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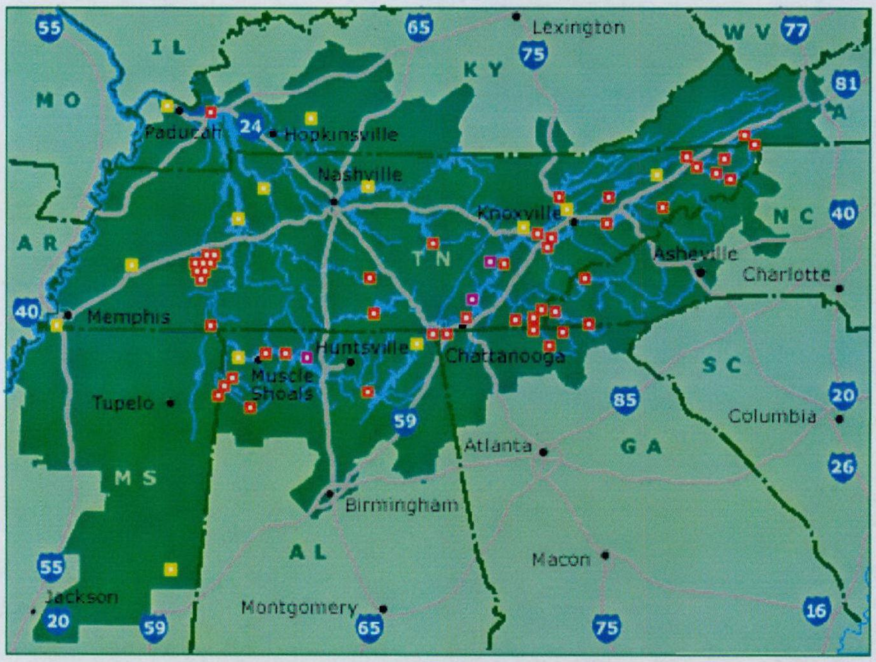
Compendium of issues surrounding the levels of contaminants contained in fish collected in tributaries leaving the Oak Ridge Reservation (ORR) and associated risks from exposure to those levels of contaminants : volume 2



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U.S. Environmental Protection Agency
Region 4

2004

Results from TVA Fish Tissue Studies on Fish Collected Autumn 1996 and Recommendations for Studies in 1997

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Second Edition, August 1997, Revised Tables 1 and 2 and Appendices A and E

Introduction/Background

Because of significant interest by the fishing public and Valley states, TVA maintains an annual program to examine contaminants in fish fillets from TVA reservoirs and their major tributary streams. This systematic approach began in 1986 for streams and in 1987 for reservoirs Prior fish tissue studies had been conducted on an "as needed" basis to address specific concerns.

This systematic approach is based on four types of studies, each with a different objective yet working in concert with the others

- Screening Study: This is the most general study category. In these studies a composite sample of the indicator species (channel catfish, if available) is collected from each site and examined for a broad array of organics and metals suggested by EPA, 1995 (see Methods section for citation). Also, largemouth bass are collected from each site and analyzed for mercury only. Results from screening studies lead either to one of the more detailed study categories below, if concentration of one or more analytes is high, or to a return to screening on a 4-year rotational basis

- Targeted Screening Study: If Screening Studies find one or more analytes with moderately elevated concentrations, then sampling is repeated at the same level the next year but only the contaminant of concern is included in the analysis. Depending on results, a Targeted Screening Study may continue at the same level of effort for a year or two to ensure that a problem does not exist; lead to an Intensive Study if high levels of the contaminant are found; or lead to the rotational screening system if concentrations are low.

- Intensive Study: In instances where concentrations in Screening or Targeted Screening Studies are sufficiently high to pose potential human health concerns, the site or reservoir is examined intensively to determine the species affected, the geographical distribution, and year-to-year variation. Analysis of individual fish (generally 10 replicates) of important species from several locations provide the data base for examinations. In selected cases, replicate composite samples have been used in Intensive Studies. These studies are conducted in close association with state agencies and usually result in some type of fish consumption advisory being issued by the appropriate state agency. This assessment phase continues until the contaminant concentration decreases to an insignificant level or until several years of repeated study indicate concentrations are changing little from year-to year. In the former case, the site or reservoir would return to the rotational system for screening In the latter case, the reservoir/site would continued be examined but at a reduced effort in a Long-Term Monitoring Study

- Long-Term Monitoring Study: The purpose of this study is to track the contaminant of concern identified in an Intensive Study so that when concentrations decrease sufficiently a follow-up Intensive Study can be conducted to provide sound evidence that the problem no longer exists. Annual or rotational collections may be used depending on the particular situation. Generally, composites of indicator species are analyzed for the analyte(s) of concern.

This fish tissue monitoring program is now in what could be considered the maintenance phase. Screening Studies have been conducted on all reservoirs and stream sites one or more times. Most reservoirs and streams remain in the rotational screening category because elevated contaminant levels have not observed. However, fish from several reservoirs and streams contain high levels of selected contaminants (most commonly PCBs). Some of these problems were first documented by this monitoring program and some were known to exist before this program began. State agencies have issued advisories as appropriate (see Appendix A). These areas have been examined in depth by conducting Intensive Studies and are now in the Long-Term Monitoring phase.

The purpose of this document is to briefly provide results of samples collected in summer and autumn 1996. Comparable documents are available for previous years from the address provided below.

Methods

Details of TVA's collection, processing, and analysis procedures are described in the report on 1993 fish tissue studies -- "Tennessee Valley Reservoir and Stream Quality - 1993; Fish Tissue Studies in the Tennessee Valley in 1993" by D.L. Williams and D.L. Dycus. The report was published in July 1994 and is available from:

Water Management Library
Tennessee Valley Authority
1101 Market Street, CST 16B
Chattanooga, TN 37402-2810
(423) 751-7338 or FAX: (423) 751-7648

Prior to 1994 the only pesticides included in the analyses were organochlorine pesticides. Beginning with that year, organophosphate and chlorophenoxy pesticides were analyzed as recommended by the U.S. EPA in their "Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories; Volume 1 Fish Sampling and Analysis" (EPA 823-R-93-007, September 1995).

These include:

Organochlorine pesticide: dicofol
Organophosphate pesticides: chlorpyrifos, diazinon, disulfoton, ethion, terbufos, and carbophenothion
Chlorophenoxy pesticide: oxyfluorfen

The list was further expanded in 1996 for selected reservoirs to include dioxin.

All laboratory analyses were performed by the TVA Environmental Chemistry Laboratory, except analysis for dioxin, which was performed under contract by Wright State University in Dayton, Ohio.

Summary of Results

Reservoirs and rivers included in fish tissue studies in 1996 are listed in Table 1. Results from the various fish tissue studies conducted in 1996 are provided Tables 2 - 14 and Figures 1 and 2. Physical information such as length and weight for each fish is in Appendix B, Tables B-1 – B-4. Appendix C contains abbreviations for species and rivers used in tables and appendices.

Table 2 – Summary Table, PCBs $\geq$0.5 µg/g

Table 3 – Summary Table, Mercury $\geq$0.4 µg/g

Reservoir Screening: Table 4 – Organics;
Table 5 – Metals;
Appendix Table B-1 – Physical Information

Stream Screening: Table 6 – Organics
Table 7 – Metals
Appendix Table B-2 – Physical Information

Long-Term Monitoring: Table 8 – Organics
Table 9 – Summary of PCB Concentrations in CHC from Watts Bar, 1987 - 1996
Table 10 – Data on Individual CHC from Fort Loudoun Reservoir in 1996
Table 11 – Summary of PCB Concentrations in Fish from Fort Loudoun 1985 - 1996
Appendix Table B-4 – Physical Information

Targeted Screening: Table 12 – Organics
Table 13 – Metals
Appendix Table B-4 – Physical Information

Dioxin Results: Table 14 – Summary
Appendix D – Detailed Results

In general, 1996 results were similar to previous years Elevated levels of contaminants were observed where they were known to exist and concentrations were low otherwise. The most common contaminant of concern was PCBs Locations (regardless of study type) with PCB concentrations ≥0.5 µg/g are listed in Table 2 Given the increasing interest in mercury, locations (regardless of study type) with total mercury ≥0 40 µg/g are listed in Table 3

Dioxin results are summarized in Table 14 with details in Appendix D. As stated above, 1996 was the first year dioxin was included in TVA studies, but state studies have included dioxin for several years. Concentrations of 2,3,7,8 TCDD ranged from 0.35 to 1.4 ppt (parts per trillion), whereas TECs (toxicity equivalent concentrations) ranged from 0.87 to 5.0 ppt.

A detailed list of recommendations for fish tissue studies in 1997 is in Appendix E. (Note. These recommendations were not final at the time this document was prepared.)

Table 1 Alphabetical Listing of Reservoirs and Streams Included in Fish Tissue Studies in 1996.

Reservoir	State	Watershed	Advisory (Yes/No)	Cause of Advisory	Type Study Screen	Target	Intensive	Long-T	Fish Species
Apalachia	NC	Hiwassee	No		X				CHC, LMB
Bear Creek	AL	Pickwick/Wilson	No		X				CHC, LMB
Cedar	AL	Pickwick/Wilson	No		X				CHC, LMB
Chatuge	GA/NC	Hiwassee	No		X				CHC, LMB
Fontana	NC	Little Tenn.	No		X				CHC, LMB
Fort Loudoun	TN	Fort Hills Bar	Yes	PCBs	X			X	CHC, LMB
Guntersville	AL/TN	G'ville/Sequach	No		X				CHC, LMB
Hiwassee	NC	Hiwassee	No		X				CHC, LMB
L'Bear	AL	Pickwick/Wilson	No		X				CHC, LMB
Melton Hill	TN	Fort Hills Bar	Yes	PCBs	X			X	CHC, LMB
Ocoee No. 3	TN	Hiwassee	No			X			BGS, LMB, RES, YP
Ocoee No. 1	TN	Hiwassee	No		X			X	CHC, LMB
Pickwick	AL/TN/MS	Pickwick/Wilson	No		X				CHC, LMB
South Holston	TN	Holston	No		X				CHC, LMB
Watauga	TN	Holston	No		X				CHC, LMB
Watts Bar	TN	Fort Hills Bar	Yes	PCBs	X			X	CHC, LMB, STB
Wilson	AL	Pickwick/Wilson	No		X				CHC, LMB
Stream									
Bear Creek	AL	Pickwick/Wilson	No		X				CHC, SPB
Buffalo River	TN	Duck	No		X				CHC, SMB
Clarks River	KY	Kentucky	No		X				CHC, LMB
Duck River	TN	Duck	No		X				CHC, SPB
French Broad R	TN	French Broad	No		X				CHC
Little Tenn. R	NC	Little Tennessee	No		X				CHC, SMB
Nolichucky R.	TN	French Broad	No		X				CHC, SMB
Pigeon River	TN	French Broad	Yes	Dioxin	X				CHC, SMB
Tuckasegee R.	NC	Little Tennessee	No		X				CHC, SMB

Table 2. Highlights of Autumn 1996 Results from Areas with Advisories and/or "High" (i.e., ≥0.5 μg/g) PCB Concentrations with Comparisons to Results from Those Areas in 1994 and 1995. All Samples Analyzed as 5-Fish Composites Unless Otherwise Noted.

Location		Species	1994	1995	1996
Reservoirs					
Guntersville Reservoir	TRM 350	CHC	NS [a]	NS	<0.7
	TRM 375	CHC	NS	NS	0.4
	TRM 424	CHC	NS	NS	0.6
Melton Hill Reservoir	CRM 24	CHC	NS	NS	1.3
	CRM 45	CHC	NS	NS	3.1
Parksville Reservoir	ORM 12	CHC	1.2	0.4	1.0
	ORM 16	CHC	1.7	0.8	1.7
Watts Bar Reservoir	TRM 530/1	CHC	1.0	0.8	0.7
		STB	NS	NS	1.2
	TRM 560	CHC	1.0	1.2	2.1
		STB	NS	NS	1.1
	TRM 600	CHC	1.0	1.5	1.1
		STB	NS	NS	1.3
	CRM 22	CHC	NS [b]	NS [b]	0.7
		STB	NS	NS	1.1
Ft. Loudoun Res	TRM 624	CHC	1.6 [c]	1.5 [d]	1.0 [e]
Streams					
Buffalo River	BuRM 18	CHC	0.4	0.4	0.5
Duck River	DRM 26	CHC	0.1	NS	0.6

a. NS - Not Sampled
b. Included in study by ORNL for DOE
c. Average of 9 channel catfish anaylzed individually
d. Average of 10 channel catfish analyzed individually
e. Average of 8 channel catfish analyzed individually

Table 3. Highlights of 1996 Results from Reservoir and Stream Locations with "Elevated" (i e., ≥0.40 µg/g) Total Mercury Concentrations. Note Black Bass (Largemouth - LMB, Smallmouth - SMB, and Spotted - SPB) Analyses Were Conducted on Five-fish Composites Plus the Largest of the Five Individuals in the Composite Channel Catfish (CHC) Were Analyzed as Five -fish 5 Composites

Location	Species	Comp./ Ind.	Weight (gm, if individual)	Mercury (Total, µg/g)
		RESERVOIRS		
Bear Creek - Bear Cr Mile 75	CHC	Comp	N/A	0.42
	LMB	Ind	2065	1.1
Fontana - L' Tennessee R 62	CHC	Comp	N/A	0 40
	LMB	Ind.	2800	0 46
L' Tennessee R. 81	LMB	Ind.	1110	0 40
Tuckasegee R 3	LMB	Ind	1014	0.59
Hiwassee - Hiwassee River 77	CHC	Comp	N/A	0.55
	LMB	Comp	N/A	0.54
	LMB	Ind.	1571	0.73
Hiwassee River 85	CHC	Comp	N/A	0.74
Pickwick - Tennessee R 230	LMB	Ind.	1020	0.66
South Holston - SFHRM 51	LMB	Comp.	N/A	0.43
	LMB	Ind.	1944	0 72
SFHRM 62	LMB	Ind.	527	0.49
		RIVERS		
Bear Creek Mile 27	SPB	Comp.	N/A	0.56
	SPB	Ind.	1757	1.0
Buffalo River Mile 18	SMB	Comp	N/A	0.61
	SMB	Ind.	335	0.57
Clarks River Mile 10	LMB	Comp.	N/A	0.58
	LMB	Ind	1099	0.62
L' Tennessee River Mile 95	SMB	Comp.	Comp.	0.43
	SMB	Ind.	289	0 47
Tuckasegee River Mile 10	CHC	Comp.	N/A	0 45
	SMB	Comp.	N/A	0.50
	SMB	Ind.	943	0 78

Note: Additional mercury data are in the following tables, and weights for all fish are in the appendices.

Table 4. Concentrations (ug/g) of Selected Pesticides and PCBs in Composited Fish Fillets Collected in 1996 For Reservoir Screening Studies.

For Calendar Year : 1996

Collection Site	Spec.	%LIPIDS	MIREX	TOXAPH	HEPTA	ALDRIN	BENZ	DDT	DIELD	ENDO	ENDRIN	CHLOR	PCB	DICOFOL
APPALACHIA														
HIW 67.0	CHC	3.3	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	<0.1	<0.01
BEAR CREEK														
BEC 75.0	CHC	3.6	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	0.1	<0.01
CEDAR CREEK														
CEC 25.0	CHC	1.9	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	<0.1	<0.01
CHATUGE														
HIW 122	CHC	4.5	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	<0.1	<0.01
SHO 1.5	CHC	3.3	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	<0.1	<0.01
FONTANA														
LTE 62.0	CHC	6.6	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	0.2	<0.01
LTE 81.0	CHC	4.0	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	0.1	<0.01
TUC 3.0	CHC	5.2	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	<0.1	<0.01
GUNTERSVILLE														
TEN 350	CHC	11.0	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	0.7	<0.01
TEN 375	CHC	10.0	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	0.4	<0.01
TEN 424	CHC	9.4	<0.008	<0.5	<0.01	<0.01	<0.01	0.03	<0.01	<0.01	<0.01	<0.01	0.6	<0.01
HIWASSEE														
HIW 77.0	CHC	5.4	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	<0.1	<0.01
HIW 85.0	CHC	3.0	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	0.3	<0.01
LITTLE BEAR CREEK														
LBC 12.0	CHC	4.0	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	<0.1	<0.01
MELTON HILL														
CLI 24.0	CHC	7.6	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	1.3	<0.01
CLI 45.0	CHC	7.7	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	3.1	<0.01
PARKSVILLE - OCOEE N														
OCO 12.0	CHC	2.7	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	1.0	<0.01

Tab Con Concentrations (ug/g) of Selected Pe ides and PCBs in Composited Fish Fillets Collected in 1996 For Reserv Screening Studies.

For Calendar Year : 1996

Collection Site	Spec.	%LIPIDS	MIREX	TOXAPH	HEPTA	ALDRIN	BENZ	DDT	DIELD	ENDO	ENDRIN	CHLOR	PCB	DICOFOL
PICKWICK														
BEC 8.0	CHC	4.3	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	0.2	<0.01
TEN 207	CHC	3.9	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	0.4	<0.01
TEN 230	CHC	5.2	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	0.4	<0.01
TEN 259	CHC	3.8	<0.008	<5.0	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	0.3	<0.01
SOUTH HOLSTON														
SFH 51.0	CHC	5.8	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	<0.1	<0.01
SFH 62.0	CHC	5.1	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	0.4	<0.01
WATAUGA														
WAT 37.0	CHC	7.0	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	<0.1	<0.01
WAT 45.0	CHC	6.4	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	<0.1	<0.01
WATTS BAR														
CLI 22.0	CHC	9.8	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	0.7	<0.01
TEN 531	CHC	6.3	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	0.7	<0.01
TEN 560	CHC	6.1	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	2.1	<0.01
TEN 600	CHC	3.3	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	1.1	<0.01
WILSON														
TEN 260	CHC	6.0	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	0.1	<0.01
TEN 272	CHC	5.1	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	0.4	<0.01

Table 4. Cont.' Concentrations (ug/g) of Selected Pesticides and PCBs in Composited Fish Fillets Collected in 1996 For Reservoir Screening Studies.

For Calendar Year : 1996

Collection Site	Spec.	%LIPIDS	DURSBAN	DIAZINON	DISULFOTON	ETHION	TERBUFOS	CARBOPHENOTHION	OXYFLUORFEN
APPALACHIA									
HIW 67.0	CHC	3.3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BEAR CREEK									
BEC 75.0	CHC	3.6	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
CEDAR CREEK									
CEC 25.0	CHC	1.9	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
CHATUGE									
HIW 122	CHC	4.5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SHO 1.5	CHC	3.3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
FONTANA									
LTE 62.0	CHC	6.6	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
LTE 81.0	CHC	4.0	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TUC 3.0	CHC	5.2	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
GUNTERSVILLE									
TEN 350	CHC	11.0	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TEN 375	CHC	10.0	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TEN 424	CHC	9.4	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
HIWASSEE									
HIW 77.0	CHC	5.4	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
HIW 85.0	CHC	3.0	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
LITTLE BEAR CREEK									
LBC 12.0	CHC	4.0	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
MELTON HILL									
CLI 24.0	CHC	7.6	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
CLI 45.0	CHC	7.7	<0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
PARKSVILLE - OCOEE N									
OCO 12.0	CHC	2.7	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
PICKWICK									
BEC	CHC	4.3	<0.01	<0.01	[illegible]	<0.01	<0.01	<0.01	[illegible]

Tab Concentrations (ug/g) of Selected Pe cides and PCBs in Composited Fish
Con Fillets Collected in 1996 For Reserv Screening Studies.

For Calendar Year : 1996

Collection Site	Spec.	%LIPIDS	DURSBAN	DIAZINON	DISULFOTON	ETHION	TERBUFOS	CARBOPHENOTHION	OXYFLUORFEN
TEN 207	CHC	3.9	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TEN 230	CHC	5.2	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TEN 259	CHC	3.8	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SOUTH HOLSTON									
SFH 51.0	CHC	5.8	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SFH 62.0	CHC	5.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
WATAUGA									
WAT 37.0	CHC	7.0	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
WAT 45.0	CHC	6.4	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
WATTS BAR									
CLI 22.0	CHC	9.8	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TEN 531	CHC	6.3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TEN 560	CHC	6.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TEN 600	CHC	3.3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
WILSON									
TEN 260	CHC	6.0	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TEN 272	CHC	5.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Table 5. **Concentrations (ug/g) of Metals in Composited Fish Fillets Collected in 1996 for Reservoir Screening Studies.**

For Calendar Year :1996

Collection Site	Species	LABID	As	Cd	Pb	Hg	Se
APPALACHIA							
HIW 67.0	LMB					0.20	
HIW 67.0	LMB					0.29 *	
HIW 67.0	CHC		<0.10	< 0.05	< 0.02	0.39	<0.2
BEAR CREEK							
BEC 75.0	CHC		<0.10	< 0.05	< 0.02	0.42	<0.2
BEC 75.0	LMB					0.32	
BEC 75.0	LMB					1.10 *	
CEDAR CREEK							
CEC 25.0	CHC		<0.10	< 0.05	< 0.02	0.22	<0.2
CEC 25.0	LMB					0.33	
CEC 25.0	LMB					0.32 *	
CHATUGE							
HIW 122	LMB					0.18	
HIW 122	LMB					0.31 *	
HIW 122	CHC		<0.10	< 0.05	< 0.02	0.17	<0.2
SHO 1.5	LMB					0.17	
SHO 1.5	LMB					0.20 *	
SHO 1.5	CHC		<0.10	< 0.05	< 0.02	0.27	0.3
FONTANA							
LTE 62.0	CHC		<0.10	< 0.05	< 0.02	0.40	<0.2
LTE 62.0	LMB					0.28	
LTE 62.0	LMB					0.46 *	
LTE 81.0	CHC		<0.10	< 0.05	0.26	0.34	<0.2
LTE 81.0	LMB					0.39	
LTE 81.0	LMB					0.40 *	
TUC 3.0	CHC		<0.10	< 0.05	< 0.02	0.16	<0.2

Table 5 Cont.' oncentrations (ug/g) of Metals in Compo d Fish Fillets Collected n 1996 for Reservoir Screening Studies.

For Calendar Year : 1996

Collection Site	Species	LABID	As	Cd	Pb	Hg	Se
TUC 3.0	LMB					0.34	
TUC 3.0	LMB					0.59*	
GUNTERSVILLE							
TEN 350	CHC		<0.10	< 0.05	< 0.02	<0.10	<0.2
TEN 350	LMB					<0.10	
TEN 350	LMB					0.14*	
TEN 375	CHC		<0.10	< 0.05	0.07	<0.10	<0.2
TEN 375	LMB					<0.10	
TEN 375	LMB					<0.10*	
TEN 424	CHC		<0.10	< 0.05	< 0.02	<0.10	<0.2
TEN 424	LMB					0.15	
TEN 424	LMB					0.10*	
HIWASSEE							
HIW 77.0	LMB					0.54	
HIW 77.0	LMB					0.73*	
HIW 77.0	CHC		<0.10	< 0.05	0.43	0.55	<0.2
HIW 85.0	CHC		<0.10	< 0.05	< 0.02	0.74	<0.2
HIW 85.0	LMB					0.25	
HIW 85.0	LMB					0.32*	
LITTLE BEAR CREEK							
LBC 12.0	CHC		<0.10	< 0.05	< 0.02	0.22	<0.2
LBC 12.0	LMB					0.20	
LBC 12.0	LMB					0.21*	
MELTON HILL							
CLI 24.0	LMB					<0.10	
CLI 24.0	LMB					0.18 *	
CLI 24.0	CHC		<0.10	< 0.05	< 0.02	0.18	<0.2

Table 5. Cont.' Concentrations (ug/g) of Metals in Composited Fish Fillets Collected in 1996 for Reservoir Screening Studies.

For Calendar Year : 1996

Collection Site	Species	LABID	As	Cd	Pb	Hg	Se
CLI 45.0	CHC		<0.10	< 0.05	< 0.02	0.14	<0.2
CLI 45.0	LMB					0.16	
CLI 45.0	LMB					0.12*	
PARKSVILLE - OCOEE N							
OCO 12.0	CHC		<0.10	< 0.05	< 0.02	0.12	0.4
OCO 12.0	LMB					0.23	
OCO 12.0	LMB					0.34*	
PICKWICK							
BEC 8.0	CHC		<0.10	< 0.05	< 0.02	0.28	<0.2
BEC 8.0	LMB		<0.10	< 0.05	< 0.02	0.19	0.2
BEC 8.0	LMB					0.32*	
TEN 207	CHC		<0.10	< 0.05	0.03	<0.10	<0.2
TEN 207	LMB		<0.10	< 0.05	< 0.02	<0.10	<0.2
TEN 207	LMB					0.16*	
TEN 230	CHC		<0.10	< 0.05	< 0.02	<0.10	<0.2
TEN 230	LMB		<0.10	< 0.05	< 0.02	0.20	<0.2
TEN 230	LMB					0.66*	
TEN 259	CHC		<0.10	< 0.05	< 0.02	<0.10	<0.2
TEN 259	LMB		0.10	< 0.05	< 0.02	<0.10	<0.2
TEN 259	LMB					<0.10*	
SOUTH HOLSTON							
SFH 51.0	CHC		<0.10	< 0.05	0.32	0.12	<0.2
SFH 51.0	LMB					0.43	
SFH 51.0	LMB					0.72*	
SFH 62.0	CHC		<0.10	< 0.05	< 0.02	0.31	<0.2
SFH 62.0	LMB					0.28	
SFH 62.0	LMB					0.49*	

Table 5 Cont.' ›ncentrations (ug/g) of Metals in Compo d Fish Fillets Collected ‥n 1996 for Reservoir Screening Studies.

For Calendar Year : 1996

Collection Site	Species	LABID	As	Cd	Pb	Hg	Se
WATAUGA							
WAT 37.0	CHC		<0.10	< 0.05	0.05	0.35	<0.2
WAT 37.0	LMB					0.44	
WAT 37.0	LMB					0.60 *	
WAT 45.0	CHC		<0.10	< 0.05	< 0.02	0.39	<0.2
WAT 45.0	LMB					0.64	
WAT 45.0	LMB					0.58 *	
WATTS BAR							
CLI 22.0	LMB					0.12	
CLI 22.0	LMB					0.27 *	
CLI 22.0	CHC		<0.10	< 0.05	< 0.02	<0.10	<0.2
TEN 531	LMB					0.12	
TEN 531	LMB					0.20 *	
TEN 531	CHC		<0.10	< 0.05	< 0.02	0.16	<0.2
TEN 560	CHC		<0.10	< 0.05	< 0.02	0.17	<0.2
TEN 560	LMB					0.16	
TEN 560	LMB					0.14 *	
TEN 600	LMB					0.13	
TEN 600	LMB					0.30 *	
TEN 600	CHC		<0.10	< 0.05	0.78	0.40	<0.2
WILSON							
TEN 260	CHC		<0.10	< 0.05	0.18	<0.10	<0.2
TEN 260	LMB		<0.10	< 0.05	< 0.02	0.11	<0.2
TEN 260	LMB					0.20 *	
TEN 272	CHC		<0.10	< 0.05	0.04	<0.10	<0.2
TEN 272	LMB		<0.10	< 0.05	< 0.02	0.13	<0.2
TEN 272	LMB					0.25 *	

* Identifies the largest LMB in the composite. This fish was analyzed individually for Hg.

. Table 6. Concentrations (ug/g) of Selected Pesticides and PCBs in Composited Fish Fillets Collected in 1996 For Stream Screening Studies.

For Calendar Year : 1996

Collection Site	Spec.	%LIPIDS	MIREX	TOXAPH	HEPTA	ALDRIN	BENZ	DDT	DIELD	ENDO	ENDRIN	CHLOR	PCB	DICOFOL
BEC 27.0	CHC	2.3	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	<0.1	<0.01
BUF 18.0	CHC	5.4	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	0.5	<0.01
CLA 10.0	CHC	8.2	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	<0.1	<0.01
DUC 26.0	CHC	7.3	<0.008	<0.5	<0.01	<0.01	<0.01	0.12	<0.01	<0.01	<0.01	<0.01	0.6	<0.01
FRE 77.0	CHC	2.7	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	<0.1	<0.01
LTE 95.0	CHC	2.4	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	<0.1	<0.01
NOL 10.0	CHC	9.2	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	<0.1	<0.01
PIG 7.0	CHC	2.8	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	<0.1	<0.01
TUC 10.0	CHC	2.3	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	<0.1	<0.01

Tab Concentrations (ug/g) of Selected Pe :ides and PCBs in Composited Fish
Con Fillets Collected in 1996 For Strean :eening Studies.

For Calendar Year : 1996

Collection Site		Spec.	%LIPIDS	DURSBAN	DIAZINON	DISULFOTON	ETHION	TERBUFOS	CARBOPHENOTHION	OXYFLUORFEN
BEC	27.0	CHC	2.3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BUF	18.0	CHC	5.4	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
CLA	10.0	CHC	8.2	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
DUC	26.0	CHC	7.3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
FRE	77.0	CHC	2.7	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
LTE	95.0	CHC	2.4	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
NOL	10.0	CHC	9.2	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
PIG	7.0	CHC	2.8	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TUC	10.0	CHC	2.3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Table 7. **Concentrations (ug/g) of Metals in Composited Fish Fillets Collected in 1996 for Stream Screening Studies.**

For Calendar Year : 1996

Collection Site		**Species**	**LABID**	**As**	**Cd**	**Pb**	**Hg**	**Se**
BEC	27.0	CHC		<0.10	< 0.05	0.15	0.17	<0.2
BEC	27.0	SPB					0.56	
BEC	27.0	SPB					1.00*	
BUF	18.0	CHC		<0.10	< 0.05	< 0.02	0.14	<0.2
BUF	18.0	SMB					0.61	
BUF	18.0	SMB					0.57*	
CLA	10.0	CHC		<0.10	< 0.05	< 0.02	0.27	0.2
CLA	10.0	LMB					0.58	
CLA	10.0	LMB					0.62*	
DUC	26.0	CHC		<0.10	< 0.05	< 0.02	0.12	<0.2
DUC	26.0	SPB					0.32	
DUC	26.0	SPB					0.30 *	
FRE	77.0	CHC		<0.10	< 0.05	0.25	0.15	<0.2
LTE	95.0	CHC		<0.10	< 0.05	< 0.02	0.25	<0.2
LTE	95.0	SMB					0.43	
LTE	95.0	SMB					0.47 *	
NOL	10.0	CHC		0.12	< 0.05	0.23	0.13	<0.2
NOL	10.0	SMB					0.17	
NOL	10.0	SMB					0.24 *	
PIG	7.0	CHC		<0.10	< 0.05	< 0.02	<0.10	<0.2
PIG	7.0	SMB					0.20	
PIG	7.0	SMB					0.29 *	
TUC	10.0	CHC		0.14	< 0.05		0.45	<0.2
TUC	10.0	SMB					0.50	
TUC	10.0	SMB					0.78 *	

* Identifies the largest LMB, SPB, or SMB in a composite. This fish was also analyzed individually for Hg.

Tabl Concentrations (ug/g) of Selected Pe ides and PCBs in Composited Fish Fillets Collected in 1996 For Long T Studies.

For Calendar Year :1996

Collection Site	Spec.	%LIPIDS	MIREX	TOXAPH	HEPTA	ALDRIN	BENZ	DDT	DIELD	ENDO	ENDRIN	CHLOR	PCB
PARKSVILLE - OCOEE N													
OCO 16.0	CHC	6.2						<0.010				<0.01	1.7
WATTS BAR													
CLI 22.0	STB	12.0						0.11				<0.01	1.1
TEN 531	STB	10.0						0.14				<0.01	1.2
TEN 560	STB	11.0						0.11				<0.01	1.1
TEN 600	STB	9.8						0.11				<0.01	1.3

Table 9. Summary of PCB Concentrations (µg/g) in Channel Catfish Fillets from Watts Bar Reservoir, 1987 - 1996

Year	Location	Number of Fish	Weight Range (gm)	Mean Weight (gm)	PCB Range	Mean PCB Conc.
1987	TRM 531	NS	-	-	-	-
	TRM 560	6-Ind.	239 - 1786	1103	0 1 - 4.4	1 4
	TRM 600*	10-Ind.	336 - 1330	757	0.4 - 3.1	1.5
1988	TRM 531	10-Ind.	494 - 4210	1763	0.1 - 4.3	1.4
	TRM 560	10-Ind.	411 - 2765	1124	1.3 - 7.5	2.7
	TRM 600	10-Ind.	829 - 2957	1289	0 8 - 4 4	2.4
1989	TRM 531 [DOE]	10-Ind.	320 - 1695	1033	0.2 - 1.5	0.8
	TRM 560 [DOE]	9-Ind.	324 - 1015	544	0 1 - 0 5	0 3
	TRM 600	7-Ind	425 - 3229	1437	0 4 - 4 2	1.8
1990	TRM 531	10-Ind.	322 - 2110	700	<0 1 - 2 7	0 6
	TRM 560	10-Ind.	282 - 1521	838	<0 1 - 1 8	0 8
	TRM 600	10-Ind.	208 - 3246	912	0.3 - 5.8	1 6
1991	TRM 531	10-Ind.	899 - 2323	1342	0 8 - 2.9	1 6
	TRM 560	10-Ind.	1149 - 2812	1571	0 8 - 4 0	2.3
	TRM 600	10-Ind.	466 - 1881	967	0.5 - 4.4	1 4
1992	TRM 531	10-Ind.	407 - 4178	1514	0 3 - 5.6	1 7
	TRM 560	10-Ind.	497 - 3563	1540	0 2 - 3.8	1 9
	TRM 600	10-Ind.	464 - 2168	1018	0 4 - 6.2	1 9
1993	TRM 531 [DOE]	-	-	-	-	
	TRM 560	9-Ind.	500 - 2590	1086	0 4 - 2.3	1 2
	TRM 600	10-Ind.	442 - 2884	931	0 1 - 3 6	1 1
1994	TRM 531	1-Comp.	511 - 2338	1213	N/A	1.0
	TRM 560	1-Comp.	523 - 2394	1302	N/A	1 0
	TRM 600	1-Comp.	496 - 2348	958	N/A	1 0
1995	TRM 531	1-Comp.	437 - 2186	1260	N/A	0 8
	TRM 560	1-Comp.	800 - 1021	907	N/A	1 2
	TRM 600	1-Comp.	626 - 2047	1251	N/A	1 5
1996	TRM 531	1-Comp.	500 - 1836	1250	N/A	0 7
	TRM 560	1-Comp.	1062 - 2877	2272	N/A	2 1
	TRM 600	1-Comp.	714 - 3623	1809	N/A	1 1

- Some blue catfish were collected from this site rather than all channel catfish

Table 10. Concentrations (ug/g) of Selected Pesticides and PCBs in Individual Fish Fillets Collected During Autumn 1996 from Fort Loudoun Reservoir for Long-Term Monitoring.

Location	Species	Collection Date	Lgt. (mm)	Wt. (gm)	Sex	Lipid (%)	DDTr	Chlord	PCBs
TRM 624	CHC 1	10/23/96	492	1222	Male	5.3	<0 01	<0.01	0 3
TRM 624	CHC 2	10/23/96	608	2182	Male	3.4	0.11	<0.01	1.3
TRM 624	CHC 3	10/23/96	426	662	Male	0.7	0.06	<0.01	1.0
TRM 624	CHC 4	10/24/96	406	524	Male	0.8	<0.01	<0.01	0 7
TRM 624	CHC 5	10/25/96	597	2094	Female	4.4	0.11	<0 01	1 3
TRM 624	CHC 6	10/25/96	480	1394	Male	3.1	0.06	<0.01	1 0
TRM 624	CHC 7	10/25/96	559	1608	Male	1.5	0.06	<0 01	1 4
TRM 624	CHC 8	10/25/96	458	1060	Male	4.2	0.08	<0 01	0.9

Table 11. Summary of PCB Concentrations in Channel Catfish, Carp, and White Bass Collected from Fort Loudoun Reservoir for Period of Record, 1985 - 1996

	Location TRM	PCB Range (ug/g)	Mean (ug/g)	No.≥2.0 (ug/g)	# Fish
Catfish					
1985	628	0.2-2.8	1.4	2	10
1987	628	0.1-4.5	1.5	2	10
1988	628	0.2-4.4	1.2	1	10
1989	628	0.6-4.3	2.3	11	20
1990	628	0.3-1.9	1.0	0	10
1991	624	1.4-4.6	2.5	7	10
1992	624	0.1-4.2	1.8	3	9
1993	624	0.4-2.2	1.2	2	10
1994	624	0.6-3.1	1.6	3	9
1995	624	0.8-2.7	1.5	3	10
1996	**624**	**0.3-1.4**	**1.0**	**0**	**8**
Carp					
1992	651	0.2-0.9	0.6	0	10
White Bass					
1987[a]	628	b	<0.1	a	5
	640	b	<0.1	a	5
1992	651	0.3-1.2	0.5	0	10

a. Catfish were sampled from TRMs 624-629. White bass and carp were collected from TRM 651 in 1992

b. Five white bass were collected from TRMs 628 and 640 in 1987. Each set of five was analyzed as a composite sample

Tab 2. Concentrations (ug/g) of Selected Pe ides and PCBs in Composited Fish Fillets Collected in 1996 For Target reening Studies.

For Calendar Year : 1996

Collection Site	Spec.	%LIPIDS	MIREX	TOXAPH	HEPTA	ALDRIN	BENZ	DDT	DIELD	ENDO	ENDRIN	CHLOR	PCB
OCOEE NO 3													
OCO 30.0	LMB	0.5						<0.010				<0.01	<0.1
OCO 30.0	BGS	3.3						<0.010				<0.01	0.3
TUM 0.5	LMB	1.2						<0.010				<0.01	0.4
TUM 0.5	BGS	4.3						<0.010				<0.01	<0.1
TUM 0.5	RES	2.4						<0.010				<0.01	<0.1
TUM 0.5	YP	1.9						<0.010				<0.01	0.2

Table 13. **Concentrations (ug/g) of Metals in Composited Fish Fillets Collected in 1996 for Targeted Screening Studies.**

For Calendar Year : 1996

Collection Site	Species	LABID	As	Cd	Pb	Hg	Se
OCOEE NO 3							
OCO 30.0	LMB					0.14	<0.2
OCO 30.0	BGS					0.12	<0.2
TUM 0.5	LMB					0.17	0.6
TUM 0.5	BGS					0.16	1.0
TUM 0.5	RES					0.17	0.9
TUM 0.5	YP					0.15	0.4

Table 14 Results of Analysis of Composited Channel Catfish Fillets from Selected TVA Reservoirs, Sampled Autumn 1996 (2,3,7,8 TCDD and Total TEC in picograms per gram - ppt)

Location	**River Mile**	**2,3,7,8 TCDD**	**Total TEC***
Pickwick Forebay	TRM 207	0.541	0.992
Trans. Zone	TRM 230	0.663	1.27
Inflow	TRM 259	0 445	0.868
Embayment	BCM 8	0.855	1 63
Wilson Forebay	TRM 260	1.30	2.52
Inflow	TRM 272	0 741	1.75
Guntersville Forebay	TRM 350	1.11	3.45
Tran. Zone	TRM 375	1.06	3.17
Inflow	TRM 424	1.41	3.43
Watts Bar Forebay	TRM 531	0.345	1.01
Trans. Zone	TRM 560	1.29	5.03
Inflow	TRM 600	1.26	4.31
Ft Loudoun Trans. Zone	TRM 624	0.802	2.00
Melton Hill Forebay	CRM 24	1.26	1.08
Trans. Zone	CRM 45	0.567	1.38

* TEC = Toxicity Equivalent Concentrations

Figure 1. Average or Composite PCB Concentration (ug/g) in Channel Catfish Fillets from Watts Bar Resevoir, 1987 – 1996

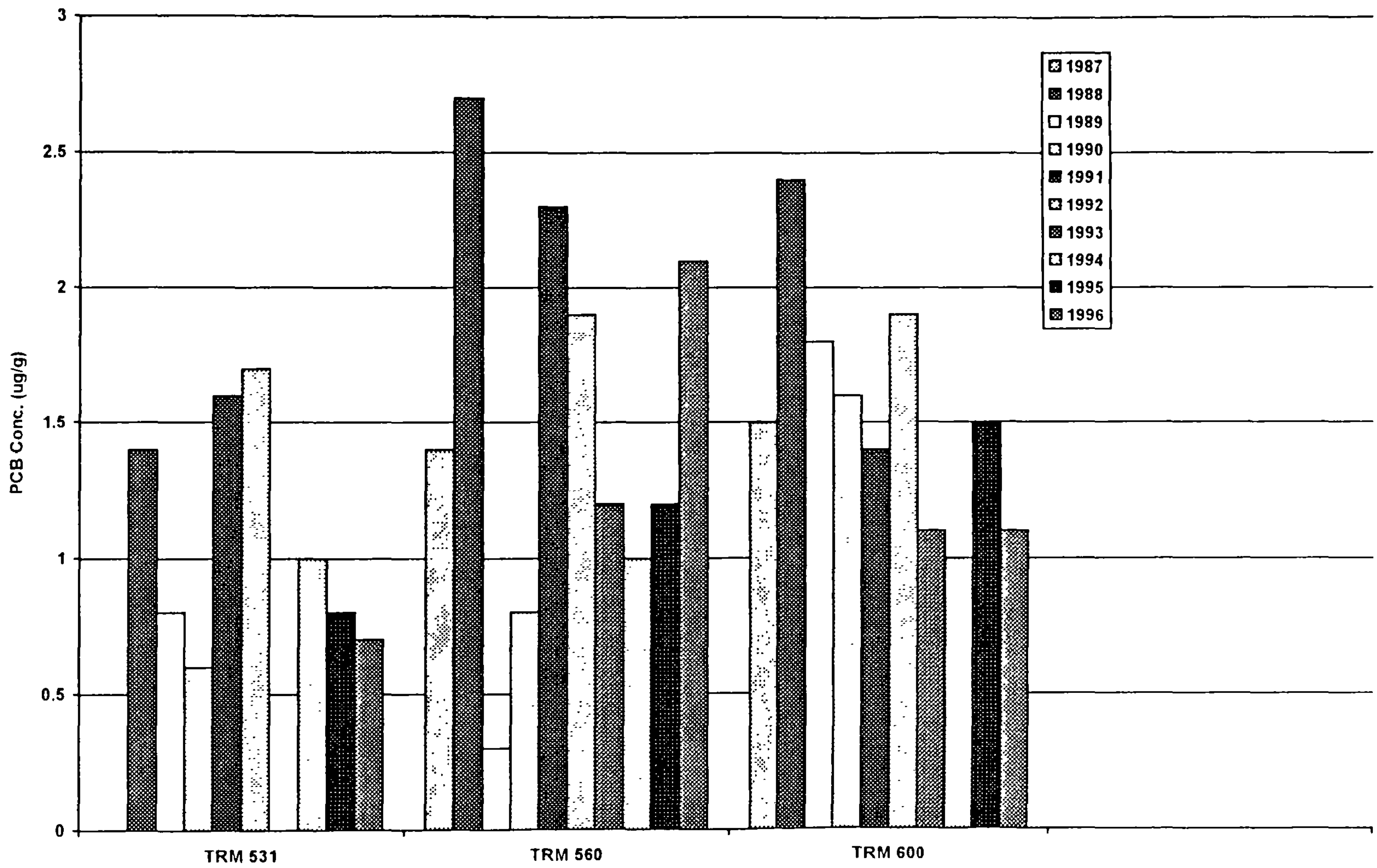
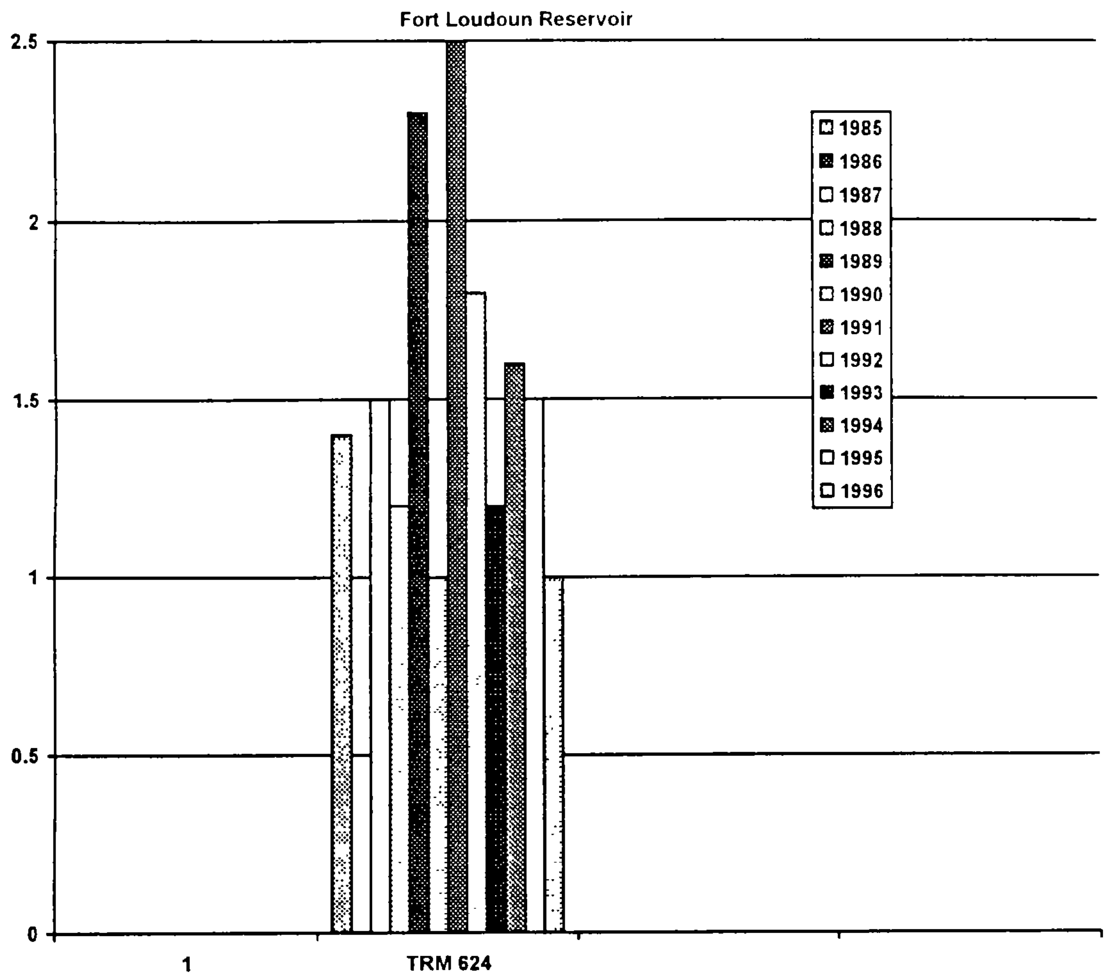


Figure 2 Average PCB Concentrations (μg/g) in Channel Catfish from Fort Loudoun Reservoir for Period of Record, 1985 - 1996



Appendix A

Fish Consumption Advisories in:

Alabama

Georgia

Tennessee

March 24, 1993
March 7, 1996
November 1996

NEWS RELEASE DEPARTMENT OF PUBLIC HEALTH
434 Monroe Street, Montgomery, Alabama 36130-3017 • (334) 613-5300 • FAX (334) 240-3097

ADPH revises fish consumption advisories

FOR IMMEDIATE RELEASE

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The Alabama Department of Public Health announces it has lifted its fish consumption advisories for the Tennessee River, but it has added new fish consumption advisories for the Fish River in Baldwin County, Logan-Martin Lake and Choccolocco Creek.

Advisories are issued because toxic chemicals in lakes or rivers accumulate in fish tissue. The people who eat these fish may face health risks. These advisories are updated based on the results of fish tissue monitoring conducted by the Alabama Department of Environmental Management and the Tennessee Valley Authority.

Previous advisories to avoid or restrict consumption of fish taken from the Tennessee River have been removed. These recommendations are based on steadily decreasing DDT concentrations which fall below the Food and Drug Administration action level of five parts per million of DDT in fish.

New advisories are as follows:

Fish River: The public is advised not to eat largemouth bass taken from the Fish River in Baldwin County because mercury levels have been found to exceed the FDA action level of 1 part per million. Mercury levels found in fish samples from the Fish River do not cause immediate health effects; however, at high levels mercury has been known to damage the nervous system and kidneys.

Choccolocco Creek: The department recommends that people not eat fish taken from Choccolocco Creek. This advisory now extends from the point where Hillabee Creek and Choccolocco Creek meet in Calhoun County downstream to Logan Martin Lake.

This action is based on the results of largemouth bass and channel catfish sampling on Choccolocco Creek 2.5 miles east southeast of Oxford. The fish in this area were found to have PCB levels above the Food and Drug Administration's recommended level of 2 parts per million.

(more)

Fish advisories
Add one

Logan Martin Lake: Another fish consumption advisory is being issued for Logan Martin Lake. The public is advised not to eat largemouth bass, spotted bass and catfish from the lake.

The department recommends that fish not be eaten from Logan Martin Lake because largemouth bass, spotted bass and catfish were found to contain levels of PCBs exceeding the FDA recommended level. The department recommends that these three species should not be consumed from an area near Riverside, Ala., in St. Clair County downstream to the dam.

PCBs are listed as possible cancer-causing agents in humans. When tested in levels greatly exceeding those typically found in the environment, PCBs have been associated with the following health effects:

- a skin disorder known as chloracne,
- changes in cholesterol and triglyceride levels in the blood, and
- tumors in certain rodents.

Advisories are made based on samples which were taken as a part of a five-year fish program in which samples are analyzed annually. The Alabama Department of Environmental Management will provide additional testing this fall in the Coosa and Fish River areas. Current fish consumption advisories are listed here:

BODY OF WATER	**PORTION**	**TYPE OF ADVISORY**
Coosa River	Between Logan Martin Dam and Riverside	Do not consume largemouth and spotted bass and all species of catfish**
Coosa River	Between Riverside & Alabama-Georgia state line	Limited consumption of catfish over 1 pound*
Huntsville Spring Branch & Indian Creek	From Redstone Arsenal to the Tennessee River	Do not consume channel catfish, smallmouth buffalo, brown bullhead, bigmouth buffalo, white bass**

(more)

Fish advisories
Add two

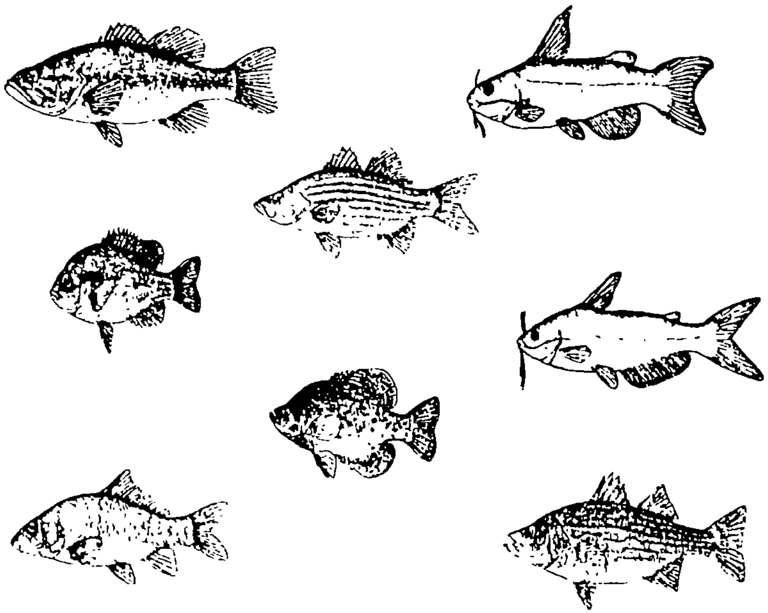
BODY OF WATER	PORTION	TYPE OF ADVISORY
West Point Lake to Lake Harding	West Point Lake, Lake Harding & the intervening stretch of the Chattahoochee River	Do not consume catfish**
Cold Creek Swamp	10 miles south of the confluence of the Tombigbee River & Alabama River adjacent to the Mobile River	Do not consume any fish**
Tombigbee River	Olin Basin at river mile 60.5	Do not consume largemouth bass, channel catfish**
Choccolocco Creek	Between the confluence of Hillabee Creek and Choccolocco Creek south of Oxford, downstream to where Choccolocco Creek flows into Logan Martin Lake	Do not consume any fish**
Fish River		Do not consume largemouth bass**

* A limited consumption advisory states that women of reproductive age and children less than 15 years old should avoid eating certain fish from these areas. Other people should limit their consumption of the particular species to one meal per month.

** Everyone should avoid eating the species of fish listed in the defined area.

1996

Guidelines for Eating Fish from Georgia Waters



Produced by:
Georgia Department of Natural Resources
Environmental Protection Division and
Wildlife Resources Division
205 Butler Street, S.E., Suite 1152
Atlanta, Georgia 30334

Georgia Lakes Fish Consumption Guidelines

Lake Allatoona

Species	Less than 12 inches	12 - 16 inches	Over 16 inches	Chemical
Crappie	No Restrictions			
Carp	No Restrictions	No Restrictions	1 meal per week	PCBs
White Bass		1 meal per week		PCBs
Largemouth Bass		No Restrictions	1 meal per week	PCBs

Lake Blackshear

Species	Less than 12 inches	12 - 16 inches	Over 16 inches	Chemical
Largemouth Bass		No Restrictions	No Restrictions	
Spotted Sucker		No Restrictions	No Restrictions	

Lake Blue Ridge

Species	Less than 12 inches	12 - 16 inches	Over 16 inches	Chemical
White Bass		1 meal per week		Mercury
Channel Catfish		No Restrictions	No Restrictions	

NEWS

Tennessee Department of Environment and Conservation
401 Church Street
Nashville Tennessee 3724[illegible]

FOR MORE INFORMATION CONTACT:
Mary Locker: 615-532-0743
Paul Davis: 615-532-0625

FOR IMMEDIATE RELEASE — WEDNESDAY, MARCH 24, 1993

NASHVILLE - The Department of Environment and Conservation's Division of Water Pollution Control has announced that there will be no revisions at this time to the fishing advisories issued in 1992.

"The department issues fish consumption advisories when testing indicates that levels of toxic materials in fish tissue exceed those considered to be protective of human health, "said Water Pollution Control Director Paul Davis. "Since the consumption of contaminated fish tissue is an avoidable risk, the department issues advisories so that citizens can make informed choices concerning their health.

"The results of 1992 studies of sites where advisories already existed or areas where additional studies were needed have not justified revising or removing existing advisories or issuing new ones at this time," Davis said. "However, the department will not hesitate to make changes in the status of advisories during 1993 should new information become available."

Sites where samples were collected in 1992 include, but are not limited to, Watts Bar, Chickamauga, Fort Loudoun, Douglas, Woods, Cheatham and Center Hill Reservoirs, as well as the Mississippi, Wolf and Loosahatchie Rivers.

A list of the current advisories in Tennessee has been printed in the Tennessee Wildlife Resources Agency's 1993 fishing regulations.

In order to assist citizens in their understanding of the stream posting process in Tennessee, the Department of Environment and Conservation has prepared a free brochure entitled "Tennessee Fishing Advisories." This publication explains the types of pollutants impacting streams and the current locations of fishing advisories.

For more detailed information, or a copy of the brochure, contact the Department of Environment and Conservation, Division of Water Pollution Control, 7th Floor, Life and Casualty Annex, 401 Church Street, Nashville, Tenness[illegible]

FISHING ADVISORY BACKGROUND INFORMATION

There are two principal reasons for posting streams in Tennessee. The first is when bacterial contamination poses a water contact threat. Sources of bacteria are most frequently from inadequately treated discharges from municipal sewage systems, but can also be from livestock holding areas and urban runoff. This type of advisory warns the public to avoid coming in contact with these waters through activities such as swimming, wading, fishing and skiing.

Streams are also posted when average levels of toxic materials in the edible portion of fish pose an increased cancer risk (or other serious illness) to the general public. The department uses information and guidance from the U.S. Food and Drug Administration and the Environmental Protection Agency on the various contaminants found in fish.

There are two levels of fish consumption advisories used in Tennessee. The mildest form is a "limit consumption advisory," sometimes referred to as a precautionary advisory. Scientific studies have shown that developing fetuses and children may be more susceptible to the harmful effects of toxic materials than are adults. Thus a precautionary advisory warns that children, pregnant women and nursing mothers should not eat the type fish that is contaminated. All others are warned to limit their consumption of these fish.

The second level of advisory is a do-not-consume warning. At this level, all persons are advised to avoid eating the type fish contaminated.

The department makes every attempt to get advisory information to the public. A press release is issued whenever a stream or lake is posted. The department also places warning signs at significant public access points on posted waters.

CURRENT FISH TISSUE ADVISORIES (MARCH 1993)

STREAM	COUNTY	PORTION	POLLUTANT	TYPE ADVISORY
Loosahatchie River	Shelby	Mile 0.0-20.9	Chlordane	Fish should not be consumed.
Wolf River	Shelby	Mile 0.0-18.9	Chlordane	Fish should not be consumed.
Mississippi River	Shelby	MS line to mile 745	Chlordane	Fish should not be consumed. Commercial fishing ban.
McKellar Lake and Nonconnah Creek	Shelby	mile 0.0 to Horn Lake Road bridge (mile 1.8)	Chlordane	Fish should not be consumed.
Boone Reservoir	Sullivan, Washington	Entirety	PCBs, chlordane	Precautionary advisory for carp and catfish.*
North Fork Holston River	Sullivan, Hawkins	Mile 0.0-6.2 TN/VA line	Mercury	Fish should not be consumed.
Fort Loudoun Reservoir	Loudon, Knox, Blount	Entirety (46 miles)	PCBs	Commercial fishing for catfish prohibited. Catfish, largemouth bass over two pounds, and largemouth bass from the Little River embayment should not be consumed.
Tellico Lake	Loudon	Entirety (32.5 miles)	PCBs	Catfish should not be consumed.
Pigeon River	Cocke	N. Carolina line to Douglas Res.	Dioxin	Fish should not be consumed.
Watts Bar Reservoir	Roane, Meigs, Rhea	Tennessee River portion	PCBs	Catfish, striped bass, and hybrid striped bass-white bass (Cherokee bass) should not be eaten. Precautionary advisory* for white bass, sauger, carp, smallmouth buffalo and largemouth bass.
	Roane	Clinch River arm	PCBs	Striped bass should not be consumed. Precautionary advisory for catfish and sauger.*
Melton Hill Reservoir	Knox, Anderson	Entirety	PCBs	Catfish should not be consumed.
East Fork of Poplar Creek (incl. Poplar Creek embayment)	Anderson, Roane	Mile 0.0 - 15.0	Mercury, metals, org. chemicals	Fish should not be consumed. Avoid contact with water.
Nickajack Reservoir	Hamilton, Marion	Entirety	PCBs	Precautionary advisory for catfish*.
Chattanooga Creek	Hamilton	GA line to mouth	PCBs, chlordane	Fish should not be consumed.
Woods Reservoir	Franklin	Entirety	PCBs	Catfish should not be consumed.

This list subject to revision.

* Precautionary Advisory - Children, pregnant women, and nursing mothers should not consume the fish species named. All other persons should limit consumption of the named species to 1.2 pounds per month.

NEWS

Tennessee Department of Environment and Conservation
401 Church Street
Nashville, Tennessee 37243

For More Information Contact:
Melissa Miller, Public Information Office
615/532-0743 or
Paul E. Davis 615/532-0625
Greg Denton 615/532-0699

For Immediate Release
March 7, 1996

Nashville: Commissioner Don Dills of the Tennessee Department of Environment and Conservation today announced a change to the fishing advisories for the state of Tennessee. The body of water affected by today's change is the **Pigeon River** in Cocke County. The pollutant of concern is dioxin.

Water Pollution Control Division Director Paul Davis said, "Fishing advisories are issued when levels of contaminants in fish pose an increased threat to the people who may eat them. Since eating contaminated fish is an avoidable risk, we provide this information so that people can make informed choices about their families' health."

"The change of advisory on the Pigeon River is a downgrading of the existing advisory made possible by a trend of generally lower dioxin levels in fish in the last four years when compared to levels documented in the 1980s," Davis said. "The old advisory stated that no one should eat any type of fish from the Pigeon River. Today's revision states that children, nursing mothers, and pregnant women should avoid eating carp, catfish, and redbreast sunfish from the Pigeon. All other persons should limit their consumption of Pigeon River carp, catfish, and redbreast sunfish to one meal per month."

The Department now uses a risk-based procedure for issuing fishing advisories. An evaluation of existing dioxin levels based on the new procedure indicate that certain Pigeon River fish continue to pose a threat to atypical consumers of fish. The new dioxin advisory levels are 0.7 parts per trillion for a precautionary advisory and 7.0 parts per trillion for a no consumption advisory. The average levels of dioxin in Pigeon River catfish, carp, and redbreast sunfish continue to exceed the 0.7 level for dioxin, but are well below 7 parts per trillion.

The Pigeon River originates in the Blue Ridge region of North Carolina and flows in a northwesterly direction into Tennessee. During the 1980's, it was targeted for dioxin monitoring during the U.S. Environmental Protection Agency's (EPA) National Dioxin Survey because of the discharge of chlorine bleached pulp mill effluent near Canton, North Carolina. That and subsequent analyses documented elevated levels of dioxin in fish.

The paper mill, Champion Paper Company, reached an agreement with EPA and the states of North Carolina and Tennessee in 1990. As part of that agreement, Champion invested over $300 million in a pollution abatement and plant modernization project.

(more)

Since 1991, annual fish tissue monitoring has taken place in the Pigeon, primarily by the Champion Paper Company as a compliance monitoring requirement of their NPDES permit and by the Tennessee Wildlife Resources Agency (TWRA). Additional samples have been collected by Carolina Power and Light and the Department of Environment and Conservation. Long-term goals of this monitoring include providing data for the periodic reevaluation of the fishing advisory and allowing the identification of trends, if any, in dioxin concentrations in fish over time.

Dioxin data collected during the period 1991 - 1995 are summarized below.

TYPE FISH	DATA RANGE	AVERAGE TEQ (ppt)	WEIGHTED * AVERAGE TEQ
Redbreast Sunfish	0.08 - 2.81	1.05	1.16
Common Carp	0.23 - 14.55	4.14	4.57
Channel Catfish	0.50 - 9.04	3.14	3.54
Smallmouth Buffalo	0.09 - 1.06	0.57	0.52
Smallmouth Bass	0.11 - 0.80	0.38	0.24
Spotted Bass	0.19 - 0.76	0.49	0.53

*Average weighted according to the number of fish in composite samples.

Davis said, "The improvement in water quality in the Pigeon River is a result of the dedicated efforts of many people. While the Pigeon is not yet as clean as it needs to be, and some dioxin remains in fish, today's downgrading of the previous fishing advisory should be seen as a success story in the making. We will continue to monitor the Pigeon River."

SUMMARY OF PIGEON RIVER ADVISORY CHANGES

SITE	PREVIOUS ADVISORY	NEW ADVISORY
Pigeon River (From North Carolina state line to confluence with French Broad River)	"Do not consume" advisory covering all types of fish.	"Precautionary advisory*" for carp, catfish, and redbreast sunfish.

* Children, pregnant women, or nursing mothers should not eat these fish. Persons with previous occupational exposure to the substance of concern should avoid eating any fish from this site. All other should limit consumption of these fish to one meal per month.

Background information available upon request.

THE STATUS OF WATER QUALITY IN TENNESSEE

1996 305(b) REPORT

prepared by

Gregory M. Denton, Carole S. Freeman, and Katherine A. Larrieu

Water Supply and Ground Water Information submitted by

Robert Foster and Thomas Moss

NOVEMBER 1996

Tennessee Department of Environment and Conservation
Division of Water Pollution Control
401 Church Street
L&C Annex, 6th Floor
Nashville, Tennessee 37243-1534
615-532-0625

CURRENT FISH TISSUE ADVISORIES
(November, 1996. This list subject to revision.)

STREAM	COUNTY	PORTION	POLLUTANT	COMMENTS
Loosahatchie River	Shelby	Mile 0 0 - 20 9	Chlordane	Fish should not be consumed
Wolf River	Shelby	Mile 0 0 - 18 9	Chlordane	Fish should not be consumed
Mississippi River	Shelby	MS line to mile 745	Chlordane	Fish should not be consumed Commercial fishing prohibited by TWRA
McKellar Lake & Nonconnah Creek	Shelby	Mile 0 0 to 1.8	Chlordane	Fish should not be consumed Advisory ends at Horn Lake Road bridge
North Fork Holston River	Sullivan, Hawkins	Mile 0.0 - 6.2	Mercury	Fish should not be consumed. Advisory goes to TN/VA line
East Fork of Poplar Creek incl Poplar Ck embayment	Anderson, Roane	Mile 0.0 - 15 0	Mercury, PCBs	Fish should not be consumed Avoid contact with water also
Chattanooga Creek	Hamilton	Mouth to GA line	PCBs, chlordane	Fish should not be consumed Avoid contact with water also
Woods Reservoir	Franklin	Entirety	PCBs	Catfish should not be consumed
Fort Loudoun Reservoir	Loudon, Knox, Blount	Entirety (46 miles)	PCBs	Commercial fishing for catfish prohibited by TWRA Catfish, largemouth bass over two pounds, or any largemouth bass from the Little River embayment should not be consumed
Tellico Lake	Loudon	Entirety	PCBs	Catfish should not be consumed
Melton Hill Reservoir	Knox, Anderson	Entirety	PCBs	Catfish should not be consumed
Watts Bar Reservoir	Roane, Meigs, Rhea, Loudon	Tennessee River portion	PCBs	Catfish, striped bass, & hybrid striped bass-white bass should not be consumed Precautionary advisory* for whitebass, sauger, carp, smallmouth buffalo and largemouth bass
Watts Bar Reservoir	Roane, Anderson	Clinch River arm	PCBs	Striped bass should not be consumed Precautionary advisory for catfish and sauger *
Boone Reservoir	Sullivan, Washington	Entirety	PCBs, chlordane	Precautionary advisory for carp and catfish *
Nickajack Reservoir	Hamilton, Marion	Entirety	PCBs	Precautionary advisory for catfish *
Pigeon River	Cocke	N.C line to Douglas Res	Dioxin	Precautionary advisory for carp, catfish, and redbreast sunfish *

*Precautionary Advisory - Children, pregnant women, and nursing mothers should not consume the fish species named. All other persons should limit consumption of the named species to one meal per month.

Appendix B

Physical Information on All Fish Collected for Fish Tissue Studies in 1996

Note: The following tables contain collection date, length, weight, and sex for each fish included in these studies. Separate tables are provided for each type of study. For each study, data are grouped by reservoir, river mile and species. Individuals of the same species which were composited for analysis are listed in successive order. In **Reservoir and Stream Screening Studies (Tables B-1 and B-2**, respectively), the largest individual from each largemouth, smallmouth, or spotted bass composite was also analyzed separately for mercury. These fish (i.e., those analyzed separately) are identified in these tables by an asterisk (*). Data for each of these fish are identical to the data for one of the entries above it because it is the same fish.

Table B-1. **Specific Information About Each Fish Collected During 1996 for Reservoir Screening Fish Tissue Study**

For Calendar Year : 1996

ection Site		Date	Species	Length(mm)	Weight(g)	Sex	LABID
[illegible]ACHIA							
HIW	67.0	11/05/96	CHC	582	1664	Female	
HIW	67.0	11/05/96	CHC	550	1290	Female	
HIW	67.0	11/20/96	CHC	583	1647	Male	
HIW	67.0	11/20/96	CHC	605	1749	Male	
HIW	67.0	11/20/96	CHC	511	885	Male	
HIW	67.0	11/05/96	LMB	552	1170	Female	
HIW	67.0	11/05/96	LMB	334	528	Male	
HIW	67.0	11/05/96	LMB	317	402	Female	
HIW	67.0	11/05/96	LMB	421	991	Female	
HIW	67.0	11/05/96	LMB	382	698	Female	
HIW	67.0	11/05/96	LMB*	552	1170	Female	
BEAR CREEK							
BEC	75.0	09/23/96	CHC	515	1375	Female	
BEC	75.0	09/23/96	CHC	570	2240	Male	
BEC	75.0	09/23/96	CHC	541	1510	Male	
BEC	75.0	09/23/96	LMB	370	705	Female	
[illegible]	75.0	09/23/96	LMB	418	1145	Male	
[illegible]	75.0	09/23/96	LMB	340	535	Female	
BEC	75.0	09/23/96	LMB	411	1030	Male	
BEC	75.0	09/23/96	LMB	488	2065	Male	
BEC	75.0	09/23/96	LMB*	488	2065	Male	
CEDAR CREEK							
CEC	25.0	09/25/96	CHC	555	2025	Female	
CEC	25.0	09/25/96	CHC	379	430	Male	
CEC	25.0	09/25/96	CHC	400	510	Female	
CEC	25.0	10/30/96	CHC	480	805	Male	
CEC	25.0	10/30/96	CHC	391	435	Male	
CEC	25.0	09/25/96	LMB	306	380	Male	
CEC	25.0	09/25/96	LMB	463	1490	Male	
CEC	25.0	10/29/96	LMB	315	375	Female	
CEC	25.0	10/29/96	LMB	468	1490	Female	
CEC	25.0	10/29/96	LMB	443	1145	Female	
CEC	25.0	10/29/96	LMB*	468	1490	Female	
CHATUGE							
HIW	122	10/01/96	LMB	466	1132	Female	
[illegible]	122	10/01/96	LMB	362	616	Female	
HIW	122	10/01/96	LMB	442	1263	Male	

Table B-1. Cont.' **Specific Information About Each Fish Collected During 1996 for Reservoir Screening Fish Tissue Study**

For Calendar Year : 1996

Collection Site		Date	Species	Length(mm)	Weight(g)	Sex	LABID
HIW	122	10/01/96	LMB	381	661	Male	
HIW	122	10/01/96	LMB	321	437	Male	
HIW	122	10/01/96	LMB*	442	1263	Male	
HIW	122	10/01/96	CHC	464	817	Female	
HIW	122	10/01/96	CHC	531	1427	Male	
HIW	122	10/01/96	CHC	392	455	Male	
HIW	122	11/05/96	CHC	459	743	Female	
HIW	122	11/05/96	CHC	553	1561	Male	
SHO	1.5	11/04/96	CHC	538	1520	Male	
SHO	1.5	11/04/96	CHC	672	3109	Male	
SHO	1.5	11/04/96	CHC	546	1429	Male	
SHO	1.5	11/04/96	CHC	488	910	Female	
SHO	1.5	11/04/96	CHC	581	1690	Male	
SHO	1.5	10/02/96	LMB	380	744	Male	
SHO	1.5	10/02/96	LMB	313	383	Male	
SHO	1.5	10/02/96	LMB	322	389	Male	
SHO	1.5	10/02/96	LMB	372	540	Male	
SHO	1.5	10/02/96	LMB	325	422	Male	
SHO	1.5	10/02/96	LMB*	380	744	Male	
FONTANA							
LTE	62.0	10/03/96	CHC	440	690	Male	
LTE	62.0	10/24/96	CHC	485	950	Female	
LTE	62.0	10/24/96	CHC	542	1121	Male	
LTE	62.0	10/24/96	CHC	512	1040	Female	
LTE	62.0	10/24/96	CHC	530	1369	Female	
LTE	62.0	10/03/96	LMB	306	375	Male	
LTE	62.0	10/03/96	LMB	386	842	Female	
LTE	62.0	10/03/96	LMB	435	1183	Female	
LTE	62.0	10/03/96	LMB	370	677	Female	
LTE	62.0	10/03/96	LMB	322	474	Male	
LTE	62.0	10/03/96	LMB*	435	1183	Female	
LTE	81.0	10/01/96	LMB	356	587	Female	
LTE	81.0	10/01/96	LMB	426	1068	Male	
LTE	81.0	10/01/96	LMB	312	389	Female	
LTE	81.0	10/01/96	LMB	397	745	Female	
LTE	81.0	10/01/96	LMB	432	1110	Female	
LTE	81.0	10/01/96	LMB*	432	1110	Female	

Table B-1. Cont.' **Specific Information About Each Fish Collected During 1996 for Reservoir Screening Fish Tissue Study**

For Calendar Year : 1996

ction Site		Date	Species	Length (mm)	Weight (g)	Sex	LABID
LTE	81.0	10/24/96	CHC	495	1232	Male	
LTE	81.0	10/01/96	CHC	438	556	Male	
LTE	81.0	10/24/96	CHC	441	891	Female	
LTE	81.0	10/24/96	CHC	535	1515	Male	
LTE	81.0	10/24/96	CHC	535	1243	Male	
TUC	3.0	10/02/96	CHC	407	543	Male	
TUC	3.0	10/02/96	CHC	496	949	Male	
TUC	3.0	10/02/96	CHC	411	549	Female	
TUC	3.0	10/02/96	CHC	414	570	Female	
TUC	3.0	10/02/96	CHC	374	368	Female	
TUC	3.0	10/02/96	LMB	363	731	Female	
TUC	3.0	10/02/96	LMB	407	1014	Male	
TUC	3.0	10/02/96	LMB	422	963	Female	
TUC	3.0	10/02/96	LMB	364	610	Male	
TUC	3.0	10/02/96	LMB	388	975	Male	
TUC	3.0	10/02/96	LMB *	407	1014	Male	
GUNTERSVILLE							
	350	10/09/96	CHC	562	2505	Female	
	350	10/09/96	CHC	560	1985	Female	
TEN	350	10/09/96	CHC	461	1190	Male	
TEN	350	10/09/96	CHC	525	1720	Male	
TEN	350	10/09/96	CHC	435	825	Male	
TEN	350	10/09/96	LMB	410	935	Female	
TEN	350	10/09/96	LMB	366	730	Female	
TEN	350	10/09/96	LMB	382	790	Female	
TEN	350	10/09/96	LMB	431	1090	Female	
TEN	350	10/09/96	LMB	365	715	Male	
TEN	350	10/09/96	LMB *	431	1090	Female	
TEN	375	10/08/96	LMB	360	770	Female	
TEN	375	10/08/96	LMB	347	640	Female	
TEN	375	10/20/96	LMB	370	1000	Female	
TEN	375	10/20/96	LMB	385	955	Female	
TEN	375	10/20/96	LMB	383	985	Male	
TEN	375	10/20/96	LMB *	370	1000	Female	
TEN	375	10/08/96	CHC	610	2850	Female	
N	375	10/08/96	CHC	576	2060	Female	
N	375	10/08/96	CHC	607	2280	Female	

Table B-1. Cont.' **Specific Information About Each Fish Collected During 1996 for Reservoir Screening Fish Tissue Study**

For Calendar Year : 1996

Collection Site	Date	Species	Length(mm)	Weight(g)	Sex	LABID
TEN 375	10/08/96	CHC	590	2520	Female	
TEN 424	10/07/96	CHC	497	1450	Male	
TEN 424	10/07/96	CHC	464	1070	Female	
TEN 424	10/07/96	CHC	502	1340	Male	
TEN 424	10/07/96	CHC	391	605	Female	
TEN 424	10/07/96	CHC	390	685	Female	
TEN 424	11/15/96	LMB	383	700	Female	
TEN 424	11/15/96	LMB	418	865	Female	
TEN 424	11/15/96	LMB	387	716	Female	
TEN 424	11/15/96	LMB	420	924	Female	
TEN 424	11/15/96	LMB	429	1292	Female	
TEN 424	11/15/96	LMB *	429	1292	Female	
HIWASSEE						
HIW 77.0	10/04/96	LMB	356	791	Male	
HIW 77.0	10/04/96	LMB	362	716	Female	
HIW 77.0	10/04/96	LMB	456	1345	Female	
HIW 77.0	10/04/96	LMB	364	645	Male	
HIW 77.0	10/04/96	LMB	466	1571	Female	
HIW 77.0	10/04/96	LMB *	466	1571	Female	
HIW 77.0	10/04/96	CHC	419	571	Male	
HIW 77.0	11/20/96	CHC	459	817	Female	
HIW 77.0	11/20/96	CHC	572	1938	Female	
HIW 77.0	11/20/96	CHC	598	2382	Male	
HIW 77.0	11/20/96	CHC	492	898	Male	
HIW 85.0	10/03/96	CHC	538	1526	Female	
HIW 85.0	10/03/96	CHC	398	475	Female	
HIW 85.0	10/03/96	CHC	521	1132	Female	
HIW 85.0	10/03/96	CHC	411	562	Female	
HIW 85.0	10/03/96	LMB	362	782	Male	
HIW 85.0	10/03/96	LMB	362	753	Male	
HIW 85.0	10/03/96	LMB	386	854	Female	
HIW 85.0	10/03/96	LMB	362	692	Female	
HIW 85.0	10/03/96	LMB	362	772	Male	
HIW 85.0	10/03/96	LMB *	386	854	Female	
LITTLE BEAR CREEK						
LBC 12.0	09/24/96	LMB	334	515	Male	
LBC 12.0	09/24/96	LMB	329	460	Female	

Table B-1. Cont.' **Specific Information About Each Fish Collected During 1996 for Reservoir Screening Fish Tissue Study**

For Calendar Year : 1996

ction Site		Date	Species	Length (mm)	Weight (g)	Sex	LABID
LBC	12.0	09/24/96	LMB	307	415	Male	
LBC	12.0	09/24/96	LMB	265	280	Female	
LBC	12.0	09/24/96	LMB	364	550	Female	
LBC	12.0	09/24/96	LMB*	364	550	Female	
LBC	12.0	09/24/96	CHC	502	1095	Female	
LBC	12.0	09/24/96	CHC	548	1405	Male	
LBC	12.0	09/24/96	CHC	504	1190	Male	
LBC	12.0	09/24/96	CHC	508	1090	Male	
LBC	12.0	09/24/96	CHC	460	905	Male	
MELTON HILL							
CLI	24.0	10/15/96	LMB	470	1638	Female	
CLI	24.0	10/15/96	LMB	339	486	Female	
CLI	24.0	10/15/96	LMB	334	510	Female	
CLI	24.0	10/15/96	LMB	403	868	Female	
CLI	24.0	10/15/96	LMB	342	504	Female	
CLI	24.0	10/15/96	LMB*	470	1638	Female	
CLI	24.0	10/16/96	CHC	427	632	Male	
	24.0	12/04/96	CHC	566	1743	Female	
	24.0	12/04/96	CHC	575	1873	Male	
CLI	24.0	12/04/96	CHC	520	1539	Female	
CLI	24.0	12/04/96	CHC	586	1789	Female	
CLI	45.0	10/17/96	CHC	646	3003	Female	
CLI	45.0	10/17/96	CHC	698	5096	Male	
CLI	45.0	10/17/96	CHC	647	3456	Male	
CLI	45.0	10/17/96	CHC	716	4820	Male	
CLI	45.0	10/17/96	CHC	635	3244	Female	
CLI	45.0	10/16/96	LMB	388	690	Male	
CLI	45.0	10/16/96	LMB	306	238	Female	
CLI	45.0	10/16/96	LMB	392	806	Female	
CLI	45.0	10/16/96	LMB	351	518	Female	
CLI	45.0	10/16/96	LMB	315	368	Male	
CLI	45.0	10/16/96	LMB*	392	806	Female	
PARKSVILLE - OCOEE N							
OCO	12.0	10/17/96	LMB	312	370	Female	
OCO	12.0	10/17/96	LMB	346	576	Female	
)	12.0	10/17/96	LMB	353	655	Female	
)	12.0	10/17/96	LMB	494	1963	Female	

Table B-1. Cont.' **Specific Information About Each Fish Collected During 1996 for Reservoir Screening Fish Tissue Study**

For Calendar Year : 1996

Collection Site		Date	Species	Length(mm)	Weight(g)	Sex	LABID
OCO	12.0	10/17/96	LMB	531	2024	Female	
OCO	12.0	10/17/96	LMB *	531	2024	Female	
OCO	12.0	10/10/96	CHC	472	835	Male	
OCO	12.0	10/17/96	CHC	447	746	Male	
OCO	12.0	10/17/96	CHC	426	574	Female	
OCO	12.0	10/17/96	CHC	424	607	Female	
OCO	12.0	10/17/96	CHC	447	654	Male	
PICKWICK							
BEC	8.0	10/22/96	LMB	366	600	Female	
BEC	8.0	10/22/96	LMB	347	625	Female	
BEC	8.0	10/22/96	LMB	324	370	Female	
BEC	8.0	10/22/96	LMB	315	400	Male	
BEC	8.0	10/22/96	LMB	310	340	Female	
BEC	8.0	10/22/96	LMB *	347	625	Female	
BEC	8.0	10/22/96	CHC	519	1160	Male	
BEC	8.0	10/22/96	CHC	492	1065	Female	
BEC	8.0	10/22/96	CHC	461	790	Female	
BEC	8.0	10/22/96	CHC	469	770	Male	
BEC	8.0	10/22/96	CHC	392	490	Male	
TEN	207	10/21/96	CHC	408	730	Male	
TEN	207	10/21/96	CHC	418	695	Male	
TEN	207	10/21/96	CHC	397	525	Male	
TEN	207	10/22/96	CHC	430	735	Female	
TEN	207	10/22/96	CHC	576	1800	Male	
TEN	207	10/21/96	LMB	427	1125	Female	
TEN	207	10/21/96	LMB	375	780	Female	
TEN	207	10/21/96	LMB	309	440	Female	
TEN	207	10/21/96	LMB	282	320	Male	
TEN	207	10/21/96	LMB *	427	1125	Female	
TEN	230	10/23/96	LMB	446	1020	Male	
TEN	230	10/23/96	LMB	380	820	Male	
TEN	230	10/23/96	LMB	282	315	Male	
TEN	230	10/23/96	LMB *	446	1020	Male	
TEN	230	10/23/96	CHC	422	650	Female	
TEN	230	10/23/96	CHC	446	895	Female	
TEN	230	10/23/96	CHC	410	705	Female	
TEN	230	10/23/96	CHC	403	625	Male	

Table B-1. Cont.' **Specific Information About Each Fish Collected During 1996 for Reservoir Screening Fish Tissue Study**

For Calendar Year : 1996

ction Site	Date	Species	Length(mm)	Weight(g)	Sex	LABID
TEN 230	10/23/96	CHC	446	750	Female	
TEN 259	10/24/96	CHC	374	385	Male	
TEN 259	10/24/96	CHC	377	425	Male	
TEN 259	10/24/96	CHC	408	465	Female	
TEN 259	10/24/96	CHC	501	1100	Male	
TEN 259	10/24/96	CHC	392	585	Male	
TEN 259	10/24/96	LMB	358	695	Female	
TEN 259	10/24/96	LMB	305	445	Female	
TEN 259	10/24/96	LMB	318	495	Male	
TEN 259	10/24/96	LMB	405	309	Male	
TEN 259	10/24/96	LMB*	358	695	Female	
SOUTH HOLSTON						
SFH 51.0	10/29/96	CHC	459	664	Female	
SFH 51.0	10/29/96	CHC	511	1124	Female	
SFH 51.0	11/13/96	CHC	507	950	Male	
SFH 51.0	10/29/96	LMB	512	1944	Female	
SFH 51.0	10/29/96	LMB	451	1376	Female	
[illegible] 51.0	10/29/96	LMB	463	1580	Female	
[illegible] 51.0	10/29/96	LMB	445	1536	Female	
SFH 51.0	11/13/96	LMB	395	1044	Female	
SFH 51.0	10/29/96	LMB*	512	1944	Female	
SFH 62.0	10/29/96	LMB	474	1414	Female	
SFH 62.0	10/29/96	LMB	527	2300	Female	
SFH 62.0	10/29/96	LMB	435	1168	Female	
SFH 62.0	10/29/96	LMB	439	1182	Female	
SFH 62.0	10/29/96	LMB	327	510	Female	
SFH 62.0	10/29/96	LMB*	527	2300	Female	
SFH 62.0	10/30/96	CHC	661	2823	Female	
SFH 62.0	10/30/96	CHC	612	2274	Male	
SFH 62.0	10/30/96	CHC	491	1041	Male	
SFH 62.0	10/30/96	CHC	445	703	Female	
WATAUGA						
WAT 37.0	11/07/96	CHC	502	1000	Male	
WAT 37.0	11/07/96	CHC	540	1139	Male	
WAT 37.0	10/31/96	LMB	421	1063	Female	
[illegible] 37.0	10/31/96	LMB	479	1596	Female	
[illegible] 37.0	10/31/96	LMB	495	2163	Female	

Table B-1. Cont.' **Specific Information About Each Fish Collected During 1996 for Reservoir Screening Fish Tissue Study**

For Calendar Year : 1996

Collection Site	Date	Species	Length(mm)	Weight(g)	Sex	LABID
WAT 37.0	10/31/96	LMB	366	690	Female	
WAT ·37.0	10/31/96	LMB	456	1865	Female	
WAT 37.0	10/31/96	LMB *	495	2163	Female	
WAT 45.0	10/31/96	LMB	531	2655	Female	
WAT 45.0	10/31/96	LMB	438	1451	Female	
WAT 45.0	10/31/96	LMB	386	811	Female	
WAT 45.0	10/31/96	LMB	406	974	Female	
WAT 45.0	10/31/96	LMB	480	1467	Female	
WAT 45.0	10/31/96	LMB *	531	2655	Female	
WAT 45.0	10/31/96	CHC	727	4001	Female	
WAT 45.0	10/31/96	CHC	385	440	Female	
WAT 45.0	11/26/96	CHC	454	939	Female	
WATTS BAR						
CLI 22.0	10/07/96	CHC	584	2334	Female	
CLI 22.0	10/07/96	CHC	506	1008	Male	
CLI 22.0	10/07/96	LMB	460	1418	Female	
CLI 22.0	10/07/96	LMB	363	732	Female	
CLI 22.0	10/07/96	LMB	314	376	Female	
CLI 22.0	10/07/96	LMB	348	614	Female	
CLI 22.0	10/07/96	LMB	315	444	Female	
CLI 22.0	10/07/96	LMB *	460	1418	Female	
TEN 531	10/08/96	LMB	457	1442	Female	
TEN 531	10/08/96	LMB	341	536	Female	
TEN 531	10/08/96	LMB	452	1402	Female	
TEN 531	10/08/96	LMB	314	438	Female	
TEN 531	10/08/96	LMB *	457	1442	Female	
TEN 531	10/08/96	CHC	394	500	Male	
TEN 531	10/09/96	CHC	547	1835	Female	
TEN 531	10/09/96	CHC	446	917	Male	
TEN 531	10/09/96	CHC	554	1836	Female	
TEN 531	10/17/96	CHC	523	1164	Female	
TEN 560	10/17/96	CHC	529	1122	Male	
TEN 560	10/17/96	CHC	595	2529	Male	
TEN 560	10/17/96	CHC	491	1062	Female	
TEN 560	10/17/96	CHC	619	2622	Male	
TEN 560	10/23/96	CHC	618	2877	Female	
TEN 560	10/09/96	LMB	417	1028	Female	

Table B-1. Cont.' **Specific Information About Each Fish Collected During 1996 for Reservoir Screening Fish Tissue Study**

For Calendar Year : 1996

(:tion Site		Date	Species	Length (mm)	Weight (g)	Sex	LABID
TEN	560	10/09/96	LMB	430	1081	Female	
TEN	560	10/09/96	LMB	409	901	Female	
TEN	560	10/09/96	LMB	415	1241	Female	
TEN	560	10/09/96	LMB	303	413	Female	
TEN	560	10/09/96	LMB*	415	1241	Female	
TEN	600	10/10/96	LMB	451	1396	Female	
TEN	600	10/10/96	LMB	3540	748	Female	
TEN	600	10/10/96	LMB	378	858	Female	
TEN	600	10/10/96	LMB	345	564	Female	
TEN	600	10/10/96	LMB	324	440	Female	
TEN	600	10/10/96	LMB*	451	1396	Female	
TEN	600	10/10/96	CHC	435	714	Male	
TEN	600	10/23/96	CHC	603	1963	Female	
TEN	600	10/23/96	CHC	676	3623	Male	
TEN	600	10/23/96	CHC	463	938	Male	
WILSON							
TEN	260	10/16/96	CHC	560	1535	Male	
	260	10/16/96	CHC	595	2075	Female	
[illegible]	260	10/16/96	CHC	495	1085	Female	
TEN	260	10/16/96	CHC	480	970	Male	
TEN	260	10/16/96	CHC	429	620	Female	
TEN	260	10/16/96	LMB	440	1295	Female	
TEN	260	10/16/96	LMB	386	750	Female	
TEN	260	10/16/96	LMB	384	860	Female	
TEN	260	10/16/96	LMB	365	745	Female	
TEN	260	10/16/96	LMB*	440	1295	Female	
TEN	272	10/17/96	LMB	390	810	Male	
TEN	272	10/17/96	LMB	347	595	Male	
TEN	272	10/17/96	LMB	305	335	Male	
TEN	272	10/17/96	LMB*	390	810	Male	
TEN	272	10/17/96	CHC	430	720	Female	
TEN	272	10/17/96	CHC	465	1090	Female	
TEN	272	10/17/96	CHC	402	510	Female	
TEN	272	10/17/96	CHC	490	1080	Male	
TEN	272	10/17/96	CHC	445	825	Female	

Table B-2. **Specific Information About Each Fish Collected During 1996 for Stream Screening Fish Tissue Study**

For Calendar Year : 1996

ction Site		Date	Species	Length(mm)	Weight(g)	Sex	LABID
BEC	27.0	07/24/96	SPB	492	1757	Female	
BEC	27.0	07/24/96	SPB	434	1088	Female	
BEC	27.0	07/24/96	SPB	454	1423	Female	
BEC	27.0	07/24/96	SPB *	492	1757	Female	
BEC	27.0	07/24/96	CHC	414	631	Female	
BEC	27.0	07/24/96	CHC	459	827	Male	
BEC	27.0	07/24/96	CHC	359	371	Female	
BEC	27.0	07/24/96	CHC	361	379	Female	
BUF	18.0	05/31/96	CHC	504	1260	Female	
BUF	18.0	05/31/96	CHC	392	463	Male	
BUF	18.0	05/31/96	CHC	484	1093	Female	
BUF	18.0	05/31/96	CHC	467	943	Female	
BUF	18.0	05/31/96	CHC	446	891	Female	
BUF	18.0	05/31/96	SMB	262	178	Female	
BUF	18.0	05/31/96	SMB	300	335	Female	
BUF	18.0	05/31/96	SMB	276	254	Female	
BUF	18.0	05/13/96	SMB *	300	335	Female	
	10.0	07/10/96	CHC	392	648	Female	
CLA	10.0	07/10/96	CHC	504	1229	Male	
CLA	10.0	07/10/96	LMB	339	703	Female	
CLA	10.0	07/10/96	LMB	414	1099	Female	
CLA	10.0	07/10/96	LMB	387	956	Female	
CLA	10.0	07/10/96	LMB *	414	1099	Female	
DUC	26.0	06/05/96	SPB	264	212	Female	
DUC	26.0	06/05/96	SPB	268	212	Female	
DUC	26.0	06/05/96	SPB	249	183	Female	
DUC	26.0	06/05/96	SPB	330	568	Female	
DUC	26.0	06/05/96	SPB *	330	568	Female	
DUC	26.0	06/05/96	CHC	661	3543	Male	
DUC	26.0	06/05/96	CHC	515	1564	Female	
DUC	26.0	06/05/96	CHC	514	1389	Female	
DUC	26.0	06/05/96	CHC	465	945	Male	
DUC	26.0	06/05/96	CHC	468	880	Female	
FRE	77.0	09/24/96	CHC	430	663	Female	
FRE	77.0	09/24/96	CHC	425	608	Female	
	77.0	09/24/96	CHC	468	930	Male	
FRE	77.0	09/24/96	CHC	379	409	Male	

Table B-2. Cont.' **Specific Information About Each Fish Collected During 1996 for Stream Screening Fish Tissue Study**

For Calendar Year : 1996

Collection Site		Date	Species	Length(mm)	Weight(g)	Sex	LABID
FRE	77.0	09/24/96	CHC	450	750	Male	
LTE	95.0	07/22/96	SMB	255	208	Female	
LTE	95.0	07/22/96	SMB	231	135	Female	
LTE	95.0	09/03/96	SMB	303	289	Female	
LTE	95.0	09/03/96	SMB*	303	289	Female	
LTE	95.0	07/22/96	CHC	405	497	Male	
LTE	95.0	07/25/96	CHC	403	563	Female	
LTE	95.0	09/03/96	CHC	379	410	Male	
NOL	10.0	07/15/96	CHC	401	574	Female	
NOL	10.0	07/15/96	CHC	604	2269	Female	
NOL	10.0	07/15/96	CHC	546	1618	Female	
NOL	10.0	09/05/96	CHC	556	2018	Female	
NOL	10.0	09/05/96	CHC	523	1467	Male	
NOL	10.0	07/15/96	SMB	365	669	Female	
NOL	10.0	09/05/96	SMB	330	537	Female	
NOL	10.0	09/05/96	SMB	223	171	Female	
NOL	10.0	09/05/96	SMB*	365	669	Female	
PIG	7.0	07/11/96	SMB	378	686	Female	
PIG	7.0	07/11/96	SMB	327	361	Female	
PIG	7.0	07/11/96	SMB	455	1370	Female	
PIG	7.0	07/11/96	SMB	333	445	Female	
PIG	7.0	07/11/96	SMB	320	481	Female	
PIG	7.0	07/17/96	SMB*	455	1370	Female	
PIG	7.0	07/11/96	CHC	383	545	Male	
PIG	7.0	07/11/96	CHC	429	759	Female	
PIG	7.0	07/11/96	CHC	430	665	Female	
PIG	7.0	07/11/96	CHC	365	502	Male	
PIG	7.0	07/11/96	CHC	310	272	Female	
TUC	10.0	08/20/96	CHC	370	430	Female	
TUC	10.0	08/20/96	CHC	391	580	Male	
TUC	10.0	09/19/96	CHC	381	464	Male	
TUC	10.0	09/19/96	CHC	376	448	Female	
TUC	10.0	08/20/96	SMB	446	943	Female	
TUC	10.0	09/19/96	SMB	290	332	Female	
TUC	10.0	09/19/96	SMB	244	331	Female	
TUC	10.0	09/19/96	SMB	326	496	Female	
TUC	10.0	09/19/96	SMB	271	264	Female	

Table B-2. Cont.' **Specific Information About Each Fish Collected During 1996 for Stream Screening Fish Tissue Study**

For Calendar Year : 1996

ction Site	Date	Species	Length(mm)	Weight(g)	Sex	LABID
TUC 10.0	08/20/96	SMB*	446	943	Female	

Table B-3. **Specific Information About Each Fish Collected During 1996 for Long Term Fish Tissue Study**

For Calendar Year : 1996

ction Site	Date	Species	Length(mm)	Weight(g)	Sex	LABID
PARKSVILLE - OCOEE N						
OCO 16.0	10/10/96	CHC	501	1027	Male	
OCO 16.0	10/10/96	CHC	560	1270	Male	
OCO 16.0	10/10/96	CHC	488	1005	Female	
OCO 16.0	10/10/96	CHC	496	1013	Female	
OCO 16.0	10/10/96	CHC	518	1215	Male	
WATTS BAR						
CLI 22.0	10/07/96	STB	742	4980	Female	
CLI 22.0	10/07/96	STB	720	4506	Female	
CLI 22.0	10/07/96	STB	909	9710	Female	
CLI 22.0	10/07/96	STB	660	3288	Female	
CLI 22.0	12/03/96	STB	717	4335	Female	
TEN 531	10/17/96	STB	726	4223	Female	
TEN 531	10/17/96	STB	642	3706	Male	
TEN 531	10/17/96	STB	708	4946	Female	
TEN 531	10/17/96	STB	643	3477	Male	
TEN 531	10/17/96	STB	683	5318	Female	
560	10/17/96	STB	585	3158	Male	
560	10/23/96	STB	651	4252	Male	
TEN 560	10/23/96	STB	520	2151	Female	
TEN 560	10/23/96	STB	741	4633	Male	
TEN 560	10/23/96	STB	631	3948	Female	
TEN 600	10/10/96	STB	686	4539	Female	
TEN 600	10/10/96	STB	888	8809	Female	
TEN 600	10/22/96	STB	737	3994	Female	
TEN 600	10/22/96	STB	619	3147	Male	
TEN 600	10/22/96	STB	733	5834	Female	

Table B-4. **Specific Information About Each Fish Collected During 1996 for Targeted Fish Tissue Study**

For Calendar Year : 1996

ction Site	Date	Species	Length(mm)	Weight(g)	Sex	LABID
OCOEE NO 3						
OCO 30.0	04/29/96	BGS	239	331	Male	
OCO 30.0	04/29/96	BGS	204	220	Male	
OCO 30.0	04/29/96	BGS	201	154	Female	
OCO 30.0	04/29/96	BGS	188	153	Male	
OCO 30.0	04/29/96	BGS	197	132	Female	
OCO 30.0	04/29/96	LMB	344	583	Female	
OCO 30.0	04/29/96	LMB	261	201	Male	
TUM 0.5	04/29/96	LMB	375	712	Male	
TUM 0.5	04/29/96	BGS	228	263	Female	
TUM 0.5	04/29/96	BGS	219	256	Female	
TUM 0.5	04/29/96	BGS	214	240	Male	
TUM 0.5	04/29/96	BGS	215	237	Male	
TUM 0.5	04/29/96	BGS	215	228	Female	
TUM 0.5	04/29/96	RES	278	443	Female	
TUM 0.5	04/29/96	RES	263	412	Female	
TUM 0.5	04/29/96	RES	265	379	Male	
[illegible] 0.5	04/29/96	RES	258	370	Female	
[illegible] 0.5	04/29/96	RES	265	362	Female	
TUM 0.5	04/29/96	YP	295	288	Female	
TUM 0.5	04/29/96	YP	256	197	Male	
TUM 0.5	04/29/96	YP	255	194	Male	
TUM 0.5	04/29/96	YP	255	191	Male	
TUM 0.5	04/29/96	YP	244	169	Male	

Appendix C

Species and River Abbreviations Used in Tables and Appendices

Appendix C. Species and River Abbreviations Used in Tables and Appendices.

Abbreviations for Species

BGS -- Bluegill sunfish
CHC -- Channel catfish
LMB -- Largemouth bass
RES -- Redear sunfish
SMB -- Smallmouth bass
SPB -- Spotted bass
STB -- Striped bass
YP -- Yellow Perch

Abbreviations with River Miles

BCM -- Bear Creek Mile
BuRM -- Buffalo River Mile
CCM -- Cedar Creek Mile
CRM -- Clinch River Mile
DRM -- Duck River Mile
ORM -- Ocoee River Mile
SFHRM -- South Fork Holston River Mile
TRM -- Tennessee River Mile
TuRM -- Tuckasegee River Mile

Abbreviations for Rivers and Creeks

BEC -- Bear Creek
BUF -- Buffalo River
CEC -- Cedar Creek
CLI -- Clinch River
CLA -- Clarks River
DUC -- Duck River
FRE -- French Broad River
HIW -- Hiwassee River
LBC -- Little Bear Creek
LTE -- Little Tennessee River
NOL -- Nolichucky River
OCO -- Ocoee River
PIG -- Pigeon River
SFH -- South Fork Holston River
SHO -- Shooting Creek
TEN -- Tennessee River
TUC -- Tuckasegee River
TUM -- Tumbling Creek
WAT -- Watauga River

Appendix D

Results of Dioxin Analysis on Channel Catfish from Selected Reservoirs in 1996

Wright State University, Dayton, Ohio

Analysis for Total Chlorinated Dioxins and Furans
Results from DB-5 Column
EPA Method 8290

Project: Tennessee Valley Authority
Project Number: 2848

Concentrations Found (picograms per gram of sample or parts-per-trillion)a

TVA Number	Tetra CDFs	Tetra CDDs	Penta CDFs	Penta CDDs	Hexa CDFs	Hexa CDDs	Hepta CDFs	Hepta CDDs	Octa CDF	Octa CDD	Total CDFs	Total CDDs	Total CDDs/CDFs
Watts Bar TZ (TRM 560)	2 93	1.29	7 98	2.42	2.54	5 02	ND 0.141	2	0 502	5.07	14	15 8	29 8
Melton Hill TZ (CRM 45)	0.716	0 567	ND 0.103	0.835	0 673	1.04	0.479	0 803	ND 0.259	2.92	1 87	6 16	8 03
Ft Loudoun TZ (TRM 624)	1.05	0 802	1.59	1.02	1.19	2.21	ND 0.147	1.3	0 257	3 57	4 09	8 91	13
Pickwick FB (TRM 207)	0.818	0 541	0.939	0.512	ND 0.109	0.625	ND 0 239	0.689	ND 0 288	2 11	1 76	4 48	6 24
Spike MS 96/50211	9.79	9.65	18 9	9.79	89.9	69 3	49.6	22.6	49.9	47.7	218	159	377
Spike Duplicate MSD 96/50211	10 8	10.7	21.2	10.1	100	76 2	57	25 1	56 3	54.2	246	176	422
Pickwick TZ (TRM 230)	0 882	0.663	1.9	0.54	ND 0.0985	1.22	ND 0.17	1.25	ND 0.257	3.72	2 78	7 38	10 2
Pickwick Inf (TRM 259)	0.873	0.445	0.673	0.436	ND 0.1	0.618	ND 0.226	0.485	ND 0.243	1 7	1.55	3 68	5 23
Pickwick Embay. (Bear Creek Mile 8)	1 35	0.855	0.924	0 776	ND 0.101	2.1	ND 0 181	1.36	ND 0 268	2 76	2 27	7 85	10 1
Wilson FB (TRM 260)	7 24	1 3	2 81	0.855	0.159	2.12	ND 0.226	3 66	ND 0 243	13 7	10.2	21 6	31 8

Wright State University, Dayton, Ohio

Analysis for Total Chlorinated Dioxins and Furans
Results from DB-5 Column
EPA Method 8290

Project: Tennessee Valley Authority
Project Number: 2848

Concentrations Found (picograms per gram of sample or parts-per-trillion)a

TVA Number	Tetra CDFs	Tetra CDDs	Penta CDFs	Penta CDDs	Hexa CDFs	Hexa CDDs	Hepta CDFs	Hepta CDDs	Octa CDF	Octa CDD	Total CDFs	Total CDDs	Total CDDs/CDFs
Wilson Inf	1.13	0.741	0.94	0.573	ND	0.772	ND	1.13	ND	2 87	2 07	6 08	8 15
(TRM 272)					0 142		0 26		0.355				
Guntersville FB	6.64	1.25	3.89	1.24	0 13	2.88	ND	2.66	ND	5 63	10 7	13 7	24 3
(TRM 350)							0 481		0 285				
Guntersville TZ	9.55	1.06	4.34	0.851	ND	1.88	ND	2.59	ND	7.84	13.9	14 2	28 1
(TRM 375)					0.13		0.313		0 341				
Guntersville Inf	3 35	1.41	2.98	1.11	0.131	1.99	ND	1 56	ND	3 47	6 46	9 54	16
(TRM 424)							0.428		0 25				
Watts Bar TZ	0 505	0.345	0 463	0.536	ND	0 434	ND	0 385	ND	1 47	0 968	3 17	4 14
(TRM 531)					0.177		0.302		0 453				
Watts Bar Inf	1.03	1.26	2.6	2.54	ND	3 43	ND	1 39	ND	3 27	3 63	11 9	15 5
(TRM 600)					0.19		0.329		0.483				
Watts Bar Inf	0 755	0.378	0.808	ND	0.366	0 897	ND	0.796	ND	2 11	1 93	4 18	6 11
(CRM 24)				0.21			0.296		0 42				
LAB BLANK	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0	0	0
	0 071	0 112	0.118	0.119	0 106	0.139	0.179	0 196	0 272	0.435			
LAB BLANK	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0	0	0
	0 104	0 165	0 177	0.211	0 166	0.228	0 282	0 328	0 43	0 661			

a. The designation ND indicates "None Detected" in excess of the minimum detectable concentration which is listed directly below the ND designation

Wright State University, Dayton, Ohio

Analysis for 2378-Substituted Chlorinated Dioxins and Furans
Combined Results from DB-5/DB-DIOXIN Columns
EPA Method 8290

Project Tennessee Valley Authority
Project Number 2848

Concentrations Found (picograms per gram of sample or parts-per-trillion)a

TVA Identification	2378 TCDF	2378 TCDD	12378 PeCDF*	23478 PeCDF*	12378 PeCDD	123478 HxCDF*	123678 HxCDF*	123789 HxCDF*	234678 HxCDF*	123478 HxCDD	123678 HxCDD	123789 HxCDD*	1234678 HpCDF	1234789 HpCDF	1234678 HpCDD	OCDF	OCDD
Watts Bar TZ	0 936	1 29	ND	3 72	2 42	0 19	0 21	ND	ND	0 702	3 58	0 74	ND	ND	2	0 502	5 07
(TRM 560)			0 125					0 0817	0 105				0 109	0 198			
Melton Hill TZ	0 587	0 567	ND	ND	0 835	ND	ND	ND	ND	ND	1 04	ND	ND	ND	0 803	ND	2 92
(CRM 45)			0 117	0 701		0 098	0 103	0 101	0 13	0 191		0 219	0 137	0 247		0 259	
Ft Loudoun TZ	ND	0 802	ND	0 801	1 02	ND	ND	ND	ND	0 275	1 6	0 336	ND	ND	1 3	0 257	3 57
(TRM 624)	0 329		0 157			0 0917	0 118	0 0949	0 122				0 114	0 206			
Pickwick FB	0 567	0 541	ND	ND	0 512	ND	ND	ND	ND	ND	0 625	ND	ND	ND	0 689	ND	2 11
(TRM 207)			0 117	0 0914		0 1	0 106	0 104	0 133	0 172		0 133	0 347	0 335		0 288	
Spike MS 96/50211	9 79	9 65	8 92	10	9 79	24 9	14 6	23 8	26 7	24 6	21 4	23 4	22 6	27	22 6	49 9	47 7
Spike Duplicate MSD 96/50211	10 8	10 7	10 4	10 8	10 1	26 9	16 3	26 7	30 4	27 2	24 1	25	26 9	30 1	25 1	56 3	54 2
Pickwick TZ	0 882	0 663	1 34	ND	0 54	ND	ND	ND	ND	0 257	0 748	0 213	ND	ND	1 25	ND	3 72
(TRM 230)				0 091		0 0903	0 0951	0 0934	0 12				0 579	0 238		0 257	
Pickwick Inf	0 785	0 445	ND	ND	0 436	ND	ND	ND	ND	ND	0 478	0 14	ND	ND	0 485	ND	1 7
(TRM 259)			0 119	0 093		0 092	0 0969	0 0952	0 123	0 155			0 422	0 318		0 243	
Pickwick Embay	1 18	0 855	ND	ND	0 776	ND	ND	ND	ND	0 263	1 54	0 298	ND	ND	1 36	ND	2 76
(Bear Creek Mile 8)			0 115	0 0893		0 0927	0 0977	0 096	0 123				0 141	0 255		0 268	
Wilson FB	4 97	1 3	ND	ND	0 855	ND	ND	ND	ND	ND	1 46	0 378	ND	ND	3 66	ND	13 7
(TRM 260)			0 108	0 0839		0 174	0 0909	0 0892	0 115	0 146			0 71	0 317		0 243	
Wilson Inf	1 02	0 741	ND	0 94	0 573	ND	ND	ND	ND	ND	0 772	ND	ND	ND	1 13	ND	2 87
(TRM 272)			0 163			0 13	0 137	0 135	0 174	0 249		0 194	0 492	0 364		0 355	
Guntersville FB	3 81	1 11	ND	1 93	1 24	0 13	ND	ND	ND	0 54	1 82	0 517	ND	ND	2 66	ND	5 63
(TRM 350)			0 132				0 0964	0 135	0 122				3 43	0 675		0 285	
Guntersville TZ	5 34	1 06	ND	1 69	0 851	ND	ND	ND	ND	0 546	1 33	ND	ND	ND	2 59	ND	7 84
(TRM 375)			0 145			0 184	0 184	0 123	0 159			0 585	3 21	0 439		0 341	

Wright State University, Dayton, Ohio

Analysis for 2378-Substituted Chlorinated Dioxins and Furans
Combined Results from DB-5/DB-DIOXIN Columns
EPA Method 8290

Project Tennessee Valley Authority
Project Number 2848

TVA Identification	2378 TCDF	2378 TCDD	12378 PeCDF*	23478 PeCDF*	12378 PeCDD	123478 HxCDF*	123678 HxCDF*	123789 HxCDF*	234678 HxCDF*	123478 HxCDD	123678 HxCDD	123789 HxCDD*	1234678 HpCDF	1234789 HpCDF	1234678 HpCDD	OCDF	OCDD
	Concentrations Found (picograms per gram of sample or parts-per-trillion)a																
Guntersville Inf	2 93	1 41	ND	1 81	1 11	ND	ND	ND	ND	0 393	1 21	0 383	ND	ND	1 56	ND	3 47
(TRM 424)			0 118			0 0861	0 0907	0 0891	0 115				5 94	0 6		0 25	
Watts Bar TZ	0 505	0 345	ND	0 463	0 536	ND	ND	ND	ND	ND	0 434	ND	ND	ND	0 385	ND	1 47
(TRM 531)			0 199			0 162	0 171	0 168	0 216	0 27		0 21	0 235	0 424		0 453	
Watts Bar Inf	0 495	1 26	ND	2 6	2 54	ND	ND	ND	ND	0 411	3 02	ND	ND	ND	1 39	ND	3 27
(TRM 600)			0 225			0 175	0 184	0 181	0 232			0 377	0 256	0 462		0 483	
Watts Bar Inf	0 755	0 378	ND	0 808	ND	ND	ND	ND	ND	ND	0 897	ND	ND	ND	0 796	ND	2 11
(CRM 24)			0 195		0 21	0 16	0 169	0 166	0 214	0 302		0 207	0 23	0 415		0 42	
LAB BLANK	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	0 071	0 112	0 135	0 105	0 119	0 097	0 102	0 1	0 129	0 163	0 134	0 126	0 139	0 251	0 196	0 272	0 435
LAB BLANK	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	0 104	0 165	0 202	0 157	0 211	0 152	0 16	0 158	0 203	0 266	0 22	0 207	0 219	0 396	0 328	0 43	0 661

a The designation ND indicates "None Detected" in excess of the minimum detectable concentration which is listed directly below the ND designation
* These isomers may be convoluted with other isomers of their congener group

Wright State University, Dayton, Ohio

Internal and Surrogate Standards Recoveries
Results from DB-5 Column

Project: Tennessee Valley Authority
Project Number: 2848

TVA Number	%Rec 13C-2378 TCDF	%Rec 13C-2378 TCDD	%Rec 13C-12378 PeCDF	%Rec 13C-12378 PeCDD	%Rec 13C-123478 HxCDF	%Rec 13C-123678 HxCDD	%Rec 13C-1234678 HpCDF	%Rec 13C-1234678 HpCDD	%Rec 13C-OCDD	Average Int %Rec
TRM 560	84	88	89	97	90	97	96	105	110	95
CRM 45	73	77	80	86	78	83	83	91	89	82
TRM 624	72	75	84	93	87	95	92	102	98	89
TRM 207	79	78	79	83	78	82	79	84	82	81
Spike	75	77	80	84	80	86	86	93	89	83
Spike Dup.	83	82	86	94	89	96	94	102	96	91
TRM 230	68	73	78	83	84	89	86	90	89	82
TRM 259	64	67	77	84	81	87	86	93	93	81
Bear Crek Mile 8	72	76	85	92	86	93	84	93	89	85
TRM 260	67	74	84	92	84	89	87	93	90	84
TRM 272	49	51	55	59	65	61	66	76	72	62
TRM 350	82	84	85	89	88	94	87	93	85	87
TRM 375	59	61	63	66	66	69	70	74	70	67
TRM 424	82	83	89	95	91	96	91	104	95	92
TRM 531	87	87	90	96	88	95	91	100	95	92

Wright State University, Dayton, Ohio

Internal and Surrogate Standards Recoveries
Results from DB-5 Column

Project: Tennessee Valley Authority
Project Number: 2848

TVA Number	%Rec 13C-2378 TCDF	%Rec 13C-2378 TCDD	%Rec 13C-12378 PeCDF	%Rec 13C-12378 PeCDD	%Rec 13C-123478 HxCDF	%Rec 13C-123678 HxCDD	%Rec 13C-1234678 HpCDF	%Rec 13C-1234678 HpCDD	%Rec 13C-OCDD	Average Int %Rec
TRM 600	72	73	81	88	85	93	87	97	93	85
CRM 24	80	87	88	96	88	95	91	100	101	92
LAB BLANK	54	53	66	88	79	85	83	88	85	76
LAB BLANK	55	53	67	74	74	77	77	78	80	71
Internal Std										
Average Rec	71	74	79	86	82	87	85	92	89	83
Std Dev	+/-11	+/-11	+/- 9	+/-10	+/- 7	+/- 9	+/- 7	+/- 9	+/- 9	

Wright State University, Dayton, Ohio

Analysis for 2378-Substituted Chlorinated Dioxins and Furans
Combined Results from DB-5/DB-DIOXIN Columns
EPA Method 8290

2,3,7,8-TCDD TEC for the 17 2,3,7,8-Substituted Isomers

Project Tennessee Valley Authority
Project Number 2848

Concentrations Found (picograms per gram of sample or parts-per-trillion)a

TVA Identification	2378 TCDF	2378 TCDD	12378 PeCDF*	23478 PeCDF*	12378 PeCDD	123478 HxCDF*	123678 HxCDF*	123789 HxCDF*	234678 HxCDF*	123478 HxCDD	123678 HxCDD	123789 HxCDD*	1234678 HpCDF	1234789 HpCDF	1234678 HpCDD	OCDF	OCDD	Total TEC b
TEF	0 1	1	0 05	0 5	0 5	0.1	0 1	0 1	0 1	0 1	0 1	0 1	0 01	0 01	0 01	0 001	0 001	
Watts Bar TZ	0 0936	1 29	ND	1 86	1 21	0 019	0 021	ND	ND	0 0702	0 358	0 074	ND	ND	0 02	0 0005	0 0051	5 03
(TRM 560)			0 0031					0 0041	0 0053				0 0005	0 001				
Melton Hill TZ	0 0587	0 567	ND	ND	0 417	ND	ND	ND	ND	ND	0 104	ND	ND	ND	0 008	ND	0 0029	1 38
(CRM 45)			0 0029	0 175		0 0049	0 0052	0 0051	0 0065	0 0095		0 0109	0 0007	0 0012		0 0001		
Ft Loudoun TZ	ND	0 802	ND	0 4	0 512	ND	ND	ND	ND	0 0275	0 16	0 0336	ND	ND	0 013	0 0003	0 0036	2
(TRM 624)	0 0165		0 0039			0 0046	0 0059	0 0047	0 0061				0 0006	0 001				
Pickwick FB	0 0567	0 541	ND	ND	0.256	ND	ND	ND	ND	ND	0 0625	ND	ND	ND	0 0069	ND	0 0021	0 992
(TRM 207)			0 0029	0 0228		0 005	0 0053	0 0052	0 0067	0 0086		0 0067	0 0017	0 0017		0 0001		
Spike	0 979	9 65	0 446	5	4 9	2 49	1 46	2 38	2 67	2 46	2 14	2 34	0 226	0 27	0 226	0 0499	0 0477	37 7
MS 96/50211																		
Spike Duplicate	1 08	10 7	0 52	5 41	5 03 •	2 69	1 63	2 67	3 04	2 72	2 41	2 5	0 269	0 301	0 251	0 0563	0 0542	41 3
MSD 96/50211																		
Pickwick TZ	0 0882	0 663	0 067	ND	0 27	ND	ND	ND	ND	0 0257	0 0748	0 0213	ND	ND	0 0125	ND	0 0037	1 27
(TRM 230)				0 0227		0 0045	0 0048	0 0047	0 006				0 0029	0 0012		0 0001		
Pickwick Inf	0 0785	0 445	ND	ND	0 218	ND	ND	ND	ND	ND	0 0478	0 014	ND	ND	0 0048	ND	0 0017	0 868
(TRM 259)			0 003	0 0233		0 0046	0 0048	0 0048	0 0061	0 0078			0 0021	0 0016		0 0001		
Pickwick Embay	0 118	0 855	ND	ND	0 388	ND	ND	ND	ND	0 0263	0 154	0 0298	ND	ND	0 0136	ND	0 0028	1 63
(Bear Creek Mile 8)			0 0029	0 0223		0 0046	0 0049	0 0048	0 0062				0 0007	0 0013		0 0001		
Wilson FB	0 497	1 3	ND	ND	0 427	ND	ND	ND	ND	ND	0 146	0 0378	ND	ND	0 0366	ND	0 0137	2 52
(TRM 260)			0 0027	0 021		0 0087	0 0045	0 0045	0 0057	0 0073			0 0035	0 0016		0 0001		
Wilson Inf	0 102	0 741	ND	0 47	0 287	ND	ND	ND	ND	ND	0 0772	ND	ND	ND	0 0113	ND	0 0029	1 75
(TRM 272)			0 0041			0 0065	0 0069	0 0068	0 0087	0 0125		0 0097	0 0025	0 0018		0 0002		

Wright State University, Dayton, Ohio

Analysis for 2378-Substituted Chlorinated Dioxins and Furans
Combined Results from DB-5/DB-DIOXIN Columns
EPA Method 8290

2,3,7,8-TCDD TEC for the 17 2,3,7,8-Substituted Isomers

Project Tennessee Valley Authority
Project Number 2848

Concentrations Found (picograms per gram of sample or parts-per-trillion)a

TVA Identification	2378 TCDF	2378 TCDD	12378 PeCDF*	23478 PeCDF*	12378 PeCDD	123478 HxCDF*	123678 HxCDF*	123789 HxCDF*	234678 HxCDF*	123478 HxCDD	123678 HxCDD	123789 HxCDD*	1234678 HpCDF	1234789 HpCDF	1234678 HpCDD	OCDF	OCDD	Total TEC b
TEF	0 1	1	0 05	0 5	0 5	0 1	0 1	0 1	0 1	0 1	0 1	0 1	0 01	0 01	0 01	0 001	0 001	
Guntersville FB (TRM 350)	0 381	1 11	ND 0 0033	0 966	0 622	0 013	ND 0 0048	ND 0 0067	ND 0 0061	0 054	0 182	0 0517	ND 0 0172	ND 0 0034	0 0266	ND 0 0001	0 0056	3 45
Guntersville TZ (TRM 375)	0 534	1 06	ND 0 0036	0 847	0 425	ND 0 0092	ND 0 0092	ND 0 0062	ND 0 0079	0 0546	0 133	ND 0 0292	ND 0 0161	ND 0 0022	0 0259	ND 0 0002	0 0078	3 17
Guntersville Inf (TRM 424)	0 293	1 41	ND 0 003	0 905	0 554	ND 0 0043	ND 0 0045	ND 0 0045	ND 0 0057	0 0393	0 121	0 0383	ND 0 0297	ND 0 003	0 0156	ND 0 0001	0 0035	3 43
Watts Bar TZ (TRM 531)	0 0505	0 345	ND 0 005	0 232	0.268	ND 0 0081	ND 0 0085	ND 0 0084	ND 0 0108	ND 0 0135	0 0434	ND 0 0105	ND 0 0012	ND 0 0021	0 0038	ND 0 0002	0 0015	1 01
Watts Bar Inf (TRM 600)	0 0495	1 26	ND 0 0056	1 3	1 27	ND 0 0087	ND 0 0092	ND 0 009	ND 0 0116	0 0411	0 302	ND 0 0189	ND 0 0013	ND 0 0023	0 0139	ND 0 0002	0 0033	4 31
Watts Bar Inf (CRM 24)	0 0755	0 378	ND 0 0049	0 404	ND 0 0525	ND 0 008	ND 0 0085	ND 0 0083	ND 0 0107	ND 0 0151	0 0897	ND 0 0103	ND 0 0011	ND 0 0021	0 008	ND 0 0002	0 0021	1 08
LAB BLANK	ND 0 0036	ND 0 0561	ND 0.0034	ND 0 0263	ND 0 0298	ND 0 0049	ND 0 0051	ND 0 005	ND 0 0065	ND 0 0081	ND 0 0067	ND 0 0063	ND 0 0007	ND 0 0013	ND 0 001	ND 0 0001	ND 0 0002	0 165
LAB BLANK	ND 0 0052	ND 0 0826	ND 0 005	ND 0 0393	ND 0 0527	ND 0 0076	ND 0 008	ND 0 0079	ND 0 0101	ND 0 0133	ND 0 011	ND 0 0104	ND 0 0011	ND 0 002	ND 0 0016	ND 0 0002	ND 0 0003	0 258

a The designation ND indicates "None Detected" in excess of the minimum detectable concentration which is listed directly below the ND designation
b This is the sum of all 2,3,7,8-substituted TECs The MDLs are counted as 0 5*TEF*MDL for TEC
* These isomers may be convoluted with other isomers of their congener group

Wright State University, Dayton, Ohio

Spike Results for 2,3,7,8-Substituted Isomers
Results from DB-5 Column

Project Tennessee Valley Authority
Project Number· 2848

Concentrations Found (nanograms per sample)

MS 96/50211

	2378 TCDF	2378 TCDD	12378 PeCDF	23478 PeCDF	12378 PeCDD	123478 HxCDF	123678 HxCDF	123789 HxCDF	234678 HxCDF	123478 HxCDD	123678 HxCDD	123789 HxCDD	1234678 HpCDF	1234789 HpCDF	1234678 HpCDD	OCDF	OCDD
Quantity found in Spiked sample	0.198	0 195	0 181	0.202	0 198	0 503	0 296	0 482	0 54	0 498	0 433	0 473	0 458	0 546	0 458	1 01	0 965
Quantity found in Unspiked sample	0 0115	0 011	ND	ND	0 0104	ND	ND	ND	ND	ND	0 0127	ND	ND	ND	0 0139	ND	0 0428
Difference (Spiked sample - Unspiked sample)	0 187	0 185	0 181	0 202	0 188	0.503	0 296	0 482	0 54	0 498	0 42	0 473	0 458	0 546	0 444	1 01	0 922
Spike Quantity	0 2	0 2	0 2	0 2	0 2	0 5	0 5	0 5	0 5	0 5	0 5	0 5	0 5	0 5	0 5	1	1
Recovery of spike	93%	92%	90%	101%	94%	101%	59%	96%	108%	100%	84%	95%	92%	109%	89%	101%	92%

Average Recovery of all isomers - 94%

MSD 96/5211

	2378 TCDF	2378 TCDD	12378 PeCDF	23478 PeCDF	12378 PeCDD	123478 HxCDF	123678 HxCDF	123789 HxCDF	234678 HxCDF	123478 HxCDD	123678 HxCDD	123789 HxCDD	1234678 HpCDF	1234789 HpCDF	1234678 HpCDD	OCDF	OCDD
Quantity found in Spiked sample	0 217	0 214	0 209	0 217	0 202	0 541	0 327	0 536	0 612	0 545	0 484	0 502	0 54	0 606	0 505	1 13	1 09
Quantity found in Unspiked sample	0 0114	0 0109	ND	ND	0 0103	ND	ND	ND	ND	ND	0 0126	ND	ND	ND	0 0138	ND	0 0425
Difference (Spiked sample - Unspiked sample)	0 206	0 203	0 209	0 217	0 192	0 541	0 327	0 536	0 612	0 545	0 471	0 502	0 54	0 606	0 491	1 13	1 05
Spike Quantity	0 2	0 2	0 2	0 2	0 2	0 5	0 5	0 5	0 5	0 5	0 5	0 5	0 5	0 5	0 5	1	1
Recovery of spike	103%	102%	104%	109%	96%	108%	65%	107%	122%	109%	94%	100%	108%	121%	98%	113%	105%

Average Recovery of all isomers - 104%

Wright State University, Dayton, Ohio

Duplicate Samples
Results from DB-5 Column

Project: Tennessee Valley Authority
Project Number: 2848

TVA Number	Concentrations Found (picograms per gram of sample or parts-per-trillion)a									
	Tetra CDFs	Tetra CDDs	Penta CDFs	Penta CDDs	Hexa CDFs	Hexa CDDs	Hepta CDFs	Hepta CDDs	Octa CDF	Octa CDD
First sample MSD 96/50211	10 8	10.7	21 2	10.1	100	76.2	57	25 1	56.3	54.2
Second sample MS 96/50211	9.79	9.65	18.9	9.79	89.9	69 3	49 6	22 6	49 9	47 7
Average	10.3	10.2	20.1	9.92	95 2	72 8	53 3	23 9	53 1	50 9
+/- % difference of samples	5%	5%	6%	1%	5%	5%	7%	5%	6%	6%

Average +/- % difference - 5%

a The designation ND indicates "None Detected" in sample extract.

Appendix E

Recommendations (Preliminary Planning) for Fish Tissue Studies in 1997

FISH TI[illegible] PLANNING REPORT

For Ca Year : 1997

Location Resevoir	River	River Mile	Studyname	This Year ?	Free Fish?	Species	# of fish	Indv / Comp	Person Resp.	Disp of Fillets	Analyze For O	SO	M	Date Coll Comp	# Coll	Comments
FORT LOUDOUN	TENNESSEE R	624	LONG-TERM	YE	YES,	CHANNEL CATFISH	10	I	AL BROWN	ONE TO LAB,	N	Y	N	/ /	0	
APPALACHIA	HIWASSEE R	67.0	RESERVOIR	YE	YES,	LARGEMOUTH BASS	5	C	AL BROWN	ONE TO LAB,	N	N	Y	/ /	0	
BLUE RIDGE	TOCCOA R	54.0	RESERVOIR	YE	YES,	CHANNEL CATFISH	5	C	AL BROWN	BOTH TO LAB	Y	N	Y	/ /	0	
BLUE RIDGE	TOCCOA R	54.0	RESERVOIR	YE	YES,	LARGEMOUTH BASS	5	C	AL BROWN	ONE TO LAB,	N	N	Y	/ /	0	
BOONE	WATAUGA R	7.0	RESERVOIR	YE	YES,	CHANNEL CATFISH	5	C	AL BROWN	BOTH TO LAB	Y	N	Y	/ /	0	
BOONE	WATAUGA R	7.0	RESERVOIR	YE	YES,	LARGEMOUTH BASS	5	C	AL BROWN	ONE TO LAB,	N	N	Y	/ /	0	
BOONE	S FK HOLSTON R	19.0	RESERVOIR	YE	YES,	CHANNEL CATFISH	5	C	AL BROWN	BOTH TO LAB	Y	N	Y	/ /	0	
BOONE	S FK HOLSTON R	19.0	RESERVOIR	YE	YES,	LARGEMOUTH BASS	5	C	AL BROWN	ONE TO LAB,	N	N	Y	/ /	0	
BOONE	S FK HOLSTON R	27.0	RESERVOIR	YE	YES,	LARGEMOUTH BASS	5	C	AL BROWN	ONE TO LAB,	N	N	Y	/ /	0	
BOONE	S FK HOLSTON R	27.0	RESERVOIR	YE	YES,	CHANNEL CATFISH	5	C	AL BROWN	BOTH TO LAB	Y	N	Y	/ /	0	
DOUGLAS	FRENCH BROAD R	33.0	RESERVOIR	YE	YES,	LARGEMOUTH BASS	5	C	AL BROWN	ONE TO LAB,	N	N	Y	/ /	0	
DOUGLAS	FRENCH BROAD R	33.0	RESERVOIR	YE	YES,	CHANNEL CATFISH	5	C	AL BROWN	BOTH TO LAB	Y	N	Y	/ /	0	
DOUGLAS	FRENCH BROAD R	51.0	RESERVOIR	YE	YES,	CHANNEL CATFISH	5	C	AL BROWN	BOTH TO LAB	Y	N	Y	/ /	0	
DOUGLAS	FRENCH BROAD R	51.0	RESERVOIR	YE	YES,	LARGEMOUTH BASS	5	C	AL BROWN	ONE TO LAB,	N	N	Y	/ /	0	
FORT PATRICK	S FK HOLSTON R	9.0	RESERVOIR	YE	YES,	LARGEMOUTH BASS	5	C	AL BROWN	ONE TO LAB,	N	N	Y	/ /	0	
FORT PATRICK	S FK HOLSTON R	9.0	RESERVOIR	YE	YES,	CHANNEL CATFISH	5	C	AL BROWN	BOTH TO LAB	Y	N	Y	/ /	0	
~~HIWASSEE~~	~~HIWASSEE R~~	~~67.0~~	~~RESERVOIR~~	~~YE~~	~~YES,~~	~~CHANNEL CATFISH~~	~~5~~	~~C~~	~~AL BROWN~~	~~BOTH TO LAB~~	~~Y~~	~~N~~	~~Y~~	/ /	0	
NICKAJACK	TENNESSEE R	424	RESERVOIR	YE	YES,	LARGEMOUTH BASS	5	C	AL BROWN	ONE TO LAB,	N	N	Y	/ /	0	
NICKAJACK	TENNESSEE R	425	RESERVOIR	YE	YES,	CHANNEL CATFISH	5	C	AL BROWN	BOTH TO LAB	Y	N	Y	/ /	0	
NICKAJACK	TENNESSEE R	457	RESERVOIR	YE	YES,	LARGEMOUTH BASS	5	C	AL BROWN	ONE TO LAB,	N	N	Y	/ /	0	
NICKAJACK	TENNESSEE R	457	RESERVOIR	YE	YES,	CHANNEL CATFISH	5	C	AL BROWN	BOTH TO LAB	Y	N	Y	/ /	0	
NORRIS	POWELL R	30.0	RESERVOIR	YE	YES,	CHANNEL CATFISH	5	C	AL BROWN	BOTH TO LAB	Y	N	Y	/ /	0	
NORRIS	POWELL R	30.0	RESERVOIR	YE	YES,	LARGEMOUTH BASS	5	C	AL BROWN	ONE TO LAB,	N	N	Y	/ /	0	
NORRIS	CLINCH R	80.0	RESERVOIR	YE	YES,	CHANNEL CATFISH	5	C	AL BROWN	BOTH TO LAB	Y	N	Y	/ /	0	
NORRIS	CLINCH R	80.0	RESERVOIR	YE	YES,	LARGEMOUTH BASS	5	C	AL BROWN	ONE TO LAB,	N	N	Y	/ /	0	
NORRIS	CLINCH R	125	RESERVOIR	YE	YES,	LARGEMOUTH BASS	5	C	AL BROWN	ONE TO LAB,	N	N	Y	/ /	0	
NORRIS	CLINCH R	125	RESERVOIR	YE	YES,	CHANNEL CATFISH	5	C	AL BROWN	BOTH TO LAB	Y	N	Y	/ /	0	
NOTTELY	NOTTELY R	24.0	RESERVOIR	YE	YES,	CHANNEL CATFISH	5	C	AL BROWN	BOTH TO LAB	Y	N	Y	/ /	0	
NOTTELY	NOTTELY R	24.0	RESERVOIR	YE	YES,	LARGEMOUTH BASS	5	C	AL BROWN	ONE TO LAB,	N	N	Y	/ /	0	
NOTTELY	NOTTELY R	31.0	RESERVOIR	YE	YES,	LARGEMOUTH BASS	5	C	AL BROWN	ONE TO LAB,	N	N	Y	/ /	0	
NOTTELY	NOTTELY R	31.0	RESERVOIR	YE	YES,	CHANNEL CATFISH	5	C	AL BROWN	BOTH TO LAB	Y	N	Y	/ /	0	
TELLICO	LITTLE TENNESSEE	1.0	RESERVOIR	YE	YES,	CHANNEL CATFISH	5	C	AL BROWN	BOTH TO LAB	Y	N	Y	/ /	0	
TELLICO	LITTLE TENNESSEE	1.0	RESERVOIR	YE	YES,	LARGEMOUTH BASS	5	C	AL BROWN	ONE TO LAB,	N	N	Y	/ /	0	
TELLICO	LITTLE TENNESSEE	15.0	RESERVOIR	YE	YES,	LARGEMOUTH BASS	5	C	AL BROWN	ONE TO LAB,	N	N	Y	/ /	0	
TELLICO	LITTLE TENNESSEE	15.0	RESERVOIR	YE	YES,	CHANNEL CATFISH	5	C	AL BROWN	BOTH TO LAB	Y	N	Y	/ /	0	

FISH TISSUE PLANNING REPORT

For Calendar Year : 1997

Location Resevoir	River	River Mile	Studyname	This Year ?	Free Fish?	Species	# of fish	Indv / Comp	Person Resp.	Disp of Fillets	Analyze For O	SO	M	Date Coll Comp	# Coll	Comments
WHEELER	ELK R (TRIB. TO	6.0	RESERVOIR	YE	YES,	LARGEMOUTH BASS	5	C	AL BROWN	ONE TO LAB,	N	N	Y	/ /	0	
WHEELER	ELK R (TRIB. TO	6.0	RESERVOIR	YE	YES,	CHANNEL CATFISH	5	C	AL BROWN	BOTH TO LAB	Y	N	Y	/ /	0	
WHEELER	TENNESSEE R	277	RESERVOIR	YE	YES,	CHANNEL CATFISH	5	C	AL BROWN	BOTH TO LAB	Y	N	Y	/ /	0	
WHEELER	TENNESSEE R	277	RESERVOIR	YE	YES,	LARGEMOUTH BASS	5	C	AL BROWN	ONE TO LAB,	N	N	Y	/ /	0	
WHEELER	TENNESSEE R	296	RESERVOIR	YE	YES,	LARGEMOUTH BASS	5	C	AL BROWN	ONE TO LAB,	N	N	Y	/ /	0	
WHEELER	TENNESSEE R	296	RESERVOIR	YE	YES,	CHANNEL CATFISH	5	C	AL BROWN	BOTH TO LAB	Y	N	Y	/ /	0	
WHEELER	TENNESSEE R	347	RESERVOIR	YE	YES,	CHANNEL CATFISH	5	C	AL BROWN	BOTH TO LAB	Y	N	Y	/ /	0	
WHEELER	TENNESSEE R	347	RESERVOIR	YE	YES,	LARGEMOUTH BASS	5	C	AL BROWN	ONE TO LAB,	N	N	Y	/ /	0	
	OCOEE R	3.0	STREAM	YE	YES,	LARGEMOUTH BASS	5	C	CHARLIE	ONE TO LAB,	N	N	Y	/ /	0	
	OCOEE R	3.0	STREAM	YE	YES,	CHANNEL CATFISH	5	C	CHARLIE	BOTH TO LAB	Y	N	Y	/ /	0	
	N FK HOLSTON R	4.6	STREAM	YE	YES,	SMALLMOUTH BASS	5	C	CHARLIE	ONE TO LAB,	N	N	Y	/ /	0	
	N FK HOLSTON R	4.6	STREAM	YE	YES,	CHANNEL CATFISH	5	C	CHARLIE	BOTH TO LAB	Y	N	Y	/ /	0	
	~~PIGEON R~~	~~7.0~~	~~STREAM~~	~~YE~~	~~YES,~~	~~SPOTTED BASS~~	~~5~~	~~C~~	~~CHARLIE~~	~~ONE TO LAB,~~	~~N~~	~~N~~	~~Y~~	/ /	0	
	~~PIGEON R~~	~~7.0~~	~~STREAM~~	~~YE~~	~~YES,~~	~~CHANNEL CATFISH~~	~~5~~	~~C~~	~~CHARLIE~~	~~ONE TO LAB,~~	~~N~~	~~N~~	~~Y~~	/ /	0	
	EMORY R	14.6	STREAM	YE	YES,	SMALLMOUTH BASS	5	C	CHARLIE	ONE TO LAB,	N	N	Y	/ /	0	
	EMORY R	14.6	STREAM	YE	YES,	CHANNEL CATFISH	5	C	CHARLIE	BOTH TO LAB	Y	N	Y	/ /	0	
	BEAR CREEK	27.0	STREAM	YE	YES,	CHANNEL CATFISH	5	C	CHARLIE	BOTH TO LAB	Y	N	Y	/ /	0	
	BEAR CREEK	27.0	STREAM	YE	YES,	LARGEMOUTH BASS	5	C	CHARLIE	ONE TO LAB,	N	N	Y	/ /	0	
	HIWASSEE R	38.0	STREAM	YE	YES,	CHANNEL CATFISH	5	C	CHARLIE	BOTH TO LAB	Y	N	Y	/ /	0	
	HIWASSEE R	38.0	STREAM	YE	YES,	SMALLMOUTH BASS	5	C	CHARLIE	ONE TO LAB,	N	N	Y	/ /	0	
	ELK R (TRIB. TO	41.0	STREAM	YE	YES,	LARGEMOUTH BASS	5	C	CHARLIE	ONE TO LAB,	N	N	Y	/ /	0	
	ELK R (TRIB. TO	41.0	STREAM	YE	YES,	CHANNEL CATFISH	5	C	CHARLIE	BOTH TO LAB	Y	N	Y	/ /	0	
	POWELL R	65.0	STREAM	YE	YES,	LARGEMOUTH BASS	5	C	CHARLIE	ONE TO LAB,	N	N	Y	/ /	0	
	POWELL R	65.0	STREAM	YE	YES,	CHANNEL CATFISH	5	C	CHARLIE	BOTH TO LAB	Y	N	Y	/ /	0	
	HOLSTON R	110	STREAM	YE	YES,	CHANNEL CATFISH	5	C	CHARLIE	BOTH TO LAB	Y	N	Y	/ /	0	
	HOLSTON R	110	STREAM	YE	YES,	SMALLMOUTH BASS	5	C	CHARLIE	ONE TO LAB,	N	N	Y	/ /	0	
	CLINCH R	172	STREAM	YE	YES,	CHANNEL CATFISH	5	C	CHARLIE	BOTH TO LAB	Y	N	Y	/ /	0	
	CLINCH R	172	STREAM	YE	YES,	SMALLMOUTH BASS	5	C	CHARLIE	ONE TO LAB,	N	N	Y	/ /	0	
CHICKAMAUGA	HIWASSEE R	8.0	TARGETED	YE	YES,	CHANNEL CATFISH	5	C	AL BROWN	ONE TO LAB,	N	Y	N	/ /	0	
CHICKAMAUGA	TENNESSEE R	472	TARGETED	YE	YES,	CHANNEL CATFISH	5	C	AL BROWN	ONE TO LAB,	N	Y	N	/ /	0	
CHICKAMAUGA	TENNESSEE R	490	TARGETED	YE	YES,	CHANNEL CATFISH	5	C	AL BROWN	ONE TO LAB,	N	Y	N	/ /	0	
CHICKAMAUGA	TENNESSEE R	529	TARGETED	YE	YES,	CHANNEL CATFISH	5	C	AL BROWN	ONE TO LAB,	N	Y	N	/ /	0	
NICKAJACK	TENNESSEE R	469	TARGETED	YE	YES,	STRIPED BASS	5	C	DON DYCUS	ONE TO LAB,	N	Y	N	/ /	0	
PARKSVILLE	OCOEE R	12.0	TARGETED	YE	YES,	CHANNEL CATFISH	5	C	AL BROWN	ONE TO LAB,	N	Y	N	/ /	0	

Results from TVA Fish Tissue Studies on Fish Collected Autumn 1995 and Recommendations for Studies in 1996

By: Don L. Dycus
TVA Water Management
May 1996

Introduction/Background

The attached tables summarize results of TVA's fish tissue studies conducted in 1995. TVA's approach to fish tissue contaminant studies is to first conduct Screening Studies in which composite samples of an indicator species, such as channel catfish for organics and largemouth bass for mercury, are examined for a broad array of analytes. Results from Screening Studies are used to provide direction for future action. If Screening finds low contaminant concentrations, the site or reservoir would be resampled at the screening level on a rotational basis in 3 to 5 years. If one or more analytes had somewhat elevated concentrations, that site would be resampled the next year and samples analyzed for the analyte(s) of concern in a Targeted Screening Study. If concentrations in Screening efforts or Targeted Screening efforts were sufficiently high to pose potential human health concerns, the site or reservoir would need to be examined in an Intensive Study aimed at determining the species affected, the geographical distribution, and year-to-year variation. Analysis of individual fish (generally 10 replicates) of important species from several locations provide the data base for examinations. In selected cases, replicate composite samples could used in Intensive Studies. The assessment phase would continue until the contaminant concentration was low enough to no longer be a concern or when year-to-year studies indicated no trend through time. If the former were the case, the site or reservoir would return to the rotational system. If the latter were the case, a Long-Term Monitoring Study, with either annual or rotational collections (whichever is appropriate), would be undertaken. The idea for Long-Term Monitoring is to track the problem analyte so that when concentrations drop below the level of concern a follow-up Intensive Study can be conducted to document the problem no longer exists. Generally, composites of indicator species are analyzed for the analyte(s) of concern in Long-Term Monitoring Studies.

Methods

Details of TVA's collection, processing, and analysis procedures are described in the report on 1993 fish tissue studies -- "Tennessee Valley Reservoir and Stream Quality - 1993; Fish Tissue Studies in the Tennessee Valley in 1993" by D.L. Williams and D.L. Dycus. The report was published in July 1994 and is available from:

Water Management Library
Tennessee Valley Authority
1101 Market Street, CST 16B
Chattanooga, TN 37402-2810
(423) 751-7338 or FAX: (423) 751-7648

One noteworthy change for fish tissue studies is that beginning in 1994 more pesticides were included in the analyses. In addition to the typical list of organochlorine pesticides analyzed, organophosphate and chlorophenoxy pesticides were analyzed as recommended by the U.S. EPA in their "Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories; Volume 1 Fish Sampling and Analysis" (EPA 823-R-93-007, September 1995). These include

Organochlorine pesticide: dicofol
Organophosphate pesticides: chlorpyrifos, diazinon, disulfoton, ethion, terbufos, and carbophenothion
Chlorophenoxy pesticide: oxyfluorfen

Summary of Results

Reservoir and rivers included in fish tissue studies in 1995 are listed in Table 1 by watershed area. Results from the various fish tissue studies conducted in 1995 are summarized Tables 2 - 16 and Figures 1 and 2. Physical information such as length and weight for each fish is in Appendix A, Tables A-1 - A-5. Details of study results are available on STORET.

In general, 1995 results were similar to previous years. The most common contaminant of concern was PCBs. Locations (regardless of study type) with PCB concentrations >0.5 µg/g are listed in Table 2. Given the increasing interest in mercury, locations (regardless of study type) with total mercury >0.40 µg/g are listed in Table 3.

Boxes on the following pages provide highlights of 1995 results and recommendations for studies in 1996. A detailed list of recommendations for fish tissue studies in 1996 is in Appendix B. (Note: These recommendations were not final at the time this document was prepared.) Appendix C contains a news release from the Alabama Department of Public Health which removed the fish consumption advisory for a portion of Wheeler Reservoir in 1996. Appendix D contains abbreviations for species and rivers used in tables and appendices.

Screening Studies

Reservoirs and rivers included in Screening Studies in 1995 are listed in Table 1.

Reservoirs: Results are provided in the following tables.

Table 4. Pesticides and PCBs results
Table 5. Metals results
Appendix Table A-1. Collection date, length, weight, etc. for each fish

Results highlights: All pesticides and four of the five metals were either not detected or found in only low concentrations in all reservoirs sampled. Mercury was the only metal which was slightly elevated but not sufficiently high to warrant follow-up investigations. PCBs concentrations were relatively high for three reservoirs. None of these was a surprise. Ft. Loudoun has a defined PCB problem and was included in screening efforts because it had not been examined for other analytes for at least three years. Elevated PCB concentrations in Chickamauga Reservoir have been documented in previous Screening and Targeted Screening studies, and it appears concentrations generally vary between 0.5 - 1.0 µg/g with highest concentrations at the upper end of the reservoir. The channel catfish composite from the upstream end of Kentucky Reservoir near Pickwick Dam had a concentration of 0.8 µg/g. Screening studies conducted since 1988 occasionally have found similar results but no consistent problems have been evident.

Recommendations: None of the above reservoirs need to be resampled until they come up again in the standard rotation. Several reservoirs have either not been sampled recently or have not been part of Scrounge efforts recently. Reservoirs to be included in Screening Studies in 1996 include Pickwick, Wilson, Guntersville, Watts Bar, Melton Hill, Boone, South Holston, Watauga, Fontana, Hiwassee, Chatuge, Parksville, Bear, Little Bear, and Cedar. See Appendix B for details about recommended Screening studies for 1996.

Rivers: Results are provided in the following tables.

Table 6. Pesticides and PCBs results
Table 7. Metals results
Appendix Table A-2. Collection date, length, weight, etc. for each fish

Results highlights: All of the pesticides and most metals were either not detected or found in only low concentrations. Mercury was the only metal and PCBs the only organic analyte found in sufficient concentrations to be of interest. Sample locations with PCB concentrations ≥0.5 are listed in Table 2, and locations with mercury concentrations ≥0.4µ/g are listed in Table 3.

Recommendations: Six of the river screening sites were sampled for the first time in 1994 and second time in 1995. Four of these (Clarks, Buffalo, Tuckasegee, and Pigeon) will be resampled in summer 1996. Fish tissue samples were first collected from Bear Creek in 1995; that site will also be sampled in 1996. Four other sites (Duck, Little Tennessee, French Broad, and Nolichucky) were not sampled in 1995 and should be in 1996 to take advantage of fish communities studies planned for those sites. Additional details for 1996 plans are in Appendix B.

Targeted Screening Studies

Reservoirs: Reservoirs sampled in Autumn 1995, including analytes and species of concern:

- Wheeler (PCBs - channel catfish)
- Nickajack (PCBs - striped bass)
- Parksville (PCBs - channel catfish)
- Cherokee (PCBs - channel catfish and striped bass/hybrids)

Results are provided in the following tables:

- Table 8 -- PCBs and selected pesticides results
- Appendix Table A-3 -- Collection date, length, weight, etc. for each fish

Results highlights: Most of the reservoirs listed above were included in Targeted screening studies in 1994 and 1995 because sampling the preceding year (1993 and 1994) had shown PCB concentrations were near or above 1.0 µg/g. This was sufficiently high to conduct Targeted screening but not so high as to warrant intensive investigations. Results for 1995 showed PCB concentrations were generally lower than in previous years (below 1.0 µg/g). The exception to this was the striped bass composite from Nickajack Reservoir which had a concentration of 1.2 µg/g. This is comparable to concentrations found in previous years. None of the screening studies conducted in 1995 indicated a need for Targeted Screening studies in 1995.

Recommendations: There are no Targeted Screening studies recommended for 1996. As stated above, most of these areas have been examined for multiple years with PCB concentrations varying between about 0.5 and about 1.0 µg/g. Further Targeted Screening would likely find comparable results. These areas will be resampled as part of Reservoir Screening Studies when their turn in rotation comes up.

Rivers: None sampled for Targeted Screening in 1995. Most of the rivers with elevated levels of mercury and PCBs in Stream Screening studies will be resampled as part of those studies in 1996.

