					S/T

In-situ measurements are collected monthly at the above locations at 1m intervals from 0.3m to 1m above bottom. Measurements are taken weekly from July-August for striped bass habitat.

CODES: Frequency Q = Quarterly (Feb, May, Aug, Nov) S = Semi-annually (Feb,Aug)
T = Top (0.3m) B = Bottom (1m above bottom)

Table 2-2. Water chemistry methods and analyte detection limits for the McGuire Nuclear Station NPDES long-term maintenance program for Lake Norman.

Variables	Method	Preservation	Detection Limit
Alkalinity, total	Electrometric titration to a pH of 5.1[3]	4°C	1mg-$CaCO_3 \cdot l^{-1}$*
Aluminum	Atomic emission/ICP-direct injection[2]	0.5% HNO_3	0.3 $mg \cdot l^{-1}$
Ammonium	Automated phenate[1]	4°C	0.050 $m \cdot gl^{-1}$
Cadmium	Atomic absorption/graphite furnace-direct injection[2]	0.5% HNO_3	0.1 $\mu g \cdot l^{-1}$
Calcium	Atomic emission/ICP-direct injection[2]	0.5% HNO_3	0.04 $mg \cdot l^{-1}$
Chloride	Automated ferricyanide[1]	4°C	1.0 $mg \cdot l^{-1}$
Conductance, specific	Temperature compensated nickel electrode[1]	In-situ	1 $\mu mho \cdot cm^{-1}$*
Copper	Atomic absorption/graphite furnace-direct injection[2]	0.5% HNO_3	0.5 $\mu g \cdot l^{-1}$
Fluoride	Potentiometric[2]	4°C	0.10 $mg \cdot l^{-1}$
Iron	Atomic emission/ICP-direct injection[2]	0.5% HNO_3	0.1 $mg \cdot l^{-1}$
Lead	Atomic absorption graphite furnace-direct injection[2]	0.5% HNO_3	2.0 $\mu g \cdot l^{-1}$
Magnesium	Atomic emission/ICP-direct injection[2]	0.5% HNO_3	0.001 $mg \cdot l^{-1}$
Manganese	Atomic emission/ICP-direct injection[2]	0.5% HNO_3	0.003 $mg \cdot l^{-1}$
Nitrite + Nitrate	Automated cadmium reduction[1]	4°C	0.050 $mg \cdot l^{-1}$
Orthophosphate	Automated ascorbic acid reduction[1]	4°C	0.005 $mg \cdot l^{-1}$
Oxygen, dissolved	Temperature compensated polarographic cell[1]	In-situ	0.1 $mg \cdot l^{-1}$*
pH	Temperature compensated glass electrode[1]	In-situ	0.1 std. units*
Phosphorus, total	Persulfate digestion followed by automated ascorbic acid reduction[1]	4°C	0.005 $mg \cdot l^{-1}$** 0.015 $mg \cdot l^{-1}$**
Potassium	Atomic absorption graphite furnace-direct injection[2]	0.5% HNO_3	0.1 $mg \cdot l^{-1}$
Silica	Automated molydosilicate[1]	4°C	0.5 $mg \cdot l^{-1}$
Sodium	Atomic emission/ICP-direct injection[2]	0.5% HNO_3	0.3 $m \cdot gl^{-1}$
Sulfate	Turbidimetric, using a spectrophotometer[3]	4°C	1.0 $mg \cdot l^{-1}$
Temperature	Thermistor/thermometer[1]	In-situ	0.1°C*
Turbidity	Nephelometric turbidity[1]	4°C	1 NTU*
Zinc	Atomic emission/ICP-direct injection[2]	0.5% HNO_3	4 $\mu g \cdot l^{-1}$

[1]United States Environmental Protection Agency 1979. Methods for chemical analysis of water and wastes. Environmental Monitoring and Support Laboratory. Cincinnati, OH.

[2]USEPA. 1982.

[3]USEPA. 1984

*Instrument sensitivity used instead of detection limit.

**Detection limit changed during 1989.

Table 2-3. Heat content calculations for the thermal regime in Lake Norman in 1993.

Maximum areal heat content	28,141 g cal cm^{2}
Maximum hypolimnetic (below 11.5 m) areal heat content	15,106 g cal cm^{2}
Birgean heat budget	19,251 g cal cm^{2}
Epilimnion (above 11.5 m) heating rate	0.114 C/day
Hypolimnion (below 11.5 m) heating rate	0.087 C/day

Table 2-4. A comparison of areal hypolimnetic oxygen deficits (AHOD), summer chlorophyll a (chl a), secchi depth (SD), and mean depth of Lake Norman and 18 TVA reservoirs.

Reservoir	AHOD ($mg/cm^2/day$)	Summer Chl a (ug/L)	Secchi Depth (m)	Mean Depth (m)
Lake Norman	0.057	5.0	3.0	10.3
TVA [a]				
Mainstem				
Kentucky	0.012	9.1	1.0	5.0
Pickwick	0.010	3.9	0.9	6.5
Wilson	0.028	5.9	1.4	12.3
Wheelee	0.012	4.4		5.3
Guntersville	0.007	4.8	1.1	5.3
Nickajack	0.016	2.8	1.1	6.8
Chickamauga	0.008	3.0	1.1	5.0
Watts Bar	0.012	6.2	1.0	7.3
Fort London	0.023	5.9	0.9	7.3
Tributary				
Chatuge	0.041	5.5	2.7	9.5
Cherokee	0.078	10.9	1.7	13.9
Douglas	0.046	6.3	1.6	10.7
Fontana	0.113	4.1	2.6	37.8
Hiwassee	0.061	5.0	2.4	20.2
Norris	0.058	2.1	3.9	16.3
South Holston	0.070	6.5	2.6	23.4
Tims Ford	0.059	6.1	2.4	14.9
Watauga	0.066	2.9	2.7	24.5

[a] Data from Higgins et al. (1980), and Higgins and Kim (1981)

Table 2-5. Quarterly surface (o.3 m) and bottom (bottom minus 1 m) water chemistry for the MNS discharge, mixing zone, and background locations on Lake Norman during 1993. Values less than detection were assumed to be the detection limit for calculating a mean.

LOCATION	Mixing Zone 1.0				Mixing Zone 2.0				MNS Discharge 4.0	
DEPTH	Surface		Bottom		Surface		Bottom		Surface	
PARAMETERS YEAR	'92	'93	'92	'93	'92	'93	'92	'93	'92	'93
Turbidity (ntu)										
Feb	2	4	3	6	3	4	3	5	3	3
May	NS	6	6	10	4	5	6	9	NS	7
Aug	2	2	1	6	2	2	2	7	2	2
Nov	3	3	4	6	2	3	7	7	3	2
Annual Mean	2.33	3.75	3.5	7	2.75	3.5	4.5	7	2.67	3.5
Specific Conductance (umho/cm)										
Feb	59	56	60	54	58	56	61	55	59	57
May	60	51	60	51	61	46	60	51	61	50
Aug	60	51	78	63	60	51	77	60	61	52
Nov	58	55	95	88	59	52	89	89	60	53
Annual Mean	59.5	53.3	73.3	64	59.5	51.3	71.8	63.8	60.3	53
pH (units)										
Feb	5.9	6.8	6.6	6.8	6.6	6.8	6.9	6.8	6.9	6.7
May	6.8	6.6	6.6	6.3	6.7	5.8	6.6	6.3	6.6	6.4
Aug	7	6.5	6.3	6.1	7	6.3	6.3	6	6.6	6
Nov	6.6	6.9	6.4	6.8	6.7	6.7	6.3	6.9	6.6	6.6
Annual Mean	6.58	6.7	6.48	6.5	6.8	6.4	6.53	6.5	6.68	6.43
Alkalinity (mg CaCO3/l)										
Feb	12.9	11.1	13	11.3	12.8	11.6	13	11.3	12.8	11.5
May	NS	10.8	12.9	10.6	12.8	10	12.8	10.6	NS	10.9
Aug	11.3	11.7	15.4	15.9	12.2	11.8	16.7	15.8	12	11.8
Nov	12.7	12.5	21.5	23.8	12.5	12.7	14.9	24.8	12.6	13.3
Annual Mean	12.3	11.5	15.7	15.4	12.6	11.5	14.4	15.7	12.5	11.9
Chloride (mg/l)										
Feb	5	2.6	5.4	2.5	5.7	2.7	6	2.3	6.4	2.6
May	NS	4.1	7.9	4	5.2	3.5	5.4	4.2	NS	3.7
Aug	5.2	4.5	6	4.7	5.2	4	5.9	3.5	6	4
Nov	4.7	4.1	5	4.1	4.7	4.4	5.6	4.2	4.9	4.2
Annual Mean	4.97	3.83	6.08	3.83	5.2	3.65	5.73	3.55	5.77	3.63
Sulfate (mg/l)										
Feb	NS	NS	NS	NS	6	13.9	5.9	4.1	5.9	3.7
Aug	NS	NS	NS	NS	NS	5	NS	5.5	NS	5.3
Annual Mean					6	7.52	5.9	4.35	5.9	4.21
Calcium (mg/l)										
Feb	2.6	2.5	2.6	2.6	2.7	2.5	2.6	2.6	2.6	2.5
May	NS	2.5	NS	2.6	NS	2.5	NS	2.6	NS	2.5
Aug	2.5	2.7	2.9	3.3	2.5	2.7	3	3.3	2.5	2.8
Nov	2.5	2.7	3.1	3.5	2.6	2.6	2.6	3.6	2.7	2.6
Annual Mean	2.53	2.6	2.87	3	2.6	2.58	2.73	3.03	2.6	2.6
Magnesium (mg/l)										
Feb	1.2	1.2	1.3	1.2	1.3	1.2	1.3	1.2	1.3	1.2
May	NS	1.1	1.2	1.1	1.1	1.1	1.1	1.1	NS	1.1
Aug	1.2	1.2	1.3	1.3	1.2	1.2	1.4	1.3	1.2	1.3
Nov	1.3	1.3	1.4	1.4	1.3	1.2	1.3	1.4	1.3	1.2
Annual Mean	1.23	1.2	1.3	1.25	1.23	1.18	1.28	1.25	1.27	1.2

LOCATION	Mixing Zone 5.0				Background 8.0				Background 11.0			
DEPTH	Surface		Bottom		Surface		Bottom		Surface		Bottom	
PARAMETERS YEAR	'92	'93	'92	'93	'92	'93	'92	'93	'92	'93	'92	'93
Turbidity (ntu)												
Feb	2	4	4	4	2	4	3	7	4	10	10	11
May	NS	5	6	9	NS	5	8	12	NS	12	10	8
Aug	2	3	4	11	2	2	4	8	3	3	4	9
Nov	2	2	6	4	2	2	10	2	2	4	12	2
Annual Mean	2	3.5	5	7	2	3.25	6.25	7.25	3	7.25	9	7.5
Specific Conductance (umho/cm)												
Feb	57	58	57	55	64	55	57	52	67	50	68	50
May	60	53	60	54	60	51	61	51	61	48	61	49
Aug	60	51	73	61	60	51	74	59	61	52	74	61
Nov	59	52	59	51	58	51	62	84	58	55	61	55
Annual Mean	59	53	62.3	55.3	60.5	52	63.5	61.5	61.8	51.3	66	53.8
pH (units)												
Feb	6.9	6.8	7	6.8	7	6.9	7	6.8	7	6.9	6.9	6.8
May	6.8	6.8	6.6	6.3	6.9	6.9	6.7	6.3	6.9	7.1	6.7	6.3
Aug	7	6.4	6.4	6.1	7.2	6.5	6.4	6	7.2	6.5	6.3	6.1
Nov	6.8	6.7	6.4	6.8	6.8	6.9	6.2	6.8	6.9	6.8	6.2	6.8
Annual Mean	6.88	6.68	6.6	6.5	6.98	6.8	6.58	6.48	7	6.83	6.53	6.5
Alkalinity (mg CaCO3/l)												
Feb	12.8	11.3	12.7	11.6	13.1	11.5	12.7	10.9	13.3	10.8	13.6	10.8
May	NS	11.4	12.8	11.4	NS	10.7	12.8	10.3	NS	10.8	12.8	10.1
Aug	12	11.9	16.5	16.2	12	11.8	16.6	16	12.5	12.3	16.6	16.4
Nov	12.4	12.7	12.8	12.5	12.5	13.1	12.1	13.1	12.3	13.3	11.9	13.6
Annual Mean	12.4	11.8	13.7	12.9	12.5	11.8	13.6	12.6	12.7	11.8	13.7	12.7
Chloride (mg/l)												
Feb	5.4	2.9	5.4	2.5	7	2.6	5.3	2.3	6.8	2.2	7.2	2
May	NS	3.7	5.1	3.8	NS	4.3	5.7	4.2	NS	3.2	5.8	3.2
Aug	5.2	5	6.6	4.1	5.6	5	6.1	5.2	5.6	7	5.8	4
Nov	4.7	4.4	4.8	4.3	3.6	4.3	5.2	4.3	6.4	5.1	5.7	4.1
Annual Mean	5.1	4	5.48	3.68	5.4	4.05	5.58	4	6.27	4.38	6.06	3.33
Sulfate (mg/l)												
Feb	NS	NS	NS	NS	7	4.1	5.3	3.8	NS	NS	NS	NS
Aug	NS	NS	NS	NS	NS	6	NS	5.6	NS	NS	NS	NS
Annual Mean					7	4.72	5.3	4.4				
Calcium (mg/l)												
Feb	2.7	2.5	2.6	2.6	2.6	2.5	2.7	2.6	2.7	2.7	2.7	2.7
May	NS	2.6	NS	2.7	NS	2.6	NS	2.6	NS	2.8	NS	2.5
Aug	2.5	2.8	3	3.1	2.5	2.8	3.1	3.4	2.8	2.9	3.1	3.4
Nov	2.6	2.7	2.5	2.6	2.7	2.6	2.3	2.6	2.8	2.6	2.3	2.6
Annual Mean	2.6	2.65	2.7	2.75	2.6	2.63	2.7	2.8	2.83	2.7	2.7	2.8
Magnesium (mg/l)												
Feb	1.3	1.2	1.3	1.2	1.3	1.2	1.3	1.2	1.3	1.2	1.3	1.2
May	NS	1.1	1.2	1.2	NS	1.1	1.1	1.1	NS	1.1	1.2	1.1
Aug	1.2	1.2	1.3	1.3	1.2	1.3	1.4	1.3	1.2	1.3	1.4	1.4
Nov	1.3	1.3	1.3	1.3	1.3	1.2	1.3	1.3	1.3	1.2	1.3	1.2
Annual Mean	1.27	1.2	1.28	1.25	1.27	1.2	1.28	1.23	1.27	1.2	1.3	1.23

NS = Not Sampled

Table 2-5. Continued.

LOCATION:	Mixing Zone 1.0				Mixing Zone 2.0				MNS Discharge 4.0		Mixing Zone 5.0				Background 8.0				Background 11.0			
DEPTH:	Surface		Bottom		Surface		Bottom		Surface		Surface		Bottom		Surface		Bottom		Surface		Bottom	
PARAMETERS YEAR:	'92	93	'92	93	'92	93	'92	93	'92	93	'92	93	'92	93	'92	93	'92	93	'92	93	'92	93
Potassium (mg/l)																						
Feb	1.6	1.6	1.6	1.7	1.9	1.8	1.6	1.7	1.6	1.8	1.6	1.7	1.8	1.7	1.7	1.8	1.8	1.7	1.8	1.7	1.9	1.8
May	NS	1.7	1.7	1.6	1.7	1.7	1.7	1.6	NS	1.5	NS	1.4	1.7	1.7	NS	1.7	1.7	1.7	NS	1.8	1.7	1.8
Aug	1.6	1.4	1.7	1.6	1.7	1.4	1.7	1.5	1.8	1.4	1.8	1.5	1.7	1.4	1.8	1.5	1.7	1.5	1.8	1.5	1.7	1.5
Nov	1.7	1.5	1.8	1.7	1.7	1.8	1.6	1.6	1.7	1.8	1.7	1.8	1.7	1.4	1.7	1.5	1.5	1.8	1.7	1.5	1.8	1.5
Annual Mean	1.63	1.6	1.7	1.65	1.75	1.63	1.75	1.6	1.63	1.58	1.63	1.55	1.88	1.35	1.67	1.63	1.7	1.83	1.7	1.63	1.78	1.6
Sodium (mg/l)																						
Feb	12.9	5.4	6.3	5	19.9	5.3	5.2	5.2	7.8	5.3	6.5	5.5	5.8	5.2	8.1	5	8.2	4.4	9.4	4.1	15.8	4
May	NS	3.9	6.8	3.8	6.4	3.8	6.4	3.8	NS	3.8	NS	3.9	6.8	4	NS	3.9	6.4	3.8	NS	3.8	6.1	3.5
Aug	5.5	4.2	6.2	4	5.5	4.2	6.2	4.1	5.4	4.2	5.5	4.2	8	4.1	5.8	4.2	6.3	4	5.8	4.3	6.2	4
Nov	5.5	5	5.9	4.3	5.5	4.8	6.1	4.2	5.8	4.8	5.7	4.9	5.8	4.8	5.7	5	6.2	5	5.7	5.3	6.4	5.3
Annual Mean	7.97	4.63	6.25	4.28	9.33	4.55	5.98	4.33	6.2	4.53	5.9	4.63	6.05	4.53	6.47	4.53	6.78	4.3	6.9	4.38	8.56	4.2
Aluminum (mg/l)																						
Feb	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
May	NS	0.2	NS	0.2	NS	0.2	NS	0.2	NS	0.2	NS	0.2	NS	0.2	NS	0.2	NS	0.2	NS	0.2	NS	0.2
Aug	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Nov	NS	0.2	NS	0.2	NS	0.2	NS	0.2	NS	0.2	NS	0.2	NS	0.2	NS	0.2	NS	0.2	NS	0.2	NS	0.2
Annual Mean	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Iron (mg/l)																						
Feb	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.1
May	NS	0.1	0.1	0.2	0.1	0.1	0.1	0.2	NS	0.1	NS	0.1	0.1	0.1	NS	0.1	0.1	0.2	NS	0.2	0.2	0.1
Aug	0.1	0.1	0.1	0.4	0.1	0.1	0.2	0.8	0.1	0.1	0.1	0.1	0.3	0.8	0.1	0.1	0.3	0.8	0.1	0.1	0.2	0.7
Nov	0.1	0.1	0.4	4.5	0.1	0.1	0.4	5.9	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.4	0.1	0.1	0.1	0.5	0.1
Annual Mean	0.1	0.1	0.16	1.3	0.1	0.1	0.2	1.7	0.1	0.1	0.1	0.1	0.18	0.28	0.1	0.1	0.23	0.3	0.1	0.13	0.3	0.25
Manganese (mg/l)																						
Feb	0.01	0.01	0.02	0.03	0.02	0.01	0.02	0.02	0.02	0.01	0.02	0.01	0.03	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.08	0.02
May	NS	0.01	0.02	0.02	0.01	0.01	0.02	0.02	HS	0.01	NS	0.01	0.02	0.05	NS	0.01	0.01	0.02	NS	1.93	0.04	0.01
Aug	0.02	0.01	0.99	1.58	0.03	0.02	1.5	1.84	0.08	0.07	0.03	0.03	1.41	1.25	0.03	0.01	1.48	1.59	0.02	0.05	1.5	1.9
Nov	0.04	0.11	3.1	3.63	0.04	0.13	1.27	3.52	0.07	0.15	0.04	0.13	0.19	0.1	0.03	0.06	0.32	0.08	0.04	0.09	0.28	0.09
Annual Mean	0.02	0.04	1.03	1.32	0.03	0.04	0.7	1.3	0.05	0.06	0.03	0.05	0.41	0.36	0.02	0.02	0.46	0.43	0.03	0.52	0.47	0.51
Cadmium (ug/l)																						
Feb	NS	0.1	NS	0.1	0.1	0.1	0.1	0.1	0.1	0.1	NS	0.1	NS	0.5	0.1	0.1	0.1	0.1	NS	0.1	NS	0.1
Aug	NS	NS	NS	NS	NS	0.1	NS	0.1	NS	0.1	NS	NS	NS	NS	NS	0.1	NS	0.1	NS	NS	NS	HS
Annual Mean		0.1		0.1	0.1	0.1	0.1	0.1	0.1	0.1		0.1		0.5	0.1	0.1	0.1	0.1		0.1		0.1
Copper (ug/l)																						
Feb	1.1	1.3	5.3	1.2	1.3	1.2	1	1.1	1.2	1.2	0.9	1	1.5	1.8	1.2	1.1	1.1	1.4	1.8	1.8	1.4	1.3
Aug	NS	NS	NS	NS	1.5	2.9	0.8	0.6	1.5	1.5	NS	NS	NS	NS	1.3	1.2	1.1	0.5	NS	NS	NS	NS
Annual Mean	1.1	1.3	5.3	1.2	1.4	2.05	0.9	0.85	1.35	1.35	0.9	1	1.5	1.8	1.25	1.15	1.1	0.95	1.8	1.8	1.4	1.3
Lead (ug/l)																						
Feb	2	NS	2	NS	2	2	2	2	2	2	2	NS	2	NS	2	2	2	2	2	NS	2	NS
Aug	2	NS	2	NS	2	2	2	2	2	2	2	NS	2	NS	2	2	2	2	2	NS	2	NS
Annual Mean	2		2		2	2	2	2	2	2	2		2		2	2	2	2	2		2	
Zinc (ug/l)																						
Feb	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
May	NS	10	NS	10	NS	10	NS	10	NS	10	NS	10	NS	10	NS	10	NS	10	NS	10	NS	10
Aug	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	20	10	10
Nov	NS	10	NS	10	NS	10	NS	10	NS	10	NS	10	NS	10	NS	10	NS	10	NS	12	NS	10
Annual Mean	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	13	10	10

NS = Not Sampled

Table 2-5. Continued.

