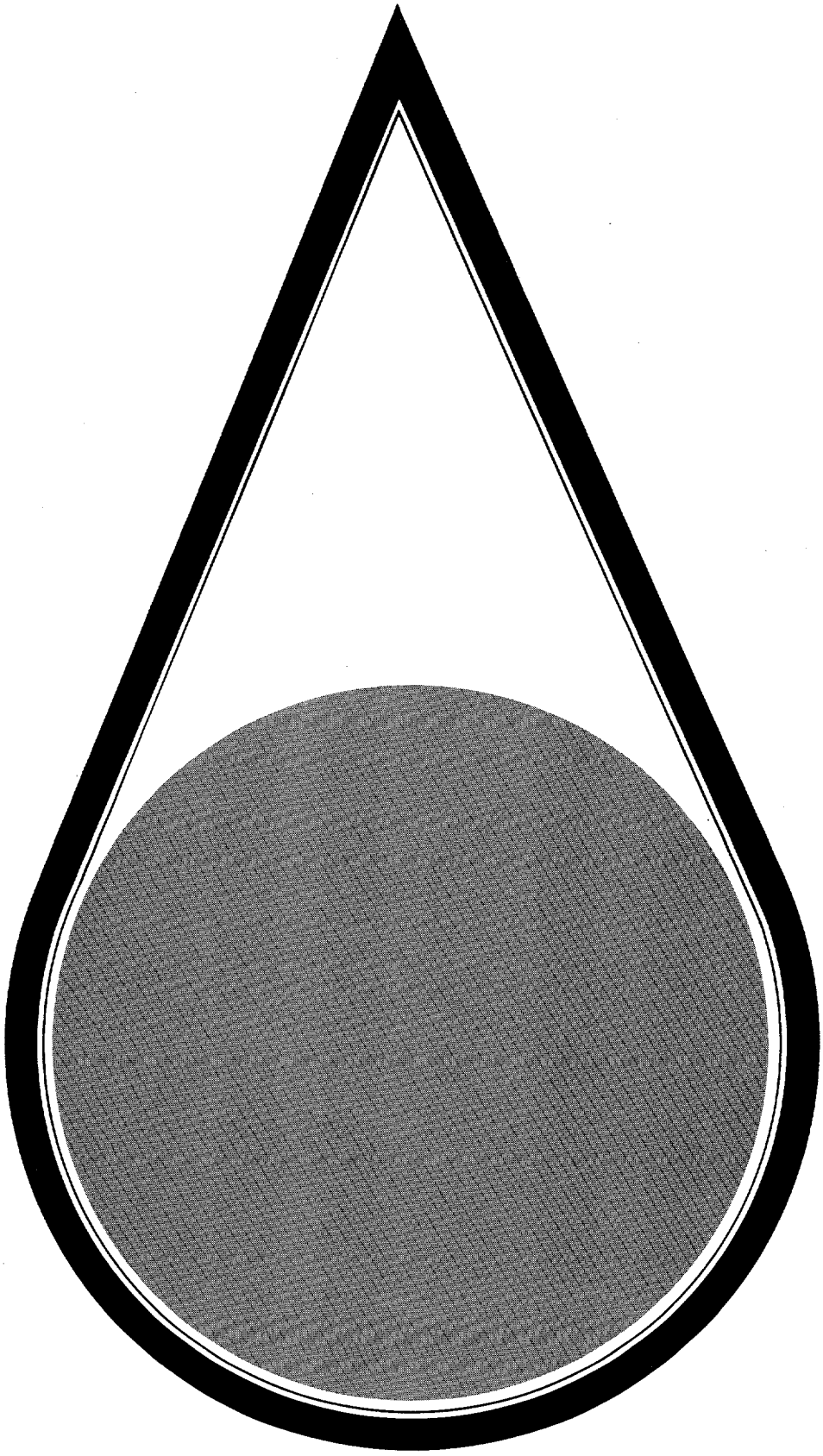
TECHNICAL REPORT SERIES

HEAVY METALS AND PCB CONCENTRATIONS IN SEDIMENTS FROM SELECTED TVA RESERVOIRS - 1982

April 1986
Division of Air and Water Resources
Office of Natural Resources
and Economic Development
Tennessee Valley Authority



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TENNESSEE VALLEY AUTHORITY

Office of Natural Resources and Economic Development
Divisions of Air and Water Resources,
and Services and Field Operations

HEAVY METALS AND PCB CONCENTRATIONS IN SEDIMENTS FROM SELECTED TVA RESERVOIRS - 1982

Chattanooga, Tennessee

April 1986

This investigation was funded through Federal appropriations to the TVA Office of Natural Resources and Economic Development, Regional Water Management Program. The report was written by Neil E. Carriker, Water Quality Branch, and Kit F. Nielsen, Field Operations East.

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Abstract

Sediment core samples were collected from the forebays of a dozen reservoirs in the Tennessee River Basin during June 1982. The concentration of priority pollutant metals and PCBs were determined along with particle size and volatile solids content. These data are briefly summarized and compared with other data from within and outside the Tennessee Valley. In general, no significant new sediment pollution problems were identified.

INTRODUCTION

Little is known about the extent of accumulation of trace contaminants in sediments behind Tennessee Valley Authority (TVA) dams. However, reservoir sediments, particularly those deposited in the forebay areas just upstream from dams, typically contain large proportions of fine-grained silts and clays. Because of their large adsorptive surface areas, such sediments usually accumulate pollutants as they settle through the water column. Consequently, concentrations of trace metals and organics in forebay sediments can be significantly higher than background levels. Conversely, under certain conditions these sediments may become sources of trace contaminants to the overlying water.

Natural weathering of minerals, and contaminants in industrial and municipal wastewaters and urban runoff are the principal sources of trace metals and organic pollutants in sediments. The study reported here and a previous study in 1973 were designed to obtain basic information on selected pollutants in TVA reservoir sediments.

EXPERIMENTAL DESIGN

The 1973 study included samples from the 9 mainstem Tennessee River reservoirs and 27 tributary reservoirs which were analyzed for 18 metals, total nitrogen, and phosphorus, and chemical oxygen demand. Samples in that study were collected using an Eckman dredge.

The 1982 study was more limited in scope. Samples were collected from the nine mainstem reservoir forebays, two tributary reservoirs (Douglas

and Melton Hill), and the Fleet Hollow embayment of Wilson Reservoir (figure 1). Analyses were limited to 13 metals, PCBs, particle size distribution, moisture content, and loss on ignition. In the 1982 study, sediments were obtained using a 2-inch diameter gravity corer modified to accept a stainless steel sleeve. The sampler was deployed from a boat, as in the 1973 study. This change from the Eckman dredge utilized in the earlier study was designed to reduce disturbance of the surface sediments and provide better control of the depth of sediment submitted for analysis. In practice, the sediments obtained with the gravity corer showed very little surface disturbance and allowed good recovery of the fine particles at the sediment surface.

Approximately nine cores were collected at each site. The top three-centimeter stratum of each core was removed from the stainless steel liner immediately following collection, composited with the upper three centimeters from the other cores at that site in a prewashed glass container, and placed into a cooler with ice for transport to the laboratory. Using only the upper three centimeters of each core ensured that the sample contained recent sediments. The compositing procedure was necessary to obtain sufficient sample volume for analysis, but it also reduced the inherent variations associated with sediment sampling and better ensured that each sample was representative of the area in which it was collected.