Intensive Studies

Reservoirs: Reservoirs sampled in 1995, including analytes and species of concern:
Wheeler (DDTr - channel catfish, smallmouth buffalo, and largemouth bass)

Results provided in the following tables:
Table 9 -- DDTr, chlordane, and PCB results for 1995
Table 10 -- DDTr results for 1991, 1992, 1993, and 1995
Appendix Table A-4 -- Collection date, length, weight, etc. for each fish

Objective: -- To determine if decreases in DDTr concentrations observed in 1992 and 1993 had continued, allowing the Alabama Department of Public Health to discontinue a fish consumption advisory in the Tennessee River portion of Wheeler Reservoir near Indian Creek Embayment

Study Synopsis: Three replicate composites of each of the three species were collected at four sites between Tennessee River Miles (TRM) 308 and 325. The Indian Creek confluence with the Tennessee River is at about TRM 320. Collections efforts were successful except for a few channel catfish and largemouth bass. Of the 180 fish sought 171 were collected. In addition to composite analysis, the largest individual of each species from each sample location was analyzed individually to indicate worst-case conditions. Only two composite samples had a DDTr concentration which exceeded 5.0 µg/g (a smallmouth buffalo composite from TRM 325 had 5.2 µg/g and another from TRM 320 had 7.5 ug/g). All other composite samples had concentrations less than 3.0 µg/g with many less than 1.0 µg/g. DDTr concentrations in the largest individuals of each species from each site were lower than might be expected. Only three fish had DDTr concentrations above 5.0 µg/g (one channel catfish from TRM 315 had 6.1 µg/g and two largemouth bass from TRM 320 had 6.3 and 5.3 µg/g). None of the others even approached 5.0 µg/g.

Recommendations: Based on these results, the Alabama Department of Public Health issued a news release (see Appendix C) in April 1996 which removed the advisory to avoid eating fish from the Tennessee River. There is no need for further intensive investigation in this area. It is recommended that TRM 320 (near the mouth of Indian Creek) be added as a routine collection site when Reservoir Screening studies are conducted on Wheeler Reservoir (currently expected in 1997).

Rivers: None sampled for Intensive Studies in 1995; none needed in 1996.

Long-Term Monitoring Studies

Reservoirs: Reservoirs sampled in autumn 1995, including analytes and species sampled in 1995:

Tellico (PCBs - channel catfish)
Nickajack (PCBs - channel catfish)
Watts Bar (PCBs - channel catfish)
Fort Loudoun (PCBs - channel catfish)

Results are provided in the following tables:

Table 11 -- Tellico, Nickajack, and Watts Bar PCB, DDTr and chlordane results for 1995
Appendix Table A-5 Tellico, Nickajack, and Watts Bar collection date, length, weight, etc. for 1995
Other Tables as identified below

Results Highlights: TDEC has issued fish consumption advisories for all these reservoirs due to PCB contamination. They have all been examined intensively during past years and are now the Long-Term monitoring phase. None of the results for Long-Term Studies in 1995 would indicate a need to change existing advisories.

Tellico Reservoir (Table 12 and Figure 1) -- PCB concentrations in channel catfish collected in 1995 were relatively high at the forebay sample site and relatively low at the mid-reservoir sample site compared to results from previous years. There are no distinct trends except possibly at the forebay site where concentrations have been higher three of the last four years than in any of the preceding years.

Nickajack Reservoir (Table 13 and Figure 1) -- PCB concentrations decreased in 1992 at both locations (especially at the forbay site) compared to previous years (1987 - 1991),and concentrations have tended to remain lower since then, including the 1995 results.

Watts Bar (Table 14 and Figure 1) -- PCB concentrations have varyied from year to year but no trend (either increasing or decreasing) is evident. PCB concentrations in catfish from Watts Bar Reservoir in 1995 were within the range of concentrations observed in past studies; again indicating no trend.

Fort Loudoun (Tables 15 and 16 and Figure 2) -- Analyses for Long-Term studies were based on 5-fish composites for all reservoirs except Fort Loudoun where 10 individual catfish were analyzed from the Long-Term, trend site at TRM 624. Individuals were examined from this site because it is has been monitored longer than any other TVA site with all previous years based on analysis of individual samples. PCB concentrations have varied from year to year but no trend (either increasing or decreasing) is evident. PCB concentrations in catfish from this site in 1995 were within the range of concentrations observed in past years, again indicating no trend.

Recommendations: Given that fish consumption advisories have been issued for these reservoirs, these studies will be repeated when fish assemblage sampling is conducted as part of TVA's Vital Signs Monitoring Program -- every other for Tellico, Nickajack, and Watts Bar and annually for Fort Loudoun.

Rivers: None sampled for Long-Term Monitoring Studies in 1995; none needed in 1996.

Table 1. Listing of Reservoirs and Rivers Included in All Types of Fish Tissue Studies in 1995

	Rivers Sampled		Reservoir Sampled	
Watershed	River	Type Study	Reservoirs	Type Study
Kentucky Lake Area	Clarks	Screening	Kentucky	Screening
			Beech	Screening
Duck River	Buffalo	Screening	Normandy	Screening
Pickwick/Wilson Area	Bear	Screening	N/A	
Wheeler/Elk Area	N/A		Wheeler	Targeted and Intensive
			Tims Ford	Screening
Guntersville/Sequatchie Area	Sequatchie	Screening	N/A	
Chickamauga/Nickajack Area	N/A		Chickamauga	Screening
			Nickajack	Targeted and Long-Term
Hiwassee River	Ocoee	Screening	Parksville	Targeted
Ft. Loudoun, Watts Bar, Melton Hill Area	N/A		Ft. Loudoun	Screening and Long-Term
			Watts Bar	Long-Term
Clinch River	N/A		N/A	
Little Tennessee River	Tuckasegee	Screening	Tellico	Long-Term
Holston River	Holston	Screening	Cherokee	Targeted
	N. Fork Hol.	Screening	Ft. Patrick Henry	Screening
French Broad River	Pigeon	Screening	N/A	

Table 2. Highlights of Autumn 1995 Results from Areas with Advisories and/or "High" (i.e., >0.5 µg/g) PCB Concentrations with Comparisons to Results from Those Areas in 1993 and 1994. All Samples Analyzed as 5-Fish Composites Unless Otherwise Noted.

Location		Species	1993	1994	1995
Kentucky Reservoir	TRM 30	CHC	NS [a]	NS	<0.1
	TRM 85	CHC	NS	NS	0.3
	TRM 206	CHC	NS	NS	0.8
	BSRM 7	CHC	NS	NS	0.2
Wheeler Reservoir	TRM 277	CHC	0.5	0.8	0.5
	TRM 296	CHC	0.8	1.0	0.6
	TRM 347	CHC	1.4	1.3	0.5
	ERM 6	CHC	NS	NS	0.2
Nickajack Reservoir	TRM 425	CHC	0.6 [b]	0.7	0.6
	TRM 457	CHC	0.7 [b]	0.7	0.6
		STB	1.0 [c]	1.2 [c]	1.2
Chick. Reservoir	TRM 472	CHC	NS	NS	0.8
	TRM 490	CHC	NS	NS	0.9
	TRM 529	CHC	NS(DOE)	1.0	1.1
	HiRM 8	CHC	NS	NS	0.4
Watts Bar Reservoir	TRM 530/1	CHC	NS(DOE)	1.0	0.8
		SBU	1.4	0.6	NS
	TRM 560	CHC	1.2 [d]	1.0	1.2
		SBU	NS	0.4	NS
	TRM 600	CHC	1.1 [b]	1.0	1.5
		SBU	0.2	0.9	NS
Ft. Loudoun Res.	TRM 603	CHC	NS	NS	0.9
	TRM 624	CHC	1.2 [b]	1.6 [d]	1.5 [b]
	TRM 652	CHC	NS	NS	1.0
Tellico Reservoir	LTRM 1	CHC	1.4	2.3	2.1
	LTRM 15	CHC	1.0	1.1	0.5
Ocoee Reservoir #1	ORM 12	CHC	0.8	1.2	0.4
	ORM 16	CHC	1.0	1.7	0.8
Cherokee Reservoir	HRM 53	CHC	0.3	0.9	0.5
		STB	NS	NS	0.4
	HRM 76	CHC	<0.1	0.8	0.8
		STB	NS	0.4	0.3

a. NS - Not Sampled
b. Average of 10 channel catfish anaylzed individually
c. Average of 10 striped bass analyzed individually
d. Average of 9 channel catfish analyzed individually

Table 3. Highlights of 1995 Results from Reservoir and Stream Locations with "Elevated" (i.e., ≥0.40 μg/g) Total Mercury Concentrations. Note: Black Bass (Largemouth - LMB, Smallmouth - SMB, and Spotted - SPB) Analysis Were Conducted on Five-fish Composites and on the Largest of the Five Individuals in the Composite. Channel Catfish (CHC) Were Analyzed as Five -fish 5 Composites.

Location	Species	Comp./ Ind.	Weight (gm, if individual)	Mercury (Total, μg/g)
RESERVOIRS				
Kentucky - Big Sandy River 7	LMB	Ind.	1800	0.40
Tennessee River 85	LMB	Ind.	1775	0.50
Beech - Beech River 36	LMB	Ind.	2800	0.46
Normandy - Duck River 250	LMB	Ind.	2819	0.67
Tims Ford - Elk River 150	LMB	Ind.	1839	0.40
Ft Loudoun - Tennessee River 652	CHC	Comp.	N/A	0.43
	LMB	Ind.	2328	0.45
RIVERS				
Clarks River Mile 9	CHC	Ind.*	1780	0.45
	LMB	Comp.	N/A	0.71
	LMB	Ind.	1590	0.87
Buffalo River Mile 17	SMB	Comp.	N/A	0.60
	SMB	Ind.	251	0.76
Bear Creek Mile 27	CHC	Comp.	N/A	0.71
Tuckasegee River Mile 15	CHC	Comp.	N/A	0.40
	SMB	Comp.	N/A	0.48
	SMB	Ind.	633	0.60
Holston River Mile 110	LMB	Comp.	Comp.	0.63
	LMB	Ind.	1657	0.78
N. Fork Hol. River Mile 4	CHC	Comp.	N/A	0.88
	SMB	Ind.	1504	1.7

*Only one Channel Catfish was collected from this site.

Note: Additional mercury data are in the following tables and weights for all fish are in the appendices.

Table 4. Concentrations (ug/g) of Selected Pesticides and PCBs in Composited Fish Fillets Collected in 1995 For Reservoir Screening Studies.

For Calendar Year : 1995

Collection Site	Spec.	%LIPIDS	MIREX	TOXAPH	HEPTA	ALDRIN	BENZ	DDT	DIELD	ENDO	ENDRIN	CHLOR	PCB	DICOFOL
BEECH LAKE														
BEE 36.0	CHC	6.6	<0.008	<0.5	<0.01	<0.01	<0.01	0.43	<0.01	<0.01	<0.01	<0.01	0.4	<0.01
CHICKAMAUGA														
HIW 8.0	CHC	8.2	<0.008	<0.5	<0.01	<0.01	<0.01	0.10	<0.01	<0.01	<0.01	<0.01	0.4	<0.01
TEN 472	CHC	13.0	<0.008	<0.5	<0.01	<0.01	<0.01	0.16	<0.01	<0.01	<0.01	<0.01	0.8	<0.01
TEN 490	CHC	14.0	<0.008	<0.5	<0.01	<0.01	<0.01	0.17	<0.01	<0.01	<0.01	<0.01	0.9	<0.01
TEN 529	CHC	8.7	<0.008	<0.5	<0.01	<0.01	<0.01	0.21	<0.01	<0.01	<0.01	<0.01	1.1	<0.01
FORT LOUDOUN														
TEN 603	CHC	3.2	<0.008	<0.5	<0.01	<0.01	<0.01	0.16	<0.01	<0.01	<0.01	<0.01	0.9	<0.01
TEN 624	CHC	3.4	<0.008	<0.5	<0.01	<0.01	<0.01	0.11	<0.01	<0.01	<0.01	<0.01	1.5	<0.01
TEN 652	CHC	4.1	<0.008	<0.5	<0.01	<0.01	<0.01	0.09	<0.01	<0.01	<0.01	<0.01	1.0	<0.01
FORT PATRICK HENRY														
HOL 9.0	CHC	7.8	<0.008	<0.5	<0.01	<0.01	<0.01	0.04	<0.01	<0.01	<0.01	<0.01	0.2	<0.01
KENTUCKY														
BLU 7.0	CHC	2.6	<0.008	<0.5	<0.01	<0.01	<0.01	0.10	0.02	<0.01	<0.01	<0.01	0.2	<0.01
TEN 30.0	CHC	8.6	<0.008	<0.5	<0.01	<0.01	<0.01	0.11	<0.01	<0.01	<0.01	<0.01	<0.1	<0.01
TEN 85.0	CHC	8.9	<0.008	<0.5	<0.01	<0.01	<0.01	0.21	<0.01	<0.01	<0.01	<0.01	0.3	<0.01
TEN 206	CHC	9.5	<0.008	<0.5	<0.01	<0.01	<0.01	0.85	<0.01	<0.01	<0.01	<0.01	0.8	<0.01
NORMANDY														
DUC 250	CHC	3.2	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	<0.1	<0.01
TIMS FORD														
ELK 135	CHC	3.5	<0.008	<0.5	<0.01	<0.01	<0.01	0.08	<0.01	<0.01	<0.01	<0.01	0.2	<0.01
ELK 150	CHC	3.1	<0.008	<0.5	<0.01	<0.01	<0.01	0.06	<0.01	<0.01	<0.01	<0.01	<0.1	<0.01

Table 4, ,t.' Concentrations (ug/g) of Selected E ;cides and PCBs in Composited Fish Fillets Collected in 1995 For Reser r Screening Studies.

For Calendar Year : 1995

Collection Site	Spec.	%LIPIDS	DURSBAN	DIAZINON	DISULFOTON	ETHION	TERBUFOS	CARBOPHENOTHION	OXYFLUORFEN
BEECH LAKE									
BEE 36.0	CHC	6.6	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
CHICKAMAUGA									
HIW 8.0	CHC	8.2	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TEN 472	CHC	13.0	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TEN 490	CHC	14.0	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TEN 529	CHC	8.7	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
FORT LOUDOUN									
TEN 603	CHC	3.2	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TEN 624	CHC	3.4	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TEN 652	CHC	4.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
FORT PATRICK HENRY									
HOL 9.0	CHC	7.8	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
KENTUCKY									
BLU 7.0	CHC	2.6	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TEN 30.0	CHC	8.6	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TEN 85.0	CHC	8.9	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TEN 206	CHC	9.5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
NORMANDY									
DUC 250	CHC	3.2	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TIMS FORD									
ELK 135	CHC	3.5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
ELK 150	CHC	3.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Table 5. **Concentrations (ug/g) of Metals in Composited Fish Fillets Collected in 1995 for Reservoir Screening Studies.**

For Calendar Year : 1995

Collection Site	Species	LABID	As	Cd	Pb	Hg	Se
BEECH LAKE							
BEE 36.0	CHC		<0.10	< 0.05	< 0.02	0.17	0.2
BEE 36.0	LMB					0.30	
BEE 36.0	LMB					0.46*	
CHICKAMAUGA							
HIW 8.0	CHC		0.20	< 0.05	< 0.02	<0.10	<0.2
HIW 8.0	LMB					0.24	
HIW 8.0	LMB					0.44*	
TEN 472	CHC		0.40	< 0.05	< 0.02	<0.10	<0.2
TEN 472	LMB					<0.10	
TEN 472	LMB					0.22*	
TEN 490	CHC		0.28	< 0.05	< 0.02	<0.10	<0.2
TEN 490	LMB					0.17	
TEN 490	LMB					0.23*	
TEN 529	CHC		0.14	< 0.05	< 0.02	<0.10	<0.2
TEN 529	LMB					0.12	
TEN 529	LMB					0.20*	
FORT LOUDOUN							
TEN 603	CHC		0.10	< 0.05	< 0.02	0.30	<0.2
TEN 603	LMB					0.18	
TEN 603	LMB					0.20*	
TEN 624	LMB					0.10	
TEN 624	LMB					0.28*	
TEN 624	CHC		<0.10	< 0.05	< 0.02	0.28	<0.2
TEN 652	CHC		0.20	< 0.05	0.06	0.43	<0.2
TEN 652	LMB					0.30	
TEN 652	LMB					0.45*	

Table ‾ :oncentrations (ug/g) of Metals in Comp ed Fish Fillets Collected
Cont .n 1995 for Reservoir Screening Studies

For Calendar Year : 1995

Collection Site	Species	LABID	As	Cd	Pb	Hg	Se
FORT PATRICK HENRY							
HOL 9.0	LMB					0.15	
HOL 9.0	LMB					0.16 *	
HOL 9.0	CHC		<0.10	< 0.05	0.02	<0.10	<0.2
KENTUCKY							
BLU 7.0	CHC		<0.10	< 0.05	0.09	<0.10	0.2
BLU 7.0	LMB					0.27	
BLU 7.0	LMB					0.40 *	
TEN 30.0	LMB					0.18	
TEN 30.0	LMB					0.27 *	
TEN 30.0	CHC		<0.10	< 0.05	< 0.02	<0.10	<0.2
TEN 85.0	CHC		0.30	< 0.05	< 0.02	<0.10	0.2
TEN 85.0	LMB					0.30	
TEN 85.0	LMB					0.50 *	
TEN 206	LMB					0.17	
TEN 206	LMB					0.17 *	
TEN 206	CHC		<0.10	< 0.05	< 0.02	0.34	<0.2
NORMANDY							
DUC 250	CHC		<0.10	< 0.05	< 0.02	0.25	<0.2
DUC 250	LMB					0.28	
DUC 250	LMB					0.67 *	
TIMS FORD							
ELK 135	LMB					0.20	
ELK 135	LMB					0.28 *	
ELK 135	CHC		<0.10	< 0.05	< 0.02	0.18	<0.2
ELK 150	LMB					0.35	
ELK 150	LMB					0.40 *	

Table 5. Cont.' **Concentrations (ug/g) of Metals in Composited Fish Fillets Collected in 1995 for Reservoir Screening Studies.**

For Calendar Year : 1995

Collection Site	Species	LABID	As	Cd	Pb	Hg	Se
ELK 150	CHC		<0.10	< 0.05	< 0.02	<0.10	<0.2

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* Represents separate analysis of largest individual fish included in the composite.

Tab Concentrations (ug/g) of Selected P ides and PCBs in Composited Fish Fillets Collected in 1995 For Strea eening Studies.

For Calendar Year : 1995

Collection Site	Spec.	%LIPIDS	MIREX	TOXAPH	HEPTA	ALDRIN	BENZ	DDT	DIELD	ENDO	ENDRIN	CHLOR	PCB	DICOFOL
BEAR CREEK														
BEC 27.3	CHC	6.1	<0.008	<0.5	<0.01	<0.01	<0.01	0.07	<0.01	<0.01	<0.01	<0.01	0.2	<0.01
BUFFALO RIVER														
BUF 17.7	CHC	3.9	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	0.4	<0.01
HOLSTON RIVER														
HOL 110	CHC	5.5	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	0.2	<0.01
NFH 4.6	CHC	8.7	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	0.07	0.5	<0.01
LOWER TENNESSE R														
CLA 9.8*	CHC	2.8	<0.008	<0.5	<0.01	<0.01	<0.01	0.05	<0.01	<0.01	<0.01	0.02	0.8	<0.01
OCOEE RIVER														
OCO 2.5	CHC	3.2	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	0.2	<0.01
PIGEON RIVER														
PIG 8.2	CHC	6.2	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	<0.1	<0.01
SEQUATCHIE RIVER														
SEQ 7.1*	CHC	1.4	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	0.5	<0.01
TUCKASEGEE RIVER														
TUC 15.0	CHC	5.3	<0.008	<0.5	<0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.01	0.2	<0.01

Table 6. Cont.' Concentrations (ug/g) of Selected Pesticides and PCBs in Composited Fish Fillets Collected in 1995 For Stream Screening Studies.

For Calendar Year : 1995

Collection Site	Spec.	%LIPIDS	DURSBAN	DIAZINON	DISULFOTON	ETHION	TERBUFOS	CARBOPHENOTHION	OXYFLUORFEN
BEAR CREEK									
BEC 27.3	CHC	6.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BUFFALO RIVER									
BUF 17.7	CHC	3.9	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
HOLSTON RIVER									
HOL 110	CHC	5.5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
NFH 4.6	CHC	8.7	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
LOWER TENNESSE R									
CLA 9.8*	CHC	2.8	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
OCOEE RIVER									
OCO 2.5	CHC	3.2	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
PIGEON RIVER									
PIG 8.2	CHC	6.2	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SEQUATCHIE RIVER									
SEQ 7.1*	CHC	1.4	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TUCKASEGEE RIVER									
TUC 15.0	CHC	5.3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

* Analysis based on only one channel catfish because insufficient fish were collected to comprise a composite.

Table 7 Concentrations (ug/g) of Metals in Comp ed Fish Fillets Collected in 1995 for Stream Screening Studies.

For Calendar Year : 1995

Collection Site	Species	LABID	As	Cd	Pb	Hg	Se
BEAR CREEK							
BEC 27.3	CHC		0.13	< 0.05	< 0.02	0.71	0.3
BEC 27.3	LMB					0.25	
BEC 27.3	LMB					0.28*	
BUFFALO RIVER							
BUF 17.7	CHC		<0.10	< 0.05	< 0.02	0.11	<0.2
BUF 17.7	SMB					0.60	
BUF 17.7	SMB					0.76*	
HOLSTON RIVER							
HOL 110	CHC		<0.10	< 0.05	0.05	0.28	0.2
HOL 110	LMB					0.63	
HOL 110	LMB					0.78*	
NFH 4.6	CHC		<0.10	< 0.05	0.02	0.88	<0.2
NFH 4.6	SMB					1.70**	
LOWER TENNESSE R							
CLA 9.8	CHC		<0.10	< 0.05	< 0.02	0.45**	<0.2
CLA 9.8	LMB					0.71	
CLA 9.8	LMB					0.87*	
OCOEE RIVER							
OCO 2.5	CHC		<0.10	< 0.05	< 0.02	0.13	0.3
OCO 2.5	SPB					0.36**	
PIGEON RIVER							
PIG 8.2	CHC		<0.10	< 0.05	< 0.02	0.14	<0.2
PIG 8.2	SMB					0.22	
PIG 8.2	SMB					0.29*	
SEQUATCHIE RIVER							
SEQ 7.1	CHC		<0.10	< 0.05	< 0.02	0.16**	0.2
SEQ 7.1	LMB					0.31	

Table 7. Cont.' **Concentrations (ug/g) of Metals in Composited Fish Fillets Collected in 1995 for Stream Screening Studies.**

For Calendar Year : 1995

Collection Site	Species	LABID	As	Cd	Pb	Hg	Se
TUCKASEGEE RIVER							
TUC 15.0	CHC		<0.10	< 0.05	< 0.02	0.40	<0.2
TUC 15.0	SMB					0.48	
TUC 15.0	SMB					0.60 *	

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* Represents separate analysis of largest individual fish included in the composite.

** Analysis based on only individual because insufficient fish were collected to comprise a composite.

Tab Concentrations (ug/g) of Selected P cides and PCBs in Composited Fish Fillets Collected in 1995 For Targe Screening Studies.

For Calendar Year :1995

Collection Site	Spec.	%LIPIDS	MIREX	TOXAPH	HEPTA	ALDRIN	BENZ	DDT	DIELD	ENDO	ENDRIN	CHLOR	PCB	DICOFOL
CHEROKEE														
HOL 53.0	STB	8.6						0.03				<0.01	0.4	
HOL 53.0	STB													
HOL 53.0	CHC	3.6						0.07				<0.01	0.5	
HOL 76.0	CHC	5.7						0.23				0.02	0.8	
HOL 76.0	STB	8.3						0.07				<0.01	0.4	
HOL 76.0	STB													
NICKAJACK														
TEN 469	STB	11.0						0.35				<0.01	1.2	
PARKSVILLE - OCOEE N														
OCO 12.0	CHC	3.4						<0.01				<0.01	0.4	
OCO 16.0	CHC	5.3						0.02				<0.01	0.8	
WHEELER														
ELK 6.0	CHC	4.3						0.07				<0.01	0.2	
TEN 277	CHC	7.9						0.78				<0.01	0.5	
TEN 296	CHC	6.9						0.94				<0.01	0.6	
TEN 347	CHC	11.0						0.65				<0.01	0.5	

Table 9. Concentrations (ug/g) of DDTr, Chlordane, and PCBs in Composited Fish Samples Collected from Wheeler Reservoir During August 1995 for an Intensive Fish Tissue Study

Location	Species	Lipids (%)	DDTr	Chlord	PCBs
TRM 308	CHC	7.4	1.41	0.02	0.3
TRM 308	CHC	5.9	0.61	<0.01	0.5
TRM 308	CHC	5.8	1.06	0.02	0.5
TRM 308	CHC	1.0	1.33	<0.01	0.4
TRM 308	LMB	0.9	0.36	<0.01	<0.1
TRM 308	LMB	1.5	0.50	0.02	0.2
TRM 308	LMB	1.4	0.24	0.02	0.3
TRM 308	LMB	2.0	2.21	<0.01	0.8
TRM 308	SBU	16.0	2.30	<0.01	0.5
TRM 308	SBU	11.0	1.99	<0.01	0.8
TRM 308	SBU	10.0	1.76	<0.01	0.8
TRM 308	SBU	20.0	2.02	<0.01	1.4
TRM 315	CHC	7.0	2.28	0.02	0.6
TRM 315	CHC	5.2	0.47	<0.01	0.5
TRM 315	CHC	4.0	0.36	<0.01	0.4
TRM 315	CHC	4.5	6.08	<0.01	3.1
TRM 315	LMB	0.8	0.36	<0.01	0.3
TRM 315	LMB	1.0	0.38	<0.01	0.4
TRM 315	LMB	0.8	0.50	<0.01	0.3
TRM 315	SBU	8.1	1.43	0.01	<0.1
TRM 315	SBU	8.2	1.13	<0.01	0.4
TRM 315	SBU	4.5	1.21	<0.01	0.5
TRM 315	SBU	7.0	3.38	0.05	1.5

Table 9 cont.

Location	Species	Lipids (%)	DDTr	Chlord	PCBs
TRM 320	CHC	7.5	1.73	<0.01	<0.1
TRM 320	CHC	5.6	0.35	0.06	<0.1
TRM 320	CHC	7.0	2.44	<0.01	0.8
TRM 320	CHC	5.8	1.69	<0.01	0.4
TRM 320	LMB	1.6	0.60	<0.01	0.3
TRM 320	LMB	2.8	2.69	<0.01	0.6
TRM 320	LMB	1.0	0.48	<0.01	0.3
TRM 320	LMB	3.4	6.33	0.05	1.4
TRM 320	LMB	7.3	5.33	0.04	1.5
TRM 320	SBU	4.9	7.50	0.02	1.2
TRM 320	SBU	6.5	0.96	<0.01	0.3
TRM 320	SBU	9.1	0.87	<0.01	0.3
TRM 320	SBU	6.6	3.05	0.03	1.3
TRM 325	CHC	7.1	0.15	<0.01	<0.1
TRM 325	CHC	5.5	1.22	<0.01	<0.1
TRM 325	CHC	7.7	0.19	0.03	<0.1
TRM 325	CHC	6.4	0.32	<0.01	0.2
TRM 325	LMB	1.2	0.90	<0.01	0.5
TRM 325	LMB	0.6	0.25	<0.01	0.3
TRM 325	LMB	1.5	0.42	<0.01	0.4
TRM 325	LMB	1.1	0.61	<0.01	0.4
TRM 325	SBU	4.7	0.67	<0.01	<0.1
TRM 325	SBU	1.3	1.02	0.02	0.4
TRM 325	SBU	6.6	5.15	<0.01	0.4
TRM 325	SBU	5.0	1.62	<0.01	1.2

Table 10. DDTr Concentrations in Fish Collected from Wheeler Reservoir in Vicinity of Indian Creek -- 1991, 1992, 1993, and 1995

	Smallmouth Buffalo				Channel Catfish				Largemouth Bass			
	TRM 308	TRM 315	TRM 320	TRM 325	TRM 308	TRM 315	TRM 320	TRM 325	TRM 308	TRM 315	TRM 320	TRM 325
1991												
Conc. Comp #1	1.7	4.7	18	5.5	13	3.4	13	2.8	1.2	2.6	5.0	11
Conc. Comp #2	2.8	2.3	20	3.1	7.7	1.9	8.8	2.6	1.0	4.3	6.6	1.6
Conc. Comp #3	2.9	8.5	43	2.2	5.7	7.8	6.1	1.1	0.5	3.1	11	0.1
Mean	2.4	5.2	27	3.5	8.4	4.3	9.4	2.2	0.9	3.3	7.4	4.3
1992												
Conc. Comp #1	1.1	2.6	5.0	9.2	3.1	2.0	1.6	0.6	2.6	7.4	1.9	2.4
Conc. Comp #2	1.2	9.2	3.4	0.9	2.3	2.2		0.7	0.6	7.4	1.5	2.3
Conc. Comp #3	1.5	2.3	2.7	1.7	0.6	2.3			0.3	0.5	1.8	1.3
Mean	1.3	4.7	3.7	3.9	2.0	2.2		0.7	1.2	5.1	1.7	2.0
1993												
Conc. Comp #1	0.8	0.4	3.7	7.2	0.8	1.3	1.5	1.5	2.0	2.0	2.5	1.5
Conc. Comp #2	1.1	0.7	13	4.0	0.7	0.7	0.9	0.9	0.5	0.5	1.3	1.1
Conc. Comp #3	1.2	0.9	21	14	0.6	1.7	2.8	0.4	0.3	1.1	0.9	6.4
Mean	1.0	0.6	13	8.4	0.7	1.2	1.7	0.9	0.9	1.2	1.6	3.0
1995												
Conc. Comp #1	2.3	1.4	7.5	0.7	1.4	2.3	1.7	0.2	0.4	0.4	0.6	0.9
Conc. Comp #2	2.0	1.1	1.0	1.0	0.6	0.5	0.4	1.2	0.5	0.4	2.7	0.3
Conc. Comp #3	1.8	1.2	0.9	5.2	1.1	0.4	2.4	0.2	0.2		0.5	0.4
Mean	2.0	1.2	3.1	2.3	1.0	1.0	1.5	0.5	0.4	0.4	1.3	0.5
1995												
Individual Analysis	2.0	3.4	3.1	1.6	1.3	6.1	1.7	0.3	2.2	0.5	6.3 5.3	0.6

Tabl Concentrations (ug/g) of Selected Pc cides and PCBs in Composited Fish Fillets Collected in 1995 For Long Studies.

For Calendar Year :1995

Collection Site	Spec.	%LIPIDS	MIREX	TOXAPH	HEPTA	ALDRIN	BENZ	DDT	DIELD	ENDO	ENDRIN	CHLOR	PCB	DICOFOL
NICKAJACK														
TEN 425	CHC	11.0						0.10				<0.01	0.6	
TEN 457	CHC	13.0						0.09				<0.01	0.6	
TELLICO														
LTE 1.0	CHC	6.2						0.31				<0.01	2.1	
LTE 15.0	CHC	3.1						0.07				<0.01	0.5	
WATTS BAR														
TEN 531	CHC	7.6						0.11				<0.01	0.8	
TEN 560	CHC	3.5						0.13				0.02	1.2	
TEN 600	CHC	6.5						0.35				0.06	1.5	

Table 12. Summary of PCB Concentrations (μg/g) in Channel Catfish Fillets from Tellico Reservoir, 1985 - 1995

Year	Location	Number of Fish	Weight Range (gm)	Mean Weight (gm)	PCB Range	Mean PCB Conc.
1985	LTRM 1	NS	-	-	-	-
	LTRM 11	3-Comp.	328 - 6200	1008	1.0 - 3.2	2.3
1986	LTRM 1	10-Ind.	444 - 3750	1600	0.2 - 3.4	1.4
	LTRM 11	10-Ind.	330 - 3650	1877	0.4 - 4.2	1.6
1987	LTRM 1	10-Ind.	451 - 2902	1110	<0.1 - 2.9	0.9
	LTRM 11	10-Ind.	331 - 1075	551	0.2 - 2.2	1.0
1988	LTRM 1	10-Ind.	452 - 2481	1092	0.3 - 4.2	1.6
	LTRM 11	10-Ind.	570 - 2610	1332	0.1 - 2.2	1.2
1989	LTRM 1	10-Ind.	459 - 2593	1024	0.3 - 4.1	1.6
	LTRM 11	10-Ind.	350 - 3104	1271	0.1 - 2.5	0.9
1990	LTRM 1	1-Comp.	713 - 3347	1771	N/A	1.3
	LTRM 11	1-Comp.	1162 - 2201	1614	N/A	1.5
1991	LTRM 1	1-Comp.	477 - 2496	1429	N/A	1.4
	LTRM 11	1-Comp.	707 - 1521	1023	N/A	1.1
1992	LTRM 1	1-Comp.	478 - 2179	970	N/A	2.7
	LTRM 11	1-Comp.	807 - 4497	1984	N/A	1.9
1993	LTRM 1	1-Comp.	594 - 2094	1389	N/A	1.4
	LTRM 15	1-Comp.	688 - 2086	1398	N/A	1.0
1994	LTRM 1	1-Comp.	667 - 2353	1388	N/A	2.3
	LTRM 15	1-Comp.	1259 - 3739	2027	N/A	1.1
1995	LTRM 1	1-Comp.	1007 - 2684	1411	N/A	2.1
	LTRM 15	1-Comp.	502 - 1269	776	N/A	0.5

Table 13. Summary of PCB Concentrations (μg/g) in Channel Catfish Fillets from Nickajack Reservoir, 1987 - 1995

Year	Location	Number of Fish	Weight Range (gm)	Mean Weight (gm)	PCB Range	Mean PCB Conc.
1987	TRM 425*	1-Comp.	218 - 2110	1150	N/A	1.9
	TRM 457	1-Comp.	636 - 2750	1401	N/A	1.3
1988	TRM 425	10-Ind.	1835 - 2705	2175	0.4 - 1.9	0.9
	TRM 457	3-Ind.	1198 - 2340	1854	0.9 - 1.7	1.3
1989	TRM 425	10-Ind.	346 - 1798	1048	0.6 - 2.0	1.3
	TRM 457	10-Ind.	308 - 1001	805	0.6 - 2.0	0.7
1990	TRM 425	10-Ind.	464 - 2332	1215	0.6 - 1.5	1.0
	TRM 457	10-Ind.	736 - 2429	1500	0.4 - 1.7	1.1
1991	TRM 425	10-Ind.	570 - 2512	1607	0.3 - 3.6	1.5
	TRM 457	10-Ind.	962 - 2839	2100	0.2 - 1.9	0.9
1992	TRM 425	10-Ind.	762 - 1845	1144	0.1 - 0.8	0.4
	TRM 457	10-Ind.	883 - 2620	1453	0.1 - 0.8	0.5
1993	TRM 425	10-Ind.	650 - 2359	1293	0.3 - 1.0	0.6
	TRM 457	10-Ind.	663 - 2141	1259	0.3 - 1.2	0.7
1994	TRM 425	1-Comp.	1023 - 2341	1574	N/A	0.7
	TRM 457	1-Comp.	975 - 2790	1755	N/A	0.7
1995	TRM 425	1-Comp.	1646 - 2294	1909	N/A	0.6
	TRM 457	1-Comp.	1315 - 2100	1811	N/A	0.6

* Blue catfish were collected from this site rather than channel catfish

Table 14. Summary of PCB Concentrations (μg/g) in Channel Catfish Fillets from Watts Bar Reservoir, 1987 - 1995

Year	Location	Number of Fish	Weight Range (gm)	Mean Weight (gm)	PCB Range	Mean PCB Conc.
1987	TRM 531	NS	-	-	-	-
	TRM 560	6-Ind.	239 - 1786	1103	0.1 - 4.4	1.4
	TRM 600*	10-Ind.	336 - 1330	757	0.4 - 3.1	1.5
1988	TRM 531	10-Ind.	494 - 4210	1763	0.1 - 4.3	1.4
	TRM 560	10-Ind.	411 - 2765	1124	1.3 - 7.5	2.7
	TRM 600	10-Ind.	829 - 2957	1289	0.8 - 4.4	2.4
1989	TRM 531 DOE	10-Ind.	320 - 1695	1033	0.2 - 1.5	0.8
	TRM 560 DOE	9-Ind.	324 - 1015	544	0.1 - 0.5	0.3
	TRM 600	7-Ind.	425 - 3229	1437	0.4 - 4.2	1.8
1990	TRM 531	10-Ind.	322 - 2110	700	<0.1 - 2.7	0.6
	TRM 560	10-Ind.	282 - 1521	838	<0.1 - 1.8	0.8
	TRM 600	10-Ind.	208 - 3246	912	0.3 - 5.8	1.6
1991	TRM 531	10-Ind.	899 - 2323	1342	0.8 - 2.9	1.6
	TRM 560	10-Ind.	1149 - 2812	1571	0.8 - 4.0	2.3
	TRM 600	10-Ind.	466 - 1881	967	0.5 - 4.4	1.4
1992	TRM 531	10-Ind.	407 - 4178	1514	0.3 - 5.6	1.7
	TRM 560	10-Ind.	497 - 3563	1540	0.2 - 3.8	1.9
	TRM 600	10-Ind.	464 - 2168	1018	0.4 - 6.2	1.9
1993	TRM 531 DOE	-	-	-	-	
	TRM 560	9-Ind.	500 - 2590	1086	0.4 - 2.3	1.2
	TRM 600	10-Ind.	442 - 2884	931	0.1 - 3.6	1.1
1994	TRM 531	1-Comp.	511 - 2338	1213	N/A	1.0
	TRM 560	1-Comp.	523 - 2394	1302	N/A	1.0
	TRM 600	1-Comp.	496 - 2348	958	N/A	1.0
1995	TRM 531	1-Comp.	437 - 2186	1260	N/A	0.8
	TRM 560	1-Comp.	800 - 1021	907	N/A	1.2
	TRM 600	1-Comp.	626 - 2047	1251	N/A	1.5

* Some blue catfish were collected from this site rather than all channel catfish

Table 15. Concentrations (ug/g) of Selected Pesticides and PCBs in Individual Fish Fillets Collected During Autumn 1995 from Fort Loudoun Reservoir for Long-Term Monitoring.

Location	Species	Collection Date	Lgt. (mm)	Wt. (gm)	Sex	Lipid (%)	DDTr	Chlord	PCBs
TRM 624	CHC 1	09/19/95	581	1716	Female	2.9	0.15	<0.01	2.1
TRM 624	CHC 2	09/19/95	456	836	Female	1.5	0.10	0.03	1.2
TRM 624	CHC 3	09/19/95	444	772	Male	4.5	0.14	<0.01	0.8
TRM 624	CHC 4	09/20/95	569	1690	Female	2.4	0.11	0.04	1.9
TRM 624	CHC 5	11/21/95	570	1699	Male	5.7	0.20	0.05	1.2
TRM 624	CHC 6	11/21/95	544	1405	Female	4.2	0.15	<0.01	2.4
TRM 624	CHC 7	11/21/95	490	1026	Male	3.1	0.16	<0.01	1.0
TRM 624	CHC 8	11/21/95	459	764	Female	1.4	0.11	<0.01	0.9
TRM 624	CHC 9	11/21/95	636	2135	Female	2.9	0.11	<0.01	2.7
TRM 624	CHC 10	11/21/95	496	1225	Female	4.1	0.16	0.03	1.1

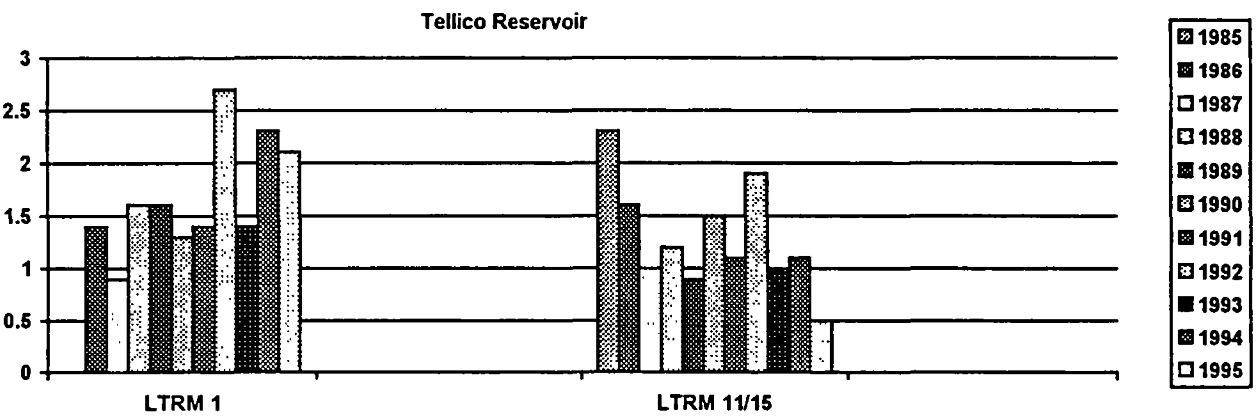
Table 16. Summary of PCB Concentrations in Channel Catfish, Carp, and White Bass Collected from Fort Loudoun Reservoir for Period of Record, 1985 - 1995

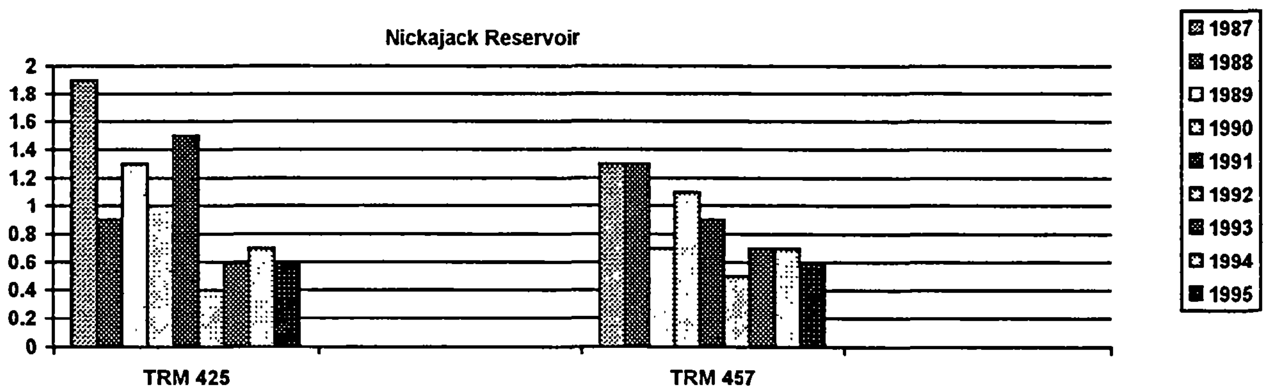
	Location TRM	PCB Range (ug/g)	Mean (ug/g)	No.≥2.0 (ug/g)	# Fish
Catfish					
1985	628	0.2-2.8	1.4	2	10
1987	628	0.1-4.5	1.5	2	10
1988	628	0.2-4.4	1.2	1	10
1989	628	0.6-4.3	2.3	11	20
1990	628	0.3-1.9	1.0	0	10
1991	624	1.4-4.6	2.5	7	10
1992	624	0.1-4.2	1.8	3	9
1993	624	0.4-2.2	1.2	2	10
1994	624	0.6-3.1	1.6	3	9
1995	**624**	**0.8-2.7**	**1.5**	**3**	**10**
Carp					
1992	651	0.2-0.9	0.6	0	10
White Bass					
1987[a]	628	b	<0.1	a	5
	640	b	<0.1	a	5
1992	651	0.3-1.2	0.5	0	10

a. Catfish were sampled from TRMs 624-629. White bass and carp were collected from TRM 651 in 1992.

b. Five white bass were collected from TRMs 628 and 640 in 1987. Each set of five was analyzed as a composite sample.

Figure 1. Average or Composite PCB Concentrations (µg/g) in Channel Cafish fromTellico, Nickajack, and Watts Bar Reservoirs for Period of Recored, Collected for Long-Term Fish Tissue Studies





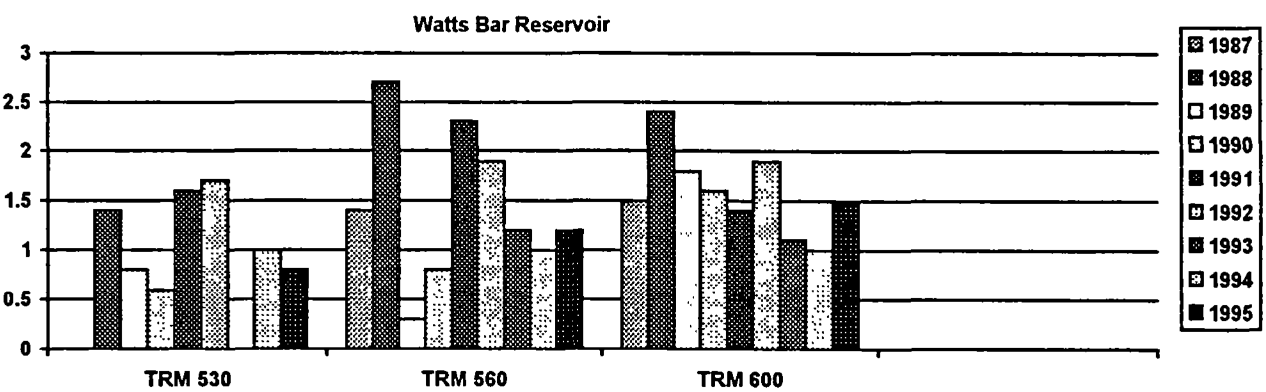


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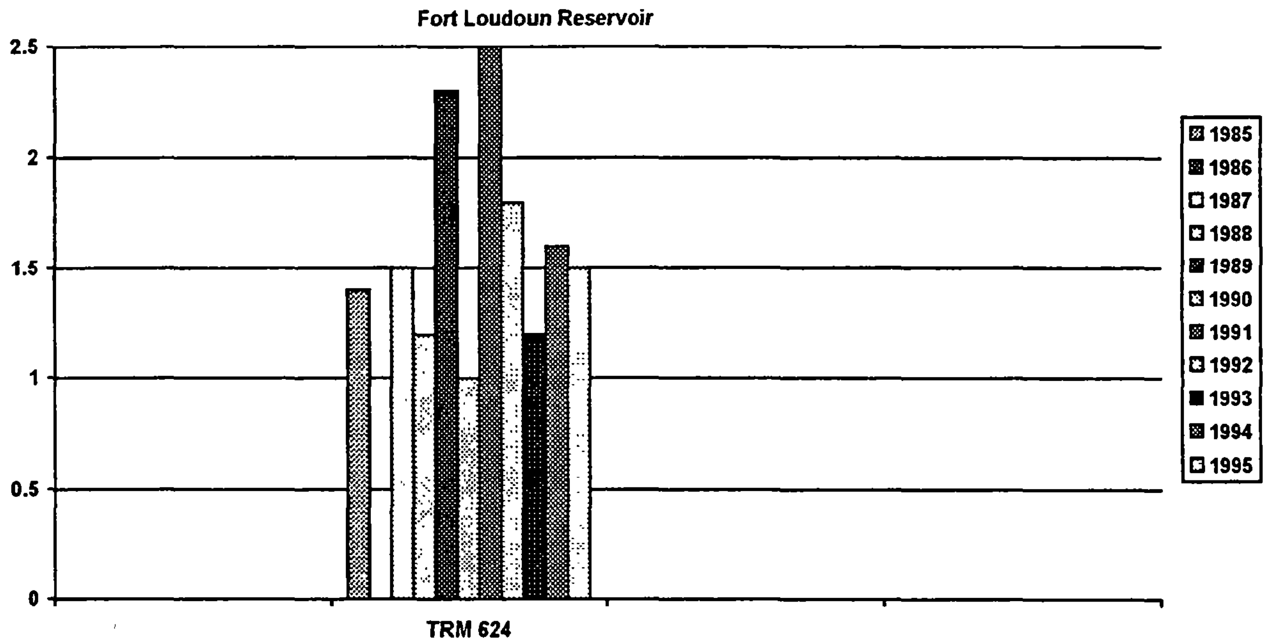
Figure 2. Average PCB Concentrations (µg/g) in Channel Cafish from Fort Loudoun Reservoir for Period of Record, 1985 - 1995



Appendix A

Physical Information on All Fish Collected for Fish Tissue Studies in 1995

* **Note**: The following tables contain collection date, length, weight, and sex for each fish included in these studies. Separate tables are provided for each type of study. For each study, data are grouped by reservoir, river mile and species. Individuals of the same species which were composited for analysis are listed in successive order. In **Reservoir and Stream Screening Studies (Tables A-1 and A-2**, respectively), the largest individual from each largemouth, smallmouth, or spotted bass composite was also analyzed separately for mercury. This also was the case for striped bass from Cherokee Reservoir for the **Targeted Screening Study (Table A-3)**. These fish (i.e., those analyzed separately) are identified in these tables by an asterisk (*). Data for each of these fish are identical to the data for one of the entries above it because it is the same fish. Fish for the **Intensive DDT Study (Table A-4)** on Wheeler Reservoir were handled similarly except the larger individuals were analyzed separately for DDT. In some cases, more than one fish from a composite was analyzed separately and in some cases only one fish could be collected from a site so it had to be analyzed individually. An asterisk (*) is used in all cases to identify fish analyzed separately as individuals.

Table A-1. **Specific Information About Each Fish Collected During 1995 for Reservoir Screening Fish Tissue Study**

For Calendar Year : 1995

ection Site		Date	Species	Length(mm)	Weight(g)	Sex	LABID
I LAKE							
BEE	36.0	09/28/95	LMB	555	2800	Female	
BEE	36.0	10/02/95	LMB	510	2220	Female	
BEE	36.0	09/28/95	LMB	515	2220	Female	
BEE	36.0	09/28/95	LMB	451	1220	Female	
BEE	36.0	09/28/95	LMB	401	960	Female	
BEE	36.0	09/28/95	LMB *	515	2220	Female	
BEE	36.0	09/28/95	LMB *	555	2800	Female	
BEE	36.0	09/28/95	CHC	494	1280	Male	
BEE	36.0	09/28/95	CHC	593	3000	Female	
BEE	36.0	09/28/95	CHC	666	3440	Male	
BEE	36.0	09/28/95	CHC	453	700	Female	
BEE	36.0	09/28/95	CHC	426	600	Female	
CHICKAMAUGA							
HIW	8.0	10/12/95	CHC	684	3707	Female	
HIW	8.0	10/12/95	CHC	472	767	Female	
HIW	8.0	11/02/95	CHC	480	974	Female	
HIW	8.0	11/02/95	CHC	501	1132	Male	
	8.0	11/02/95	CHC	458	717	Female	
HIW	8.0	10/12/95	LMB	520	1823	Female	
HIW	8.0	10/12/95	LMB	323	414	Female	
HIW	8.0	10/12/95	LMB	328	403	Male	
HIW	8.0	10/12/95	LMB	300	337	Female	
HIW	8.0	10/12/95	LMB	296	317	Male	
HIW	8.0	10/12/95	LMB *	520	1823	Female	
TEN	472	10/10/95	CHC	491	1211	Male	
TEN	472	10/10/95	CHC	551	1701	Female	
TEN	472	10/10/95	CHC	531	1132	Male	
TEN	472	10/10/95	CHC	480	1259	Female	
TEN	472	10/10/95	CHC	484	1185	Male	
TEN	472	10/10/95	LMB	358	528	Female	
TEN	472	10/09/95	LMB	305	312	Male	
TEN	472	10/10/95	LMB	528	2369	Female	
TEN	472	10/10/95	LMB	437	1126	Female	
TEN	472	10/10/95	LMB	315	418	Female	
	472	10/10/95	LMB *	528	2369	Female	
	490	10/11/95	LMB	505	1879	Female	
TEN	490	10/11/95	LMB	551	2649	Female	

Table A-1. Cont.' **Specific Information About Each Fish Collected During 1995 for Reservoir Screening Fish Tissue Study**

For Calendar Year : 1995

Collection Site		Date	Species	Length(mm)	Weight(g)	Sex	LABID
TEN	490	10/10/95	LMB	502	1758	Female	
TEN	490	10/10/95	LMB	387	760	Female	
TEN	490	10/10/95	LMB	432	955	Female	
TEN	490	10/10/95	LMB*	551	2649	Female	
TEN	490	10/10/95	CHC	535	1466	Male	
TEN	490	10/10/95	CHC	400	600	Male	
TEN	490	10/11/95	CHC	547	1659	Female	
TEN	490	10/11/95	CHC	556	1631	Female	
TEN	490	10/11/95	CHC	490	1274	Female	
TEN	529	10/16/95	CHC	637	3159	Male	
TEN	529	10/16/95	CHC	445	724	Female	
TEN	529	10/16/95	CHC	542	1675	Female	
TEN	529	10/16/95	CHC	478	967	Male	
TEN	529	10/16/95	CHC	465	806	Male	
TEN	529	10/16/95	CHC	0	0	Female	
TEN	529	10/16/95	LMB	485	2060	Female	
TEN	529	10/16/95	LMB	418	921	Female	
TEN	529	10/16/95	LMB	353	574	Female	
TEN	529	10/16/95	LMB	349	432	Female	
TEN	529	10/16/95	LMB	324	460	Female	
TEN	529	10/16/95	LMB*	485	2060	Female	
FORT LOUDOUN							
TEN	603	09/19/95	CHC	494	913	Male	
TEN	603	09/19/95	CHC	435	793	Male	
TEN	603	09/19/95	CHC	595	1644	Male	
TEN	603	09/19/95	CHC	494	918	Male	
TEN	603	09/19/95	CHC	470	1056	Female	
TEN	603	11/06/95	LMB	450	1354	Female	
TEN	603	11/06/95	LMB	391	788	Male	
TEN	603	11/06/95	LMB	481	1993	Female	
TEN	603	11/06/95	LMB	477	1352	Male	
TEN	603	11/06/95	LMB	365	712	Male	
TEN	603	11/06/95	LMB*	481	1993	Female	
TEN	624	09/19/95	LMB	400	1073	Male	
TEN	624	09/19/95	LMB	398	1098	Male	
TEN	624	09/19/95	LMB	454	1591	Female	
TEN	624	09/19/95	LMB	385	820	Female	

Table A-1. **Specific Information About Each Fish Collected During 1995 for**
Cont.' **Reservoir Screening Fish Tissue Study**

For Calendar Year : 1995

:ction Site		Date	Species	Length(mm)	Weight(g)	Sex	LABID
	624	09/19/95	LMB	330	405	Female	
TEN	624	09/19/95	LMB *	454	1591	Female	
TEN	624	09/19/95	CHC	581	1716	Female	
TEN	624	09/19/95	CHC	456	836	Female	
TEN	624	09/19/95	CHC	444	772	Male	
TEN	624	09/20/95	CHC	569	1690	Female	
TEN	624	11/21/95	CHC	570	1699	Male	
TEN	652	09/20/95	CHC	359	362	Male	
TEN	652	09/20/95	CHC	497	968	Male	
TEN	652	09/20/95	CHC	460	973	Female	
TEN	652	09/20/95	CHC	435	663	Female	
TEN	652	09/20/95	LMB	370	741	Male	
TEN	652	09/20/95	LMB	454	1358	Female	
TEN	652	09/20/95	LMB	520	2328	Female	
TEN	652	09/20/95	LMB	381	904	Male	
TEN	652	09/20/95	LMB	280	331	Male	
TEN	652	09/20/95	LMB *	520	2328	Female	
PATRICK HENRY							
	9.0	11/28/95	CHC	445	799	Female	
HOL	9.0	11/28/95	CHC	471	937	Male	
HOL	9.0	12/12/95	CHC	521	1328	Male	
HOL	9.0	11/28/95	LMB	489	2640	Female	
HOL	9.0	11/28/95	LMB	492	1920	Female	
HOL	9.0	11/28/95	LMB	507	2289	Female	
HOL	9.0	11/28/95	LMB	425	1351	Female	
HOL	9.0	11/28/95	LMB	351	622	Male	
HOL	9.0	11/28/95	LMB *	489	2640	Female	
KENTUCKY							
BLU	7.0	09/21/95	LMB	480	1800	Female	
BLU	7.0	09/21/95	LMB	438	1260	Female	
BLU	7.0	09/21/95	LMB	342	620	Male	
BLU	7.0	09/21/95	LMB	310	420	Female	
BLU	7.0	09/21/95	LMB	287	360	Female	
BLU	7.0	09/21/95	LMB *	480	1800	Female	
BLU	7.0	09/20/95	CHC	506	980	Female	
	7.0	09/20/95	CHC	432	600	Female	
	7.0	09/20/95	CHC	477	1000	Male	
BLU	7.0	09/20/95	CHC	412	580	Female	

Table A-1. Cont.' **Specific Information About Each Fish Collected During 1995 for Reservoir Screening Fish Tissue Study**

For Calendar Year : 1995

Collection Site	Date	Species	Length(mm)	Weight(g)	Sex	LABID
BLU 7.0	09/20/95	CHC	462	800	Female	
TEN 30.0	11/06/95	CHC	545	1910	Female	
TEN 30.0	11/06/95	CHC	491	1255	Male	
TEN 30.0	11/06/95	CHC	463	1060	Female	
TEN 30.0	11/06/95	CHC	465	955	Female	
TEN 30.0	11/06/95	CHC	451	940	Female	
TEN 30.0	09/19/95	LMB	409	1200	Female	
TEN 30.0	09/19/95	LMB	401	1160	Male	
TEN 30.0	09/19/95	LMB	465	1600	Female	
TEN 30.0	09/19/95	LMB	380	920	Male	
TEN 30.0	09/19/95	LMB	383	820	Male	
TEN 30.0	09/19/95	LMB *	465	1600	Female	
TEN 85.0	09/20/95	LMB	396	1000	Male	
TEN 85.0	11/09/95	LMB	478	1420	Female	
TEN 85.0	11/09/95	LMB	413	990	Male	
TEN 85.0	11/09/95	LMB	485	1775	Male	
TEN 85.0	11/09/95	LMB	367	805	Female	
TEN 85.0	11/09/95	LMB *	485	1775	Male	
TEN 85.0	09/22/95	CHC	450	980	Male	
TEN 85.0	09/22/95	CHC	450	960	Male	
TEN 85.0	09/22/95	CHC	410	780	Female	
TEN 85.0	09/22/95	CHC	506	1080	Male	
TEN 85.0	09/22/95	CHC	430	760	Male	
TEN 206	09/18/95	CHC	516	1360	Male	
TEN 206	11/09/95	CHC	609	2745	Male	
TEN 206	11/15/95	CHC	505	1455	Female	
TEN 206	09/18/95	LMB	376	1000	Female	
TEN 206	09/18/95	LMB	324	640	Female	
TEN 206	09/18/95	LMB	331	580	Female	
TEN 206	09/18/95	LMB	423	1300	Male	
TEN 206	09/18/95	LMB	356	860	Female	
TEN 206	09/18/95	LMB *	423	1300	Male	
NORMANDY						
DUC 250	09/25/95	CHC	530	1191	Male	
DUC 250	09/25/95	CHC	468	763	Male	
DUC 250	09/25/95	CHC	439	615	Female	
DUC 250	09/25/95	CHC	658	430	Male	

Table A-1. **Specific Information About Each Fish Collected During 1995 for**
Cont.' **Reservoir Screening Fish Tissue Study**

For Calendar Year : 1995

ection Site		Date	Species	Length(mm)	Weight(g)	Sex	LABID
	250	09/25/95	CHC	475	928	Female	
DUC	250	09/25/95	LMB	395	891	Female	
DUC	250	09/25/95	LMB	343	591	Female	
DUC	250	09/25/95	LMB	558	2819	Female	
DUC	250	09/25/95	LMB	303	424	Female	
DUC	250	11/17/95	LMB	427	1119	Female	
DUC	250	09/25/95	LMB*	558	2819	Female	
TIMS FORD							
ELK	135	11/15/95	CHC	453	821	Male	
ELK	135	11/15/95	CHC	532	1585	Female	
ELK	135	11/15/95	CHC	380	419	Male	
ELK	135	11/15/95	CHC	373	401	Male	
ELK	135	11/15/95	CHC	475	915	Male	
ELK	135	09/27/95	LMB	449	1342	Male	
ELK	135	09/27/95	LMB	508	1872	Female	
ELK	135	09/27/95	LMB	377	678	Female	
ELK	135	09/27/95	LMB	425	1069	Female	
	135	09/27/95	LMB	385	713	Male	
	135	09/27/95	LMB*	508	1872	Female	
ELK	150	09/27/95	CHC	474	813	Male	
ELK	150	11/15/95	CHC	449	753	Male	
ELK	150	11/15/95	CHC	443	749	Male	
ELK	150	11/15/95	CHC	442	603	Male	
ELK	150	11/15/95	CHC	500	910	Male	
ELK	150	09/26/95	LMB	448	1116	Female	
ELK	150	09/26/95	LMB	477	1839	Female	
ELK	150	09/26/95	LMB	431	1085	Male	
ELK	150	09/26/95	LMB	465	1471	Female	
ELK	150	09/26/95	LMB	382	864	Female	
ELK	150	09/26/95	LMB*	477	1839	Female	

Table A-2. **Specific Information About Each Fish Collected During 1995 for Stream Screening Fish Tissue Study**

For Calendar Year : 1995

ection Site		Date	Species	Length(mm)	Weight(g)	Sex	LABID
CREEK							
BEC	27.3	05/23/95	LMB	326	371	Female	
BEC	27.3	05/23/95	LMB	290	335	Female	
BEC	27.3	05/23/95	LMB	355	681	Female	
BEC	27.3	05/23/95	LMB *	355	681	Female	
BEC	27.3	05/23/95	CHC	431	661	Female	
BEC	27.3	05/23/95	CHC	354	366	Male	
BEC	27.3	05/23/95	CHC	484	1103	Male	
BUFFALO RIVER							
BUF	17.7	07/25/95	SMB	250	193	Female	
BUF	17.7	07/25/95	SMB	265	206	Female	
BUF	17.7	07/25/95	SMB	271	206	Female	
BUF	17.7	07/25/95	SMB	274	244	Female	
BUF	17.7	07/25/95	SMB	284	251	Female	
BUF	17.7	07/25/95	SMB *	284	251	Female	
BUF	17.7	07/25/95	CHC	440	736	Male	
BUF	17.7	07/25/95	CHC	414	587	Male	
----	17.7	07/25/95	CHC	430	745	Female	
	17.7	07/25/95	CHC	433	699	Male	
BUF	17.7	07/25/95	CHC	446	750	Male	
HOLSTON RIVER							
HOL	110	07/10/95	LMB	395	997	Female	
HOL	110	07/10/95	LMB	294	393	Female	
HOL	110	07/11/95	LMB	459	1657	Female	
HOL	110	07/11/95	LMB	346	536	Female	
HOL	110	07/11/95	LMB	341	536	Female	
HOL	110	07/11/95	LMB *	459	1657	Female	
HOL	110	07/10/95	CHC	508	1377	Female	
HOL	110	07/10/95	CHC	466	1009	Male	
HOL	110	07/10/95	CHC	494	1297	Female	
HOL	110	07/10/95	CHC	493	1307	Male	
HOL	110	07/10/95	CHC	525	1204	Male	
NFH	4.6	07/13/95	CHC	574	2038	Female	
NFH	4.6	07/13/95	CHC	463	1002	Female	
NFH	4.6	07/13/95	CHC	556	1551	Female	
[illegible]	4.6	07/13/95	CHC	453	823	Male	
	4.6	07/13/95	CHC	455	854	Female	
NFH	4.6	07/13/95	SMB*	481	1504	Male	

Table A-2. **Specific Information About Each Fish Collected During 1995 for**
Cont.' **Stream Screening Fish Tissue Study**

For Calendar Year : 1995

Collection Site	Date	Species	Length(mm)	Weight(g)	Sex	LABID
LOWER TENNESSE R						
CLA 9.8	08/29/95	LMB	416	1129	Female	
CLA 9.8	08/29/95	LMB	456	1590	Female	
CLA 9.8	08/29/95	LMB	425	1280	Female	
CLA 9.8	08/29/95	LMB	423	1319	Female	
CLA 9.8	08/29/95	LMB	366	759	Female	
CLA 9.8	08/29/95	LMB *	456	1590	Female	
CLA 9.8	08/29/95	CHC	585	1780	Female	
CLA 9.8	08/29/95	CHC	585	1780	Female	
OCOEE RIVER						
OCO 2.5	06/20/95	SPB *	383	694	Female	
OCO 2.5	06/20/95	CHC	410	485	Female	
OCO 2.5	06/20/95	CHC	439	618	Female	
OCO 2.5	06/20/95	CHC	429	670	Male	
OCO 2.5	06/20/95	CHC	420	592	Female	
OCO 2.5	06/20/95	CHC	423	601	Female	
PIGEON RIVER						
PIG 8.2	07/13/95	CHC	418	547	Female	
PIG 8.2	07/13/95	CHC	368	448	Female	
PIG 8.2	07/13/95	CHC	359	400	Male	
PIG 8.2	07/13/95	CHC	370	395	Female	
PIG 8.2	07/13/95	CHC	328	281	Female	
PIG 8.2	07/13/95	SMB	360	658	Female	
PIG 8.2	07/13/95	SMB	450	1155	Female	
PIG 8.2	07/13/95	SMB	470	1481	Female	
PIG 8.2	07/13/95	SMB	336	489	Female	
PIG 8.2	07/13/95	SMB	304	436	Female	
PIG 8.2	07/13/95	SMB *	470	1481	Female	
SEQUATCHIE RIVER						
SEQ 7.1	06/06/95	LMB *	365	614	Male	
SEQ 7.1	06/06/95	CHC	453	734	Female	
SEQ 7.1	06/06/95	CHC	478	846	Female	
TUCKASEGEE RIVER						
TUC 15.0	07/20/95	SMB	347	626	Male	
TUC 15.0	07/20/95	SMB	318	569	Male	
TUC 15.0	07/20/95	SMB	350	633	Female	
TUC 15.0	07/20/95	SMB	305	430	Female	
TUC 15.0	07/20/95	SMB	357	633	Female	

Table A-2. Cont.' **Specific Information About Each Fish Collected During 1995 for Stream Screening Fish Tissue Study**

For Calendar Year : 1995

ction Site		Date	Species	Length(mm)	Weight(g)	Sex	LABID
[illegible]	15.0	07/20/95	SMB*	357	633	Female	
TUC	15.0	09/28/95	CHC	464	963	Male	
TUC	15.0	09/28/95	CHC	449	755	Male	
TUC	15.0	09/28/95	CHC	459	908	Female	
TUC	15.0	09/28/95	CHC	419	728	Female	
TUC	15.0	09/28/95	CHC	530	1692	Female	

Table A-3. **Specific Information About Each Fish Collected During 1995 for Targeted Fish Tissue Study**

For Calendar Year : 1995

ction Site		Date	Species	Length(mm)	Weight(g)	Sex	LABID
KEE							
HOL	53.0	09/28/95	CHC	460	832	Male	
HOL	53.0	12/12/95	CHC	461	780	Male	
HOL	53.0	12/15/95	CHC	405	534	Female	
HOL	53.0	12/15/95	CHC	455	790	Male	
HOL	53.0	12/15/95	CHC	371	436	Male	
HOL	53.0	09/28/95	STB	674	2952	Female	
HOL	53.0	09/28/95	STB	675	2942	Female	
HOL	53.0	09/28/95	STB	575	1879	Male	
HOL	53.0	09/28/95	STB	503	1447	Female	
HOL	53.0	09/28/95	STB	501	1346	Female	
HOL	53.0	09/28/95	STB *	674	2952	Female	
HOL	76.0	09/27/95	CHC	455	712	Male	
HOL	76.0	09/29/95	CHC	412	598	Female	
HOL	76.0	09/29/95	CHC	503	980	Female	
HOL	76.0	09/29/95	CHC	558	1723	Female	
HOL	76.0	09/29/95	CHC	459	872	Female	
	76.0	09/29/95	STB	556	1918	Female	
	76.0	09/29/95	STB	449	1061	Male	
HOL	76.0	12/08/95	STB	689	3836	Male	
HOL	76.0	12/08/95	STB	601	2782	Male	
HOL	76.0	12/08/95	STB	641	3084	Male	
HOL	76.0	12/08/95	STB *	689	3836	Male	
NICKAJACK							
TEN	469	11/16/95	STB	700	4163	Female	
TEN	469	11/16/95	STB	842	8703	Female	
TEN	469	11/17/95	STB	823	7840	Male	
TEN	469	11/17/95	STB	688	4568	Female	
TEN	469	11/17/95	STB	873	8882	Female	
PARKSVILLE - OCOEE N							
OCO	12.0	10/18/95	CHC	465	810	Male	
OCO	12.0	10/18/95	CHC	473	560	Male	
OCO	12.0	10/18/95	CHC	437	670	Female	
OCO	12.0	10/19/95	CHC	462	774	Male	
OCO	12.0	10/19/95	CHC	446	714	Male	
	16.0	10/20/95	CHC	516	1224	Male	
	16.0	10/20/95	CHC	470	881	Female	
OCO	16.0	10/20/95	CHC	610	2075	Male	

Table A-3. Cont.' **Specific Information About Each Fish Collected During 1995 for Targeted Fish Tissue Study**

For Calendar Year : 1995

Collection Site	Date	Species	Length(mm)	Weight(g)	Sex	LABID
OCO 16.0	10/20/95	CHC	513	1220	Female	
OCO 16.0	10/20/95	CHC	497	1150	Female	
WHEELER						
ELK 6.0	10/03/95	CHC	483	1080	Male	
ELK 6.0	10/03/95	CHC	466	1040	Female	
ELK 6.0	11/22/95	CHC	470	890	Female	
ELK 6.0	11/22/95	CHC	380	395	Female	
ELK 6.0	11/22/95	CHC	362	310	Female	
TEN 277	10/02/95	CHC	547	2060	Female	
TEN 277	10/02/95	CHC	516	1440	Male	
TEN 277	10/02/95	CHC	475	840	Female	
TEN 277	10/02/95	CHC	431	680	Female	
TEN 277	10/02/95	CHC	456	1950	Male	
TEN 296	12/05/95	CHC	643	3245	Female	
TEN 296	12/05/95	CHC	564	2090	Female	
TEN 296	12/05/95	CHC	496	1340	Male	
TEN 296	12/04/95	CHC	451	805	Male	
TEN 296	12/05/95	CHC	481	1055	Male	
TEN 347	10/11/95	CHC	457	975	Female	
TEN 347	10/11/95	CHC	520	1735	Female	
TEN 347	10/11/95	CHC	455	985	Male	
TEN 347	10/11/95	CHC	560	1885	Male	
TEN 347	10/11/95	CHC	434	840	Male	

Table A-4. **Specific Information About Each Fish Collected During 1995 for Intensive Fish Tissue Study**

For Calendar Year : 1995

ction Site ER		Date	Species	Length(mm)	Weight(g)	Sex	LABID
TEN	308	08/28/95	SBU	670	4784	Female	
TEN	308	08/28/95	SBU	632	3850	Male	
TEN	308	08/28/95	SBU	456	2182	Male	
TEN	308	08/28/95	SBU	518	2617	Male	
TEN	308	08/28/95	SBU	660	5232	Female	
TEN	308	08/28/95	SBU	528	2122	Male	
TEN	308	08/28/95	SBU	535	2711	Male	
TEN	308	08/28/95	SBU	528	2573	Male	
TEN	308	08/28/95	SBU	518	2348	Male	
TEN	308	08/28/95	SBU	541	2382	Male	
TEN	308	08/28/95	SBU	606	5541	Female	
TEN	308	08/28/95	SBU	630	4092	Female	
TEN	308	08/28/95	SBU	559	2611	Male	
TEN	308	08/28/95	SBU	541	2420	Male	
TEN	308	08/28/95	SBU	618	3289	Male	
TEN	308	08/28/95	SBU*	606	5541	Female	
	308	08/28/95	CHC	454	868	Male	
	308	08/28/95	CHC	371	458	Male	
TEN	308	08/28/95	CHC	496	1133	Female	
TEN	308	08/28/95	CHC	421	548	Male	
TEN	308	08/28/95	CHC	545	1740	Female	
TEN	308	08/28/95	CHC	610	1800	Male	
TEN	308	08/28/95	CHC	430	799	Male	
TEN	308	08/28/95	CHC	600	1843	Male	
TEN	308	08/28/95	CHC	416	587	Male	
TEN	308	08/28/95	CHC	528	1596	Male	
TEN	308	08/28/95	CHC	425	760	Female	
TEN	308	08/28/95	CHC	576	1966	Female	
TEN	308	08/28/95	CHC	605	2079	Male	
TEN	308	08/29/95	CHC	593	1868	Male	
TEN	308	08/29/95	CHC	576	1504	Male	
TEN	308	08/28/95	CHC*	605	2079	Male	
TEN	308	08/29/95	LMB	308	379	Male	
TEN	308	08/29/95	LMB	314	427	Male	
	308	08/29/95	LMB	310	362	Female	
[illegible]	308	08/29/95	LMB	351	525	Female	

Table A-4. Cont.' **Specific Information About Each Fish Collected During 1995 for Intensive Fish Tissue Study**

For Calendar Year : 1995

Collection Site		Date	Species	Length(mm)	Weight(g)	Sex	LABID
TEN	308	08/29/95	LMB	307	354	Male	
TEN	308	08/29/95	LMB	329	363	Male	
TEN	308	08/29/95	LMB	535	2619	Female	
TEN	308	08/29/95	LMB	300	332	Male	
TEN	308	08/29/95	LMB	287	313	Female	
TEN	308	08/29/95	LMB	316	412	Male	
TEN	308	08/29/95	LMB	342	501	Male	
TEN	308	08/29/95	LMB	290	345	Male	
TEN	308	08/29/95	LMB	351	637	Female	
TEN	308	08/29/95	LMB	316	417	Male	
TEN	308	08/29/95	LMB	268	268	Female	
TEN	308	08/29/95	LMB *	535	2619	Female	
TEN	315	08/23/95	LMB	325	290	Male	
TEN	315	08/23/95	LMB	291	304	Male	
TEN	315	08/24/95	LMB	426	1011	Male	
TEN	315	08/24/95	LMB	308	366	Female	
TEN	315	08/24/95	LMB	402	804	Male	
TEN	315	08/24/95	LMB	326	416	Male	
TEN	315	08/24/95	LMB	294	260	Male	
TEN	315	08/29/95	LMB	310	410	Male	
TEN	315	08/29/95	LMB	416	931	Female	
TEN	315	08/24/95	LMB *	426	1011	Male	
TEN	315	08/24/95	CHC	568	1902	Female	
TEN	315	08/24/95	CHC	552	767	Female	
TEN	315	08/28/95	CHC	463	1056	Female	
TEN	315	08/28/95	CHC	486	1150	Female	
TEN	315	08/28/95	CHC	473	884	Male	
TEN	315	08/28/95	CHC	400	451	Male	
TEN	315	08/28/95	CHC	472	1109	Female	
TEN	315	08/30/95	CHC	413	513	Female	
TEN	315	08/30/95	CHC	491	848	Female	
TEN	315	08/30/95	CHC	607	1569	Male	
TEN	315	08/30/95	CHC	570	1504	Male	
TEN	315	08/30/95	CHC	558	1735	Male	
TEN	315	08/30/95	CHC	522	1403	Male	
TEN	315	08/24/95	CHC*	568	1902	Female	
TEN	315	08/23/95	SBU	450	1257	Male	

Table A-4 Cont.' **Specific Information About Each Fish Collected During 1995 for Intensive Fish Tissue Study**

For Calendar Year : 1995

ection	Site	Date	Species	Length(mm)	Weight(g)	Sex	LABID
	315	08/23/95	SBU	430	1054	Male	
TEN	315	08/23/95	SBU	450	1224	Male	
TEN	315	08/23/95	SBU	510	1963	Female	
TEN	315	08/24/95	SBU	464	1455	Male	
TEN	315	08/24/95	SBU	450	1216	Male	
TEN	315	08/24/95	SBU	466	1576	Male	
TEN	315	08/24/95	SBU	464	1435	Female	
TEN	315	08/24/95	SBU	510	2230	Male	
TEN	315	08/24/95	SBU	495	2068	Male	
TEN	315	08/28/95	SBU	492	1806	Male	
TEN	315	08/28/95	SBU	340	512	Female	
TEN	315	08/28/95	SBU	324	461	Male	
TEN	315	08/28/95	SBU	565	2982	Male	
TEN	315	08/28/95	SBU	451	1191	Male	
TEN	315	08/28/95	SBU*	565	2982	Male	
TEN	320	08/22/95	SBU	455	1352	Male	
TEN	320	08/22/95	SBU	495	1700	Female	
	320	08/22/95	SBU	551	2273	Male	
	320	08/22/95	SBU	505	1672	Female	
TEN	320	08/23/95	SBU	480	1715	Male	
TEN	320	08/23/95	SBU	540	2343	Female	
TEN	320	08/28/95	SBU	485	1598	Male	
TEN	320	08/28/95	SBU	535	2420	Female	
TEN	320	08/28/95	SBU	526	2044	Male	
TEN	320	08/28/95	SBU	447	1366	Female	
TEN	320	08/28/95	SBU	574	2743	Female	
TEN	320	08/30/95	SBU	535	2468	Female	
TEN	320	08/30/95	SBU	362	707	Male	
TEN	320	08/30/95	SBU	420	1079	Male	
TEN	320	08/30/95	SBU	499	1820	Female	
TEN	320	08/28/95	SBU*	574	2743	Female	
TEN	320	08/22/95	CHC	454	849	Male	
TEN	320	08/22/95	CHC	490	1156	Female	
TEN	320	08/23/95	CHC	502	1152	Female	
TEN	320	08/23/95	CHC	483	901	Female	
	320	08/24/95	CHC	476	924	Female	
TEN	320	08/24/95	CHC	455	954	Male	

Table A-4. **Specific Information About Each Fish Collected During 1995 for**
Cont.' **Intensive Fish Tissue Study**

For Calendar Year : 1995

Collection Site		Date	Species	Length(mm)	Weight(g)	Sex	LABID
TEN	320	08/24/95	CHC	547	1459	Female	
TEN	320	08/28/95	CHC	468	911	Female	
TEN	320	08/28/95	CHC	315	304	Male	
TEN	320	08/28/95	CHC	383	507	Female	
TEN	320	08/28/95	CHC	460	822	Male	
TEN	320	08/28/95	CHC	505	1378	Male	
TEN	320	08/28/95	CHC	538	1566	Female	
TEN	320	08/30/95	CHC	519	1010	Female	
TEN	320	08/30/95	CHC	558	1702	Female	
TEN	320	08/30/95	CHC*	558	1702	Female	
TEN	320	08/22/95	LMB	360	597	Male	
TEN	320	08/23/95	LMB	315	390	Male	
TEN	320	08/23/95	LMB	332	485	Female	
TEN	320	08/23/95	LMB	345	472	Male	
TEN	320	08/23/95	LMB	343	494	Female	
TEN	320	08/23/95	LMB	318	435	Male	
TEN	320	08/23/95	LMB	304	330	Male	
TEN	320	08/23/95	LMB	290	323	Male	
TEN	320	08/23/95	LMB	530	2004	Male	
TEN	320	08/23/95	LMB	493	1916	Male	
TEN	320	08/24/95	LMB	300	358	Male	
TEN	320	08/24/95	LMB	358	644	Female	
TEN	320	08/24/95	LMB	350	528	Male	
TEN	320	08/24/95	LMB	324	410	Female	
TEN	320	08/24/95	LMB	360	551	Male	
TEN	320	08/23/95	LMB*	530	2004	Male	
TEN	320	08/23/95	LMB*	493	1916	Male	
TEN	325	08/21/95	LMB	300	339	Male	
TEN	325	08/21/95	LMB	350	589	Male	
TEN	325	08/21/95	LMB	310	343	Male	
TEN	325	08/21/95	LMB	359	598	Male	
TEN	325	08/21/95	LMB	321	386	Female	
TEN	325	08/21/95	LMB	313	375	Male	
TEN	325	08/22/95	LMB	391	735	Female	
TEN	325	08/22/95	LMB	277	278	Female	
TEN	325	08/22/95	LMB	290	331	Male	
TEN	325	08/22/95	LMB	289	257	Female	

Table A-4. Cont.' **Specific Information About Each Fish Collected During 1995 for Intensive Fish Tissue Study**

For Calendar Year : 1995

ction Site	Date	Species	Length(mm)	Weight(g)	Sex	LABID
325	08/22/95	LMB	501	1888	Male	
TEN 325	08/23/95	LMB	355	556	Male	
TEN 325	08/23/95	LMB	475	1615	Male	
TEN 325	08/23/95	LMB	300	290	Male	
TEN 325	08/23/95	LMB	365	755	Female	
TEN 325	08/22/95	LMB *	501	1888	Male	
TEN 325	08/22/95	CHC	475	911	Female	
TEN 325	08/28/95	CHC	425	977	Female	
TEN 325	08/28/95	CHC	394	451	Female	
TEN 325	08/28/95	CHC	557	800	Male	
TEN 325	08/30/95	CHC	485	1004	Female	
TEN 325	08/30/95	CHC	474	1032	Female	
TEN 325	08/30/95	CHC	538	1086	Male	
TEN 325	08/30/95	CHC	439	717	Male	
TEN 325	08/30/95	CHC	491	1129	Male	
TEN 325	08/30/95	CHC	474	927	Female	
TEN 325	08/30/95	CHC	599	1852	Male	
325	08/30/95	CHC	475	1039	Male	
TEN 325	08/30/95	CHC	471	902	Female	
TEN 325	08/30/95	CHC	402	643	Female	
TEN 325	08/30/95	CHC *	599	1852	Male	
TEN 325	08/21/95	SBU	455	1243	Male	
TEN 325	08/21/95	SBU	486	1709	Female	
TEN 325	08/21/95	SBU	469	1513	Female	
TEN 325	08/21/95	SBU	446	1358	Male	
TEN 325	08/23/95	SBU	370	1190	Female	
TEN 325	08/23/95	SBU	348	624	Male	
TEN 325	08/23/95	SBU	450	1302	Female	
TEN 325	08/23/95	SBU	454	1525	Male	
TEN 325	08/23/95	SBU	472	1460	Female	
TEN 325	08/28/95	SBU	569	2648	Female	
TEN 325	08/28/95	SBU	442	1410	Female	
TEN 325	08/30/95	SBU	556	2460	Female	
TEN 325	08/30/95	SBU	476	1656	Female	
TEN 325	08/30/95	SBU	465	1404	Male	
325	08/30/95	SBU	450	1272	Male	
TEN 325	08/28/95	SBU *	569	2648	Female	

Table A-5. **Specific Information About Each Fish Collected During 1995 for Long Term Fish Tissue Study**

For Calendar Year : 1995

:tion Site	Date	Species	Length(mm)	Weight(g)	Sex	LABID
JACK						
TEN 425	10/18/95	CHC	519	1646	Male	
TEN 425	10/18/95	CHC	570	1688	Male	
TEN 425	10/19/95	CHC	555	1949	Male	
TEN 425	10/19/95	CHC	548	1966	Male	
TEN 425	11/13/95	CHC	590	2294	Male	
TEN 457	10/23/95	CHC	575	2100	Female	
TEN 457	10/23/95	CHC	577	2090	Male	
TEN 457	10/23/95	CHC	573	1797	Female	
TEN 457	10/23/95	CHC	506	1315	Male	
TEN 457	10/23/95	CHC	548	1755	Male	
TELLICO						
LTE 1.0	11/06/95	CHC	598	2684	Female	
LTE 1.0	11/06/95	CHC	498	1018	Female	
LTE 1.0	11/06/95	CHC	558	1263	Male	
LTE 1.0	11/06/95	CHC	470	1007	Male	
LTE 1.0	11/06/95	CHC	490	1083	Female	
15.0	11/07/95	CHC	458	807	Male	
15.0	11/07/95	CHC	532	1269	Female	
LTE 15.0	11/08/95	CHC	410	502	Female	
LTE 15.0	11/08/95	CHC	429	526	Male	
WATTS BAR						
TEN 531	10/31/95	CHC	506	987	Male	
TEN 531	09/12/95	CHC	430	646	Female	
TEN 531	10/31/95	CHC	595	2186	Female	
TEN 531	09/12/95	CHC	373	437	Male	
TEN 531	10/31/95	CHC	600	2044	Female	
TEN 560	11/09/95	CHC	495	968	Male	
TEN 560	11/09/95	CHC	480	800	Female	
TEN 560	11/08/95	CHC	521	1021	Female	
TEN 560	11/09/95	CHC	461	837	Female	
TEN 600	11/08/95	CHC	570	2047	Male	
TEN 600	11/08/95	CHC	420	626	Male	
TEN 600	11/09/95	CHC	496	1355	Female	
TEN 600	11/09/95	CHC	474	971	Female	
600	11/09/95	CHC	511	1257	Male	

Appendix B

Recommendations for Fish Tissue Studies in 1996

Appendix B. Recommendations for fish tissue studies in 1996[a]

Study Type/Location	River Mile	Species	# Needed	Ind/Comp	Analytes
Reservoir Screening					
Pickwick Res.	TRM 207	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
	TRM 230	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
	TRM 259	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
	BCRM 8	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
Wilson Res	TRM 260	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
	TRM 272	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
Guntersville Res	TRM 350	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
	TRM 375	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
	TRM 423	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
Watts Bar Res	TRM 531	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
	TRM 560	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
	TRM 600	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
	CRM 22	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only

Appendix B, Continued

Study Type/Location	River Mile	Species	# Needed	Ind/Comp	Analytes
Reservoir Screening, cont.'					
Melton Hill Res	CRM 24	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
	CRM 45	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
	CRM 64	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
So. Holston. Res	SFHRM 51	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
	SFHRM 62	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
Watagua. Res	WRM 37	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
	WRM 45	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
Fontana Res	LTRM 62	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
	LTRM 81	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
	TuRM 3	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
Hiwassee Res	HiRM 77	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
	HiRM 85	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only

Appendix B, Continued

Study Type/Location	River Mile	Species	# Needed	Ind/Comp	Analytes
Reservoir Screening, cont.'					
Chatuge Res	HiRM 122	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
	ShoCrM 1.5	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
Parksville Res	ORM 12	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
Bear Creek Res	BCM 75	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
L' Bear Cr. Res	LBCM 12	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
Cedar Creek Res	CCM 25	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
Stream Screening					
Clarks River	ClRM 10	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
Duck River	DRM 26	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
Buffalo River	BuRM 18	CHC	5	Composite	Screening - Metals and Organics
		SMB	5	Composite	Mercury only
Bear Creek	BCM 27	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only

Appendix B, Continued

Study Type/Location	River Mile	Species	# Needed	Ind/Comp	Analytes
Stream Screening, cont.'					
L'Tenn River	LTRM 95	CHC	5	Composite	Screening - Metals and Organics
		SMB	5	Composite	Mercury only
Tuckasegee River	TuRM 10	CHC	5	Composite	Screening - Metals and Organics
		SMB	5	Composite	Mercury only
French Br. River	FBRM 77	CHC	5	Composite	Screening Metals and Organics
		LMB	5	Composite	Mercury only
Nolichucky River	NolRM 10	CHC	5	Composite	Screening - Metals and Organics
		SMB	5	Composite	Screening - Mercury only
Pigeon River	PiRM 7	CHC	5	Composite	Screening - Metals and Organics
		SPB	5	Composite	Mercury only

Targeted Screening -- None Planned for 1996

Intensive Study -- None Planned for 1996

Appendix B, Continued

Study Type/Location	River Mile	Species	# Needed	Ind/Comp	Analytes
Long-Term Monitoring					
Fort Loudoun Res	TRM 624	CHC	10	Ind	PCBs, DDTr, and Chlordane
Watts Bar Res	TRM 531	STB	5	Composite	PCBs, DDTr, Chlordane
	TRM 560	STB	5	Composite	PCBs, DDTr, Chlordane
	TRM 600	STB	5	Composite	PCBs, DDTr, Chlordane
	CRM 22	STB	5	Composite	PCBs, DDTr, Chlordane
Parksville Res	ORM 16	CHC	5	Comp.	PCBs, DDTr, and Chlordane

a. Note: These recommendations were not final at the time this document was prepared.

Appendix C

New Release from the Alabama Department of Public Health Revising Fish Consumption Advisories

April 24, 1996

NEWS RELEASE DEPARTMENT OF PUBLIC HEALTH

434 Monroe Street, Montgomery, Alabama 36130-3017 • (334) 613-5300 • FAX (334) 240-3097

ADPH revises fish consumption advisories

FOR IMMEDIATE RELEASE

CONTACT: Brian Hughes, Ph.D.
(334) 613-5347

The Alabama Department of Public Health announces it has lifted its fish consumption advisories for the Tennessee River, but it has added new fish consumption advisories for the Fish River in Baldwin County, Logan-Martin Lake and Choccolocco Creek.

Advisories are issued because toxic chemicals in lakes or rivers accumulate in fish tissue. The people who eat these fish may face health risks. These advisories are updated based on the results of fish tissue monitoring conducted by the Alabama Department of Environmental Management and the Tennessee Valley Authority.

Previous advisories to avoid or restrict consumption of fish taken from the Tennessee River have been removed. These recommendations are based on steadily decreasing DDT concentrations which fall below the Food and Drug Administration action level of five parts per million of DDT in fish.

New advisories are as follows:

Fish River: The public is advised not to eat largemouth bass taken from the Fish River in Baldwin County because mercury levels have been found to exceed the FDA action level of 1 part per million. Mercury levels found in fish samples from the Fish River do not cause immediate health effects; however, at high levels mercury has been known to damage the nervous system and kidneys.

Choccolocco Creek: The department recommends that people not eat fish taken from Choccolocco Creek. This advisory now extends from the point where Hillabee Creek and Choccolocco Creek meet in Calhoun County downstream to Logan Martin Lake.

This action is based on the results of largemouth bass and channel catfish sampling on Choccolocco Creek 2.5 miles east southeast of Oxford. The fish in this area were found to have PCB levels above the Food and Drug Administration's recommended level of 2 parts per million.

(more)

Fish advisories
Add one

Logan Martin Lake: Another fish consumption advisory is being issued for Logan Martin Lake. The public is advised not to eat largemouth bass, spotted bass and catfish from the lake.

The department recommends that fish not be eaten from Logan Martin Lake because largemouth bass, spotted bass and catfish were found to contain levels of PCBs exceeding the FDA recommended level. The department recommends that these three species should not be consumed from an area near Riverside, Ala., in St. Clair County downstream to the dam.

PCBs are listed as possible cancer-causing agents in humans. When tested in levels greatly exceeding those typically found in the environment, PCBs have been associated with the following health effects:

- a skin disorder known as chloracne,
- changes in cholesterol and triglyceride levels in the blood, and
- tumors in certain rodents.

Advisories are made based on samples which were taken as a part of a five-year fish program in which samples are analyzed annually. The Alabama Department of Environmental Management will provide additional testing this fall in the Coosa and Fish River areas. Current fish consumption advisories are listed here:

BODY OF WATER	PORTION	TYPE OF ADVISORY
Coosa River	Between Logan Martin Dam and Riverside	Do not consume largemouth and spotted bass and all species of catfish**
Coosa River	Between Riverside & Alabama-Georgia state line	Limited consumption of catfish over 1 pound*
Huntsville Spring Branch & Indian Creek	From Redstone Arsenal to the Tennessee River	Do not consume channel catfish, smallmouth buffalo, brown bullhead, bigmouth buffalo, white bass**

(more)

Fish advisories
Add two

BODY OF WATER	PORTION	TYPE OF ADVISORY
West Point Lake to Lake Harding	West Point Lake, Lake Harding & the intervening stretch of the Chattahoochee River	Do not consume catfish**
Cold Creek Swamp	10 miles south of the confluence of the Tombigbee River & Alabama River adjacent to the Mobile River	Do not consume any fish**
Tombigbee River	Olin Basin at river mile 60.5	Do not consume largemouth bass, channel catfish**
Choccolocco Creek	Between the confluence of Hillabee Creek and Choccolocco Creek south of Oxford, downstream to where Choccolocco Creek flows into Logan Martin Lake	Do not consume any fish**
Fish River		Do not consume largemouth bass**

* A limited consumption advisory states that women of reproductive age and children less than 15 years old should avoid eating certain fish from these areas. Other people should limit their consumption of the particular species to one meal per month.

** Everyone should avoid eating the species of fish listed in the defined area.

Appendix D

Species and River Abbreviations Used in Tables and Appendices

Appendix D. Species and River Abbreviations Used in Tables and Appendicies.

Abbreviations for Species

CHC -- Channel catfish
LMB -- Largemouth bass
SBU -- Smallmouth buffalo
SMB -- Smallmouth bass
SPB -- Spotted bass
STB -- Striped bass

Abbreviations for Rivers and Creeks

BEC -- Bear Creek
BEE -- Beech River
BLU -- Big Sandy River
BUF -- Buffalo River
CLA -- Clarks River
DUC -- Duck River
ELK -- Elk River
HIW -- Hiwassee River
HOL -- Holston River
LTE -- Little Tennessee River
NFH -- North Fork Holston River
OCO -- Ocoee River
PIG -- Pigeon River
SEQ -- Sequatchie River
TEN -- Tennessee River Mile
TUC -- Tuckasegee River

Abbreviations with River Miles

BCM -- Bear Creek Mile
BCRM -- Bear Creek River (Creek) Mile
BSRM -- Big Sandy River Mile
BuRM -- Buffalo River Mile
CCM -- Cedar Creek Mile
ClRM -- Clarks River Mile
CRM -- Clinch River Mile
DRM -- Duck River Mile
ERM -- Elk River Mile
FBRM -- French Broad River Mile
HiRM -- Hiwassee River Mile
HRM -- Holston River Mile
LBCM -- Little Bear Creek Mile
LTRM -- Little Tennessee River Mile
NolRM -- Nolichucky River Mile
ORM -- Ocoee River Mile
PiRM -- Pigeon River Mile
ShoCrM -- Shooting Creek Mile
TRM -- Tennessee River Mile
TuRM -- Tuckasegee River Mile

Results from TVA Fish Tissue Studies on Fish Collected Autumn 1994 and Recommendations for Studies in 1995

By: Don L. Dycus
TVA Water Management
June 1995

Introduction/Background

The attached tables summarize results of TVA's fish tissue studies conducted in autumn 1994. These tables and this cover text constitute TVA's report on these results.

TVA's approach to fish tissue contaminant examination is to first conduct screening studies in which composited samples of an indicator species, such as channel catfish for organics and largemouth bass for mercury, are examined for a broad array of analytes. Results from screening studies are used to provide direction for future action. If screening finds low contaminant concentrations, the site or reservoir would be resampled at the screening level on a rotational basis in 3 to 5 years. If one or more analytes had somewhat elevated concentrations, that site would be resampled the next year and samples analyzed for the analyte(s) of concern in a targeted screening study. If concentrations in screening efforts or targeted screening efforts were sufficiently high to pose potential human health concerns, the site or reservoir would need to be examined in an intensive study aimed at determining the species affected, the geographical distribution, and year-to-year variation. Analysis of individual fish (generally 10 replicates) of important species from several locations provide the data base for statistical examinations. The assessment phase would continue until the contaminant concentration was low enough to no longer be a concern or when year-to-year studies indicated no trend through time. If the former were the case, the site or reservoir would return to the rotational system. If the latter were the case, a long-term monitoring study, with either annual or rotational collections (whichever is appropriate), would be undertaken. The idea for long-term monitoring is to track the problem analyte so that when concentrations drop below the level of concern a follow-up intensive study can be conducted to document the problem no longer exists. Generally, composites of indicator species are analyzed in the contaminant of concern in long-term monitoring studies.

Methods

Details of TVA's collection, processing, and analysis procedures are described in the report on 1993 fish tissue studies -- "Tennessee Valley Reservoir and Stream Quality - 1993; Fish Tissue Studies in the Tennessee Valley in 1993" by D.L. Williams and D.L. Dycus. The report was published in July 1994 and is available from:

Water Management Library
Tennessee Valley Authority
1101 Market Street, CST 16B
Chattanooga, TN 37402-2810
(615) 751-7338 or FAX: (615) 751-7479

One noteworthy change for samples collected for 1994 fish tissue studies is that in addition to the typical list of organochlorine pesticides analyzed, organophosphate and chlorophenoxy pesticides were analyzed as recommended by the U.S. EPA in their "Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories; Volume 1 Fish Sampling and Analysis" (EPA 823-R-93-002, August 1993). These include

New organochlorine pesticides: dicofol

Organophosphate pesticides: chlorpyrifos, diazinon, disulfoton, ethion, terbufos, and carbophenothion

Chlorophenoxy pesticides: oxyfluorfen

Summary of Results

Results from the various fish tissue studies conducted in 1994 are summarized in Tables 1 - Table 11. Physical information such as length and weight for each fish is in Appendix A, Tables 1 - 6. Details of study results are available on STORET.

In general, 1994 results were similar to previous years. The most common contaminant of concern was PCBs. Locations (regardless of study type) with PCB concentrations >0.5 µ/g are listed in **Table 1**. Given the increasing interest in mercury, locations (regardless of study type) with total mercury >0.40 µ/g are listed in **Table 2**.

Boxes on the following pages summarize, by study type, locations examined in 1994, highlights of results, and recommendations for fish tissue studies in 1995. Recommendations for fish tissue studies in 1995 are listed in Appendix B. (Note: These recommendations were not final at the time this document was prepared.)

Screening Studies

Reservoirs: Results in Table 3 and Appendix Table A-1.

Reservoirs sampled in Autumn 1994: Beech and Douglas.

Results highlights: None of the analytes in either reservoir were sufficiently high to be noteworthy.

Recommendations: Neither of these reservoirs need to be resampled until they come up again in the standard 3-year rotation. Several reservoirs have not been sampled recently and need to be included in the rotation in 1995. However, routine fish community studies, which usually provide most of the fish for analysis, will not be conducted on all of these reservoirs in 1995 so they will not be sampled until 1996. Reservoirs to be sampled in 1995 include: Kentucky, Normandy, Beech, Tims Ford, Chickamauga, Fort Loudoun, and Fort Patrick Henry.

Rivers: Results in Table 4 and Appendix Table A-2.

Rivers sampled in summer 1994: Clarks, Duck, Buffalo, Elk, Hiwassee, Ocoee, Little Tennessee, Tuckasegee, French Broad, Nolichucky, Pigeon, North Fork Holston.

Results highlights: None of the organochlorine pesticides or PCBs were high enough to be noteworthy. Only one sample contained detectable levels of one of new pesticides examined for the first time on 1994 fish (see methods). The channel catfish sample from Hiwassee River Mile 38 contained 0.05μ/g of ethion. None of the other samples, regardless of location or study, had detectable levels of any of these pesticides. Mercury was the only metal found in sufficiently concentrations to be of interest. Sample locations with mercury concentrations >0.4μ/g are listed in Table 2.

Recommendations: Six of the river screening sites were sampled for the first time in 1994. These (Clarks, Buffalo, Ocoee, Tuckasegee, Pigeon, and North Fork Holston) should be resampled in summer 1995. Fish tissue samples have never been collected from Bear Creek, so that site should be sampled in 1995. Two other sites (Sequatchie and Holston) were not sampled in 1994 and should be in 1995 to take advantage of fish communities studies planned for those sites.

Targeted Screening Studies

Reservoirs: Results in Table 5 and Appendix Table A-3.

Reservoirs sampled in Autumn 1994, including analytes and species of concern:

- Wheeler (PCBs - channel catfish)
- Chickamauga (inflow only, PCBs - channel catfish)
- Parksville (PCBs - channel catfish)
- Tellico (mercury - largemouth bass)
- Cherokee (PCBs - channel catfish).

Results highlights: PCB concentrations were near or above 1.0 μ/g in the reservoirs listed above. This is sufficiently high to repeated targeted screening in 1995, but not so high as to warrant intensive investigations. Mercury concentrations in Tellico largemouth bass were relatively low, indicating no need for further sampling in 1995. None of the screening studies conducted in 1994 indicated a need for Targeted Screening studies in 1995.

Recommendations: Targeted screening studies will be conducted on the following reservoirs in 1995: Wheeler (PCBs - channel catfish), Cherokee (PCBs - channel catfish and striped bass/hybrids), Nickajack (PCBs - channel catfish and striped bass/hybrids, Parksville (PCBs - channel catfish). Targeted screening samples will not be conducted on Chickamauga in 1995 because channel catfish from that reservoir will examined in Reservoir Screening studies, which include a broad list of analytes including PCBs.

Rivers: None sampled for Targeted Screening in 1994; none needed in 1995.

Intensive Studies

Reservoirs: Results in Table 6, 7, and 8 and Appendix Table A-4.

Reservoirs sampled in 1994, including analytes and species of concern: Nickajack (PCBs - striped bass).

Results highlights: The average of the 10 striped bass collected from TRM 469 in autumn 1995 was 1.2μ/g and the range was 0.7 to 2.1μ/g. In 1992 the mean was 0.8μ/g and in 1993 1.0μ/g. Striped bass collected for analysis in 1994 were larger than in the previous years (mean weights were 2305g in 1992, 4360g in 1993, and 7987g in 1994. Preliminary examination for covariance analysis indicated a relationship between PCB concentrations and fish weights (but not lipid content), hence adjustment of PCB concentrations for fish weights was necessary for statistical comparisons among years. Adjusted PCB concentrations were not significantly different among years at $\alpha = 0.05$.

Recommendations: These results were provided to the Tennessee Department of Environment and Conservation for evaluation of potential human health implications. TDEC has advised pregnant women, nursing mothers, and children should not eat channel catfish from Nickajack, others should limit consumption to 1.2 pounds per month. Given the consistency in PCB concentrations for the past three years, striped bass from Nickajack will not be sampled for an Intensive Study in 1995, rather they will be sampled as part of a Targeted Screening study in 1995. This means a 5-fish composite will be collected from TRM 469-470 and analyzed for selected organics including PCBs. Channel catfish will also be collected for that study.

Rivers: None sampled for Intensive Studies in 1994; none needed in 1995.

Long-Term Monitoring Studies

Reservoirs: Results in Table 9, 10, and 11 and Appendix Tables A-5 and A-6.

Reservoirs sampled in autumn 1994, including analytes and species of concern:

Nickajack (PCBs - channel catfish)
Watts Bar (PCBs - channel catfish and smallmouth buffalo)
Fort Loudoun (PCBs - channel catfish)
Tellico (PCBs - channel catfish).

Results Highlights: TDEC has issued fish consumption advisories on all these reservoirs due to PCB contamination. They have all been examined intensively during past years and are now the long-term monitoring phase. Nickajack is the only reservoir which has exhibited a decrease in PCB concentrations. Table 8 summarizes PCB concentrations in various species over the past seven years. Mean concentrations in channel catfish taken from near Nickajack Dam (TRM 425) for the period 1988 - 1994 have been 0.9, 1.3, 1.0, 1.5, 0.4, 0.6, and 0.7μ/g, respectively and at TRM 457 for the same period 1.3, 0.7, 1.1, 0.9, 0.5, 0.7, and 0.7μ/g, respectively. (Note: data for all years except 1994 are means from fish analyzed individually; whereas, one, 5-fish composite was analyzed from each location in 1994.)

PCB concentrations in channel catfish from Watts Bar, Fort Loudoun, and Tellico have varied from year to year but no trend (either increasing or decreasing) is evident. PCB concentrations in catfish from these three reservoirs in 1994 were within the range of concentrations observed in past studies; again indicating no trend.

Analyses were based on 5-fish composites for all reservoirs except Fort Loudoun where 9 individual catfish were analyzed from the long-term, trend site at TRM 624. Individuals were examined from this site because it is has been monitored longer than any other TVA site with all previous years based on analysis of individual samples. PCB concentration each fish is shown in Table 10 along with other important results. Concentrations averaged 1.6μ/g with a range of 0.6 to 3.1μ/g in 1994. Table 11 compares 1994 results to previous year; mean concentrations from 1985 and 1986 to 1994 were 1.4, 1.5, 1.2, 2.3, 1.0, 2.5, 1.8, 1.2, and 1.6, respectively. Fish weights, an important variable in fish tissue studies, have varied among years. Preliminary examination for covariance analysis identified a relationship between fish weight and PCB concentration but not for lipid content, another important variable. Covariance analysis found a significant difference in adjusted PCB concentrations among years but there was no pattern or trend.

Recommendations: Given that fish consumption advisories have been issued for these reservoirs, these studies will be repeated in 1995.

Rivers: None sampled for Long-Term Monitoring Studies in 1994; none needed in 1995.

Table 1. Highlights of Autumn 1994 Results from Areas with Advisories and/or "High" (i.e., >0.5 µg/g) PCB Concentrations. All Samples Analyzed as 5-Fish Unless Otherwise Noted

Location		Species	PCBs	DDTr	Chlordane
Wheeler Reservoir	TRM 277	CHC	0.8	1.0	0.02
	TRM 296	CHC	1.0	0.8	0.02
	TRM 347	CHC	1.3	0.55	0.03
Nickajack Reservoir	TRM 425	CHC	0.7	0.08	0.03
	TRM 457	CHC	0.7	0.07	0.02
		STB[a]	1.2	0.23	0.07
Chick. Reservoir	TRM 529	CHC	1.0	0.10	0.04
Watts Bar Reservoir	TRM 530	CHC	1.0	0.12	0.06
		SMB	0.6	0.07	0.02
	TRM 560	CHC	1.0	0.12	0.05
		SMB	0.4	0.05	0.02
	TRM 600	CHC	1.0	0.16	<0.01
Ft. Loudoun Res.	TRM 624	CHC[b]	1.6	0.10	0.06
Tellico Reservoir	LTRM 1	CHC	2.3	0.26	0.10
	LTRM 15	CHC	1.1	0.18	0.04
Ocoee Reservoir #3	ORM 12	CHC	1.2	0.04	0.01
		CHC	1.7	0.05	<0.01
Cherokee Reservoir	HRM 53	CHC	0.9	0.04	0.04
	HRM 76	CHC	0.8	0.02	0.04

a. Average of 10 striped bass analyzed individually
b. Average of 9 channel catfish analyzed individually

Table 2. Highlights of Autumn 1994 Results from Areas with "Elevated" (i.e., >0.40 µg/g) Total Mercury Concentrations. For Largemouth (LMB), Smallmouth (SMB), and Spotted (SPB) Bass, Analysis Conducted on Largest of Five Individuals Collected from a Site. For Channel Catfish (CHC), Analysis conducted on 5 Composited Individuals

Location	Species	Weight (gm, if individual)	Mercury (Total, µg/g)
Clarks River Mile 9	LMB	1434	0.57
Duck River Mile 22	LMB	1670	0.50
Buffalo River Mile 17	SMB	708	0.52
Elk River Mile 41	SPB	548	0.48
Hiwassee River Mile 38	LMB	964	0.58
Ocoee River Mile 2	LMB	996	0.91
Little Tenn. River Mile 94	SMB	415	0.60
Tuckasegee River Mile 15	SMB	410	0.63
French Broad River Mile 78	SMB	1474	0.82
N. Fork Hol. River Mile 4	CHC	Composite	0.74

Note: Additional bass samples were collected from the Nolichucky (SPB), Pigeon (SPB), and North Fork Holston (SMB) rivers; all had concentrations < 0.40 µg/g. Additional mercury data are in the following tables.

Table 3. Concentrations (ug/g) of organics and metals in composited fish samples from reservoir screening locations collected in autumn 1994

Organochlorine Pesticides and PCBs

Reservoir/River	Species	Lipid	Mirex	Toxa	Hepta	Aldrin	Benz	DDTr	Dield	Endosu	Endri	Chlor	PCBs	Dicofol
Beech Reservoir														
BeeRM 36	CHC	7.8	<0.008	<0.5	<0.01	<0.01	<0.01	0.32	<0.01	<0.01	<0.01	<0.01	<0.1	<0.01
Douglas Reservoir														
FBRM 33	CHC	4.0	<0.008	<0.5	<0.01	<0.01	<0.01	0.11	<0.01	<0.01	<0.01	0.04	0.2	<0.01
FBRM 51	CHC	7.8	<0.008	<0.5	<0.01	<0.01	<0.01	0.11	<0.01	<0.01	<0.01	0.05	0.2	<0.01

Organophosphate and Chlorophenoxy Pesticides

Reservoir/River	Species	Lipid	Chlorpyrif	Diazinon	Disulfoton	Ethioin	Terbufos	Carbophen	Oxyfluor
Beech Reservoir									
BeeRM 10	CHC	7.8	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.5
Douglas Reservoir									
FBRM 33	CHC	4.0	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.5
FBRM 51	CHC	7.8	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.5

Metals

Reservoir/River	Species	Arsenic	Cadmium	Lead	Mercury	Selenium
Beech Reservoir						
BeeRM 10	CHC	<0.10	<0.05	<0.02	0.14	<0.2
	LMB				0.25	
Douglas Reservoir						
FBRM 33	CHC	<0.10	<0.05	<0.02	0.26	<0.2
FBRM 51	CHC	<0.10	0.05	0.04	0.18	<0.2

Table 4. Concentrations of organics and metals in composited fish samples from stream screening locations in summer 1994

Organochlorine Pesticides and PCBs

River	Mile	Spec	Lipid	Mirex	Toxa	Hepta	Aldri	BenzHe	DDTr	Dieldr	Endosu	Endri	Chlor	PCBs	Dicofol
Buffalo R	18	CHC	3.9	<0.008	<0.5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.4	<0.01
Clarks R	10	CHC	9.8	<0.008	<0.5	<0.01	<0.01	<0.01	0.02	0.04	<0.01	<0.01	0.02	0.1	<0.01
Duck R	22	CHC	4.7	<0.008	<0.5	<0.01	<0.01	<0.01	0.05	0.01	<0.01	<0.01	<0.01	0.1	<0.01
Elk R	41	CHC	5.8	<0.008	<0.5	<0.01	<0.01	<0.01	0.36	<0.01	<0.01	<0.01	<0.01	<0.1	<0.01
French Broad R	78	CHC	4.8	<0.008	<0.5	<0.01	<0.01	<0.01	0.03	<0.01	<0.01	<0.01	0.01	<0.1	<0.01
Hiwassee R	38	CHC	9.1	<0.008	<0.5	<0.01	<0.01	<0.01	0.03	<0.01	<0.01	<0.01	0.01	0.2	<0.01
Little Tennessee R	94	CHC	6.8	<0.008	<0.5	<0.01	<0.01	<0.01	0.04	<0.01	<0.01	<0.01	0.02	0.1	<0.01
N. Fk. Holston R	4	CHC	9.5	<0.008	<0.5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.3	<0.01
Nolichucky R	8	C	6.9	<0.008	<0.5	<0.01	<0.01	<0.01	0.04	<0.01	<0.01	<0.01	<0.01	<0.1	<0.01
Ocoee R	3	CHC	3.3	<0.008	<0.5	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	0.01	0.2	<0.01
Pigeon R	8	CHC	3.1	<0.008	<0.5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1	<0.01
Tuckasegee R	15	CHC	9.5	<0.008	<0.5	<0.01	<0.01	<0.01	0.04	<0.01	<0.01	<0.01	0.01	<0.1	<0.01

Organophosphate and Chlorophenoxy Pesticides

River	Mile	Species	Lipid	Chlorpyrif	Diazinon	Disulfoton	Ethion	Terbufos	Carbophen	Oxyfluor
Buffalo	18	CHC	3.9	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.5
Clarks R	10	CHC	9.8	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.5
Duck R	22	CHC	4.7	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.5

Table 4. Continued

Organophosphate and Chlorophenoxy Pesticides, Cont'

River	Mile	Species	Lipid	Dursban	Diazinon	Disulfoton	Ethion	Terbufos	Carbophen	Oxyfluor
Elk R	41	CHC	5.8	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.5
French Broad R	78	CHC	4.8	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.5
Hiwassee R	38	CHC	9.1	<0.01	<0.01	<0.01	0.05	<0.01	<0.01	<0.5
Little Tennessee R	94	CHC	6.8	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.5
N. Fk. Holston R	4	CHC	9.5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.5
Nolichucky R	8	C	6.9	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.5
Ocoee R	3	CHC	3.3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.5
Pigeon R	8	CHC	3.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.5
Tuckasegee R	15	CHC	9.5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.5

Metals

River	Mile	Species	Arsenic	Cadmium	Lead	Mercury	Selenium
Buffalo R	18	CHC	<0.10	<0.05	<0.02	0.11	<0.2
		SMB				0.52	
Clarks R	10	CHC	<0.10	<0.05	0.03	0.10	<0.2
		LMB				0.57	
Duck R	22	CHC	<0.10	<0.05	<0.02	<0.10	<0.2
		LMB				0.50	
Elk R	41	CHC	<0.10	<0.05	<0.02	<0.10	<0.2
		SPB				0.48	

Table 4. Continued

River	Mile	Species	Arsenic	Cadmium	Lead	Mercury	Selenium
				Metals, Cont'			
French Broad R	78	CHC	<0.10	<0.05	0.05	<0.10	<0.2
		SMB				0.82	
Hiwassee R	38	CHC	<0.10	<0.05	0.02	<0.10	<0.2
		LMB				0.58	
Little Tennessee R	94	CHC	<0.10	<0.05	<0.02	0.38	<0.2
		SMB				0.60	
N. Fk. Holston R	4	CHC	<0.10	<0.05	0.04	0.74	<0.2
		SMB				0.31	
Nolichucky R	8	C	<0.10	<0.05	0.11	0.20	<0.2
		SPB				0.38	
Ocoee R	3	CHC	<0.10	<0.05	0.05	0.12	0.2
		LMB				0.91	
Pigeon R	8	CHC	<0.10	<0.05	0.04	0.12	<0.2
		SPB				0.34	
Tuckasegee R	15	CHC	<0.10	<0.05	<0.02	0.19	<0.2
		SMB				0.63	

Table 5. Concentrations (ug/g) of selected organics and metals in composited fish samples from reservoir targeted screening locations in 1994

Selected Organochlorine Pesticides and PCBs

Reservoir/River	Species	Lipid	Mirex	Toxa	Hepta	Aldrin	Benz	DDTr	Diel	Endosul	Endri	Chlor	PCBs	Dicofol
Chickamauga Reservoir -														
TRM 529	CHC	13						0.10				0.04	1.0	
Cherokee Reservoir														
HolRM 53	CHC	4.6						0.04				0.04	0.9	
HolRM 76	CHC	6.1						0.02				0.04	0.8	
Parksville(Ocoee #1) Reservoir														
OcoRM 12	CHC	4.9						0.04				0.01	1.2	
OcoRM 16	CHC	7.4						0.05				0.01	1.7	
Wheeler Reservoir														
TRM 277	CHC	5.6						1.02				0.02	0.8	
TRM 296	CHC	9.5						0.80				0.02	1.0	
TRM 347	CHC	6.6						0.55				0.03	1.3	

Metals

Reservoir/River	Species	Arsenic	Cadmium	Lead	Mercury	Selenium
Tellico Reservoir						
LTRM 1	LMB				0.13	
LTRM 15	LMB				0.18	
Parksville (Ocoee #1) Reservoir						
OcoRM 12	CHC					0.4
OcoRM 16	CHC					0.5

'able 6. Concentrations of selected pesticides and PCBs in individual fish collected for a reservoir intensive tudy on Nickajack Reservoir in autumn 1994

Fish Number	Collection Date	Length (mm)	Weigth (gm)	Sex	Lipid (%)	PCBs (ug/gm)	Chlordane (ug/g)	DDTr (ug/g)
1	11/18/94	872	8809	female	13	1.1	0.1	0.15
2	11/18/94	774	5179	female	11	0.9	0.08	0.18
3	11/21/94	1010	12500	female	11	1.8	0.1	0.36
4	11/21/94	874	7627	female	9.4	1.2	0.07	0.15
5	11/21/94	776	5590	male	9.1	1.1	0.06	0.2
6	11/21/94	804	7711	female	12	0.7	0.05	0.1
7	11/21/94	791	6330	male	12	1	0.06	0.18
8	11/21/94	937	9895	female	10	2.1	0.11	0.6
9	11/21/94	830	7917	female	11	0.8	0.05	0.15
10	11/21/94	852	8309	female	11	1.3	0.06	0.18
Mean		852	7987		11	1.2	0.07	0.23

T . Summary of lengths, total weights, and percent lipids of el catfish, carp, and striped bass from Nickajack Reservoir, collected from 1988 to 1994

	Weight Range	Mean Weight	Length Range	Mean Length	% Lipid Range	Mean % Lipid
1988						
Catfish[a]						
TRM 425	1835-2705	2175	555--650	587	0.9--18.0	11.4
TRM 457	1198-2340	1854	472--602	540	8.9--20 0	13.6
1989						
Catfish						
TRM 425	346-1798	1048	331--565	458	3.0--20.0	10.3
TRM 457	308-1001	805	332--470	397	3 2--17.0	10.9
1990						
Catfish						
TRM 425	464-2332	1215	370--596	484	5.4--20.0	10.7
TRM 457	736-2429	1500	426--656	528	3.6--24.0	12.4
1991						
Catfish						
TRM 425	570-2512	1607	395--597	521	4.8--14.0	8.1
TRM 457	962-2839	2100	451--625	565	0.1--27.0	14.1
Carp						
TRM 425	1602-5017	3350	477--725	617	4.0--16.0	10.1
TRM 457	3522-7932	4958	633--780	686	3.9--14.0	9.4
1992						
Catfish						
TRM 425	762-1845	1144	446--585	497	2.3--12.0	7.3
TRM 457	883-2620	1453	463--610	516	2.3--20.0	10.1
Carp						
TRM 425	3460-8414	5150	633--846	708	2.6--12.0	6.2
TRM 457	3635-8943	6552	646--799	749	3.5--12.0	6.5
Striped Bass						
TRM 470	1619-3311	2305	494--686	594	7 3--12.0	9.1

T Continued

	Weight Range	Mean Weight	Length Range	Mean Length	% Lipid Range	Mean % Lipid
1993						
Catfish						
TRM 425	650-2359	1293	422-595	506	1.8-13.0	6.8
TRM 457	663-2141	1259	412-575	488	3.7-14.0	8.1
Carp						
TRM 425	2602-6881	5238	569-760	689	3.5-9.1	6.8
TRM 457	3768-6547	4972	655-750	704	2.9-10.0	5.3
Striped Bass						
TRM 469	1618-7324	4360	542-850	712	5.3-13.0	8.3
1994						
Catfish[b]						
TRM 425	1023-2341	1574	482-591	531	N/A	8.0
TRM 457	975-2790	1755	486-627	557	N/A	15.0
Striped Bass						
TRM 469	5179-12500	7987	776-1010	852	9.1-13.0	11.0

a. Collected in January and February 1989
b. Samples analyzed as single, 5-fish composites

T Summary of total PCB concentrations (μg/g) in catfish, c mallmouth buffalo, and striped bass fillets from Nickajack Reservoir, collected from 1988 to 1994

	Catfish		Carp		Smallmouth Buffalo		Striped Bass
	TRM 425	TRM 457	TRM 425	TRM 457	TRM 425	TRM 457	TRM 470
1988[a]							
Range	0.4-1.9	0.9-1.7					
Mean	0.9	1.3					
Number ≥ 2.0μg/g	0	0					
Number of fish	10	3					
1989							
Range	0.6-2.0	0.6-2.0					
Mean	1.3	0.7					
Number ≥ 2.0μg/g	1	1					
Number of fish	10	10					
1990							
Range	0.6-1.5	0.4-1.7					
Mean	1.0	1.1					
Number ≥2.0μg/g	0	0					
Number of fish	10	10					
1991							
Range	0 3-3.6	0.2-1.9	0.1-0.8	0.3-2.7	0 1-0.7	0.1-0 7	
Mean	1 5	0.9	0.3	1.2	0.2	0 4	
Number ≥2.0μg/g	2	0	0	1	0	0	
Number of fish	10	10	10	9	10	4	
1992							
Range	0.1-0.8	0.1-0.8	0.1-0 7	0.1-0.6			0.5-1.1
Mean	0.4	0.5	0 3	0.3			0.8
Number ≥2.0μg/g	0	0	0	0			0
Number of fish	10	10	10	9			8
1993							
Range	0.3-1.0	0.3-1.2	0.2-0.6	0.4-1.8			0 6-1.9
Mean	0.6	0.7	0.3	0.7			1.0
Number ≥ 2.0μg/g	0	0	0	0			0
Number of fish	10	10	10	10			10
1994							
Range							0.7-2.1
Mean	0.7	0.7					1.2
Number ≥2.0μg/g							1
Number of fish	b	b					10

a. Catfish collected in January and February 1989.

b. One, 5-fish composite analyzed

Table [illegible]. Concentrations (ug/g) of selected organochlorine pestic[illegible] and PCBs in composited fish samples for reservoir long-term monitoring studies in autumn 1994

Reservoir/River	Species	Lipid	Mirex	Toxa	Hepta	Aldrin	BenzHe	DDTr	Dield	Endosu	Endri	Chlor	PCBs	Dicofol
Tellico Reservoir														
LTRM 1	CHC	6.4						0.26				0.10	2.3	
LTRM 15	CHC	2.6						0.18				0.04	1.1	
Nickajack Reservoir														
TRM 425	CHC	8.0						0.08				0.04	0.7	
TRM 457	CHC	15						0.07				0.02	0.7	
Watts Bar Reservoir														
TRM 530	CHC	5.5						0.12				0.06	1.0	
	SBU	11						0.07				0.02	0.6	
TRM 560	CHC	4.6						0.12				0.05	1.0	
	SBU	10						0.05				0.02	0.4	
TRM 600	CHC	2.5						0.16				<0.01	1.0	
	SBU	10						0.10				0.16	0.9	

'able 10. Concentrations of selected organochlorine pesticides and PCBs in individual fish samples for reservoir ɔng-term monitoring studies on Fort Loudoun Reservoir in autumn 1994

Number	Collection Date	Length (mm)	Weigth (g)	Sex	Lipid (%)	PCBs (ug/g)	Chlordane (ug/g)	DDTr (ug/g)
1	10/4/94	480	1166	male	3	3.1	0.04	0.22
2	10/4/94	390	500	male	3.2	2.2	0.09	0.13
3	10/4/94	485	1026	male	5.7	1.6	0.04	0.08
4	10/4/94	385	442	male	2.4	0.9	0.02	0.04
5	10/4/94	662	2676	female	1.6	0.9	0.03	0.06
6	10/5/94	417	538	male	0.7	1.1	0.03	0.07
7	10/5/94	455	822	male	4.1	2.5	0.17	0.17
8	10/5/94	416	515	female	1.7	0.6	0.06	0.06
9	10/5/94	365	425	male	4	1.1	0.03	0.06
Mean		451	901		2.9	1.6	0.06	0.10

Table 11. Summary of PCB concentrations in channel catfish (the only species sampled in 1994), carp, and white bass collected from Fort Loudoun Reservoir since 1985; collected in autumn 1994 for long-term monitoring study

	Location TRM	PCB Range (ug/g)	Mean (ug/g)	No.≥2.0 (ug/g)	# Fish
Catfish					
1985	628	0.2-2.8	1.4	2	10
1987	628	0.1-4.5	1.5	2	10
1988	628	0.2-4.4	1.2	1	10
1989	628	0.6-4.3	2.3	11	20
1990	628	0.3-1.9	1.0	0	10
1991	624	1.4-4.6	2.5	7	10
1992	624	0.1-4.2	1.8	3	9
1993	624	0.4-2.2	1.2	2	10
1994	**624**	**0.6-3.1**	**1.6**	**3**	**9**
Carp					
1992	651	0.2-0.9	0.6	0	10
White Bass					
1987[a]	628	b	<0.1	a	5
	640	b	<0.1	a	5
1992	651	0.3-1.2	0.5	0	10

a. Catfish were sampled from TRMs 624-629. White bass and carp were collected from TRM 651 in 1992.

b. Five white bass were collected from TRMs 628 and 640 in 1987. Each set of five was analyzed as a composite sample.

Appendix A

Specific physical information on all fish collected for fish tissue sstudies in 1995

Table A-1
Specific physical information on composite fish collected for tissue ~~stream and~~ reservoir locations as part of screening studies.

Co'``on Site	Date	Species	Length(mm)	Weight(g)	Sex	LABID
BE KE						
BEECH R 10.0	10/03/94	CHC	595	2220	Female	
BEECH R 10.0	10/03/94	CHC	560	2300	Female	
BEECH R 10.0	10/03/94	CHC	495	820	Female	
BEECH R 10.0	10/03/94	CHC	420	480	Female	
BEECH R 10.0	10/03/94	CHC	500	1220	Female	
BEECH R 10.0	10/03/94	LMB	545	2640	Female	
BEECH R 10.0	10/03/94	LMB	340	460	Male	
BEECH R 10.0	10/03/94	LMB	345	560	Male	
BEECH R 10.0	10/03/94	LMB	315	380	Female	
BEECH R 10.0	10/03/94	LMB	330	460	Female	
DOUGLAS						
FRENCH BROAD R	09/09/94	CHC	567	1758	Male	
FRENCH BROAD R	09/09/94	CHC	595	1640	Male	
FRENCH BROAD R	09/09/94	CHC	394	460	Male	
FRENCH BROAD R	11/22/94	CHC	527	1398	Male	
FRENCH BROAD R	11/22/94	CHC	547	1834	Male	
~~FRENCH BROAD R~~	~~/ /~~	~~CHC~~	~~0~~	~~0~~	~~Female~~	
~~FRENCH BROAD R~~	~~/ /~~	~~CHC~~	~~0~~	~~0~~	~~Female~~	
~~FRENCH BROAD R~~	~~/ /~~	~~CHC~~	~~0~~	~~0~~	~~Female~~	
H BROAD R	09/09/94	CHC	477	1182	Female	
H BROAD R	11/30/94	CHC	420	679	Male	
FRENCH BROAD R	11/30/94	CHC	480	1138	Female	
FRENCH BROAD R	11/30/94	CHC	413	601	Female	
FRENCH BROAD R	11/30/94	CHC	447	780	Female	

Table A-2
Specific physical information on composite fish collected for tissue stream ~~and reservoir~~ locations as part of screening studies.

Cc' -ion Site	Date	Species	Length(mm)	Weight(g)	Sex	LABID
3L RIVER						
BUFFALO R 17.7	07/13/94	CHC	386	602	Female	
BUFFALO R 17.7	07/13/94	CHC	444	754	Male	
BUFFALO R 17.7	07/13/94	CHC	458	962	Male	
BUFFALO R 17.7	07/13/94	CHC	379	524	Female	
BUFFALO R 17.7	07/13/94	CHC	392	484	Female	
BUFFALO R 17.7	07/13/94	SMB	378	708	Female	
BUFFALO R 17.7	07/13/94	SMB	245	178	Male	
BUFFALO R 17.7	07/13/94	SMB	258	208	Male	
BUFFALO R 17.7	07/13/94	SMB	264	218	Female	
LOWER TENNESSE R						
CLARKS R 9.8	07/14/94	CHC	546	2230	Female	
CLARKS R 9.8	07/14/94	CHC	399	586	Female	
CLARKS R 9.8	07/14/94	CHC	418	718	Female	
CLARKS R 9.8	07/14/94	CHC	413	694	Female	
CLARKS R 9.8	07/14/94	LMB	414	1202	Female	
CLARKS R 9.8	07/14/94	LMB	366	882	Male	
CLARKS R 9.8	07/14/94	LMB	430	1434	Female	
CLARKS R 9.8	07/14/94	LMB	356	724	Female	
CLARKS R 9.8	07/14/94	LMB	390	1004	Female	
I ; R 9.8	07/14/94	LMB	0	0	Female	
DU VER						
DUCK RIVER 22.5	07/12/94	CHC	389	460	Male	
DUCK RIVER 22.5	07/12/94	CHC	404	604	Male	
DUCK RIVER 22.5	07/12/94	CHC	375	504	Male	
DUCK RIVER 22.5	07/12/94	CHC	351	390	Female	
DUCK RIVER 22.5	07/12/94	CHC	352	392	Male	
DUCK RIVER 22.5	07/12/94	LMB	467	1670	Female	
DUCK RIVER 22.5	07/12/94	LMB	471	1534	Female	
ELK RIVER						
ELK R (TRIB. TO	05/10/94	CHC	458	958	Male	
ELK R (TRIB. TO	05/10/94	CHC	443	892	Male	
ELK R (TRIB. TO	05/10/94	CHC	417	652	Male	
ELK R (TRIB. TO	05/10/94	CHC	431	778	Male	
ELK R (TRIB. TO	05/10/94	CHC	445	826	Male	
ELK R (TRIB. TO	06/30/94	SPB	233	168	Female	
ELK R (TRIB. TO	06/30/94	SPB	274	545	Male	
ELK R (TRIB. TO	06/30/94	SPB	248	440	Female	
ELK R (TRIB. TO	06/30/94	SPB	235	475	Female	
FRENCH BROAD RIVER						
FRFNCH BROAD R	06/13/94	CHC	420	728	Male	
H BROAD R	06/13/94	CHC	440	696	Male	
H BROAD R	06/13/94	CHC	448	632	Female	
FRENCH BROAD R	06/13/94	CHC	379	404	Male	

Table A-2

Specific physical information on composite fish collected for tissue stream ~~and reservoir~~ locations as part of screening studies.

C[illegible]ion Site	Date	Species	Length(mm)	Weight(g)	Sex	LABID
[illegible] BROAD R	06/16/94	CHC	314	262	Male	
FRENCH BROAD R	06/17/94	CHC	500	1016	Female	
FRENCH BROAD R	06/01/94	SMB	260	280	Male	
FRENCH BROAD R	06/01/94	SMB	260	214	Male	
FRENCH BROAD R	06/09/94	SMB	360	620	Female	
FRENCH BROAD R	06/09/94	SMB	460	1502	Female	
FRENCH BROAD R	06/16/94	SMB	486	1474	Female	
FRENCH BROAD R	06/16/94	SMB	215	114	Female	
FRENCH BROAD R	06/16/94	SMB	245	184	Female	
FRENCH BROAD R	06/17/94	SMB	230	162	Female	
HIWASSEE RIVER						
HIWASSEE R 38.0	07/05/94	CHC	317	286	Female	
HIWASSEE R 38.0	07/06/94	CHC	362	498	Male	
HIWASSEE R 38.0	07/07/94	CHC	331	364	Male	
HIWASSEE R 38.0	07/07/94	CHC	469	1046	Female	
HIWASSEE R 38.0	07/07/94	CHC	455	936	Male	
HIWASSEE						
HIWASSEE R 38.0	05/04/94	LMB	302	370	Female	
HIWASSEE R 38.0	07/05/94	LMB	344	500	Female	
HIWASSEE R 38.0	07/06/94	LMB	338	566	Female	
[illegible]SEE R 38.0	07/05/94	LMB	453	964	Female	
[illegible]SEE R 38.0	07/05/94	LMB	375	547	Male	
LITTLE TENNESSEE						
LITTLE TENNESSEE R	08/08/94	CHC	540	1674	Female	
LITTLE TENNESSEE R	08/08/94	CHC	350	382	Male	
LITTLE TENNESSEE R	06/20/94	SMB	250	198	Male	
LITTLE TENNESSEE R	06/21/94	SMB	265	220	Male	
LITTLE TENNESSEE R	06/21/94	SMB	305	415	Female	
LITTLE TENNESSEE R	06/21/94	SMB	250	232	Female	
LITTLE TENNESSEE R	06/21/94	SMB	275	256	Male	
HOLSTON RIVER						
N FK HOLSTON R	05/17/94	CHC	534	1522	Male	
N FK HOLSTON R	05/17/94	CHC	495	1232	Female	
N FK HOLSTON R	05/17/94	CHC	464	386	Male	
N FK HOLSTON R	05/17/94	CHC	453	950	Male	
N FK HOLSTON R	05/19/94	CHC	638	3102	Female	
N FK HOLSTON R	05/17/94	SMB	371	658	Female	
N FK HOLSTON R	05/17/94	SMB	436	1254	Male	
N FK HOLSTON R	05/17/94	SMB	341	502	Male	
N FK HOLSTON R	05/17/94	SMB	384	842	Female	
N FK HOLSTON R	05/17/94	SMB	364	590	Male	
N[illegible]CKY RIVER						
[illegible]HUCKY R 8.5	05/31/94	C	791	8534	Female	
NOLICHUCKY R 8.5	05/31/94	C	808	8232	Female	

Table A-2
Specific physical information on composite fish collected for tissue stream ~~and reservoir~~ locations as part of screening studies.

Collection Site		Date	Species	Length(mm)	Weight(g)	Sex	LABID
[illegible]UCKY R	8.5	05/31/94	C	622	2984	Male	
NOLICHUCKY R	8.5	05/31/94	C	580	2842	Male	
NOLICHUCKY R	8.5	05/31/94	C	492	1698	Male	
NOLICHUCKY R	8.5	05/31/94	SPB	377	806	Female	
NOLICHUCKY R	8.5	05/31/94	SPB	310	438	Female	
NOLICHUCKY R	8.5	05/31/94	SPB	291	336	Male	
NOLICHUCKY R	8.5	05/31/94	SPB	245	228	Female	
NOLICHUCKY R	8.5	05/31/94	SPB	259	240	Female	
OCOEE RIVER							
OCOEE R	2.5	07/19/94	CHC	382	392	Female	
OCOEE R	2.5	07/20/94	CHC	420	688	Female	
OCOEE R	2.5	07/20/94	CHC	501	1024	Female	
OCOEE R	2.5	07/20/94	CHC	391	500	Male	
OCOEE R	2.5	07/20/94	CHC	391	530	Male	
OCOEE R	2.5	07/19/94	LMB	308	316	Female	
OCOEE R	2.5	07/20/94	LMB	407	996	Male	
OCOEE R	2.5	07/20/94	LMB	334	408	Female	
OCOEE R	2.5	07/20/94	LMB	284	274	Male	
PIGEON RIVER							
PIGEON R	8.2	07/08/94	CHC	558	1935	Female	
[illegible]N R	8.2	07/08/94	CHC	414	585	Male	
[illegible]N R	8.2	07/08/94	CHC	336	380	Female	
PIGEON R	8.2	07/08/94	CHC	485	975	Female	
PIGEON R	8.2	07/08/94	CHC	464	855	Male	
PIGEON R	8.2	07/08/94	SPB	395	840	Female	
PIGEON R	8.2	07/08/94	SPB	360	660	Female	
PIGEON R	8.2	07/08/94	SPB	300	330	Male	
PIGEON R	8.2	07/08/94	SPB	330	500	Female	
PIGEON R	8.2	07/08/94	SPB	373	780	Female	
TUCKASEGEE RIVER							
TUCKASEGEE R	15.0	08/09/94	CHC	464	1034	Female	
TUCKASEGEE R	15.0	08/09/94	CHC	434	664	Female	
TUCKASEGEE R	15.0	08/09/94	CHC	405	592	Female	
TUCKASEGEE R	15.0	08/09/94	CHC	376	478	Male	
TUCKASEGEE R	15.0	08/09/94	CHC	402	562	Female	
TUCKASEGEE R	15.0	08/09/94	SMB	295	332	Male	
TUCKASEGEE R	15.0	08/09/94	SMB	250	210	Male	
TUCKASEGEE R	15.0	08/09/94	SMB	250	208	Male	
TUCKASEGEE R	15.0	08/09/94	SMB	315	410	Female	
TUCKASEGEE R	15.0	08/09/94	SMB	295	384	Female	

Table A-3

Specific physical information on composite fish collected for tissue ~~stream and~~ reservoir locations as part of targeted screening studies.

Co :ion Site	Date	Species	Length(mm)	Weight(g)	Sex	LABID
CH :E						
HOLSTON R 53.0	09/08/94	CHC	572	1902	Female	
HOLSTON R 53.0	09/08/94	CHC	362	430	Female	
HOLSTON R 53.0	11/29/94	CHC	554	1728	Male	
HOLSTON R 53.0	11/29/94	CHC	503	1135	Male	
HOLSTON R 53.0	11/29/94	CHC	492	1032	Male	
HOLSTON R 53.0	11/29/94	CHC	0	0	Female	
HOLSTON R 76.0	09/08/94	CHC	453	812	Female	
HOLSTON R 76.0	09/08/94	CHC	506	1300	Male	
HOLSTON R 76.0	09/08/94	CHC	445	712	Female	
HOLSTON R 76.0	09/08/94	CHC	364	484	Female	
HOLSTON R 76.0	09/08/94	CHC	370	560	Female	
TELLICO						
LITTLE TENNESSEE R	10/20/94	LMB	317	454	Male	
LITTLE TENNESSEE R	10/20/94	LMB	503	1954	Female	
LITTLE TENNESSEE R	10/20/94	LMB	447	1178	Female	
LITTLE TENNESSEE R	10/20/94	LMB	392	844	Male	
LITTLE TENNESSEE R	10/20/94	LMB	376	720	Male	
LITTLE TENNESSEE R	10/21/94	LMB	530	2650	Female	
LITTLE TENNESSEE R	10/21/94	LMB	336	460	Female	
E TENNESSEE R	10/21/94	LMB	350	518	Female	
E TENNESSEE R	10/21/94	LMB	336	340	Female	
PARKSVILLE - OCOEE N						
OCOEE R 12.0	11/08/94	CHC	415	634	Male	
OCOEE R 12.0	11/08/94	CHC	550	1680	Male	
OCOEE R 12.0	11/08/94	CHC	465	965	Female	
OCOEE R 12.0	11/08/94	CHC	505	1139	Female	
OCOEE R 12.0	11/08/94	CHC	464	837	Female	
OCOEE R 16.0	11/16/94	CHC	545	1608	Female	
OCOEE R 16.0	11/16/94	CHC	484	1099	Female	
OCOEE R 16.0	11/16/94	CHC	470	978	Female	
OCOEE R 16.0	11/16/94	CHC	463	807	Male	
OCOEE R 16.0	11/16/94	CHC	543	1588	Male	
WHEELER						
TENNESSEE R 277	10/27/94	CHC	477	953	Female	
TENNESSEE R 277	10/27/94	CHC	442	636	Female	
TENNESSEE R 277	11/02/94	CHC	440	772	Male	
TENNESSEE R 277	11/02/94	CHC	344	295	Female	
TENNESSEE R 277	11/08/94	CHC	511	1420	Female	
TENNESSEE R 296	11/07/94	CHC	510	1140	Female	
TENNESSEE R 296	11/07/94	CHC	441	740	Female	
:SSEE R 296	11/07/94	CHC	475	1000	Female	
TENNESSEE R 296	11/07/94	CHC	505	1340	Female	
TENNESSEE R 296	11/07/94	CHC	600	2380	Male	

Table A-3

Specific physical information on composite fish collected for tissue ~~stream and~~ reservoir locations as part of targeted screening studies.

Co ion Site		Date	Species	Length (mm)	Weight (g)	Sex	LABID
' SSEE R	347	11/03/94	CHC	495	1160	Female	
TENNESSEE R	347	11/03/94	CHC	485	1120	Female	
TENNESSEE R	347	11/03/94	CHC	474	980	Female	
TENNESSEE R	347	11/03/94	CHC	545	1240	Male	
TENNESSEE R	347	11/03/94	CHC	581	2120	Female	

Table A-4

Specific physical information on individual fish collected for tissue ~~stream and~~ reservoir locations as part of intensive ~~screening~~ studies.

C :ion Site		Date	Species	Length(mm)	Weight(g)	Sex	LABID
N ACK							
TENNESSEE R	469	11/18/94	STB	872	8809	Female	
TENNESSEE R	469	11/18/94	STB	774	5179	Female	
TENNESSEE R	469	11/21/94	STB	1010	12500	Female	
TENNESSEE R	469	11/21/94	STB	874	7627	Female	
TENNESSEE R	469	11/21/94	STB	776	5590	Male	
TENNESSEE R	469	11/21/94	STB	804	7711	Female	
TENNESSEE R	469	11/21/94	STB	791	6330	Male	
TENNESSEE R	469	11/21/94	STB	937	9895	Female	
TENNESSEE R	469	11/21/94	STB	830	7917	Female	
TENNESSEE R	469	11/21/94	STB	852	8309	Female	

Table A-5

Specific physical information on composite fish collected for tissue ~~stream and~~ reservoir locations as part of ~~screening~~ long-term monitoring studies.

Co[illegible]tion Site		Date	Species	Length(mm)	Weight(g)	Sex	LABID
TE[illegible])							
LITTLE TENNESSEE R		10/20/94	CHC	614	2353	Male	
LITTLE TENNESSEE R		10/20/94	CHC	474	951	Female	
LITTLE TENNESSEE R		10/20/94	CHC	570	1970	Female	
LITTLE TENNESSEE R		10/20/94	CHC	425	667	Male	
LITTLE TENNESSEE R		10/20/94	CHC	461	999	Female	
LITTLE TENNESSEE R		10/21/94	CHC	684	3739	Female	
LITTLE TENNESSEE R		10/21/94	CHC	565	1621	Female	
LITTLE TENNESSEE R		10/21/94	CHC	595	1856	Female	
LITTLE TENNESSEE R		10/21/94	CHC	572	1654	Female	
LITTLE TENNESSEE R		10/21/94	CHC	524	1259	Female	
NICKAJACK							
TENNESSEE R	425	10/10/94	CHC	591	2841	Male	
TENNESSEE R	425	10/10/94	CHC	538	1865	Female	
TENNESSEE R	425	10/10/94	CHC	535	1484	Male	
TENNESSEE R	425	10/10/94	CHC	482	1023	Female	
TENNESSEE R	425	10/10/94	CHC	511	1156	Female	
TENNESSEE R	457	11/09/94	CHC	486	975	Female	
TENNESSEE R	457	11/09/94	CHC	516	1331	Female	
TENNESSEE R	457	11/09/94	CHC	599	2140	Male	
SSEE R	457	11/09/94	CHC	556	1540	Male	
SSEE R	457	11/09/94	CHC	627	2790	Female	
TENNESSEE R	457	11/09/94	CHC	0	154	Female	
CHICKAMAUGA							
TENNESSEE R	529	10/20/94	CHC	527	1335	Male	
TENNESSEE R	529	10/20/94	CHC	546	1628	Male	
TENNESSEE R	529	10/20/94	CHC	542	1445	Male	
TENNESSEE R	529	10/20/94	CHC	523	1198	Male	
TENNESSEE R	529	10/20/94	CHC	523	1546	Female	
WATTS BAR							
TENNESSEE R	530	10/28/94	CHC	520	1259	Female	
TENNESSEE R	530	10/28/94	CHC	480	1013	Male	
TENNESSEE R	530	10/28/94	CHC	400	511	Male	
TENNESSEE R	530	11/22/94	CHC	637	2338	Male	
TENNESSEE R	530	11/22/94	CHC	492	943	Female	
TENNESSEE R	530	10/28/94	SBU	580	3109	Male	
TENNESSEE R	530	10/28/94	SBU	570	3160	Male	
TENNESSEE R	530	11/22/94	SBU	510	1892	Female	
TENNESSEE R	530	11/22/94	SBU	645	4655	Female	
TENNESSEE R	530	11/22/94	SBU	532	2695	Male	
TENNESSEE R	560	11/09/94	CHC	424	523	Male	
SSEE R	560	11/09/94	CHC	483	969	Male	
SSEE R	560	11/09/94	CHC	522	1547	Male	
TENNESSEE R	560	11/09/94	CHC	607	2394	Male	

Table A-5
Specific physical information on composite fish collected for tissue ~~stream and~~ reservoir locations as part of ~~screening~~ long-term monitoring studies.

Collection Site		Date	Species	Length(mm)	Weight(g)	Sex	LABID
SEE R	560	11/09/94	CHC	484	1076	Female	
TENNESSEE R	560	11/23/94	SBU	478	1685	Male	
TENNESSEE R	560	11/23/94	SBU	463	1427	Male	
TENNESSEE R	560	11/23/94	SBU	520	1982	Female	
TENNESSEE R	560	11/23/94	SBU	451	1245	Male	
TENNESSEE R	560	11/30/94	SBU	556	2880	Male	
TENNESSEE R	600	10/26/94	CHC	396	507	Female	
TENNESSEE R	600	10/26/94	CHC	395	496	Female	
TENNESSEE R	600	10/26/94	CHC	406	522	Female	
TENNESSEE R	600	11/23/94	CHC	659	2348	Female	
TENNESSEE R	600	11/30/94	CHC	490	919	Male	
TENNESSEE R	600	10/26/94	SBU	607	3643	Female	
TENNESSEE R	600	10/26/94	SBU	507	1946	Male	
TENNESSEE R	600	10/26/94	SBU	572	3066	Male	
TENNESSEE R	600	10/26/94	SBU	485	1737	Male	
TENNESSEE R	600	11/23/94	SBU	586	3230	Female	

Table A-6

Specific physical information on individual fish collected for tissue ~~stream and~~ reservoir locations as part of ~~screening~~ long-term monitoring studies

C -- ion Site	Date	Species	Length (mm)	Weight (g)	Sex	LABID
F UDOUN						
TENNESSEE R 624	10/04/94	CHC	480	1166	Male	
TENNESSEE R 624	10/04/94	CHC	390	500	Male	
TENNESSEE R 624	10/04/94	CHC	485	1026	Male	
TENNESSEE R 624	10/04/94	CHC	385	442	Male	
TENNESSEE R 624	10/04/94	CHC	662	2676	Female	
TENNESSEE R 624	10/05/94	CHC	417	538	Male	
TENNESSEE R 624	10/05/94	CHC	455	822	Male	
TENNESSEE R 624	10/05/94	CHC	416	515	Female	
TENNESSEE R 624	10/05/94	CHC	365	425	Male	

Appendix B

Recommendations for fish tissue studies in 1995

Appendix B. Recommendations for fish tissue studies in 1995[a]

Study Type/Location	River Mile	Species	# Needed	Ind/Comp	Analytes
Reservoir Screening					
Kentucky Res.	TRM 30	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
	TRM 85	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
	TRM 206	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
	BSRM 7	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
Normandy Res	DRM 250	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
Beech Res	BeRM 36	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
		LMB	5	Composite	Mercury only
Tims Ford Res	ERM 135	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
	ERM 150	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
Chickamauga Res	TRM 472	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
	TRM 490	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
	TRM 529	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
	HiRM 8	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only

Appendix B, Continued

Study Type/Location	River Mile	Species	# Needed	Ind/Comp	Analytes
Reservoir Screening, cont.'					
Fort Loudoun Res	TRM 603	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
	TRM 624	CHC	10	Ind+Comp	Comp = Screening - Metals/Organics Ind = PCBs, DDTr, Chlordane
		LMB	5	Composite	Mercury only
	TRM 652	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
Fort Pat. Res	HRM 9	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
Stream Screening					
Clarks River	ClRM 10	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
Buffalo River	BuRM 18	CHC	5	Composite	Screening - Metals and Organics
		SMB	5	Composite	Mercury only
Bear CreekRiver	BCM 27	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
Sequatchie River	SeRM 10	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
Ocoee River	ORM 4	CHC	5	Composite	Screening - Metals and Organics
		LMB	5	Composite	Mercury only
Tuckasegee River	TuRM 10	CHC	5	Composite	Screening - Metals and Organics
		SMB	5	Composite	Mercury only
Holston River	HRM 110	CHC	5	Composite	Screening Metals and Organics
		LMB	5	Composite	Mercury only

Appencix B, Continued

Study Type/Location	River Mile	Species	# Needed	Ind/Comp	Analytes
Stream Screening, cont.'					
N. Fork Holston R	NFHRM 4	CHC	5	Composite	Screening - Metals and Organics
		SMB	5	Composite	Screening - Mercury only
Pigeon River	PiRM 7	CHC	5	Composite	Screening - Metals and Organics
		SPB	5	Composite	Mercury only
Targeted Screening					
Wheeler Res	TRM 277	CHC	5	Composite	PCBs, DDTr, Chlordane
	TRM 295	CHC	5	Composite	PCBs, DDTr, Chlordane
	TRM 347	CHC	5	Composite	PCBs, DDTr, Chlordane
	ElRM 6	CHC	5	Composite	PCBs, DDTr, Chlordane
Cherokee	HRM 53	CHC	5	Composite	PCBs, DDTr, Chlordane
		STB	5	Composite	PCBs, DDTr, Chlordane
	HRM 76	CHC	5	Composite	PCBs, DDTr, Chlordane
		STB	5	Composite	PCBs, DDTr, Chlordane
Nickajack Res	TRM 469	STB	5	Composite	PCBs, DDTr, Chlordane
Parksville Res	ORM 12	CHC	5	Composite	PCBs, DDTr, Chlordane
	ORM 16	CHC	5	Composite	PCBs, DDTr, Chlordane

Intensive Study

Note: The only Intensive study under consideration at the time this document was prepared was on Wheeler Reservoir--four locations in the vicinity of Indian Creek (3 replicates of CHC, LMB, and SMB). The primary study objective would be to determine if DDTr concentrations were sufficiently low for the Alabama Department of Public Health to alter or remove the fish consumption advisory in that section of the Tennessee River. Final decision on this study effort was to be made at a later date.