LOCATION:	Mixing Zone 1.0				Mixing Zone 2.0				MNS Discharge 4.0		Mixing Zone 5.0				Background 8.0				Background 11.0			
DEPTH:	Surface		Bottom		Surface		Bottom		Surface		Surface		Bottom		Surface		Bottom		Surface		Bottom	
PARAMETERS YEAR:	'92	93	'92	93	'92	93	'92	93	'92	93	'92	93	'92	93	'92	93	'92	93	'92	93	'92	93
Nitrate (ug/l)																						
Feb	177	143	189	158	174	140	203	148	180	148	160	140	158	148	219	142	158	188	248	203	283	205
May	NS	270	228	386	219	296	266	359	NS	292	NS	288	220	329	NS	285	247	358		237	273	356
Aug	127	83	335	[illegible]	150	305	309	95	211	128	153	114	227	88	127	88	298	288	89	67	299	223
Nov	106	88	87	50	137	89	183	50	99	85	90	107	98	83	94	91	178	94	145	104	187	149
Annual Mean	137	148	210	225	170	208	235	183	183	183	134	157	178	157	147	141	220	232	153	153	283	233
Ammonia (ug/l)																						
Feb	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	74	50
May	NS	50	50	50	50	50	50	50	NS	50	NS	50	50	50	NS	50	50	50		50	50	50
Aug	50	50	50	82	50	99	81	50	89	50	50	50	83	188	89	50	111	117	50	78	73	101
Nov	50	191	253	861	82	119	178	729	50	151	80	129	74	101	50	98	112	105	50	145	88	149
Annual Mean	50	85.3	101	211	58	79.5	84.3	220	56.3	75.3	53.3	89.8	84.3	92.3	56.3	81.5	80.8	80.5	50	80.3	71.3	87.5
Total Phosphorous (ug/l)																						
Feb	NS	18	NS	9	NS	18	NS	13	NS	12	NS	9	NS	11	NS	15	NS	14	NS	28	NS	19
May	NS	11	NS	14	NS	12	NS	14	NS	13	NS	1	NS	1	NS	13	NS	17	NS	16	NS	20
Aug	9	5	6	5	7	7	7	7	7	7	11	6	10	7	8	7	8	8	5	7	8	8
Nov	9	8	7	8	9	8	18	11	7	5	8	6	12	6	7	8	22	8	6	7	23	8
Annual Mean	9	9.5	6.5	9	9	10.3	12.5	11.3	7	9.25	9.5	5.5	11	6.25	7.5	10.3	15	11.8	5.5	14	15.5	13.3
Orthophosphate (ug/l)																						
Feb	NS	5	NS	6	NS	5	NS	5	NS	5	NS	5	NS	5	NS	5	NS	7	NS	6	NS	6
May	NS	5	NS	10	NF	5	NS	7	NS	1	NS	7	NS	8	NS	5	NS	8	NS	12	NS	13
Aug	11	5	8	7	5	5	9	5	9	5	5	5	7	5	5	5	5	4	6	5	7	5
Nov	8	7	8	8	8	8	13	8	10	5	10	5	11	5	11	5	12	6	13	7	11	11
Annual Mean	9.5	5.5	8	7.75	6.5	5.75	9.5	6.25	9.5	4	7.5	5.5	9	5.75	8	5	8.5	6.25	9.5	6	9	8.75
Silica (mg/l)																						
Feb	5.3	4.2	5.1	4.3	5.1	4.2	5.2	4.2	5.1	4.2	5	4.1	5	4.2	5.4	4.2	4.9	4.5	5.[illegible]	4.5	5.5	4.8
May	NS	4.2	5	4.5	4.9	4.1	5	4.3	NS	4.3	NS	4.2	5	4.4	NS	4.1	5	4.3	NS	4.1	5.1	4.5
Aug	3.7	3.5	4.9	4.5	3.7	4.7	5	3.6	3.8	3.6	3.8	3.5	4.8	4.4	3.8	3.4	5.1	4.8	3.8	3.9	4.9	4.6
Nov	4	4.4	4.9	5.6	4.2	4.3	4.7	5.7	3.9	4.4	3.9	4.4	4.2	4.4	3.8	4.3	4.8	4.4	4.1	4.9	5	5
Annual Mean	4.33	4.[illegible]	4.98	4.73	4.48	4.33	4.98	4.45	4.27	4.13	4.23	4.05	4.75	4.35	4.27	4	4.95	4.5	4.33	4.35	5.13	4.88

NS = Not Sampled

Figure 2-1. Sampling locations on Lake Norman, North Carolina during maintenance monitoring program for McGuire Nuclear Station.

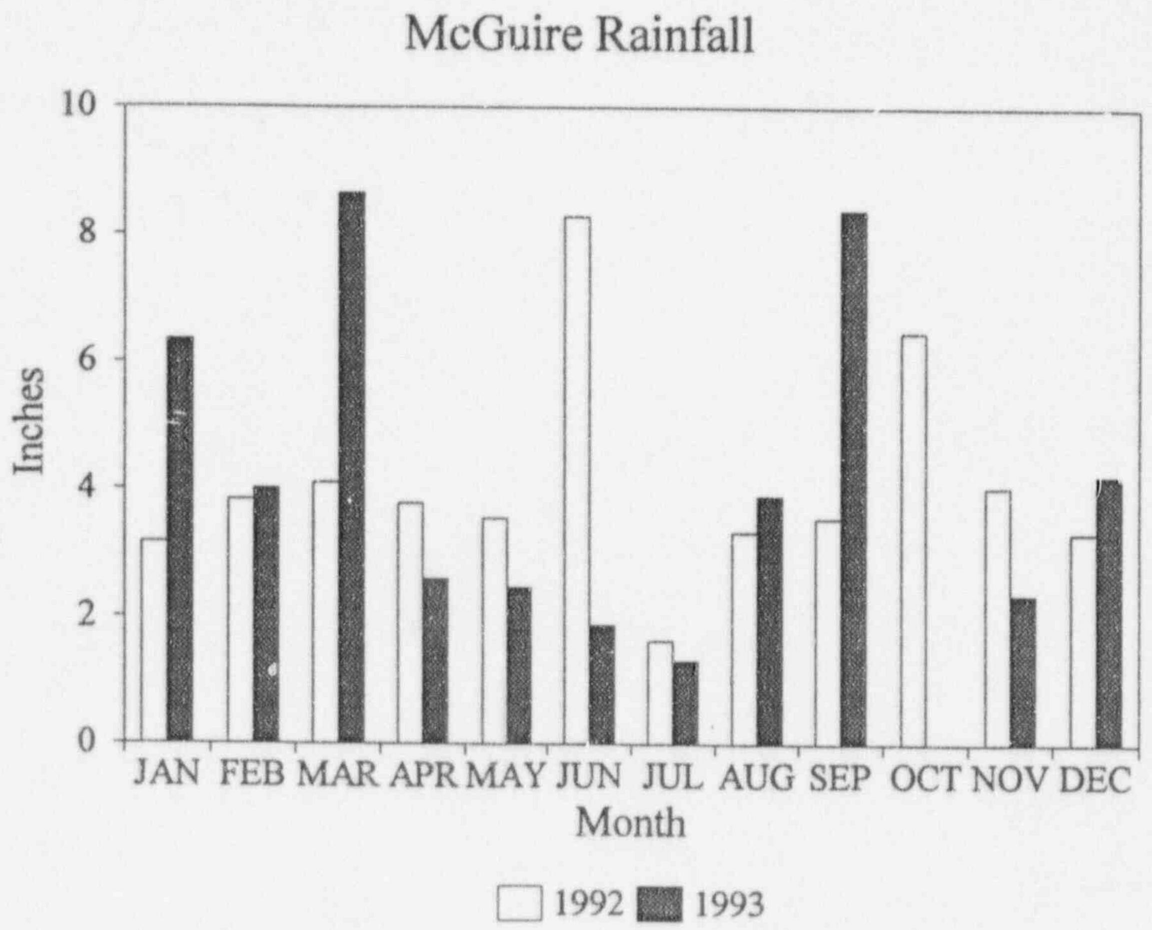

Figure 2-2. Monthly precipitation in the vicinity of McGuire Nuclear Station.

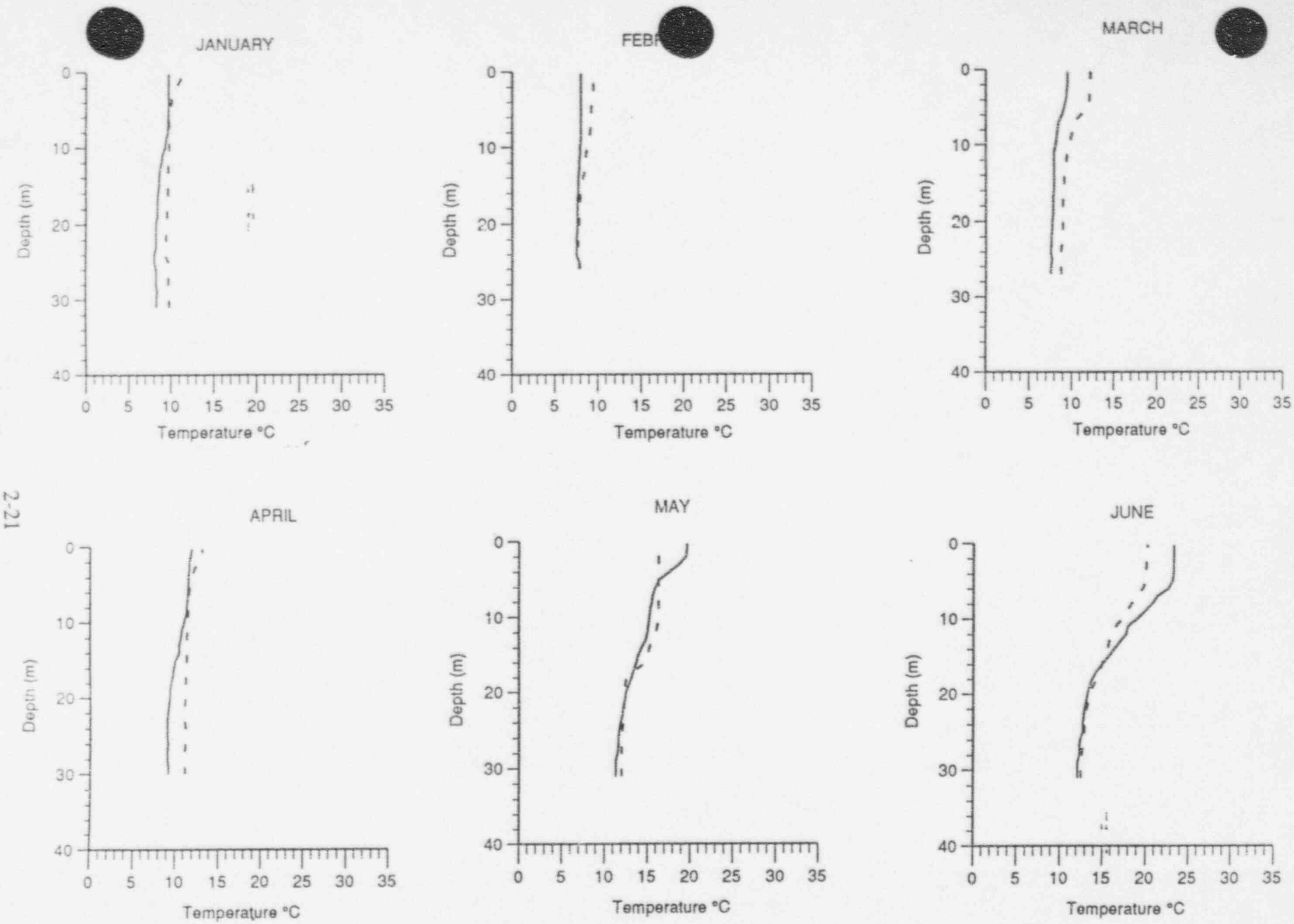

Figure 2-3. Monthly mean temperature profiles for the McGuire Nuclear Station background zone in 1992 (…) and 1993 (—).

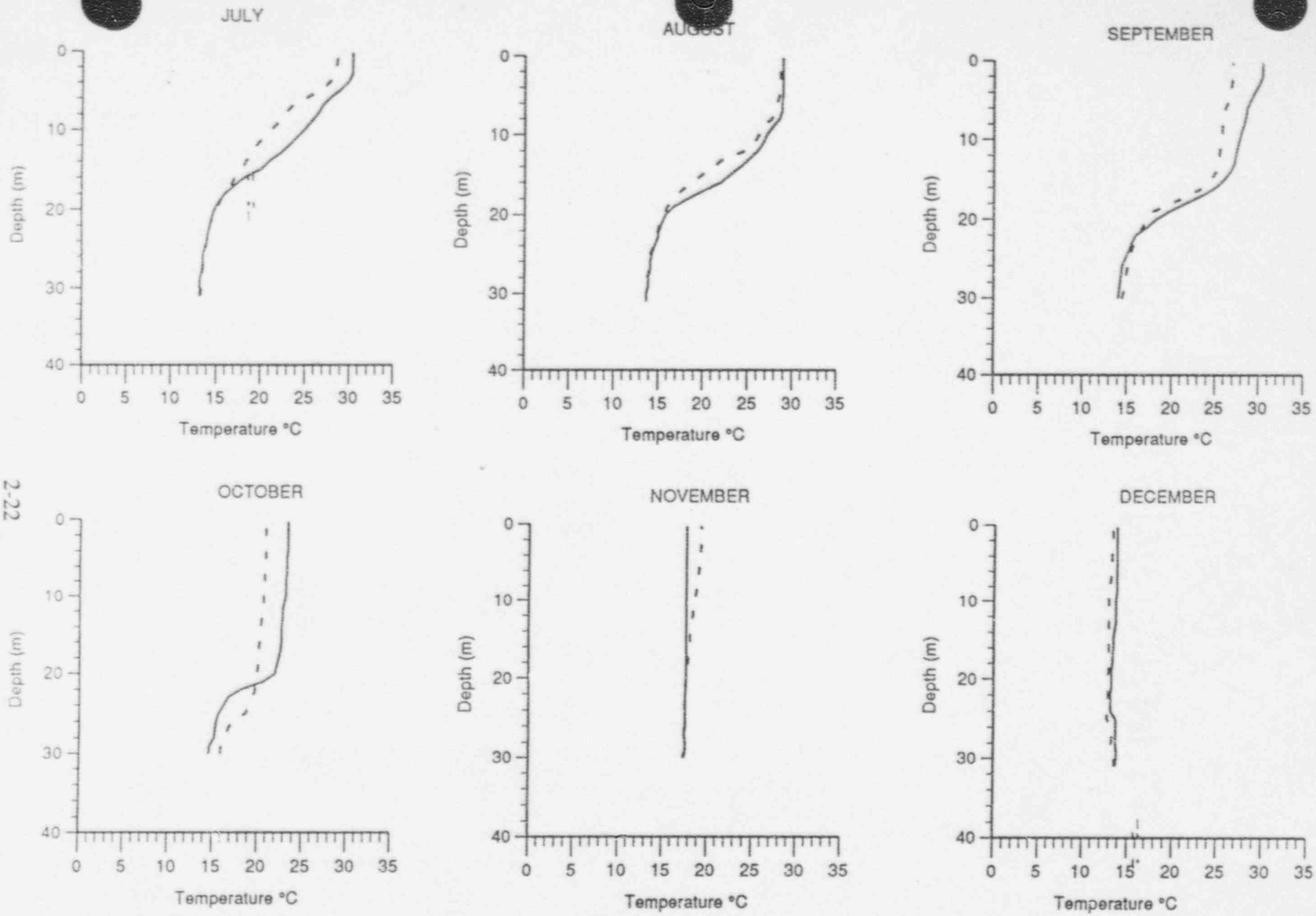

Figure 2-3. Continued.

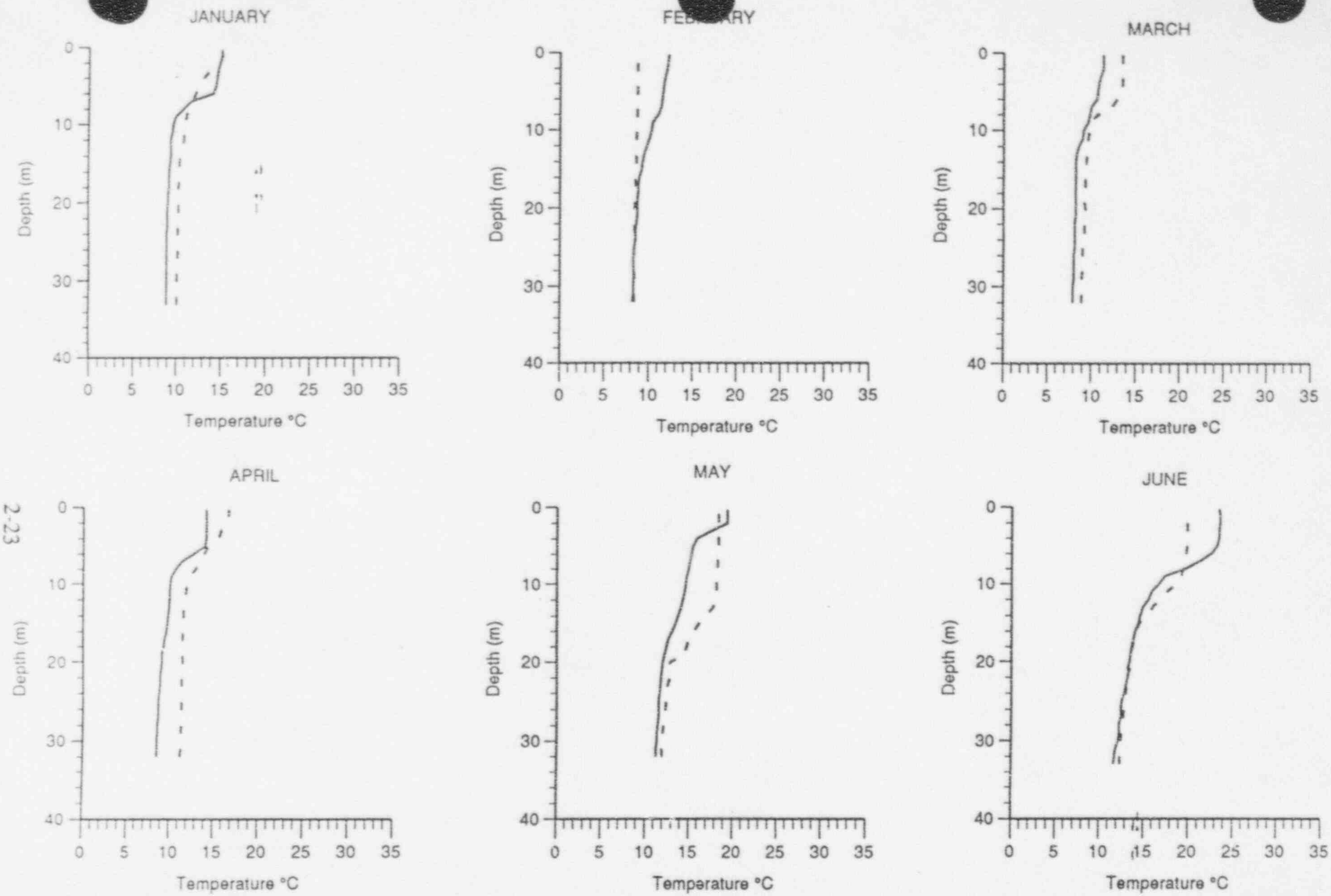

Figure 2-4. Monthly mean temperature profiles for the McGuire Nuclear Station mixing zone in 1992 (...) and 1993 (—).