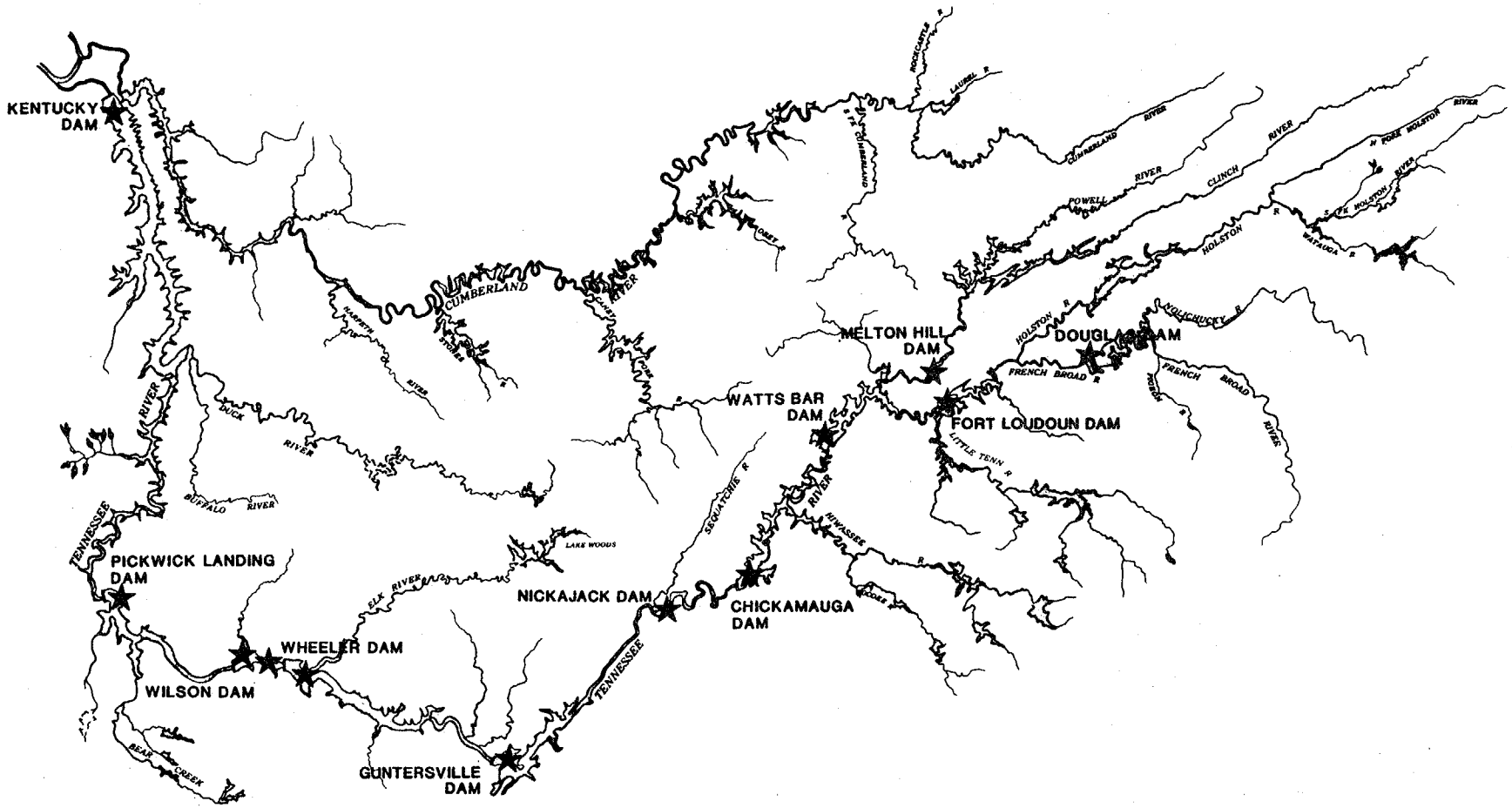


Figure 1. FOREBAY SEDIMENT SURVEY SAMPLING LOCATIONS

PHYSICAL ANALYSES

Wet sieve analysis was used to fractionate each composite sample into five particle size classifications: gravel (diameter >2 mm), coarse and very coarse sand (0.5 to 2.0 mm diameter), fine and medium sand (0.125 to 0.5 mm), very fine sand (0.063 to 0.125 mm) and silt plus clay (diameter <0.063 mm). Continuous asedigraph analysis of the silt/clay fraction determined the relative proportion of silt (0.063 to 0.002 mm) and clay (2 µm to 0.25 µm) in each sample.

Results of these analyses, along with the moisture content and loss on ignition (a crude measure of organic content, or volatile solids content) indicate that forebay sediments in TVA reservoirs have very similar compositions (table 1 and figure 2). Clays were the largest component of eleven of the twelve samples, followed by silts, sands, and gravel, in that order. Clays and silts together accounted for over 97 percent of the total sediment material in all but Kentucky (92.8 percent), Melton Hill (84.4 percent), Guntersville (70.9 percent), and Pickwick (51.9 percent) Reservoirs. Sands were the largest component (44.9 percent) of the Pickwick sediment, and were present in appreciable amounts in Guntersville (23.1 percent), Melton Hill (15.2 percent), and Kentucky (7.2 percent) sediments. Only two samples (Pickwick and Guntersville) contained any gravel. Moisture content and loss on ignition (organic content) closely correlated with the combined clay and silt content of the sediments.