TENNESSEE VALLEY AUTHORITY

Resource Group
Water Management
Clean Water Initiative

TENNESSEE VALLEY RESERVOIR AND STREAM QUALITY - 1993

FISH TISSUE STUDIES IN THE TENNESSEE VALLEY IN 1993

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Chattanooga, Tennessee

July 1994

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EXECUTIVE SUMMARY

TVA has been involved in fish tissue studies for a number of years. Because of the significant interest expressed by Valley states and the fishing public, TVA's involvement in these studies has continued from year to year. TVA coordinates these efforts with state and federal agencies to avoid duplication.

TVA analyzes tissues of Tennessee Valley fish as part of both intensive and screening evaluations. Screening studies are conducted to identify sites having potential contamination problems. Intensive studies are conducted to define the extent of problems identified by screening studies.

Fish collected for screening studies are usually analyzed for metals, PCBs, and pesticides on EPA's Priority Pollutant List. Fish for intensive studies are analyzed only for the contaminant of concern, which has been identified by screening studies, or is known as an historic problem. Lipid content is determined on all samples.

Principal results of fish tissue studies in 1993 were:

(1). Screening studies did not indicate a need for new intensive studies, although other studies are warranted (see item 2 below).

(2). Largemouth bass were collected from tributary reservoirs as part of reservoir screening studies and were analyzed as composites for mercury. Many large fish (1200+ grams) were also analyzed as individuals in an attempt to describe worst-case conditions. Relatively high concentrations of mercury in many of these fish from tributary reservoirs, especially large fish, indicate a need for further examination.

(3). PCB concentrations in fish from Nickajack, Watts Bar, and Fort Loudoun Reservoirs continued to be high. Continued monitoring of these reservoirs is recommended.

(4). DDTr concentrations in fish collected near the Indian Creek embayment on Wheeler Reservoir were relatively high in some samples, especially smallmouth buffalo. Continued examination in this area is recommended to help document chages through time.

(5). Fish collected near a former battery dumpsite in Cave Spring Branch Embayment of South Holston Reservoir contained levels of mercury and lead consistent with levels in fish from other reservoirs indicating no impact from the battery dump.

(6). Fish were collected from three embayments near CRM 51 on Melton Hill Reservoir to determine why previous studies have typically found one or two fish in that area with unusually high PCB concentrations. Although a more in-depth study would be necessary to rule out these embayments as potential contributors of high PCB concentrations in fish collected in previous years, results of this special study do not support the need for a more in-depth investigation.

FISH TISSUE STUDIES IN THE TENNESSEE VALLEY IN 1993

1.0 INTRODUCTION

TVA analyzes tissues of Tennessee Valley fish as part of both screening and intensive evaluations. Screening studies are based on analysis of composited fillets and are intended to identify possible problem areas where intensive investigations may be needed. Table 1-1 includes the contaminant concentrations used as the guidelines for planning follow-up fish tissue studies. Sites with fish containing concentrations less than those listed as Tier 1 are sampled on a three-year rotation. Sites with fish containing contaminant concentrations higher than the values listed under Tier 2 are sampled at the screening level the following year. Sites with fish containing levels above Tier 3 are in nedd of intensive investigation.

Intensive studies usually include analysis of individual fillets from important fish species from several areas in the reservoir. The primary objectives of intensive studies are to define the species affected, geographical boundaries of contamination, and to document trends in contaminant concentrations. This information is used by state public health officials to determine if fish consumption advisories are necessary to protect human health.

Included in the screening study are reservoir and stream monitoring locations. There are about 80 reservoir sites which are generally monitored on a three-year rotational basis. There are 11 stream monitoring locations which have been sampled on an annual basis through 1993. Six additional stations will be included in 1994, and a two year on, one year off rotation will be implemented.

The results from both intensive studies and screening studies conducted in 1993 are provided in this report. Originally a separate report was written for the intensive and screening studies. However, the screening and intensive studies for 1989 were combined into one report with separate chapters for each type of study. The same format was followed for the 1990 and 1991 and 1992 reports. In response to changing customer base and in keeping with TVA's focus on watershed management, this report contains separate chapters on each watershed. Each chapter begins with a drainage map of the watershed with designated sampling locations, followed by an introduction, information on screening studies, information on any intensive studies conducted within the watershed, and finally information on any special studies conducted within the watershed. Appendix A contains physical information and results of chemical analyses for the screening studies conducted in 1993. Appendix B is a chronological listing of TVA reports relating to contaminants in fish. Appendix C identifies rationales and procedures used in the collection, processing, and laboratory and data analysis of fish tissue samples. Appendix D is the latest fish advisory information for water bodies in Tennessee. Appendix E includes 1991 and 1992 fish consumption advisories on Wheeler Reservoir in Alabama. Appendix F contains information on special mercury analyses performed on selected largemouth bass (i.e. those weighing over three pounds) collected as part of the fish tissue screening studies in 1993.

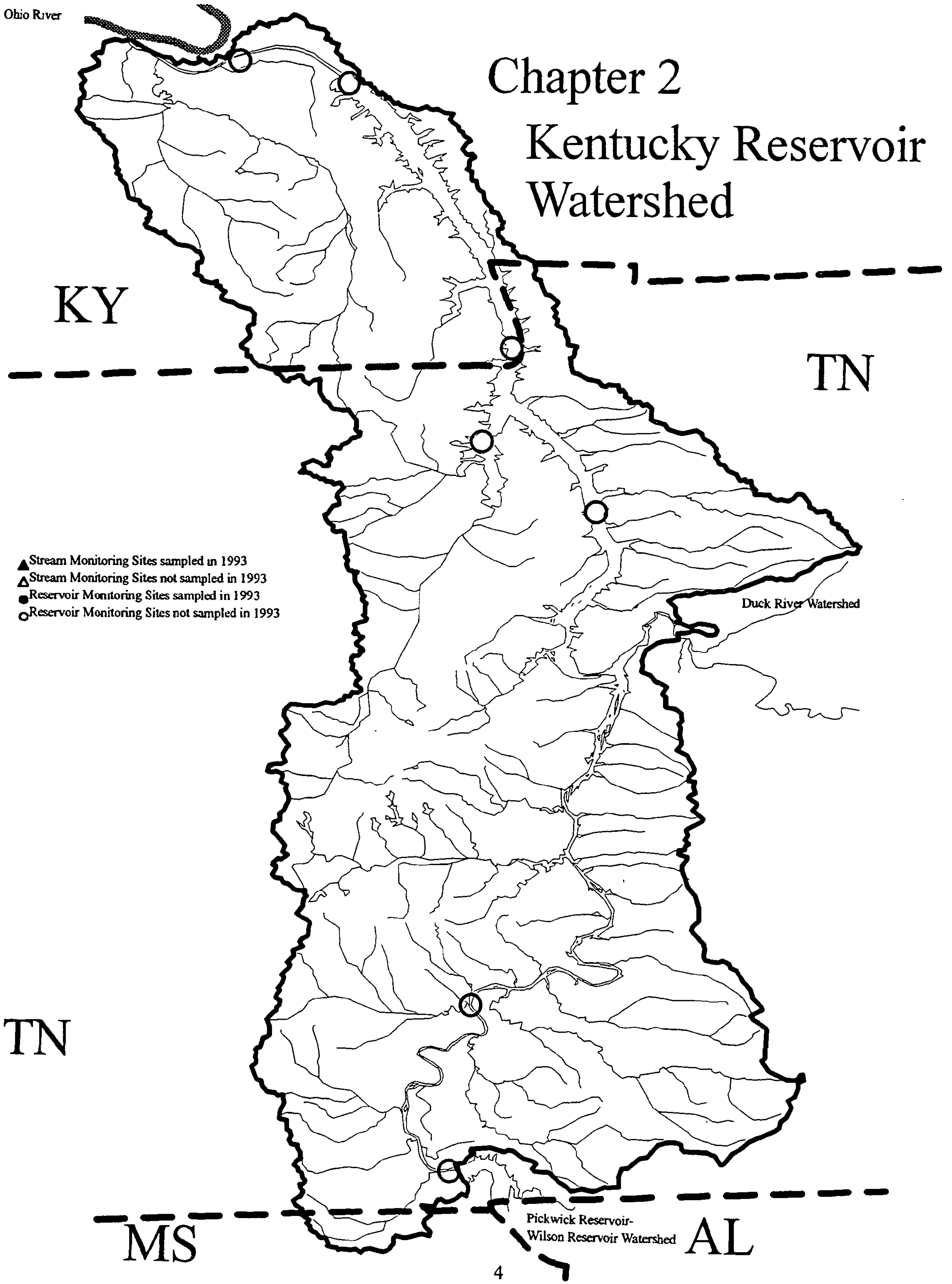
Table 1-1 Contaminant concentrations[a] used as guidelines for planning the level of continued fish tissue studies in Tennessee Valley waters.

Parameter	Laboratory Detection Limit (µg/g)	Tier 1 Return to Rotation System (µg/g)	Tier 2 Resample at Screening Level Following Year (µg/g)	Tier 3 Recommend Intensive Study (µg/g)
Arsenic	0.02	<0.5	≥0.5	≥0.7
Cadmium	0.05	<0.5	≥0.5	≥1.0
Lead	0.02	<1.5	≥1.5	≥2.0
Mercury	0.1	<0.5	≥0.5	≥0.7
Selenium	0.02	<1.0	≥1.0	≥3.0
Aldrin	0.01	<0.1	≥0.1	≥0.2
Benzene Hexachloride	0.01	<0.1	≥0.1	≥0.2
Chlordane	0.01	<0.1	≥0.1	≥0.2
DDT	0.01	<2.0	≥2.0	≥4.0
Dieldrin	0.01	<0.1	≥0.1	≥0.2
Endosulfan	0.01	<3.0	≥3.0	≥5.0
Endrin	0.01	<0.1	≥0.1	≥0.2
Heptachlor	0.01	<0.1	≥0.1	≥0.2
Toxaphene	0.5	<2.0	≥2.0	≥3.0
PCBs	0.1	<1.0	≥1.0	≥1.5

a. These levels will be used as a general guide. Specific recommendations will be made on a case-by-case basis.

b. Selection of a level for this metal, which would result in a recommendation to conduct intensive studies, cannot be made at this time.

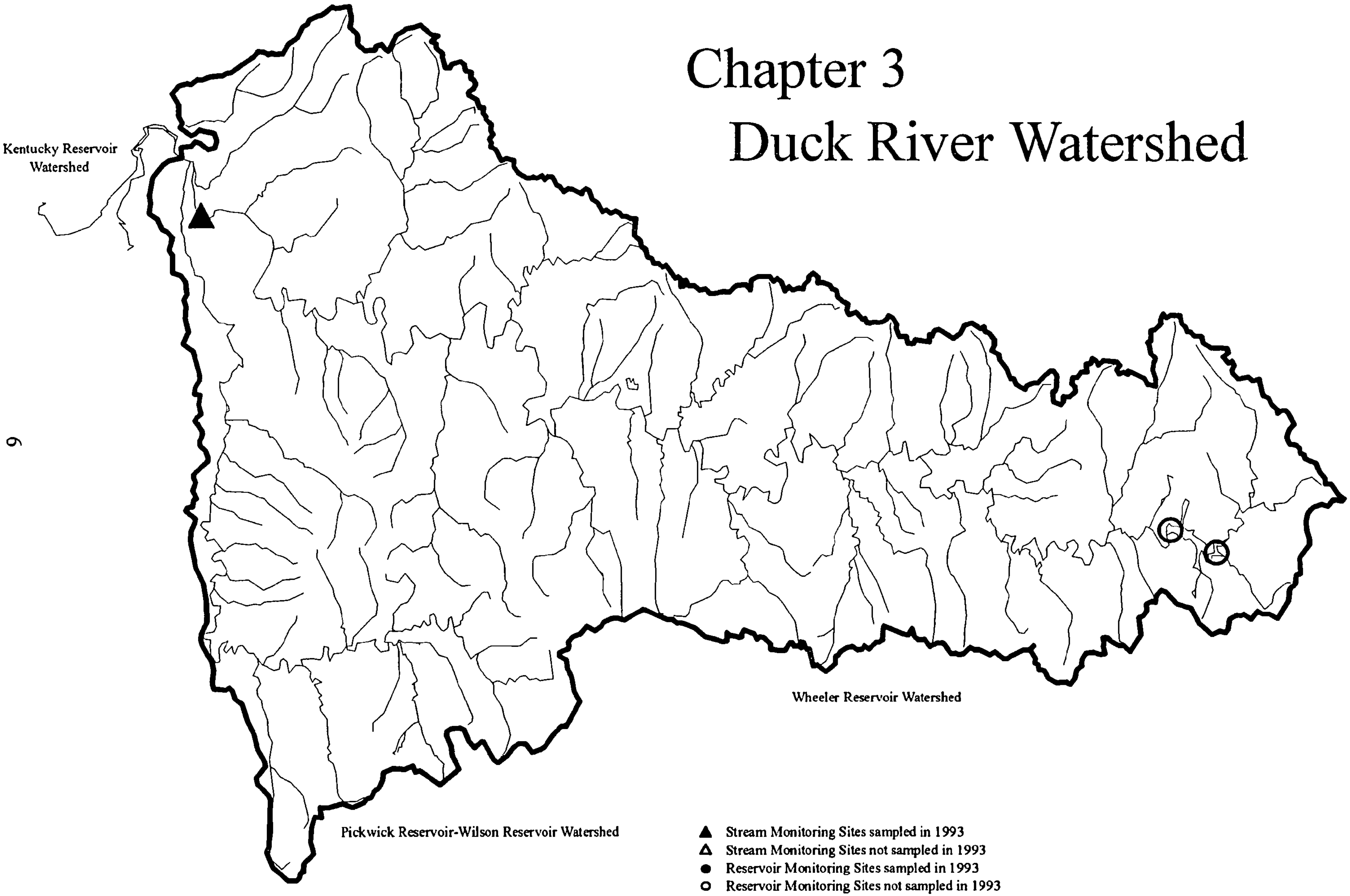
Chapter 2
Kentucky Reservoir Watershed



Chapter 2.0 Kentucky Reservoir Watershed

No fish tissue samples were taken from the Kentucky Reservoir Watershed in 1993 because the sites were sampled each year between 1988 and 1992 and contaminant concentrations were either low or slightly elevated with no consistent temporal or spatial trends. Historical data from monitoring sites within the Kentucky Reservoir Watershed are available in publications listed in Appendix B.

Chapter 3
Duck River Watershed



Chapter 3.0 Duck River Watershed

3.1 Introduction

In 1993, the only location in the Duck River Watershed where fish tissue samples were collected was a stream monitoring site at DRM 22.5. No problems were found when the reservoir monitoring sites on Normandy Reservoir were sampled in 1987, 1988, and 1992. Therefore, these sites were not sampled in 1993. Publications describing historical data from monitoring sites within the Duck River Watershed are in Appendix B.

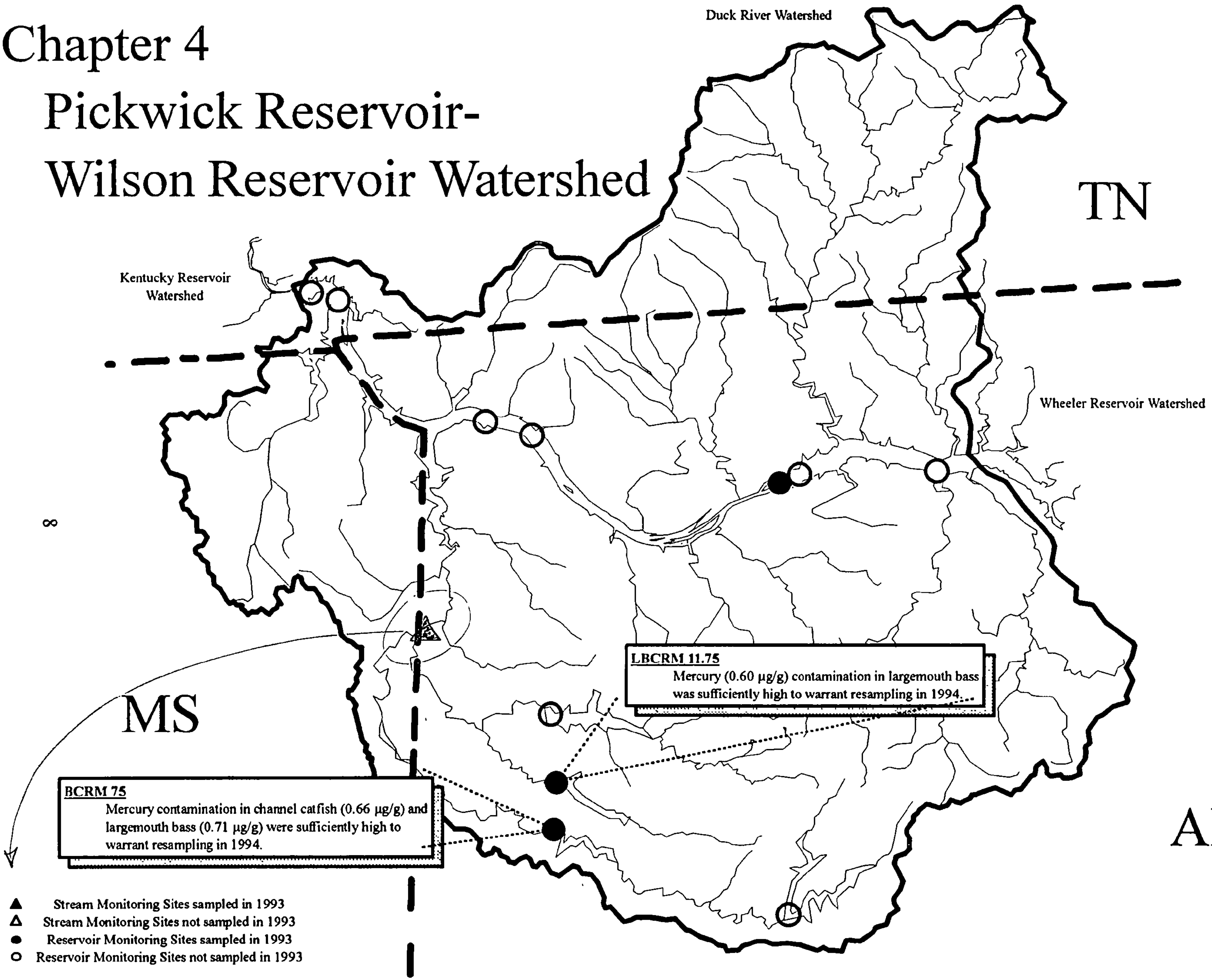
3.2 Methods

Five channel catfish and four spotted bass were collected at DRM 22.5. These fish were composited by species and analyzed for lipids, metals and organics. Field handling and processing and laboratory processing were performed according to the methods outlined in Appendix C.

3.3 Results and Recommendations

Physical information and the results of metals and organics analyses are contained in Appendix A along with data for other stream and reservoir monitoring sites. Metal and organic analytes were below detection limits or found in low concentrations. This stream monitoring station will be sampled in summer 1994 along with a new stream monitoring site on the Buffalo River at approximately mile 17.7.

Chapter 4
Pickwick Reservoir-Wilson Reservoir Watershed



Chapter 4.0 Pickwick Reservoir-Wilson Reservoir Watershed

4.1 Introduction

Fish tissue samples were collected at only three reservoir monitoring sites in the Pickwick Reservoir-Wilson Reservoir Watershed in 1993; Pickwick Reservoir inflow from Wilson Dam (TRM 259), and the forebays of Bear Creek Reservoir (Bear Creek Mile 57) and Little Bear Creek Reservoir (Little Bear Creek Mile 12). The Pickwick Reservoir inflow site was sampled because of a high DDT level (2.5 µg/g) evident in the composite sample of channel catfish from this location in 1992. The sites on Bear Creek and Little Bear Creek Reservoirs were sampled because of high levels of mercury (0.45 and 0.56 µg/g, respectively) in channel catfish composites from these sites in 1992. Publications containing historical data from monitoring sites within the Pickwick Reservoir-Wilson Reservoir Watershed are in Appendix B.

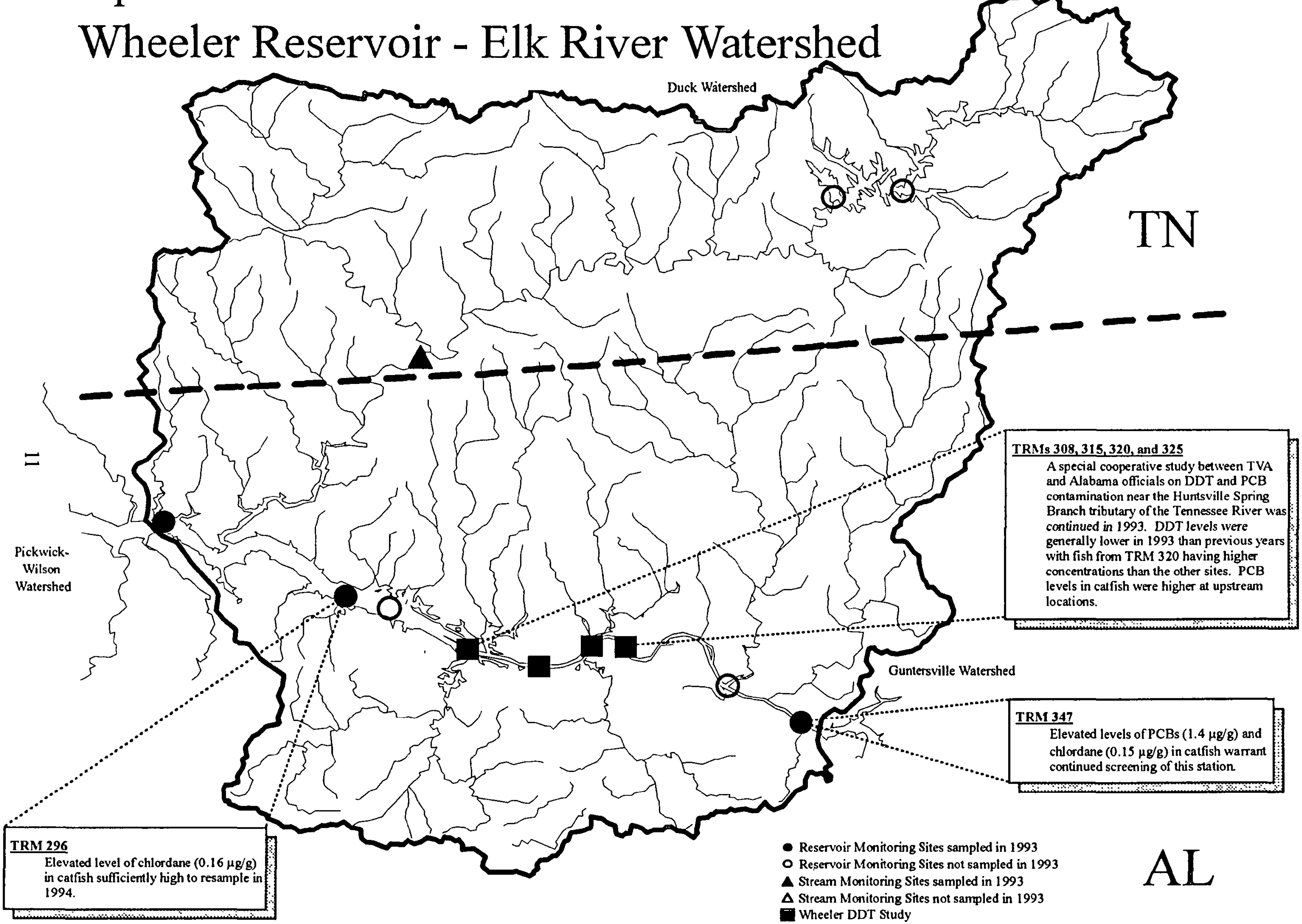
4.2 Methods

A composite sample of five channel catfish was collected from Pickwick Reservoir inflow. Composites of five channel catfish and five largemouth bass were collected from the forebays of Bear Creek Reservoir and Little Bear Creek Reservoir. Catfish samples were analyzed as composites for pesticides, PCBs, selected metals on the EPA Priority Pollutant List and lipids. Largemouth bass samples were analyzed as composites only for mercury. In addition to composite analysis, each largemouth bass that weighed more than 1200 grams was analyzed individually for mercury; results for these individual analyses are included in Appendix F. Field handling and processing and laboratory processing were performed according to the methods for screening studies outlined in Appendix C.

4.3 Results and Recommendations

Physical information and the results of metals and organics analyses are included in Appendix A. None of the metal or organic analytes in channel catfish from Pickwick Reservoir inflow (TRM 259) were sufficiently high to warrant resampling in 1994. Except mercury, analytes were either not detected or found in low concentrations in samples from Little Bear Creek and Bear Creek Reservoirs. Mercury concentrations in both channel catfish (0.66 µg/g) and largemouth bass (0.71 µg/g) from Bear Creek Reservoir and largemouth bass (0.60 µg/g) from Little Bear Creek Reservoir were sufficiently high to warrant further investigation in autumn 1994.

Chapter 5
Wheeler Reservoir - Elk River Watershed



Chapter 5.0 Wheeler Reservoir - Elk River Watershed

5.1 Introduction

The Tennessee Department of Environment and Conservation (TDEC) has issued a fish consumption advisory against consuming catfish caught in Woods Reservoir, a non-TVA reservoir, because of PCB contamination (Appendix D). The Alabama Department of Public Health has also issued advisories against consuming certain fish caught in selected areas of Wheeler Reservoir because of DDT contamination (Appendix E).

Fish for screening purposes were collected from four locations in Wheeler Reservoir - Elk River Watershed for fish tissue screening studies in 1993. Three of these locations were reservoir monitoring sites (TRM 277, TRM 296, and TRM 347). The fourth location was a stream monitoring site at ERM 41.5. Fish for intensive study purposes were collected from four other locations in Wheeler Reservoir, TRMs 308, 315, 320, and 325, as part of the continuing study of DDT near the Indian Creek embayment. Historical data from monitoring sites within the Wheeler Reservoir - Elk River Watershed are available in publications listed in Appendix B.

5.2 Screening Studies

5.2.1 Methods

Five channel catfish were collected from TRMs 277, 296, and 347 and ERM 41.5 in 1993. Four largemouth bass were also collected from ERM 41.5. These fish were analyzed as composites for lipids, pesticides, PCBs, and selected metals on the EPA Priority Pollutant List. Field handling and processing and laboratory processing were performed according to the methods outlined in Appendix C.

5.2.2 Results and Recommendations

Physical information and the results of metals and organics analyses for channel catfish and largemouth bass composites from Wheeler Reservoir and the Elk River are contained in Appendix A, along with data for other stream and reservoir monitoring sites. Contaminant levels in fish from ERM 41.5 and TRM 277 were not high enough to warrant concern. Chlordane levels in channel catfish from TRM 296 (0.16 µg/g) and chlordane (0.15 µg/g) and PCB (1.4 µg/g) levels in channel catfish from TRM 347 warrant further efforts.

Screening efforts at TRMs 296 and 347 as well as TRM 277 will be continued in autumn 1994 to further investigate the elevated chlordane and PCB concentrations found in 1993. Elk River Mile 41.5 will be sampled in summer 1994 because of relatively high mercury concentrations found in previous years.

5.3 Wheeler DDT Study

5.3.1 Introduction

The Alabama Department of Public Health (ADPH) issued a fish consumption advisory for several fish species from the Indian Creek drainage area of Wheeler Reservoir in September 1991 due to DDT contamination. This was a historic problem area but an advisory had not been issued previously. To evaluate the possible need to extend the advisory into the Tennessee River, a special study was designed by TVA and Alabama officials and conducted in fall 1991. Based on the 1991 results, the ADPH extended the advisory on selected species into the Tennessee River. Details of the species and locations for the latest advisory are in appendix E.

As a result of the high concentrations found in 1991, the study was scheduled to be repeated in autumn 1992. Because of technical difficulties, fish were not collected until January 1993. Concentrations of DDTr (total DDT) were substantially lower in the fish collected in

January 1993 (collections made in January 1993 will be referred to as 1992 collections throughout the remainder of this section). These lower concentrations prompted TVA and Alabama officials to continue the study in autumn 1993.

5.3.2 Methods

The design of the special study was established by TVA and the Alabama Departments of Public Health, Environment Management, and Conservation. The design specified three, 5-fish composites of each of three species (channel catfish, largemouth bass and smallmouth buffalo) to be collected from four locations (TRMs 308, 315, 320 near the mouth of the Indian Creek embayment, and 325). The sampling effort was successful as planned in autumn 1993.

Field handling and processing were similar to the methods described in appendix C. Several fish collected for this study were shared with a group of researchers from the Registry of Tumors in Lower Animals, National Museum of Natural History, Smithsonian Institution, Washington, D.C. External, internal, and sex observations for these fish were not recorded.

The laboratory analyses for lipids, PCBs, and DDTr were conducted similar to the screening study methods described in appendix C. Ortho-para isomers of DDT, DDD, and DDE were examined in addition to the routine examination of para-para isomers.

Statistical analyses for these results varied from that described in Appendix C in that covariance analyses were not performed because laboratory analyses were conducted on composites preventing examination of relationships between contaminant concentration and fish weight or lipid content. One-way and two-way ANOVAs were performed.

Included in the design of this special study was the sharing between TVA and Alabama Department of Environmental Management (ADEM) of aliquots of homogenized fish tissue from one composite sample of each species (channel catfish, smallmouth buffalo, and largemouth bass) from each sampling location (TRMs 308, 315, 320 and 325). These aliquots, 12 for each year, were analyzed by TVA and ADEM laboratories for PCBs, chlordane and para-para DDT, DDD and DDE concentrations and lipid content. Results from these split samples for 1991 and 1992 were provided in Williams and Dycus, 1993. Results from the 1993 split samples were not available at the time this report was prepared.

5.3.3 Results and Recommendations

All results are presented in tables 5.3-1 through 5.3-11. Neither weights nor lipid content of largemouth bass or smallmouth buffalo were significantly different among locations or years. This was not the case for channel catfish, both lipid content and weight were significantly different. Lipid concentrations in composite samples of channel catfish did not vary significantly between locations but did vary among years with samples from 1991 having significantly higher lipid content than ones from 1992 and 1993. Catfish weight distribution varied among years, resulting in a significant interaction between year and location. Larger catfish were collected from all locations in 1991 compared to the other two years. When locations were examined by years, test results varied substantially (Table 5.3-5). In 1993 catfish from TRM 325 weighed significantly less than individuals from the other three sites.

DDT concentrations were highest in all species in 1991. At least one composite of one species exceeded 5 ug/g at each site. Highest concentrations were in smallmouth buffalo (maximum 43 ug/g) from near the mouth of Indian Creek. Largemouth bass tended to have lower concentrations than the other two species.

Samples for 1992 had substantially lower concentrations than observed in 1991. Of the 36 samples for 1992, only two exceed 5 ug/g, while 15 collected in 1991 exceeded that concentration. Highest concentrations in 1992 were in smallmouth buffalo (maximum of 9.2

ug/g) and largemouth bass (maximum of 7.4 ug/g). Concentrations in channel catfish in 1992 (maximum of 3.1 ug/g) were much lower than in 1991 (maximum of 13 ug/g); none of the channel catfish samples exceeded 5 ug/g in 1992 compared to seven of 12 exceeding that level in 1991.

In 1993, five of the 36 samples exceeded 5 ug/g; all from TRM 320 (near Indian Creek) and TRM 325. Of these four were smallmouth buffalo (maximum of 21 ug/g) and one was largemouth bass (maximum of 6.4 ug/g). As in 1992, all channel catfish samples had relatively low concentrations (maximum of 2.8 ug/g). Smaller size and lower lipid content in catfish collected in 1992 and 1993 may have contributed to this difference.

Two-way ANOVAs (location and year effects) were conducted on DDT concentrations in channel catfish, largemouth bass, and smallmouth buffalo. DDT concentrations in channel catfish samples collected in 1992 (January 1993) and 1993 were significantly lower than concentrations in 1991. DDT concentrations in channel catfish were significantly lower at TRM 325 than at TRMs 308 and 320. DDT concentrations in largemouth bass were not significantly different among locations or years.

A significant interaction was found in smallmouth buffalo. The interaction was caused primarily by differing trends in contaminant concentration among sites. One-way ANOVAs were used as an indication of temporal differences at each location. At TRM 308 and TRM 315 smallmouth buffalo contained significantly less DDT in 1993 than in 1991. DDT concentrations in buffalo were not significantly different in 1993 or 1991 at TRMs 320 and 325. When 1993 results were tested alone, smallmouth buffalo from the two upper sites (TRMs 320 and 325) had significantly higher DDT levels than those from the two lower sites.

PCB concentrations in these samples were also tested for location effects using a one-way ANOVA on 1993 results. PCB concentrations in channel catfish were significantly higher at the uppermost site than at the lowermost site. PCB concentrations in largemouth bass and smallmouth buffalo were not significantly different among locations in 1993. Two-way ANOVAs of PCB concentrations found significant interaction between location and year effects for all three species included in the study.

Results for 1993 confirm that high concentrations of DDTr can be found in smallmouth buffalo samples from Wheeler Reservoir near the Indian Creek embayment. Concentrations have tended to be quite variable, especially among years. Substantial variability is expected based on studies within the Indian Creek embayment conducted by Olin Corporation (1994). Individual fish with high concentrations likely move out of the embayment into the Tennessee River. Collection of one of these individuals and subsequent compositing with four other fish would result in a high sample concentration relative to a composite without such an individual. Analysis of individual fish would allow resolution of this question.

The temporal variation in DDTr concentrations in channel catfish during this three-year period is unexpected. The first year of the study in 1991 identified high concentrations at several sites. Greatly reduced concentrations in both 1992 and 1993 were unexpected. The existing advisory covers a greater area for channel catfish than for the other species, primarily because of the high concentrations at the sites from the downstream portion of the study area. Smaller fish with lower lipid content may be an important consideration in these year-to-year differences. Sampling of channel catfish in autumn 1994 with emphasis on larger individuals, comparable to those in 1991, is needed to determine if the expanded advisory area is still warranted.

Results for largemouth bass during the three-year study have been somewhat perplexing, especially for 1992 and 1993. The primary issue is the sporadic occurrence of high concentrations; at times similar or higher than in channel catfish and smallmouth buffalo. Also, some samples have had higher concentrations than in largemouth bass from the Indian Creek embayment reported in the Olin Corporation studies (1994). These issues need further investigation. An analysis based on replicate individuals from the study area could help define variation in the population.

Design of autumn-1994 studies will be determined based on these recommendations, discussions with the Alabama Departments of Environmental Management, Public Health, and Conservation, and availability of funding.

Table 5.3-1 Physical information for individual fish collected from Wheeler Reservoir, 1993.

Collection Site	Date			Species[a]	Length (mm)	Weight (g)	Sex	LABID[b]
TRM 308	10	5	93	CHC	497	1225	FMALE	32604
TRM 308	10	5	93	CHC	438	755	FMALE	32604
TRM 308	10	7	93	CHC	469	935	FMALE	32604
TRM 308	10	7	93	CHC	431	795	FMALE	32604
TRM 308	10	7	93	CHC	447	990	MALE	32604
TRM 308	10	7	93	CHC	525	1700	FMALE	32606
TRM 308	10	7	93	CHC	433	695	MALE	32606
TRM 308	10	7	93	CHC	470	1225	FMALE	32606
TRM 308	10	7	93	CHC	421	595	FMALE	32606
TRM 308	10	7	93	CHC	521	1605	FMALE	32606
TRM 308	10	7	93	CHC	424	690	FMALE	32609
TRM 308	10	19	93	CHC	525	1625	MALE	32609
TRM 308	10	19	93	CHC	521	1550	MALE	32609
TRM 308	10	19	93	CHC	435	745	MALE	32609
TRM 308	10	19	93	CHC	525	1590	MALE	32609
TRM 308	10	5	93	LMB	385	855	FMALE	32610
TRM 308	10	5	93	LMB	327	495	FMALE	32610
TRM 308	10	7	93	LMB	423	1075	FMALE	32610
TRM 308	10	7	93	LMB	350	725	FMALE	32610
TRM 308	10	20	93	LMB	305	350	FMALE	32610
TRM 308	10	20	93	LMB	315	425	FMALE	32611
TRM 308	10	20	93	LMB	315	375	FMALE	32611
TRM 308	10	20	93	LMB	322	445	FMALE	32611
TRM 308	10	20	93	LMB	329	440	FMALE	32611
TRM 308	10	20	93	LMB	366	705	FMALE	32611
TRM 308	10	20	93	LMB	375	650	FMALE	32612
TRM 308	10	20	93	LMB	305	330	FMALE	32612
TRM 308	10	20	93	LMB	321	395	FMALE	32612
TRM 308	10	20	93	LMB	516	2285	FMALE	32612
TRM 308	10	20	93	LMB	305	330	FMALE	32612
TRM 308	10	5	93	SBU	474	1565	MALE	32613
TRM 308	10	5	93	SBU	553	3030	MALE	32613
TRM 308	10	5	93	SBU	477	1665	MALE	32613
TRM 308	10	5	93	SBU	484	1850	MALE	32613
TRM 308	10	5	93	SBU	518	2065	MALE	32613
TRM 308	10	5	93	SBU	471	1805	MALE	32614
TRM 308	10	5	93	SBU	536	2440	MALE	32614
TRM 308	10	5	93	SBU	540	2565	MALE	32614
TRM 308	10	5	93	SBU	550	2795	FMALE	32614
TRM 308	10	5	93	SBU	502	2390	MALE	32614
TRM 308	10	5	93	SBU	470	1875	FMALE	32615
TRM 308	10	5	93	SBU	499	2100	MALE	32615

Collection Site	Date			Species[a]	Length (mm)	Weight (g)	Sex	LABID[b]
TRM 308	10	5	93	SBU	547	2525	MALE	32615
TRM 308	10	5	93	SBU	431	1290	MALE	32615
TRM 308	10	5	93	SBU	513	2340	MALE	32615
TRM 315	11	2	93	CHC	531	1620	MALE	33003
TRM 315	11	2	93	CHC	517	1320	FMALE	33003
TRM 315	11	2	93	CHC	503	1440	FMALE	33003
TRM 315	11	2	93	CHC	586	2370	FMALE	33003
TRM 315	11	2	93	CHC	554	1540	MALE	33003
TRM 315	11	2	93	CHC	486	1060	MALE	33005
TRM 315	11	2	93	CHC	434	865	MALE	33005
TRM 315	11	3	93	CHC	577	1895	FMALE	33005
TRM 315	11	3	93	CHC	452	925	FMALE	33005
TRM 315	11	3	93	CHC	455	1015	FMALE	33005
TRM 315	11	3	93	CHC	479	1440	FMALE	33008
TRM 315	11	3	93	CHC	528	1235	FMALE	33008
TRM 315	11	3	93	CHC	477	960	MALE	33008
TRM 315	11	3	93	CHC	482	1205	MALE	33008
TRM 315	11	9	93	CHC	435	710	FMALE	33008
TRM 315	11	1	93	LMB	381	700	FMALE	33009
TRM 315	11	1	93	LMB	400	920	FMALE	33009
TRM 315	11	1	93	LMB	347	375	FMALE	33009
TRM 315	11	1	93	LMB	408	1045	FMALE	33009
TRM 315	11	1	93	LMB	386	855	FMALE	33009
TRM 315	11	1	93	LMB	355	560	FMALE	33010
TRM 315	11	1	93	LMB	312	410	FMALE	33010
TRM 315	11	1	93	LMB	306	345	FMALE	33010
TRM 315	11	3	93	LMB	401	925	FMALE	33010
TRM 315	11	3	93	LMB	382	695	MALE	33010
TRM 315	11	3	93	LMB	345	625	FMALE	33011
TRM 315	11	3	93	LMB	336	535	FMALE	33011
TRM 315	11	3	93	LMB	323	485	FMALE	33011
TRM 315	11	3	93	LMB	334	530	MALE	33011
TRM 315	11	3	93	LMB	316	435	MALE	33011
TRM 315	11	2	93	SBU	542	2510	MALE	33021
TRM 315	11	2	93	SBU	431	1310	MALE	33021
TRM 315	11	2	93	SBU	403	960	MALE	33021
TRM 315	11	2	93	SBU	328	500	FMALE	33021
TRM 315	11	2	93	SBU	366	465	FMALE	33021
TRM 315	11	3	93	SBU	503	1825	MALE	33022
TRM 315	11	3	93	SBU	557	3040	MALE	33022
TRM 315	11	3	93	SBU	481	1815	MALE	33022
TRM 315	11	3	93	SBU	439	1710	MALE	33022
TRM 315	11	3	93	SBU	446	1495	MALE	33022
TRM 315	11	3	93	SBU	496	1825	MALE	33023
TRM 315	11	4	93	SBU	480	1630	MALE	33023
TRM 315	11	4	93	SBU	424	1620	MALE	33023
TRM 315	12	8	93	SBU	507	2145	FMALE	33023
TRM 315	12	8	93	SBU	507	2145	FMALE	33023

Collection Site	Date			Species[a]	Length (mm)	Weight (g)	Sex	LABID[b]
TRM 320	10	13	93	CHC	454	850	FMALE	32618
TRM 320	10	13	93	CHC	490	1340	FMALE	32618
TRM 320	10	13	93	CHC	523	1645	FMALE	32618
TRM 320	10	13	93	CHC	542	1625	FMALE	32618
TRM 320	10	13	93	CHC	457	975	FMALE	32618
TRM 320	10	12	93	CHC	510	1400	[c]	32619
TRM 320	10	12	93	CHC	470	930	[c]	32619
TRM 320	10	12	93	CHC	440	750	[c]	32619
TRM 320	10	22	93	CHC	538	1735	FMALE	32619
TRM 320	10	22	93	CHC	450	665	MALE	32619
TRM 320	10	22	93	CHC	494	1155	FMALE	32620
TRM 320	10	26	93	CHC	476	1040	FMALE	32620
TRM 320	10	26	93	CHC	512	1215	MALE	32620
TRM 320	10	26	93	CHC	507	1110	FMALE	32620
TRM 320	10	26	93	CHC	467	825	FMALE	32620
TRM 320	10	13	93	LMB	405	1040	[c]	32621
TRM 320	10	13	93	LMB	360	720	[c]	32621
TRM 320	10	14	93	LMB	383	865	FMALE	32621
TRM 320	10	22	93	LMB	402	1065	FMALE	32621
TRM 320	10	22	93	LMB	412	1115	MALE	32621
TRM 320	10	27	93	LMB	360	615	FMALE	32623
TRM 320	10	27	93	LMB	380	780	FMALE	32623
TRM 320	10	27	93	LMB	476	1540	FMALE	32623
TRM 320	10	27	93	LMB	568	2775	FMALE	32623
TRM 320	10	27	93	LMB	503	1750	FMALE	32623
TRM 320	10	27	93	LMB	548	2750	MALE	32626
TRM 320	10	27	93	LMB	378	675	FMALE	32626
TRM 320	10	27	93	LMB	314	395	FMALE	32626
TRM 320	10	27	93	LMB	323	470	MALE	32626
TRM 320	10	27	93	LMB	318	400	FMALE	32626
TRM 320	10	13	93	SBU	402	915	MALE	32627
TRM 320	10	13	93	SBU	442	1365	MALE	32627
TRM 320	10	13	93	SBU	520	2265	MALE	32627
TRM 320	10	13	93	SBU	345	605	MALE	32627
TRM 320	10	13	93	SBU	375	765	FMALE	32627
TRM 320	10	13	93	SBU	397	975	FMALE	32628
TRM 320	10	13	93	SBU	488	2245	MALE	32628
TRM 320	10	13	93	SBU	430	1530	FMALE	32628
TRM 320	10	14	93	SBU	532	2245	FMALE	32628
TRM 320	10	14	93	SBU	468	1600	MALE	32628
TRM 320	10	14	93	SBU	421	1275	MALE	32629
TRM 320	10	12	93	SBU	485	1880	[c]	32629
TRM 320	10	22	93	SBU	524	2195	MALE	32629
TRM 320	10	22	93	SBU	564	2045	FMALE	32629
TRM 320	10	22	93	SBU	495	1885	MALE	32629
TRM 325	11	9	93	CHC	505	1280	[c]	33024
TRM 325	11	9	93	CHC	490	1120	[c]	33024
TRM 325	11	9	93	CHC	550	1480	[c]	33024
TRM 325	11	9	93	CHC	440	760	[c]	33024
TRM 325	11	22	93	CHC	596	2175	MALE	33024

Collection Site	Date			Species[a]	Length (mm)	Weight (g)	Sex	LABID[b]
TRM 325	11	29	93	CHC	265	395	FMALE	33025
TRM 325	11	29	93	CHC	381	405	FMALE	33025
TRM 325	12	2	93	CHC	376	420	MALE	33025
TRM 325	12	2	93	CHC	400	465	MALE	33025
TRM 325	12	2	93	CHC	395	560	MALE	33025
TRM 325	12	2	93	CHC	395	450	MALE	33026
TRM 325	12	2	93	CHC	362	395	FMALE	33026
TRM 325	12	2	93	CHC	421	640	MALE	33026
TRM 325	12	2	93	CHC	458	710	MALE	33026
TRM 325	12	2	93	CHC	480	1060	FMALE	33026
TRM 325	11	9	93	LMB	295	300	[c]	33012
TRM 325	11	9	93	LMB	398	880	[c]	33012
TRM 325	11	9	93	LMB	320	460	[c]	33012
TRM 325	11	9	93	LMB	380	760	[c]	33012
TRM 325	11	9	93	LMB	295	360	[c]	33012
TRM 325	11	9	93	LMB	375	760	[c]	33014
TRM 325	11	9	93	LMB	355	620	[c]	33014
TRM 325	11	9	93	LMB	310	400	[c]	33014
TRM 325	11	9	93	LMB	290	320	[c]	33014
TRM 325	11	9	93	LMB	295	300	[c]	33014
TRM 325	11	9	93	LMB	480	1620	[c]	33017
TRM 325	11	9	93	LMB	445	1120	[c]	33017
TRM 325	11	9	93	LMB	540	2120	[c]	33017
TRM 325	11	9	93	LMB	540	1660	[c]	33017
TRM 325	11	9	93	LMB	495	2100	[c]	33017
TRM 325	11	2	93	SBU	428	1285	MALE	33027
TRM 325	11	2	93	SBU	445	1280	MALE	33027
TRM 325	11	10	93	SBU	475	1500	[c]	33027
TRM 325	11	11	93	SBU	455	1655	MALE	33027
TRM 325	11	26	93	SBU	520	1625	MALE	33027
TRM 325	11	26	93	SBU	454	1575	MALE	33028
TRM 325	11	26	93	SBU	508	2275	MALE	33028
TRM 325	11	29	93	SBU	455	1690	MALE	33028
TRM 325	11	29	93	SBU	505	1890	MALE	33028
TRM 325	11	29	93	SBU	510	1695	MALE	33028
TRM 325	11	29	93	SBU	498	2155	MALE	33029
TRM 325	11	29	93	SBU	530	2485	MALE	33029
TRM 325	11	29	93	SBU	488	1765	MALE	33029
TRM 325	11	29	93	SBU	559	2620	MALE	33029
TRM 325	11	29	93	SBU	533	2455	FMALE	33029

a CHC = channel catfish, LMB = largemouth bass, SBU = smallmouth buffalo

b LABID = number assigned by TVA's Environmental Chemistry Laboratory. It is used to link laboratory analysis data with physical data from fish.

c Preprocessed by the research group from the Smithsonian Institution. Sex of these fish were not determined.

Table 5.3-2 Concentrations (μg/g) of organics in composite samples from Wheeler Reservoir, 1993.

Collection Site	Species[a]	LABID[b]	PCB	DDT	Chlordane	% Lipid
TRM 308	CHC	32604	0.5	0.81	<0.01	5.6
TRM 308	CHC	32606	0.5	0.66	0.01	6.0
TRM 308	CHC	32609	0.3	0.55	0.01	6.3
TRM 308	LMB	32610	0.3	2.0	0.01	3.0
TRM 308	LMB	32611	0.2	0.47	<0.01	2.0
TRM 308	LMB	32612	0.2	0.30	<0.01	1.1
TRM 308	SBU	32613	0.3	0.79	0.01	7.2
TRM 308	SBU	32614	0.3	1.1	0.01	5.3
TRM 308	SBU	32615	0.3	1.2	0.01	5.9
TRM 315	CHC	33003	0.4	1.3	<0.01	5.1
TRM 315	CHC	33005	0.7	0.69	<0.01	6.3
TRM 315	CHC	33008	0.6	1.7	<0.01	9.2
TRM 315	LMB	33009	0.7	2.0	<0.01	0.8
TRM 315	LMB	33010	0.3	9.5	<0.01	0.6
TRM 315	LMB	33011	0.2	1.1	<0.01	0.9
TRM 315	SBU	33021	0.3	0.37	0.01	5.0
TRM 315	SBU	33022	0.4	0.68	0.03	11
TRM 315	SBU	33023	0.5	0.88	0.06	7.2
TRM 320	CHC	32618	0.6	1.5	0.03	8.1
TRM 320	CHC	32619	0.6	0.91	0.03	8.0
TRM 320	CHC	32620	0.7	2.8	0.02	5.5
TRM 320	LMB	32621	0.9	2.5	0.03	3.7
TRM 320	LMB	32623	0.7	1.3	0.01	1.4
TRM 320	LMB	32626	0.5	0.91	<0.01	0.9
TRM 320	SBU	32627	0.3	3.7	0.01	4.8
TRM 320	SBU	32628	0.3	13	0.03	12
TRM 320	SBU	32629	0.7	21	0.04	6.7
TRM 325	CHC	33024	1.0	1.5	0.04	7.4
TRM 325	CHC	33025	1.3	0.88	0.02	5.2
TRM 325	CHC	33026	0.9	0.43	0.04	5.8
TRM 325	LMB	33012	0.4	1.5	<0.01	1.6
TRM 325	LMB	33014	0.5	1.1	<0.01	1.9
TRM 325	LMB	33017	1.2	6.4	<0.01	2.5
TRM 325	SBU	33027	1.0	7.2	0.01	6.0
TRM 325	SBU	33028	0.6	4.0	0.02	8.1
TRM 325	SBU	33029	1.5	14	0.04	9.3

a CHC = channel catfish, LMB = largemouth bass, SBU = smallmouth buffalo

b LABID = number assigned by TVA's Environmental Chemistry Laboratory. It is used to link laboratory analysis data with physical data from fish.

Table 5.3-3 Summary of weight, length, and percent lipid content in catfish, largemouth bass and smallmouth buffalo from Wheeler Reservoir, 1991-1993.

	Channel Catfish				Largemouth Bass				Smallmouth Buffalo			
	TRM 308	TRM 315	TRM 320	TRM 325	TRM 308	TRM 315	TRM 320	TRM 325	TRM 308	TRM 315	TRM 320	TRM 325
1991												
Weight Range	322-3170	288-3262	486-3240	580-4280	222-2260	292-1550	402-1636	400-2542	902-2374	682-2932	776-3662	802-4294
Mean Weight	1338	1859	1521	1811	703	693	1121	1032	1807	1698	1951	1949
Length Range	350-660	317-621	412-623	393-669	270-530	290-470	311-502	309-536	410-555	355-560	376-588	375-670
Mean Length	492	491	508	530	349	355	386	397	487	469	487	486
Number of Fish	15	15	15	15	15	15	15	15	15	15	15	15
% Lipid Range[a]	9.5-11.0	6.0-11.0	5.9-16.0	5.1-9.7	0.6-2.3	0 6-2.0	1.2-2.1	1.9-2.6	6.4-8.0	3.0-5.3	5.0-6.4	5.0-9.9
Mean % Lipid	10.5	8.7	9.7	8.1	1.4	1.3	1.7	2.2	7.1	4.2	5.7	6.7
Number of Composites	3	3	3	3	3	3	3	3	3	3	3	3
1992[b]												
Weight Range	300-2470	615-1345	365-890	660-1415	300-2955	320-1630	360-3380	335-2350	695-2775	1005-3020	810-2100	1135-4000
Mean Weight	1198	958	643	962	1203	914	1166	942	1573	1616	1404	1796
Length Range	319-617	433-541	350-477	432-545	282-547	300-465	300-570	294-525	363-576	410-586	380-500	406-606
Mean Length	484	479	421	470	405	385	404	387	457	469	452	481
Number of Fish	15	12	3	9	15	15	15	15	15	15	15	15
% Lipid Range[a]	5.0-6.8	5.1-6.8	6	3.6-5.3	1.0-3.1	1.1-2.6	0.7-2.9	1.7-2.5	6.2-7.8	4.4-6.7	4.5-6.9	4.0-7.1
Mean % Lipid	5.8	5.9		4.5	1.8	1.9	1.7	2.1	6.9	5.2	5.3	5.2
Number of Composites	3	3	1	2	3	3	3	3	3	3	3	3
1993												
Weight Range	595-1700	710--2370	665-1735	385-2175	330-2285	345--1045	395-2775	300-2120	1290-3030	465--3040	605-2265	1280--2620
Mean Weight	1115	1307	1256	820	659	629	1130	918	2153	1607	1587	1763
Length Range	421-525	434--586	440-583	265-596	305-516	306--408	314-568	290-540	431-553	328--557	345-532	428--559
Mean Length	472	500	528	434	351	355	409	387	504	453	455	459
Number of Fish	15	15	15	15	15	15	15	15	15	15	15	15
% Lipid Range[a]	5.6-6.3	5.1--9.2	5.5-8 1	5.2-7.4	1.1-3 0	0.6-0.9	0.9-3.7	1.6-2.5	5.3-7.2	5.0--11	4.8-12	6.0--8.1
Mean % Lipid	6.0	6.9	7.2	6.1	2.0	0.8	2.0	2.0	6.1	7.7	7.8	7.1
Number of Composites	3	3	3	3	3	3	3	3	3	3	3	3

a The values listed as "% Lipid Range" correspond to the lipid content of composites.
b Actually collected in January 1993.

Table 5.3-4 Two-way analysis of variance (location and year main effects) and Ryan-Einot-Gabriel-Welsch Multiple Range Test on lipid content and total weight in catfish, largemouth bass, and smallmouth buffalo from Wheeler Reservoir, 1991-1993.

Variable	Source of Variation	P>F	REGW Multiple Range Test[a] Mean Rank Low to High
		CATFISH	
Lipid content	Location	0.5764	
	Year	0.0031	1992 1993 1991
	Interaction	0.9316	
Total Weight	Location	0.7446	
	Year	0.0016	
	Interaction	0.0102	Significant Interaction
		LARGEMOUTH BASS	
Lipid content	Location	0.1984	No
	Year	0.8201	Significant
	Interaction	0.6036	Difference
Total Weight	Location	0.0716	No
	Year	0.0815	Significant
	Interaction	0.4131	Difference
		SMALLMOUTH BUFFALO	
Lipid content	Location	0.5539	No
	Year	0.8739	Significant
	Interaction	0.4024	Difference
Total Weight	Location	0.1648	No
	Year	0.0926	Significant
	Interaction	0.2411	Difference

a Years or locations underscored by the same lines were not significantly different at $\alpha = 0.05$. Years and locations not so underscored were significantly different.

Table 5.3-5 One-way analysis of variance and Ryan-Einot-Gabriel-Welsch Multiple Range Test on total weight in channel catfish collected from Wheeler Reservoir, 1991-1993.

Year/Location	Variable	P>F	REGW Multiple Range Test[a] Mean Rank Low to High
1993	Location	0.0013	325 308 320 315
308	Year	0.8657	No Significant Difference
315	Year	0.2665	No Significant Difference
320	Year	0.0404	1992[b] 1993 1991
325	Year	0.0007	1993 1992[b] 1991

a Years or locations underscored by the same lines were not significantly different at $\alpha = 0.05$. Years and locations not so underscored were significantly different.

b Actually collected in January 1993.

Table 5.3-6 Summary of total PCB concentrations (μg/g) in catfish, largemouth bass and smallmouth buffalo composites[a] from Wheeler Reservoir, 1991-1993.

	Channel Catfish				Largemouth Bass				Smallmouth Buffalo			
	TRM 308	TRM 315	TRM 320	TRM 325	TRM 308	TRM 315	TRM 320	TRM 325	TRM 308	TRM 315	TRM 320	TRM 325
1991												
Range	1.0-1.6	0.9-1.7	1.3-1.6	0.9-1.3	0.1-0.3	0 1-0.2	0.5-2.3	0.1-0.6	0.2-0.2	0.3-0.6	0.8-1.2	0.4-0.6
Mean	1.3	1.3	1.5	1.1	0.2	0.1	1.4	0.3	0.2	0.5	1.0	0.5
Number ≥ 2 0μg/g	0	0	0	0	0	0	1	0	0	0	0	0
Number of composites[a]	3	3	3	3	3	3	3	3	3	3	3	3
1992[b]												
Range	0.2-0.7	0.9-1.1	0.6	0.8-0.9	0.1-0.7	0.1-0.9	0.3-0.5	0.3-0.5	0.2-0.3	0.3-0.7	0.3-0.5	0.6-0.9
Mean	0.5	1.0		0.9	0.3	0.6	0.4	0.4	0.3	0.5	0.4	0.7
Number ≥ 2.0μg/g	0	0		0	0	0	0	0	0	0	0	0
Number of composites[a]	3	3	1	2	3	3	3	3	3	3	3	3
1993												
Range	0.5-0.3	0.6-0.7	0.6-0.9	0.9-1.3	0.2-0.4	0.2-0.3	0.3-0.7	0.4-1.2	0.3-0.4	0.4-0.6	0.3-1.0	0.6-1.5
Mean	0.4	0.7	0.7	1.1	0.3	0.3	0.5	0.7	0.3	0.5	0.6	1.0
Number ≥ 2.0μg/g	0	0	0	0	0	0	0	0	0	0	0	0
Number of composites[a]	3	3	3	3	3	3	3	3	3	3	3	3

a Catfish, largemouth bass, and smallmouth buffalo were analyzed as five-fish composites using methods similar to screening studies. The values listed as "Number of composites" correspond to the number of five-fish composites from a particular location in a particular year.

b Actually collected in January 1993

Table 5.3-7 Summary of total DDT concentrations (μg/g) in catfish, largemouth bass and smallmouth buffalo composites[a] from Wheeler Reservoir, 1991-1993.

	Channel Catfish				Largemouth Bass				Smallmouth Buffalo			
	TRM 308	TRM 315	TRM 320	TRM 325	TRM 308	TRM 315	TRM 320	TRM 325	TRM 308	TRM 315	TRM 320	TRM 325
1991												
Range	5.7-13	1.9-7.8	6.1-13	1.1-2.8	0.49-1.2	2.6-3.3	5.0-11	0.12-11	1.7-2.9	2.3-8.5	18-43	2.0-5.5
Mean	8.4	4.3	9.4	2.2	0.89	3.4	7.4	4.3	2.4	5.2	27	3.5
Number of composites[a]	3	3	3	3	3	3	3	3	3	3	3	3
1992[b]												
Range	0.63-3.1	2.0-2.3	1.6	0.60-0.72	0.34-2.6	0.52-7.4	1.5-1.9	1.3-2 4	1.1-1.5	2.3-9.2	2.7-5.0	0.94-9.2
Mean	2	2.2		0.66	1.2	5.1	1.7	2	1.3	4.7	3.7	3.9
Number of composites[a]	3	3	1	2	3	3	3	3	3	3	3	3
1993												
Range	0.55-0.81	0.69-1.7	0.91-2.8	0.43-1.5	0.30-2.0	0.53-2.0	0.91-2.5	1.1-6.4	0.79-1.2	0.37-0.88	3.7-21	4.0-14
Mean	0.67	1.2	1 7	0.94	0.92	1.2	1.6	3.0	1.0	0.64	13	8.4
Number of composites[a]	3	3	3	3	3	3	3	3	3	3	3	3

a Catfish, largemouth bass, and smallmouth buffalo were analyzed as five-fish composites using methods similar to screening studies. The values listed as "Number of composites" correspond to the number of five-fish composites from a particular location in a particular year.

b Actually collected in January 1993

Table 5.3-8 Two-way analysis of variance (location and year main effects) and Ryan-Einot-Gabriel-Welsch Multiple Range Test on PCB and DDT concentrations in catfish, largemouth bass, and smallmouth buffalo from Wheeler Reservoir, 1991-1993.

		P>F	REGW Multiple Range Test[a] Mean Rank Low to High
		CATFISH	
PCB	Location	0.0159	
	Year	0.0001	
	Interaction	0.0220	Significant Interaction
DDT	Location	0.0104	325 315 308 320
	Year	0.0001	1993 1992 1991
	Interaction	0.0698	
		LARGEMOUTH BASS	
PCB	Location	0.0162	
	Year	0.9818	
	Interaction	0.0235	Significant Interaction
DDT	Location	0.0589	No
	Year	0.1414	Significant
	Interaction	0.3117	Difference
		SMALLMOUTH BUFFALO	
PCB	Location	0.0001	
	Year	0.1281	
	Interaction	0.0167	Significant Interaction
DDT	Location	0.0001	
	Year	0.0146	
	Interaction	0.0034	Significant Interaction

a Years or locations underscored by the same lines were not significantly different at $\alpha = 0.05$. Years and locations not so underscored were significantly different.

Table 5.3-9 One-way analysis of variance (location effects) and Ryan-Einot-Gabriel-Welsch Multiple Range Test on PCB and DDT concentrations in channel catfish, largemouth bass and smallmouth buffalo from Wheeler Reservoir, 1993.

Analyte		P>F	REGW Multiple Range Test[a] Mean Rank Low to High
		Channel Catfish	
PCB	Location	0.0037	308 315 320 325
DDT	Location	0.2396	No Significant Difference
		Largemouth Bass	
PCB	Location	0.0972	No Significant Difference
DDT	Location	0.4553	No Significant Difference
		Smallmouth Buffalo	
PCB	Location	0.0732	No Significant Difference
DDT	Location	0.0024	315 308 325 320

a Years or locations underscored by the same lines were not significantly different at $\alpha = 0.05$. Years and locations not so underscored were significantly different.

Table 5.3-10 One-way analysis of variance (year effects) and Ryan-Einot-Gabriel-Welsch Multiple Range Test on PCB concentrations among years for each location in channel catfish, largemouth bass, and smallmouth buffalo from Wheeler Reservoir, 1991-1993.

Location	P>F	REGW Multiple Range Test[a] Mean Rank Low to High
	Channel Catfish	
308	0.0131	1993 1992[b] 1991
315	0.0327	1993 1992[b] 1991
320	0.0075	1992 1993 1991
325	0.3491	No Significant Difference
	Largemouth Bass	
308	0.8944	No Significant Difference
315	0.1792	No Significant Difference
320	0.0959	No Significant Difference
325	0.2870	No Significant Difference
	Smallmouth Buffalo	
308	0.0344	1991 1992[b] 1993
315	0.9433	No Significant Difference
320	0.0627	No Significant Difference
325	0.1278	No Significant Difference

a Years or locations underscored by the same lines were not significantly different at $\alpha = 0.05$. Years and locations not so underscored were significantly different.

b Actually collected in January 1993.

Table 5.3-11 One-way analysis of variance (year effects) and Ryan-Einot-Gabriel-Welsch Multiple Range Test on DDT concentrations in smallmouth buffalo from Wheeler Reservoir, 1991-1993.

Location		P>F	REGW Multiple Range Test[a] Mean Rank Low to High
308	Year	0.0139	1993 1992[b] 1991
315	Year	0.0376	1993 1992 1991
320	Year	0.0220	1992 1993 1991
325	Year	0.3132	No Significant Difference

a Years or locations underscored by the same lines were not significantly different at $\alpha = 0.05$. Years and locations not so underscored were significantly different.

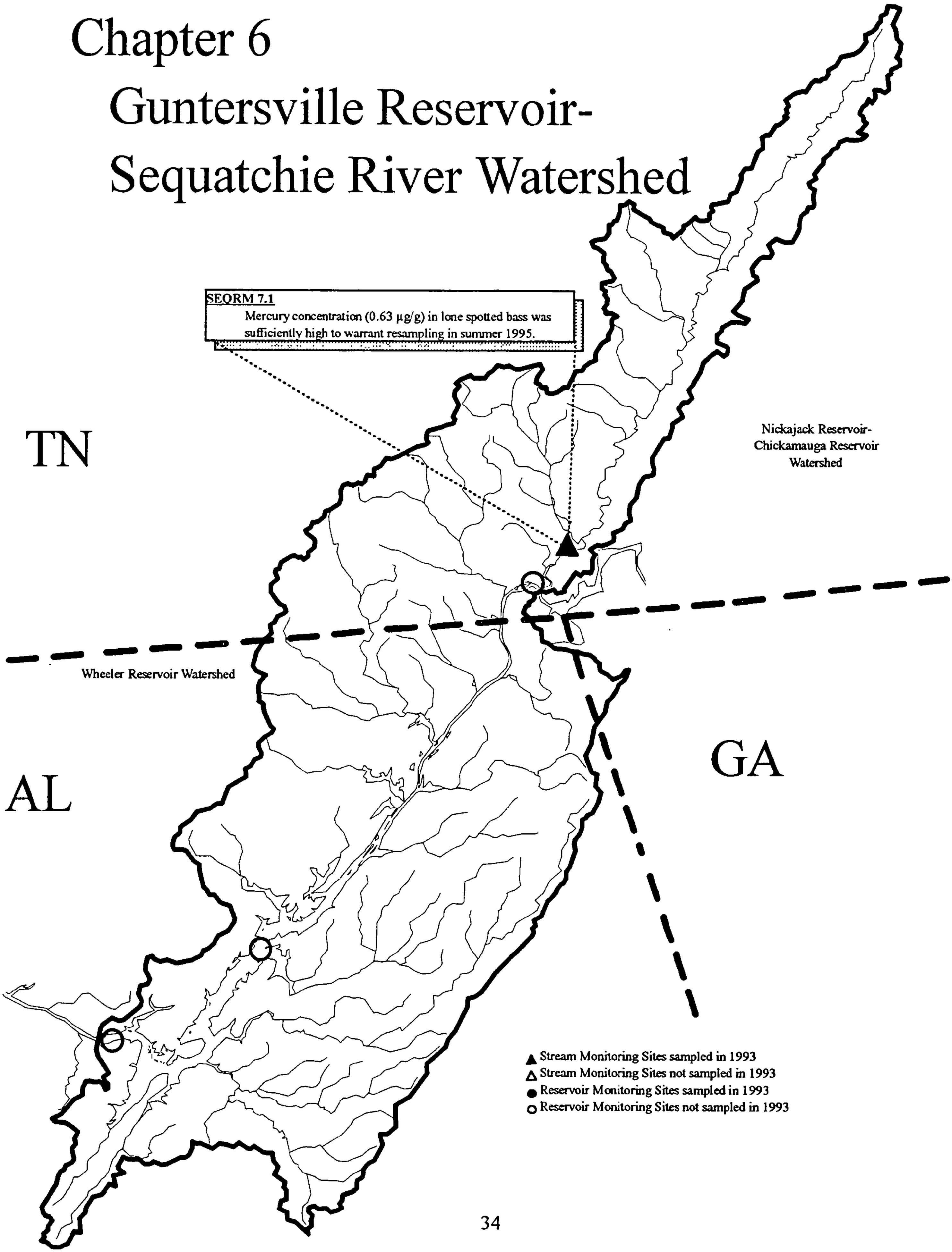
b Actually collected in January 1993.

Table 5.3-12 DDT concentrations (µg/g wet weight) in composites of channel catfish, largemouth bass, and smallmouth buffalo from Wheeler Reservoir, 1991-1993.

	TRM 308			TRM 315			TRM 320			TRM 325		
	1991[a]	1992[a]	1993[a]	1991	1992	1993	1991	1992	1993	1991	1992	1993
Channel Catfish												
1-5	13	3.1	0.81	3.3	2.0	1.3	13	1.6	1.5	2.8	0.60	1.5
6-10	6.7	2.3	0.66	1.9	2.2	0.69	8.8		0.91	2.6	0.72	0.88
11-15	5.7	0.63	0.55	7.7	2.3	1.7	6.1		2.8	1.1		0.43
Mean	8.4	2.0	0.67	4.3	2.2	1.2	9.4		1.7	2.2	0.66	0.95
Smallmouth Buffalo												
1-5	1.6	1.1	0.79	4.6	2.6	0.37	18	5.0	3.7	5.5	9.2	7.2
6-10	2.7	1.2	1.1	2.3	9.2	0.68	20	3.4	13	3.1	0.9	4.0
11-15	2.9	1.5	1.2	8.5	2.3	0.88	43	2.7	21	2.0	1.7	14
Mean	2.4	1.3	1.0	5.1	4.7	0.64	27	3.7	13	3.5	3.7	8.4
Largemouth Bass												
1-5	1.1	2.6	2.0	2.6	7.4	2.0	4.9	1.9	2.5	11	2.4	1.5
6-10	1.0	0.55	0.47	4.3	7.4	0.53	6.6	1.5	1.3	1.6	2.3	1.1
11-15	0.5	0.34	0.3	3.1	0.5	1.1	11	1.8	0.91	0.1	1.3	6.4
Mean	0.9	1.2	0.92	3.3	5.0	1.2	7.4	1.7	1.6	4.3	2.0	3.0

a 1991 = October 1991; 1992 = January 1993; 1993 = October-November 1993

Chapter 6
Guntersville Reservoir-Sequatchie River Watershed



6.0 Guntersville Reservoir-Sequatchie River Watershed

6.1 Introduction

Fish for fish tissue screening studies were collected from only one site in the Guntersville Reservoir-Sequatchie River Watershed in 1993, a stream monitoring site at Sequatchie River Mile (SEQRM) 7.1. Publications containing historical data from monitoring sites within the Guntersville Reservoir- Sequatchie River Watershed are in Appendix B.

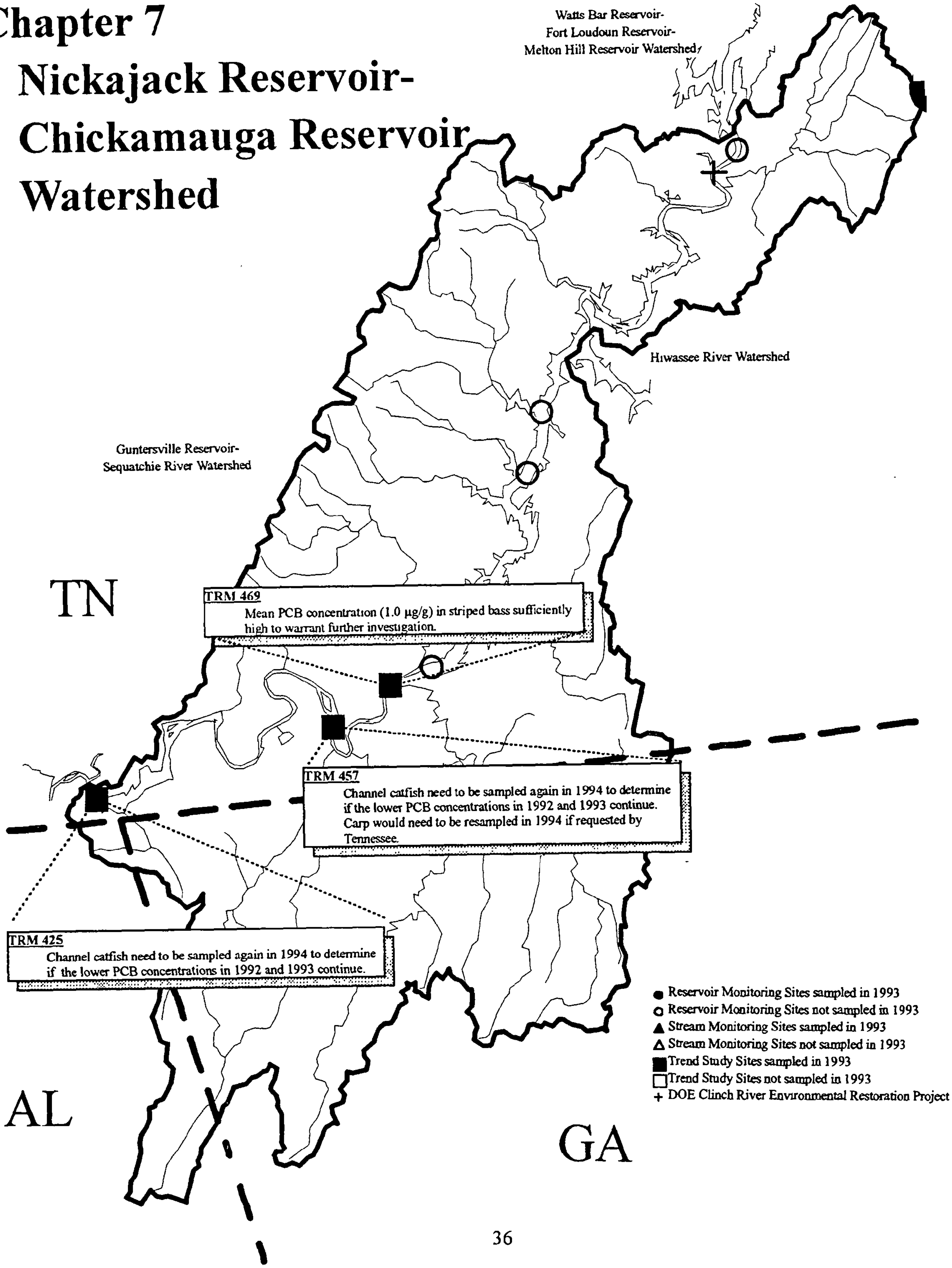
6.2 Methods

A composite of five channel catfish was collected from the stream monitoring site along with one largemouth bass and one spotted bass. These fish were analyzed for lipids, PCBs, pesticides and selected metals on the EPA Priority Pollutant List according to the methods for screening studies in Appendix C.

6.3 Results and Recommendations

Physical information and results from the chemical analyses for these fish are contained in Appendix A along with data from other stream and reservoir monitoring sites. Mercury concentration (0.63 µg/g) in the single spotted bass from SEQRM 7.1 was the only analyte to exceed Tier 2 levels. Elevated mercury concentrations had not been found in previous years. This station is part of the newly implemented two-year rotation for streams and will be sampled in summer 1995.

Chapter 7
Nickajack Reservoir-Chickamauga Reservoir Watershed



Chapter 7.0 Chickamauga Reservoir - Nickajack Reservoir Watershed

7.1 Introduction

In 1989, the Tennessee Department of Environment and Conservation (TDEC) issued a precautionary advisory suggesting, "that children, pregnant women, and nursing mothers avoid eating catfish from Nickajack Reservoir and that others persons limit their consumption of catfish to 1.2 pounds per week." The most current fish consumption advisory from TDEC is Appendix D.

Fish tissue samples were collected at four locations in the Chickamauga Reservoir - Nickajack Reservoir Watershed in 1993. Three of these locations (TRMs 425, 457, and 469) were within Nickajack Reservoir and were part of a long-term trend study on PCBs and chlordane. The other location was in Watts Bar Dam tailwater and fish were collected as part of a contract with DOE for their Clinch River Environmental Restoration Project (CRERP). Data from the fish collected in 1993 for the CRERP were no available at the time this report was written. Historical data from monitoring sites within the Chickamauga Reservoir - Nickajack Reservoir Watershed are available in publications listed in Appendix B.

7.2 Nickajack Trend Analysis Study

Results of the Valley-wide Fish Tissue Screening Study in 1987 found sufficiently high concentrations of both PCBs and chlordane in channel catfish (the indicator species) from Nickajack Reservoir to warrant further investigation. PCB concentrations exceeded the predetermined Tier 3 levels (Table 1-1) established to trigger more in-depth studies to better define apparent problems. The five-catfish fillet composite sample from the lower reservoir location (TRM 425) contained 1.9 µg/g PCBs and 0.21 µg/g chlordane, while the composite sample from the upper area (TRM 457) contained 1.3 µg/g PCBs and 0.25 µg/g chlordane (Dycus 1989a).

Follow-up studies were conducted in autumn 1988, 1989, 1990, 1991, 1992, and 1993 to further define the temporal trend of PCB and chlordane contamination in Nickajack Reservoir catfish and to investigate concentrations in other important species. The results of the 1993 study are presented in this report as well as comparisons among catfish for the six years of data (1988-1993).

Methods

Ten channel catfish and ten carp were collected from TRMs 425 and 457 in 1993. Ten striped bass were collected from TRM 469. These fish were analyzed individually for lipids, PCBs, and chlordane. All procedures involved in field sampling, processing, and laboratory and data analysis were similar to those described in Appendix C and will not be repeated here.

Results and Recommendations

Physical information and the results of analyses are presented in Tables 7.2-1 through 7.2-8. The two-way ANOVA on channel catfish weights with location and year as the two main effects had a significant interaction term, primarily because quite small fish were collected at TRM 457 in 1989. A one-way ANOVA on weight of catfish collected in 1993 failed to detect a significant difference between TRMs 425 and 457. Lipid content of catfish was not significantly different among years or locations.

PCB concentrations in channel catfish were slightly higher in 1993 (mean at TRMs 425 and 457 was 0.6 and 0.7 µg/g, respectively) than in 1992, but still lower than in previous years. Statistical analyses indicated concentrations in 1992 and 1993 were significantly lower than in previous years. PCB concentrations were not significantly related to either total weight or lipid content.

Total weight of individual carp was significantly lower and lipid content significantly higher in 1991 than in 1992 and 1993. The two-way ANOVA on PCB concentrations in carp had a significant interaction term, primarily because PCB concentrations in carp have been consistent at TRM 425 (mean concentrations = 0.3 µg/g in 1991, 1992, and 1993) but inconsistent at TRM 457 (mean PCB concentrations = 1.2 µg/g in 1991, 0.3 µg/g in 1992, and 0.7 µg/g in 1993). PCB concentrations in 1993 were significantly higher at TRM 457 than 425.

Striped bass from TRM 469 weighed significantly more in 1993 than in 1992, but lipid content and PCB concentrations were not significantly different. PCB concentrations in striped bass have been higher than in channel catfish in both 1992 and 1993.

Further examination of striped bass is warranted because concentrations in 1992 and 1993 were near the level used by TDEC to issue a "limit-consumption" advisory. Also, channel catfish should be sampled again in 1994 to determine if the lower concentration of PCBs seen in 1992 and 1993 continue, possibly leading to altering the advisory. Carp would not be sampled unless TDEC recognizes a specific need.

Table 7.2-1 Physical data and analyte concentrations (µg/g) in carp, channel catfish, and striped bass from Nickajack Reservoir, 1993.

Collection Site	Species[a]	Length (mm)	Weight (g)	Sex	LABID[b]	%LIPIDS	PCB	Chlordane
TRM 425	C	610	3461	MALE	32916	9.1	0.3	0.01
TRM 425	C	569	2602	MALE	32918	6.9	0.2	<0.01
TRM 425	C	624	3701	MALE	32921	6.4	0.2	<0.01
TRM 425	C	695	6881	FMALE	32923	8.7	0.4	0.02
TRM 425	C	694	5146	MALE	32926	8.7	0.4	0.02
TRM 425	C	696	4994	FMALE	32928	3.5	0.2	<0.01
TRM 425	C	746	6516	MALE	32931	6.4	0.4	<0.01
TRM 425	C	760	6223	FMALE	32932	5.8	0.4	<0.01
TRM 425	C	751	6507	FMALE	32933	8.0	0.6	<0.01
TRM 425	C	748	6345	FMALE	32934	4.6	0.3	<0.01
TRM 425	CHC	590	2359	FMALE	32906	3.7	0.4	0.01
TRM 425	CHC	481	1071	MALE	32907	13	0.8	0.03
TRM 425	CHC	517	1436	I[c]	32908	6.0	0.5	0.01
TRM 425	CHC	556	1370	FMALE	32909	4.8	1.0	0.03
TRM 425	CHC	475	989	FMALE	32910	6.6	0.3	0.01
TRM 425	CHC	470	921	I[c]	32911	10	0.7	0.02
TRM 425	CHC	496	1069	MALE	32912	5.8	0.3	<0.01
TRM 425	CHC	422	650	MALE	32913	1.8	0.4	0.01
TRM 425	CHC	595	2226	FMALE	32914	5.4	0.7	<0.01
TRM 425	CHC	460	836	FMALE	32915	11	0.8	0.02
TRM 457	CHC	470	1060	MALE	32935	9.6	0.6	<0.01
TRM 457	CHC	419	714	FMALE	32936	5.9	0.9	<0.01
TRM 457	CHC	432	869	FMALE	32939	6.9	0.7	0.01
TRM 457	CHC	575	2141	MALE	32940	13	1.0	0.01
TRM 457	CHC	529	1653	FMALE	32941	14	1.2	<0.01
TRM 457	CHC	536	1540	MALE	32942	8.3	0.7	<0.01
TRM 457	CHC	412	663	FMALE	32943	6.4	0.3	<0.01
TRM 457	CHC	461	945	FMALE	32944	3.7	0.3	<0.01
TRM 457	CHC	570	1939	FMALE	32945	3.8	0.6	<0.01
TRM 457	CHC	476	1061	MALE	32946	9.0	0.7	0.01

Collection Site	Species[a]	Length (mm)	Weight (g)	Sex	LABID[b]	%LIPIDS	PCB	Chlordane
TRM 457	C	713	5147	MALE	32947	4.9	1.8	<0.01
TRM 457	C	701	6547	MALE	32949	3.1	0.5	<0.01
TRM 457	C	671	4298	MALE	32952	3.6	0.5	<0.01
TRM 457	C	710	4692	MALE	32954	10	0.6	<0.01
TRM 457	C	655	3768	MALE	32960	6.0	0.4	0.02
TRM 457	C	695	4603	MALE	32962	2.9	0.6	0.02
TRM 457	C	747	5672	MALE	32965	5.4	0.9	0.12
TRM 457	C	715	5071	MALE	32967	3.2	0.5	0.05
TRM 457	C	750	5559	MALE	32970	7.5	0.8	0.21
TRM 457	C	687	4362	MALE	32972	6.2	0.7	0.10
TRM 469	STB	542	1618	FMALE	32975	5.3	0.6	0.06
TRM 469	STB	685	3388	FMALE	32976	8.2	0.8	0.03
TRM 469	STB	698	3953	MALE	32977	13	1.2	0.11
TRM 469	STB	706	4268	FMALE	32978	9.9	0.8	0.05
TRM 469	STB	700	3856	FMALE	32981	6.5	1.0	0.03
TRM 469	STB	768	6513	FMALE	32983	9.1	0.8	0.04
TRM 469	STB	700	3929	FMALE	32986	8.2	0.8	0.03
TRM 469	STB	724	3823	FMALE	32987	5.6	0.9	0.04
TRM 469	STB	749	4925	FMALE	32988	10	0.7	<0.01
TRM 469	STB	850	7324	MALE	32989	7.0	1.9	0.13

a CHC = channel catfish, C = carp, STB = striped bass

b LABID = number assigned by TVA's Environmental Chemistry Laboratory. It is used to link laboratory analysis data with physical data from fish.

c I = immature (sex could not be determined).

Table 7.2-2 Summary of lengths, total weights, and percent lipids of catfish, carp, and striped bass from Nickajack Reservoir, collected from 1988 to 1993.

Year	Species	Site	Weight Range	Mean Weight	Length Range	Mean Length	% Lipid Range	Mean % Lipid
1988	Catfish	TRM 425	1835-2705	2175	555--650	587	0.9--18.0	11.4
		TRM 457	1198-2340	1854	472--602	540	8.9--20.0	13.6
1989	Catfish	TRM 425	346-1798	1048	331--565	458	3.0--20.0	10.3
		TRM 457	308-1001	805	332--470	397	3.2--17.0	10.9
1990	Catfish	TRM 425	464-2332	1215	370--596	484	5.4--20 0	10.7
		TRM 457	736-2429	1500	426--656	528	3.6--24 0	12.4
1991	Catfish	TRM 425	570-2512	1607	395--597	521	4.8--14.0	8.1
		TRM 457	962-2839	2100	451--625	565	0.1--27 0	14.1
	Carp	TRM 425	1602-5017	3350	477--725	617	4.0--16.0	10.1
		TRM 457	3522-7932	4958	633--780	686	3.9--14.0	9.4
1992	Catfish	TRM 425	762-1845	1144	446--585	497	2.3--12.0	7.3
		TRM 457	883-2620	1453	463--610	516	2.3--20.0	10 1
	Carp	TRM 425	3460-8414	5150	633--846	708	2.6--12.0	6.2
		TRM 457	3635-8943	6552	646--799	749	3.5--12.0	6.5
	Striped Bass	TRM 470	1619-3311	2305	494--686	594	7 3--12.0	9.1
1993	Catfish	TRM 425	650-2359	1293	422-595	506	1.8-13.0	6.8
		TRM 457	663-2141	1259	412-575	488	3.7-14.0	8.1
	Carp	TRM 425	2602-6881	5238	569-760	689	3.5-9.1	6.8
		TRM 457	3768-6547	4972	655-750	704	2.9-10.0	5.3
	Striped Bass	TRM 469	1618-7324	4360	542-850	712	5.3-13.0	8.3

Table 7.2-3 Two-way analysis of variance (location and year main effects) and Ryan-Einot-Gabriel-Welsch Multiple Range Test on lipid content and total weight in catfish and carp from Nickajack Reservoir, 1988-1993.

Variable	Source of Variation	P>F	REGW Multiple Range Test[a] Mean Rank Low to High
		CATFISH	
Lipid content	Location	0.0573	No
	Year	0.1160	Significant
	Interaction	0.8646	Difference
Total Weight	Location	0.9384	
	Year	0.0001	
	Interaction	0.0090	Significant Interaction
		CARP	
Lipid content	Location	0.4305	
	Year	0.0006	1993 1992 1991
	Interaction	0.5315	
Total Weight	Location	0.0049	425 457
	Year	0.0008	1991 1993 1992
	Interaction	0.0602	

a Years underscored by the same lines were not significantly different at $\alpha = 0.05$. Years not so underscored were significantly different.

Table 7.2-4 One-way analysis of variance and Ryan-Einot-Gabriel-Welsch Multiple Range Test on total weight in channel catfish from Nickajack Reservoir, 1988-1993.

Fixed	Variable	P>F	REGW Multiple Range Test[a] Mean Rank Low to High
1993	Location	0.8993	No Significant Difference
425	Year	0.0008	1989 1992 1990 1993 1991 1988
457	Year	0.0001	1989 1993 1992 1990 1988 1991

a Years underscored by the same lines were not significantly different at $\alpha = 0.05$. Years not so underscored were significantly different.

Table 7.2-5 Summary of total PCB concentrations (μg/g) in individual catfish, carp, smallmouth buffalo, and striped bass fillets from Nickajack Reservoir, collected from 1988 to 1992.

	Catfish		Carp		Smallmouth Buffalo		Striped Bass
	TRM 425	TRM 457	TRM 425	TRM 457	TRM 425	TRM 457	TRM 470
1988[a]							
Range	0.4-1.9	0.9-1.7					
Mean	0.9	1.3					
Number ≥ 2.0μg/g	0	0					
Number of fish	10	3					
1989							
Range	0.6-2.0	0 6-2.0					
Mean	1.3	0.7					
Number ≥ 2.0μg/g	1	1					
Number of fish	10	10					
1990							
Range	0.6-1.5	0.4-1.7					
Mean	1.0	1.1					
Number ≥ 2.0μg/g	0	0					
Number of fish	10	10					
1991							
Range	0.3-3.6	0.2-1.9	0.1-0.8	0.3-2.7	0.1-0.7	0.1-0.7	
Mean	1.5	0.9	0.3	1.2	0.2	0.4	
Number ≥ 2.0μg/g	2	0	0	1	0	0	
Number of fish	10	10	10	9	10	4	
1992							
Range	0.1-0.8	0.1-0.8	0.1-0.7	0.1-0.6			0.5-1.1
Mean	0.4	0.5	0.3	0.3			0.8
Number ≥ 2.0μg/g	0	0	0	0			0
Number of fish	10	10	10	9			8
1993							
Range	0.3-1.0	0.3-1.2	0.2-0.6	0.4-1.8			0.6-1.9
Mean	0.6	0.7	0.3	0.7			1.0
Number ≥ 2.0μg/g	0	0	0	0			0
Number of fish	10	10	10	10			10

a Catfish collected in January and February 1989.

Table 7.2-6 Two-way analysis of variance[a] (location and year main effects) and Ryan-Einot-Gabriel-Welsch Multiple Range test on PCB concentrations in catfish and carp from Nickajack Reservoir, 1988-1993.

		P>F	REGW Multiple Range Test[b] Mean Rank Low to High
Catfish	Location	0.7155	
	Year	0.0001	1992 1993 1990 1988 1991 1989
	Interaction	0.0725	
Carp	Location	0.0001	
	Year	0.0011	
	Interaction	0.0018	Significant Interaction

a Preliminary test indicated PCB concentrations in catfish and carp were not related to lipid content or weight, hence, ANOVA was the appropriate test

b Years or locations underscored by the same lines were not significantly different at $\alpha = 0.05$. Years and locations not so underscored were significantly different.

Table 7.2-7 One-way analysis of variance and Ryan-Einot-Gabriel-Welsch Multiple Range test on PCB concentrations in carp from Nickajack Reservoir, 1991-1993.

Year/Location	Variable	P>F	REGW Multiple Range Test[a] Mean Rank Low to High
1993	Location	0.0021	425 457
425	Year	0.6300	No Significant Difference
457	Year	0.0013	1992 1993 1991

a Years underscored by the same lines were not significantly different at $\alpha = 0.05$.
Years not so underscored were significantly different.

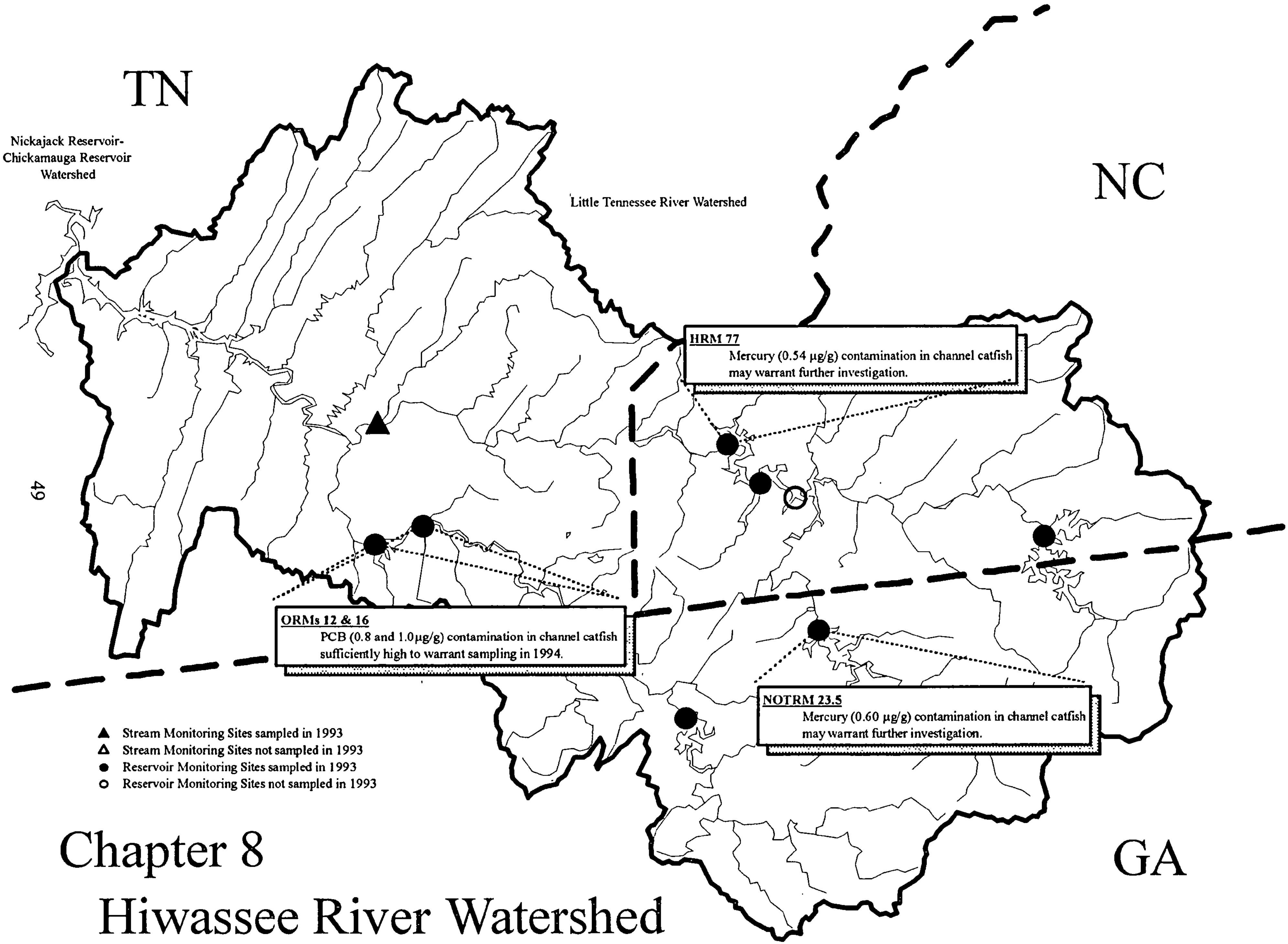
Table 7.2-8 One-way analysis of variance (year effects) and Ryan-Einot-Gabriel-Welsch Multiple Range test on lipid content, total weight, and PCB concentrations in striped bass from TRM 469, Nickajack Reservoir, 1992-1993.

		P>F	REGW Multiple Range Test[b] Mean Rank Low to High
Lipid	Year	0.3623	No Significant Difference
Weight	Year	0.0362	1992 1993
PCB	Year	0.2064	No Significant Difference

a Preliminary test indicated PCB concentrations in striped bass were not related to lipid content or weight, hence, ANOVA was the appropriate test

b Years underscored by the same lines were not significantly different at $\alpha = 0.05$. Years not so underscored were significantly different.

Chapter 8
Hiwassee River Watershed



8.0 Hiwassee River Watershed

8.1 Introduction

Fish tissue samples were collected at one stream monitoring site and seven reservoir monitoring sites in the Hiwassee River Watershed in 1993. The stream monitoring site was located at Hiwassee River mile (HiRM) 38. Three of the seven reservoir monitoring sites were in the forebays of Chatuge Reservoir (HiRM 122), Nottely Reservoir (Nottely River Mile (NRM) 24), and Blue Ridge Reservoir (Toccoa River Mile (ToRM) 54). The other four reservoir monitoring sites were in the forebays and transition zones of Hiwassee Reservoir (HiRMs 77 and 85) and Ocoee #1 (Ocoee River mile (ORM) 12 and mouth of Sylco Creek embayment (ORM 16). The sites in Hiwassee, Chatuge, Nottely, and Blue Ridge Reservoirs were sampled to examine mercury levels in tributary reservoirs. The samples from Ocoee #1 Reservoir were a continuation of a study of PCBs.

Screening studies in Ocoee #1 Reservoir in 1987 had indicated relatively high PCB concentrations (≥ 1.0 µg/g). Additional screening samples in 1988, 1989, 1990, and 1991 found similar levels. A more detailed study in autumn 1992 confirmed an average PCB concentration in channel catfish of 1.0-1.5 µg/g. A final decision about issuing an advisory had not been made by TDEC at the time sample collection was planned for autumn 1993. As a result, samples were collected at the screening level to continue the database for this reservoir. Final decision on issuance of an advisory had not been made at the time this report was prepared. Historical data from monitoring sites within the Hiwassee River Watershed are available in publications listed in Appendix B.

8.2 Methods

Five channel catfish and largemouth bass were collected from the stream monitoring site at HiRM 38. Five channel catfish were collected from the seven reservoir monitoring sites. These fish were analyzed as composites for lipids, pesticides, PCBs, and selected metals on the EPA Priority Pollutant List.

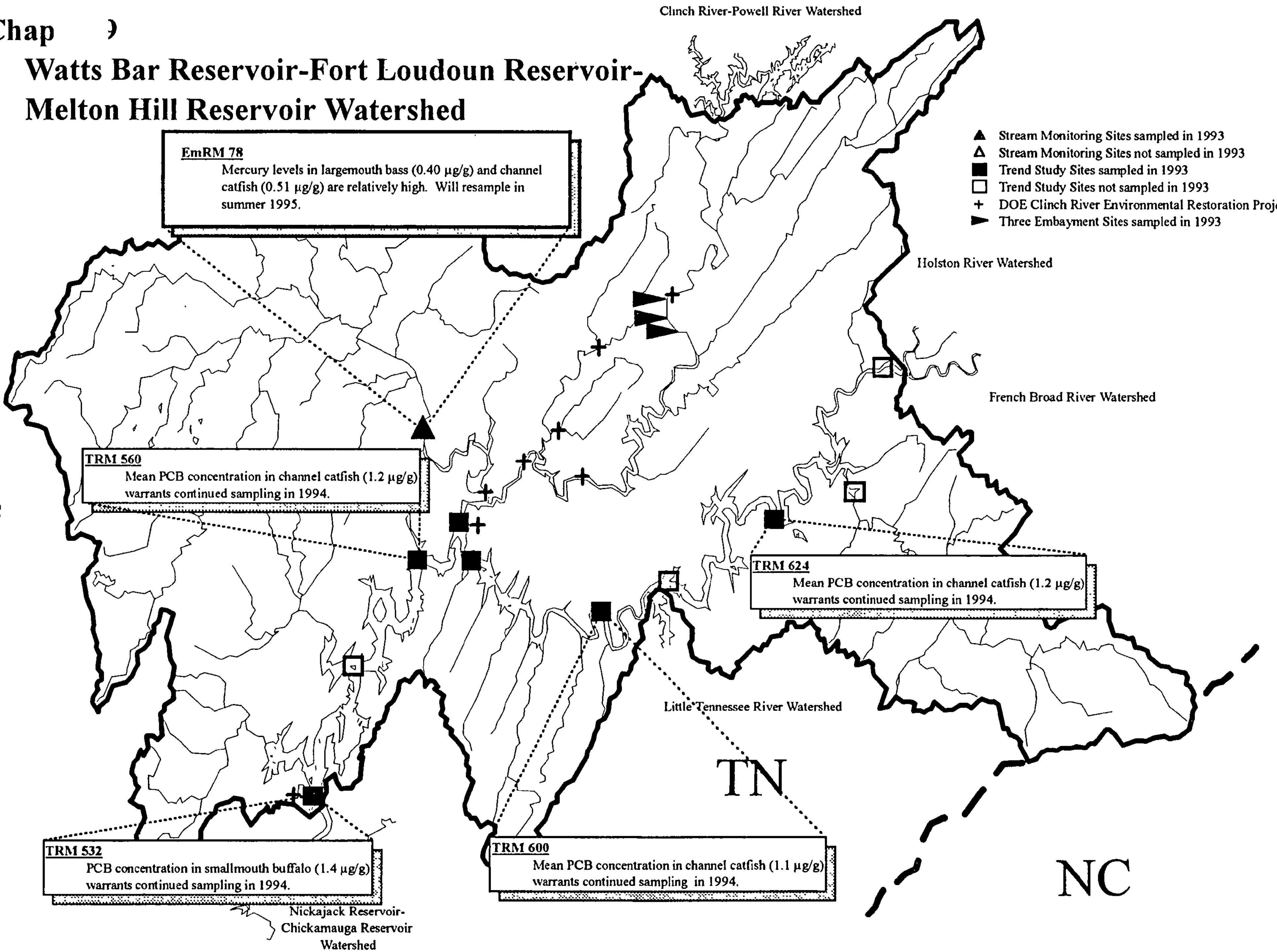
Five largemouth bass were collected from HiRMs 85 and 122, NRM 24, and ToRM 54. Four largemouth bass were collected from HiRM 77. These bass were analyzed as composites for mercury only. In addition to complete analysis, many largemouth bass weighing more than 1200 grams were analyzed individually in an attempt to describe worse-case conditions. Further, all largemouth bass, regaurdless of size, from Hiwassee Reservoir were analyzed individually. Results of mercury analyses are in Appendix F. Field handling and processing and laboratory processing were performed according to the methods for screening studies outlined in Appendix C.

8.3 Results and Recommendations

Physical information and the results of metals and organics analyses for the stream and reservoir monitoring sites are included in Appendix A. Results of mercury analyses on largemouth bass are in Appendix F. PCB concentrations in channel catfish from the forebay (0.8 μg/g) and upper region (1.0 μg/g) of Ocoee #1 and mercury concentrations in channel catfish from the forebays of Hiwassee (0.54 μg/g) and Nottley Reservoirs (0.60 μg/g) were the only analytes from the Hiwassee River Watershed to approach or exceed Tier 2 levels. Mercury results from individual, large largemouth bass were also near the 0.5 µg/g level, possibly indicating need for further investigation (Appendix F).

Continued sampling of channel catfish from Ocoee #1 is needed because PCB concentrations continue to be near the level used by TDEC to issue a precautionary advisory. Implications of the relatively high mercury concentrations were still under consideration when this report was prepared. It is likely that further investigation of this possible concern is warranted.

Watts Bar Reservoir-Fort Loudoun Reservoir-Melton Hill Reservoir Watershed



Chapter 9.0 Watts Bar Reservoir - Fort Loudoun Reservoir - Melton Hill Reservoir Watershed

9.1 Introduction

The Tennessee Department of Environment and Conservation (TDEC) has issued advisories against consuming certain fish from all three reservoirs in this watershed, Watts Bar, Melton Hill, and Fort Loudoun. The most current advisory is Appendix D.

Fish tissue samples were collected at eighteen locations in the Watts Bar Reservoir - Fort Loudoun Reservoir - Melton Hill Reservoir Watershed in 1993. One of these sites was a stream monitoring site at Emory River mile (EmRM) 14.5. Six of the locations (TRMs 530, 560, 570, 600, and 625 and CRM 1) were sampled for continuation of the trend studies on Watts Bar and Fort Loudoun Reservoirs initiated in the mid to late 1980s. Three locations on Melton Hill Reservoir were sampled for a special study on embayments near CRM 50. The remaining eight locations were sampled under contract to DOE for their Clinch River Environmental Restoration Project (CRERP). The data for the fish collected from the CRERP sites in 1993 were not available at the time this report was prepared. Historical data from monitoring sites within the watersned are available in publications listed in Appendix B.

9.2 Screening Studies

Five channel catfish and largemouth bass were collected from a stream monitoring location at EmRM 14.5 and analyzed for lipids, pesticides, PCBs, and selected metals from the EPA Priority Pollutant List. Field handling and processing and laboratory processing were performed according to the methods for screening studies outlined in Appendix C.

Physical information and the results of metals and organics analyses for this stream monitoring site are included in Appendix A. Mercury contamination in channel catfish (0.40

μg/g) and largemouth bass (0.51 μg/g) were the only analytes which were near or above Tier 2 levels. Several years of fish tissue data exist for this site, so it will not be sampled until summer 1995.

9.3 Trend Studies

9.3.1 Watts Bar Reservoir

Extensive PCB examinations of fish from Watts Bar Reservoir have been conducted for several years. Earlier collections (1985-88) identified substantial PCB contamination in catfish and striped bass (Dycus and Hickman 1988; Dycus 1990c). The tailwaters area of Fort Loudoun Dam was first examined in 1985, and the study reach was expanded downstream each year thereafter. The first collection of fish from the entire length of Watts Bar Lake was in 1988.

This report describes the results of PCB analyses for the trend study on Watts Bar Reservoir in the fall of 1993 and compares the results with those from previous years. The latest Public Health Advisory for Watts Bar Reservoir is included in Appendix D.

Methods -- Fish were collected from five locations within Watts Bar Reservoir in 1993, TRMs 530, 560, 570, and 601 and CRM 1. Ten carp were collected from TRMs 530, 560, and 601 and CRM 1; five analyzed as composites and five stored for future reference. Nine channel catfish from TRM 560 and ten channel catfish from TRM 601 were analyzed individually. Five white bass collected from each location except TRM 570 and five smallmouth buffalo from TRMs 530, 570 and 601 were analyzed as composites. All fish samples were analyzed for lipids, PCBs, and chlordane according to the methods in Appendix C.

Results and Recommendations -- Physical information and results of chemical analyses are presented in Tables 9.3.1-1 to 9.3.1-11 and Figure 9.3.1-1. Lipid content in catfish was significantly different among years but did not reveal any consistent trend. There was a significant interaction between years and locations for catfish weight. This may be the result of smaller fish captured at certain locations during 1989 and 1990.

Preliminary tests indicated a need to adjust PCB concentration for lipid content and fish weight in channel catfish. After adjustment, the two-way co-ANOVA statistics for years and locations indicated inconsistent relationships between lipid content and PCB concentration (non-parallel lines). However, since the P value for parallel line test for lipid content was very near the acceptance level (α=0.05), the results of the co-ANOVA are valid for fish with close to mean weight and lipid content. The co-ANOVA indicated, except for fish collected in 1992, fish collected in 1988 had significantly higher PCB concentrations than ones collected in the other years. Fish with weights and lipid contents near the extremes may show a different pattern.

Visual examination of the results and a one-way ANOVA comparing year differences for each site indicate lower mean PCB concentrations in catfish from TRM 560 in 1989 and 1990 than in other years. These low mean PCB concentrations coincide with lower mean weight of fish.

PCB concentrations in white bass (maximum in 1993 of 0.6 µg/g), smallmouth buffalo (maximum in 1993 of 1.4 µg/g), and carp (maximum in 1993 of 0.7 µg/g) are lower than levels found in previous years from corresponding sites. Fish tissue studies need to be continued on Watts Bar Reservoir. Specific plans for autumn 1994 will be developed after coordination with state agencies and ORNL. At a minimum, channel catfish should be collected at selected locations to examine the trend in PCB concentrations; possibly one to three 5-fish composites from TRMs 532, 560, and 600.

Table 9.3.1-1 Physical information for channel catfish, carp, white bass, and smallmouth buffalo collected from Watts Bar Reservoir, 1993.

Collection Site	Collection Date			Species[a]	Length (mm)	Weight (g)	Sex[c]	LABID[b]
TRM 530.2	10	6	93	WHB	362	680	MALE	33056
TRM 530.2	10	6	93	WHB	403	848	FMALE	33056
TRM 530.2	10	6	93	WHB	360	638	FMALE	33056
TRM 530.2	10	6	93	WHB	365	690	FMALE	33056
TRM 530.2	10	6	93	WHB	391	756	FMALE	33056
TRM 530.2	10	6	93	SBU	653	4524	MALE	33054
TRM 530.2	10	6	93	SBU	653	4886	MALE	33054
TRM 530.2	10	6	93	SBU	489	2136	MALE	33054
TRM 530.2	10	6	93	SBU	561	3516	FMALE	33054
TRM 530.2	10	6	93	SBU	595	4230	MALE	33054
TRM 530.2	10	6	93	C	628	3600	FMALE	33033
TRM 530.2	10	6	93	C	583	2998	FMALE	33033
TRM 530.2	10	6	93	C	619	3568	FMALE	33033
TRM 530.2	10	6	93	C	597	2698	MALE	33033
TRM 530.2	10	6	93	C	636	3350	FMALE	33033
TRM 559.6	10	22	93	CHC	629	2590	FMALE	33059
TRM 559.6	10	22	93	CHC	609	1190	MALE	33061
TRM 559.6	10	22	93	CHC	549	1440	FMALE	33064
TRM 559.6	10	22	93	CHC	471	1048	MALE	33066
TRM 559.6	10	22	93	CHC	395	500	FMALE	33069
TRM 559.6	10	22	93	CHC	400	510	FMALE	33070
TRM 559.6	12	3	93	CHC	490	1054	FMALE	33071
TRM 559.6	12	3	93	CHC	475	822	FMALE	33072
TRM 559.6	12	3	93	CHC	428	620	MALE	33075
TRM 559.6	10	22	93	C	722	5272	FMALE	33077
TRM 559.6	10	22	93	C	618	3176	FMALE	33077
TRM 559.6	10	22	93	C	650	4732	FMALE	33077
TRM 559.6	10	22	93	C	515	1936	I	33077
TRM 559.6	12	2	93	C	602	3118	FMALE	33077
TRM 559.6	10	22	93	WHB	362	642	FMALE	33098
TRM 559.6	10	22	93	WHB	399	902	FMALE	33098
TRM 559.6	10	22	93	WHB	373	750	FMALE	33098
TRM 559.6	10	22	93	WHB	343	616	FMALE	33098
TRM 559.6	10	22	93	WHB	347	560	MALE	33098
TRM 570	10	20	93	SBU	590	3418	FMALE	33101
TRM 570	10	20	93	SBU	656	4456	FMALE	33101
TRM 570	10	20	93	SBU	588	3538	I	33101
TRM 570	10	20	93	SBU	573	3410	I	33101
TRM 570	10	20	93	SBU	517	1056	I	33101
TRM 570	10	20	93	WHB	331	506	MALE	33117
TRM 570	10	20	93	WHB	356	578	FMALE	33117
TRM 570	10	20	93	WHB	357	608	FMALE	33117
TRM 570	10	20	93	WHB	354	558	FMALE	33117
TRM 570	10	20	93	WHB	339	524	MALE	33117
TRM 600	10	8	93	CHC	418	588	DL	33132
TRM 600	10	8	93	CHC	438	848	DL	33133
TRM 600	10	8	93	CHC	390	564	DL	33134

Collection Site	Collection Date			Species[a]	Length (mm)	Weight (g)	Sex[c]	LABID[b]
TRM 600	10	8	93	CHC	645	2058	DL	33119
TRM 600	10	8	93	CHC	626	2884	DL	33122
TRM 600	10	8	93	CHC	385	442	DL	33135
TRM 600	10	8	93	CHC	408	462	DL	33153
TRM 600	12	9	93	CHC	387	458	MALE	33154
TRM 600	12	9	93	CHC	430	518	MALE	33155
TRM 600	12	9	93	CHC	409	484	MALE	33156
TRM 600	10	8	93	SBU	482	1584	DL	33159
TRM 600	10	8	93	SBU	490	2044	DL	33159
TRM 600	10	8	93	SBU	352	628	DL	33159
TRM 600	10	8	93	SBU	322	542	DL	33159
TRM 600	10	8	93	SBU	332	538	DL	33159
TRM 600	10	8	93	C	522	1910	DL	33124
TRM 600	10	8	93	C	557	2004	DL	33124
TRM 600	10	8	93	C	629	3724	DL	33124
TRM 600	10	8	93	C	512	1952	DL	33124
TRM 600	10	8	93	C	488	1482	DL	33124
TRM 600	10	8	93	WHB	334	460	DL	33161
TRM 600	10	8	93	WHB	335	584	DL	33161
TRM 600	10	8	93	WHB	331	458	DL	33161
TRM 600	10	8	93	WHB	313	402	DL	33161
TRM 600	10	8	93	WHB	279	317	DL	33161
CRM 1.0	10	18	93	C	607	2984	DL	33164
CRM 1.0	10	18	93	C	711	5504	DL	33164
CRM 1.0	10	18	93	C	603	3016	DL	33164
CRM 1.0	10	18	93	C	591	2890	DL	33164
CRM 1.0	10	18	93	C	653	3656	DL	33164
CRM 1.0	10	19	93	WHB	378	694	FMALE	33187
CRM 1.0	10	19	93	WHB	366	596	FMALE	33187
CRM 1.0	10	19	93	WHB	356	662	MALE	33187
CRM 1.0	10	19	93	WHB	331	492	MALE	33187
CRM 1.0	10	19	93	WHB	318	468	FMALE	33187

a WHB = white bass, SBU = smallmouth buffalo, C = carp, CHC = channel catfish

b LABID is a tracking number issued by TVA's Environmental Chemistry Lab. It is used to link a sample's physical and chemical data.

c I = immature, DL = Data on sex and internal and external observations for these fish were lost because of an error in a prototype computer program

Table 9.3.1-2 Concentrations of analytes in channel catfish, carp, white bass, and smallmouth buffalo collected from Watts Bar Reservoir, 1993.

Collection Site	Species[a]	LABID[b]	% Lipid	PCB	Chlordane
TRM 530.2	C	33033	3.7	0.4	<0.01
TRM 559.6	C	33077	3.6	0.5	0.01
TRM 600	C	33124	3.0	0.6	<0.01
CRM 1.0	C	33164	3.2	0.7	0.05
TRM 559.6	CHC	33059	4.4	2.1	0.02
TRM 559.6	CHC	33061	1.3	1.1	0.01
TRM 559.6	CHC	33064	2.0	2.0	0.04
TRM 559.6	CHC	33066	4.8	1.0	0.01
TRM 559.6	CHC	33069	3.8	0.4	<0.01
TRM 559.6	CHC	33070	5.3	0.4	<0.01
TRM 559.6	CHC	33071	4.3	2.3	0.05
TRM 559.6	CHC	33072	2.0	0.5	0.01
TRM 559.6	CHC	33075	3.3	0.7	0.01
TRM 600	CHC	33132	1.4	0.2	<0.01
TRM 600	CHC	33133	4.5	2.0	0.15
TRM 600	CHC	33134	4.9	1.0	0.04
TRM 600	CHC	33119	1.1	0.9	0.04
TRM 600	CHC	33122	8.1	3.6	0.21
TRM 600	CHC	33135	2.1	0.4	<0.01
TRM 600	CHC	33153	0.5	<0.1	<0.01
TRM 600	CHC	33154	0.7	0.2	<0.01
TRM 600	CHC	33155	0.6	1.6	0.4
TRM 600	CHC	33156	1.4	0.6	0.05
TRM 530.2	SBU	33054	8.8	1.4	0.02
TRM 570	SBU	33101	7.3	0.7	0.02
TRM 600	SBU	33159	4 1	0.2	0.01
TRM 530.2	WHB	33056	2.6	0.3	<0.01
TRM 559.6	WHB	33098	3.4	0.3	0.01
TRM 570	WHB	33117	4.6	0.6	<0.01
TRM 600	WHB	33161	3.7	0.1	<0.01
CRM 1.0	WHB	33187	3.1	0.6	<0.01

a WHB = white bass, SBU = smallmouth buffalo, C = carp, CHC = channel catfish

b LABID is a tracking number issued by TVA's Environmental Chemistry Lab. It is used to link a sample's physical and chemical data.

Table 9.3.1-3 Summary of lengths, total weights, and percent lipids of catfish from the Tennessee River portion of Watts Bar Reservoir, 1993 and previous years.

	Year	Length Range	Mean Length	Weight Range	Mean Weight	% Lipid Range	Mean % Lipid
TRM 530/532	1988	398-706	531	494-4210	1763	0.7-16.0	4.6
	1989[a]	342-562	465	320-1695	1033	1.0-5.0	2.9
	1990	354-560	423	322-2110	700	0.2-7.1	3.1
	1991	464-609	515	899-2323	1342	1.6-11.0	5.3
	1992	380-695	500	407-4178	1514	2.4-11.0	5.4
	1993[b]	b	b	b	b	b	b
TRM 545	1991	385-555	451	548-1358	898	1.4-11.4	3.9
	1992[b]	b	b	b	b	b	b
TRM 557-565	1987	310-561	470	239-1786	1103	1.4-3.8	2.5
	1988	390-657	492	411-2765	1124	0.9-13.0	5.5
	1989[a]	347-500	398	324-1015	544	0.8-4.3	2.1
	1990	341-544	438	282-1521	838	0.2-6.0	3.2
	1991	488-653	557	1149-2812	1571	0.4-20.0	7.2
	1992	427-1559	641	497-3563	1540	0.3-15.0	6.9
	1993	395-629	494	500-2590	1086	1.3-5.3	3.5
TRM 570/573	1987	436-640	492	806-2814	1225	1.5-8.3	4.9
	1988	346-615	450	264-2425	929	0.2-7.6	3.7
	1989	339-649	466	431-2742	1063	1.5-6.4	3.9
	1990	427-512	473	627-1557	930	0.2-8.7	3.5
	1991	391-603	505	537-1815	1189	1.0-15.0	5.7
	1992[b]	b	b	b	b	b	b
TRM 598/600	1987	360-523	457	336-1330	757	3.3-7.3	5.3
	1988	452-659	504	829-2957	1289	2.1-8.5	5.2
	1989	382-666	514	425-3229	1437	0.8-14.0	5.9
	1990	325-600	436	208-3246	912	0.7-14.0	3.8
	1991	304-584	446	466-1881	967	1.1-11.0	5.1
	1992	360-590	476	464-2168	1018	1.0-9.9	4.4
	1993	385-645	454	442-2884	931	0.5-8.1	2.5

a. ORNL data

b. Channel catfish collected by TVA for DOE as part of Clinch River Environmental Restoration, data not available at the time this report was prepared.

Table 9.3.1-4 Summary of lengths, total weights, and percent lipids of catfish from the Clinch River portion of Watts Bar Reservoir, 1993 and previous years.

		Length Range	Mean Length	Weight Range	Mean Weight	% Lipid	Mean %
CRM 0.5/2.0	1988	435-605	510	745-2262	1278	0.1-11.0	5.3
	1989[a]	368-620	435	393-2380	794	1.0-5.8	3.3
	1990	365-529	437	361-1854	846	2.1-8.2	4.9
	1991	475-564	516	585-2151	1199	1.5-14.0	6.5
	1992[b]	b	b	b	b	b	b
	1993[b]	b	b	b	b	b	b
CRM 9/10	1989[a]	400-523	440	521-1505	755	0.4-6.4	3.5
	1990[a]	371-574	451	402-2152	835	0.1-7.3	1.7
	1991[a]	390-514	436	450-1334	725	0.9-7.2	4.4
	1992[a]	390-528	439	506-1494	767	0.9-5.12	2.7
	1993[b]	b	b	b	b	b	b
CRM 20/21	1988	370-790	513	406-6118	1774	1.0-11.5	3.8
	1989[a]	374-530	443	414-1321	736	0.3-7.0	3.3
	1990[a]	370-520	429	373-996	588	0.1-3.1	1.3
	1991[a]	405-502	457	465-1003	760	0.1-6.2	2.6
	1992[a]	374-581	447	452-1985	809	0.2-5.1	3.0
EmRM 1	1993[b]	b	b	b	b	b	b

a. ORNL data

b. Channel catfish collected by TVA for DOE as part of Clinch River Environmental Restoration Project, data not available at the time this report was prepared.

Table 9.3.1-5 Two-way analysis of variance (location and year main effects) and Ryan-Einot-Gabriel-Welsch Multiple Range Test on lipid content and total weight in channel catfish from Watts Bar Reservoir, 1988-1993.

CHANNEL CATFISH

		P>F	REGW Multiple Range Test[a] Mean Rank Low to High
Lipid content	Location	0.7200	
	Year	0.0158	1993 1990 1989 1987 1992 1988 1991
	Interaction	0.1351	
Total Weight	Location	0.8119	
	Year	0.0448	
	Interaction	0.0330	Significant Interaction

a Years or locations underscored by the same lines were not significantly different at $\alpha = 0.05$. Years and locations not so underscored were significantly different.

Table 9.3.1-6 Summary of total PCB concentrations (μg/g) in catfish fillets from Watts Bar Reservoir, 1987 to 1993.

	TRM 530-532	TRM 545	TRM 557-562	TRM 570-573	TRM 598-600	CRM 0.5-2.0	CRM 9.0-9.3	CRM 19-20.5
1987								
Range			0.1-4.4	0.9-3.0	0.4-3.1			
Mean			1.4	2.1	1.5			
Number ≥ 2.0μg/g			1	6	3			
Number of fish			6	10	10			
1988								
Range	0.1-4.3		1.3-7.5	0.1-7.4	0.8-4.4	0.1-4.6		0.2-2.4
Mean	1.4		2.7	2.1	2.4	2.2		0.6
Number ≥ 2.0μg/g	4		6	4	5	4		1
Number of fish	10		10	10	10	8		8
1989								
Range	0.2-1.5[a]		0.1-0.5[a]	0.2-2.5	0.4-4.2	0.2-3.8[a]	0.3-2.1[a]	0.9-3.1[a]
Mean	0.8		0.3	1.3	1.8	1.0	0.8	1.2
Number ≥ 2.0μg/g	0		0	3	2	1	1	1
Number of fish	10		9	10	7	10	8	8
1990								
Range	<0.1-2.7		<0.1-1.8	<0 1-2.2	0.3-5.8	0.2-4.2	0.2-0.8[a]	0.5-1.1[a]
Mean	0.6		0.8	0.7	1.6	1.1	0.4	0.8
Number ≥ 2.0μg/g	1		0	1	3	1	0	0
Number of fish	10		10	10	10	10	8	8
1991								
Range	0.8-2.9[d]	0.3-3.6	0.8-4.0[d]	0.7-2.4[d]	0.5-4.4	1.2-5.2[d]	0.2-2.2[a]	0.4-2.4[a]
Mean	1.6	1.1	2.3	1.4	1.4	2.6	1.1	1.4
Number ≥ 2.0μg/g	3	1	6	2	2	8	1	1
Number of fish	10	10	10	10	10	10	8	8
1992								
Range	0.3-5.6		0.2-3.8		0.4-6.2		0.36-3.9[a]	<0.1-1.1[a,c]
Mean	1.7		1.9		1.9		1.3	0.4
Number ≥ 2.0μg/g	3		6		2		2	0
Number of fish	10	(20)[b]	10	(20)[b]	10	(19)[b]	8	8
1993								
Range			0.4-2.3		0.1-3 6			
Mean			1.2		1.1			
Number ≥ 2.0μg/g			3		2			
Number of fish	(10)[b]		9		10	(10)[b]	(10)[b]	

a. ORNL data
b. number in ( ) is number of fish collected for DOE
c. 20 additional channel catfish were collected from CRM 20 in spring 1993 for DOE, data not available at the time this report was prepared
d. These results are part of the Clinch River Environmental Restoration Project conducted by TVA under contract to the United States Department of Energy. Data should be considered preliminary until validated by DOE.

Table 9.3.1-7 Results of preliminary tests to determine if PCBs should be adjusted for weight and lipid content and Two-Way Analysis of Covariance used to compare location and year differences in PCB concentrations in channel catfish from Watts Bar Reservoir, 1987-1993.

	Parameter	Preliminary Test (Is there a significant relationship between analyte and parameter)	Decision based on preliminary test	Test for parallel lines	Analysis of covariance results assuming parallel lines[b]
PCB	Lipid content	Yes[a] (P>F = 0.0001)	Adjust for lipid[a]	P>F = 0.0439 lines not parallel	0.2524 (locations not significantly different)
	Weight	Yes (P>F = 0.0002)	Adjust for weight	P>F = 0.1263 lines parallel	0.0231 (significant difference among years)[c]

a. Since preliminary tests (not shown) indicated adjusting for both lipids and weight, a test was conducted where lipids and weight were considered together. This test indicated a need to adjust for both lipid content and weight .

b. Since tests for parallel lines for lipid content was very close to the acceptance level (a=0.05), the analysis of covariance results hold true for fish with weights and lipid contents near the mean, but not for fish with weights and lipid contents near the extremes.

c. 1989 1993 1990 1991 1987 1992 1988

Table 9.3.1-8 One-Way Analysis of Variance and Ryan-Einot- Gabriel-Welsch Multiple Range Test comparing year differences for individual sites in PCB concentrations in channel catfish from Watts Bar Reservoir, 1993.

Location		P>F	REGW Multiple Range Test[a] Mean Rank Low to High
560	Year	0.0001	1989 1990 1987 1993 1992 1991 1988
600	Year	0.2420	No Significant Difference

a Years or locations underscored by the same lines were not significantly different at $\alpha = 0.05$. Years and locations not so underscored were significantly different.

Table 9.3.1-9 Summary of lengths, total weights, percent lipids, and PCB concentration in white bass from Watts Bar Reservoir, 1993 and previous years.

	Year	Length Range	Mean Length	Weight Range	Mean Weight	% Lipid Range	Mean % Lipid	PCB Range	Mean PCB
TRM 530	1993[a]	360-403	376	638-848	722	[a]	2.6	[a]	0.3
TRM 560	1993[a]	343-399	365	560-902	694	[a]	3.4	[a]	0.3
TRM 570/573	1987[a]	344-396	370	606-904	738	[a]	6.1	[a]	0.8
	1992	329-395	359	483-744	583	0.4-7.8	3.8	<0.1-1.7	0.7
	1993[a]	331-357	343	506-608	555	[a]	4.6	[a]	0.6
TRM 585	1987[a]	352-363	357	518-708	644	[a]	6.1	[a]	0.9
TRM 601	1993[a]	279-335	318	317-584	444	[a]	3.7	[a]	0.1
CRM 1	1993[a]	318-378	350	468-694	582	[a]	3.1	[a]	0.6

a White bass analyzed as composites (no ranges for analytes)

Table 9.3.1-10 Summary of lengths, total weights, percent lipids, and PCB concentration in carp from Watts Bar Reservoir, 1993 and previous years.

	Year	Length Range	Mean Length	Weight Range	Mean Weight	Mean % Lipid	Mean PCB
TRM 530	1993[a]	583-636	613	2698-360	3243	3.7	0.4
TRM 560	1993[a]	515-722	621	1936-527	3647	3.6	0.5
TRM 598/601	1987[a]	469-583	543	1575-256	2238	1.6	2.7
	1993[a]	488-629	542	1482-372	2214	3.0	0.6
CRM 1	1993[a]	591-711	633	2890-550	3610	3.2	0.7

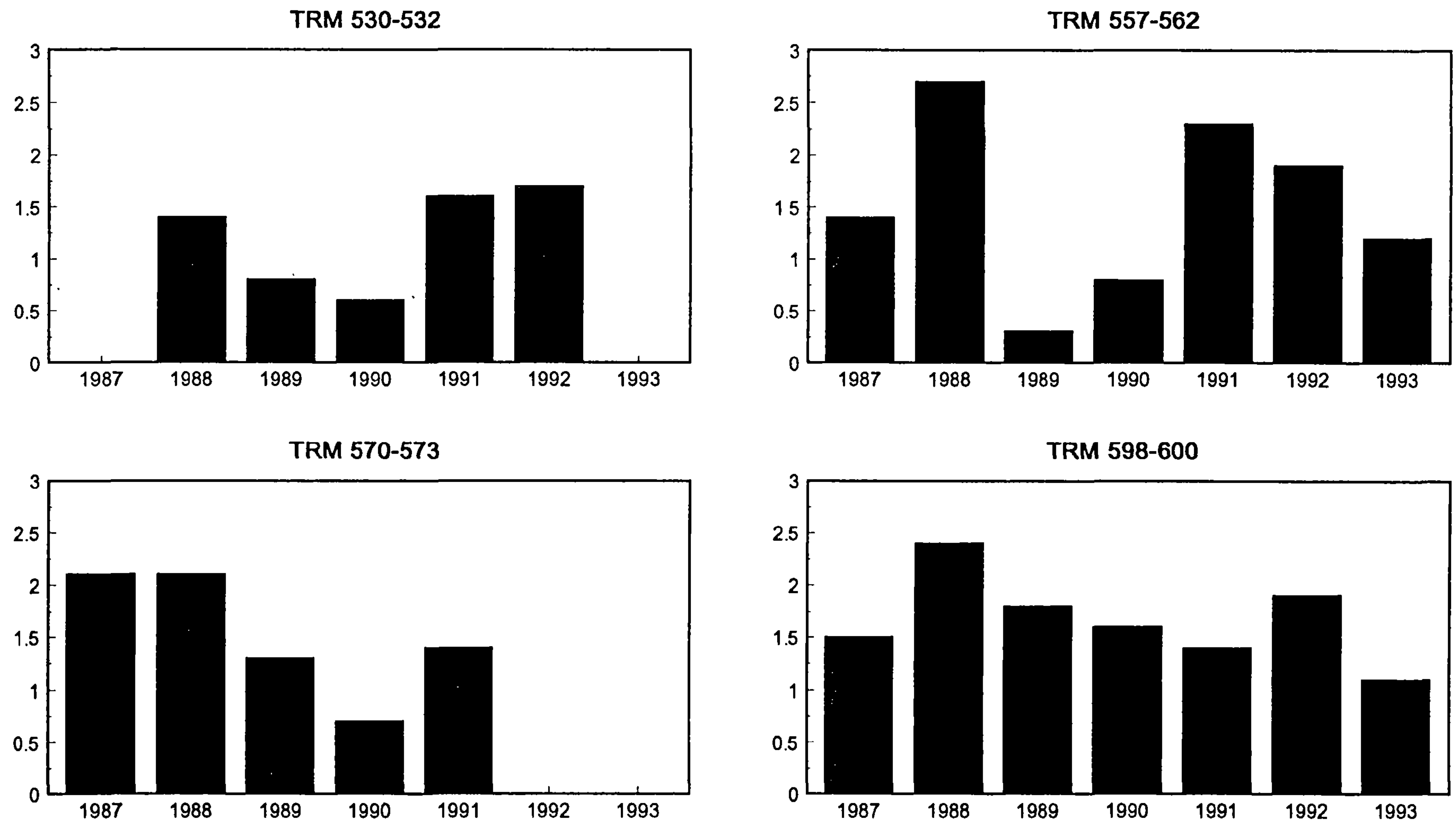
a Carp analyzed as composites (no ranges for analytes)

Table 9.3.1-11 Summary of lengths, total weights, percent lipids, and PCB concentration in smallmouth buffalo from Watts Bar Reservoir, 1993 and previous years.

	Year	Length Range	Mean Length	Weight Range	Mean Weight	% Lipid Range	Mean % Lipid	PCB Range	Mean PCB
TRM 532	1988[b]	580	[b]	3280	[b]	12.0	[b]	0.4	[b]
	1993[a]	489-653	590	2136-4886	3858	[a]	8.8	[a]	1.4
TRM 570/573	1987[a]	436-608	526	1276-4261	2619	[a]	8.4	[a]	3.1
	1988	480-537	505	1750-2933	2289	9.2-20.0	14.6	0.2-1.4	0.8
	1993[a]	517-656	585	1056-4456	3176	[a]	7.3	[a]	0.7
TRM 601	1993[a]	322-490	396	538-2044	1067	[a]	4.1	[a]	0.2

a Smallmouth Buffalo analyzed as composites (no ranges for analytes)
b Only one smallmouth buffalo collected (no means)

Figure 9.3.1-1 Mean PCB concentrations (µg/g) in catfish from individual sites, TRM 530-532, TRM 557-562, TRM 570-573 and TRM 598-600, on Watts Bar Reservoir, 1987-1993.



9.3.2 Fort Loudoun Reservoir

Contamination of catfish (mostly channel catfish) and largemouth bass with PCBs in Fort Loudoun Reservoir, especially the Little River embayment, has been known for several years. Several warnings and advisories (the latest is Appendix D) have been issued by TDEC against consumption of catfish and certain largemouth bass from Fort Loudoun Lake. Tennessee Wildlife Resources Agency (TWRA) has banned commercial fishing for catfish from this reservoir.

Intensive sampling of channel catfish has continued at TRM 624-628 to examine long-term trends. Although significant differences among years have been found, no consistent temporal pattern has been perceptible through 1992 (Williams and Dycus, 1993). PCB concentrations in white bass (0.5 µg/g) and carp (0.6 µg/g) collected from TRM 651 in 1992 were relatively low.

This document describes the results of PCB analyses of catfish from TRM 624 collected in autumn 1993 and compares them to results from previous years. Sample site was moved from TRM 628 to TRM 624 to obtain "free" fish from other sampling activities.

Methods -- Ten channel catfish were collected from TRM 624 in 1993 and analyzed individually for lipids, PCBs, and chlordane. Field handling and processing and laboratory processing were performed according to the methods outlined in Appendix C and will not be repeated here.

Results and Recommendations -- Physical information and the results of analyses on channel catfish collected from TRMs 624-629 are contained in tables 9.3.2-1 through 9.3.2-5. Weights and lipid content of catfish collected in 1993 were not significantly different from previous years. Results of a co-ANOVA on PCB concentrations adjusted for weight indicated concentrations in 1993 were significantly lower than concentrations in 1989, 1991, and 1992 but were not significantly different from other years. No overall trend in PCB concentrations in channel catfish from this site can be determined.

Channel catfish from this site should continue to be analyzed to keep abreast of the situation and provide data for fish consumption advisories issued by TDEC.

Table 9.3.2-1 Physical data and analyte concentrations (µg/g) in channel catfish collected from TRM 624, Fort Loudoun Reservoir, on November 12, 1993.

LABID[a]	Sex	Length	Weight	% Lipids	PCB	Chlordane
33198	FMALE	526	1286	0.9	1.3	0.07
33200	FMALE	569	1950	2.4	1.1	0.02
33203	FMALE	586	1824	2.5	1.7	0.02
33205	FMALE	542	1466	5.4	2.2	0.02
33208	FMALE	515	1110	3.4	1.3	0.04
33210	FMALE	491	978	5.2	2.0	0.04
33213	MALE	516	1276	6.4	0.8	0.01
33214	MALE	408	490	1.1	0.5	<0.01
33215	MALE	407	566	1.2	0.7	<0.01
33216	MALE	381	432	2.7	0.4	<0.01

a LABID is a tracking number issued by TVA's Environmental Chemistry Lab. It is used to link a sample's physical and chemical data.

Table 9.3.2-2 Summary of lengths, total weights, and % lipids of catfish, carp, and white bass from Fort Loudoun Reservoir, collected from 1985 to 1993.

	Location TRM	Weight Range	Mean Weight	Length Range	Mean Length	% Lipid Range	Mean % Lipid
Catfish							
1985	628	270-2720	834	330-655	441	2.8-5.6	3.9
1987	628	580-2275	1385	410-645	507	0.2-11.0	4.5
1988	628	538-1732	968	391-577	465	0.8-11.0	5.4
1989	628	292-2169	1002	344-573	474	0.6-14.0	4.4
1990	628	375-1720	866	375-545	458	0.3-5.0	2.5
1991	624	461-2139	1049	401-605	489	0.8-5.6	3.3
1992	624	430-1291	679	368-520	432	0.5-6.1	2.7
1993	624	432-1950	1138	381-586	494	0.9-6.4	3.1
Carp							
1992	651	1219-1937	1594	438-520	489	3.2-12.0	6.9
White Bass							
1987[a]	628	162-180	181	221-239	233	a	3.1
	640	275-606	435	259-330	302	a	5.8
1992	651	460-633	534	318-356	337	3.6-5.6	4.6

a. Five white bass were collected from TRMs 628 and 640 in 1987. Each set of five was analyzed as a composite sample.

Table 9.3.2-3 Results of one-way ANOVA and REGW Multiple Range Test examining differences among years in lipid content and total weight in catfish from TRM 624-629, Fort Loudoun Reservoir.

		CATFISH	
		P>F	REGW Multiple Range Test[a] Mean Rank Low to High
Lipid content	Year	0.2397	No Significant Difference
Total Weight	Year	0.0236	1985 1992 1990 1989 1991 1988 1993 1987

a. Years underscored by the same lines were not significantly different at $\alpha = 0.05$.

Table 9.3.2-4 Summary of PCB concentrations in catfish, carp, and white bass from Fort Loudoun Reservoir, collected from 1985 to 1993.

	Location TRM	PCB Range	Mean	Number ≥ 2.0 µg/g	Number of fish
Catfish					
1985	628	0.2-2.8	1.4	2	10
1987	628	0.1-4.5	1.5	2	10
1988	628	0.2-4.4	1.2	1	10
1989	628	0.6-4.3	2.3	11	10
1990	628	0.3-1.9	1.0	0	10
1991	624	1.4-4.6	2.5	7	10
1992	624	0.1-4.2	1.8	3	9
1993	624	0.4-2.2	1.2	2	10
Carp					
1992	651	0.2-0.9	0.6	0	10
White Bass					
1987[a]	628	b	<0.1	a	5
	640	b	<0.1	a	5
1992	651	0.3-1.2	0.5	0	10

a. Catfish were sampled from TRMs 624-629. White bass and carp were collected from TRM 651 in 1992.

b. Five white bass were collected from TRMs 628 and 640 in 1987. Each set of five was analyzed as a composite sample.

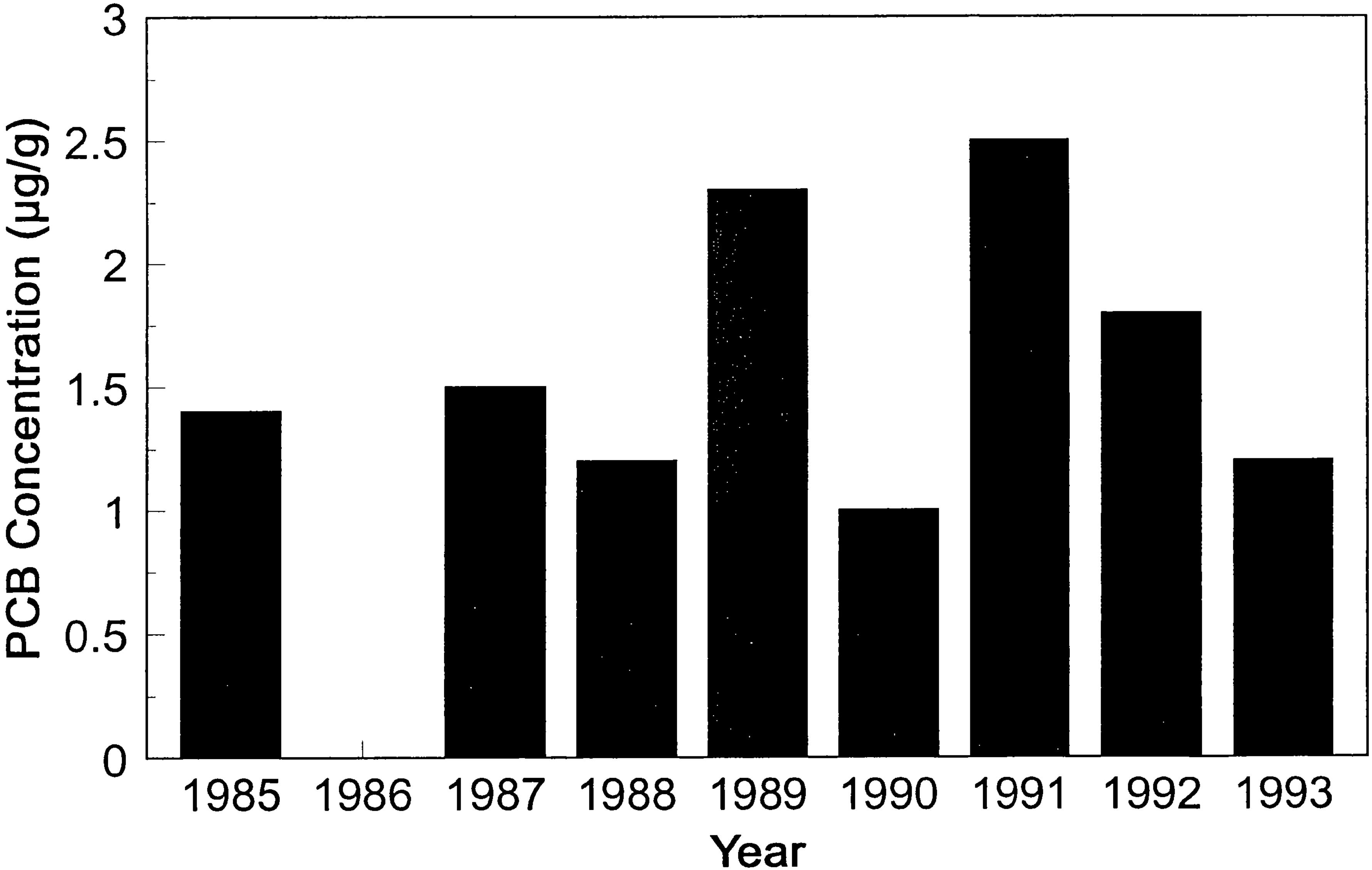
Table 9.3.2-5 Results of statistical tests used to compare yearly differences in PCB concentrations in catfish from TRMs 624-629, Fort Loudoun Reservoir, 1985-1993.

Analyte	Parameter	Preliminary Test (Is there a significant relationship between analyte and parameter)	Decision based on preliminary test	Test of parallel lines	Analysis of covariance results
PCB	Lipid content	No (P>F = 0.1632)	Do not adjust for lipid		
	Weight	Yes (P>F = 0.0128)	Adjust for weight	P>F = 0.8877 lines parallel	P>F = 0.0001 Years are different

Years underscored by the same lines were not significantly different at $\alpha = 0.05$.

1990 1988 1993 1987 1985 1992 1989 1991

Figure 9.3.2-1 Mean PCB concentrations (μg/g) in catfish from TRM 624 on Fort Loudoun Reservoir, 1985-1993.



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9.4 Special Study -- Three Embayments on Melton Hill Reservoir

Melton Hill Reservoir is currently in the trend study stage. A potential PCB problem (in catfish only) was first documented in 1984. Two of 22 catfish collected from Melton Hill reservoir had detectable PCB concentrations (one in McCoy Branch, 1.0 μg/g; one at Melton Hill Dam, 4.7 μg/g) (TVA 1985). Since the latter was collected at the face of the dam, it could have been transported from below the dam during navigation lock operations.

Results from the Valley-wide Fish Tissue Screening Study in 1987 found concentrations of PCBs and chlordane sufficiently high to warrant more in-depth study (Dycus 1989a). The five-fish composites from lower and mid-reservoir areas (CRMs 23 and 39) contained 1.2 and 2.0 μg/g PCBs and 0.16 μg/g chlordane each.

Subsequent studies in 1988 and 1989 lead to the TDEC issuing an advisory against consumption of catfish from Melton Hill Reservoir in April 1989 (Dycus 1990c). The most recent advisory is included in Appendix D.

The study was continued in 1990 - two of ten channel catfish (mean of 1.2 μg/g) collected by TVA at CRM 51 had PCB concentrations above 2.0 μg/g. The mean PCB concentration of channel catfish at CRM 23, collected and analyzed by ORNL, was 0.5 μg/g (after adjustment (actual PCB value multiplied by 1.5) to account for low spike recoveries in Q/A samples).

In 1991 and 1992 channel catfish were collected and analyzed from CRMs 24, 39, and 51 by TVA and ORNL. PCB concentrations were generally higher in 1991 than in previous years, with concentrations in 1992 generally similar to previous years. There were no statistically significant differences among years or sites.

This section describes the results of PCB analyses of catfish collected from three embayments near CRM 51 on Melton Hill Reservoir in the autumn of 1993 by TVA. Historically one or two catfish collected each year at the CRM 51 had high levels of PCBs. This could suggest that some of the fish move into and out of areas of locally high PCB concentrations. To further examine this possibility, Tennessee DOE Oversight Division identified three embayments (Figure 9.4-1) near the CRM 51 monitoring site which might be potential sources of PCBs. TVA collected and analyzed channel catfish from two of the embayments (CRMs 51.1 and 50.1) and carp (no catfish could be collected) from the other (CRM 49.5) for PCBs, chlordane, and lipids.

Methods -- In 1993, five channel catfish were collected from embayments at CRMs 51.1 (embayment #1) and 50.1 (embayment #2) and five carp (catfish were not available) were collected from the embayment at CRM 49.5 (embayment #3). These fish were analyzed as composites for PCBs, chlordane and lipids. Procedures involved in field sampling and processing, laboratory and data analyses were similar to those described Appendix C, except fish baskets were used to collect catfish at embayment #1 because of inaccessibility of the embayment.

Results and Recommendations -- Results of the 1993 study are in Table 9.4-1. PCB concentrations in channel catfish from embayments #1 (0.7 µg/g) and #2 (0.9 µg/g) were similar to one another. PCB concentration in carp (embayment #3) was only 0.1 µg/g. Although a more in-depth study would be necessary to rule out these embayments as potential contributors of high PCB concentrations in fish collected in previous years, results of this special study do not support the need for a more in-depth investigation. Ten channel catfish should be collected from CRM 51 in autumn 1994 to determine how concentrations compare to previous years. ORNL will examine catfish from CRM 23 in 1994.

Table 9.4.1-1 Physical information, lipid content, PCB, and chlordane concentrations of channel catfish and carp composites collected for the three embayment study on Melton Hill Reservoir, 1993.

