ORNL/TM-13743

ornl

OAK RIDGE NATIONAL LABORATORY

LOCKHEED MARTIN

ENVIRONMENTAL SCIENCES DIVISION

Report on the Watershed Monitoring Program at the Paducah Site January–December 1998

L. A. Kszos
M. J. Peterson
M. G. Ryon
G. R. Southworth

Environmental Sciences Division
Publication No. 4855

March 1999

MANAGED AND OPERATED BY
LOCKHEED MARTIN ENERGY RESEARCH CORPORATION
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

ORNL-27 (3-96)

ORNL/TM-13743

ENVIRONMENTAL SCIENCES DIVISION

Report on the Watershed Monitoring Program at the Paducah Site January–December 1998

L. A. Kszos
M. J. Peterson
M. G. Ryon
G. R. Southworth

Environmental Sciences Division
Publication No. 4855

Date of Issue — March 1999

Prepared for
V. W. Jones
Environmental Compliance
Bechtel Jacobs Company LLC

Prepared by the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831-6285
managed by
LOCKHEED MARTIN ENERGY RESEARCH CORP.
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-96OR22464

CONTENTS

CONTENTS (Continued)

FIGURES

Figure **Page**

TABLES

Table **Page**

TABLES (Continued)

Table **Page**

ACRONYMS

ANOVA	analysis of variance
BMAP	Biological Monitoring and Abatement Program
BMP	Biological Monitoring Program
BBK	Big Bayou Creek kilometer
DCBP	decachlorobiphenyl
DOE	U.S. Department of Energy
ESD	Environmental Sciences Division
EPA	U.S. Environmental Protection Agency
FDA	U.S. Department of Agriculture Food and Drug Administration
GC/ECD	gas chromatography/electron capture detection
GLM	general linear model
IC	inhibition concentration
KDOW	Kentucky Division of Water
KPDES	Kentucky Pollutant Discharge Elimination System
LOAEL	Lowest observable adverse effect level
LMES	Lockheed Martin Energy Systems, Inc.
LMUS	Lockheed Martin Utility Systems, Inc.
LUK	Little Bayou Creek kilometer
MAK	Massac Creek kilometer
MS-222	tricaine methanesulfonate
NOAEL	No observable adverse effect level
NCBP	National Contaminant Biomonitoring Program
NOEC	no-observed-effect concentration
NPDES	National Pollutant Discharge Elimination System
ORNL	Oak Ridge National Laboratory
PCB	polychlorinated biphenyl
PGDP	Paducah Gaseous Diffusion Plant
QA	quality assurance
RCRA	Resource Conservation and Recovery Act
RGA	regional gravel aquifer
RCW	recirculating cooling water
SAS	statistical analysis system
SD	standard deviation
SE	standard error
TRC	total residual chlorine
TU	toxicity unit(s)
TU_a	acute toxicity units
TUc	chronic toxicity unit(s)
USEC	United States Enrichment Corporation
USFWS	U.S. Fish and Wildlife Service

USGS	U.S. Geological Service
WKWMA	West Kentucky Wildlife Management Area

ACKNOWLEDGMENTS

We thank all those individuals who assisted with the field sampling, including W. K. Roy, J. G. Smith, and M. K. McCracken of the Oak Ridge National Laboratory (Environmental Sciences Division ESD); and B. A. Carrico of American Aquatics. We thank the staff of the ORNL ESD toxicology laboratory, including B. K. Konetsky and G. W. Morris for providing outstanding technical assistance. We thank S. A. Harper, D. S. Zingg, and M. L. Moore of the ORNL Analytical Services Organization for conducting contaminant analyses. We thank Paducah Community College for the use of their facilities for toxicity monitoring. We thank P. L. Henry for electronic publishing support, E. B. Bryant for editorial support, and J. G. Smith for reviewing an earlier draft.

This project was funded by Environmental Management, Bechtel Jacobs Company LLC. The Environmental Management Activities at the Paducah Site are managed by Bechtel Jacobs Company LLC, under contract DE-AC05-98OR22700 with the U.S. Department of Energy. Oak Ridge National Laboratory is managed by Lockheed Martin Energy Research Corp. for the U.S. Department of Energy under contract number DE-AC05-96OR22464.

EXECUTIVE SUMMARY

Watershed Monitoring of Big Bayou and Little Bayou creeks has been conducted since 1987. The monitoring was conducted by the University of Kentucky between 1987 and 1991 and by staff of the Environmental Sciences Division (ESD) at Oak Ridge National Laboratory (ORNL) from 1991 to present. The goals of monitoring are to (1) demonstrate that the effluent limitations established for DOE protect and maintain the use of Little Bayou and Big Bayou creeks for growth and propagation of fish and other aquatic life, (2) characterize potential environmental impacts, and (3) document the effects of pollution abatement facilities on stream biota. The watershed (biological) monitoring discussed in this report was conducted under DOE Order 5400.1, General Environmental Protection Program. Future monitoring will be conducted as required by the Kentucky Pollutant Discharge Elimination System (KPDES) permit issued to the Department of Energy (DOE) in March 1998. A draft Watershed Monitoring Program plan was approved by the Kentucky Division of Water and will be finalized in 1999. The DOE permit also requires toxicity monitoring of one continuous outfall and of three intermittent outfalls on a quarterly basis.

The Watershed Monitoring Program for the Paducah Site during calendar year 1998 consisted of three major tasks: (1) effluent toxicity monitoring, (2) bioaccumulation studies, and (3) ecological surveys of fish communities. This report focuses on ESD activities occurring from January 1998 to December 1998, although activities conducted outside this time period are included as appropriate.

Study Area

The Paducah Site is located in western Kentucky and owned by DOE. Effective July 1, 1993, DOE leased the plant production operations facilities to the United States Enrichment Corporation (USEC). Lockheed Martin Corporation created a new subsidiary, Lockheed Martin Utility Services (Utility Services), to manage the leased facilities for USEC under the prior management contract. Under the terms of the lease, USEC has assumed responsibility for compliance activities directly associated with uranium enrichment operations. Bechtel Jacobs Company LLC is the management contractor for DOE responsibilities at the site. These responsibilities include the site Environmental Restoration Program; the Depleted Uranium Hexafluoride (DUF_6 Cylinder Program); the bulk of the Waste Management Program, including waste inventories predating July 1, 1993; wastes generated by current DOE activities; wastes containing "legacy" constituents, such as asbestos, polychlorinated biphenyls (PCBs) and transuranics; and KPDES compliance at outfalls not leased to USEC.

The Paducah Site is located in the western part of the Ohio River basin. Surface drainage from the Site enters Big Bayou Creek and Little Bayou Creek, two small tributaries to the Ohio River. Big Bayou Creek is a perennial stream with a drainage basin extending from ~4 km south of the Paducah Site to the Ohio River. Part of its 14.5-km course flows along the western boundary of the Reservation. Little Bayou Creek originates in the Western Kentucky Wildlife Management Area and flows for 10.5 km north toward the Ohio River; its course includes part of the eastern boundary of the Paducah Site.

Three sites on Big Bayou Creek—Big Bayou Creek kilometer (BBK) 12.5, BBK 10.0, and BBK 9.1—one site on Little Bayou Creek, Little Bayou Creek kilometer (LUK) 7.2; and one off-site reference station on Massac Creek, Massac Creek kilometer (MAK) 13.8, were sampled to assess the fish communities. Three sites on Little Bayou Creek (LUK 9.0, LUK 7.2, LUK 4.3) and one site on Big Bayou Creek (BBK 9.1) were sampled to assess the bioaccumulation of contaminants in fish. An offsite reference site (MAK 13.8) served as a source of non-contaminated fish. Fish community sampling was conducted in the fall. Sampling for the bioaccumulation of PCBs and mercury in fish was conducted twice per year and once per year, respectively. KPDES outfalls evaluated for effluent toxicity in 1998 included 001, 015, 017, and 019.

Toxicity Monitoring

Ceriodaphnia dubia[1] and fathead minnow toxicity tests of effluents from the continuously flowing outfall 001 and intermittently flowing outfalls 015, 017, and 019 were conducted quarterly as required by the KPDES permit. As required by the KPDES permit, short-term, 48-h toxicity tests (also known as acute tests) were conducted for outfalls 015, 017, and 019; and longer term, 6- or 7-d toxicity tests (also known as chronic tests) were conducted for Outfall 001. For the acute toxicity test data, the 48-h LC_{50} (concentration that is lethal to 50% of the test organisms) was determined and the acute toxicity unit (TUa) was calculated ($TUa = 100/LC_{50}$). For the chronic toxicity test data, the 25% inhibition concentration (IC25, that concentration causing a 25% reduction in fathead minnow growth or *Ceriodaphnia* reproduction compared to a control) was determined and the chronic toxicity unit (TUc) was calculated ($TUc = 100/IC25$) . The TUa and TUc are compliance endpoints in the KPDES permit. For permitting purposes, the Kentucky Division of Water (KDOW) has determined that Little Bayou and Big Bayou creeks have a low flow of zero; thus a $TU > 1.0$ for the would be considered a noncompliance and an indicator of potential instream toxicity. A $TU \geq 1.2$ is considered a significant non-compliance.

During 1998, effluent from outfalls 001, 015, and 019 never exceeded the permit limit (TUc or $TUa = 1.0$). Effluent from Outfall 017 exceeded the permit limit in October with a TUa of 1.5. The confirmatory test conducted in December resulted in a TUa of 2.2. An analysis of the chronic toxicity test data from January 1993 to July 1998 for acute toxicity (LC_{50}) showed that, during this time period, there were no occurrences of an $LC_{50} \leq 100\%$ or a $TUa \geq 1.0$. Because the toxicity test results for Outfall 017 in October and December were each considered a significant noncompliance ($TUa > 1.2$), a plan for a Toxicity Reduction Evaluation per EPA guidance has been submitted to the KDOW for approval. This plan will be used to determine which measures are necessary to maintain the toxicity of effluent from Outfall 017 at permitted levels ($TUa < 1.0$).

---

[1]*Ceriodaphnia dubia*, commonly known as the waterflea, is a small crustacean commonly accepted as a standard test organism.

Bioaccumulation

Bioaccumulation monitoring conducted to date identified PCB contamination in fish in Little Bayou Creek, and to a lesser extent, Big Bayou Creek, as primary concerns. Mercury concentrations in fish in Big Bayou Creek were found to be higher in fish downstream from Paducah Site discharges than in fish from an upstream site. The main objective of the 1997–1998 bioaccumulation monitoring was to evaluate spatial and temporal changes in PCB contamination in fish from Little Bayou creek. Monitoring for mercury and PCBs in fish from Big Bayou Creek was restricted to spotted bass. Longear sunfish (*Lepomis megalotis*) were collected for PCB and mercury analysis from Little Bayou Creek in October 1997, April 1998, and October 1998. Spotted bass were collected from Big Bayou Creek in October 1997 and October 1998. Massac Creek in McCracken County, Kentucky, was used as reference site, providing data on background concentrations at an uncontaminated site and samples for use as analytical controls.

Mean PCB concentrations in *L. megalotis* from Little Bayou Creek were higher than in fish from the reference site on all sampling dates. Highest concentrations were found at LUK 9.0, the site nearest Paducah Site discharges, although in October 1997 and April 1998 there was little difference in mean PCB concentration in sunfish at LUK 9.0 and LUK 7.2, the next site downstream. In October 1998, the pattern typical of the early 1990s was observed, with PCB concentrations at LUK 9.0 being much higher than those at sites downstream. The flattening of the downstream profile and generally decreasing mean PCB concentrations over time that was observed prior to fall 1998 were taken as evidence of decreased PCB inputs from nonpoint sources within the Paducah Site storm drain network. The increase in concentration levels in fall 1998 points out the highly variable nature of those sources and illustrates the need for a better understanding of the nature of PCB sources within the Paducah Site and the mechanisms by which PCBs are mobilized from those sources. The fact that levels of PCB contamination in fish in Little Bayou Creek continue to be low provides evidence of effective controls and remediation of sources within the Paducah Site. Continued monitoring will help assess whether additional controls are needed.

Mean mercury concentrations in bass from Big Bayou and Little Bayou creeks in 1998 were substantially lower than was observed in previous years. Low mercury concentrations in 1997, previously assumed to be an artifact of fish size, may indeed have been part of a decreasing trend. Mercury concentration in bass from Big Bayou Creek appear to be typical of, or perhaps now lower than, concentrations in fish from uncontaminated streams in the vicinity of the Paducah Site. The decline in mercury bioaccumulation may be associated with increased addition of sodium thiosulfate at USEC Outfall 004. We hypothesize that such additions may have affected the bioavailability of inorganic mercury or the population of microorganisms that convert inorganic mercury to methylmercury (the form of mercury which bioaccumulates in fish).

Fish Community Monitoring

Quantitative sampling of the fish community was conducted at three sites in Big Bayou Creek, one site in Little Bayou Creek, and at one offsite reference station (Massac Creek) during September 1998. Data on the fish communities of Big Bayou Creek and Little Bayou Creek downstream of the Paducah Site were compared to data from reference sites located on Big Bayou Creek above KPDES discharges from the Paducah Site and on Massac Creek. These comparisons indicated a slight but noticeable degradation in the communities downstream of inputs from the Paducah Site. Effects on the fish community were greatest at BBK 10.0. The fish community at this site had a low species richness and were missing more sensitive fish species such as benthic insectivores, suckers, and darters. The lower species richness, compared with reference sites, may be a result of thermal influences associated with outfalls (see Roy et al. 1996). Although the temperatures are not lethal, they could produce avoidance of the areas of Big Bayou Creek near the plant discharges.

The fish community at BBK 9.1 showed signs of impact but at less severe levels than at BBK 10.0 and less severe than earlier sampling at this site. Species richness was at a high level, and two new species were taken at the site. One species, the brook silverside (*Labidesthes sicculus*), had not been reported previously from the Big Bayou Creek watershed. The number of intolerant species was higher than at BBK 10.0, indicating that the fish community was intermediate between that site and the reference site. As with conditions at BBK 10.0, productivity estimates at BBK 9.1 continued to improve from past years. These trends indicate a lessening of impacts on recruitment success for the fish community at BBK 9.1.

The fish community at LUK 7.2 was similar in many ways to that at the BBK 12.5 reference site. The species richness and biomass were similar to those of the reference site. However, density declined to a new low for fall sampling at this site. The general decline in density at LUK 7.2 appears linked to a widely based decline in richness and abundance of the minnow species at the site. Also, unlike conditions in Big Bayou Creek sites, productivity declined in 1998. Generally, the conditions at LUK 7.2 indicate minor impacts associated with operations at the Paducah Site, but the decline in densities should be closely monitored as it could be indicative of more substantial long-term impacts.

Monitoring of the fish communities associated with streams at the Paducah Site indicated some depressed conditions but did not specifically identify causative agents. The impacts were limited to sites closest to the plant, which suggests that discharges from the Paducah Site (e.g., increases in sedimentation) may be the cause.