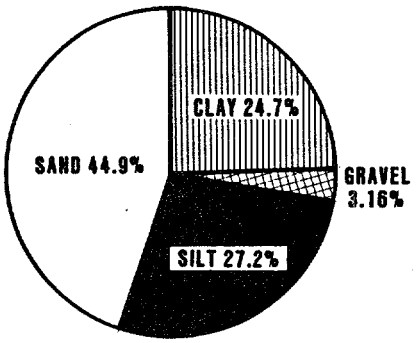
Table I

MOISTURE AND VOLATILE SOLIDS CONTENT AND PARTICLE SIZE DISTRIBUTIONS OF SELECTED TVA RESERVOIR FOREBAY SEDIMENTS

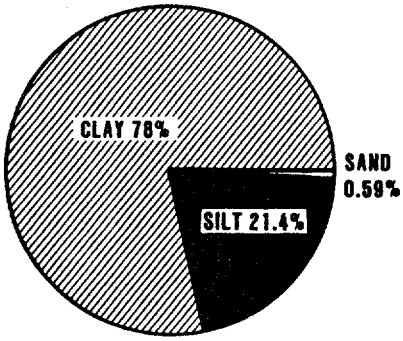
Reservoir	Sampling Date	Percent Moisture	Percent Loss on Ignition	Percent Clay (<2 µm)	Percent Silt (2 µm-63 µm)	Percent Sand (63 µm-2 mm)	Percent Gravel (>2 mm)	Percent Very Fine Sand (63 µm-0.125 mm)	Percent Fine and Medium Sand (0.125-0.5 mm)	Percent Coarse and Very Coarse Sand (0.5-2.0 mm)	Percent Silt & Clay (<63 µm)
Kentucky	6/23/82	54.6	5.70	52.0	40.8	7.20	0	5.62	0.79	0.79	92.8
Pickwick	6/16/82	29.3	4.20	24.7	27.2	44.9	3.16	15.4	25.6	3.88	51.8
Wilson	6/18/82	66.4	8.83	78.0	21.4	0.59	0	0.14	0.29	0.16	99.4
Wheeler	6/17/82	64.6	8.37	74.7	24.9	0.41	0	0	0.41	0	99.6
Guntersville	6/17/82	52.6	6.22	48.6	22.3	23.1	6.00	5.07	8.69	9.31	70.9
Nickajack	6/10/82	66.8	8.91	57.0	40.5	2.49	0	2.18	0.31	0	97.5
Chickamauga	6/08/82	67.3	8.36	65.9	33.2	0.89	0	0.89	0	0	99.1
Watts Bar	6/08/82	70.8	9.12	66.0	34.0	0	0	0	0	0	100
Fort Loudoun	6/29/82	66.4	8.73	67.2	29.5	3.28	0	1.64	1.04	0.60	96.7
Melton Hill	6/29/82	62.7	7.28	53.4	31.4	15.2	0	3.66	9.70	1.83	84.8
Douglas	6/29/82	67.2	9.54	85.9	13.4	0.74	0	0.30	0.44	0	99.3
Wilson (Fleet Hollow Embayment)	6/24/82	67.8	9.72	83.0	14.6	2.40	0	0.75	0.90	0.75	97.6

Figure 2. COMPOSITION OF RESERVOIR FOREBAY SEDIMENTS

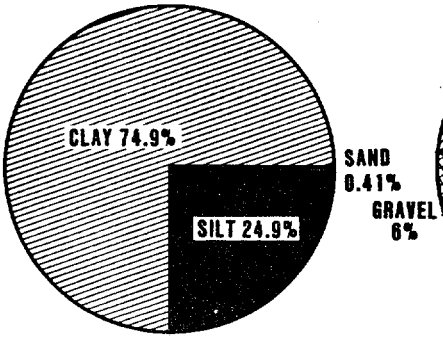
KENTUCKY RESERVOIR



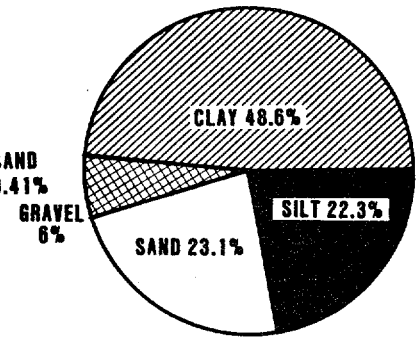
PICKWICK RESERVOIR



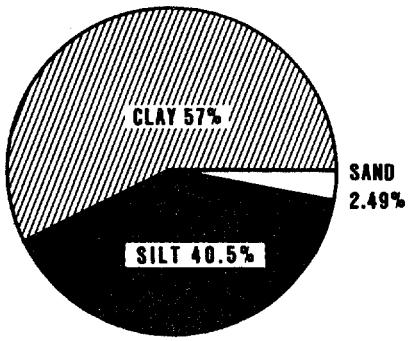
WILSON RESERVOIR



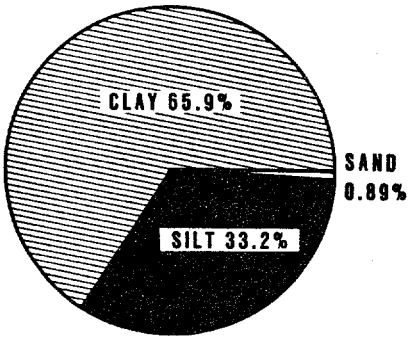
WHEELER RESERVOIR



GUNTERSVILLE RESERVOIR

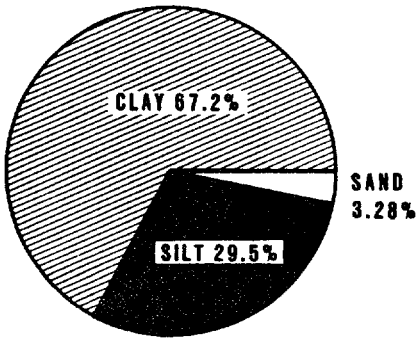


NICKAJACK RESERVOIR

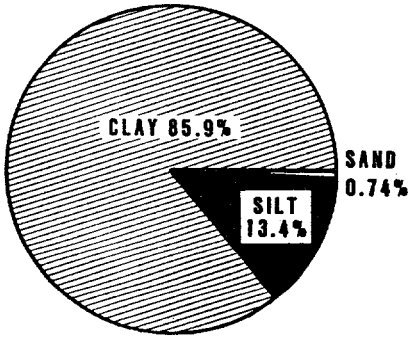


CHICKAMAUGA RESERVOIR

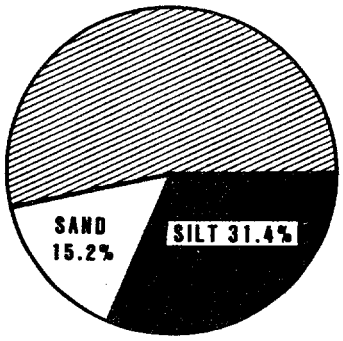
WATTS BAR RESERVOIR



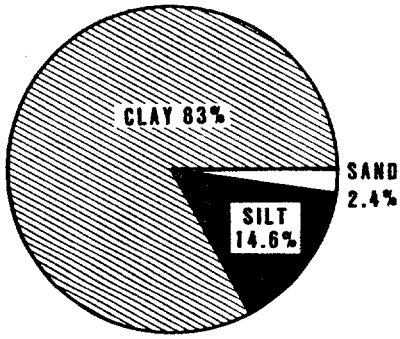
FT. LOUDOUN RESERVOIR



DOUGLAS RESERVOIR



MELTON HILL RESERVOIR



FLEET HOLLOW EMBAYMENT, WILSON RESERVOIR

The geology of the immediate drainage area appears to be the dominant factor in determining the physical composition of sediments deposited in the forebays of TVA reservoirs. The relatively high fraction of sand in Pickwick and Guntersville sediments probably results from weathering of the extensive sandstone formations in the Bear Creek watershed in northwest Alabama, and in the Sand Mountain drainage in northeast Alabama, respectively. Higher proportions of clay in Wheeler and Wilson sediments may result from erosion of the extensively tilled clay-loam and silt clay-loam soils in northcentral Alabama and the Elk River valley.

CHEMICAL ANALYSES

Results of chemical analyses of the 1982 samples (table 2) show that concentrations of silver, cadmium, and polychlorinated biphenyls were less than one part per million in all samples. Comparison with the 1973 results (table 3) shows comparable values for selenium, beryllium, nickel, lead, chromium, and manganese. Mercury levels were generally lower in the 1982 samples, and concentrations of arsenic, copper, and iron were generally higher in 1982 (figure 3).