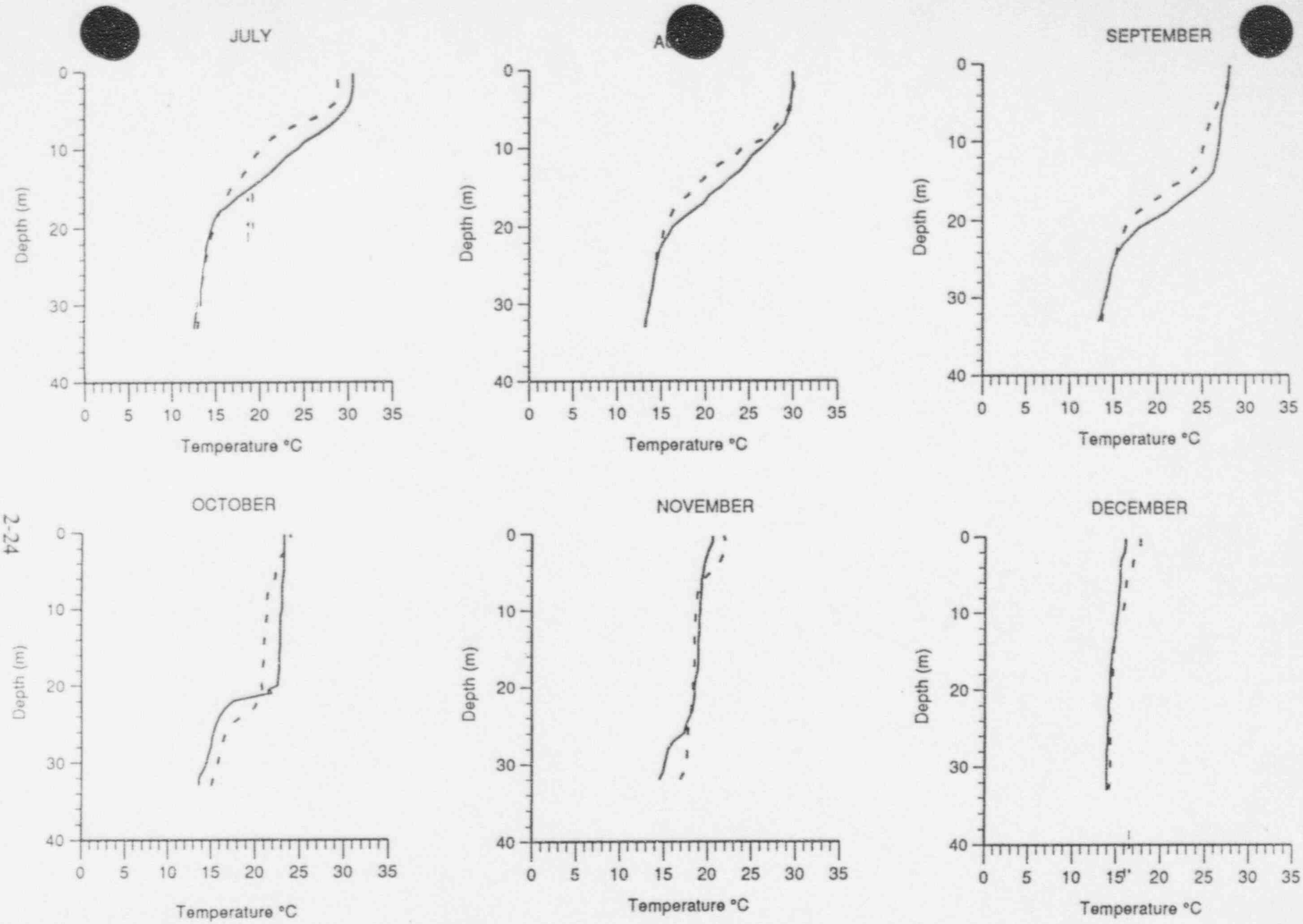

Figure 2-4. Continued.

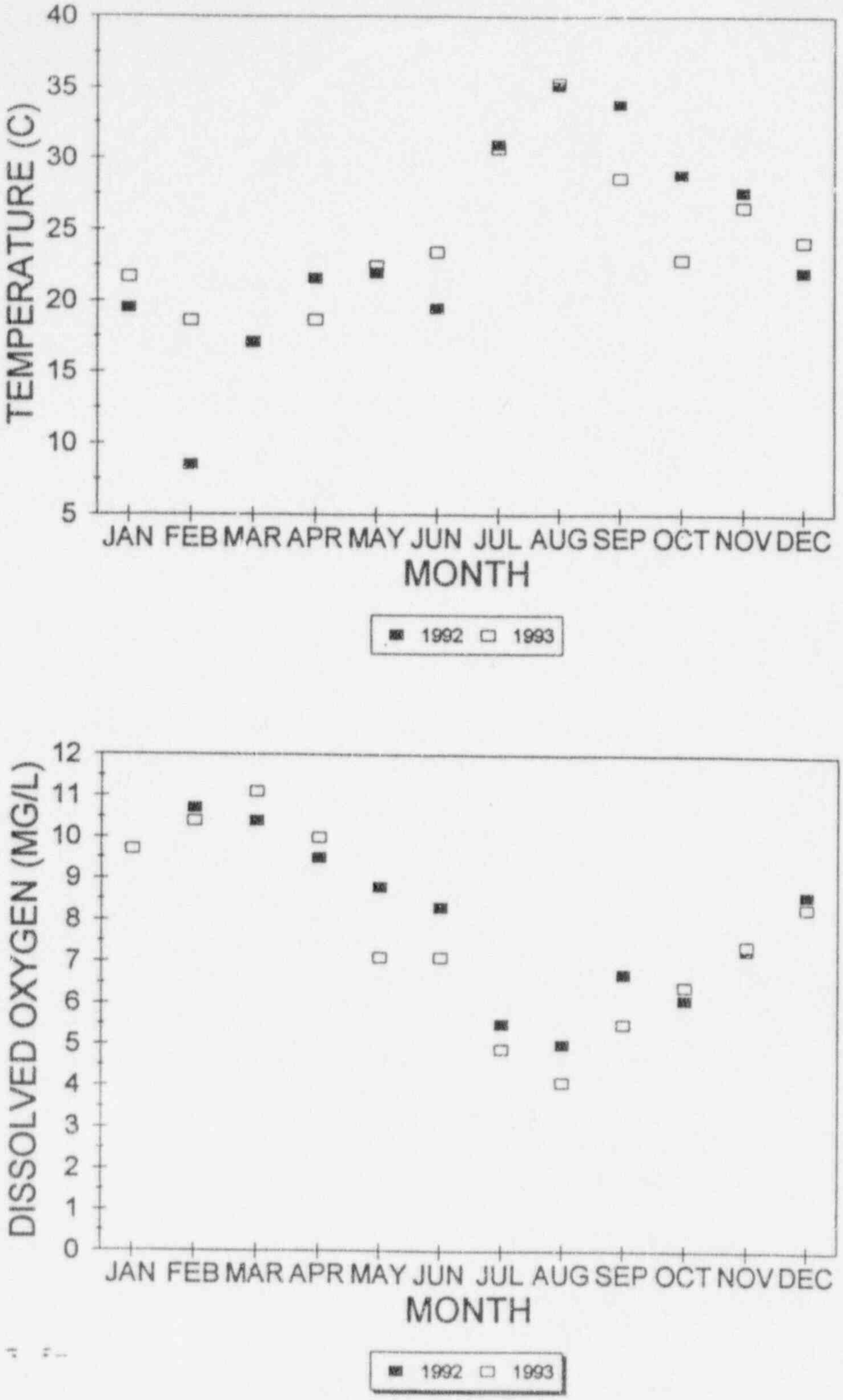

Figure 2-5. Monthly temperature and dissolved oxygen data at the discharge location in 1992 and 1993.

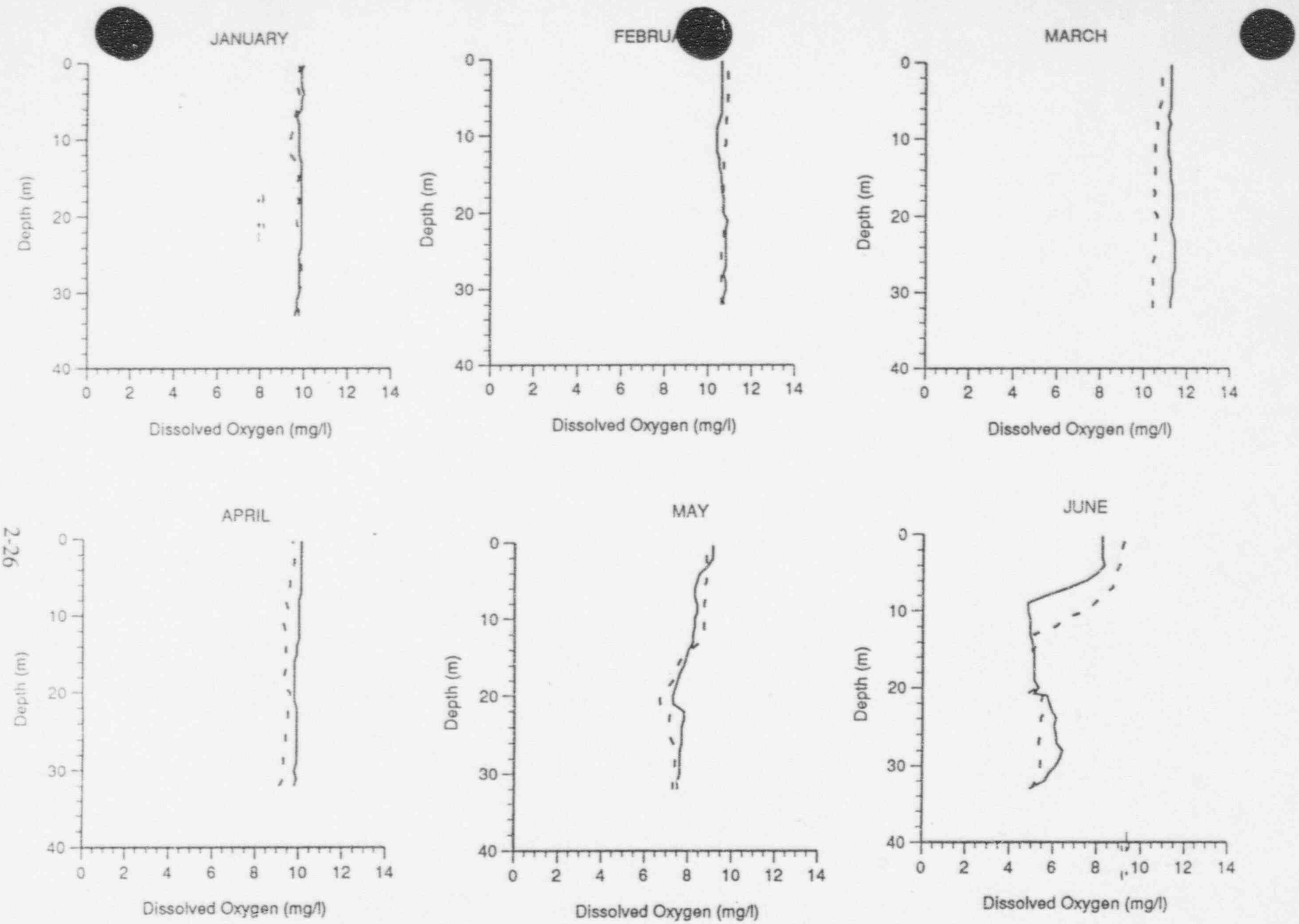

Figure 2-6. Monthly mean dissolved oxygen profiles for the McGuire Nuclear Station mixing zone in 1992 (…) and 1993 (—).

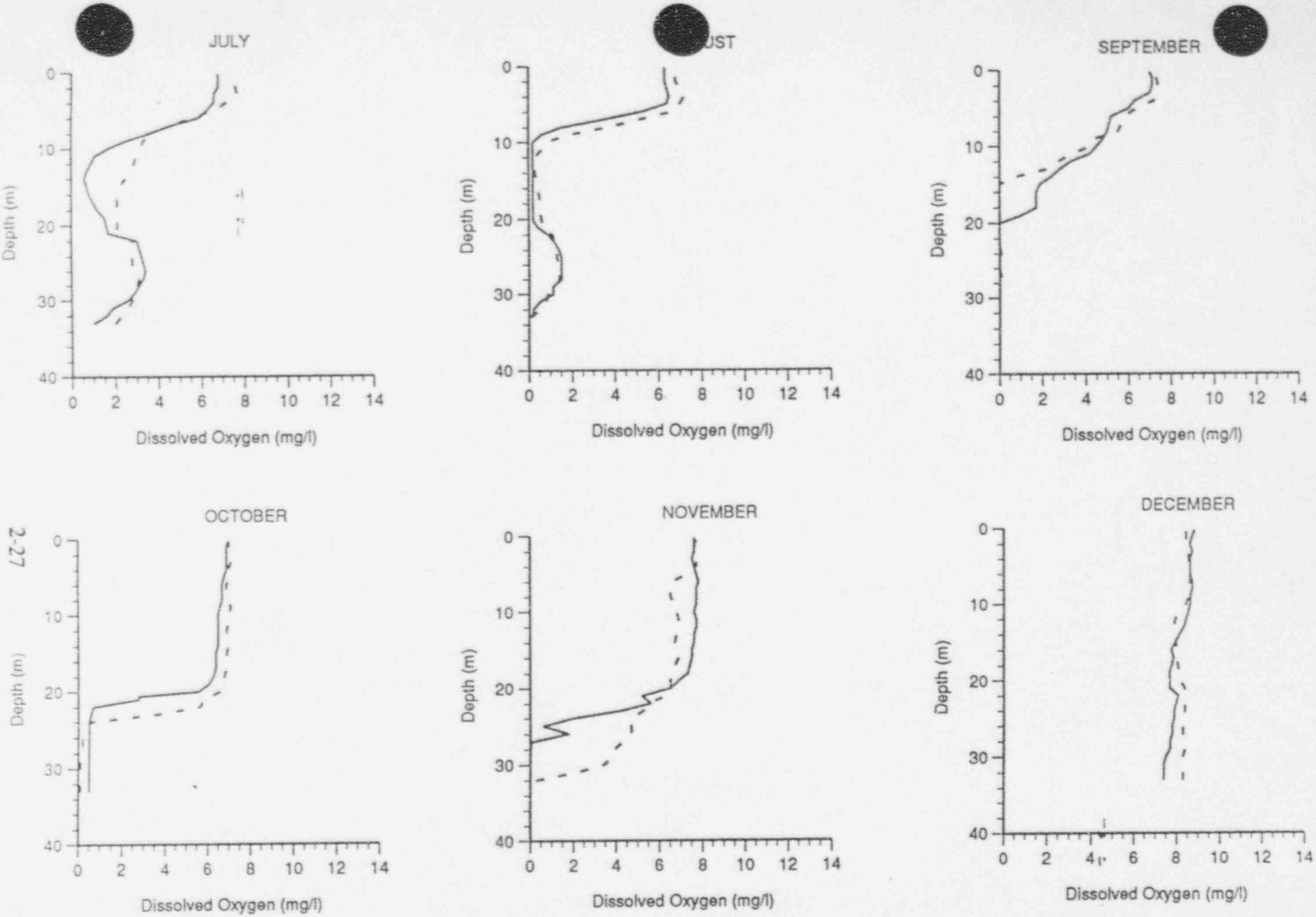

Figure 2-6. Continued.

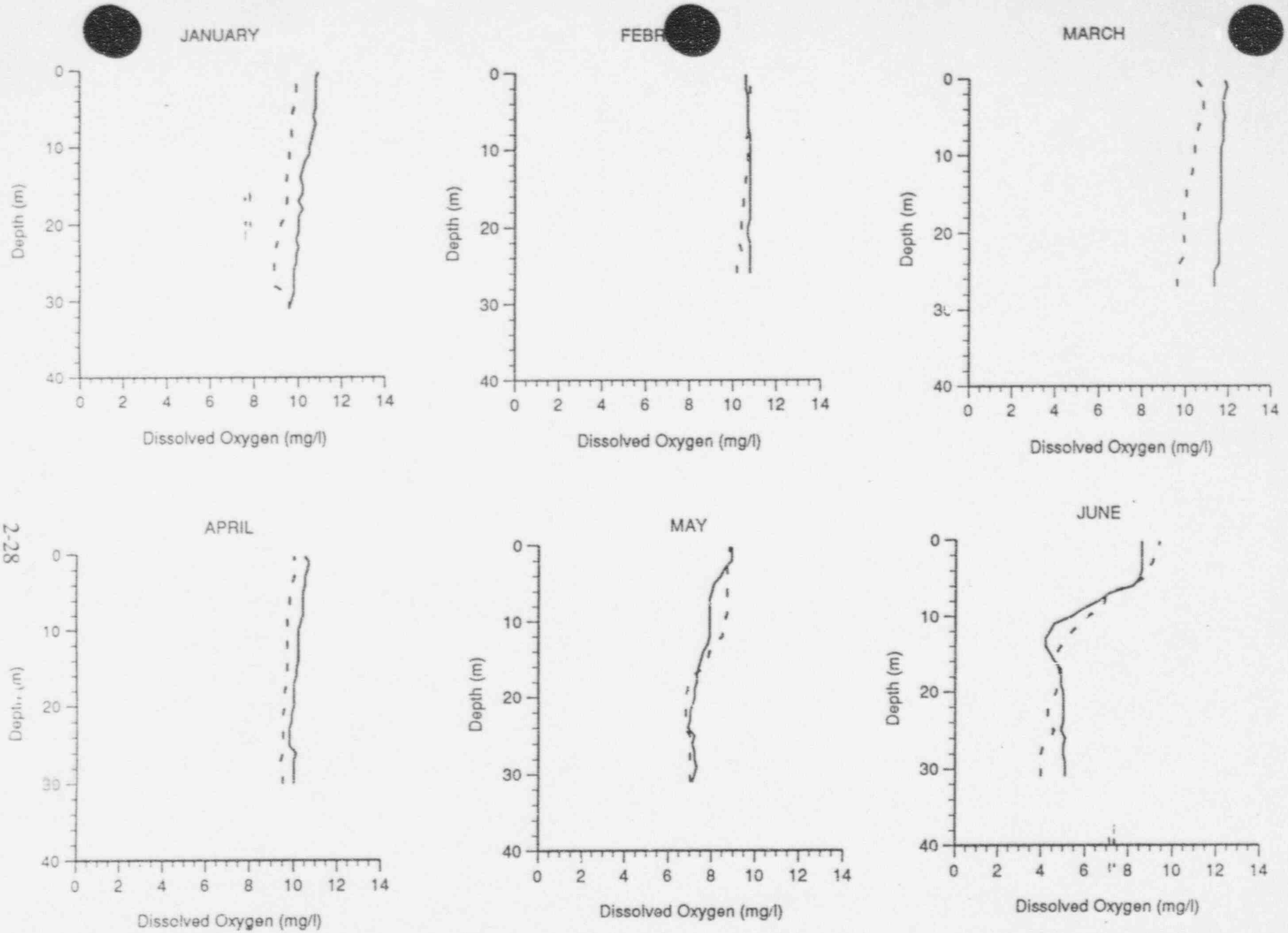

Figure 2-7. Monthly mean dissolved oxygen profiles for the McGuire Nuclear Station background zone in 1992 (…) and 1993 (—).

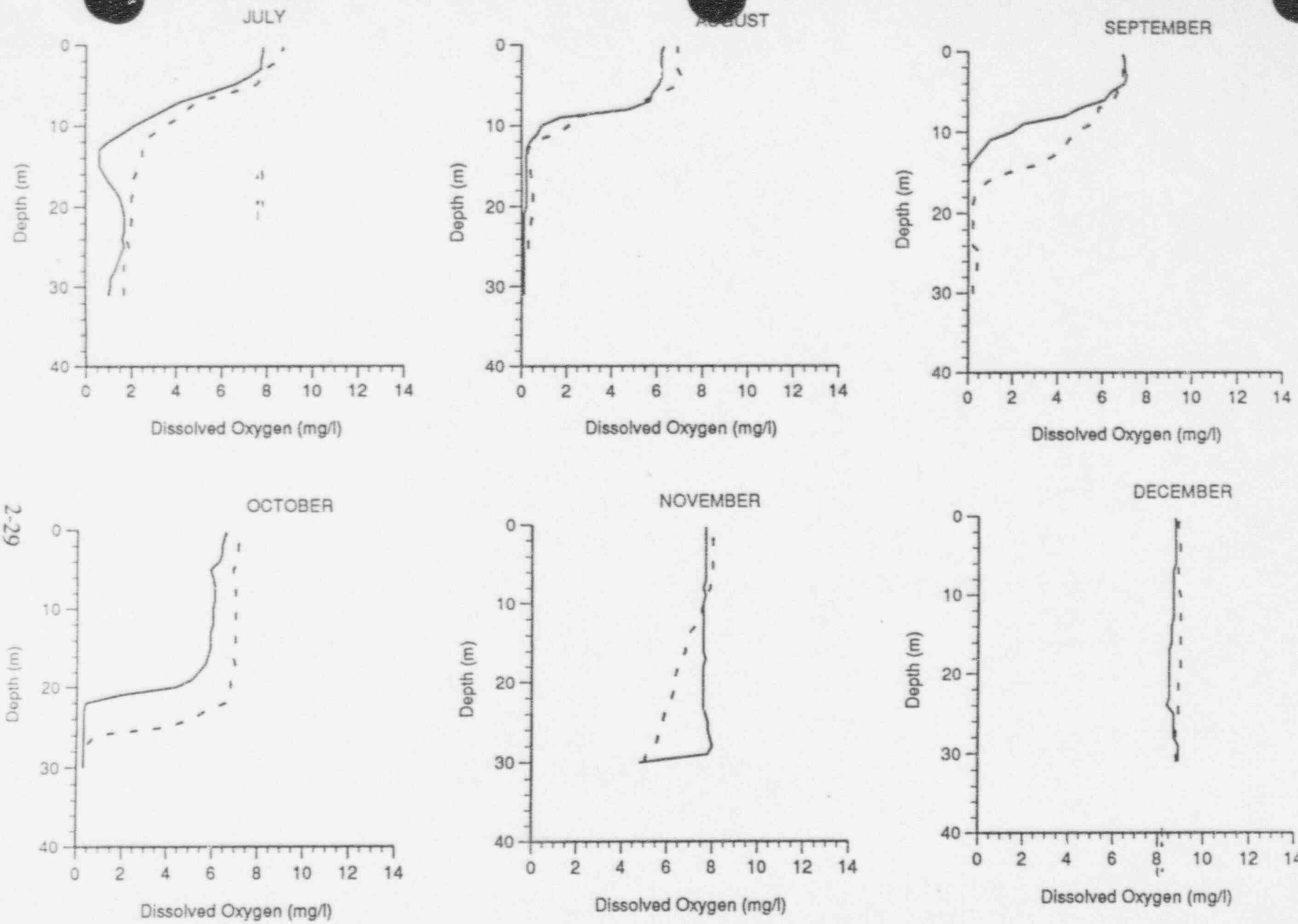

Figure 2-7. Continued.