1. INTRODUCTION

L. A. Kszos

On September 24, 1987, the Commonwealth of Kentucky Natural Resources and Environmental Protection Cabinet issued an Agreed Order that required the development of a Watershed Monitoring Program (BMP) for the Paducah Site. A plan for the biological monitoring of the receiving streams (Little Bayou Creek and Big Bayou Creek) was prepared by the University of Kentucky, reviewed by staff at the Paducah Site and Oak Ridge National Laboratory (ORNL), and submitted by the U.S. Department of Energy (DOE) to the Kentucky Division of Water (KDOW) for approval. The Paducah Site BMP was implemented in 1987 and consisted of ecological surveys, toxicity monitoring of effluents and receiving streams, evaluation of bioaccumulation of trace contaminants in biota, and supplemental chemical characterization of effluents. The BMP was patterned after plans that were implemented in 1985 for the Oak Ridge Y-12 Plant (Loar et al. 1989) and in 1986 for ORNL (Loar et al. 1991) and the Oak Ridge Gaseous Diffusion Plant (presently known as the East Tennessee Technology Park, Kszos et al. 1993). Because research staff from the Environmental Sciences Division (ESD) at ORNL were experienced in biological monitoring, they served as reviewers and advisers throughout the planning and implementation of the Paducah Site BMP. Data resulting from BMP conducted by the University of Kentucky were presented in a 3-year report issued in December 1990 (Birge et al. 1990) and a progress report issued in December 1991 (Birge et al. 1992).

Beginning in fall 1991, ESD added data collection and report preparation to its responsibilities for the Paducah Site BMP. The BMP has been continued because it has proven to be extremely valuable in (1) identifying those effluents with the potential for adversely affecting instream fauna, (2) assessing the ecological health of receiving streams, and (3) guiding plans for remediation and protecting human health. For example, BMP has documented the improved health of the streams in the vicinity of the Paducah Site. The BMP has also shown that contaminants bioaccumulate to a significant degree in aquatic species. The continued documentation of ecological recovery and improvement of water quality may be used to develop appropriate chemical limits and monitoring requirements. Continued biological monitoring will assess the degree to which abatement actions ecologically benefit Big Bayou Creek and Little Bayou Creek. Data from continued monitoring can also be used to evaluate the need for additional remediation and to assess the impact of inadvertent spills or fish kills. Furthermore, BMP results can be used to educate the public about the Site's commitment to environmental protection.

In March 1998, renewed KPDES permits were issued to DOE and USEC. The renewed DOE permit required development of a watershed monitoring program and that a report of the monitoring be submitted each April. A watershed monitoring program plan was developed and approved by the KDOW in October 1998 (Kszos et al. 1999) and became effective January 1999. The watershed monitoring in this report (January to December 1998) reflects the requirements in the Paducah Site Environmental Monitoring Plan (Bechtel Jacobs Company 1998) and was designed to maintain surveillance of the effects of DOE operations on the aquatic environment. Subsequent reports will reflect the data requirements in the Watershed Monitoring Program (Kszos et al. 1999).

The watershed monitoring for the Paducah Site in 1998 consisted of three major tasks: (1) effluent monitoring, (2) bioaccumulation studies, and (3) ecological surveys of fish communities. This report focuses on activities from January to December 1998. Activities conducted outside this time period, particularly historical data used to describe trends, are also included as appropriate.

2. DESCRIPTION OF STUDY AREA[1]

L. A. Kszos

2.1 SITE DESCRIPTION

The Paducah Site is located in western Kentucky and owned by the United States Department of Energy (DOE). Effective July 1, 1993, DOE leased the plant production operations facilities (e.g., the Paducah Gaseous Diffusion Plant) to the United States Enrichment Corporation (USEC). Lockheed Martin Corporation created a new subsidiary, Lockheed Martin Utility Services (Utility Services), to manage the leased facilities for USEC under the prior management contract. Under the terms of the lease, USEC has assumed responsibility for compliance activities directly associated with uranium enrichment operations. Bechtel Jacobs Company LLC is the management contractor for DOE responsibilities at the Site. These responsibilities include the site Environmental Restoration Program; the Depleted Uranium Hexafluoride (DUF_6 Cylinder Program); the bulk of the Waste Management Program, including waste inventories predating July 1, 1993; wastes generated by current DOE activities; wastes containing "legacy" constituents, such as asbestos, polychlorinated biphenyls (PCBs) and transuranics; and Kentucky Pollutant Discharge Elimination System (KPDES) compliance at outfalls not leased to USEC. DOE has also retained manager and cooperator status of Resource Conservation and Recovery Act (RCRA) storage facilities, prepared memorandums of agreement to define their respective roles and responsibilities under the lease, and developed organizations and budgets to support their respective functions.

2.1.1 Land Use

The area surrounding the Paducah Site is mostly rural, with residences and farms surrounding the plant. Immediately adjacent to the Paducah Site is the West Kentucky Wildlife Management Area (WKWMA), 850 ha of managed habitat either deeded or leased to the Commonwealth of Kentucky.

The population within a 80-km radius of the plant is about 300,500 people. The unincorporated communities of Grahamville and Heath are within 2–3 km, east of the facility. The largest cities in the region are Paducah, Kentucky, and Cape Girardeau, Missouri, located about 16 and 64 air km away respectively (U.S. Department of Commerce 1991).

For information on the geohydrology of the region, see D'Appolonia 1983; GeoTrans 1990; TERRAN 1990; CH2M Hill 1991; Kszos 1994a, 1994b; and Jones et al.1997.

[1]Sections 2.1 and 2.2 contain large excerpts from Jones et al. 1997. Paducah Site 1996 Annual Environmental Report. KY/EM-206. Lockheed Martin Energy Systems, Inc., Kevil, Kentucky.

2.1.2 Surface Water

The Paducah Site is located in the western part of the Ohio River basin. The confluence of the Ohio River with the Tennessee River is ~24 km upstream of the Site, and the confluence of the Ohio River with the Mississippi River is ~90 km downstream of the Site. Surface drainage from the Site is two small tributaries of the Ohio River, Big Bayou Creek, and Little Bayou Creek (Fig. 2.1). These streams meet ~4.8 km north of the Site and discharge to the Ohio River at kilometer 1524 (Fig. 2.2). The Paducah Site is located on a local drainage divide; surface flow is east-northeast toward Little Bayou Creek and west-northwest toward Big Bayou Creek. Big Bayou Creek is a perennial stream with a drainage basin extending from ~4 km south of the Site to the Ohio River; part of its 14.5-km course flows along the western boundary of the Site. Little Bayou Creek originates in the WKWMA and flows for 10.5 km north toward the Ohio River; its course includes part of the eastern boundary of the Site. The watershed areas for Big Bayou Creek and Little Bayou Creek are about 4819 and 2428 ha respectively. These streams exhibit widely fluctuating discharge characteristics that are closely tied to local precipitation and facility effluent discharge rates. Natural runoff makes up a small portion of the flow and, during dry weather, effluents from all DOE and USEC operations can constitute about 85% of the normal base flow in Big Bayou Creek and 100% in Little Bayou Creek. During the dry season that extends from summer to early fall, no-flow conditions may occur in the upper section of Little Bayou Creek.

Precipitation in the region averages about 120 cm per year. Precipitation was 133.38 cm (52.7 inches) in 1998 with the highest rainfall occurring in June (Table 2.1). There were seven major storms (≥5 cm in 24–48 hours): one each in February, June, August, and two each in June and October. Daily rainfall data for 1998 are provided in Appendix A. See Kszos (1994, 1995, 1996a, 1997, 1998) and Kszos (1996b) for information on precipitation during 1992–97. The lower Bayou drainage has low to moderate gradient, and the lower reaches are within the flood plain of the Ohio River. The drainage basin is included in ecoregion 72 (Interior River Lowland) of the contiguous United States (Omernik 1987). Vegetation is a mosaic of forest, woodland, pasture, and cropland.

2.2 WATER QUALITY AND PADUCAH SITE EFFLUENTS

The Clean Water Act is currently administered for the Paducah Site by the Kentucky Division of Water (KDOW) through the KPDES Wastewater Discharge Permitting Program. The current DOE KPDES permit (No. KY0004049) became effective on April 1, 1998. As per the KPDES permit, DOE has responsibility for four outfalls (015, 017, 019, and 001) on the Paducah Site. Outfalls 015, 017, and 019 contain only surface runoff from the Site. Outfall 001 discharge consists of combined treated wastewaters from the C-752 Waste Storage and Treatment Building, the C-616 Wastewater Treatment Facility, the Vortec Vitrification Project (construction not completed), the C-612 Northwest Groundwater Treatment System, and miscellaneous untreated nonprocess wastewaters (stormwater runoff) associated with the C-335, C-337, C535, C0537, C-746-A, and C-616 building and ancillary areas, C-600 Steam Plant and C-614 Pump and Treat Facility.

The majority of effluents discharged to Big Bayou and Little Bayou creeks are from USEC outfalls and consist primarily of once-through cooling water, although a variety of effluents (uranium-contaminated as well as noncontaminated) result from activities associated with uranium precipitation and facility-cleaning operations. Conventional liquid discharges such as domestic sewage, steam-plant wastewaters, and coal-pile runoff also occur.

ORNL 95-7163A/abh

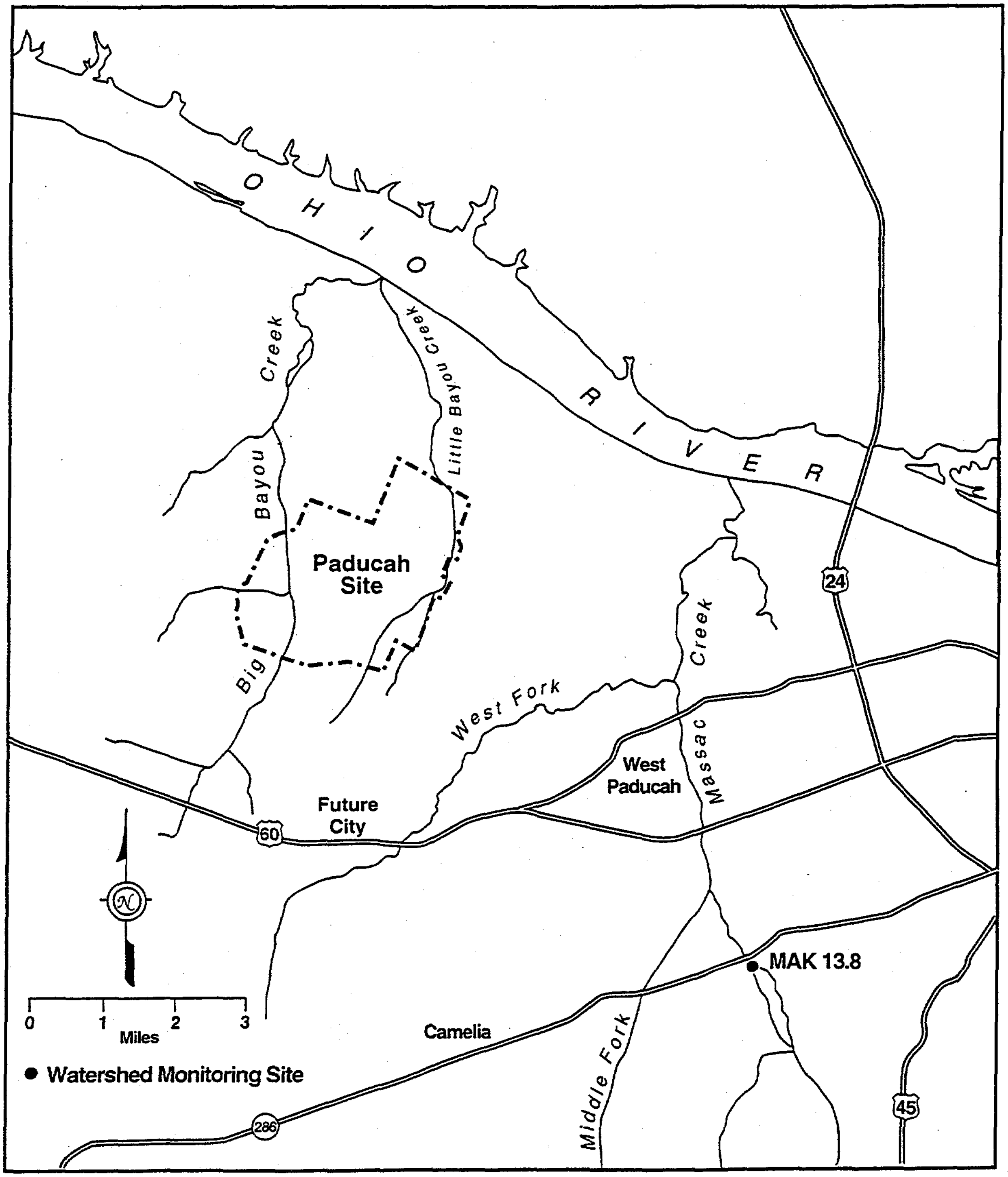
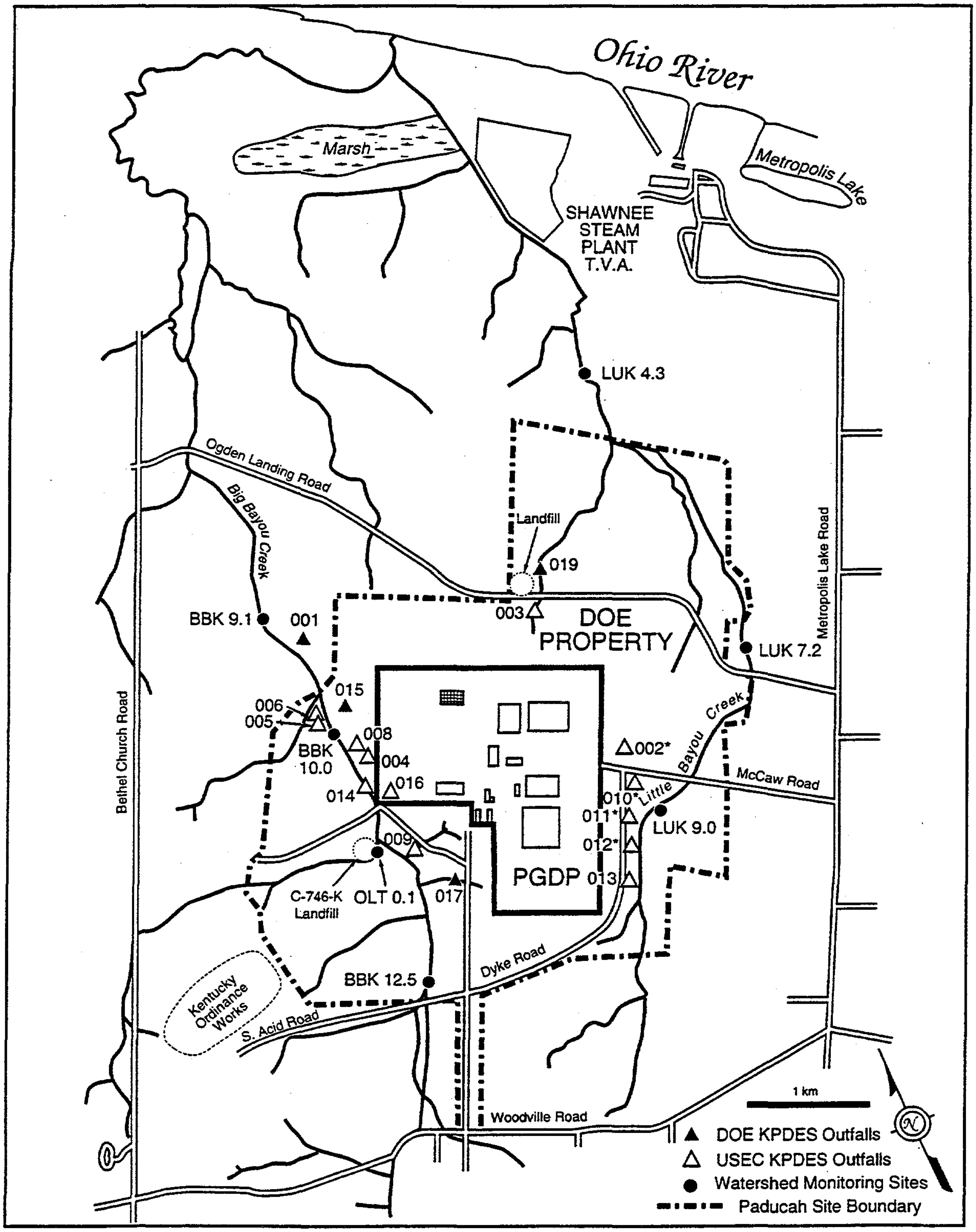


Fig. 2.1. Map of Paducah Site in relation to the geographic region. The reference site for watershed monitoring activities is located on Massac Creek at kilometer (MAK) 13.8.