	LABID	Weight	Length	Lipid	Chlordane	PCB
Embayment #1 CRM 51.2						
Channel Catfish #1		1132	490			
Channel Catfish #2		1064	462			
Channel Catfish #3		626	432			
Channel Catfish #4		566	428			
Channel Catfish #5		506	391			
Composite	33190			5.3	0.02	0.7
Embayment #2 CRM 50.1						
Channel Catfish #1		1328	547			
Channel Catfish #2		964	458			
Channel Catfish #3		1004	482			
Channel Catfish #4		1038	472			
Channel Catfish #5		886	478			
Composite	33192			5.2	0.06	0.9
Embayment #3 CRM 49.5						
Carp #1		1678	523			
Carp #2		1866	537			
Carp #3		2086	549			
Carp #4		1046	425			
Carp #5		694	367			
Composite	33195			1.1	<0.01	0.1

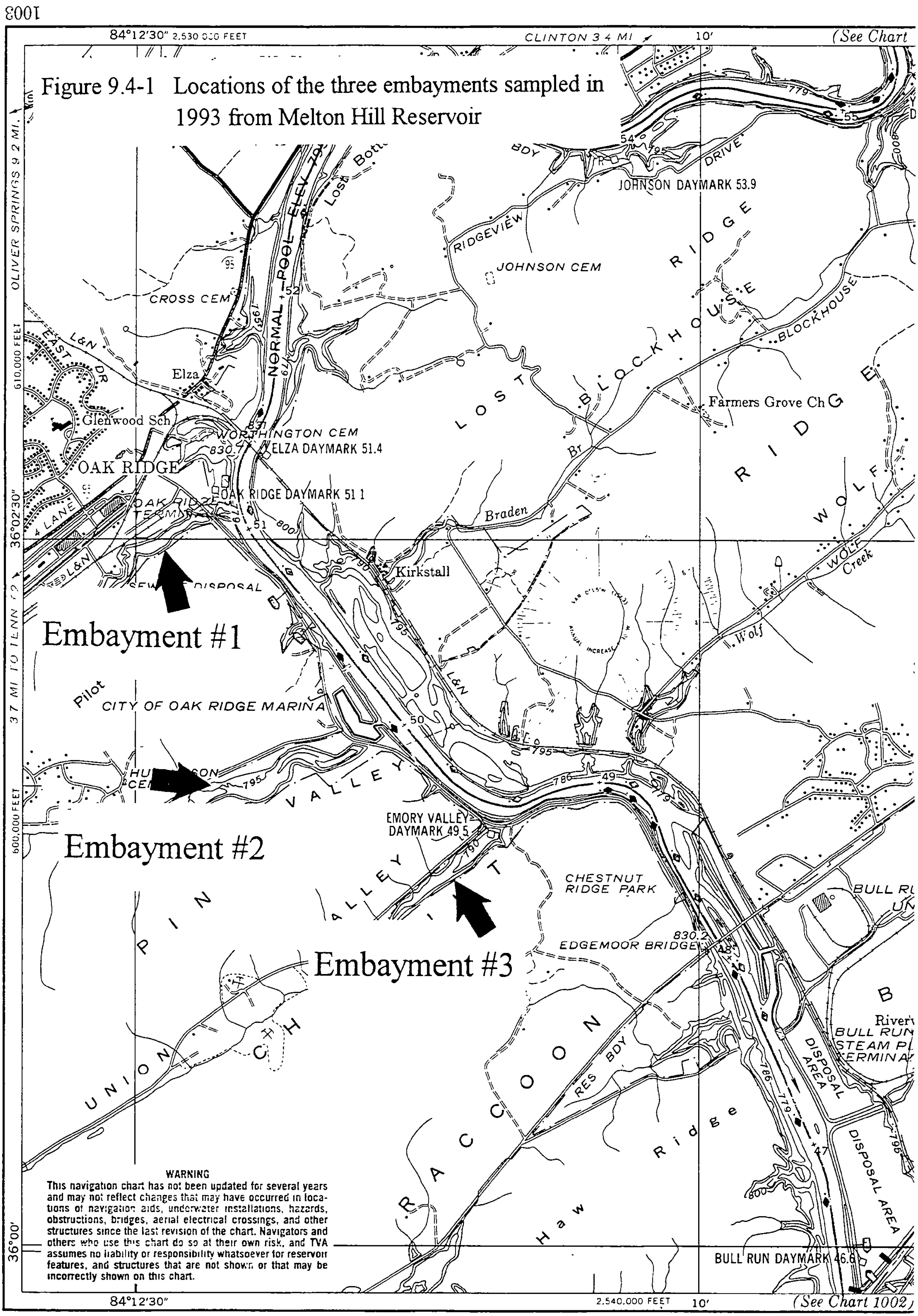
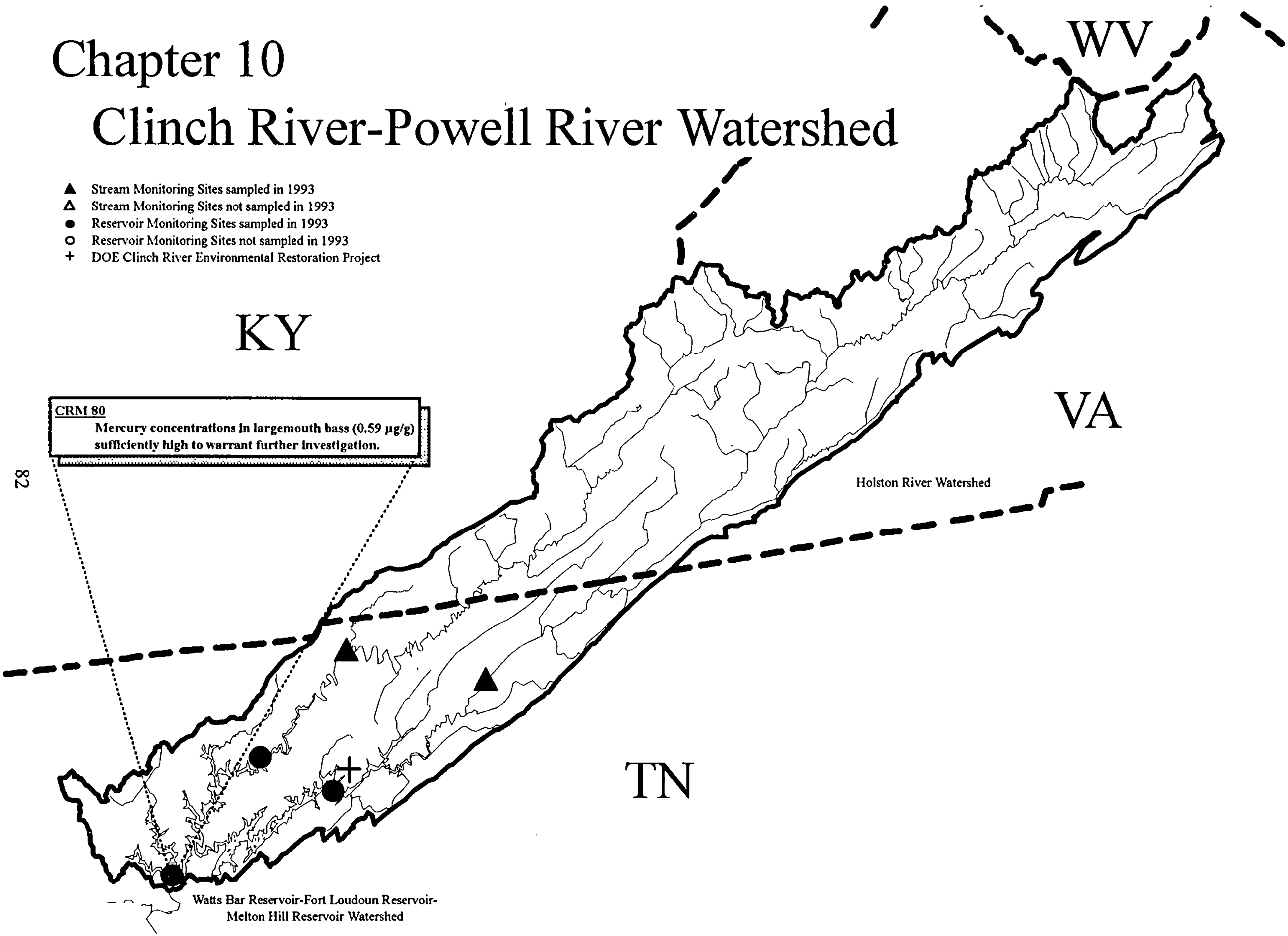


Figure 9.4-1 Locations of the three embayments sampled in 1993 from Melton Hill Reservoir

The Tennessee Valley Authority plans to make periodic revisions and additions to the navigation aids on this chart, but beca... on the river. For latest revisions see published Coast Guard Light List. Copies of this series of charts may be purchased

Chapter 10
Clinch River-Powell River Watershed



Chapter 10.0 Clinch River - Powell River Watershed

10.1 Introduction

Fish tissue samples were collected from five sites in the Clinch River - Powell River Watershed in 1993. Two of the locations were stream monitoring sites, one on the Powell River (PRM 65) and one on the Clinch River (CRM 172). Three locations were reservoir monitoring sites in Norris Reservoir, CRMs 80 and 125 and PRM 30. CRM 125 also served as a reference site for the DOE Clinch River Environmental Restoration Project. Results of the 1993 DOE samples were not complete at the time this report was written. Historical data from monitoring sites within the Clinch River - Powell River Watershed are available in publications listed in Appendix B.

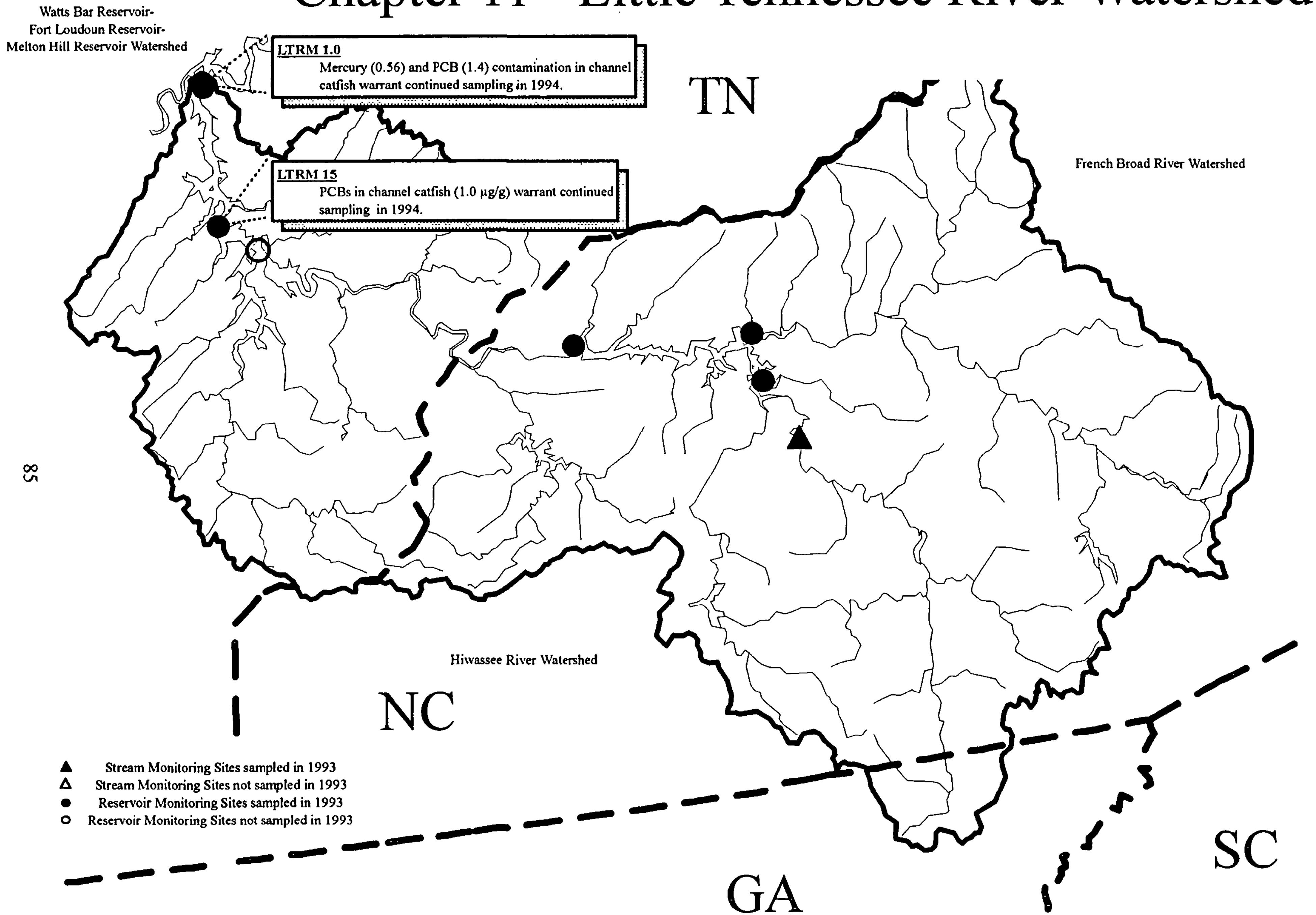
10.2 Methods

Five channel catfish and five smallmouth bass were collected from the two stream monitoring sites. Five channel catfish and five largemouth bass were collected from each of the three reservoir monitoring sites on Norris Reservoir. The smallmouth bass and channel catfish were analyzed as composites for lipids, pesticides, PCBs, and selected metals on the EPA Priority Pollutant List. The largemouth bass were analyzed as composites for mercury only. In addition to composite analysis, each largemouth bass that weighed more than 1200 grams was analyzed individually for mercury; results for these analyses are included in Appendix F. Field handling and processing and laboratory processing were performed according to the methods for screening studies outlined in Appendix C.

10.3 Results and Recommendation

Physical information and the results of metals and organics analyses for the stream and reservoir monitoring sites are included in Appendix A. Mercury concentration (0.59 µg/g) in largemouth bass composite (maximum of 0.83 µg/g in one large individual, Appendix F) from the forebay region of Norris Reservoir was the only contaminant to indicate a need for further investigation. Reservoir sampling of largemouth bass should be repeated in autumn 1994 to more thoroughly examine a possible concern for mercury levels. The two stream monitoring sites should be placed on a two-year rotation and sampled again in 1995.

Chapter 11 - Little Tennessee River Watershed



Chapter 11.0 Little Tennessee River Watershed

11.1 Introduction

A fish consumption advisory is in effect for catfish for all of Tellico Reservoir. Catfish should not be eaten because of PCB contamination. The most current fish consumption advisory from TDEC is Appendix D.

Fish tissue samples were collected from six locations in the Little Tennessee River Watershed in 1993. One was a stream monitoring site at LTRM 94.3. The other five were reservoir monitoring sites; two in Tellico Reservoir (LTRMs 1 and 15) and three in Fontana Reservoir (LTRMs 62 and 81 and Tuckasegee River mile (TucRM) 3). The locations in Tellico Reservoir were sampled as an ongoing trend study of PCB concentrations. The locations in Fontana Reservoir were sampled to further examine relatively high PCBs and mercury concentrations observed in autumn 1992. Historical data from monitoring sites within the Little Tennessee River Watershed are available in publications listed in Appendix B.

11.2 Methods

Five channel catfish and five smallmouth bass were collected from the stream monitoring site at LTRM 94.3. Five channel catfish were collected from LTRMs 1, 15, and 81 and TucRM 3. Four channel catfish were collected from LTRM 62. These fish were analyzed as composites for lipids, pesticides, PCBs, and selected metals on the EPA Priority Pollutant List following the methods outlined in Appendix C.

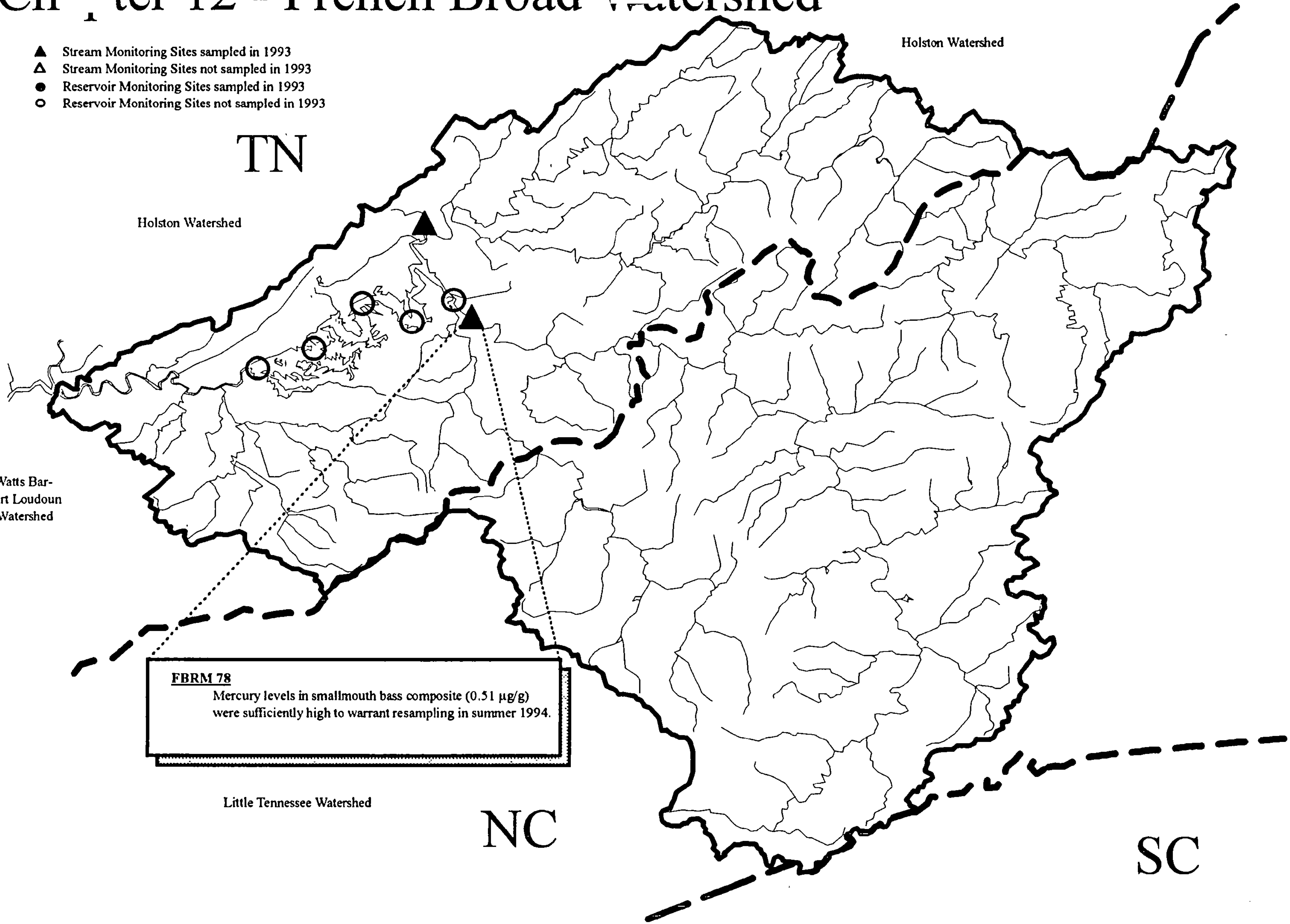
Five largemouth bass were collected from each of the reservoir monitoring sites and analyzed as composites for mercury only. In addition to composite analysis, each largemouth bass that weighed more than 1200 grams was analyzed individually for mercury; results for these individual analyses are included in Appendix F. Field handling and processing and laboratory processing were performed according to the methods for screening studies outlined in Appendix C.

11.3 Results and Recommendations

Physical information and the results of metals and organics analyses for the stream and reservoir monitoring sites are included in Appendix A. Results for Tellico Reservoir indicate that PCB levels in channel catfish from the forebay (1.4 µg/g) and mid-reservoir (1.0 µg/g) locations continue to remain relatively high. Mercury concentrations (0.56 µg/g) in catfish from the forebay of Tellico were sufficiently high to be of interest and possibly warrant further investigation in autumn 1994. Sampling on Tellico Reservoir should be repeated in autumn 1994. Results from Fontana Reservoir in 1993 differed substantially from those in 1992, in that PCB concentrations were much reduced (maximum of 0.4 µg/g in autumn 1993 compared to 1.4 µg/g in 1992). Mercury concentrations were also somewhat lower in 1993. Further screening of Fontana Reservoir should be conducted in 1994 to help determine which data set (1992 or 1993) is most representative of conditions in Fontana Reservoir. The stream monitoring location at LTRM 94.3 will be resampled in summer 1994 because this is a relatively new sample site.

Additional mercury results for analyses of largemouth bass from both these reservoirs is in Appendix F. Interestingly, mercury concentrations in largemouth bass from Tellico Reservoir were lower than in channel catfish, contrary to what would normally be expected. One large largemouth bass (2774 grams) from Fontana Reservoir contained a high concentration of mercury (0.94 µg/g).

Chapter 12 - French Broad Watershed



Chapter 12.0 French Broad Watershed

12.1 Introduction

Tennessee and North Carolina have issued fish consumption advisories for fish from the Pigeon River because of dioxin contamination. The most current Tennessee fish consumption advisory is Appendix D.

Fish tissue samples were collected only from two stream monitoring locations in 1993, Nolichucky River mile (NRM) 8.5 and French Broad River mile (FBRM) 78. Historical data from monitoring sites within the French Broad Watershed are available in publications listed in Appendix B.

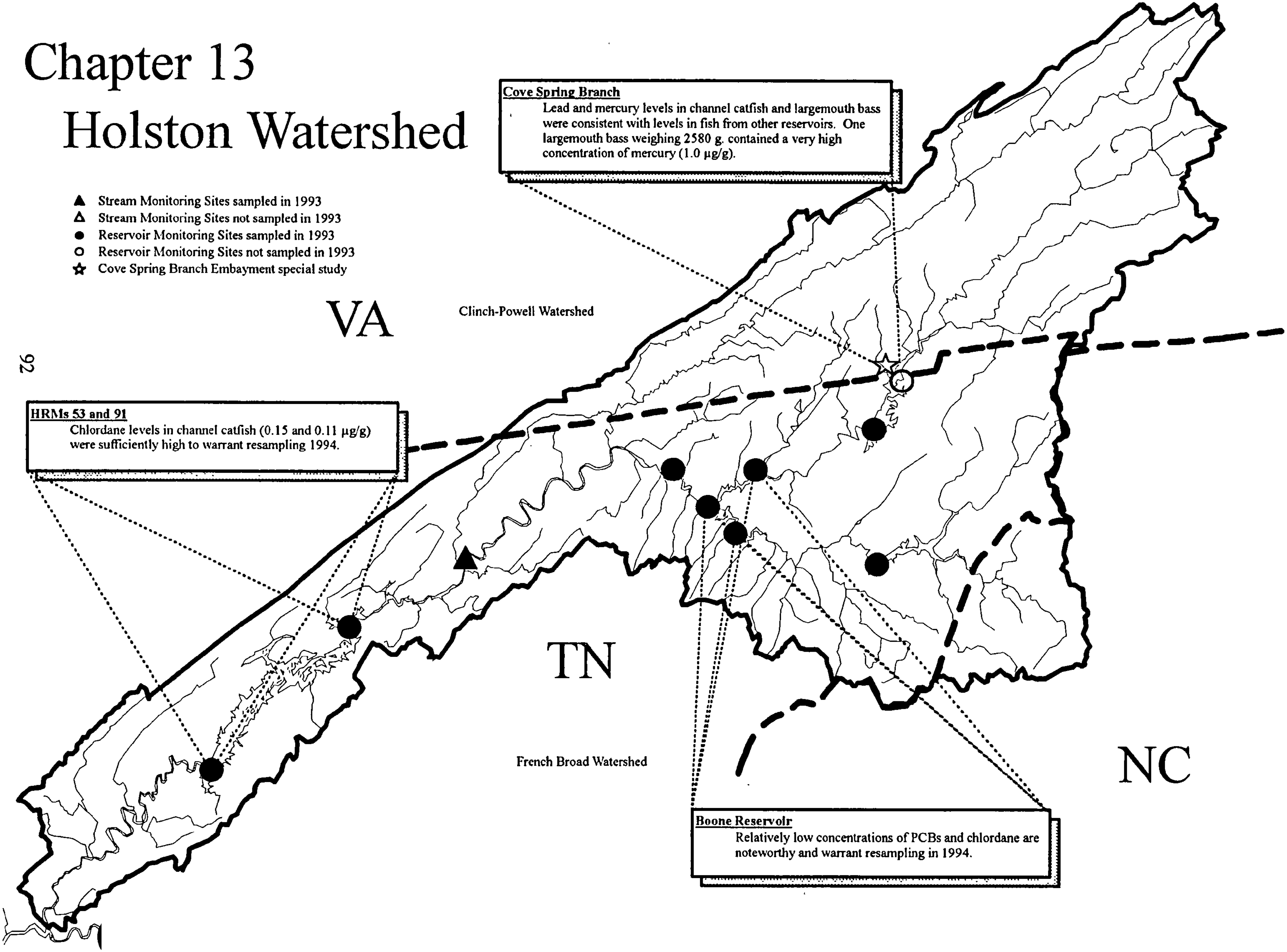
12.2 Methods

Five carp and four spotted bass were collected from NRM 8.5 and five channel catfish, two largemouth bass, and two smallmouth bass were collected from FBRM 78. These fish were analyzed for lipids, pesticides, PCBs, and selected metals on the EPA Priority Pollutant List. Field handling and processing and laboratory processing were performed according to the methods for screening studies outlined in Appendix C.

12.3 Results and Recommendations

Physical information and the results of metals and organics analyses for the stream sites are included in Appendix A. All analytes, except mercury, had low or nondetectable concentrations. Relatively high concentrations of mercury were found in smallmouth bass (0.51 μg/g) but not in largemouth bass (0.19 μg/g) from FBRM 78. The stream monitoring sites at FBRM 78 and NRM 8.5 will be sampled in summer 1994.

Chapter 13
Holston Watershed



Chapter 13.0 Holston River Watershed

13.1 Introduction

TDEC as issued a precautionary advisory to limit consumption of catfish and carp from Boone Reservoir because of PCB and chlordane contamination and an advisory against consuming any fish from the Tennessee portion of the North Fork Holston River because of mercury contamination. The most current fish advisory is Appendix D.

Fish tissue samples were collected from one stream monitoring site (HRM 109.9) and nine reservoir monitoring sites in the Holston River Watershed in 1993. Three of the reservoir monitoring sites were in Cherokee Reservoir (HRMs 53, 75, and 91) and three were in Boone Reservoir (South Fork Holston River miles (SFHRM) 19 and 27 and Watauga River mile (WRM) 8). Of the remaining three reservoir sites, one was in Fort Patrick Henry Reservoir (SFHRM 9), one was in Watauga Reservoir (WRM 37), and the other was in South Holston Reservoir (SFHRM 51). Historical data from monitoring sites within the Holston River Watershed are available in publications listed in Appendix B.

A special study was conducted in Cove Spring Branch on South Holston Reservoir in 1994. Ten channel catfish and 11 largemouth bass were collected from this site.

13.2 Screening Study

13.2.1 Methods

Five channel catfish and five largemouth bass were collected from each of the ten monitoring sites. The largemouth bass from HRM 109.9 and the channel catfish from all the sites were analyzed as composites for lipids, pesticides, PCBs, and selected metals on the EPA Priority Pollutant List. The largemouth bass from the reservoir monitoring sites were analyzed as composites for mercury only. Largemouth bass weighing over 1360 grams (3 lb.) were analyzed individually and reported in Appendix F. Field handling and processing and laboratory processing were performed according to the methods outlined in Appendix C.

13.2.2 Results and Recommendations

Physical information and the results of metals and organics analyses for the stream and reservoir monitoring sites are included in Appendix A. Chlordane in channel catfish from Cherokee Reservoir (HRMs 53 and 91) was the only contaminant sufficiently high to be of interest.

Channel catfish from Cherokee Reservoir should be resampled in autumn 1994 to better examine chlordane concentrations. The stream monitoring location will be placed on two-year rotation cycle and be sampled in 1995.

Relatively low or nondetectable concentrations of PCBs and chlordane in channel catfish samples from Boone Reservoir are noteworthy and could have implications for the precautionary advisory there. Additional samples from Boone Reservoir should be examined in autumn 1994 to document if these relatively low concentrations continue to exist.

13.3 Cove Spring Branch Study

Late in 1993, interest was drawn toward an old battery casing dump site on South Holston Reservoir. This dump is located in Cove Spring Branch embayment and there was concern over potential mercury and lead contamination. Therefore, a special study was initiated by TVA, the State of Tennessee, and U.S. Forest Service.

The TVA Holston River Action Team funded a special fish tissue investigation within Cove Spring Branch embayment. Two composites of five channel catfish, two composites of five largemouth bass, and one large individual largemouth bass were analyzed for lead and mercury. Also five fish from the composite samples (one channel catfish and four largemouth bass) weighing more than 1400 grams were analyzed individually for mercury content. Field handling and processing and laboratory processing were similar to the methods outlined in Appendix C.

Results of the special study on Cove Spring Branch embayment are in Table 12.3-1. Fish from Cove Spring Branch did not contain elevated levels of lead. Lead concentrations were either below or slightly above the laboratory detection limit.

Mercury concentrations in fish composites from Cove Spring Branch were similar to those in other area reservoirs, indicating no impact from the battery dump. All except one of the large largemouth bass contained mercury levels near or above the levels suggesting need for further screening studies.

As might be expected due to its size and age, one largemouth bass weighing over 2580 grams contained a very high concentration of mercury (1 μg/g). Similarly high mercury concentrations were found in large largemouth bass from several other reservoirs in autumn 1993 as reported in Appendix F. This issue needs to be further examined by additional sampling in autumn 1994. Specifics for further study had not been developed at the time this report was prepared.

Table 13.3-1 Results of the special study conducted on lead and mercury concentrations in channel catfish and largemouth bass from Cove Spring Branch Embayment, South Holston Reservoir, 1993.

		Composites		Individuals
	Fish Weight	Hg	Pb	Hg
Channel Catfish				
#1	976			
#2	1,414			0.58
#3	890			
#4	754			
#5	842			
Composite		0.42	<0.02	
#9	1,110			
#10	906			
#11	828			
#12	876			
#13	684			
Composite		0.36	0.05	
Largemouth Bass				
#1	1,402			0.51
#2	1,492			0.43
#3	1,118			
#4	1,264			
#5	948			
Composite		0.41	<0.02	
#6	890			
#7	1,908			0.63
#8	1,154			
#9	1,452			0.24
#10	790			
Composite		0.36	0.04	
#12	2,580			1.0

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APPENDIX A

RESULTS OF THE
1993 FISH TISSUE
SCREENING STUDIES
IN THE TENNESSEE VALLEY

Table A-1 Specific physical information on individual fish collected for tissue analysis from stream and reservoir locations as part of screening studies, 1993.

Collection Site	Date			Species[a]	Length (mm)	Weight (g)	Sex	LABID[b]
Duck River								
DRM 22.5	6	10	93	CHC	430	704	[c]	32548
DRM 22.5	6	10	93	CHC	458	834	[c]	32548
DRM 22.5	6	10	93	CHC	361	370	[c]	32548
DRM 22.5	6	10	93	CHC	338	313	[c]	32548
DRM 22.5	6	10	93	CHC	305	226	[c]	32548
DRM 22.5	6	10	93	SPB	205	107	[c]	32550
DRM 22.5	6	10	93	SPB	222	125	[c]	32550
DRM 22.5	6	10	93	SPB	255	196	[c]	32550
DRM 22.5	6	10	93	SPB	305	362	[c]	32550
Bear Creek Reservoir								
BCM 75	11	3	93	CHC	593	2020	FMALE	33238
BCM 75	11	3	93	CHC	532	1350	MALE	33238
BCM 75	11	3	93	CHC	522	1525	FMALE	33238
BCM 75	11	3	93	CHC	476	980	FMALE	33238
BCM 75	11	3	93	CHC	440	720	FMALE	33238
BCM 75	11	3	93	LMB	522	2265	FMALE	33444
BCM 75	11	3	93	LMB	475	1480	MALE	33295
BCM 75	11	3	93	LMB	409	990	FMALE	33295
BCM 75	11	3	93	LMB	401	925	FMALE	33295
Little Bear Creek Reservoir								
LBCRM 12	11	2	93	LMB	356	585	FMALE	33296
LBCRM 12	11	2	93	LMB	377	720	MALE	33296
LBCRM 12	11	2	93	LMB	382	810	FMALE	33296
LBCRM 12	11	2	93	LMB	562	2085	FMALE	33442
LBCRM 12	11	2	93	LMB	406	980	MALE	33296
LBCRM 12	11	2	93	CHC	468	865	MALE	33239
LBCRM 12	11	2	93	CHC	430	710	FMALE	33239
LBCRM 12	11	2	93	CHC	470	855	MALE	33239
LBCRM 12	11	2	93	CHC	536	1510	FMALE	33239
LBCRM 12	11	2	93	CHC	631	3000	FMALE	33239

Collection Site	Date			Species[a]	Length (mm)	Weight (g)	Sex	LABID[b]
Pickwick Reservoir								
TRM 259	9	23	93	CHC	552	1555	FMALE	33223
TRM 259	9	23	93	CHC	414	525	MALE	33223
TRM 259	9	23	93	CHC	461	790	FMALE	33223
TRM 259	9	23	93	CHC	440	595	MALE	33223
TRM 259	9	24	93	CHC	556	1550	FMALE	33223
Wheeler Reservoir								
TRM 277	9	30	93	CHC	468	965	FMALE	33225
TRM 277	9	30	93	CHC	473	950	FMALE	33225
TRM 277	9	30	93	CHC	498	870	FMALE	33225
TRM 277	9	30	93	CHC	491	990	FMALE	33225
TRM 277	9	30	93	CHC	396	475	FMALE	33225
TRM 296	12	7	93	CHC	438	1065	FMALE	33228
TRM 296	12	8	93	CHC	510	1850	FMALE	33228
TRM 296	12	8	93	CHC	520	1725	FMALE	33228
TRM 296	12	8	93	CHC	550	1775	FMALE	33228
TRM 296	12	8	93	CHC	572	2045	FMALE	33228
TRM 346	9	30	93	CHC	470	973	MALE	33230
TRM 346	9	30	93	CHC	430	774	I[d]	33230
TRM 346	9	30	93	CHC	503	1330	FMALE	33230
TRM 346	9	30	93	CHC	444	904	FMALE	33230
TRM 346	9	30	93	CHC	648	3289	FMALE	33230
Elk River								
ERM 41	6	29	93	CHC	437	832	[c]	32551
ERM 41	6	29	93	CHC	599	2592	[c]	32551
ERM 41	6	29	93	CHC	349	278	[c]	32551
ERM 41	6	29	93	CHC	347	344	[c]	32551
ERM 41	6	29	93	CHC	295	228	[c]	32551
ERM 41	6	29	93	LMB	495	2230	[c]	32552
ERM 41	6	29	93	LMB	375	858	[c]	32552
ERM 41	6	29	93	LMB	325	526	[c]	32552
ERM 41	6	29	93	LMB	295	334	[c]	32552

Collection Site	Date			Species[a]	Length (mm)	Weight (g)	Sex	LABID[b]
Sequatchie River								
SEQRM 7.1	6	22	93	CHC	503	1156	[c]	32555
SEQRM 7.1	6	22	93	CHC	482	1072	[c]	32555
SEQRM 7.1	6	22	93	CHC	381	496	[c]	32555
SEQRM 7.1	7	28	93	CHC	489	934	[c]	32555
SEQRM 7.1	7	28	93	CHC	437	648	[c]	32555
SEQRM 7.1	7	28	93	LMB	345	682	[c]	32557
SEQRM 7.1	6	22	93	SPB	231	174	[c]	32558
Hiwassee River								
HIRM 38	5	27	93	CHC	435	751	[c]	32559
HIRM 38	6	4	93	CHC	346	381	[c]	32559
HIRM 38	7	19	93	CHC	492	1216	[c]	32559
HIRM 38	7	19	93	CHC	491	1456	[c]	32559
HIRM 38	7	19	93	CHC	541	1914	[c]	32559
HIRM 38	5	20	93	LMB	403	865	[c]	32562
HIRM 38	5	20	93	LMB	346	644	[c]	32562
HIRM 38	7	19	93	LMB	294	304	[c]	32562
HIRM 38	7	19	93	LMB	320	480	[c]	32562
HIRM 38	7	19	93	LMB	372	648	[c]	32562
Hiwassee Reservoir								
HIRM 77	9	23	93	CHC	380	918	FMALE	33240
HIRM 77	10	21	93	CHC	463	692	MALE	33240
HIRM 77	10	21	93	CHC	569	1767	MALE	33240
HIRM 77	10	21	93	CHC	509	1100	FMALE	33240
HIRM 77	10	21	93	CHC	328	234	I[d]	33240
HIRM 77	9	23	93	LMB	395	848	FMALE	33411
HIRM 77	9	23	93	LMB	357	577	FMALE	33413
HIRM 77	9	23	93	LMB	351	594	MALE	33416
HIRM 77	9	23	93	LMB	340	511	FMALE	33417
HIRM 85	9	22	93	CHC	554	1669	MALE	33241
HIRM 85	9	22	93	CHC	474	932	MALE	33241
HIRM 85	9	22	93	CHC	383	396	MALE	33241
HIRM 85	9	21	93	CHC	470	877	MALE	33241
HIRM 85	9	21	93	CHC	381	386	MALE	33241
HIRM 85	9	22	93	LMB	380	874	FMALE	33418
HIRM 85	9	22	93	LMB	370	732	FMALE	33419
HIRM 85	9	22	93	LMB	345	545	FMALE	33420
HIRM 85	9	22	93	LMB	344	589	MALE	33421
HIRM 85	9	23	93	LMB	433	1214	FMALE	33422

Collection Site	Date			Species[a]	Length (mm)	Weight (g)	Sex	LABID[b]
Chatuge Reservoir								
HIRM 122	11	9	93	CHC	443	711	FMALE	32246
HIRM 122	11	9	93	CHC	491	961	MALE	32246
HIRM 122	11	9	93	CHC	483	963	MALE	32246
HIRM 122	11	9	93	CHC	422	667	FMALE	32246
HIRM 122	11	9	93	CHC	472	948	FMALE	32246
HIRM 122	11	9	93	LMB	484	1255	FMALE	33423
HIRM 122	11	9	93	LMB	365	610	FMALE	33299
HIRM 122	11	9	93	LMB	424	839	FMALE	33299
HIRM 122	11	9	93	LMB	388	725	FMALE	33299
HIRM 122	11	9	93	LMB	355	482	FMALE	33299
Ocoee #1								
OCRM 12	11	11	93	CHC	410	664	FMALE	33251
OCRM 12	11	11	93	CHC	429	623	FMALE	33251
OCRM 12	11	11	93	CHC	545	1738	MALE	33251
OCRM 12	11	11	93	CHC	448	871	FMALE	33251
OCRM 12	11	11	93	CHC	398	398	FMALE	33251
OCRM 16	11	18	93	CHC	524	1198	MALE	33253
OCRM 16	11	18	93	CHC	452	736	FMALE	33253
OCRM 16	11	18	93	CHC	622	2488	MALE	33253
OCRM 16	11	19	93	CHC	510	1185	MALE	33253
OCRM 16	11	19	93	CHC	506	1041	FMALE	33253
Nottley Reservoir								
NOTRM 24	11	11	93	CHC	565	1778	FMALE	33248
NOTRM 24	11	11	93	CHC	553	1594	FMALE	33248
NOTRM 24	11	11	93	CHC	430	512	I[d]	33248
NOTRM 24	11	11	93	CHC	541	1412	MALE	33248
NOTRM 24	11	11	93	CHC	620	2163	MALE	33248
NOTRM 24	11	10	93	LMB	547	2424	FMALE	33424
NOTRM 24	11	10	93	LMB	453	1287	FMALE	33300
NOTRM 24	11	10	93	LMB	484	1619	FMALE	33300
NOTRM 24	11	10	93	LMB	386	926	MALE	33300
NOTRM 24	11	10	93	LMB	359	546	MALE	33300

Collection Site	Date			Species[a]	Length (mm)	Weight (g)	Sex	LABID[b]
Blue Ridge Reservoir								
TOCRM 54	8	24	93	CHC	410	532	FMALE	33256
TOCRM 54	8	24	93	CHC	472	855	MALE	33256
TOCRM 54	8	24	93	CHC	487	974	MALE	33256
TOCRM 54	8	24	93	CHC	620	2068	MALE	33256
TOCRM 54	8	24	93	CHC	586	2113	FMALE	33256
TOCRM 54	8	24	93	LMB	360	668	MALE	33301
TOCRM 54	8	24	93	LMB	358	578	MALE	33301
TOCRM 54	8	24	93	LMB	323	491	I[d]	33301
TOCRM 54	8	24	93	LMB	331	520	FMALE	33301
TOCRM 54	8	24	93	LMB	417	912	FMALE	33301
Emory River								
EMORY RM 14.6	6	14	93	CHC	377	352	[c]	32569
EMORY RM 14.6	6	15	93	CHC	454	946	[c]	32569
EMORY RM 14.6	6	15	93	CHC	439	962	[c]	32569
EMORY RM 14.6	7	13	93	CHC	595	1838	[c]	32569
EMORY RM 14.6	7	13	93	CHC	375	536	[c]	32569
EMORY RM 14.6	6	14	93	LMB	295	390	[c]	32570
EMORY RM 14.6	6	15	93	LMB	414	992	[c]	32570
EMORY RM 14.6	6	15	93	LMB	445	1490	[c]	32570
EMORY RM 14.6	6	15	93	LMB	399	1032	[c]	32570
EMORY RM 14.6	6	15	93	LMB	327	478	[c]	32570
Norris Reservoir								
CRM 80	11	5	93	CHC	435	756	FMALE	33258
CRM 80	11	5	93	CHC	455	806	FMALE	33258
CRM 80	11	5	93	CHC	369	432	FMALE	33258
CRM 80	11	5	93	CHC	373	422	MALE	33258
CRM 80	11	5	93	CHC	368	442	MALE	33258
CRM 80	11	11	93	LMB	416	932	MALE	33302
CRM 80	11	11	93	LMB	332	468	MALE	33302
CRM 80	11	23	93	LMB	470	1438	FMALE	33451
CRM 80	11	23	93	LMB	395	876	MALE	33302
CRM 80	11	23	93	LMB	365	660	MALE	33302
CRM 125	11	10	93	CHC	464	772	MALE	33261
CRM 125	11	10	93	CHC	453	844	MALE	33261
CRM 125	11	11	93	CHC	512	1246	MALE	33261
CRM 125	11	11	93	CHC	495	1242	MALE	33261
CRM 125	11	11	93	CHC	450	806	MALE	33261

Collection Site	Date			Species[a]	Length (mm)	Weight (g)	Sex	LABID[b]
CRM 125	11	12	93	LMB	418	948	FMALE	33305
CRM 125	11	12	93	LMB	385	902	FMALE	33305
CRM 125	11	12	93	LMB	387	848	MALE	33305
CRM 125	11	12	93	LMB	397	866	FMALE	33305
CRM 125	11	12	93	LMB	376	864	MALE	33305
PRM 30	11	9	93	CHC	531	1244	FMALE	33262
PRM 30	11	9	93	CHC	554	1644	MALE	33262
PRM 30	11	9	93	CHC	559	1502	MALE	33262
PRM 30	11	9	93	CHC	512	1224	FMALE	33262
PRM 30	11	9	93	CHC	461	724	MALE	33262
PRM 30	11	9	93	LMB	353	528	FMALE	33307
PRM 30	11	15	93	LMB	387	856	FMALE	33307
PRM 30	11	15	93	LMB	441	1106	FMALE	33307
PRM 30	11	15	93	LMB	401	828	FMALE	33307
PRM 30	11	15	93	LMB	403	956	FMALE	33307
PRM 30	11	15	93	LMB	385	704	MALE	33307
<u>Clinch River</u>								
CRM 172	5	17	93	CHC	519	2035	FMALE	32573
CRM 172	5	17	93	CHC	473	1270	MALE	32573
CRM 172	5	17	93	CHC	520	1521	FMALE	32573
CRM 172	5	17	93	CHC	521	1628	MALE	32573
CRM 172	5	17	93	CHC	449	805	FMALE	32573
CRM 172	5	17	93	SMB	365	637	FMALE	32575
CRM 172	5	17	93	SMB	285	308	FMALE	32575
CRM 172	5	18	93	SMB	330	425	FMALE	32575
CRM 172	5	18	93	SMB	329	439	MALE	32575
CRM 172	5	18	93	SMB	234	171	FMALE	32575
<u>Powell River</u>								
PRM 65.27	6	3	93	CHC	518	1642	FMALE	32576
PRM 65.27	6	3	93	CHC	595	2155	FMALE	32576
PRM 65.27	6	3	93	CHC	439	816	FMALE	32576
PRM 65.27	6	3	93	CHC	439	812	FMALE	32576
PRM 65.27	6	3	93	CHC	375	483	FMALE	32576
PRM 65.27	6	3	93	SMB	275	296	FMALE	32579
PRM 65.27	6	3	93	SMB	259	261	FMALE	32579
PRM 65.27	6	3	93	SMB	240	161	FMALE	32579
PRM 65.27	6	22	93	SMB	240	188	MALE	32579
PRM 65.27	6	22	93	SMB	303	352	FMALE	32579

Collection Site	Date			Species[a]	Length (mm)	Weight (g)	Sex	LABID[b]
Tellico Reservoir								
LTRM 1.0	10	7	93	CHC	569	1968	FMALE	33233
LTRM 1.0	10	7	93	CHC	579	2094	MALE	33233
LTRM 1.0	10	7	93	CHC	518	1150	FMALE	33233
LTRM 1.0	10	7	93	CHC	495	1138	MALE	33233
LTRM 1.0	10	7	93	CHC	423	594	FMALE	33233
LTRM 1.0	10	7	93	LMB	435	1185	FMALE	33447
LTRM 1.0	10	7	93	LMB	409	1042	FMALE	33290
LTRM 1.0	10	7	93	LMB	355	694	FMALE	33290
LTRM 1.0	10	7	93	LMB	357	540	MALE	33290
LTRM 1.0	10	7	93	LMB	333	478	FMALE	33290
LTRM 15	10	7	93	CHC	605	2086	MALE	33235
LTRM 15	10	7	93	CHC	589	1932	FMALE	33235
LTRM 15	10	7	93	CHC	519	1152	MALE	33235
LTRM 15	10	7	93	CHC	476	1148	FMALE	33235
LTRM 15	10	7	93	CHC	439	688	MALE	33235
LTRM 15	10	7	93	LMB	312	428	MALE	33292
LTRM 15	10	7	93	LMB	442	1122	FMALE	33292
LTRM 15	10	7	93	LMB	432	1280	FMALE	33448
LTRM 15	10	7	93	LMB	325	402	MALE	33292
LTRM 15	10	7	93	LMB	395	898	FMALE	33292
Fontana Reservoir								
LTRM 62	11	18	93	CHC	505	1198	MALE	33263
LTRM 62	11	18	93	CHC	459	784	MALE	33263
LTRM 62	11	18	93	CHC	505	1076	MALE	33263
LTRM 62	11	18	93	CHC	421	514	MALE	33263
LTRM 62	11	18	93	LMB	445	1352	FMALE	33449
LTRM 62	11	18	93	LMB	374	858	MALE	33310
LTRM 62	11	18	93	LMB	350	814	MALE	33310
LTRM 62	11	18	93	LMB	341	670	MALE	33310
LTRM 62	11	18	93	LMB	368	800	MALE	33310
LTRM 81	11	16	93	CHC	471	842	MALE	33264
LTRM 81	11	16	93	CHC	397	419	FMALE	33264
LTRM 81	11	16	93	CHC	476	897	MALE	33264
LTRM 81	11	16	93	CHC	480	913	MALE	33264
LTRM 81	11	16	93	CHC	500	1015	MALE	33264
LTRM 81	11	16	93	LMB	356	716	MALE	33311
LTRM 81	11	16	93	LMB	383	977	FMALE	33311
LTRM 81	11	16	93	LMB	340	637	MALE	33311

Collection Site	Date			Species[a]	Length (mm)	Weight (g)	Sex	LABID[b]
LTRM 81	11	16	93	LMB	347	539	FMALE	33311
LTRM 81	11	16	93	LMB	300	346	MALE	33311
TUCKRM 3	11	17	93	CHC	497	1286	FMALE	33269
TUCKRM 3	11	17	93	CHC	567	1760	MALE	33269
TUCKRM 3	11	17	93	CHC	413	490	MALE	33269
TUCKRM 3	11	17	93	CHC	409	468	FMALE	33269
TUCKRM 3	11	17	93	CHC	374	378	MALE	33269
TUCKRM 3	11	17	93	LMB	549	2774	FMALE	33450
TUCKRM 3	11	17	93	LMB	374	790	FMALE	33312
TUCKRM 3	11	17	93	LMB	353	584	FMALE	33312
TUCKRM 3	11	17	93	LMB	309	434	FMALE	33312
TUCKRM 3	11	17	93	LMB	329	490	MALE	33312
Little Tennessee River								
LTRM 94.77	6	2	93	CHC	392	645	FMALE	32580
LTRM 94.77	6	2	93	CHC	498	1160	FMALE	32580
LTRM 94.77	6	2	93	CHC	425	594	FMALE	32580
LTRM 94.77	6	2	93	CHC	375	456	FMALE	32580
LTRM 94.77	6	2	93	CHC	399	587	FMALE	32580
LTRM 94.77	7	15	93	SMB	352	562	FMALE	32582
LTRM 94.77	7	15	93	SMB	289	352	[c]	32582
LTRM 94.77	7	15	93	SMB	295	312	[c]	32582
LTRM 94.77	7	15	93	SMB	285	280	[c]	32582
LTRM 94.77	7	15	93	SMB	220	128	[c]	32582
French Broad River								
FBRM 77.5	6	24	93	CHC	494	1124	[c]	32591
FBRM 77.5	6	24	93	CHC	393	488	[c]	32591
FBRM 77.5	6	24	93	CHC	377	464	[c]	32591
FBRM 77.5	7	14	93	CHC	405	454	[c]	32591
FBRM 77.5	7	14	93	CHC	595	1764	[c]	32591
FBRM 77.5	7	14	93	LMB	440	1334	[c]	32593
FBRM 77.5	7	14	93	LMB	276	300	[c]	32593
FBRM 77.5	7	14	93	SMB	380	940	[c]	32594
FBRM 77.5	7	14	93	SMB	359	754	[c]	32594

Collection Site	Date			Species[a]	Length (mm)	Weight (g)	Sex	LABID[b]
Nolichucky River								
NRM 8.5	6	7	93	C	672	5305	[c]	32583
NRM 8.5	6	7	93	C	585	2925	[c]	32583
NRM 8.5	6	7	93	C	638	3750	[c]	32583
NRM 8.5	6	7	93	C	490	1765	[c]	32583
NRM 8.5	6	18	93	C	685	3692	[c]	32583
NRM 8.5	6	7	93	SPB	365	736	[c]	32586
NRM 8.5	6	18	93	SPB	226	182	[c]	32586
NRM 8.5	6	18	93	SPB	199	102	[c]	32586
NRM 8.5	6	18	93	SPB	290	364	[c]	32586
Cherokee Reservoir								
HRM 53	10	29	93	CHC	557	1672	MALE	33271
HRM 53	10	29	93	CHC	520	1262	MALE	33271
HRM 53	10	29	93	CHC	493	1080	MALE	33271
HRM 53	10	29	93	CHC	518	1046	MALE	33271
HRM 53	10	29	93	CHC	438	746	FMALE	33271
HRM 53	10	28	93	LMB	376	772	MALE	33313
HRM 53	10	28	93	LMB	378	812	FMALE	33313
HRM 53	10	28	93	LMB	372	670	MALE	33313
HRM 53	10	28	93	LMB	342	560	FMALE	33313
HRM 53	10	28	93	LMB	302	340	FMALE	33313
HRM 75	11	17	93	CHC	510	1378	MALE	33274
HRM 75	11	17	93	CHC	512	1478	FMALE	33274
HRM 75	11	17	93	CHC	509	1328	MALE	33274
HRM 75	11	17	93	CHC	403	696	FMALE	33274
HRM 75	11	17	93	CHC	425	702	FMALE	33274
HRM 75	10	29	93	LMB	424	1228	FMALE	33314
HRM 75	10	29	93	LMB	512	1972	FMALE	33428
HRM 75	10	29	93	LMB	388	920	MALE	33314
HRM 75	10	29	93	LMB	351	670	MALE	33314
HRM 75	10	29	93	LMB	337	556	FMALE	33314
HRM 91	10	28	93	CHC	676	3698	MALE	33276
HRM 91	10	28	93	CHC	543	1716	FMALE	33276
HRM 91	10	28	93	CHC	459	974	MALE	33276
HRM 91	10	28	93	CHC	487	908	MALE	33276
HRM 91	10	28	93	CHC	392	478	FMALE	33276

Collection Site	Date			Species[a]	Length (mm)	Weight (g)	Sex	LABID[b]
HRM 91	10	28	93	LMB	435	1194	FMALE	33430
HRM 91	10	28	93	LMB	414	1098	FMALE	33315
HRM 91	10	28	93	LMB	385	802	FMALE	33315
HRM 91	10	28	93	LMB	340	542	FMALE	33315
HRM 91	10	28	93	LMB	331	512	FMALE	33315
Holston River								
HRM 109.9	6	14	93	LMB	412	926	[c]	32599
HRM 109.9	6	14	93	LMB	383	830	[c]	32599
HRM 109.9	6	14	93	LMB	325	438	[c]	32599
HRM 109.9	6	14	93	LMB	285	332	[c]	32599
HRM 109.9	6	15	93	LMB	430	1066	[c]	32599
HRM 109.9	6	15	93	CHC	536	1800	[c]	32597
HRM 109.9	6	15	93	CHC	593	3274	[c]	32597
HRM 109.9	6	15	93	CHC	563	2136	[c]	32597
HRM 109.9	6	15	93	CHC	468	1148	[c]	32597
HRM 109.9	6	15	93	CHC	563	1970	[c]	32597
Fort Patrick Henry Reservoir								
SFHRM 9	10	12	93	CHC	569	1418	[c]	33279
SFHRM 9	10	12	93	CHC	547	1562	[c]	33279
SFHRM 9	10	12	93	CHC	519	1344	[c]	33279
SFHRM 9	10	12	93	CHC	495	1065	[c]	33279
SFHRM 9	10	1	93	LMB	489	2040	FMALE	33316
SFHRM 9	10	1	93	LMB	385	960	MALE	33433
SFHRM 9	10	1	93	LMB	401	1040	MALE	33316
SFHRM 9	10	1	93	LMB	373	858	MALE	33316
SFHRM 9	10	1	93	LMB	344	574	FMALE	33316

Collection Site	Date			Species[a]	Length (mm)	Weight (g)	Sex	LABID[b]
Boone Reservoir								
SFHRM 19	9	28	93	CHC	524	1190	MALE	33281
SFHRM 19	9	28	93	CHC	378	404	MALE	33281
SFHRM 19	9	28	93	CHC	368	348	FMALE	33281
SFHRM 19	9	28	93	CHC	381	368	FMALE	33281
SFHRM 19	9	28	93	CHC	411	480	FMALE	33281
SFHRM 19	9	28	93	LMB	421	1106	FMALE	33317
SFHRM 19	9	28	93	LMB	453	1362	FMALE	33434
SFHRM 19	9	28	93	LMB	435	1188	FMALE	33317
SFHRM 19	9	28	93	LMB	403	852	FMALE	33317
SFHRM 19	9	28	93	LMB	402	906	FMALE	33317
SFHRM 27	9	30	93	CHC	582	1926	FMALE	33284
SFHRM 27	9	30	93	CHC	939	1520	FMALE	33284
SFHRM 27	9	30	93	CHC	463	834	FMALE	33284
SFHRM 27	9	30	93	CHC	405	484	MALE	33284
SFHRM 27	9	30	93	CHC	437	664	FMALE	33435
SFHRM 27	9	30	93	LMB	463	1720	MALE	33435
SFHRM 27	9	30	93	LMB	474	1252	FMALE	33320
SFHRM 27	9	30	93	LMB	372	742	MALE	33320
SFHRM 27	9	30	93	LMB	379	740	MALE	33320
SFHRM 27	9	30	93	LMB	343	568	FMALE	33320
WRM 7	9	29	93	CHC	588	2000	MALE	33285
WRM 7	9	29	93	CHC	1604	1604	FMALE	33285
WRM 7	9	29	93	CHC	1114	1114	FMALE	33285
WRM 7	9	29	93	CHC	854	854	MALE	33285
WRM 7	9	29	93	CHC	458	458	MALE	33285
WRM 7	9	29	93	LMB	412	1046	FMALE	33322
WRM 7	9	29	93	LMB	486	1636	FMALE	33436
WRM 7	9	29	93	LMB	392	922	MALE	33322
WRM 7	9	29	93	LMB	393	992	FMALE	33322
WRM 7	9	29	93	LMB	336	566	MALE	33322

Collection Site	Date			Species[a]	Length (mm)	Weight (g)	Sex	LABID[b]
Watauga Reservoir								
WRM 37	11	5	93	CHC	645	2644	FMALE	33286
WRM 37	11	5	93	CHC	620	2126	FMALE	33286
WRM 37	11	5	93	CHC	581	2190	FMALE	33286
WRM 37	11	5	93	CHC	508	970	MALE	33286
WRM 37	11	5	93	CHC	421	530	FMALE	33286
WRM 37	11	5	93	LMB	495	2276	FMALE	33437
WRM 37	11	5	93	LMB	450	1418	FMALE	33325
WRM 37	11	5	93	LMB	420	1258	FMALE	33325
WRM 37	11	5	93	LMB	410	1068	FMALE	33325
WRM 37	11	5	93	LMB	392	988	FMALE	33325
South Holston Reservoir								
SFHRM 51	11	2	93	CHC	570	1718	MALE	33287
SFHRM 51	11	2	93	CHC	517	1398	FMALE	33287
SFHRM 51	12	8	93	CHC	631	2984	MALE	33287
SFHRM 51	12	8	93	CHC	435	718	FMALE	33287
SFHRM 51	12	8	93	CHC	533	998	MALE	33287
SFHRM 51	11	2	93	LMB	390	940	FMALE	33326
SFHRM 51	11	2	93	LMB	469	1572	FMALE	33438
SFHRM 51	11	2	93	LMB	447	1412	FMALE	33326
SFHRM 51	11	2	93	LMB	415	764	MALE	33326
SFHRM 51	12	8	93	LMB	397	758	MALE	33326

a CHC = channel catfish, SPB = spotted bass, LMB = largemouth bass,. SMB = smallmouth bass

b LABID = number assigned by TVA's Environmental Chemistry Laboratory. It is used to link laboratory analysis data with physical data from fish.

c Observations on sex and external and internal characteristics of these fish were lost because of an error in a prototype computer program.

d I = immature (sex could not be determined).

Table A.2 Concentrations (µg/g) of organics in composited fish samples from stream and reservoir monitoring locations, 1993.

Collection Site	Species[a]	LABID[b]	% LIPIDS	PCBs	MIREX	TOXAPH	HEPTA	ALDRIN	BENZ	DDTr	DIELD	ENDO	ENDRIN	CHLOR
Duck River														
DRM 22.5	CHC	32548	2.3	0.1	<0.008	0.5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
DRM 22.5	SPB	32550	0.1	<0.1	<0.008	0.5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Bear Creek Reservoir														
BCM 75	CHC	33238	2.9	<0.1	<0.008	<0.5	<0.01	<0.01	<0.01	0.06	<0.01	<0.01	<0.01	<0.01
Little Bear Creek Reservoir														
LBCRM 12	CHC	33239	3.1	<0.1	<0.008	<0.5	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01
Pickwick Reservoir														
TRM 259	CHC	33223	3.8	0.5	<0.008	<0.5	<0.01	<0.01	<0.01	0.41	<0.01	<0.01	<0.01	0.04
Wheeler Reservoir														
TRM 277	CHC	33225	2.8	0.5	<0.008	<0.5	<0.01	<0.01	<0.01	0.57	<0.01	<0.01	<0.01	0.07
TRM 296	CHC	33228	6.9	0.8	<0.008	<0.5	<0.01	<0.01	<0.01	1.06	<0.01	<0.01	<0.01	0.16
TRM 346	CHC	33230	8.3	1.4	<0.008	<0.5	<0.01	<0.01	<0.01	0.73	<0.01	<0.01	<0.01	0.15
Emory River														
ERM 41	CHC	32551	2.8	0.3	<0.008	<0.5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
ERM 41	LMB	32552	0.7	0.2	<0.008	<0.5	<0.01	<0.01	<0.01	0.10	<0.01	<0.01	<0.01	<0.01
Sequatchie River														
SEQRM 7.1	CHC	32555	3.9	0.6	<0.008	<0.5	<0.01	<0.01	<0.01	0.10	<0.01	<0.01	<0.01	0.03
SEQRM 7.1	LMB	32557	0.5	<0.1	<0.008	<0.5	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	0.01
SEQRM 7.1	SPB	32558	0.2	<0.1	<0.008	<0.5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Hiwassee River														
HIRM 38	CHC	32559	8.4	0.7	<0.008	<0.5	<0.01	<0.01	<0.01	0.05	<0.01	<0.01	<0.01	0.05
HIRM 38	LMB	32562	1.6	<0.1	<0.008	<0.5	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	0.01

Collection Site	Species[a]	LABID[b]	% LIPIDS	PCBs	MIREX	TOXAPH	HEPTA	ALDRIN	BENZ	DDTr	DIELD	ENDO	ENDRIN	CHLOR
Hiwassee Reservoir														
HIRM 77	CHC	33240	2.7	<0.1	<0.008	<0.5	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01
HIRM 85	CHC	33241	1.4	<0.1	<0.008	<0.5	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01
Chatuge Reservoir														
HIRM 122	CHC	32246	3.6	<0.1	<0.008	<0.5	<0.01	<0.01	<0.01	0.04	<0.01	<0.01	<0.01	<0.01
Nottley Reservoir														
NOTRM 24	CHC	33248	2.0	<0.1	<0.008	<0.5	<0.01	<0.01	<0.01	0.15	<0.01	<0.01	<0.01	<0.01
Ocoee #1														
OCRM 12.5	CHC	33251	2.5	0.8	<0.008	<0.5	<0.01	<0.01	<0.01	0.05	<0.01	<0.01	<0.01	0.02
OCRM 16	CHC	33253	4.3	1.0	<0.008	<0.5	<0.01	<0.01	<0.01	0.07	<0.01	<0.01	<0.01	0.02
Blue Ridge Reservoir														
TOCRM 54	CHC	33256	1.4	<0.1	<0.008	<0.5	<0.01	<0.01	<0.01	0.06	<0.01	<0.01	<0.01	<0.01
Emory River														
EMORY RM 14.6	CHC	32569	4.2	0.8	<0.008	<0.5	<0.01	<0.01	<0.01	0.07	<0.01	<0.01	<0.01	0.05
EMORY RM 14.6	LMB	32570	1.9	0.2	<0.008	<0.5	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	0.01
Norris Reservoir														
CRM 80	CHC	33258	6.3	0.2	<0.008	<0.5	<0.01	<0.01	<0.01	0.06	<0.01	<0.01	<0.01	<0.01
CRM 125	CHC	33261	2.5	0.2	<0.008	<0.5	<0.01	<0.01	<0.01	0.06	<0.01	<0.01	<0.01	<0.01
PRM 30	CHC	33262	3.8	0.2	<0.008	<0.5	<0.01	<0.01	<0.01	0.05	<0.01	<0.01	<0.01	<0.01
Clinch River														
CRM 172	CHC	32573	6.6	<0.1	<0.008	<0.5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
CRM 172	SMB	32575	0.4	<0.1	<0.008	<0.5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Powell River														
PRM 65.27	CHC	32576	3.5	<0.1	<0.008	<0.5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
PRM 65.27	SMB	32579	0.8	<0.1	<0.008	<0.5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Collection Site	Species[a]	LABID[b]	% LIPIDS	PCBs	MIREX	TOXAPH	HEPTA	ALDRIN	BENZ	DDTr	DIELD	ENDO	ENDRIN	CHLOR
Tellico Reservoir														
LTRM 1.0	CHC	33233	3.3	1.4	<0.008	<0.5	<0.01	<0 01	<0.01	0.10	<0.01	<0.01	<0.01	0.06
LTRM 15	CHC	33235	3.7	1.0	<0.008	<0.5	<0.01	<0.01	<0.01	0.06	<0.01	<0.01	<0.01	0.04
Fontana Reservoir														
LTRM 62	CHC	33263	1.9	<0.1	<0.008	<0.5	<0.01	<0.01	<0.01	0.04	<0.01	<0.01	<0.01	<0.01
LTRM 81	CHC	33264	2.3	0.4	<0.008	<0.5	<0.01	<0.01	<0.01	0.06	<0.01	<0.01	<0.01	<0.01
TUCKRM 3	CHC	33269	2.7	0.1	<0.008	<0.5	<0.01	<0.01	<0.01	0.06	<0.01	<0.01	<0.01	<0.01
Little Tennessee River														
LTRM 94.77	CHC	32580	5.2	<0.1	<0.008	<0.5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
LTRM 94.77	SMB	32580	0.5	<0.1	<0.008	<0.5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
French Broad River														
FBRM 77.5	CHC	32591	1.9	<0.1	<0.008	<0.5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0 01	<0 01
FBRM 77.5	SMB	32594	1.2	<0.1	<0.008	<0.5	<0.01	<0.01	<0.01	<0.01	<0 01	<0 01	<0.01	<0.01
Nolichucky River														
NRM 8.5	C	32583	2.1	<0.1	<0.008	<0.5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
NRM 8.5	SPB	32586	0 5	<0.1	<0.008	<0 5	<0.01	<0 01	<0 01	<0.01	<0.01	<0 01	<0 01	<0.01
Cherokee Reservoir														
HRM 53	CHC	33271	7.4	0.3	<0.008	<0.5	<0.01	<0.01	<0.01	0.06	<0.01	<0.01	<0.01	0.11
HRM 75	CHC	33274	3.0	<0.1	<0.008	<0.5	<0.01	<0.01	<0.01	0.05	<0 01	<0.01	<0.01	0.04
HRM 91	CHC	33276	4.2	0.6	<0.008	<0.5	<0.01	<0.01	<0.01	0.06	<0.01	<0.01	<0.01	0.15
Holston River														
HRM 109.9	CHC	32597	4.7	<0.1	<0.008	<0.5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03
HRM 109.9	LMB	32599	0.2	<0.1	<0.008	<0.5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fork Patrick Henry Reservoir														
SFHRM 9	CHC	33279	2.7	0.2	<0.008	<0.5	<0.01	<0.01	<0.01	0.05	<0.01	<0.01	<0.01	<0.01

Collection Site	Species[a]	LABID[b]	% LIPIDS	PCBs	MIREX	TOXAPH	HEPTA	ALDRIN	BENZ	DDTr	DIELD	ENDO	ENDRIN	CHLOR
Boone Reservoir														
SFHRM 19	CHC	33281	2.6	0.7	<0.008	<0.5	<0.01	<0.01	<0.01	0.06	<0.01	<0.01	<0.01	0.02
SFHRM 27	CHC	33284	5.0	0.5	<0.008	<0.5	<0.01	<0.01	<0.01	0.06	<0.01	<0.01	<0.01	<0.01
WRM 6.5	CHC	33285	3.1	0.4	<0.008	<0.5	<0.01	<0.01	<0.01	0.06	<0.01	<0.01	<0.01	<0.01
Watauga Reservoir														
WRM 37.4	CHC	33286	6.8	0.1	<0.008	<0.5	<0.01	<0.01	<0.01	0.1	<0.01	<0.01	<0.01	<0.01
South Holston Reservoir														
SFHRM 51	CHC	33287	6.0	0.2	<0.008	<0.5	<0.01	<0.01	<0.01	0.08	<0.01	<0.01	<0.01	<0.01

a CHC = channel catfish, SPB = spotted bass, LMB = largemouth bass, SMB = smallmouth bass

b LABID = number assigned by TVA's Environmental Chemistry Laboratory. It is used to link laboratory analysis data with physical data from fish.

Table A-3 Concentrations (µg/g) of metals in composited fish flesh samples from stream and reservoir monitoring locations, 1993.

Collection Site	Species[a]	LABID[b]	As	Cd	Pb	Hg	Se
Duck River							
DRM 22.5	CHC	32548	<0.1	<0.05	<0.02	<0.1	0.2
DRM 22.5	SPB	32550	<0.1	<0.05	<0.02	<0.1	0.2
Bear Creek Reservoir							
BCM 75	CHC	33238	<0.1	<0.05	0.02	0.66	0.2
BCM 75	LMB	33295				0.71	
Little Bear Creek Reservoir							
LBCRM 12	LMB	33296				0.60	
LBCRM 12	CHC	33239	<0.1	<0.05	<0.02	0.22	<0.2
Pickwick Reservoir							
TRM 259	CHC	33223	<0.1	<0.05	0.02	0.12	<0.2
Wheeler Reservoir							
TRM 277	CHC	33225	<0.1	<0.05	0.02	0.13	<0.2
TRM 296	CHC	33228	<0.1	<0.05	0.05	<0.1	<0.2
TRM 346	CHC	33230	0.12	<0.05	<0.02	<0.1	<0.2
Elk River							
ERM 41	CHC	32551	<0.1	<0.05	<0.02	<0.1	<0.2
ERM 41	LMB	32552	<0.1	<0.05	<0.02	0.31	0.2
Sequatchie River							
SEQRM 7.1	CHC	32555	<0.1	<0.05	<0.02	0.13	<0.2
SEQRM 7.1	LMB	32557	<0.1	<0.05	<0.02	0.35	0.3
SEQRM 7.1	SPB	32558	<0.1	<0.05	0.24	0.63	0.3
Hiwassee River							
HIRM 38	CHC	32559	<0.1	<0.05	<0.02	0.17	<0.2
HIRM 38	LMB	32562	<0.1	<0.05	<0.02	0.26	0.3
Hiwassee Reservoir							
HIRM 77	CHC	33240	<0.1	<0.05	0.03	0.54	0.2
HIRM 77	LMB	33297				0.33	
HIRM 85	CHC	33241	<0.1	<0.05	0.02	0.40	<0.2
HIRM 85	LMB	33298				0.30	
Chatuge Reservoir							
HIRM 122	CHC	32246	<0.1	<0.05	<0.02	0.13	0.3
HIRM 122	LMB	33299				0.45	

Collection Site	Species[a]	LABID[b]	As	Cd	Pb	Hg	Se
Nottley Reservoir							
NOTRM 24	CHC	33248	<0.1	<0.05	0.16	0.60	<0.2
NOTRM 24	LMB	33300				0.44	
Ocoee #1							
OCRM 12	CHC	33251	<0.1	<0.05	0.06	<0.1	0.5
OCRM 16	CHC	33253	<0.1	<0.05	0.04	<0.1	0.4
Blue Ridge Reservoir							
TOCRM 54	CHC	33256	<0.1	<0.05	<0.02	0.13	0.2
TOCRM 54	LMB	33301				0.12	
Emory River							
EMORY RM 14.6	CHC	32569	<0.1	<0.05	<0.02	0.51	<0.2
EMORY RM 14.6	LMB	32569	<0.1	<0.05	<0.02	0.40	0.3
Norris Reservoir							
CRM 80	CHC	33258	<0.1	<0.05	0.15	0.24	<0.2
CRM 80	LMB	33302				0.59	
CRM 125	CHC	33261	<0.1	<0.05	0.02	<0.1	<0.2
CRM 125	LMB	33305				0.24	
PRM 30	CHC	33262	<0.1	<0.05	<0.02	<0.1	<0.2
PRM 30	LMB	33307				0.12	
Clinch River							
CRM 172	CHC	32573	<0.1	<0.05	<0.02	0.13	0.2
CRM 172	SMB	32575	<0.1	<0.05	0.06	0.14	0.6
Powell River							
PRM 65.27	CHC	32576	<0.1	<0.05	<0.02	<0.1	0.2
PRM 65.27	SMB	32579	<0.1	<0.05	<0.02	0.23	0.4
Tellico Reservoir							
LTRM 1.0	CHC	33233	<0.1	<0.05	0.02	0.56	<0.2
LTRM 1.0	LMB	33290				0.15	
LTRM 15	CHC	33235	<0.1	<0.05	<0.02	0.29	<0.2
LTRM 15	LMB	33292				0.22	
Fontana Reservoir							
LTRM 62	CHC	33263	<0.1	<0.05	0.04	0.30	<0.2
LTRM 62	LMB	33310				0.18	
LTRM 81	CHC	33264	<0.1	<0.05	<0.02	0.43	<0.2
LTRM 81	LMB	33311				0.18	
TUCKRM 3	CHC	33269	<0.1	<0.05	0.06	0.38	<0.2
TUCKRM 3	LMB	33312				0.32	

Collection Site	Species[a]	LABID[b]	As	Cd	Pb	Hg	Se
Little Tennessee River							
LTRM 94.77	CHC	32580	<0.1	<0.05	<0.02	0.27	<0.2
LTRM 94.77	LMB	32582	<0.1	<0.05	0.10	0.44	0.2
French Broad River							
FBRM 77.5	CHC	32591	<0.1	<0.05	0.07	0.24	<0.2
FBRM 77.5	LMB	32593	<0.1	<0.05	<0.02	0.19	0.2
FBRM 77.5	SMB	32594	<0.1	<0.05	0.11	0.51	0.4
Nolichucky River							
NRM 8.5	C	32583	<0.1	<0.05	0.02	0.15	0.3
NRM 8.5	SPB	32586	<0.1	<0.05	0.10	0.14	0.2
Cherokee Reservoir							
HRM 53	CHC	33271	<0.1	<0.05	<0.02	0.11	<0.2
HRM 53	LMB	33313				0.17	
HRM 75	CHC	33274	<0.1	<0.05	<0.02	0.18	<0.2
HRM 75	LMB	33314				0.17	
HRM 91	CHC	33276	<0.1	<0.05	0.03	0.38	<0.2
HRM 91	LMB	33315				0.24	
Holston River							
HRM 109.9	CHC	32597	<0.1	<0.05	<0.02	<0.1	0.3
HRM 109.9	LMB	32599	<0.1	<0.05	0.08	0.40	<0.2
Fork Patrick Henry Reservoir							
SFHRM 9	CHC	33279	<0.1	<0.05	<0.02	<0.1	<0.2
SFHRM 9	LMB	33316				<0.1	
Boone Reservoir							
SFHRM 19	CHC	33281	<0.1	<0.05	0.15	0.13	<0.2
SFHRM 19	LMB	33317				0.14	
SFHRM 27	CHC	33284	<0.1	<0.05	<0.02	0.21	<0.2
SFHRM 27	LMB	33320				0.22	
WRM 7	CHC	33285	<0.1	<0.05	0.03	0.14	<0.2
WRM 7	LMB	33322				0.12	
Watauga Reservoir							
WRM 38	CHC	33286	<0.1	<0.05	<0.02	0.48	<0.2
WRM 38	LMB						
South Holston Reservoir							
SFHRM 51	CHC	33287	<0.1	<0.05	0.18	0.47	<0.2
SFHRM 51	LMB	33326				0 45	

a CHC = channel catfish, SPB = spotted bass, LMB = largemouth bass, SMB = smallmouth bass

b LABID = number assigned by TVA's Environmental Chemistry Laboratory. It is used to link laboratory analysis data with physical data from fish.

APPENDIX B

CHRONOLOGICAL LISTING OF TVA REPORTS RELATING TO TOXICS IN FISH

NOTE: Copies of reports are available from:

Water Management Library
Tennessee Valley Authority
CST 16B
1101 Market Street
Chattanooga, TN 37402-2801
(615) 751-7338
Fax: (615) 751-7479

CHRONOLOGICAL LISTING OF TVA REPORTS RELATING TO TOXICS IN FISH

MONITORING OF MERCURY CONCENTRATIONS IN FISHES COLLECTED FROM PICKWICK AND KENTUCKY RESERVOIRS MAY 1970 - FEBRUARY 1971 - April 1971

CONTROL AND CONFIDENCE INTERVAL CHARTS FOR MONITORING MERCURY CONTAMINATION OF FISH - A. L. Jensen - June 1971

SUMMARY OF OCOEE RIVER WATER QUALITY, SEDIMENT, AND BIOLOGICAL DATA COLLECTED THROUGH SEPTEMBER 1975 - Ralph Brown and Dennis Meinert I-WQ-76-1 - May 1976

EVALUATION OF THE MERCURY MONITORING PROGRAM FROM THE NORTH FORK HOLSTON RIVER - Thomas W. Toole and Richard Ruane - E-WQ-76-2 - September 1976

TRENDS IN THE MERCURY CONTENT OF FISH FROM KENTUCKY, PICKWICK, AND CHICKAMAUGA RESERVOIRS 1970-1977 - Jack Milligan - I-WQ-78-15 - December 1978

ANALYSIS OF MERCURY DATA COLLECTED FROM THE NORTH FORK OF THE HOLSTON RIVER - Jack Milligan and Richard Ruane - TVA/EP-78/12 - December 1978

ENGINEERING AND ENVIRONMENTAL STUDY OF DDT CONTAMINATION HUNTSVILLE SPRING BRANCH, INDIAN CREEK, AND ADJACENT LANDS AND WATERS, WHEELER RESERVOIR, ALABAMA-TASK 1-DDT LEVELS IN IMPORTANT FISH SPECIES THROUGHOUT WILSON, WHEELER, AND GUNTERSVILLE RESERVOIRS-Final Data Report - August 1980

ENGINEERING AND ENVIRONMENTAL STUDY OF DDT CONTAMINATION HUNTSVILLE SPRING BRANCH, INDIAN CREEK, AND ADJACENT LANDS AND WATERS, WHEELER RESERVOIR, ALABAMA-TASK 2 FISH POPULATION ESTIMATES AND DDT CONCENTRATIONS IN YOUNG-OF-YEAR FISHES FROM INDIAN CREEK AND HUNTSVILLE SPRING BRANCH EMBAYMENTS OF WHEELER RESERVOIR-Final Data Report - August 1980

ENGINEERING AND ENVIRONMENTAL STUDY OF DDT CONTAMINATION HUNTSVILLE SPRING BRANCH, INDIAN CREEK, AND ADJACENT LANDS AND WATERS, WHEELER RESERVOIR, ALABAMA-TASK 3-ASSESSMENT OF DDT CONCENTRATIONS IN SEDIMENTS CORRESPONDING TO AREA-WIDE FISHERIES STUDIES-Final Data Report - August 1980

ENGINEERING AND ENVIRONMENTAL STUDY OF DDT CONTAMINATION HUNTSVILLE SPRING BRANCH, INDIAN CREEK, AND ADJACENT LANDS AND WATERS, WHEELER RESERVOIR, ALABAMA-TASK 4-ASSESSMENT OF DDT CONCENTRATIONS AND OTHER CONTAMINANTS IN SEDIMENTS IN REDSTONE ARSENAL VICINITY-Final Data Report - August 1980

ENGINEERING AND ENVIRONMENTAL STUDY OF DDT CONTAMINATION HUNTSVILLE SPRING BRANCH, INDIAN CREEK, AND ADJACENT LANDS AND WATERS, WHEELER RESERVOIR, ALABAMA-TASK 5-AQUATIC BIOTRANSPORT (EXCLUDING VERTEBRATES)-Final Data Report - August 1980

ENGINEERING AND ENVIRONMENTAL STUDY OF DDT CONTAMINATION HUNTSVILLE SPRING BRANCH, INDIAN CREEK, AND ADJACENT LANDS AND WATERS, WHEELER RESERVOIR, ALABAMA-TASK 6-Vol. I-HYDROLOGIC AND SEDIMENT DATA-Final Data Report - August 1980

ENGINEERING AND ENVIRONMENTAL STUDY OF DDT CONTAMINATION HUNTSVILLE SPRING BRANCH, INDIAN CREEK AND ADJACENT LANDS AND WATERS, WHEELER RESERVOIR, ALABAMA-TASK 6-Vol II-HYDROLOGICAL AND SEDIMENTOLOGICAL CALCULATIONS-DATA ANALYSIS-Final Data Report - August 1980

ENGINEERING AND ENVIRONMENTAL STUDY OF DDT CONTAMINATION HUNTSVILLE SPRING BRANCH, INDIAN CREEK AND ADJACENT LANDS AND WATERS, WHEELER RESERVOIR, ALABAMA-TASK 6-Vol III-HYDROLOGICAL AND SEDIMENTOLOGICAL CALCULATIONS-INPUT DATA-Final Data Report - August 1980

ENGINEERING AND ENVIRONMENTAL STUDY OF DDT CONTAMINATION HUNTSVILLE SPRING BRANCH, INDIAN CREEK, AND ADJACENT LANDS AND WATERS, WHEELER RESERVOIR, ALABAMA-TASK 7-ASSESSMENT OF DDT LEVELS OF SELECTED VERTEBRATES IN AND ADJACENT TO WHEELER, WILSON, AND GUNTERSVILLE RESERVOIRS (SPATIAL EXTENT OF CONTAMINATION)-Final Data Report - August 1980

ENGINEERING AND ENVIRONMENTAL STUDY OF DDT CONTAMINATION HUNTSVILLE SPRING BRANCH, INDIAN CREEK, AND ADJACENT LANDS AND WATERS, WHEELER RESERVOIR, ALABAMA-QUALITY ASSURANCE DOCUMENT-Final Data Report - August 1980

TRENDS IN THE MERCURY CONCENTRATION IN LARGEMOUTH BASS, CARP, AND DRUM FROM KENTUCKY AND PICKWICK RESERVOIRS 1970-1979 - Jack Milligan - TVA/ONR/WRF-83/4 - May 1983

POLYCHLORINATED BIPHENYL (PCB) CONCENTRATIONS IN CATFISH FROM FLEET HOLLOW, WILSON RESERVOIR - Donald Dycus, Peter Hackney, and William Barr - TVA/ONR/WRF-83/11 - May 1983

SUMMARY OF EXISTING WATER, SEDIMENT, FISH, AND SOIL DATA IN THE VICINITY OF THE OAK RIDGE RESERVATION - August 1983

DETERMINATION OF THE RELATIONSHIP BETWEEN CONCENTRATION OF DDT IN SEDIMENT AND CONCENTRATION OF DDT IN FISH FOR THE HSB-IC TRIBUTARY SYSTEM - January 1984

PHYSICAL, CHEMICAL, AND BIOLOGICAL PROCESSES AFFECTING THE UPTAKE AND LOSS OF DDT BY FISH FROM DDT CONTAMINATED SEDIMENTS: REVIEW AND EVALUATION OF LITERATURE PERTINENT TO HUNTSVILLE SPRING BRANCH-INDIAN CREEK REMEDIAL ACTIONS - TVA/ONRED/AWR-84/9 - May 1984

ORGANIC COMPOUNDS AND METALS IN FISH FROM CHATTANOOGA CREEK AND NICKAJACK RESERVOIR - Jack D. Milligan and Barney S. Neal - TVA/ONRED/AWR-85-1 - November 1984

POLYCHLORINATED BIPHENYL CONTAMINATION OF FORT LOUDOUN RESERVOIR: A MANAGEMENT RESPONSE TO THE FOOD AND DRUG ADMINISTRATION 1984 REVISION OF LIMITS FOR PCB IN FISH FLESH - Neil Carriker and David McKinney - 1985

INSTREAM CONTAMINANT STUDY - TASK 4 - FISH SAMPLING AND ANALYSIS - Prepared for USDOE, Oak Ridge, Tennessee - TVA/ONRED/April 1985

WATER QUALITY IN OCOEE NO. 1 RESERVOIR-VOLUME 1: SUMMARY REPORT - Janice Cox - TVA/ONRED/AWR-86/13 - January 1986

WATER QUALITY IN OCOEE NO. 1 RESERVOIR-VOLUME 2: TECHNICAL REPORT - Janice Cox - TVA/ONRED/AWR-86/13 - January 1986

HEAVY METAL AND PCB CONCENTRATIONS IN SEDIMENTS FROM SELECTED TVA RESERVOIRS - TVA/ONRED/AWR-86/35 - April 1986

NORTH ALABAMA WATER QUALITY ASSESSMENT: VOLUME VII-CONTAMINANTS IN BIOTA - Donald Dycus - TVA/ONRED/AWR-86/33 - April 1986

PCB CONCENTRATIONS IN WILSON RESERVOIR CATFISH-1985 - Donald Dycus and Donny Lowery - TVA/ONRED/AWR-86/57 - September 1986

CONCENTRATIONS OF PCBs, DDTr, AND SELECTED METALS IN BIOTA FROM GUNTERSVILLE RESERVOIR - Donald Dycus and Donny Lowery - TVA/ONRED/AWR-87/18 - October 1986

NORTH ALABAMA WATER QUALITY ASSESSMENT: VOLUME X CONCENTRATIONS OF PCBs, DDTr, AND SELECTED METALS IN CATFISH FROM WHEELER RESERVOIR - Donald Dycus and Donny Lowery - October 1986

CONCENTRATIONS OF PCBs, DDTr, AND METALS IN FISH FROM TELLICO RESERVOIR - Donald Dycus and Gary Hickman - TVA/ONRED/AWR-87/25 - November 1986

ESTIMATION OF THE BIOACCUMULATION OF MERCURY BY BLUEGILL SUNFISH IN EAST FORK POPLAR CREEK-Final Report - Richard Young - April 1987

SCREENING FOR TOXICS IN BIOTA AND SEDIMENT FROM THE LOWER TENNESSEE RIVER - John Jenkinson - TVA/ONR/AWR-87/34 - July 1987

PCB CONCENTRATIONS IN WILSON RESERVOIR CATFISH-1986 - Donald Dycus and Donny Lowery - TVA/ONRED/AWR-88/2 - August 1987

NORTH ALABAMA WATER QUALITY ASSESSMENT: VOLUME 14-CONCENTRATIONS OF PCBs, AND DDTr IN CATFISH FROM UPPER PICKWICK RESERVOIR AND PCBs FROM WILSON RESERVOIR - Donald Dycus and Donny Lowery - TVA/ONRED/AWR 85/22 - September 1987

PCB CONCENTRATIONS IN FISH AND SEDIMENT FROM FORT LOUDOUN RESERVOIR-1985 - Donald Dycus, Joseph Fehring, and Gary Hickman - TVA/ONRED/AWR 88/8 - October 1987

SURFACE WATER MONITORING STRATEGY-AMBIENT MONITORING-RESULTS FROM ANALYSES ON FISH TISSUE COLLECTED IN 1986 - Donald Dycus - May 1988

PCB LEVELS IN FISH FROM FORT LOUDOUN RESERVOIR, FORT LOUDOUN DAM TAILRACE, TELLICO RESERVOIR, AND CHILHOWEE RESERVOIR AUTUMN 1986 TO WINTER 1987 - Donald Dycus and Gary Hickman - TVA/ONRED/AWR 88/19 - June 1988

LEVELS OF SELECTED METALS AND PCBs IN CHANNEL AND BLUE CATFISH FROM CHICKAMAUGA RESERVOIR-1987 - Donald Dycus - July 1988

PCB CONCENTRATIONS IN WILSON RESERVOIR CATFISH-1987 - Donald Dycus and Donny Lowery - August 1988

CONCENTRATIONS OF PCBs IN FISH AND SEDIMENTS FROM UPPER GUNTERSVILLE RESERVOIR-1987 - Donald Dycus - TVA/WR/AB--89/4 - May 1989

RESULTS OF FISH TISSUE SCREENING STUDIES FROM SITES IN THE TENNESSEE AND CUMBERLAND RIVERS-1987 - Donald Dycus - TVA/WR/AB--89/5 - May 1989

PCB STUDIES ON FISH FROM WATTS BAR, FORT LOUDOUN, TELLICO, AND CHILHOWEE RESERVOIRS-1987 - Donald Dycus - TVA/WR/AB--89/10 - July 1989

LEVELS OF SELECTED METALS AND PCBs IN CHANNEL CATFISH FROM CHICKAMAUGA RESERVOIR-1988 - Donald Dycus - TVA/WR/AB--90/3 - February 1990

RESULTS OF FISH TISSUE SCREENING STUDIES IN THE TENNESSEE AND CUMBERLAND RIVERS IN 1988 - Donald Dycus - TVA/WR/AB--90/7 - July 1990

RESULTS OF PCB AND CHLORDANE ANALYSES ON FISH COLLECTED FROM NICKAJACK RESERVOIR IN JANUARY AND FEBRUARY 1989 - Donald Dycus - TVA/WR/AB--90/9 - July 1990

PCB STUDIES ON FISH FROM WATTS BAR, FORT LOUDOUN, TELLICO, AND MELTON HILL RESERVOIRS - 1988 - Donald Dycus - TVA/WR/AB--90/11 - September 1990

RESERVOIR MONITORING - 1990 - FISH TISSUE STUDIES IN THE TENNESSEE VALLEY IN 1989 - Gordon E. Hall and Donald Dycus - TVA/WR/AB--91/12 - October 1991

RESERVOIR MONITORING - 1991 - FISH TISSUE STUDIES IN THE TENNESSEE VALLEY IN 1990 - Joella A. Bates, Donald L. Dycus, and Gordon E. Hall - TVA/WR--92/7 - December 1992

RESERVOIR MONITORING - 1992 - FISH TISSUE STUDIES IN THE TENNESSEE VALLEY IN 1991 AND 1992 - Donald L. Williams and Donald L. Dycus - December 1993

RESERVOIR MONITORING - 1993 - FISH TISSUE STUDIES IN THE TENNESSEE VALLEY IN 1993 - Donald L. Williams and Donald L. Dycus - July 1994

APPENDIX C

RATIONALE AND PROCEDURES FOR COLLECTION, PROCESSING, AND ANALYSIS OF FISH TISSUE SAMPLES

Appendix C

RATIONALE AND PROCEDURES FOR COLLECTION, PROCESSING, AND ANALYSIS OF FISH TISSUE SAMPLES

RATIONALE

All fish tissue studies are closely coordinated among TVA and various state agencies to ensure all needs are met, avoid duplication of effort, and ensure efficient use of available funds. Planning meetings are usually held in the summer followed by collection efforts in autumn. In many cases efforts are combined so that one organization collects the fish and another analyzes them. When more than one analytical laboratory is involved, samples are split between the labs to allow comparison of results.

Several important decisions must be made in studies such as these. Should analyses be conducted on fish composites or individual fish? Should whole fish or fillets be analyzed? Should fillets have the skin on or off? Should the bellyflap (which is rich in lipids and lipophilic contaminants) be left on the fillet or removed? These are all valid options and all have been used in previous studies (McCracken 1983). Selection of specific protocols is dependent upon the objective of the study.

Should analyses be conducted on fish composites or individual fish?--TVA's approach differs between screening studies and intensive studies because the objectives of those studies differ. Screening studies are intended to identify sites with potential problems, whereas intensive studies are intended to define the extent of the problem identified by the screening studies. Therefore, screening studies are based on composited samples analyzed for a broad array of contaminants, and intensive studies are based on analysis of individual samples for only those analytes identified to be a potential problem. Analysis of individual samples provides a measure of variation in the population thus allowing statistical testing among locations and over time.

Should whole fish or fillets be analyzed?--The primary objective of most TVA fish tissue studies is oriented toward human health. In that case, it makes little sense to examine whole fish. Therefore, in most cases, TVA fish tissue studies are based on analysis of fillets. Typically, analysis of whole fish is preferable when fish are used as "environmental monitors" to determine the condition of the environment or to identify previously unknown contaminants (FWGPM 1974 and McCracken 1983).

Should fillets have skin on or off? Should the bellyflap be left on the fillet?--The decision point for both these questions is whether one wishes to produce a "worst-case," or a less conservative, scenario. Fillets with skin and bellyflap left usually have higher concentrations of most contaminants (worst-case), especially organochlorine contaminants, than skin-off (best-case) fillets without the bellyflap. A study by Cornell University has shown up to a 50 percent reduction in concentration of PCBs and mirex when comparing "best-case" and "worst-case" prepared fillets (Gall and Voiland 1990). Based on the need for a conservative approach in protection of public health, TVA studies are designed to produce a worst-case estimate of contamination. This approach provides the best protection to the fish consumer. All TVA analyses are conducted on fillets with bellyflap left on for all species and skin left on for all species except catfish. Skin is removed from the catfish since catfish skin is rarely, if ever, eaten with the fillet.

Species Examined

The approach most commonly used in these studies is to examine a site as part of the Reservoir or Stream Monitoring Fish Tissue Study (described in detail in Chapter 1), using channel catfish as an indicator species. Channel catfish was selected as the indicator species because it is highly sought by both commercial and sport fisherman, because individuals usually have relatively high concentrations of most contaminants compared to other species, and because a historical data base exists for that species.

If problems are identified, an intensive study is usually undertaken the next year that would include analysis of individual channel catfish at a greater number of locations than sampled in the screening study. Also, other important species would be examined at the screening level. Depending upon their importance in the reservoir or stream and the availability of funds, these species would include one or more of the following: largemouth bass, striped bass, buffalo, crappie, carp, white bass, and possibly others. If problems are identified in any of these species, they would be examined intensively (i.e., fillets analyzed individually) during the subsequent year.

PROCEDURES

Field Handling

Fish processing techniques have an influence on the accuracy and reliability of data derived from tissue analysis. For this reason, consistency in the handling and processing of fish for tissue analysis is vital.

Fish Collection

Fish can be collected by a variety of methods, for example, by various types of nets, by electrofishing, or by commercial fishing gear. If fish come from commercial fisherman, a biologist (TVA, state, or contractor) must accompany the fisherman and see that the fish pulled are from an approved fishing/sampling area. Fish are removed from the gear, and the appropriate number of each species, as specified in the workplan, are put in plastic bags (one species per bag) in a cooler of ice. Dead fish may only be used if the gills are still red; otherwise they are discarded. Fish cannot be held more than 24 hours in a cooler after collection. No fish with flesh deteriorated beyond that desired for human consumption can be included in the sample. Every reasonable effort is made to collect the desired number of fish of each species as outlined in the workplan. Minimum length of black bass is 12 inches for reservoir collections and 10 inches for stream collections. Channel catfish must weigh at least one pound; striped bass/hybrids should be a minimum of two pounds, however, larger fish are desired. If repeated attempts to collect large fish fail, smaller fish may be accepted. The lab transfer sheet (attachment 1) originates with the person collecting the fish and accompanies the sample until analyzed in the laboratory and/or archived. Each transfer of the sample from one location and/or person to another should be logged on the transfer sheet with the signatures of the people delivering and receiving even if it is the same person.

Biological Lab Preparation

All work surfaces and cutting equipment used in fish processing should be washed with soap, rinsed with tap water, followed by rinsing with pesticide grade propanol and finally rinsing with distilled water. The cutting board is covered with heavy-duty aluminum foil. Persons processing fish should wear sterile rubber gloves to prevent fish contamination.

At least two people are needed to process the fish, transcribe data and process fillets. Data should be recorded using a No.2 pencil, or permanent pen and waterproof paper. Much of the label can be completed prior to fish processing. The proper date for the record sheet is that when the fish was collected, and not the date of processing. A sheet of clean aluminum foil is used for wrapping each fillet, one sheet for the liver composite, and one sheet to lay each fish on the scale while weighing.

Processing

Two waterproof labels (attachment 2) are completed for each fish (one for each fillet). Total length and weight and the external observations, specified on the lab sheet (attachment 3), are recorded for each fish. A mid-ventral cut is made from the vent anteriorly with the scissors lifted to prevent damage to internal organs. The proportion of the internal organs that are covered by fat after first opening the body cavity are noted, along with the sex of the individual and complete observations of the internal organs as specified on the lab sheet. Any organs having abnormalities are removed and preserved in formaldehyde for later study. After observations are recorded, the liver and then the gall bladder are removed from the fish; care is taken not to rupture and contaminate the liver. If the liver should be contaminated by the gall bladder it should be thoroughly rinsed with distilled water. After the liver is weighed, it is discarded. Livers are not removed from carp and smallmouth buffalo because of difficulty in removing livers from these fish without contamination. Remaining viscera are then removed from the body cavity.

All scaled fish should have scales removed prior to opening the gut cavity; the skin is left on. All catfish should have the skin removed with skinners or pliers (external cuts are optional for skinning purposes). As little tissue as possible should be discarded with the skin. Skin should also be removed from the belly section. When removing the fillets, start as close to the head as possible and cut around the dorsal spine. Each fillet should be removed by a mid-ventral cut that removes as much of the tissue as possible and includes the ribs and belly. Any abnormalities present in the tissue of the fillet should be removed with as little of the surrounding tissue as possible and preserved in formaldehyde for later study.

After both fillets are removed, the pelvic fin is cut out with scissors in a manner that discards as little tissue as possible. Fat and entrails should be scraped off the inside of the fillets with a knife. Fillets are rinsed in tap water followed by distilled water. Each fillet is weighed and the fillet weight recorded on both the lab sheet and the label. Each fillet is individually wrapped in the piece of foil on which it was weighed. If the fillet is very large, it may be cut from the inside toward the outside, with a small amount near the skinned side remaining in tact, and then folded on itself; foil should not be folded within the fillet. Each wrapped fillet and the label are placed individually in a plastic bag. As much air as possible should be removed from the bag in order to conserve storage space. The above processing procedures are repeated for all individuals of a species from each site.

After the electronic weight scales are tared, each subsequent liver should be added to the aluminum foil containing the liver composite and weighed. If the workplan specifies livers are to be archived, they are wrapped together in the aluminum foil, labeled, and placed in a plastic bag then stored in a freezer.

Fillet Disposition

The two fillets from a fish will either be sent to the chemistry laboratory (one for organic analysis and one for metals), or one will be sent to the chemistry laboratory for appropriate analysis and the other archived. Random selection (coin toss) will decide which fillet will be used for organics analysis and which for metals. If appropriate; a coin toss will determine which fillet is sent to the laboratory for analysis and which one archived. This information is indicated on the lab sheet.

All fillets from the same species from one site that will be used for organics will be placed in a plastic bag with a common label that includes the following information: study, river/reservoir, station or river mile, species, collection date and fish numbers with the side (right or left) that will be used for this analysis. The label should also have "Organics" boldly printed on it. The metals (or archived) fillets should be packaged the same way. The bag of organics and the bag of metals will then be placed together in another plastic bag labeled with the following information: study, reservoir/river, river mile, date, and species. All samples are to be placed in a freezer as soon as possible after processing. These same procedures should be repeated for the next species and/or sampling location.

When more than one species is sampled from a site (intensive study), all species from that site should be grouped together in another common bag for convenience later in finding samples in the freezer. That bag should be labeled with the following information: study, reservoir/river, river mile, species collected and their respective collection dates. If screening studies include numerous sampling sites within a reservoir, these samples can be bagged together and labeled appropriately.

All fillets slated for archival and ground tissue remaining from laboratory analyses are stored frozen in Norris for approximately one year (until the following year's tissue samples are ready to be stored). In special cases, tissue samples may be stored longer.

Chemical Laboratory Analyses

Laboratory Processing

Preparation of fillets for individual analysis is accomplished by homogenizing the entire fillet. This is necessary because contaminants are not evenly distributed throughout the fillet, and homogenization of only a portion would bias the results. Each fillet was partially thawed and diced with a knife. Diced tissue was then thoroughly ground using a mechanical grinder. After grinding, tissue was dispersed into glass jars and frozen pending analysis.

A composite sample is prepared by taking an equal aliquot from each of five independently homogenized fillets. Preparation of composite samples in this manner is necessary to avoid biasing results due to compositing fillets of different sizes. The alternative way to avoid a size bias is to collect fish of a consistent size. This would allow homogenizing all five fillets at the same time, thereby reducing time required for that step. However, TVA's experience has shown that this alternative is not desirable because it increases collection costs, limits applicability of results to only the size of fish tested, and prevents samples from maintaining their identity, if the need arises later for individual analysis.

Analytes

Fish collected for screening studies are usually analyzed for selected metals, PCBs, and pesticides on EPA's Priority Pollutant List. Fish for intensive studies are analyzed only for the contaminant of concern, which has been identified by screening studies or is known as a historic problem. The most common contaminant of concern in the Tennessee Valley is PCBs, with chlordane a distant second. Several TVA reservoirs have fish consumption advisories due to PCB-contaminated fish.

The lipid content of a sample (determined gravimetrically and expressed as a percentage) has been found to be an invaluable quality assurance tool, as well as being essential in conducting spatial or temporal statistical analyses. For these reasons, lipid content is determined on all samples.

PCBs are extracted with petroleum ether from homogenized fillets using a cell disrupter. The extract is then cleaned with concentrated sulfuric acid and analyzed for

Aroclors 1016, 1221, 1232, 1242, 1248, 1254, and 1260 using a precalibrated gas chromatograph equipped with an electron capture detector and an electronic integrator.

Laboratory procedures for chlordane were provided in a previous report on fish from Nickajack Reservoir in 1989 (Dycus 1990a) and will not be repeated here. Analyses for pesticides are conducted using the 608 procedure.

Quality Assurance

TVA's standard Quality Assurance (QA) program requires running one replicate, one spike, one blank, and one surrogate out of every ten samples. TVA also routinely splits samples with other analytical laboratories if that agency is participating in fish tissue studies on TVA waters.

Data Analyses

Screening Studies

Statistical analyses are not conducted on results from screening studies because replicate samples are not collected. Results from these studies are compared to preselected, tiered concentrations. If measured concentrations are low relative to the tiered concentrations, then no follow-up studies are warranted. If measured concentrations are high, follow-up studies would be conducted. More thorough explanation of this tiered approach is provided in Chapter 1.

Intensive Studies

A broad array of statistical techniques is used to further examine the results of the laboratory analysis. A two-way analysis of variance (ANOVA) is used to compare lipid content and/or fish size (length and weight) among sample locations or years.

Differences in PCB levels among locations and years are examined using either ANOVA and Ryan-Einot-Gabriel-Welsch Multiple Range Test (REGW) or analysis of covariance. Because PCBs are lipophilic compounds and have been found to accumulate with fish size, these data are examined closely to determine if analysis of covariance is needed to control PCB variability due to lipid content or fish size. The first step is to test the null hypothesis that PCB levels do not depend upon lipid content or fish size for one or more stations. This involves regressing PCB concentration against lipid content and fish size simultaneously for each station. If the slopes for all stations are not different from zero (failure to reject the null hypothesis), then no adjustment for lipid content is necessary and ANOVA is the appropriate test. If the slopes differ from zero (rejection of null hypothesis), covariance analysis is needed. Before proceeding to covariance analysis, data are tested for homogeneity of slopes (parallel lines). If this null hypothesis is accepted, data are analyzed using covariance analysis, comparing distances between the parallel regression lines.

Statistical analyses for chlordane concentrations are not reported due to interference between PCB 1254 and cis-chlordane and interference between PCB 1260 and trans-nanochlor. As a result, if PCB 1254 and/or 1260 are present, the appropriate chlordane isomers would be reported as "interference" and no concentration provided. In such cases the reported levels of chlordane would be conservative. This situation was recognized while analyzing the 1991 samples. Hence, chlordane concentrations for all previous studies would over-estimate the true concentration.

Prior to statistical analyses, concentrations of PCBs are transformed to approximate a normal distribution using a $\log_{10}(x + 1)$ transformation ($x + 1$ is used because some values are between zero and one). Lipid content is transformed using arc sine. An α of 0.05 is chosen as the level of significance. Samples with less than detectable levels are included at the detection limit in statistical analysis and developing averages.

Attachment 1

FISH TISSUE SAMPLE LOG/TRANSFER FORM

Project______________ Reservoir/River______________ Location______________

Species	Fish Number	Collection Date	E. Chem. Number	Fillets * Left	Fillets * Right	Liver	Species	Fish Number	Collection Date	E. Chem. Number	Fillets * Left	Fillets * Right	Liver

* Indicate disposition of fillets and liver for analysis by placing the letter in the appropriate column. M = Metals O = Organics A = Archived

Date	Delivered by (Signature)	Received by (Signature)	Action (e.g., N Lab to Chem Lab)

ABDO966R

Attachment 2

STUDY____________________________

F OIR____________________________

F ___________________MILE________

SPECIES__________________________

SAMPLE NO.______________DATE___/___/___

RIGHT FILLET ( ) LEFT FILLET ( ) LIVER ( )

TOTAL LENGTH____mm

TOTAL WEIGHT____grams

FILLET WEIGHT___grams

STUDY____________________________

RESERVOIR________________________

RIVER___________________MILE________

SPECIES__________________________

SAMPLE NO.______________DATE___/___/___

RIGHT FILLET ( ) LEFT FILLET ( ) LIVER ( )

TOTAL LENGTH____mm

TOTAL WEIGHT____grams

FILLET WEIGHT___grams

STUDY____________________________

RESERVOIR________________________

RIVER___________________MILE________

SPECIES__________________________

SAMPLE NO.______________DATE___/___/___

RI ILLET ( ) LEFT FILLET ( ) LIVER ( )

TC ENGTH____mm

TOTAL WEIGHT____grams

FILLET WEIGHT___grams

STUDY____________________________

RESERVOIR________________________

RIVER___________________MILE________

SPECIES__________________________

SAMPLE NO.______________DATE___/___/___

RIGHT FILLET ( ) LEFT FILLET ( ) LIVER ( )

TOTAL LENGTH____mm

TOTAL WEIGHT____grams

FILLET WEIGHT___grams

STUDY____________________________

RESERVOIR________________________

RIVER___________________MILE________

SPECIES__________________________

SAMPLE NO.______________DATE___/___/___

RIGHT FILLET ( ) LEFT FILLET ( ) LIVER ( )

TOTAL LENGTH____mm

TOTAL WEIGHT____grams

FILLET WEIGHT___grams

STUDY____________________________

RESERVOIR________________________

RIVER___________________MILE________

SPECIES__________________________

SAMPLE NO.______________DATE___/___/___

RIGHT FILLET ( ) LEFT FILLET ( ) LIVER ( )

TOTAL LENGTH____mm

TOTAL WEIGHT____grams

FILLET WEIGHT___grams

Attachment 3

Fish Tissue Studies - Biological Laboratory Form

Page ___ of ___

Project ____________________

River : ____________________

Reservoir : ____________________

Sta/River Mile : ____________________

Sample Method : __________

Collectors : __________

Processors : __________

Sample ID : Catfish __________
Gamefish __________
Rough fish __________
Other __________

Fish Status : Anesthetized
Near Dead
Dead
Other (frozen)

Sample No.	Collect Date	Species	Lt. (mm)	Wt. (gm)	External Observations: Eye	Oper.	Gill	Fin	Cond.	Internal Observations: Fat	Liv.	Bile	Spl.	Kid.	Sex	Para	Left Filet wt (gm)	Right Filet wt (gm)	Liver wt (gm)	REMARKS
Code		P84014	P39	P19													P85666	P85665	P85664	

EYE	OPERCULUM	GILL	FIN	CONDITION	FAT	LIVER	BILE	SPLEEN	KIDNEY	PARASITES
N = NORMAL E (1 or 2) = EXOPTHALMIA H (1 or 2) = HEMORRHAGIC B (1 or 2) = BLIND M (1 or 2) = MISSING OT = OTHER	O = NO SHORTENING 1 = MILD SHORTENING 2 = SEVERE SHORTENING	N = NORMAL F = FRAYED C = CLUBBED M = MARGINATE OT = OTHER	0 = HEALED OR NO EROSION 1 = MILD, ACTIVE EROSION 2 = SEVERE, ACTIVE EROSION	N = NORMAL R = ROBUST S = SKINNY I = INFECTIONS	0 - 100% USE 10% INCREMENTS TO IDENTIFY PROPORTION OF ORGANS COVEF BY FA]	A = NORMAL B = NODULES OR UNUSUAL GROWTHS C = OTHER	0 = YELLOW, NOT FULL 1 = YELLOW, FULL 2 = LT. GREEN 3 = DK. GREEN	B = BLACK R = RED G = GRANULAR NO = NODULES E = ENLARGED OT = THER	N = NORMAL S = SWOLLEN G = GRANULAR U = UROLITHIC	0 = NONE 1 = FEW 2 = NUMEROUS

APPENDIX D

STATE OF TENNESSEE
LATEST FISH ADVISORY

NEWS

Tennessee Department of Environment and Conservation
401 Church Street
Nashville, Tennessee

FOR MORE INFORMATION CONTACT:
Mary Locker: 615-532-0743
Paul Davis: 615-532-0625

FOR IMMEDIATE RELEASE **WEDNESDAY, MARCH 24, 1993**

NASHVILLE - The Department of Environment and Conservation's Division of Water Pollution Control has announced that there will be no revisions at this time to the fishing advisories issued in 1992.

"The department issues fish consumption advisories when testing indicates that levels of toxic materials in fish tissue exceed those considered to be protective of human health, "said Water Pollution Control Director Paul Davis. "Since the consumption of contaminated fish tissue is an avoidable risk, the department issues advisories so that citizens can make informed choices concerning their health.

"The results of 1992 studies of sites where advisories already existed or areas where additional studies were needed have not justified revising or removing existing advisories or issuing new ones at this time," Davis said. "However, the department will not hesitate to make changes in the status of advisories during 1993 should new information become available."

Sites where samples were collected in 1992 include, but are not limited to, Watts Bar, Chickamauga, Fort Loudoun, Douglas, Woods, Cheatham and Center Hill Reservoirs, as well as the Mississippi, Wolf and Loosahatchie Rivers.

A list of the current advisories in Tennessee has been printed in the Tennessee Wildlife Resources Agency's 1993 fishing regulations.

In order to assist citizens in their understanding of the stream posting process in Tennessee, the Department of Environment and Conservation has prepared a free brochure entitled "Tennessee Fishing Advisories." This publication explains the types of pollutants impacting streams and the current locations of fishing advisories.

For more detailed information, or a copy of the brochure, contact the Department of Environment and Conservation, Division of Water Pollution Control, 7th Floor, Life and Casualty Annex, 401 Church Street, Nashville, Tennessee 37243-1534.

FISHING ADVISORY BACKGROUND INFORMATION

There are two principal reasons for posting streams in Tennessee. The first is when bacterial contamination poses a water contact threat. Sources of bacteria are most frequently from inadequately treated discharges from municipal sewage systems, but can also be from livestock holding areas and urban runoff. This type of advisory warns the public to avoid coming in contact with these waters through activities such as swimming, wading, fishing and skiing.

Streams are also posted when average levels of toxic materials in the edible portion of fish pose an increased cancer risk (or other serious illness) to the general public. The department uses information and guidance from the U.S. Food and Drug Administration and the Environmental Protection Agency on the various contaminants found in fish.

There are two levels of fish consumption advisories used in Tennessee. The mildest form is a "limit consumption advisory," sometimes referred to as a precautionary advisory. Scientific studies have shown that developing fetuses and children may be more susceptible to the harmful effects of toxic materials than are adults. Thus a precautionary advisory warns that children, pregnant women and nursing mothers should not eat the type fish that is contaminated. All others are warned to limit their consumption of these fish.

The second level of advisory is a do-not-consume warning. At this level, all persons are advised to avoid eating the type fish contaminated.

The department makes every attempt to get advisory information to the public. A press release is issued whenever a stream or lake is posted. The department also places warning signs at significant public access points on posted waters.

CURRENT FISH TISSUE ADVISORIES (MARCH 1993)

STREAM	COUNTY	PORTION	POLLUTANT	TYPE ADVISORY
Loosahatchie River	Shelby	Mile 0.0-20.9	Chlordane	Fish should not be consumed.
Wolf River	Shelby	Mile 0.0-18.9	Chlordane	Fish should not be consumed.
Mississippi River	Shelby	MS line to mile 745	Chlordane	Fish should not be consumed. Commercial fishing ban.
McKellar Lake and Nonconnah Creek	Shelby	mile 0.0 to Horn Lake Road bridge (mile 1.8)	Chlordane	Fish should not be consumed.
Boone Reservoir	Sullivan, Washington	Entirety	PCBs, chlordane	Precautionary advisory for carp and catfish.*
North Fork Holston River	Sullivan, Hawkins	Mile 0.0-6.2 TN/VA line	Mercury	Fish should not be consumed.
Fort Loudoun Reservoir	Loudon, Knox, Blount	Entirety (46 miles)	PCBs	Commercial fishing for catfish prohibited. Catfish, largemouth bass over two pounds, and largemouth bass from the Little River embayment should not be consumed.
Tellico Lake	Loudon	Entirety (32.5 miles)	PCBs	Catfish should not be consumed.
Pigeon River	Cocke	N. Carolina line to Douglas Res.	Dioxin	Fish should not be consumed.
Watts Bar Reservoir	Roane, Meigs, Rhea	Tennessee River portion	PCBs	Catfish, striped bass, and hybrid striped bass-white bass (Cherokee bass) should not be eaten. Precautionary advisory* for white bass, sauger, carp, smallmouth buffalo and largemouth bass.
	Roane	Clinch River arm	PCBs	Striped bass should not be consumed. Precautionary advisory for catfish and sauger.*
Melton Hill Reservoir	Knox, Anderson	Entirety	PCBs	Catfish should not be consumed.
East Fork of Poplar Creek (incl. Poplar Creek embayment)	Anderson, Roane	Mile 0.0 - 15.0	Mercury, metals, org. chemicals	Fish should not be consumed. Avoid contact with water.
Nickajack Reservoir	Hamilton, Marion	Entirety	PCBs	Precautionary advisory for catfish*.
Chattanooga Creek	Hamilton	GA line to mouth	PCBs, chlordane	Fish should not be consumed.
Woods Reservoir	Franklin	Entirety	PCBs	Catfish should not be consumed.

This list subject to revision.

* Precautionary Advisory - Children, pregnant women, and nursing mothers should not consume the fish species named. All other persons should limit consumption of the named species to 1.2 pounds per month.

APPENDIX E

ALABAMA DEPARTMENT OF PUBLIC HEALTH
FISH CONSUMPTION ADVISORIES FOR THE
INDIAN CREEK EMBAYMENT (SPETEMBER 30, 1991)
ON WHEELER RESERVOIR AND SELECTED PORTIONS
OF WHEELER RESERVOIR (NOVEMBER 16, 1992)

NEWS Alabama Department of Public Health
OFFICE OF HEALTH PROMOTION AND INFORMATION STATE OFFICE BUILDING, ROOM 557, MONTGOMERY, ALABAMA 36130-1701 205/24

FOR IMMEDIATE RELEASE

CONTACT: Brian J. Hughes, Ph.D.
242-5131

Charles H. Woernle, M.D.
242-5131

The Alabama Department of Public Health announces the issuance of a fish consumption advisory for the Indian Creek drainage area, including Huntsville Spring Branch, near Triana. The department bases this decision on data indicating that certain species of fish continue to exceed the Food and Drug Administration action level of 5.0 parts per million of DDT in fish tissue. The species of fish with elevated levels of DDT are channel catfish, smallmouth buffalo, brown bullhead, bigmouth buffalo and white bass.

The Environmental Protection Agency banned the manufacture, sale and use of DDT in 1972. However, a DDT manufacturing plant existed in this area between 1948 and 1970 with Olin Chemical Co. operating this facility under lease from Redstone Arsenal for most of this period. Discharges from this plant contaminated Huntsville Spring Branch and Indian Creek.

During the 1980s, Olin Chemical Co. developed and implemented remedial action to protect humans and the environment from further DDT exposure. The remedial action is a result of a consent decree which settled litigation between Olin and various plaintiffs including the State of Alabama.

The data on DDT levels in fish tissue are a part of a long-term monitoring program established pursuant to that consent decree.

Dr. Claude Earl Fox, state health officer, said, "The DDT levels have declined significantly in recent years due to the remediation of the contamination by industry, and is expected to continue to decrease. In the early 1980s, before remediation

(more)

DDT advisory
Add one

began, the average concentration level among the above species ranged from 21 to 180 parts per million. In 1990 the range was from 3.1 to 41 parts per million.

"However, the levels remain high enough that I remind fishermen to refrain from eating these species of fish and other bottom-feeding species from this area. The issuance of this advisory represents an effort to update the surrounding community about the current situation."

DDT has been found to be a weak ca   nogen in animal studies; however, no evidence exists as to DDT's carcinogenic potential in man. Adverse effects on the liver may occur but only at very high levels. A 1979 Centers for Disease Control study of the residents of Triana revealed no DDT-related adverse health effects.

This advisory covers Indian Creek and Huntsville Spring Branch. The Alabama Department of Public Health, Alabama Department of Environmental Management, Alabama Department of Conservation and Natural Resources, and the Tennessee Valley Authority will work together to collect additional data this fall on the Tennessee River in the vicinity of Indian Creek. Results from these studies will be used to determine if advisories for the Ten essee River are appropriate.

-30-

9/23/91

FOR IMMEDIATE RELEASE

CONTACT: Brian J. Hughes, Ph.D.
Charles H. Woernle, M.D.
242-5131

The Alabama Department of Public Health announces the expansion of an existing fish consumption advisory for certain areas of the Tennessee River near Triana, a small Madison County community.

The department bases this decision on fish sampling data from the Tennessee Valley Authority indicating that certain species of fish exceed the Food and Drug Administration tolerance level of 5.0 parts per million of DDT in fish tissue.

The information given to the Health Department by the TVA indicates elevated levels of DDT in largemouth bass, channel catfish, and smallmouth buffalo one mile either side of the area where Indian Creek and the Tennessee River join.

The public is advised not to eat these species from this area. Other bottom feeding species (such as carp or sucker) in this area may also have high levels of DDT in their tissues and should also be avoided.

Furthermore, elevated levels of DDT were found in channel catfish obtained in the area where Indian Creek and the Tennessee River join downstream to the Interstate 65 bridge. The public is advised not to eat channel catfish from this extended area.

The contamination resulted from the manufacturing of DDT in this area between 1948 and 1970. The DDT manufacturing plant near Redstone Arsenal discharged DDT into the Huntsville Spring Branch and Indian Creek and may have also contaminated fish in the Tennessee River.

Dr. Charles Woernle, state epidemiologist, said, "TVA agreed to obtain additional information on DDT levels in fish tissue last year after meeting with the l and state health departments, and the Alabama Departments of Environmental

(more)

Management and Conservation and Natural Resources."

The DDT levels in fish tissue ranged from 5.0 to 43.3 parts per million in the designated area among all species of fish tested. Channel catfish further downstream of the area ranged from 1.9 to 12.8 parts per million. A similar study will be conducted this fall.

Dr. Woernle stated, "Many of the residents know about the previous advisory issued last year regarding DDT contaminated fish tissue in the Huntsville Spring Branch and Indian Creek area. Reductions in DDT levels in fish from this area have been observed each year since cleanup and annual testing began in April 1986. The issuance of a further advisory in this area represents an effort to keep people informed about the current situation as new data develop."

The EPA banned the manufacture, sale and use of DDT in 1972. DDT has been found to a weak cancer causing agent in animal studies; however, no evidence exists as to DDT's cancer causing potential in man.

Adverse effects on the liver occur only at very high amounts. A former Centers for Disease Control and Prevention study found no DDT-related adverse health effects in the residents of Triana.

Follow-up tests of fish in the expanded advisory area will be conducted this fall.

-30-

11/16/92

APPENDIX F

RESULTS OF A STUDY ON MERCURY CONTAMINATION IN LARGEMOUTH BASS FROM TRIBUTARY RESERVOIRS

Mercury Accumulation in Largemouth Bass

Initial fish tissue screening studies conducted by TVA found generally high concentrations of mercury in channel catfish from tributary reservoirs compared to mainstream reservoirs. Subsequent screening substantiated this observation. A more thorough examination of mercury concentrations in fish from tributary reservoirs was conducted in autumn 1993 to futher define and provide a database of mercury problems in tributary reservoirs. Largemouth bass were collected from these reservoirs and analyzed for total mercury only. Handling and processing procedures are described in Appendix C. Laboratory analyses were performed on composites of five fish each. In an attempt to describe worse-case conditions, many largemouth bass weighing over 1200 grams were also analyzed as individuals. All largemouth bass from Hiwassee Reservoir were analyzed as individuals, as well as composites, to help evaluate fish size:mercury concentration relationships.

The results of mercury analyses on largemouth bass are in Table F-1. Mercury concentrations in largemouth bass composites were near or exceeded 0.5 µg/g from six tributary reservoirs.

Many of the large largemouth bass which were analyzed individually had relatively high mercury concentrations, several approaching 1.0 µg/g. Nine of 17 largemouth bass over 1200 grams had concentrations over 0.5 µg/g, the level to suggest further screening.

The relationship between total mercury concentration and total weight was examined with regression analysis (Figure F-1). Generally, as weight increased, so did mercury concentration, as evidenced by the regression line plotted in Figure F-1.

The relatively high concentrations of mercury in fish from many tributary reservoirs, especially large fish, need further examination. Specifics of such a study had not been worked out at the time this report was prepared. Final study design will be developed by appropriate state agencies and TVA.

Table F-1 Physical information and concentrations (µg/g) of total mercury in individual and composited largemouth bass in the Tennessee Valley in 1993.

Collection Site	Species	Length (mm)	Weight (g)	Sex	LABID[a]	Hg Individual	Hg Composite
Bear Creek Reservoir							
BCM 75	LMB	522	2265	FMALE	33444	0.91	
BCM 75	LMB	475	1480	MALE	33295		
BCM 75	LMB	409	990	FMALE	33295		
BCM 75	LMB	401	925	FMALE	33295		
BCM 75	LMB	395	855	FMALE	33295		
BCM 75	LMB				33295		0.71
Little Bear Creek Reservoir							
LBCRM 12	LMB	356	585	FMALE	33296		
LBCRM 12	LMB	377	720	MALE	33296		
LBCRM 12	LMB	382	810	FMALE	33296		
LBCRM 12	LMB	562	2085	FMALE	33442	0.97	
LBCRM 12	LMB	406	980	MALE	33296		
LBCRM 12	LMB				33296		0.6 0
Hiwassee Reservoir							
HIRM 77	LMB	395	848	FMALE	33411	0.40	
HIRM 77	LMB	357	577	FMALE	33413	0.21	
HIRM 77	LMB	351	594	MALE	33416	0.5 0	
HIRM 77	LMB	340	511	FMALE	33417	0.2 0	
HIRM 77	LMB				33297		0.33
HIRM 85	LMB	380	874	FMALE	33418	0.40	
HIRM 85	LMB	370	732	FMALE	33419	0.40	
HIRM 85	LMB	345	545	FMALE	33420	0.22	
HIRM 85	LMB	344	589	MALE	33421	0.17	
HIRM 85	LMB	433	1214	FMALE	33422	0.39	
HIRM 85	LMB				33298		0.30
Chatuge Reservoir							
HIRM 122	LMB	484	1255	FMALE	33423	0.45	
HIRM 122	LMB	365	610	FMALE	33299		
HIRM 122	LMB	424	839	FMALE	33299		
HIRM 122	LMB	388	725	FMALE	33299		
HIRM 122	LMB	355	482	FMALE	33299		
HIRM 122	LMB				33299		0.23
Nottely Reservoir							
NOTRM 24	LMB	547	2424	FMALE	33424	0.52	
NOTRM 24	LMB	453	1287	FMALE	33300		
NOTRM 24	LMB	484	1619	FMALE	33300		
NOTRM 24	LMB	386	926	MALE	33300		
NOTRM 24	LMB	359	546	MALE	33300		
NOTRM 24	LMB				33300		0.44

Collection Site	Species	Length (mm)	Weight (g)	Sex	LABID[a]	Hg Individual	Hg Composite
Blue Ridge Reservoir							
TOCCRM 54	LMB	360	668	MALE	33301		
TOCCRM 54	LMB	358	578	MALE	33301		
TOCCRM 54	LMB	323	491	I[b]	33301		
TOCCRM 54	LMB	331	520	FMALE	33301		
TOCCRM 54	LMB	417	912	FMALE	33301		
TOCCRM 54	LMB				33301		0.12
Norris Reservoir							
CRM 80	LMB	416	932	MALE	33302		
CRM 80	LMB	332	468	MALE	33302		
CRM 80	LMB	470	1438	FMALE	33451	0.83	
CRM 80	LMB	395	876	MALE	33302		
CRM 80	LMB	365	660	MALE	33302		
CRM 80	LMB				33302		0.59
CRM 125	LMB	418	948	FMALE	33305		
CRM 125	LMB	385	902	FMALE	33305		
CRM 125	LMB	387	848	MALE	33305		
CRM 125	LMB	397	866	FMALE	33305		
CRM 125	LMB	376	864	MALE	33305		
CRM 125	LMB				33305		0.24
PRM 30	LMB	353	528	FMALE	33307		
PRM 30	LMB	387	856	FMALE	33307		
PRM 30	LMB	441	1106	FMALE	33307		
PRM 30	LMB	401	828	FMALE	33307		
PRM 30	LMB	403	956	FMALE	33307		
PRM 30	LMB				33307		0.12
Tellico Reservoir							
LTRM 1.0	LMB	435	1185	FMALE	33447	0.19	
LTRM 1.0	LMB	409	1042	FMALE	33290		
LTRM 1.0	LMB	355	694	FMALE	33290		
LTRM 1.0	LMB	357	540	MALE	33290		
LTRM 1.0	LMB	333	478	FMALE	33290		
LTRM 1.0	LMB				33290		0.15
LTRM 15	LMB	312	428	MALE	33292		
LTRM 15	LMB	442	1122	FMALE	33292		
LTRM 15	LMB	432	1280	FMALE	33448	0.27	
LTRM 15	LMB	325	402	MALE	33292		
LTRM 15	LMB	395	898	FMALE	33292		
LTRM 15	LMB				33292		0.22

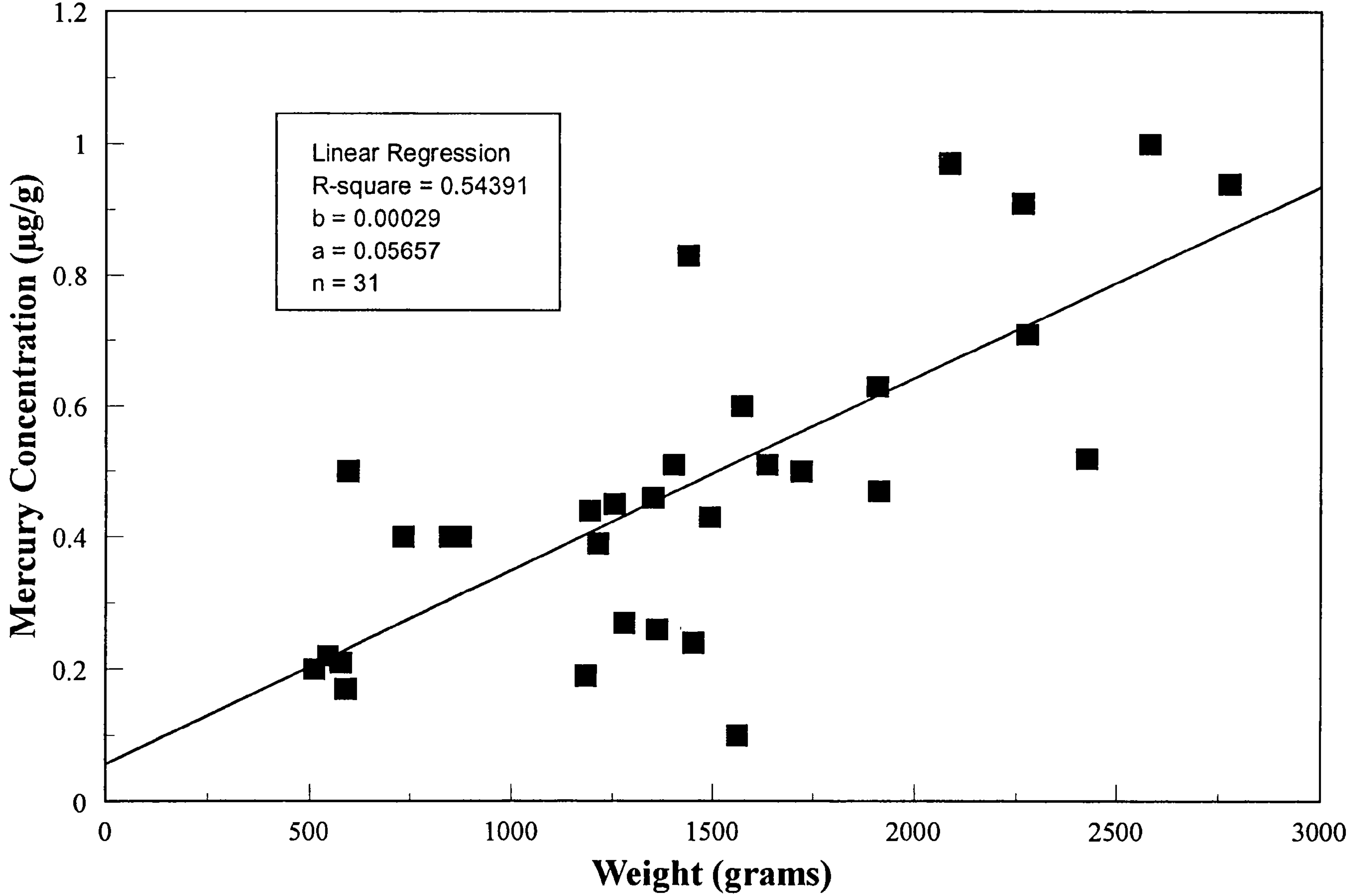
Collection Site	Species	Length (mm)	Weight (g)	Sex	LABID[a]	Hg Individual	Hg Composite
Fontana Reservoir							
LTRM 62	LMB	445	1352	FMALE	33449	0.46	
LTRM 62	LMB	374	858	MALE	33310		
LTRM 62	LMB	350	814	MALE	33310		
LTRM 62	LMB	341	670	MALE	33310		
LTRM 62	LMB	368	800	MALE	33310		
LTRM 62	LMB				33310		0.18
LTRM 81	LMB	356	716	MALE	33311		
LTRM 81	LMB	383	977	FMALE	33311		
LTRM 81	LMB	340	637	MALE	33311		
LTRM 81	LMB	347	539	FMALE	33311		
LTRM 81	LMB	300	346	MALE	33311		
LTRM 81	LMB				33311		0.18
TUCKRM 3	LMB	549	2774	FMALE	33450	0.94	
TUCKRM 3	LMB	374	790	FMALE	33312		
TUCKRM 3	LMB	353	584	FMALE	33312		
TUCKRM 3	LMB	309	434	FMALE	33312		
TUCKRM 3	LMB	329	490	MALE	33312		
TUCKRM 3	LMB				33312		0.32
Cherokee Reservoir							
HRM 53	LMB	376	772	MALE	33313		
HRM 53	LMB	378	812	FMALE	33313		
HRM 53	LMB	372	670	MALE	33313		
HRM 53	LMB	342	560	FMALE	33313		
HRM 53	LMB	302	340	FMALE	33313		
HRM 53	LMB				33313		0.17
HRM 75	LMB	424	1228	FMALE	33314		
HRM 75	LMB	512	1972	FMALE	33428	0.47	
HRM 75	LMB	388	920	MALE	33314		
HRM 75	LMB	351	670	MALE	33314		
HRM 75	LMB	337	556	FMALE	33314		
HRM 75	LMB				33314		0.17
HRM 91	LMB	435	1194	FMALE	33430	0.44	
HRM 91	LMB	414	1098	FMALE	33315		
HRM 91	LMB	385	802	FMALE	33315		
HRM 91	LMB	340	542	FMALE	33315		
HRM 91	LMB	331	512	FMALE	33315		
HRM 91	LMB				33315		0.24
Fort Patrick Henry Reservoir							
SFHRM 9	LMB	489	2040	FMALE	33316		
SFHRM 9	LMB	385	960	MALE	33433	<0.1	
SFHRM 9	LMB	401	1040	MALE	33316		
SFHRM 9	LMB	373	858	MALE	33316		
SFHRM 9	LMB	344	574	FMALE	33316		
SFHRM 9	LMB				33316		<0.1

Collection Site	Species	Length (mm)	Weight (g)	Sex	LABID[a]	Hg Individual	Hg Composite
Boone Reservoir							
SFHRM 19	LMB	421	1106	FMALE	33317		
SFHRM 19	LMB	453	1362	FMALE	33434	0.26	
SFHRM 19	LMB	435	1188	FMALE	33317		
SFHRM 19	LMB	403	852	FMALE	33317		
SFHRM 19	LMB	402	906	FMALE	33317		
SFHRM 19	LMB				33317		0.14
SFHRM 27	LMB	463	1720	MALE	33435	0.50	
SFHRM 27	LMB	474	1252	FMALE	33320		
SFHRM 27	LMB	372	742	MALE	33320		
SFHRM 27	LMB	379	740	MALE	33320		
SFHRM 27	LMB	343	568	FMALE	33320		
SFHRM 27	LMB				33320		0.22
WRM 7	LMB	412	1046	FMALE	33322		
WRM 7	LMB	486	1636	FMALE	33436	0.51	
WRM 7	LMB	392	922	MALE	33322		
WRM 7	LMB	393	992	FMALE	33322		
WRM 7	LMB	336	566	MALE	33322		
WRM 7	LMB				33322		0.12
Wautaga Reservoir							
WRM 37	LMB	495	2276	FMALE	33437	0.71	
WRM 37	LMB	450	1418	FMALE	33325		
WRM 37	LMB	420	1258	FMALE	33325		
WRM 37	LMB	410	1068	FMALE	33325		
WRM 37	LMB	392	988	FMALE	33325		
WRM 37	LMB						0.56
South Holston Reservoir							
SFHRM 51	LMB	390	940	FMALE	33326		
SFHRM 51	LMB	469	1572	FMALE	33438	0.60	
SFHRM 51	LMB	447	1412	FMALE	33326		
SFHRM 51	LMB	415	764	MALE	33326		
SFHRM 51	LMB	397	758	MALE	33326		
SFHRM 51	LMB				33326		0.45

a LABID = number assigned by TVA's Environmental Chemistry Laboratory. It is used to link laboratory analysis data with physical data from fish.

b I = individual fish whose sex could not be determined.

Figure F-1 Regression of mercury concentration vs total weight of largemouth bass from tributary reservoirs in the Tennessee Valley in 1993.



Tennessee Valley Authority

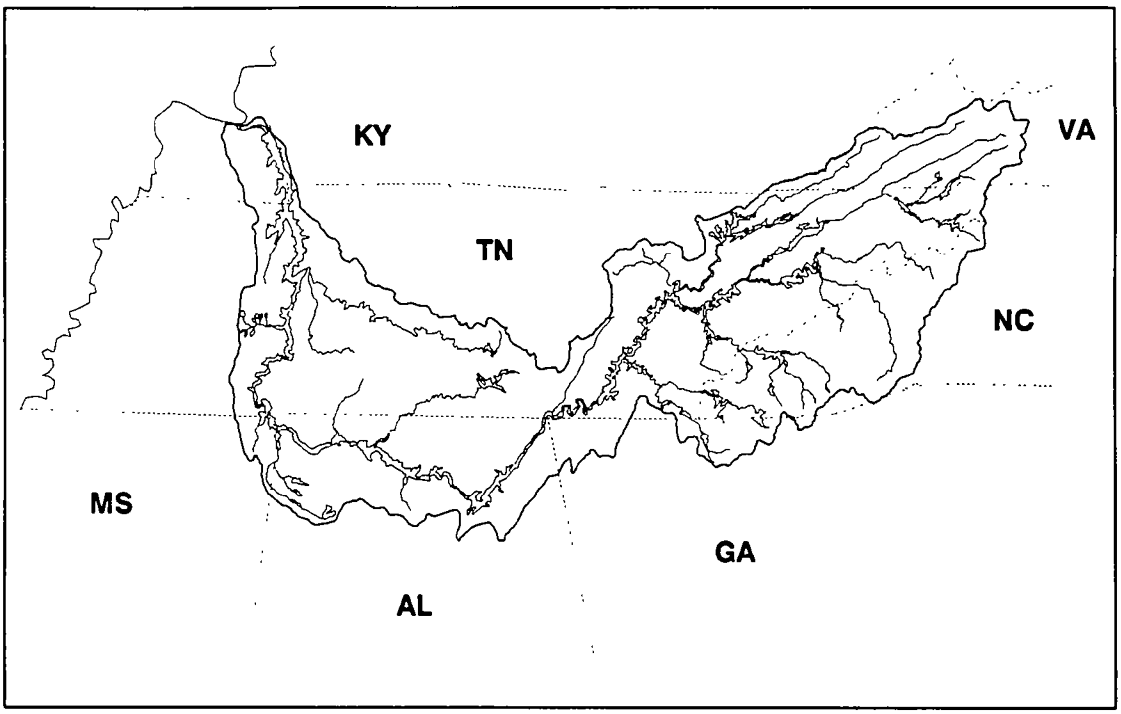
Water Management
Chattanooga, Tennessee

May 1994

TENNESSEE VALLEY RESERVOIR AND STREAM QUALITY - 1993

SUMMARY OF VITAL SIGNS AND USE SUITABILITY MONITORING

VOLUME I



CLEAN WATER INITIATIVE

TENNESSEE VALLEY AUTHORITY
Resource Group
Water Management

TENNESSEE VALLEY RESERVOIR AND STREAM QUALITY - 1993
SUMMARY OF VITAL SIGNS AND USE SUITABILITY MONITORING

Volume I

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EXECUTIVE SUMMARY

TVA initiated a systematic, Valley-wide water quality and aquatic ecological monitoring program in 1986. The program started with a stream component, and a reservoir monitoring component was added in 1990. The two primary objectives of these monitoring efforts are to evaluate the ecological health (Vital Signs Monitoring) of major streams and reservoirs in the Tennessee Valley and to examine how well these water resources meet the swimmable and fishable goals of the Clean Water Act (Use Suitability Monitoring).

Vital Signs Monitoring

Stream monitoring has been conducted on 12 large tributaries since 1986. Beginning in 1994, six additional tributaries will be monitored; all with watersheds of at least 500 square miles. Reservoir monitoring started with 12 reservoirs (mostly mainstream reservoirs) in 1990 and has expanded progressively to the full complement of 30 reservoirs in 1993. No further expansion of either stream or reservoir monitoring is planned. This report summarizes results of these monitoring efforts in 1993. Volume I is the main body of the report and Volume II is a data summary organized by sample locations within watershed areas.

Until 1991, the ecological health evaluations were based on subjective evaluation of the data. A weight-of-evidence approach was used--a stream or reservoir was deemed healthy if most of the physical, chemical, and biological monitoring components appeared healthy. Beginning with the 1991 results, a more quantitative approach was developed that has been used the last three years. This approach integrates information on important indicators of ecological health. For reservoirs, five indicators are used--dissolved oxygen, chlorophyll, sediment quality, benthic macroinvertebrates, and fishes. Stream evaluations are similar except dissolved oxygen is not rated and nutrient concentrations are substituted for chlorophyll concentrations. For each indicator (or metric), scoring criteria are developed that assign a score ranging from 1 to 5 representing very poor to excellent conditions, respectively. Scores for all indicators at a location are summed. For streams and smaller reservoirs, only one site is monitored. For larger reservoirs, multiple sites are monitored, and the overall reservoir score is achieved by totaling scores for all locations. The resulting total is divided by the maximum possible score. Thus, the possible range of scores is from 20 percent (all metrics very poor) to 100 percent (all metrics excellent). Hence, an overall ecological health rating of good, fair, or poor is obtained for each stream site or reservoir. A health rating border-line between two of these categories is considered poor-fair or fair-good. Each year, the most recent information is evaluated with the same basic approach, modified to incorporate improvements based on comments from reviewers and additional data.

Stream monitoring results for 1993 indicated seven streams rated good (three of these received perfect scores), three streams rated fair to good, and one stream rated poor. Full evaluation was not possible for one stream because only three of the four indicators were monitored in 1993. The only stream to receive a poor rating was the French Broad River. This overall rating was caused by poor scores for nutrients and fishes, a fair score for benthos, and a good score for sediment quality.

Reservoirs are stratified into two groups for evaluation: run-of-river reservoirs and deep storage reservoirs. Separate scoring criteria were used for the two categories. Overall ratings for the 11 run-of-river reservoirs in 1993 ranged from 58 to 88 percent. Four reservoirs rated good (75 to 88 percent), three rated fair to good (71 to 73 percent), three rated fair (63 to 68 percent), and one rated poor to fair (58 percent). Overall ratings for the 19 storage reservoirs ranged from 52 to 72 percent. Two reservoirs rated fair to good (both 72 percent), 14 rated fair (58 to 67 percent), and three rated poor (52 to 56 percent).

Most streams and reservoirs had ratings comparable to those observed in 1991 and 1992. Tributary reservoirs had generally poorer ratings, primarily because of low dissolved oxygen in the hypolimnion. This is an ecologically undesirable condition that is partly due to the strong thermal stratification that occurs in deep reservoirs with relatively long retention times.

Use Suitability Monitoring

Use Suitability Monitoring provides screening level information on the suitability of selected areas within TVA reservoirs for water contact activities (swimmable) as determined by bacteriological studies and suitability of fish from TVA reservoirs for human consumption (fishable) as determined by fish tissue studies.

Bacteriological Studies--Bacteriological samples are collected at over 260 sites in the Tennessee Valley. These include designated swimming areas, canoe access sites, highly used recreational areas, and selected nonrecreation sites that provide information on pollution sources or inflow stream water quality. Recreation sites are sampled at least once every two years.

In 1993, 71 swimming areas and 14 canoe access points were sampled for bacteriological conditions. All but two swimming areas met the regulatory criterion to be considered safe. Even those two sites met the criterion if samples collected after heavy rains were excluded. Four canoe access points on the Duck River exceeded the criterion, both in dry and wet weather.

Bacteriological sampling at nonrecreational areas was conducted at 35 sites in 1993. Only one reservoir site and two stream sites failed to meet recreation criteria.

These results are consistent with previous surveys. Fecal coliform concentrations were generally lower in 1993 due to lower than normal summer rainfall. Bacteriological water quality in most areas of TVA reservoirs is good. In streams it is much poorer, especially after rainfall.

Fish Tissue Studies--Fish tissue studies examine fillets from important fish species for selected metals, pesticides, and polychlorinated biphenyls (PCBs) on the U.S. Environmental Protection Agency's list of priority pollutants. Resulting data are provided to appropriate state agencies to determine whether further study is needed or fish consumption advisories should be issued. Fish tissue data reported here represent autumn 1992 collections. Results for fish collected in autumn 1993 were not available at the time this report was prepared due to the time delay required for laboratory analysis.

Results of fish tissue screening studies in 1992 did not reveal any new areas in need of intensive investigations. Concentrations of at least one contaminant were high enough to warrant sampling again at the screening level in 1993. Results of intensive studies (i.e., in-depth studies on waterbodies where there are known or suspected problems) did not indicate substantial changes from previous years.

1.0 INTRODUCTION

1.1 Background

The Tennessee Valley Authority (TVA) started a Stream Monitoring Program in 1986 to evaluate the major tributaries of the Tennessee Valley at fixed locations. A parallel program, Reservoir Monitoring, was begun in 1990 when funds were appropriated by Congress for TVA to strengthen its stewardship responsibilities. The combined Stream and Reservoir Monitoring efforts consolidated several newly-developed activities along with several existing activities to form an integrated program. These monitoring efforts, in addition to River Action Team watershed examinations and public information/educational activities, are now part of TVA's comprehensive Clean Water Initiative.

1.2 Objectives

Objectives of these monitoring efforts are to provide information on the "health" or integrity of the aquatic ecosystem in major Tennessee River tributaries and reservoirs and to provide screening level information for describing how well these water resources meet the "fishable" and "swimmable" goals of the Clean Water Act.

The ecological integrity of stream and reservoir ecosystems is examined as part of an activity called Vital Signs monitoring. The basis of Vital Signs monitoring is examination of key physical, chemical, and biological indicators to evaluate the health of each stream or reservoir and to target detailed assessment studies if significant problems are found. In addition, this information establishes a baseline for comparing future water quality conditions as watershed improvements are made.

Another activity, Use Suitability monitoring, examines how well streams and reservoirs meet the fishable and swimmable goals of the Clean Water Act. Examination of levels of toxic contaminants in fillets from important fish species is the basis for the fishable use evaluation. Swimmable or water contact uses are examined by conducting bacteriological sampling at designated swimming beaches and other highly used recreation areas.

Using a quantitative approach to evaluate ecological health of water resources is relatively new, especially for reservoirs. This is only the third year TVA has used this approach, and we continue to make improvements based on experience gained each year. Ecological health evaluations drawn from this newly implemented monitoring program are subject to revision in future years as more data and experience are acquired on each reservoir. We welcome comments and suggestions for improvements in these ecological health evaluation methodologies. Please send comments/suggestions to the address above or contact appropriate individuals listed under key contacts on page ii.

1.3 Summary Report Description

Volume I of this report summarizes and integrates results from TVA's stream and reservoir monitoring activities in 1993. Chapter 1 provides background and objectives for the monitoring program. Chapter 2 describes the basis for study design and specific methods for sample collection. Chapter 3 describes the philosophical approach and data evaluation methods used for each indicator to determine stream and reservoir ecological health.

Chapter 4 provides an overview of hydrologic and meteorologic conditions for 1993. Conditions in streams and reservoirs are greatly affected by streamflow, rainfall, and temperature, as well as by physical and geologic characteristics of the watershed. Dams, and resulting reservoirs' dynamics, are important factors in the ecological health of regulated river systems. It is important to consider all these variables and their effects in evaluating ecological conditions of the Tennessee River system in any given year.

Chapter 5 discusses the 1993 monitoring results from a Valley-wide perspective. Discussion topics include an overview of ecological conditions, ecological indicators which "drove" the health ratings, changes from previous years, embayment monitoring (initiated in 1993), and swimmable and fishable conditions.

Chapters 6-17 provide a watershed-by-watershed summary and conclusions for each of the 12 watershed drainage areas in the Tennessee Valley. Each chapter provides a physical description of the watershed followed by a description of the physical characteristics, ecological health, and use suitability of each reservoir and stream monitoring site within the watershed. The ecological health evaluation is based on an integration of physical, chemical, and biological information gathered using the different Vital Signs monitoring tools.

Detailed summaries of 1993 results on each reservoir and stream are provided in Volume II of this report. Volume II is for technical audiences who prefer to form their own evaluation of conditions. It also serves as a detailed technical summary of conditions at TVA monitoring sites in 1993.

In addition to this technical summary report, a nontechnical document, *RiverPulse*, is available. *RiverPulse* (TVA, 1994) is broadly distributed to Tennessee Valley residents and users of TVA reservoirs. Annual issues of the technical report have been prepared since 1990, and annual issues of *Riverpulse* are available for 1991, 1992, and 1993. There also is a series of annual activity reports providing detailed results for each monitoring tool (e.g., water, sediment, benthos, fish, etc.). These detailed reports provide the basis for the summary report. Specific citations for summary and detailed reports are in the list of references. Copies of any of these documents are available from: TVA Water Management Library, 1101 Market Street, HB 2C-C, Chattanooga, TN 37402, Telephone: (615) 751-7338, FAX: (615) 751-7479.

2.0 DATA COLLECTION METHODS

2.1 Vital Signs Monitoring

2.1.1 Introduction

The study design for Vital Signs Monitoring is based on meeting the objectives outlined in Section 1.2. Several assumptions are fundamental to the study design:

1. Ecological health evaluations must be based on information on physical, chemical, and biological components of the ecosystem;

2. Vital Signs monitoring is a long-term effort to document the status of the river/reservoir system and track results of water quality improvement efforts;

3. Monitoring methods must be responsive by providing current information to resource managers;

4. The basic design must be considered dynamic and flexible, rather than rigid and static, and must allow adoption of new environmental monitoring techniques as they develop to meet specific needs; and

5. This is a monitoring program; it does not address specific cause/effect mechanisms. (The step beyond monitoring is assessment in which cause/effect investigations would target specific, identified concerns.)