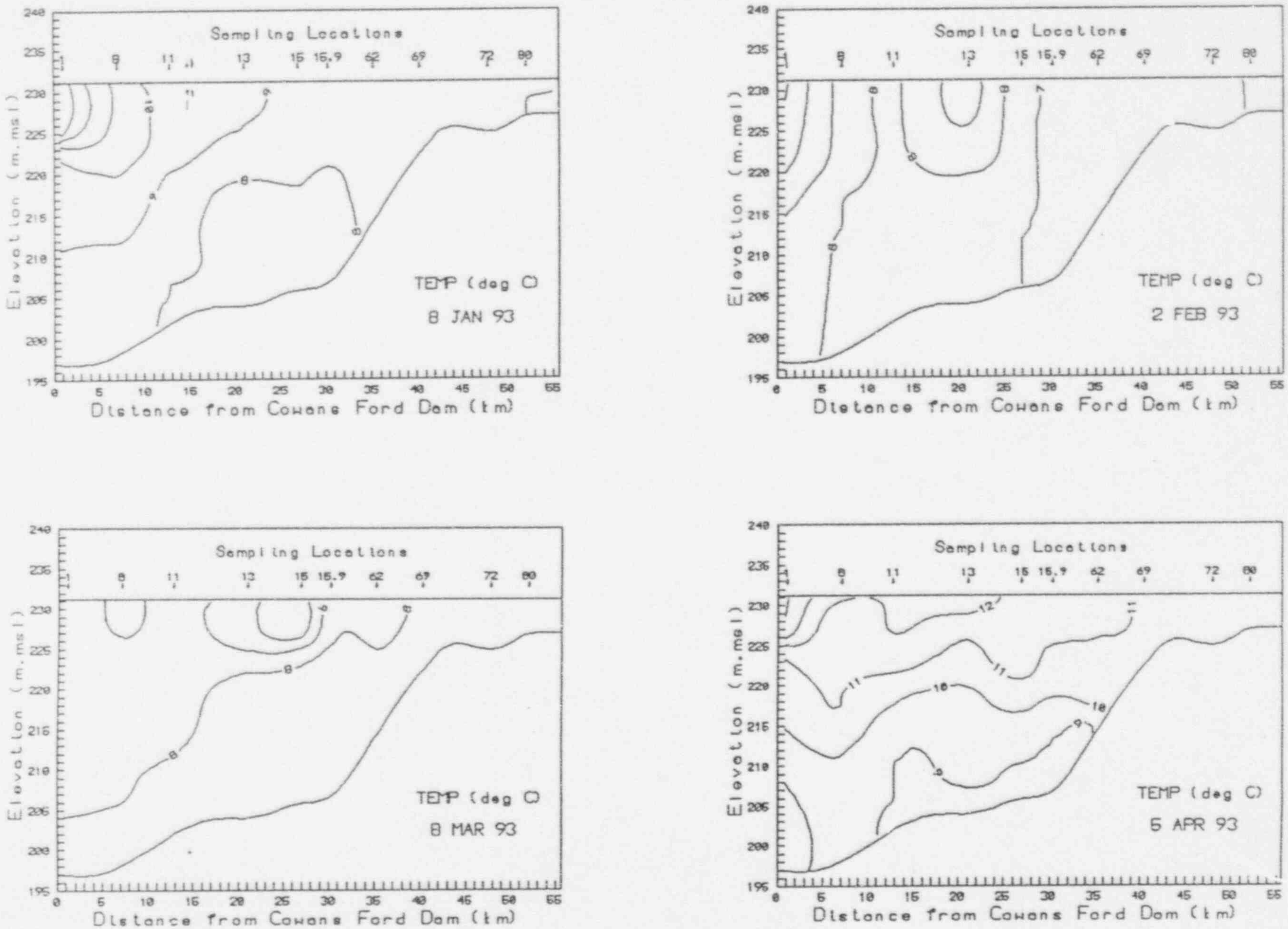

Figure 2-8 Monthly reservoir-wide temperature isotherms for Lake Norman in 1993.

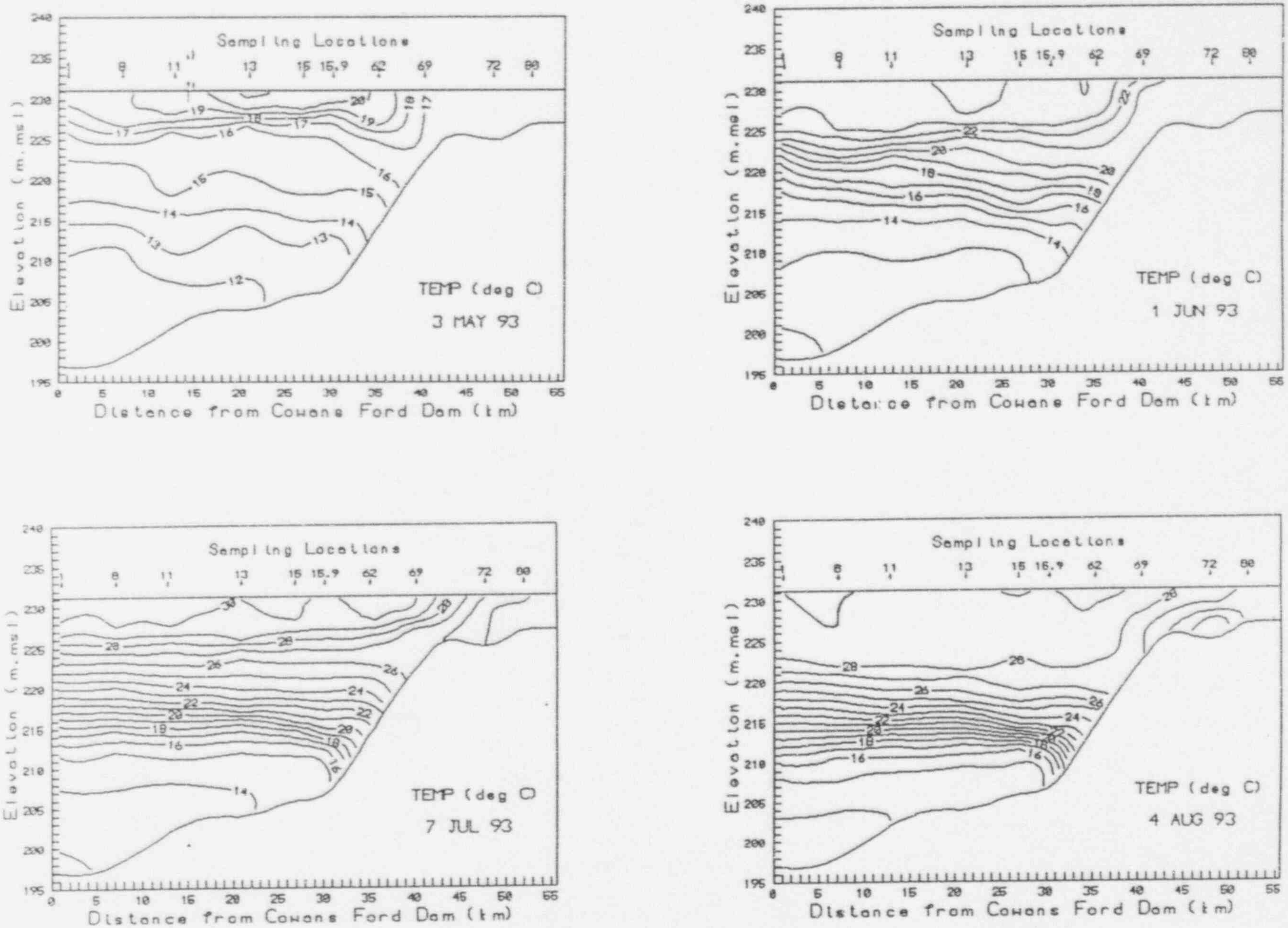

Figure 2-8. Continued.

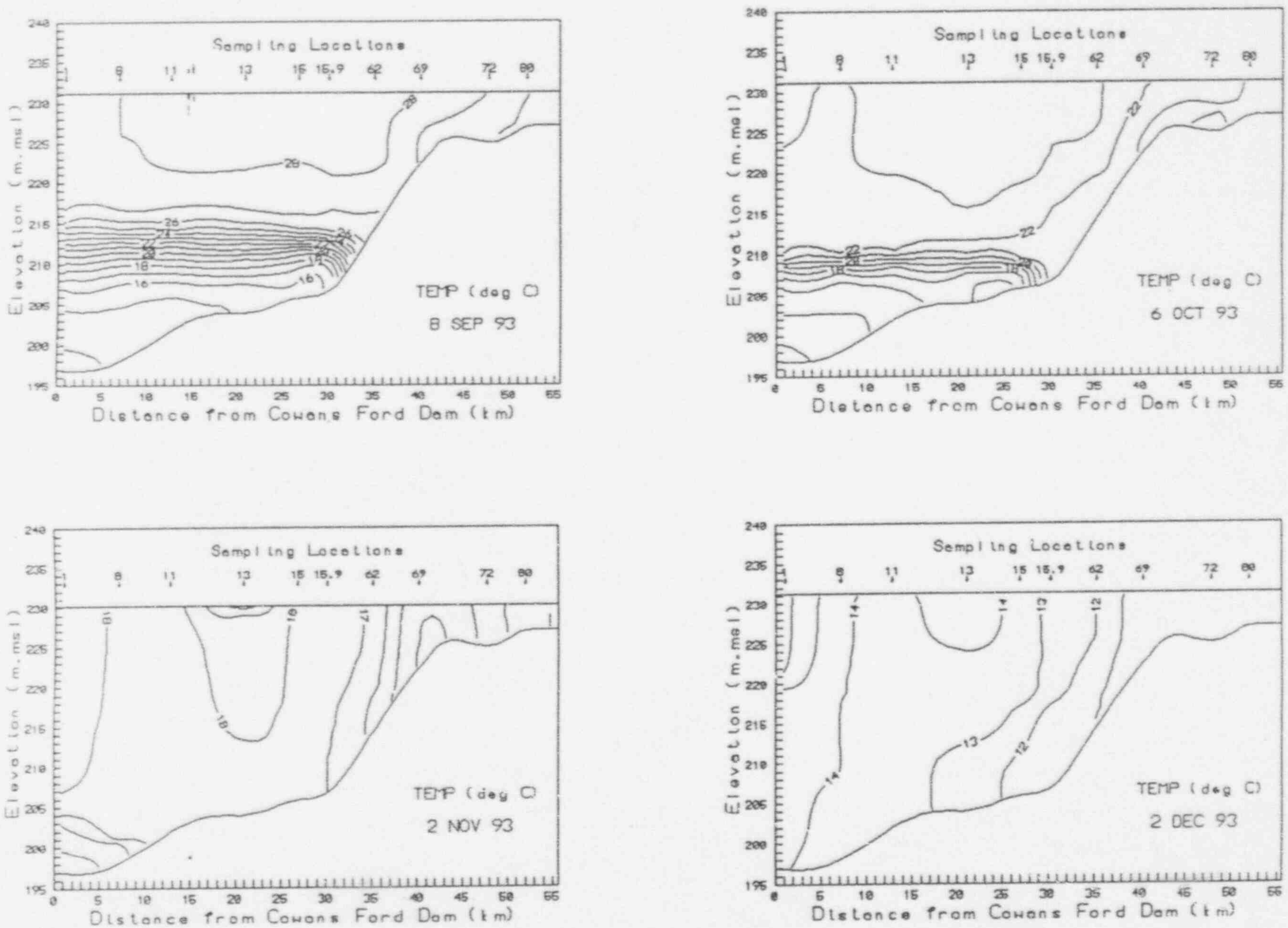

Figure 2-8. Continued.

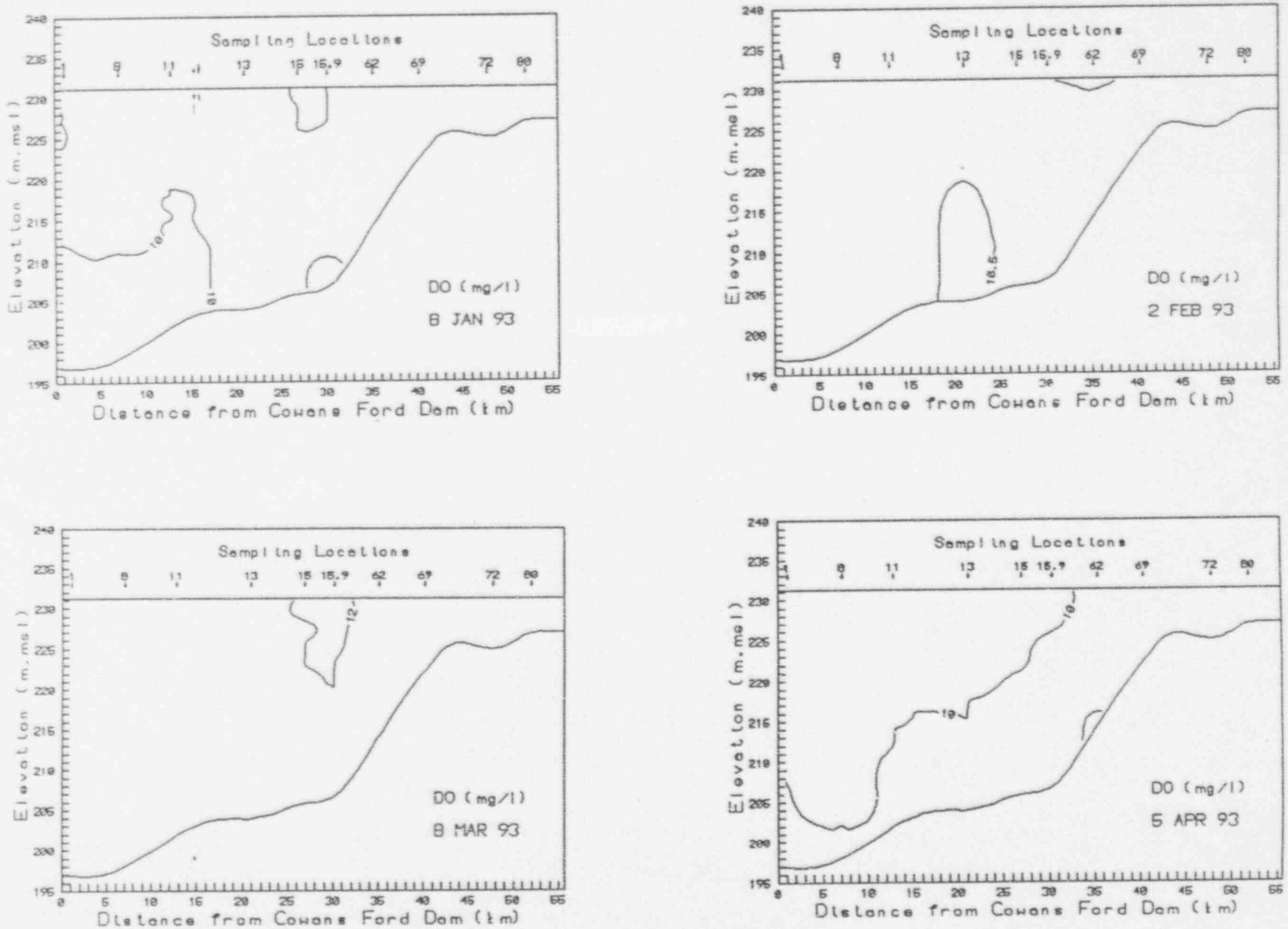

Figure 2-9. Monthly reservoir-wide dissolved oxygen isopleths for Lake Norman in 1993.

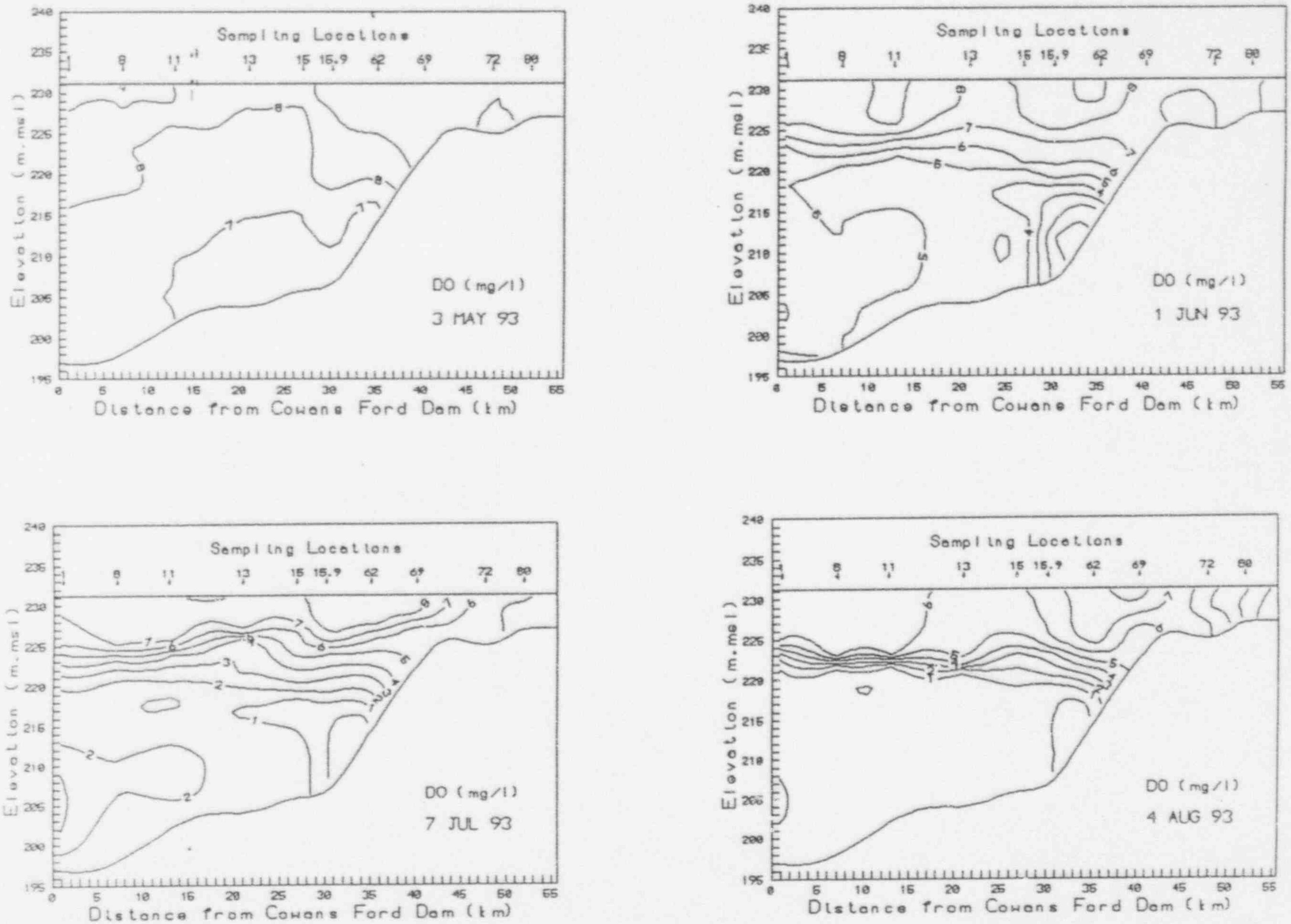

Figure 2-9. Continued.