ORNL 95-7164C/abh



*Combined at C617 pond and discharged through 011/010

Fig. 2.2. Location of Watershed Monitoring sites and Kentucky Pollutant Discharge Elimination System (KPDES) permitted outfalls for the Paducah Site. BBK = Big Bayou Creek kilometer; LUK = Little Bayou Creek kilometer; T.V.A. = Tennessee Valley Authority; DOE = U.S. Department of Energy.

Table 2.1 Summary of rainfall during 1998 at Barkley Regional Airport, Paducah, Kentucky

Month	Total (cm)
January	7.78
February	12.07
March	8.94
April	13.74
May	8.20
June	27.89
July	20.42
August	8.00
September	0.30
October	16.00
November	4.19
December	5.84
Total	133.37

Source: Midwestern Climate Center, Champaign, IL, Station ID156110, Barkley Regional Airport, Paducah National Weather Service.

Monitoring of individual outfalls and the landfill outfall is conducted in accordance with the KPDES Permit. Table 2.2 lists the outfalls in the DOE and USEC permit and their contributing processes; Fig. 2.2 shows the location of the outfalls. Of the 17 outfalls, 8 discharge continuously to the receiving streams. Outfalls 001, 006, 008, and 009 discharge continuously to Big Bayou Creek; outfalls 002, 010, 011, and 012 are combined at the C-617 pond and discharge through Outfall 010 continuously to Little Bayou Creek. After PCBs were detected in sediments from Outfall 011 in June 1994, the combined C-617 lagoon discharge was diverted on a full-time basis to Outfall 010. Outfall 011 has been a stormwater outfall since the change (C. C. Travis, USEC, Environmental Waste Management Division, Environmental Compliance Department, personal communication).

Table 2.2. Kentucky Pollutant Discharge Elimination System (KPDES) permitted outfalls at the Paducah Site

Locations in bold are responsibility of Department of Energy

Location[a]	Discharge source	Contributing processes
001	**C-616, C-600, C-400, C-410, C-635, C-335, C-337, C-535, C-537, C-746-A, C-747-A, C-635-6**	**Recirculating cooling water blowdown treatment effluent, coal-pile runoff, once-through cooling water, surface runoff, roof and floor drains, treated uranium solutions, sink drains, discharge from the Northwest Plume Pump and Treat Facility**
002	C-360, C-637, C-337-A	Once through cooling water, roof and floor drains, sink drains, extended aeration sewage treatment system
003	North edge of plant	Storm overflow of north/south diversion ditch discharges
004	C-615 sewage treatment plant, C-710, C-728, C-750, C-100, C-620, C-400	Domestic sewage, laboratory sink drains, motor cleaning, garage drains, laundry, machine coolant treatment filtrate, condensate blowdown, once-through cooling water
005	C-611 primary sludge lagoon	Water treatment plant sludge, sand filter backwash, laboratory sink drains
006	C-611 secondary lagoon	Water treatment plant sludge, sand filter backwash, laboratory sink drains from Outfall 005
007	Although this outfall is still listed on the permit, the only discharge is storm water runoff, which has no monitoring requirements or limitations	
008	C-743, C-742, C-741, C-723, C-721, C-728, C-729, C-400, C-420, C-410, C-727, C-411, C-331, C-310, C-724, C-744, C-600, C-405, C-409, C-631, C-720	Surface drainage, roof and floor drains, once-through cooling water, paint shop discharge, condensate, instrument shop cleaning area, metal-cleaning rinse water, sink drains
009	C-810, C-811, C-331, C-333, C-310, C-100, C-102, C-101, C-212, C-200, C-300, C-320, C-302, C-750, C-710, C-720	Surface drainage, roof and floor drains, condensate, once-through cooling water, sink drains
010	C-531, C-331	Switchyard runoff, roof and floor drains, condensate, sink drains
011	C-340, C-533, C-532, C-315, C-333, C-331	Once-through cooling water, roof and floor drains, switchyard runoff, condensate, sink drains
012	C-633, C-533, C-333-A	Roof, floor, and sink drains, condensate, surface runoff, extended aeration sewage treatment system
013	Southeast corner of the plant	Surface runoff
014	C-611 U-shaped sludge lagoon	Sand filter backwash, sanitary water
015	**West central plant areas**	**Surface runoff**
016	Southwest corner of the plant	Surface runoff
017	**Extreme south area of the plant**	**Surface runoff**
019	**Landfill at north of plant**	**Surface runoff**

[a]Numeral indicates outfall designation. Locations also identified in Fig. 2.2 of this report.

Note: This table modified from Kornegay et al. 1994 (Paducah Gaseous Diffusion Plant Environmental Report for 1993. ES/ESH-53. Oak Ridge National Laboratory, Oak Ridge, Tennessee)

2.3 DESCRIPTION OF STUDY SITES

Three study sites on Big Bayou Creek (Fig. 2.2), Big Bayou Creek kilometer (BBK) 12.5, BBK 10.0, and BBK 9.1; one site on Little Bayou Creek (Fig. 2.2), Little Bayou Creek kilometer (LUK) 7.2; and one off-site reference site on Massac Creek (Fig. 2.1), Massac Creek kilometer (MAK) 13.8, were sampled to evaluate the fish communities. These two sites on Little Bayou Creek (LUK 9.0, and LUK 4.3; Fig 2.2) and one site on Big Bayou Creek (BBK 9.1) were sampled to assess the bioaccumulation of contaminants in fish. Massac Creek (MAK 13.8) served as a local source of uncontaminated fish in 1998. A more detailed description of the sampling locations for the bioaccumulation monitoring task is provided in Sect. 4. A summary of the site locations is given in Table 2.3. Biological monitoring activities conducted during 1998 are outlined in Table 2.4. Toxicity monitoring was conducted quarterly. Fish community sampling was conducted in the fall; bioaccumulation sampling was conducted in the spring and fall.

Table 2.3. Locations and names of sampling sites included in Paducah Site Watershed Monitoring Program 1998

Current site name[a]	Location[b]
Big Bayou Creek	
BBK 12.5[c]	~200 m downstream of bridge on South Acid Road
BBK 10.0	~50 m upstream of Outfall 006
BBK 9.1	~25 m upstream of flume at gaging station at Bobo Road
Little Bayou Creek	
LUK 9.0	~25 m downstream of Outfall 010
LUK 7.2	~110 m downstream of bridge on Route 358
LUK 4.3	~500 m downstream of Outfall 018
Massac Creek	
MAK 13.8[c]	~40 m upstream of bridge on Route 62, 10 km SE of the Paducah Site
Old Landfill Tributary	
OLT 0.1	Adjacent to landfill C-746-K

[a]Site names are based on stream name and distance of the site from the mouth of the stream. For example, Big Bayou Creek Kilometer (BBK) 9.1 is located 9.1 km upstream of the mouth. LUK = Little Bayou Creek kilometer; MAK = Massac Creek kilometer; OLT = Old Landfill tributary.

[b]Locations are based on approximate distances from a major landmark (e.g., bridge or outfall) to the bottom of the reach.

[c]Reference site.

Table 2.4. Sampling schedule for the three components of the Watershed Monitoring Program at the Paducah Site, January–December 1998

Month	Toxicity monitoring	Bioaccumulation	Fishes
Jan.	001, 015, 017, 019		
Feb.			
Mar.			
Apr.	001, 015, 017, 019		
May		X	
Jun.	015, 017		
Jul.			
Aug.	001, 019		
Sept.			X
Oct.	015, 017	X	
Nov.	001		
Dec.	017		

3. TOXICITY MONITORING

L. A. Kszos

The toxicity monitoring task measures the toxicity of effluents as required by the KPDES permit. Until 1996, ambient water toxicity was monitored at four sites in Big Bayou Creek, one site in Little Bayou Creek, and one reference site in Massac Creek. The ambient monitoring was eliminated because there has been no consistent evidence of chronic toxicity in water from the ambient locations, no correlation of reductions in fathead minnow survival or growth at the continuously flowing outfalls with reductions in fathead minnow survival or growth at ambient locations, and no significant change in the water chemistry of the ambient sites or outfalls (Kszos 1996b).

3.1 INTRODUCTION

The ESD Toxicology Laboratory at ORNL began evaluating the toxicity of continuous and intermittent outfalls at the Paducah Site in October 1991. As required by a draft Agreed Order, *Ceriodaphnia* and fathead minnow tests of the continuous and intermittent outfalls were conducted quarterly. In September 1992, a renewed KPDES permit was issued to the Paducah Site. Under the requirements of this permit, *Ceriodaphnia dubia* and fathead minnow tests were continued on a quarterly basis. As required, the test methods used are the Cladoceran (*C. dubia*) 3-brood, Survival, and Reproduction Test (hereinafter referred to as the *Ceriodaphnia* test) and the Fathead Minnow (*Pimephales promelas*) 7-d, Larval Survival and Growth Test (hereinafter referred to as the fathead minnow test; Lewis et al. 1994). After May 1995, toxicity tests of continuously flowing outfalls 006, 008, 009, and 010 were conducted with fathead minnow larvae because they were shown to be the more sensitive species. Tests of continuously flowing Outfall 001 were conducted with *Ceriodaphnia* and fathead minnow larvae. After January 1996, tests of intermittently flowing outfalls 013, 015, 016, 017, and 018 were reduced to the more sensitive species (fathead minnow larvae). In March 1998, renewed KPDES permits were issued to the DOE and USEC for the Paducah Site. The renewed DOE permit requires toxicity monitoring of one continuous outfall (Outfall 001) and three intermittent (storm water) outfalls (outfalls 015, 017, and 018) on a quarterly basis.

3.2 MATERIALS AND METHODS

Toxicity tests of effluents from the continuously flowing outfall 001 and the intermittently flowing outfalls 015, 017, and 019 were conducted according to the schedule shown in Table 3.1. This report summarizes the toxicity test results for all tests conducted during 1998. Toxicity test results from 1991 to 1996 are summarized in Kszos (1997) and for 1997 in Kszos et al. (1998).

Samples from the outfalls were collected by personnel at the Paducah Site, refrigerated, and shipped to ESD using 24-h delivery. The effluent samples were used the same day they

Table 3.1. Summary of toxicity test dates for Department of Energy outfalls, 1998

Outfall	Test date	Species
001	Jan. 27–Feb 3	Fathead minnow, *Ceriodaphnia*
015, 017, 019	Jan. 7–14	Fathead minnow, *Ceriodaphnia*
001	Apr. 28–May 5	Fathead minnow, *Ceriodaphnia*
015, 017	Apr. 29–May 1	Fathead minnow, *Ceriodaphnia*
015, 017	Jul. 15–17	Fathead minnow, *Ceriodaphnia*
019	Aug. 11–13	Fathead minnow, *Ceriodaphnia*
001	Aug. 11–18	Fathead minnow, *Ceriodaphnia*
015, 017	Oct. 7–9	Fathead minnow, *Ceriodaphnia*
001	Nov. 10–17	Fathead minnow, *Ceriodaphnia*
017	Dec. 22–24	*Ceriodaphnia*

were received. All samples were collected and delivered using established chain-of-custody procedures (Kszos et al. 1996). Time of collection, water temperature, and arrival time in the laboratory were recorded. The tests of Outfall 001 were conducted using three, 24-h time-dependant composite samples. The intermittently flowing outfalls were rainfall dependent; thus, tests were conducted using one grab sample.

In January 1998, prior to the issuance of a renewed KPDES permit, chronic toxicity tests of effluent from all the outfalls were conducted. Beginning in March 1998, chronic toxicity tests were only required for effluent from Outfall 001. Chronic toxicity tests were conducted using the *Ceriodaphnia* test (EPA method 1002.0) and the fathead minnow test (EPA method 1000.0) (Lewis et al. 1994). The *Ceriodaphnia* and fathead minnow tests were static-renewal tests, meaning that test water was replaced daily for 6 or 7 consecutive days. The fathead minnow test consisted of four replicates per test concentration with ten animals per replicate. Each day before the water was replaced, the number of surviving larvae was recorded. At the end of 7 days, the larvae were dried and weighed to obtain an estimate of growth. The *Ceriodaphnia* test consisted of ten replicates per test concentration with one animal per replicate. Each day the animals were transferred from a beaker containing old test solution and placed in a beaker containing fresh test solution. At this time, survival and the number of offspring produced were recorded. A control consisting of dilute mineral water augmented with trace metals was included with each test. On each fresh sample, subsamples of each effluent were routinely analyzed for pH, conductivity, alkalinity, and water hardness (Kszos et al. 1996).