Three important aspects were considered in establishing the study design: representative sampling locations; important ecological indicators; and frequency of sampling. The program that emerged balances these considerations as follows.

Sampling Locations--For reservoirs, the following three areas were selected for monitoring: the inflow area, generally riverine in nature; the transition zone or mid-reservoir area where water velocity decreases due to increased cross-sectional area, suspended materials begin to settle, and algal productivity increases due to increased water clarity; and the forebay, the lacustrine area near the dam, Figure 2.1. Overbanks, basically the floodplain which was inundated when the dam was built, were included in transition zone and forebay areas. Another important reservoir area, embayments, also was considered. However, monitoring all embayments is beyond the scope of this program. Previous studies have shown that ecosystem interactions within an embayment are mostly controlled by activities and characteristics within the embayment watershed, usually with relatively little influence from the main body of the reservoir. As a result, only four, large embayments, all with drainage areas greater than 500 square miles and surface areas greater than 4500 acres, are included in the Vital Signs Monitoring Program. These were added in 1993 and are reported on here for the first time.

The stream monitoring sampling locations were located to sample the cumulative water quality for as large a percentage of a tributary watershed as possible, with sampling locations located in the free-flowing reaches of the river near the downstream end of the watershed, but upstream of any impounded water.

Ecological Indicators--Selection of appropriate ecological indicators for monitoring was tailored to the specific objective and type of monitoring location. Physical, chemical, and biological indicators were selected to provide information from various habitats or ecological compartments on the health of that particular habitat or compartment. In reservoirs (Figure 2.1) the open water or pelagic area was represented by physical and chemical characteristics of water (including chlorophyll) in midchannel. The shoreline or littoral area was evaluated by sampling the fish community. The bottom or benthic compartment was evaluated using two indicators: quality of surface sediments in midchannel (determined by chemical analysis of sediments and acute toxicity testing of pore water); and examination of benthic macroinvertebrates from a transect across the full width of the sample area (including overbanks if present).

In streams, all available habitats were included to truly characterize the sample site. This is more easily accomplished in streams than in reservoirs because most habitats are visible. The same basic indicators used for reservoirs were also used in streams.

For both reservoirs and streams, information from each indicator was evaluated separately and results were then combined (without weighing) to arrive at an overall evaluation of reservoir ecological health. (See Chapter 3 for more details on the ecological health evaluation and scoring process.)

Sampling Frequency--Sampling frequencies were selected to take into consideration the expected temporal variation for each indicator. Physical and chemical components vary significantly in the short term, whereas biological components are more representative of long-term conditions. As a result, sampling for physical and chemical indicators is needed more frequently than biological indicators. In reservoirs, physical and chemical indicators were examined monthly from spring to fall and in streams every other month throughout the year. Biological indicators were sampled once each year for reservoir and stream sites. In reservoirs, benthic macroinvertebrate sampling was conducted in early spring (February-April), and fish assemblage sampling was conducted in autumn

(September-November). In streams, benthic and fish community sampling is conducted in late spring-early summer (May-June).

2.1.2 Reservoir Vital Signs Monitoring

The Vital Signs component of reservoir monitoring includes four main activities to examine and evaluate reservoir health:

(1) physical/chemical characteristics of water;

(2) acute toxicity and physical/chemical characteristics of sediment;

(3) benthic macroinvertebrate community sampling; and,

(4) fish assemblage sampling.

(In addition, aquatic macrophyte community information is included to provide a more comprehensive evaluation of each reservoir's ecological health.)

Data collection methods for each of these activities are given below. Sampling locations and specific monitoring activities for each reservoir are listed in Table 2.1 and shown in Figure 2.2.

Physical/Chemical Characteristics of Water--In 1993, physical/chemical water quality variables were measured at a total of 57 sampling locations on 30 reservoirs. Three specific QA/QC measures were incorporated in the reservoir physical/chemical water sampling activities. These included: (1) collection and analysis of triplicate sets of water samples once during the year at all forebay sampling locations to assess sample collection, laboratory analysis, and natural sample variability; (2) preparation and analysis of sample container blanks each collection day to assess the degree of contamination associated with the sample bottles and/or the sample handling processes; and, (3) preparation and analysis of sample filtration blanks with each set of filtered samples to assess the degree of contamination associated with the field sample filtration and handling.

The water quality monitoring activities on the Vital Signs reservoirs followed a "basic" (11 run-of-the-river reservoirs) or a "limited" (19 tributary reservoirs) sampling strategy (Table 2.1).

Basic--Monitoring on the run-of-the-river reservoirs included monthly water quality surveys (April through September) at forebays and transition zones. Basic monthly water quality sampling included in situ water column measurements of temperature, dissolved oxygen, pH, and conductivity; Secchi depth measurements; surface fecal coliform; photic zone (defined as twice the Secchi depth) composite chlorophyll-a samples; and photic zone composite and near-bottom samples for nutrients (organic nitrogen, ammonia nitrogen, nitrate+nitrite nitrogen, total phosphorus, and dissolved orthophosphorus), total organic carbon, color, and suspended solids. Physical/chemical water quality sampling was not conducted at most run-of-the-river reservoir inflows because most of these locations are tailwater areas of upstream dams; water quality characteristics there are more representative of processes in the upstream reservoir.

Limited--Tributary storage reservoirs were sampled monthly (April through October) for a smaller list of parameters. The approach was the same as for the run-of-the-river reservoirs, except that no fecal coliform, color, or suspended solids samples were collected, and only photic zone composites for nutrients and organic carbon samples were collected and only in April and August. The April and August nutrient samplings were designed to provide information on nutrient concentrations available at the beginning of the growing season, then near the end of the growing season. Forebays were sampled on all these reservoirs, and mid-reservoir locations were sampled on all but the smaller reservoirs.

Physical/chemical water quality data were stored on EPA's water quality data storage and retrieval (STORET) system. Reservoir health evaluation methods used to assess physical/chemical quality are described below (Section 3.1.2).

Acute Toxicity and Physical/Chemical Characteristics of Sediment--Annual sediment samples and near-bottom water samples were collected during the summer of 1993 from 59 locations, i.e., the forebays and transition zones (or mid-reservoir) of the 11 mainstream reservoirs and 19 tributary reservoirs as shown in Table 2.1. In addition, ten of the 59 locations were randomly selected for replicate QA/QC sampling. Sampling efforts were repeated at each of the ten sites. Replicate samples were handled and processed independently. Results from these ten sets of replicates were used to assess field methods consistency, variations in laboratory toxicity and physical/chemical analyses, and spatial homogeneity of the sediment. Eckman dredge samplers were used to collect the top three centimeters of sediment and Kemmerer or Isco water samplers were used to collect the near-bottom water. Each sediment sample was a composite of at least three subsamples independently collected at each sampling location from the original stream channel bed. At each sampling site, the subsamples were composited, thoroughly mixed to uniform color and consistency, and split into two fractions: one fraction for acute toxicity testing, and one fraction for physical/chemical analyses. Samples were placed on ice immediately after collection, compositing, and splitting, and were shipped or carried to the appropriate laboratory. One split from each sampling location and the sample of near-bottom water were shipped to the Toxicity Testing Laboratory (TTL) for toxicity testing; the other split at each sampling location was shipped or carried to the Environmental Chemistry Laboratory (ECHE) for chemical and physical analyses.

Acute Toxicity Testing--Within 36 hours of collection, all sediment samples were screened for toxicity using Rotox® (rotifer, Brachionus calyciflorus survival) and daphnid (Ceriodaphnia dubia) acute tests. Organisms were exposed to undiluted interstitial (pore) water from the sediment and near bottom water. Interstitial water was obtained by refrigerated centrifugation of sediment. Control water consisted of Moderately Hard Reconstituted Water, MHRW (TVA, 1992b), (hardness of 80-100 mg/L as $CaCO_3$) enriched with 10 percent Tennessee River water from TTL's experimental channels for the daphnid test and MHRW adjusted to pH=7.5 using HCl for the rotifer test. All samples were aerated to bring dissolved oxygen levels to near saturation (8.4 mg/L at 25°C) before testing. Water chemistry (temperature, DO, pH, conductivity, alkalinity, and hardness) was measured for all samples and controls. After centrifugation of the sediment, pore water samples were collected and preserved and sent to the Environmental Chemistry Laboratory for un-ionized ammonia analysis. Four replicates of five individuals each were used in both tests. Rotifer (24-hr) and daphnid (48-hr) acute toxicity was reported if average survival in the four replicates was significantly reduced (95 percent probability) from the control.

Physical/Chemical Characteristics--Splits of the same sediment samples used in the toxicity testing were analyzed for 13 metals, un-ionized ammonia (in pore water), total and volatile solids, particle size, and 26 selected trace organics (organochlorine pesticides and PCBs, Table 2.3).

Additional details for the collection methods, acute toxicity testing protocols and results, and the physical/chemical analytical results are given in TVA technical report (Moses, Simbeck, and Wade, 1994). How this sediment quality information was used in the reservoir health evaluations is described below in Section 3.1.2, Reservoir Sediment Quality Rating Scheme.

Benthic Macroinvertebrate Community Sampling--Benthic macroinvertebrate community samples were collected in the spring (March and April) of 1993 at 69 locations on the 30 Vital Signs reservoirs, Table 2.1. At each sample location, a line-of-sight transect was established across the width of the reservoir, and Ponar grab samples were collected at ten equally-spaced locations along this transect. When rocky substrates were encountered, a Peterson dredge was used. Only those samples which were collected from the permanently wetted bottom portion of the reservoir (i.e., those Ponar or Peterson samples collected below the elevation of the minimum winter pool level) were used to evaluate the condition of the benthic community. Samples were washed in the field, transferred to a labeled collection jar, and fixed with 10 percent buffered formalin solution. Specimens were sent to the laboratory where they were sorted, counted, and identified to the lowest practical taxon, typically genus or species, and reported as number per square meter. Six metrics (Table 3.1) were chosen to evaluate the benthic macroinvertebrate community as it relates to the overall ecological health of the reservoir. These metrics and the rating scheme are described in Section 3.1.2, Reservoir Benthic Community Rating Scheme.

To assess the reproducibility of benthic macroinvertebrate sampling results, replicate samples were collected at nine of the 69 sampling locations in 1993, with all types of reservoir locations (i.e., forebay, transition zone, and inflow) included. At each of the replicate sampling locations, the sampling protocol involved collection of a first set of ten samples, leaving the sampling location, and then returning as near as possible to the original transect site (on the same day) and repeating the collection of a second (replicate) set of ten samples. The results from the nine sets of replicate samples were then evaluated for reproducibility. Benthic macroinvertebrate data are available in computer-readable form from TVA upon request.

Fish Assemblage Sampling--In the autumn of 1993, electrofishing and/or gill netting data were collected from 69 locations on the 30 Vital Signs reservoirs to evaluate the fish assemblage, Table 2.1. Fifteen electrofishing runs (300 meters in length) were made at each location (forebay, transition or mid-reservoir, and inflow) with all habitats sampled in approximate proportion to their occurrence at the sampling location. Habitat distinctions were based on major changes in substrate (e.g., bluff, rip-rap, mud, etc.) and/or presence of cover such as brush or boat docks. Twelve experimental gill nets were also set overnight at each location covering all habitat types where conditions permitted. At some inflow locations, flow and/or lack of suitable sites limited the number of nets that could be set. All fish collected from either electrofishing or gill netting were enumerated, with length and weight measurements taken on important sport species. Estimated numbers were used when high densities of fish were encountered during electrofishing. Young-of-the-year (YOY) fish were counted separately from adults. All fish measured were inspected for external diseases, parasites, and anomalies. Twelve metrics (Table 3.3) were chosen to evaluate the fish assemblage as it relates to the overall ecological health of the reservoir and are described in Section 3.1.2, Reservoir Fish Assemblage Rating Scheme.

If the fish assemblage at a particular sampling location appeared to have changed substantially (up or down) from the previous year, the site was resampled (within one to two weeks) to assure that sampling conditions were not causing anomalous results. Resample results were used for two sampling locations (Cherokee Reservoir forebay and Guntersville Reservoir transition zone) during 1993 fish assemblage evaluations.

All data were recorded on a portable field data logger and downloaded to a personal computer before being added to the TVA mainframe fisheries data base. Fish assemblage data are available in computer-readable form from TVA upon request.

Aquatic Macrophytes--Coverage of aquatic macrophytes was determined from large-scale (1 inch=600 feet or 1 inch=1000 feet) color aerial photography flown during maximum submerged macrophyte coverage (late summer or early fall of 1993). Boat surveys to determine species composition of the dominant macrophyte communities were conducted at selected sites at the approximate time of the aerial overflight. Aquatic macrophyte colonies were delineated on mylar overlays attached to photographic prints, labeled according to species, and areal coverage determined using an electronic planimeter. Reservoirs flown for aerial photography in 1993 included Kentucky, Wilson, Wheeler, Guntersville, Nickajack, Chickamauga, Tellico, South Holston, and lakes in the Beech River project. For reservoirs where aerial photography was unavailable, standard field surveys and historical information were used to estimate community composition and coverage. Submersed aquatic plant populations generally are rare in tributary reservoirs because of the wide fluctuations of water surface elevations associated with their operation for floodwater storage. Known populations have been extremely small, short-lived, and of little significance.

A detailed summary of TVA's Aquatic Plant Management Program for 1993 and planned work for 1994 is available in a technical report (Burns, Bates, and Webb, 1994) that is updated and published annually.

2.1.3 Stream Vital Signs Monitoring

In 1993, Vital Signs stream sampling locations were located on 12 major tributaries to the Tennessee River (Figure 2.3 and Table 2.2). At each stream sampling location, four types of information were collected and examined to assess the ecological health of the stream and to provide information for evaluating the conditions found in the downstream receiving reservoir. These four components of stream monitoring (which complement the same four components for reservoir monitoring) were:

(1) physical/chemical characteristics of water;
(2) acute toxicity and physical/chemical characteristics of sediment;
(3) benthic macroinvertebrate community sampling; and
(4) fish community sampling.

Physical/Chemical Characteristics of Water--In 1993, physical/chemical water quality characteristics were measured bimonthly (odd numbered months) at 12 stream locations (Table 2.2). QA/QC methods for the stream water quality sampling activities included: (1) collection and analysis of duplicate sets of water samples at five stream locations to assess sample collection, laboratory analysis, and natural sample variability; (2) preparation and analysis of sample container blanks (for metals and nutrient analyses) each collection day to assess the degree of contamination associated with the sample bottles and/or the sample handling processes; and, (3) preparation and analysis of sample filtration blanks (dissolved nutrients and dissolved metals) with each set of filtered samples to assess the degree of contamination associated with the field sample filtration and handling. Physical/chemical water quality characteristics measured in 1993 included:

On-Site Measurements--flow, temperature, dissolved oxygen, pH, conductivity, alkalinity, and fecal coliform bacteria; and

Laboratory Measurements--physical analyses (hardness, color, turbidity, total suspended solids, total dissolved solids, and chemical oxygen demand), nutrient analyses (organic nitrogen, ammonia nitrogen, nitrite+nitrate nitrogen, total phosphorus, dissolved orthophosphorus, and total organic carbon), major cations/anions analyses (calcium, magnesium, sodium, potassium, chloride, and sulfate), and metal analyses (total and dissolved aluminum, dissolved cadmium, total and dissolved copper, total and dissolved iron, dissolved lead, total and dissolved manganese, dissolved nickel, dissolved silver, and total and dissolved zinc).

The physical/chemical water quality data are stored on EPA's water quality data storage and retrieval (STORET) system. Methods used to assess physical/chemical quality of each stream sampling location in regard to the ecological health evaluations are described in Section 3.1.3.

Acute Toxicity and Physical/Chemical Characteristics of Sediment--During the summer of 1993, an annual sediment and bottom water sample was collected at each of the 12 Vital Signs stream sampling locations, Table 2.2. Each sediment sample was a composite of at least five surficial sediment subsamples. At stream sampling locations with shallow and wadable water, subsamples were collected using clean stainless steel spoons. At sampling locations with deeper water, divers collected subsamples using one-liter glass jars. The subsamples were composited and thoroughly mixed to ensure uniform color and texture. At each sampling location the composited sample was then split for acute toxicity and for physical/chemical analyses. The split samples were placed on ice immediately and shipped to the Toxicity Testing Laboratory (TTL) at Browns Ferry Nuclear Plant for toxicity testing and to the Environmental Chemistry Laboratory (ECHE) for chemical and physical analyses.

Acute toxicity testing and physical/chemical analyses of the split samples were performed in exactly the same manner as described in Section 2.1.2, Reservoir Acute Toxicity and Physical/Chemical Characteristics of Sediment. Additional details for the collection methods, acute toxicity testing protocols and results, and the physical/chemical analytical results are given in a TVA technical report (Moses, Simbeck, and Wade, 1994b). How this sediment quality information was used in the stream health evaluations is described in Section 3.1.3, Stream Sediment Quality Rating Scheme.

Benthic Macroinvertebrate Community Sampling--Benthic macroinvertebrates were sampled at the 12 stream sites between mid-May and early July (streamflow conditions permitting) in order to maximize collection before hatching of winged adults. The benthic sampling sites were located as close as possible to the corresponding water quality sampling location (Table 2.2), with exact site selection depending upon the presence of suitable habitat types. Stream habitat in Tennessee Valley rivers and streams can generally be classified as riffle, run, or pool.

Both quantitative (Hess and Surber) and qualitative (D-net and handpicking) samples were collected to define relative abundance and species occurrence at each site. Quantitative sampling was completed in substrate types ranging from rubble to gravel in both riffle and pool habitats. Qualitative sampling was limited to a maximum of two man-hours per site, or was discontinued when redundancy in organisms being collected was observed. In total, seven samples were collected per station. These include: (a) three Hess samples in pools at the head of a riffle in substrate that contained a light covering of silt; (b) three Surber samples collected in shallow riffle habitat and along the borders of emergent vegetation (limited to areas where the water did not exceed the depth of the sampling frame); and (c) a single qualitative sample of bottom fauna organisms using D-nets and handpicking from all habitats present. Habitats targeted for qualitative sampling were leaf packs, woody debris, emergent aquatic vegetation, and boulders.

All specimens were preserved in 10 percent formalin solution and returned to the laboratory for sorting, enumeration, and identification. Specimens were identified to the lowest practical taxon, typically genus or species. Twelve metrics, based on a classification system developed by Kerans et.al (1992), were used to evaluate the stream benthic ecological health (Table 3.4). Methods used to assess the ecological health of the benthic community at each stream sampling location are described below (Section 3.1.3, Stream Benthic Community Rating Scheme). Benthic macroinvertebrate data are available in computer-compatible form from TVA, upon request.

Fish Community Sampling--Fish community sampling was conducted in summer (May-July) at 11 of the 12 stream sampling locations in 1993, Table 2.2. (The Elk River site was not sampled.) A boat-mounted electrofishing unit was used for deep pool habitats, and a backpack electrofishing unit, dip nets, and seine were used for wadable habitats. At each stream site, at least four general habitats (run, riffle, shallow pool, and deep pool) were sampled until three consecutive units of sampling effort (seine haul or timed shocking run) produced no additional species per habitat. Additional habitats were sampled as determined by the field crew leader. Fish specimens that were difficult to identify were preserved and their identity later confirmed. All fish collected were enumerated. Numbers were estimated if high densities were encountered during electrofishing. Young-of-the-year (YOY) fish were counted separately from adults. All fish measured were inspected for external diseases, parasites, and anomalies.

A modified version of Karr's (1981) index of biotic integrity (IBI) was used to assess the condition of the resident fish community, Table 3.5. This evaluation scheme is described in Section 3.1.3, Stream Fish Community Rating Scheme. Fish community data are available in computer-readable form from TVA upon request.

2.2 Use Suitability Monitoring

Use Suitability monitoring provides screening level information on the suitability of selected reservoir areas and stream reaches in the Tennessee Valley for water contact recreation (swimmable) and suitability of fish for human consumption (fishable). The use suitability evaluation is based on results of: (1) bacteriological sampling at recreation areas, and (2) collection and analysis of fish tissue.

2.2.1 Bacteriological Sampling

In 1989, TVA began periodically sampling recreation sites in the Tennessee Valley for fecal coliform bacteria to determine each site's suitability for water contact recreation. In addition to swimming beaches, many other recreation sites were also included in the program, such as canoe launch areas, picnic areas, boat ramps, and marinas. This bacteriological sampling program now includes approximately 260 sites and is designed to sample all locations on a frequency of about once every other year. Prior to 1993, the sampling frequency was approximately once every five years.

Samples are collected in a manner to conform with state criteria and federal guidelines; at each site at least ten fecal coliform samples are collected within a 30-day sampling period during the summer recreation season. QA/QC procedures include running at least one duplicate sample at each site and preparation and analyses of sample container blanks each collection day to assess degree of contamination associated with sample containers, handling process, and analytical equipment. The suitability of a recreation site for water contact recreation is based on EPA guidelines for fecal coliform bacteria (EPA, 1991).

In 1993, fecal coliform samples were collected in spring and summer at 59 designated swimming beaches and 14 canoe access sites to evaluate use suitability for whole body water contact recreation. In addition, 53 informal recreation sites where incidental water contact may occur (e.g., boat launch ramps, picnic areas, parks, marinas, etc.), were sampled.

Monthly (April through September) bacteriological samples were collected at 20 forebay and transition zone locations and four major tributary embayments on the run-of-the-river reservoirs as part of the basic Vital Signs Reservoir Monitoring (Table 2.1).

All TVA bacteriological sampling data are stored on EPA's water quality data storage and retrieval (STORET) system. A technical report (Fehring, 1994) provides specific details and evaluations of TVA's 1993 bacteriological monitoring results, and is available upon request.

2.2.2 Fish Tissue Sampling

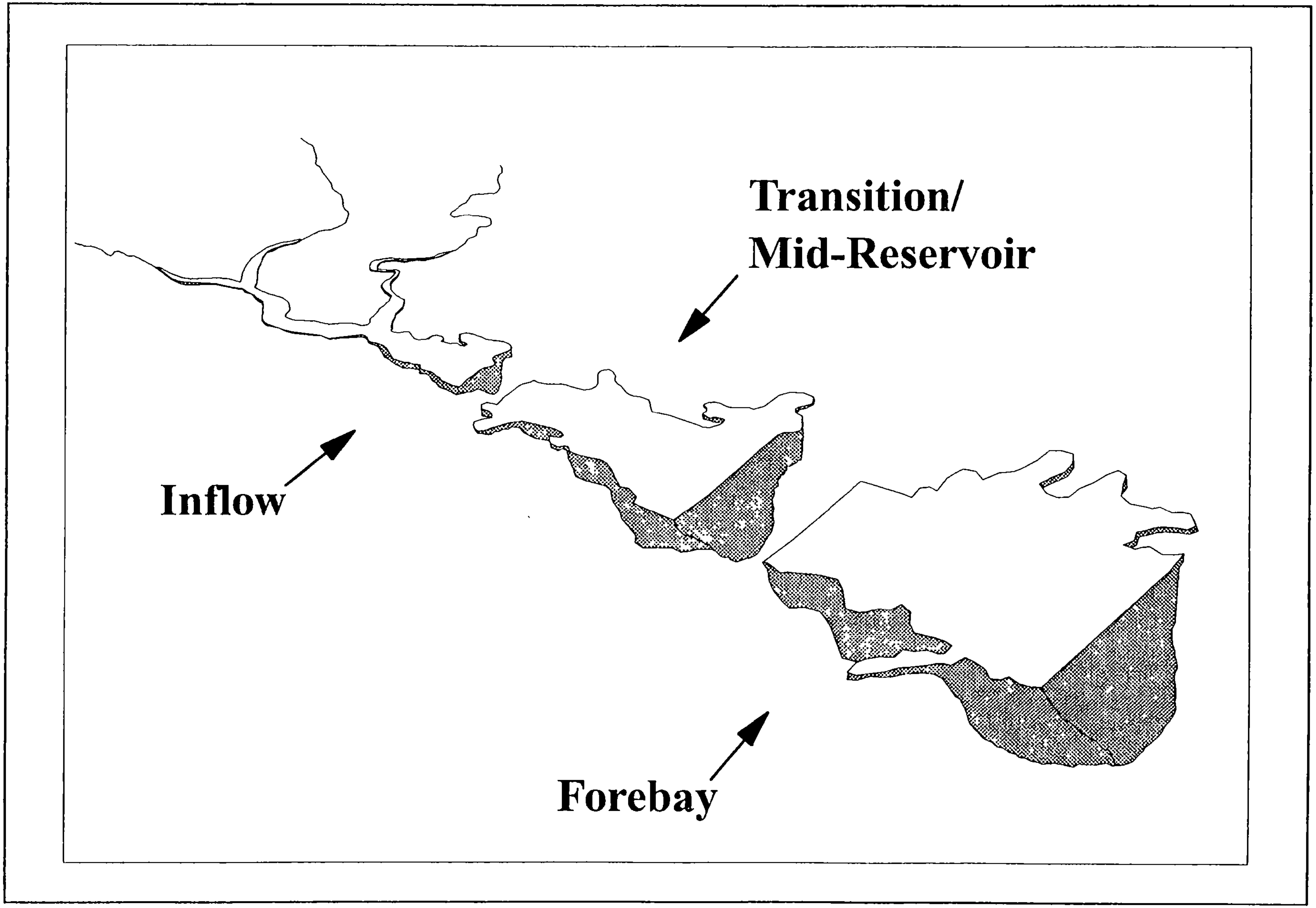
In cooperation with Valley states, since 1987 TVA has collected and analyzed fish from over 80 Tennessee Valley reservoir and stream locations as part of both "screening" and "intensive" evaluations. In screening studies, composited fillets of indicator fish species (primarily channel catfish) are analyzed for a wide range of potential contaminants to identify possible problem areas where intensive investigation may be needed. Intensive studies are conducted on reservoirs or streams where contamination problems are known or suspected, based on the screening study information. For intensive studies, individual fillets from several important fish species are analyzed for specific contaminants to better document the number of species contaminated and level of contamination in each species. Intensive studies also include a higher density of sampling locations in the reservoir or stream of interest to better define the spatial extent of the contamination. The intent is to provide information that state public health officials can use to determine whether fish consumption advisories should be issued to protect human health.

> ***Screening Studies***--Channel catfish were collected from 16 reservoirs in autumn of 1992. Fillets were removed, composited by location, and analyzed for metals, PCBs, and pesticides on EPA's Priority Pollutant List (Table 2.3). During the preparation process, observations of external and internal conditions of each fish were recorded along with length, weight, sex, fillet weight, and liver weight.
>
> ***Intensive Studies***--The following six TVA reservoirs were examined intensively in 1992: Wheeler, Nickajack, Watts Bar, Fort Loudoun, Melton Hill, and Ocoee No. 1 (Parksville Reservoir). In each case, the contaminant of concern was PCBs, except for Wheeler, where DDT is the problem. Chlordane was also of concern in some reservoirs. Fish consumption advisories that recommend either limiting the quantity of fish eaten or avoiding any consumption are in effect for all these reservoirs except Ocoee No. 1.

All fish tissue data are stored on EPA's water quality data storage and retrieval (STORET) system. A technical report (Williams and Dycus, 1993) provides specific details and evaluations of TVA's 1991 and 1992 fish tissue studies and is available on request.

Figure 2.1

Schematic of Key Reservoir Sampling Areas



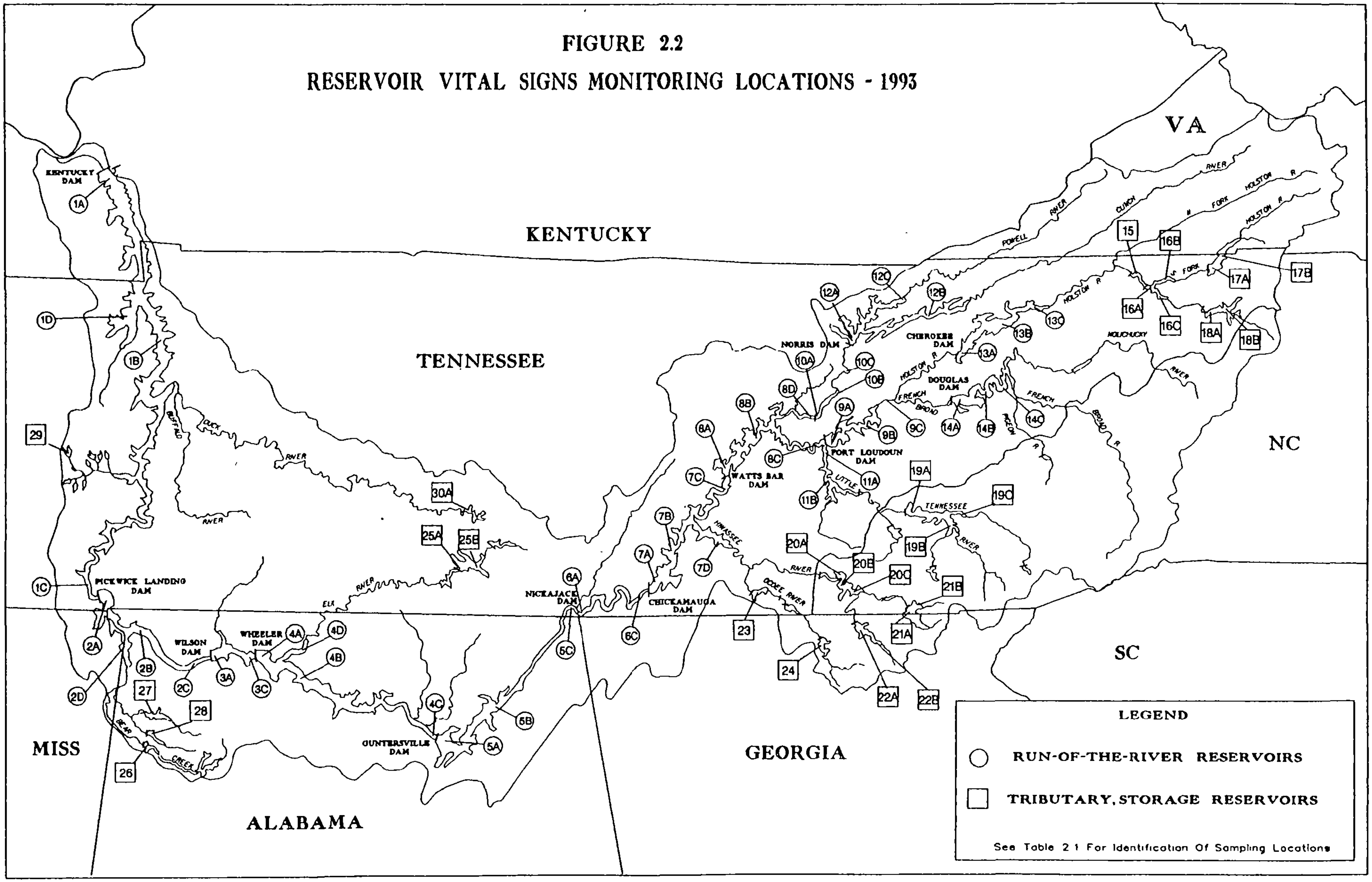
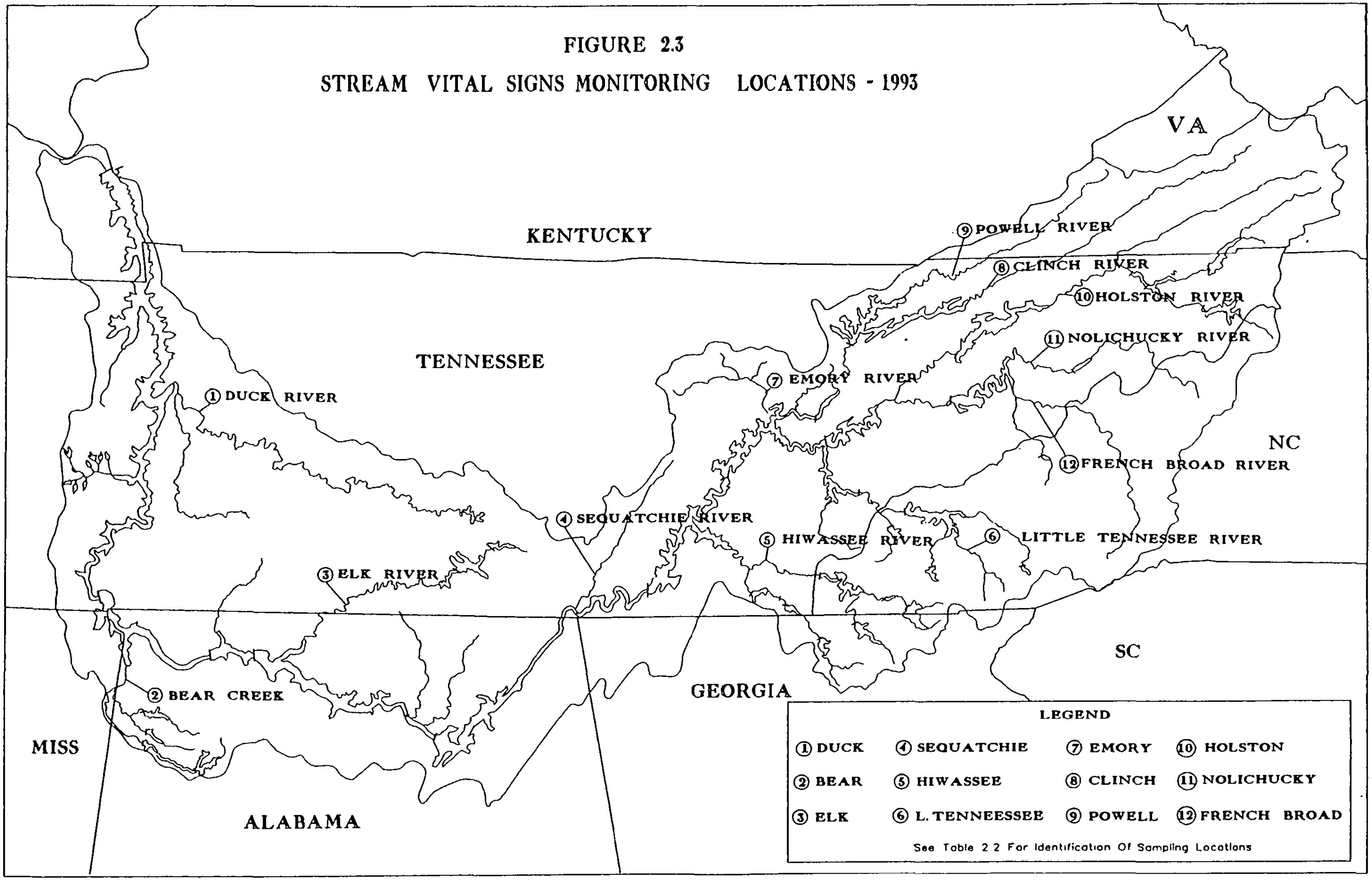


FIGURE 2.2
RESERVOIR VITAL SIGNS MONITORING LOCATIONS - 1993

PRODUCED BY TVA MAPPING SERVICES

FIGURE 2.3
STREAM VITAL SIGNS MONITORING LOCATIONS - 1993



PRODUCED BY TVA MAPPING SERVICES

Table 2.1
1993 Vital Signs Monitoring

Run-of-the-River Reservoirs
--Basic Monitoring Strategy--

Reservoir	Sampling Locations[a]	STORET ID #	Description[b]	Reservoir Vital Signs Monitoring Tools: Water Quality[c]	Sediment Quality[d]: Toxicity	Sediment Quality[d]: Phy/Chem	Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
Kentucky	TRM 23.0	202832	1A-FB	M	A	A	A	A
	TRM 85.0	477403	1B-TZ	M	A	A	A	A
	TRM 200-206	--	1C-I	-	-	-	A	A
	Big Sandy 7.4	477210	1D-E	M	A	A	A	A
Pickwick	TRM 207.3	476799	2A-FB	M	A	A	A	A
	TRM 230.0	016923	2B-TZ	M	A	A	A	A
	TRM 253-259	--	2C-I	-	-	-	A	A
	Bear Cr 8.4	017849	2D-E	M	A	A	A	A
Wilson	TRM 260.8	016912	3A-FB	M	A	A	A	A
	TRM 273-274	--	3C-I	-	-	-	A	A
Wheeler	TRM 277.0	016900	4A-FB	M	A	A	A	A
	TRM 295.9	017009	4B-TZ	M	A	A	A	A
	TRM 347-348	--	4C-I	-	-	-	A	A
	Elk River 6.0	017850	4D-E	M	A	A	A	A
Guntersville	TRM 350.0	017261	5A-FB	M	A	A	A	A
	TRM 375.2	017522	5B-TZ	M	A	A	A	A
	TRM 420-424	--	5C-I	-	-	-	A	A
Nickajack	TRM 425.5	476344	6A-FB	M	A	A	A	A
	TRM 469-470	--	6C-I	-	-	-	A	A
Chickamuaga	TRM 472.3	475358	7A-FB	M	A	A	A	A
	TRM 490.5	475265	7B-TZ	M	A	A	A	A
	TRM 518-529	--	7C-I	-	-	-	A	A
	Hiwassee 8.5	477512	7D-E	M	A	A	A	A

Table 2.1 (continued)
1993 Vital Signs Monitoring

Run-of-the-River Reservoirs
--Basic Monitoring Strategy (continued)--

Reservoir	Sampling Locations[a]	STORET ID #	Description[b]	Reservoir Vital Signs Monitoring Tools: Water Quality[c]	Sediment Quality[d]: Toxicity	Sediment Quality[d]: Phy/Chem	Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
Watts Bar	TRM 531.0	475317	8A-FB	M	A	A	A	A
	TRM 560.8	476041	8B-TZ	M	A	A	A	A
	TRM 600-601	--	8C-I	-	-	-	A	A
	CRM 19-22	--	8D-I	-	-	-	A	A
Fort Loudoun	TRM 605.5	477404	9A-FB	M	A	A	A	A
	TRM 624.6	475603	9B-TZ	M	A	A	A	A
	TRM 652	--	9C-I	-	-	-	A	A
Melton Hill	CRM 24.0	477064	10A-FB	M	A	A	A	A
	CRM 45.0	476194	10B-TZ	M	A	A	A	A
	CRM 59-66	--	10C-I	-	-	-	A	A
Tellico	LTRM 1.0	476260	11A-FB	M	A	A	A	A
	LTRM 15.0	476456	11B-TZ	M	A	A	A	A
	LTRM 21.0	476295	-	-	A	A	-	-
			Totals	24	25	25	35	35

Table 2.1 (continued)
1993 Vital Signs Monitoring

Tributary Storage Reservoirs
--Limited Monitoring Strategy--

Reservoir	Sampling Locations[a]	STORET ID #	Description[b]	Reservoir Vital Signs Monitoring Tools: Water Quality[c]	Sediment Quality[d]: Toxicity	Sediment Quality[d]: Phy/Chem	Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
Norris	CRM 80.0	476009	12A-FB	M	A	A	A	A
	CRM 125.0	477186	12B-MR	M	A	A	A	A
	PRM 30.0	477187	12C-MR	M	A	A	A	A
Cherokee	HRM 53.0	475025	13A-FB	M	A	A	A	A
	HRM 76.0	475028	13B-MR	M	A	A	-	A
	HRM 91	--	13C-I	-	-	-	A	A
Douglas	FBRM 33.0	475081	14A-FB	M	A	A	A	A
	FBRM 51.0	477510	14B-MR	M	A	A	-	A
	FBRM 61	--	14C-I	-	-	-	A	-
Ft.Pat Henry	SFHR 8.7	477509	15-FB	M	A	A	A	A
Boone	SFHR 19.0	475858	16A-FB	M	A	A	A	A
	SFHR 27.0	476221	16B-MR	M	A	A	A	A
	WRM 6.5	477511	16C-MR	M	A	A	A	A
South Holston	SFHR 51.0	475859	17A-FB	M	A	A	A	A
	SFHR 62.5	475573	17B-MR/I	M	A	A	A	A
Watauga	WRM 37.4	475576	18A-FB	M	A	A	A	A
	WRM 45.5	477513	18B-MR	M	A	A	A	A
Fontana	LTRM 62.0	370004	19A-FB	M	A	A	A	A
	LTRM 81.5	370177	19B-MR	M	A	A	A	A
	TkRM 3.0	370162	19C-MR	M	A	A	A	A

Table 2.1 (continued)
1993 Vital Signs Monitoring

Tributary Storage Reservoirs
--Limited Monitoring Strategy (continued)--

Reservoir	Sampling Locations[a]	STORET ID #	Description[b]	Reservoir Vital Signs Monitoring Tools: Water Quality[c]	Sediment Quality[d]: Toxicity	Sediment Quality[d]: Phy/Chem	Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
Hiwassee	HiRM 77.0	370001	20A-FB	M	A	A	A	A
	HiRM 85.0	370154	20B-MR	M	A	A	A	A
	HiRM 90	--	20C-I	-	-	-	A	A
Chatuge	HiRM 122.0	370003	21A-FB	M	A	A	A	A
	Shooting Cr 1.5	370178	21B-FB	M	A	A	A	A
Nottely	NRM 23.5	120883	22A-FB	M	A	A	A	A
	NRM 31.0	120806	22B-MR	M	A	A	A	A
Ocoee No.1	ORM 12.5	475684	23-FB	M	A	A	A	A
	ORM 16.5	--	-	-	A	-	-	-
Blue Ridge	ToRM 54.1	130032	24-FB	M	A	A	A	A
Tims Ford	ERM 135.0	477072	25A-FB	M	A	A	A	A
	ERM 150.0	475768	25B-MR	M	A	A	A	A
Bear Creek	BCM 75.0	017041	26-FB	M	A	A	A	A
Cedar Creek	CCM 25.2	017233	27-FB	M	A	A	A	A
L.Bear Creek	LBCM 12.5	017474	28-FB	M	A	A	A	A
Beech	BRM 36.0	475876	29-FB	M	A	A	A	-
Normandy	DRM 249.5	477453	30-FB	M	A	A	A	A
			Totals	33	34	33	34	34

Footnotes

a.

BCM - Bear Creek Mile	BRM - Beech River Mile	CCM Cedar Creek Mile
CRM - Clinch River Mile	DRM - Duck River Mile	ERM - Elk River Mile
FBRM - French Broad River	HiRM - Hiwassee River Mile	HRM - Holston River Mile
LBCM - Little Bear Creek Mile	LTRM - Little Tennessee River Mile	NRM - Nottely River Mile
ORM - Ocoee River Mile	PRM - Powell River Mile	SFHR - So Fork Holston River Mile
TRM - Tennessee River Mile	ToRM - Toccoa River Mile	TkRM - Tuckaseegee River Mile
WRM - Watauga River Mile	PRM - Powell River Mile	

b. Numbers are keyed to Figure 2.2. FB - forebay; TZ - transition zone; MR - mid-reservoir; I - Inflow; and E - embayment. MR/I - Sampling location was referred to as an inflow location in the fish community evaluation (sampling done in autumn at lower reservoir water level elevations); and, as a mid-reservoir location in the evaluation of the water quality data (sampling done in summer at higher water level elevations).

c. --Basic Monitoring Strategy--

M - monthly water quality surveys (April through September). The surveys include: in situ water column measurements of temperature, dissolved oxygen, pH, and conductivity; Secchi depth measurements; surface fecal coliform and photic zone chlorophyll-a samples; and surface and near-bottom water samples for nutrients (organic nitrogen, ammonia nitrogen, nitrate+nitrite nitrogen, phosphorus, and dissolved ortho phosphorus), total organic carbon, color, and suspended solids.

--Limited Monitoring Strategy--

M - monthly water quality surveys (April through October). The surveys include: in situ water column measurements of temperature, dissolved oxygen, pH, and conductivity; Secchi depth measurements; and, photic zone chlorophyll-a samples. Twice a year (April and August) surface water samples are collected for nutrients (organic nitrogen, ammonia nitrogen, nitrate+nitrite nitrogen, phosphorus, and dissolved ortho phosphorus), and total organic carbon. Once a year (August) bottom water samples are collected for ammonia nitrogen. No samples are collected for fecal coliform, color, and suspended solids.

d. A - annual summer samples of sediment pore water and bottom water are examined for acute toxicity (rotifers and Ceriodaphnia). At the same time, the sediment is collected and analyzed for metals, total and volatile solids, particle size, and twenty-six trace organics (organochlorine pesticides and PCBs).

e. A - annual benthic invertebrate samples are collected, enumerated and identified to lowest practical taxon (genus or species) in the spring of year.

f. A - annual electroshocking and gill-netting techniques are used to evaluate the near-shore fish community, during autumn.

Table 2.2
1993 Vital Signs Monitoring

STREAM VITAL SIGNS MONITORING LOCATIONS, 1993

Tributary Stream	River Mile	STORET ID #	Description
Duck River	26.0	475793	USGS stream gage above Hurricane Mills, TN
Bear Creek	27.3	017019	TVA stream gage near Bishop, AL
Elk River	36.5	477330	USGS stream gage at Veto Road bridge near Prospect, TN
Sequatchie River	6.3	477177	Valley Road bridge near Jasper, TN
Hiwassee River	36.9	477369	East Patty Road bridge near Benton, TN
Little Tennessee River	94.7	370158	USGS stream gage near Needmore, NC
Emory River	18.3	475838	USGS stream gage at Oakdale, TN
Clinch River	159.8	475846	USGS stream gage near Tazewell, TN
Powell River	65.4	475098	TVA stream gage near Arthur, TN
Holston River	118.7	475945	TVA stream gage near Surgoinsville, TN
Nolichucky River	10.3	477150	TVA stream gage at David Thomas bridge near Lowland, TN
French Broad River	77.5	475086	US Hwy 411 bridge at Oldtown, TN

Table 2.3
1993 Vital Signs Monitoring

PHYSICAL/CHEMICAL MEASUREMENTS - SEDIMENT		
Description, units	**Detection Limits (dry weight)**	**Sediment Quality Guidelines[a]**
Metals and Ammonia		
Aluminum, mg/g	1 mg/g	--
Arsenic, mg/kg	1 mg/kg	8 mg/kg[b]
Cadmium, mg/kg	0.5 mg/kg	6 mg/kg[b]
Calcium, mg/g	0.5 mg/g	--
Chromium, mg/kg	10 mg/kg	75 mg/kg[b]
Copper, mg/kg	2 mg/kg	50 mg/kg[b]
Iron, mg/g	1 mg/g	--
Lead, mg/kg	5 mg/kg	60 mg/kg[b]
Magnesium, mg/g	0.5 mg/g	--
Manganese, mg/g	0.1 mg/g	--
Mercury, mg/kg	0.1 mg/kg	1 mg/kg[b]
Nickel, mg/kg	5 mg/kg	50 mg/kg[b]
Zinc, mg/kg	10 mg/kg	300 mg/kg
Un-ionized Ammonia (in pore water), µg NH_3/l	10 µg/l	200 µg/l
Solids		
Total solids, %	0.1%	--
Total volatile solids, %	0.1%	--
Particle size, <0.062 mm diameter, %	0.1%	--
Particle size, <0.125 mm diameter, %	0.1%	--
Particle size, <0.50 mm diameter, %	0.1%	--
Particle size, <2.0 mm diameter, %	0.1%	--
Organochlorine Pesticides and PCB's		
Aldrin, µg/kg	10 µg/kg	10 µg/kg
α-Benzene Hexachloride (BHC), µg/kg	10 µg/kg	10 µg/kg
β-Benzene Hexachloride (BHC), µg/kg	10 µg/kg	10 µg/kg
γ-Benzene Hexachloride (Lindane), µg/kg	10 µg/kg	10 µg/kg
δ-Benzene Hexachloride (BHC), µg/kg	10 µg/kg	10 µg/kg
Chlordane, µg/kg	10 µg/kg	10 µg/kg
Dieldrin, µg/kg	10 µg/kg	10 µg/kg
ρ,ρ DDT, µg/kg	10 µg/kg	10 µg/kg
ρ,ρ DDD, µg/kg	10 µg/kg	10 µg/kg
ρ,ρ DDE, µg/kg	10 µg/kg	10 µg/kg

Table 2.3 (continued)
1993 Vital Signs Monitoring

PHYSICAL/CHEMICAL MEASUREMENTS - SEDIMENT		
Description, units	**Detection Limits (dry weight)**	**Sediment Quality Guidelines[a]**
Organochlorine Pesticides and PCB's (continued)		
α-Endosulfan, μg/kg	10 μg/kg	10 μg/kg
ß-Endosulfan, μg/kg	10 μg/kg	10 μg/kg
Endosulfan Sulfate, μg/kg	10 μg/kg	10 μg/kg
Endrin, μg/kg	10 μg/kg	10 μg/kg
Endrin Aldehyde, μg/kg	10 μg/kg	10 μg/kg
Heptachlor, μg/kg	10 μg/kg	10 μg/kg
Heptachlor Epoxide, μg/kg	10 μg/kg	10 μg/kg
Methoxychlor, μg/kg	10 μg/kg	10 μg/kg
PCB-1221, μg/kg	100 μg/kg	100 μg/kg
PCB-1232, μg/kg	100 μg/kg	100 μg/kg
PCB-1242, μg/kg	100 μg/kg	100 μg/kg
PCB-1248, μg/kg	100 μg/kg	100 μg/kg
PCB-1254, μg/kg	100 μg/kg	100 μg/kg
PCB-1260, μg/kg	100 μg/kg	100 μg/kg
PCB-1016, μg/kg	100 μg/kg	100 μg/kg
PCBs, Total, μg/kg	100 μg/kg	100 μg/kg
Toxaphene, μg/kg	500 μg/kg	500 μg/kg

[a] Unless otherwise noted, guidelines are suggested TVA Sediment Quality Guidelines.
[b] EPA Region V Guidelines for polluted freshwater sediment (EPA, 1977).

3.0 ECOLOGICAL HEALTH AND USE SUITABILITY DETERMINATION METHODS

3.1 Vital Signs Monitoring

3.1.1 Introduction

The objective of Vital Signs monitoring is to determine the health or integrity of the aquatic ecosystem within each reservoir or at each stream sampling location. There are no official or universally accepted guidelines or criteria upon which to base such an evaluation. Consequently, an evaluation methodology was developed to assess the overall ecological health or condition of each of the 30 TVA Vital Signs reservoirs and 12 Vital Signs stream monitoring locations. The ecological health evaluation system combines both biological and physical/chemical information to examine reservoir and stream health. Five aquatic ecosystem indicators are used for reservoirs: dissolved oxygen, chlorophyll-a, sediment quality, benthic macroinvertebrates, and fish community; and four aquatic ecosystem indicators are used for streams: nutrient concentration, sediment quality, benthic macroinvertebrates, and fish community.

A critical step in developing an ecological health evaluation is deciding for each indicator what represents good conditions and what indicates poor conditions. This is more easily done for evaluation of streams because there usually are essentially unaltered reference sites that can be examined to define "good" conditions for each indicator, for example the various indices of biotic integrity for fish and benthic stream communities. Because reservoirs are man-made alterations of natural streams, there are no "reference reservoirs." An alternative approach to "reference conditions" is required.

3.1.2 Reservoir Ecological Health

Scoring criteria for the reservoir dissolved oxygen and chlorophyll-a indicators were based on what could be considered a conceptual model. This simply means that the criteria were developed subjectively, based on several years experience in evaluating biological systems in reservoirs. This experience has shown that below a threshold level of chlorophyll, primary production is not sufficient to support an active, biologically healthy food chain. In addition, chlorophyll concentrations above a higher threshold levels result in undesirable eutrophic conditions. Minimum and maximum chlorophyll concentrations were selected based on this experience and professional judgment. The conceptual model for dissolved oxygen criteria for a reservoir is quite complicated due to the combined effects of flow regulation and the potential for oxygen depletion in the hypolimnion. The scoring criteria described below attempt a multidimensional approach that includes considering dissolved oxygen levels both in the water column and near the bottom of the reservoir.

For the benthic macroinvertebrate and fish community indicators, scoring criteria are developed based on statistical examination of two or more years of data from TVA reservoirs. For these indicators, all previously collected TVA reservoir data for a selected community characteristic (e.g., number of taxa, total abundance, etc.) were ranked and divided into good, fair, and poor groupings. (Specific procedures used to determine scoring criteria for each grouping are given in Section 3.1.2, Benthic Community Rating Scheme and Fish Assemblage Rating Scheme.) Data for the current year of monitoring (e.g., 1993) are then compared to these criteria and scored accordingly. This approach is valid if the data base is sufficiently large and if it can be safely assumed that the data base covers the full spectrum of good to poor conditions.

The sediment quality indicator scoring criteria uses a combination of two characteristics: sediment toxicity to test organisms; and sediment chemical analyses for ammonia, heavy metals, pesticides, and PCBs (using published guidelines for many of these analytes).

Dissolved Oxygen (DO) Rating Scheme--Oxygen is vital for life. In situations where funding is limited and only one indicator of reservoir health could be measured, DO would likely be the indicator of choice. Hutchinson (1975) states that probably more can be learned about the nature of a lake from a series of oxygen measurements than from any other kind of chemical data. The presence, absence, and levels of DO in a lake or reservoir both control and are controlled by many physical, chemical, and biological processes (e.g., photosynthesis, respiration, oxidation-reduction reactions, bacterial decomposition, temperature). DO measurements coupled with observations of water clarity (Secchi depth), temperature, nutrients, and some basic hydrologic and morphometric information provide meaningful insight into the ecological health of a reservoir.

Ideally, a reservoir has near-saturation concentrations of DO throughout the water column available to fish, insects, and zooplankton for respiration. This is usually the case during winter and spring, when most reservoirs are well mixed. However, in summer (characterized by more available sunlight, warmer water temperatures, and lower flows) both thermal stratification and increased biological activity may combine to produce a greater biochemical demand for oxygen than is available, particularly in the deeper portions of the reservoir. As a result, summer levels of DO often are low in the metalimnion and hypolimnion. Hypolimnetic and metalimnetic oxygen depletion are common, but undesirable, occurrences in many reservoirs, especially storage impoundments. Not only do lower concentrations of DO in the water column affect the assimilative capacity of a reservoir, but if they are low enough and/or sustained long enough, they adversely affect the health and diversity of the fish and benthic communities. Sustained near-bottom anoxia also promotes the biochemical release of ammonia, sulfide, and dissolved metals into the interstitial pore and near-bottom waters. If this phenomenon persists long enough, these chemicals can cause chronic or acute toxicity to bottom-dwelling animals.

A dissolved oxygen concentration of 2 mg/L was selected as a level below which undesirable ecological conditions exist. Values below this level primarily cause adverse impacts on benthic macroinvertebrate organisms and loss of quality habitat for fish. Historic information for reservoirs in the Tennessee Valley has shown that the burrowing mayfly (Hexagenia sp.) disappears from the benthic community at DO concentrations of 2 mg/L and below (Masters and McDonough, 1993). Most fish species avoid areas with DO concentrations below 2.0 mg/L (loss of habitat); fish growth and reproduction is reduced at these levels, and many highly desirable species such as sauger and walleye simply cannot survive at such low levels of DO.

The ecological health evaluation considers oxygen concentrations in both the water column (WC_{DO}) and near the bottom of the reservoir (B_{DO}). The DO rating at each sampling location (ranging from 1 "poor" to 5 "good") is based on monthly summer water column and bottom water DO concentrations. (Summer is defined as a six-month period when maximum thermal stratification and maximum hypolimnetic anoxia is expected to occur: April through September for the run-of-the-river reservoirs and May through October for the tributary reservoirs.) The final DO rating is the average of the water column DO rating and the bottom DO rating:

$$\text{DO Rating} = 0.5\,(WC_{DO}\text{ rating} + B_{DO}\text{ rating}),\text{ where:}$$

WC_{DO} (Water Column DO) Rating--a six-month average of the percent of the reservoir cross-sectional area (at the location where the sampling was conducted--see Figure 3.1) that has a dissolved oxygen (DO) concentration less than 2.0 mg/L.

Average Cross-Sectional Area (DO less than 2 mg/L)	WC_{DO} Rating for Sampling Location
<5%	5 (good);
≥5% but ≤10%	3 (fair);
>10%	1 (poor).

Because most state DO water quality criteria for fish and aquatic life specify a minimum of 5.0 mg/L DO at the 1.5 meter (5 foot) depth, the WC_{DO} rating was lowered if the measured DO at the 1.5 meter depth at a sampling location was below 5.0 mg/L at any time. These adjustments were as follows:

Minimum DO at 1.5 meter depth	Sampling Location WC_{DO} Rating Change
<5.0 mg/L	Decreased one unit (e.g., 5 to 4);
<4.0 mg/L	Decreased two units (e.g., 5 to 3);
<3.0 mg/L	Decreased three units (e.g., 5 to 2);
etc.	etc.

B_{DO} (Bottom DO) Rating--a six month average of the percent of the reservoir cross-sectional bottom length (at the location where sampling was conducted, Figure 3.1) that has a DO concentration less than 2.0 mg/L, as follows:

Average Cross-Sectional Length (DO less than 2 mg/L)	B_{DO} Rating for Sampling Location
0%	5 (good);
0 to 10%	4
10 to 20%	3 (fair);
20 to 30%	2
>30%	1 (poor).

The average percent cross-sectional bottom length was computed based on the total cross-sectional bottom length at average minimum winter pool elevation. In addition, if anoxic bottom conditions (i.e., 0 mg/L) were observed at a location, the B_{DO} rating was lowered one unit, with a minimum rating of 1.

Chlorophyll Rating Scheme--Algae are the base of the aquatic food chain. Consequently, measuring algal biomass or primary productivity is important in evaluating ecological health. Without algae converting sunlight energy, carbon dioxide, and nutrients into oxygen and new plant material, a lake or reservoir could not support other aquatic life. Chlorophyll-a is a simple, long-standing, and well-accepted measurement for estimating algal biomass, algal productivity, and trophic condition of a lake or reservoir (Carlson, 1977). Too little primary productivity in reservoirs (mean summer chlorophyll-a concentrations less than 3 $\mu g/L$) indicates an inability to sustain a well-fed, growing, balanced, and healthy aquatic community. This eventually results in low standing stocks of fish. Too much primary productivity (mean summer concentrations greater than 15 $\mu g/L$) often is evidenced by occasional dense algal blooms, poor water clarity, and the predominance of noxious blue-green algae, and indicates poor ecological health. The large amounts of algal plant material produced under these conditions also deplete oxygen concentrations as the algae die and decompose. This can cause or aggravate problems of low DO in bottom waters.

Chlorophyll ratings at each sampling location are based on the average summer concentration of monthly, photic zone chlorophyll-a samples (corrected) collected from April through September (or October), as shown below. If triplicate samples are collected at a sampling location, the median value of the triplicate is used in calculating the summer average and the maximum.

Average Chlorophyll-a Concentration*	Sampling Location Chlorophyll Rating
Less than 3 μg/L	3 (fair);**
3 to 10 μg/L	5 (good);
10.1 to 15 μg/L	3 (fair);
Greater than 15 μg/L	1 (poor).

* If any single chlorophyll-a sample exceeds 30 μg/L, the value is not included in calculating the average, but the rating is decreased one unit, (i.e., 5 to 4, or 4 to 3, etc.) for each sample that exceeded 30 μg/L.

** If nutrients are present (e.g., nitrate+nitrite greater than 0.05 mg/L and total phosphorus greater than 0.01 mg/L) but chlorophyll-a concentrations are generally low (e.g., ≤ 2 μg/L), another/other limiting or inhibiting factors such as toxicity is likely. When these conditions exist, chlorophyll is rated 2 (poor).

Sediment Quality Rating Scheme--Contaminated bottom sediments can have direct adverse impacts on bottom fauna and can often be long-term sources of toxic substances to the aquatic environment. They may impact wildlife and humans through the consumption of contaminated food or water or through direct contact. These impacts may occur even though the water above the sediments meets water quality criteria. There are many sediment assessment methods, but there is no single method that measures all contaminated sediment impacts at all times and to all biological organisms (EPA, 1992). TVA's approach combines two sediment assessment methods--one biological, the other chemical--to evaluate sediment quality. TVA's scoring criterion is based on ratings for the toxicity of sediment pore water (S_{TOX}) to test organisms, and the chemical analysis of sediment (S_{CHM}) for heavy metals, PCBs, organochlorine pesticides, and un-ionized ammonia (Table 2.3). The final sediment quality score or rating is the average of these two ratings:

Sediment Quality Rating = 0.5 (S_{TOX} rating + S_{CHM} rating), where:

S_{TOX} (Sediment Toxicity) Rating--Sediment toxicity is evaluated using both Rotox® (rotifer Brachionus calyciflorus survival) and daphnid (Ceriodaphnia dubia) acute tests. The acute toxicity evaluations entail the exposure of these organisms (zooplankton) to interstitial pore water from sediment. The survival rates of the organisms are based on the average survival in four replicates of five individuals each, compared to a control. If average survival is significantly reduced (95 percent probability) from the control, the sample is considered to be toxic. Sampling locations are rated as follows:

Sampling Location S_{TOX} Rating	Percent Survival of Ceriodaphnia and/or Branchionus
5 (good)	Survival not significantly different than control and greater than or equal to 80 percent for both species, (i.e., no significant toxicity);
3 (fair)	Survival not significantly different from control, but less than 80 percent survival for either species; or
1 (poor)	Survival of either organism significantly less than control, (i.e., significant toxicity).

S_{CHM} (Sediment Chemistry) Rating--Splits of the same sediment used in the sediment toxicity testing are analyzed for heavy metals, organochlorine pesticides and PCBs, and un-ionized ammonia. Sediment chemistry ratings are based on: (a) concentrations of heavy metals (Cd, Cr, Cu, Pb, Hg, Ni, and Zn) that exceed freshwater sediment guidelines (EPA, 1977); (b) detectable amounts of PCBs or pesticides; and (c) concentrations of un-ionized ammonia in pore water above 200 μg NH_3/L. Each sampling location is rated as follows:

Sampling Location S_{CHM} Rating	Sediment Chemistry*
5 (good)	No analytes exceed guidelines;
3 (fair)	One or two analytes exceed guidelines;
1 (poor)	Three or more exceed guidelines.

* Analytes (i.e., heavy metals, pesticides, PCBs and ammonia) and guidelines are listed in Table 2.3.

Benthic Community Rating Scheme--Six community characteristics (or metrics), with scoring criteria specific to either run-of-the-river or storage reservoirs, are used to evaluate the ecological health of the benthic macroinvertebrate community (Table 3.1). These characteristics are:

1. **Taxa Richness**--The number of different taxa present. An increase in total taxa or taxa richness is used to indicate better conditions than low taxa richness.

2. **Longed-Lived species**--The number of taxa (Corbicula, Hexagenia, mussels, and snails) present. These organisms are long-lived and their presence indicate conditions which allow long-term survival.

3. **EPT**--The number of different taxa within these orders (Ephemeroptera-mayflies, Plecoptera-stoneflies, and Tricoptera-caddisflies). Higher numbers of this metric indicate good water quality conditions in streams. A similar use is incorporated here despite expected lower numbers in reservoirs than in streams.

4. **Proportion as Chironomidae**--The percent of the total organisms in the sample that are chironomids. A higher proportion indicates poor conditions.

5. **Proportion as Tubificidae**--The percent of the total organisms present that are tubificids. A higher proportion indicates poor quality.

6. **Proportion as Dominant Taxa**--The percent of total organisms present that are members of the dominant taxon. This metric is used as an evenness indicator. A large proportion comprised by one or two taxa indicates poor conditions.

Specific scoring criteria were developed for each of the six metrics for both run-of-the-river reservoirs and tributary reservoirs. And given the substantial habitat differences among forebays, transition zones/mid-reservoirs, and inflows, specific scoring criteria were also developed for each of these areas (Table 3.1). Data handling also differed among the metrics. Metric 1, taxa richness, is the average total number of taxa per sample at each site. Metrics 2 and 3 are handled similarly. For Metric 4 the proportion of chironomids in each sample is calculated, then these proportions are averaged for a location. An alternative that was considered was to sum the number of chironomids in all samples and divide by the sum of the total individuals for all samples. The approach selected gives equal weight to all samples regardless of sample size or sampling gear (Ponar or Peterson dredge). This eliminates the bias introduced in the alternate approach when one sample at a site has an exceptionally large or small density. Metric 5 is calculated in the same way. Metric 6, proportion as dominant taxa, is calculated as proportion for each sample, similar to computations for Metrics 4 and 5. The proportion is calculated for the dominant taxon in each sample even if the dominant taxon differed among the samples at a site. This allows more discretion to identify imbalances at a site than developing an average for a single dominant taxon for all samples at the site.

A quantitative approach is used to evaluate the benthic macroinvertebrate community information. The range of values for each of the six metrics found in the available data base (in this case, all the 1991, 1992, and 1993 Vital Signs benthic monitoring data) serves as the basis for evaluation criteria. For each metric at each of the three reservoir sampling zones (forebay, transition zone/mid-reservoir, and inflow) and two reservoir types (run-of-the-river and tributary) the data base values are divided into three groups using Ward's minimum variance analysis (SAS, 1989). This procedure places observations into three homogenous groups of approximate equal size. The groups are sorted and categorized as poor, fair, or good. Scoring criteria represent values between the highest and the lowest value in each group (Table 3.1). Results for each metric for the current year are then compared with these criteria and assigned quantitative values of 1 (poor), 3 (fair), or 5 (good) if they fall within the bottom-, middle-, or top-group, respectively. This results in a minimum score of 6 if all metrics at a site are poor, and a maximum score of 30 if all metrics are good. Detailed scoring criteria for each metric are provided in Table 3.1.

Metrics are summed for each reservoir sampling site to yield a final benthic score and are evaluated as follows:

Sum of Benthic Community Metric Scores	Sampling Location Benthic Rating
6-10	1 (poor)
11-15	2
16-20	3 (fair)
21-25	4
26-30	5 (good)

Fish Assemblage Rating Scheme--In 1993, a Reservoir Fish Assemblage Index (RFAI) (Hickman et.al, 1994) was used to rate fish assemblages as they relate to the overall ecological health of the reservoir. The RFAI is based on 12 metrics with scoring criteria specific to either run-of-the-river or storage reservoirs. Scoring criteria also are specific for the type of sample location within reservoirs--forebay, transition zone/mid-reservoir, or inflow; and for the type of sampling gear used (i.e., electrofishing for littoral fish communities and gill netting for pelagic fish communities). The metrics address the following 12 reservoir fish assemblage characteristics. Table 3.2 lists the trophic, reproductive, and tolerance designations of fish species collected as part of Vital Signs Reservoir Monitoring activities.

Species Richness and Composition

1. **Total number of species**--Greater numbers of species are considered representative of healthier aquatic ecosystems. As conditions degrade, numbers of species at a site decline.

2. **Number of piscivore species**--Higher diversity of piscivores is indicative of better quality environment.

3. **Number of sunfish species**--Lepomid sunfish (excludes black basses, crappies, and rock bass) are basically insectivores, and high diversity of this group is indicative of reduced siltation and high sediment quality in littoral areas.

4. **Number of sucker species**--Suckers are also insectivores but inhabit the pelagic and more riverine sections of reservoirs. This metric closely parallels the lithophilic spawning species metric (Metric 10) and may be deleted from future RFAI calculations.

5. **Number of intolerant species**--This group is made up of species that are particularly intolerant of habitat degradation. Higher densities of intolerant individuals represent better environmental quality.

6. **Percentage of tolerant individuals** (excluding Young-of-Year)--This metric signifies poorer quality with increasing proportions of individuals tolerant of degraded conditions.

7. **Percent dominance by one species**--Ecological quality is considered reduced if one species dominates the resident fish community.

Trophic Composition

8. **Percentage of individuals as omnivores**--Omnivores are less sensitive to environmental stresses due to their ability to vary their diets. As trophic links are disrupted due to degraded conditions, specialist species such as insectivores decline while opportunistic omnivorous species increase in relative abundance.

9. **Percentage of individuals as insectivores**--Due to the special dietary requirements of this group of species and the limitations of their food source in degraded environments, proportion of insectivores increases with environmental quality.

Reproductive Composition

10. **Number of lithophilic spawning species**--Lithophilic broadcast spawners are selected due to their sensitivity to siltation. Numbers of lithophilic spawning species increase in reservoirs providing suitable conditions reflective of good environmental quality.

Abundance and Fish Health

11. **Total catch per unit effort** (number of individuals)--This metric is based upon the assumption that high quality fish assemblages support large numbers of individuals.

12. **Percent individuals with anomalies**--Incidence of diseases, lesions, tumors, external parasites, deformities, blindness, and natural hybridization are noted for all fish measured, with higher incidence indicating poor environmental conditions.

Each metric is assigned a score of 5, 3, or 1 -- representing "good," "fair," or "poor," conditions, respectively. Due to the distinct habitat differences among reservoirs and sampling locations--and the differences in fish assemblages they support--different scoring criteria are used for each of the 12 metrics for: (a) each reservoir type (i.e., run-of-the-river and tributary storage reservoirs); (b) each sampling location (forebay, transition/mid-reservoir, and inflow); and (c) each type of sampling gear used to collect the fish data (electrofishing and gill netting). Scoring criteria by reservoir type, by sampling location, and by sampling gear type are listed for each of the 12 fish community metrics in Table 3.3. There is not yet enough information for inflow sampling locations on tributary reservoirs to establish criteria for the fish community metrics at these particular sites.

The average of the sum of the electrofishing scores and the sum of the gill netting scores results in the Reservoir Fish Assemblage Index (RFAI) for each sampling location. The range of "attainable" RFAI values could be from 12 (if all metrics scored 1) to 60 (if all metrics scored 5). This range of RFAI values, from 12 to 60, is divided into five equal groupings to evaluate the overall health of the fish assemblage at each sampling location, as follows:

RFAI Score	Sampling Location Rating
12-21	1 (poor)
21-31	2
32-41	3 (fair)
42-51	4
52-60	5 (good)

A discussion of the development of the RFAI and results of the fish evaluations for the 1991-1993 Vital Signs Monitoring data are available in TVA technical reports (Scott, et. al, 1992; Brown, et. al, 1993; and Hickman et. al, 1994).

Overall Reservoir Health Determination--The overall ecological evaluation methodology combines the five previously discussed aquatic ecosystem indicators (DO, chlorophyll, sediment quality, benthic macroinvertebrates, and fish assemblage) into a single numeric value. This facilitates spatial comparisons among reservoirs and temporal comparisons for a reservoir through time.

The first step in determining an overall reservoir health score is to sum the ratings for all indicators (ranging from 1-poor to 5-excellent) at a sample site. The number of indicators monitored at each site varies. Generally, all five indicators are included; however, this is not always the case. For example, chlorophyll and sediment quality are not monitored at the inflows on run-of-the-river reservoirs because in situ plankton production of chlorophyll does not occur significantly in that part of a reservoir and because sediments do not accumulate there. The number of sites per reservoir also varies from one (the forebay) in small tributary reservoirs to four (forebay, transition zone, inflow, and embayment) in selected run-of-the-river reservoirs. As a result, the number of ratings vary from five to 18 for the 30 reservoirs monitored in 1993. Specific information on what indicators were sampled in each reservoir is in Table 2.1.

To arrive at an overall health evaluation for a reservoir, the sum of the ratings from all sites are totaled, divided by the maximum potential ratings for that reservoir, and expressed as a percentage. For example, a small reservoir with only one sample site, the minimum health evaluation would be 20 percent (all five indicators rated poor-1 for a total score of 5 divided by the maximum possible total of 25) and the maximum would be 100 percent (all five indicators rated good-5). This same range of 20 to 100 percent applies to all reservoirs regardless of the number of sample sites, and the same calculation process is used.

The next step is to divide the 20-100 percent scoring range into categories representing good, fair, and poor ecological health conditions. This has been achieved as follows:

1. Results are plotted and examined for apparent groupings.

2. Groupings are compared to known, a priori conditions (focusing on reservoirs with known poor conditions), and good-fair and fair-poor boundaries were established subjectively.

3. The groupings are compared to a trisection of the overall scoring range. A scoring range is adjusted up or down a few percentage points to ensure a reservoir with known conditions falls within the appropriate category. This is done only in circumstances where a nominal adjustment is necessary.

Based on these considerations, during the first two years of development (1991-1992), scoring ranges were as follows:

	Poor	Fair	Good
Run-of-the-river reservoirs	≤52%	>52-72%	>72%
Tributary, storage reservoirs	≤56%	>56-72%	>72%

The difference in the poor scoring range between the two types of reservoirs is due to the fact that two storage reservoirs with known poor conditions rated slightly higher than the boundary for the lower (poor) grouping on the run-of-the-river reservoirs. Hence, the high end of the lower scoring range for storage reservoirs was shifted upward from 52 to 56 percent to accommodate these reservoirs with known poor conditions.

Based on the experience gained in developing this evaluation process, review of the evaluation scheme by other state and federal professionals, and results of another year of monitoring, slight modifications were made in the original evaluation process and the numerical scoring criteria for each of the five ecological health indicators. In 1993, run-of-the-river reservoirs with overall scores greater than 72 percent were evaluated as "good"; those between 52 percent and 72 percent were rated "fair"; and those whose overall scores were less than 52 percent were rated "poor." Similarly, in 1993, tributary storage reservoirs were evaluated as "good" if their overall reservoir percentage was greater than or equal to 72 percent; "fair" if its overall reservoir percentage was between 57 percent and 72 percent; and "poor" if its overall reservoir percentage was less than 57 percent. The 1993 scoring ranges were:

	Poor	Fair	Good
Run-of-the-river reservoirs	<52%	52-72%	>72%
Tributary, storage reservoirs	<57%	57-72%	≥72%

Two examples that illustrate the overall reservoir health evaluation methodology are presented in Tables 3.6 and 3.7. Wilson Reservoir (Table 3.6) has five aquatic health indicators at one location and three indicators at another location. Cherokee Reservoir (Table 3.7) has five aquatic health indicators at one location and four indicators at another location.

3.1.3 Stream Ecological Health

An evaluation methodology similar to the Reservoir Ecological Health Evaluation (Section 3.1.2) is used to assess the overall ecological health at each of the 12 stream monitoring locations. Particular emphasis is given to the relationship between the conditions found at the stream sampling site and the potential for impacts on conditions in the downstream reservoir. The following overview summarizes TVA's stream ecological health evaluation methodology. The evaluations are based on four aquatic health indicators: (1) total phosphorus (as a measure of nutrient enrichment and potential for excessive algal productivity); (2) sediment quality; (3) benthic community; and (4) fish community.

At each stream sampling location the four aquatic health indicators are rated as "good," "fair," or "poor." Equal weights are given to each indicator, and each rating is assigned a numeric value of 1, 3, or 5 corresponding to "poor," "fair," or "good." The four scores are summed to produce an overall stream health evaluation at the sampling location ranging from 4 to 20. A stream sampling location with an overall rating of 9 or less ($\leq$45 percent) was rated "poor"; 10 to 15 (50 percent to 75 percent) "fair"; and 16 to 20 (80 percent to 100 percent) "good."

Nutrient Concentration Rating Scheme--Phosphorus is an essential nutrient required by aquatic plants for photosynthesis and growth. In freshwater ecosystems phosphorus is most often the nutrient least available to plants relative to their needs, and thus can limit algal productivity. When present in excess of critical concentrations, in combination with sufficient nitrogen phosphates, it can stimulate algae and other aquatic plant growth, sometimes to an undesirable level that interferes with water uses. To prevent the development of biological nuisances and to control accelerated phosphorus loading for the protection of downstream receiving waterways, EPA recommends a guideline for maximum total phosphorus concentration of 0.10 mg/L for streams or flowing waters and 0.05 mg/L at the point where any stream enters a lake or reservoir (EPA, 1986). These guidelines are used as the basis to evaluate total phosphorus concentrations in Tennessee Valley streams (average of 6 samples per year):

Average Total Phosphorus Concentration*	Sampling Location Nutrient Enrichment Rating
Less than 0.05 mg/L	5 (good);
0.05 to 0.10 mg/L	3 (fair);
Greater than 0.10 mg/L	1 (poor).

* In addition, waters that receive high nitrogen concentrations in the presence of sufficient phosphorus often stimulate the growth of algae and other aquatic plants to an undesirable extent. High average (relative to the majority of Valley streams) nitrate+nitrite nitrogen concentrations greater than 0.65 mg/L resulted in lowering a rating from "good" to "fair" or from "fair" to "poor," as appropriate.

Sediment Quality Rating Scheme--The stream sediment quality evaluation methodology is the same as for reservoir sediment quality. The scoring criterion is based on ratings for the acute toxicity of sediment pore water (S_{TOX}) to both Rotox® (rotifer, Brachionus calyciflorus survival) and daphnid (Ceriodaphnia dubia), and the chemical analysis of sediment (S_{CHM}) for heavy metals, PCBs, organochlorine pesticides, and un-ionized ammonia. The final sediment quality score or rating is the average of these two ratings. (Details are given in Section 2.1.2, Reservoir Sediment Quality Rating Scheme.)

$$\text{Sediment Quality Rating} = 0.5\ (S_{TOX}\ \text{rating} + S_{CHM}\ \text{rating}).$$

Benthic Community Rating Scheme--A modified version of the benthic index of biotic integrity (BIBI) (Kerans et. al, 1992) is used to rate the condition of the benthic community. Twelve benthic community attributes such as total taxa richness and richness of specific taxa, relative abundance of functional and trophic groups and certain tolerant organisms, and total abundance are used. Each of the 12 metrics is scored based on best expected conditions at reference sites supporting healthy benthic communities and good water quality. At each site three Surber (riffle), three Hess (pool), and one qualitative sample were taken. EPT, intolerant snail and mussel species metrics were computed pooling all qualitative and quantitative samples. Total abundance was computed pooling all quantitative samples. The remaining metrics were computed separately for each quantitative sample at a site.

Taxa Richness and Community Composition

1. Taxa richness
2. Occurrence of intolerant snail and mussel species*
3. Number of mayfly (Ephemeroptera) taxa
4. Number of stonefly (Plecoptera) taxa
5. Number of caddisfly (Trichoptera) taxa
6. Total number of EPT taxa*
7. Percentage as oligochaetes
8. Percentage in the two most dominant taxa

Trophic and Functional-Feeding Group

9. Percent as omnivores and scavengers
10. Percent as collector-filterers
11. Percent as predators

Abundance

12. Total abundance of individuals (combined quantitative samples, lower score given for extremely low values or extremely high values)

* Metric applied to qualitative and quantitative samples combined. All other metrics applied to individual quantitative samples and resultant scores averaged.

Values obtained for each of these metrics are scored (1-poor, 3-fair, or 5-good) against best expected value based on data from reference sites supporting healthy fish communities and having good water quality (Table 3.4). Metric scores are then summed to produce an index ranging from 12 to 60. The resultant benthic community index for each stream location is classified as "poor" (<30), "fair" (34-44), or "good" (>45). If the index score falls between 30-33, professional judgment is used to categorize the benthic community as either poor or fair.

Fish Community--A modified version of Karr's (1981) index of biotic integrity (IBI) is used to assess the condition of the resident fish community at 11 of the 12 stream monitoring locations. (Fish community sampling was not conducted on the Elk River in 1993.) An index and rating are produced for each site by applying the following 12 metrics.

Species richness and composition

1. Number of native species
2. Number of darter species
3. Number of native sunfish species (excluding Micropterus sp.)
4. Number of sucker species
5. Number of intolerant species
6. Percentage of individuals as tolerant species

Trophic structure

7. Percentage of individuals as omnivores
8. Percentage of individuals as specialized insectivorous minnows and darters
9. Percentage of individuals as piscivores

Fish abundance and condition

10. Catch rate (average number per unit of sampling effort, seine hauls and shocking runs)
11. Percentage of individuals as hybrids
12. Percentage of individuals with poor condition, injury, deformity, disease, or other anomaly

Actual values obtained for each of these metrics are scored (1-poor, 3-fair, or 5-good) against values expected under pristine conditions (i.e., best expected value, Table 3.5). The 12 metric scores are then summed to produce an index ranging from 12 to 60, and the fish community at the stream sampling location is rated as "poor" (index <36), "fair" (index 40-44), or "good" (index >46). Professional judgment is involved when a fish community index falls between ratings. For example, an index of 38 falls between "poor" and "fair" and would be either "poor" or "fair" depending on the judgment of the biologist taking the sample. Judgment usually is influenced by which of the 12 metrics rates poorest, condition of the coexisting macroinvertebrate community, or previous IBI ratings obtained for the site.

3.2 Use Suitability

3.2.1 Bacteriological Quality Evaluation

Each of the seven Valley states follows the EPA guideline of using a geometric mean fecal coliform concentration of 200 colonies per 100 milliliters (200/100 mL) of water to determine use suitability for whole body water contact recreation (EPA, 1991). Six of the states use an additional fecal coliform criterion to determine if a site is unsuitable for water contact recreation; either a percentage of samples exceeds 400/100 mL, or a maximum concentration of 1000/100 mL for any one sample.

TVA reports on the bacteriological condition of stream and reservoirs throughout the Valley in its publication *RiverPulse* using the following three categories:

Posted by the State:

+ The state has issued a public advisory against water contact and has posted signs near the body of water with the advisory.

+ Each area presently posted exceeds the geometric mean criterion due to a known human source of contamination.

Exceeds Criterion:

+ The geometric mean of a minimum of ten fecal coliform bacteria samples collected by TVA over a period of not more than 30 days from May through September exceeds 200/100 mL.

+ Each site identified is believed to exceed criterion due to animal waste.

Meets Criterion:

+ The geometric mean of a minimum of ten fecal coliform bacteria samples collected by TVA over a period of not more than 30 days from May through September is less than 200/100 mL.

TVA recommends no water contact recreation for at least two days following rain events at locations which only partially support water contact because of the bacteria which are washed into the water. In addition, TVA recommends no water contact recreation in the immediate vicinity of wastewater discharges regardless of what fecal bacteria data show, because of the possibility of mechanical breakdowns and sewage bypasses or overflows.

3.2.2 Fish Tissue Consumption Advisories

TVA and state agencies coordinate with one another in conducting fish tissue studies in the Tennessee Valley. There is a shared interest in the status of TVA reservoirs as important and valuable resources. As the government organizations responsible for regulatory and public health decisions related to lakes and streams, state agencies are interested in knowing both the ecological health of Valley reservoirs and whether the fish are safe to eat.

Prior to initiating sample collections each autumn, TVA and involved Valley state agencies meet to discuss the previous year's results and decide appropriate direction for further study. The group reaches agreement on species to collect, locations to sample, and the agencies responsible for conducting each part of the work. TVA provides its results to the appropriate states, then the states take action to protect public health. This usually involves deciding whether to issue an advisory against consuming selected species or age classes of fish. TVA's role in this process is to provide accurate results, to provide consultation to the state(s) as appropriate, and support the state's decisions.

Figure 3.1

Cross-section of Tellico Reservoir Forebay Showing Areas where Summer DO Concentrations averaged less than or equal to 2 mg/l.

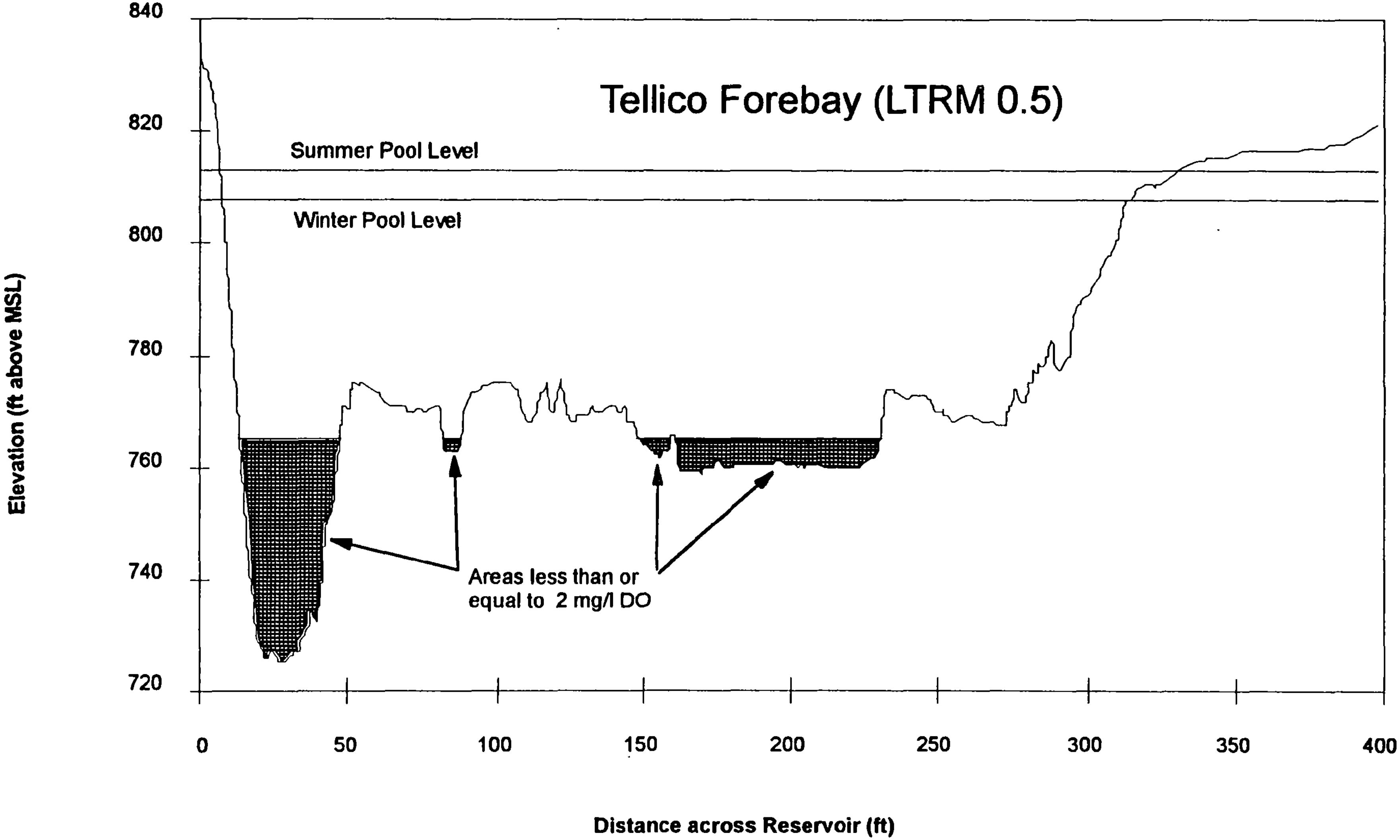


Table 3.1
1993 Vital Signs Monitoring

Reservoir Benthic Macroinvertebrate Community metrics and scoring criteria developed for Tennessee Valley Reservoirs, with a score of 5 representing highest quality, and a score of 1 the poorest.

Run-of-the-River Reservoirs

Benthic Community Metrics	Forebay			Transition			Inflow		
	5	3	1	5	3	1	5	3	1
Taxa Richness	>6.1	4.6-6.1	<4.6	>7.6	6.5-7.6	<6.5	>8.0	5.2-8.0	<5.2
Long Lived Species	>1.2	0.35-1.2	<0.35	>2.4	1.3-2.4	<1.3	>1.9	1.3-1.9	<1.3
EPT (mayfly, stonefly, caddisfly)	>0.95	0.5-0.95	<0.5	>0.95	0.6-0.95	<0.6	>1.4	0.6-1.4	<0.6
% Chironomidae	<30	30-45	>45	<25	25-40	>40	<10	10-30	>30
% Tubificidae	<25	25-50	>50	<20	20-40	>40	<11	11-25	>25
% Dominant Taxa	<75	75-90	>90	<65	65-70	>70	<70	70-80	>80

Tributary Reservoirs

Benthic Community Metrics	Forebay						Mid-Res/Inflow		
	5	3	1				5	3	1
Taxa Richness	>4.3	2.3-4.3	<2.3	–	–	–	>6.2	3.4-6.2	<3.4
Long Lived Species	>1.0	0.15-1.0	<0.15	–	–	–	>0.45	0.15-0.45	<0.15
EPT (mayfly, stonefly, caddisfly)	>0.35	0.15-0.35	<0.15	–	–	–	>0.3	0.09-0.3	<0.09
% Chironomidae	<30	30-50	>50	–	–	–	<25	25-70	>70
% Tubificidae	<30	30-60	>60	–	–	–	<45	45-75	>75
% Dominant Taxa	<78	78-91	>91	–	–	–	<70	70-80	>80

Table 3.2
1993 Vital Signs Monitoring

Core fish species list with trophic tolerance, and reproductive designations (*) for use in Reservoir Fish Assemblage Index (RFAI) for TVA reservoirs, 1993.

Species	Trophic Guild	Tolerance	Lithophilic Spawner
Chestnut lamprey	PS		L
Spotted gar	PI		
Longnose gar	PI	TOL	
Shortnose gar	PI	TOL	
Bowfin	PI		
American eel	PI		
Skipjack herring	PI	INT	
Gizzard shad	OM	TOL	
Threadfin shad	PL		
Mooneye	IN		L
Chain pickerel	PI		
Central stoneroller	HB		
Common carp	OM	TOL	
Goldfish	OM	TOL	
Silver chub	IN	INT	
Golden shiner	OM	TOL	
Emerald shiner	IN		
Ghost shiner	IN		
Spotfin shiner	IN		
Mimic shiner	IN	INT	
Steelcolor shiner	IN		
Pugnose minnow	IN		
Bluntnose minnow	OM		
Fathead minnow	OM		
Bullhead minnow	IN		
River carpsucker	OM		
Quillback	OM		
Northern hog sucker	IN	INT	L
Smallmouth buffalo	OM		
Bigmouth buffalo	PL		
Black buffalo	OM		
Spotted sucker	IN	INT	L
Silver redhorse	IN		L
Shorthead redhorse	IN		L
River redhorse	IN	INT	L
Black redhorse	IN	INT	L
Golden redhorse	IN		L

Table 3.2 (continued)
1993 Vital Signs Monitoring

Core fish species list with trophic tolerance, and reproductive designations (*) for use in Reservoir Fish Assemblage Index (RFAI) for TVA reservoirs, 1993.

Species	Trophic Guild	Tolerance	Lithophilic Spawner
Blue catfish	OM		
Black bullhead	OM	TOL	
Yellow bullhead	OM	TOL	
Brown bullhead	OM	TOL	
Channel catfish	OM		
Flathead catfish	PI		
Blackstripe topminnow	IN		
Blackspotted topminnow	IN		
Mosquitofish	IN	TOL	
Brook Silverside	IN		
White bass	PI		L
Yellow bass	PI		L
Rock bass	PI	INT	
Redbreast sunfish	IN	TOL	
Green sunfish	IN	TOL	
Warmouth	IN		
Orangespotted sunfish	IN		
Bluegill	IN		
Longear sunfish	IN	INT	
Redear sunfish	IN		
Spotted sunfish	IN		
Smallmouth bass	PI		
Spotted bass	PI		
Largemouth bass	PI		
White crappie	PI		
Black crappie	PI		
Yellow perch	IN		
Logperch	IN		L
Sauger	PI		L
Walleye	PI		L
Freshwater drum	IN		

*Designations:
Trophic: herbivore (HB), parasitic (PS), planktivore (PL), omnivore (OM), insectivore (IN), piscivore (PI)
Tolerance: tolerant (TOL), intolerant (INT)
Lithophilic spawning species (L)

Table 3.3
1993 Vital Signs Monitoring

Reservoir Fish Assemblage Index metrics and scoring criteria developed for TVA ***Run-of-the-River*** reservoirs. Scoring reflects fish community quality, with a score of 5 representing highest quality, and a score of 1 the poorest.

Metric	Gear*	Inflow			Transition			Forebay		
		5	3	1	5	3	1	5	3	1
Species Richness										
1. Total species	E	>27	21-27	<21	>25	19-25	<19	>25	21-25	<21
	G	--	--	--	>21	18-21	<18	>19	17-19	<17
2. Piscivore species	E	>9	5-9	<5	>8	6-8	<6	>8	7-8	<7
	G	--	--	--	>9	7-9	<7	>9	8-9	<8
3. Sunfish species	E	>4	3-4	<3	>5	4-5	<4	>5	4-5	<4
	G	--	--	--	>2	2	<2	>2	2	<2
4. Sucker species	E	>5	4-5	<4	>3	2-3	<2	>2	2	<2
	G	--	--	--	>3	2-3	<2	>3	2-3	<2
5. Intolerant species	E	>4	3-4	<3	>2	2	<2	>2	2	<2
	G	--	--	--	>2	2	<2	>2	2	<2
6. Percent tolerant individuals	E	<40	40-60	>60	<30	30-60	>60	<30	30-60	>60
	G	--	--	--	<20	20-35	>35	<25	25-40	>40
7. Percent dominance by one species	E	<30	30-50	>50	<40	40-60	>60	<40	40-60	>60
	G	--	--	--	<30	30-40	>40	<30	30-40	>40
Trophic Composition										
8. Percent individuals as omnivores	E	<30	30-60	>60	<30	30-60	>60	<30	30-60	>60
	G	--	--	--	<35	35-55	>55	<35	35-50	>50
9. Percent individuals as insectivores	E	>50	30-50	<30	>70	40-70	<40	>60	30-60	<30
	G	--	--	--	>15	5-15	<5	>10	5-10	<5
Reproductive Composition										
10. Lithophilic spawning species	E	>7	5-7	<5	>4	3-4	<3	>5	4-5	<4
	G	--	--	--	>5	5	<5	>5	5	<5
Abundance and Health										
11. Total catch per unit effort	E	>120	70-120	<70	>130	70-130	<70	>130	80-130	<80
	G	--	--	--	>30	15-30	<15	>40	20-40	<20
12. Percent individuals with anomalies	E	<1	1-3	>3	<1	1-3	>3	<1	1-3	>3
	G	--	--	--	<1	1-3	>3	<1	1-3	>3

* E=electrofishing; G=gill netting

Table 3.3 (continued)
1993 Vital Signs Monitoring

Reservoir Fish Assemblage Index metrics and scoring criteria developed for TVA ***Tributary*** reservoirs. Scoring reflects fish community quality, with a score of 5 representing highest quality, and a score of 1 the poorest.

Metric	Gear*	Inflow			Mid-Reservoir			Forebay		
		5	3	1	5	3	1	5	3	1
Species Richness										
1. Total species	E	--	--	--	>17	15-17	<15	>25	21-25	<21
	G	--	--	--	>16	13-16	<13	>14	11-14	<11
2. Piscivore species	E	--	--	--	>6	5-6	<5	>5	4-5	<4
	G	--	--	--	>7	7	<7	>6	5-6	<5
3. Sunfish species	E	--	--	--	>3	3	<3	>4	3-4	<3
	G	--	--	--	>1	1	<1	>1	1	<1
4. Sucker species	E	--	--	--	>3	2-3	<2	>2	2	<2
	G	--	--	--	>3	2-3	<2	>3	2-3	<2
5. Intolerant species	E	--	--	--	>2	2	<2	>3	2-3	<3
	G	--	--	--	>1	1	<1	>1	1	<1
6. Percent tolerant individuals	E	--	--	--	<20	20-40	>40	<20	20-40	>40
	G	--	--	--	<20	20-40	>40	<20	20-40	>40
7. Percent dominance by one species	E	--	--	--	<40	40-60	>60	<40	40-60	>60
	G	--	--	--	<30	30-50	>50	<30	30-50	>50
Trophic Composition										
8. Percent individuals as omnivores	E	--	--	--	<15	15-30	>30	<20	20-40	>40
	G	--	--	--	<30	30-50	>50	<30	30-50	>50
9. Percent individuals as insectivores	E	--	--	--	>70	50-70	<50	>70	40-70	<40
	G	--	--	--	>10	5-10	<5	>15	5-15	<5
Reproductive Composition										
10. Lithophilic spawning species	E	--	--	--	>5	4-5	<4	>4	3-4	<3
	G	--	--	--	>4	3-4	<3	>3	2-3	<2
Abundance and Health										
11. Total catch per unit effort	E	--	--	--	>100	60-100	<60	>120	60-120	<60
	G	--	--	--	>25	15-25	<15	>20	10-20	<10
12. Percent individuals with anomalies	E	--	--	--	<1	1-3	>3	<1	1-3	>3
	G	--	--	--	<1	1-3	>3	<1	1-3	>3

* E=electrofishing; G=gill netting

Table 3.4
1993 Vital Signs Monitoring

Benthic Macroinvertebrate Community Index of Biotic Integrity (IBI) metrics and scoring criteria developed for Tennessee Valley Streams, with a score of 5 representing highest quality, and a score of 1 the poorest.

Stream Benthic Index of Biotic Integrity Metrics				
Metric	Sampling Gear	Score		
		1	3	5
Taxa Richness and Community Composition				
1. Taxa Richness	Surber or Hess	<9	9-17	≥18
2. Occurrence of mollusk species*	Combined	0	--	≥1
3. Number of mayfly (Ephemeroptera) taxa	Surber or Hess	<3	3-5	≥6
4. Number of stonefly (Plecoptera) taxa	Surber or Hess	<2	--	≥2
5. Number of caddisfly (Trichoptera) taxa	Surber or Hess	<2	2-3	≥4
6. Number of EPT taxa*	Combined	<14	14-24	≥25
7. Proportion of oligochaetes	Surber or Hess	≥0.05	0.01-0.049	<0.01
8. Proportion of the two most abundant taxa	Surber or Hess	≥0.75	0.5-0.749	<0.5
Trophic and Functional-Feeding Group				
9. Proportion as omnivores and scavangers	Surber or Hess	≥0.9	0.6-0.89	<0.6
10. Proportion as collectors/filterers	Hess	≥0.5	0.2-0.49	<0.2
	Surber	≥0.6	0.3-0.59	<0.3
11. Proportion as predators	Surber or Hess	≤0.04	--	>0.04
Abundance				
12. Total abundance in quantitative samples (Lower scores given for extremely low and high values)	Combined	≤400 >5000	401-500 4001-5000	501-4000

* Metric applied to qualitative and quantitative samples combined. All other metrics applied to individual quantitative samples and resultant scores averaged.

Table 3.5
1993 Vital Signs Monitoring

Fish Community Index of Biotic Integrity (IBI) metrics and scoring criteria developed for Tennessee Valley Streams, with a score of 5 representing highest quality, and a score of 1 the poorest.

Stream Fish Community Index of Biotic Integrity Metrics												
Metric	Duck River 22.5			Bear Creek 25.2			Sequatchie River 7.1			Hiwassee River 37.0		
	1	3	5	1	3	5	1	3	5	1	3	5
Species Richness and Composition												
1. Number of native species	<27	27-53	>53	<23	23-44	>44	<23	23-45	>45	<21	21-41	>41
2. Number of darter species	<5	5-9	>9	<4	4-7	>7	<5	5-8	>8	<5	5-8	>8
3. Sunfish species, less Micropterus	<3	3-5	>5	<3	3-5	>5	<3	3-5	>5	<2	2-3	>3
4. Number of sucker species	<4	4-7	>7	<4	4-7	>7	<4	4-7	>7	<4	4-7	>7
5. Number of intolerant species	<4	4-6	>6	<2	2-3	>3	<3	3-4	>4	<2	2	>2
6. Percent tolerant individuals	>20	10-20	<10	>20	10-20	<10	>20	10-20	<10	>20	10-20	<10
Trophic Composition												
7. Percent omnivores	>30	15-30	<15	>30	15-30	<15	>30	15-30	<15	>30	15-30	<15
8. Percent specialized insectivores	<25	25-50	>50	<25	25-50	>50	<25	25-50	>50	<25	25-50	>50
9. Percent piscivores	<2	2-5	>5	<2	2-5	>5	<2	2-5	>5	<2	2-5	>5
Abundance and Health												
10. Catch rate*	<8	8-16	>16	<8	8-16	>16	<8	8-16	>16	<8	8-16	>16
11. Percentage hybrids	>1	0-1	0	>1	0-1	0	>1	0-1	0	>1	0-1	0
12. Percent individuals with anomalies	>5	2-5	>2	>5	2-5	>2	>5	2-5	>2	>5	2-5	>2

* Average number per seine haul or five minutes of boat electroshocking

Table 3.5 (continued)
1993 Vital Signs Monitoring

Fish Community Index of Biotic Integrity (IBI) metrics and scoring criteria developed for Tennessee Valley Streams, with a score of 5 representing highest quality, and a score of 1 the poorest.

Stream Fish Community Index of Biotic Integrity Metrics

Metric	Little Tenn River 94.3			Emory River 21.7			Powell River 65.4			Clinch River 172.3		
	1	3	5	1	3	5	1	3	5	1	3	5
Species Richness and Composition												
1. Number of native species	<11	11-20	>20	<15	15-29	>29	<21	21-39	>39	<22	22-42	>42
2. Number of darter species	<3	3-4	>4	<5	5-8	>8	<5	5-8	>8	<5	5-8	>8
3. Sunfish species, less Micropterus	0	1	>1	<2	2	>2	<2	2-3	>3	<2	2-3	>3
4. Number of sucker species	<2	2-3	>3	<2	2	>2	<3	3-4	>4	<3	3-5	>5
5. Number of intolerant species	<2	2	>2	<2	2	>2	<3	3-4	>4	<3	3-5	>5
6. Percent tolerant individuals	>20	10-20	<10	>20	10-20	<10	>20	10-20	<10	>20	10-20	<10
Trophic Composition												
7. Percent omnivores	>30	15-30	<15	>30	15-30	<15	>30	15-30	<15	>30	15-30	<15
8. Percent specialized insectivores	<25	25-50	>50	<25	25-50	>50	<25	25-50	>50	<25	25-50	>50
9. Percent piscivores	<2	2-5	>5	<2	2-5	>5	<2	2-5	>5	<2	2-5	>5
Abundance and Health												
10. Catch rate*	<7	7-13	>13	<7	7-13	>13	<8	8-16	>16	<8	8-16	>16
11. Percentage hybrids	>1	0-1	0	>1	0-1	0	>1	0-1	0	>1	0-1	0
12. Percent individuals with anomalies	>5	2-5	>2	>5	2-5	>2	>5	2-5	>2	>5	2-5	>2

* Average number per seine haul or five minutes of boat electroshocking

Table 3.5 (continued)
1993 Vital Signs Monitoring

Fish Community Index of Biotic Integrity (IBI) metrics and scoring criteria developed for Tennessee Valley Streams, with a score of 5 representing highest quality, and a score of 1 the poorest.

Stream Fish Community Index of Biotic Integrity Metrics									
Metric	Holston River 118.0			Nolichucky River 8.5			French Broad R 78.0		
	1	3	5	1	3	5	1	3	5
Species Richness and Composition									
1. Number of native species	<20	20-38	>38	<19	19-36	>36	<21	21-40	>40
2. Number of darter species	<4	4-7	>7	<5	5-8	>8	<4	4-7	>7
3. Sunfish species, less *Micropterus*	<2	2-3	>3	<2	2-3	>3	<2	2-3	>3
4. Number of sucker species	<3	3-5	>5	<4	4-6	>6	<4	4-6	>6
5. Number of intolerant species	<3	3-4	>4	<2	2-3	>3	<2	2-3	>3
6. Percent tolerant individuals	>20	10-20	<10	>20	10-20	<10	>20	10-20	<10
Trophic Composition									
7. Percent omnivores	>30	15-30	<15	>30	15-30	<15	>30	15-30	<15
8. Percent specialized insectivores	<25	25-50	>50	<25	25-50	>50	<25	25-50	>50
9. Percent piscivores	<2	2-5	>5	<2	2-5	>5	<2	2-5	>5
Abundance and Health									
10. Catch rate*	<8	8-16	>16	<8	8-16	>16	<7	7-13	>13
11. Percentage hybrids	>1	0-1	0	>1	0-1	0	>1	0-1	0
12. Percent individuals with anomalies	>5	2-5	>2	>5	2-5	>2	>5	2-5	>2

* Average number per seine haul or five minutes of boat electroshocking

Table 3.6
1993 Vital Signs Monitoring

Computational Method For Evaluation of Reservoir Health

Wilson Reservoir - 1993 (Run-of-the-river reservoir)

Aquatic Health Indicators	Observations			Ratings		
	Forebay	Transition Zone	Inflow	Forebay	Transition Zone	Inflow
Dissolved Oxygen:		No Samples	Tailrace DOs	1	No Rating	4
Less Than 2 mg/L (Summer Avg.)				(poor)		(fair)
% of X-Sectional Area	11.0 (1)	-	-			
% of X-Sectional Bottom Length	44.2 (1)*	-	-	*DO was 0 mg/L on the bottom		
Less Than 5 mg/l at 1.5m						
Yes/No	No	-	Yes*	*Minimum DO was 4.3 mg/L		
Chlorophyll-a, µg/L:		No Samples	No Samples	3	No Rating	No Rating
Summertime Average	10.2	-	-	(fair)		
Maximum Concentration	25.0	-	-			
Sediment Quality:		No Samples	No Samples	4.5	No Rating	No Rating
Toxicity	T1 T2			(good)		
Ceriodaphnia Survival	100% 95%	-	-			
Rotifer Survival	65% 85%	-	-			
Chemistry						
Metals/NH3/pesticides	None (5)	-	-			
Benthic Community:		No Samples		3	No Rating	5
Dominance	5		5	(fair)		(good)
Tubificidae	5		5			
Chironomidae	1		5			
EPT	1		5			
Long-lived	3		5			
Taxa richness	5		5			
Total	20	-	30			
Fish Community:		No Samples		4	No Rating	4
Electrofishing Score	46		-	(fair)		(fair)
Gill Netting Score	38		42			
Overall	42	-	42			

Sampling Location Sum	15.5 of 25	--	13 of 15
Reservoir Sum	28.5 of 40 [71%]		
OVERALL RESERVOIR EVALUATION	"fair" (yellow)		

Overall Reservoir Evaluation Key:
Less than 52% - poor (red)
52% to 72% - fair (yellow)
Greater than 72% - good (green)

Table 3.7
1993 Vital Signs Monitoring

Computational Method For Evaluation of Reservoir Health

Cherokee Reservoir - 1993 (Tributary storage reservoir)

Aquatic Health Indicators	Observations			Ratings		
	Forebay	Transition Zone	Inflow	Forebay	Transition Zone	Inflow
Dissolved Oxygen:			No Samples	1 (poor)	1 (poor)	No Rating
Less Than 2 mg/L (Summer Avg.)						
% of X-Sectional Area	21.5 (1)	26.0 (1)	-			
% of X-Sectional Bottom Length	43.0 (1)*	52.0 (1)*	-	*DO was 0 mg/L on the bottom		
Less Than 5 mg/l at 1.5m						
Yes/No	No	No				
Chlorophyll-a, µg/L:			No Samples	5 (good)	5 (good)	No Rating
Summertime Average	7.6	9.4	-			
Maximum Concentration	17.0	14.0	-			
Sediment Quality:			No Samples	4 (fair)	2 (poor)	No Rating
Toxicity						
Ceriodaphnia Survival	100% (5)	95% (1)	-			
Rotifer Survival	90%	75%	-			
Chemistry						
Metals/NH3/pesticides	NH3 (3)	Cu, NH3 (3)	-			
Benthic Community:		No Samples		3 (fair)	No Rating	5 (good)
Dominance	3		5			
Tubificidae	3		5			
Chironomidae	1		3			
EPT	3		5			
Long-lived	1		5			
Taxa richness	5		5			
Total	16	-	28			
Fish Community:				3 (fair)	3 (fair)	3 (fair)
Electrofishing Score	32	30	34			
Gill Netting Score	40	38	36			
Overall	36	34	35			
		Sampling Location Sum		16 of 25	11 of 20	8 of 10
		Reservoir Sum		35 of 55 [64%]		
		OVERALL RESERVOIR EVALUATION		"fair" (yellow)		

Overall Reservoir Evaluation Key:
- Less than 57% - poor (red)
- >57% and <72% - fair (yellow)
- Greater than 72% - good (green)

4.0 HYDROLOGIC OVERVIEW OF 1993

Many water quality characteristics (e.g., temperature, dissolved oxygen, conductivity, water clarity, suspended solids, etc.) exhibit changes due to seasonal variations in atmospheric temperature and rainfall. During those times of the year when runoff is minimal (normally August-October), streamflow is largely derived from the base flow of groundwater. Because of greater contact between the water and the soil/rock and the longer groundwater residence times, groundwater contains more dissolved minerals (i.e., higher concentrations of hardness and alkalinity, higher pHs and conductivities, etc.) than does surface water. During those times of the year when runoff is higher (normally January-March), streamflow is principally derived from rapid overland runoff that allows little time for mineral dissolution.

Consequently, during those times of the year with higher rainfall and subsequent higher flows, base flow accounts for a smaller proportion of the total streamflow, resulting in lower concentrations of most dissolved constituents. In addition, periods of intense rainfall and high overland flows wash off or "flush" a watershed and transport soil particles to streams, often carrying large loads of nonpoint source pollutants (nutrients, suspended solids, fecal bacteria, etc.) to streams and rivers.

In addition to flood control, electric power generation, and navigation, an important benefit of the TVA's system of dams and reservoirs is its ability to maintain adequate streamflow during extended periods of low rainfall and low runoff by the controlled release of water from tributary storage impoundments. However, this alteration of natural streamflow (diminishing high flows during floods and augmenting low flows during droughts) by storing and then slowly releasing water from tributary storage impoundments creates conditions of strong thermal stratification and low dissolved oxygen in the bottom waters of these tributary storage impoundments. (Additional details about reservoir stratification and water quality impacts are discussed in Chapter 5.)

From a water quality perspective, the lower streamflows occurring during the warmer summer months, combined with naturally occurring higher water temperatures and lower dissolved oxygen concentrations, result not only in lakes becoming thermally stratified but also having less water and less oxygen available to dilute and assimilate the wastes discharged to them. In addition, the warmer water temperatures increase aquatic biological processes (respiration, bacteriological decomposition, etc.). This results in oxygen being used at a faster rate, which can further lower oxygen concentrations. In combination, these factors (low streamflows and diminished assimilative capacity, warmer temperatures and higher biological oxygen consumption rates, and the inhibition of mixing and reaeration caused by thermal stratification) result in low dissolved oxygen concentrations and adversely impact the health of aquatic life. The summer of 1993 was a case in point. July 1993 was the hottest month on record (since 1890s) in the Tennessee Valley. Valley-wide temperatures averaged almost 83°F (28.3°C), about 5°F (2.8°C) above normal for July. For example, in Chattanooga, all 31 days in July had temperatures above 90°F (32.2°C), with temperatures up to 104°F (40.0°C) and 15 days with temperatures 98°F (36.7°C) or higher. This record-breaking heat (and low streamflows) resulted in high water temperatures in the Tennessee River. In fact, all nine mainstem Tennessee River reservoirs had surface water temperatures that exceeded 86°F (30.0°C), some with highs up to 90°F (32.2°C).

In addition, Tennessee Valley rainfall and runoff were well below normal in the summer of 1993. In July, Valley-wide rainfall averaged only 1.76 inches (45 mm), a deficit of 3 inches (76 mm) below the long-term July mean of 4.77 inches (121 mm) as a result rainfall runoff was only 0.66 inches (17 mm), compared to the long-term July mean of 1.03 inches (26 mm). Further, runoff was significantly lower in the western half of the Tennessee Valley than in the eastern half. In July, runoff above Chattanooga was 90 percent of the long-term mean, while runoff was only 64 percent of the long-term mean above Kentucky Dam. For the period of January through July, runoff above Chattanooga was 80 percent of the long-term mean, while runoff was 72 percent of the long-term mean above Kentucky Dam. Consequently, flows in the Tennessee River in 1993 increasingly fell below the long-term average as the river flowed downstream from Fort Loudoun Dam to Kentucky Dam.

The high temperatures and low flows of July 1993 adversely impacted dissolved oxygen concentrations in the Tennessee River, particularly in the downstream reservoirs. In mid-July, hypolimnetic anoxia (DOs equal to 0 mg/L) was found in the forebays of Kentucky, Pickwick, Wilson, Wheeler, and Chickamauga Reservoirs. All time low concentrations of DO were recorded in the releases from Chickamauga Dam on July 16 (2.2 mg/L) and Nickajack Dam on July 19 (1.8 mg/L) when flows from both dams were only 9000 cfs. During the first two weeks of July (July 1 to 15), daily flows averaged only about 17,250-17,500 cfs at Chickamauga and Nickajack Dams, or about 55 percent of the normal flow for this period of time. Once the effects of the high temperatures and low flows on DOs in the Tennessee River were recognized, flows were immediately increased (by drawing water from tributary storage reservoirs) and DO concentrations improved. For example, at Chickamauga Dam, from July 16-31, average daily flows were increased to an average of about

24,500 cfs (about 80 percent of the normal flow for July) and DOs in the releases increased to an average of about 4.3 mg/L, ranging from 3.2 to 6.3 mg/L. Compounding this whole situation were the record-setting rains and flooding occurring in the mid-West along the Mississippi and Missouri Rivers during the "flood of the century." During this period, TVA minimized discharge from the Tennessee River through Kentucky Dam so as to not increase flood crests on the lower Ohio and Mississippi Rivers and worsen the already catastrophic flooding in those areas.

Obviously, examining atmospheric temperature, rainfall, and runoff patterns during 1993 aids in interpretation of the Vital Signs monitoring data and the ecological health assessments of the streams and reservoirs. Interestingly, interpretation of the biological components of stream monitoring results for 1993 is not influenced by these extreme hydrologic conditions. The low rainfall and low streamflows during the spring and early summer allowed benthic sample collection before the more stressed conditions developed in mid-to-late summer.

4.1 Atmospheric Temperature

Average annual temperature in the TVA region is approximately 60 degrees Fahrenheit, °F (15.6 degrees Celsius, °C), with January usually being the coldest month and July the hottest. According to U.S. Department of Commerce (USDOC) climatic data, atmospheric temperatures in the TVA region averaged only about 0.3°F (0.2°C) warmer than normal in 1993; however, 1993 was a year of extremes (USDOC, 1993). January and July were unusually warm with 5.0°F (2.8°C) and 4.7°F (2.6°C) above normal, respectively; while, March and April were below normal with departures greater than -2.0°F (-1.1°C) (Figure 4.1a).

In review, 1993 began with an unusually warm January but cooled to below normal in February. As has often occurred in the last 15 years, another cold spring with late freezes was experienced. A record-breaking late season blizzard struck the Valley in mid-March and hit hardest in the eastern half. Summer was hotter than normal, with Tennessee, Alabama, Georgia, North Carolina, and Virginia all having the hottest July on record since the 1890s. The persistent heat and high humidity created great stress on livestock and people. The daily records for Chattanooga Airport provide an indication of the unusual conditions. All 31 days had maximums above 90°F (32.2°C), with the observed maximums ranging from 92°F (33.3°C) to 104°F (40°C) and 15 days of 98°F (36.7°C) or higher. The last four months had near or below normal temperatures, and the annual average temperature was only slightly above normal.

4.2 Rainfall

The Tennessee River basin averages about 51-52 inches (1295-1320 millimeters [mm]) of precipitation annually. However, there are large variations in the spatial distribution of precipitation. The range is from a high of about 93 inches (2360 mm) in the mountains of southwestern North Carolina near Highlands, North Carolina, to a low of about 37 inches (940 mm) in the shielded valleys of these same mountains near Asheville, North Carolina. Elsewhere in the Valley, precipitation usually ranges within five to ten inches (127 mm to 254 mm) of the basin average. March is usually the wettest month and October the driest.

Rainfall across the Tennessee Valley in 1993 averaged only 39.8 inches (1011 mm), almost 12 inches (about 300 mm) or 23 percent less than the long-term 100-year average. The diminished rainfall in 1993 followed another dry year, 1992, when annual rainfall was about 8 inches (204 mm) or about 15 percent below the long-term average. The period January-May 1992 ranked as one of the ten driest on record in the Tennessee Valley. During 1993, only the month of December had rainfall greater than normal (6.1 inches [155 mm] compared to normal December rainfall of 4.8 inches [122 mm]); the greatest rainfall deficit occurred in July (1.8 inches [45 mm] compared to the normal July rainfall of 4.8 inches [122mm]). In addition to the extremes of December and July, March and September precipitation was close to average while February, April, June and October were more than an inch (254 mm) below average (Figure 4.1b). During March 1993, the Tennessee Valley received the equivalent of 5.4 inches (137 mm) of rain, much of this during the "Winter Snow Storm of the Century" when many areas received record amounts (greater than 20 inches [about 500 mm]) of snowfall.

The unusually persistent hot weather and below average rainfall in the summer was related to an unusual upper air pattern, which kept the storm track well west and north of the region and allowed very few cold fronts to reach the Tennessee Valley. This nearly stationary position of a strong upper air trough over the Rocky Mountains was associated with the record flooding in the middle of the country and kept the Southeast hot and dry. This general pattern was most persistent in the summer, but frequently alternated with a pattern having an upper trough over or to the east of the Valley in the other seasons. This latter trough kept most storms associated with it to the south of the TVA region. These two upper air patterns dominated the weather during 1993, so significant rainfall events tended to occur only when there was a transition period between one and the other.

4.3 Streamflow

Streamflow varies seasonally with rainfall, although during the spring and summer evaporation and transpiration also significantly reduce the amount of runoff. Watersheds that receive 50 to 60 inches (1270 to 1524 mm) of precipitation annually average about 20 to 30 inches (508 to 762 mm) of runoff. In a normal year, the discharge of the Tennessee River (approximately 66,000 cfs [1868 $meters^3$/second]) corresponds to about 22 inches (about 560 mm) of runoff distributed over the 40,900 square mile (105,930 square kilometer) drainage basin. A larger amount of runoff occurs during the wet winter and spring months (January-April) when precipitation events are frequent, temperatures are low, and there are no leaves on deciduous vegetation. Consequently, soil absorption, evaporation, and plant transpiration losses are low at that time of year, and both runoff and streamflow are higher than during the summer and autumn months. Average rainfall in the eastern and western portions of the Tennessee Valley (above and below Chattanooga) is about equal. However, topographic differences (viz. the largely steep and mountainous terrain in the eastern portion of the Valley, compared with the mostly flat and rolling terrain in the western portion of the Valley) and generally shallower soils result in higher amounts of runoff above Chattanooga.

In 1993, runoff for the Tennessee River basin was well below normal, particularly from February through July and particularly in the western half of the Valley. Runoff above Chattanooga was only slightly below normal in 1993, 21.4 inches, or 92 percent of the long-term mean of 23.4 inches. However, runoff above Kentucky Dam was only 17.6 inches, a deficit of almost 5 inches and only 78 percent of the long-term mean of 22.5 inches (Figure 4.1c.). Table 4.1 shows that the 1993 releases from tributary reservoirs in the western part of the Valley (e.g., Normandy, Tims Ford, etc.) were below their long-term means, while the releases from tributary reservoirs in the eastern part of the Valley (e.g., South Holston, Watauga, etc.) were close to normal. Consequently, flows in the Tennessee River in 1993 increasingly fell below the long-term average as the river flowed downstream from Fort Loudoun Dam to Kentucky Dam.

Figure 4.2 presents the relative contributions of streamflow based on long term averages from major tributaries and local inflows to each of the mainstem Tennessee River reservoirs. The flow through each mainstem reservoir is dominated by the inflow from the immediately adjacent upstream reservoir. However, several large tributaries (e.g., Hiwassee River, Elk River, Duck River) do provide substantial inputs to a few mainstem reservoirs, and consequently can have a significant impact on water quality, depending on the volume and chemical quality of the inflows.

FIGURE 4.1 Temperature, Precipitation, and Runoff – Tennessee River Basin, 1993

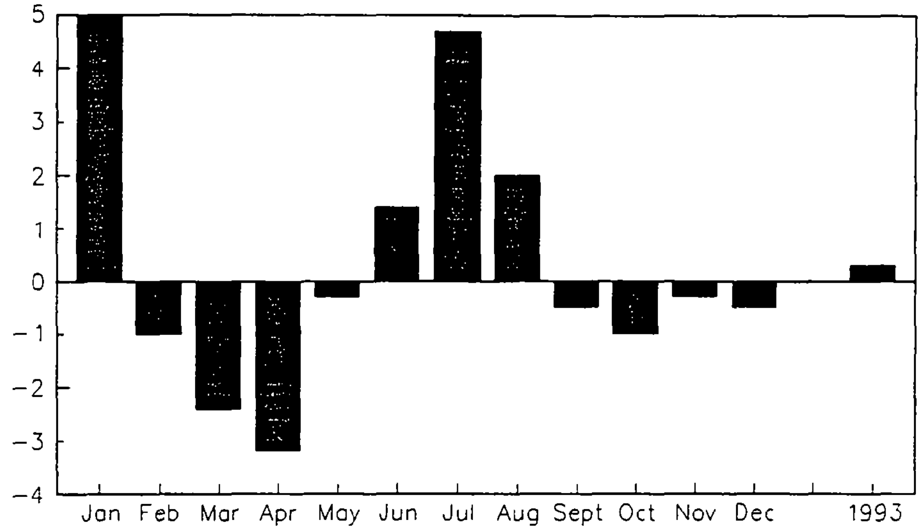


FIGURE 4.1a Temperature Departures From Long-Term Mean (deg F) in the TVA Region

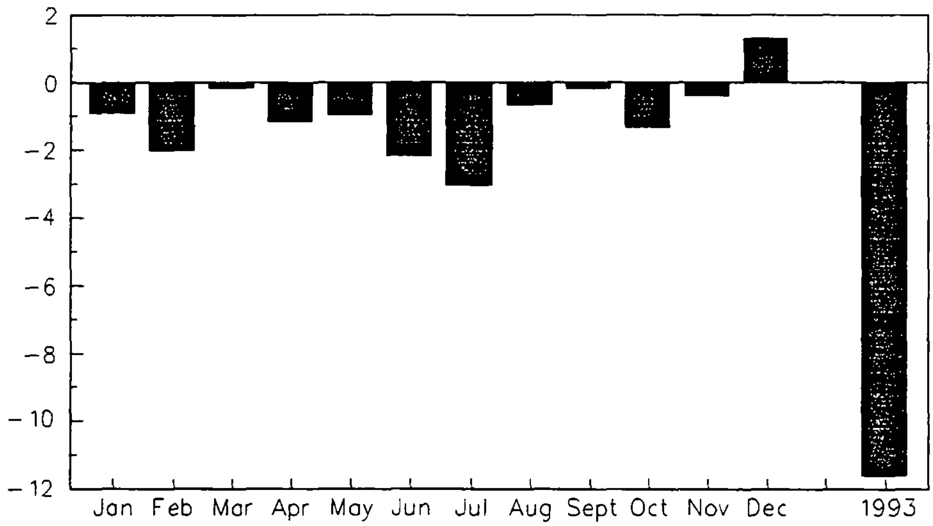


FIGURE 4.1b Precipitation Departures From Long-Term Mean (Inches) For The Tennessee River Basin

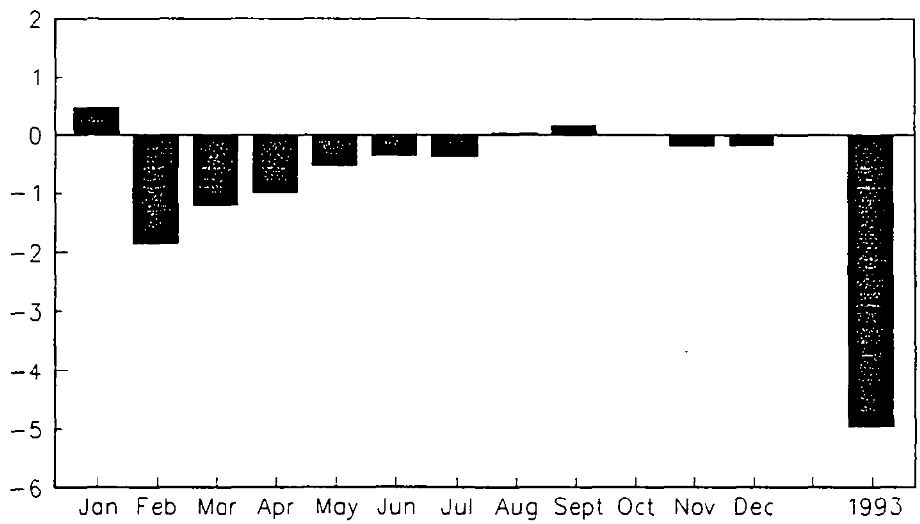


FIGURE 4.1c Runoff Departures From Long-Term Mean (Inches) For Tennessee River Basin, Above Kentucky Dam

Figure 4.2 Average Annual Tennessee River Flows Showing Contributions of Major Tributaries and Local Inflows.

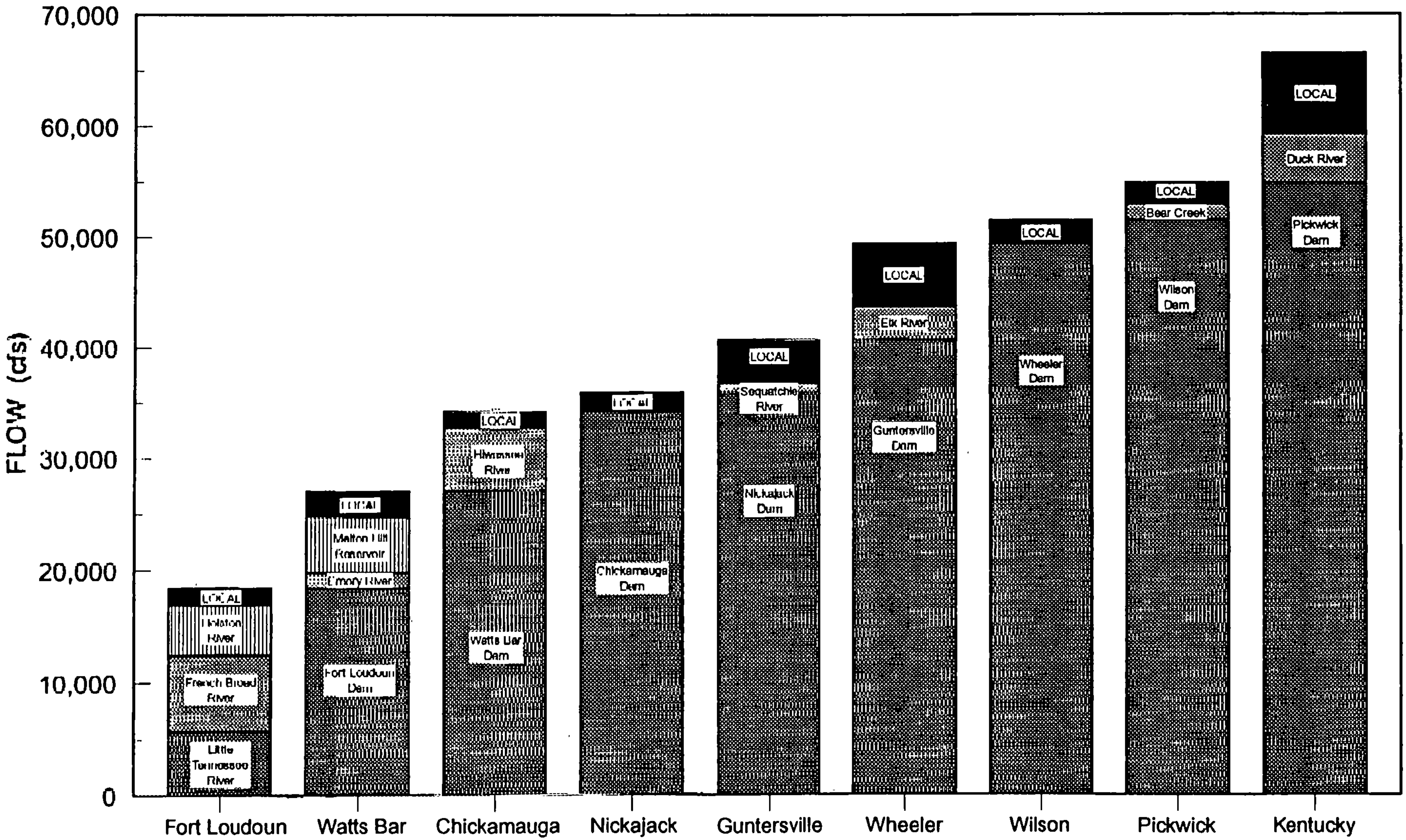


Table 4.1

CHARACTERISTICS OF VITAL SIGNS RESERVOIRS

Reservoir Name	Drainage Area (sq. miles)	Reservoir Length[a] (miles)	Surface Area[a] (acres) 1000's	Depth at Dam[a] (ft)	Volume[a] (ac-ft) 1000's	Average Annual Drawdown[b] (ft)	Average Reservoir Flow-POR (cfs)	Average Hydraulic Residence Time-1993[a] (days)	CY 1993 Reservoir Flow (cfs)
Run-of-the-River Reservoirs									
Kentucky	40,200	184.3	160.3	88	2,839	5	66,600	27.5	52,097
Pickwick	32,820	52.7	43.1	84	924	6	54,900	9.6	48,566
Wilson	30,750	15.5	15.5	108	634	3	51,500	6.8	47,236
Wheeler	29,590	74.1	67.1	66	1,050	6	49,400	11.4	46,264
Guntersville	24,450	75.7	67.9	65	1,018	2	40,700	12.9	39,691
Nickajack	21,870	46.3	10.4	60	241	0	35,900	3.6	34,092
Chickamauga	20,790	58.9	35.4	83	628	7	34,200	9.6	32,887
Watts Bar	17,300	72.0/24.0[c]	39.0	105	1,010	6	27,100	19.5	26,145
Fort Loudoun	9,550	50.0	14.6	94	363	6	18,400	9.7	18,897
Melton Hill	3,343	44.0	5.7	69	120	0	4,920	12.7	4,764
Tellico	2,627	33.2	16.5	80	415	6	6,300[d]	34.0	6,159[d]
Tributary, Storage Reservoirs									
Norris	2,912	73.0/53.0[c]	34.2	202	2,040	32	4,190	249.4	4,124
Cherokee	3,428	54.0	30.3	163	1,481	28	4,460	162.2	4,604
Douglas	4,541	43.1	30.4	127	1,408	48	6,780	109.4	6,490
Ft Patrick Henry	1,903	10.4	0.9	81	27	0	2,650	5.6	2,423
Boone	1,840	17.4/15.3[c]	4.3	129	189	25	2,550	38.5	2,477
South Holston	703	23.7	7.6	239	658	33	976	341.3	972
Watauga	468	16.3	6.4	274	569	26	714	403.5	711
Fontana	1,571	29.0	10.6	460	1,420	64	3,840	173.5	4,126
Hiwassee	968	22.2	6.1	255	422	45	2,020	98.8	2,154
Chatuge	189	13.0	7.0	124	234	10	459	291.3	405
Nottely	214	20.2	4.2	167	170	24	416	228.0	376
Ocoee #1 (Parksville)	595	7.5	1.9	115	85	7	1,420	33.1	1,296
Blue Ridge	232	11.0	3.3	156	193	36	614	156.2	623
Tims Ford	529	34.2	10.6	143	530	12	940	328.7	813
Bear Creek	232	16.0	0.7	74	10	11[e]	380	14.4	337
Cedar Creek	179	9.0	4.2	79	94	14[e]	282	185.7	255
Little Bear Creek	61	7.1	1.6	82	45	12[e]	101	253.9	90
Beech	16	5.3	0.9	32	11	1[e]	14	616.2	9
Normandy	195	17.0	3.2	83	110	11	320	201.7	275

[a] Measurements based on normal maximum pool.
[b] Tennessee River and Reservoir System Operation and Planning Review, Final EIS, TVA/RDG/EQS-91/1, 1990.
[c] Major/minor arms of reservoir.
[d] Estimated flow based on releases from Chilhowee Dam (POR avg. = 4770cfs), and adjusted based on the additional drainage area between Chilhowee Dam (1977 sq miles) and Tellico Dam (2627 sq miles).
[e] Estimated based on difference between normal maximum summer pool and average minimum winter pool elevations.

5.0 DISCUSSION

The quality of water in a river system is a result of the quality of water flowing into it from many sources (e.g., tributary streams, discharges from metropolitan areas, overland runoff) and the internal physical, chemical, and biological processes which occur within the river. The water quality of major tributaries to a river is governed by geologic characteristics, rainfall, and human activities within the watershed.

The Tennessee River originates with the confluence of the French Broad and Holston Rivers at Knoxville, Tennessee. It receives water from a variety of tributaries reflecting the geochemical characteristics of the watersheds they drain. For example, the French Broad and Holston Rivers are nutrient-rich and moderately hard, with greater hardness in the Holston; the Little Tennessee and Hiwassee Rivers are soft and nutrient-poor; the Clinch River is hard with moderate nutrients; while the other two large tributaries, the Elk and Duck Rivers, are relatively hard and nutrient-rich.

Each tributary exerts its influence based on a wide variety of factors, but primarily the volume of inflow and concentrations of various chemical constituents. Nutrient levels are particularly important because of their direct influences on algal primary production and indirect influences on dissolved oxygen.

Just as the characteristics of the Tennessee River are a composite of its major tributaries, each major tributary has characteristics of its tributaries. Given the widely varying geochemical attributes and many different types of land use within a watershed, characteristics of streams and reservoirs vary greatly among major tributary watersheds. These characteristics are further influenced by the location, design, and operation of dams on streams in the watershed.

This report summarizes results and conclusions from 1993 monitoring activities in the Tennessee Valley. This chapter (Chapter 5) examines these results from a Valley-wide perspective. Chapters 6-17 present a watershed-by-watershed perspective for each of 12 delineated drainages that together comprise the Tennessee Valley. Volume II of this report is a detailed summary of the 1993 monitoring results in each of these 12 watershed areas.

5.1 Vital Signs Monitoring

5.1.1 Reservoirs

Reservoirs were divided into two categories for comparative purposes: run-of-the-river reservoirs (the nine mainstream reservoirs plus the two navigable tributary reservoirs) and the 19 tributary storage reservoirs. The primary differences between these two categories are retention time and changes in pool level due to winter drawdown; both have a great effect on the aquatic ecosystem. For comparative purposes, all reservoirs were categorized as good, fair, or poor based on their respective ecological health evaluations.

Run-Of-The-River Reservoirs--The ecological health of all 11 run-of-the-river reservoirs rated fair or better in 1993. The score for Fort Loudoun Reservoir (58 percent) was the lowest of the run-of-the-river reservoirs. This score fell just within the fair range; but low enough to be considered poor-fair. Three reservoirs rated fair - Tellico (63 percent), Watts Bar (68 percent) and Melton Hill (68 percent); four rated good - Nickajack (88 percent), Chickamauga (83 percent), Guntersville (78 percent), and Kentucky (75 percent); and the remaining three reservoirs fell close to the break point used to separate good and fair reservoirs ($\geq$72 percent) - Pickwick (73 percent), Wheeler (72 percent), and Wilson (71 percent).

Figure 5.1 shows an interesting geographical trend to these results. Reservoirs with the lowest scores were at the upstream end of the Tennessee River, followed by reservoirs with the highest scores, and then reservoirs with intermediate scores in the downstream portion of the Tennessee River. There are many factors which in combination result in the observed ecological conditions, and care must be taken not to oversimplify complex ecosystem dynamics. However, one obvious consideration would be the nutrient rich waters from the French Broad and Holston Rivers, coupled with high human population densities in east Tennessee. Together, these create a high potential for undesirable ecological conditions to exist in the upper Tennessee River. Inputs of fairly pristine waters from the Little Tennessee River, further supplemented by inflows from Hiwassee River with low nutrients further downstream, act to dilute the water in the Tennessee River and help diminish the potential for eutrophic conditions in Chickamauga, Nickajack, and Guntersville Reservoirs. In the lower half of the Tennessee River, water naturally rich in nutrients flows from the Elk River to Wheeler Reservoir and from the Duck River to Kentucky Reservoir, stimulating algal growth and potentially shifting ecological conditions toward a more productive state.

The four reservoirs with the lowest ecological health scores (Fort Loudoun, Tellico, Melton Hill, and Watts Bar) had multiple indicators that rated poor or very poor. These were generally dissolved oxygen, sediment, benthos, and/or fish assemblage. For the three reservoirs which scored good (Chickamauga, Nickajack, and Guntersville), all ecological health indicators rated fair or better, except for dissolved oxygen at the inflows to Nickajack and Guntersville Reservoirs. Scores for the next four reservoirs which scored fair to good (Wheeler, Wilson, Pickwick, and Kentucky) varied greatly depending upon the number and location of sample sites within the reservoir. Indicator ratings at sample sites on the Tennessee River portion of each reservoir (i.e., the main body of the reservoir) were fair or better, except for dissolved oxygen at the Wheeler and Wilson forebays. Sample sites in major embayments generally had several indicators with poor or very poor ratings.

Embayments were not monitored prior to 1993. Four of the largest embayments in the Tennessee Valley were included in 1993 monitoring activities--Big Sandy River embayment on Kentucky Reservoir, Bear Creek embayment on Pickwick Reservoir, Elk River embayment on Wheeler Reservoir, and Hiwassee River embayment on Chickamauga Reservoir. All four embayments have surface areas of about 5000 acres (about 2000 hectares) or greater and local drainage areas greater than 500 square miles (1295 km^2). Water quality characteristics within an embayment and the resulting ecological health conditions are largely controlled by factors within the embayment's immediate watershed and the rate of water exchange between the embayment and the main body of the reservoir. The Hiwassee and Elk River embayments have substantial flow through them. The Big Sandy and Bear Creek embayments have much smaller inflows and less water exchange with the main body of the reservoir.

Results from the Hiwassee River and Elk River embayment sites substantiate the above discussion of the potential for inflows from these rivers to affect conditions in the Tennessee River. All five ecological indicators rated good or excellent in the Hiwassee embayment. Three ecological health indicators were poor or very poor, one fair and one good in the Elk River embayment.

Inclusion of monitoring results from embayments had a substantial effect on reservoir health ratings for three of the reservoirs compared to previous years. For example, Kentucky Reservoir rated good (75 percent) in 1993, lower than the 1992 rating, when Kentucky had the best rating (88 percent) of all reservoirs examined. The primary factor responsible for this decrease was addition of the sample site in Big Sandy River embayment. If results from the Big Sandy River embayment were excluded from the overall reservoir score, the revised rating (83 percent) would be similar to that observed for 1992. Pickwick Reservoir had an ecological health rating of 73 percent for 1993. However, if the Bear Creek embayment information were deleted, the reservoir score would be 80 percent. A similar situation is true for Wheeler. The overall health rating for Wheeler would change from 72 percent to 82 percent if results from the Elk River embayment were excluded. Interestingly, the overall ecological health score for Chickamauga Reservoir would change little if results from the site in Hiwassee River embayment were excluded (i.e., 83 percent with and 81 percent without).

Another factor which lowered ecological health scores in the run-of-the-river reservoirs in 1993 was relatively low dissolved oxygen during summer 1993. Extreme summer weather in 1993 caused record high water temperatures and low DO in much of the Tennessee River. Special dam operations and water releases to reduce impacts from these conditions were started as soon as the low DO conditions were detected. Special monitoring showed these releases improved DO concentrations. However, DO concentrations were lower than in previous years causing lower scores for the overall health rating. (See Chapter 4, Hydrologic Overview of 1993, for additional detail.)

The ecological health score for one other reservoir (Tellico) changed substantially from previous years. The rating was 63 percent (fair) for 1993 compared to 48 percent in 1992 and 44 percent in 1991 (both poor). The primary causes of the higher score were better ratings for DO at the forebay (mostly the result of an improved, more accurate method of calculating the score for this indicator) and addition of information from the transition zone collection site which was relocated in 1993. The change in DO scoring resulted in forebay DO being rated fair in 1993; it had previously been rated poor. Two indicators, chlorophyll and DO, received excellent ratings at the new transition zone site; and the other three indicators rated poor. The higher ecological health score for 1993 is considered to be more representative of the true environmental conditions in Tellico Reservoir than scores in previous years.

<u>Tributary Reservoirs</u>--Monitoring on tributary reservoirs was not fully implemented until 1993. The number of tributary reservoirs included in Vital Signs monitoring expanded from three in 1990 to 19 in 1993. Also, the number of ecological health indicators expanded in 1993 when sediment quality and benthic macroinvertebrates were sampled for the first time on tributary reservoirs. Sample design for tributary reservoirs specifies less intensive monitoring for water chemistry constituents (most notably nutrients) than on the run-of-the-river reservoirs because of the more static nature of water within tributary reservoirs. Monitoring efforts for other ecological

indicators (chlorophyll, sediment, benthos, and fish) were the same on both run-of-the-river and tributary reservoirs for the first time in 1993.

The ecological health evaluations for the tributary reservoirs are more tentative than for the run-of-the-river reservoirs. The data base generally is quite small, and our understanding of how to weigh and integrate results from various ecological health indicators is still in development.

A problem associated with evaluating the ecological health of tributary reservoirs is the individuality of each reservoir. There is substantial variation in physical characteristics (depth, shoreline development, area, length), reservoir operations (retention time, drawdown, depth of outflow, etc.), watershed geochemistry, and land use. This individuality makes it difficult to establish reference or expected conditions, against which to rate the observed ecological characteristics as good, fair, or poor ecological health. (See Section 3.1 for additional discussion.)

Two attributes, long retention times and deep drawdowns, of tributary reservoirs particularly are significant. Long retention times create high potential for thermal and chemical stratification. As solar warming occurs in upper strata during spring and summer, bottom strata remain cold, and thermal stratification develops. If oxygen demand is sufficient, which is the typically the case, anoxia occurs in the bottom waters. Under these conditions, iron and manganese become more soluble, and their concentrations increase. If anoxia continues long enough, high levels of ammonia and sulfide also can develop. These conditions cause stresses to aquatic life and result in low ecological health ratings.

Deep drawdowns of the pool during winter, sometimes below the elevation of the summer thermocline, also have a pronounced effect on aquatic systems of tributary reservoirs. For example: (1) stable shoreline habitats cannot develop or persist; (2) benthic substrates in upper riverine reaches of the reservoir can be covered with sand and silt when the reservoir is full but be washed to gravel or bedrock when the area returns to a riverine environment at winter, low pool elevations; and (3) spring spawning sites can be left dry or covered with many feet of water depending upon dam operations during spring filling. Again, these have undesirable ecological effects.

Considering these factors, the ecological health of tributary reservoirs is not expected to be as good as run-of-the-river reservoirs. Results for 1993 support this expectation. No tributary reservoir rated good for ecological health, and only two rated fair-to-good. Both Fort Patrick Henry Reservoir and Blue Ridge Reservoir scored 72 percent, just at the break point used to indicate good or fair ecological health conditions. Interestingly, Fort Patrick Henry, even though a tributary reservoir, has retention time and drawdown characteristics like a run-of-the-river reservoir. Blue

Ridge Reservoir has quite low primary productivity, which, coupled with essentially a full depth withdrawal from the dam, helps prevent dissolved oxygen problems.

Only one tributary reservoir rated poor. Parksville (Ocoee No. 1) Reservoir scored 52 percent with poor scores for four of the five indicators. Dissolved oxygen had an excellent rating. This is contrary to expectations for a tributary reservoir, but this reservoir represents an unusual case. A very low oxygen demand exists in the hypolimnion due to very low primary productivity rates. The reservoir is recovering from years of pollution problems related to copper mining and industrial activities at Copperhill. A more thorough discussion of Parksville Reservoir is provided in Section 12.5. Two reservoirs (Normandy and Cedar) scored 56 percent, right at the break point between poor and fair. Dissolved oxygen was the primary problem in both cases. Of the remaining 14 reservoirs, eight rated near the middle of the fair range and six rated in the fair range just above poor (Figure 5.2).

Figure 5.2 indicates there were no geographical patterns associated with overall reservoir scores. No particular watershed had mostly high scoring or low scoring reservoirs. Also, physical characteristics such as size or depth seemed to have little influence on reservoir score.

The ecological health indicator which was most often associated with low ecological health scores was DO. As discussed above, this was expected. Poor or very poor DO scores occurred at one or more sample sites in 13 of the 19 tributary reservoirs sampled. All six tributary reservoirs in the middle and western part of the Tennessee Valley were in this group, along with seven of the 13 tributary reservoirs in the eastern, mountainous area of the Valley. The six reservoirs in the middle and western end of the Valley (Tims Ford, Normandy, Bear Creek, Little Bear Creek, Cedar Creek, and Beech Creek) exhibit strong thermal stratification, generally have high chlorophyll concentrations, and have substantial agriculture activities in their watersheds. The seven in the eastern end of the Valley vary greatly in a number of characteristics. Of these, four (Norris, Douglas, Cherokee, and Nottely Reservoirs) had all or mostly very poor DO ratings, followed by South Holston with one very poor rating and Boone and Fontana with only one poor rating and no very poor ratings.

Of the six reservoirs with fair, good, or excellent DO scores, two were in the Holston watershed (Fort Patrick Henry and Watauga), and four were in the Hiwassee watershed (Hiwassee, Chatuge, Blue Ridge, and Parksville). All except Fort Patrick Henry had relatively low nutrient and chlorophyll concentrations (most with seasonal chlorophyll averages below 3.0 $\mu g/L$). Although Fort Patrick Henry had high chlorophyll values, lack of stratification and short retention time helped maintain good DO concentrations.

In most cases, reservoirs with poor DO concentrations would be expected to have poor benthic macroinvertebrate communities. This was true for seven of the 13 reservoirs with DO problems. Interestingly, the remaining six reservoirs with poor DO had fair, good, or even excellent benthos scores. Norris and Cherokee Reservoirs in east Tennessee and Little Bear Creek, Cedar Creek, and Beech Creek Reservoirs in the western end of the Valley had very poor DO scores, yet fair benthic macroinvertebrate communities. Bear Creek, also in the western end of the Valley, had a very poor DO score yet an excellent benthos score. These results and their potential implications are difficult to interpret with only one year of benthic macroinvertebrate data available. Additional monitoring results should help clarify these results. An initial interpretation is that the benthic community is able to recover quickly between autumn reoxygenation of bottom sediments and sample collection the following spring. Another possibility is that some of the samples collected along the transect were above the oxygen-stressed stratum. Results from individual samples suggest both factors may have contributed to the observed ratings.

Just as reservoirs with poor DO ratings typically would be expected to have poor benthos, reservoirs with good DO levels would be expected to have a good benthos community, unless some other factor was negatively influencing the benthos. This was the case on Watauga, Hiwassee, and Parksville Reservoirs. All had fair to excellent DO scores yet all had poor or very poor benthic macroinvertebrate communities. Poor scores for Parksville Reservoir were not surprising, given the problems that reservoir has experienced over the years from upstream mining activities. Results for the other two reservoirs were unexpected. Acute toxicity to at least one test animal was observed in all three reservoirs. More detailed assessment efforts would be required to determine whether there is a real relationship between the apparent toxicity and poor benthic communities. Results from additional monitoring in 1994 will be examined closely to determine whether more detailed assessments should be planned.