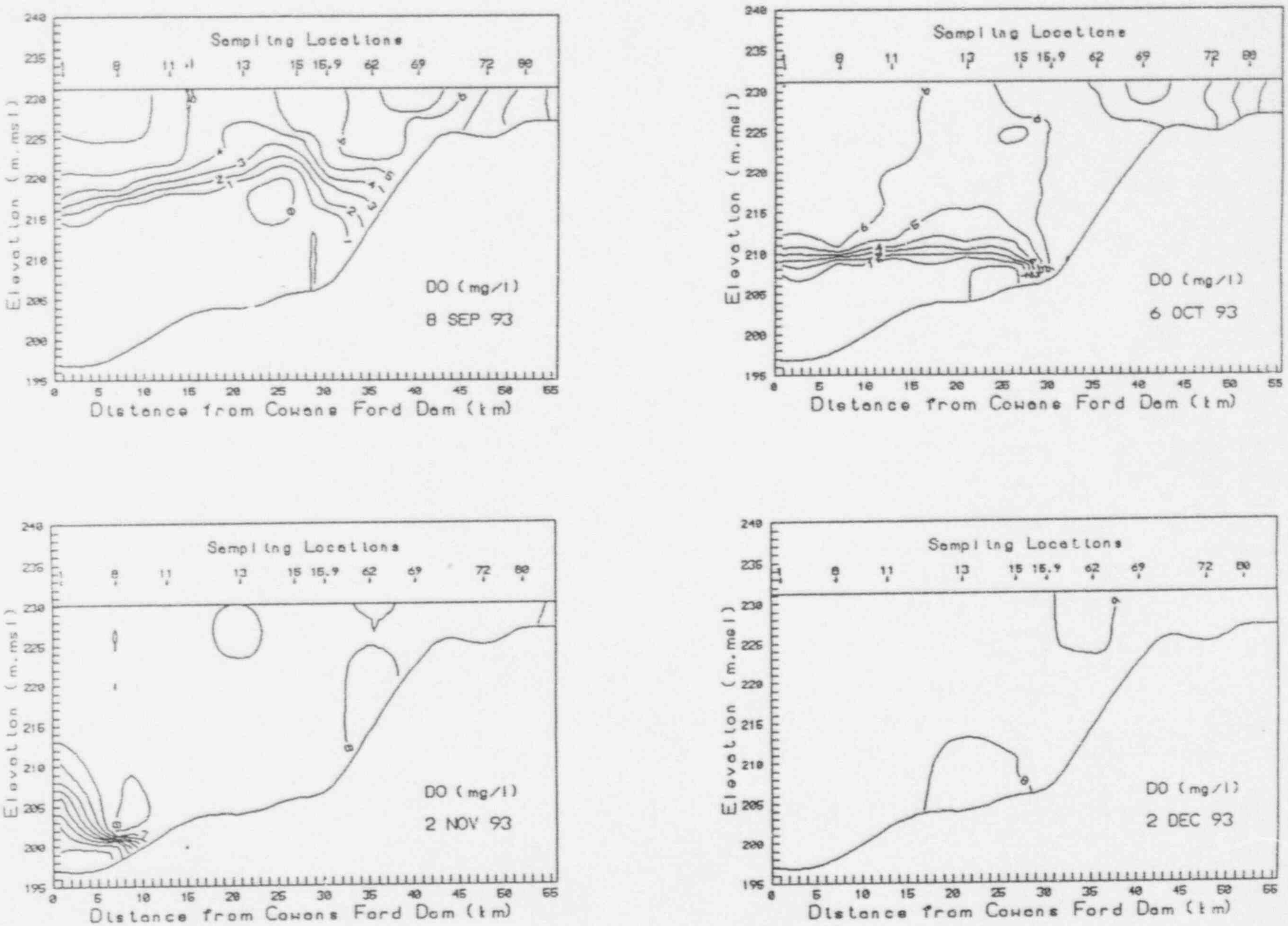

Figure 2-9. Continued.

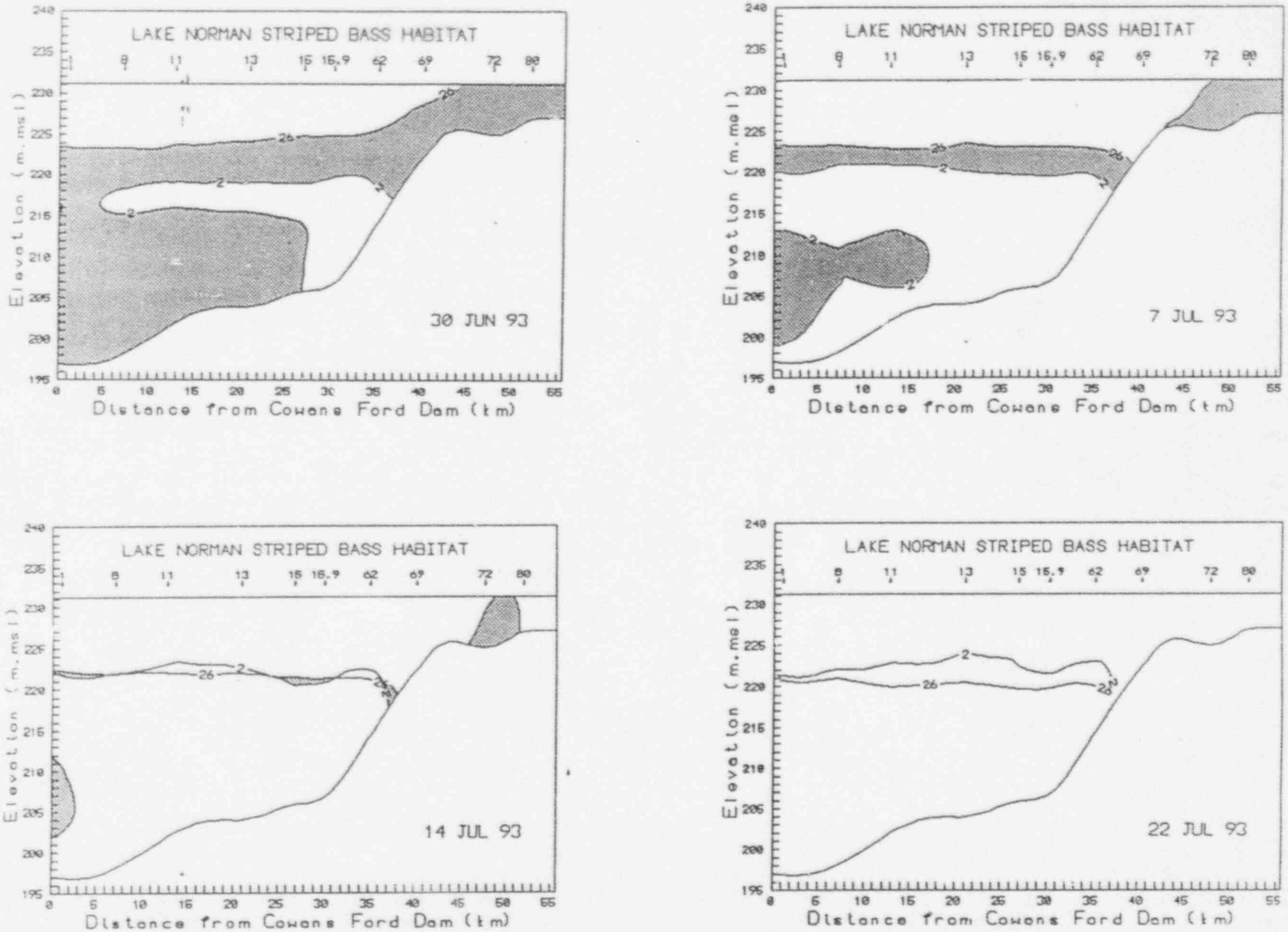

Figure 2-10. Striped bass habitat (temperatures ≤ 26 C and dissolved oxygen ≥ 2.0 mg/L in Lake Norman in June, July, August and September 1993.

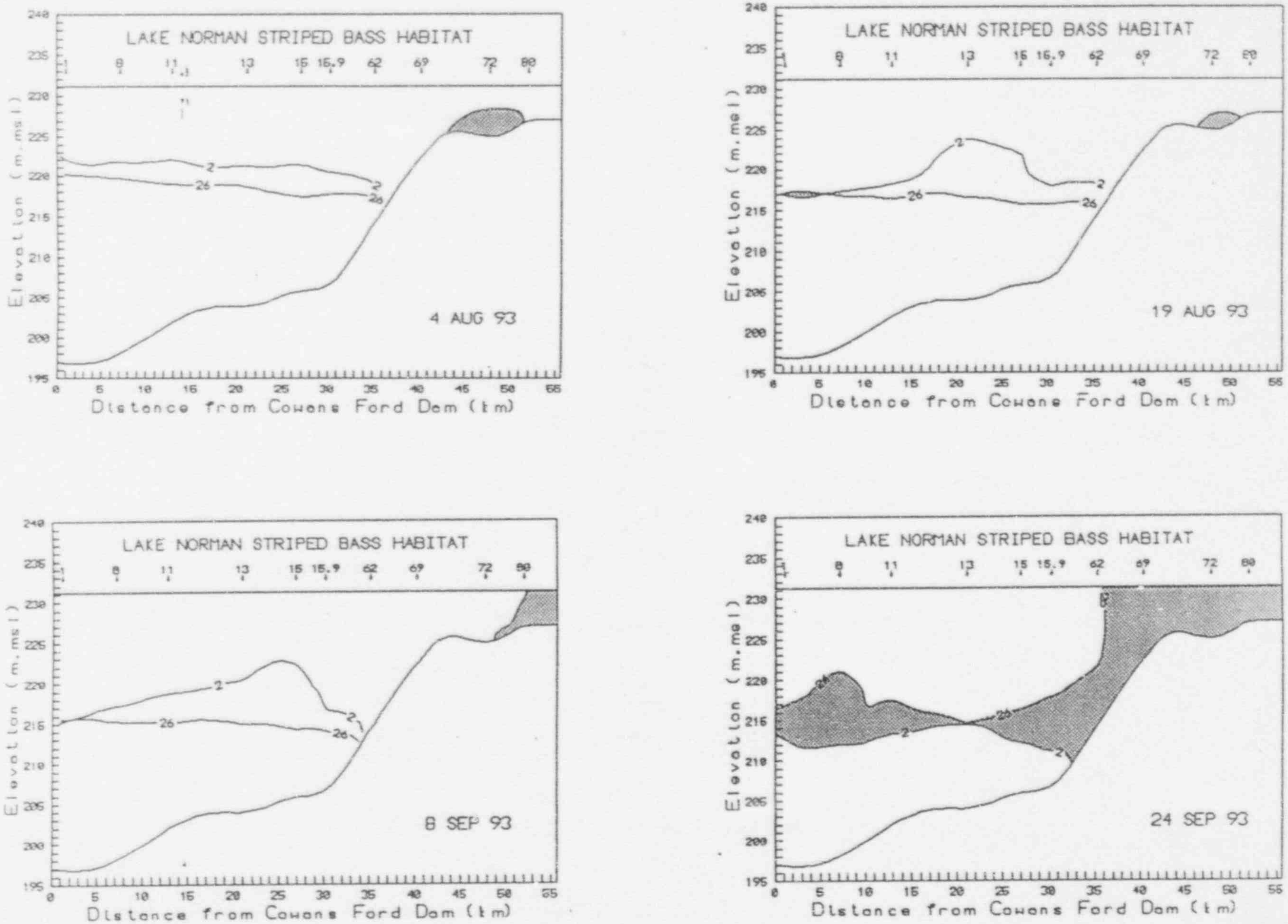

Figure 2-10. Continued.

CHAPTER 3
PHYTOPLANKTON

INTRODUCTION

Phytoplankton population parameters were monitored in 1993 in accordance with the NPDES permit for McGuire Nuclear Station. The objectives of the phytoplankton section for the Lake Norman Maintenance Monitoring Program are to:

1. Describe quarterly patterns of phytoplankton standing crop and species composition throughout Lake Norman; and
2. Compare phytoplankton data collected during this study (February, May, August, November 1993) with historical data collected during these same months.

Previous studies on Lake Norman have reported considerable spatial and temporal variability in phytoplankton standing crops and taxonomic composition (Duke Power Company 1976, 1985; Menhinick and Jensen 1974; Rodriguez 1982). Rodriguez (1982) classified the lake as oligo-mesotrophic based on phytoplankton abundance, distribution, and taxonomic composition.

METHODS AND MATERIALS

Quarterly phytoplankton sampling was conducted at Locations 2.0, 5.0, 8.0, 9.5, 11.0, 13.0, 15.9, and 69.0 in Lake Norman (see map of locations in Chapter 1, Figure 1-1). Duplicate composite grabs from 0.3, 4.0, and 8.0 m (i.e., the euphotic zone) were taken at all locations. Sampling was conducted on 23 February, 25 May, 12 August, and 30 November 1993. Phytoplankton density, biovolume and taxonomic composition were determined for samples collected at Locations 2.0, 5.0, 9.5, 11.0, and 15.9; chlorophyll *a* concentrations and seston dry and ash-free dry weights were determined for samples from all locations. Chlorophyll *a* and total phytoplankton densities and biovolumes are used in determining phytoplankton standing crop. Field sampling methods and laboratory methods used for chlorophyll *a*, seston dry weights, secchi depth, and population identification and enumeration were identical to those used by Rodriguez (1982). Data collected in 1993 were compared with corresponding data from quarterly monitoring beginning in August 1987.

A one way ANOVA was performed on chlorophyll *a* concentrations, phytoplankton densities and seston dry and ash free dry weights by quarter. This was followed by a Duncan's Multiple Range Test to determine which location means were significantly different. The significance level of comparison among means was 0.05.

RESULTS AND DISCUSSION

Chlorophyll *a*

Chlorophyll *a* concentrations from all locations except Location 69.0 ranged from about 5 mg/m^3 to 14 mg/m^3 in 1993 (Table 3-1; Figure 3-1). Chlorophyll *a* concentrations observed at the uplake riverine Location 69.0 were more variable; ranging from 1.9 mg/m^3 in May to 23.5 mg/m^3 in August, the highest value recorded since the Maintenance Monitoring Program was begun in 1987. However, even this value is well below the N. C. Water Quality Standard of 40 mg/m^3 for chlorophyll. Overall, the range of chlorophyll *a* values observed in Lake Norman in 1993 was similar to that observed in 1991 and 1992 and continue to place this reservoir in the mesotrophic range.

Chlorophyll *a* values at the riverine Location 69.0 were significantly lower than all other locations in February and May and significantly higher than all other locations in August based on the results of Duncan's Multiple Range Test (Table 3-2). The riverine zone of a reservoir is subject to fluctuations in inflow depending on meteorological conditions (Thornton 1992). Typically, algal production would be suppressed during periods of high flow, due in part to washout; production would increase during periods of low flow when retention time is greater and washout is decreased. Apparently, the former conditions prevailed in February and May and the latter conditions prevailed in August. Chlorophyll *a* concentrations at the transitional zone Location 15.9 were significantly higher than other locations in November of 1993. The transitional zone is typically the area of a reservoir with highest algal production (Thornton 1992). Few other consistent patterns in chlorophyll *a* concentrations were observed in 1993. In general, chlorophyll *a* concentrations observed at Mixing Zone Locations (2.0 and 5.0) were similar to those observed at other main body locations in Lake Norman.

Lakewide, chlorophyll *a* values for 1993 were similar to 1992 and 1991 but were higher than those observed in 1987 through 1990 (Figure 3-2). Lake means of chlorophyll in 1991 and

1992 by quarter were in the 8 to 10 mg/m^3 range compared with the 2 to 7 mg/m^3 range observed in 1987 through 1989. This increase in the lake wide average by quarter appears to be due to increased chlorophyll concentrations from Location 13.0 downlake to Location 2.0 (Figure 3-3). The greatest increase occurred in February, May, and August.

Total Abundance

Total phytoplankton densities ranged from a low of 793 units/ml at Location 15.9 in February to a high of 4373 units/ml at Location 11.0 in May (Table 3-3, Figure 3-1). Total phytoplankton biovolumes ranged from a low of 280 mm^3/m^3 at Location 15.9 in February to a high of 1589 mm^3/m^3 at Location 9.5 in May. Total phytoplankton densities in the Mixing Zone (Locations 2.0 and 5.0) were significantly lower than other lake locations during May and November (Table 3-4). Total densities at Location 15.9 was always significantly different from the Mixing Zone. During February and May the separation between the Mixing Zone locations was similar to that of the chlorophylls (Table 3-2). In general, trends in phytoplankton densities parallel trends in chlorophyll *a* concentrations.

Seston

Seston dry weights in 1993 ranged from a low of 2.26 mg/l at Location 2.0 in August to a high of 10.65 mg/l at Location 69.0 in November (Figure 3-1). Seston ash free dry weights ranged from a low of 0.75 mg/l at Location 8.0 and 11.0 in November to a high of 3.05 mg/l at Location 69.0 in August. Seston dry weights were significantly higher at uplake Location 69.0 than other locations in May, August and November (Table 3-5), possibly due to allocthonous inputs of sediment and high algal abundance. Ash free dry weights were significantly higher at Location 69.0 than other locations in August (Table 3-6). These weights did not correspond well with chlorophyll and densities indicating varying inputs of allochthonous and autochthonous materials. No consistent pattern of seston weights was observed at the downlake locations.

Secchi Depths

Secchi depths were generally lowest at uplake Location 69.0 due to the previously mentioned higher amounts of suspended materials (Table 3-1). Secchi depths ranged from a low of 0.5 m at Location 69.0 in November to a high of 2.38 m at Location 2.0 in August.

Community Composition

Eleven classes comprising 104 genera and 262 taxa of phytoplankton were identified from samples collected in Lake Norman in 1993. The distribution of taxa within classes was as follows: Chlorophyceae (Green algae), 132; Bacillariophyceae (Diatoms), 49; Chrysophyceae, 21; Haptophyceae, 1; Xanthophyceae, 2; Cryptophyceae, 7; Myxophyceae (Blue-green algae), 23; Euglenophyceae, 9; Dinophyceae, 14; Chloromonadophyceae, 3; and 1 Unidentified taxon (see DPC 1992 for species list). Two new taxa, green algae in the desmid order, (*Tetraedron lobulatum* v. *crassum* Prescott and *Staurastrum gladiosum* Prescott), were identified in 1993 which had not previously been recorded in the Maintenance Monitoring Program.

Species Composition and Seasonal Succession

Species composition in February differed slightly from past years. Cryptophytes numerically dominated phytoplankton assemblages in February due to the abundance of *Rhodomonas minuta* which comprised over 28.0% of the total density at all locations. *Rhodomonas minuta* is the most frequent numerical dominant observed in Lake Norman although typically not in February when diatoms generally dominate (Duke Power Company 1992). Diatoms were second in abundance in February due primarily to *Melosira ambigua* which comprised more than 15.0% of the total biovolume at all locations except 9.5. *Melosira ambigua*, formerly called *Melosira italica*, typically exhibits a large peak in abundance in late winter/early spring (February) followed by a rapid decline prior to the onset of stratification. In February, the Chrysophyceae density (*Kephyrion* spp.) at Loc. 15.9 and Dinophyceae biovolume (*Peridinium umbonatum*) at Loc. 2.0 were important.

Phytoplankton species composition in May was dominated by cryptophytes and diatoms much like in February. *Fragilaria crotonensis* was an important component of the biovolume (at all locations except 5.0) and *Achnanthes* spp. was important in terms of density at Locations 9.5 and 11.0. Diatoms and cryptophytes were numerically codominant in the mixing zone, diatoms were numerically dominant at Loc. 9.5 and 11.0 and chrysophytes were numerically dominant at Loc. 15.9. *Rhodomonas minuta* was the numerical dominant at all locations except Location 9.5.

As in past years, the phytoplankton community in August consisted of a diverse assemblage dominated by chlorophyceae (green algae) species. Green algae were numerically dominant at all locations except Location 15.9 where diatoms were dominant. A small desmid, *Cosmarium asphaerophorum* v. *strigosum*, was the numerical dominant comprising more than 20% of the total density at down lake lacustrine locations (2.0, 5.0 and 9.5). Small coccoid greens were also important downlake and they were numerically dominant at midlake Location 11.0. In terms of biovolume, dinoflagellates (*Peridinium* spp.) were dominant at Locations 5.0, 9.5 and 11.0 in August with diatoms dominant at Locations 2.0 and 15.9. The phytoplankton assemblage at the transition zone Location 15.9 in August was quite different than other locations. It was dominated in numbers and biovolume by a diatom, *Synedra* spp., and also had higher numbers of blue green algae. Blue-green algae comprised about 15% of the density at Location 15.9 in August compared with about 5% of the total density at all other locations. Typically, the highest numbers of blue green algae are observed at Location 15.9 in August (DPC 1989, 1990, 1991, 1992).

In November, except for Location 15.9, diatoms were the dominant class due primarily to the abundance of the large filamentous diatom *Melosira ambigua*. Also, *Melosira ambigua* comprised more than 50% of the biovolume at Locations 2.0, 5.0 and 9.5 and more than 35% of the biovolume at Location 11.0. *Melosira ambigua* is typically most abundant during the unstratified periods in Lake Norman (Duke Power Company 1989, 1990, 1991, 1992. The phytoplankton community at the uplake transition zone location 15.9 was different from the other locations. It was dominated by cryptophytes, numerically by *Rhodomonas minuta* and in biovolume by *Cryptomonas ovata*.