Acute toxicity tests of the intermittent outfalls were conducted as per the EPA methodology referenced in the KPDES permit (Weber 1993). The acute *Ceriodaphnia* and fathead minnow tests were 48-h static tests, meaning that test water was not replaced for 48-h; the animals were not fed during the test. The fathead minnow test consisted of four replicates per test concentration with ten animals per replicate. The *Ceriodaphnia* test consisted of four replicates per test concentration with six animals per replicate. For both species, the number of surviving animals was recorded at 24- and 48-h. A control consisting of dilute mineral water augmented with trace metals was included with each test. On each fresh sample, subsamples of each effluent were routinely analyzed for pH, conductivity, alkalinity, and water hardness (Kszos et al. 1996).

For the chronic toxicity test data, a linear interpolation method (Norberg-King 1993) was used to determine the 25% inhibition concentration (IC25, that concentration causing a 25% reduction in fathead minnow growth or *Ceriodaphnia* reproduction compared to a control). A computer program [A Linear Interpolation Method for Sublethal Toxicity: Inhibition Concentration (ICp) Approach, version 2.0] distributed by the EPA (Environmental Research Laboratory, Duluth, Minnesota) was used for the calculation. The chronic toxicity unit (TUc = 100/IC25) is required as a compliance endpoint in the renewed permit (September 1992 to present). The higher the TUc, the more toxic an effluent. For permitting purposes, the KDOW has determined that Big Bayou Creek has a low flow of zero, thus, a TUc > 1.0 for Outfall 001 would be considered a noncompliance and an indicator of potential instream toxicity.

For the acute toxicity test data, the EPA recommendations for determining the 48-h LC_{50} (concentration that is lethal to 50% of the test organisms) were used for each test. A computer program (Trimmed-Spearman Karber Program, version 1.5) distributed by the EPA (Environmental Monitoring Systems Laboratory, Cincinnati, Ohio) was typically used for the calculation. The acute toxicity unit (TUa = $100/LC_{50}$) is required as a compliance endpoint in the renewed permit. The higher the TUa, the more toxic an effluent. Because Little Bayou and Big Bayou creeks have been determined to have a low flow of zero, a TUa > 1.0 for outfalls 015, 017, and 019 would be considered a noncompliance and an indicator of potential instream toxicity. A TUa ≥1.2 is considered a significant noncompliance.

3.3 RESULTS AND DISCUSSION

A summary of the TUs for all toxicity tests of effluents from outfalls 001, 015, 017, and 019 conducted during 1998 is provided in Table 3.2. The data reported to the KDOW for each outfall and test during 1998 are provided in Appendix B. During 1998, effluent from outfalls 001, 015, and 019 never exceeded the permit limit (TUc or TUa < 1.0). Effluent from Outfall 017 exceeded the permit limit in October with a TUa of 1.5. The confirmatory test conducted in December resulted in a TUa of 2.2. An analysis of the chronic toxicity test data from January 1993 to July 1998 for acute toxicity (LC_{50}) showed that during this time period, there were no occurrences of an LC_{50} ≤100% or a TUa ≥1.0; thus, the October and December tests resulted in the first noncompliance since 1993. Because the toxicity test results for Outfall 017 in October and December were each considered a significant noncompliance (TUa >1.2), a plan for a Toxicity Reduction Evaluation per EPA guidance is being drafted for submittal to the KDOW. This plan will be used to determine which measures are necessary to maintain the toxicity of effluent from Outfall 017 at acceptable levels (TUa <1.0).

A summary of flow of Outfall 017 during the time that samples were taken for toxicity tests as well as the alkalinity and hardness of full-strength effluent used in the toxicity tests are shown in Fig. 3.1. The alkalinity and hardness of the October and December samples were among the lowest values recorded during testing from 1993 to 1998. Concurrent with the low water chemistry values were high flows (Fig 3.1; 5.5 and 10.5 million gallons/day, respectively). The increased flow and increased toxicity appear to be related to changes in the cylinder yards, which drain to Outfall 017 during storm events. Many cylinders within the yards

Table 3.2. Summary of toxicity test results for continuous and intermittent outfalls, 1998

Outfall	Test date	Toxicity units (TU)[a]	
		Fathead minnow	*Ceriodaphnia*
	Continuous outfall		
001	January	<1	<1
	April	<1	<1
	August	<1	<1
	November	<1	<1
	Intermittent Outfalls		
015	January	<1	<1
	April	<1	<1
	July	<1	<1
	October	<1	<1
017	January	<1	<1
	April	<1	<1
	July	<1	<1
	October	<1	1.5
	December (retest)	<1	2.2
019	January	<1	<1
	April	<1	<1
	August	<1	<1

[a]For Outfall 001: Chronic toxicity unit = 100/IC25; IC25 = the concentration causing a 25% reduction in fathead minnow growth or *Ceriodaphnia* reproduction. IC = inhibition concentration. For Outfalls 015, 017, and 019: Acute toxicity unit = $100/LC_{50}$; LC_{50} = the concentration causing 50% mortality in 48-h.

have been repainted and the yards have been covered with concrete. The Toxicity Reduction Evaluation will investigate the possible sources and causes of toxicity in effluent from Outfall 017.

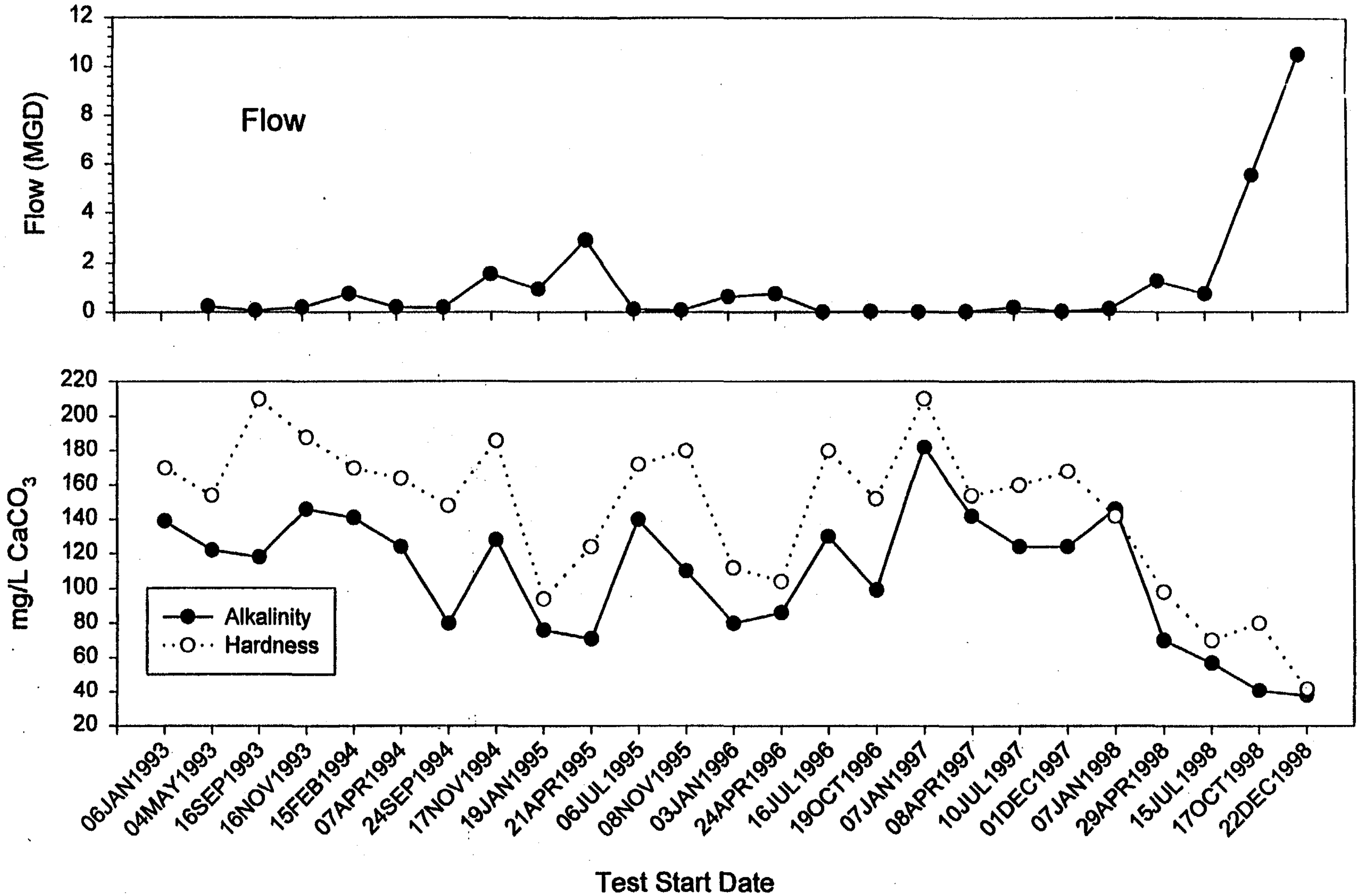


Fig. 3.1. Flow (million gallons per day) of Outfall 017 during the period that samples were obtained for toxicity tests. Alkalinity and hardness of full-strength effluent used in toxicity tests.

4. BIOACCUMULATION

M. J. Peterson and G. R. Southworth

4.1 INTRODUCTION

Previous bioaccumulation monitoring conducted as part of the Watershed Monitoring Program at the Paducah Site has identified PCB contamination in fish in Big Bayou Creek and Little Bayou Creek as a major concern (Kszos 1996a,b; 1997; 1998). Mercury concentrations in fish from Big Bayou Creek were also found to be higher in fish collected downstream from Paducah Site discharges than in fish from an upstream site (Kszos 1996a,b, 1997). Concentrations of various other metals and organics in fish from Big Bayou Creek and Little Bayou Creek were well below levels of concern for human consumption.

The primary objective of the 1997–98 bioaccumulation monitoring was to evaluate spatial and temporal changes in PCB contamination in longear sunfish (*Lepomis megalotis*) from Little Bayou Creek. PCB contamination in fish in Big Bayou Creek had declined to near background levels over the 1992–95 period, and monitoring in this stream was consequently reduced to a single site immediately downstream from the lowermost Paducah Site input to Big Bayou Creek. Similarly, mercury monitoring was conducted only at that site in Big Bayou Creek. Because Big Bayou Creek is capable of supporting a limited sport fishery for larger game fish, spotted bass (*Micropterus punctulatus*) were analyzed for mercury and PCBs to evaluate the maximum concentrations likely in fish near the Paducah Site.

Whole-body fish samples were collected in May 1998 while conducting the routine sunfish filet monitoring. The primary objective of this effort was to provide whole-body fish data that could be used in the assessment of the potential risks to terrestrial piscivores (e.g., kingfishers, mink) that may eat contaminated fish from waters near the Paducah Site. The focus of the evaluation was on the contaminants of most concern (i.e., PCBs and metals) in Little Bayou Creek and Big Bayou Creek.

4.2 MATERIALS AND METHODS

Because sunfish are short-lived and have small home ranges, they represent recent contaminant exposure at the site of collection, and are thus ideal monitoring tools for evaluating spatial and temporal trends in contamination. Collections of sunfish were restricted whenever possible to fish of a size large enough to be taken by sport fisherman in order to minimize effects of covariance between size and contaminant concentrations and to provide data directly applicable to assessing risks to people who might eat fish from these creeks. In general, high fish densities enabled the collection of 6 to 8 specimens of sunfish >30 g at all sites except the upper Little Bayou Creek sites.

All fish were collected by backpack electrofishing. Longear sunfish were collected at Paducah sites on April 30–May 1, 1998, and October 27–28, 1998, as part of routine twice-yearly monitoring of PCB concentrations in this species. Longear sunfish were collected for PCB analysis at three sites on Little Bayou Creek, LUK 9.0, LUK 7.2, and LUK 4.3

(Fig. 2.2). Spotted bass were collected from BBK 9.1 in the fall 1998 for mercury and PCB analysis. Massac Creek (at MAK 13.8) served as a local source of uncontaminated reference fish.

Forage fish (central stoneroller, *Campostoma anomalum* and small longear sunfish) were collected from sites in Little Bayou Creek and Big Bayou Creek during the April 1998 sampling. Small longear sunfish (*Lepomis megalotis*) were collected from four sites in the Little Bayou Creek drainage (Outfall 010 ditch, lower half; LUK 9.0; LUK 7.2; and LUK 4.3); one site on Big Bayou Creek (BBK 9.1), and one offsite reference station on Massac Creek (MAK 13.8). Stonerollers (*Campostoma anomalum*) were collected only at sites where they were common (LUK 7.2, BBK 9.1, Old Landfill tributary [OLT] 0.1, and MAK 13.8). The site at OLT 0.1 was located immediately adjacent to the closed landfill C-746-K, a tributary of Big Bayou Creek (Fig. 2.2). These fish were analyzed for PCBs and a suite of metals to provide data for evaluating ecological risks to fish-eating birds and mammals.

For filet analysis, each fish was individually tagged with a unique four-digit tag wired to the lower jaw and placed on ice in a labeled ice chest. Fish were held on ice overnight and processed within 48 hours. Each fish was weighed and measured, then filleted, scaled, and rinsed in process tap water. Samples of sunfish for specific analyses were excised, wrapped in heavy duty aluminum foil, labeled, and frozen in a standard freezer at −15° C. For larger fish (bass), filets were wrapped and labeled as were sunfish samples, but at a later date the frozen filets were partially thawed, cut into 2- to 4-cm pieces and homogenized in a stainless steel blender. A 25-g sample of the ground tissue was wrapped in heavy duty aluminum foil, labeled, frozen, and submitted to LMES Analytical Chemistry Organization for PCB and mercury analyses. Any remaining tissue from filets of sunfish or larger fish was wrapped in foil, labeled, and placed in the freezer for short-term archival storage. Forage fish were collected by electrofishing, and grouped into three subgroups each containing ten fish. Individuals in each subgroup were weighed and measured, and the sample of ten fish was then homogenized in a stainless steel blender, packaged in aluminum foil, and frozen for delivery to the analytical laboratory.

PCB analyses were conducted using Soxhlet extraction techniques according to SW-846 Method 3540 and analysis by capillary column gas chromatography using SW-846 Method 8080 (EPA 1986). Fish were analyzed for total mercury by cold vapor atomic absorption spectrophotometry following digestion in HNO_3/H_2SO_4 (EPA 1991, procedure 245.6). Metals were analyzed using inductively coupled plasma mass spectrometry (ICP/MS) according to EPA procedure 200.8 (EPA 1991).