Results for the mainstem Tennessee River reservoirs indicate that trace metal concentrations in sediments gradually decrease going downstream. However, chromium, copper, and lead reached peak concentrations in sediment from Nickajack Reservoir. This may reflect the effects of urban runoff from the Chattanooga metropolitan area and the long-term disposal of poorly treated sewage and sewage sludge into that reservoir. The second highest lead concentration occurred in Fort Loudoun Reservoir

Table 2

CHEMICAL ANALYSES OF 1982 TVA RESERVOIR FOREBAY SEDIMENTS

(µg/g dry weight basis)

Reservoir	Stream	Mile	Horizontal Location (%)	Collection Date	Ag	As	Be	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Se	Zn	PCBs
Kentucky	Tennessee	24.0	75	6/23/82	<1	8	1.8	<1	24	22	30,000	0.22	1,500	21	35	0.2	110	<1
Pickwick	Tennessee	207.6	50	6/16/82	<1	6	<1	<1	17	14	26,000	0.69	1,700	14	25	<0.2	87	<1
Wilson	Tennessee	260.0	50	6/18/82	<1	13	1.6	<1	34	34	39,000	0.17	4,800	31	45	<0.2	210	<1
Wheeler	Tennessee	277.0	40	6/17/82	<1	12	1.4	<1	35	41	43,000	0.22	2,400	30	52	0.5	240	<1
Guntersville	Tennessee	350.4	50	6/17/82	<1	9	<1	<1	28	35	32,000	0.69	2,300	23	50	0.4	300	<1
Nickajack	Tennessee	425.5	50	6/10/82	<1	10	1.6	<1	50	63	39,000	0.48	2,700	27	77	0.9	380	<1
Chickamauga	Tennessee	472.3	80	6/08/82	<1	15	1.8	<1	35	63	46,000	0.77	4,900	30	59	0.8	490	<1
Watts Bar	Tennessee	531.0	20	6/08/82	<1	16	1.6	<1	34	40	40,000	0.62	3,600	24	53	0.8	220	<1
Fort Loudoun	Tennessee	603.2	50	6/29/82	<1	12	1.6	<1	39	45	44,000	0.10	2,600	27	75	<0.2	500	<1
Melton Hill	Clinch	23.7	90	6/29/82	<1	13	1.6	<1	18	34	30,000	<0.10	3,500	23	60	<0.2	120	<1
Douglas	French Broad	33.0	60	6/29/82	<1	9	1.8	<1	40	39	48,000	0.18	1,100	30	64	0.3	900	<1
Wilson	Fleet Hollow Embayment	0.1	50	6/24/82	<1	11	1.9	<1	36	41	40,000	0.1	54,100	33	63	0.6	200	<1

Table 3

INVENTORY OF SELECTED CHEMICAL ELEMENTS
1973 RESERVOIR FOREBAY
SEDIMENT SURVEY

(µg/g dry weight basis)

Reservoir	Stream	Mile	Horizontal Location	Collection Date	Al	As	Ba	Be	Cd	Cr	Co	Cu	Fe	Pb	Li
Kentucky	Tennessee River	24.0	75	4/27/73	3,800	2.6	110	0.7	0.3	12	9.2	10	9,400	10	2.4
Pickwick	Tennessee River	207.6	50	4/24/73	6,100	4.5	190	0.6	1.1	17	15	20	14,000	35	3.5
Wilson	Tennessee River	260.0	50	4/23/73	11,000	7.2	190	1.3	3.3	34	27	39	27,000	55	8.7
Wheeler	Tennessee River	277.0	40	7/10/73	14,000	4.4	220	1.3	2.0	34	24	25	26,000	55	8.8
Guntersville	Tennessee River	350.4	90	7/05/73	7,500	6.0	160	<0.7	1.6	22	21	26	17,000	50	4.3
Nickajack	Tennessee River	425.5	54	6/21/73	8,500	6.1	13	1.3	2.5	41	25	33	18,000	64	6.5
Chickamauga	Tennessee River	472.3	80	6/18/73	9,100	8.1	150	1.3	2.6	23	31	35	19,000	59	7.1
Watts Bar	Tennessee River	531.0	20	8/01/73	3,000	<2.0	55	<0.6	0.4	14	6.0	7.8	8,000	10	2.9
Fort Loudoun	Tennessee River	603.2	50	8/30/73	8,900	<2.0	230	<0.7	1.0	39	21	20	25,000	62	5.3
Beech	Beech River	35.0	50	4/25/73	6,500	9.6	190	0.7	0.7	13	16	12	23,000	27	2.6
Bear Creek	Bear Creek	75.0	90	6/11/73	4,500	5.0	78	0.6	<0.3	5	7.3	6.7	8,800	13	1.7
Tims Ford	Elk River	134.0	25	6/13/73	6,700	5.6	170	0.7	0.6	11	26	14	19,000	19	3.9
Woods	Elk River	170.5	99	6/13/73	2,100	10	36	<0.7	<0.4	8	2.0	10	5,300	6	0.76
Hiwassee	Hiwassee River	76.2	50	6/22/73	5,200	2.5	23	<0.7	<0.4	6	5.6	4.9	6,800	<3	6.4
Chatuge	Hiwassee River	121.5	50	6/21/73	21,000	<2.0	120	0.7	<0.5	29	27	30	29,000	21	2.9
Nottely	Nottely River	23.5	60	6/21/73	1,200	2.7	91	0.7	0.4	14	17	11	17,000	20	4.2
Ocoee No. 1	Ocoee River	12.0	60	6/22/73	10,000	12	33	1.3	3.3	13	49	680	60,000	1,400	3.2
Ocoee No. 3	Ocoee River	29.3	10	6/22/73	4,300	5.8	63	<0.6	2.2	7	14	39	12,000	4	2.0
Blue Ridge	Toccoa River	53.5	50	6/21/73	1,400	2.6	95	0.7	0.5	16	16	23	22,000	31	4.5

Table 3

(Continued)

(µg/g dry weight basis)

Reservoir	Stream	Mile	Horizontal Location	Collection Date	Al	As	Ba	Be	Cd	Cr	Co	Cu	Fe	Pb	Li
Melton Hill	Clinch River	23.4	80	6/07/73	7,600	5.5	140	1.3	0.8	13	20	27	17,000	42	7.6
Norris	Clinch River	80.0	60	8/02/73	7,500	8.4	180	<0.7	0.4	14	23	17	16,000	72	9.1
Ollis	Ollis Creek	3.5	40	10/11/73	6,900	6.2	72	1.3	0.5	12	11	23	19,000	16	7.9
Chilhowee	Little Tenn. River	35.0	50	6/27/73	11,000	<2.0	110	<0.7	0.7	13	21	19	21,000	29	6.7
Fontana	Little Tenn. River	62.5	50	6/27/73	16,000	<2.0	130	1.4	0.8	14	25	23	27,000	33	12
Santeetlah	Cheoah River	11±	50	6/27/73	18,000	3.8	98	<0.7	0.8	12	31	19	47,000	34	6.4
Thorpe	W.Fk.Tuckasegee R.	12±	-	6/26/73	11,000	6.6	88	1.3	0.6	11	6.4	14	11,000	300	12
Cherokee	Holston River	53.0	50	7/23/73	7,400	6.5	110	0.7	1.0	22	20	40	16,000	44	5.1
Ft. Pat. Henry	S.Fk.Holston River	10.8	50	7/25/73	5,400	<2.0	67	0.7	1.2	11	12	73	11,000	26	6.7
Boone	S.Fk. Holston River	19.0	75	7/25/73	2,700	13	22	<0.5	<0.3	9	2.7	5.9	10,000	5	0.68
South Holston	S.Fk.Holston River	51.0	75	7/24/73	8,000	<2.0	130	0.6	0.7	12	14	16	190	24	9.2
Watauga	Watauga River	37.0	50	7/25/73	3,400	14	52	1.3	0.4	6	11	9.0	13,000	34	1.7
Douglas	French Broad River	33.0	90	7/26/73	13,000	<2.0	200	<0.7	1.6	34	20	26	26,000	60	9.4
Nolichucky	Nolichucky River	45.9	90	7/25/73	9,600	2.1	160	<0.7	0.8	23	16	62	18,000	78	5.7
Barkley	Cumberland River	50.0	95	4/18/73	6,800	5.4	180	0.7	0.7	18	22	24	140	38	3.8
Old Hickory	Cumberland River	300±	80	5/22/73	5,800	7.6	98	0.7	0.9	13	44	74	13,000	20	3.3
Great Falls	Caney Fork River	92.0	50	4/16/73	4,000	4.1	110	<0.7	0.8	9	14	8	8,100	21	2.2