5.1.2 Streams

Twelve of the major Tennessee River tributaries were included in Vital Signs Stream Monitoring in 1993 (Table 2.2). Six additional streams will be monitored beginning in 1994.

Results for 1993 showed a wide range of ecological conditions among the 12 streams. Three, Clinch, Powell, and Little Tennessee Rivers, had the highest possible scores for all four ecological health indicators (nutrients, sediment, benthic macroinvertebrates, and fish community).

The lowest score (50 percent) was for the French Broad River where nutrients and fish rated poor, benthos rated fair, and sediments rated good.

Scores for the remaining eight streams were evenly distributed within this range. The Emory and Hiwassee Rivers had good overall scores (90 and 88 percent, respectively) with fair ratings for benthos, the only indicator rating less than the maximum score at each stream. The Nolichucky and Sequatchie Rivers also rated good with scores of 80 percent each. At both streams, two indicators rated good and two fair. Three streams rated fair (Duck River-70 percent, Bear Creek-70 percent, and Holston River-68 percent). High nutrient concentrations on the Duck and Holston Rivers caused a poor rating for nutrients; the other three indicators rated fair or good. The lower score for Bear Creek was due to most indicators rating fair, rather than due to any indicator rating poor. Ratings for the remaining stream, Elk River, must be used conservatively because only three indicators were monitored in 1993. The fish community was not sampled in 1993. The overall score for the other indicators was 60 percent; nutrients rated poor, benthos fair, and sediment good. The fish community will be sampled in 1994.

The ecological health indicator that rated poor most often was nutrients. Four streams (Duck, Elk, Holston, and French Broad Rivers) received poor ratings for nutrients. Bear Creek and the Nolichucky River received a fair rating for nutrients and the remaining six streams rated good. All of these results were expected based on individual watershed characteristics.

5.2 Use Suitability Monitoring

5.2.1 Bacteriological Studies

Fifty-nine designated swimming beaches, 12 informal swimming areas, and 14 canoe launching or landing sites were sampled in 1993. All of the designated swimming beaches and informal swimming areas and eight of the canoe access sites met the regulatory criterion of having geometric mean concentrations of fecal coliform bacteria less than 200/100 mL if rainfall samples were excluded. Two swimming beaches, one each on Tims Ford and Watts Bar Reservoirs, and the canoe site sampled on the Elk River, slightly exceeded the criterion when rainfall samples were included. The four access sites on the Duck River exceeded the geometric mean criterion for both rainfall and nonrainfall samples.

Thirty-five nonrecreation sites were also sampled to provide generic bacteriological water quality data on Wilson, Guntersville, Nickajack, Fort Loudoun, Norris, Douglas, Cherokee, Fort Patrick Henry, Boone, South Holston, and Watauga Reservoirs; four sites were sampled on the

Duck, Clinch, and South Holston Rivers; and three sites on Spring, Beidleman, and Thomas Creeks. All but one reservoir site (Nickajack) and two stream sites (Beidleman and Thomas Creeks) met recreation criteria.

A comparison of the results of this survey with surveys in 1974, 1986, and 1989 through 1992 shows bacteria concentrations in 1974 and 1993 were similar, and lower than during the other years. The differences are probably caused by different weather conditions and sampling methods rather than reflecting long-term changes in bacteriological water quality.

Fecal coliform samples were taken in conjunction with Vital Signs monitoring activities on the 11 run-of-the-river reservoirs from April through September 1993. Fifteen of the 155 samples analyzed had concentrations greater than the normal detection limit of 10/100 mL, seven exceeded 100/100 mL. No location had more than one sample exceed 100/100 mL.

The results of studies summarized above are consistent with previous surveys. Fecal coliform concentrations were generally lower in 1993 due to lower than normal summer rainfall. Bacteriological water quality in most areas of TVA reservoirs is good. In streams it is much poorer, especially after rainfall.

5.2.2 Fish Tissue Studies

Availability of results for fish tissue studies is usually delayed because of the intricate laboratory procedures required to analyze fish tissue samples. This process usually takes several months; so results for samples collected in autumn usually are not available until the next spring. Results in this report are for fish collected during summer and autumn 1992. Additional fish were collected in summer and autumn 1993 but results were not available in time to be included in this report.

Screening Studies--Results of screening studies in 1992 did not indicate any new reservoirs or streams in need of intensive investigations. Two streams and six reservoirs had at least one analyte slightly elevated indicating a need to resample in autumn 1993 at the screening level. Streams included the Emory River (PCB concentration in channel catfish 1.1 μg/g) and the Holston River (mercury concentration in largemouth bass 0.57 μg/g). Reservoirs included Pickwick (DDTr 2.5 μg/g), Bear Creek (mercury 0.45 μg/g), Little Bear Creek (mercury 0.56 μg/g), Norris (PCBs 0.9 μg/g), Fontana (PCBs 1.1 μg/g and mercury 0.53 μg/g), and Cherokee (PCBs 0.8 μg/g). Although most reservoirs had multiple sites sampled, an elevated concentration of an analyte at any site would cause that reservoir to be included in this list.

All sites listed above were resampled in autumn 1993 for the same fish species. In addition, because several tributary reservoirs had somewhat elevated mercury concentrations, efforts in autumn 1993 were directed at better evaluating this condition by analyzing both channel catfish, the species typically used as the indicator, and largemouth bass, a top predator which would be expected to have higher mercury concentrations than catfish.

Intensive Studies--Six TVA reservoirs (Wheeler, Nickajack, Watts Bar, Fort Loudoun, Melton Hill, and Parksville) were examined intensively in 1992. Intensive studies are conducted on reservoirs where a contaminant problem is known or suspected. PCBs was the contaminant of interest on all these reservoirs, except Wheeler, where DDTr (total DDT) is the problem. Chlordane was also of interest in some of these reservoirs. Fish consumption advisories which recommend either limiting the quantity of fish eaten or avoiding any consumption are in effect for all six reservoirs except Parksville. These advisories issued by the Tennessee Department of Environment and Conservation and by the Alabama Department of Public Health are based in part on the results of these studies.

Results from autumn 1992 collections indicated somewhat lower concentrations of DDTr in fish from Wheeler Reservoir and PCBs in fish from Nickajack Reservoir. Lower concentrations in one year should not be interpreted as a significant decrease in contaminant concentration. Previous results have shown substantial year-to-year variability. The long-term study on Watts Bar Reservoir identified substantially lower PCB concentrations in 1989 and 1990 than in previous years. Subsequent results for 1991 and 1992 returned to the higher concentrations of previous years. For this reason, comparable studies were repeated on these reservoirs in autumn 1993.

Results of 1992 fish tissue samples from Watts Bar, Fort Loudoun, and Melton Hill Reservoirs generally fell within the range observed in previous years. Likewise, limited results for Tellico Reservoir fell within historical ranges.

Screening studies on Parksville (Ocoee No. 1) Reservoir over the past several years have found PCB concentrations near the level used by the state of Tennessee to issue a "Limit Consumption" advisory. As a result, TVA and the state designed and conducted a more detailed sampling of fish from there in autumn 1992. Results of the 1992 effort confirmed previous results of relatively high PCB concentrations in channel catfish - the average of ten fish was 1.5 $\mu g/g$ at the forebay and 1.0 $\mu g/g$ at an upper reservoir location. Largemouth bass were also examined and found to have lower concentrations than catfish--averages at the two sites were 0.6 and 0.7 $\mu g/g$, respectively. Bluegill sunfish and rainbow trout composites from these areas had low concentrations. There had been no action taken on these results at the time this report was prepared.

Figure 5.1 Overall Ecological Health of Run-of-the-River Reservoirs in the Tennessee Valley in 1993. (Ecological Health Indicators are shown as a proportion of their contribution to the overall score for each reservoir.)

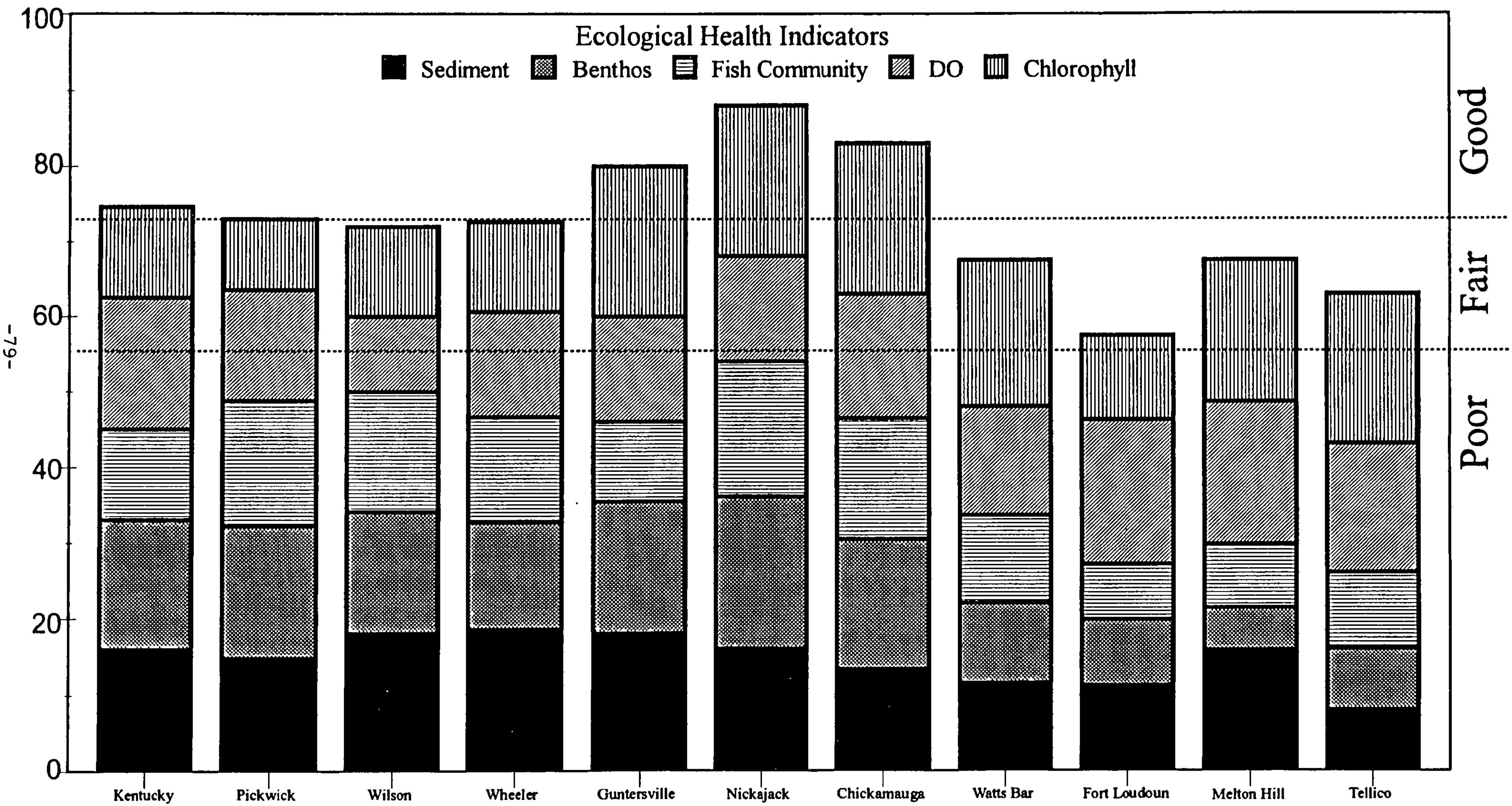
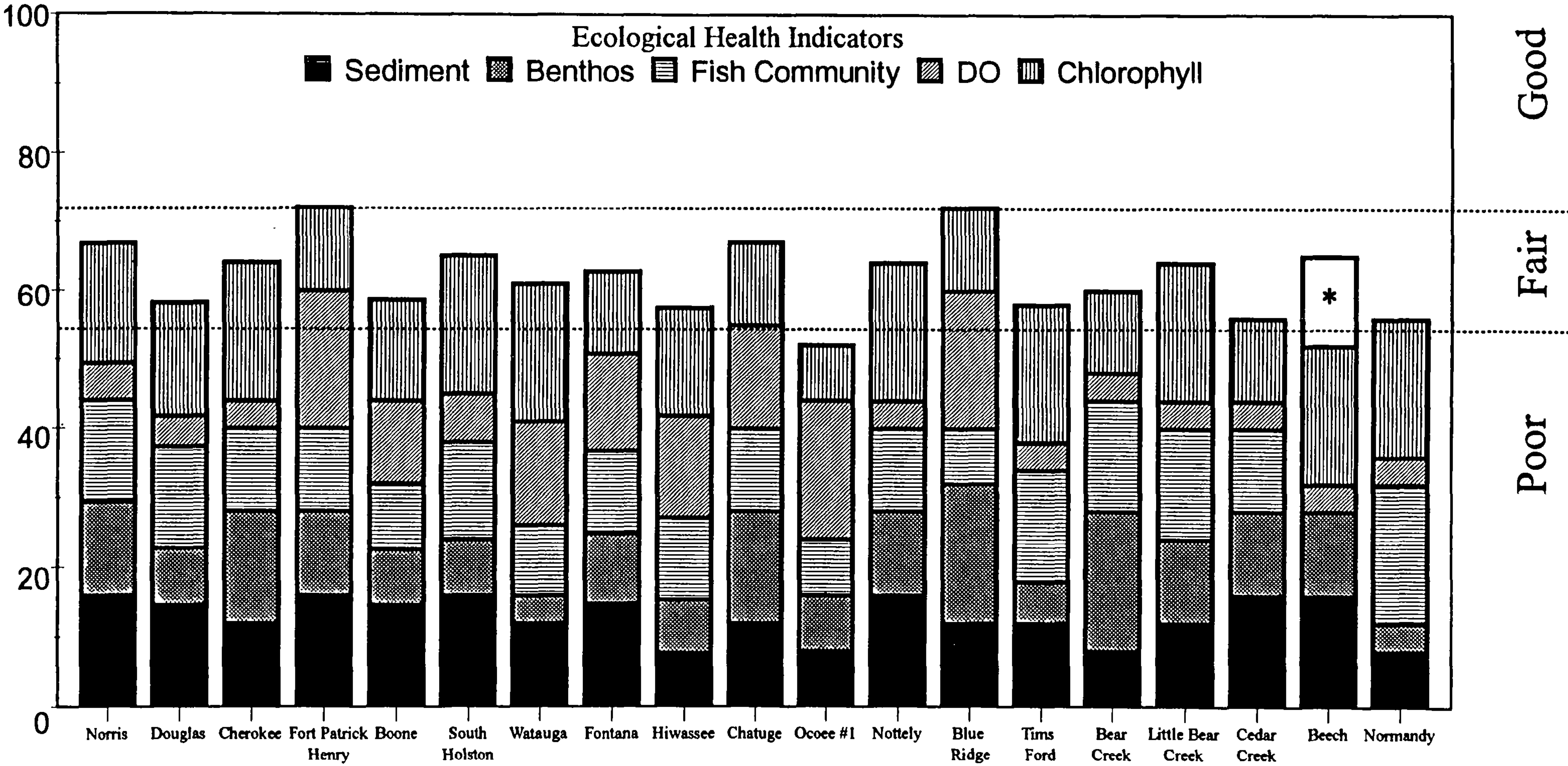


Figure 5.2 Overall Ecological Health of Tributary Reservoirs in the Tennessee Valley in 1993.

(Ecological Health Indicators are shown as a proportion of their contribution to the overall score for each reservoir.)



* Beech Reservoir score is based on four rather than five indicators; indicator and overall scores are shown on the same scale as other reservoirs to facilitate comparisons.

6.0 KENTUCKY RESERVOIR WATERSHED

The Kentucky Reservoir watershed area includes all streams flowing into the Tennessee River downstream of Pickwick Landing Dam at Tennessee River mile (TRM) 206.7 to the confluence of the Tennessee River with the Ohio River. The one exception is the Duck River which is considered a separate watershed. The Kentucky Reservoir watershed area is relatively large (4590 square miles) and has an average annual discharge of about 66,600 cfs. Of that, about 82 percent (54,000 cfs) comes into Kentucky Reservoir from Pickwick Landing Dam. The Duck River supplies about 6 percent (4075 cfs), with the remaining 11 percent coming from local inflows.

Kentucky Reservoir is the dominant feature of this watershed. There are four monitoring sites on Kentucky Reservoir--forebay, transition zone, inflow, and Big Sandy River embayment (Figure 6.1 and Table 2.1). Information from 1993 monitoring activities on Kentucky Reservoir is provided in Section 6.1.

The watershed also includes the seven small reservoirs on the Beech River. The largest, Beech Reservoir, is the only one included in Vital Signs monitoring. Given its small size, the forebay is the only site monitored (Figure 6.1). Monitoring information for Beech Reservoir for 1993 is in Section 6.2.

There were no stream monitoring sites in this watershed in 1993. Beginning in 1994, a site will be established on the Clarks River for monitoring biological conditions.

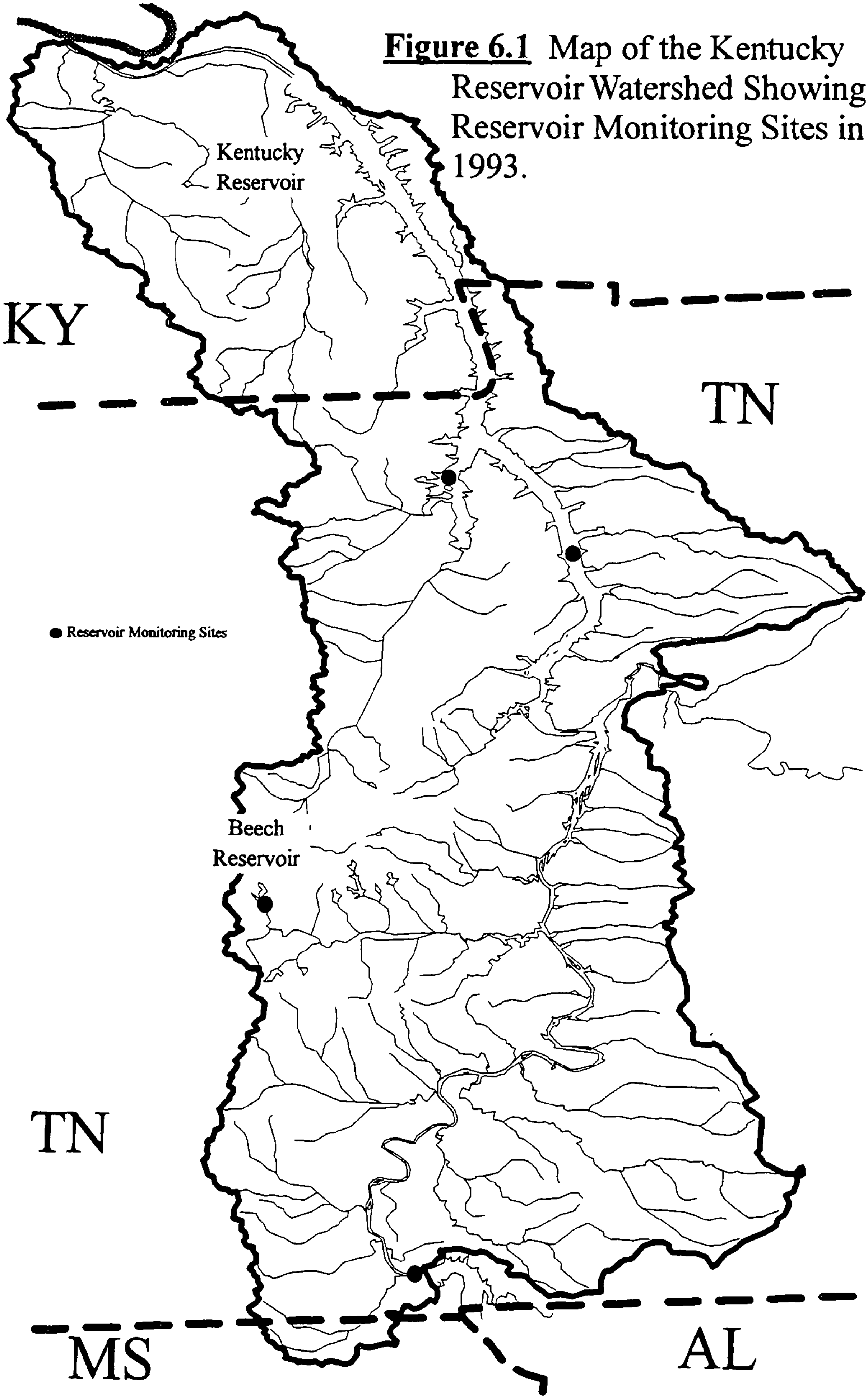


Figure 6.1 Map of the Kentucky Reservoir Watershed Showing Reservoir Monitoring Sites in 1993.

6.1 Kentucky Reservoir

Physical Description

Kentucky Reservoir is the largest reservoir on the Tennessee River. The dam is located at Tennessee River Mile (TRM) 22.4, and the reservoir extends 184 miles upstream to Pickwick Dam at TRM 206.7. At full pool the surface area is 160,300 acres, and the shoreline is 2280 miles. Average annual discharge is about 66,600 cfs, which provides an average hydraulic retention time of about 22 days. Additional information about Kentucky Reservoir is provided in Table 4.1.

The Duck River, a major tributary to the Tennessee River (and Kentucky Reservoir), provides about 6 percent of the total flow through Kentucky Reservoir. The confluence of the Duck River with the Tennessee River is at TRM 110.7.

The transition zone sample location was moved prior to the 1992 sample season from TRM 112.0 to TRM 85.0. Results for 1990 and 1991 at TRM 112.0 indicated that location was more representative of a riverine environment than a transition environment. The 1992 and 1993 results indicate the new transition zone site is correctly located.

Vital Signs monitoring was expanded in 1993 to include a sample site in four of the largest embayments in the Tennessee Valley. One, the Big Sandy River embayment on Kentucky Reservoir, is the largest embayment in the Tennessee Valley. It covers 15,238 surface acres and has over 93 miles of shoreline. Because its watershed is only 629 square miles, there is very little water exchange.

Ecological Health

The ecological health of Kentucky Reservoir rated good (75 percent) in 1993. This is lower than the ecological health index for 1992, when Kentucky had the best rating (88 percent) of all reservoirs examined. It is also lower than the overall rating in 1991. Primary factors responsible for this decrease were lower dissolved oxygen (DO) concentrations due to the hot, dry summer of 1993, and the addition of a sample site in Big Sandy River embayment. If results for the sample site in Big Sandy embayment were excluded from calculating the overall reservoir score, the revised rating (83 percent) would be similar to that observed for 1992.

The transition zone was the best of the four sites examined in 1993. All ecological health indicators (DO, chlorophyll-a, sediment quality, benthos, and fish) rated good or excellent at that site. The site in the Big Sandy embayment approached the other extreme. Three indicators rated poor or very poor: chlorophyll because of high concentrations, sediment quality because of high ammonia and toxicity to test organisms, and fish assemblage because of low fish abundance and species richness. No indicators at the other two sites (forebay and inflow) rated poor or very poor.

Aquatic plants covered about 3465 acres in 1993 compared to about 2600 acres in 1992 and 2800 in 1991. Most plants were found around islands and shallow embayments downstream of the Duck River.

Reservoir Use Suitability

Use Suitability monitoring activities did not identify any impairments on Kentucky Reservoir in 1993. Twenty-four recreation sites have been sampled for fecal coliform bacteria one or more times on Kentucky Reservoir since 1989. None has exceeded the geometric mean criteria for recreation. In 1992 three sites exceeded one of EPA's recommended guidelines--more than 10 percent of the samples had fecal coliform concentrations greater than 400/100 mL. In 1993 these three sites were resampled, and all met the EPA guideline. Fecal coliform bacteria concentrations have been very low at the Vital Signs locations sampled since 1990.

Examination of channel catfish fillets in autumn 1992 from six locations between Kentucky and Pickwick Dams found only low levels of heavy metals and pesticides at all locations. The only analyte high enough to be of interest was lead at 0.6 $\mu g/g$ at one location in 1992. Similar concentrations have been found sporadically in previous years, but there has been no pattern in space or time.

6.2 Beech Reservoir

Physical Description

Beech Reservoir, the largest of seven small flood control projects on the Beech River system in western Tennessee, is formed by Beech Dam at Beech River mile 35.0. Beech Reservoir is only 5.3 miles long and averages only about 12 feet deep. It has no hydropower generating facilities, but is the primary source of water for the city of Lexington. The reservoir is an urban lake with considerable residential lakefront development. Consequently, it receives a large amount of recreational use relative to its small size (about 900 acres). Discharge from Beech Dam averages only about 14 cfs per day, resulting in a long hydraulic residence times of 300 to 400 days.

Reservoir Health

During 1991 and 1992 only water quality monitoring was conducted in Beech Reservoir. The 1991 and 1992 data indicated poor ecological health in Beech Reservoir, as evidenced by very low concentrations of dissolved oxygen and high chlorophyll-a concentrations.

In 1993 four of the five ecological health indicators (algae, dissolved oxygen, sediment quality, and benthos) were sampled on Beech Reservoir. Overall, the ecological health rated fair (65 percent). Chlorophyll rated excellent (at the upper end of the mesotrophic range), below observed concentrations during 1991 and 1992. As expected, DO rated very poor. Sediment quality rated good and benthic macroinvertebrates rated fair. The fish assemblage will be added to the sampling regime in 1994.

Reservoir Use Suitability

No bacteriological studies were conducted in 1993. Fecal coliform concentrations were low at the swimming beach in 1990. There are no fish consumption advisories on Beech Reservoir. Fish tissue samples have not been collected by TVA from this reservoir.

7.0 DUCK RIVER WATERSHED

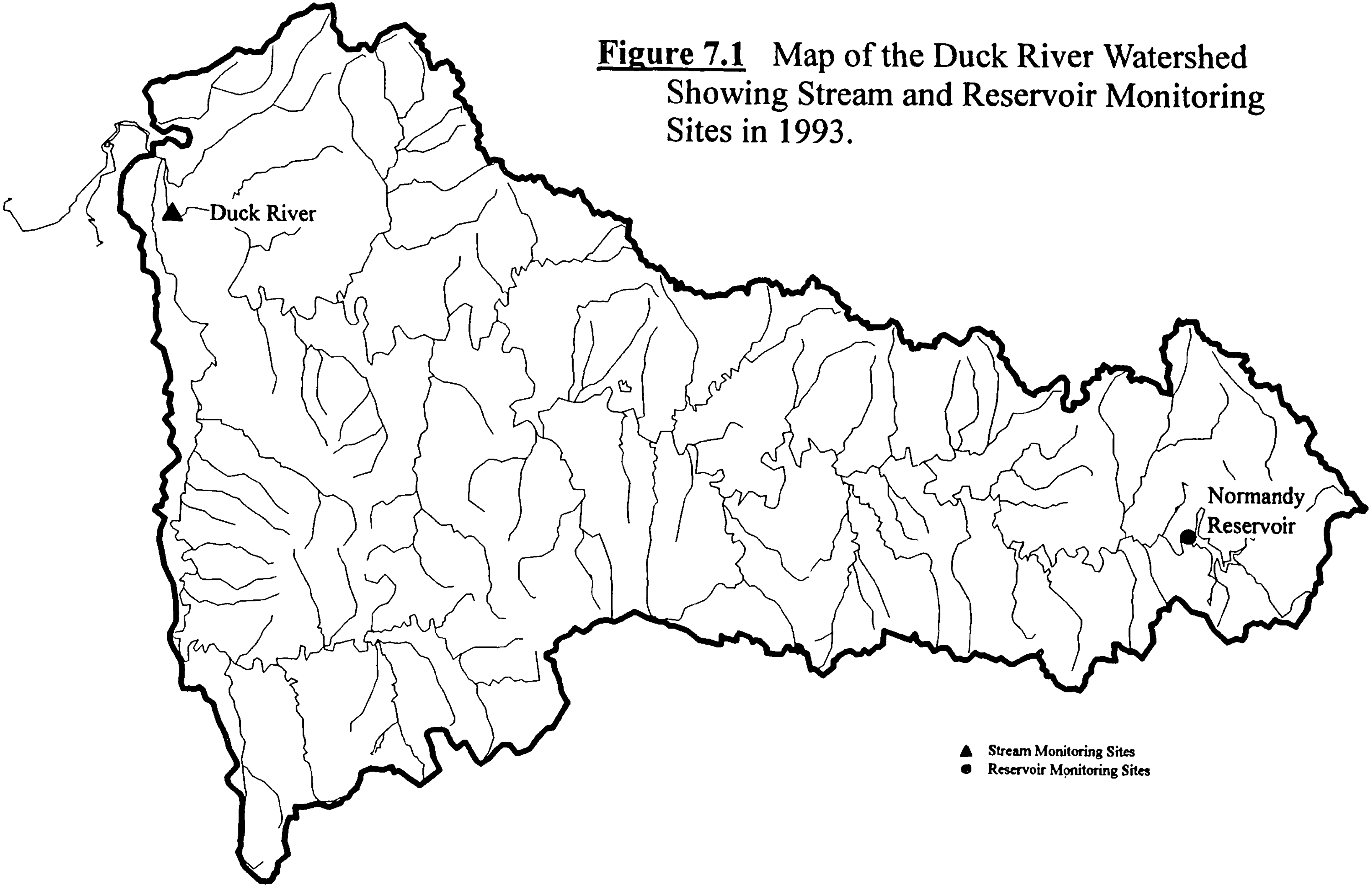
The Duck River Watershed includes all streams flowing into the Duck River. It has an area of 3500 square miles and an average annual discharge of 4075 cfs to Kentucky Reservoir on the Tennessee River. The Duck River basin is underlain almost entirely by limestone, or phosphatic limestone; consequently, waters in the streams draining this basin are fairly hard and contain large concentrations of minerals. Large deposits of phosphate ores permit phosphate mining and refining operations in the basin. Phosphate concentrations in surface and groundwater are significantly higher than in most of the Tennessee Valley. The soils are thin with limestone outcrops at the surface in many places, and sinkholes are common throughout the watershed.

Normandy Reservoir is the only reservoir in this watershed. This is a relatively small reservoir and only the forebay is included in the Vital Signs monitoring program (Figure 7.1).

There is one stream monitoring site on the Duck River at mile 26.0 (Figure 7.1).

Information from monitoring activities on Normandy Reservoir and the Duck River are in Sections 7.1 and 7.2, respectively.

Figure 7.1 Map of the Duck River Watershed Showing Stream and Reservoir Monitoring Sites in 1993.



7.1 Normandy Reservoir

Physical Description

Normandy Reservoir is formed by Normandy Dam at Duck River mile (DRM) 248.6. Normandy Reservoir, constructed primarily for flood control and water supply, has a drainage area of 195 square miles and no electric power generation capacity. One of TVA's smaller reservoirs, Normandy at full pool elevation has about 3200 surface acres, 73 miles of shoreline, and about 17 miles of impounded backwater. The reservoir has an average depth of about 35 feet and an average annual drawdown of about 11 feet. The average annual discharge from Normandy Dam is about 320 cfs, providing an average annual retention time of about 175 days.

Ecological Health

The ecological health of Normandy Reservoir rated poor-fair (56 percent) in 1993. Vital Signs monitoring previously had not been conducted on this reservoir, although several special studies had been completed. As expected, DO conditions were among the poorest observed on any Vital Signs reservoir in 1993. DO rated very poor because anoxia existed, 77 percent of the cross-sectional bottom length had DO concentrations <2.0 mg/L, and 48 percent of the cross-sectional area had DO levels <2.0 mg/L. Sediment quality rated poor due to high levels of ammonia and toxicity to test animals. Benthic macroinvertebrates also rated very poor, likely due to such poor bottom conditions.

Based on past studies, there was concern about very high levels of primary productivity in Normandy Reservoir. Sampling in 1993 did not find this to be the case. Chlorophyll rated good at the forebay sample location because the annual average chlorophyll concentration was within the mesotrophic range, and no single sample had a very high chlorophyll concentration.

The other indicator, fish assemblage, rated excellent. Normandy Reservoir had one of the best fish assemblages examined on tributary reservoirs in 1993. Most of the 12 metrics received the highest possible score.

Reservoir Use Suitability

Fecal coliform samples were collected at two swimming beaches and three boat ramps in 1992. While concentrations were low at the boat ramps, several samples were high at each of the beaches, although the geometric means were well within recreation criteria. The two beaches were sampled again in 1993. Fecal coliform concentrations were much higher, but the geometric means were still within criteria. Local geese populations are the probable source of the high bacteria concentrations.

There are no fish consumption advisories on Normandy Reservoir. A composite sample of channel catfish collected from the forebay in autumn 1992 was screened for pesticides, PCBs, and selected metals. All analytes were either not detected or found in only low concentrations.

7.2 Duck River Stream Monitoring Site

Physical Description

The Duck River flows westward from its headwaters in northwestern Coffee County, Tennessee, for more than 280 miles through the Nashville basin and Highland Rim physiographic provinces in middle Tennessee to meet the Tennessee River. The basin is approximately 125 miles long and 30 miles wide and drains 3500 square miles.

The stream monitoring location is at the USGS stream gage above Hurricane Mills, Tennessee. The Duck River basin above Hurricane Mills is 2557 square miles or 73 percent of the entire Duck River basin. Principal tributaries in the monitored area include the Piney River (223 square miles), Big Swan Creek (155 square miles), Lick Creek (101 square miles), and Big Bigby Creek (129 square miles) which drain the Highland Rim province; and Rutherford Creek (116 square miles), Fountain Creek (103 square miles), Big Rock Creek (121 square miles), and Garrison Fork (130 square miles) which drain the Nashville Basin. Normandy Dam forms the only major impoundment located on the upstream reach of the Duck River stream monitoring site.

A principal tributary that flows into the Duck River below the stream monitoring location is the Buffalo River that drains 764 square miles (22 percent of the Duck River basin). The Buffalo River basin lies entirely within the Highland Rim province and the streams generally contain low concentrations of dissolved minerals.

Ecological Health

The stream monitoring site on the Duck River showed generally fair ecological health in 1993, similar to 1992. This was driven by high phosphorus concentrations and fair conditions for the fish community. Sediment quality and the benthic macroinvertebrate community both rated good, an improvement over 1992 observations. Undesirable conditions at this site included extensive bank erosion and unstable bottom substrate conditions. Although the Duck contributes only about 6.5 percent of the total flow of Kentucky Reservoir under average flow conditions, it can contribute significant amounts of nutrients and sediment to the reservoir.

Use Suitability

A reach of the Duck River from 3.5 to 7.1 miles downstream of Normandy Dam was found to greatly exceed bacteriological criteria for water contact recreation in 1993, probably due to dairies.

All metal and organic analytes in fish tissue samples were not detected or found in low concentration.

8.0 PICKWICK RESERVOIR - WILSON RESERVOIR WATERSHED

Pickwick Reservoir and Wilson Reservoir on the Tennessee River are the most notable features of this drainage area. Only a small part of the flow leaving this watershed actually originates within the watershed itself. The average annual discharge from Pickwick Dam is 54,900 cfs. Of that, 49,500 cfs (90 percent) is the discharge from Wheeler Dam into Wilson Reservoir. About 2100 cfs enters Wilson Reservoir through local tributaries and about 3400 cfs originates in tributaries to Pickwick Reservoir. The streams within this watershed drain an area of about 3230 square miles. The largest tributaries are Bear Creek, a tributary to Pickwick Reservoir with a drainage area of about 945 square miles, and Shoal Creek, a tributary to Wilson Reservoir, with a drainage area of about 445 square miles.

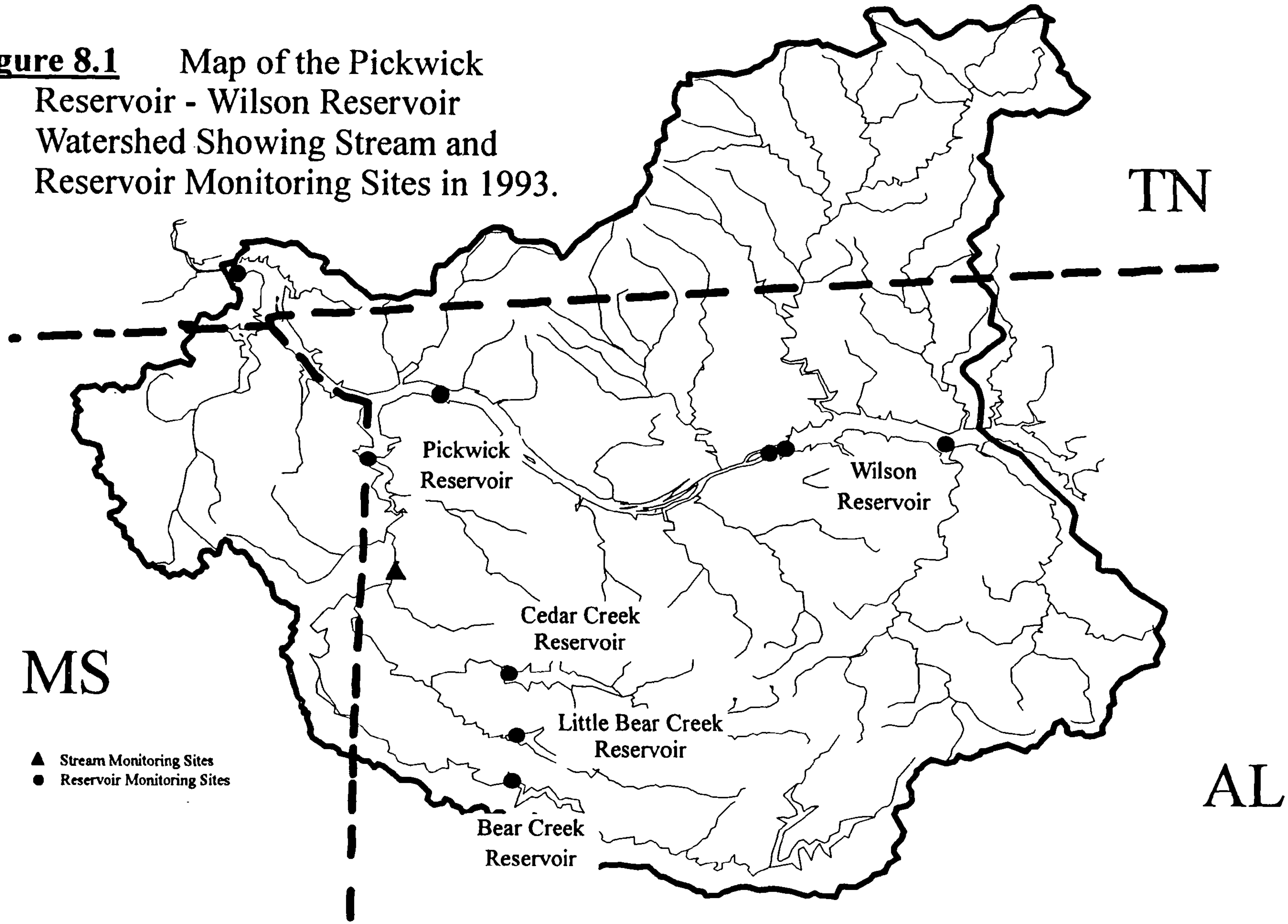
Four small reservoirs were built on Bear Creek in the late 1970s and early 1980s for flood control and recreation. These are Bear Creek, Little Bear Creek, Cedar Creek, and Upper Bear Creek Reservoirs.

Reservoir monitoring activities occur at the forebay, transition zone, and inflow on Pickwick Reservoir and at the forebay and inflow on Wilson Reservoir (Figure 8.1). Wilson is relatively short and has no definable transition zone. Because of their smaller size, only the forebays of Bear Creek, Little Bear Creek, and Cedar Creek Reservoirs are monitored. No monitoring activities are conducted on Upper Bear Creek because of TVA's program to destratify and oxygenate water in the forebay.

The only stream monitoring site is on Bear Creek at Bear Creek mile 27.3. Results for 1993 reservoir and stream monitoring activities within this watershed are provided in the following sections:

- 8.1 Pickwick Reservoir
- 8.2 Wilson Reservoir
- 8.3 Bear Creek Reservoir
- 8.4 Little Bear Creek Reservoir
- 8.5 Cedar Creek Reservoir
- 8.6 Bear Creek Stream Monitoring Site

Figure 8.1 Map of the Pickwick Reservoir - Wilson Reservoir Watershed Showing Stream and Reservoir Monitoring Sites in 1993.



8.1 Pickwick Reservoir

Physical Description

Pickwick Reservoir is immediately upstream of Kentucky Reservoir on the Tennessee River. Pickwick Dam is located at TRM 206.7. Like the rest of the mainstream, run-of-the-river reservoirs, Pickwick is much shorter (53 miles long) and smaller (43,100 acres and shoreline of 496 miles) than Kentucky Reservoir. Average annual discharge is about 55,000 cfs, which provides an average hydraulic retention time of about eight days. Additional information about reservoir characteristics is in Table 4.1.

A major tributary, Bear Creek, joins the Tennessee River in Pickwick Reservoir at about mile 225. Bear Creek provides, on the average, about 2.5 percent of the flow through Pickwick Reservoir.

Reservoir Monitoring activities were expanded on Pickwick Reservoir in 1993 to include a Vital Signs monitoring site in Bear Creek embayment. This rather large embayment (7200 acres) extends from the mouth of Bear Creek upstream about 17 miles to the point where flow is not affected by backwater from Pickwick Dam.

Ecological Health

The ecological health of Pickwick Reservoir was fair to good in 1993 (73 percent), similar to 1992 and 1991. All ecological health indicators rated between fair and excellent at all locations, except chlorophyll, which rated very poor (indicating high algal productivity) at the new sample site in Bear Creek embayment. There was a general decline in DO conditions throughout the reservoir in 1993 with DO rated fair to good at all locations. In 1992 DO was good to excellent at all locations. Summer 1993 was characterized by low rainfall, low flows, and high temperatures, hence lower DO concentrations were expected.

Conditions at the transition zone improved in 1993 for chlorophyll and sediment quality. Sediments contained lower mercury concentrations than in previous years; however, concentrations were still slightly above background. Although chlorophyll concentrations were in the fair range in 1993 (because of relatively high average concentrations), this was an improvement over 1992 when concentrations were even higher.

Benthic macroinvertebrates at the inflow location, downstream of Wilson Dam, were improved in 1993, rating excellent as compared to fair in 1992 and poor in 1991. The improvement between 1991 and 1992 was partly due to an improved evaluation system and partly due to actual improvements in the health of the community of bottom animals. The 1993 results indicate continued improvements in the benthos.

At the forebay, the fish assemblage evaluation has shown substantial variation from year to year. The rating was good in 1991, poor in 1992 (very few fish collected), and good in 1993. Interestingly, a low number of fish were collected from this location by electrofishing in 1993, yet an abundance of fish were collected by gill netting. The 1992 rating was based only on electrofishing results, whereas the 1993 rating was based on results from both techniques. Overall, there appeared to be little change in the fish assemblage among years.

The new sample site in Bear Creek embayment had one very poor indicator (chlorophyll--too high), three fair indicators (DO--zero on bottom; sediment--toxicity to test organisms; benthos--mostly tolerant organisms present), and one good indicator (fish). Of the four sites sampled on Pickwick Reservoir in 1993, the Bear Creek embayment site had the poorest ecological health. If results for this site were deleted from calculating the overall reservoir score, the reservoir score would be 80 percent.

There were only about 105 acres of aquatic plants on Pickwick Reservoir in 1993, similar to the 100 acres in 1992.

Reservoir Use Suitability

Use Suitability monitoring did not identify bacteriological nor fish tissue contamination problems. There are no fish consumption advisories on Pickwick Reservoir based on fish collected from 1988 through 1992. Concentrations of metals, PCBs, and pesticides in composited catfish fillets were relatively low except for total DDT concentrations in the fall 1992 inflow sample. Given the rare occurrence of elevated total DDT concentrations in fish from Pickwick, it is likely that one of the catfish in the composite came from Wheeler Reservoir, which has a significant, localized DDT contamination problem. Fecal coliform bacteria concentrations were low at ten swimming areas sampled in 1993. Bacteria concentrations at the Vital Signs locations sampled since 1990 have been low.

8.2 Wilson Reservoir

Physical Description

Wilson Reservoir is quite different from other mainstream Tennessee River reservoirs in both length and depth. Wilson Dam is located at TRM 259.4 and Wheeler Dam is at TRM 274.9, providing a length of only 15.5 miles, a shoreline of 154 miles, and surface area of 15,500 acres. Water depth in the forebay is slightly over 100 feet. This short, deep pool, coupled with the largest hydroelectric generating plant in the TVA system, provides for short hydraulic retention times (six days). Average annual discharge from Wilson is 51,500 cfs. Because of the physical characteristics, design, and operation of Wilson Dam (primarily upper strata withdrawal for hydropower generation), low DO conditions develop in deeper strata of the forebay during summer months.

Ecological Health

Ecological health of Wilson Reservoir improved somewhat in 1993 compared to 1992 and 1991. Overall, Wilson Reservoir rated fair to good (71 percent) in 1993 compared to 60-70 percent in previous years. One of the persistent problems in Wilson Reservoir is low concentrations of dissolved oxygen (< 1 mg/L) in the forebay during summer months. The problem was more severe in summer 1993 due to the drought conditions (high temperatures, low rainfall, and low flows). Anoxia developed near the bottom, and a large proportion of the bottom and water column had DO concentrations <2.0 mg/L, leading to a very poor rating.

A massive algal bloom caused extremely high chlorophyll concentrations at the forebay in 1992 resulting in a poor rating that year. Chlorophyll concentrations were lower in 1993, but still relatively high and, therefore, rated fair in 1993. The benthic macroinvertebrate community at the forebay rated better in 1993 (fair) compared to previous years (consistently poor). Poor ratings had been attributed to the low concentrations of DO near bottom during summer. Given that benthos collections were made in March 1993, prior to the severe DO problems later that summer, these samples would have been more representative of 1992 conditions. Even though DO concentrations in summer 1992 were not good, they were the best documented on Wilson since the Vital Signs monitoring program began in 1990. The duration of low DO concentrations was relatively short in 1992 and the proportion of bottom with low DO concentrations was small. These conditions may have provided sufficient opportunity for recolonization of several benthic species resulting in the improved community rating for 1993. Samples to be collected in March 1994 will help determine whether this hypothesis is correct. If correct, the benthos rating for 1994 should be poor because of the severe DO conditions in summer 1993.

Sediment quality at the forebay was good in 1992 and 1993, indicating no impairment due to bottom substrates. This was an improvement over 1991 when fair sediment quality conditions were found due to lower survival rates for test organisms. All ecological health indicators measured at the inflow location (DO, fish, and benthos) were good or excellent in 1993.

There were only 54 acres of aquatic plants on Wilson Reservoir in 1993.

Reservoir Use Suitability

There are no fish consumption advisories on Wilson Reservoir based on fish tissue studies conducted over the past several years.

Fecal coliform bacteria concentrations were very low at the two boat ramps tested in 1993 and at the Vital Signs location in the forebay. The low rainfall in 1993 may have contributed to low concentrations at the boat ramps. All fecal coliform samples collected in the forebay since 1990 have been low.

8.3 Bear Creek Reservoir

Physical Description

With a surface of only 700 acres, Bear Creek is one of the smallest reservoirs in the TVA system. It is relatively long (16 miles), narrow, and deep (74 feet at the dam). The average annual discharge is 380 cfs providing an average hydraulic retention time of about 13 days. Average annual drawdown is about 11 feet. Bear Creek Reservoir stratifies in the summer and develops hypolimnetic anoxia. Another water quality concern is abandoned strip mines in the watershed.

Ecological Health

The ecological health of Bear Creek Reservoir rated fair (60 percent) in 1993. Vital Signs monitoring previously had not been conducted on this reservoir. This reservoir appears to have a high rate of primary productivity and significant hypolimnetic DO depletion. Summer chlorophyll concentrations were higher on Bear Creek Reservoir than on any of the other tributary reservoirs monitored in 1993. Only one of the five indicators (benthic macroinvertebrates) rated excellent and one rated good (fish). Such high ratings would not be expected given the very poor rating for DO (anoxia and large proportion of the water column with low DO concentrations) and poor rating for sediment quality (high ammonia and toxicity to test animals). Continued monitoring in future years will help to better define the ecological health of Bear Creek Reservoir.

Use Suitability

Fecal coliform bacteria concentrations were low at both of the swimming areas surveyed in 1993. The low rainfall in 1993 may have contributed to low concentrations. During a wetter period in 1991, fecal coliform concentrations were higher, but still well within water quality criteria for recreation. A single composite of channel catfish was collected from the forebay in autumn 1992. All metal and organic analytes were low or not detected, except for mercury which was high enough to warrant reexamination in autumn 1993 but not high enough to indicate a need for an in-depth, intensive study.

8.4 Little Bear Creek Reservoir

Physical Description

Little Bear Creek Reservoir is relatively short (7.1 miles long) and deep (84 feet at the dam). It has a surface area of 1600 acres. With an average annual discharge of 101 cfs, the hydraulic retention time is 225 days. Compared to Bear Creek Reservoir, the lower flow into the reservoir and larger reservoir volume make the retention time much longer in Little Bear Creek Reservoir. Average annual drawdown is about 12 feet.

Ecological Health

Little Bear Creek Reservoir had a fair (64 percent) ecological health rating in 1993. This was the first year for Vital Signs monitoring on Little Bear Creek Reservoir. Similar to the other reservoirs in the Bear Creek watershed, the most obvious problem was very poor DO conditions at the forebay. Other indicators rated good (chlorophyll and fish assemblage) or fair (sediment quality and benthos). Given the hot, dry summer of 1993, additional information in future years will help to better evaluate and define the ecological health of Little Bear Creek Reservoir.

Reservoir Use Suitability

Fecal coliform bacteria concentrations were very low at both swimming areas tested in 1993. The low rainfall in 1993 may have contributed to low concentrations. During a wetter period in 1991, fecal coliform concentrations were much higher at both beaches. During the 1991 survey period, bacteriological water quality at both sites was within state water quality criteria for recreation; however, both exceeded one of EPA's recommended guidelines--more than 10 percent of the samples had fecal coliform concentrations greater than 400/100 mL.

A composite of channel catfish was collected from the forebay of Little Bear Creek Reservoir in autumn 1992. Only one metal analyte (mercury) was detected, and no PCB or pesticide analytes were detected. The mercury concentration (0.56 $\mu g/g$) was relatively high. As a result, channel catfish from this site were reexamined in autumn 1993. Results were not available at the time this report was prepared.

8.5 Cedar Creek Reservoir

Physical Description

Like the other reservoirs in the Bear Creek watershed, Cedar Creek Reservoir is small (only nine miles long and 4200 acres surface area) and deep (79 feet at the dam). The low average annual discharge from the dam (282 cfs) creates a relatively long average retention time (168 days). This combination of physical features lead to thermal stratification and hypolimnetic anoxia in the summer. Average annual drawdown is about 14 feet.

Ecological Health

The ecological health of Cedar Creek Reservoir rated poor-fair (56 percent) in 1993, the first year of Vital Signs monitoring. As expected based on the other reservoirs in the Bear Creek watershed, DO rated very poor because of anoxic conditions and a very large proportion of both the bottom and the water column with DO concentrations <2.0 mg/L. Chlorophyll, benthos, and fish assemblage all rated fair. The only fair to good rating was for sediment quality. There were no excellent ratings.

Reservoir Use Suitability

Fecal coliform bacteria concentrations were low at the Slickrock Ford swimming area in 1993. The low rainfall in 1993 may have contributed to low concentrations. During a previous survey period in 1991 with more normal rainfall, higher fecal coliform concentrations were found. Despite being higher, they were within state water quality criteria for recreation.

A single composite of channel catfish fillets collected from the forebay of Cedar Creek Reservoir in autumn 1992 did not have detectable concentrations of any pesticide or PCB analyte. Mercury, found at a low concentration, was the only metal analyte detected.

8.6 Bear Creek Stream Monitoring Site

Physical Description

Bear Creek flows through the southwest boundary of the Highland Rim physiographic province in northwestern Alabama (85 percent) and northeastern Mississippi to join the Tennessee River as an embayment of Pickwick Reservoir. The Bear Creek watershed is approximately 65 miles long and 15 miles wide and drains 946 square miles.

The watershed area above the Bishop, Alabama, monitoring location is 667 square miles or 70 percent of the entire Bear Creek basin. Within the monitored area, Cedar Creek, with a drainage area of 329 square miles, is the principal tributary. There are four reservoirs (Cedar Creek, Little Bear Creek, Bear Creek, and Upper Bear Creek) that control the runoff from about half of the watershed.

The Bear Creek basin is underlain by sandstone or has limestone outcroppings. Approximately 70 percent of the watershed is forested, the remainder agricultural. Some iron ore has been mined in the basin and bacterial pollution from agricultural operations has been recognized as a water quality concern. Several active and abandoned coal mines are located on the uppermost portions of the watershed above the upper Bear Creek Reservoir. Russellville and Haleyville, Alabama, are the primary urban areas.

Ecological Health

The monitoring location on Bear Creek, far upstream of any influence of impoundment from Pickwick Reservoir, showed fair ecological health in 1993. The fish community was fair in 1993; but not as good as in 1992, which was much improved over past years. Benthic macroinvertebrates also rated fair in 1993, similar to 1992.

Use Suitability

The only bacteriological samples collected from the Bear Creek watershed in 1993 were those collected for reservoir Vital Signs monitoring and are reported with those sections.

Fish for tissue analysis are not collected from the Bear Creek stream monitoring site.

9.0 WHEELER RESERVOIR - ELK RIVER WATERSHED

The Wheeler Reservoir - Elk River watershed drains about 5140 square miles in north central Alabama and south central Tennessee. Wheeler Reservoir is the fourth of nine reservoirs on the Tennessee River. About 24,500 square miles of the Tennessee Valley are upstream of this watershed. Wheeler Reservoir receives an average annual inflow of 40,700 cfs from Guntersville Dam. Discharges from Wheeler Dam average 49,400 cfs on an annual basis leaving 8700 cfs which originate within the watershed.

The largest tributary to Wheeler Reservoir is the Elk River, which has a drainage area of about 2250 square miles and contributes about 3000 cfs. The remaining flow enters from tributaries directly to Wheeler Reservoir.

Wheeler Reservoir is the largest reservoir within this watershed followed by Tims Ford Reservoir on the Elk River. There are four Vital Signs monitoring sites on Wheeler Reservoir--forebay, transition zone, inflow, and the Elk River embayment (Figure 9.1 and Table 2.1). Two sites are monitored for Vital Signs on Tims Ford Reservoir--forebay and mid-reservoir. Woods Reservoir on the Elk River is not included in this monitoring program because it is property of the Arnold Engineering Development Center, Arnold Air Force Base.

The only stream monitoring site within this watershed is on the Elk River at mile 36.5.

Results from 1993 monitoring activities are provided in Section 9.1 for Wheeler Reservoir, Section 9.2 for Tims Ford Reservoir, and Section 9.3 for the stream site on the Elk River.

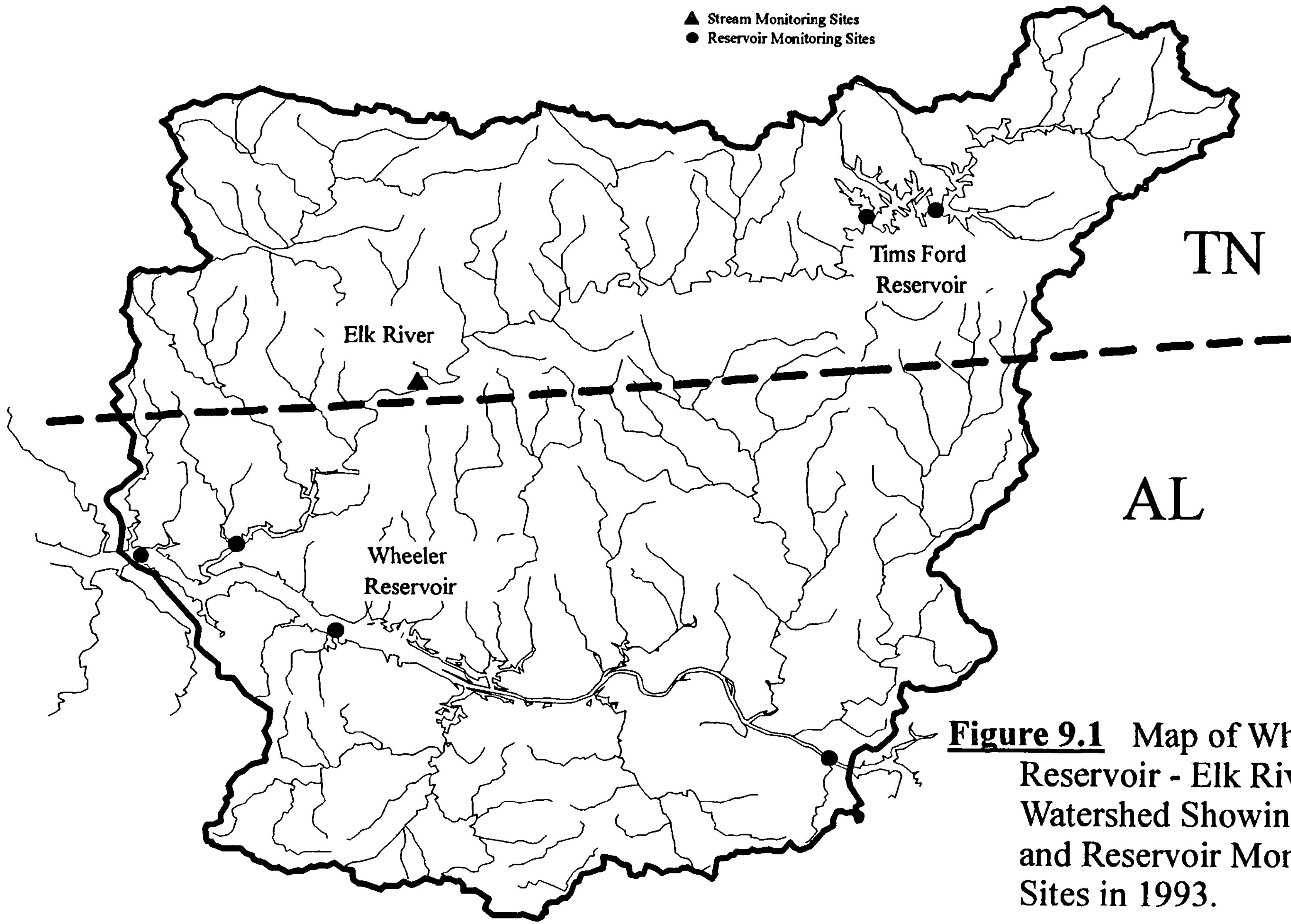


Figure 9.1 Map of Wheeler Reservoir - Elk River Watershed Showing Stream and Reservoir Monitoring Sites in 1993.

9.1 Wheeler Reservoir

Physical Description

Wheeler Reservoir has the third-largest surface area (67,100 acres) of all reservoirs in the TVA system. It is 74 miles long (dam at TRM 274.9) and has 1063 miles of shoreline. Average annual discharge is about 49,400 cfs which provides an average hydraulic retention time of about 11 days. Information collected in 1990 and 1991 indicated a more riverine than transition environment at TRM 307.5; consequently, in 1992 the transition zone sampling location was relocated further downstream to TRM 295.9. Results for 1992 and 1993 are being evaluated to determine if this new site is suitably located or if it needs to be moved further downstream.

The Elk River joins the Tennessee River in the downstream portion of Wheeler Reservoir at about mile 284 and provides, on the average, about 6 percent of the flow through Wheeler Reservoir.

Vital Signs monitoring activities were expanded in 1993 to include a site in the Elk River embayment. This was one of four embayments added to the Vital Signs program in 1993. The Elk River embayment covers about 4900 acres. Given the relatively high flows in the Elk River (about 3000 cfs annual average), there is substantial water exchange in this embayment.

Reservoir Health

Like several other Tennessee River reservoirs, the overall ecological health index of Wheeler Reservoir was lower in 1993 compared to 1992 and 1991. Overall, Wheeler Reservoir rated fair to good (72 percent) in 1993 compared to good in 1992 (80 percent) and in 1991 (87 percent). The primary contributor to this lower reservoir rating was addition of information from the Elk River embayment, which had three poor ratings (chlorophyll--very poor; DO and benthos--poor). Of the four sites monitored on Wheeler Reservoir in 1993, the Elk River embayment site had the poorest ecological health. If data from the Elk River site were deleted from the overall score, Wheeler would rate good (82 percent), consistent with findings in 1991 and 1992.

DOs less than 2 mg/L were measured at lower depths in the forebay during summer with an anoxic area near bottom. As a result, DO rated poor at the forebay. (Ratings for DO at the forebay had been good in 1991 and fair in 1992.) This stressed condition was likely related to the low flows during the 1993 summer. Interestingly, DO rated excellent at the inflow and transition zone, indicating the problem developed within the downstream, forebay region of the reservoir. When low reservoir flows and high water temperatures occur, respiration and oxygen demand (both sediment and biological) increase and can exceed the DO made available by reaeration and photosynthesis. This downstream portion of Wheeler Reservoir usually has relatively high algal productivity due to input of high levels of phosphorus from Elk River. The combination of stagnant water and a high oxygen demand required to decompose dead algae settling to the bottom contributes to low DOs in lower depths at the forebay. All other ecological health indicators rated fair, good, or excellent, similar to previous years. The transition zone and inflow had mostly good or excellent rating for all indicators. The fish assemblage and sediment quality were fair, good, or excellent at all sample sites.

Aquatic macrophytes colonized about 6600 acres on Wheeler Reservoir in 1993, compared to about 4400 acres in 1992 and 3500 acres in 1991.

Reservoir Use Suitability

No bacteriological studies were conducted at recreation sites in Wheeler Reservoir in 1993. In 1990, bacteriological water quality met the Alabama criterion for recreation at the four swimming beaches and four boat ramps tested. Fecal coliform bacteria concentrations have generally been low at the Vital Signs locations in the forebay and transition zones. Since 1990, only two samples have been high, one in 1990 and one in 1993, both in the transition zone.

The Alabama Department of Public Health advises that most fish species from within the Indian Creek embayment on Wheeler Reservoir should not be eaten due to DDT contamination. An intensive study was conducted in autumn 1991 to determine if high concentrations existed in fish from the Tennessee River in an area 15 miles downstream to five miles upstream of the Indian Creek embayment. Based on the 1991 results the public was further advised not to eat largemouth bass, channel catfish, and smallmouth buffalo from within one mile either side of the area where Indian Creek and the Tennessee River join. Other bottom feeding fish species (such as carp and suckers) from the area should also be avoided. Furthermore, channel catfish caught from the Tennessee River between Indian Creek and the Interstate 65 bridge should not be eaten. Fish were again collected from these areas in the Tennessee River in 1992 to continue examining DDT concentrations. The 1992 fish had much lower concentrations than those in 1991. The study was reported in autumn 1993, but results were not available at the time this report was prepared.

9.3 Elk River Stream Monitoring Site

Physical Description

The Elk River flows for more than 200 miles from its headwaters near Monteagle, Tennessee, on the edge of the Cumberland plateau, southwest through south-central Tennessee into northern Alabama where it meets the Tennessee River about nine miles above Wheeler Dam. The basin, which lies principally in the Highland Rim province, is approximately 100 miles long and 50 miles wide at its greatest width, but it averages only 25 miles wide. Approximately one-third of the north central basin above the Elk River lies in the Nashville basin. The Elk River drainage basin area is 2249 square miles.

The TVA monitoring station is located at the USGS stream gage near Prospect, Tennessee. At this location, 1784 square miles or 79 percent of the entire Elk River basin is monitored. Major tributaries of the Elk River basin include Sugar Creek (177 square miles), Richland Creek (488 square miles), Cane Creek (106 square miles), Mulberry Creek (99 square miles), and Beans Creek (92 square miles). Tims Ford Dam and Elk River Dam control most of the runoff from the upper quarter of the watershed.

The Elk River drains an area underlain for the most part by limestone. Consequently, the water is high in dissolved minerals and fairly hard. About 60 percent of the Elk River basin is farmland. Urban areas include Pulaski, Fayetteville, Tullahoma, and Winchester, Tennessee.

Ecological Health

The monitoring site on the Elk River, far upstream of any influence of backwater from Wheeler Reservoir, was rated poor to fair in 1993, a slight improvement over 1992. Improvements were noted in sediment quality and benthic macroinvertebrates. (Fish were not sampled in 1993.) Nutrient concentrations were quite high, resulting from phosphorus-rich soils in the watershed. These high nutrient inflows from the Elk River can stimulate algal blooms in Wheeler Reservoir.

Use Suitability

Bacteriological water quality at an access location about one and one-half miles downstream of Tims Ford Dam was poor immediately after rainfall, but met recreation criterion if samples collected within 24-hours of rainstorms were excluded.

All analytes in fish tissue samples collected in summer 1992 were either not detected or found in low concentrations.

9.2 Tims Ford Reservoir

Physical Description

Tims Ford Reservoir in middle Tennessee is formed by Tims Ford Dam at Elk River mile (ERM) 133.3. The reservoir is 34 miles long at full pool and has a surface area of 10,600 acres. The depth at the dam is 143 feet and the average depth is about 50 feet. Average annual discharges from Tims Ford Dam are about 940 cfs, resulting in a hydraulic residence time of about 280 days. Tims Ford Reservoir is designed for a useful controlled drawdown of 30 feet (895-865 feet MSL) for flood protection; however, annual drawdowns average about 18 feet.

Ecological Health

The ecological health of Tims Ford Reservoir rated poor-fair (58 percent) in 1993 with very little change from previous years of Vital Signs monitoring. The most obvious ecological health problem was the low concentrations of DO near bottom (rated very poor at both the forebay and mid-reservoir sites in 1993). Although undesirable, low DO concentrations often exist in deep, tributary storage reservoirs like Tims Ford with long detention times and strong summer stratification. In spite of these low dissolved oxygen conditions, the fish assemblage rated good at both monitoring sites in 1993. However, the benthos, sampled for the first time in 1993, rated very poor at the forebay and poor at the mid-reservoir site. Sediment quality, also sampled for the first time in 1993, had high levels of ammonia at both locations and toxicity to test animals at the mid-reservoir site which rated poor. Chlorophyll ratings at both locations on Tims Ford Reservoir were good in 1993, indicating adequate primary productivity to support the food web, but not overly productive, potentially leading to eutrophic conditions.

Reservoir Use Suitability

Four sites were tested for fecal coliform bacteria in 1992; two sites were retested in 1993 because of high concentrations. The 1993 concentrations were low at the Estill Springs Park, but at the Dry Fork swimming area, bacteria concentrations were within state criteria only if samples collected within 24-hours of rainfall are excluded.

There are no fish consumption advisories for Tims Ford Reservoir. All analytes were either not detected or found in only low concentrations in channel catfish composites collected from the forebay and transition zone in autumn 1992.

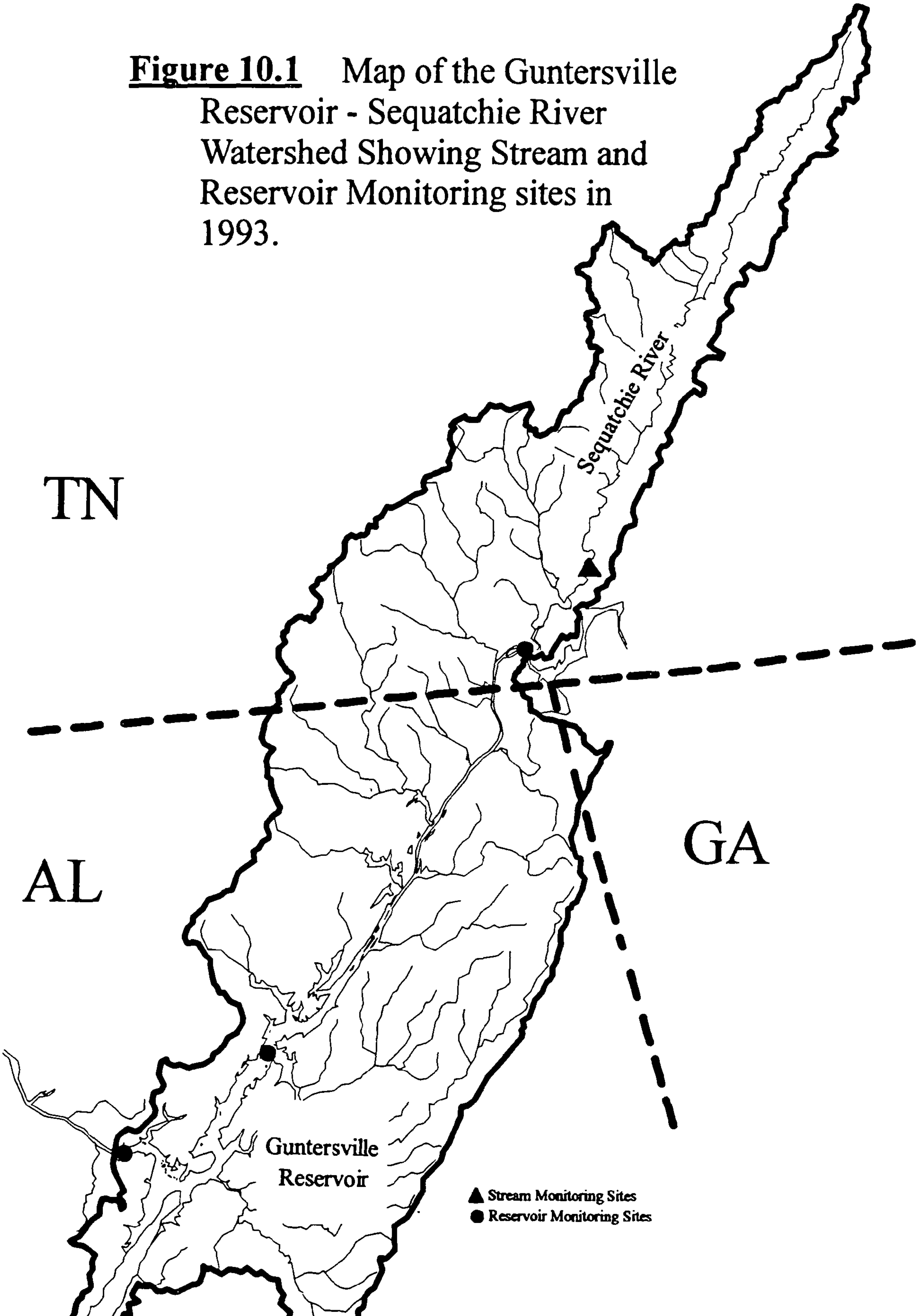
10.0 GUNTERSVILLE RESERVOIR - SEQUATCHIE RIVER WATERSHED

This watershed includes Guntersville Reservoir and all tributaries draining directly to Guntersville Reservoir. As with the other watershed areas on the mainstem of the Tennessee River, most of the water leaving the watershed through Guntersville Dam enters the watershed area through discharges from the upstream dam (Nickajack). About 35,900 cfs enter from Nickajack Dam and about 40,700 cfs is discharged from Guntersville Dam on an annual average basis. The remaining 4800 cfs originates with the Guntersville Reservoir-Sequatchie River watershed area. The largest contributor of this flow is the Sequatchie River (about 800 cfs). The total watershed area is 2669 square miles. The area drained by the Sequatchie River is about 600 square miles.

Guntersville Reservoir is the dominant characteristic of this watershed. There are three Vital Signs monitoring site on Guntersville Reservoir: forebay, transition zone, and inflow (Figure 10.1 and Table 2.1). Information from 1993 monitoring activities is provided in Section 10.1.

There is a stream monitoring site on the Sequatchie River at mile 6.3. Monitoring information for this site for 1993 is provided in Section 10.2.

Figure 10.1 Map of the Guntersville Reservoir - Sequatchie River Watershed Showing Stream and Reservoir Monitoring sites in 1993.



10.1 Guntersville Reservoir

Guntersville Dam, located at TRM 349.0, creates a 76 mile long reservoir with a surface area of 67,900 acres and a shoreline of 949 miles at full pool. Average annual discharge is about 40,700 cfs, corresponding to an average hydraulic retention time of about 13 days.

Guntersville Reservoir is similar to Wheeler Reservoir in several size characteristics, but it differs in one important feature. The average controlled storage volume of Guntersville is about half that of Wheeler. This is due to the shallow nature of Guntersville Reservoir at the inflow area and extensive shallow overbank areas. As a result, winter drawdown on Guntersville Reservoir is nominal to maintain navigation. The shallow drawdown allows the large overbank areas to be permanently wetted creating good habitat for aquatic macrophytes. Guntersville has the greatest area coverage of aquatic plants of any TVA reservoir.

The Sequatchie River joins the Tennessee River at about TRM 423, in the upstream portion of Guntersville Reservoir, just downstream from Nickajack Dam. On the average the Sequatchie River contributes less than 2 percent to the total flow of the Tennessee River through Guntersville Reservoir.

Data collected in 1990 and 1991, indicated a more riverine than transition environment at TRM 396.8. Consequently, in 1992 the transition zone sampling location was relocated further downstream to TRM 375.2. Results from the new site are being reviewed to determine if it is suitably located.

Ecological Health

Ecological health conditions were good (78 percent) in Guntersville Reservoir in 1993, similar to those observed in 1992 (83 percent). All ecological health indicators rated fair, good, or excellent at all reservoir sites, except for DO at the inflow, which rated very poor (compared to fair in previous years). A very low DO concentration (1.8 mg/L, the lowest ever recorded in the discharge from Nickajack Dam) was measured in July and was related to the usual flow patterns associated with the summer drought and special hydroelectric operations.

As in 1992, 1993 results indicated the transition zone had the best ecological health of the three sample sites on Guntersville Reservoir. Four of the five aquatic health indicators from this site had excellent ratings both years; only the fish assemblage rated less than excellent (fair).

Aquatic macrophytes covered about 7600 acres in 1993 compared to 5993 acres in 1992 and 5165 acres in 1991. Guntersville Reservoir contains more acres of aquatic plants than any other reservoir in the TVA system.

Reservoir Use Suitability

All sites tested for fecal coliform bacteria in 1992 and 1993 in Guntersville Reservoir met the Alabama water quality criterion for recreation. At most sites, bacteria concentrations were quite low. High fecal coliform concentrations were found in the Vital Signs sampling at the forebay in 1990 and 1991, but bacteria concentrations at both the forebay and transition zone were very low in 1992 and 1993.

There are no fish consumption advisories on Guntersville Reservoir. Channel catfish composites collected from Guntersville Reservoir in autumn 1990 had sufficiently high PCB concentrations to warrant further examination but were not high enough for the state to issue an advisory. Catfish collected from the same locations in 1991 and 1992 had progressively lower concentrations than those from 1990 with the 1992 concentrations generally indicative of "background" levels found in channel catfish throughout the Tennessee River. Other analytes were low or nondetectable in the 1992 samples.

10.2 Sequatchie River Stream Monitoring Site

Physical Description

The Sequatchie River basin is a narrow limestone valley of the Valley and Ridge physiographic province, surrounded by the Cumberland Plateau to the west and Walden Ridge to the east. The Sequatchie flows from its headwaters south of the Emory-Obed River basin for more than 110 miles to form an embayment at the upstream end of Guntersville Reservoir, just downstream from Nickajack Dam. The Sequatchie River drainage basin is 605 square miles.

The TVA monitoring station is located at the Valley Road bridge near Jasper, Tennessee. The upstream drainage basin is 575 square miles or 95 percent of the entire Sequatchie River basin. Principal tributaries in the monitored area include the Little Sequatchie River (132 square miles) and Big Brush Creek (69 square miles).

Dolomite and limestone underlie the floor of the Sequatchie River valley, which is predominantly farmland. Sandstones underlie the surrounding steep escarpments and plateaus, which are predominantly forested. Coal mines operate in some areas of the Cumberland Plateau. Whitwell, Dunlap, and Pikeville, Tennessee, are the primary urban area in the basin.

Ecological Health

The ecological health of the Sequatchie River monitoring site was good in 1993. All ecological health indicators were either good or fair. Coal mining activities may be hindering the fish community and bottom-dwelling animals as indicated by deposits of coal fines and other sediments.

Use Suitability

Four canoe sites were sampled in 1992 and 1993 for fecal coliform bacteria. Although some samples collected after rainfall had high concentrations, all sites met Tennessee water quality criterion for recreation both years.

Fish tissue samples from the Sequatchie River collected during summer 1992 had nondetectable or only low concentrations of all analytes.

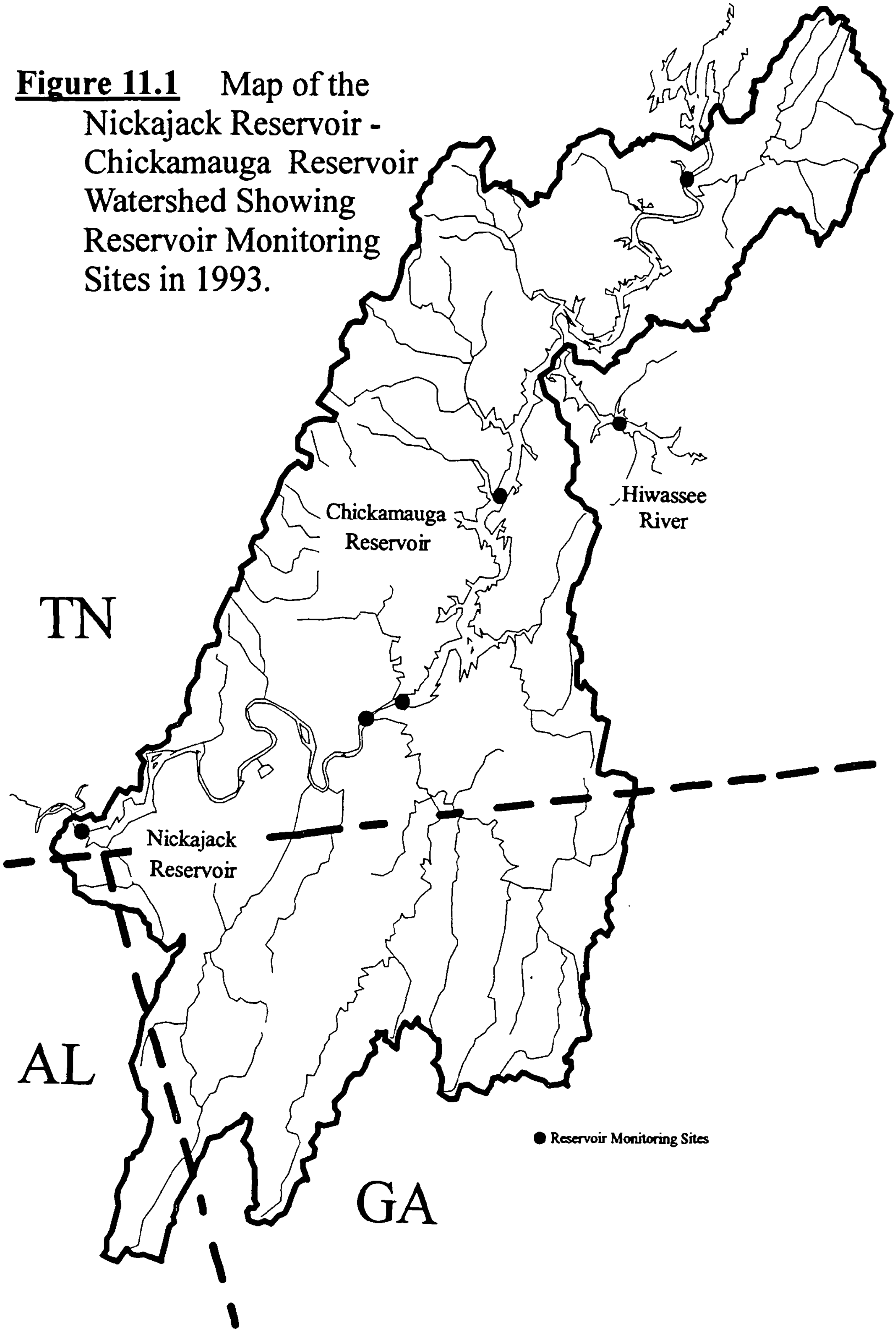
11.0 NICKAJACK RESERVOIR - CHICKAMAUGA RESERVOIR WATERSHED

Nickajack and Chickamauga Reservoirs are primary features of this watershed. The Hiwassee River is the only sizeable tributary which merges with the Tennessee River within the watershed area. The drainage basin of the Hiwassee River is large enough to be designated a separate watershed (see Section 12). The remaining area drained by tributaries to these two reservoirs is 1780 square miles. On an annual average basis, about 3200 cfs is contributed to the Tennessee River from streams within this watershed. This compares to 27,100 cfs entering the upper end of Chickamauga Reservoir from Watts Bar Dam and 5600 cfs from the Hiwassee River, for a total average annual discharge from Nickajack Dam of 35,900 cfs.

There are two Vital Signs monitoring sites on Nickajack Reservoir, one at the forebay and one at the inflow. There is no transition zone site on Nickajack because the reservoir is short and water exchange is quite rapid. This causes conditions at the location that might be considered the transition zone to be similar to those at the forebay. Chickamauga Reservoir has four Vital Signs monitoring sites--the forebay, the transition zone, the inflow, and a new site established in 1993 in the Hiwassee River embayment (Figure 11.1).

Results from 1993 monitoring activities are in Section 11.1 for Nickajack Reservoir and 11.2 for Chickamauga Reservoir.

Figure 11.1 Map of the Nickajack Reservoir - Chickamauga Reservoir Watershed Showing Reservoir Monitoring Sites in 1993.



11.1 Nickajack Reservoir

Physical Description

Nickajack Reservoir is one of the smallest reservoirs on the mainstem of the Tennessee River. With the dam at TRM 424.7, Nickajack has a length of 46 miles, surface area of 10,370 acres, and a shoreline of 192 miles at full pool. Average annual discharge from Nickajack is approximately 35,900 cfs which provides an average hydraulic retention time of only about three or four days, the shortest retention time among the reservoirs monitored in this program.

Results from the 1990 and 1991 monitoring indicated that both the forebay and transition zone sampling sites had quite similar water quality. This was expected since the two sites are relatively close together (separated by only 7.5 river miles), and Nickajack is a well-mixed, run-of-the-river reservoir. Therefore, sampling at the transition zone in Nickajack Reservoir was discontinued in 1992.

Ecological Health

Nickajack Reservoir had a good ecological health rating (88 percent) in 1993, the same as in 1992 and 1991 (83 percent both years). Nickajack had the highest overall ecological health rating of all Vital Signs reservoirs in 1993. The only poor rating was for DO at the upper end of Nickajack Reservoir. This was due to low DOs (minimum 2.2 mg/L) in the releases from Chickamauga Dam in July 1993. Low DO concentrations had been observed there in previous years, but concentrations measured in 1993 were the lowest ever recorded from Chickamauga Dam. These concentrations were not low enough to cause mortality for common species present, but were low enough to affect organism health and growth. Although the DO rating at the Nickajack forebay was excellent (no DO concentrations less than 2.0 mg/L were measured), it cannot be concluded that no DO problems existed. Because low DO concentrations were found in water entering Nickajack Reservoir from Chickamauga Dam and low DO concentrations were found in water leaving Nickajack Dam, it is clear that low DOs existed in the Nickajack forebay at some time. The lack of low measurements at the forebay likely is due to the timing of monthly measurements; sampling dates in July and August bracketed the period with most severe DO problems.

Other than the poor DO rating for the inflow, all other ecological health indicators at the forebay and inflow sample sites scored good or excellent. Even if low DO concentrations had been measured at the forebay, the high scores for the other indicators would have kept the overall rating for Nickajack Reservoir in the good range.

Aquatic macrophytes on Nickajack Reservoir covered about 1000 acres in 1993 compared to 830 acres in 1991 to 580 acres in 1992.

Reservoir Use Suitability

The Tennessee Department of Environment and Conservation has issued an advisory that catfish should not be eaten by children, pregnant women, and nursing mothers because of PCB levels (about 1.0 $\mu g/g$); other individuals should limit consumption to no more than 1.2 pounds per month. Fillets from catfish collected autumn 1992 had PCB concentrations about half those previously found in the five years of fish tissue studies on Nickajack Reservoir. The study was repeated in autumn 1993 to determine if lower PCB concentrations are found again. Results were not available at the time this report was prepared.

Fecal coliform bacteria concentrations in areas of Nickajack Reservoir tested during the recreation site sampling in 1992 and 1993 and Vital Signs sampling since 1990 were generally low. Exceptions include the boat ramp at Smith's Camp-On-The-Lake, where large populations of geese probably account for the high concentrations, and North Chickamauga Creek after rainfall.

11.2 Chickamauga Reservoir

Physical Description

Chickamauga Dam is located at TRM 471.0. The reservoir is 59 miles long, has 810 miles of shoreline, and has a surface area of 35,400 acres at full pool. The average annual discharge is approximately 34,200 cfs which provides an average hydraulic retention of nine to ten days (Table 4.1).

The Hiwassee River, a major tributary to the Tennessee River, flows into the middle portion of Chickamauga Reservoir at about TRM 499. The flow from the entire Hiwassee River watershed contributes approximately 16.5 percent of the flow through Chickamauga Reservoir. About 10 percent of the 16.5 percent is from the Ocoee River and tributaries in the lower end of the Hiwassee watershed (i.e., downstream of Apalachia Dam).

Vital Signs monitoring activities were expanded in 1993 to include a site in the Hiwassee River embayment, which covers about 6500 acres. Given the relatively high flows in the Hiwassee River (about 5600 cfs annual average), there is substantial water exchange in this embayment, much greater than in any of the other three embayments monitored.

Ecological Health

The overall ecological health rating for Chickamauga Reservoir was good in 1993 (83 percent), the second-highest rating of all reservoirs. This is an improvement over the fair to good rating in 1992 (73 percent) and is more like the good rating in 1991 (90 percent). Unlike the other three reservoirs which had a major embayment monitored for the first time in 1993 (Kentucky, Pickwick, and Wheeler), results from the Hiwassee River embayment did not lower the overall rating of Chickamauga Reservoir. Of the five ecological health indicators, two were excellent (chlorophyll and DO) and three were good (sediment quality, benthos, and fish assemblage) at the Hiwassee embayment site. If results from the Hiwassee River embayment site were excluded from determining the overall score for Chickamauga Reservoir, the score would be changed slightly to 81 percent.

Several health indicators had higher ratings in 1993 than in 1992. In particular, the sediment quality rating improved from poor in 1992 to fair in 1993 at both the forebay and transition zone. The poor ratings at these two sites in 1992 resulted from elevated concentrations of copper and zinc and toxicity to test organisms. In 1993 copper and zinc (in addition to trace levels of chlordane) were again found at the forebay, but no toxicity was found, resulting in a fair rating. The fair rating at the transition zone in 1993 was caused by an indication of toxicity (some mortality of rotifers, although not significantly different from controls) and presence of chlordane in the sediment; copper and zinc were not elevated. Chlordane in sediments was detected for the first time in 1993. This is related to improved laboratory methods rather than a true environmental change. New equipment which allowed better extraction of organic contaminants from sediments was used on 1993 samples.

DO levels on Chickamauga Reservoir were not impacted as much by the hot, dry summer as on several other Tennessee River reservoirs in 1993. The DO ratings at the forebay and transition zone were good, but there were small areas during June and July with very low DO concentrations. These areas are thought to have been too short in duration and too small in area to have had a significant impact. DO at the inflow rated fair due to a relatively low concentration (3.7 mg/L) in one sample from the releases of Watts Bar Dam.

Improvements in ratings for both the benthos (poor in 1992 and fair in 1993) and fish assemblage (fair in 1992 and excellent in 1993) were noted at the inflow. About twice as many benthic macroinvertebrate taxa were found in 1993 as in 1992, indicating improved conditions. Most fish assemblage metrics were excellent; this was a distinct improvement over 1992 results. Aquatic macrophytes on Chickamauga Reservoir covered 1185 acres in 1993 compared to 387 acres in 1992 and 680 acres in 1991. Aquatic macrophytes peaked at about 7500 acres in 1988 and continuously declined until summer 1993.

Reservoir Use Suitability

There are no fish consumption advisories for Chickamauga Reservoir. Fillets from Chickamauga Reservoir catfish have been examined for several years as part of a variety of studies. Study results have indicated no consistent or reservoir-wide problems. Results from most of these studies have usually found higher concentrations of PCBs in catfish from the inflow area than from other sites in the reservoir. Channel catfish were collected for screening purposes in autumn 1992 from the inflow, transition zone, and forebay. Concentrations of all analytes from all locations were low, including PCBs.

No bacteriological studies were conducted at recreation sites on Chickamauga Reservoir in 1993. Bacteriological water quality met the Tennessee criterion for recreation at the ten sites tested in 1989 and 1990. Fecal coliform bacteria concentrations have generally been low at the Vital Signs locations during all years monitoring activities have occurred.

12.0 HIWASSEE RIVER WATERSHED

The headwaters of the Hiwassee River extend into the Blue Ridge Mountains in Tennessee, North Carolina, and Georgia. Streams in this watershed have naturally low concentrations of nutrients and dissolved minerals. These streams change from steep gradient, cold water trout streams in the mountains to lower gradient warm water streams in the valley.

The Hiwassee River Watershed has an area of 2700 square miles and an average annual discharge to the Tennessee River of 5640 cfs. The confluence of the Hiwassee River with the Tennessee River is in Chickamauga Reservoir at Tennessee River Mile 499.4. The lower portion of the Hiwassee River is impounded by backwater from Chickamauga Dam. The impounded portion of the Hiwassee River forms a large embayment (about 6500 surface acres) which extends over 20 miles up the Hiwassee River.

The largest tributary to the Hiwassee River is the Ocoee River, with a drainage area of about 640 square miles. Due to past copper mining and industrial activities in the Copperhill area, several streams and reservoirs in the Ocoee River basin have degraded water quality.

There are eight TVA reservoirs in the Hiwassee River watershed (Figure 12.1 and Table 2.1). Vital Signs monitoring activities are conducted on the five largest reservoirs: Hiwassee Reservoir (forebay, mid-reservoir, and inflow); Chatuge Reservoir (forebay sites on the Hiwassee River and Shooting Creek arms); Nottely Reservoir (forebay and mid-reservoir); Ocoee Reservoir No. 1 (forebay only); and Blue Ridge Reservoir (forebay only). Apalachia, Ocoee No. 2, and Ocoee No. 3 Reservoirs are not included in this monitoring because of their small size.

There is a stream monitoring site on the Hiwassee River at HiRM 36.9, about 2.5 miles upstream of the confluence of the Ocoee River. A new site will be added in 1994 on the Ocoee River at mile 2.5. Vital Signs monitoring also includes a site on the Hiwassee River embayment (at HiRM 10) of Chickamauga Reservoir. Results from that monitoring site are provided in Chapter 11.

Results from 1993 reservoir and stream Vital Signs and Use Suitability monitoring activities are provided in the following sections:

12.1 Hiwassee Reservoir

12.2 Chatuge Reservoir

12.3 Nottely Reservoir

12.4 Blue Ridge Reservoir

12.5 Ocoee Reservoir No. 1 (Parksville Reservoir)

12.6 Hiwassee River Stream Monitoring Site

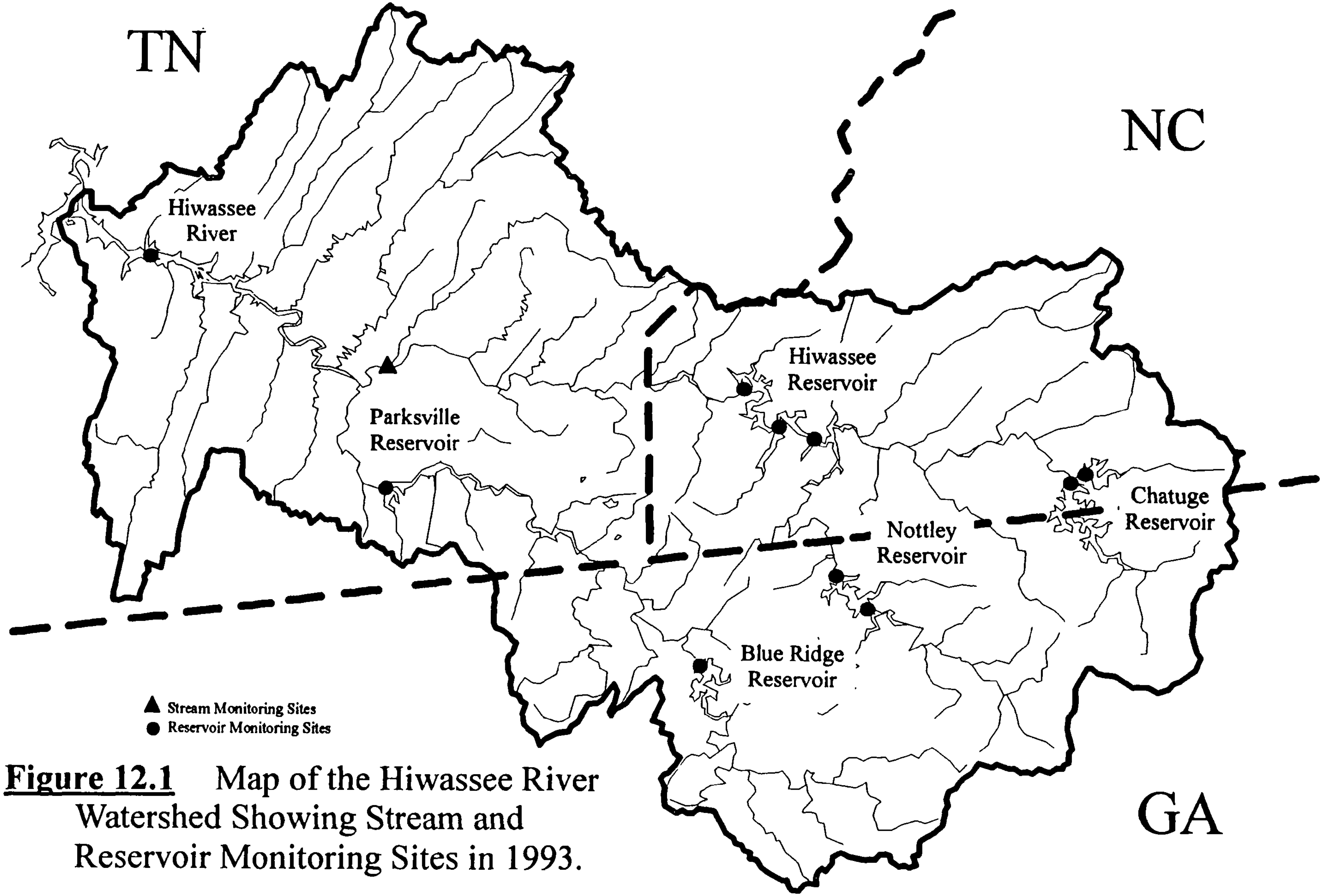


Figure 12.1 Map of the Hiwassee River Watershed Showing Stream and Reservoir Monitoring Sites in 1993.

12.1 Hiwassee Reservoir

Physical Description

Hiwassee Reservoir, in the southwestern corner of North Carolina, is the second-largest of the five reservoirs in the Hiwassee River watershed included in the Vital Signs monitoring program. Hiwassee Reservoir is impounded by Hiwassee Dam at river mile 75.8. At full pool level, its backwater storage pool is about 22 miles long, 6100 acres in surface area, and has a mean depth of about 69 feet (with a maximum depth of about 255 feet at the dam). It has an average annual discharge of about 2020 cfs and average residence time of about 105 days. Hiwassee Reservoir has an average annual drawdown of 45 feet.

Ecological Health

Ecological health of Hiwassee Reservoir rated poor-fair (58 percent) in 1993; lower than in 1992 and 1991. The primary factor contributing to reduced ecological health rating was addition of sediment quality and benthic macroinvertebrates sampling in 1993. Both these indicators rated poor or very poor at both the forebay and mid-reservoir sites. There were no other poor ratings for any indicator, not even for DO, which was poor at the forebay in 1992. If scores for these two new indicators (sediment quality and benthos) were deleted from calculating the overall ecological health rating for Hiwassee Reservoir, the rating would change substantially to fair-good (72 percent), consistent with rating for previous years. Poor ratings for sediment quality were due to toxicity to test organisms and detectable concentrations of chlordane. Most benthos metrics were very poor and received the lowest score possible.

Like most deep, tributary storage reservoirs with long retention times, thermal stratification occurs during the summer in Hiwassee Reservoir. During periods of extended thermal stratification, low concentrations of dissolved oxygen develop near the bottom of the reservoir when oxygen is consumed by respiration and biochemical processes in the reservoir and in the sediment at a faster rate than it is replenished by photosynthesis and reaeration from the atmosphere. Although this low DO area develops in Hiwassee Reservoir, especially in the forebay, it is relatively small. Hence, DO rated fair at the forebay and good at the mid-reservoir site in 1993.

The upper Hiwassee River watershed is largely forested with few sources of waste to the river. Consequently, concentrations of nutrients are generally low and primary productivity in the Hiwassee watershed reservoirs is also generally low. This can be seen in the fair chlorophyll rating at the Hiwassee Reservoir forebay in 1993 caused by low chlorophyll concentrations. Chlorophyll concentrations were just high enough at the mid-reservoir site to rate in the good range. As is frequently the case in oligotrophic reservoirs, lower standing stocks of fish reflect the small food base. The fish assemblage rated fair at all locations.

Reservoir Use Suitability

No bacteriological studies were conducted in 1993. In 1990, bacteriological water quality at four boat ramps was sampled. Fecal coliform bacteria concentrations were very low at all four sites.

There are no fish consumption advisories on Hiwassee Reservoir. The most recent fish tissue information is for a channel catfish composite from the forebay collected in autumn 1991. No pesticide or PCB analytes were detected. With the exception of mercury, metal concentrations in fish tissue were low or at expected concentrations. The mercury concentration, however, was relatively high (0.69 $\mu g/g$) and so was further investigated in autumn 1993. Both channel catfish and largemouth bass composites were collected from the forebay and transition zone during autumn 1993. Results were not available at the time this report was prepared.

12.2 Chatuge Reservoir

Physical Description

Chatuge Reservoir is located on the Georgia-North Carolina state line in northeastern Georgia and is formed by Chatuge Dam at Hiwassee River mile (HiRM) 121.0. At full pool elevation, the reservoir is 13 miles long and has a surface area of about 7000 acres. Its maximum depth at the dam is 124 feet, and it has a mean depth of 33 feet. An average annual discharge of 459 cfs results in an average hydraulic residence time of about 260 days. Chatuge Reservoir has a potential useful controlled storage of 23 feet (1928-1905 feet MSL), however, the annual drawdown averages only ten feet.

Only the forebay of Chatuge Reservoir was monitored prior to 1993. A new monitoring site was added in 1993 in the Shooting Creek arm to further evaluate this rather large part of the lake. Because of its physical features, the Shooting Creek site would be expected to be representative of forebay conditions.

Ecological Health

The ecological health of Chatuge Reservoir rated better in 1993 than in previous years of Vital Signs monitoring. Chatuge rated fair (67 percent) in 1993 compared to poor-fair in 1992 (56 percent) and 1991 (60 percent). One of the reasons for the higher rating in 1993 was improved scores for DO, which rated good at the forebay site on the Hiwassee River and fair at the forebay site on Shooting Creek. In 1992 DO rated poor at the forebay and a mid-reservoir site. Besides an actual slight improvement in DO conditions, the higher DO rating in 1993 was due to an improvement in the method for scoring for DO. Also, inclusion of scores for benthic macroinvertebrates, sampled for the first time in 1993 and rated good at both sample sites, helped to elevate the overall ecological health rating for Chatuge.

All other indicators (chlorophyll, sediment quality, and fish assemblage) rated fair at both sample sites. The fair ratings for chlorophyll were due to naturally low concentrations, indicative of the low availability of nutrients characteristic of the Hiwassee watershed. The fair ratings for sediment quality were due to toxicity to test organisms at the forebay site on the Hiwassee River and elevated concentrations of chromium, copper, and nickel at the Shooting Creek site.

Reservoir Use Suitability

There are no fish consumption advisories on Chatuge Reservoir. The most recent information available is from a channel catfish composite collected from the forebay in autumn 1991. None of the pesticide or PCB analytes were detected. Although several metals were detected, they occurred at low or expected concentrations.

No bacteriological studies were conducted in 1993. In 1990, bacteriological water quality at three swimming beaches, three boat ramps, and five locations in the middle of the channel were sampled. Fecal coliform bacteria concentrations were very low at all sites.

12.3 Nottely Reservoir

Physical Description

Nottely Reservoir is formed by Nottely Dam at Nottely River mile 21.0 in northern Georgia. At full pool elevation, the reservoir is 20 miles long, covers 4200 acres, and has a mean depth of 40 feet, with a maximum depth of about 165 feet at the dam. Long-term flows from Nottely Dam average about 415 cfs which result in an average hydraulic retention time of about 206 days. The annual drawdown averages about 24 feet on Nottely Reservoir.

Ecological Health

The ecological health of Nottely Reservoir rated fair again in 1993 (64 percent), slightly higher than the fair rating in 1992 and 1991 (60 percent). The primary concern in Nottely Reservoir is low DO conditions near bottom as evidenced by very poor DO ratings at both the forebay and mid-reservoir locations in 1993. The only other poor rating for an indicator in 1993 was benthos at the forebay. Interestingly, the benthos rated good at the mid-reservoir despite the very poor DO conditions. Chlorophyll rated good at both sample sites in 1993 and sediment quality rated excellent at the mid-reservoir site. The fish assemblage rated fair at both sample sites in 1993.

Nottely Reservoir's ecological health may not be as good as these monitoring results suggest, however. For example, there was a fish kill near the dam in the fall of 1992 which was probably related to low dissolved oxygen. Also, the water in Nottely Reservoir is frequently turbid due to excessive erosion on the lands surrounding the reservoir. Of the five reservoirs in the Hiwassee watershed (Hiwassee, Chatuge, Nottely, Blue Ridge, and Ocoee No. 1), Nottely has had the lowest water clarity, highest chlorophyll concentrations, and highest phosphorus concentrations over the last three years.

Reservoir Use Suitability

No fish consumption advisories have been issued for Nottely Reservoir. The most recent fish tissue results are for a channel catfish composite collected from the forebay in autumn 1991. The only organic analyte detected was PCBs (at a concentration of 0.2 μg/g) just above the detection limit. A few metals were detected but only mercury (0.47 μg/g) was sufficiently high to be of interest. Similar concentrations have been found, although not consistently, in previous screening studies on reservoirs in the Hiwassee basin. Both channel catfish and largemouth bass composites were collected from the forebay in autumn 1993 and analyzed for mercury to further examine this situation. Results were not available at the time this report was prepared.

No information was collected for bacteriological contamination at recreation areas on Nottely Reservoir in 1993. However, the recreation area at Poteet Creek was sampled in 1990 for fecal coliform bacteria and found to fully support water contact recreation.

12.4 Blue Ridge Reservoir

Physical Description

Blue Ridge Dam impounds the Toccoa River at mile 53.0 in rural northwest Georgia. The watershed is mountainous and forested, with a significant portion of the basin lying within the Chattahoochee National Forest. At full pool, Blue Ridge Reservoir is about 11 miles long, 3300 acres in surface area, and 155 feet deep at the dam, with a average depth of 59 feet. The rate of discharge of water from Blue Ridge Reservoir averages about 610 cfs, which results in an average theoretical residence time of about 159 days. The annual drawdown of Blue Ridge Reservoir averages 36 feet.

Ecological Health

The ecological health of Blue Ridge Reservoir was good in 1993 (72 percent), similar to that found in 1992 and 1991. Blue Ridge is an oligotrophic reservoir as evidenced by very low summer chlorophyll concentrations at the forebay, rated fair in 1993. The excellent rating for DO was in part related to the low primary productivity because a low oxygen demand would be required to decompose relatively few dead algal cells. The benthic macroinvertebrate community, sampled for the first time in 1993, rated excellent at the forebay. The fish assemblage rated poor due to low abundance and diversity, as might be expected in an oligotrophic reservoir. Compared to the other reservoirs in the Hiwassee watershed, Blue Ridge has had the highest water clarity and lowest nitrogen concentrations over the three years of Vital Signs monitoring.

Reservoir Use Suitability

There are no fish consumption advisories on Blue Ridge Reservoir. The most recent fish tissue information from Blue Ridge Reservoir is from a channel catfish composite from the forebay collected in autumn 1991. Most pesticide and PCB analytes were not detected; those that were, occurred in low concentrations. Likewise, all metal analytes were either not detected or were found in low or expected concentrations.

No bacteriological studies were conducted in 1993. In 1990, bacteriological water quality at one swimming beach was sampled. Fecal coliform bacteria concentrations were very low.

12.5 Ocoee Reservoir No. 1 (Parksville Reservoir)

Physical Description

Ocoee No. 1 Reservoir, also known as Parksville Reservoir, is formed by Ocoee No. 1 Dam at Ocoee River mile 11.9. At full pool elevation, the reservoir has a surface area of about 1900 acres and length of 7.5 miles. Ocoee No. 1 Reservoir is located downstream from the Copper Basin, and decades of erosion have caused significant filling of the reservoir. Ocoee No. 1 Reservoir has lost about 25 percent of its original volume, has an average depth of 45 feet and is about 115 feet deep at the dam. An average annual discharge of about 1400 cfs from Ocoee No. 1 Dam results in a reservoir retention time of approximately 30 days. Although Ocoee No. 1 Reservoir is not operated for flood control (only for peaking power generation), its annual drawdown averages about seven feet.

Ecological Health

The ecological health of Ocoee No. 1 Reservoir rated poor in 1993 (52 percent), with little change from the previous years of Vital Signs monitoring activities. Four indicators rated poor--chlorophyll, sediment quality, benthic macroinvertebrates, and the fish assemblage. The reservoir is recovering from years of pollution problems related to copper mining and industrial activities at Copperhill. Sediment quality, sampled for the first time in 1993, reflected these historic problems with very high concentrations of copper, lead, and zinc. Also, PCBs were detected in forebay sediments in 1993.

In spite of the apparent availability of nutrients, algal productivity was low. High DO concentrations (rated excellent in 1993) existed in Parksville Reservoir throughout the year. High DO concentrations were present even in the hypolimnion at the forebay. As expected under such conditions, the fish assemblage rated poor in 1993, comparable to previous years.

Reservoir Use Suitability

There are no fish consumption advisories in effect for Parksville Reservoir. However, screening studies over the past several years have found PCB concentrations near the level used by the state of Tennessee to issue a "Limit Consumption" advisory. As a result, TVA and the state designed and conducted a more detailed sampling of fish in autumn 1992. Results of the 1992 effort confirmed previous results of relatively high PCB concentrations in channel catfish; the average of ten fish was 1.5 μg/g at the forebay and 1.0 μg/g at an upper reservoir location. Largemouth bass were also examined and found to have lower concentrations than catfish; averages at the two sites were 0.6 and 0.7 μg/g, respectively. Bluegill sunfish and rainbow trout composites from these areas had low PCB concentrations ($\leq$0.3 μg/g). The state of Tennessee had taken no action on these results at the time this report was prepared.

No bacteriological studies were conducted in 1993. In 1991, the swimming area at Mac Point was surveyed. Fecal coliform bacteria concentrations were low.

12.6 Hiwassee River Stream Monitoring Site

Physical Description

The headwaters of the Hiwassee River are in the Chattahoochee, Nantahala, and Cherokee Forests of the Blue Ridge physiographic province. It emerges from the mountains to flow through the Valley and Ridge province to join the Tennessee River as an embayment of Chickamauga Reservoir.

The TVA monitoring station is located at the Patty Bridge near Benton, Tennessee. The watershed area above the sampling site is 1300 square miles or 48 percent of the Hiwassee River basin. Principal tributaries in the Hiwassee watershed include the Valley River (117 square miles), Nottely River (287 square miles), Conasauga Creek (103 square miles), Toccoa-Ocoee River (639 square miles), Chestuee Creek (132 square miles), and Oostanaula Creek (69 square miles). Oostanaula Creek, Chestuee Creek, and the Ocoee River are located below this station.

Igneous and metamorphic rocks underlie much of the basin yielding water that is very soft and low in dissolved minerals. The major urban areas of the Hiwassee River basin include Athens, Etowah, and Cleveland, Tennessee, in the lower basin. The smaller urban communities of the mountains include Andrews and Murphy in North Carolina, Blue Ridge and McCaysville in Georgia, and Copperhill in Tennessee. Runoff from land denuded by historical mining and ore processing near Copperhill affects water quality in the Ocoee River and its three reservoirs downstream to the confluence with the Hiwassee River.

Ecological Health

The ecological health of the stream monitoring site on the Hiwassee River was good in 1993, as in 1992. All ecological health indicators (nutrients, sediment quality, benthos, and fish community) rated either good or fair.

Use Suitability

No fecal coliform samples were collected in 1993. In 1989, the canoe sites, Shallow Ford Bridge on Toccoa River upstream of Blue Ridge Reservoir, and at Mission Dam on the Hiwassee River between Chatuge and Hiwassee Reservoirs were sampled. In 1991, the two access locations on the Ocoee River upstream of Parksville Reservoir, and the three access sites on Hiwassee River upstream of Chickamauga Reservoir were sampled. Bacteriological water quality at each of the sites met the appropriate state's criterion for recreation.

All metal and organic analytes in fish tissue samples were either not detected or found in low concentrations.

13.0 WATTS BAR RESERVOIR, FORT LOUDOUN RESERVOIR, AND MELTON HILL RESERVOIR WATERSHED

This watershed area is relatively small (1370 square miles) and includes three reservoirs: Fort Loudoun and Watts Bar Reservoirs on the Tennessee River and Melton Hill Reservoir on the Clinch River. All three are run-of-the-river reservoirs with relatively short retention times and annual pool drawdowns of only a few feet. The inflow of Fort Loudoun Reservoir is actually the origin of the Tennessee River. The Holston and French Broad Rivers merge at that point to form the Tennessee River. The Little Tennessee River, another major tributary to the Tennessee River, enters Fort Loudoun Reservoir near the forebay. Watts Bar Reservoir is immediately downstream of Fort Loudoun. The Clinch River, another major tributary, merges with the Tennessee River upstream of the transition zone on Watts Bar Reservoir. Melton Hill Dam bounds the upper end of Watts Bar Reservoir on the Clinch River and Fort Loudoun Reservoir bounds it on the Tennessee River.

Like the other watershed areas formed around one or more of the reservoirs on the mainstream of the Tennessee River, very little of the water leaving this watershed area originates from within. The average annual discharge through Watts Bar Reservoir is about 27,000 cfs. Of this, about 25 percent (6800 cfs) enters from the French Broad River, 16 percent (4500 cfs) from the Holston River, 21 percent (5700 cfs) from the Little Tennessee River, and 15 percent (4200 cfs) from the Melton Hill Dam on the Clinch River. Another five percent (1400 cfs) is contributed by the Emory River, a tributary to the Clinch River near the confluence with the Tennessee River. The remaining 18 percent (4800 cfs) originates from streams which drain directly to one of these reservoirs.

Vital Signs monitoring activities are conducted at the forebays, transition zones, and inflows of all three of these reservoirs. Watt Bar Reservoir has two inflow sites, one near Fort Loudoun Dam and one near Melton Hill Dam. There is one stream monitoring site on the Emory River at Emory River Mile 18.3 (Figure 13.1).

Results for 1993 monitoring activities are provided in the following sections:

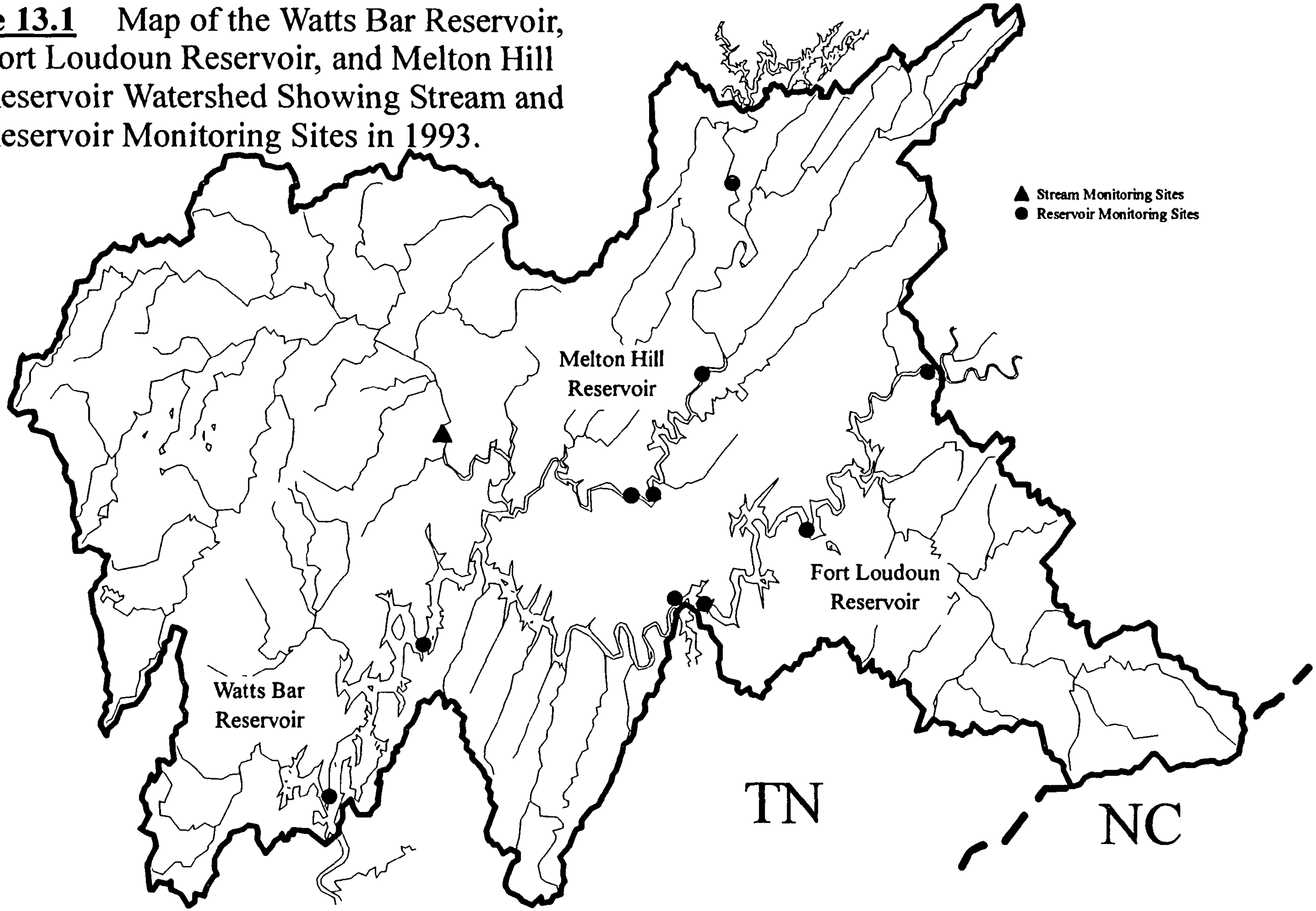
13.1 Watts Bar Reservoir

13.2 Fort Loudoun Reservoir

13.3 Melton Hill Reservoir

13.4 Emory River Stream Monitoring Site

Figure 13.1 Map of the Watts Bar Reservoir, Fort Loudoun Reservoir, and Melton Hill Reservoir Watershed Showing Stream and Reservoir Monitoring Sites in 1993.



13.1 Watts Bar Reservoir

Physical Description

Watts Bar Reservoir impounds water from both the Tennessee River and one of the major tributaries to the Tennessee River, the Clinch River. The three dams which bound Watts Bar Reservoir are: Watts Bar Dam located at Tennessee River Mile (TRM) 529.9, Fort Loudoun Dam located at TRM 602.3, and Melton Hill Dam located at Clinch River mile (CRM) 23.1. The total length of Watts Bar Reservoir, including the Clinch River arm is 96 miles, the shoreline length is 783 miles, and the surface area is 39,000 acres. The average annual discharge from Watts Bar is approximately 27,000 cfs, providing an average hydraulic retention time of about 19 days.

The confluence of the Clinch and Tennessee Rivers is upstream of the transition zone sampling location in Watts Bar, so biological sampling was conducted at the forebay, transition zone, and both the Tennessee River and Clinch River inflows. Water entering Watts Bar from Melton Hill Reservoir is quite cool due to the hypolimnetic withdrawal from Norris Reservoir (a deep storage impoundment) upstream from Melton Hill. Water entering Watts Bar Reservoir from Fort Loudoun Dam is usually warmer and lower in DO during summer months than water entering from Melton Hill Dam.

The Emory River is a major tributary to the Clinch River arm of Watts Bar Reservoir and supplies about 5 percent of the average annual flow through Watts Bar Reservoir. The Tennessee and Little Tennessee Rivers (i.e., discharge from Fort Loudoun Dam) account for about 75 percent of the flow, and the Clinch River (i.e., discharge from Melton Hill Dam) accounts for about 15 percent through Watts Bar Reservoir.

Ecological Health

The ecological health of Watts Bar Reservoir was fair in 1993 (68 percent), similar to 1992 (71 percent) and 1991 (69 percent). Chlorophyll rated good at both the forebay and transition zone locations. Sediment quality testing at the forebay found low survival of test organisms and high concentrations of ammonia, leading to a poor rating. A fair to good rating for sediments at the transition zone was due to traces of chlordane; no other chemical analyte was problematic and no toxicity was found. Because of the release of water with low DOs from Fort Loudoun Dam, DO concentrations were less than 5 mg/L (minimum 3.9 mg/L) in the Tennessee River inflow to Watts Bar Reservoir. Benthic macroinvertebrates rated poor in 1993 at this site (as in both 1992 and 1991), possibly related to the low DO concentrations. The fish assemblage was also poor at this inflow site in 1993. The inflow site on the Clinch River, downstream of Melton Hill Dam, had good DOs, but the benthos were poor and fish assemblage fair. Compared to 1992, this was a slight decrease for the benthos, but was similar to the previous results. All aquatic health indicators were good or excellent at the transition zone, generally similar to 1992 observations.

Aquatic plants have declined from about 700 acres in the late 1980s to about ten acres in 1993.

<u>Reservoir Use Suitability</u>

Fourteen swimming areas were tested for fecal coliform concentrations in 1993. Two other swimming sites were tested in 1990. Bacteriological water quality was within criteria at 14 sites. The other two sites met criteria if rainfall samples are excluded. Fecal coliform concentrations at Watts Bar swimming beaches are generally higher than at other Tennessee River Reservoirs. Monthly fecal coliform bacteria samples have been collected at the Vital Signs locations since 1990. All samples collected from April through September have been very low.

As a result of PCB contamination, the Tennessee Department of Environment and Conservation (TDEC) has issued advisories on consumption of several fish species from Watts Bar Reservoir. In the Tennessee River portion a "do not consume" advisory exists for catfish, striped bass, and striped bass/white bass hybrids. A precautionary advisory (children and pregnant or lactating women do not eat fish; all others limit fish consumption to 1.2 pounds per month) is in effect for largemouth bass, white bass, sauger, carp and smallmouth buffalo. In the Clinch River arm striped bass should not be eaten, and a precautionary advisory is in effect for catfish and sauger.

Also, TDEC has issued a "do not consume" advisory for fish taken from the east fork of Poplar Creek due to mercury, metals, and organic chemical contamination.

13.2 Fort Loudoun Reservoir

Physical Description

Fort Loudoun Reservoir is the ninth and uppermost reservoir on the Tennessee River with the dam located at TRM 602.3. The surface area and shoreline are relatively small (14,600 acres and 360 miles, respectively) considering the length (61 miles), indicating it is mostly a run-of-the-river reservoir. The average annual discharge from Fort Loudoun Dam is 18,400 cfs which provides an average hydraulic retention time of about ten days.

Fort Loudoun Reservoir (and the Tennessee River) is formed by the confluence of the French Broad and Holston Rivers, with both of these rivers having a major reservoir upstream. Douglas Dam, 32.3 miles up the French Broad River, and Cherokee Dam, 52.3 miles up the Holston River, form deep storage impoundments, each having long retention times. Both of these deep storage impoundments become strongly stratified during summer months resulting in the release of cool, low DO, hypolimnetic water during operation of the hydroelectric units. Some warming and reaeration of the water occurs downstream from Cherokee and Douglas Dams, but both temperature and DO levels are sometimes low when the water reaches Fort Loudoun Reservoir.

Fort Loudoun Reservoir also receives surface waters from the Little Tennessee River, via the Tellico Reservoir canal, which connects the forebays of the two reservoirs. (Since Tellico Dam has no outlet, under most normal conditions, water flows into Fort Loudoun Reservoir from Tellico Reservoir.) Water from Tellico Reservoir (Little Tennessee River) is often cooler and higher in DO, and has a much lower conductivity than water in Fort Loudoun Reservoir (Tennessee River). In 1992, the forebay sampling location on Fort Loudoun Reservoir (originally located at TRM 603.2) was moved upstream to TRM 605.5. This resulted in a better assessment of the water quality conditions of the Tennessee River in the forebay portion of Fort Loudoun Reservoir by minimizing the effects of the Little Tennessee River and Tellico Reservoir on the data gathered in the forebay of Fort Loudoun Reservoir.

Although Fort Loudoun Reservoir is a mainstream reservoir, its complex set of hydrologic conditions (cool water inflows from the Holston, French Broad, and Little Tennessee Rivers) often causes it to exhibit several characteristics that are more typical of a storage impoundment. In fact, analysis of historical fisheries data for the Tennessee Valley indicates the fish community of Fort Loudoun Reservoir is more similar to that in Valley storage impoundments than in other mainstream reservoirs.

Ecological Health

Vital Signs monitoring information showed the ecological health of Fort Loudoun Reservoir was between fair and poor in 1993 (58 percent), basically similar to 1992 (53 percent) and 1991 (60 percent). The only ecological health indicator which rated good or excellent on Fort Loudoun was DO at the forebay and transitions zone (no data were available from the inflow). Such good ratings for DO were surprising based on observations of lower DOs in 1993 in other mainstream reservoirs and historical concerns about DO in Fort Loudoun Reservoir.

Several indicators rated poor or very poor. Sediment quality at the forebay rated poor due to high zinc concentrations, presence of chlordane, and toxicity to Ceriodaphnia. Transition zone sediments rated fair with similar conditions as the forebay, but no toxicity to test organisms was found. These findings are consistent with results found in previous years. The fish assemblage rated poor at all three sample sites (forebay, transition zone, and inflow) mostly due to low species richness and low capture rate of individuals (similar to previous years). Benthic macroinvertebrates rated very poor at the inflow site due to low species richness and abundance (comparable to previous years). Benthos rated fair at the forebay and transition zone. Similar results had been found at the transition zone in previous years, but benthic invertebrates at the forebay improved in several metrics, especially species richness and reduced dominance by tolerant organisms.

Aquatic macrophytes only covered 25 acres on Fort Loudoun Reservoir in 1993. Coverage over the past decade has ranged 25 to 140 acres.

Reservoir Use Suitability

TDEC has issued advisories on consumption of two fish species from Fort Loudoun Reservoir. Tennessee advises people not to eat catfish taken from Fort Loudoun Reservoir because of high levels of PCBs. Also, largemouth bass should not be eaten if they weigh over two pounds or are caught in the Little River embayment due to PCB contamination.

Fort Loudoun Reservoir has had a PCB problem for more than 20 years. Initially, TVA and state agencies examined a variety of species from throughout the reservoir to document the geographical and species variation. The study now continues as a trend study in which there is an annual collection of catfish from one location. PCB concentrations in catfish have varied over the years with no distinct trend.

Fecal coliform concentrations at one boat ramp tested in 1993 were within criteria for recreation. In 1989, 1990, and 1992, fecal coliform samples were collected at a total of three swimming beaches and 16 other sites. Bacteria concentrations were low at the swimming beaches and other sites in the downstream portion of the reservoir. Concentrations in the upstream portion of the reservoir, especially near downtown Knoxville, were much higher, with four sites exceeding Tennessee criteria. Fecal coliform concentrations at the monthly Vital Signs locations sampled since 1990 have been very low except for the April 1993 samples.

13.3 Melton Hill Reservoir

Physical Description

Melton Hill Dam is located at mile 23.1 on the Clinch River and is 56.7 miles downstream of Norris Dam. Impounded water extends upstream from Melton Hill Dam about 44 miles. Melton Hill Reservoir has about 170 miles of shoreline and 5690 surface acres at full pool. Average flow through Melton Hill is about 4900 cfs resulting in an average retention time of approximately 12 days. Melton Hill is TVA's only tributary dam with a navigation lock.

The predominant factor influencing the aquatic resources of Melton Hill Reservoir, especially the inflow and mid-reservoir areas, is the cold water entering from Norris Dam discharges. During summer, water discharged from Norris is cold and low in oxygen content. Oxygen concentrations are improved by a re-regulation weir downstream of Norris Dam and by atmospheric reaeration in the river reach between Norris Dam and upper Melton Hill Reservoir. However, water is warmed little and is still quite cool when it enters upper Melton Hill Reservoir. Bull Run Steam Plant, located at about CRM 47, warms the water some, but water temperatures are still too cool to support warm water biota and too warm to support cold water biota.

Ecological Health

The ecological health of Melton Hill Reservoir was in the upper end of the fair range in 1993 (68 percent, similar to 1992 and 1991). Chlorophyll and DO were excellent at both the forebay and the transition zone. However, a poor fish assemblage was found at forebay and inflow, generally similar to previous years. Primary problems in the fish assemblage were low species richness and abundance in electrofishing samples. Cool water flowing in from the bottom layer of Norris Lake causes problems for fish in Melton Hill, especially in the middle and upper sections. The water is too cold to support fish that like warm water, but too warm to support fish that thrive in cold water. The benthic macroinvertebrate community rated poor at the forebay and very poor at the transition zone and inflow, generally similar to previous years. Components of the benthos resulting in poor metrics were absence of long-lived and intolerant species and dominance by tolerant species.

Aquatic macrophyte coverage on Melton Hill Lake in 1993 was about 240 acres. During the past decade, coverage has ranged from about 100 to 250 acres.

Reservoir Use Suitability

No bacteriological studies were conducted at recreation areas in 1993. In 1989, samples were collected at four boat ramps during a period of high rainfall, and fecal coliform concentrations were high. In 1990, two swimming beaches and six other sites were tested during a more normal rainfall period. Concentrations were lower and within recreation criteria. Fecal coliform concentrations at the monthly Vital Signs locations sampled since 1991 have generally been low.

TDEC has advised the public to avoid consumption of catfish from Melton Hill Reservoir because of PCB contamination. Samples are collected annually from the transition zone and near the inflow by TVA and from the forebay by the Oak Ridge National Laboratory as part of ongoing, cooperative studies. PCB concentrations in catfish collected in autumn 1992 generally fell within the range found in previous years.

13.4 Emory River Stream Monitoring Site

Physical Description

The majority of the Emory River drainage area lies in the Cumberland Plateau and flows through the Tennessee counties of Cumberland, Morgan, and Roane. The Emory River leaves the plateau and cuts more than 600 feet down the eastern escarpment to join the Clinch River in the Valley and Ridge physiographic province as a major embayment to Watts Bar Reservoir.

The TVA monitoring station is located at the USGS stream gage at Oakdale. The Emory River drainage above Oakdale is 764 square miles or 88 percent of the entire Emory River basin. The principal tributary to the Emory is the Obed River (520 square miles). The principal tributaries to the Obed are Clear Creek (173 square miles) and Daddy's Creek (175 square miles).

Sandstone, shale, and conglomerates underlie most of the Emory River basin. Most of the basin is forested. About one-fourth of the basin lies within the Catoosa Wildlife Management Area, while about 5 percent is used for agriculture and 1 percent is used for surface coal mining. The only urban area above Oakdale is Crossville, Tennessee, near the headwaters of the Obed River.

Ecological Health

The overall ecological health of the Emory River at the stream monitoring site was good in 1993. This is an improvement over 1992 when fair conditions were found. The primary problem found in 1992 was poor sediment quality, evidenced by poor survival of test organisms. This was not the case for 1993 as no sediment toxicity was found.

Use Suitability

There were no bacteriological studies conducted on the Emory River in 1993.

A five fish composite each of carp, channel catfish, and largemouth were collected during summer 1992 and analyzed for selected metals, pesticides, and PCBs. Only PCBs in channel catfish were high enough to be of interest. The concentration was near that used to indicate need of more intensive investigation. Samples collected in summer 1993 should help evaluation of this situation.

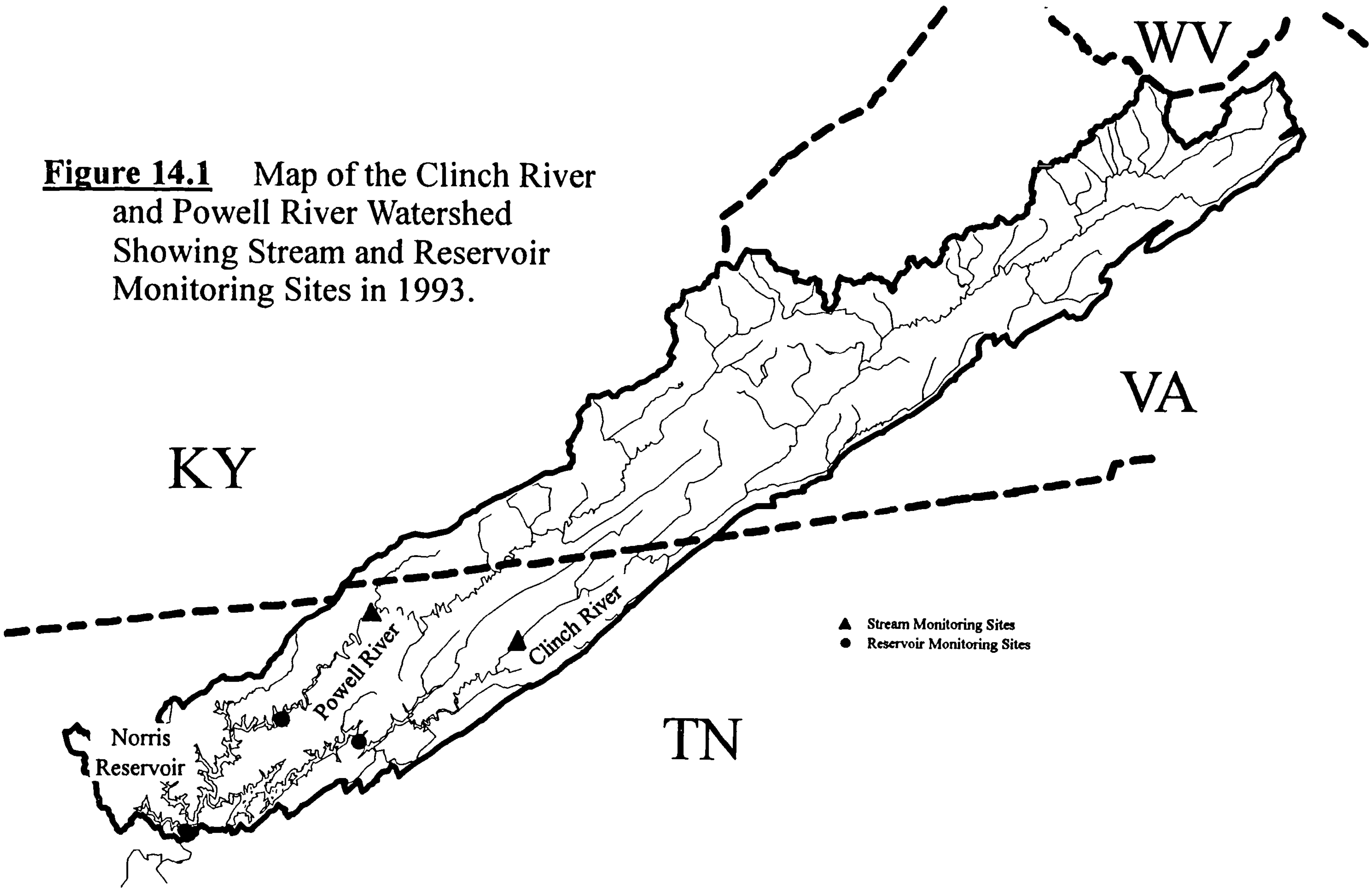
14.0 CLINCH RIVER AND POWELL RIVER WATERSHED

This long, narrow watershed lies in southwest Virginia and northeast Tennessee. Streams in the watershed have high concentrations of dissolved minerals and generally low concentrations of nutrients.

For management purposes, an artificial ending point of the watershed has been established at Norris Dam, which is near Clinch River mile 80. The remainder of the Clinch River is associated with the Watts Bar, Fort Loudoun, and Melton Hill Reservoir Watershed area. As defined, this watershed drains an area of 2912 square miles and has an average annual discharge of about 4200 cfs. The Clinch and Powell Rivers contribute about 80 percent of this flow.

Norris Reservoir is the only major reservoir in the watershed; essentially all streams upstream from Norris are free flowing. There are three Vital Signs monitoring sites in Norris Reservoir (forebay and mid-reservoir sites on the Clinch and Powell arms) and two stream sites, one each on the Clinch and Powell Rivers (Figure 14.1). Results from 1993 monitoring activities are in Section 14.1 for Norris Reservoir, Section 14.2 for the Clinch River stream monitoring site, and Section 14.3 for the Powell River stream monitoring site.

Figure 14.1 Map of the Clinch River and Powell River Watershed Showing Stream and Reservoir Monitoring Sites in 1993.



14.1 Norris Reservoir

Physical Description

Norris Reservoir is formed by Norris Dam at Clinch River mile (CRM) 79.8. It is a large, dendritic, tributary storage impoundment of the Clinch and Powell Rivers which flow together about nine miles upstream of the dam. Norris is one of the deeper TVA tributary reservoirs, with depths over 200 feet. Annual drawdown averages about 32 feet. At full pool, the surface area of the reservoir is 34,200 acres, the shoreline is about 800 miles in length, and water is impounded 73 miles upstream on the Clinch River and 53 miles upstream on the Powell River. Norris Reservoir has a long average retention time (about 245 days) and an average annual discharge of approximately 4200 cfs. Due to the great depth and long retention time of Norris Reservoir, significant vertical stratification is expected. Additional information about the physical and hydrologic characteristics of Norris Reservoir are given in Table 4.1.

Because of the confluence of the Clinch and Powell Rivers relatively close to the dam, three reservoir sampling locations were established: one forebay site; and two mid-reservoir sites--one on the Clinch River and one on the Powell River.

Ecological Health

Norris is an oligotrophic reservoir with very clear water. There is little algal primary production because of phosphorus limitations. The ecological health of Norris Reservoir in 1993 was fair (67 percent), with conditions about the same as in 1992 and 1991 (60-67 percent). Dissolved oxygen concentrations in the deeper portions of Norris Reservoir, particularly at the mid-reservoir locations on the Clinch and Powell Rivers, have historically been low. This condition, although undesirable, is often observed in deep, thermally stratified tributary reservoirs with long retention times.

As expected, 1993 DO concentrations rated very poor at both mid-reservoir sites. The rating for DO at the forebay was poor in 1993 compared to fair in 1992. The 1992 results had indicated a slight improvement over 1991 conditions.

As in the past, low nutrient concentrations in the forebay resulted in low algal levels and a fair rating for chlorophyll in 1993. The effects of low primary productivity usually manifests itself throughout the food chain and results in a low overall abundance of fish. The fish assemblage rated fair at the forebay in 1993, primarily due to low abundance and low species richness. At both mid-reservoir sites, both chlorophyll and fish assemblages rated good. The benthic macroinvertebrate community rated fair at the forebay and mid-reservoir site on the Clinch arm of Norris Reservoir and good at the mid-reservoir site on the Powell arm. Given the low DO concentrations near the bottom, fair to good ratings for benthic macroinvertebrates are better than would be expected. This suggests that the benthic community is able to recover quickly between autumn reoxygenation of bottom sediments and sample collection the following spring. Another possible explanation is that some of the samples collected along the transect were above the oxygen-stressed stratum. Results from individual samples suggest both factors contributed to the observed ratings.

Reservoir Use Suitability

There are no fish consumption advisories on Norris Reservoir. Channel catfish were collected for screening purposes in autumn 1992. All analytes were low or not detected except PCBs. The highest PCB concentration was 0.9 $\mu g/g$. Concentrations this high had not been found before. Areas were resampled in autumn 1993 to further examine PCB concentrations, but results were not available at the time this report was prepared.

Fecal coliform bacteria samples were collected at five sites in 1993. Concentrations were very low at all five sites. In 1991, ten sites were sampled. Fecal coliform concentrations were generally higher in 1991 than in 1993, possibly due to higher rainfall in 1991. However, in 1991 all sites met the geometric mean bacteriological water quality criterion for recreation. In 1991 three sites exceeded one of EPA's recommended guidelines; more than 10 percent of the samples had fecal coliform concentrations greater than 400/100 mL. Fecal coliform sampling at the Vital Signs locations was discontinued in 1993. Fecal coliform concentrations at the three Vital Signs stations sampled from 1990 to 1991 were very low.

14.2 Clinch River Stream Monitoring Site

Physical Description

The TVA stream monitoring station is located at the USGS stream gage near Tazewell, Tennessee, just upstream of the impounded water of Norris Reservoir, at CRM 159.8. The Clinch River basin above the monitoring site is 1474 square miles or 33 percent of the total Clinch River basin. Three-quarters of the monitored area lies within Virginia. Principal tributaries in the monitored area are the North Fork Clinch River (87 square miles), Guest River (102 square miles), Little River (126 square miles), Copper Creek (133 square miles), and Big Cedar Creek (86 square miles).

The headwaters of the upper Clinch River drain the eastern escarpment of the Cumberland Plateau (including portions of the Jefferson National Forest), then flow southwest through the Valley and Ridge physiographic province in a valley parallel to and southeast of the Powell River. Land use in the basin is 70 percent forestry and 30 percent agriculture. Coal mining occurs in some areas.

Ecological Health

The overall ecological health of the Clinch River at this site was good as in 1992. Conditions for fish and bottom-dwelling animals remained good in 1993. Sediment quality showed an improvement over 1992, with the rating changing from fair to good.

Use Suitability

Concentrations of fecal coliform bacteria were very low in 1993 at the weir and canoe launch site in the Clinch River downstream of Norris Dam. Concentrations were higher in 1991 when the canoe launch site had been tested.

All analytes in fish tissue samples collected during summer 1992 were either not detected or found in low concentrations.

14.3 Powell River Stream Monitoring Site

Physical Description

The Powell River joins the Clinch River 10 miles upstream from Norris Dam and forms a major embayment to Norris Reservoir. Most of the Powell River headwaters and tributary streams drain portions of the eastern border of the Cumberland Plateau, but the main river is predominantly in the Valley and Ridge physiographic province. The river flows for more than 195 miles through southwestern Virginia and northeastern Tennessee. The total drainage of the Powell River basin is 938 square miles.

The TVA monitoring station is located near Arthur, Tennessee. Above this location the area of the basin is 685 square miles or 73 percent of the entire Powell River watershed. Principal tributaries above Arthur include Indian Creek (66 square miles) and the North Fork Powell River (90 square miles).

Land use in the basin is 75 percent forest, 20 percent agriculture, and almost 5 percent surface mining, primarily in the upper reaches in southwestern Virginia. Only small urban areas are located in the Powell River watershed.

Ecological Health

Conditions for fish and bottom-dwelling animals improved to good in 1993. The change from a fair to a good classification was a result of greater numbers and higher quality bottom-dwelling organisms present. The Powell River watershed is heavily mined for coal and has a history of illegal discharges of blackwater into the river from coal washing facilities.

Use Suitability

There were no bacteriological studies conducted on the Powell River in 1993.

All analytes in fish tissue samples collected in summer 1993 wre either nondetectable or found low concentrations.

15.0 LITTLE TENNESSEE RIVER WATERSHED

The Little Tennessee River Watershed encompasses 2672 square miles, mostly in Tennessee and North Carolina with a small area in Georgia. Much of the watershed is forested, with the headwaters in the Blue Ridge Mountains. The basin is underlain mostly by crystalline and metasedimentary rocks of the Blue Ridge province. This watershed is home to a large variety of federally listed threatened and endangered species.

Most of the streams in the watershed are steep gradient and generally have low concentrations of both dissolved minerals and nutrients. The two largest tributaries to the Little Tennessee River are the Tuckasegee River which merges with the Little Tennessee in Fontana Reservoir and the Tellico River which merges with the Little Tennessee in Tellico Reservoir.

There are several reservoirs in the watershed but only Fontana Reservoir in the mountainous area and Tellico Reservoir at the lower end of the watershed are monitored (Figure 15.1). TVA does not monitor the other reservoirs either because of their small size or because they are owned by the Aluminum Company of America (ALCOA).

Two sites are monitored on Tellico Reservoir (the forebay and transition zone) and three sites on Fontana Reservoir (the forebay and mid-reservoir sites on the Little Tennessee River and Tuckasegee River). There is one stream monitoring site in the watershed, on the Little Tennessee River upstream of Fontana Reservoir. Another stream monitoring site (on the Tuckasegee River) is being added in 1994. Results of 1993 monitoring activities are provided in the following sections:

15.1 Tellico Reservoir

15.2 Fontana Reservoir

15.3 Little Tennessee River Stream Monitoring Site

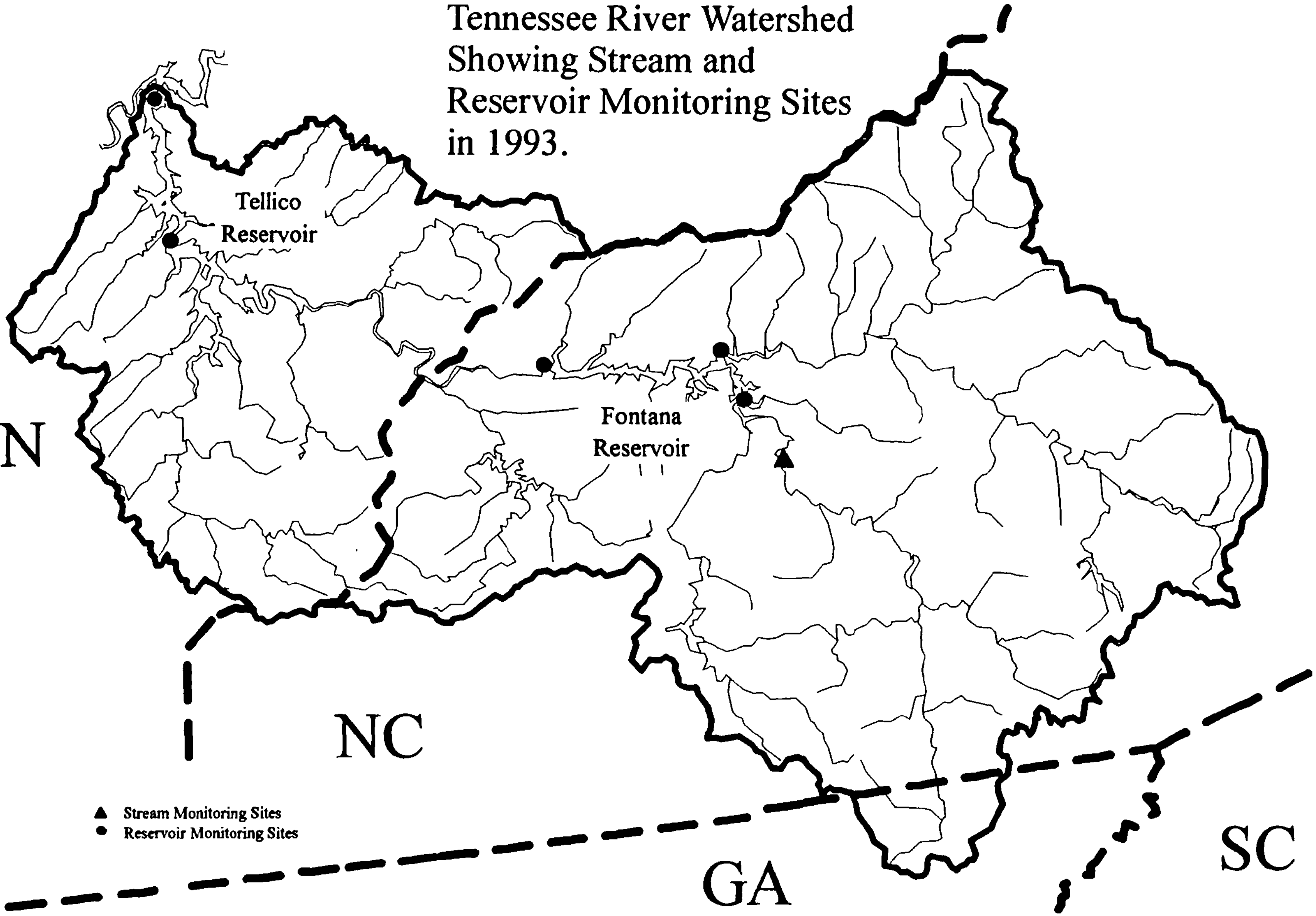


Figure 15.1 Map of the Little Tennessee River Watershed Showing Stream and Reservoir Monitoring Sites in 1993.

15.1 Tellico Reservoir

Physical Description

Tellico Dam is located on the Little Tennessee River just upstream of the confluence of the Little Tennessee and Tennessee Rivers. It is the last dam completed in the TVA system with dam closure in 1979. Tellico Reservoir is 33 miles long, has a shoreline of 373 miles, and has a surface area of about 16,000 acres at full pool. The average estimated flow through Tellico Reservoir is approximately 5700 cfs which provides an average retention time of about 37 days. Very little of this water is discharged through Tellico Dam. Rather, it is diverted through a navigation canal to Fort Loudoun Reservoir near the dam for hydroelectric power production. Water characteristics in these two reservoirs differ considerably as discussed in Section 13.2, Fort Loudoun Reservoir. The hydrodynamics and exchange of water via the inter-connecting canal significantly affect water quality within Tellico Reservoir (and Fort Loudoun Reservoir). The canal is only 20-25 feet deep, but the depth of Tellico Reservoir at the forebay is about 80 feet. Thus, water at strata below about 25 feet is essentially trapped and becomes anoxic during much of the summer in the forebay of Tellico Reservoir.

The impounded water of Tellico Reservoir extends upstream of the confluence of the Little Tennessee and Tellico Rivers. The transition zone site selected for sample collection in 1990, 1991, and 1992 was in the Little Tennessee River, just upstream of the confluence with the Tellico River at Little Tennessee River Mile (LTRM) 21.0. Water conditions at that site are largely controlled by discharges from Chilhowee Dam at LTRM 33.6. This water is cold, nutrient poor, and has a low mineral content, conditions that are not conducive to establishing a diverse, abundant aquatic community. In 1993, the transition zone sampling location in Tellico Reservoir was moved six miles downstream to LTRM 15.0, just below the confluence of the Tellico River--a site more characteristic of lacustrine rather than riverine conditions.