Samples were processed according to project-specific standardized technical procedures developed for the Watershed Monitoring Program to ensure quality and integrity (QAP-X-90-ES-065, Rev. 1: Biological Monitoring and Abatement Program Quality Assurance Plan, Bioaccumulation Monitoring Aquatic). Quality assurance was evaluated by a combination of blind duplicate analyses, analysis of biological reference standards and uncontaminated fish, and determination of recoveries of analyte spikes to uncontaminated fish. Task protocols have been effective in ensuring consistent results; for example, quality assurance evaluations of the fall 1997 data detected discrepancies in the Aroclor distribution pattern in comparison to past years and the results were recalculated by the analytical laboratory (revision in Appendix C). It is standard policy that the bioaccumulation data are considered preliminary until all quality assurance/quality control checks are completed and data are entered into the Oak Ridge Environmental Information System (OREIS). Currently bioaccumulation data over the 1991–1995 period are included in OREIS. Bioaccumulation data over the 1995–1998 period have been submitted to data managers, and this dataset will be entered into OREIS soon. SAS software and procedures were used to calculate the mean, standard error, and standard deviation of the contaminant concentrations listed in the tables of this section (SAS 1985 a, b).

4.3 RESULTS AND DISCUSSION

4.3.1 PCBs

4.3.1.1 Spatial Trends

Over much of the 1992–1998 period, the spatial pattern of PCB contamination in fish from Little Bayou Creek was consistent with what might be expected based on what was known of historical PCB sources; that is, PCB concentrations in fish were highest in fish collected near the Paducah Site and decreased with distance downstream. The "decrease with distance" pattern was most pronounced in the early years of monitoring. Since October of 1996, PCB concentrations in fish were more similar between LUK 9.0 and LUK 7.2; and, in some seasons, concentrations at LUK 7.2 exceeded concentrations in fish at the site further upstream (LUK 9.0). In all years of monitoring, a more precipitous drop in fish PCB concentrations was evident between LUK 7.2 and LUK 4.3. In general, PCB concentrations in fish at the two uppermost sites (LUK 9.0 and LUK 7.2) have been in the 0.5 μg/g range in recent years, with concentrations generally less than 0.2 μg/g at the lowermost site (LUK 4.3). Two main conclusions can be drawn from the spatial patterns previously observed in Little Bayou Creek: (1) high PCB concentrations in fish are highly localized in the upper 2–3 kilometers of Little Bayou Creek, and (2) the flattening of the downstream profile in recent years suggests decreased PCB inputs from Paducah Site outfalls.

Results of PCB analyses of sunfish collected from Little Bayou Creek in April and October 1998 are presented in Table 4.1 and Appendix C. PCB concentrations in sunfish collected in April 1998 in Little Bayou Creek were atypically low when compared to the previous year's data, and the downstream gradient was relatively flat (Fig. 4.1). Longear sunfish filets averaged ($\pm$ SE) 0.27 $\pm$ 0.02 μg/g at LUK 9.0, 0.27 $\pm$ 0.04 at LUK 7.2, and 0.11 $\pm$ 0.01 at LUK 4.3. Both changes are consistent with a possible decrease in PCB inputs from the storm drain network over the 3- to 6-month period preceding the sampling, or unusually high dilution or sequestration of PCB inputs over that period. The spatial pattern of PCB contamination in fish from Little Bayou Creek changed again in October 1998, when the downstream pattern of mean PCB concentrations in sunfish again resembled that typical of the 1992–1996 period. Mean PCB concentrations in fish at the uppermost site (LUK 9.0) exceeded those at downstream sites by a wide margin (Table 4.1, Fig. 4.1), averaging 1.33 $\pm$ 0.30 μg/g at LUK 9.0, 0.32 $\pm$ 0.06 μg/g at LUK 7.2, and 0.16 $\pm$ 0.03 μg/g at LUK 4.3. Two fish from LUK 9.0 exceeded the FDA threshold limit of 2 ppm. The mean concentration in fish from LUK 9.0 exceeded 1.0 μg/g for the first time since 1994. Mean concentrations at downstream sites in October 1998 were not unusually high compared with previous years, suggesting that PCB inputs resulting in an increase at LUK 9.0 may have been relatively recent. The fluctuating pattern of PCB accumulation in fish in upper Little Bayou Creek in 1998 illustrates the need for a better understanding of the nature of PCB sources within the Paducah Site and the mechanisms by which PCBs are mobilized from those sources.

Table 4.1. Mean concentration of PCBs (μg/g wet weight) in filets of fish from streams near the Paducah Site, April 1998, and October 1998

Site	Species	Mean[a]	SE	Range	n
		April 1998			
LUK 9.0	Longear sunfish	0.27	0.02	0.19–0.32	6
LUK7.2	Longear sunfish	0.27	0.04	0.13– 0.36	6
LUK4.3	Longear sunfish	0.11	0.01	0.07–0.14	6
Reference (Massac Creek, Kentucky)	Longear sunfish	0.06	0.03	<0.01–0.18	6
		October 1998			
BBK 9.1	Spotted bass	0.26	0.06	0.10–0.36	4
LUK 9.0	Longear sunfish	1.33	0.30	0.70–2.42	6
LUK7.2	Longear sunfish	0.32	0.06	0.18–0.59	6
LUK4.3	Longear sunfish	0.16	0.03	0.07–0.25	6
Reference (Massac Creek, Kentucky)	Longear sunfish	<0.01			6

[a]A value of ½ the detection limit was used in calculating means for samples in which no PCBs were detected.
Note: BBK = Big Bayou Creek kilometer; LUK = Little Bayou Creek kilometer.

4.3.1.2 Temporal trends

The long-term pattern of mean PCB concentrations in fish at the uppermost site in Little Bayou Creek gives evidence of continued but decreased inputs of PCBs to the creek headwaters (Fig. 4.2). Considerable improvement was evident in PCB contamination in Little Bayou Creek, where average concentrations in sunfish at LUK 9.0 have decreased from nearly 2 μg/g in spring 1992 to less than 0.3 μg/g in spring 1998. However, in fall 1998, PCB concentrations in sunfish at LUK 9.0 rebounded to levels typical of the 1992–94 period.

The bulk of the evidence from bioaccumulation monitoring over the past seven years (decreased mean PCB concentrations at LUK 9.0 and flattening of the downstream profile of PCB concentrations in sunfish in Little Bayou Creek) support the conclusion that PCB inputs associated with the Paducah Site stormdrain network have decreased over that period. The recent increase, however, highlights the fact that, despite improvement, the Site's stormdrain network remains a continuing source of PCB contamination to Little Bayou Creek, and that

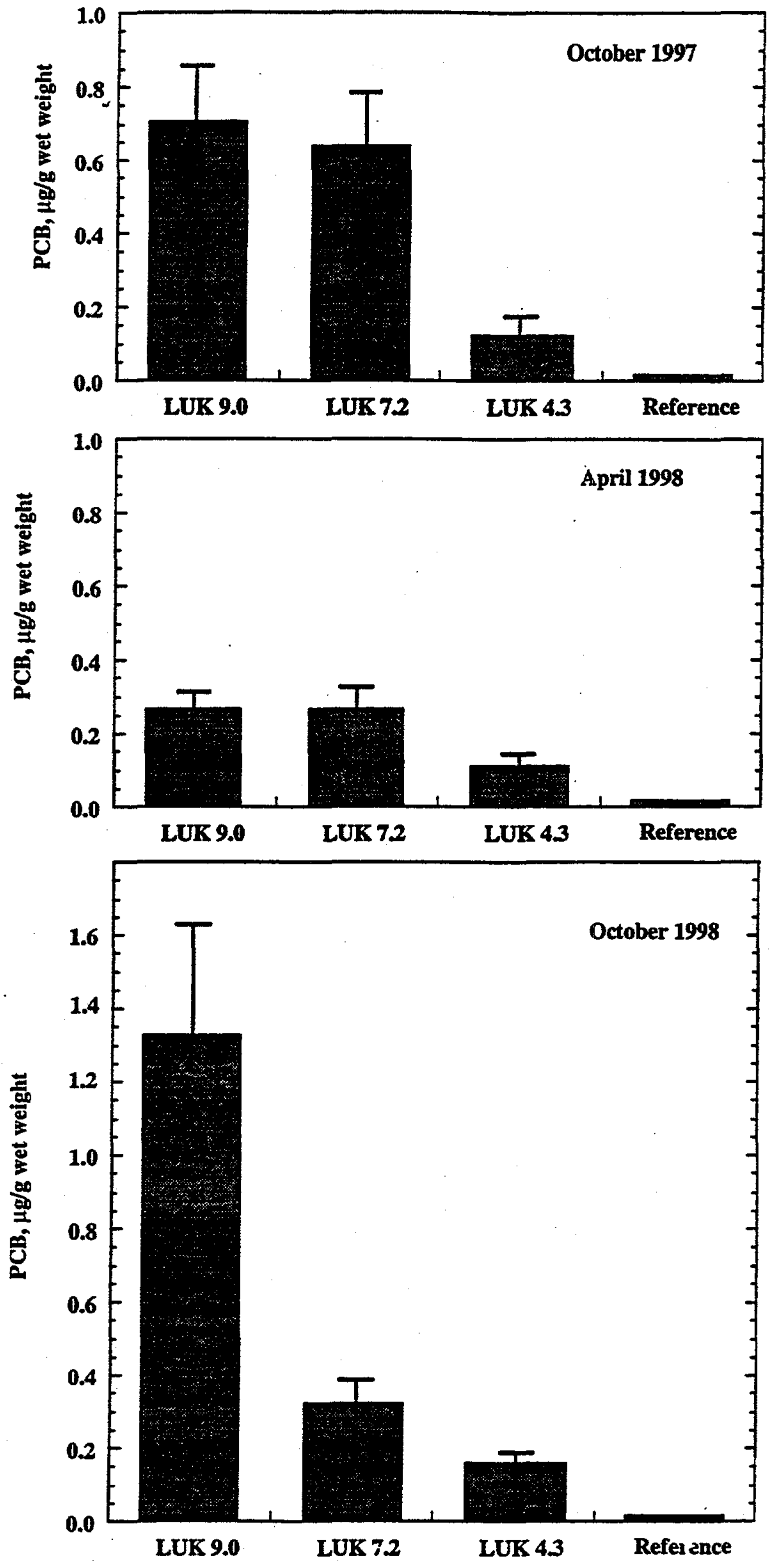


Fig. 4.1. Downstream profiles of mean (± SE) PCB concentrations in filets of longear sunfish (*Lepomis megalotis*) collected from Little Bayou Creek, fall 1997–fall 1998.

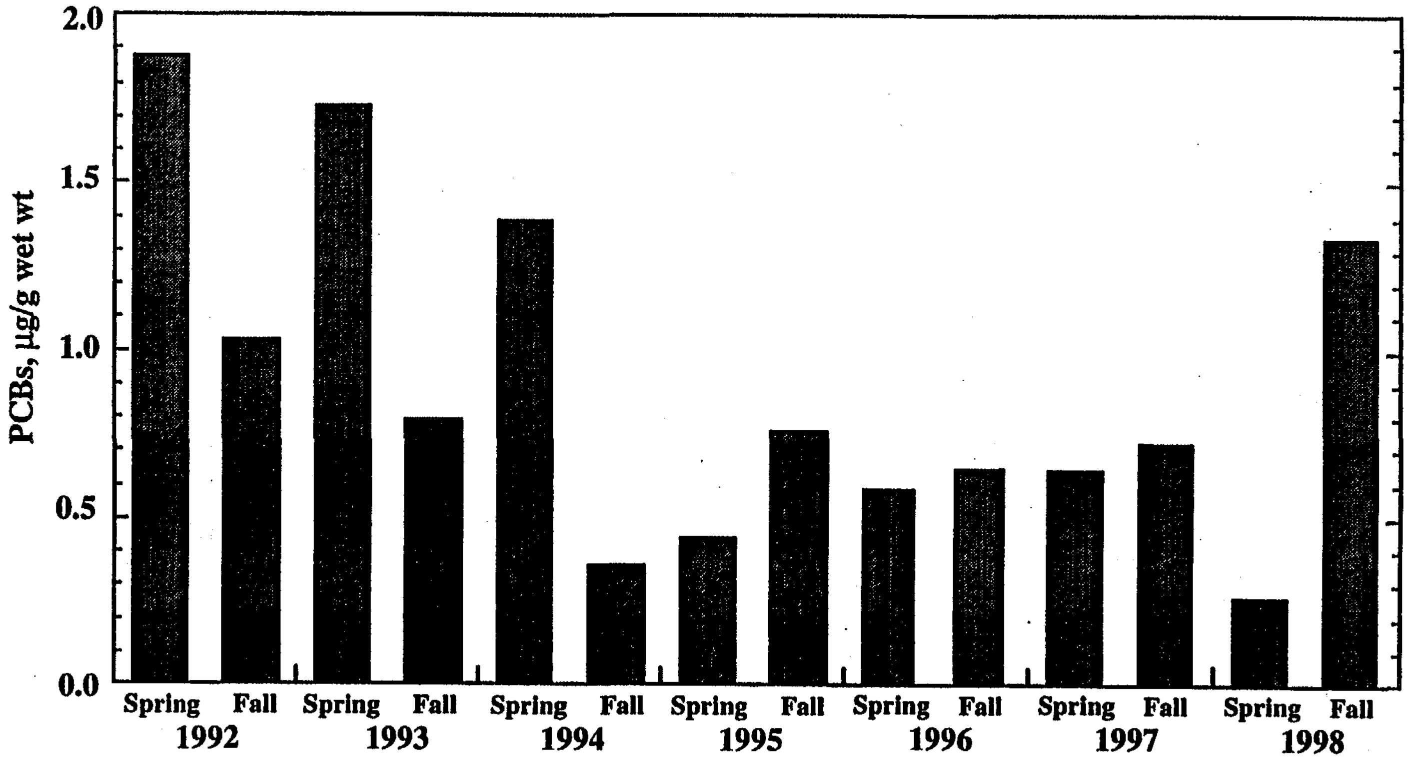


Fig. 4.2. Changes over time in average PCB concentrations in longear sunfish (*Lepomis negalotis*) from Little Bayou Creek near the Paducah Site (LUK 9.0).

concentrations in fish can return to levels approaching guidelines for protection of human health over a short period of time. PCBs in spotted bass were slightly higher in fall 1998 than in fall 1997, averaging 0.26 μg/L in 1998 versus 0.15 μg/L in 1997 (Table 4.1 Kszos et al. 1998). This may be due in part to the small size of individual fish in the fall 1997 collection. Overall, spotted bass provide evidence of continuing low level inputs of PCBs to Big Bayou Creek, but the concentrations attained in this game fish are well below levels that would result in issuance of a fish consumption advisory by the Commonwealth of Kentucky.