Table 3

(Continued)

(µg/g dry weight basis)

Reservoir	Stream	Mile	Horizontal Location	Collection Date	Mn	Hg	Ni	N	P	Se	Ag	Sr	Zn	COD
Kentucky	Tennessee River	24.0	75	4/27/73	1,100	0.33	9.2	5,200	760	<1	<0.4	<3.3	37	30,800
Pickwick	Tennessee River	207.6	50	4/24/73	2,200	2.5	16	1,600	1,000	<1	0.6	<3.2	120	82,300
Wilson	Tennessee River	260.0	50	4/23/73	2,200	0.44	23	1,400	1,300	<1	1.9	<3.2	650	51,200
Wheeler	Tennessee River	277.0	40	7/10/73	3,600	0.43	30	1,500	1,300	<1	1.9	3.9	260	52,700
Guntersville	Tennessee River	350.4	90	7/05/73	2,500	0.70	25	2,100	800	<1	2.7	<3.4	290	51,900
Nickajack	Tennessee River	425.5	54	6/21/73	2,200	0.71	27	2,000	850	<1	3.3	<3.3	440	59,400
Chickamauga	Tennessee River	472.3	80	6/18/73	3,100	1.4	23	1,200	760	<1	1.3	<3.3	480	45,700
Watts Bar	Tennessee River	531.0	20	8/01/73	670	0.44	6.6	46	230	2	1.2	<3.0	85	11,000
Fort Loudoun	Tennessee River	603.2	50	8/30/73	2,300	0.36	22	2,200	1,000	<1	2.0	<3.3	160	57,100
Beech	Beech River	35.0	50	4/25/73	630	0.10	10	2,500	540	2	1.3	<3.3	31	60,800
Bear Creek	Bear Creek	75.0	90	6/11/73	550	0.10	8.5	680	290	1	1.2	<3.0	22	26,500
Tims Ford	Elk River	134.0	25	6/13/73	12,000	<0.10	25	2,800	1,200	<1	1.3	<3.0	43	100,000
Woods	Elk River	170.5	99	6/13/73	320	0.20	4.4	440	260	6	0.6	<3.2	29	13,600
Hiwassee	Hiwassee River	76.2	50	6/22/73	150	0.13	3.7	100	240	1	0.6	<3.1	28	4,600
Chatuge	Hiwassee River	121.5	50	6/21/73	560	0.19	16	1,900	590	<1	1.3	<3.3	51	73,600
Nottely	Nottely River	23.5	60	6/21/73	540	0.20	11	1,500	510	3	1.3	<3.3	38	61,300
Ocoee No. 1	Ocoee River	12.0	60	6/22/73	240	0.41	11	2,200	450	<1	2.6	<3.2	480	56,400
Ocoee No. 3	Ocoee River	29.3	10	6/22/73	320	0.30	4.6	280	350	6	1.7	<2.9	350	39,600
Blue Ridge	Toccoa River	53.5	50	6/21/73	260	0.13	46	1,400	560	<1	0.7	<3.3	48	52,500

Table 3

(Continued)

(µg/g dry weight basis)

Reservoir	Stream	Mile	Horizontal Location	Collection Date	Mn	Hg	Ni	N	P	Se	Ag	Sr	Zn	COD
Melton Hill	Clinch River	23.4	80	6/07/73	3,100	0.19	18	1,800	530	<1	1.3	<3.2	66	44,900
Norris	Clinch River	80.0	60	8/02/73	1,700	0.21	18	1,700	430	<1	2.0	<3.3	62	36,800
Ollis	Ollis Creek	3.5	40	10/11/73	240	0.14	20	1,300	-	<1	0.6	<3.1	66	32,600
Chilhowee	Little Tenn. River	35.0	50	6/27/73	1,000	0.20	<3.3	2,500	620	<1	2.0	<3.3	80	76,400
Fontana	Little Tenn. River	62.5	50	6/27/73	430	0.21	12	4,300	620	<1	2.1	<3.5	90	65,600
Santeetlah	Cheoah River	11±	50	6/27/73	460	0.16	14	3,800	750	<1	2.0	<3.3	84	101,000
Thorpe	W.Fk.Tuckasegee R.	12±	-	6/26/73	170	0.14	17	1,400	410	2	1.3	<3.2	100	77,100
Cherokee	Holston River	53.0	50	7/23/73	1,300	0.51	17	2,200	840	<1	2.0	<3.4	270	53,900
Ft. Pat. Henry	S.Fk.Holston River	10.8	50	7/25/73	690	0.29	11	1,500	500	2	2.0	<3.3	580	49,600
Boone	S.Fk.Holston River	19.0	75	7/25/73	92	0.32	<2.3	340	220	1	0.9	<2.3	110	6,910
South Holston	S.Fk.Holston River	51.0	75	7/24/73	4,000	0.22	16	3,500	570	<1	1.8	<3.0	55	60,500
Watauga	Watauga River	37.0	50	7/25/73	1,500	0.32	5.2	350	140	<1	1.3	<3.2	21	9,890
Douglas	French Broad River	33.0	90	7/26/73	860	0.40	23	2,500	960	<1	2.6	<3.3	120	51,700
Nolichucky	Nolichucky River	45.9	90	7/25/73	900	0.39	19	2,100	610	<1	1.3	<3.3	210	80,100
Barkley	Cumberland River	50.0	95	4/18/73	1,700	0.13	20	1,600	1,800	<1	1.3	3.9	34	73,100
Old Hickory	Cumberland River	300±	80	5/22/73	1,400	0.23	18	1,700	1,400	<1	1.4	<3.4	50	41,200
Great Falls	Caney Fork River	92.0	50	4/16/73	880	0.15	17	1,100	340	<1	<0.7	<3.3	41	57,700