Ecological Health

Tellico Reservoir received a better ecological health rating in 1993 than in previous years. The rating was 63 percent (fair) for 1993 compared to 48 percent in 1992 and 44 percent in 1991 (both poor). The primary causes of the higher score were better ratings for DO at the forebay (mostly the result of an improved, more accurate method of calculating the score for this indicator) and addition of information from the transition zone collection site which was relocated in 1993. The change in DO scoring resulted in forebay DO being rated fair in 1993, whereas it had preciously been rated poor every year. Other than that change, all indicators at the forebay rated the same in 1993 as in previous years--poor sediment quality and benthic macroinvertebrate community, good chlorophyll, and fair fish assemblage.

Two indicators, chlorophyll and DO, received excellent ratings at the new transition zone site. The other three rated poor--sediment quality (presence of chlordane and significant toxicity), benthos (mostly due to absence of long-lived and sensitive organisms), and fish assemblage (few fish collected in gill netting efforts, which affected several metrics).

The higher ecological health score for 1993 is considered to be more representative of the true environmental conditions in Tellico Reservoir than previous scores.

Most of the 246 acres of aquatic macrophytes on Tellico Lake in 1993 were in the Tellico River arm of the reservoir.

Reservoir Use Suitability

No bacteriological studies were conducted at recreation areas in 1993. In 1992, fecal coliform samples were collected at four swimming beaches and five other sites on the reservoir. Bacteria concentrations were low. Fecal coliform concentrations at the monthly Vital Signs locations sampled since 1991 have been very low.

The state has advised that catfish from Tellico Reservoir should not be eaten because of PCB contamination. Fish were collected in autumn 1992 for tissue analysis. Channel catfish were collected as part of a continuing effort to examine the trend in PCB concentrations. Results indicate the PCB problem continued to exist with no downward trend.

15.2 Fontana Reservoir

Physical Description

Fontana Reservoir is located in the Blue Ridge Mountains of western North Carolina. Fontana is the deepest reservoir in the TVA system. At full pool it has a maximum depth of 460 feet, a length of 29 miles, a shoreline of 248 miles, and a surface area of 10,640 acres. Fontana Reservoir has a relatively large drawdown, which averages about 64 feet annually. Every fifth year Fontana is drawn even deeper to allow sluice gate access for maintenance.

Fontana Dam is located at Little Tennessee River Mile 61.0. Average annual discharge is 3840 cfs which provides an average hydraulic retention time in the reservoir of 186 days.

Water in Fontana Reservoir is quite clear due to limited photosynthetic activity and a mostly forested watershed. Water entering the reservoir is low in nutrients and dissolved minerals.

Ecological Health

Fontana Reservoir rated fair in 1993 (64 percent), the first year of Vital Signs monitoring. Fontana is an oligotrophic reservoir with very low chlorophyll concentrations resulting in fair ratings at all three sites. Further evidence of the low primary productivity is the clear, blue water (indicating low abundance of algae and lack of green phytoplankton pigments). Secchi depths averaged almost 6 meters in the forebay of Fontana in 1993. The fish assemblage also rated fair at all locations, probably related to the low primary productivity. Ratings for DO varied from excellent at the mid-reservoir site on the Little Tennessee River to poor at the mid-reservoir site on the Tuckasegee River, with a fair rating at the forebay. Sediment quality also varied greatly among the three locations--poor at the forebay, good at the mid-reservoir site on the Tuckasegee arm, and excellent on the Little Tennessee arm. Rating for the benthic macroinvertebrate community also varied greatly from very poor at the forebay to fair at the Little Tennessee River mid-reservoir site. The benthos rating at the forebay was not included in determining the overall ecological health score because part of the transect sampled was in the drawdown zone.

Reservoir Use Suitability

Channel catfish were collected in autumn 1992 from the forebay and mid-reservoir site on the Little Tennessee River. Analysis of composited fillets from each area found most analytes were not detected or had low concentrations. The exceptions to this were mercury at both locations (maximum of 0.53 $\mu g/g$) and PCBs at the forebay (1.1 $\mu g/g$). Channel catfish were collected again in 1993 from both locations and analyzed for the same analytes with close attention for PCBs at the forebay. Largemouth bass were also collected in autumn 1993 from both locations to further examine mercury concentrations. Results were not available at the time this report was prepared.

There were no bacteriological studies conducted on Fontana Reservoir in 1993.

15.3 Little Tennessee River Stream Monitoring Site

Physical Description

The Little Tennessee River drains 2727 square miles and flows more than 140 miles through the Blue Ridge physiographic province of western North Carolina and the Valley and Ridge province of East Tennessee. It joins the Tennessee River near Lenoir City, Tennessee.

The TVA monitoring station is located near Needmore, North Carolina. The drainage area upstream from the monitoring site is 440 square miles or 16 percent of the entire Little Tennessee River basin. Principal tributaries to the Little Tennessee River include Abrams Creek (88 square miles), Cheoah River (215 square miles), Nantahala River (175 square miles), Cullasaja River (93 square miles), and the Tuckasegee-Oconaluftee River (734 square miles). The Cullasaja River is the only major tributary within the monitored area. The basin has been extensively developed with TVA reservoirs (Tellico and Fontana) and private power dams (Chilhowee, Calderwood, Cheoah, Santeetlah, Nantahala, Franklin, and Thorpe).

Igneous and metamorphic rock underlies all of the basin. Much of the basin is located within the federally managed lands of the Great Smoky Mountains National Park and Cherokee and Nantahala National Forests. Franklin, Sylva, Bryson City, and Robbinsville, North Carolina, are the primary urban areas in the basin.

Ecological Health

The stream monitoring site on the Little Tennessee River (at LTRM 94.5) had a very good ecological health rating in 1993 (as in 1992). All indicators (nutrients, sediment quality, benthos, and fish) were rated good.

Use Suitability

No bacteriological studies have been conducted in the streams of this watershed under this monitoring program.

All analytes in fish tissue samples collected during summer 1993 were either below detection limits or found in low concentrations.

16.0 FRENCH BROAD RIVER WATERSHED

The French Broad River watershed is one of the largest (5124 square miles) watersheds in the Tennessee Valley. About half the watershed is in Tennessee and half is in North Carolina. The French Broad River and its two large tributaries (Nolichucky and Pigeon Rivers) originate in the Blue Ridge Mountains. All three of these rivers merge at the upper end of Douglas Reservoir, the only sizable reservoir in the watershed. The water in the French Broad River is moderately hard and relatively high in nutrients.

There are three reservoir Vital Signs monitoring sites on Douglas Reservoir and one stream monitoring site each on the French Broad and Nolichucky Rivers (Figure 16.1). A stream monitoring site on the Pigeon River is being added in 1994. All stream monitoring sites are upstream of Douglas Reservoir.

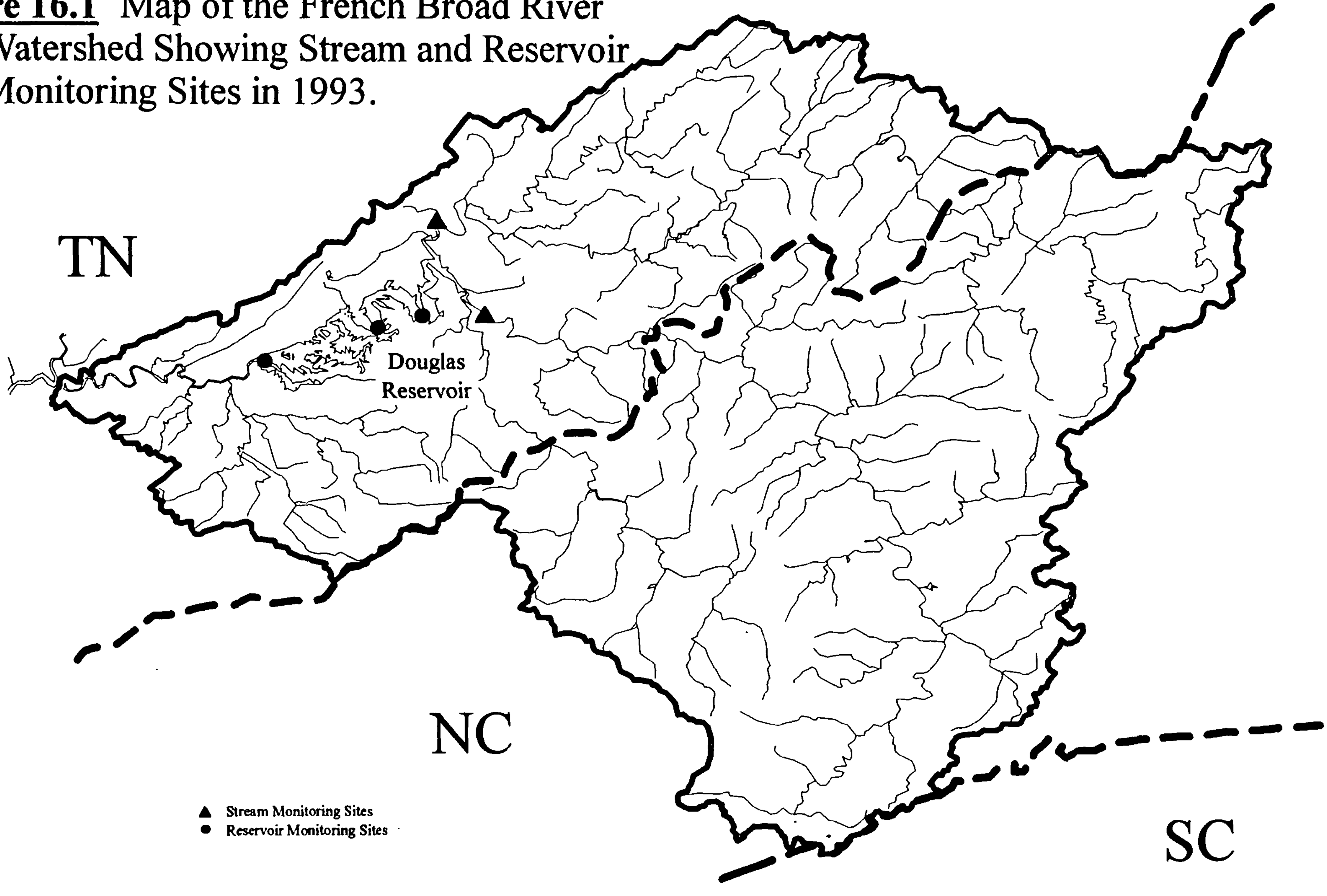
Results from 1993 Vital Signs monitoring activities are provided in the following sections:

16.1 Douglas Reservoir

16.2 French Broad River Stream Monitoring Site

16.3 Nolichucky River Stream Monitoring Site

Figure 16.1 Map of the French Broad River Watershed Showing Stream and Reservoir Monitoring Sites in 1993.



16.1 Douglas Reservoir

Physical Description

Douglas Reservoir is a deep storage impoundment (tributary reservoir) on the French Broad River. Douglas Dam is located 32.3 miles upstream of the confluence of the French Broad and Holston Rivers which form the Tennessee River. Reservoir drawdown during late summer and autumn is rather large, with an annual average of about 48 feet. The large annual fluctuation in surface water elevation causes other physical characteristics such as surface area, reservoir length, and retention time to vary greatly during the year. At full pool, maximum depth at the dam is 127 feet, surface area is 30,400 acres, the shoreline is 555 miles, and the length is 43 miles. Average annual discharge is approximately 6780 cfs, which provides an average hydraulic retention time of about 105 days.

Lengthy retention times and lack of mixing due to their deep nature tend to cause storage impoundments to have strong thermal stratification during summer months. Undesirable conditions often develop in the hypolimnion due to anoxia, which in most cases extends from the forebay to the mid-reservoir sampling location.

Ecological Health

The ecological health of Douglas Reservoir was fair to poor (58 percent) in 1993, with little change compared to 1991 and 1992. Factors adversely affecting the ecological health of Douglas Reservoir were strong thermal stratification and high nutrient loadings. This combination results in hypolimnetic anoxia and release of iron and manganese, phosphorus, and ammonia from the sediment and excessive eutrophication of the reservoir. Ratings for DO were very poor at both the forebay and mid-reservoir sites in 1993 due to very low hypolimnetic DO at both locations and low surface DO at the forebay. This hypolimnetic anoxia promoted the release of ammonia (and sulfide) from the sediment and negatively impacted the benthic community. The benthic macroinvertebrates rated poor at the forebay (samples were not collected from the mid-reservoir site). Sediment quality rated good at the forebay but poor at the mid-reservoir site. The fish assemblage was fair at the forebay and good at the mid-reservoir site. Chlorophyll rated good at the forebay, but only fair at the mid-reservoir site because concentrations were relatively high, indicative of high nutrients and high primary productivity.

Reservoir Use Suitability

There are no fish consumption advisories on Douglas Reservoir. However, fish from the Pigeon River upstream of Douglas Reservoir should not be eaten because of dioxin contamination. The most recent collection of fish from Douglas Reservoir was in autumn 1992. TVA collected fish samples and provided fillets to the Tennessee Department of Environment and Conservation for analysis. Results were not available at the time this report was prepared.

Fecal coliform concentrations were very low at the swimming beach and two boat ramps tested in 1993. Fecal coliform bacteria sampling at the two Vital Signs stations was dropped in 1993. From 1990 to 1992, concentrations were very low.

16.2 French Broad River Stream Monitoring Site

Physical Description

The French Broad River is a major tributary to the Tennessee River system, flowing westward out of the Appalachian Mountains for more than 220 miles to meet the Holston River and form the Tennessee River.

The drainage basin above the stream monitoring site at the USGS stream gage at near Newport, Tennessee, is 1858 square miles or 36 percent of the watershed. Principal tributaries in the monitored area include Big Laurel Creek (132 square miles), Ivy Creek (161 square miles), the Swannanoa River (133 square miles), Hominy Creek (104 square miles), and Mud Creek (113 square miles). Two major tributaries enter the French Broad River below the monitoring site. They include the Nolichucky River (1756 square miles) and the Pigeon River (689 square miles).

Ecological Health

The ecological health of the stream monitoring site at the French Broad River site rated poor in both 1993 and 1992. Nutrients rated poor because of high concentrations of phosphorus. Inflows of nutrients promote the excessive algal productivity in Douglas Reservoir. The fish community on the French Broad River was poor in 1993, same as in 1992. Given the poor water quality of the Nolichucky and French Broad Rivers flowing into Douglas Reservoir, the poor-fair ecological health of the reservoir is not unexpected. Together the Nolichucky and French Broad Rivers provide about 75 percent of the total inflow to Douglas Reservoir.

Use Suitability

No bacteriological studies were conducted as part of the monitoring program in 1993. All analytes in fish tissue samples collected during summer 1993 were either not detected or found in low concentrations.

16.3 Nolichucky River Stream Monitoring Site

Physical Description

The Nolichucky River is a major tributary to the French Broad River basin and joins the French Broad River at the upstream end of Douglas Reservoir. The Nolichucky River Basin is 1756 square miles. The upper portion of the basin (approximately 60 percent) lies in the Blue Ridge physiographic province while the remainder lies in the Valley and Ridge province.

The stream monitoring location is at the TVA stream gage at the David Thomas bridge near Lowlands, Tennessee. The Nolichucky River basin above the monitoring site is 1686 square miles or 96 percent of the entire Nolichucky River basin. Principal tributaries in the monitored area include North Toe River (442 square miles) and Cane River (158 square miles) in the Blue Ridge physiographic province and Lick Creek (266 square miles) in the lower Valley and Ridge province.

The upper portion of the Nolichucky River basin is primarily forested, while the lower portion is agricultural. High concentrations of solids from mica and feldspar mining and processing near Spruce Pine on the North Toe River have severely impacted the streambed downstream. In addition to Spruce Pine, other urbanized areas include Greeneville and Erwin, Tennessee.

Ecological Health

The overall ecological health of the Nolichucky River at this site was good in 1993, as opposed to fair in 1992. The change was driven by improvements in the fish community, the absence of acute sediment toxicity, and improvements in nutrient concentrations. The conditions for bottom-dwelling animals remained unchanged.

Use Suitability

Bacteriological studies were not conducted as part of this monitoring program in this watershed in 1993.

All analytes in fish tissue samples collected during summer 1993 were either not detected or found in low concentrations.

17.0 HOLSTON RIVER WATERSHED

The Holston River Watershed encompasses 3776 square miles, mostly in upper east Tennessee and southwest Virginia and a small area in North Carolina. The area is relatively highly populated with substantial industrial development.

Much of the area is underlain with limestone and dolomite which results in high concentrations of dissolved minerals in the streams. There is also substantial zinc mining in the watershed.

There are several reservoirs in the watershed with varying size, depth, flow, and water quality characteristics. The largest is Cherokee Reservoir on the Holston River near the lower end of the watershed. The uppermost reservoirs are Watauga Reservoir on the Watauga River and South Holston Reservoir on the South Fork Holston River. Downstream from these reservoirs, the Watauga and South Holston Rivers merge in Boone Reservoir. Immediately downstream from Boone Dam is Fort Patrick Henry Reservoir, the smallest of the five reservoirs in this watershed included in the Vital Signs Monitoring Program. A few miles downstream from Fort Patrick Henry Dam the South Fork and North Fork Holston Rivers merge to form the Holston River.

Vital Signs monitoring activities are conducted at one, two, or three locations depending on reservoir size and characteristics (Figure 17.1). There is also a stream monitoring site on the Holston River upstream of Cherokee Reservoir.

The average annual discharge from Cherokee Dam is 4460 cfs. The Holston River merges with the French Broad River at Knoxville to form the Tennessee River.

Results from Vital Signs monitoring activities in 1993 are in the following sections:

17.1 Cherokee Reservoir

17.2 Fort Patrick Henry Reservoir

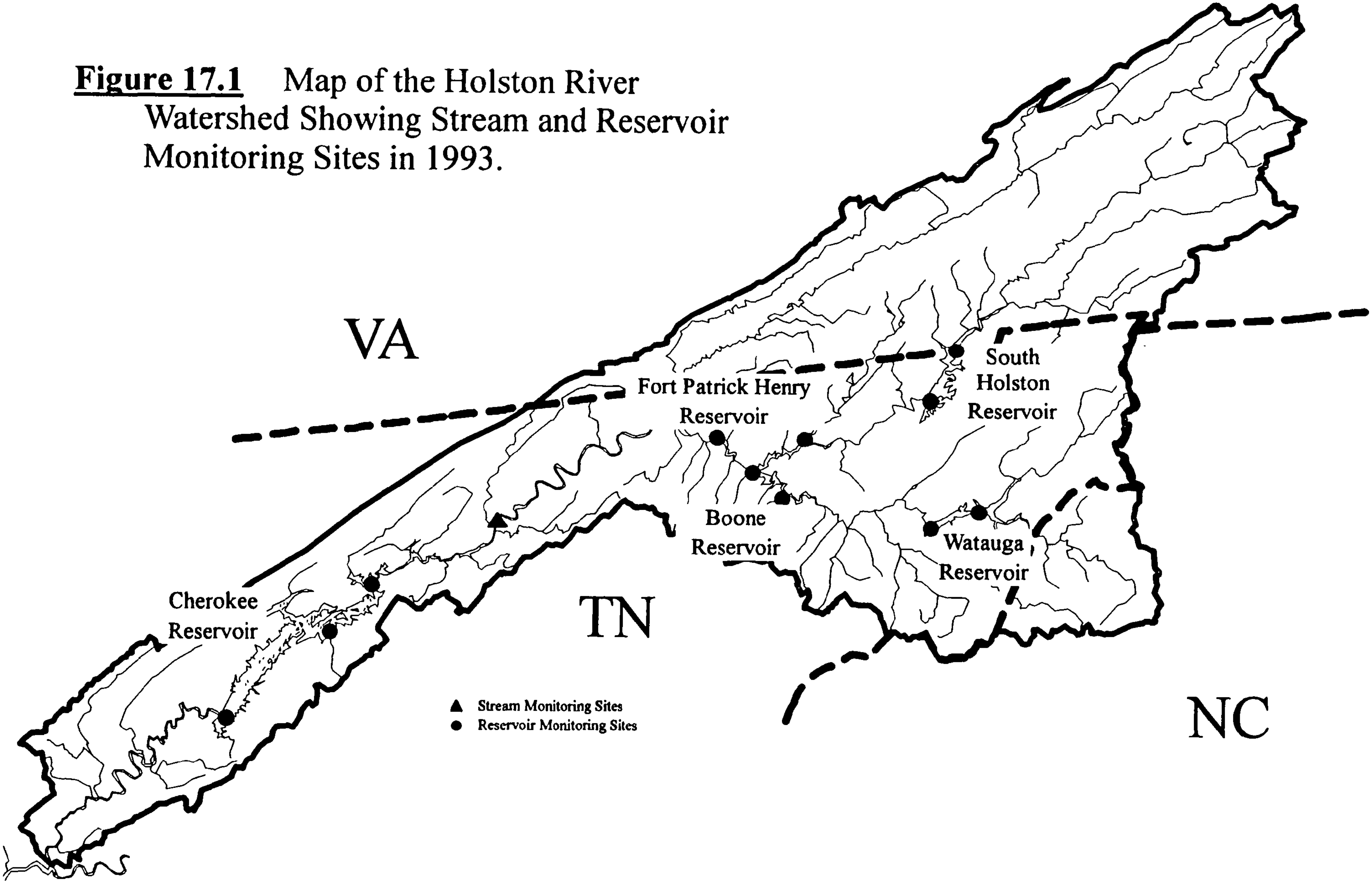
17.3 Boone Reservoir

17.4 South Holston Reservoir

17.5 Watauga Reservoir

17.6 Holston River Stream Monitoring Site

Figure 17.1 Map of the Holston River Watershed Showing Stream and Reservoir Monitoring Sites in 1993.



17.1 Cherokee Reservoir

Physical Description

Cherokee Reservoir is formed by Cherokee Dam at Holston River mile (HRM) 52.3. Like Norris and Douglas Reservoirs, it is a large, relatively deep, tributary storage impoundment with a substantial drawdown which begins in late summer. When the water surface is at full pool, maximum depth at the dam is 163 feet and winter drawdown is 53 feet. However, full pool is not reached most years, and the long-term average drawdown is about 28 feet. At full pool, Cherokee Reservoir is 54 miles long, has a surface area of 30,300 acres, and a shoreline of 393 miles. Average annual discharge is about 4500 cfs which provides an average hydraulic retention time (at full pool) of approximately 165 days.

Like other deep storage impoundments with long retention times, Cherokee Reservoir exhibits strong vertical stratification during summer months. The hypolimnetic oxygen deficit on Cherokee is one of the worst of all Vital Signs monitoring reservoirs and has been well documented in numerous past studies (Iwanski, 1978; Iwanski et al., 1980; Hauser et al., 1987).

Ecological Health

The ecological health of Cherokee Reservoir rated fair (64 percent) in 1993, which was higher than poor ratings in 1992 (55 percent) and poor to fair ratings in 1991 (60 percent). The improved ecological health rating compared to 1992 resulted mostly from addition of benthic macroinvertebrate information from the upper reservoir sample site, and from slight improvements (decreases) in chlorophyll concentrations at the mid-reservoir site. Although benthos data were collected from Cherokee Reservoir in 1992, ratings were not available for 1992 results because of an insufficient data base to establish expected (reference) conditions for the benthic macroinvertebrate community in tributary storage reservoirs. Additional benthos sampling in 1993 on Cherokee plus several other similar reservoirs provided sufficient data to establish at least preliminary expectations for reservoirs of this type. The benthic community rated fair at the forebay and excellent at the upper monitoring site indicating very good conditions there. Improvements noted for chlorophyll at the mid-reservoir site in 1993, rated good compared to fair in 1992 (due to high averages during summer), also helped elevate the overall ecological rating in 1993 compared to 1992.

A problem consistently found in Cherokee Reservoir is very low DO concentrations at the forebay and mid-reservoir sites. Both rated very poor in 1993. This near-bottom low dissolved oxygen condition, often observed in deep tributary reservoirs with long retention times, is especially severe in Cherokee Reservoir, resulting in high concentrations of un-ionized ammonia in sediment. The fair fish community observed at all monitoring sites in 1993 was probably also influenced to some extent by the low oxygen concentrations in Cherokee Reservoir. Sediment quality rated poor at the mid-reservoir site due to high ammonia and copper concentrations coupled with significant toxicity to rotifers.

Reservoir Use Suitability

There are no fish consumption advisories on Cherokee Reservoir. Channel catfish for screening tissue analysis were collected in autumn 1992. All analytes were not detected or found in low concentrations except PCBs. Maximum PCB concentrations were 0.8 $\mu g/g$ at the forebay in 1992. Screening samples were collected again in 1993 to further examine PCB concentrations, but results were not available at the time this report was prepared.

Fecal coliform concentrations were low at all test sites in 1993--a swimming beach, seven boat ramps, and one other site tested. Fecal coliform bacteria sampling at the two Vital Signs stations was discontinued in 1993. From 1990 to 1992, concentrations were very low.

17.2 Fort Patrick Henry Reservoir

Physical Description

Fort Patrick Henry Reservoir is one of the smaller reservoirs included in the Vital Signs Monitoring Program. It is only ten miles long, has a surface area of about 870 acres, and has a shoreline of 37 miles. Although it is a tributary reservoir, it has characteristics of a run-of-river reservoir, rather than a storage reservoir. Annual fluctuation in elevation is only five feet. Also, retention time is short; with an average discharge of 2650 cfs, the hydraulic retention time is only about five days. Maximum depth is about 80 feet. Fort Patrick Henry Dam is located at South Fork Holston River mile 8.2.

This reservoir had not been sampled as part of this monitoring effort prior to 1993. Because of its small size, only the forebay is monitored for Vital Signs.

Ecological Health

The ecological health of Fort Patrick Henry Reservoir was fair to good (72 percent) in 1993. DO was the only indicator which rated excellent and sediment quality was the only indicator which rated good. Chlorophyll rated fair, with the average annual concentration only slightly above the level considered good. The benthos and fish assemblage also rated fair.

Reservoir Use Suitability

Fecal coliform concentrations at Warriors Path State Park were within Tennessee's criteria for recreation during 1993 studies. TVA's first fish tissue studies on this reservoir were conducted in autumn 1993; results were not available at the time this report was prepared.

17.3 Boone Reservoir

Physical Description

Boone Dam is located at South Fork Holston River mile (SFHRM) 18.6, approximately 1.4 miles downstream of the confluence of the South Fork Holston and the Watauga Rivers. At normal maximum pool (1384 feet MSL), Boone Reservoir extends upstream approximately 17.4 miles on the South Fork Holston River and 15.3 miles on the Watauga River for a total reservoir length of approximately 32.7 miles. Boone Reservoir has a surface area of 4300 acres, a shoreline length of approximately 122 miles, an average depth of 44 feet, and a maximum depth of 129 feet near the dam. Annual average discharge from Boone Dam is about 2500 cfs, which results in an average hydraulic residence time of about 38 days. Annual drawdowns of Boone Reservoir usually average about 25 feet.

Three locations were selected for ecological health monitoring in Boone Reservoir, one at the forebay and two mid-reservoir sampling locations, one on the Watauga River arm and one on the South Fork Holston River arm. Sediment and benthic macroinvertebrate sampling were added for the first time in 1993.

Ecological Health

The ecological health evaluation of Boone Reservoir was lower in 1993 compared to 1992. The rating for 1993 was toward the low end of the fair range (59 percent) whereas it was in the middle of the range in 1992 (64 percent). Ecological health ratings in both 1992 and 1993 were higher than in 1991 when poor conditions were found (51 percent). Primary contributors to lower scores in 1993 compared to 1992 were lower ratings for DO (fair at two locations and poor at one); lower ratings for the fish assemblage (poor at two locations and fair at one); and addition of ratings for the benthic macroinvertebrates (fair at two locations and poor at one). The ecological health indicator with the best rating in 1993 was chlorophyll, which rated good at the forebay.

The DO problem at the forebay and mid-reservoir site on the South Fork Holston River arm is different than other tributary, storage reservoirs. The typical problem is hypolimnetic anoxia, which is the case at the Watagua River mid-reservoir site. At the other two Boone Reservoir sites, the DO problem occurs in the middle stratum of the water column (metalimnion) due to oxygen demand of local sewage treatment plant discharges.

Reservoir Use Suitability

Studies conducted by the state of Tennessee found PCBs and chlordane in fish tissue, resulting in a state-issued advisory that catfish and carp should not be eaten by children, pregnant women, and nursing mothers. Further, all other people should limit their consumption of these particular fish. Additional fish samples were collected by TVA in autumn 1993, but results were not available at the time this report was prepared.

Bacteriological sampling was conducted at two swimming areas and four boat ramps in 1993. The geometric mean concentrations of fecal coliform bacteria were well within Tennessee's criteria for recreation, although one sample at the Boone Dam swimming area was high.

17.4 South Holston Reservoir

Physical Description

South Holston Reservoir in northeastern Tennessee and southwestern Virginia is created by South Holston Dam, located on the South Fork of the Holston River at mile 49.8. The dam creates a storage pool approximately 24 miles long, over 230 feet deep near the dam, with an average depth of 86.5 feet and approximately 7600 acres in surface area. With an average annual discharge of about 980 cfs from the dam, the average hydraulic residence time is almost one year (340 days)--one of the longest residence times of any TVA reservoir. Average annual drawdown of South Holston Reservoir is about 33 feet.

Two locations are monitored for Vital Signs--the forebay and mid-reservoir. Sediment and benthic macroinvertebrate sampling were added for the first time in 1993.

Ecological Health

The ecological health evaluation of South Holston Reservoir was fair (65 percent) in 1993, slightly better than in 1992 (57 percent) and 1991 (60 percent). A consistent problem has been with DO concentrations (as is the case with most deep storage impoundments), which rated poor at the forebay and very poor at the mid-reservoir site in 1993. Despite the poor ratings for DO, conditions were slightly improved at the forebay in 1993, compared to 1992. The ecological health indicator primarily responsible for the higher overall reservoir rating in 1993 was sediment quality (rated good at both sample sites). Sediments had not been sampled in previous years. Another indicator added in 1993, the benthic macroinvertebrate community, received a very poor rating at the forebay (with most metrics receiving the lowest score possible) and a fair rating at the mid-reservoir sample site. Interestingly, scores for the benthos do not parallel those for DO at the two sample sites, indicating other factor(s) may be affecting benthic macroinvertebrates at the forebay. The fish assemblage rated good at the forebay and fair at the mid-reservoir site.

Reservoir Use Suitability

There are no fish consumption advisories on South Holston Reservoir. The most recent TVA data for fish tissue samples for fish collected in autumn 1991 found low or nondetectable concentrations of all pesticides, PCBs, and metals (except mercury which was slightly elevated).

17.5 Watauga Reservoir

Physical Description

Watauga Dam in the northeastern corner of Tennessee impounds the Watauga River at mile 36.7. It forms a pool 16 miles in length, approximately 6400 acres in surface area, about 274 feet deep at the dam, and an average depth of about 89 feet, making it the second-deepest reservoir sampled as part of TVA's Vital Signs Monitoring Program. With an annual average discharge of about 700 cfs, Watauga Reservoir also has the longest hydraulic residence time of any of the Vital Signs reservoirs (about 400 days). Average annual drawdown of Watauga Reservoir is about 26 feet.

Two locations are monitored on Watauga Reservoir, the forebay and mid-reservoir. Sediment quality and benthic macroinvertebrates were examined for the first time in 1993.

Ecological Health

The overall ecological health for Watauga Reservoir was fair in 1993 (61 percent), about the same as in 1992 (57 percent). The ecological health in both 1992 and 1993 rated lower than in 1991, although all three years fell within the fair range. Similar to previous years, chlorophyll rated good at both sample sites in 1993. DO rated excellent at the forebay and fair at the mid-reservoir sites in 1993, a slight improvement compared to 1992. The fish assemblage was poor at the forebay in 1993 due to low abundance and diversity and rated fair at the mid-reservoir site, mostly due to low abundance. The benthic macroinvertebrate community, not sampled in Watauga Reservoir prior to 1993, was very poor at both locations. The benthos community was among the poorest in all Vital Signs reservoirs examined in 1993. This would not appear to be related to low DO concentrations; instead, the poor sediment quality at the forebay (due to toxicity to test animals and high ammonia) may have contributed to the poor benthos.

Reservoir Use Suitability

There are no fish consumption advisories on Watauga Reservoir. The most recent fish tissue collections by TVA were made in autumn 1991. All pesticides, PCBs, and metals (except mercury which was sightly elevated) were low or not detected.

Fecal coliform bacteria concentrations were very low at all five sites tested in 1993, which included one designated and an informal swimming area.

17.6 Holston River Stream Monitoring Site

Physical Description

The TVA stream monitoring station on the Holston River is located near Church Hill, Tennessee. The Holston River basin above this location is 2819 square miles or 74 percent of the entire Holston River basin. Two major tributaries, the North Fork Holston River (729 square miles) and the South Fork Holston River (2048 square miles), meet above Church Hill to form the Holston River. Principal tributaries to the South Fork Holston River include the Watauga River (869 square miles) and the Middle Fork Holston River (244 square miles). Two notable tributaries to the Watauga River include the Doe River (137 square miles) and Roan Creek (167 square miles).

There are five reservoirs in the basin. Fort Patrick Henry Dam and Boone Dam impound the lower South Fork Holston River. The South Fork Holston Dam impounds the upper South Fork Holston River and the Middle Fork Holston River. Wilbur Dam and Watauga Dam impound the Watauga River.

Although most of the basin land use is agricultural or forestry, several urban areas (Kingsport, Johnson City, and Elizabethton, Tennessee, and Marion and Abingdon, Virginia) are within the basin.

Ecological Health

The overall ecological health of the Holston River at this site was fair for 1993 as in 1992. Sediment quality improved from fair to good, and the fish community showed a slight improvement over 1992. Bottom-dwelling animals and nutrient ratings remain unchanged.

Use Suitability

Seven sites between Fort Patrick Henry Reservoir and South Holston Dam were tested for fecal coliform bacteria in 1993. South Fork Holston River met bacteriological water quality criteria for water contact recreation, and was only slightly impacted by the two tributaries tested. Thomas and Beidleman Creeks did not meet criteria.

A five fish composite each of carp, channel catfish, and largemouth bass were collected during summer 1992 and analyzed for selected metals, pesticides, and PCBs. All analytes were not detected or found in low concentrations except slightly elevated levels of mercury in largemouth (0.5 μg/g), PCBs in carp (0.6 μg/g), and chlordane in channel catfish (0.08 μg/g).

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TENNESSEE VALLEY RESERVOIR AND STREAM QUALITY - 1993

SUMMARY OF VITAL SIGNS AND USE SUITABILITY MONITORING

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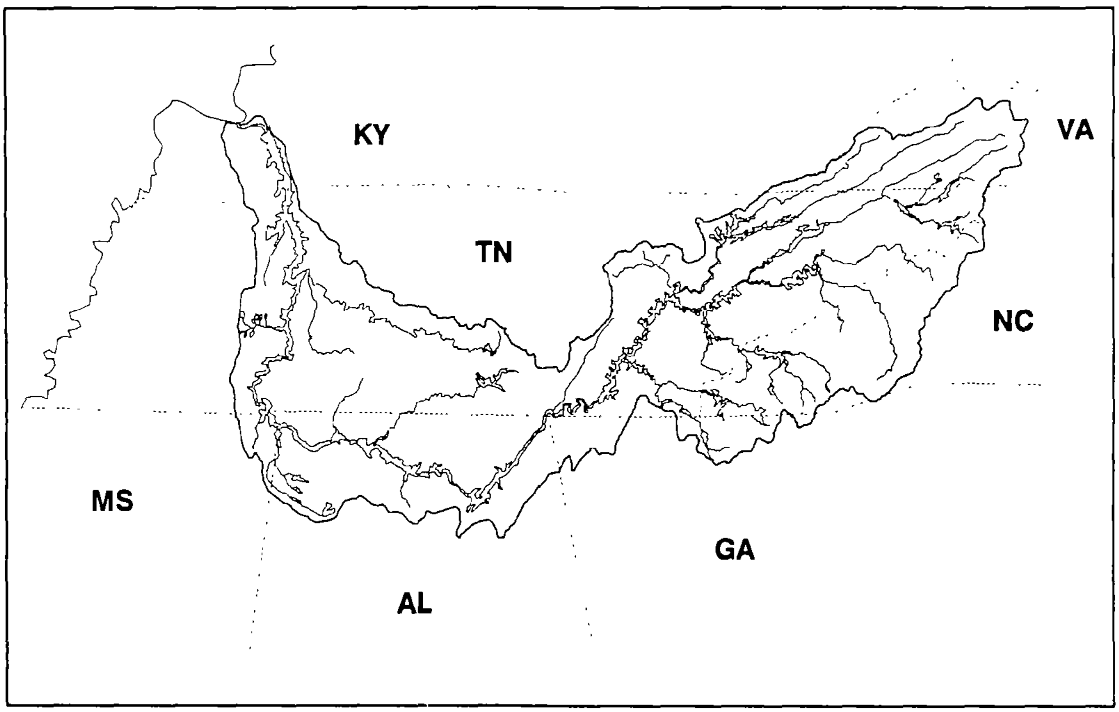

CLEAN WATER INITIATIVE

TENNESSEE VALLEY AUTHORITY
Resource Group
Water Management

TENNESSEE VALLEY RESERVOIR AND STREAM QUALITY - 1993
SUMMARY OF VITAL SIGNS AND USE SUITABILITY MONITORING

Volume II

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INTRODUCTION

The Tennessee Valley Authority (TVA) initiated a systematic, Valley-wide water quality and aquatic ecological monitoring program in 1986. The program started with a stream component and a reservoir component was added in 1990. The two primary objectives of these monitoring efforts are to evaluate the ecological health (Vital Signs Monitoring) of major streams and reservoirs in the Tennessee Valley and to examine how well these water resources meet the swimmable and fishable goals of the Clean Water Act (Use Suitability Monitoring).

Vital Signs Monitoring

Stream monitoring has been conducted on 12 large tributaries since 1986. Beginning in 1994, six additional tributaries will be monitored; all with watersheds of at least 500 square miles. Reservoir monitoring started with 12 reservoirs (mostly mainstream reservoirs) in 1990 and has expanded progressively to the full complement of 30 reservoirs in 1993. No further expansion of either stream or reservoir monitoring is planned. This report summarizes results of these monitoring efforts in 1993. Volume I is the main body of the report and Volume II is a data summary by sampling location within watershed areas.

Until 1991, the ecological health evaluations were based on subjective evaluation of the data. A weight-or-evidence approach was used— a stream or reservoir was deemed healthy if most of the physical, chemical, and biological components appeared healthy. Beginning with the 1991 results, a more quantitative approach was developed that has been used the last three years. This approach integrates information on important indicators of ecological health. For reservoirs, five indicators are used— dissolved oxygen, chlorophyll *a*, sediment quality, benthic macroinvertebrates, and fishes. Stream evaluations are similar except dissolved oxygen is not rated and nutrient concentrations are substituted for chlorophyll *a* concentrations. For each indicator (or metric), scoring criteria are developed that assign a score ranging form 1 to 5 representing very poor to excellent conditions. Scores for all indicators at a location are summed. For streams and smaller reservoirs, only one site is monitored. For larger reservoirs, multiple sites are monitored, and the overall reservoir score is achieved by totaling scores for all locations. The resulting total is divided by the maximum possible score. Thus, the possible range of scores is from 20 percent (all metrics very poor) to 100 percent (all metrics excellent). Hence, an overall ecological health rating of good, fair, or poor is obtained for each stream site or reservoir. A health rating border-line between two of these categories is considered poor-fair or fair-good. Each year , the most recent information is evaluated with the same basic approach, modified to incorporate improvements based on comments from reviewers and additional data.

Stream monitoring results for 1993 indicated seven streams rated good (three of these with perfect scores), three streams rated fair to good, and one stream rated poor Full evaluation was not possible for one stream because only three of the four indicators were monitored in 1993 The only stream to receive a poor rating was the French Broad River. This overall rating was caused by poor scores for nutrients and fishes, a fair score for benthos, and a good score for sediment quality.

Reservoirs are stratified into two groups for evaluation: run-of -the-river reservoirs and deep storage reservoirs. Separate scoring criteria are used for the two categories Overall ratings for the 11 run-of-the-river reservoirs in 1993 ranged from 58 to 88 percent. Four reservoirs rated good (74 to 88 percent), three rated fair to good (71 to 73 percent), three rated fair (63 to 68 percent), and one rated poor to fair (58 percent) Overall ratings for the 19 storage reservoirs ranged from 52 to 72 percent. Two reservoirs rated fair to good (both 72 percent), fourteen rated fair (58 to 67 percent), and three rated poor (52 to 56 percent).

Results did not yield any "big surprises"— most streams and reservoirs fell within expected categories. Similar results were observed in both 1991 and 1992, primarily due to similar meteorological conditions and reservoir flows during the period. Generally poorer ratings observed in storage reservoirs were primarily because of low dissolved oxygen in the hypolimnion. This is an ecologically undesirable condition that is mostly due to strong thermal stratification that occurs in deep reservoirs.

Use Suitability Monitoring

Use Suitability Monitoring provides screening level information on the suitability of selected areas within TVA reservoirs for water contact activities (swimmable) as determined by bacteriological studies and suitability of fish from TVA reservoirs for human consumption (fishable) as determined by fish tissue studies

Bacteriological Studies

Bacteriological samples are collected at over 200 sites in the Tennessee Valley: designated swimming areas, canoe access sites, highly used recreational areas, and selected non-recreation sites that provide information on pollution sources or inflow stream quality. Not all sites are sampled each year. Beginning in 1993, each recreation site will be revisited at least every other year.

In 1993, bacteriological sampling at recreation sites was conducted at 71 swimming areas and 14 canoe access points. All but two swimming areas met the regulatory criterion to be considered safe. Even those two sites met the criterion if samples collected after heavy rains were excluded. Four canoe access points (all on the Duck River) exceeded the criterion, in dry or wet weather.

Bacteriological sampling at non-recreation areas was conducted at 35 sites in 1993. Only one reservoir site and two stream sites failed to meet recreation criteria.

The results of studies summarized above are consistent with previous surveys. Fecal coliform concentrations were generally lower in 1993 due to lower than normal summer rainfall. Bacteriological water quality is most areas of TVA reservoirs is good. In streams it is much poorer, especially after rainfall.

Fish Tissue Studies

Fish tissues studies examine fillets from important fish species for selected metals, pesticides, and polychlorinated biphenyls (PCBs) on the U.S. Environmental Protection Agency's list of priority pollutants Resulting data are provided to appropriate state agencies to determine the need for further study and possible issuance of fish consumption advisories. Fish tissue data reported here represent autumn 1992 collections Results for fish collected in autumn 1993 were not available at the time this report was prepared due to the time required for laboratory analysis.

Results of screening studies in 1992 did not reveal any new areas in need of intensive investigations. Concentrations of at least one contaminant were high enough to warrant sampling again at the screening level in 1993. Results of intensive studies (i.e., in-depth studies where there are know or suspected problems) did not indicate substantial changes from previous years

KENTUCKY RESERVOIR WATERSHED

Kentucky Reservoir

Summary of 1993 Conditions - Ecological Health

Water—During the summer of 1993 (April-September), the coolest surface water temperatures in Kentucky Reservoir were in April and the warmest in July. Surface temperatures ranged from a minimum of 13.6°C to a maximum of 31.5°C at the forebay; from 15.8°C to 31.6°C at the transition zone; and from 16.1°C to 30.9°C at the sampling location in Big Sandy embayment. The State of Tennessee's maximum water temperature criteria for the protection of fish and aquatic life is 30.5°C.

Dissolved oxygen (DO) concentrations at the 1.5m depth ranged from a low of 6.2 mg/l in July to a high of 10.4 mg/l in April at the forebay; from 5.8 mg/l in August to 10.1 mg/l in June at the transition zone; and from 6.2 mg/l in July to 10.3 mg/l in April at the sampling location in Big Sandy embayment. At the inflow sampling site (i.e. the tailrace of Pickwick Dam) a minimum DO of 4.2 mg/l was recorded in July The State of Tennessee's minimum dissolved oxygen criteria for the protection of fish and aquatic life is 5.0 mg/l, measured at the 1.5m depth.

The temperature and DO data depict a seasonal warming and very weak thermal stratification of Kentucky Reservoir in June-July 1993. The greatest surface-to-bottom temperature differential (ΔT) was only about 3°C in June and July at the forebay and about 4½°C in Big Sandy embayment in June. However, during July, a rather strong oxycline developed at Kentucky forebay and in the Big Sandy embayment due to the drought like conditions and low flows through Kentucky Reservoir and the Tennessee River system (see discussion in Section 4 0, Hydrologic Overview of 1993). In late July, forebay dissolved oxygen ranged from surface concentrations of about 8-9 mg/l to bottom concentrations approaching 0 mg/l. (The minimum DO observed in Kentucky Reservoir in 1993 was 0.1 mg/l in July at the bottom of the reservoir in the forebay.) Similar conditions were found in Big Sandy embayment, although near bottom DO concentrations were never actually measured below 1 mg/l. The transition zone DO concentrations were much more uniform and well mixed with the minimum bottom DO being 3.6 mg/l in July.

For the overall reservoir ecological health evaluation for Kentucky Reservoir, DO rated excellent at the transition zone; good to excellent in Big Sandy embayment; and good at the forebay and inflow (i.e., Pickwick Dam tailrace). The good rating at the forebay would have rated higher had it not been for the anoxic conditions which were found to exist for a short time (i.e. July) in the hypolimnion near Kentucky dam. Likewise, the good rating at the inflow would also have been higher if oxygen levels had not fallen below 5 mg/l in the releases from Pickwick dam (i.e DO concentrations less than State of Tennessee's 5 mg/l criteria, measured at the 1.5m depth).

In 1993, values of pH ranged from 6.7 to 9.2 on Kentucky Reservoir. Near surface values exceeding 8.5 were observed at the forebay in July and in Big Sandy embayment in June and August. These high pH's were coincident with high DO saturation values (exceeding 100 percent) and elevated chlorophyll *a* concentrations, indicative of significant photosynthetic activity. The State of Tennessee's maximum pH criteria for the protection of fish and aquatic life is 8.5.

Average total phosphorus (0.073 mg/l) and dissolved ortho phosphorus (0.029 mg/l) concentrations at the transition zone were higher than at all other monitoring locations on the Tennessee River, an effect of the upstream inflows from the Duck River with naturally high concentrations of phosphorus (median total phosphorus concentrations of about 0.24 mg/l). Total phosphorus concentrations in the Tennessee River are approximately doubled by the inflows from the Duck River (annual mean daily flow of approximately 4,100 cfs), and gradually decline downstream. The Duck River joins with the Tennessee River at TRM 110.7, about 25 river miles upstream from the Kentucky Reservoir transition zone sampling site. (For additional information see Section 5.0, Duck River Watershed.) Because of high phosphorus concentrations, TN/TP ratios for samples collected at both the forebay and transition zone were quite low ranging from 5 to 13, indicating very little nutrient limitation and conditions highly supportive of primary productivity.

Chlorophyll *a* concentrations averaged 10.4 µg/l at the forebay, 9.2 µg/l at the transition zone, and 18.0 µg/l in Big Sandy embayment during the summer of 1993. In addition, high chlorophyll *a* concentrations were measured in August (31 µg/l) and September (35 µg/l) in Big Sandy embayment, indicative of nuisance level algal blooms. [It is also interesting to note that the Big Sandy embayment had among the highest organic nitrogen (= 0.51 mg/l), organic carbon (= 4.2 mg/l), and color (= 19 PCU) concentrations measured at any Vital Signs reservoir monitoring location in 1993.] Chlorophyll *a* values which average greater than 10 µg/l are generally indicative of eutrophic conditions while values greater than 15 µg/l are often indicative of hyper-eutrophic conditions. Consequently, the chlorophyll *a* ratings used in the 1993 ecological health evaluation for Kentucky Reservoir were fair at the forebay, good at the transition zone, and poor in the Big Sandy embayment.

Sediment Quality—Chemical analyses of sediments in Kentucky Reservoir in 1993 did not reveal any metal or organic analyte to be a concern in the two sample locations (i.e. forebay and transition zone) in the main reservoir. However, high levels of un-ionized ammonia were measured (510 µg/l) in the Big Sandy embayment. Toxicity tests detected no acute toxicity in the main reservoir, however, acute toxicity to both daphnids (15 percent survival) and rotifers (20 percent survival) was detected in the Big Sandy embayment. Particle size analysis showed sediments from the forebay and the Big Sandy embayment to be almost entirely silt and clay (99 percent at each site), while those from the transition zone were 65 percent silt and clay, 35 percent sand.

Sediment quality ratings used in the overall Kentucky Reservoir ecological health evaluation for 1993 were excellent at the forebay and transition zone, and poor in the Big Sandy embayment (due to the presence of ammonia and toxicity to the test organisms).

Benthic Macroinvertebrates—The benthic communities were excellent in the forebay and transition zone, fair in the inflow, and good in the Big Sandy embayment. The forebay had a total of 26 taxa with 1,658 organisms/m^2 The dominant taxa at the forebay were Tubificidae (18%), Corbicula sp (17 percent), and Musculium sp (17 percent). The transition zone represented a more diverse (33 taxa) but less abundant (1,307 organisms/m^2) community than the forebay with Tubificidae as the dominant taxa (22 percent), followed closely by Hexagenia limbata (22 percent) The inflow site had 25 taxa and a total of 234 organisms/m^2 with Cheumatopsyche sp (32 percent) and Corbicula sp (29 percent) as the dominant taxa The Big Sandy embayment site had 20 taxa and 1,683 organisms/m^2 with Chironomus sp (37 percent), and Coelotanypus tricolor (33 percent) as the principal taxa.

The forebay and transition zone sites on Kentucky Reservoir rated excellent primarily because of the abundance of long-lived species such as Corbicula sp and Hexagenia sp, and because of a diverse and balanced benthic community. The inflow rated only fair, in spite of an abundance of Corbicula sp, because of reduced diversity and EPT (Ephemeroptera, Plecoptera, and Trichoptera) taxa. The Big Sandy embayment received a good rating due to the diversity of organisms present and the evenness of dominant organisms. An abundance of chironomids resulted in this site receiving a good rating instead of an excellent rating.

Though not included in the overall health survey, the Kentucky tailwater benthic community was also sampled. Diversity and a good EPT community, as well as low numbers of chironomids and tubificids, allowed this site to obtain an excellent rating.

Aquatic Macrophytes—Aquatic plants increased from 2,616 acres in 1992 to 3,465 acres in 1993. Kentucky Reservoir had the third largest amount of aquatic vegetation within the TVA system. Aquatic macrophytes peaked at about 7,100 acres in 1987. Significant declines in spinyleaf and southern naiad populations have occurred in recent years. Eurasian watermilfoil was the dominant macrophyte on Kentucky Reservoir and generally occurred in monospecific stands. However, it was sometimes mixed with coontail and naiads. Aquatic vegetation on Kentucky Reservoir was primarily found from TRM 107 downstream to near the vicinity of Kentucky Dam.

Fish Assemblage—Fish data collection at near shore (45 electrofishing transects) and offshore bottom areas (26 net-nights) showed a diverse fish assemblage of 46 species dominated in numbers by gizzard shad (64 percent). Other abundant species included emerald shiners (5.6 percent), bluegill (4.8 percent), and largemouth bass (2 percent). Electrofishing results indicated total numbers of fish were approximately the same in the forebay (1,634) and transition zones (1,762) with considerably lower numbers in the inflow zone (405) Gill netting fish abundance was also highest in the forebay (696) and transition (494) areas Abundance at the inflow zone (69) was not comparable because of reduced effort. Gizzard shad made up 36 percent of the total fish collected in gill net samples followed by yellow bass (15.7 percent), skipjack herring (9.9 percent), and channel catfish (6.0 percent).

The Reservoir Fish Assemblage Index (RFAI) rated the littoral fish community (based on results of electrofishing samples) fair in the forebay (RFAI=32), transition (RFAI=34), and inflow (RFAI=40) zones of Kentucky Reservoir The lower scores in transition and forebay zones were influenced by low numbers of sucker species, a high percentage of tolerant species and omnivorous individuals, and high percentage of dominance by a single species. The gill netting RFAI rated the transition zone excellent (RFAI=56) and the forebay good (RFAI=42) Gill netting RFAI values were not calculated for inflow zones of run-of-the-river reservoirs due to low numbers of replicate samples. The excellent score of 56 in the transition was the highest ever observed and resulted from maximum scores in all metrics except number of sucker species and percent tolerant species.

Combined electrofishing and gill netting RFAI scores for the forebay (RFAI=37) and the electrofishing RFAI for the inflow (RFAI=40) were rated fair. The combined transition RFAI (RFAI=45) ranked good exhibiting the second highest score of all run-of-the-river transition zones, due primarily to the excellent gill netting results noted above.

Combined fish samples in shoreline electrofishing (15 transects) and offshore gill netting (24 net-nights) produced a total of 1,587 individuals including 27 species in the Big Sandy River embayment. There were four times as many fish collected by electrofishing as gill netting, largely attributed to high numbers of gizzard shad which made up 71 percent of the total sample.

The electrofishing RFAI score of 32 rated fair. The gill netting RFAI of 22 was the lowest recorded for any of the embayment study sites in 1993, and resulted from minimum scores for eight of the twelve metrics. The combined RFAI scores (RFAI=27) rated the Big Sandy embayment poor.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—Fourteen swimming beaches and one informal swimming area were tested for fecal coliform bacteria in 1993. Bacteria concentrations were generally low at all 15 sites. The highest geometric mean at any site was 47 colonies per 100 milliliters (47/100 ml), well below the recreation criterion of 200/100 ml No site had more than one sample exceed 400/100 ml, so EPA's guideline of no more than 10 percent of all samples exceeding 400/100 ml was also met. Two sites, Eva Park and Greenhead Recreation Area, each had one sample exceed the Tennessee single sample criterion of 1,000/100 ml. The geometric mean of all samples at these two sites were 14 and 15/100 ml. The six monthly Vital Signs samples collected at the forebay and transition zones were all at or below the detection limit of 10/100 ml.

Fish Tissue—Channel catfish composites were collected in 1992 from generally the same locations (except TRM 85 was sampled instead of TRM 100 to coincide with the transition zone location) as in previous years. As in past years, concentrations of all analytes were low. One analyte of interest was lead with a concentration of 0.6 µg/g at TRM 85. Similar levels have occurred sporadically with no pattern in locations over the five years screening samples have been collected from Kentucky Reservoir.

Beech Reservoir

Summary of 1993 Conditions - Ecological Conditions

Water—Beech Reservoir is the smallest and shallowest of the monitored reservoirs. The average flow through the reservoir in 1993 was only 64 percent of normal, making the average residence time over 600 days. The maximum temperature difference in the water column was 9.2°C in July, and had disappeared by September. The maximum surface temperature was 29.7°C in July. The extent of the area of depleted DO gave Beech Reservoir a poor DO rating for the reservoir ecological health index. DO depletion (<1.0 mg/l) began at the bottom of the water column in May and expanded to within four meters of the surface in June and July. As the reservoir destratified the bottom waters became re-aerated, although there was some low DO (2.2 mg/l) at the bottom in October.

Conductivities were generally in the 31 to 45 µmhos/cm range, but were much higher at the bottom during times of DO depletion, reaching a maximum of 141 µmhos/cm in August. Only in April and June did pH exceed 8.0, and the maximum was only 8 3 The minimum pH was 6.6 and occurred at greater depths during DO depletion.

Virtually all of the nitrogen was in the form of organic nitrogen Total nitrogen increased slightly from 0.42 mg/l in April to 0.51 mg/l in August. Total and dissolved ortho phosphorus concentrations dropped from 0.04 and 0.01 mg/l in April to 0.02 and 0.002 mg/l in August, respectively. The TN/TP ratio thus increased from 11 to 26.5 from April to August. Secchi depths varied only from 1.0m in April and September to 1.5m in May and June, the second lowest water clarity of the 19 tributary reservoir forebays in 1993. Chlorophyll *a* concentrations were 3 µg/l in April, 6 µg/l in May, and varied from 9 to 14 µg/l for the rest of the sampling period. The average chlorophyll *a* concentration was 9.0 µg/l, in the good range (near the upper end) for the reservoir ecological health index. Total organic carbon dropped from 5.4 mg/l in April to 3.3 mg/l in August. Total phosphorus and total organic carbon concentrations were the second lowest concentrations of the 19 tributary reservoir forebays in 1993.

Sediment—Chemical analyses of sediments in the forebay of Beech Reservoir in 1993 did not reveal any metal or organic analyte to be a concern. Toxicity tests detected no acute toxicity to the two organisms tested; however, survival of daphnids (68 percent survival) was reduced. Particle size analysis showed sediments in the forebay were 97 percent silt and clay.

Because of the slightly reduced survival of daphnids, the forebay sediment quality rating used in the 1993 Beech Reservoir ecological health evaluation was good.

Benthic Macroinvertebrates—The forebay on Beech Reservoir supported a fair benthic community. There were 24 taxa and 1,417 organisms/m^2, with Einfeldia sp (39 percent of the total) and Chironomus sp (35 percent of the total) as the dominant species. This site had 2 metrics which rated good: diversity and proportion of the sample composed of tubificids. Fair representations of EPT and long-lived taxa were observed An abundance chironomids negatively impacted the benthic community rating.

Fish Assemblage—No fish assemblage information was collected in autumn 1993 because water levels prevented access to the lake.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—No bacteriological studies were conducted in 1993.

Fish Tissue—TVA has not conducted fish tissue studies on Beech Reservoir.

DUCK RIVER WATERSHED

Normandy Reservoir

Summary of 1993 Conditions - Ecological Health

Water—The average residence time in Normandy Reservoir was 201 days in 1993 as flows were 91 percent of normal. The maximum temperature difference in the water column was 23°C in July. The maximum surface temperature was 32.3°C in July, the only month when the maximum temperature exceeded 30.5°C, Tennessee's criteria for aquatic life. Metalimnetic and near-bottom oxygen depletion began in June. By August, DO was below 0.1 mg/l from the bottom to six meters from the surface. Surface temperatures had cooled enough to mix with the metalimnion in October, increasing the depth of aerated water to 10m The extent of the area of depleted DO gave Normandy a poor DO rating for the reservoir ecological health index. Surface DO reached saturation levels of 120 percent or more on each sample date from May through July.

Conductivities were about 100 μmhos/cm early in the year, began increasing at the bottom in June and reached about 160 μmhos/cm in September and October. Normandy had slightly basic water (pH from 7.5 to 8.3) in April. Surface pH was over 9 from May through July, with a maximum pH of 9.5 in May. Bottom pH dropped slightly during the summer to a minimum of 6.6 in September.

Total nitrogen concentration dropped from 0.72 mg/l in April to 0.46 mg/l in August. The decline was due to the elimination of nitrates, 0.25 mg/l in April and <0.01 mg/l in August. Total phosphorus and dissolved ortho-phosphorus concentrations were 0.04 and 0.004 mg/l in April and 0 01 and <0.002 mg/l in August, respectively. The TN/TP ratio went from 18 in April to 46 in August. Secchi depths generally increased through the sampling period from 1.1m in April to 3.0m in October Chlorophyll *a* was 10 μg/l in April, increased to 12 μg/l in May and July, and then dropped to 5 μg/l in August as available nutrients were depleted. The average chlorophyll *a* concentration was 8.9 μg/l, in the good range (near the upper end) for the reservoir ecological health index. Total organic carbon varied little from 3.6 mg/l in April to 4.2 mg/l in August. Total phosphorus and total organic carbon concentrations in the forebay were the third highest concentrations of the 19 tributary reservoir forebays in 1993.

Sediment Quality—Chemical analyses of sediments in the forebay of Normandy Reservoir in 1993 indicated very high levels of un-ionized ammonia (720 μg/l). Toxicity tests detected acute toxicity to daphnids (60 percent survival) in the forebay sediment. Particle size analysis showed sediments in the forebay were 99 percent silt and clay.

Because of the acute toxicity of the forebay sediment to daphnids and the high concentrations of ammonia, a poor sediment quality rating was used in the 1993 Normandy Reservoir ecological health evaluation.

Benthic Macroinvertebrates—The Normandy forebay received a poor rating for its benthic community. There were 198 organisms/m^2 representing only 6 taxa; the dominant organisms were Tubificidae, Limnodrilus sp, and Chironomus sp, which comprised 38, 35, and 24 percent of the total, respectively The low diversity, paucity of EPT and long-lived taxa, and the abundance of tubificids all negatively impacted the benthic community rating at the Normandy forebay.

Fish Assemblage—Only the forebay zone was sampled on Normandy in fall 1993. Shoreline electrofishing (15 transects) and offshore experimental gill netting (12 net-nights) yielded 1,307 individuals with 29 species represented. Sixty-four percent of the total catch consisted of the sunfish species (rock bass, warmouth, redbreast, green, bluegill, and longear).

The Reservoir Fish Assemblage Index (RFAI) rated the Normandy Reservoir forebay fish community excellent, as determined by both electrofishing (RFAI=52) and gill netting (RFAI=54). The electrofishing and gill netting RFAI's, as well as the combined scores (RFAI=53), were the highest recorded for tributary forebays. Normandy received midrange or maximum scores in most metrics for both gear types; the only minimum score was percent anomalies in the electrofishing sample.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—Two swimming beaches were tested for fecal coliform bacteria in 1993. The geometric mean of bacteria concentrations were relatively high, 146 and 174/100 ml, but within criterion for water contact recreation. At both sites, geometric means after rainfall were over 200/100 ml, and both sites had three of twelve samples exceed 400/100 ml. EPA recommends that not more than 10 percent of samples exceed 400/100 ml. Both sites had large flocks of resident geese which were the probable cause of the high fecal coliform concentrations.

Fish Tissue—Because of the small size of Normandy Reservoir, only the forebay was sampled for fish tissue screening. Five channel catfish were collected in autumn 1992. Fillets were composited and analyzed for selected metals, pesticides, and PCBs. Of the five metal analytes, only lead and mercury were detected, both at low levels. The only organic analyte detected was chlordane, also at a low level

Duck River Stream Monitoring Site

Summary of 1993 Conditions - Ecological Health

Water—The water of the Duck River is moderately hard (average hardness of 130 mg/l) and alkaline (average total alkalinity of 118 mg/l). The median pH for the stream monitoring site was 7.7 The river was well oxygenated with dissolved oxygen levels of 82 to 115 percent of saturation.

Of the 12 streams monitored across the Tennessee Valley, the Duck River ranked among the highest in average concentrations of organic nitrogen (0.421 mg/l), total phosphorus (0.617 mg/l), and dissolved orthophosphate (0.177 mg/l). The average concentrations of ammonia nitrogen (0.027 mg/l) and nitrate+nitrite-nitrogen (0.48 mg/l) were near median for all sites. The high total phosphorus concentration yielded a poor rating for nutrients at the site.

Seven analyses for priority pollutant metals (dissolved cadmium, lead, nickel, and zinc and total copper and zinc) were performed bi-monthly Dissolved cadmium (4 of 6 samples) and total zinc (2 of 6 samples) were detected but neither exceeded the EPA guidelines for protection of aquatic life and human health.

Sediment—Sediment quality rated good in 1993 with no acute toxicity observed and no metals, PCBs, or pesticides exceeding the EPA guidelines This is an improvement over 1992 when sediment quality rated fair

Benthic Macroinvertebrates—In 1993, benthic macroinvertebrate results rated good with a Modified Benthic Index of Biotic Integrity (MBIBI) score of 47, with 105 taxa and 3,789 organisms/m^2 Conditions in 1992 rated fair (MBIBI score 34) with 61 taxa and 528 organisms/m^2. The benthic fauna improved one classification since 1992. Dominant organisms in 1993 were dipteran midge larvae (62 percent), mayflies (20 percent), and caddisflies (7 percent). Dipteran midge larvae were also the dominant organism in 1992 (26 percent), followed by coleopteran riffle beetles (22 percent) and caddisflies (17 percent). Excessive nutrients, streambank erosion, and substrate instability are a continuous problem at this site.

Fish Community Assessment—The fish community rated fair with an Index of Biotic Integrity (IBI) score of 46 and showed little improvement since it rated fair (IBI = 42) in 1992. Improvement in 1993 was seen mostly in increased fish density and absence of hybrid fish. Problems persisted in species composition and trophic structure indicating less than optimum conditions. Diversity was low for darter, sunfish, and intolerant species, and the proportion of tolerant fish was abnormally high. Fish most dependent on a diverse and stable aquatic macroinvertebrate community were out-numbered by fish that live by a more flexible feeding strategies, and the proportion of piscivorous fish was abnormally low. Adverse conditions observed were extensive bank erosion and the predominance of unstable substrate.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—Five sites on the Duck River from 1.7 miles downstream of Normandy Dam to Shelbyville were tested for fecal coliform bacteria At the first site downstream of Normandy Dam, the geometric mean of all fecal coliform samples was 104/100 ml. At the other four sites from 1 8 to 5.4 miles further downstream, the geometric mean ranged from 1100 to 2150/100 ml. There were several rainstorms during the sampling period, and concentrations were much higher after rainfall. If all samples within 24-hours of rainfall are excluded, the geometric mean of the four most downstream site range from 510 to 960/100 ml. These are among the highest concentrations found anywhere in the Tennessee Valley during the five years of sampling under the current program. The probable cause of the high concentrations are dairies.

Fish Tissue—A five-fish composite each of carp, channel catfish, and largemouth bass were collected during summer 1992 and analyzed for selected metals, pesticides, and PCBs. Lead and mercury were detected in all samples but at low concentrations. Chlordane was detected in one sample and PCBs in two, again at only low concentrations.

PICKWICK RESERVOIR - WILSON RESERVOIR WATERSHED

Pickwick Reservoir

Summary of 1993 Conditions - Ecological Health

Water—During the summer of 1993 (April-September), coolest surface water temperatures in Pickwick Reservoir were in April and the warmest in July. Surface temperatures ranged from a minimum of 18.4°C to a maximum of 30.5°C at the forebay; from 16.2°C to 29.1°C at the transition zone; and from 22.8°C (in May-no samples in April) to 29.6°C in Bear Creek embayment. The State of Alabama's maximum water temperature criteria for the protection of fish and aquatic life is 30.0°C.

Dissolved oxygen (DO) concentrations at the 1.5m depth ranged from a low of 6.6 mg/l in August to a high of 12.0 mg/l in April at the forebay; from 6.6 mg/l in August to 11.6 mg/l in June at the transition zone; and from 6.7 mg/l in September to 10.1 mg/l in August at the sampling location in Bear Creek embayment. At the inflow sampling site (i.e. the tailrace of Wilson dam) a minimum DO of 3.1 mg/l was recorded in July. The State of Alabama's minimum dissolved oxygen criteria for the protection of fish and aquatic life is 5.0 mg/l, measured at the 1.5 meter depth.

Temperature data depict a seasonal warming and very weak, transient thermal stratification of Pickwick Reservoir. The maximum observed surface to bottom temperature differential (ΔT), in Pickwick Reservoir in 1993 was 4.7°C at the forebay in June. However, there was a rather strong oxycline at all three sampling locations in June and July when differences between surface and bottom DO's were about 7 to 9 mg/l at the forebay, transition zone, and in Bear Creek embayment. In July 1993, a minimum DO of less than 0.1 mg/l was measured on the bottom at all three sampling locations (the forebay, transition zone, and Bear Creek embayment) in Pickwick Reservoir. Due to the drought like conditions and low flows into and through Pickwick Reservoir (see discussion in Section 4.0, Hydrologic Overview of 1993) sediment oxygen demands were consuming oxygen at a rate greater than it was being replenished by inflowing water. Flows increased to normal levels in August and September, resulting in less stratification and higher near bottom DO levels.

DO ratings used in the overall reservoir ecological health evaluation for Pickwick Reservoir were good at the forebay and transition zone; fair to good in Bear Creek embayment; and fair at the inflow. The forebay, transition zone, and Bear Creek embayment would all have rated higher had it not been for the very low near bottom oxygen concentrations which existed in July The fair rating at the inflow sampling site on Pickwick Reservoir was a result of oxygen levels being measured approximately 2 mg/l below the Alabama criteria in the releases from Wilson dam in the summer of 1993 as mentioned above.

Values of pH ranged from 6.8 to 9.0 on Pickwick Reservoir in 1993. Near surface pH values exceeding 8.5 (and DO saturation values exceeding 100 percent) were observed at all three sampling locations. Many of these periods of high pH and high oxygen saturations were also coincident with high chlorophyll *a* concentrations, indicative of periods of high photosynthetic activity. The State of Alabama's maximum pH criteria for the protection of fish and aquatic life is 8 5.

In 1993, all three sampling locations on Pickwick Reservoir also had fairly high chlorophyll *a* concentrations averaging 15 μg/l, 12 μg/l, and 16.8 μg/l, respectively, at the forebay, transition zone, and Bear Creek embayment. The chlorophyll *a* concentrations measured in Pickwick Reservoir were among the highest measured in the Tennessee River reservoirs in 1993, indicative of eutrophic conditions.

Consequently, the chlorophyll *a* ratings used in the 1993 ecological health evaluation for Pickwick Reservoir were only fair at the forebay and transition zone, and poor in Bear Creek embayment.

Sediment—Although mercury has been found in sediment in Pickwick Reservoir at levels of concern in past years, levels in 1993 were lower and not above sediment quality guidelines for mercury (i.e., 1.0 mg/kg). Mercury levels in 1993 were 0.47 mg/kg at the forebay and 0.62 mg/kg at the transition zone sampling sites. Un-ionized ammonia was detected at levels of concern (220 µg/l) in one of the two forebay samples. Although no acute toxicity was detected in the main reservoir, acute toxicity to both daphnids (30 percent survival) and rotifers (45 percent survival) was detected in the Bear Creek embayment. Tests in 1991 and 1992 showed a potential for toxicity with MicrotoxR at the forebay. Particle size analysis showed sediments from the forebay were about 66 percent silt and clay, 34 percent sand; from the transition zone were 47 percent silt and clay, 53 percent sand; and from Bear Creek embayment were 99 percent silt and clay.

Sediment quality ratings used in the overall Pickwick Reservoir ecological health evaluation for 1993 were good at the forebay (presence of ammonia); excellent at the transition zone; and, fair in the Bear Creek embayment (toxicity to the test organisms)

Benthic Macroinvertebrates—The benthic communities at the forebay and inflow sites were excellent, the transition zone was good, and the Bear Creek embayment rated fair The forebay site had 23 taxa and 533 organisms/m^2 with Coelotanypus sp (26 percent), Corbicula fluminea (20 percent), and Hydrobiidae (15 percent) as the dominant taxa. The transition zone had a slightly more diverse fauna than the forebay, with 25 taxa and 745 organisms/m^2. Corbicula fluminea (23 percent) and Hexagenia sp (21 percent) were the most abundant taxa. The inflow had the greatest diversity and of all sites sampled, with 42 taxa and 699 organisms/m^2. The benthic community there was dominated by Corbicula fluminea (65 percent).

Bear Creek embayment, a major component of Pickwick Reservoir, was also sampled and received a fair rating. It had a total of 1,188 organisms/m^2 and 15 taxa. Tubificidae (33 percent), Einfeldia (25 percent) and Coelotanypus tricolor (21 percent) were the dominant taxa. Although this site had a good diversity of benthic organisms and an evenness of dominant taxa, the abundance of chironomids and the paucity of EPT taxa contributed to this site only receiving a fair rating.

Aquatic Macrophytes—There were an estimated 105 acres of submersed plants on Pickwick Reservoir in 1993, primarily in the upstream portion of Yellow Creek embayment. Historically, most of the aquatic vegetation on Pickwick Reservoir has been in the Yellow Creek embayment, and in 1993 naiads and muskgrass were the most abundant macrophytes.

Fish Assemblage—Fish collections at near shore areas (45 electrofishing transects) and offshore bottom areas (30 net-nights) from the three zones of Pickwick Reservoir resulted in the collection of 2,526 fish including 42 species. Three non-game species, including skipjack herring, gizzard shad, and brook silverside, comprised 50 percent of all fish collected Other dominant species groups were the sunfishes (green, bluegill, longear, and redear), catfishes (blue, channel, and flathead), and black basses (smallmouth, spotted, and largemouth), which made up 12, 7, and 6 percent of the total sample, respectively Fish abundance was greatest in the forebay zone (1,563) followed by the transition (659), and inflow zones (304). Total catch was significantly higher in the forebay than the other two zones with both gear types (even considering reduced netting effort in the inflow).

The Reservoir Fish Assemblage Index (RFAI) rated the littoral fish community (based on results of electrofishing samples) good in all three zones of the reservoir (forebay RFAI=46, transition RFAI=42, and inflow RFAI=46). The Pickwick forebay score of 46 was, along with Wilson forebay, the highest recorded in run-of-the-river reservoirs in 1993. The slightly lower transition score was influenced by lesser numbers of piscivorous and sunfish species. The gill netting RFAI rated the transition (RFAI=46) and forebay (RFAI=42) good. Gill netting RFAI values were not calculated for inflow zones of run-of-the-river reservoirs. Combined electrofishing and gill netting RFAI scores for the forebay (RFAI=44), transition (RFAI=44), and the electrofishing RFAI for the inflow (RFAI=46) rated all areas as good.

Fish samples taken in the shoreline areas (15 electrofishing transects) and offshore/deep areas (12 net-nights) in Bear Creek embayment produced a total of 975 individuals represented by 36 species. By far the two most dominant species were gizzard shad (35 percent) and skipjack herring (22 percent). No other species were captured in significant numbers Number of individuals captured was similar with both gear types.

Both electrofishing (RFAI=42) and gill netting (RFAI=46) RFAI's rated the Bear Creek embayment good, ranking it the highest of the four embayment study sites Both gear types received the highest score for five of the twelve metrics.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—Four swimming beaches and six informal swimming areas were tested for fecal coliform bacteria in 1993. Bacteria concentrations at all ten sites were very low (geometric mean <20/100 ml). There were no significant rainfall events during the survey. This may have contributed to the very low concentrations at some sites. Monthly sampling at the three Vital Signs locations (forebay, transition zone, and Bear Creek Embayment) produced equally low fecal coliform concentrations.

Fish Tissue—One composite sample of five channel catfish was collected at the forebay, transition zone, and inflow in autumn 1992. Concentrations of all metals were low. Mercury was detected in most samples but at relatively low concentrations (maximum of 0.24 µg/g). Pesticides and PCBs were generally low. The exception was DDTr, which was relatively high at the inflow (2.4 µg/g) yet not detected at the other two locations. This is not thought to represent a problem because concentrations of this magnitude have not been observed in previous years of screening. It is possible that one of the catfish in the composite was from Wheeler Reservoir where there is a problem with DDT contamination in one area resulting in high concentrations in fish Relatively high concentrations of chlordane in 1990 were not found in 1991 or 1992. PCBs were detected in all samples (range 0.2 to 0.7 µg/g) with concentrations tending to be higher at the inflow. Samples were recollected at the inflow site in autumn 1993 to ensure that a possible problem with DDTr, chlordane, or PCBs is not overlooked; results were not available at the time this report was prepared.

Wilson Reservoir

Summary of 1993 Conditions - Ecological Health

Water—During the summer of 1993 (April-September), surface water temperatures ranged from 13 7°C in April to 31.6°C in July at the forebay sampling location. Temperatures above 30.0°C exceed State of Alabama water quality criteria for fish and aquatic life. Values for DO at the 1.5m depth ranged from a high of 13.8 mg/l in May (during a large algal bloom) to a low of 5.7 mg/l in September at the forebay. At the Wheeler dam tailrace a minimum DO of 4.3 mg/l was recorded in July. The State of Alabama's minimum dissolved oxygen criteria for the protection of fish and aquatic life is 5.0 mg/l, measured at the 1.5 meter depth.

Temperature and DO data show seasonal warming and both thermal and oxygen stratification in the forebay from May through August. The greatest degree of thermal stratification was observed in July, as might be expected, during the period of high temperatures and low flows (see discussion in Section 3.0, Hydrologic Overview of 1993). In July, temperatures at the forebay ranged from 31.6°C (surface) to 21.5°C (bottom), a differential of 10.1°C.

Periods of strong DO stratification, with surface to bottom DO differentials ranging from about 7 to 12 mg/l, were also observed during these four months, May through August. For example, in June, surface DO concentrations of about 12 mg/l (during a large algal bloom) were contrasted with near bottom DO concentrations of about 0 mg/l. The depth of Wilson Reservoir (approximately 100 feet at the dam) and the unseasonably low flows during the summer of 1993 combined to have a pronounced effect on hypolimnetic DO in Wilson forebay. Bottom DO concentrations were at or near 0 mg/l for approximately three months (June, July, and August), and the volume of hypolimnetic anoxia was greater in the summer of 1993 than has been observed in the prior three years of Vital Signs monitoring (1992 to 1990). For the summer, DO concentrations in Wilson forebay averaged only 5.9 mg/l, lower than at any other Vital Signs monitoring location on run-of-the-river reservoirs.

Consequently, the forebay DO rating used in the overall ecological health rating of Wilson for 1993 was very poor. A good rating for DO was assigned to the Wilson reservoir inflow sampling site (i.e., Wheeler dam tailrace) because oxygen levels fell only slightly below 5 mg/l in releases from Wheeler dam during the summer of 1993 (i e. DO's less than State of Alabama's 5 mg/l criteria, measured at the 1.5 meter depth).

Values of pH ranged from 6.7 to 9.1. In May and June near-surface values of pH were measured greater than 9 0 These high pH values coincided with periods of high photosynthetic activity, high temperatures, high dissolved oxygen measurements (percent oxygen saturation values exceeding 150%), and high chlorophyll a concentrations. The State of Alabama's maximum pH criteria for the protection of fish and aquatic life is 8.5

Summer chlorophyll *a* concentrations in Wilson forebay averaged about 10.2 µg/l in 1993, slightly higher than preferred, but much better than in 1992 when a massive algal bloom (chlorophyll *a* concentrations of 146 µg/l) occurred in May on Wilson reservoir. A forebay chlorophyll *a* rating of fair was used in the ecological health evaluation of Wilson Reservoir in 1993.

Historically, the water in the forebay of Wilson is quite clear relative to the other Tennessee River reservoirs. In the summer of 1993, Secchi depths averaged over 1.7 meters and suspended solids (TSS) averaged only about 3.2 mg/l, among the highest Secchi's and lowest TSS's measured on the run-of-the-river reservoirs.

Sediment—Chemical analyses of sediment did not reveal any metal or organic analyte to be a concern. Toxicity tests detected no acute toxicity to either species tested; however, reduced survival of rotifers (65 and 85 percent survival) was seen in samples from the forebay. Toxicity to rotifers was detected in 1991. Particle size analysis showed sediments from the forebay were about 99 percent silt and clay.

The forebay sediment quality rating used in the overall Wilson Reservoir ecological health evaluation for 1993 was very good, instead of excellent, due to the slightly reduced survival of rotifers.

Benthic Macroinvertebrates—Wilson forebay and inflow sites showed improvements in their benthic communities. The forebay improved from poor to fair, and the inflow from good to excellent. The forebay had 803 organisms/m^2 representing 22 taxa with Chironomus sp (42 percent) as the dominant organism. The inflow site had 683 organisms/m^2 representing 48 taxa with Corbicula sp (41 percent) as the dominant organism.

The Wilson forebay scored as high as possible on three metrics. taxa richness, percentage of the community comprised of tubificids, and the evenness of dominant organisms. The two metrics that brought down the overall benthic score were the high numbers of chironomids present and the low number of EPT taxa present. These factors resulted in a fair rating for the forebay site. The inflow site received a perfect score for every metric and received an excellent rating. This epitomizes a healthy benthic community: high diversity, the presence of a good EPT community, an abundance of long-lived organisms, low numbers of tubificids and chironomids, and an evenness of dominant organisms

Aquatic Macrophytes—There were 54 acres of aquatic plants on Wilson Reservoir in 1993. Muskgrass was the dominant species and colonized shallow water sloughs. Eurasian watermilfoil historically occurred as localized populations on Wilson Reservoir, but has not been observed on Wilson in several years

Fish Assemblage—Shoreline electrofishing (30 transects) and offshore gill netting (19 net-nights) at the forebay and inflow of Wilson Reservoir produced 3,567 individuals of 38 species, and showed fish were most abundant in the inflow (69 percent of the total fish collected). Species representing the largest portion of the Wilson fish assemblage included emerald shiners (25 percent), brook silversides (22 percent), gizzard shad (19 percent), and bluegill (11 percent). Most of the inflow electrofishing catch (66 percent) consisted of emerald shiners and gizzard shad. There were also moderate numbers (CPUE= 234 per transect) of young-of-year (YOY) threadfin shad in the inflow area.

The 12 electrofishing RFAI metrics described the littoral fish community of both the inflow (RFAI=42) and the forebay (RFAI=46) zones as good. The Wilson and Pickwick forebay ratings of 46 were the highest recorded in run-of-the-river reservoirs in 1993. The 1993 forebay (RFAI=46) rating also represented an increase over the 1992 RFAI score of 38. The forebay scores were the same or higher for all metrics with exception of the average number of individuals (i.e., average catch per transect). The gill netting RFAI rated the forebay (38) fair. Gill netting RFAI values were not calculated for inflow zones of run-of-the-river reservoirs due to low numbers of replicate samples. Combined electrofishing and gill netting RFAI scores rated the forebay (RFAI=42) and the electrofishing RFAI for the inflow (RFAI=42) good.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—The boat ramps at Fleet Hollow and Lock Six were tested for fecal coliform bacteria in 1993. Bacteria concentrations were very low (geometric mean <20/100 ml). The monthly Vital Signs samples collected in the forebay were all less than 10/100 ml.

Fish Tissue—Composited channel catfish samples were collected from the forebay and inflow areas in autumn 1992. All analytes were low or not detected. PCB concentrations have been relatively high in occasional samples during past years Interestingly, 1992 samples from both locations were below the detection limit.

Bear Creek Reservoir

Summary of 1993 Conditions - Ecological Health

Water—The average flow in 1993 was about 89 percent of normal Even with the relatively short average residence time, 14.4 days, the maximum temperature difference in the forebay water column was 14.6°C in July. The maximum surface temperature was 31.3°C in July. The Alabama maximum water temperature criterion for fish and wildlife is 32.2°C (90 F). Depleted DO conditions began at the bottom in May and by June 21 the area of DO <2.0 mg/l extended to within four meters of the surface, resulting in a poor DO rating in the reservoir's ecological health index. The cooling surface temperatures in September allowed surface mixing with the metalimnion, extending the depth with DO >2.0 mg/l to seven meters.

Conductivities in April were about 50 µmhos/cm. Conductivities in the DO depleted zone rose throughout the summer reaching 182 µmhos/cm in September. The maximum pH was about 8.5 at the surface in July. The minimum pH was about 6 1 in the upper portion of the depleted DO zone in August and September.

The total nitrogen concentration was 0.79 mg/l in April, about 60 percent as nitrates. By August, nitrates had disappeared, reducing the total nitrogen concentration to 0.37 mg/l Total phosphorus and dissolved ortho phosphorus concentrations were 0.02 and 0.002 mg/l in April, and 0.01 and <0.002 in August, respectively. The TN/TP ratio was between 37 and 40 in both surveys. Secchi depths were the lowest of the 19 tributary reservoir forebays, ranging from 0 75 to 1.75 meters. Chlorophyll *a* concentrations were the highest of the 33 tributary stations, ranging from 8 to 17 µg/l. The average chlorophyll *a* concentration of 12 3 µg/l gave Bear Creek a fair rating for chlorophyll in the reservoir's ecological health index. Total organic carbon concentrations were 2.5 and 2 8 mg/l in April and August, respectively.

Sediment Quality—Chemical analyses of sediments in the forebay of Bear Creek Reservoir in 1993 indicated elevated levels of un-ionized ammonia (280 µg/l). Toxicity tests detected acute toxicity to daphnids (0 percent survival) and rotifers (65 percent survival) in the forebay sediment. Particle size analysis showed sediments in the forebay were 94 percent silt and clay.

Because of the acute toxicity of the forebay sediment to daphnids and rotifers and the presence of ammonia, a very poor sediment quality rating was used in the overall 1993 Bear Creek Reservoir ecological health evaluation.

Benthic Macroinvertebrates—Bear Creek forebay, the only site sampled on the reservoir, had 18 taxa and 216 organisms/m^2. Procladius sp accounted for 37 percent of the total Bear Creek forebay supported an excellent benthic community in 1993, with 5 of the 6 metrics receiving a good score. The proportion of the sample comprised by chironomids was the only metric to receive a poor score.

Fish Assemblage—Only the forebay zone was sampled on Bear Creek Reservoir in fall 1993. Electrofishing samples (15 transects) in shoreline areas and experimental gill netting samples (12 net-nights) offshore collected 1,632 individuals with 28 species represented. Bluegill was the most abundant taxon in Bear Creek Reservoir (28 percent of total fish sampled) Green sunfish (14 percent), gizzard shad

(7 percent), spotted bass (7 percent), and longear sunfish (6 percent) followed in order of density. Species diversity was much higher in electrofishing samples (24 species) than in gill netting efforts (14 species).

The Reservoir Fish Assemblage Index (RFAI) rated the littoral fish community (based on results of electrofishing samples) excellent (RFAI=52) and received maximum scores in all metrics except percent tolerant species, average number of individuals, and percent anomalies. Fifty-two was the highest RFAI recorded in all TVA tributary reservoir forebays (Normandy Reservoir forebay also scored 52). The gill netting RFAI of 40 was rated fair. The combined electrofishing and gill netting RFAI of 46 rated Bear Creek forebay good.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—The swimming beaches at Piney Point and Horseshoe Bend were tested for fecal coliform bacteria in 1993. Bacteria concentrations were very low (geometric mean <20/100 ml) except for one sample at Horseshoe Bend (4800/100 ml).

Fish Tissue—A five fish composite of channel catfish was collected from the forebay during autumn 1992. There were no pesticides or PCBs detected in the sample. Of the five metals examined, only mercury was found above the detection limit. The concentration (0.45 μg/g) was relatively high, although far below the concentration of 1.0 μg/g used by the U.S. Food and Drug Administration to remove products from commerce. Another sample of channel catfish was collected from the same area in autumn 1993 to further evaluate this result.

Little Bear Creek Reservoir

Summary of 1993 Conditions - Ecological Health

Water—The average flow through the reservoir in 1993 was about 89 percent of normal, with an average residence time of 254 days. The reservoir was thermally stratified throughout the sampling period with a maximum temperature difference in the water column of 20.5°C in July. The maximum surface temperature of 31.1°C in July was less than the Alabama water quality criterion for fish and wildlife of 32.2°C (90 F). The area of DO depletion (DO < 2.0 mg/l) began at the bottom in June, extended to within 8 meters of the surface in July and August, and still comprised over one-half the water column in October. This resulted in a poor DO rating in the reservoir ecological health index. During June, very high DO concentrations and corresponding high pH values occurred in the metalimnion. DO was 16.2 mg/l and pH was 9 4 at the six meter depth; a DO saturation of 172 percent. This was below the area at which the composited surface sample was collected, thus the chlorophyll concentration in June was probably much higher than the measured 5 µg/l.

Surface pH varied from 8.0 to 8.9 from April to August. The minimum pH was 6 7 near the bottom in September. Conductivities throughout the water column were slightly over 100 µmhos/cm until DO was depleted at the bottom. Then bottom conductivities rose continually to a maximum of 167 µmhos/cm in October.

Organic nitrogen concentrations were constant, 0.28 mg/l in April and 0.29 mg/l in August, while nitrates dropped from 0.2 mg/l in April to <0.01 mg/l in August. Total and dissolved ortho phosphorus concentrations were 0.02 and 0.002 mg/l in April and 0.008 and <0 002 mg/l in August. Total organic carbon concentrations were 2.3 mg/l in April and 2.9 mg/l in August The water was relatively clear, with Secchi depths ranging from 2.0 meters in April to 4.0 meters in August. Productivity was relatively low—the chlorophyll concentration averaged 3.8 µg/l with a maximum of 7 µg/l in August. These chlorophyll concentrations are in the range considered good in the reservoir ecological health index.

Sediment Quality—Chemical analyses of sediments in the forebay of Little Bear Creek Reservoir in 1993 did not reveal any metal or organic analyte to be a concern. Toxicity tests detected acute toxicity to daphnids (45 percent survival) in the forebay sediment. This resulted in a fair rating for sediments in the ecological health index. Particle size analysis showed sediments in the forebay were 94 percent silt and clay.

Benthic Macroinvertebrates—The Little Bear Creek forebay site had a fair benthic community, with high densities and low diversity. There were 3,898 organisms/m^2 representing only 11 taxa, primarily Tubificidae (96 percent of the total). The abundance of Tubificidae, essentially a tolerant family, had the largest negative impact on the benthic community The metrics of number of EPT taxa, number of long-lived taxa, and diversity all received fair scores The only metric to receive a good score was the low proportion of the sample comprised of chironomids.

Fish Assemblage—Only the forebay was sampled on Little Bear Creek Reservoir in fall 1993. Shoreline electrofishing (15 transects) and offshore experimental gill netting (10 net-nights) yielded 2,946 individuals represented by 27 species. Thirty-eight percent of the total catch consisted of bluntnose minnows, followed by bluegill (21 percent), largemouth bass (6 percent), and green sunfish (5 percent) The primary forage base in Little Bear Creek Reservoir was comprised mainly of sunfish and minnows, as shad were collected in very low numbers in both electrofishing and gill netting samples.

Fish assemblage rated good for both electrofishing (RFAI=46) and gill netting (RFAI=50) in the forebay. Scores for the electrofishing sample were midrange or maximum for all metrics except number of piscivore species and percent omnivores. Scores in the gill netting samples were midrange or maximum for all metrics. The overall RFAI (combining electrofishing and gill netting results) rated Little Bear Creek forebay as good.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—The swimming beaches at Eliott Branch and Williams Hollow were tested for fecal coliform bacteria in 1993. Bacteria concentrations were very low (geometric mean <20/100 ml).

Fish Tissue—A five-fish composite of channel catfish was collected from the forebay in autumn 1992. There were no pesticides or PCBs detected in the sample. Mercury was the only metal analyte found; arsenic, cadmium, lead, and selenium were not detected. The mercury concentration (0.56 μg/g) was high enough to warrant further examination in autumn 1993 but not high enough to warrant a detailed study. The 1993 results were not available at the time this report was prepared.

Cedar Creek Reservoir

Summary of 1993 Conditions - Ecological Health

Water—The average flow was about 90 percent of normal The average residence time was about 186 days, and thermal stratification was moderate to strong. The maximum temperature difference in the water column was 17.9°C in July. The maximum temperature was 30.9°C in July, less than the Alabama water quality criterion for fish and wildlife of 32.2°C (90 F). DO depletion (DO < 2.0 mg/l) began at the bottom in May, extended to within 7 meters of the surface in August, and remained depleted at the bottom in October. This resulted in a poor rating for DO in the reservoir ecological health index. Conductivities in Cedar Creek were the third highest of the 19 tributary reservoirs, averaging about 240 μmhos/cm in the water column in April, and increasing in the anoxic zone throughout the summer to a maximum of 295 μmhos/cm at the bottom in October Surface pH was over 8.0 from April through September, with a maximum of 8 6 in May. Cedar Creek water is slightly basic, the minimum bottom pH was 7.1 in September.

Both organic and nitrate nitrogen concentrations decreased sharply from April to August. Organic nitrogen concentrations were 0.41 and 0.11 mg/l, while nitrate concentrations were 0.17 and <0.01 mg/l, respectively. Total and dissolved ortho phosphorus concentrations were 0 02 and 0.004 mg/l in April, and 0.004 and <0.002 mg/l in August. Total organic carbon concentrations were 2.9 and 2.7 mg/l in April and August, respectively. Water clarity was low to moderate, Secchi depths varied from 1.0 meter in April to 2.75 meters in June Chlorophyll *a* concentrations were low, averaging 2.8 μg/l with a maximum of 5 μg/l in May. These low chlorophyll concentrations gave Cedar Creek Reservoir a fair chlorophyll rating in the reservoir ecological health index.

Sediment Quality—Chemical analyses of sediments in the forebay of Little Bear Creek Reservoir in 1993 did not reveal any metal or organic analyte to be a concern. Toxicity tests detected acute toxicity to daphnids (45 percent survival) in the forebay sediment. Particle size analysis showed sediments in the forebay were 94 percent silt and clay.

Because of the acute toxicity of the forebay sediment to daphnids, a fair sediment quality rating was used in the overall 1993 ecological health evaluation.

Benthic Macroinvertebrates—The Cedar Creek forebay supported a fair benthic community with 387 organisms/m^2 representing 10 species. Chironomus sp and Tubificidae were the dominant taxa, comprising 42 and 40 percent of the total, respectively. All 6 metrics received a fair score

Fish Assemblage—Only the forebay zone was sampled on Cedar Creek Reservoir in fall 1993. Shoreline electrofishing (15 transects) and offshore experimental gill netting (12 net-nights) yielded 662 individuals represented by 18 species (second lowest diversity in all TVA reservoirs). Thirty-eight percent of the total catch consisted of brook silversides, followed by gizzard shad (20 percent), spotted bass (13 percent), and spotted suckers (11 percent)

The Reservoir Fish Assemblage Index (RFAI) rated the forebay of Cedar Creek Reservoir fair (RFAI=32) as determined by electrofishing samples and good (RFAI=46) as determined by gill netting. The low electrofishing rating could be attributed to low diversity, and low catch. Combined electrofishing and gill netting ratings (RFAI=38) determined the reservoir fish community to be fair.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—The swimming beach at Slickrock Ford was tested for fecal coliform bacteria in 1993. Bacteria concentrations were very low (geometric mean <20/100 ml).

Fish Tissue—Five channel catfish were collected from the Cedar Creek forebay in autumn 1992. Composited fillets were analyzed for pesticides, PCBs, and selected metals. All pesticides and PCBs were below detection limits. Of the five metal analytes, only mercury was detected - at a relatively low concentration of 0.21 µg/g.

Bear Creek Stream Monitoring Site

Summary of 1993 conditions - Ecological Health

Water— The water of Bear Creek is soft (average hardness of 50 mg/l) and moderately alkaline (average total alkalinity of 50 mg/l). The median pH for the stream monitoring site was 7.6 . The river is well oxygenated with dissolved oxygen levels ranging from 80 to 94 percent of saturation.

Of the 12 streams monitored across the Tennessee Valley, Bear Creek ranked among the lowest in average concentrations of nitrate+nitrite-nitrogen (0.24 mg/l) and dissolved orthophosphate (0.005 mg/l). It was among the highest stations with average ammonia nitrogen and organic nitrogen concentrations of 0.044 mg/l and 0.332 mg/l. The average total phosphorus concentration of 0.065 mg/l was near the median for all stations. The fair total phosphorus and acceptable nitrate+nitrite-nitrogen concentrations yielded a fair rating for nutrients at the site.

Seven analyses for priority pollutant metals (dissolved cadmium, lead, nickel, silver, and zinc and total and dissolved copper and zinc) were performed bi-monthly. Dissolved cadmium (6 of 6 samples), dissolved nickel (2 of 6 samples), and dissolved zinc (1 of 6 samples) were detected, but at levels within the EPA guideline for protection of human health and aquatic life. Dissolved lead in one of six samples exceeded the EPA guideline for chronic toxicity to aquatic life.

Sediment—Sediment quality rated good in 1993 with no acute toxicity observed and no metals, PCBs, or pesticides exceeding the EPA guidelines. This is an improvement over 1992 when sediment quality rated fair.

Benthic Macroinvertebrates—In 1993, benthic macroinvertebrate results rated fair with a Modified Benthic Index of Biotic Integrity (MBIBI) score of 40, with 91 taxa and 1,697 organisms/m^2. Conditions in 1992 also rated fair (MBIBI score 38) with 74 taxa and 2,044 organisms/m^2 The number of taxa was greater in 1993 but densities were lower. The benthic fauna in 1993 was composed mostly of dipteran midge larvae (31 percent), the Asian clam Corbicula (22 percent), and river snails (21 percent). Dipteran midge larvae were also dominant in 1992 (52 percent), followed by Asian clams (17 percent) and nutrient-tolerant oligochaeta worms (12 percent). Streambank erosion and unstable substrates are a continuing problem affecting benthic organisms at this site.

Fish Community Assessment—The fish community rated fair with an Index of Biotic Integrity (IBI) score of 40), deteriorating considerably from the good (IBI = 48) rating in 1992. Fish sampled in 1993 included fewer native species and fewer intolerant species. A decrease was also seen in the proportion of specialized insectivores, fish that depend most on a diverse and stable macroinvertebrate community. Fish density changed most drastically, declining by approximately 50 percent since 1992. Adverse conditions observed at this station include extensive bank erosion and a predominance of shifting gravel substrate.

Summary of 1993 conditions - Use Suitability

There were no bacteriological samples or fish tissue samples collected from the Bear Creek stream site in 1993.

WHEELER RESERVOIR - ELK RIVER WATERSHED

Wheeler Reservoir

Summary of 1993 Conditions - Ecological Health

Water—Wheeler Reservoir was generally well mixed and lacked persistent thermal stratification in 1993. During the April-September monitoring period, coolest surface water temperatures in Wheeler Reservoir were in April and the warmest in July. Surface temperatures ranged from a minimum of 17.3°C to a maximum of 31.9°C at the forebay; from 15.4°C to 29.6°C at the transition zone; and from 18.7°C to 31.2°C in the Elk River embayment. The 31.9°C temperature in the forebay of Wheeler Reservoir was the warmest Tennessee River temperature measured as part of the Vital Signs monitoring program (1990-1993), and is evidence of the effect the very warm meteorological conditions had on surface water temperatures in July of 1993. (See discussion in Section 4.0, Hydrologic Overview of 1993). Temperatures above 30.0°C exceed the State of Alabama's water quality criteria for fish and aquatic life.

Dissolved oxygen (DO) concentrations at the 1.5m depth ranged from a low of 6.6 mg/l in September to a high of 11.6 mg/l in April at the forebay; from 6.2 mg/l in August to 9.4 mg/l in April at the transition zone, and from 6.1 mg/l in September to 14.1 mg/l in April at the sampling location in the Elk River embayment. At the inflow sampling station site (i.e. the tailrace of Guntersville dam) a minimum DO of 5.4 mg/l was recorded in July. The State of Alabama's minimum dissolved oxygen criteria for the protection of fish and aquatic life is 5.0 mg/l, measured at the 1.5 meter depth

Temperature data give evidence of the seasonal warming and a weak thermal stratification in the downstream portion of Wheeler Reservoir (i.e at the forebay and Elk River embayment). The maximum surface to bottom temperature differential (ΔT) occurred in June and was 5.8°C at the forebay and 7 0°C in the Elk River embayment. The transition zone was well mixed throughout the summer with ΔT's almost never exceeding 1.0°C.

As was the case for several other Tennessee River reservoirs, during the drought like conditions of the summer of 1993, a strong oxycline developed in June, July, and August in the downstream portions of Wheeler Reservoir. At the forebay, surface to bottom DO differentials (DO) were 9.7, 9.5, and 7.1 mg/l, respectively, in June, July, and August. In the Elk River embayment DO's of 11.0, 10.4, and 11.4 mg/l were measured in June, July, and August, respectively. As streamflows decreased and water temperatures increased, naturally occurring decomposition processes at the bottom of the reservoir used available oxygen at a rate faster than it was replenished by inflows DO's at or near 0 mg/l occurred at the bottom in the forebay in July; and in the Elk River embayment in June, July, and August. However, in contrast, the transition zone was well mixed and lacked any DO stratification (DO differentials never exceeded 1 mg/l and minimum DO's were never less than 6 mg/l) In addition, DO's were never observed to fall below 5 mg/l at the inflow sampling site (i.e. the tailrace of Guntersville dam).

Based on the above information, the DO component of the overall reservoir ecological health evaluation for Wheeler Reservoir rated poor at the forebay and Elk River embayment; and excellent at the transition zone and inflow The forebay and Elk River embayment rated poor because of the near bottom anoxia and the duration and volume of water with oxygen concentrations less than 2 mg/l.

Values of pH ranged from 6 7 to 9.1 in Wheeler Reservoir during the summer of 1993. Near surface values of pH equal to or greater than 8.5 were observed in April, June, July, and August at the forebay and in the Elk River embayment; but no pH's were ever less than 7.2 nor greater than 7.8 at the transition zone. Coincident with these pH's greater than 8.5 (particularly in the Elk River embayment) were oxygen saturation values ranging from 120% to 175% and high chlorophyll *a* concentrations, evidence of very high photosynthetic activity.

Ammonia nitrogen concentrations measured in Wheeler Reservoir, at both the forebay and the transition zone, were relatively high. As has been the case in previous years (1990-1992), ammonia nitrogen concentrations measured in 1993 were higher than at any other Vital Signs Monitoring location on the Tennessee River and averaged approximately 0.07 mg/l at the forebay and 0.11 mg/l at the transition zone. Given the volume of flow of the Tennessee River through Wheeler Reservoir and the lack extended periods of anoxia, the high ammonia concentrations could be indicative of large point and non-point waste discharge(s) to Wheeler Reservoir.

Historically (1990-1992), the forebay of Wheeler Reservoir has the highest total organic carbon (TOC) and organic nitrogen concentrations of any Vital Signs sampling site on the Tennessee River. In 1993, TOC averaged 2.6 mg/l (one of the highest TOC concentrations) and organic nitrogen averaged 0.32 mg/l (highest organic nitrogen concentration among the Tennessee River sampling sites) at the forebay. These data and other water quality characteristics (total phosphorus, total nitrogen, and chlorophyll *a*,) show substantial increases in concentration between the transition zone sampling site at Tennessee River Mile (TRM) 295.9 and the forebay sampling site at TRM 277.0. These data suggest a dramatic increase in primary productivity between the two sampling sites, likely stimulated by the input of large amounts of nutrients from the Elk River which joins Wheeler Reservoir about seven miles upstream of the forebay at TRM 284.3. The Elk River has a median total phosphorus and total nitrogen concentration of about 0.18 mg/l and 1.10 mg/l, respectively, and an annual mean daily flow of about 3050 cfs (For additional information see discussion below on the Elk River embayment.)

The dramatic increase in primary productivity in Wheeler Reservoir between the transition zone and the forebay is reflected in the chlorophyll *a* results. During the summer of 1993, chlorophyll *a* concentrations measured at the forebay were as high as 24 µg/l in April and August, and averaged about 13.5 µg/l. This is over a 300% increase in chlorophyll *a* concentrations from those measured at the transition zone, where chlorophyll *a* concentrations averaged only about 4 µg/l during the summer of 1993.

Water quality in the Elk River embayment was unique in several aspects, largely reflecting the natural characteristics of the Elk River. During the summer of 1993, concentrations of several water quality parameters were higher in the Elk River embayment than at any other embayment or run-of-the-river sampling site. For example, total nitrogen and ammonia nitrogen averaged 0.72 mg/l and 0.11 mg/l, respectively. Total phosphorus and dissolved ortho phosphorus averaged 0.175 mg/l and 0.067 mg/l, respectively. Consequently, as might be expected, chlorophyll *a* concentrations were very high, averaging 23 µg/l and with concentrations as high as 39 µg/l measured during massive algal blooms. These chlorophyll *a* concentrations measured in the Elk River embayment were higher than at any of the other Vital Signs monitoring locations during 1993.

The chlorophyll *a* ratings used in the 1993 ecological health evaluation for Wheeler Reservoir were fair at the forebay (average exceeding 10 µg/l), good at the transition zone, and poor in the Elk River embayment (average exceeding 15 µg/l and large algal blooms).

Finally, true color values in the forebay of Wheeler Reservoir are among the highest measured on the Tennessee River and show a relatively large increase between the transition zone and the forebay. The

1990-1992 average for true color was 15.4 and 11.8 PCU's at the forebay and transition zone, respectively. During the summer of 1993, true color values averaged 12.5 PCU's at the forebay (the highest among the Tennessee River sampling sites in 1993) and 7.0 PCU's at the transition zone (one of the lowest of the Tennessee River sampling sites in 1993). These summer color values at the forebay are even higher than those measured throughout the year in the Elk River, which averaged about 12 PCU's, from 1986-1991. These data suggest that even though some color is added to the Tennessee River by inflows from the Elk River, there are other additional sources of color to Wheeler Reservoir between the transition zone and the forebay.

Sediment Quality—Chemical analyses of sediment in Wheeler Reservoir in 1993 indicated elevated levels of un-ionized ammonia (340 µg/l) from the Elk River embayment. Toxicity tests did not reveal acute toxicity to daphnids or rotifers from the three sites tested. Particle size analysis showed sediments from the forebay were 98 percent silt and clay, from the transition zone were 25 percent silt and clay, 75 percent sand; and from the Elk River embayment were 73 percent silt and clay, 27 percent sand.

Sediment quality ratings used in the overall Wheeler Reservoir ecological health evaluation for 1993 were excellent at the forebay and transition zone; and slightly lower, i e. good, in the Elk River embayment due to the presence of ammonia

Benthic Macroinvertebrates—The benthos rated fair at the forebay in 1993, same as in 1992. The transition zone improved from fair in 1992 to good in 1993, and the inflow improved from good in 1992 to excellent in 1993. A major are of Wheeler Reservoir, the Elk River embayment, was sampled for the first time in 1993 and received a poor rating. The forebay location had 14 taxa and 633 organisms/m^2, dominated by the chironomid Coelotanypus (71 percent). The transition zone had 32 taxa and 870 organisms/m^2, with Hexagenia limbata as the dominant taxon comprising 38 percent of the total. The inflow site had 30 taxa present and 651 organisms/m^2 with Corbicula fluminea as the dominant organism present (61 percent) The Elk River embayment had 25 taxa and 1,488 organisms/m^2 with Tubificidae (37 percent) and Coelotanypus sp (16 percent) as the two dominant taxa.

Wheeler forebay received a fair rating; this is partially due to the high numbers of chironomids and low EPT taxa present at the site. Interestingly, tubificids made up only a small portion of the sample, and this boosted the rating slightly. The other metrics, taxa richness and abundance of long-lived species, were mediocre. At the transition site, a good rating was attained because of good diversity, EPT taxa richness, and low numbers of chironomids and tubificids. The only metric that brought the rating down was the evenness of dominant organisms; in this case one organism comprised an inordinate amount of the total organisms present The inflow site on Wheeler received a perfect score due to its taxa richness, presence of a good EPT community, presence of several long-lived taxa, evenness of dominant organisms, and low numbers of tubificids and chironomids. Elk River embayment did not fare as well as the rest of the sites on Wheeler, primarily because it had large numbers of chironomids and tubificids, and very few EPT taxa and long-lived organisms. A perfect score on the taxa richness metric kept this site from receiving a very poor rating.

Aquatic Macrophytes—Aquatic plants increased from 4,412 acres in 1992 to 6,597 acres in 1993. Wheeler Reservoir had the second largest amount of aquatic vegetation within the TVA system. Dominant submersed species were Eurasian watermilfoil and spinyleaf naiad. These were most abundant in shallow overbank habitats from TRM 296 upstream to TRM 309. Wheeler Reservoir also had large populations (1,431 acres) of American lotus concentrated in Flint Creek embayment, overbank sloughs upstream of Flint Creek, and in Swan Creek embayment.

Fish Assemblage—Fish data collected in near shore and offshore bottom areas showed that 3,211 individuals of 47 species were recorded in both electrofishing (45 transects) and gill netting (26 net-nights) samples. Electrofishing results indicated total numbers of fish captured were higher in the inflow (1,277) than in the transition (934) or forebay (473) zones of the reservoir. Gizzard shad (32 percent) comprised the majority of the total individuals collected, followed by emerald shiners (18 percent), bluegill (8 percent), and skipjack herring (7 percent). Threadfin shad numbers were moderate in the transition (catch per unit effort, CPUE=271 per 300m transect) and high in the forebay (CPUE=851 per 300m transect) of Wheeler Reservoir. Gill netting catch rates were slightly higher in the forebay (CPUE=30 per net night) than the transition (CPUE=11 per net night) or the inflow (CPUE=14), due to much higher numbers of skipjack herring in the forebay.

The Reservoir Fish Assemblage Index (RFAI) rated the littoral fish community (based on electrofishing results) good in the forebay (RFAI=44) and inflow (RFAI=44) and fair in the transition (RFAI=40). A high percentage of tolerant individuals (75 percent) and a lower average number of individuals (62) influenced the fair rating in the transition. Indices, determined by gill netting, for the transition and forebay zones of Wheeler Reservoir were 42 (good) and 40 (fair), respectively. Gill netting RFAI values were not calculated for inflow zones of run-of-the-river reservoirs due to low numbers of replicate samples

Combined electrofishing and gill netting RFAI scores for the forebay (RFAI=42) and the electrofishing RFAI for the inflow (RFAI=44) were rated good. The combined transition RFAI (RFAI=41) ranked fair.

Electrofishing (15 transects) and gill netting (12 net-nights) results from the Elk River embayment yielded 5,126 individuals of 30 species. Gizzard shad were the most abundant species, comprising 78 percent of the total number of fish sampled. Other species of interest were bluegill (8 percent) and largemouth bass (2 percent). High numbers of gizzard shad accounted for the wide margin in catch rates for both gear types (4,776 individuals in electrofishing and 350 for gill netting). Unusually high numbers of young-of-year threadfin shad (3,356 per transect) were also observed in the electrofishing sample.

The Reservoir Fish Assemblage Index (RFAI) rated the quality of the littoral community (as determined by electrofishing samples) good in the Elk River embayment (RFAI=42). Metrics receiving high scores were number of species, and number of piscivorous, intolerant, and lithophilic spawning species. The gill netting RFAI of 34 rated fair with metric values being somewhat evenly distributed throughout the range of possible scores. The combined electrofishing and gill netting RFAI of 34 rated the Elk River embayment of Wheeler Reservoir as fair.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—No bacteriological studies were conducted at recreation sites in Wheeler Reservoir in 1993 Fecal coliform bacteria concentrations at the monthly Vital Signs locations, the forebay, transition zone, and Elk River Embayment, were very low (geometric mean <20/100 ml). The highest concentration for any sample was 219/100 ml in the transition zone in September.

Fish Tissue—Composite catfish samples for screening purposes were collected from the forebay, transition zone, and inflow in autumn 1992. Intensive studies were also conducted during this same time period to examine DDTr concentrations in a 20 mile stretch of Wheeler Reservoir near the Indian Creek embayment, located between the inflow and the transition zone. Three five-fish composites of channel catfish, largemouth bass, and smallmouth buffalo were collected from four locations for the intensive study.

Samples for screening purposes indicated all metals were low or not detected. DDTr was the only pesticide detected with a range of 1.0 to 1.6 μg/g Relatively high PCB concentrations reported for 1990 (maximum 1.4 μg/g) were again found in 1991 (maximum 1.3 μg/g) but generally lower levels were found in 1992 (maximum 0.8 μg/g). PCB concentrations during all years were higher at upstream locations.

Samples from the intensive study in 1991 found quite high concentrations of DDTr. At least one sample of one test species exceeded 5 μg/g at all four sites. Highest concentrations were in smallmouth buffalo (maximum 43 μg/g) from near the mouth of Indian Creek with lower concentrations at the upstream location and the location at the downstream end of the study reach. Largemouth bass tended to have lower concentrations than the other two species Samples for the intensive study in autumn 1992 (samples actually collected in January 1993) had substantially reduced concentrations. Only two samples exceed 5 μg/g whereas 15 from 1991 exceeded that concentration. Also, the geographical pattern was not distinct in these samples. Because of the discrepancy between the two years, the intensive study was repeated in autumn 1993 but results were not available at the time this report was prepared.

Tims Ford Reservoir

Summary of 1993 Conditions - Ecological Health

Water—The average flow through Tims Ford Reservoir in 1993 was about 86 percent of normal, making the average residence time about 329 days The reservoir was strongly stratified with a maximum temperature difference of 22.9°C in the water column at the forebay in July. Tennessee's maximum temperature criterion for aquatic life is 30.5°C. July surface temperatures were 31.3°C at the forebay and 31.5°C at the mid-reservoir station, the only time the temperature criterion was exceeded. DO depletion (DO <2.0 mg/l) began in May at the bottom of the water column at mid-reservoir, and in June in the metalimnion at mid-reservoir and in the forebay in both the metalimnion and at the bottom. The two areas of depleted DO expanded and met in July at mid-reservoir and September at the forebay. The extensive area of depleted DO resulted in a poor DO rating for Tims Ford in the reservoir ecological health index. As surface temperatures cooled in the early fall, the area of depleted DO declined as metalimnetic water mixed with surface water Some extremely high DO concentrations occurred at the forebay in the upper part of the metalimnion. Both June and July DO concentrations exceeded 15 mg/l.

Conductivities in Tims Ford Reservoir were the fifth highest of the 19 tributary reservoirs. Conductivities were about 180 μmhos/cm in April, increased throughout the year in the DO depleted bottom waters to a maximum of 242 and 285 μmhos/cm in October at the forebay and mid-reservoir, respectively Conductivities declined in the DO supersaturated surface water in the summer to a minimum of 145 μmhos/cm at the forebay in July and 136 μmhos/cm in June at mid-reservoir. The waters in Tims Ford are somewhat basic, as the minimum pH in April was 7.6 in the mid-reservoir In June, surface pH was over 9.0 in both the forebay and mid-reservoir. The minimum pH was 6.8 at the bottom of the water column in September in mid-reservoir.

Organic nitrogen concentrations in June were 0.30 and 0.38 mg/l at the forebay and mid-reservoir, respectively, and 0.22 and 0.43 mg/l in August Nitrates were 0.30 and 0.76 mg/l in April, declining to <0.01 at both locations in August. Total nitrogen concentrations at mid-reservoir in 1993 was the second highest concentration of the 33 tributary reservoir stations Total phosphorus concentrations were 0.01 mg/l during both surveys at the forebay, and 0.02 and 0.005 mg/l at mid-reservoir in April and August, respectively. The TN/TP ratios were very high, ranging from 24 at the forebay to 90 at mid-reservoir, both in August Dissolved ortho phosphorus concentrations were <0.002 mg/l at both stations during both surveys. Average total organic carbon concentrations in Tims Ford Reservoir were the fifth highest of the 19 tributary reservoirs. The minimum total organic carbon concentration was 2.6 mg/l in April, the maximum was 3.2 mg/l in August, both at mid-reservoir

Chlorophyll *a* concentrations averaged 5 4 μg/l at mid-reservoir and 4.3 μg/l at the forebay. Some of the highest DO concentrations were below the depth at which the chlorophyll composite was collected in the forebay, thus the average sampled forebay concentration may be a little lower than actual values. The chlorophyll concentrations rated good in the reservoir ecological health index Secchi depths varied from 1.3 meters in April to 5.5 meters in May at the forebay, and 1.3 meters in April to 8.0 meters in September at mid-reservoir.

Sediment Quality—Chemical analyses of sediments in Tims Ford Reservoir in 1993 indicated high levels of nickel in the forebay (51 mg/kg). Elevated levels of un-ionized ammonia were also found in both the forebay (230 µg/l) and mid-reservoir (410 µg/l) sediment samples. Toxicity tests detected acute toxicity to daphnids (5 percent survival) and rotifers (65 percent survival) in the mid-reservoir. Particle size analysis showed sediments in the forebay were 99 percent silt and clay; and in the mid-reservoir were 55 percent silt and clay, and 45 percent sand.

Sediment quality ratings used in the overall Tims Ford Reservoir ecological health evaluation for 1993 were good at the forebay sampling site, rather than excellent due to nickel and ammonia; and poor at the mid-reservoir sampling site (because of acute toxicity to daphnids and rotifers and presence of ammonia).

Benthic Macroinvertebrates—Two sites were chosen for sampling the first year on Tims Ford Reservoir, a forebay site and a mid-reservoir site of the Elk River arm. The forebay location had only 2 taxa and 122 organisms/m^2. Tubificidae accounted for 90 percent of the total. The inflow site had 108 organisms/m^2 representing 12 species and was dominated by Chironomus sp (32 percent) and Branchiura sowerbyi (27 percent). The forebay had a very poor benthic community, and scored poor on 5 of the 6 metrics. diversity, number of long-lived species, number of EPT species, proportion of the sample as tubificids, and unevenness of the dominant species. The only metric to get a good score was the proportion of the sample represented by chironomids. The inflow site rated only a little better than the forebay with a poor benthic community. Low diversity, absence of long-lived species, and a disproportionate number of the dominant taxa accounted for this site rating poor

Fish Assemblage—Shoreline electrofishing (30 transects) and offshore experimental gill netting (24 net-nights) yielded 2,726 individuals with 32 species represented. The dominant species by number included bluegill (50 percent), green sunfish (8 percent), spotfin shiners (7 percent), and brook silversides (6 percent). Catch rates for most species (except for bluegill and green sunfish), utilizing both gear types, were higher at the transition zone than the forebay.

The Reservoir Fish Assemblage Index (RFAI) rated the littoral fish community (based on electrofishing results) fair in the forebay zone (RFAI=40) and good in the transition (RFAI=46) of Tims Ford Reservoir. The transition received midrange to maximum scores for all metrics, except average number of individuals per transect, resulting in a slightly higher rating than the forebay. Identical gill netting scores for ten of the twelve metrics resulted in a good rating (RFAI=44) at both reservoir sample zones. Combined electrofishing and gill netting RFAI scores rated both the forebay (RFAI=42) and the transition (RFAI=45) zone good.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—The swimming area on Dry Creek and an area in Estill Springs Park were tested for fecal coliform bacteria in 1993. Bacteria concentrations were low at Estill Springs Park, geometric mean of 38/100 ml for all samples. In Dry Fork, bacteria concentrations were high in samples collected within 24-hours of rainfall, geometric mean of 389/100 ml, but were within Tennessee criteria if the rainfall samples were excluded, geometric mean of 151/100 ml.

Fish Tissue—Channel catfish composites collected from the forebay and transition zone in autumn 1992 were screened for pesticides, PCBs, and selected metals. All analytes were either not detected or found in only low concentrations. One point of interest was absence of PCBs in these samples because previous screening studies had typically found PCBs, sometimes at slightly elevated levels.

Elk River Stream Monitoring Site

Summary of 1993 Conditions - Ecological Health

Water—The water of the Elk River is moderately hard (average hardness of 130 mg/l) and moderately alkaline (average total alkalinity of 103 mg/l). The median pH for the stream monitoring site was 7.7 The river was generally well oxygenated with dissolved oxygen levels ranging from 54 to 108 percent of saturation. Five of the six dissolved oxygen levels were above 85 percent of saturation. At the lowest dissolved oxygen saturation level, the dissolved oxygen concentration was 5.4 mg/l.

Of the 12 streams monitored across the Tennessee Valley, the Elk River ranked among the highest in average concentrations of total phosphorus (0.374 mg/l), dissolved orthophosphate (0.173 mg/l), nitrate+nitrite-nitrogen (0.68 mg/l), ammonia nitrogen (0.042 mg/l). The high total phosphorus and nitrate+nitrite-nitrogen concentrations yielded a poor rating for nutrients at the site.

Seven analyses for priority pollutant metals (dissolved cadmium, lead, nickel, silver, and zinc and total and dissolved copper and zinc) were performed bi-monthly Dissolved cadmium (5 of 6 samples) and total zinc (2 of 6 samples) were detected but neither exceeded EPA guidelines for the protection of aquatic life or human health.

Sediment—Sediment quality rated good in 1993 with no acute toxicity observed and no metals, PCBs, or pesticides exceeding the EPA guidelines. This is an improvement over 1992 when the sediment quality rated only fair.

Benthic Macroinvertebrates—In 1993, benthic macroinvertebrate results rated fair with a Modified Benthic Index of Biotic Integrity (MBIBI) score of 39, with 73 taxa and 2,384 organisms/m^2. Conditions in 1992 rated poor (MBIBI score 27) with 52 taxa and 2,454 organisms/m^2 The benthic fauna improved one classification since 1992. Dominant organisms in 1993 were dipteran midge larvae (69 percent), coleopteran riffle beetles (8 percent), and caddisflies (7 percent). Dipteran midge larvae were also the most dominant organism in 1992 (70 percent), followed by nutrient tolerant oligochaeta worms (18 percent) and coleopteran riffle beetles (5 percent). Siltation from agricultural land usage along the river and unstable substrates are a serious problem affecting benthic organisms at this site.

Fish Community Assessment—Fish community was not evaluated in the Elk River in 1993.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—The canoe access location at Garner Ford on the Elk River, about one and one-half miles downstream of Tims Ford Dam, was tested for fecal coliform bacteria in 1993. Five of the 12 samples were collected within 48-hours of rainfall of at least one-half inch Bacteriological water quality for samples collected more than 24-hours after rainfall easily met the Tennessee water quality criterion for recreation, but rainfall samples greatly exceeded criterion.

Fish Tissue—Smallmouth Buffalo, channel catfish, and spotted bass were collected in summer 1992. One five fillet of each species was analyzed for selected metals, pesticides, and PCBs. All analytes were either not detected or found in low concentrations.

GUNTERSVILLE RESERVOIR - SEQUATCHIE RIVER WATERSHED

Guntersville Reservoir

Summary of 1993 Conditions - Ecological Health

Water—During the summer of 1993, Guntersville Reservoir was well mixed and exhibited only weak thermal stratification. Surface water temperatures ranged from 16.2°C in April to 30.5°C in July at the forebay and from 15.1°C to 30.9°C for the same months at the transition zone. Temperatures above 30.0°C exceed the state of Alabama's water quality criteria for fish and aquatic life.

Values for DO at the 1.5m depth ranged from 10.1 mg/l in April to 6.5 mg/l in September at the forebay and from 9 3 mg/l in April to 5.6 mg/l in August at the transition zone At the inflow sampling station site (i.e. the tailrace of Nickajack Dam) a minimum DO of 1.8 mg/l was recorded in July. The State of Alabama's minimum dissolved oxygen criteria for the protection of fish and aquatic life is 5.0 mg/l, measured at the 1.5 meter depth.

Summer (April-September) temperature data for the forebay depict weak thermal stratification in the downstream portion of Guntersville Reservoir in 1993. Maximum surface to bottom temperature differentials
(ΔT's = 3.3°C) occurred at the forebay in May and June. However, June and July showed the development of a oxycline in the forebay, with surface DO's being 5.5 and 6.3 mg/l, respectively, greater than bottom DO's The minimum DO measured in Guntersville reservoir in 1993 was 0.6 mg/l at the bottom in July in the forebay, however, this apparently persisted for only a short period of time and by August bottom DO's were back up to 5 mg/l

The transition zone was well mixed throughout the summer with maximum ΔT's (2.2°C) and ΔDO's (3.4 mg/l) occurring in June. One interesting observation was the very warm temperatures which existed throughout the water column at the transition zone in July, when surface temperatures were 30.9°C and bottom temperatures were 30.0C. The minimum DO measured at the transition zone was 5.5 mg/l at the bottom in July

The very low DO concentration of 1.8 mg/l, measured in July in the tailrace below Nickajack Dam (i.e., the inflow site), was the lowest ever recorded in the releases from Nickajack Dam. In addition, releases of water from Nickajack Dam were consistently below Alabama's DO water quality criteria for the protection of fish and aquatic life of 5.0 mg/l (at the 1.5 meter depth) in July, potentially impacting the ecological health of the inflow site on Guntersville Reservoir.

These data resulted in DO ratings used in the overall reservoir ecological health evaluation for Guntersville Reservoir to be good at the forebay (minor hypolimnetic anoxia); excellent at the transition zone, and very poor at the inflow (due to low DO's in the releases from Nickajack dam).

Values of pH ranged from 6.9 to 8 3 Surface water pH values in excess of 8.5 (Alabama's pH water quality criteria for the protection of fish and aquatic life of 8.5) were not observed in Guntersville Reservoir in the summer of 1993.

At the forebay, the highest chlorophyll *a* concentration of 9 µg/l was measured in July (average summer chlorophyll *a* concentration was 5-6 µg/l in 1993). At the transition zone chlorophyll *a* concentrations were lower, averaging about 4 µg/l TN/TP ratios frequently exceeded 20 at both the forebay and transition zone, indicating conditions when phosphorus concentrations may have limited photosynthesis

The chlorophyll *a* ratings used in the 1993 ecological health evaluation for Guntersville Reservoir were good at both the forebay and the transition zone (i.e., average concentrations between 3 and 10 μg/l).

Historically, water clarity on Guntersville Reservoir has been among the highest of the mainstem Tennessee River reservoirs. In 1993, at the forebay and transition zone, respectively, average Secchi depth was 1.8 and 1.6 meters, total suspended solids was 3.7 and 3.2 mg/l; and true color was 8.3 and 7.1 PCU.

Sediment—Chemical analyses of sediment in Guntersville Reservoir in 1993 indicated the presence of chlordane (15 μg/g) in samples collected at the forebay. Toxicity tests did not reveal acute toxicity to daphnids or rotifers from the two sites tested (i.e. forebay and transition zone). Particle size analysis showed sediments from the forebay were 98 percent silt and clay; and from the transition zone were 39 percent silt and clay, 61 percent sand.

Sediment quality ratings used in the overall Guntersville Reservoir ecological health evaluation for 1993 were good at the forebay (presence of chlordane); and excellent at the transition zone.

Benthic Macroinvertebrates—The forebay site had a good benthic macroinvertebrate community, the transition zone had an excellent benthic community, and the inflow had a fair benthic community. The forebay had 20 taxa and 772 organisms/m^2 with Coelotanypus tricolor (27 percent) and Corbicula fluminea (18 percent) as the dominant taxa. The transition zone had 1340 organisms/m^2 representing 38 taxa, the dominant taxa were Corbicula fluminea (26 percent) and Coelotanypus tricolor (17 percent). The inflow site had 35 taxa and 672 organisms/m^2 with Corbicula fluminea (39 percent) and Tubificidae (24 percent) as the dominant taxa

The forebay site fell short of an excellent rating primarily because high numbers of chironomids and a mediocre EPT community. All other metrics were excellent. The transition zone scored excellent, and fell just short of perfect because the percentage of the community made of chironomids was slightly elevated The absence of adequate long-lived taxa, depressed diversity and EPT taxa, and unevenness of the dominant organisms all contributed to the inflow site receiving a fair rating. Metrics which rated food at the inflow were (due to their relatively low numbers) were tubificids and chironomids.

Aquatic Macrophytes—Aquatic macrophytes on Guntersville Reservoir increased from 5,993 acres in 1992 to 7,613 acres in 1993. The reservoir had the largest acreage of aquatic plants in the TVA system. About 99 percent of the total amount of vegetation was upstream of TRM 363 and primarily confined to shallow embayments and overbank areas adjacent to the river channel. Eurasian watermilfoil was the dominant submersed macrophyte species and colonized about 6,500 acres in 1993. About three acres of "topped out" hydrilla occurred on Guntersville Reservoir in 1993 compared to about 2,900 acres in 1988 when aquatic vegetation coverage peaked at about 20,200 acres. In 1990, the reservoir was stocked with 100,000 triploid grass carp for aquatic vegetation control.

Fish Assemblage—Shoreline electrofishing (45 transects) and offshore gill netting (29 net-nights) produced 8,441 fish representing 41 species. Both sampling techniques indicated higher catch rates in the forebay than the other two zones of the reservoir. Gizzard shad (19 percent) was the dominant species, followed by bluegill (17 percent), and emerald shiners (14 percent). Results indicated that largemouth bass

(4 3 percent) was the only major sport fish species to comprise more that one percent of the electrofishing sample. As in previous years, largemouth bass were five times more abundant in the transition zone than either of the other two zones.

Electrofishing RFAI analysis determined that fish communities in both the inflow (RFAI=30) and transition zone (RFAI=28) rated poor, while that present in the forebay zone (RFAI=38) rated fair. Compared to other mainstream reservoirs, the Guntersville inflow and transition zones were in the lower third and the forebay zone the upper third. The poor designation of the transition also represented a significant decrease from the good rating in 1992. Metrics contributing to the poor designation for the inflow and transition areas were low numbers of sucker and intolerant species, depressed fish abundance, and high percentages of anomalies. Gill netting results showed both zones to be fair (transition RFAI=34 and forebay RFAI=38). Transition zone scores were midrange (most metrics received a score of three), while forebay scores tended to be very low or very high (metrics received a score of one or five) for most metrics. Gill netting RFAI values were not calculated for inflow zones of run-of-the-river reservoirs due to low numbers of replicate samples.

Combined electrofishing and gill netting RFAI values for both the forebay (RFAI=38) and transition (RFAI=31) were classified as fair, followed by the electrofishing RFAI for the inflow (RFAI=30) which was poor.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—Two swimming beaches, one boat ramp, the middle of the channel under five causeways, both Vital Signs locations, and an area downstream of Guntersville sewage treatment plant were each tested twelve times in 1993 for fecal coliform bacteria. No samples were collected within 48-hours of a rainfall of one-half inch or greater. The sampled swimming beaches were the Camp Barber Boy Scout Camp, and the Camp Trico Girl Scout Camp.

The 1993 survey at the causeways was intended to identify the watersheds having the most potential for affecting the bacteriological water quality in the main channel of Guntersville Reservoir. The other sites were selected to determine the impacts discharges or runoff from urban areas have on Guntersville Reservoir. At all but two sites, the bacteria concentrations were very low (geometric means <20/100 ml). At the Polecat Creek Causeway and at the Crow Creek boat ramp the fecal coliform bacteria samples had geometric mean concentrations of 69 and 67/100 ml, respectively. The lack of rainfall during the sampling period may have resulted in lower concentrations at some sites. For the regular monthly Vital Signs sampling, all fecal coliform concentrations were very low.

Fish Tissue—Composite catfish samples were collected from the forebay, transition zone, and near the inflow in autumn 1992. One reason for resampling was that relatively high PCB concentrations of chlordane and PCBs had been found in 1990 (chlordane levels at the forebay were 0.10 μg/g and those from near the inflow were 0.11 μg/g, whereas, PCB concentrations at these two locations were 1 2 and 1.3 μg/g, respectively). Chlordane was not detected in any of the 1992 samples and PCB concentrations decreased progressively from year to year (maximum 0.9 μg/g in 1991 and 0.4 μg/g in 1992). Other pesticides and metals were relatively low during all years at all locations.

Sequatchie River Stream Monitoring Site

Summary of 1993 Conditions - Ecological Health

Water—The water of the Sequatchie River is moderately hard (average hardness of 90 mg/l) and moderately alkaline (average total alkalinity of 74 mg/l). The median pH for the stream monitoring site was 7.4. The river was well oxygenated with dissolved oxygen levels ranging from 72 to 93 percent of saturation.

Of the 12 streams monitored across the Tennessee Valley, the Sequatchie River ranked among the highest in average concentrations of organic nitrogen (0.372 mg/l) and ammonia nitrogen (0.090 mg/l). It was among the lowest in average total phosphorus with a concentration of 0.022 mg/l. The average nitrate+nitrite-nitrogen (0.42 mg/l) and average dissolved orthophosphate (0.009 mg/l) concentrations ranked mid-way of all station medians. The low average total phosphorus and acceptable nitrate+nitrite-nitrogen concentrations yielded a good rating for nutrients at the site.

Seven analyses for priority pollutant metals (dissolved cadmium, lead, nickel, silver, and zinc and total and dissolved copper and zinc) were performed bi-monthly. Dissolved cadmium was detected in 4 of 5 samples. However, the concentrations did not exceed the EPA guideline for the protection of aquatic life or human health. Additional metals analyses included total and dissolved forms of iron and manganese. Total iron (2 of 6 samples) and total manganese (1 of 6 samples) exceeded the EPA guideline for combined consumption of fish and water.

Sediment—Sediment quality rated good in 1993 with no acute toxicity observed and no metals, PCBs, or pesticides exceeding the EPA guidelines The sediment quality also rated good in 1992.

Benthic Macroinvertebrates—In 1993, benthic macroinvertebrate results were rated fair with a Modified Benthic Index of Biotic Integrity (MBIBI) score of 44, with 80 taxa and 3,951 organisms/m^2. Conditions in 1992 also rated fair (MBIBI score 41) with 93 taxa and 2,096 organisms/m^2. Dominant organisms in 1993 were dipteran midge larvae (38 percent), caddisflies (27 percent), and mayflies (12 percent). Nutrient tolerant oligochaete worms were the dominant group in 1992 (22 percent), followed by dipteran midge larvae (20 percent) and caddisflies (16 percent). Conditions have improved between sampling years The fair rating (score 44) given for 1993 is borderline good for this site; however, siltation from agricultural land use along the river and coal mining in the Sequatchie watershed continues to impact benthic communities in the river

Fish Community Assessment—No change was seen as the fish community rated fair with an Index of Biotic Integrity (IBI) score of 42 during both 1993 and 1992. Problems continued to occur in species richness and composition and in fish density. Forty-six to 69 native fish species were expected at this station, but only 38 were found This loss of diversity was most noticeable among darters and intolerant species Fish density was one of the lowest found at the 11 stations sampled in 1993. Poor conditions observed at this station were sedimentation of shoreline habitats and occasional bank erosion.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—Four canoe access sites on the Sequatchie River from river mile 35.6 to 51.3 were tested for fecal coliform bacteria twelve times each in 1993. Two samples were collected within 48-hours of a rainfall greater than one-half inch. The geometric mean of fecal coliform bacteria concentrations for all samples at the four sites ranged from 43 to 103/100 ml, all well within the Tennessee bacteriological criterion for recreation. Concentrations were higher in the two rainfall samples.

Fish Tissue—Five freshwater drum, channel catfish, and largemouth bass were collected from the Sequatchie River during summer 1992. Composited fillets for each species were analyzed for selected metals, pesticides, and PCBs. Most analytes were not detected. Those that were had low concentrations.

NICKAJACK RESERVOIR - CHICKAMAUGA RESERVOIR WATERSHED

Nickajack Reservoir

Summary of 1993 Conditions - Ecological Health

Water—Surface water temperatures during the April to September monitoring period ranged from a 17.6°C in April to 29.2°C in July at the forebay; and DO at the 1.5m depth ranged from 5.6 mg/l in August to 10.2 mg/l in April at the forebay. At the inflow sampling station site (i.e., the tailrace of Chickamauga dam) a minimum DO of 2.2 mg/l was recorded in July. Tennessee's minimum dissolved oxygen criteria for the protection of fish and aquatic life is 5.0 mg/l, measured at the 1.5 meter depth.

The riverine character of Nickajack Reservoir, with an average hydraulic residence time of only three to four days, results in it being the best mixed of any of the Vital Signs reservoirs. Temperature data reflect a lack of thermal stratification in Nickajack Reservoir in 1993. A maximum surface to bottom temperature differential of 1.8°C was measured at the forebay in May. However, summer DO data reflect a small oxycline in the forebay of Nickajack Reservoir when surface to bottom DO differentials were 3.0, 3 1, 4.8, and 2.1 mg/l, respectively, from May through August. The drought like conditions and low flows also depressed concentrations of oxygen. For example, minimum oxygen concentrations measured at the bottom in the forebay of Nickajack Reservoir were 4.6, 4.7, and 5 0 mg/l, respectively, for 1990, 1991, and 1992. However, in 1993, minimum DO concentrations at the bottom in the forebay of Nickajack Reservoir were 3.0 mg/l In addition, in late July (between the mid-July and mid-August field surveys), releases from Nickajack Dam were recorded as low as 1.8 mg/l, indicating a short period when DO concentrations in the hypolimnion of the forebay were less than 2 mg/l. Also in July, DO's as low as 2.2 mg/l and frequently in the mid-3's mg/l were measured in the releases from Chickamauga dam (i.e., the inflow to Nickajack Reservoir).

Because DO concentrations were frequently below Tennessee's minimum dissolved oxygen criteria for the protection of fish and aquatic life (5 0 mg/l at the 1.5 meter depth), the DO rated poor at inflow sampling site in the overall ecological health evaluation of Nickajack Reservoir. Based on no DO's actually being measured in the hypolimnion of the forebay of Nickajack Reservoir below 2 mg/l, the forebay sampling site's DO rating was excellent.

Values of pH varied over a rather narrow range, from 7.0-8.0 during the summer of 1993. At the forebay, the highest chlorophyll *a* concentration of about 10 µg/l was measured in May and averaged about 6 µg/l in the summer of 1993 Consequently, the chlorophyll *a* rating used in the 1993 ecological health evaluation for Nickajack Reservoir was good (i.e., average concentration between 3 and 10 µg/l).

Sediment—Chemical analyses of sediments in Nickajack Reservoir in 1993 indicated the presence of chlordane (21 µg/g) from the forebay. Toxicity tests did not reveal acute toxicity to daphnids or rotifers from the forebay Particle size analysis showed sediments from the forebay about 92 percent silt and clay.

The sediment quality rating used in the overall Nickajack Reservoir ecological health evaluation for 1993 was good (rather than excellent because chlordane was detected.

Benthic Macroinvertebrates—Both the forebay and inflow sites on Nickajack had excellent benthic macroinvertebrate communities, an improvement from the previous years. The forebay site had 21 taxa and 535 organisms/m^2 with Hexagenia limbata comprising 30 percent of the total. The inflow site had 38 taxa and 1458 organisms/m^2; Cheumatopsyche sp and Tubificidae were dominant, comprising 22 and 19 percent of the total organisms present, respectively.

The forebay site fell short of a perfect score due to a slightly elevated chironomid community, but still received an excellent rating. All other metrics were perfect. The inflow site scored perfect for each metric evaluated, resulting in an excellent benthic community evaluation.

Aquatic Macrophytes—Aquatic plants on Nickajack Reservoir increased from 583 acres in 1992 to 1,000 acres in 1993. Eurasian watermilfoil and spinyleaf naiad were the dominant species and occurred in mixed colonies or occasionally with other species such as American pondweed and southern naiad. Aquatic macrophytes were most abundant from TRM 425 upstream to TRM 440.

Fish Assemblage—Fish collections in the littoral (30 electrofishing transects) and offshore/benthic areas (16 net-nights) of Nickajack Reservoir found fish to be more concentrated in the inflow zone (2,181) than the forebay (1,337) particularly as indicated by electrofishing results. Although gill netting effort was reduced in the inflow, catch per unit effort (CPUE) was similar between forebay and inflow zones. Bluegill was the most abundant species (29 percent), followed by emerald shiners (20 percent). The majority of the forage base in the Nickajack sample was comprised of several shiner species (golden, emerald, spotfin, and steelcolor) instead of shad, which is unusual for run-of-the-river reservoirs.

The Reservoir Fish Assemblage Index (RFAI) rated the littoral fish (based on electrofishing results) excellent in the inflow (RFAI=52) and fair in the forebay (RFAI=40) zones of Nickajack Reservoir. The inflow index of 52 was the highest score observed for run-of-the-river reservoir inflows and received maximum scores for all metrics except number of piscivorous, sucker, and intolerant species, and percent anomalies The gill netting RFAI rated the forebay good (RFAI=48). Gill netting RFAI values were not calculated for inflow zones of run-of-the-river reservoirs due to low numbers of replicate samples.

The combined electrofishing and gill netting RFAI score for the forebay (RFAI=44) was determined to be good. The electrofishing RFAI for the inflow (RFAI=52) was rated excellent. High inflow RFAI indices in 1992 and 1993 indicate Nickajack to have possibly the best fish community among run-of-the-river inflows.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—Four swimming beaches and a boat ramp near Nickajack Dam, and one boat ramp and two informal swimming areas in the North Chickamauga Creek Embayment were tested for fecal coliform bacteria twelve times each in 1993 Two samples at each site were collected within 48-hours of a rainfall of at least one-half inch. The geometric mean of the bacteria concentrations were very low (<20/100 ml) at five of the eight sites. The geometric means at one formal and one informal swimming area was 49 and 31/100 ml, well within Tennessee water quality criterion for recreation. At Smith's Camp-On-The-Lake boat ramp, the geometric mean was 657/100 ml All the Vital Signs monthly samples at the forebay were 10/100 ml or less.

Fish Tissue—The PCB concentration in channel catfish has averaged about 1.0 µg/g over the last three years. The TDEC has issued a precautionary advisory due to PCB contamination in catfish from

Nickajack Reservoir This means that children, pregnant women, and nursing mothers should not consume catfish, and all others should limit consumption to 1.2 pounds per month.

Fish tissue studies conducted in autumn 1992 were aimed at examining the long-term trend of PCB concentrations in channel catfish and developing a data base for carp. Ten individuals of both species were collected at two sites, one near the forebay, and the other in the upper end of the reservoir about 13 miles downstream of the inflow. The 1992 study also included collection of striped bass (including hybrid striped bass x white bass) from just downstream of Chickamauga Dam. PCB concentrations in the catfish and carp were substantially reduced (about half) from those previously found. The average for channel catfish was 0.4 and 0.5 μg/g (maximum 0.8 μg/g) at the forebay and upper location, respectively. Concentrations in carp were similar to those in catfish Highest concentrations were found in striped bass (average 0.8 μg/g and maximum 1.1 μg/g). The reduced concentrations in catfish and carp need to be verified, so these species, along with striped bass, were resampled in autumn 1993. Results were not available at the time this report was prepared.

Chickamauga Reservoir

Summary of 1993 Conditions - Ecological Health

Water—During the April-September 1993 monitoring period, coolest surface water temperatures in Chickamauga Reservoir were in April and the warmest in July. Surface temperatures ranged from a minimum of 17.0°C to a maximum of 31 7°C at the forebay; from 16.2°C to 30.1°C at the transition zone; and from 19.1°C to 28.8°C in the Hiwassee River embayment. Tennessee's maximum water temperature criteria for the protection of fish and aquatic life is 30.5°C.

Dissolved oxygen (DO) concentrations at the 1.5m depth ranged from a low of 6.9 mg/l in September to a high of 11.4 mg/l in April at the forebay; from 5.7 mg/l in September to 10.3 mg/l in April at the transition zone; and from 7.3 mg/l in August to 9.9 mg/l in April at the sampling location in the Hiwassee River embayment. At the inflow sampling site (i.e., the tailrace of Watts Bar dam) a minimum DO of 3.7 mg/l was recorded in August. Tennessee's minimum dissolved oxygen criteria for the protection of fish and aquatic life is 5.0 mg/l, measured at the 1.5 meter depth.

Temperature data depict seasonal warming and weak thermal stratification in Chickamauga Reservoir from May through July. The maximum observed surface to bottom temperature differentials (ΔT's), occurred in July. ΔT's were 5.5°C at the forebay, 3.2°C at the transition zone, and 4.1°C in the Hiwassee River embayment. There was also an oxycline at the forebay and transition zone in June and July when differences between surface and bottom DO's (DO's) were about 6 to 9 mg/l at the forebay and transition zone. In July 1993, a minimum DO of less than 0.1 mg/l was measured on the bottom at the forebay and a minimum of 1.6 mg/l was measured on the bottom at the transition zone. Better DO conditions were observed in the Hiwassee River embayment portion of Chickamauga Reservoir, where maximum DO's were only 1.7 mg/l and near bottom DO's only slightly below 6 mg/l

DO ratings used in the overall reservoir ecological health evaluation for Chickamauga Reservoir were good at the forebay; good to excellent at the transition zone, excellent in Hiwassee River embayment; and fair at the inflow. The forebay would have rated higher had it not been for the low near bottom oxygen concentrations which existed in July. The fair rating at the inflow sampling site on Chickamauga Reservoir was a result of oxygen levels being measured about 1.5 mg/l below the Tennessee criteria (5 mg/l, at the 1.5 meter depth) in the releases from Watts Bar dam.

Values of pH ranged from 6.8 to 8.8 on Chickamauga Reservoir, in 1993. Near surface pH values exceeding 8.5 (and DO saturation values exceeding 100 percent) were observed on only two occasions (April and July), both at the forebay. Both of these periods of high pH and high oxygen saturations were also coincident with high chlorophyll *a* concentrations, indicative of periods of high photosynthetic activity Tennessee's maximum pH criteria for the protection of fish and aquatic life is 8.5.

Total nitrogen (TN), total phosphorus (TP), and dissolved ortho phosphorus (DOP) were low in the Tennessee River portion of Chickamauga Reservoir in 1993. TN averaged only 0.37 mg/l at the forebay, the lowest TN concentration measured at any of the Tennessee River sampling sites in 1993. At both the forebay and the transition zone, TP and DOP concentrations averaged only about 0.026 mg/l and 0.005 mg/l, respectively, and were among the lowest TP and DOP concentrations measured at any of the Tennessee River sampling sites in 1993 Because of these low concentrations (and because TN/TP ratios often exceeded 20), periods of phosphorus limitation on algal productivity were likely to have occurred.

In 1993, Chickamauga Reservoir chlorophyll *a* concentrations averaged 8.5 µg/l, 7.8 µg/l, and 5.5 µg/l, respectively, at the forebay, transition zone, and Hiwassee River embayment. Consequently, the chlorophyll *a* ratings used in the 1993 ecological health evaluation for Chickamauga Reservoir were good (i.e., falling in the 3 to 10 µg/l range) at all three locations.

Sediment Quality—As in 1990, 1991, and 1992, chemical analyses of sediments from Chickamauga Reservoir in 1993 found high levels of copper (64 mg/kg) and zinc (320 mg/kg) in the forebay. High levels of copper (50 mg/kg) were also found in the Hiwassee River embayment, which was sampled for the first time in 1993. Chlordane was also detected in the forebay (16 µg/g) and the transition zone (15 µg/g). Toxicity tests indicated no acute toxicity to either species from the three sites tested, but survival of rotifers (75 percent survival) was reduced in the transition zone. Toxicity to rotifers was detected in both forebay and transition zone samples in 1992. Particle size analysis showed sediments from the forebay were 97 percent silt and clay; from the transition zone were 86 percent silt and clay, 14 percent sand; and from the Hiwassee River embayment were 63 percent silt and clay, 37 percent sand

Sediment quality ratings used in the overall Chickamauga Reservoir ecological health evaluation for 1993 were fair at the forebay (presence of copper, zinc and chlordane), fair at the transition zone (presence of chlordane and reduced survival of rotifers); and, good in the Hiwassee River embayment (presence of copper).

Benthic Macroinvertebrates—The forebay and transition zone sites had excellent benthic communities, and the inflow site was fair. The Hiwassee embayment, a major component of Chickamauga Reservoir, was also included in the ecological health rating. It was shown to support a good benthic community. The forebay site had 19 taxa and 847 organisms/m^2. The most numerous taxa collected were the chironomid Coelotanypus sp (29 percent), the mayfly Hexagenia limbata (20 percent), the asiatic clam Corbicula fluminea (19 percent) and Tubificidae (17 percent). The transition zone was represented by 25 taxa and 897 organisms/m^2 with Hexagenia limbata comprising 26 percent of the total organisms and Tubificidae comprising 18 percent of the total organisms. The inflow had 21 taxa and 845 organisms/m^2. Gammarus fasciatus, an amphipod, was the dominant species present comprising 36 percent of the total organisms. The Hiwassee embayment had the greatest diversity and abundance of organisms than any other site on Chickamauga Reservoir. It had 2312 organisms/m^2 representing 49 species; Tubificidae were the dominant taxa collected (36 percent) followed by the snail Musculium transversum (17 percent).