4.3.2 Mercury

The bioaccumulation of mercury by fish is predominantly a food chain mediated process, thus predatory species that occupy trophic positions at or near the top of the aquatic food web would be expected to contain higher concentrations of mercury than species lower in the food chain. Spotted bass in Big Bayou Creek occupy that role of terminal predator and are monitored by this task to evaluate the maximum mercury level likely in fish from that creek. In October 1998, the mercury concentration of the collection averaged (± SE) 0.23 ± 0.06 μg/g wet weight, with a range of 0.13–0.38 μg/g. Mercury concentrations in predatory fish, such as bass and walleye, typically increase as a function of fish size; thus, it is usually necessary to adjust for differences in fish sizes among collections made at different times, using analysis of covariance. Mean mercury concentrations adjusted for the variation in mercury concentration with fish weight are plotted in Fig. 4.3. A slight decreasing trend was noted in 1997, and addition of the 1998 data makes a decrease over time clearly evident. The cause of this decline may be related to chemical changes in Paducah Site discharges to Big Bayou Creek that may have been initiated in the 1996 time frame. In late 1996, the addition rate of thiosulfate at Outfall 004 was increased to better deal with occasional KPDES noncompliances for total residual chlorine at Outfall 004. Thereafter, effects of excess thiosulfate were occasionally visibly evident in Big Bayou Creek as luxurious growth of greenish-black periphyton, presumably rich in reduced sulfur compounds. It is possible that substances produced by the growth of sulfur-utilizing microorganisms combines with the minute traces of mercury in Big Bayou Creek, making mercury less available for methylation and subsequent bioaccumulation. Alternatively, thiosulfate enrichment may have stimulated the capability of microorganisms to demethylate methylmercury, reducing exposure of biota.

4.3.3 PCBs and Metals in Forage Fish

Whole-body samples of longear sunfish and stonerollers were collected in April 1998 while conducting the routine collection of sunfish filets. The primary objective of this effort was to provide whole-body fish data that could be used in an assessment of the potential risks to terrestrial piscivores (e.g., kingfishers, mink) that may eat contaminated fish from waters near the Paducah Site. An initial collection for evaluating ecological risks associated with bioaccumulation in forage fish was made in May 1997 (Kszos et al. 1998). The 1998 collection consisted of the same sites and species with the addition of a site within a tributary stream of Big Bayou Creek near the closed C-0746-K landfill (herein designated as OLT 0.1). The focus of the evaluation was on persistent, bioaccumulative toxic substances (i.e., PCBs and metals) in Little Bayou Creek and Big Bayou Creek.

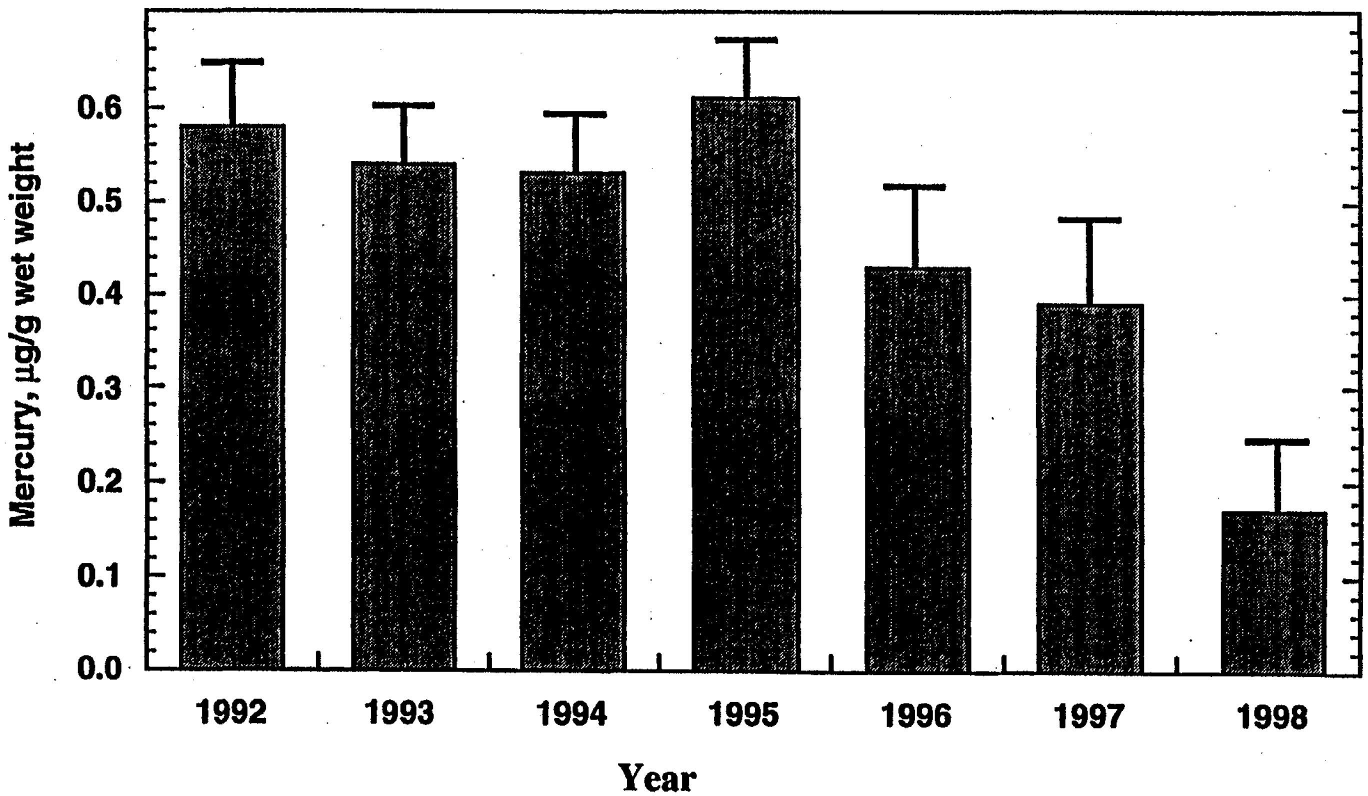


Fig. 4.3. **Average concentrations of total mercury (adjusted for covariance of mercury with fish weight) in spotted bass (*Micropterus punctulatus*) from Big Bayou Creek downstream from the Paducah Site (BBK 9.1), 1992–1998.** Error bars represent one standard error about the mean.

Because PCBs are the primary contaminants of concern, a PCB subsample was prepared for composited collections at all sites. Metals (including mercury) subsamples were prepared for only the most upstream sites on Little Bayou Creek and Big Bayou Creek, and the OLT 0.1 site.

The mean concentrations of total PCBs and metals in longear sunfish and stonerollers are reported in Tables 4.2 and 4.3. The concentrations of PCBs stand out as posing the highest potential ecological concern to fish-eating birds and mammals. PCBs in fish from the Paducah Site averaged greater than two orders of magnitude higher than concentrations in fish from a local reference site, Massac Creek. In contrast, most average metal concentrations in fish near the Paducah Site were similar to reference stream values. Exceptions at some sites were levels of copper, lead, selenium, and uranium. Levels of these metals averaged two to ten times greater in fish at some Paducah sites in comparison to concentrations in fish at the reference site.

PCBs. The highest average PCB concentration (2.50 μg/g) was found in longear sunfish collected from LUK 9.0. Mean PCB concentrations in sunfish decreased with distance downstream, averaging 1.71 μg/g at LUK 7.2 and 1.44 μg/g at LUK 4.3. High PCB concentrations were also found in longear sunfish from Outfall 010 (1.63 μg/g in one composite sample of eight fish), suggesting that this outfall is a major source of PCBs to downstream waters. This is not surprising since Outfall 010 is the primary dry-weather discharge to Little Bayou Creek; however, it is surprising that the PCB concentration in fish was lower in Outfall 010 than at the LUK 9.0 site downstream. One possible explanation is that residual PCB deposits from other outfalls/locations upstream of the 010 discharge on Little Bayou Creek may be resuspended with seasonally high flows. The mean PCB concentration in Big Bayou Creek sunfish was also elevated in comparison to reference values (averaging 0.95 μg/g), but was lower than any concentration reported for Little Bayou Creek fish.

PCB concentrations were also elevated in stoneroller minnows collected from Little Bayou Creek and Big Bayou Creek, averaging 1.52 and 0.95 μg/g respectively. PCB concentrations in stonerollers collected from OLT 0.1 were detectable, but much lower (average of 0.25 μg/g). Unlike the 1997 results, stoneroller PCB concentrations were similar to those in longear sunfish collected from the same site. PCBs in stonerollers collected in May of 1997 were approximately 30–40% higher than in longear sunfish collected from the same Paducah site. Lower PCB concentrations in 1998 stonerollers can be explained in part by the smaller size of the individuals collected. Smaller sizes were taken by necessity because fewer individuals were obtainable.

PCB concentrations in fish from the uppermost sites in the Little Bayou Creek watershed (LUK 9.0 and Outfall 010) were lower in 1998 than in 1997. Average PCB concentrations in fish from LUK 7.2 and LUK 4.3 in 1998 were similar to the average observed the previous year. This pattern is consistent with the premise that PCB exposure in fish from lower sites on Little Bayou Creek are more closely related to in-stream sediment contamination, while fish concentrations from upper sites are more closely linked to the fluctuating PCB inputs from the Paducah Site's ditch and storm drain system. Previous monitoring in Little Bayou Creek suggested that PCB concentrations are often higher in water and fish during high rainfall periods when it is presumed that trapped PCBs are resuspended by greater flows. Despite lower values in 1998 at the upper sites, PCB concentrations in fish from the Paducah Site continued to exceed food-based benchmarks that may indicate risks to terrestrial piscivores (Sample 1997).

Table 4.2. Mean (± SE) concentrations (μg/g, wet wt.), of various analytes in composited longear sunfish (*Lepomis megalotis*) samples collected from stream sites near the Paducah Site and Massac Creek, a reference stream, April 1998

	Little Bayou Creek sites[a]			Big Bayou Creek and Outfall 010[a]		Massac Creek
Analytes	LUK 9.0	LUK 7.2	LUK 4.3	BBK 9.1	Outfall 010	MAK 13.8
PCBs, total	2.50 ± 0.04	1.71 ± 0.12	1.44 ± 0.08	0.95 ± 0.12	1.63	< 0.01
Antimony	--	0.07 ± 0.007	--	0.07 ± 0.003	--	0.04 ± 0.01
Arsenic	--	0.37 ± 0.02[b]	--	0.55 ± 0.04	--	0.74 ± 0.004
Beryllium	--	< 0.04	--	< 0.04	--	< 0.04
Cadmium	--	0.04 ± 0.002[b]	--	< 0.04	--	0.04 ± 0.01
Chromium	--	0.82 ± 0.13	--	0.75 ± 0.07	--	0.58 ± 0.03
Copper	--	0.65 ± 0.02	--	0.79 ± 0.05	--	0.80 ± 0.06
Lead	--	0.20 ± 0.04	--	0.11 ± 0.01	--	0.16 ± 0.04
Mercury	--	0.03 ± 0.003	--	0.04 ± 0.002	--	0.06 ± 0.0
Nickel	--	0.38 ± 0.009	-	0.35 ± 0.03[b]	--	0.41 ± 0.05
Selenium	--	0.94 ± 0.05	--	0.94 ± 0.10	--	< 0.67
Silver	--	< 0.04	--	< 0.04	--	< 0.04
Thallium	--	< 0.04	--	< 0.04	--	< 0.04
Uranium	--	0.34 ± 0.08	--	0.12 ± 0.01	--	< 0.04
Zinc	--	23.57 ± 0.49	--	23.63 ± 0.63	--	26.10 ± 0.70

[a]LUK = Little Bayou Creek kilometer, BBK = Big Bayou Creek kilometer, Outfall 010 is a tributary ditch of Little Bayou Creek. N=3 composite samples at each site except Massac Creek (N=2).

[b]Undetected values were used to calculate the means where at least one detected value was reported.

Table 4.3. Mean (± SE) concentrations (μg/g, wet weight.), of various analytes in composited stoneroller (*Campostoma anomalum*) samples collected from stream sites near the Paducah Site and a reference stream, Massac Creek, April 1998

	Sampling sites[a]			Massac Creek
Analytes	LUK 7.2	BBK 9.1	OLT 0.1	MAK 13.8
PCBs, total	1.52	0.95 ± 0.12	0.25 ± 0.02	< 0.01
Antimony	0.07	0.06 ± 0.001	0.05 ± 0.004	0.05 ± 0.001
Arsenic	0.52	0.71 ± 0.08	0.84 ± 0.10	0.80 ± 0.06
Beryllium	< 0.04	< 0.04	< 0.04	< 0.03
Cadmium	< 0.04	< 0.04	0.04 ± 0.006[b]	0.04 ± 0.01[b]
Chromium	0.91	0.72 ± 005	0.75 ± 0.10	0.68 ± 0.10
Copper	1.56	3.28 ± 0.02	1.43 ± 0.12	1.28 ± 0.03
Lead	0.19	0.20 ± 0.09	0.48 ± 0.12	0.24 ± 0.01
Mercury	--	--	0.03 ± 0.003	--
Nickel	<0.35	<0.40	0.39 ± 0.03	0.35 ± 0.04
Selenium	1.15	0.91 ± 0.05	0.73 ± 0.08[b]	0.57 ± 0.02[b]
Silver	< 0.04	0.04 ± 0.002	< 0.04	< 0.03
Thallium	< 0.04	< 0.04	< 0.04	< 0.03
Uranium	0.45	0.27 ± 0.05	0.05 ± 0.007[b]	< 0.03
Zinc	26.50	33.10 ± 0.35	31.07 ± 2.19	27.50 ± .10

[a]LUK = Little Bayou Creek kilometer, BBK = Big Bayou Creek kilometer, and OLT = Old Landfill Tributary that flows into Big Bayou Creek. N=3 at BBK 9.1 and OLT 0.1. N=2 at Massac Creek and N=1 at LUK 7.2.

[b]Undetected values were used to calculate the means where at least one detected value was reported.

Metals. In Little Bayou Creek, mean uranium and selenium concentrations in both longear sunfish and stonerollers were higher than reference fish concentrations. The average uranium concentration was approximately ten times higher in Little Bayou Creek fish (in both species). Although selenium was elevated in both species collected from Little Bayou Creek, the difference (in comparison to the reference site) was relatively small (< 2X). All other metal concentrations, in both species in Little Bayou Creek, were similar to reference concentrations.

Mean uranium concentrations in Big Bayou Creek fish were also elevated in comparison to the average reference concentration, but were not as high as in Little Bayou Creek. Mean copper concentrations in Big Bayou Creek stonerollers were approximately three times higher than reference concentrations, but copper was not elevated in longear sunfish collected from the same site. The average lead concentration in fish from OLT 0.1 was twice that found in reference stream fish, and selenium was also slightly higher. Other metals in Big Bayou Creek fish and fish from the tributary near the old landfill were similar or lower than background. The absence of appreciable mercury concentrations in fish whole-bodies is surprising, given that mercury has been elevated in fish filet samples collected from Big Bayou Creek for many years.

The 1998 metal results were very similar to the results in 1997 (Kszos et al. 1998); uranium, selenium, and copper concentrations in fish at the Paducah Site continue to be elevated over fish from the reference stream. As in 1997, 1998 studies revealed that most other metals in fish were not higher than background.