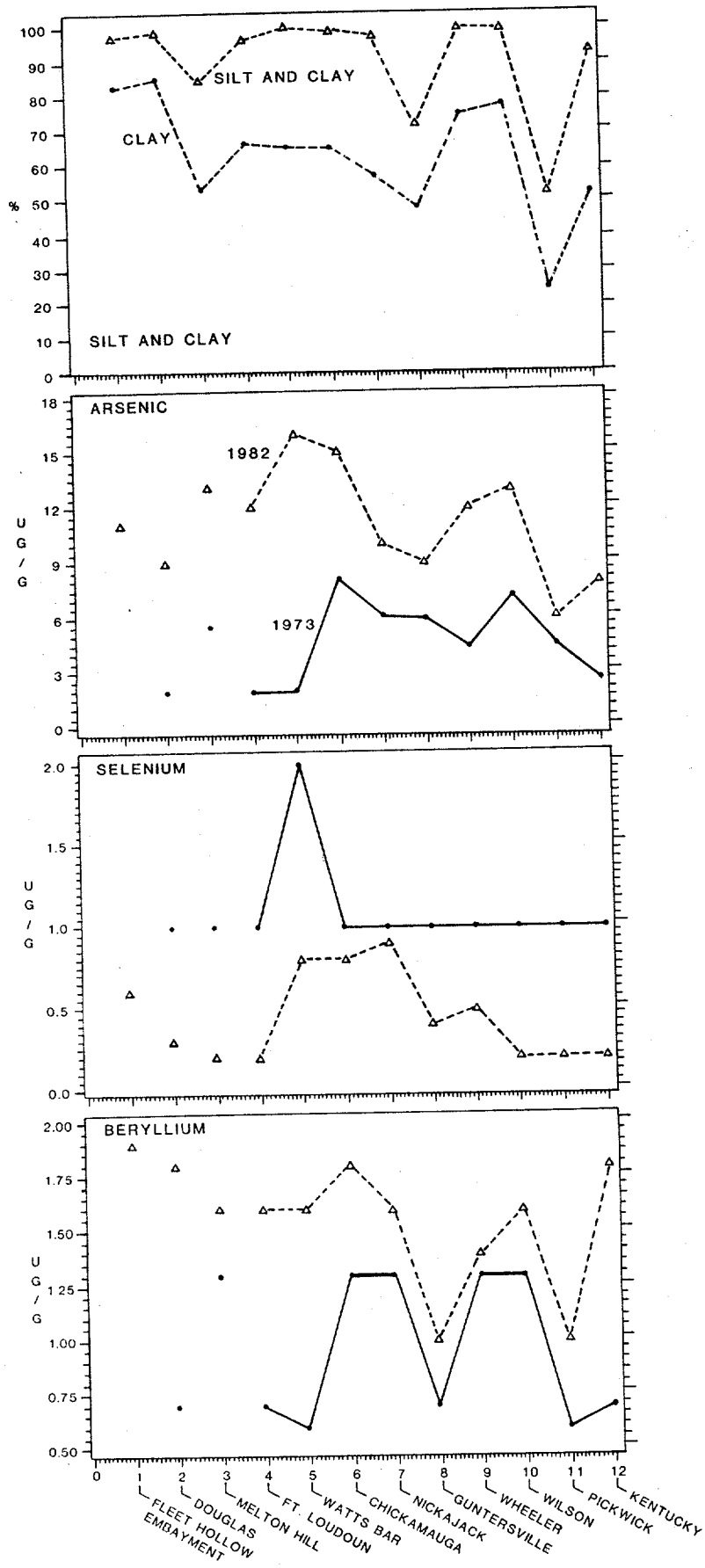


Figure 3.

LONGITUDINAL DISTRIBUTION OF SELECTED PARAMETERS IN TVA RESERVOIR FOREBAY SEDIMENTS

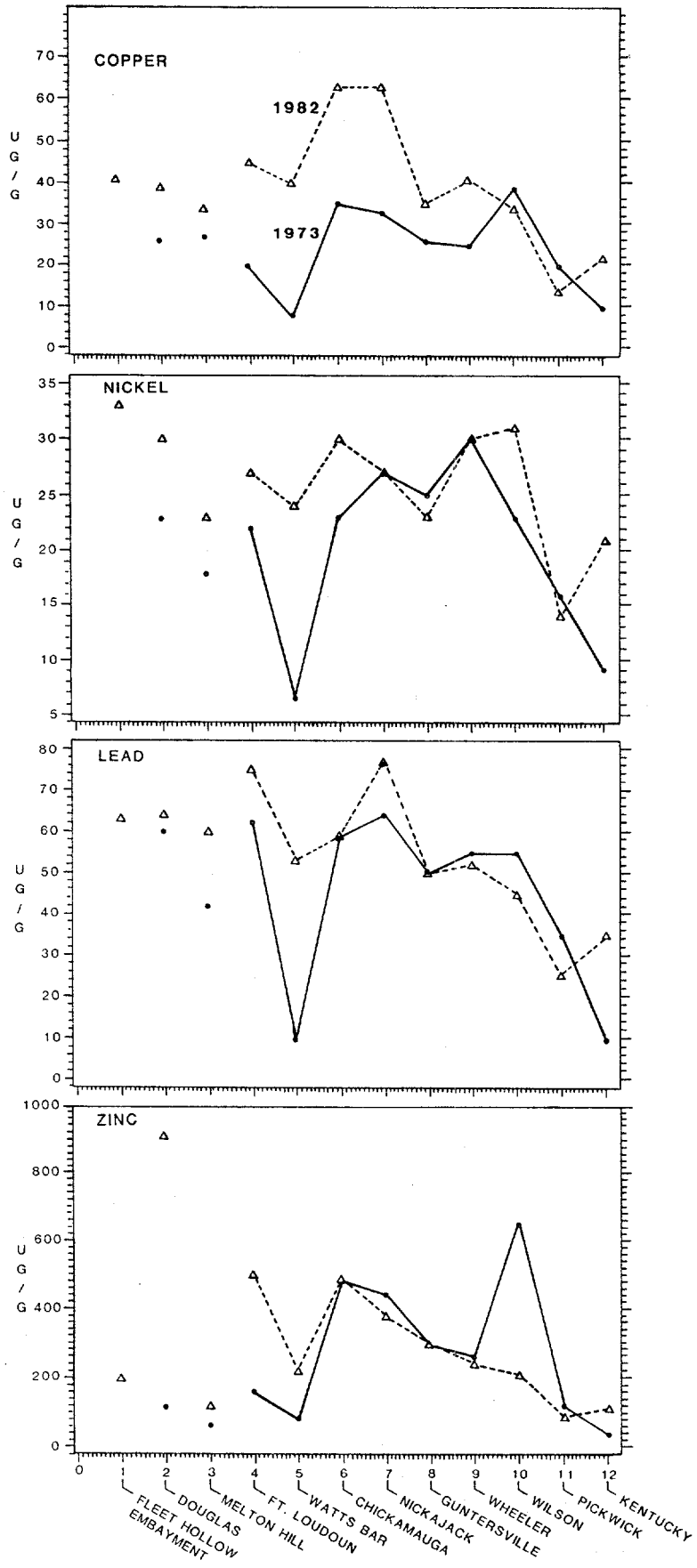


Figure 3. (cont'd)