In 1993, other species comprising more than 10% of the total density or biovolume were coccoid greens, unidentified flagellates, *Nitzschia agnita* and in terms of density and *Cryptomonas erosa*, *Cryptomonasovata*, and *Melosira varians* in terms of biovolume. All major taxa observed in 1993 have been common in previous years.

FUTURE STUDIES

No changes are planned for the phytoplankton portion of the Lake Norman maintenance monitoring program.

SUMMARY

* Chlorophyll *a*, seston weights and dry weights were most often significantly different at Location 69.0 than other locations in 1993. This location is more riverine in nature and is subject to flucuations in flow. Few significant differences were observed between parameters sampled in the mixing zone and other locations in 1993.

* Chlorophyll *a* concentrations at all locations during 1993 were within historical ranges and in the mesotrophic range. They were generally higher than those observed during 1987 through 1990 but were similar to those observed in 1991 and 1992.

* Total phytoplankton densities and biovolumes remained similar to those observed in previous years.

* Phytoplankton taxonomic composition during 1993 was similar to that observed during the same months of 1992. Diatoms, green algae and cryptophytes were the most numerically abundant classes of algae observed. Diatoms and cryptophytes generally dominated the phytoplankton biovolumes in all months except August when the phytoplankton community consisted of a diverse assemblage dominated by small green algae. Dinoflagellates were sporadically dominant in terms of biovolume at some locations during all months except November. Blue-green algae were never dominant part at any location or time in 1993.

* Major taxa observed in 1993 were similar to those observed in 1992. *Rhodomonas minuta* was the most frequent numerical dominant during 1993 as in previous years. *Melosira ambigua* dominated the algal biovolume at most locations during the unstratified periods (February and November).

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Table 3-1. Mean chlorophyll *a* concentrations (mg/m^3) and secchi depths recorded during 1993 from locations in Lake Norman, NC.

Lake Norman Chlorophyll a - 1993

Location	FEB Mean	MAY Mean	AUG Mean	NOV Mean
2.0	6.83	5.80	5.88	5.55
5.0	6.67	6.02	7.11	4.86
8.0	7.18	8.54	11.61	4.91
9.5	6.44	10.05	13.39	7.52
11.0	7.06	9.84	8.67	6.01
13.0	6.39	12.42	7.00	5.01
15.9	4.60	11.09	13.73	9.15
69.0	2.85	1.92	23.50	3.84

Secchi Depths - 1993

Location	FEB	MAY	AUG	NOV
2.0	1.74	1.95	2.38	1.25
5.0	1.46	1.95	1.81	1.05
8.0	1.53	2.20	2.16	1.28
9.5	2.01	1.80	1.80	1.17
11.0	0.95	1.80	2.23	1.36
13.0	0.79	1.70	1.22	1.06
15.9	0.67	1.60	1.78	1.52
69.0	0.85	0.90	1.34	0.50

Table 3-2. Duncan's Multiple Range Test on Chlorophyll *a* concentrations in Lake Norman, NC during 1993. (Means connected by lines are not significantly different.)

February	Location	**69.0**	**15.9**	**13.0**	**9.5**	**5.0**	**2.0**	**11.0**	**8.0**
	Mean	2.85	4.60	6.39	6.44	6.67	6.83	7.06	7.18
May	Location	**69.0**	**2.0**	**5.0**	**8.0**	**11.0**	**9.5**	**15.9**	**13.0**
	Mean	1.92	5.80	6.02	8.54	9.84	10.04	11.09	12.42
August	Location	**2.0**	**13.0**	**5.0**	**11.0**	**8.0**	**9.5**	**15.9**	**69.0**
	Mean	5.88	7.00	7.11	8.67	11.61	13.40	13.73	23.50
November	Location	**69.0**	**5.0**	**8.0**	**13.0**	**2.0**	**11.0**	**9.5**	**15.9**
	Mean	3.84	4.86	4.91	5.01	5.55	6.01	7.52	9.15

Table 3-3. Total phytoplankton densities and biovolumes from samples collected in Lake Norman, NC in February, May, August and November 1993.

Total Phytoplankton - Lake Norman - 1993

Density

	Locations					
Class	2.0	5.0	9.5	11.0	15.9	Mean
FEB	1507	1673	1765	1702	793	1488
MAY	2045	1824	3766	4372	3612	3124
AUG	1638	2230	2881	1445	3742	2387
NOV	937	1138	1431	1451	1614	1314

Biovolume

	2.0	5.0	9.5	11.0	15.9	Mean
FEB	671	465	490	577	280	497
MAY	797	652	1589	1391	1411	1168
AUG	423	786	1387	1050	1236	976
NOV	773	536	955	722	489	695

Table 3-4. Duncan's Multiple Range Test on Phytoplankton Densities in Lake Norman, NC during 1993. (Means connected by lines are not significantly different.)

<table>
<tr><td>February</td><td>Location</td><td>15.9</td><td>2.0</td><td>5.0</td><td>11.0</td><td>9.5</td></tr>
<tr><td></td><td>Mean</td><td>793</td><td>1507</td><td>1673</td><td>1703</td><td>1765</td></tr>
<tr><td></td><td></td><td>______</td><td colspan="4">______________________________</td></tr>
<tr><td>May</td><td>Location</td><td>5.0</td><td>2.0</td><td>15.9</td><td>9.5</td><td>11.0</td></tr>
<tr><td></td><td>Mean</td><td>1824</td><td>2045</td><td>3612</td><td>3766</td><td>4373</td></tr>
<tr><td></td><td></td><td colspan="2">____________</td><td colspan="3">______________________</td></tr>
<tr><td>August</td><td>Location</td><td>11.0</td><td>2.0</td><td>5.0</td><td>9.5</td><td>15.9</td></tr>
<tr><td></td><td>Mean</td><td>1445</td><td>1639</td><td>2230</td><td>2882</td><td>3742</td></tr>
<tr><td></td><td></td><td colspan="2">____________</td><td>______</td><td>______</td><td>______</td></tr>
<tr><td>November</td><td>Location</td><td>2.0</td><td>5.0</td><td>9.5</td><td>11.0</td><td>15.9</td></tr>
<tr><td></td><td>Mean</td><td>938</td><td>1138</td><td>1431</td><td>1451</td><td>1615</td></tr>
<tr><td></td><td></td><td colspan="2">____________</td><td colspan="3">______________________</td></tr>
</table>

Table 3-5 . Duncan's Multiple Range Test on Seston Dry and Ash Free Dry Weight concentrations in Lake Norman, NC during 1993.

Dry Weight

February	Location	**2.0**	**9.5**	**5.0**	**8.0**	**11.0**	**13.0**	**69.0**	**15.9**
	Mean	2.67	2.74	2.96	3.08	3.85	4.32	4.70	4.99
May	Location	**8.0**	**9.5**	**11.0**	**5.0**	**13.0**	**2.0**	**15.9**	**69.0**
	Mean	2.76	3.24	3.28	3.52	3.68	4.06	4.37	8.60
August	Location	**2.0**	**11.0**	**13.0**	**8.0**	**15.9**	**9.5**	**5.0**	**69.0**
	Mean	2.26	2.27	2.27	2.34	2.50	3.02	3.09	7.98
November	Location	**15.9**	**11.0**	**2.0**	**8.0**	**5.0**	**13.0**	**9.5**	**69.0**
	Mean	3.41	3.41	3.50	4.00	4.49	4.74	4.80	10.65

Ash Free Dry Weight

February	Location	**9.5**	**69.0**	**5.0**	**2.0**	**8.0**	**11.0**	**13.0**	**15.9**
	Mean	0.82	0.90	1.00	1.01	1.06	1.08	1.13	1.21
May	Location	**5.0**	**8.0**	**2.0**	**9.5**	**11.0**	**15.9**	**13.0**	**69.0**
	Mean	1.24	1.37	1.51	1.58	1.69	1.71	1.85	1.98
August	Location	**13.0**	**2.0**	**11.0**	**15.9**	**8.0**	**5.0**	**9.5**	**69.0**
	Mean	1.02	1.23	1.35	1.44	1.48	1.53	1.78	3.05
November	Location	**11.0**	**8.0**	**2.0**	**13.0**	**15.9**	**9.5**	**5.0**	**69.0**
	Mean	0.75	0.75	0.76	0.82	0.94	0.99	1.04	1.99

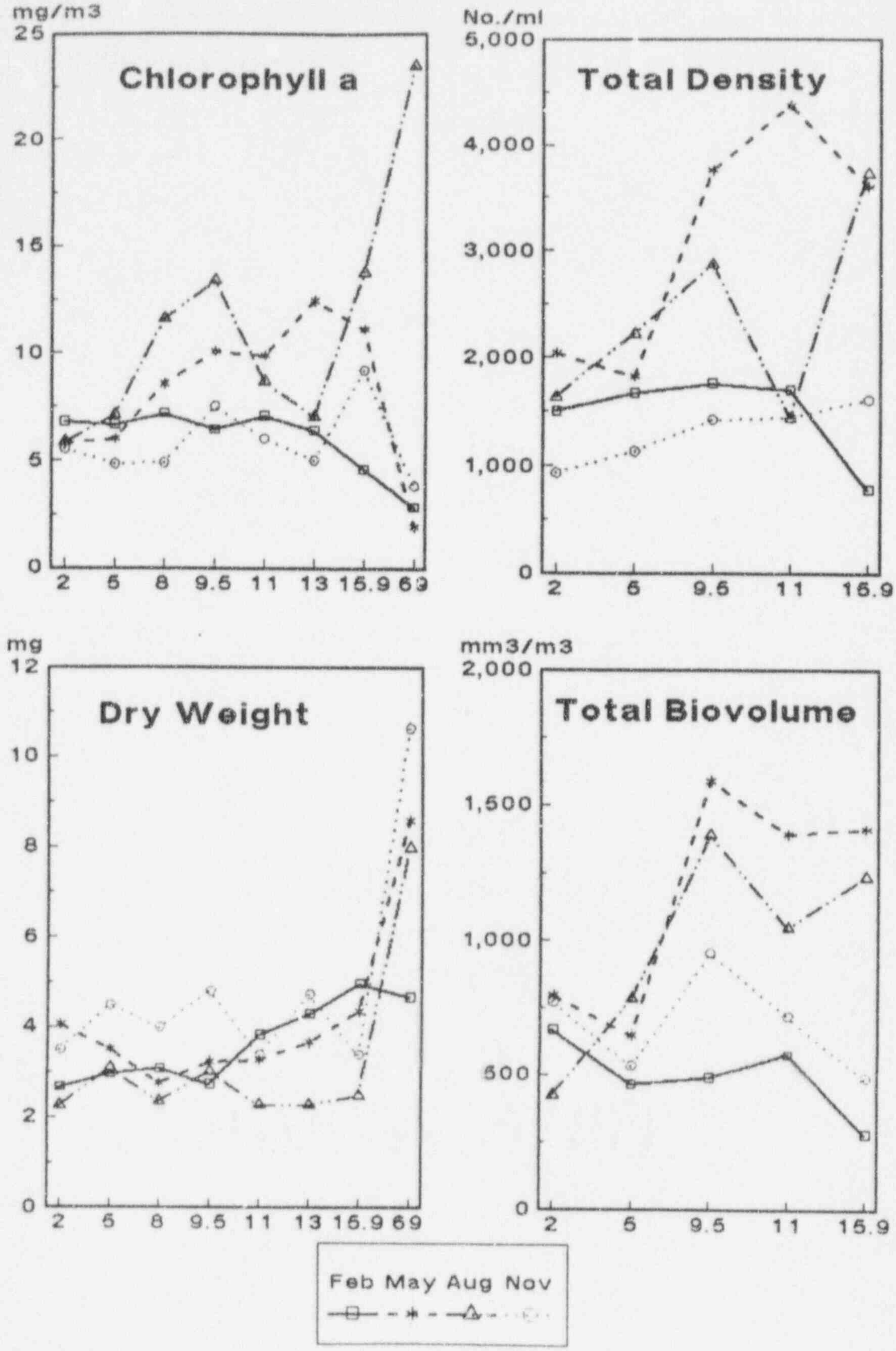

Figure 3-1. Chlorophyll a, dry weights, total densities and total biovolumes for locations in Lake Norman, North Carolina, in February, May, August, and November 1993.

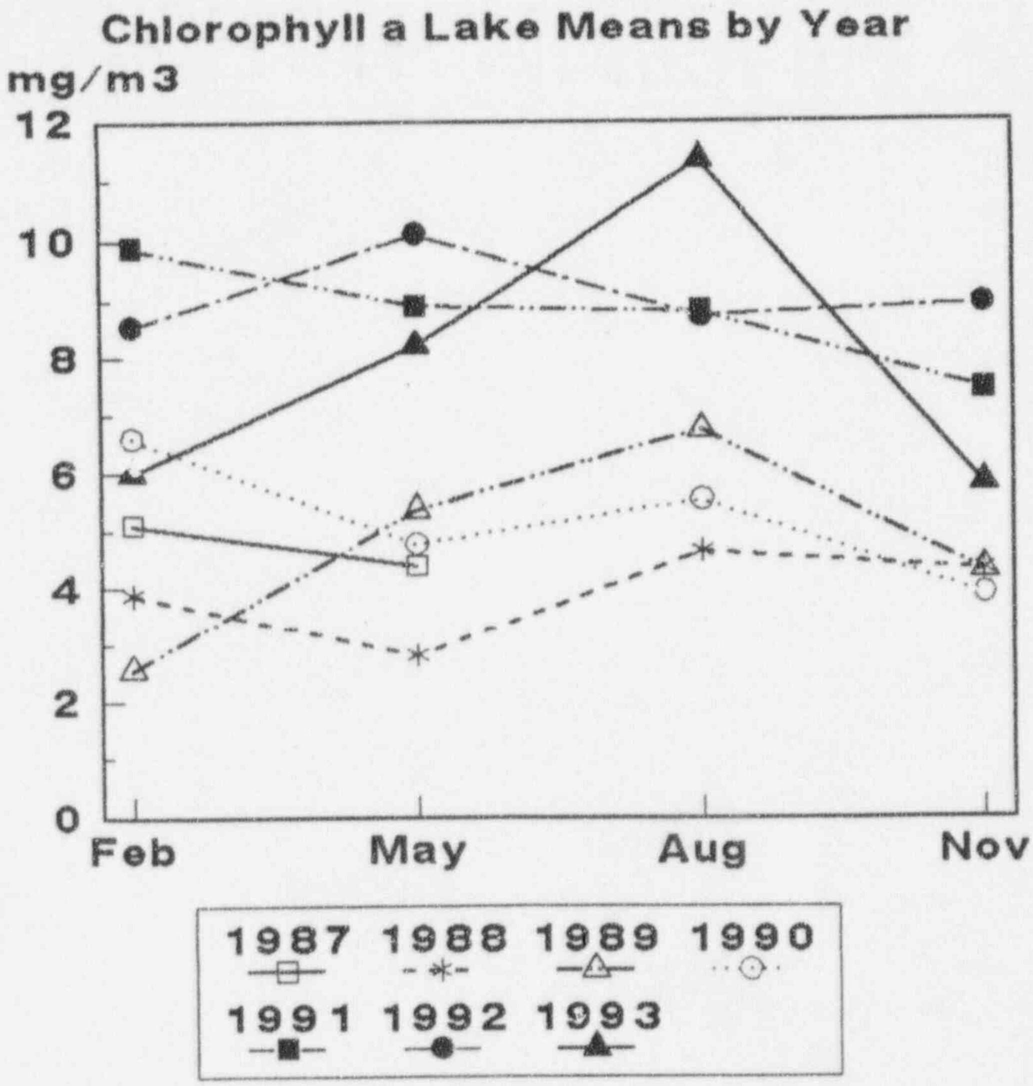

Figure 3-2. Chlorophyll a, lake means by year samples were collected in Lake Norman, North Carolina, from August 1987 through November 1993.

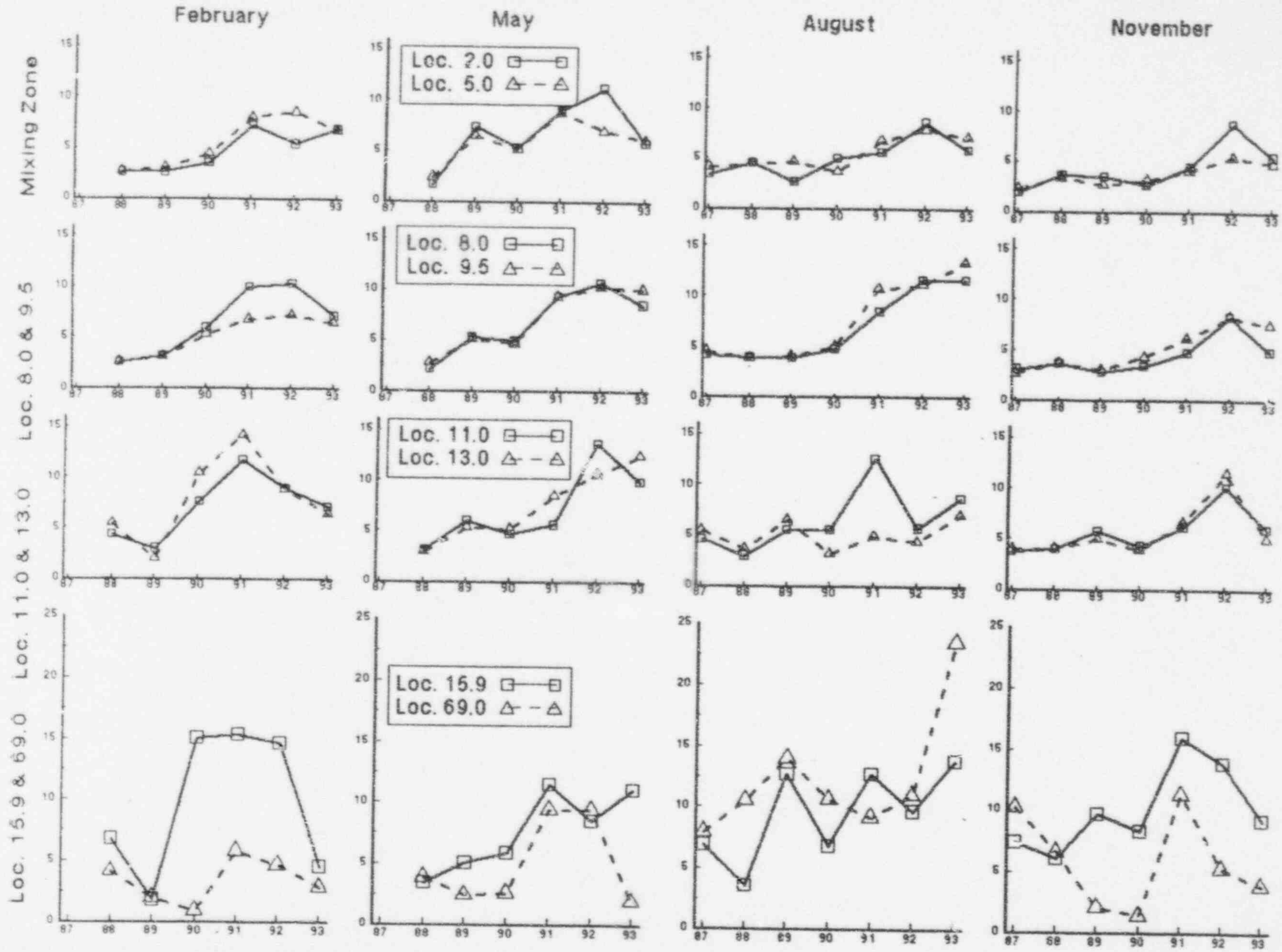

Figure 3-3. Chlorophyll a concentrations (mg/m^3) by location for samples collected in Lake Norman, North Carolina, from August 1987 through November 1993.