5. FISH COMMUNITY MONITORING

M. G. Ryon

5.1 INTRODUCTION

Fish population and community studies can be used to assess the ecological effects of changes in water quality and habitat. These studies offer several advantages as indicators of environmental quality (see Karr et al. 1986, Karr 1987) and are especially relevant to assessment of the biotic integrity of Little Bayou and Big Bayou creeks. These creeks receive mixed effluents with a variety of stressors; the fish community includes species that may be sensitive to only one (e.g., temperature) or many of these stressors. Thus, analysis of the fish community may provide some indication as to which stressors are having the most impact. Monitoring of fish communities has been conducted by ESD for receiving streams at the Paducah Site since 1991. Changes in the fish communities in these streams have indicated impacts close to the Paducah Site (in Big Bayou Creek near Outfall 008; Ryon 1994) and impacts associated with elevated temperatures (Roy et al. 1996). Fish community data have also indicated an absence of impacts at downstream locations where the Paducah Site is less of an influence (e.g., at LUK 4.3 in Little Bayou Creek; Ryon 1996).

The objectives of the instream fish monitoring task are (1) to characterize spatial and temporal patterns in the distribution and abundance of fishes in Little Bayou and Big Bayou creeks, (2) to document the effects of operations at the Paducah Site on fish community structure and function, and (3) to document any recovery of the community associated with remedial actions at the Paducah Site.

5.2 STUDY SITES

Quantitative sampling of the fish community was conducted at five stream sites. Three sites are located on Big Bayou Creek (BBK 12.5, BBK 10.0, and BBK 9.1; Fig. 2.2); one is on Little Bayou Creek (LUK 7.2, Fig. 2.2); and one offsite reference site is located on Massac Creek (MAK 13.8, Fig. 2.1). MAK 13.8 was chosen as a reference site for BBK 9.1 and BBK 10.0. The upper site on Big Bayou Creek (BBK 12.5) was selected as a smaller reference site to be comparable to LUK 7.2. As a special study, qualitative samples of the fish community were made in a small, unnamed tributary (OLT 0.1; Fig. 2.2) that enters Big Bayou Creek just upstream of Water Works Road and is adjacent to the closed landfill C-746-K.

5.3 MATERIALS AND METHODS

Quantitative sampling of the fish populations at the five stream sites near the Paducah Site was conducted by electrofishing on September 15–17, 1998. Data from these samples were used to estimate species richness and population size (numbers and biomass per unit area) and calculate annual production. Qualitative sampling was conducted by electrofishing on September 14, 1998. Data from this sample were used to estimate species richness and relative abundance. All field sampling was conducted according to standard operating procedures (Ryon 1999).

5.3.1 Quantitative Field Sampling Procedures

All stream sampling was conducted using two or three Smith-Root backpack electrofishers, depending on stream size. Each unit can deliver up to 1200 V of pulsed, direct current to stun fish.

After 0.64-cm-mesh seines were placed across the upper and lower boundaries of the fish sampling site to restrict fish movement, a six-person sampling team electrofished the site in an upstream direction on three consecutive passes. Stunned fish were collected and stored, by pass, in seine-net holding pens (0.64-cm-diam mesh) or buckets during further sampling.

Following the electrofishing, fish were anesthetized with MS-222 (tricaine methanesulfonate), identified, measured (total length), and weighed using Pesola® spring scales. Individuals were recorded by 1-cm size classes and species. After ten individuals of a species-size class were measured and weighed, additional members of that size class were only measured. Length-weight regressions and length frequency distributions, based on the measured individuals, were used to estimate missing length and weight data.

5.3.2 Qualitative Field Sampling Procedures

Qualitative sampling involved electrofishing a limited length of stream for one pass and collecting all stunned fish. A four-person sampling team electrofished the site moving upstream for approximately 30 min with one Smith-Root backpack electrofisher. The sample reach was divided into a segment below a seep from the landfill and a segment above the seep. Stunned fish were netted, placed in buckets, and given to a two-person shore crew for processing. The shore crew counted and identified all specimens separately for each segment; fish were immediately released downstream from the sampling crew. The duration of the electrofishing effort (in minutes) and the length of stream sampled (in meters) were recorded. Temperature and conductivity were measured along the stream sampling reach.

5.3.3 Data Analysis

Population Size. Quantitative species population estimates were calculated using the method of Carle and Strub (1978). Biomass was estimated by multiplying the population estimate by the mean weight per size class. To calculate density and biomass per unit area, total numbers and biomass were divided by the surface area (in square meters) of the study reach. These data were compiled and analyzed by a comprehensive Fortran 77 program developed by ESD staff (Railsback et al. 1989). For the qualitative sample, a relative measure of abundance (catch/unit effort) was calculated by adding up numbers of fish captured and dividing by duration of sample effort in minutes.

Annual Production. Annual production was estimated at each site using a size-frequency method (Garman and Waters 1983) as modified by Railsback et al. (1989). Production was calculated for the period between the fall 1997 and 1998 sampling dates.

5.4 RESULTS

The physical characteristics of the sample sites showed only minor differences between the 1997 and 1998 September samples (Table 5.1). In 1997, the sites were generally deeper with more riffle/runs than in 1998, which might be a reflection of drier summer and fall conditions in 1998.

The unnamed tributary (OLT 0.1) that drained the landfill, was a small (generally less than 0.5 m in width and depth, except for one pool), slow-flowing stream. Below the seep from the landfill, the stream had a noticeable oily sheen on the surface and the substrate was coated with a thick red precipitate. Above the seep, the oil and precipitate were absent. In both sections, the substrate was packed hard clay overlain by loose, small gravels. At the time of our sample, there was little if any runoff entering the tributary from the seep and, in general, low discharge from the unnamed tributary to Big Bayou Creek. Temperatures were very similar above (26.4° C) and below (25.7° C) the seep. However, conductivities were markedly higher below (894 ± 354 μS) the seep in comparison to those above (228 ± 21 μS).

5.4.1 Species Richness and Composition

The species composition of 1998 quantitative samples is listed in Table 5.2. Twenty-nine species were found at the five sites, with BBK 9.1 and MAK 13.8 having the most species. At most sites, the species composition was typical compared to past sampling; two new species were found at BBK 9.1, the brook silverside (*Labidesthes sicculus*) and the channel catfish (*Ictalurus punctatus*). Brook silverside had been collected in other coastal plain streams near the Paducah Site (Ryon and Carrico 1998), but never before in Big Bayou Creek. It is a sensitive species and is more common in larger streams. Channel catfish had been collected previously, downstream in Big Bayou Creek near stream kilometer 3, and is also more common in larger streams. The number of species (or species richness) at the sites was similar in 1998 to previous sampling (Table 5.3), with the lowest richness at BBK 10.0.

The composition of the fish community samples at the five sites is given in Table 5.4. In this context, community composition includes trophic level or feeding guild, taxonomic relationship or type of species, and tolerance or intolerance/sensitivity to stress or disruption (see Table E.1 in Kszos et al. 1998). The intolerant species are those species susceptible to habitat degradation and/or pollution (see Karr et al. 1986; Ohio EPA 1988; Mills et al. 1993). Benthic insectivores are a specialized feeding guild that can reflect impacts (e.g., increased sedimentation) on the benthic macroinvertebrate availability (Miller et al. 1988). Generalist feeders are species that are capable of switching easily between food types and, therefore, can be more successful in streams exposed to a variety of stresses (Leonard and Orth 1986). Generally, a stream with better water and habitat quality will have more trophic levels, more taxonomic groups, more sensitive species, more benthic insectivores, fewer generalists, and fewer tolerant species and specimens than streams that are under atypical ecological stress.

The 1998 sample data indicate that BBK 10.0 is a more limited community than the MAK 13.8 reference. Furthermore, this site also appears limited compared to BBK 12.5 and BBK 9.1. For many categories [darters (Percidae), suckers (Catostomidae), minnows (Cyprinidae), benthic insectivores and intolerant species], this site has fewer representatives than MAK 13.8. At the BBK 9.1 site, the fish community is more similar to MAK 13.8 than BBK 10.0, and lacks only in the number of darters and benthic insectivores. The LUK 7.2 site and the BBK 12.5 reference are very similar. LUK 7.2 did maintain the higher percentage of tolerant species first seen in 1997 samples at that site.

Table 5.1. Length, mean width, mean depth, surface area, and pool:riffle ratio of fish sampling sites in Big Bayou Creek, Little Bayou Creek, and a reference stream, Massac Creek for September 1997 and 1998

Site[a]	Length (m)	Mean width (m)	Mean depth (cm)	Surface area (m^2)	Pool:riffle ratio
			September 1998		
BBK 9.1	99	6.7	18.3	660	1.7
BBK 10.0	85	5.8	11.9	490	1.6
BBK 12.5	100	7.3	9.1	731	4.9
LUK 7.2	110	3.5	8.6	386	1.5
MAK 13.8	100	4.6	15.0	460	2.3
			September 1997		
BBK 9.1	110	6.5	25.4	719	0.6
BBK 10.0	105	4.6	18.3	479	1.1
BBK 12.5	97	5.9	11.6	573	3.9
LUK 7.2	110	3.8	10.2	416	0.5
MAK 13.8	108	3.8	17.5	413	1.2

[a]Site designations are Big Bayou Creek kilometer (BBK), Little Bayou Creek kilometer (LUK), and Massac Creek kilometer (MAK).

5.4.2 Density

Quantitative estimates of total density (number of individuals) for 1998 samples, and density estimates for individual species are given in Tables 5.2 and 5.3. Densities for 1998 were generally similar to September 1997 values and/or historic means (Table 5.3). Density was low at LUK 7.2, a trend first seen in 1996. The low density at LUK 7.2 was outside the normal range for this site (Fig. 5.1), with the 1998 density being the lowest ever measured at this site in fall sampling. Other sites showed a pattern more typical of previous fall samples (Figs. 5.1 and 5.2).

Although there were pronounced differences between sites in total densities, there was more agreement on which species were most abundant at the sites. The central stoneroller (*Campostoma anomalum*) and longear sunfish (*Lepomis megalotis*) were usually the most abundant species at all sites in Big Bayou Creek and at MAK 13.8 (Table 5.2). At LUK 7.2, the most abundant species were the Mississippi silvery minnow (*Hybognathus nuchalis*) and the western mosquitofish (*Gambusia affinis*), two species that utilize slow velocity or shallow habitats.

5.4.3 Biomass

The biomass (weight of fish) estimates of the 1998 sampling are given in Tables 5.2 and 5.3. The 1998 values were generally within the range of previous samples (Figs. 5.1 and 5.2). The 1998 biomass values at BBK 9.1 and BBK 10.0 were up to twice as high as the MAK 13.8 reference site, a pattern also seen in the historic data for these sites. The biomass values at LUK 7.2 did not indicate a change that would correlate with the low density in 1998, but the values

Table 5.2. Species richness, density (individuals/m^2), and biomass (g/m^2), in parentheses, for fish community sampling sites in Big Bayou Creek, Little Bayou Creek, and Massac Creek, 1998

Species[b]	Sites[a]				
	BBK 9.1	BBK 10.0	BBK 12.5	LUK 7.2	MAK 13.8
Clupeidae					
Gizzard shad (*Dorosoma cepedianum*)	0.01 (1.24)/	-	-	-	0.06 (0.39)
Cyprinidae					
Central stoneroller (*Campostoma anomalum*)	0.73 (1.59)	1.80 (6.29)	0.99 (4.78)	0.02 (0.06)	0.39 (1.54)
Red shiner (*Cyprinella lutrensis*)	<0.01 (0.01)	-	-	0.06 (0.10)	<0.01 (<0.01)
Steelcolor shiner (*C. whipplei*)	0.02 (0.09)	-	-	-	0.07 (0.25)
Common carp (*Cyprinus carpio*)	0.01 (2.92)	-	-	-	<0.01 (0.09)
Mississippi silvery minnow (*Hybognathus nuchalis*)	-	<0.01 (0.01)	0.40 (1.93)	0.29 (2.40)	0.09 (0.43)
Ribbon shiner (*Lythrurus fumeus*)	<0.01 (<0.01)	-	-	-	0.15 (0.11)
Redfin shiner (*L. umbratilis*)	-	-	0.03 (0.07)	-	0.03 (0.04)
Bluntnose minnow (*Pimephales notatus*)	<0.01 (0.01)	-	0.03 (0.11)	0.10 (0.16)	0.14 (0.22)
Creek chub (*Semotilus atromaculatus*)	-	-	0.26 (1.85)	0.07 (0.67)	0.26 (1.79)
Catostomidae					
White sucker (*Catostomus commersoni*)	<0.01 (0.40)	-	-	-	0.01 (0.37)
Creek chubsucker (*Erimyzon oblongus*)	-	<0.01 (0.21)	-	-	0.08 (1.16)
Spotted sucker (*Minytrema melanops*)	0.01 (0.84)	-	-	-	-
Golden redhorse (*Moxostoma erythrurum*)	-	-	-	-	0.02 (0.65)
Ictaluridae					
Yellow bullhead (*Ameiurus natalis*)	<0.01 (0.32)	0.01 (0.57)	0.03 (0.18)	0.04 (0.54)	0.05 (0.45)
Channel catfish (*Ictalurus punctatus*)	<0.01 (0.19)	-	-	-	-

Table 5.2 (continued)

Species[b]	Sites[a] BBK 9.1	BBK 10.0	BBK 12.5	LUK 7.2	MAK ¯13.8
Aphredoderidae					
Pirate perch (*Aphredoderus sayanus*)	0.02 (0.03)	-	-	0.01 (0.05)	<0.01 (0.03)
Cyprinodontidae					
Blackspotted topminnow (*Fundulus olivaceus*)	0.13 (0.20)	0.30 (0.52)	0.28 (0.54)	0.27 (0.60)	0.37 (0.72)
Poeciliidae					
Western mosquitofish (*Gambusia affinis*)	0.14 (0.05)	0.33 (0.13)	0.77 (0.20)	0.38 (0.13)	0.02 (<0.01)
Atherinidae					
Brook silverside (*Labidesthes sicculus*)	<0.01 (<0.01)	-	-	-	-
Centrarchidae					
Green sunfish (*Lepomis cyanellus*)	0.14 (0.82)	0.31 (1.51)	0.68 (1.71)	0.15 (0.77)	0.11 (0.58)
Warmouth (*L. gulosus*)	<0.01 (0.08)	-	-	0.06 (0.60)	-
Bluegill (*L. macrochirus*)	0.09 (1.95)	0.12 (2.02)	0.01 (0.05)	0.02 (0.10)	0.12 (0.31)
Longear sunfish (*L. megalotis*)	0.58 (11.88)	0.53 (8.07)	0.63 (2.93)	0.08 (0.75)	0.44 (3.07)
Hybrid sunfish	-	-	-	0.01 (0.10)	-
Spotted bass (*Micropterus punctulatus*)	0.01 (2.84)	0.02 (0.45)	0.01 (0.04)	-	0.01 (0.04)
Largemouth bass (*M. salmoides*)	0.01 (0.55)	0.02 (1.18)	0.01 (0.25)	<0.01 (0.02)	<0.01 (0.08)
Percidae					
Slough darter (*Etheostoma gracile*)	-	-	<0.01 (<0.01)	0.01 (<0.01)	<0.01 (<0.01)
Logperch (*Percina caprodes*)	-	-	-	-	0.03 (0.35)
Blackside darter (*P. maculata*)	-	-	-	-	0.01 (0.03)

[a]BBK = Big Bayou Creek kilometer, LUK = Little Bayou Creek kilometer, MAK = Massac Creek kilometer.
[b]Common and scientific names according to the American Fisheries Society (Robins et al. 1991) and Etnier and Starnes (1993).