LONGITUDINAL DISTRIBUTION OF SELECTED PARAMETERS IN

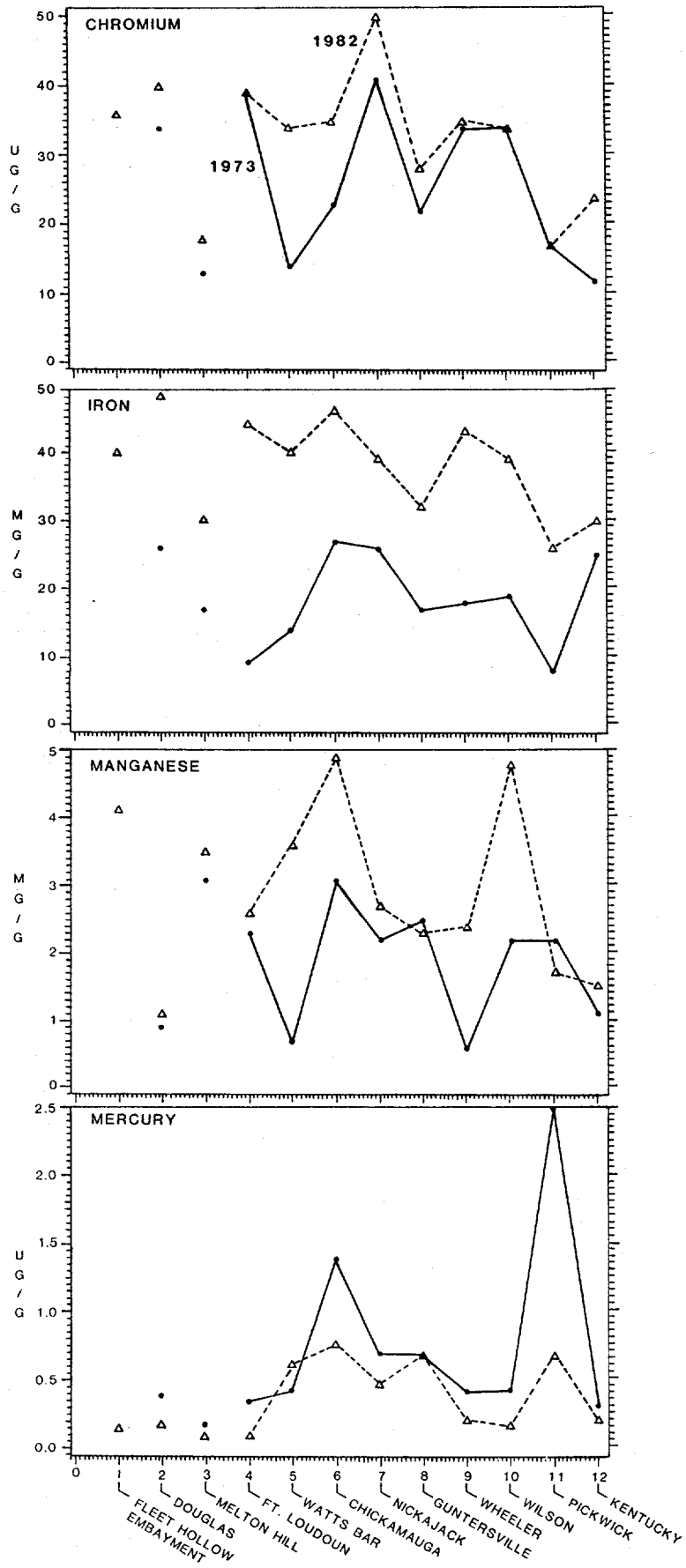


Figure 3. (cont'd)

LONGITUDINAL DISTRIBUTION OF SELECTED PARAMETERS IN TVA RESERVOIR FOREBAY SEDIMENTS

sediments. The city of Knoxville drains directly to Fort Loudoun, and municipal sewage from Knoxville also is discharged to that reservoir. This combination of the two highest lead concentrations occurring in reservoirs immediately downstream of two large urban areas indicates that urban runoff is an important factor influencing lead concentrations in reservoir sediments.

The copper concentration was also elevated in Chickamauga sediments. This probably is due to transport of copper-rich sediments into Chickamauga Reservoir from the Ocoee and Hiwassee Rivers, which drain the Copper Basin area of southeast Tennessee. The higher values in Nickajack also may be partly attributable to the Ocoee and Hiwassee drainage.

Although lower than in 1973, mercury concentrations in sediments from Pickwick, Guntersville, Nickajack, Chickamauga, and Watts Bar Reservoirs are substantially higher than the other reservoirs. The higher level in Pickwick is the remnant of historical contamination from a chlor-alkali plant at Muscle Shoals, Alabama. The higher levels in Watts Bar Reservoir may reflect contamination from mercury losses at the Department of Energy facilities at Oak Ridge, Tennessee, and the higher levels in Nickajack and Guntersville Reservoirs may reflect industrial activity in the Chattanooga area.

The highest value for zinc occurred in Douglas Reservoir sediments in 1982. This may be related to discharge of zinc-containing wastewaters from a synthetic fibers plant at mile 7 on the Nolichucky River, the second largest tributary to Douglas Reservoir.

Comparison with published investigations of sediments in other river systems shows that for most heavy metals, results of both the 1973 and 1982 TVA surveys fall in the lower range of values reported (table 4). The principal exceptions were those at the high end of the range for the TVA reservoirs for arsenic, copper, mercury, and zinc. These fell into range of values observed for more polluted systems (upper Peoria Lake, southern Lake Michigan, Lake Erie near Cleveland, and the Rhine River industrial area values in table 4). Probable causes for the highest copper, mercury, and zinc values in the TVA reservoirs are discussed above. Another possible contributor to the zinc levels in Fort Loudoun, Chickamauga, and Nickajack Reservoir sediments is urban runoff from the Knoxville and Chattanooga metropolitan areas. Arsenic concentrations in TVA reservoir sediments appear to be uniformly higher than background levels reported by Moore and Ramamoorthy (1984). This is not particularly surprising, recognizing the fact that arsenic occurs in nature as a trace contaminant of phosphate-rich minerals. As a result, it also is a trace contaminant of phosphate fertilizers and phosphate-based detergents. The facts that (1) there are naturally occurring phosphate deposits in parts of the Tennessee Valley, (2) phosphate fertilizers are manufactured in the Valley and are widely used in the Valley's agricultural production, and (3) there have never been any local or State restrictions on sales of phosphate-based detergents in the Valley, probably all are factors in the enriched arsenic values in TVA reservoir sediments.