The forebay on Chickamauga supported an excellent benthic community, however, the overall benthic score was lowered due to an elevated chironomid community and lowered EPT community. The transition zone also received an excellent rating but fell short of perfect because of an elevated chironomid community and lowered numbers of long-lived taxa. The inflow site rated fair primarily because of an absence of long-lived organisms such as Corbicula sp and Hexagenia sp, and because of reduced diversity and EPT taxa present. The Hiwassee embayment supported a good benthic community in 1993 because of an excellent EPT representation, diversity, low numbers of Chironomids, and evenness of the dominant species. An abundance of tubificids and a lack of long-lived species contributed to this site receiving a good rating instead of an excellent rating.

Aquatic Macrophytes—Coverage of aquatic macrophytes increased from 387 acres in 1992 to 1,185 acres in 1993. Most macrophytes were in Dallas Bay embayment and in small embayments and overbank habitat upstream of TRM 499. Aquatic macrophytes on Chickamauga Reservoir peaked at about 7,500 acres in 1988 and continuously declined until 1993 when coverage increased. Spinyleaf and southern naiad were the dominant species in 1993 although small colonies of Eurasian watermilfoil, American pondweed, and American lotus also were present.

Fish Assemblage—Fish data collected in littoral (45 electrofishing transects) and offshore zones (28 net-nights) of the forebay resulted in the collection of 44 species (6,994 individuals). Emerald shiner was the most abundant species (collected at the rate of 56 per 300 meter electrofishing transect), accounting for 36 percent of the total number of fish collected. Gizzard shad comprised 16 percent of the sample, followed closely by bluegill at 14 percent. Electrofishing results showed approximately twice as many individuals in the inflow (2,624) and transition (2,300) zones as the forebay (1,229), due to numbers of gizzard shad and bluegill in the sample Numbers of YOY threadfin shad followed a similar pattern with high catch rates in the forebay (CPUE=810 per 300m transect) and transition (CPUE=1,707 per 300m transect) and very high catch rates in the inflow zone (CPUE=3,559 per 300m transect). Gill netting fish abundance was higher in the transition (454) than the forebay (229); although abundance at the inflow zone (158) was lower because of reduced effort, catch rate was similar to the transition zone.

The Reservoir Fish Assemblage Index (RFAI) rated the littoral fish community (based on results of electrofishing samples) fair in the forebay (RFAI=32), good in the transition (RFAI=46), and excellent in the inflow (RFAI=52) zones of Chickamauga Reservoir. The inflow index of 52 was the highest score observed for run-of-the-river reservoir inflows and received maximum scores for all metrics except number of sucker and tolerant species, dominance by a single specie, and percent anomalies. In 1992 the inflow rated only fair (RFAI=34).

The gill netting RFAI rated the transition zone excellent (RFAI=52) and the forebay fair (RFAI=36) The excellent score of 52 in the transition zone was the second highest ever observed for run-of-the-river reservoirs and resulted from maximum scores for all metrics except number of sucker, intolerant, and lithophilic spawning species, and percent insectivores. Gill netting RFAI values were not calculated for inflow zones of run-of-the-river reservoirs due to low numbers of replicate samples.

The combined electrofishing and gill netting RFAI score for the transition (RFAI=49) and forebay (RFAI=34) were rated good and fair, respectively The electrofishing RFAI for the inflow (RFAI=52) zone received an excellent rating, which was one of the highest scores for all inflows sampled in 1993.

Combined fish samples in shoreline electrofishing (15 transects) and offshore gill netting (12 net-nights) produced a total of 2263 individuals including 31 species in the Hiwassee River embayment of Chickamauga Reservoir The three most abundant species were redear sunfish (29 percent), gizzard shad (19 percent), and bluegill (16 percent) There were six times as many fish collected by electrofishing as gill netting, largely attributed to high numbers of sunfishes inhabiting shoreline areas

The electrofishing RFAI score of 36 rated the embayment community as fair and gill netting results indicated good (RFAI=50) fish community conditions. Combining RFAI scores (RFAI=43) rated the Hiwassee River embayment good (scoring criteria for run-of-the-river transition was used to obtain RFAI ratings). Metrics for both electrofishing and gill netting that influenced the high scoring included low percent dominance by a single species, low percent omnivores, and high numbers of lithophilic spawning species.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—No bacteriological studies were conducted at recreation sites in Chickamauga Reservoir in 1993. Fecal coliform bacteria concentrations at the monthly Vital Signs locations, the forebay, transition zone, and Hiwassee River Embayment, were all 10/100 ml or less except for one sample The April sample in the Hiwassee River Embayment had a concentration of 300/100 ml.

Fish Tissue—There are no fish tissue consumption advisories in effect for Chickamauga Reservoir. Samples for screening studies were conducted in autumn 1991 and 1992. Fillets from five channel catfish were collected from the inflow, transition zone, and forebay, composited by site, and examined for a broad array of analyses (selected metals, pesticides, and PCBs on the EPA priority pollutant list). Results from samples collected from all locations in 1991 had low or nondetectable levels of metals and pesticides. PCB concentrations were 0.4, 0.7, and 1.2 µg/g at the forebay, transition zone, and inflow, respectively. This general trend had been documented in several previous studies but not always as pronounced as in the 1991 results. Such was the case for 1992 results - PCB concentrations were 0.6, 0.7, and 0.7 µg/g at the forebay, transition zone, and forebay, respectively. All other analytes were not detected or found in low concentrations in the 1992 fish samples.

HIWASSEE RIVER WATERSHED

Hiwassee Reservoir

Summary of 1993 Conditions - Ecological Health

Water—The average flow through Hiwassee Reservoir was about 107 percent of normal and the average residence time was about 99 days. The reservoir was strongly stratified with a maximum temperature difference in the water column at the forebay of 20.9°C in July. The maximum surface temperature was 28.7°C in July, both at the forebay and mid-reservoir. North Carolina's standard for maximum temperature of Class C waters is 29°C. Low DO water (DO <5.0 mg/l) first appeared at mid-reservoir in June and at the forebay in July at the bottom of the water column at both locations. Depleted DO water (DO < 2.0 mg/l) occurred at both locations at the bottom of the water column in August and September. The limited area of DO depletion provided ratings for the reservoir ecological health index of fair at the forebay and good at mid-reservoir.

Conductivities averaged about 30 μmhos/cm in April, increased slightly in the DO-depleted area to a maximum of 40 and 38 μmhos/cm at the forebay and mid-reservoir, respectively The average conductivity in Hiwassee Reservoir was the fourth lowest of the 19 tributary reservoirs. Only in June, July, and August did pH reach or exceed 8.4, and only in the four to eight meter depth. Summer DO concentrations were normally higher at these depths.

The organic nitrogen concentration, in April and August respectively, was 0.12 and 0.26 mg/l at the forebay, and 0.14 and 0 09 mg/l at mid-reservoir. The April nitrate-nitrogen concentration was 0.12 and 0.10 mg/l at the forebay and mid-reservoir, respectively. The August concentrations were <0.01 mg/ at both locations. Total phosphorus concentrations were 0.007 mg/l in April and 0.002 mg/l in August at both locations. Dissolved ortho phosphorus concentration was 0.01 mg/l in April at mid-reservoir, and otherwise <0.002 mg/l.

These low concentrations of nutrients resulted in low concentrations of total organic carbon and chlorophyll and high water clarity Total organic carbon concentrations were 0.9 mg/l in April and approximately double that in August at both locations. Chlorophyll *a* concentrations averaged 2.2 μg/l at the forebay (third lowest of 19 tributary reservoir forebays) and 3.7 μg/l at mid-reservoir. The chlorophyll concentrations rated fair at the forebay and good (near the low end of the range) at mid-reservoir for the reservoir ecological health index. Hiwassee Reservoir water clarity was the third highest of the tributary reservoir forebays, and the highest of all tributary mid-reservoir stations. Secchi depths varied from 2.4 m at both locations in April, to 5.1 m at mid-reservoir and 5.6 m at the forebay in July.

Sediment Quality—Chemical analyses of sediments in Hiwassee Reservoir in 1993 indicated the presence of chlordane in the forebay (15 μg/g) and mid-reservoir (16 μg/g). Toxicity tests detected acute toxicity to daphnids in both forebay (15 percent survival) and mid-reservoir (10 percent survival) samples. Toxicity to rotifers was also detected in the mid-reservoir (65 percent survival). Particle size analysis showed sediments in the forebay were 99 percent silt and clay, and in the mid-reservoir were 90 percent silt and clay.

Sediment quality ratings used in the overall Hiwassee Reservoir ecological health evaluation for 1993 were poor at the forebay (due to toxicity to daphnids and presence of chlordane) and poor at the mid-reservoir site (due to toxicity to daphnids and rotifers and presence of chlordane).

Benthic Macroinvertebrates—Until 1993, no TVA data on the benthic macroinvertebrate community in Hiwassee Reservoir existed. Sampling revealed that the forebay and mid-reservoir sites had poor benthic communities, and the inflow had a fair benthic community. The forebay site had 5 taxa and 127 organisms/m^2 and was dominated by Tubificidae (86 percent). The mid-reservoir site had 11 taxa and 2,111 organisms/m^2 with Tubificidae as the dominant taxon comprising 86 percent of the total. The Hiwassee inflow had the greatest number of taxa (16) and had 1,605 organisms/m^2. Tubificidae (61 percent) was the dominant taxon followed by Procladius sp (21 percent).

The Hiwassee forebay and mid-reservoir benthic samples rated poor due to low diversity, an absence of EPT and long-lived taxa, and an abundance of tubificids. The inflow fared better than the previous sites, but still rated only fair.

Fish Assemblage—Shoreline electrofishing (45 transects) and offshore gill netting (36 net-nights) from the three zones of Hiwassee Reservoir resulted in the collection of 2,958 fish including 27 species. When green sunfish (39 percent of total catch) were disregarded, the dominant taxa by number in the remaining sample were bluegill (43 percent), gizzard shad (9 percent), smallmouth bass (8 percent), white bass (7 percent), and black crappie (6 percent). Electrofishing results indicated total numbers of fish were approximately the same in the forebay (952) and transition (931) zones with considerably lower numbers in the inflow (326) zone.

The Reservoir Fish Assemblage Index (RFAI) showed the littoral fish community (based on results of electrofishing samples) to be poor in all three sample zones of Hiwassee Reservoir (forebay RFAI=28, transition RFAI=26, and inflow RFAI=28). Gill netting RFAI results rated all three zones good (forebay RFAI=50, transition RFAI=46, and inflow RFAI=42).

The trophic composition metric group showed maximum scores for both gear types; all other metric group scores generally reflected the total RFAI score. Combined electrofishing and gill netting RFAI scores for the forebay (RFAI=39), transition (RFAI=36) and inflow (RFAI=35)zones were rated fair.

Summary of 1993 Conditions - Use Suitability

There were no bacteriological studies conducted on Hiwassee Reservoir in 1993. Although fish tissue samples were collected in autumn 1993, results were not available at the time this report was prepared.

Chatuge Reservoir

Summary of 1993 Conditions - Ecological Health

Water—The average flow through Chatuge Reservoir in 1993 was about 88 percent of normal. The average residence time was 291 days. The reservoir was strongly stratified, with a maximum temperature difference of 19.1°C in the water column at the forebay in July. The maximum surface temperature was 29.0°C at the forebay and 28.6°C in Shooting Creek Embayment, both measurements in July. North Carolina's standard for maximum temperature of Class °C waters is 29°C. At both locations, low DO (<5.0 mg/l) conditions began developing at the bottom of the water column in July, and depleted DO (<2.0 mg/l) conditions occurred from August through October. Depleted DO conditions also occurred in the metalimnion at the forebay in September. The limited extent of the area of DO depletion gave the forebay a good rating and Shooting Creek Embayment a fair rating in the reservoir ecological health index.

Conductivities were the fourth lowest of the 19 tributary reservoirs, averaging about 25 µmhos/cm in April. Conductivities decreased slightly in the photic zone (supersaturated with DO) in the summer and increased to a maximum of 45 µmhos/cm at the bottom of the water column at the forebay in September. The only time pH exceeded 8.0 was in June and July from the four to eight meter depth. The minimum pH was 5.8 at the forebay and 5.9 in Shooting Creek Embayment, both in September.

Organic nitrogen concentrations increased from April to August at both locations, 0.04 and 0.23 mg/l at the forebay and 0.09 and 0.30 mg/l in Shooting Creek Embayment. Nitrate concentrations dropped from 0.09 to <0.01 mg/l at both locations. Total phosphorus concentrations at the two sites tied for the third lowest concentrations of the 33 tributary reservoir stations. The maximum concentration was 0.004 mg/l in Shooting Creek Embayment in April. Consequently, TN/TP ratios were very high, ranging from 47 at the forebay in April to 160 in Shooting Creek Embayment in August. Total organic carbon concentrations were low, 0.8 and 0.7 mg/l in April, and 1.5 and 1.8 mg/l in August at the forebay and Shooting Creek Embayment, respectively. Chlorophyll *a* concentrations averaged 2.8 µg/l at both locations. This concentration is in the range considered fair in the reservoir ecological health index. Chatuge had the fourth clearest water of the tributary reservoirs. Secchi depths varied from 2.4 m in August to 4.6 m in July in Shooting Creek Embayment, and from 3.1 m in April and August to 4.4 m in July at the forebay.

Sediment Quality—Chemical analyses of sediments in 1993 indicated high levels of chromium (89 mg/kg), copper (56 mg/kg) and nickel (48 mg/kg) in the Shooting Creek forebay area of Chatuge Reservoir. Toxicity tests detected acute toxicity to daphnids (55 percent survival) in the Hiwassee River forebay. Toxicity to daphnids (50 percent survival) was also detected in the water column in this forebay. Reduced survival of daphnids was also detected (60 percent survival) in the Shooting Creek forebay water column Particle size analysis showed sediments in the forebay were about 75 percent silt and clay, 25 percent sand. In the Shooting Creek forebay sediments were 99 percent silt and clay

Sediment quality ratings used in the overall Chatuge Reservoir ecological health evaluation for 1993 were fair at the Hiwassee River forebay sampling site (toxicity to daphnids in both water and sediment); and also fair at the Shooting Creek forebay sampling site (presence of chromium, copper, and nickel and reduced survival of daphnids)

Benthic Macroinvertebrates—The first year that the benthic macroinvertebrate community was evaluated on Chatuge Reservoir was 1993. Two forebay sites were chosen on Chatuge, and both had good benthic communities. The first forebay site, at HiRM 122.0, had 1,431 organisms/m^2 representing 22 taxa; Tubificidae was the dominant taxon comprising 52 percent of the total. The other site, at Shooting Creek mile 1.5, had 23 taxa and 1,065 organisms/m^2 with Tubificidae (37 percent) and the chironomid Zalutschia zalutschicola (19 percent) as the dominant taxon.

Both forebay sites had excellent diversity and excellent EPT representations, and an average amount of long-lived organisms in the community. The Shooting Creek site suffered slightly from an above average density of tubificids, and the HiRM 122 site was slightly impacted from an above average density of chironomids.

Fish Assemblage—Electrofishing samples (30 transects) in shoreline areas and experimental gill netting samples (24 net-nights) offshore collected 1,999 individuals with 20 species represented. Bluegill was the most abundant taxon in Chatuge Reservoir (47 percent of total fish sampled). Redbreast sunfish (19 percent), spotted bass (7 percent), white bass (5 percent), and gizzard shad (5 percent) followed in order of density. Note: Three percent of the total sample was comprised of snail bullheads which is the first documentation of this species in a TVA reservoir. Electrofishing catch rates were much higher in the forebay zone (78 per 300m transect) than the Shooting Creek arm (32 per 300m transect) However, gill netting catch rates were similar between the two stations.

The Reservoir Fish Assemblage Index (RFAI) rated both the forebay and Shooting Creek sites fair for electrofishing (Forebay RFAI=36 and Shooting Creek RFAI=32) and gill netting (forebay RFAI=34 and Shooting Creek RFAI=32) samples. The only metric grouping with consistently high scores was trophic composition (percent omnivores and insectivores) in the electrofishing sample. Combined electrofishing and gill netting RFAI's rated both areas fair.

Summary of 1993 Conditions - Use Suitability

There were no bacteriological studies conducted on Chatuge Reservoir in 1993. Although fish tissue samples were collected in autumn 1993, results were not available at the time this report was prepared.

Nottely Reservoir

Summary of 1993 Conditions - Ecological Health

Water—The average flow through Nottely Reservoir in 1993 was about 90 percent of normal, with an average residence time of 228 days. The reservoir was stratified from April through September, with a maximum temperature difference in the water column at the forebay of 18.9°C in July. The maximum surface temperature was 29.3°C at both the forebay and mid-reservoir in July. Georgia's standard for maximum temperature for protection of aquatic life is 30°C. In June, low DO (<5.0 mg/l) conditions began developing in the forebay bottom waters, while depleted DO (<2.0 mg/l) conditions had already developed at mid-reservoir. An area of depleted DO developed at the forebay in July, and remained at both locations through September. The extensive areas of depleted DO gave both locations poor ratings for DO in the reservoir ecological health index. The vertical mixing of the reservoir in October eliminated areas of low DO. The area of DO depletion extended to within 7 meters of the surface in July at mid-reservoir.

Conductivities were the fifth lowest of the 19 tributary reservoirs, with an average of about 30 µmhos/cm in April, decreased slightly in the supersaturated (DO) photic zone in the summer and increased to a maximum of 49 and 79 µmhos/cm in September at the bottom of the water column at the forebay and mid-reservoir, respectively. The only time pH exceeded 8.0 was in June and July. The highest values at the forebay were from the 4 to 7 m depth, and from the 3 to 5 m depth at mid-reservoir. The maximum pH was 8.8 at both locations The minimum pH was 5.9 in the depths at both locations from July to September.

Organic nitrogen concentrations were 0 14 mg/l in April at both locations, and 0.17 and 0.13 mg/l in August at the forebay and mid-reservoir, respectively. Nitrate-nitrogen concentrations were 0.12 and 0.15 mg/l in April at the forebay and midreservoir, respectively, dropping in <0 01 mg/l in August at both locations. Total phosphorus concentrations at both locations were 0.02 mg/l in April, dropping to 0.005 and 0.008 mg/l in August at the forebay mid-reservoir, respectively. Dissolved ortho phosphorus ranged from a maximum concentration of 0 004 mg/l in April at mid-reservoir to a minimum of 0.002 mg/l at both locations in August. Total organic carbon concentrations varied from a low of 1.2 mg/l in April to a maximum of 2.2 mg/l in August, both at mid-reservoir Chlorophyll *a* concentrations averaged 3.4 µg/l at the forebay and 5.0 µg/l at mid-reservoir. These concentrations are in the range considered good in the reservoir ecological health index Secchi depths varied from 1.4 m in April at both locations, to 4.2 and 2.4 m in June at the forebay and mid-reservoir, respectively.

Sediment Quality—Chemical analyses of sediments in Nottely Reservoir in 1993 did not reveal any metal or organic analytes to be of concern Toxicity tests detected acute toxicity to daphnids (70 percent survival) and rotifers (60 percent survival) in the forebay. Particle size analysis showed sediments in the forebay were 89 percent silt and clay, 11 percent sand; and in the mid-reservoir were about 100 percent silt and clay.

Sediment quality ratings used in the overall Nottely Reservoir ecological health evaluation for 1993 were fair at the forebay sampling site (toxicity to daphnids and rotifers); and excellent at the mid-reservoir sampling site.

Benthic Macroinvertebrates—The first year that the benthic macroinvertebrate community was evaluated on Nottely Reservoir was 1993. The forebay site, which had a poor benthic community, had 11 taxa, 452 organisms/m^2, and was dominated by Tubificidae (50 percent) and Chironomus sp (29 percent). The inflow site had a good benthic community. There were more taxa (20) and a greater density (933 organisms/m^2) than at the forebay site. Tubificidae (34 percent), Chironomus sp (26 percent), and Procladius sp (23 percent) dominated the benthic community.

A deficiency of EPT taxa and long-lived organisms were the two primary contributing factors for the poor benthic community at the forebay. Elevated numbers of chironomids and tubificids also contributed to the poor rating. At the inflow, an opposite scenario surfaced: EPT and long-lived taxa had an excellent representation, and the tubificid metric was excellent, therefore contributing to a good benthic community structure.

Fish Assemblage—Only the forebay of Nottely Reservoir was sampled in fall 1992. However, in 1993 a transition zone sample was added to better assess the quality of the fish community. Shoreline electrofishing (30 transects) in the littoral zone and experimental gill netting (24 net-nights) in the offshore/deeper areas collected 2,275 individuals with 20 species represented. The four most abundant species represented in the samples were bluegill (63 percent), black crappie (6 percent), green sunfish (5 percent), and carp (5 percent). Electrofishing results indicated the primary forage available in Nottely consisted of sunfish species (69 percent of total catch) instead of shad, as is usually the case.

The Reservoir Fish Assemblage Index (RFAI) rated the littoral fish community (based on results of electrofishing samples) fair in the transition zone (RFAI=36) and poor in the forebay (RFAI=30) of Nottely Reservoir. Generally low metric scores in both zones were directly related to low species diversity. Both areas (transition RFAI=32, and forebay RFAI=34) of Nottely were rated fair by gill netting RFAI analysis. When electrofishing and gill netting RFAI scores are combined both forebay (RFAI=32) and transition (RFAI=34) zones rated fair.

Summary of 1993 Conditions - Use Suitability

There were no bacteriological studies conducted on Nottely Reservoir in 1993. Although fish tissue samples were collected in autumn 1993, results were not available at the time this report was prepared.

Blue Ridge Reservoir

Summary of 1993 Conditions - Ecological Health

Water—The flow through Blue Ridge Reservoir in 1993 was about normal, with an average residence time of about 156 days The reservoir was thermally stratified from April through September; there was no sampling in October. The maximum temperature difference in the water column was 17.7°C, and the maximum surface temperature was 29.8°C, both in July. Georgia's standard for maximum temperature for protection of aquatic life is 30°C. Low DO (<5.0 mg/l) conditions developed in August; the lowest DO measured was 3.4 mg/l in September. The absence of an area of depleted DO gave Blue Ridge a good rating for DO in the reservoir ecological health index.

Conductivities averaged about 20 µmhos/cm, the lowest of the 19 tributary reservoirs, and showed little stratification. The maximum pH was 8.8 at the 7 m depth in July. The minimum pH was 5.6 at the 20 m depth in September.

Organic nitrogen concentrations were 0.04 and 0.08 mg/l in April and August, respectively. Nitrate-nitrogen concentrations decreased from 0.06 to <0.01 mg/l from April to August. Total and dissolved ortho phosphorus concentrations were 0.003 for both in April, and 0.004 and <0.002 in August. Total organic carbon concentrations went from 0.7 mg/l in April to 1.5 mg/l in August, tied for the second lowest concentrations in the tributary reservoirs. Chlorophyll *a* concentrations were the second lowest of the 33 tributary reservoir stations, averaging 1.8 µg/l. This concentration is in the fair range in the reservoir ecological health index Water clarity was the second highest of the tributary reservoir forebays, with Secchi depths varying from 3.4 meters in April to 5 4 meters in June.

Sediment Quality—Chemical analyses of sediments in Blue Ridge Reservoir in 1993 did not reveal any metals or organic analytes to be a concern. Toxicity tests detected acute toxicity to daphnids (20 percent survival) in the forebay. Particle size analysis showed sediments in the forebay were 95 percent silt and clay.

Because of the toxicity of the forebay sediment to daphnids, a fair sediment quality rating was used in the overall 1993 Blue Ridge Reservoir ecological health evaluation.

Benthic Macroinvertebrates—The first year that the benthic macroinvertebrate community was evaluated on Blue Ridge Reservoir was 1993. The forebay, the only sample location, had an excellent benthic fauna, with 1,308 organisms/m^2 representing 23 taxa The dominant taxa were Pisidium sp (33 percent), Procladius sp (21 percent), Spirosperma nikolskyi (18 percent), and Tubificidae (17 percent). This site received good scores for five of the six metrics: diversity, number of EPT taxa, number of chironomids, number of tubificids, and evenness of dominant species. Depressed numbers of long-lived taxa was the only metric that rated fair.

Fish Assemblage—Only the forebay of Blue Ridge Reservoir was sampled in fall 1993. Electrofishing samples (15 transects) in shoreline areas and experimental gill netting samples (12 net-nights) offshore collected 856 individuals with 15 species represented. By far the predominant species captured was bluegill (59 percent) followed distantly by white bass (10 percent), smallmouth bass

(8 percent), and redbreast sunfish (5 percent). There were three times as many fish collected by electrofishing as gill netting, largely attributed to high numbers of bluegill inhabiting shoreline areas.

The electrofishing RFAI score of 28 rated poor and gill netting results indicated fair (RFAI=34) fish community conditions. The combined RFAI scores (RFAI=31) rated the Blue Ridge forebay fair. Scoring for both electrofishing and gill netting RFAI metrics was influenced by low diversity, low catch, and dominance by a single species (bluegill).

Summary of 1993 Conditions - Use Suitability

There were no bacteriological studies conducted on Blue Ridge Reservoir in 1993. Although fish tissue samples were collected in autumn 1993, results were not available at the time this report was prepared.

Ocoee Reservoir No. 1 (Parksville Reservoir)

Summary of 1993 Conditions - Ecological Health

Water—The average flow in 1993 was about 91 percent of normal. The high elevation outlet at the dam allows the hypolimnetic water to remain in place all spring and summer. In October, the bottom temperature was 7.7°C. The very cold bottom temperatures mean that the reservoir was strongly stratified; there was a temperature difference in the water column of 21.4°C in July. The maximum surface temperature was 28.7°C in July. Tennessee's maximum temperature criterion for aquatic life is 30.5°C. Very little DO depletion occurs in the reservoir; the minimum DO during the survey was 5.8 mg/l at the bottom in October. The maximum DO saturation was 108 percent at the surface in May. The lack of low DO in the reservoir resulted in a good rating for DO in the reservoir ecological health index.

Conductivities were low, usually between 50 and 60 µmhos/cm with little stratification. The lack of DO depletion and low primary productivity resulted in little variation in pH, which varied from 7.5 to 6.3.

Concentrations of total nitrogen, total phosphorus, total organic carbon, and chlorophyll were all among the lowest six of the 33 tributary reservoir stations. Organic- and nitrate-nitrogen concentrations were 0.03 and 0.09 mg/l in April, and 0.06 and 0.04 mg/l in August Total and dissolved ortho phosphorus concentrations were 0.005 and 0.003 mg/l in April, and 0 002 and <0.002 mg/l in August. Total organic carbon concentrations were very low, 0.8 and 1.4 mg/l in April and August, respectively. Chlorophyll *a* concentrations averaged 2.5 µg/l. This chlorophyll concentration is considered fair in the reservoir ecological health index. Secchi depths varied from 1.6 m in April to 3.6 m in July, September, and October.

Sediment Quality—Chemical analysis of sediments in Parksville Reservoir in 1993 indicated extremely high levels of copper (1,500 mg/kg), lead (1,300 mg/kg) and zinc (1,500 mg/kg) in the forebay sediment. Toxicity tests detected acute toxicity to daphnids (0 percent survival) and rotifers (10 percent survival) at an upper reservoir site sampled only for sediments (not included in the overall ecological health score). Acute toxicity to daphnids and rotifers was also detected in near bottom water collected at the forebay (0 and 20 percent survival, respectively); and at the upper reservoir sampling site (0 percent survival for both species). Particle size analysis showed sediments in the forebay were 99 percent silt and clay. No chemical analyses or particle size analyses were conducted for the upper reservoir sediment sample.

Because of the acute toxicity of the forebay bottom water to daphnids and rotifers and the very high concentrations of copper, lead, and zinc found in the forebay sediment, a poor sediment quality rating was used in the overall 1993 Parksville Reservoir ecological health evaluation.

Benthic Macroinvertebrates—Only one site was chosen for sampling the first year on Ocoee No. 1, located in the forebay. The benthic community there was poor, with only 10 taxa, 372 organisms/m^2, and dominated by Tubificidae (65 percent) and Limnodrilus hoffmeisteri (27 percent). This site rated poor on 3 of the 5 metrics: number of EPT taxa, number of long-lived taxa, and proportion of tubificids. It received a good score only on the proportion of chironomids metric, and diversity was fair.

Fish Community—Only the forebay of Parksville Reservoir was sampled in fall 1993. Shoreline electrofishing (15 transects) and offshore netting (12 net-nights) produced a total of 524 individuals including 15 species Bluegill and largemouth bass were the most abundant species collected, comprising 76 and 7 percent of the total sample, respectively. Channel catfish (4 percent) and yellow perch (3 percent) were also frequently encountered.

The electrofishing Reservoir Fish Assemblage Index (RFAI) rated the Parksville littoral fish community as poor (RFAI=28) and the gill netting RFAI rated the limnetic bottom fish community as very poor (RFAI=20).

Overall RFAI analysis (combined electrofishing and gill netting) determined that the quality of the reservoir fish community was poor. The Parksville Reservoir forebay RFAI of 24 was the lowest recorded for storage reservoir forebays, receiving minimum scores for seven of the twelve metrics utilized for the electrofishing RFAI analysis, and ten of the twelve metrics analyzed for gill netting.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—No bacteriological studies were conducted in 1993.

Fish Tissue—There are no fish consumption advisories on Parksville Reservoir. However, screening studies conducted 1987 through 1991 consistently found relatively high PCB concentrations (about 1.0 μg/g) and higher than expected selenium concentrations (about 1.0 μg/g) at the forebay. Because of the consistently elevated PCB concentrations, TVA, TDEC, and TWRA designed and conducted a more intensive effort on Parksville Reservoir for autumn 1992. The study included individual analyses on channel catfish and largemouth bass from the forebay and upper reservoir area and composite analysis of bluegill sunfish from both areas and rainbow trout from the lower portion of the reservoir. PCBs, chlordane, selenium, and mercury were the analytes of interest. Results generally fell along expected lines. PCB concentrations in channel catfish were relatively high (averages 1.5 and 1.0 μg/g and maxima 3.0 and 1.9 μg/g at the forebay and upper locations, respectively). PCB concentrations in largemouth bass were not as high (averages 0.6 and 0.7 μg/g and maxima 1 7 and 2.0 μg/g at the forebay and upper location, respectively). PCB concentrations in the bluegill and trout composites were only slightly above detection limits. Chlordane and mercury concentrations were low or not detected in all samples. Selenium concentrations fell generally as expected (around 1.0 μg/g). At the time this report was prepared, no action had been taken on these results. Additional composite samples of channel catfish from the forebay and inflow areas were collected in autumn 1993, but results were not available at the time this report was prepared.

Hiwassee River Stream Monitoring Site

Summary of 1993 Conditions - Ecological Health

Water—The water of the Hiwassee River is soft (average hardness of 15 mg/l) and slightly alkaline (average total alkalinity of 16 mg/l). The median pH for the stream monitoring site was 7.2. The river was well oxygenated with dissolved oxygen levels remaining around 100 percent of saturation.

Of the 12 streams monitored across the Tennessee Valley, the Hiwassee River ranked among the lowest average concentrations of organic nitrogen (0.089 mg/l), nitrate+nitrite-nitrogen (0.16 mg/l), and total phosphorus (0.025 mg/l). It ranked near the middle in average ammonia nitrogen (0.030 mg/l) and dissolved orthophosphate (0.007 mg/l) concentrations. The low total phosphorus and nitrate+nitrite-nitrogen concentrations yielded a good rating for nutrients at the site.

Seven analyses for priority pollutant metals (dissolved cadmium, lead, nickel, silver, and zinc and total and dissolved copper and zinc) were performed bi-monthly. Dissolved cadmium was detected in 5 of 6 samples One sample exceeded the EPA guidelines for both chronic and acute toxicity to aquatic life. Another sample exceeded the guideline only for chronic toxicity to aquatic life.

Sediment— Sediment quality rated good in 1993 with no acute toxicity observed. No PCBs or pesticides exceeded the EPA guidelines; however, nickel exceeded the EPA guidelines. This is an improvement over 1992 when the sediment quality rated fair.

Benthic Macroinvertebrates—In 1993, benthic macroinvertebrate results rated fair with a Modified Benthic Index of Biotic Integrity (MBIBI) score of 38, with 81 taxa and 828 organisms/m^2. Conditions in 1992 also rated fair (MBIBI score 34) with 65 taxa and 953 organisms/m^2; however, the MBIBI score of 34 was very close to a poor rating. Dominant organisms in 1993 were dipteran midge larvae (33 percent), caddisflies (18 percent), and mayflies (13 percent). Dipteran midge larvae was the most dominant organism in 1992 (28 percent), followed by the Asian clam Corbicula (20 percent) and caddisflies (14 percent). Regulated stream flows and cold water releases from Appalachia Powerhouse stress warmwater benthic communities in the river.

Fish Community Assessment—No meaningful change was seen in the fish community as ratings for both 1993 and 1992 were good with Index of Biotic Integrity (IBI) score 48 each year. Limited deficiencies in number of native species, numbers of darter and sunfish species, proportion of fish as specialized insectivores, and fish density indicated less than optimum conditions. Problems found in the fish community may be partially attributed to altered flows due to releases from Apalachia Powerhouse.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—No fecal coliform bacteria samples were collected in 1993.

Fish Tissue—A five-fish composite each of carp, channel catfish, and largemouth was collected during summer and analyzed for selected metals, pesticides, and PCBs. All analytes were either not detected or found in low concentrations. The only analyte high enough to be noteworthy was PCBs in carp with a slightly elevated concentration of 0.6 µg/g.

WATTS BAR RESERVOIR, FORT LOUDOUN RESERVOIR, AND MELTON HILL RESERVOIR WATERSHED

Watts Bar Reservoir

Summary of 1993 Conditions - Ecological Health

Water—During the April-September 1993 monitoring period, surface water temperatures ranged from a minimum of 18.3°C in April to a maximum of 30.2°C in July in the forebay; and from 16.7°C to 29.8°C (for the same months) at the transition zone. The State of Tennessee's maximum water temperature criteria for the protection of fish and aquatic life is 30.5°C.

Values for DO at the 1.5m depth ranged from a low of 6.5 mg/l in September to a high of 12.6 mg/l in April at the forebay, and from 7.1 mg/l to 11.3 mg/l (for the same months) at the transition zone. At the inflow sampling site on the Tennessee River arm of Watts Bar Reservoir (i.e. the tailrace of Fort Loudoun dam) a minimum DO of 3.9 mg/l was recorded in September. At the inflow sampling site on the Clinch River arm of Watts Bar Reservoir (i.e., the tailrace of Melton Hill dam) a minimum DO of 6.3 mg/l was recorded in March Tennessee's minimum dissolved oxygen criteria for the protection of fish and aquatic life is 5.0 mg/l, measured at the 1 5 meter depth

Temperature and dissolved oxygen data show that Watts Bar Reservoir developed a moderate degree of both thermal and oxygen stratification throughout most of the summer of 1993 For the period April through August, monthly surface to bottom temperature differentials (ΔT's) were: 5.2°C, 5.5°C, 7.4° C, 7.3°C, and 4.0°C at the forebay; and 2.3°C, 2.6°C, 3.9°C, 6.2°C, and 2.2°C at the transition zone.

DO versus depth data show that a rather strong oxycline also developed in Watts Bar Reservoir, particularly from June through August. During these three months, surface to bottom differences in DO were: 9 2 mg/l, 9.2 mg/l, and 5 8 mg/l at the forebay; and 7.2 mg/l, 5.8 mg/l, and 3.1 mg/l at the transition zone. At the forebay, near bottom DO concentrations in the hypolimnion were less than 2 mg/l in June and July In addition, the proportion of the hypolimnion with low DO's (i.e less than 2 mg/l) averaged about 13 percent of the total cross sectional area, higher than in any other Tennessee River reservoir. The minimum observed DO concentration in Watts Bar Reservoir in 1993 was 0.6 mg/l at the bottom of the forebay in July, but DO's were never less than 4 mg/l at the transition zone.

DO ratings used in the overall reservoir ecological health evaluation for Watts Bar Reservoir were poor at the forebay; excellent at the transition zone and at the inflow sampling site on the Clinch River; and fair at the inflow site on the Tennessee River The low forebay rating was due to the large proportion of the forebay hypolimnion with low DO concentrations (i.e., less than 2 mg/l). The fair rating at the inflow sampling site on the Tennessee River arm of Watts Bar Reservoir was a result of oxygen levels being measured about 1 mg/l, below the Tennessee criteria (5 mg/l, at the 1.5 meter depth) in the releases from Fort Loudoun dam.

Historically, the pH's of water in Watts Bar Reservoir has been higher than other Tennessee River sampling site This is due to the addition of the cool, clear, well oxygenated, nitrate rich, and hard water of the Clinch River which combines with the Tennessee River (and Watts Bar Reservoir) at TRM 567.9, about seven miles upstream from the transition zone sampling site. In the summer of 1993, values of pH ranged from 6.8 to 9.0 on Watts Bar Reservoir. During much of the April-September sample period, near surface values of pH frequently exceeded 8.5 at both the forebay and the transition zone, with DO saturation values commonly exceeding 100 percent, indicating high rates of photosynthesis. Tennessee's maximum pH criteria for the protection of fish and aquatic life is 8.5.

The average total phosphorus concentrations observed in Watts Bar Reservoir (0.029 mg/l at the forebay and 0.035 mg/l at the transition zone) were among the lowest of the Tennessee River Vital Signs Monitoring locations in 1993. In addition, the average dissolved ortho phosphorus concentrations of 0.007 mg/l and 0.004 mg/l, respectively, at the forebay and transition zones were also among the lowest observed at any of the Tennessee River Vital Signs Monitoring locations in 1993. TN/TP ratios on Watts Bar Reservoir are higher than on any other Tennessee River reservoir. The low phosphorus concentrations in combination with the relatively high nitrogen concentrations (supplied by both the Clinch and Tennessee River inflows) results in the high TN/TP ratios in Watts Bar (particularly at the transition zone) and suggest periods of phosphorus limitation on primary productivity.

The highest chlorophyll *a* concentrations were measured in August at the forebay (10 µg/l) and in May at the transition zone (11 µg/l). Surface concentrations of chlorophyll *a* averaged about 7 µg/l at the forebay and about 8 µg/l at the transition zone in 1993. Consequently, the chlorophyll *a* ratings used in the 1993 ecological health evaluation for Watts Bar Reservoir were good (i.e., falling in the 3 to 10 µg/l range) at both locations.

Forebay Secchi depth and suspended solids measurements averaged 1 5 m and 6.3 mg/l, respectively. These values indicate the light transparency of Watts Bar Reservoir forebay to be relatively high compared with other mainstem Tennessee River reservoirs in 1993.

Sediment—Chemical analyses of sediments in Watts Bar Reservoir in 1993 indicated elevated levels of un-ionized ammonia (240 µg/l) in the forebay, and the presence of chlordane (18 µg/kg) in the transition zone. Mercury was also detected at the transition zone at a slightly elevated level (0.72 mg/kg), but at a level below sediment quality guidelines for mercury (i.e. 1.0 mg/kg). Toxicity tests detected acute toxicity to daphnids and rotifers (40 percent survival each) in the forebay. The forebay was also toxic to rotifers in 1992. Particle size analysis showed sediments from the forebay were near 100 percent silt and clay; and 98 percent silt and clay from the transition zone.

Sediment quality ratings used in the overall Watts Bar Reservoir ecological health evaluation for 1993 were "poor" at the forebay (acute toxicity to test animals and presence of ammonia); and "good" at the transition zone (presence of chlordane).

Benthic Macroinvertebrates—The forebay site had a good benthic macroinvertebrate community, the transition zone fair, and both the Tennessee River and Clinch River inflow sites had poor benthic communities. The forebay on Watts Bar had 805 organisms/m^2 representing 18 taxa; the dominant species were the chironomids Chironomus sp (32 percent) and Coelotanypus tricolor (16 percent). The transition zone had 14 taxa and 1,280 organisms/2 with the snail Musculium transversum (34 percent), the mayfly Hexagenia limbata (27 percent) and the chironomid Chironomus sp (17 percent) as the dominant species present The Tennessee River inflow site had 314 organisms/m^2 representing 20 taxa; Corbicula fluminea was the dominant species comprising 71 percent of the total organisms The Clinch River inflow site had 145 organisms/m^2 made up of 16 taxa; Corbicula fluminea (49 percent), Pseudochironomus sp (18 percent) and Tubificidae (18 percent), were the dominant taxa.

The Watts Bar forebay scored well on all metrics except for the paucity of EPT taxa and the preponderance of chironomids. Those two factors kept this site from obtaining an excellent rating. The transition zone exhibited a fair community. Reduced diversity, minimal numbers of long-lived species, above average numbers of chironomids, and unevenness associated with the dominant species all contributed to the fair rating this site received. The Tennessee River and Clinch River inflow sites both had a poor benthic communities because of the lack of diversity, EPT taxa, and long-lived species. The unevenness of dominant taxa also negatively impacted these benthic communities. Interestingly, the percent of the total organisms comprised of tubificids and chironomids, normally considered tolerant organisms, was relatively low at both inflows.

Aquatic Macrophytes—Aquatic plants have declined from about 700 acres in the late 1980's to an estimated 10 acres in 1993. Eurasian watermilfoil and spinyleaf naiad were the dominant species prior to the recent decline.

Fish Community—Shoreline electrofishing (60 transects) and offshore gill netting (39 net-nights) sampled a total of 5,174 fish represented by 50 species. Three species made up the majority of the overall sample: gizzard shad (37 percent), bluegill (13 percent), and emerald shiners (12 percent). Electrofishing results showed catch rates to be similar in the Clinch River inflow (CPUE=51 per 300m transect), Tennessee River inflow (CPUE=53 per 300m transect), and forebay (CPUE=56 per 300m transect) but much higher at the transition zone (CPUE=129 per 300m transect). The higher catch rate in the transition was attributed mainly to abundance of emerald shiners and bluegill. Threadfin shad YOY catch rates were moderate in all sample zones except the Tennessee River inflow which was considered high Gill netting catch rates were much the same in all four sample areas.

The Reservoir Fish Assemblage Index (RFAI) rated the littoral fish community (based on results of electrofishing samples) good in the transition (RFAI=48), fair in the forebay (RFAI=34) and Tennessee River inflow (RFAI=34), and poor in the Clinch River inflow (RFAI=30). The lower Clinch River inflow rating (compared to the Tennessee River inflow) resulted from slightly fewer numbers of sunfish and intolerant species The gill netting RFAI rated both the transition zone (RFAI=38) and forebay (RFAI=32) fair Gill netting RFAI values were not calculated for inflow zones of run-of-the-river reservoirs due to low numbers of replicate samples.

Combined electrofishing and gill netting RFAI scores for the forebay (RFAI=33) received a fair rating, followed by the transition (RFAI=43) zones which was rated good. Electrofishing RFAI scores for the Tennessee (RFAI=34) and Clinch River (RFAI=30) inflow zones were rated fair and poor, respectively

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—Fourteen swimming areas were tested for fecal coliform bacteria 12 times each in 1993. Only one sample at each site was collected within 48 hours of a rainfall of at least one-half inch. Bacteria concentrations were generally higher after rainfall If the one rainfall sample is excluded, all sites met Tennessee's water quality criteria for geometric mean concentration However, four sites had one or more concentrations to exceed 1000/100 ml, Tennessee's maximum concentration for one sample Only three of the fourteen areas had very low geometric mean concentrations for all samples (<20/100 ml), a much lower ratio than the other Tennessee River Reservoirs. All monthly fecal coliform bacteria samples taken at the two Vital Signs locations were <10/100 ml.

Fish Tissue—Fish from Watts Bar Reservoir have been under intensive investigation for several years because of PCB contamination. TDEC has issued an advisory warning the public to avoid eating certain species and to limit consumption of other species. Four of these species (channel catfish, striped bass including striped bass/white bass hybrids, sauger, and white bass) were reexamined in autumn in 1992. Average PCB concentrations among sample sites ranged from 0.4 to 1.9 μg/g for channel catfish (five sites), 1.0 to 1.1 μg/g for striped bass (two sites), 0.2 to 0.6 μg/g for sauger (three sites), and the average for white bass at the single location was 0 7 μg/g. Additional data for channel catfish and striped bass collected in autumn 1992 will be available in the future from studies conducted for DOE study. This is also true for additional fish collected for TVA studies in autumn 1993.

Fort Loudoun Reservoir

Summary of 1993 Conditions - Ecological Health

Water—Temperature and dissolved oxygen (DO) data show the establishment of stratification (both a thermocline and oxycline) in Fort Loudoun Reservoir which persisted throughout most of the summer (April through September) of 1993. Summer surface water temperatures were warmest in July and coolest in April They ranged from a maximum of 29.3°C to a minimum of 15.8°C at the forebay; and from 30.4°C to 15.5°C at the transition zone. Surface to bottom temperatures differentials (ΔT's) exceeded 5°C each month from April through August at the forebay and from May through July at the transition zone. Maximum thermal stratification occurred in July when ΔT's were 9.6°C at the forebay, and 10.2°C at the transition zone.

In Fort Loudoun Reservoir in 1993, DO at the 1.5m depth ranged from a high of 14.5 mg/l in May (algal bloom) to a low of 5 4 mg/l in September at the forebay; and from 12.6 mg/l to 5.4 mg/l (for the same months) at the transition zone. The minimum DO observed in Fort Loudoun Reservoir in 1993 was 2.5 mg/l at the bottom of the forebay during September. Maximum surface to bottom dissolved oxygen differentials (DO's) exceeded 5 mg/l each month, May through August, at the forebay; and, exceeded 4 mg/l April through June at the transition zone, with a minimum bottom DO of 4.9 mg/l in September. DO ratings used in the overall reservoir ecological health evaluation for Fort Loudoun Reservoir were excellent at both the forebay and the transition zone.

Summer values of pH ranged from 6.9 to 9.4 in Fort Loudoun Reservoir in 1993. At the forebay, near surface pH values exceeding 8.5 (ranged from 8 8 to 9.3), and DO saturation values exceeding 120 percent (ranged from 121% to 163%) were measured each month from April through August indicating substantial photosynthetic activity. During May, June, and July, a similar pattern of high pH's (range 8.6 to 9.4) and high DO saturations (range 132% to 161%) was observed at the transition zone. Tennessee's maximum pH criteria for the protection of fish and aquatic life is 8.5.

Conductivity ranged from 107 to 221 µmhos/cm, averaging about 185 µmhos/cm at the forebay and 200 µmhos/cm at the transition zone. The slightly lower conductivities measured at the forebay were caused by the mixing of the soft water inflows from the Little Tennessee River, via the Tellico Reservoir canal with the harder water of the Tennessee River. During the summer, the water in the forebay of Tellico Reservoir is often cooler (1993 average summer forebay temperature was 16.5C) than the water in the forebay of Fort Loudoun Reservoir (1993 average summer forebay temperature was 20.6C). During hydro-electric power generation, water from Tellico Reservoir forebay is pulled into Ft Loudoun forebay and being cooler (higher density) flows under the warmer water of Fort Loudoun Reservoir. For example, in Fort Loudoun forebay in September 1993, surface conductivity was approximately 200 µmhos/cm and near bottom conductivity was about 115 µmhos/cm (i e. lower conductivity because of the addition of cooler, lower conductivity water from Tellico Reservoir). At the same time, this cooler, epilimnetic water from Tellico Reservoir has higher DO's than the bottom water in the forebay of Fort Loudoun Reservoir, resulting in improved hypolimnetic DO's in Fort Loudoun's forebay, and improved DO's in the releases from Fort Loudoun dam.

Nutrient concentrations (total nitrogen and total phosphorus) have historically (1990-1993) been high at both the forebay and the transition zone. The average nitrite plus nitrate-nitrogen concentrations of

0.34 mg/l (forebay) and 0.43 mg/l (transition zone); and the average total nitrogen concentrations of 0.60 mg/l (forebay) and 0.71 mg/l (transition zone) were the highest average concentrations of these nutrients measured in 1993 at any of the Tennessee River Vital Signs Monitoring locations. These high concentrations of nitrogen are due to a combination of the effect of wastewater discharges in the Knoxville metropolitan area and the inflows to Fort Loudoun Reservoir from the Holston and French Broad Rivers, which have relatively high nitrogen concentrations.

The transition zone area of Fort Loudoun Reservoir has historically had lower water clarity than any of the other Tennessee River Vital Signs sampling sites. In 1993, total suspended solids (TSS) averaged 13.4 mg/l, while Secchi depths averaged less than 1 meter. One final interesting piece of data was the high fecal coliform concentrations, with no antecedent rainfall, measured at both the forebay and transition zone sampling sites in April (greater than 600 fecal coliform (FC) colonies per 100 ml of water), which may indicate municipal wastewater treatment interruptions in the Knoxville area. On no other occasion throughout the summer did fecal coliform concentrations exceed 5 F°C colonies/100 ml.

The highest chlorophyll *a* concentrations in the forebay occurred in April (24 μg/l) and in the transition zone in May (19 μg/l). Surface concentrations of chlorophyll *a* averaged about 14.7 μg/l and 13.7 μg/l, at the forebay and transition zone, respectively, among the highest measured at Tennessee River sampling sites in 1993. The chlorophyll *a* ratings used in the 1993 ecological health evaluation for Fort Loudoun Reservoir were fair (i.e., falling in the 10 to 15 μg/l range), at both locations; just below the level considered poor (i.e. greater than 15 μg/l).

Sediment—As 1990-1992, chemical analyses of sediments in 1993 from Fort Loudoun Reservoir indicated high levels of zinc (300 mg/kg) in both forebay and in transition zone samples. Chlordane was also detected in sediment at both the forebay (12 μg/kg) and the transition zone (27 μg/kg). Toxicity tests detected acute toxicity to daphnids (55 percent survival) in the forebay. Particle size analysis showed sediments from the forebay and the transition zone were 99 percent silt and clay

Sediment quality ratings used in the overall Fort Loudoun Reservoir ecological health evaluation for 1993 were poor at the forebay (acute toxicity to test animals and presence of chlordane and zinc); and good at the transition zone (presence of chlordane and zinc).

Benthic Macroinvertebrates—In 1993, the benthic macroinvertebrate sampling showed fair communities in the forebay and transition zone, and a very poor community in the inflow. The forebay benthic community improved and the inflow benthic community declined from 1992. The forebay site on Fort Loudoun had 1,178 organisms/m^2 representing 15 taxa; Chironomus (45 percent) and Tubificidae (26 percent) were the dominant organisms. The transition zone had fewer total organisms (987 organisms/m^2) but greater taxa richness (22 total taxa) than the forebay site. The transition zone benthic community this year was more diverse and abundant than the 1992 community. Tubificidae (27 percent) and the chironomids Chironomus sp (23 percent) and Procladius sp (24 percent) were the most abundant taxa. The inflow macroinvertebrate community had 747 organisms/m^2 and 18 taxa. Polypedilum sp comprised 31 percent of the sample, and Tubificidae and Corbicula fluminea comprised 24 percent of the total each

The Fort Loudoun forebay benthic community rating was negatively impacted by the abundance of chironomids and the lack of EPT taxa. This was balanced by the positive influence of a diverse assemblage with evenness among the dominant taxa, allowing this site to achieve an overall fair rating. The benthic community at the transition zone was negatively impacted by the shortage of long-lived taxa and the abundance of chironomids. This was off-set by the taxa richness and evenness of dominant species observed at the site, resulting in a fair rating. The inflow site on Fort Loudoun had a very poor benthic community in 1993 because of low diversity, a shortage of EPT and long-lived taxa, and an overabundance of the dominant species.

Aquatic Macrophytes—Aquatic plants on Ft Loudoun Reservoir were primarily upstream of TRM 635. An estimated 25 acres of aquatic plants were present in 1993. Coverage over the past decade has ranged from 25 to 140 acres, and Eurasian watermilfoil has been the dominant species.

Fish Community—Fish samples from the littoral (45 electrofishing transects) and profundal areas (34 net-nights) of Fort Loudoun Reservoir produced 3,211 individuals, representing 40 species. The most abundant taxa was gizzard shad which accounted for 42 percent of the total number collected. Other abundant species included bluegill (11 percent), yellow bass (10 percent), largemouth bass (9 percent), and carp (7 percent). Electrofishing results indicated total numbers of fish were approximately the same in the forebay (907) and transition zones (1,027) Considerably lower numbers in the inflow zone (420) were due to reduced catch of gizzard shad, bluegill, and largemouth bass. Very high numbers of YOY threadfin shad were collected by electrofishing in both the transition (CPUE=7,775 per 300m transect) and forebay (CPUE=7,953 per 300m transect) zones of Fort Loudoun Reservoir. Gill netting catch rate decreased from 37 fish per net night in the forebay to 30 and 6 in the transition and inflow zones, respectively.

The Reservoir Fish Assemblage Index (RFAI) rated the littoral fish community (based on results of electrofishing samples) very poor in the transition zone (RFAI=14) and poor in the forebay (RFAI=24) and inflow zones (RFAI=26). The transition RFAI of 14, which was the lowest score ever observed in TVA reservoirs, resulted from the lowest possible score for all metrics except percent anomalies. The gill netting RFAI rated the transition (RFAI=36) and forebay (RFAI=36) both fair High metric scores were observed at both areas for percent of tolerant and omnivorous species, and percent anomalies, with low scores for intolerant and lithophilic spawning species Gill netting RFAI values were not calculated for inflow zones of run-of-the-river reservoirs due to low numbers of replicate samples. Combined electrofishing and gill netting RFAI scores for the forebay (RFAI=30) and transition (RFAI=25) zones and the electrofishing RFAI for the inflow (RFAI=26) were all rated poor, resulting in the poorest fish community conditions in TVA run-of-the-river reservoirs.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—One boat ramp was tested for fecal coliform bacteria in 1993. Fecal coliform concentrations met Tennessee's bacteriological criteria for water contact recreation. The only fecal coliform bacteria concentrations in the monthly Vital Signs monitoring >10/100 ml were the April samples. Concentrations were >600/100 ml at both stations.

Fish Tissue—The sample site for the PCB trend study is near the transition zone at TRM 625. Ten channel catfish were collected there in autumn 1992. Concentrations in 1992 were higher than had been found in 1990 (average of 1.0 g/g and range of 0.3 to 1.9 g/g) but lower than in 1991 (average of 2.5 g/g and range 1.4 to 4.6 g/g). The 1992 samples had an average of 1.8 g/g and ranged from <0.1 to 4.2 g/g).

Melton Hill Reservoir

Summary of 1993 Conditions - Ecological Health

Water—In the summer of 1993, thermal stratification began to develop in May and persisted through September at both the forebay and the transition zone in Melton Hill Reservoir. Temperature differentials (ΔT's) exceeding 10°C between the water surface and the bottom were found each month at the forebay from May through August; and each month at the transition zone from May through July. This fairly strong thermal stratification of Melton Hill Reservoir is enhanced by the upstream release of cool water from Norris Dam, which during the summer flows along the bottom of Melton Hill Reservoir. Surface water temperatures were warmest in July and coolest in April. They ranged from a high of 29.7°C to a low of 11.5°C at the forebay; and from 28.8°C to 10.9°C at the transition zone. In the late summer the release of cool water from Norris Dam into the upstream end of Melton Hill Reservoir and the solar warming as the water moves downstream into the forebay often results in water surface temperatures being 4-5°C cooler at the transition zone than at the forebay In 1993, the average summer water temperatures in Melton Hill Reservoir (16.7°C at the forebay and 16.5°C at the transition zone) were lower than all other run-of-the-river sampling sites except at Tellico Reservoir forebay.

In spite of the thermal stratification, little oxygen stratification and no hypolimnetic anoxia were found in Melton Hill Reservoir in 1993. Minimum DO's measured in the summer of 1993 were 4.3 mg/l on the bottom at the forebay in July; and 6.5 mg/l on the bottom at the transition zone in September. DO's at the 1 5m depth in Melton Hill Reservoir in the summer of 1993, ranged from a high of 11 5 mg/l in May and June to a low of 9.3 mg/l in September at the forebay, and from 10.8 mg/l in April to 7.6 mg/l in September at the transition zone Average summer DO's (= 9 1 mg/l) and percent oxygen saturation values (= 92 percent) were higher at the Melton Hill transition zone than any other reservoir Vital Signs sampling site in 1993. DO ratings used in the overall reservoir ecological health evaluation for Melton Hill Reservoir were excellent at both the forebay and the transition zone.

The Clinch River flows through the Valley and Ridge physiographic province, a region underlain by large amounts of limestone and dolomite. Consequently, Melton Hill Reservoir has relatively high pH and conductance; in fact, the highest among the run-of-the-river reservoirs. In the summer of 1993, pH ranged from 7.3 to 8.8 and conductivity ranged from 223 to 272 µmhos/cm and averaged about 255 µmhos/cm in Melton Hill Reservoir. At the forebay, near surface water pH's exceeded 8.5 each month from May through August, coincident with DO super-saturation values (>110%), and indicative of photosynthetic activity. Tennessee's maximum pH criteria for the protection of fish and aquatic life is 8.5.

Average nitrite plus nitrate-nitrogen concentrations were quite high in Melton Hill Reservoir. As in past years, the 1993 average concentration at the transition zone (0.56 mg/l) was the highest nitrite plus nitrate-nitrogen among all Vital Signs locations sampled.

Dissolved ortho phosphorus concentrations (the only form of phosphorus assimilated by algal cells) averaged only about 0.003-0.004 mg/l at the forebay and transition zone, respectively, among the lowest measured at run-of-the-river sampling sites in 1993. Further, TN/TP ratios were often high (>50) indicating frequent episodes of phosphorus limitation to algal productivity in Melton Hill Reservoir. Consequently, average summer chlorophyll *a* concentrations of 5.3 µg/l at the forebay and 4 µg/l at the transition zone, may reflect a limiting nutrient effect. The highest chlorophyll *a* concentrations measured were 6-7 µg/l at both the transition zone and the forebay. The chlorophyll *a* ratings used in the 1993 ecological health evaluation for Melton Hill Reservoir were "good" (i.e., falling in the 3 to 10 µg/l range), at both locations; just above the level considered fair (i.e., less than 3 µg/l).

The water clarity (Secchi depth, suspended solids, color, etc.) of Melton Hill Reservoir was comparatively high and measurements were generally stable throughout the year, being largely influenced by discharges from Norris Dam rather than localized rainfall runoff events.

Sediment—Chemical analyses of sediments in Melton Hill Reservoir in 1993 indicated the presence of chlordane in one of two forebay samples (25 µg/kg) and also in the transition zone (32 µg/kg) sample. Toxicity tests detected no acute toxicity to the two organisms tested. Particle size analysis showed sediment in the forebay were 99 percent silt and clay and from the transition zone were 90 percent silt and clay.

Sediment quality ratings used in the overall Melton Hill Reservoir ecological health evaluation for 1993 were "good" at both the forebay and the transition zone (presence of chlordane).

Benthic Macroinvertebrates—The 1993 benthic communities at all three sites on Melton Hill declined from 1992. The forebay and inflow had a poor benthic macroinvertebrate community and the transition zone had a very poor benthic community. Melton Hill forebay had 16 taxa and 363 organisms/m^2, a decrease in both diversity and dominance from 1992. The benthic community was dominated by Chironomus sp (49 percent) and Tubificidae 17 percent. The transition zone had 362 organisms/m^2 representing 21 taxa, predominately Tubificidae (36 percent) and Chironomus (27 percent). The inflow location had the greatest abundance (1,649 organisms/m^2) and diversity (29 taxa) of all locations sampled on Melton Hill There was a substantial increase in diversity and density in the inflow compared to the previous year. Tubificidae (49 percent) and Paratendipes (17 percent) were the dominant organisms at this site.

Several factors contributed to the poor benthic communities found on Melton Hill Reservoir. Three factors that negatively impacted all three locations were a preponderance of chironomids, and low numbers of EPT and long-lived taxa. The problems were further compounded at the transition and inflow sites because of decreased diversity and inflated numbers of tubificids.

Aquatic Macrophytes—An estimated 240 acres of aquatic macrophytes occurred on Melton Hill Reservoir in 1993. Eurasian watermilfoil was the dominant aquatic plant and was most abundant from CRM 24 to 51. Coverage over the past decade has generally ranged from about 100 to 250 acres.

Fish Community—Electrofishing (45 transects) and gill netting efforts (34 net-nights) on Melton Hill Reservoir produced a total of 2,437 fish representing 42 species. Gizzard shad was the most numerous species (56 percent of the total number of fish sampled), followed in abundance by yellow bass (8 percent), largemouth bass (5 percent), carp (5 percent), and bluegill (4 percent). The threadfin shad YOY catch rate (CPUE=335 per 300m electrofishing transect) was moderate in the forebay zone of Melton Hill Reservoir and insignificant in the transition and inflow areas. Overall fish abundance was much the same in the forebay (1,172) and transition (1,108) zones but substantially less in the inflow (157). Fewer species were also collected from the inflow zone (16) than the forebay (28) or transition zone (36).

The Reservoir Fish Assemblage Index (RFAI) rated the littoral fish community (based on results of electrofishing samples) fair in the transition (RFAI=32), poor in the inflow (RFAI=22), and very poor in the forebay (RFAI=18) zones of Melton Hill Reservoir. The very poor rating in the forebay, which represented the lowest RFAI score for all run-of-the-river forebays, resulted from minimum scores for all metrics except number of sucker and intolerant species. The gill netting RFAI rated both the forebay (RFAI=38) and transition (RFAI=40) zones fair. The only extreme difference between the two zones in metric scoring resulted from higher numbers of lithophilic spawning species in the transition. Gill netting RFAI values were not calculated for inflow zones of run-of-the-river reservoirs due to low numbers of replicate samples.

Combined electrofishing and gill netting RFAI scores rated the transition zone (RFAI=36) fair. The poor RFAI's of 28 and 22 in the forebay and inflow zones, respectively, were the lowest recorded for comparable zones of run-of-the-river reservoirs in 1993 (Note: Results from biomonitoring on Melton Hill Reservoir like Tellico, were compared to results from mainstream reservoirs due to similar operational characteristics. These reservoirs lack deep drawdown which occurs in storage impoundments and have a navigation lock.)

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—No bacteriological studies were conducted at recreation areas in 1993. The April fecal coliform bacteria concentrations at the Vital Signs locations were 113 and 191/100 ml at the forebay and transition zone, respectively. All other concentrations were <20/100 ml.

Fish Tissue—PCB contamination in catfish from Melton Hill Reservoir has been under study for several years. Because of this contamination, the TDEC has advised the public not to eat these catfish. TVA participates on a study team with TDEC, TWRA, and ORNL to investigate PCBs and other contaminants in fish from east Tennessee Reservoirs. In 1992 ORNL collected and analyzed channel catfish from the forebay, while channel catfish from near the transition zone and inflow were collected and analyzed by TVA. Average PCB concentrations from these same locations were 0.8, 1.0, and 0.5 µg/g, respectively, and average chlordane concentrations were 0.07, 0.10, and 0.05 µg/g, respectively.

Emory River Stream Monitoring Site

Summary of 1993 Conditions - Ecological Health

Water—The water of the Emory River is soft (average hardness of 24 mg/l) and slightly alkaline (average total alkalinity of 16 mg/l). The median pH for the stream monitoring site was 7.5. The river was well oxygenated with dissolved oxygen levels ranging from 88 to 102 percent of saturation.

Of the 12 stations monitored in the Tennessee Valley, the Emory River had the lowest concentrations of nitrate+nitrite-nitrogen (0.10 mg/l), total phosphorus (0.020 mg/l), and dissolved orthophosphate (0.002 mg/l). The low organic nitrogen (0.195 mg/l) and ammonia nitrogen (0.002 mg/l) concentrations were in the lower third of all stations. The good total phosphorus and nitrate+nitrite-nitrogen concentrations, in particular, contributed to a good nutrient rating for the station.

Seven analyses for priority pollutant metals (dissolved cadmium, lead, nickel, silver, and zinc and total copper and zinc) were performed bi-monthly. Dissolved cadmium (5 of 6 samples), dissolved nickel (2 of 6 samples) and zinc were detected. All were within EPA guidelines for the protection of aquatic life and human health.

Sediment—Sediment quality rated good in 1993 with no acute toxicity observed and no metals, PCBs, or pesticides exceeding the EPA guidelines. This is a significant improvement over 1992 when sediment quality rated poor

Benthic Macroinvertebrates—In 1993, benthic macroinvertebrate community rated fair with a Modified Benthic Index of Biotic Integrity (MBIBI) score of 39, with 102 taxa and 4,308 organisms/m^2. Conditions in 1992 also rated fair (MBIBI score 38) with 77 taxa and 3,137 organisms/m^2. Benthic organisms have essentially remained unchanged between sampling years with the exception of a 25 percent increase in total taxa reported in the qualitative sample. Dominant organisms in 1993 were dipteran midge larvae (62 percent), coleopteran riffle beetles (13 percent), and caddisflies (10 percent) Dipteran midge larvae was also the most dominant organism in 1992 (56 percent), followed by caddisflies (14 percent) and mayflies (12 percent) Siltation from coal mining practices in the Emory River watershed are a continuing problem for benthic organisms at this site.

Fish Community Assessment—The fish community rated good with an Index of Biotic Integrity (IBI) score of 52, improving from the borderline good (IBI = 46) rated in 1992. The 1993 fish sample contained no hybrids and fewer diseased fish, and had a slightly increased fish density suggesting less stressful conditions for fish since 1992. Minor problems, however, continued to be seen in species composition and trophic structure A contributing factor of stress on fish at this station is naturally-occurring low flow (usually less than 50 cfs) during mid to late summer. Low flow reduces fish habitat, reduces the river's ability to assimilate pollutants, and generally makes the aquatic fauna more vulnerable to environmental degradation.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—There were no bacteriological studies conducted on the Emory River in 1993.

Fish Tissue—A five fish composite each of carp, channel catfish, and largemouth were collected during summer 1992 and analyzed for selected metals, pesticides, and PCBs. Mercury was detected in all three samples but at concentrations which would not be considered elevated. Chlordane was detected at low concentrations in two samples, and PCBs were found in all samples (carp 0.4 μg/g; channel catfish 1.2 μg/g; and largemouth bass 0.6 μg/g). Additional catfish and largemouth bass were collected in summer 1993, but results were not available at the time this report was prepared.

CLINCH RIVER AND POWELL RIVER WATERSHED

Norris Reservoir

Summary of 1993 Conditions - Ecological Health

Water—Surface water temperature ranged, for the months it was measured (April-October), from 12.6°C in April to 29.8°C in July in the forebay, from 14.9°C to 30.0°C for the same months at the Clinch mid-reservoir sampling location, and from 14.6°C to 30 1°C for the same months at the Powell mid-reservoir sampling location. Thermal stratification was evident in Norris Reservoir in 1993. While this stratification was evident in April, when the first measurements for the year were made, it became much stronger beginning in May, due to drastically decreased streamflow combined with solar heating. Maximum surface to bottom water column temperature differentials occurred in July, when the surface temperatures were about 22°C warmer than bottom temperatures in the forebay, and about 19°C at the mid-reservoir sampling locations. The strong thermal stratification in Norris Reservoir persisted through October for the forebay, and through September for the mid-reservoir locations.

Dissolved oxygen at the 1.5m depth ranged from 9.7 mg/l in May to 7.4 mg/l in September at the forebay, from 10.8 mg/l in April to 7.0 mg/l in August at the Clinch mid-reservoir sampling location, and from 10.2 mg/l in May to 6.7 mg/l in October at the Powell mid-reservoir sampling location. During the summer of 1993, (as in past summers) anoxic conditions developed at all three sampling locations on Norris Reservoir At the mid-reservoir sampling locations, dissolved oxygen concentrations near the bottom were approximately 0 mg/l in July, August, and September. Further, in August this anoxia development resulted in hypolimnetic dissolved oxygen concentrations being less than 1 mg/l over approximately two-thirds of the water column depths in the mid-reservoir sampling locations. For the forebay, anoxic conditions existed at the bottom in September and October.

DO ratings used in the overall reservoir ecological health evaluation for Norris Reservoir were poor at the forebay and very poor at the mid-reservoir sampling locations. The forebay DO rating was poor because approximately 10 percent of the cross-sectional area (six-month summertime average) of the forebay had a dissolved oxygen concentration less than 2.0 mg/l; anoxic bottom conditions existed; and, over 20% of this site's cross-sectional bottom length (six-month summertime average) had a dissolved oxygen concentration less than 2.0 mg/l. The mid-reservoir sites both received very poor ratings for dissolved oxygen because of even poorer DO conditions. At both sites over 20 percent of the cross-sectional areas (six-month summertime average) had a dissolved oxygen concentration less than 2.0 mg/l; both had anoxic bottom conditions; and both had over 50 percent of each site's cross-sectional bottom length (six-month summertime average) with dissolved oxygen concentrations less than 2.0 mg/l.

In 1993, values of pH in Norris Reservoir ranged from 7.0 to 8.7 for the three monitoring locations Surface water pH values slightly exceeded 8.5 (Tennessee's maximum pH criteria for the protection of fish and aquatic life is 8.5) at the forebay in August, at the Clinch mid-reservoir location in June, and at the Powell mid-reservoir location in May and June. In each of these cases, dissolved oxygen saturation concentrations were high (>100 percent), which indicates substantial photosynthetic activity. The conductivity of the water in Norris Reservoir is among the highest of all the reservoirs in the Tennessee River drainage. Reservoir-wide, conductivities ranged from 172 to 382 μmhos/cm. They averaged 244 μmhos/cm at the forebay, 277 μmhos/cm at the Clinch mid-reservoir sampling location, and 295 μmhos/cm at the Powell mid-reservoir sampling location.

Concentrations of nutrients were very low, which is typical for Norris Reservoir. Average total phosphorus (TP) and dissolved ortho phosphorus (DOP) were especially low reservoir-wide At the forebay, both TP and DOP averaged less than 0.002 mg/l and were among the lowest average total phosphorus concentrations measured in 1993. Further, TN/TP ratios for individual samples often exceeded 100 at all Norris sampling sites, which indicates extremely limiting phosphorus conditions on algal productivity in the reservoir.

Concentrations of chlorophyll *a* averaged only 1.7 µg/l at the forebay, 4.1 µg/l at the Clinch mid-reservoir sampling location, and 3.6 µg/l at the Powell location. The chlorophyll *a* ratings used in the 1993 ecological health evaluation for Norris Reservoir were fair at the forebay (i.e. less than 3 µg/l) and good (i.e. falling in the 3 to 10 µg/l range), at both mid-reservoir locations; just above the level considered fair (i.e. less than 3 µg/l).

The water of Norris Reservoir, especially in the forebay area has historically been quite clear. However, Norris Reservoir forebay in 1993 was less clear than 1992 with an average Secchi depth of 2.5 meters. The Clinch mid-reservoir Secchi depth was slightly clearer than in 1992, averaging 2.5 meters, and the Powell was about the same, averaging 2.2 meters.

Sediment—As in 1990-92, chemical analyses of sediments in Norris Reservoir in 1993 found high levels of lead (76 mg/kg) in the forebay, and elevated levels of un-ionized ammonia in both the Clinch (375 µg/l) and Powell (370 µg/l) mid-reservoir regions. Toxicity tests detected no acute toxicity to the two organisms tested. Particle size analysis showed sediments from the forebay were about 100 percent silt and clay; from the Clinch mid-reservoir were about 95 percent silt and clay; and from the Powell mid-reservoir were 98 percent silt and clay.

Sediment quality ratings used in the overall Norris Reservoir ecological health evaluation for 1993 were good at the forebay (presence of lead); and good at both of the mid-reservoir sites (presence of ammonia).

Benthic Macroinvertebrates—Among the three reservoir monitoring locations on Norris Reservoir, the Powell River mid-reservoir site had the highest number of benthic taxa (23) and greatest density (1,887 organisms/m^2), and received the best overall benthic rating of good. The dominant taxa were Tubificidae (39 percent), Limnodrilus sp (21 percent) and Chironomus sp (22 percent). The forebay and Clinch River mid-reservoir site both had fair benthic communities. The forebay site had 16 taxa and 751 organisms/m^2; Tubificidae, the dominant taxon, comprised 56 percent of the total, followed by Corbicula fluminea (26 percent). The Clinch River mid-reservoir location had 1,214 organisms/m^2 representing 17 taxa and was dominated by Tubificidae (52 percent) and Chironomus sp (36 percent).

The Norris forebay could have achieved a good rating had it not been for the abundance of tubificids and the dearth of EPT taxa These negative influences were offset by the abundance of long-lived taxa and low numbers of chironomids. The Powell River site, which received a good rating, scored well because of its diversity and evenness of the dominant taxa. All other metrics evaluated were fair. The Clinch River site had an average benthic community primarily because all metrics evaluated received only a fair score. The only metric that rated very low was the dominance metric; in this instance, Tubificidae comprised an overwhelmingly large percentage of the total organisms collected.

Fish Assemblage—The fish samples from the littoral (45 electrofishing transects) and profundal areas (36 net-nights) of Norris Reservoir produced a total of 1,602 individuals representing 29 species. Highest concentrations of fish were found in the Clinch River transition zone (43 percent of total fish sampled) due to the abundance of walleye in the gill netting sample (10 per net night) and black basses (smallmouth, spotted, and largemouth) in the electrofishing sample (9 per 300m transect). The forebay electrofishing catch rate (CPUE=15 per 300m transect) was the lowest recorded among all tributary reservoir forebays The forebay gill netting catch rate (CPUE=7 per net night) was the second lowest recorded (Parksville forebay was the lowest). Twenty-five species were collected at both transition zones and 16 in the forebay.

The Reservoir Fish Assemblage Index (RFAI) rated the littoral fish community (based on results of electrofishing samples) good in the Powell River transition (RFAI=46) zone and fair in both the Clinch River transition (RFAI=40) and forebay (RFAI=34) zones The higher RFAI in the Powell River transition zone was influenced by maximum metric scores for diversity, number of piscivore, sucker, intolerant, and lithophilic spawning species, percent tolerant species and dominance by a single species. Both the Powell and Clinch rivers received gill netting RFAI values of 50 classifying them good. The forebay (RFAI=28) was poor; only one metric (percent anomalies) had a maximum score in the forebay of Norris; all other scores were either minimum or midrange Combined electrofishing and gill netting RFAI scores for both the Clinch (RFAI=45) and Powell (RFAI=48) river transitions were rated good, followed by a fair rating in the forebay (RFAI=31).

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—Two swimming beaches, one boat ramp, and one site upstream and another downstream of the Jacksboro sewage treatment plant were tested for fecal coliform bacteria twelve times each in 1993 Two samples at each site were collected within 48-hours of rainfall of at least one-half inch. Bacteria concentrations at all five sites were very low (geometric mean <20/100 ml)

Fish Tissue—Fish tissue samples for screening studies were collected on Norris Reservoir in autumn 1992. All analytes were low except for PCBs, which were highest at the forebay where the concentration was 0.9 μg/g. Concentrations at the other two locations were low. Screening samples were collected again in autumn 1993 to further evaluate PCB concentrations but results were not available at the time this report was prepared.

Clinch River Stream Monitoring Site

Summary of 1993 Conditions - Ecological Health

Water—The water of the Clinch River is moderately hard (average hardness of 147 mg/l) and alkaline (average total alkalinity of 120 mg/l) The median pH for the stream monitoring site was 8.0 The river was well oxygenated with dissolved oxygen levels ranging from 81 to 106 percent of saturation.

Of the 12 streams monitored across the Tennessee Valley, the Clinch River ranked among the lowest in average concentrations of ammonia nitrogen (0.015 mg/l) and dissolved orthophosphate (0.003 mg/l). It ranked just below the median in average concentrations of organic nitrogen (0.198 mg/l), nitrate+nitrite-nitrogen (0.30 mg/l), and total phosphorus (0.020 mg/l). The low concentrations of total phosphorus and nitrate+nitrite-nitrogen yielded a good nutrients rating for the station

Seven analyses for priority pollutant metals (dissolved cadmium, lead, nickel, silver, and zinc and total copper and zinc) were performed bi-monthly Dissolved cadmium was detected in 4 of 6 samples, but did not exceed the EPA guidelines for the protection of aquatic life and human health

Sediment—Sediment quality rated good in 1993 with no acute toxicity observed and no metals, PCBs, or pesticides exceeding the EPA guidelines. This is an improvement over 1992 when sediment quality rated fair.

Benthic Macroinvertebrates—In 1993, benthic macroinvertebrate results rated good with a Modified Benthic Index of Biotic Integrity (MBIBI) score of 53, with 83 taxa and 2,726 organisms/m^2 Conditions in 1992 also rated good (MBIBI score 50) with 85 taxa and 3,326 organisms/m^2. The Clinch River is rated the best among the 12 stream monitoring sites. The benthic fauna in 1993 was composed mostly of river snails (33 percent), nutrient tolerant oligochaeta worms (16 percent), and mayflies (14 percent). Mayflies were the dominant organism in 1992 (46 percent), followed by river snails (13 percent) and coleopteran riffle beetles (9 percent). Overall, conditions remain unchanged between sampling years

Fish Community Assessment—The fish community rated good with an Index of Biotic Integrity (IBI) of 50 in 1993, showing no change since 1992 Minor problems were seen in species composition, trophic structure, and fish condition The fish assemblage was basically intact with a good number of native species and a healthy compliment of darter, sucker, and intolerant species. Trophic structure was good at the lower levels, as most fish found were specialized insectivores. Fish density was also at a normal level. Detrimental conditions observed at this station included occasional bank erosion and siltation

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—The weir downstream of Norris Dam and the canoe launch site downstream of the weir were tested for fecal coliform bacteria twelve times each in 1993. Two samples were collected within 48 hours of rainfall of at least one-half inch. The geometric mean of fecal coliform bacteria concentrations were very low (<20/100 ml)at both sites.

Fish Tissue—A five fish composite each of carp, channel catfish, and largemouth bass were collected during summer 1992 and analyzed for selected metals, pesticides, and PCBs. All analytes were not detected or found in low concentrations.

Powell River Stream Monitoring Site

Summary of 1993 Conditions - Ecological Health

Water—The water of the Powell River is moderately hard to hard (average hardness of 150 mg/l) and alkaline (average total alkalinity of 125 mg/l). The median pH for the stream monitoring site was 8.0. The river was well oxygenated with dissolved oxygen levels ranging from 88 to 105 percent of saturation

Of the 12 streams monitored across the Tennessee Valley, the Powell River ranked in the lower half in concentrations of nutrients The average ammonia nitrogen concentration (0.013 mg/l) was the lowest for the network. The good average total phosphorus (0.035 mg/l) and nitrate+nitrite-nitrogen (0.47 mg/l), in particular, yielded a good rating for nutrients at the site.

Seven analyses for priority pollutant metals (dissolved cadmium, lead, nickel, silver, and zinc and total copper and zinc) were performed bi-monthly. Dissolved cadmium (5 of 6 samples) and dissolved nickel (1 of 6 samples) were detected. Neither metal exceeded the EPA guidelines for the protection of aquatic life or human health Additional metals analyses included total and dissolved forms of iron and manganese. Total iron exceeded the EPA guideline for combined consumption of fish and water in one sample. Total manganese was detected in 4 of 6 samples, but none exceeded EPA guidelines.

Sediment—Sediment quality rated good in 1993 with no acute toxicity observed and no metals, PCBs, or pesticides exceeding the EPA guidelines. This is a significant improvement over 1992 when sediment quality rated poor.

Benthic Macroinvertebrates—In 1993, the benthic macroinvertebrate community rated good with a Modified Benthic Index of Biotic Integrity (MBIBI) score of 47, with 94 taxa and 2,586 organisms/m^2 Conditions in 1992 rated fair (MBIBI score 42) with 66 taxa and 2,167 organisms/m^2. Dominant organisms in 1993 were dipteran midge larvae (27 percent), river snails (24 percent), and coleopteran riffle beetles (16 percent) River snails were the most dominant group in 1992 (43 percent), followed by dipteran midge larvae (24 percent) and the Asian clam Corbicula (10 percent) Overall, conditions improved from fair to good over the previous year

Fish Community Assessment—Meaningful improvement was seen in the fish community in 1993. Ratings of good were found for both 1993 and 1992, however the Index of Biotic Integrity (IBI), on which the ratings are based, increased from 48 in 1992 to 56 in 1993 and was approaching an excellent rating. Improvement was seen in species richness and composition, trophic structure, and fish density. Only slight deficiencies in number of darter species and proportion of piscivorous fish prevented a higher rating. Accumulations of sand, coal, and gravel were observed in some pool areas, but apparently were not a major problem for the fish community.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—No fecal coliform bacteria samples were collected and analyzed above the stream monitoring site

Fish Tissue—A five fish composite each of freshwater drum, channel catfish, and largemouth bass were collected during summer 1992 and analyzed for selected metals, pesticides, and PCBs. All analytes were not detected or found in low concentrations.

LITTLE TENNESSEE RIVER WATERSHED

Tellico Reservoir

Summary of 1993 Conditions - Ecological Health

Water—Fairly strong thermal stratification persisted from April through September 1993 at both the forebay and transition zone. From June through August, temperature differentials between the water surface and bottom equaled or exceeded 11°C at the forebay and 10°C at the transition zone. These differentials were due to a combination of atmospheric warming of surface water—intensified by the low streamflows in April and May and the intrusion of surface waters from Fort Loudoun forebay—contrasted with the inflow of cool bottom water from the releases of Chilhowee Dam upstream. Surface water temperatures ranged from lows in April to highs in July (i.e. from 16.1°C to 28.0°C at the forebay and from 16.3°C to 29.5°C at the transition zone). Water in Tellico Reservoir was relatively cool, particularly at the transition zone which was influenced by the releases from Chilhowee Dam. Summer temperatures averaged 16.5°C and 17.5°C at the forebay and transition zone, respectively, among the lowest temperatures for run-of-the-river Vital Signs sampling sites in 1993.

DO at the 1.5m depth ranged from a high of 11.4 mg/l in April to a low of 6.8 mg/l in September at the forebay; and from 10.6 mg/l to 8.1 mg/l (for the same months) at the transition zone. From June through September a persistent oxycline was present in the forebay. Differences between surface and bottom DO concentrations were 5 to 9 mg/l, and near bottom concentrations were less than 1 mg/l in August and September This near bottom, cool, low DO water was very low in conductivity (<50 µmhos/cm). This suggests that cool water, which is fairly high in DO when it is released from Chilhowee Dam, becomes trapped in the hypolimnion of Tellico Reservoir and is slowly depleted of oxygen content during the summer. The minimum DO was 4.1 mg/l in July, on the bottom at the transition zone DO ratings used in the overall reservoir ecological health evaluation for Tellico Reservoir were fair at the forebay (due to the hypolimnetic anoxia in August and September) and excellent at the transition zone

The Little Tennessee River drains through the Blue Ridge physiographic province—a mountainous, largely forested region underlain, for the most part, by crystalline rocks The upper slopes of the watershed have generally thin soils and weathered rock. In addition, the underlying rocks, broadly speaking are siliceous and not easily dissolved Surface drainage is rapid, and consequently, the water of the Little Tennessee River (and Tellico Reservoir) are quite soft, low in pH and conductivity, and low in nutrients.

In 1993, Tellico Reservoir pH values ranged from 6.0 to 8.9. Near surface pH's exceeded 8.5 at the forebay in June and July and at the transition zone in July, coincident with DO super-saturation values indicative of photosynthetic activity. Values of pH in Tellico Reservoir were the lowest of any of the run-of-the-river Vital Signs reservoirs, averaging 7.0 at both the forebay and transition zone. Values of pH below the Tennessee minimum criterion of 6 5 for fish and aquatic life were observed in the hypolimnion of Tellico Reservoir at both the forebay and transition zone in 1993.

The conductivity of water in Tellico Reservoir was also quite low, averaging about 35 µmhos/cm at the transition zone and 65 µmhos/cm at the forebay. Mixing of forebay surface waters between Fort Loudoun and Tellico reservoirs via the inter-reservoir canal influences water quality and causes the higher measured conductivity at Tellico forebay compared with Tellico transition zone

Total nitrogen concentrations were low and averaged only 0.33 mg/l at the forebay and 0.22 mg/l at the transition zone. Dissolved ortho phosphorus concentrations (the only form of phosphorus assimilated by algal cells) were also quite low, averaging only 0.003 mg/l at the forebay and transition zone. Together, these nutrient concentrations were among the lowest measured concentrations at Vital Signs Monitoring locations in 1993; and consequently, primary productivity could be expected to be limited much of the time.

Average summer chlorophyll *a* concentrations were 7 µg/l at the forebay and 3 µg/l at the transition zone. The highest single sample chlorophyll *a* concentrations measured in 1993 were 9 µg/l at the forebay and only 6 µg/l at the transition zone. The chlorophyll *a* ratings used in the 1993 ecological health evaluation for Tellico Reservoir were good (i.e. falling in the 3 to 10 µg/l range), at both locations; just above the level considered fair (i.e. less than 3 µg/l).

Water clarity data (as measured by Secchi depth, suspended solids, color, etc.) was comparatively high with little relative variation throughout the year. This is because inflows to Tellico Reservoir are primarily a result of Chilhowee Dam discharges which are of high clarity and low color, rather than rainfall runoff events.

Sediment—Samples for toxicity testing and chemical analyses were collected at three sites in Tellico Reservoir in 1993: the forebay (LTRM 1.0); and two transition zone locations (LTRM 15.0, downstream of the confluence of the Tellico River, and LTRM 21.0, upstream of the confluence of the Tellico River). Chemical analyses of sediments in Tellico Reservoir in 1993 indicated the presence of chlordane in the forebay (21 µg/kg) and in one of two transition zone (LTRM 15.0) samples (16 µg/kg). Toxicity tests detected acute toxicity to daphnids (0 percent survival) at all sampling sites tested; however, for the first time since 1990, toxicity to rotifers was not detected. Particle size analysis showed sediments from the forebay were about 97 percent silt and clay; from LTRM 15.0 transition zone were 91 percent silt and clay; and from LTRM 21.0 transition zone were about 66 percent silt and clay, 34 percent sand.

Sediment quality ratings used in the overall Tellico Reservoir ecological health evaluation for 1993 were poor at the forebay (acute toxicity to test animals and presence of chlordane); poor at the transition zone site-LTRM 15.0 (acute toxicity to test animals and presence of chlordane). Information from the transition zone site at LTRM 21.0 was not included in the overall ecological health rating.

Benthic Macroinvertebrates—The benthic community in Tellico Reservoir in 1993 rated poor at both the forebay and transition zone. The forebay zone had 17 taxa and 433 organisms/m^2 dominated by Tubificidae (65 percent of the total), which is very similar to the benthic community observed the previous year. The transition zone had 13 taxa and 320 organisms/m^2. As in 1992, Tubificidae was the dominant taxon (28 percent) and the chironomid Zalutschia zalutschicoia was the second most abundant (18 percent).

Reduced diversity, few EPT taxa, and an abundance of tubificids resulted in the forebay and transition zone communities receiving poor ratings were . The transition zone was further impacted because relatively few long-lived taxa were present.

Aquatic Macrophytes—The 246 acres of aquatic macrophytes on Tellico Reservoir were most abundant in the Tellico River portion (between miles 1 and 13) of the reservoir and along the Little

Tennessee River portion from LTRM 9 to 15. Eurasian watermilfoil was the dominant submersed macrophyte on Tellico Reservoir.

Fish Assemblage—Electrofishing (30 transects) and gill netting samples (24 net-nights) in the transition zone and forebay produced 1,498 individuals of 36 species. More fish (66 percent) as well as more species (31 compared to 29) were found in the forebay than in the transition zone. Gizzard shad comprised 37 percent of the total sample, followed by spotfin shiners, bluegill, and the black basses (smallmouth, spotted, and largemouth) all at 9 percent. Electrofishing and gill netting results indicated most species were present in higher numbers in the forebay than the transition zone. Walleye and sauger were more numerous in 1993 than in previous years, which may be of interest to sport anglers in the future.

The Reservoir Fish Assemblage Index (RFAI) rated the littoral fish community (based on electrofishing results) fair in both the forebay (RFAI=34) and transition (RFAI=38) zones. All metric scores for both zones were identical with the exception of percent tolerant and omnivorous species which received higher scores in the transition. Gill netting RFAI's rated the forebay (RFAI=34) fair and the transition (RFAI=22) poor, due primarily to lower scores for the number of species, number of sucker, intolerant, lithophilic spawning species, and percent anomalies and dominance by a single species. Gill netting RFAI values were not calculated for inflow zones of run-of-the-river reservoirs due to low numbers of replicate samples.

Combined electrofishing and gill netting RFAI scores rated the forebay (RFAI=34) fair and the transition (RFAI=30) zone poor The RFAI rating of poor in the transition resulted from a low gill netting RFAI (22) which was the lowest score observed for run-of-the-river reservoirs in 1993. (Note: Results from biomonitoring on Tellico Reservoir were compared to results from mainstream reservoirs because of the lack of a deep drawdown as occurs in storage impoundments and the presence of a navigation lock allowing recruitment of fish species.)

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—No bacteriological studies were conducted at recreation sites in 1993. Fecal coliform bacteria concentrations were very low (geometric mean <20/100 ml) at the Vital Signs stations. The highest individual concentrations were April samples, 114 and 54/100 ml, at the forebay and transition zone, respectively.

Fish Tissue—An advisory not to eat catfish from Tellico Reservoir has been in effect for several years. Documentation of the PCB problem in what was thought to be a background study in 1985 came as a surprise because there was basically no industrial development in the watershed. Subsequently, more intensive studies supported the initial results and showed very little change in concentrations during the late 1980s Several attempts at locating potential sources were fruitless and the source remains unknown. A less intensive sampling effort was begun in autumn 1990. Since then one composite of five channel catfish has been collected annually from the forebay and one from an area about 10 miles upstream (several miles downstream of the transition zone) to continue examination of the temporal trend in PCB concentrations.

Channel catfish samples collected in autumn 1992 had relatively high PCB concentrations - 2.7 µg/g at the forebay and 1 9 µg/g at the mid-reservoir location. Chlordane concentrations were also relatively high - 0.22 and 0.20 μg/g, respectively. Other organics were either not detected or found in very low concentrations. Arsenic, cadmium, lead, and selenium were not detected in either sample. Mercury concentrations were relatively high - 0.65 and 0.36 μg/g at the forebay and mid-reservoir locations. Due to these high concentrations of mercury, largemouth bass were collected along with channel catfish in autumn 1993; results were not available at the time this report was prepared.

Fontana Reservoir

Summary of Conditions in 1993 - Ecological Health

Water—Average flow through Fontana Reservoir in 1993 was about 107 percent of normal, with an average residence time of 174 days Fontana Reservoir was strongly stratified, with a maximum temperature difference in the water column at the forebay of 21.8°C in July, and remaining 14.3°C in October. Due to the fall drawdown, the two mid-reservoir sampling locations were weakly stratified in September and mixed in October. Maximum surface temperatures were 27.8°C at the forebay, 29.8°C at the Little Tennessee River mid-reservoir station, and 29.0°C at the Tuckasegee River mid-reservoir station. The maximum temperatures were in July. North Carolina's standard for maximum temperature of Class°C waters is 29°C. Depleted DO (<2 0 mg/l) only developed at the forebay at depths of over 100 meters in September and October. Depleted DO conditions also occurred at the Tuckasegee River mid-reservoir station in August and September, but not in the Little Tennessee River mid-reservoir station. The DO rating in the reservoir ecological health index was good for the forebay and Little Tennessee River mid-reservoir sites and poor for the Tuckasegee site.

Conductivities were generally in the 20 to 30 µmhos/cm range, the second lowest of the tributary reservoirs, with little stratification except for late summer when a maximum conductivity of 39 µmhos/cm occurred. The minimum pH was 6 0 at all three sites, the maximum was 8.8 in June at the Little Tennessee River mid-reservoir station.

Total nitrogen concentrations at the three stations were the third, fourth, and fifth lowest concentrations of the 33 tributary reservoir stations Total nitrogen concentrations at the three sites averaged 0.21 mg/l in April, mostly as nitrates, and 0.07 mg/l in August, mostly as organic nitrogen. Total phosphorus concentrations were 0.01 mg/l at both mid-reservoir locations and 0.003 mg/l at the forebay in April, and dropped to an average of 0 003 mg/l at the three locations in August Total phosphorus concentrations at the forebay were the lowest concentrations of the tributary reservoir stations. Total organic carbon concentrations averaged 0.8 mg/l in April and 1.4 mg/l in August, with little variation between locations. Chlorophyll *a* concentrations averaged 1.4 µg/l at the forebay, and 2.7 and 2.4 µg/l at the Little Tennessee and Tuckasegee River mid-reservoir locations, respectively. These were the fourth, fifth, and sixth lowest concentrations of the tributary reservoir stations, and were within the range considered fair. Secchi depths at the mid-reservoir stations varied from 2.1 meters in April to 4.9 meters in June, both in the Tuckasegee River. The water at the forebay was the clearest of all tributary reservoir stations, ranging from 5 1 meters in September to 8.1 meters in June.

Sediment—Chemical analyses and toxicity testing of sediments were conducted on sediment samples collected at three locations in Fontana Reservoir in 1993: a forebay site (LTRM 62.0); a mid-reservoir site on the Tuckasegee River (TkRM 3.0) arm; and, a mid-reservoir site on the Little Tennessee River (LTRM 81.5) arm. The presence of chlordane was detected in the forebay (12 µg/kg) and in the Tuckasegee River mid-reservoir region (14 µg/kg). Toxicity tests detected acute toxicity to daphnids (60 percent survival) and rotifers (55 percent survival) in the forebay. Particle size analysis showed sediments in the forebay were 75 percent silt and clay, 25 percent sand; in the Little Tennessee River mid-reservoir were 94 percent silt and clay; and in the Tuckasegee River mid-reservoir were 76 percent silt and clay, 24 percent sand.

Sediment quality ratings used in the overall Fontana Reservoir ecological health evaluation for 1993 were poor at the forebay (presence of chlordane and toxicity to test animals); good at the Tuckasegee mid-reservoir site (presence of chlordane); and excellent at the Little Tennessee mid-reservoir site

Benthic Macroinvertebrates—The first year that the benthic macroinvertebrate community was evaluated on Fontana Reservoir was 1993. The benthic community at the forebay site rated very poor, the Tuckasegee River mid-reservoir site rated poor, and the Little Tennessee River mid-reservoir site rated fair. The forebay had 1,040 organisms/m^2 representing 4 taxa. The Tuckasegee site had 15 taxa and by far the greatest density of all three sites sampled (6,328 organisms/m^2). The Little Tennessee mid-reservoir site had the greatest diversity of the three sites, with 23 taxa and 3,753 organisms/m^2. The dominant taxon at all three sites was Tubificidae, accounting for 90 percent of the total at the forebay and Tuskasegee inflow, and 77 percent of the total at the Little Tennessee River inflow.

The three sites sampled on Fontana Reservoir had several common problems: an absence of long-lived taxa, an absence of EPT taxa, and an abundance of tubificids. It is also worthy to note that a common observation at all three locations on Fontana was low numbers of chironomids. In addition to the above elements, the forebay benthic community was further impacted by very low diversity. The Little Tennessee mid-reservoir site had greater diversity and fewer tubificids than the other two sites which allowed it to receive the best overall benthic rating.

Fish Assemblage—Shoreline electrofishing (45 transects) and offshore experimental gill netting (36 net-nights) yielded 1782 individuals with 22 species represented. Green sunfish and smallmouth bass were the most abundant species collected, comprising 39 and 16 percent of the total sample, respectively Bluegill (7 percent) and white bass (7 percent) were also frequently encountered. Catch rates for both gill netting and electrofishing were approximately the same for all three sample areas (forebay, Little Tennessee River transition, and the Tuckasegee River transition).

The Reservoir Fish Assemblage Index (RFAI) rated the littoral fish community (based on electrofishing results) poor in all three sample areas (forebay RFAI=28, Little Tennessee River transition RFAI=28, and Tuckasegee River transition RFAI=22) of Fontana Reservoir. All electrofishing metrics received low to moderate scores except for percent omnivores and insectivores. Gill netting RFAI results rated the forebay zone (RFAI=36) fair, and both the Little Tennessee River transition (RFAI=42) and the Tuckasegee River transition (RFAI=48) zones good. Combined electrofishing and gill netting RFAI scores rated all three zones of Fontana Reservoir fair.

Summary of Conditions in 1993 - Use Suitability

Fecal Coliform Bacteria—There were no bacteriological studies conducted on Fontana Reservoir in 1993.

Fish Tissue—Five channel catfish were collected in autumn 1992 from both the forebay and mid-reservoir site on the Little Tennessee River Fillets were composited by area and analyzed for selected metals, pesticides, and PCBs on EPA's priority pollutant list. Most analytes were not detected or had low concentrations. Exceptions to this were mercury at both locations (0.40 μg/g at the forebay and 0.53 μg/g at the mid-reservoir site), and PCBs at the forebay (1.1 μg/g). PCBs were not detected in the sample from the mid-reservoir site. Channel catfish were collected again in 1993 from both locations and analyzed for the same analytes with close attention for PCBs at the forebay. Largemouth bass were also collected in autumn 1993 from both locations to further examine mercury concentrations. Results were not available at the time this report was prepared.

Little Tennessee River Stream Monitoring Site

Summary of 1993 Conditions - Ecological Health

Water—The water of the Little Tennessee River is soft (average hardness of 7 mg/l) and slightly alkaline (average total alkalinity of 10 mg/l). The median pH for the stream monitoring site was 7.5. The river was well oxygenated with dissolved oxygen levels ranging from 95 to 110 percent of saturation.

Of the 12 streams monitored across the Tennessee Valley, the Little Tennessee River ranked among the lowest in average concentrations of organic nitrogen (0.188 mg/l), nitrate+nitrite-nitrogen (0.14 mg/l), total phosphorus (0.030 mg/l), and dissolved orthophosphate (0.006 mg/l). The highest average concentration of ammonia nitrogen (0.138 mg/l) was found at this site. The good total phosphorus and nitrate+nitrite-nitrogen concentrations yielded a good rating for nutrients at the site.

Seven analyses for priority pollutant metals (dissolved cadmium, lead, nickel, silver, and zinc and total and dissolved copper and zinc) were performed bi-monthly. Dissolved cadmium was detected in 4 of 6 samples. Three of the samples exceeded the EPA guidelines for both chronic and acute toxicity to aquatic life. Another sample exceeded the guideline for chronic toxicity. Dissolved lead exceeded the guideline for chronic toxicity. (Chronic toxicity bioassays are not routinely performed at stream monitoring sites As seen below, there was no acute toxicity testing apparent in these samples.)

Sediment—Sediment quality rated good in 1993 with no acute toxicity observed and no metals, PCBs, or pesticides exceeding the EPA guidelines.

Benthic Macroinvertebrates—In 1993, benthic macroinvertebrate results were rated good with a Modified Benthic Index of Biotic Integrity (MBIBI) of score 44, with 92 taxa and 11,086 organisms/m^2. Conditions in 1992 also rated good (MBIBI score 46) with 84 taxa and 9,079 organisms/m^2. Dominant organisms in 1993 were dipteran midge larvae (54 percent), nutrient tolerant oligochaete worms (15 percent), and caddisflies (9 percent). Mayflies were the most dominant group in 1992 (27 percent), followed by dipteran midge larvae (23 percent) and caddisflies (19 percent). Conditions have essentially remained unchanged between sampling years, however, an increase was noted in the numbers of silt and nutrient tolerant organisms.

Fish Community Assessment—The fish community rated excellent with an Index of Biotic Integrity (IBI) of 58 and showed little change since rating borderline good (IBI = 56) in 1992. With the exception of low fish density (catch rate), measures of the fish community indicated nearly optimum conditions. Siltation, however, was conspicuous and is suspected of effecting low fish density at this station.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—No studies conducted in 1993.

Fish Tissue—A five fish composite each of river redhorse, channel catfish, and largemouth bass were collected during summer 1992 and analyzed for selected metals, pesticides, and PCBs. All analytes were either not detected or found in low concentrations.

FRENCH BROAD RIVER WATERSHED

Douglas Reservoir

Summary of 1993 Conditions - Ecological Health

Water—During the summer of 1993, surface water temperatures ranged from 13.4°C in April to 28.5°C in July at the forebay, and from 15.4°C to 30.2°C (for the same months) at the mid-reservoir sampling location. Some thermal stratification was observed beginning in May at both the forebay and mid-reservoir locations, and was strongest in July when the temperature differentials between the bottom and the surface were 15.1°C at the forebay, and 12.1°C at the mid-reservoir location. This stratification existed through August at the mid-reservoir location, and through September at the forebay.

Dissolved oxygen at the 1.5m depth ranged from 12.5 mg/l in May to 4.6 mg/l in October at the forebay, and from 11.8 mg/l in May to 5.5 mg/l in September at the mid-reservoir location. (The State of Tennessee's minimum dissolved oxygen criteria for the protection of fish and aquatic life is 5 mg/l, at the 1.5m depth.) Anoxic conditions near the bottom existed from June through September at the forebay, and from June through August at mid-reservoir. This hypolimnetic anoxia peaked at the forebay in August and at the mid-reservoir in July. In each case, about two-thirds of the water column had dissolved oxygen concentrations of less than 1 mg/l. The forebay and mid-reservoir sampling sites had, respectively, about 30% and 20% of their cross-sectional areas (six-month summertime average) with dissolved oxygen concentration less than 2.0 mg/l; and, over 60% of each site's cross-sectional bottom length (six-month summertime average) had a dissolved oxygen concentration less than 2.0 mg/l. Because of the conditions described above (and the low surface concentration in October at the forebay, 4.6 mg/l), DO ratings used in the overall reservoir ecological health evaluation for Douglas Reservoir were very poor at both the forebay and at the mid-reservoir sampling locations.

Values of pH ranged from 6.6 to 9.4 for both locations in Douglas Reservoir in 1993. In April through August at the forebay, and May through August at the mid-reservoir location, near surface pH's equal to or exceeding 8.5 were observed. In almost all of these cases, when the pH was above 8.5, surface dissolved oxygen saturation values exceeded 100 percent, indicating high levels of photosynthesis

In 1993, the average concentrations of total phosphorus (average 0.035 mg/l at the forebay and 0.040 mg/l at the mid-reservoir) were higher in Douglas Reservoir than any of the other tributary Vital Signs reservoirs; and, at the mid-reservoir sampling location the dissolved ortho phosphorus (average 0.013 mg/l) was also higher than any of the other tributary reservoirs. The Douglas mid-reservoir sampling site historically has had the lowest average TN/TP ratios of all the tributary reservoirs.

In 1993, concentrations of chlorophyll *a* averaged 6.6 µg/l at the forebay and 10.3 µg/l at the mid-reservoir site. These concentrations are somewhat lower than those measured in 1992, when they were among the highest of the Vital Signs reservoirs. The chlorophyll *a* ratings used in the 1993 ecological health evaluation for Douglas Reservoir were good at the forebay (i.e. falling in the 3 to 10 µg/l range); and fair at the mid-reservoir location (i e. falling in the 10 to 15 µg/l range)

The water of Douglas Reservoir, especially in the mid-reservoir area has historically had low water clarity In 1993, the Secchi depth averaged only 1.2 m, the lowest of all the tributary reservoir sampling locations.

Sediment—Chemical analyses of sediments in Douglas Reservoir in 1993 indicated the presence of chlordane (18 μg/kg) at the mid-reservoir site. Toxicity tests detected acute toxicity to rotifers (55 percent survival) in the mid-reservoir. Particle size analysis showed sediments from the forebay were about 100 percent silt and clay and from the mid-reservoir were 83 percent silt and clay, 17 percent sand.

Sediment quality ratings used in the overall Douglas Reservoir ecological health evaluation for 1993 were excellent at the forebay; and poor at the mid-reservoir site (presence of chlordane and toxicity to rotifers).

Benthic Macroinvertebrates—The forebay on Douglas Reservoir did not change significantly from the previous year. Only 265 organisms/m^2 representing 6 taxa were found, similar to the number of taxa (7) and density (282 organisms/m^2) found in 1992. The dominant taxa were Chironomus (50 percent) and Tubificidae (31 percent). The benthic macroinvertebrate community at this site was poor primarily because of the absence of long-lived and EPT taxa, and because of the abundance of chironomids. The benthic community structure observed at the forebay is indicative of low near-bottom dissolved oxygen concentrations.

The inflow site on Douglas Reservoir was not evaluated in 1993 because it was determined that 90 percent of the samples taken at that site were above the average winter pool level.

Fish Assemblage—Shoreline electrofishing (30 transects) and offshore/deep netting (24 net-nights) samples collected 2,679 fish of 29 species. The most abundant species were gizzard shad (29 percent), followed by white bass (20 percent), and largemouth bass (13 percent). The crappie species (black and white) represented 10 percent of the total sample. Electrofishing results indicated fish abundance in the transition (1,075) was twice that of the forebay (533) due mainly to much higher numbers of white bass, largemouth bass, and white crappie. Gill netting efforts showed a similar pattern, with the transition catch (884) considerably higher than the forebay (187). The only species that were more abundant in the forebay samples were smallmouth buffalo and black crappie.

The Reservoir Fish Assemblage Index (RFAI) analysis of shoreline electrofishing data showed the forebay (RFAI=42) zone to be good and the transition (RFAI=36) fair. Maximum metric scores were recorded at both sample areas for species diversity, number of sucker species, and dominance by a single species, and minimum scores for percent insectivores The gill netting RFAI rated the transition zone (RFAI=50) good and the forebay (RFAI=30) poor. Transition zone scores were midrange or maximum (3's or 5's) for all metrics except for number of intolerant species. Combined electrofishing and gill netting RFAI scores indicated good fish community conditions in the transition (RFAI=43) zone and fair in the forebay (RFAI=36).

Summary of Conditions in 1993 - Use Suitability

Fecal Coliform Bacteria—One swimming beach and two boat ramps were tested for fecal coliform bacteria twelve times in 1993 Two samples were collected within 48-hours of a rainfall of at least one-half inch. Fecal coliform bacteria concentrations were very low (geometric mean <20/100 ml) at every site.

Fish Tissue—TVA worked with the Tennessee Department of Environment and Conservation in 1992 to conduct fish tissue studies on Douglas Reservoir TVA collected the fish samples and provided fillets to TDEC for analysis. Results were not available at the time this report was prepared

French Broad River Stream Monitoring Site

Summary of 1993 Conditions - Ecological Health

Water—The water of the French Broad River is soft (average hardness of 18 mg/l) and only slightly alkaline (average total alkalinity of 20 mg/l), reflecting the underlying geology of the area The median pH for the stream monitoring site was 7.4. The river was well oxygenated with dissolved oxygen levels ranging from 87 to 99 percent of saturation.

Of the 12 streams monitored across the Tennessee Valley, the French Broad River station ranked among the highest in mean concentrations of total phosphorus (0.122 mg/l), dissolved orthophosphate (0.087 mg/l), and nitrate+nitrite-nitrogen (0.56 mg/l). Average concentrations of 0.220 mg/l and 0.030 mg/l for organic nitrogen and ammonia nitrogen placed the site near median for these variables. The high average total phosphorus concentration yielded a poor rating for nutrients at the site.

Seven analyses for priority pollutant metals (dissolved cadmium, lead, nickel, silver, and zinc and total copper and zinc) were performed bi-monthly. Dissolved cadmium was detected in 5 of 6 samples. Three of those exceeded the EPA criterion for chronic toxicity to freshwater aquatic life. (Chronic toxicity bioassays are not routinely performed at stream monitoring sites However, the acute toxicity test data is consistent with the water chemistry. See "Sediment" for additional information on toxicity testing results.)

Sediment—Sediment quality rated good in 1993 with no acute toxicity observed and no metals, PCBs, or pesticides exceeding the EPA guidelines This is an improvement over 1992 when sediment quality rated fair

Benthic Macroinvertebrates—In 1993, benthic macroinvertebrates rated fair with a Modified Benthic Index of Biotic Integrity (MBIBI) score of 36, with 77 taxa and 12,121 organisms/m^2. Conditions in 1992 also rated fair (MBIBI score 35) with 81 taxa and 10,961 organisms/m^2. Benthic organisms have essentially remained unchanged between sampling years. Dominant organisms in 1993 were dipteran midge larvae (67 percent), caddisflies (15 percent), and dipteran black-fly larvae (6 percent). Dipteran black-fly larvae was the most dominant organism in 1992 (49 percent), followed by dipteran midge larvae (36 percent) and caddisflies (5 percent). The French Broad River consistently ranks the poorest of the 12 stream monitoring sites. Siltation from agricultural land usage along the river severely affects benthic communities at this site.

Fish Community Assessment—The fish community continued to be depressed rating borderline poor with an Index of Biotic Integrity (IBI) score of 38 in 1993 and borderline poor (IBI = 36) in 1992. Serious problems were found in species richness and composition, and in fish density, indicating poor conditions Forty to 60 native species were expected to occur at this station, but only 30 were found. Diversity was low among darters, sunfish, suckers, and intolerant species. The proportion of tolerant fish was excessive representing approximately 41 percent of the fish found, and fish density was among the lowest found at the 11 stations sampled in 1993. Turbidity, siltation, and nutrient enrichment were evident and probably played some part in the disorder exhibited by the fish community.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—No bacteriological studies were conducted in this watershed by TVA in 1993.

Fish Tissue—A five fish composite each of carp, channel catfish, and largemouth bass were collected during summer 1992 and analyzed for selected metals, pesticides, and PCBs. All analytes were not detected or found in low concentrations.

Nolichucky River Stream Monitoring Site

Summary of 1993 Conditions - Ecological Health

Water—The water of the Nolichucky River is moderately hard (average hardness of 79 mg/l) and moderately alkaline (average total alkalinity of 67 mg/l). The median pH for the stream monitoring site was 7.8. The river was well oxygenated with dissolved oxygen levels ranging from 87 to 100 percent of saturation.

Of the 12 streams monitored across the Tennessee Valley, the Nolichucky River station ranked just above the median concentrations for average organic nitrogen (0.223 mg/l), nitrate+nitrite-nitrogen (0.56 mg/l), total phosphorus (0.075 mg/l), and dissolved orthophosphate (0.024 mg/l). An average concentration of ammonia nitrogen of 0.022 mg/l placed the site among the best for the variable. The moderately high average total phosphorus concentration yielded a fair rating for nutrients at the site.

Seven analyses for priority pollutant metals (dissolved cadmium, lead, nickel, silver, and zinc and total copper and zinc) were performed bi-monthly Dissolved cadmium was detected in 5 of 6 samples. Dissolved lead was detected in 2 of 6 samples. Neither metal exceeded the EPA criteria for protection of aquatic life or human health Additional metals analyses included both total and dissolved forms of manganese and iron. Total iron exceeded the chronic toxicity criterion for freshwater aquatic life in one sample and the criterion for combined consumption of fish and water in 4 samples. Total manganese was detected in 5 of 6 samples, although only one sample exceeded an EPA criterion value (for combined consumption of fish and water).

Sediment—Sediment quality rated good in 1993 with no acute toxicity observed and no metals, PCBs, or pesticides exceeding the EPA guidelines This is a significant improvement over 1992 when sediment quality rated poor.

Benthic Macroinvertebrates—In 1993, benthic macroinvertebrates rated fair with a Modified Benthic Index of Biotic Integrity (MBIBI) of score 39, with 81 taxa and 5,543 organisms/m^2. Conditions in 1992 were also rated fair (MBIBI score 39) with 91 taxa and 6,195 organisms/m^2. Dominant organisms in 1993 were dipteran midge larvae (32 percent), caddisflies (24 percent), and mayflies (19 percent). Dipteran midge larvae were also the most dominant group in 1992 (46 percent), followed by dipteran black-fly larvae (18 percent) and caddisflies (14 percent). Conditions have essentially remained unchanged between sampling years. Siltation from agricultural land usage along the river and mica and mica and feldspar mining in the watershed adversely affect benthic communities at this site.

Fish Community Assessment—The fish community rated good with an Index of Biotic Integrity (IBI) score of 48, improving considerably from the borderline fair (IBI = 38) rated in 1992. Improvement included a lower proportion of tolerant fish, a higher proportion of piscivorous fish, increased fish density, and absence of hybrids. Deficiencies in number of native species and in numbers of darter, sunfish, and intolerant species continued to indicate poor conditions. Excessive turbidity and heavy siltation have been observed at this station during all sampling trips, 1990-93.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—Bacteriological studies were not conducted in this watershed by TVA in 1993.

Fish Tissue—A five fish composite each of carp, channel catfish, and largemouth bass were collected during summer 1992 and analyzed for selected metals, pesticides, and PCBs. All analytes were not detected or found in low concentrations.

HOLSTON RIVER WATERSHED

Cherokee Reservoir

Summary of 1993 Conditions - Ecological Health

Water—Summer surface water temperatures ranged from 12.2°C in April to 29.8°C in July at the forebay, and from 14.4°C to 30.9°C for the same months at the mid-reservoir sampling location (Tennessee's maximum temperature criterion for the protection of fish and aquatic life is 30.5C). Thermal stratification was evident in Cherokee Reservoir in 1993. Stratification was strongest in June, when the temperature difference between the surface and the bottom of the reservoir was about 20°C at the forebay and about 18°C at the mid-reservoir location. Thermal stratification persisted through September at the forebay and through August at the mid-reservoir site

Dissolved oxygen at the 1 5m depth ranged from 15.2 mg/l (algal bloom) in April to 5.2 mg/l in September at the forebay, and from 14.2 mg/l (algal bloom) in April to 5.6 mg/l in July at the mid-reservoir sampling location. Anoxic conditions in the hypolimnion developed in the forebay in July and existed through October In July and August, dissolved oxygen concentrations were less than 1 mg/l for about three-fourths of the water column. Dissolved oxygen gradients (DO's) were high in the forebay (about 7 mg/l) in June, July, and August. The gradients were not as high in September and October because of the low surface dissolved oxygen. Similar conditions existed at the mid-reservoir sampling location where hypolimnetic anoxia existed near the bottom in July and August In July in the mid-reservoir location, three-fourths of the water column contained less than 1 mg/l dissolved oxygen. Dissolved oxygen gradients of 9.4 mg/l and 7 6 mg/l were observed in June and August, respectively Such a high gradient did not exist in July because of the low surface dissolved oxygen for that month The forebay and mid-reservoir sampling sites both had over 20% of their cross-sectional areas (six-month summertime average) with dissolved oxygen concentration less than 2.0 mg/l, and, over 40 percent of each site's cross-sectional bottom length (six-month summertime average) had a dissolved oxygen concentration less than 2.0 mg/l. Because of the conditions described above, DO ratings used in the overall reservoir ecological health evaluation for Cherokee Reservoir were very poor at both the forebay and at the mid-reservoir sampling locations.

In 1993, values of pH in Cherokee Reservoir ranged from 6.9 to 8.8 for both monitoring locations. Surface water pH values slightly exceeded 8.5 (Tennessee's maximum pH criterion for the protection of fish and aquatic life is 8 5) at the forebay in April through August, and at the mid-reservoir location in May through August. In each of these cases, with the exception of July at the mid-reservoir section, high dissolved oxygen saturation values coincided with the high pH's, sometimes up to 140 percent, indicating substantial photosynthetic activity.

Historically, the mid-reservoir sampling site has had the highest nutrient concentrations among all reservoir Vital Signs sampling locations. Average nutrient concentrations at the mid-reservoir location in 1993 were observed to be only about half of 1992 concentrations In 1993, the average total nitrogen concentration was 0.45 mg/l and the average total phosphorus concentration was 0.030 mg/l. Lower nutrient concentrations at the forebay as well as higher TN/TP ratios indicate a higher productivity potential at the mid-reservoir sampling site than at the forebay sampling site

Concentrations of chlorophyll *a* support this hypothesis where chlorophyll *a* averaged 7.6 µg/l at the forebay and 9.4 µg/l at the mid-reservoir site. The chlorophyll *a* ratings used in the 1993 ecological health evaluation for Cherokee Reservoir were good (i.e. falling in the 3 to 10 μg/l range), at both the forebay and the mid-reservoir locations

Sediment—Chemical analyses of sediments in Cherokee Reservoir in 1993 indicated high levels of copper (57 mg/kg) from the mid-reservoir and elevated levels of un-ionized ammonia from both the forebay (390 μg/l) and mid-reservoir (290 μg/l). Toxicity tests detected acute toxicity to rotifers (75 percent survival) in the mid-reservoir. Particle size analysis showed sediments from the forebay were about 100 percent silt and clay and from the mid-reservoir were 99 percent silt and clay.

Sediment quality ratings used in the overall Cherokee Reservoir ecological health evaluation for 1993 were good at the forebay (presence of ammonia); and poor at the mid-reservoir site (presence of copper and ammonia and toxicity to rotifers).

Benthic Macroinvertebrates—In 1993, the overall condition of the benthic macroinvertebrate community in the forebay of Cherokee Reservoir remained approximately the same as in 1992. However, there was a slight increase in taxa (14) and decrease in density (510 organisms/m^2). As in 1992, Tubificidae (45 percent) and Chironomus sp (26 percent) were the dominant taxa.

The forebay had a fair macroinvertebrate benthic community; problem characteristics were numbers of long-lived species and the abundance of chironomids. On a more positive note, this site exhibited excellent species diversity The Cherokee inflow benthic macroinvertebrate community improved substantially since last year, resulting in an excellent rating. The only factor that kept this site from receiving a perfect score for the benthic component was a slightly elevated number of chironomids in the sample The abundance of mayfly Hexagenia limbata, considered to be an intolerant, long-lived species, greatly improved the benthic community rating at the inflow.

Fish Assemblage—Fish sampling in shoreline (45 electrofishing transects) and offshore/deep areas (34 net-nights) of Cherokee Reservoir produced a total of 4,086 individuals including 33 species. The most numerous species was gizzard shad (35 percent), followed by bluegill (20 percent), and largemouth bass (14 percent) Species richness ranged from 24 in the transition , 25 in the forebay, to 27 in the inflow. Electrofishing results indicated higher abundance in the inflow (1,458), where gizzard shad and largemouth bass were most numerous, and in the forebay (1,104) where bluegill numbers were very high. Gill netting catch rates were progressively higher from inflow to forebay areas due largely to abundance of gizzard shad, quillback carpsuckers, and striped bass.

The Reservoir Fish Assemblage Index (RFAI) analysis of shoreline electrofishing data determined the quality of the littoral fish communities of the forebay (RFAI=32) and inflow (RFAI=34) zones to be fair and the transition (RFAI=30) to be poor. All three reservoir sample areas were rated fair based on gill netting RFAI's. Combined electrofishing and gill netting RFAI scores for the forebay (RFAI=36), transition (RFAI=34), and inflow (RFAI=35) zones of Cherokee Reservoir were all rated fair.

Summary of Conditions in 1993 - Use Suitability

Fecal Coliform Bacteria—One swimming beach, seven boat ramps, and the head of one small embayment were tested for fecal coliform bacteria twelve times in 1993. Two samples were collected within 48-hours of a rainfall of at least one-half inch Fecal coliform bacteria concentrations were very low (geometric mean <20/100 ml) at the swimming beach and at six of the boat ramps. At the Malinda Bridge boat ramp and at the head of Spring Creek Embayment, the geometric mean fecal coliform concentrations were between 20 and 50/100 ml, well below the Tennessee criterion for recreation.

Fish Tissue—Channel catfish were collected from Cherokee Reservoir as part of screening studies in autumn 1992 Results indicated low or nondetectable concentrations of metals. Mercury, known to be a problem in the North Fork Holston River, was 0.29 μg/g at the forebay with lower concentrations at the other two locations. The only organics found were PCBs and chlordane. Chlordane concentrations were low (maximum 0.07 μg/g) and PCB concentrations were generally similar to those in past years - 0.8, 0.5, and 0.5 μg/g at the forebay, transition zone, and inflow, respectively.

Fort Patrick Henry Reservoir

Summary of Conditions in 1993 - Ecological Health

Water—Average flow through Fort Patrick Henry Reservoir in 1993 was about 91 percent of normal. It is only stratified due to the continual release of cold water from the three upstream dams. The maximum temperature difference in the water column was 12.5°C in July. The maximum surface temperature was 27.8°C in July, well below Tennessee's maximum temperature criterion for aquatic life of 30.5°C. Low DO (<5.0 mg/l) conditions developed in July, August, and October, but DO never dropped below 2.2 mg/l. Absence of DO <2.0 mg/l gave Fort Patrick Henry Reservoir a good rating for DO in the reservoir ecological health index.

Conductivities varied widely from month to month and in the water column, but averaged the fourth highest of the 19 tributary reservoirs. The minimum was 150 µmhos/cm at the bottom of the water column in May, and the maximum was 216 µmhos/cm in September, also at the bottom of the water column. Surface pH reached or exceeded 9.0 in July, August, and September, while bottom pH never fell below 7.1.

Relatively high nutrient concentrations were found: the total nitrogen concentration in April was 1.08 mg/l, 72 percent as nitrates, and 0.63 mg/l in August, 62 percent as organic nitrogen. Total phosphorus concentrations were 0.02 mg/l in both surveys. Total organic concentrations were 2.0 mg/l in April and 2.8 mg/l in August Chlorophyll *a* concentrations tied for the fourth highest of the 33 tributary reservoir stations, averaging 10.3 µg/l. This chlorophyll concentration was considered fair in the reservoir ecological health index. Water clarity was low. Secchi depths ranged from 1.3 meters in September to 1.7 meters in July and August.

Sediment—Chemical analyses of sediments from the forebay of Fort Patrick Henry Reservoir in 1993 indicated slightly elevated levels of un-ionized ammonia (210 µg/l). Toxicity tests detected no toxicity to the two organisms tested. Particle size analysis showed sediments from the forebay were 99 percent silt and clay.

The sediment quality rating used in the overall Fort Patrick Henry Reservoir ecological health evaluation for 1993 was good at the forebay (presence of ammonia)

Benthic Macroinvertebrates—The first year that the benthic community in this tributary reservoir was evaluated was 1993 The forebay, the only sample location, had a fair benthic macroinvertebrate community with 11 taxa, 438 organisms/m^2, and Tubificidae as the dominant taxa (63 percent). The absence of EPT taxa and the abundance of tubificids negatively impacted the benthic community. An average representation of the long-lived species Corbicula fluminea, average taxa richness, and low numbers of chironomids were all positive attributes of the benthic community.

Fish Assemblage—Only the forebay zone was sampled on Fort Patrick Henry Reservoir in fall 1993. Shoreline electrofishing (15 transects) and offshore experimental gill netting (12 net-nights) yielded 1,251 individuals represented by 22 species. Fifty-one percent of the total catch consisted of spotfin shiners, followed by gizzard shad (23 percent), bluegill (7 percent), carp (6 percent), and largemouth bass (5 percent).

Fish community conditions were rated fair for both electrofishing (RFAI=38) and gill netting (RFAI=34) in the forebay zone of Fort Patrick Henry Reservoir. The overall RFAI of 36 also rated the reservoir forebay as fair.

Summary of Conditions in 1993 - Use Suitability

Fecal Coliform Bacteria—The boat ramp at Warriors Path State Park was tested for fecal coliform bacteria in 1993 The geometric mean concentration was 94/100 ml, well within Tennessee's Criterion for water contact recreation.

Fish Tissue—Autumn 1993 was the first time TVA had conducted fish tissue samples from Fort Patrick Henry Reservoir. Results were not available at the time this report was prepared.

Boone Reservoir

Summary of Conditions in 1993 - Ecological Health

Water—The average flow through Boone Reservoir in 1993 was about 97 percent of normal, with an average residence time of 38.5 days. Boone Reservoir has two large arms, the South Fork Holston River and Watauga River, their confluence is slightly more than one mile upstream of Boone Dam. Both arms receive cold water releases from the deep impoundments upstream. Consequently, Boone Reservoir remains stratified throughout the sampling period, with a maximum temperature difference in the water column at the forebay of 16.3°C in July. The maximum surface temperature was 28.9°C at the forebay in July, well below Tennessee's maximum temperature criterion for aquatic life of 30.5°C. DO depletion (DO <2.0 mg/l) at the forebay and in the South Fork Holston River arm was limited to the metalimnion from July through October. In the Watauga arm, DO depletion occurred at the bottom in September. The limited amount of DO depletion gave the forebay a good rating and both mid-reservoir stations fair ratings for DO in the reservoir ecological health index

Conductivities varied widely by month and depth. In the Watauga arm, conductivities ranged from 74 μmhos/cm at the bottom in May to 236 μmhos/cm in the metalimnion in September. In the South Fork Holston River arm, conductivities varied from 177 μmhos/cm at the surface to 264 μmhos/cm in the metalimnion in July. Conductivities in the forebay reflected the mixing of these two rivers. The minimum pH was 6.7 in the Watauga arm in September, while pH reached 9.1 in both the forebay and Watauga arm in the summer.

Total nitrogen concentrations on South Fork Holston River were the third highest of the 33 tributary reservoir stations. Total nitrogen concentrations in April ranged from 0.76 mg/l on the Watauga River to 1.07 mg/l on South Fork Holston River. About 60 percent of the total nitrogen was nitrates at each site. Nitrate concentrations had dropped by August to 0.03 mg/l or less at each station, bringing the average total nitrogen concentration to 0.41 mg/l, slightly higher at the mid-reservoir stations than at the forebay. Total phosphorus concentrations were 0.01 mg/l on the Watauga River and 0.02 mg/l at the other two sites in April. Total phosphorus concentrations dropped at the forebay from April to August to 0.008 mg/l, remained constant in the South Fork Holston River, and increased in the Watauga River to 0.03 mg/l. Dissolved ortho phosphorus concentrations were 0.003 mg/l in the Watauga River both months and at the forebay in April, and <0.002 for the other three samples The TN/TP ratios were high, 50:1 at the forebay and higher at the other two stations. Total organic carbon concentrations were high, ranging from 1 8 mg/l in the Watauga River to 2.7 mg/l in the forebay in April, and 3.8 mg/l at both mid-reservoir stations to 4 5 mg/l at the forebay in August. The forebay concentrations of total organic carbon were the fourth highest of the tributary reservoir locations.

The two mid-reservoir stations had the second and third highest chlorophyll concentrations of the tributary reservoir stations. Average chlorophyll *a* concentrations were 8.7 μg/l at the forebay, 11.9 μg/l in the South Fork Holston River, and 10.4 μg/l in the Watauga River. These concentrations are in the ranges considered good for the forebay and fair for the two mid-reservoir locations in the reservoir ecological health index. Water clarity was low at the mid-reservoir stations, Secchi depths varied from 1.0 meter in the South Fork Holston River in June to 1.5 meters at both stations in October. The South Fork Holston

River mid-reservoir station had the second lowest water clarity of the tributary reservoir stations. At the forebay, Secchi depths varied from 1.3 meters in May to 2.2 meters in October.

Sediment—Chemical analyses of sediments collected from three locations in Boone Reservoir in 1993 indicated very high levels of un-ionized ammonia at all three sites: 790 µg/l at the forebay sampling site, 660 µg/l at the South Fork Holston River (SFHR) mid-reservoir sampling site; and, 990 µg/l at the Watauga River (WR) mid-reservoir sampling site. Chlordane was also detected in sediment at all three sampling sites: 22 µg/kg at the forebay site; 35 µg/kg at the SFHR mid-reservoir site, and, 35 µg/kg at the WR mid-reservoir site. In addition, high levels of copper (58 mg/kg) and zinc (370 mg/kg) were found at the Watauga River mid-reservoir sampling site. However, no acute toxicity to daphnids nor rotifers was found at any of the three sampling sites. Particle size analysis showed sediments in the forebay were about 100 percent silt and clay; in the S. F. Holston River mid-reservoir were 99 percent silt and clay; and in the Watauga River mid-reservoir were 86 percent silt and clay, 14 percent sand.

Sediment quality ratings used in the overall Boone Reservoir ecological health evaluation for 1993 were good at the forebay as opposed to excellent because ammonia was elevated; good at the SFHR mid-reservoir site (presence of ammonia); and fair at the WR mid-reservoir site (presence of copper, zinc, and ammonia).

Benthic Macroinvertebrates—The first year that the benthic macroinvertebrate community was evaluated on Boone Reservoir was 1993. The forebay site had a poor benthic community, with 1,107 organisms representing a mere 10 taxa; Tubificidae (58 percent) and the tubificid Limnodrilus hoffmeisteri (38 percent) were the dominant taxa. The South Fork Holston River and the Watauga River mid-reservoir sites both had poor benthic communities. Both had only 11 taxa, but the South Fork Holston inflow had a lower density (615 organisms/m^2) than the Watauga inflow (267). The tubificids Limnodrilus sp and Tubificidae were the dominant taxa at both mid-reservoir sites comprising 91 percent of the total at the South Fork Holston site and 96 percent of the total at the Watauga site.

The forebay and both inflows were negatively impacted by the absence of long-lived and EPT taxa, and the abundance of tubificids. If not for the relatively low proportion of chironomids, all sites would have received a "very poor" benthic rating.

Fish Assemblage—Electrofishing (45 transects) and gill netting (34 net-nights) results from Boone Reservoir yielded 2,439 individuals of 23 species. Bluegill were the most abundant species, comprising 29 percent of the total number of fish sampled. Other species making up a significant portion of the reservoir sample included gizzard shad (21 percent), spotfin shiners (21 percent), and carp (9 percent). Fish abundance was greater in the Watauga River transition zone (1,414), followed by the South Fork Holston River transition (632) and the forebay (393). Both electrofishing and gill netting total catch rates followed the same pattern as abundance.

The Reservoir Fish Assemblage Index (RFAI) rated the quality of the littoral community (as determined by electrofishing samples) fair in the Holston River transition (RFAI=32) and poor in both the Watauga River transition (RFAI=28) and forebay zones (RFAI=26). Minimum metric scores for diversity, and number of intolerant and lithophilic spawning species were recorded for all stations. The gill netting RFAI followed the same pattern as electrofishing, rating the Holston River transition (RFAI=36) fair, and both the Watauga River transition (RFAI=28) and forebay (RFAI=26) zones poor. Scoring at all zones revealed scattered values for most metrics with the exception of maximum scores (5) for percent anomalies, and minimum scores (1) for percent tolerant and omnivorous species.

Combined electrofishing and gill netting RFAI scores for both the forebay (RFAI=26) and Watauga River transition (RFAI=28, which was the lowest tributary transition RFAI recorded in 1993) rated poor and the Holston River transition zone (RFAI=34) rated fair.

Summary of Conditions in 1993 - Use Suitability

Fecal Coliform Bacteria—Two swimming areas and four boat ramps were each tested for fecal coliform bacteria twelve times in 1993. No samples were collected within 48-hours of a rainfall of at least one-half inch. Bacteria concentrations were very low (geometric mean <20/100 ml) at the four boat ramps. The geometric mean fecal coliform concentration at the swimming beaches were 106 and 51/100 ml, well within Tennessee's criterion of 200/100 ml for water contact recreation. One sample at the Boone Dam recreation area exceeded Tennessee's maximum concentration criterion for one sample of 1000/100 ml.

Fish Tissue—Past studies conducted by the state of Tennessee found PCBs and chlordane in fish tissue, resulting in a state issued advisory that catfish and carp should not be eaten by children, pregnant women, and nursing mothers. Further, all other people should limit their consumption of these particular fish Fish samples were collected by TVA in autumn 1993, but results were not available at the time this report was prepared.

South Holston Reservoir

Summary of Conditions in 1993 - Ecological Health

Water—The average flow through South Holston Reservoir in 1993 was near normal with an average residence time of about 341 days. The reservoir was strongly stratified, with a maximum temperature difference in the forebay water column of 21.9°C in July. The maximum surface temperature was 28.3°C at the forebay in July, well below Tennessee's maximum temperature criterion for aquatic life of 30.5°C. DO depletion (DO <2.0 mg/l) occurred in both the metalimnion and at the bottom of the water column. Areas of DO depletion began in July at mid-reservoir and August at mid-reservoir. Because the water was clearer at the forebay than at mid-reservoir and the photic zone was deeper, metalimnetic DO depletion occurred at deeper depths in the forebay than at mid-reservoir and the area of low DO was not mixed as the surface cooled in October as was the case at mid-reservoir. For the reservoir ecological health index, DO was considered fair at the forebay and poor at mid-reservoir.

Conductivities varied widely by month and depth, from a minimum of 72 µmhos/cm in May near the bottom at the forebay to 270 µmhos/cm at the mid-reservoir bottom in September. Surface pH was between 8.5 and 9.0 at both stations each month except for April at the forebay The minimum pH was 7.1 at mid-reservoir in September

Total nitrogen concentrations were 0 75 and 1.08 mg/l in April at the forebay and mid-reservoir, respectively, about three-fourths as nitrates. In August, the total nitrogen concentration had dropped to 0 36 mg/l at both stations, primarily due to a decline in nitrates. The mid-reservoir total nitrogen concentrations were the fourth highest of the 33 tributary reservoir stations. In April, total and dissolved ortho phosphorus concentrations were 0.01 and 0.003 mg/l at the forebay and 0.02 and 0.003 mg/l at mid-reservoir. In August, total phosphorus was <0.002 mg/l at the forebay and 0.003 at mid-reservoir TN/TP ratios were very high, over 50 in April and over 100 in August. Total organic carbon concentrations varied only from 1.7 mg/l in April to 2 7 mg/l in August, both concentrations at mid-reservoir.

Average chlorophyll *a* concentrations were 3.4 µg/l at the forebay and 7.0 µg/l at mid-reservoir. These concentrations are in the range considered good in the reservoir ecological health index. Secchi depths varied from 1.6 m in April to 2.3 m in September and October at mid-reservoir and from 2.0 m in May to 5.75 m in June at the forebay. The forebay had the fourth clearest water of the 19 tributary reservoir forebays

Sediment—Chemical analyses of sediments in South Holston Reservoir in 1993 indicated the presence of chlordane (12 µg/kg) and un-ionized ammonia (310 µg/l) in the mid-reservoir. Toxicity tests detected no acute toxicity to daphnids or rotifers, however survival of daphnids (75 percent survival) was reduced in the forebay Particle size analysis showed sediment in the forebay were 99 percent silt and clay, and in the mid-reservoir were 98 percent silt and clay.

Sediment quality ratings used in the overall South Holston Reservoir ecological health evaluation for 1993 were good at the forebay as opposed to excellent due to reduced survival of daphnids) and good at the mid-reservoir site (presence of ammonia and chlordane).

Benthic Macroinvertebrates—The first year that the benthic macroinvertebrate community was evaluated on the South Holston Reservoir was 1993. The forebay site had a very poor community, with only 3 taxa, 98 organisms/m^2, and the tolerant Tubificidae comprising 97 percent of the total. The inflow site rated somewhat better with 13 taxa and 354 organisms/m^2, dominated by Tubificidae (69 percent).

The forebay site had very poor benthic community structure as indicated by low diversity, the absence of EPT and long-lived taxa, and the preponderance of tubificids; a low number of chironomids was the only metric that kept this site from receiving the lowest possible score. The inflow site had a fair benthic representation, but an absence of EPT taxa and an abundance of tubificids were negative attributes of the community. As was the case at the forebay, a low number of chironomids found at the site was a considered a positive indicator. Diversity and the presence of long-lived species allowed the inflow site to receive a better rating than the forebay site.

Fish Assemblage—Fish samples taken in the shoreline areas (30 electrofishing transects) and offshore/deep areas (24 net-nights) of South Holston Reservoir produced a total of 2,160 individuals represented by 27 species. Fish density and diversity was similar between the forebay (1,246 individuals of 20 taxa) and transition zone (914 individuals of 23 taxa) No inflow zone sample was collected from South Holston Reservoir. The three most abundant species were spotfin shiner (46 percent), gizzard shad (10 percent), and bluegill (8 percent). Other abundant species included black crappie and walleye at six percent, and white bass at five percent of the total catch. Gill netting results indicated an increase from 1992 estimates in black crappie numbers in both forebay and transition zones.

RFAI analysis of electrofishing data determined the quality of the littoral fish community in the transition zone (RFAI=40) and forebay (RFAI=38) to be fair. Gill netting RFAI rated the transition (RFAI=32) fair and forebay (RFAI=50) good. Forebay scores for all metrics were maximum except for number of sunfish and sucker species, and percent insectivores. The forebay score of 50 represented a substantial improvement from the previous sample season (1992 RFAI=28). Combined electrofishing and gill netting RFAI scores rated the forebay (RFAI=44) zone good and the transition (RFAI=36) fair.

Summary of Conditions in 1993 - Use Suitability

Fecal Coliform Bacteria—One informal swimming area and three boat ramps were each tested for fecal coliform bacteria twelve times in 1993. No samples were collected within 48-hours of a rainfall of at least one-half inch. Fecal coliform bacteria concentrations were very low (geometric mean concentration <20/100 ml) at all four sites.

Fish Tissue—There are no fish consumption advisories on South Holston Reservoir. The most recent TVA data for fish tissue samples are for fish collected in autumn 1991. The single composite of channel catfish from the forebay had low or nondetectable concentrations of all pesticides, PCBs, and metals (except mercury). The mercury concentration was 0.42 µg/g, just high enough to be of interest. Additional fish tissue samples were collected from the forebay in autumn 1993, but results were not available at the time this report was prepared.

Watauga Reservoir

Summary of Conditions in 1993 - Ecological Health

Water—The average flow through Watauga Reservoir in 1993 was near normal with an average residence time of about 404 days. Watauga Reservoir was strongly stratified with a maximum temperature difference in the forebay water column of 21.3°C in July. The maximum surface temperature was 28.8°C at mid-reservoir in July, less than Tennessee's maximum temperature criterion for aquatic life of 30.5°C. At the forebay, the area of DO depletion (DO < 2.0 mg/l) was limited to the bottom of the water column in October. At mid-reservoir, areas of DO depletion developed in both the metalimnion and at the bottom of the reservoir in September and October. The limited amount of DO depletion gave the forebay a rating of good and mid-reservoir a rating of fair for DO in the reservoir ecological health index.

The maximum conductivity was 101 µmhos/cm at the forebay and 96 µmhos/cm at mid-reservoir, both at the bottom of the water column in September. At both stations pH reached 9.0 near the surface, the minimum pH was 6.5 in the mid-reservoir metalimnion in September.

Total nitrogen concentrations in April were 0.80 mg/l at mid-reservoir and 0.61 mg/l at the forebay, about three-fourths of the total at each site as nitrates. The total nitrogen concentration in August was about half the April total with the reduction due to a decline in nitrate concentrations as organic nitrogen concentrations rose slightly. Total phosphorus concentrations in April were 0.02 mg/l at mid-reservoir and 0.01 mg/l at the forebay. August concentrations were about half of the April total. TN/TP ratios were 40 or higher for each sample Dissolved ortho phosphorus concentrations were at or below the detection limit of 0.002 mg/l for all four samples. Total organic carbon concentrations at mid-reservoir were 1.8 and 3.2 mg/l in April and August, respectively, and 2.1 mg/l at the forebay in August.

The average chlorophyll *a* concentration was 4.1 µg/l at the forebay and 5.9 µg/l at mid-reservoir. These concentrations are in the good range for the reservoir ecological health index. Secchi depths varied at the forebay from 1.3 m in April to 3.9 m in May, and at mid-reservoir from 1.7 m in April to 4.2 m in September.

Sediment—Chemical analyses of sediments in Watauga Reservoir in 1993 indicated the presence of chlordane in both forebay (22 µg/kg) and in the mid-reservoir (36 µg/kg) Elevated levels of un-ionized ammonia (260 µg/l) were found in the forebay Toxicity tests detected acute toxicity to daphnids (0 percent survival) and rotifers (5 percent survival) in the forebay. Particle size analysis showed sediments in the forebay were about 100 percent silt and clay, and in the mid-reservoir were 99 percent silt and clay.

Sediment quality ratings used in the overall Watauga Reservoir ecological health evaluation for 1993 were poor at the forebay (acute toxicity to daphnids and rotifers and presence of chlordane and ammonia); and good at the mid-reservoir site (presence of chlordane).

Benthic Macroinvertebrates—The first year that the benthic macroinvertebrate community was evaluated on Watauga Reservoir was 1993. The forebay and mid-reservoir sites both had very poor benthic communities with only 7 and 9 taxa, respectively, and 158 and 60 organisms/m^2, respectively. The forebay was dominated by Tubificidae (79 percent of the total) and the inflow was dominated by the chironomid Einfeldia sp (53 percent).

Scores at both sites were negatively influenced by three common factors: low diversity, the absence of EPT taxa, and the absence of long-lived taxa. An interesting difference was observed between the forebay and inflow sites on Watauga: the forebay site was overwhelmingly dominated by the tubificids which negatively impacted the community rating, but very few chironomids were found, whereas the inflow site was overwhelmingly dominated by chironomids which negatively impacted the rating at that site, but very few tubificids were found.

Fish Assemblage—Combined fish samples in shoreline electrofishing (30 transects) and offshore gill netting (24 net-nights) produced a total of 1,102 individuals including 20 species in the transition and forebay zones of Watauga Reservoir. No sampling was conducted in the inflow zone. Fish were more abundant in the transition zone (63 percent of total) but diversity was similar in both sample areas (14 taxa in the forebay and 17 in the transition). The three dominant species by number were bluegill (23 percent), gizzard shad (20 percent), and walleye (16 percent). Other common species were spotfin shiners (11 percent), and rockbass (9 percent).

Analysis of shoreline electrofishing data identified a very poor littoral fish community in the forebay zone (RFAI=20) of Watauga Reservoir. In fact, the forebay score of 20 was the lowest observed (in both 1992 and 1993) in comparable areas of other tributary reservoirs that were sampled. The low forebay RFAI resulted from minimum scores in eight of the twelve metrics used for evaluation. Although the transition zone (RFAI=40) fish community rated only fair, it did receive maximum scores in five of the twelve metrics. Gill netting RFAI evaluations rated the transition zone (RFAI=34) fair and forebay (RFAI=30) poor. The slightly lower forebay rating resulted from minimum scores for six of the twelve metrics.

Combined electrofishing and gill netting RFAI score of 25 indicated a poor rating for the forebay (only Parksville Reservoir had a lower forebay score). The transition zone (RFAI=37) rated fair.

Summary of Conditions in 1993 - Use Suitability

Fecal Coliform Bacteria—The swimming beach at Shook Branch Recreation Area and an informal swimming area at Watauga Point and three boat ramps were tested for fecal coliform bacteria twelve times each in 1993. No sample was collected within 48-hours of a rainfall of one-half inch or greater Fecal coliform bacteria concentrations were very low (geometric mean concentration <20/100 ml) at all five sites.

Fish Tissue—There are no fish consumption advisories on Watauga Reservoir. The most recent fish tissue collections by TVA were made in autumn 1991. All pesticides, PCBs, and metals (except mercury) were low or not detected in the single channel catfish composite from the forebay. The mercury concentration was 0.53 μg/g. Additional fish tissue screening samples were collected in autumn 1993, but results were not available at the time this report was prepared.

Holston River Stream Monitoring Site

Summary of 1993 Conditions - Ecological Health

Water—The water of the Holston River is moderately hard (average hardness of 113 mg/l) and moderately alkaline (average total alkalinity of 94 mg/l). The median pH for the stream monitoring site was 8.0. The river was well oxygenated with dissolved oxygen levels ranging from 88 to 106 percent of saturation.

Of the 12 streams monitored across the Tennessee Valley, the Holston River station ranked among the highest in average nitrate+nitrite-nitrogen (0.67 mg/l) and just above the median for average total phosphorus (0.112 mg/l), dissolved orthophosphate (0.057 mg/l), and ammonia nitrogen (0.038 mg/l). The average concentration of organic nitrogen (0.185 mg/l) was among the lowest recorded. The high average total phosphorus and average nitrate+nitrite-nitrogen concentrations yielded a poor rating for nutrients at the site.

Seven analyses for priority pollutant metals (dissolved cadmium, lead, nickel, silver, and zinc and total copper and zinc) were performed bi-monthly. Dissolved cadmium was detected in 4 of 6 samples. Dissolved nickel was detected in 1 of 6 samples. Neither metal exceeded EPA criteria for protection of aquatic life or human health.

Sediment—Sediment quality rated good in 1993 with no acute toxicity observed No PCBs or pesticides exceeding the EPA guidelines. However, copper was detected at a level slightly above the EPA guideline for copper in sediment. This was an improvement over 1992 when sediment quality rated fair.

Benthic Macroinvertebrates—In 1993, benthic macroinvertebrates rated fair with a Modified Benthic Index of Biotic Integrity (MBIBI) score of 36, with 59 taxa and 4,673 organisms/m^2. Conditions in 1992 also rated fair (MBIBI score 41) with 50 taxa and 3,311 organisms/m^2. Dominant organisms in 1993 were dipteran midge larvae (30 percent), dipteran black-fly larvae (25 percent), and river snails (10 percent). River snails were the most dominant group in 1992 (43 percent), followed by coleopteran riffle beetles (10 percent) and caddisflies (7 percent). Siltation from agricultural land usage along the river and pollution from industries located upstream have a major impact on benthic organisms at this site.

Fish Community Assessment—The fish community rated good with an Index of Biotic Integrity (IBI) score of 48, improving from a rating of fair (IBI = 44) in 1992. Improvement was seen mainly in decreased proportions of both tolerant fish and omnivorous fish suggesting some relief from chronic nutrient enrichment of the river. Other problems for the fish community continued to be reflected by low numbers of darter, sunfish, sucker, and other native species, and low proportions of piscivorous fish. Adverse conditions observed were nutrient enrichment (evident in the abundance of aquatic vegetation), and alteration of flow by releases from Fort Patrick Henry Dam.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—Seven sites on South Fork Holston River were tested twelve times each for fecal coliform bacteria in 1993. No samples were collected within 48-hours of a rainfall of at least one-half inch. Six sites were located between South Holston Dam and Boone Reservoir. Thomas and Beidleman Creeks were sampled near their confluence with South Fork Holston River. The geometric mean concentration of fecal coliforms on both streams were about 250/100 ml, a little higher than Tennessee's water quality criterion for recreation of 200/100 ml. The other sites were on South Fork Holston River. The two sites between the South Holston Weir and the confluence with Thomas Creek and the site downstream of Thomas Creek but upstream of Beidleman Creek all had very low fecal coliform bacteria concentrations (geometric mean <20/100 ml). The site downstream of Beidleman Creek had a geometric mean concentration of 31/100 ml, and the site downstream of Boone Dam at Fordtown Bridge had a geometric mean concentration of 52/100 ml Three sites on South Fork Holston River are boat launching sites. Samples at the other sites were taken from the middle of the stream off a bridge, including a footbridge at the most upstream site.

Fish Tissue—A five fish composite each of carp, channel catfish, and largemouth bass were collected during summer 1992 and analyzed for selected metals, pesticides, and PCBs. All analytes were not detected or found in low concentrations except slightly elevated levels of mercury in largemouth (0.57 μg/g), PCBs in carp (0.6 μg/g), and chlordane in channel catfish (0.08 μg/g).

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