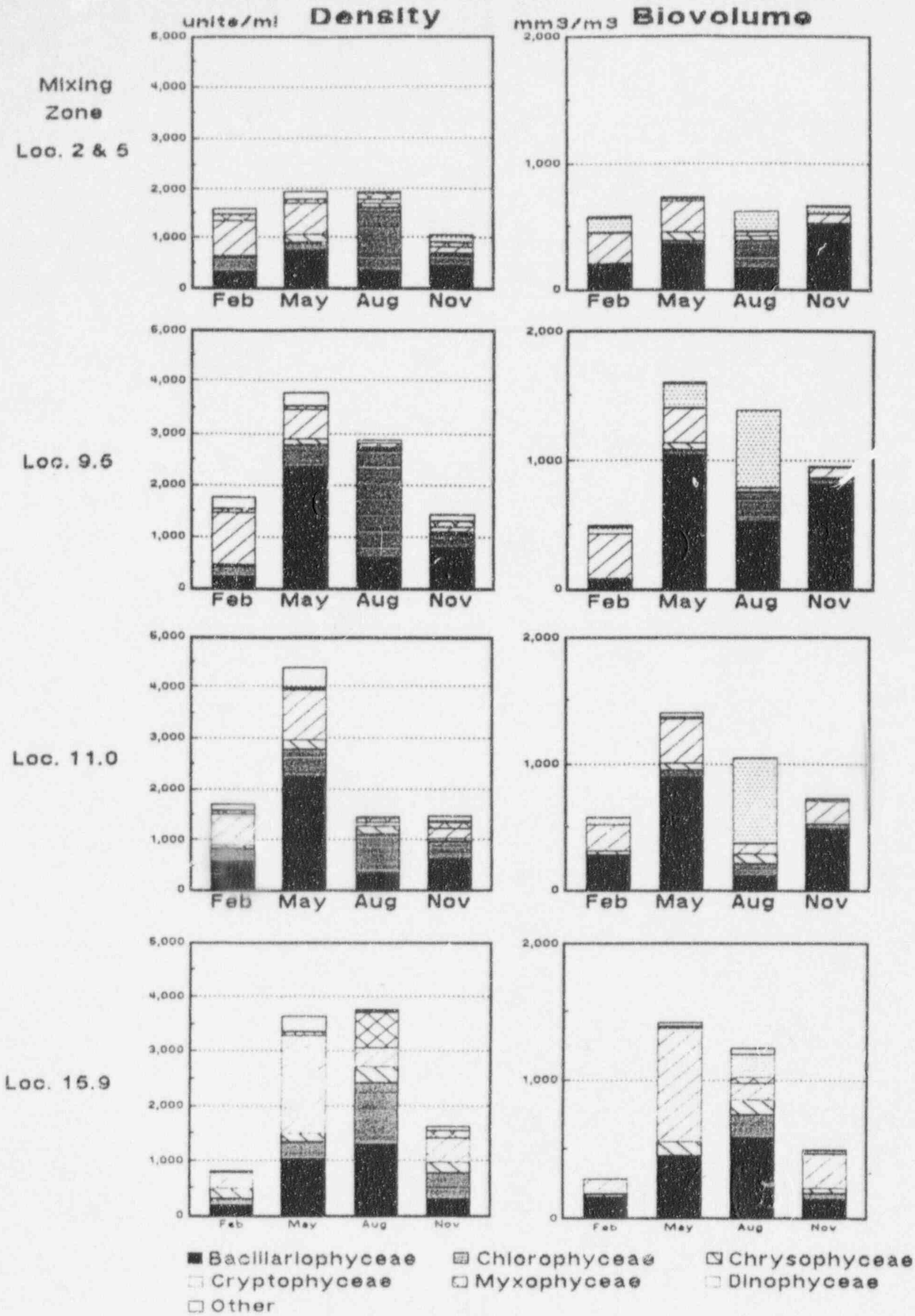

Figure 3-4. Class composition of phytoplankton from euphotic zone composite samples collected at locations in lake Norman, North Carolina, during 1993.

CHAPTER 4
ZOOPLANKTON

INTRODUCTION

The objectives of the Lake Norman Maintenance Monitoring Program for zooplankton are to:

1. Describe quarterly patterns of zooplankton standing crops at selected locations on Lake Norman and

2. Compare zooplankton data collected during this study (February, May, August, and November 1993) with historical data collected for this Program during the period 1987-1991 for these same months.

Previous studies of Lake Norman zooplankton populations have demonstrated a bimodal seasonal distribution with highest recorded values occurring in spring and a less pronounced fall peak. Considerable spatial and year to year variability has been observed in zooplankton abundance in Lake Norman (Duke Power Company 1976, 1985; Hamme 1982; Menhinick and Jensen 1974).

METHODS AND MATERIALS

Duplicate 10 m to surface and bottom to surface net tows were taken at Locations 2.0, 5.0, 9.5, 11.0, and 15.9 in Lake Norman (Chapter 2, Figure 1-1) on February 23. May 25, August 12, and November 30, 1993. For discussion purposes the 10 m to surface tow samples will be referred to as eplimnetic samples and the bottom to surface net tow samples will be referred to as whole column samples. Locations 2.0 and 5.0 are defined as the Mixing Zone and Locations 9.5, 1' 0 and 15.9 are defined as Background locations. Field and laboratory methods for zooplankton standing crop analysis were the same as those reported in Hamme (1982). Zooplankton standing crop data from 1992 were compared with corresponding data from quarterly monitoring begun in August 1987.

A one way ANOVA was performed on epilimnetic total zooplankton densities by quarter. This was followed by a Duncan's Multiple Range Test to determine which location means were significantly different. The significance level of comparison among means was 0.05.

RESULTS AND DISCUSSION

Total Abundance

Lakewide, total zooplankton densities in both epilimnetic and whole column samples in 1993 were highest in May and lowest in November (Table 4-1). Spring is historically the time of maximum zooplankton standing crop in Lake Norman (Hamme 1982). The greatest observed zooplankton densities in 1993 for eplimnetic samples were observed at Location 2.0 in February (115,300/m^3) and for whole column samples were observed at Location 5.0 in May (132,600/m^3). The lowest zooplankton densities for both eplimnetic and whole column samples were observed in November at Location 9.5 (16,000/m^3 and 12,600/m^3, respectively). The trend of increasing zooplankton population densities from downlake to uplake observed in previous years was only evident in November of 1993 (Figure 4-1).

Total zooplankton densities were generally greater in epilimnetic samples than in whole column samples in 1993 as in previous years (Duke Power Company 1988, 1989, 1990, 1991 and 1992). This phenomenon is related to the ability of zooplankton to orient vertically in the water column in response to a variety of physical and chemical gradients and the distribution of food sources, primarily phytoplankton (Hutchinson 1967).

Location Comparisons

A one way ANOVA on total zooplankton densities in eplimnetic samples showed no consistent spatial pattern among locations in 1993 (Table 4-2). Zooplankton densities from Locations 2.0 and 9.5 were significantly higher than other locations in February, the month with the greatest differences in observed densities between locations. Total zooplankton density at Location 9.5 was significantly higher than other locations in August. Both zooplankton densities from Location 11.0 and 15.9 were significantly different from the lower lake locations in an increasing pattern moving uplake in November.

Year to Year Comparisons

Total zooplankton densities from eplimnetic samples collected during February, May, August and November of 1993 were generally within the range of those reported for these months in previous years (Figure 4-2). Major trends in epilimnetic zooplankton abundance included higher total zooplankton densities at Locations 2.0 and 9.5 in February than those observed since 1987. The November 1993 densities in the Mixing Zone were the lowest recorded since 1987, while the highest densities occurred in the Mixing Zone in May during the same period. No consistent patterns were noted for the Background locations.

Community Composition

Fifty-seven zooplankton taxa have been identified in samples collected since the Lake Norman Maintenance Monitoring Program was initiated in August 1987 (Table 4-3). No new zooplankton taxa were identified in samples collected in 1993. Rotifers most often dominated zooplankton assemblages in Lake Norman during 1993 as in previous years, followed by copepods (Table 4-1; Figure 4-3). Cladocerans were numerically dominant only at Location 2.0 in November in 1993. Rotifers were most consistently abundant lakewide during the warmer months when they comprised an average 60.7% and 76.0% of the total density in eplimnetic tows in May and August, respectively. Copepods were second most abundant during each sampling period except August when they comprised less than 10% of

the total density in epilimnetic samples at all locations. In November, rotifers exhibited increasing densities from downlake to uplake in both eplimnetic and whole water column samples,eg. 2,100/m^3 at Location 2.0 to 47,500/m^3 at Location 15.9 in eplimnetic samples. This was the only month in 1993 in which a consistent downlake uplake trend of increasing rotifer densities occurred as had been observed in past years. Hamme (1982) found that the highest rotifer densities generally occurred at uplake locations.

During February 1993 *Polyarthra* and *Synchaeta* were the major constituents of rotifer populations. *Keratella* and *Polyarthra* were the dominant rotifers at all locations in May. *Conchiloides, Conochilus* and *Trichocerca* joined *Keratella* as the most important rotifer taxa in August of 1993. *Conochilus* was the overall dominant in August of 1993 at Location 15.9 where it comprised more than 40% of the total density in both eplimnetic and whole column samples. *Keratella* and *Polyarthra* were again the major components of the rotifers in November. Major rotifer taxa observed in 1993 were also the most abundant rotifers observed in previous years (Duke Power Company 1988, 1989, 1990, 1991, 1992; Hamme 1982).

Copepod populations were dominated by immature forms (primarily nauplii and cyclopoid copepodids with some calanoid copepodids) during all sampling periods of 1993 as was the case in 1991. *Mesocyclops* spp. was the only major adult copepod taxon observed in 1993, comprising more than 5% of the total densities in the whole column samples at Location 9.5 in May. No distinct spatial trend in copepod abundance was noted for samples collected in 1993 (Figure 4-3).

Bosmina was the most abundant cladoceran observed in samples collected in 1993, as in 1992 (Duke Power Company 1993) and in previous years (Hamme 1982). *Bosmina* comprised more than 25% of the total zooplankton density in both epilimnetic and whole column samples at Location 2.0 in February. In November of 1993 as in 1992, *Bosmina* comprised more than 20% of the total density in whole column samples in the Mixing Zone. The only other major cladoceran taxa observed in 1993 was *Bosminopsis deitersi* at downlake locations 2.0, 5.0 and 9.5 (both epilimnetic and whole column samples) in August

where it comprised between 13% to 37% of the total zooplankton density. No consistent spatial trend in cladoceran abundance was observed in 1993 (Figure 4-3).

Several patterns are evident in comparison of group composition during 1993 with the past four years (Figure 4-4). Group densities at Location 9.5 for copepods and Cladocerans in February and Cladocerans in August are above historical ranges. Rotifer densities in the Mixing Zone during May and August are above the historical range while rotifer densities at Location 15.9 in 1993 were lower overall than observed in the past four years.

FUTURE STUDIES

No changes are planned for the zooplankton portion of the Lake Norman maintenance monitoring program.

SUMMARY

* Total zooplankton standing crops were generally highest in May and lowest in November. Zooplankton densities, in general, were slightly higher in eplimnetic samples than in whole column samples. Total zooplankton densities at Mixing Zone locations were not significantly different from background locations during any quarter in 1993. The typical trend of increasing zooplankton densities from downlake to uplake was observed only in November in 1993. The range of total zooplankton densities observed during 1993 was similar to the ranges observed since 1987.

* Overall, rotifers dominated zooplankton standing crops in 1993, as they did in 1992, followed closely in importance by copepods. Cladocerans were dominant numerically on only one occasion in 1993. Major rotifer taxa observed in 1993 were *Keratella*, *Polyarthra* and *Synchaeta*. Copepod populations were dominated by immature forms (nauplii and cyclopoid copepodids). As in previous years, *Bosmina* was the most abundant cladoceran taxa observed at all locations. Overall,

zooplankton taxonomic composition in 1993 was similar to that observed in previous years.

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Table 4-1. Total zooplankton densities (no. x $1000/m^3$), densities of major zooplankton taxonomic groups, and percent composition (in parentheses) of major taxa in 10 m to surface (10-S) and bottom to surface (B-S) net tow samples collected from Lake Norman in February, May, August, and November 1993.

			Locations				
Date	Sample Type	Taxon	2.0	5.0	9.5	11.0	15.9
02/23/93	10-S	COPEPODA	40.0	8.8	65.0	13.8	3.0
			(34.7)	(22.7)	(56.7)	(16.3)	(25.4)
		CLADOCERA	31.6	3.8	34.7	7.6	1.2
			(27.4)	(9.8)	(30.3)	(9.0)	(10.1)
		ROTIFERA	43.7	26.3	14.9	62.9	7.7
			(37.9)	(67.6)	(13.0)	(74.6)	(64.5)
		TOTAL	115.3	39.0	114.6	84.3	11.9
	B-S	COPEPODA	9.2	6.3	81.3	10.4	3.9
	(depth[m]		(29.2)	(19.7)	(65.1)	(33.6)	(26.6)
	of tow						
	for each	CLADOCERA	7.9	5.5	28.3	7.7	0.5
	location:		(25.0)	(17.2)	(22.7)	(24.8)	(3.1)
	2.0-31						
	5.0-18	ROTIFERA	14.4	20.1	15.2	12.9	10.3
	9.5-20		(45.8)	(63.1)	(12.2)	(41.7)	(70.3)
	11.0-26	TOTAL	31.5	31.8	124.8	31.0	14.7
	15.9-20)						
05/25/93	10-S	COPEPODA	27.4	25.6	39.0	31.2	37.7
			(28.3)	(42.0)	(34.8)	(30.8)	(39.1)
		CLADOCERA	3.8	7.1	2.5	1.3	2.2
			(4.0)	(11.6)	(2.2)	(1.3)	(2.3)
		ROTIFERA	65.7	28.2	70.7	68.6	56.5
			(67.7)	(46.3)	(63.0)	(67.9)	(58.6)
		TOTAL	96.9	61.0	112.1	101.1	96.4
	B-S	COPEPODA	18.6	21.6	35.8	26.0	33.2
	(depth[m]		(35.3)	(16.3)	(34.7)	(45.5)	(46.0)
	of tow						
	for each	CLADOCERA	3.7	4.0	3.5	1.6	2.7
	location:		(7.0)	(3.0)	(3.4)	(2.8)	(3.7)
	2.0-30						
	5.0-19	ROTIFERA	30.5	107.0	63.8	29.7	36.3
	9.5-20		(57.7)	(80.7)	(61.9)	(45.5)	(50.3)
	11.0-28						
	15.9-21)	TOTAL	52.8	132.6	103.1	57.3	72.1

Table 4-1. (continued

Date	Sample Type	Taxon	Locations 2.0	5.0	9.5	11.0	15.9
08/12/93	10-S	COPEPODA	1.9 (3.6)	5.3 (9.9)	3.8 (4.2)	3.4 (7.0)	4.9 (7.4)
		CLADOCERA	10.7 (20.6)	9.3 (17.3)	30.1 (33.5)	2.9 (6.0)	7.0 (10.5)
		ROTIFERA	39.3 (75.8)	39.1 (72.8)	56.1 (62.3)	42.3 (87.0)	54.7 (82.1)
		TOTAL	51.9	53.7	90.0	48.6	66.5
	B-S (depth[m] of tow for each location: 2.0-29 5.0-18 9.5-20 11.0-26 15.9-20)	COPEPODA	2.2 (8.2)	7.5 (22.0)	4.7 (9.4)	2.4 (10.6)	8.5 (12.5)
		CLADOCERA	6.5 (24.6)	5.5 (16.0)	19.6 (39.5)	2.9 (13.2)	9.2 (13.6)
		ROTIFERA	17.7 (67.2)	21.1 (62.0)	25.4 (51.1)	17.0 (76.2)	49.9 (73.9)
		TOTAL	26.3	34.1	49.8	22.3	67.5
11/30/93	10-S	COPEPODA	7.2 (45.0)	9.6 (43.0)	9.7 (60.9)	15.3 (33.4)	22.0 (27.3)
		CLADOCERA	6.7 (41.8)	4.9 (21.9)	1.7 (10.7)	4.4 (9.7)	11.1 (13.7)
		ROTIFERA	2.1 (13.2)	7.8 (21.9)	4.5 (28.4)	26.1 (56.9)	47.5 (59.0)
		TOTAL	16.0	22.3	16.0	45.8	80.6
	B-S (depth[m] of tow for each location: 2.0-30 5.0-18 9.5-20 11.0-26 15.9-19)	COPEPODA	9.9 (43.9)	10.6 (44.1)	6.4 (50.6)	14.0 (33.3)	16.1 (27.1)
		CLADOCERA	10.3 (45.8)	8.2 (34.0)	1.2 (9.7)	4.2 (9.9)	7.9 (13.3)
		ROTIFERA	2.3 (10.3)	5.3 (21.9)	5.0 (39.7)	23.9 (56.8)	35.4 (59.6)
		TOTAL	22.5	24.0	12.6	42.1	59.4

Table 4-2. Duncan's Multiple Range Test on Zooplankton Densities in Lake Norman, NC during 1993.

February	Location	**15.9**	**11.0**	**5.0**	**9.5**	**2.0**
	Mean	11.9	35.1	37.2	114.5	115.2
May	Location	**15.9**	**2.0**	**11.0**	**9.5**	**5.0**
	Mean	96.4	96.8	101.0	112.1	132.5
August	Location	**11.0**	**2.0**	**5.0**	**15.9**	**9.5**
	Mean	48.6	49.5	53.7	66.5	89.9
November	Location	**9.5**	**2.0**	**5.0**	**11.0**	**15.9**
	Mean	16.0	16.0	22.3	45.8	80.5

Table 4-3. Zooplankton taxa identified from samples collected in Lake Norman quarterly from August 1987 through November 1993.

COPEPODA

Cyclops thomasi S. A. Forbes
C. spp. Fischer
Diaptomus birgei Marsh
D. mississippiensis Marsh
D. pallidus Herick
D. spp. Marsh
Mesocyclops edax (S. A. Forbes)
M. spp. Sars
Tropocyclops prasinus (Fischer)
T. spp. Kiefer
Calanoid copepodites
Cyclopoid copepodites
Nauplii

CLADOCERA

Bosmina longirostris (O. F. Muller)
B. spp. Baird
Bosminopsis dietersi Richard
Ceriodaphnia spp. Dana
Daphnia ambigua Scourfield
D. parvula Fordyce
D. spp. Mullen
Diaphanosoma spp. Fischer
Holopedium amazonicum Stingelin
H. spp. Stingelin
Leptodora kindtii (Focke)
Ilyocryptus sordidus (Lieven)
Sida crystallina O. F. Muller

ROTIFERA

Anuraeopsis spp. Lauterborne
Asplanchna spp. Gosse
Brachionus caudata Barrois and Daday
B. havanaensis Rousselet
B. patulus O. F. Muller
Chromogaster spp. Lauterborne
Collotheca spp. Harring
Conochiloides spp. Hlava
Conochilus unicornis (Rousselet)
C. spp. Hlava
Gastropus spp. Imhof
Hexarthra spp. Schmada
Kellicotia bostoniensis (Rousselet)
K. spp. Rouselet
Keratella spp. Bory de St. Vincent
Lecane spp. Nitzsch
Macrocheatus spp. Perty
Monostyla stenroosi (Meissener)
M. spp. Ehrenberg
Ploeosoma truncatum (Levander)
P. spp. Herrick
Polyarthra euryptera (Weirzeijski)
P. vulgaris Carlin
P. spp. Ehrenberg
Ptygura spp. Ehrenberg
Synchaeta spp. Ehrenberg
Trichocerca capucina (Weireijski)
T. cylindrica (Imhof)
T. spp. Lamark
Unidentified Bdelloidea

INSECTA

Chaoborus spp. Lichtenstein

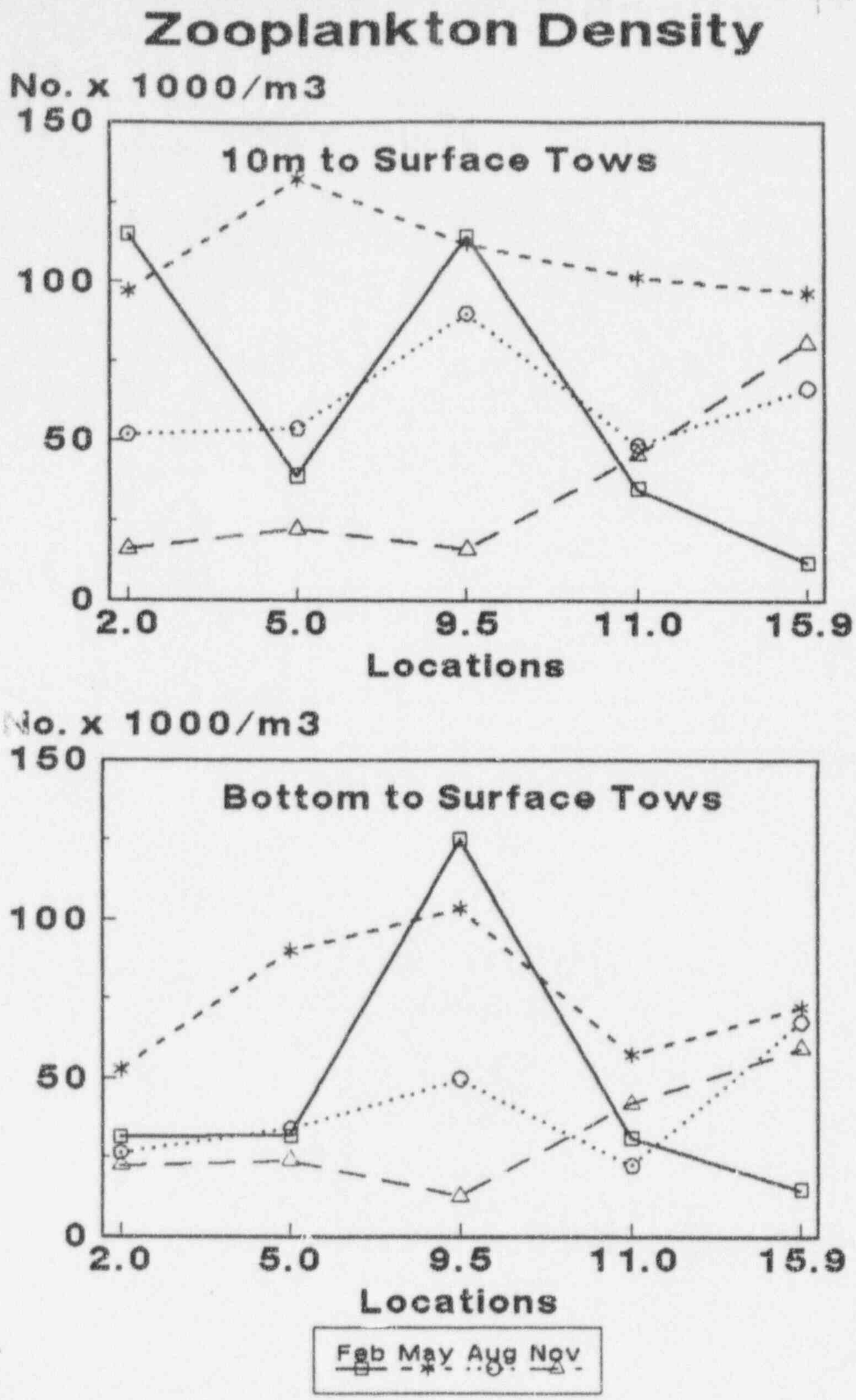

Figure 4-1. Total zooplankton density (units x1000/m^3) by location for samples collected in Lake Norman, North Carolina in 1993.