Table 4

COMPARISON OF TVA RESERVOIR SEDIMENT HEAVY METALS LEVELS WITH OTHER PUBLISHED SEDIMENT STUDIES

Location	Ag (µg/g)	As (µg/g)	Be (µg/g)	Cd (µg/g)	Cr (µg/g)	Cu (µg/g)	Fe (%)	Reference
				Tennessee Valley Reservoirs				
Eleven TVA Reservoir Forebays - 1982	<1	6-16	<1-1.8	<1	17-50	14-63	2.6-4.8	This study.
Thirty-six TVA Reservoir Forebays - 1973	<0.4-3.3	<2-14	<0.6-1.4	<0.3-3.3	5-41	7.8-74	0.8-4.7	Unpublished TVA study.
Nickjack Reservoir, Tennessee (six sites - 1982, see) Appendix A)	<1	7.2-12	<1	<1	23-41	29-58	NA	Unpublished TVA study.
Fort Loudoun Reservoir, Tennessee (Two Forebay Sites)	NA NA	NA NA	NA NA	9 15	253 117	38 40	3.4 2.8	Perhac, 1974
				Unpolluted Lakes and Reservoirs				
Lake Constance (Rhine River headwaters, West Germany)	NA	NA	NA	0.2	50	30	NA	Förstner, et al., 1974
Recent Sediments from 87 Unpolluted Lakes	NA	NA	NA	0.1-1.5	20-190	20-90	1.1-6.7	Förstner, & Wittman, 1983, p. 136

Table 4

(Continued)

Location	Ag (µg/g)	As (µg/g)	Be (µg/g)	Cd (µg/g)	Cr (µg/g)	Cu (µg/g)	Fe (%)	Reference
				Heavily Polluted Lakes and Reservoirs				
Upper Peoria Lake, Illinois	NA	10-14	1.8-3.0	3-13	60-250	25-90	NA	Collinson & Shimp, 1972
Southern Lake Michigan, Illinois	NA	15-25	0.5-3.0	NA	20-100	20-100	NA	Shimp, et al., 1970
Lake Erie near Cleveland, Ohio - Surface Sediments	NA	3.2	NA	2.4	42	59	NA	Walters, et al., 1974
Rhine River, Industrial Area, West Germany	NA	NA	NA	13	493	286	NA	Banat, et al., 1972

Table 4

(Continued)

Location	Hg (µg/g)	Mn (µg/g)	Ni (µg/g)	Pb (µg/g)	Se (µg/g)	Zn (µg/g)	Reference
				Tennessee Valley Reservoirs			
Eleven TVA Reservoir Forebays - 1982	<0.1-0.77	1100-4900	14-31	25-77	<0.2-0.9	87-900	This study.
Thirty-six TVA Reservoir Forebays - 1973	<0.1-2.5	670-4000	<2.3-46	<3-300	<1-6	21-650	Unpublished TVA study.
Nickjack Reservoir, Tennessee (six sites - 1982, see) Appendix A)	0.23-3.8	NA	18-24	51-90	<0.8-3.0	180-550	Unpublished TVA study.
Fort Loudoun Reservoir, Tennessee(Two Forebay Sites)	NA NA	1420 2800	122 103	141 148	NA NA	748 189	Perhac, 1974
				Unpolluted Lakes and Reservoirs			
Lake Constance (Rhine River headwaters, West Germany)	0.2	NA	55	19	NA	184	Förstner, et al., 1974
Recent Sediments from 87 Unpolluted Lakes	0.15-1.5	100-1800	30-250	10-100	NA	50-250	Förstner, & Wittman, 1983, p. 136

Table 4

(Continued)

Location	Hg (µg/g)	Mn (µg/g)	Ni (µg/g)	Pb (µg/g)	Se (µg/g)	Zn (µg/g)	Reference
			Heavily Polluted Lakes and Reservoirs				
Upper Peoria Lake, Illinois	0.1-0.4	NA	20-75	50-200	NA	200-550	Collinson & Shimp, 1972
Southern Lake Michigan, Illinois	0.05-0.4	NA	20-60	25-175	NA	75-400	Shimp, et al., 1970
Lake Erie near Cleveland, Ohio - Surface Sediments	4.48	NA	95	NA	NA	42	Walters, et al., 1974
Rhine River, Industrial Area, West Germany	9	NA	175	369	NA	1240	Banat, et al., 1972

NOTE: NA = Not Analyzed

CONCLUSIONS

The data obtained in the 1973 and 1982 surveys indicate that analysis of sediments for trace constituents can be a useful way to evaluate the spatial extent of the effects of major point and nonpoint pollution sources. Although no significant new problems were discerned from the concentrations in forebay sediments, higher levels of some constituents apparently are related to identifiable upstream activities. It is also gratifying to note that although there is a known PCB contamination problem in an embayment of Fort Loudoun Reservoir, that problem has had no discernable effect on sediments in the forebay of the reservoir.

In contrast to observed downstream transport of trace metals from known pollution sources through several reservoirs, the physical characteristics of reservoir sediments suggest that local geology is the dominant factor in determining particle size distribution. The relatively high percentages of sand in the Pickwick and Guntersville sediments was surprising, although there appear to be reasonable explanations.

Periodic repetition of this type of survey using the same sample collection technique would be useful in evaluating temporal trends. More comprehensive surveys of sediments in the reservoirs which exhibited higher concentrations of some metals would better define the spatial extent of enriched sediments, identify sources, and quantify deposition rates and downstream transport.

REFERENCES

Banat, K., U. Förstner, and G. Müller. 1972. Schwermetalle in der Sedimenten des Rheins. Umsch. Wiss. Tech. 72:192-193.

Collinson, C., and N. F. Shimp. 1972. Trace Elements in Bottom Sediments from Upper Peoria Lake, Middle Illinois River - A Pilot Project. Illinois Geological Survey Environmental Geology Note 56.

Förstner, U. and G.T.W. Wittmann. 1983. Metal Pollution in the Aquatic Environment (Second Revised Edition). Springer-Verlag, Heidelberg.

Förstner, U.,G. Müller, and G. Wagner. Schwermetalle in Sedimenten des Bodensees, natürliche und Zivilsatorische Anteile. Naturwissenschaften 61:270.

Perhac, R. M. 1974. Heavy Metal Distribution in Bottom Sediment and Water in the Tennessee River - Loudoun Lake Reservoir System. Research Report No. 40. Water Resources Research Center, The University of Tennessee, Knoxville.

Shimp, N. F., H. V. Leland, and W. A. White. 1970. Distribution of Major, Minor, and Trace Constituents in Unconsolidated Sediments from Southern Lake Michigan. Illinois Geological Survey Environmental Geology Note 32. .

Walters, L. J., Jr., T. J. Walery, and R. D. Myser. 1974. Occurrence of As, Cd, Co, Ca, Cu, Fe, Hg, Ni, Sb, and Zn in Lake Erie Sediments. Proceedings of the 17th Conference on Great Lakes Research, pp. 219-234.

APPENDIX A

METALS CONCENTRATIONS IN NICKAJACK RESERVOIR SEDIMENTS COLLECTED IN APRIL 1982

METALS CONCENTRATIONS IN NICKAJACK RESERVOIR
SEDIMENTS COLLECTED IN APRIL 1985

Location (Tennessee River Mile)	Concentration, µg/g dry weight													
	Ag	As	Ba	Be	Cd	Cr	Cu	Hg	Ni	Pb	Se	Sb	Tl	Zn
425.5	<1	11	190	<1	<1	41	58	0.60	24	86	<0.8	<0.2	<5	550
435.4	<1	8.6	180	<1	<1	33	57	0.60	21	74	1.3	<0.2	<5	330
445.8	<1	7.8	160	<1	<1	35	52	0.38	23	54	<0.8	<0.2	<5	270
459.3	<1	8.6	140	<1	<1	23	29	0.23	19	65	3.0	<0.2	<5	180
460.3	<1	12	170	<1	<1	37	48	0.57	23	90	<0.8	<0.2	<5	290
461.4	<1	7.2	100	<1	<1	36	32	3.8	18	51	<0.8	<0.2	<5	290