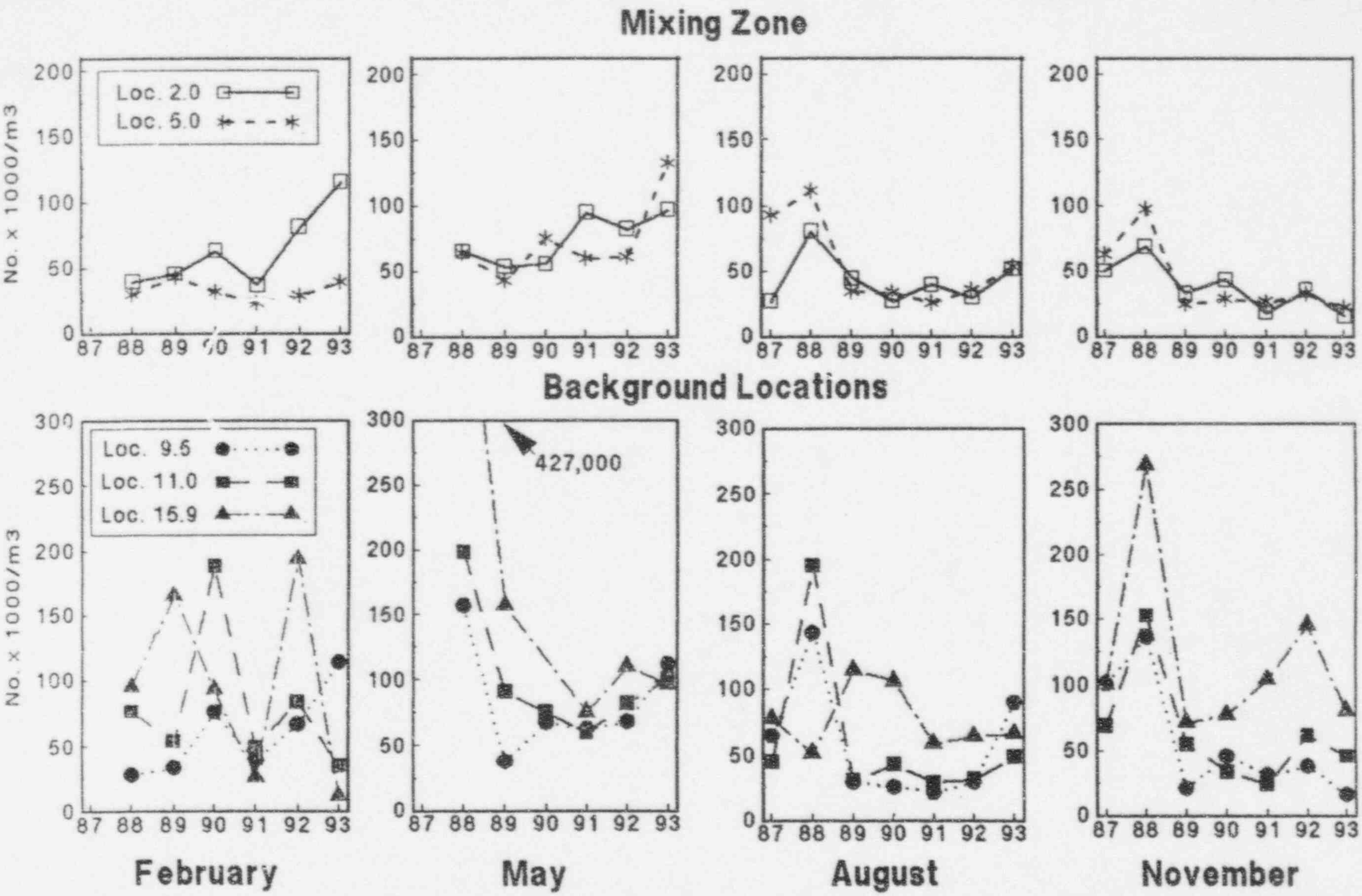

Figure 4-2. Total zooplankton density (units x1000/m^3) by location for samples collected during 1993 in Lake Norman, North Carolina.

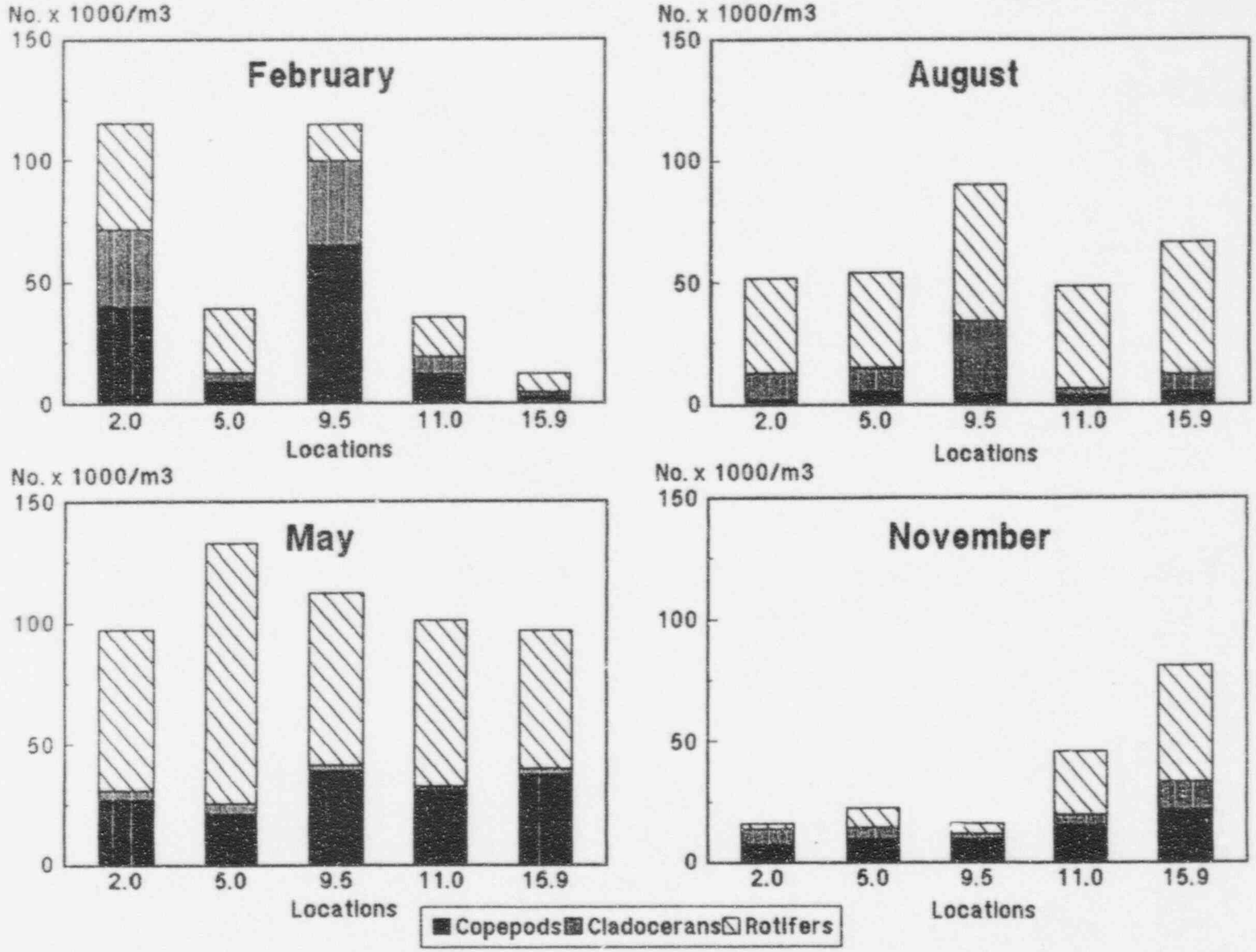

Figure 4-3. Zooplankton composition by month for epilimnetic samples collected during 1993 in Lake Norman, North Carolina.

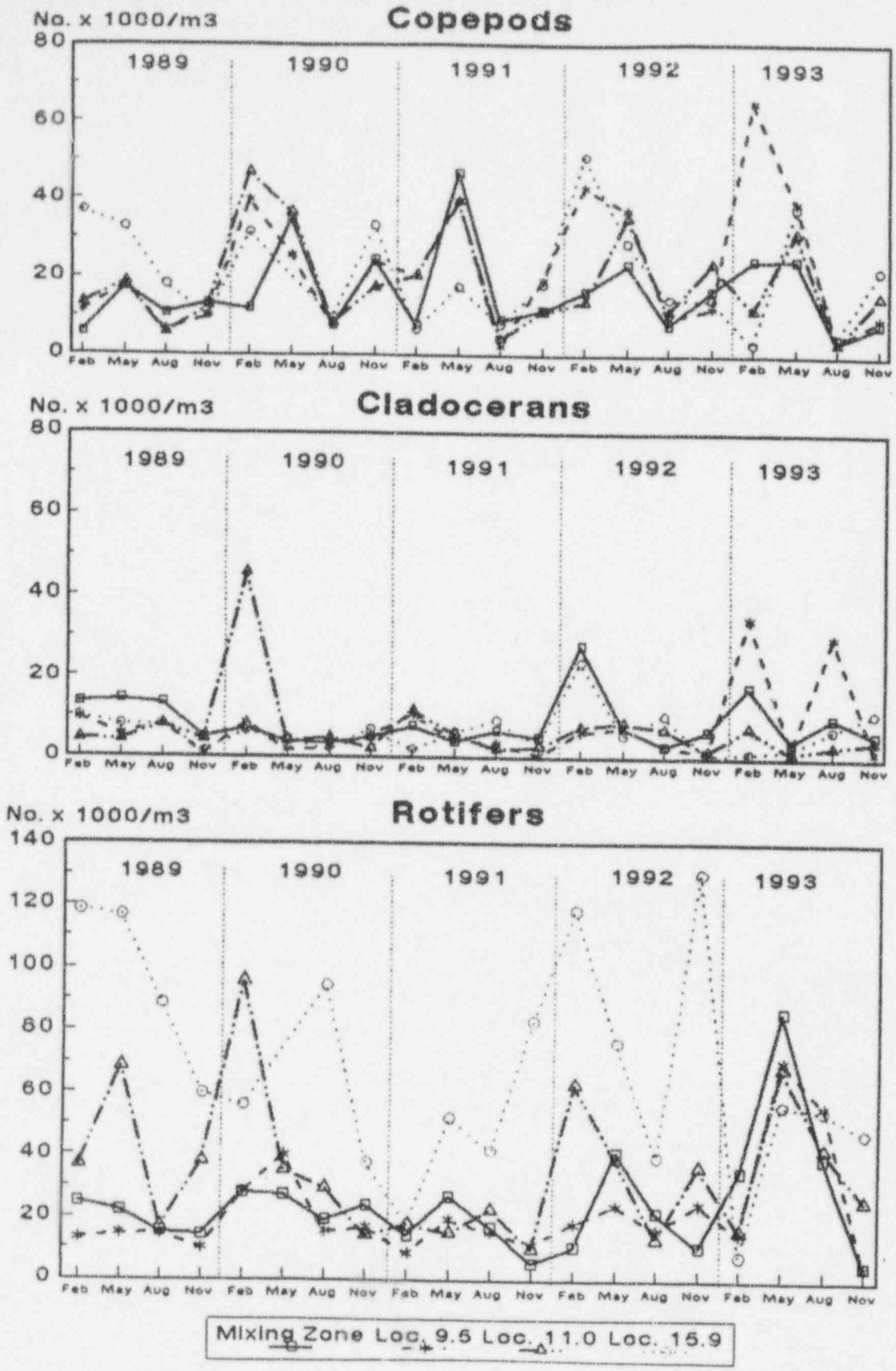

Figure 4-4. Comparison of zooplankton density by group in epilimnetic samples collected from 1989 through 1993 in Lake Norman, North Carolina.

CHAPTER 5
FISHERIES

INTRODUCTION

In accordance with the NPDES permit for McGuire Nuclear Station (MNS), monitoring of specific fish population parameters was continued during 1993. The objectives of the fish monitoring program for Lake Norman during 1993 were to:

* Continue striped bass mortality monitoring throughout the summer.

* Collect striped bass distribution information required for the NPDES permit by radio tagging striped bass and tracking the striped bass during the summer period in cooperation with North Carolina Wildlife Resources Commission (NCWRC).

* Measure limnetic fish distribution, density, and species composition in lower Lake Norman in 1993 using hydroacoustics and purse seine.

The mixing zone was monitored for striped bass mortalities through the summer during sampling trips on the lake, while tracking striped bass with NCWRC biologists. During the last 2 weeks of July and the first 2 weeks of August specific trips to search for dead or dying fish were conducted.

NCWRC and Duke studied striped bass movement and habitat selection by radio tagging fish in 1992 and 1993. Both NCWRC and Duke believe that this sampling program will identify critical summer striped bass habitat in Lake Norman. See appendix report 5.1 (NCWRC 1993 Federal Aid in Fish Restoration Project F23-17) for the sampling methodology and results of the program.

Hydroacoustics and a purse seine were used to determine fish distribution and species composition, respectively, in Lake Norman in August 1993.

METHODS AND MATERIALS

A 400-ft x 30-ft deep x 3/16-inch mesh purse seine was set near the MNS discharge after sunset on August 10, 1993, to collect limnetic fish. Fish captured were identified to species, counted, and a subsample of 500 threadfin shad were measured (mm, TL).

Fish density in the limnetic areas of the MNS mixing zone were determined with 120-KHz hydroacoustic gear on 4 August 1993. Lake Norman was sampled using methods similar to that reported in 1988 through 1990 (Duke Pow · Company 1990). Hydroacoustic samples were collected along transects in the main channel of the lake and all major tributaries, including Ramsey Creek and near the MNS discharge. Fish densities were plotted using a geographic identification system (GIS).

RESULTS AND DISCUSSION

Hydroacoustic density estimates of limnetic fish in lower Lake Norman were similar to ranges observed in other areas of the reservoir. Densities were lower in the heated water plume on August 4, 1993, than in the surrounding areas, but were not any less than in other areas of the reservoir (Figure 5-1). A clumped distribution pattern is evident, with densities ranging from less than 10,000 to greater than 90,000/ha in the MNS mixing zone and in areas of the reservoir with ambient water temperatures. Surface water temperatures in the discharge area during August were 35°C. This is higher than the preferred temperatures of threadfin shad, the predominant species in the limnetic area of the reservoir (Duke Power Company 1993).

Nearly all (99.6%) of the fish collected in the purse seine in August were threadfin shad. The only other species sampled with the purse seine in lower Lake Norman was black crappie.

Dead and dying striped bass were observed during the last 2 weeks in July 1993 in the MNS mixing zone. On July 23, fourteen dead striped bass were counted in the main channel from the dam to Marker 7, approximately 6 miles above the dam and 2 miles above the confluence of Davidson Creek and the main channel. On July 30, eleven dead striped bass were counted from the dam to Marker 1A, approximately 1.5 miles above the dam. Only two of the 25 dead striped bass observed were larger than 5 pounds. Anglers fishing the area for striped

bass were catching large numbers of fish less than the 20 inch size limit and returning them to the lake. This likely contributed to the large number of dead small fish observed. Striped bass less than 5 pounds have not been reported in the literature as stressed by high summer water temperatures; however, recent research in Tennessee has shown angling mortalities of greater than 60% for striped bass caught in the summer (Phil Bettoli, personal communication).

FUTURE FISH STUDIES

* Continue striped bass mortality monitoring throughout the summer.

* Determine fish distribution and conduct angler surveys to determine angler harvest, pressure, and success on Lake Norman from March 1994 through February 1995.

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Duke Power Company. 1993. Lake Norman: 1992 maintenance monitoring program, McGuire Nuclear Station. Duke Power Company, Charlotte, NC.

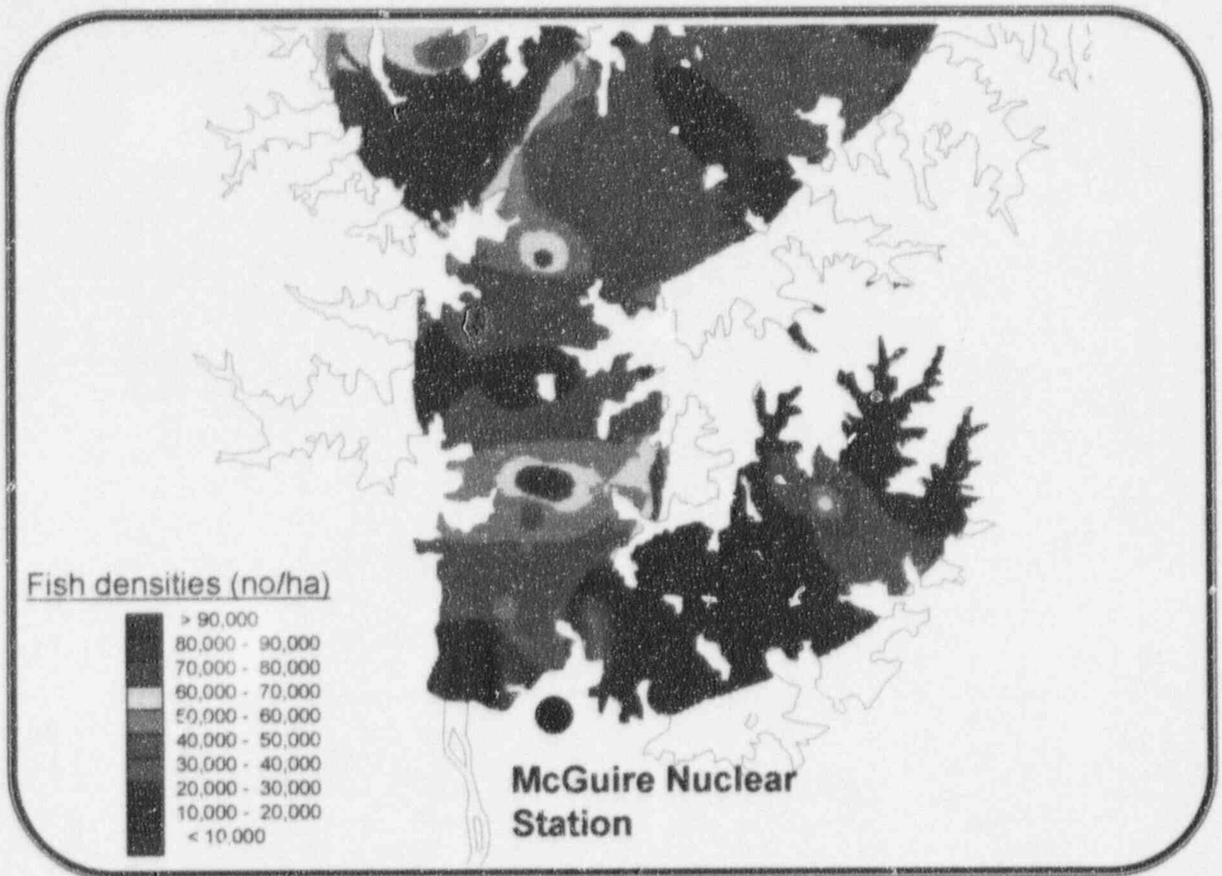

Figure 5-1. Hydroacoustic estimates of fish distribution and density in lower Lake Norman on 4 August 1993.

APPENDIX

Progress report on summer habitat selection of striped bass in Lake Norman (Federal Aid in Fish Restoration Project F23-17). A cooperative study between the North Carolina Wildlife Resources Commission and Duke Power Company.

A copy will be forwarded when completed.