Table 5.3. Total fish community density (individuals/m^2), biomass (g/m^2), and species richness (total number of species) for September 1997 and 1998, and means (±SD) for 1991–1996 at sampling sites in Big Bayou Creek, Little Bayou Creek, and a reference stream, Massac Creek

Indicator per sampling periods	Sites[a]				
	BBK 9.1	BBK 10.0	BBK 12.5	LUK 7.2	MAK 13.8
September 1998					
Density	1.91	3.44	4.13	1.57	2.46
Biomass	26.01	20.96	14.64	7.05	12.50
Species richness	21	11	14	15	25
September 1997					
Density	1.70	5.50	4.04	1.74	6.16
Biomass	17.60	23.89	13.11	6.29	19.10
Species richness	23	14	15	16	20
Means 1991–96[b]					
Density	1.69±0.97	3.91±2.54	3.73±1.21	3.21±1.54	3.11±1.64
Biomass	21.56±10.53	18.35±9.78	14.25±2.38	6.27±2.75	12.37±6.72
Species Richness	15.7±3.7	11.4±2.1	14.5±2.0	15.6±3.9	20.7±3.4

[a]BBK = Big Bayou Creek kilometer, LUK = Little Bayou Creek kilometer, MAK = Massac Creek kilometer.

[b]Means include data from spring samples.

Table 5.4. Fish community composition based on 1998 quantitative samples of Big Bayou Creek, Little Bayou Creek, and Massac Creek

Species category	Sites[a]				
	BBK 9.1	BBK 10.0	BBK 12.5	LUK 7.2	MAK 13.8
Cyprinidae	6 (28)[b]	2 (18)	5 (36)	5 (33)	9 (36)
Catostomidae	2 (10)	1 (9)	0	0	3 (12)
Centrarchidae	6 (28)	5 (45)	5 (36)	6 (40)	5 (25)
Percidae	0	0	1 (7)	1 (7)	3 (12)
Tolerant species	6 (28)	2 (18)	3 (21)	4(27)	7 (28)
Intolerant species	4 (19)	0	1 (7)	0	5 (25)
Piscivore	2 (10)	2 (18)	2 (14)	1 (7)	2(8)
Benthic Insectivore	1 (5)	1 (9)	1 (7)	2 (13)	6 (24)
Generalist feeder	8 (38)	3 (27)	3 (21)	4 (27)	7 (28)

[a]BBK = Big Bayou Creek kilometer; LUK = Little Bayou Creek kilometer; MAK = Massac Creek kilometer.

[b]Number of species at that site with percent of total species at that site in parentheses.

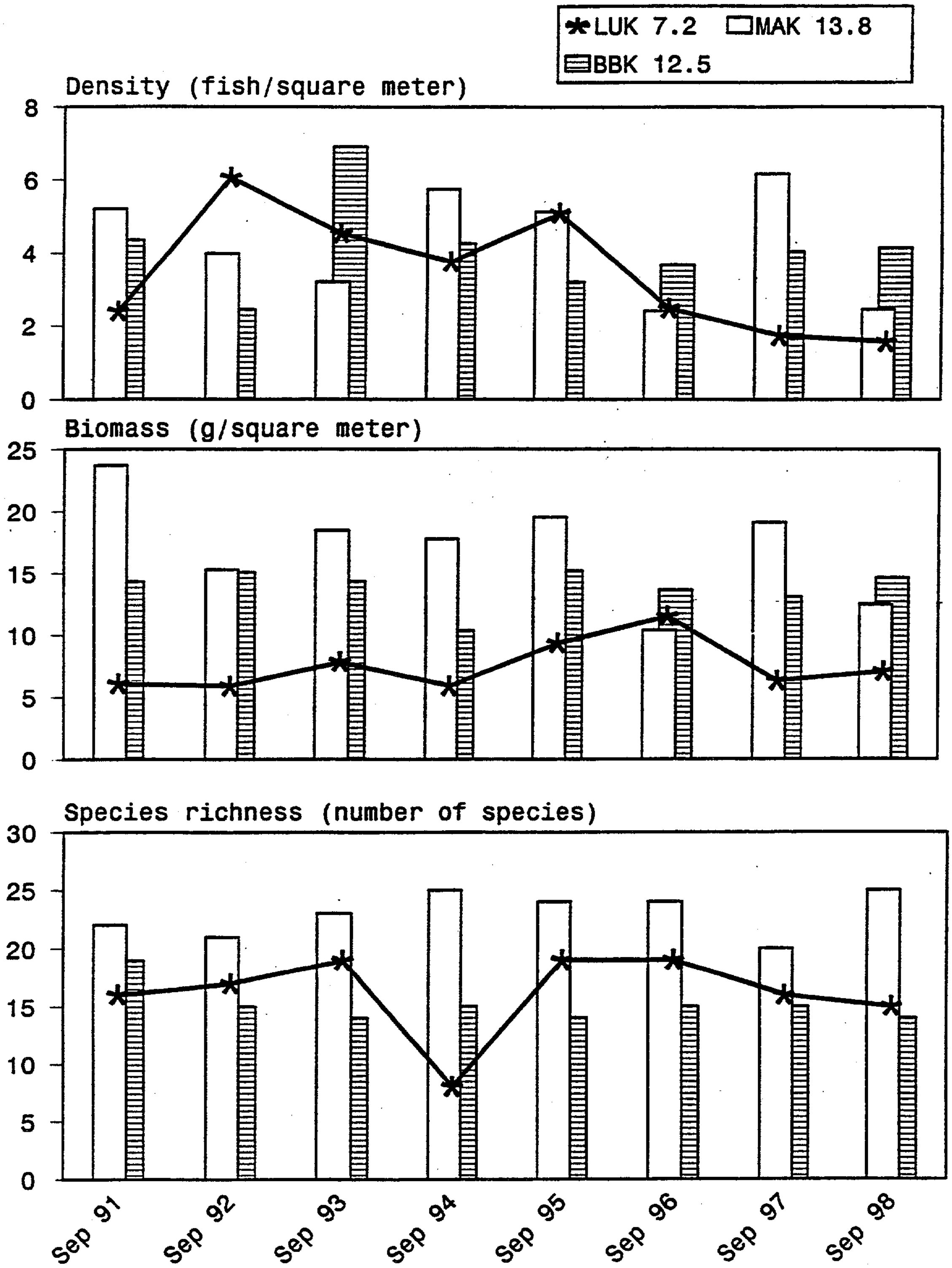


Fig. 5.1. Species richness, biomass, and density in fall samples at one Little Bayou Creek site and two reference sites. LUK = Little Bayou Creek kilometer; MAK = Massac Creek kilometer; BBK = Big Bayou Creek kilometer.

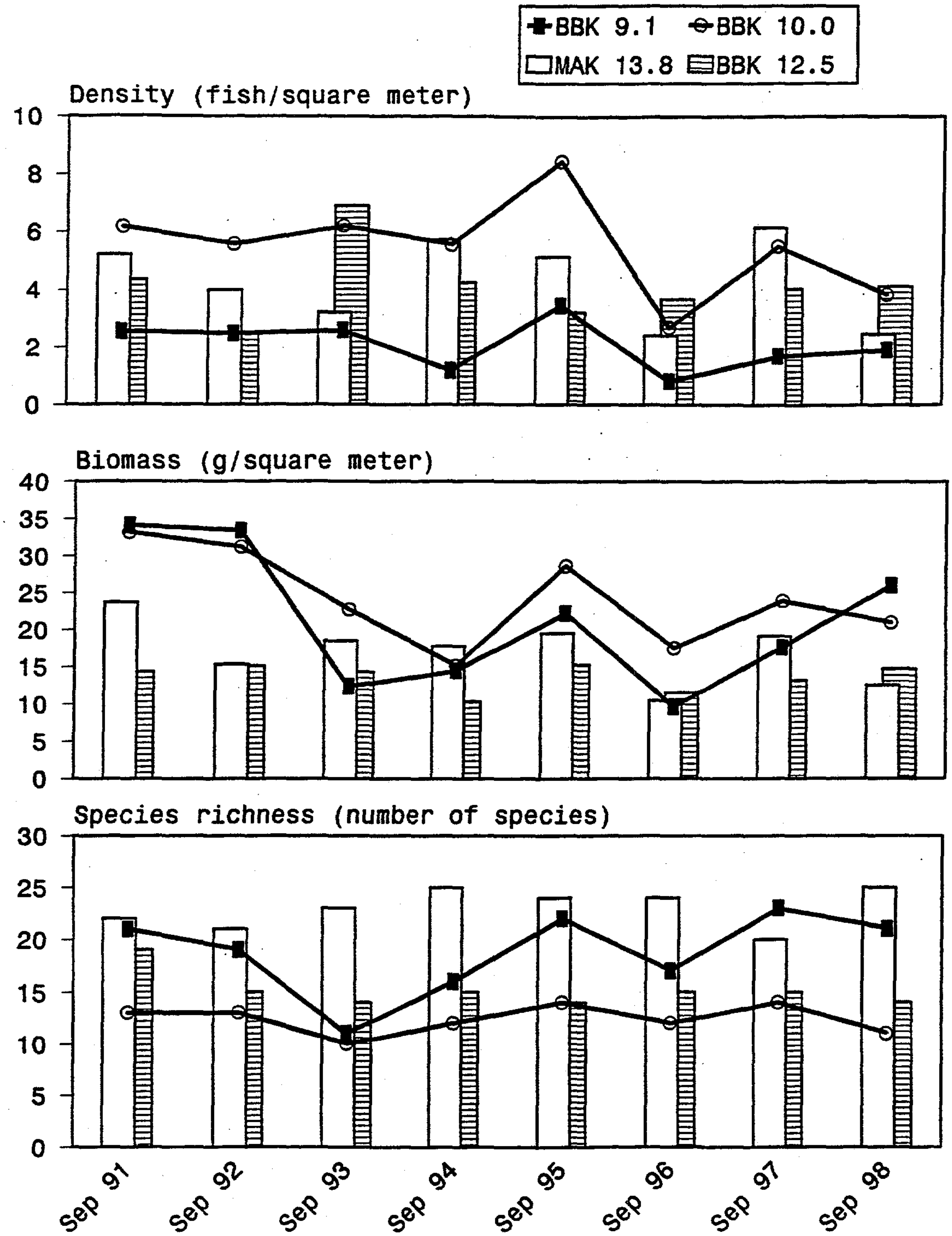


Fig. 5.2. Species richness, biomass, and density in fall samples at Big Bayou Creek sites and a reference stream. BBK = Big Bayou Creek kilometer; MAK = Massac Creek kilometer.

were less than the mean biomass at the BBK 12.5 reference site. The lower biomass at LUK 7.2 compared to BBK 12.5 is also a pattern seen in previous samples.

As might be expected, based on the density analysis, the longear sunfish and central stoneroller contributed the highest or next highest biomass at the Big Bayou Creek sites (Table 5.2). Other fish species that were among the larger biomass contributors at each site included the common carp (*Cyprinus carpio*) at BBK 9.1 and creek chub at MAK 13.8. At LUK 7.2, the two highest biomass contributors were the Mississippi silvery minnow and green sunfish (*Lepomis cyanellus*).

5.4.4 Production

Estimates of fish community "production" are a broader representation of individual species productivity. They represent a measurement of the accumulation of matter (or tissue) and, indirectly, a measurement of nutritional energy flow in the streams (MacFadyen 1948). The estimates track the success of reproduction in adding new individuals to a community (recruitment) and the growth of existing individuals in length and weight. This measurement goes beyond a biomass estimate in that it compares the accumulated mass from one point in time to another and accounts for changes between size classes within species. Thus, in this measurement, it is important not only to identify new individuals entering a size class, but growth in weight within a size class as well. Low production would suggest a failure in one or both of these components.

Production estimates for fall 1997 to 1998 indicated a pattern of increased production since 1996–97 (Table 5.5 and Fig. 5.3). Production rates were higher at all sites except LUK 7.2. The decline in fall production rates at LUK 7.2 was about a quarter of the rates at BBK 12.5 and MAK 13.8. The fall production at MAK 13.8 was similar to that at BBK 10.0 and BBK 9.1. The lower production at LUK 7.2 is related to the absence of central stoneroller and longear sunfish, which dominate at the other four sites.

5.4.5 Qualitative Samples

The qualitative samples of OLT 0.1 indicated that the stream, although small, contained an abundant and rich fish community. A total of 13 species was taken in the stream, with 11 found above and nine below the landfill seep (Table 5.6). Although more species were found above the seep, the number of tolerant species was the same in both sections, as was the number of benthic insectivores. In both sections, the relative abundance (catch/unit effort) of the fish was high, higher than that found in other qualitative samples in the vicinity of the Paducah Site (Roy et al. 1996, Ryon 1997). This high abundance may be due in part to the proximity of the sections to the confluence with Big Bayou Creek (<50 m), which could serve as a source for fish. Based on this one-time evaluation, the impact of the runoff/seepage from the landfill seep would appear to be minimal.

5.5 DISCUSSION

Data on the fish communities of Big Bayou and Little Bayou creeks downstream of the Paducah Site were compared to data from reference sites located on Big Bayou Creek above Paducah Site and on Massac Creek. These comparisons indicated a slight degradation in the communities downstream of the Paducah Site.

Table 5.5 Annual fish production ($g/m^2/yr$) in Big Bayou Creek, Little Bayou Creek, and a reference stream, Massac Creek, September 1997 to September 1998

	Sites[a]				
Species[b]	BBK 9.1	BBK 10.0	BBK 12.5	LUK 7.2	MAK 13.8
Gizzard shad	0.12	-	-	-	0.09
Central stoneroller	2.69	6.98	4.31	-0.05	4.19
Red shiner	-<0.01	-	-	0.04	-<0.01
Steelcolor shiner	-0.02	-	-	-	0.08
Common carp	-0.12	-	-	-	-<0.01
Mississippi silvery minnow	-0.01	-<0.01	0.52	0.54	1.74
Ribbon shiner	<0.01	-	-	-	-0.01
Redfin shiner	<0.01	-<0.01	0.02	-	- 0.01
Bluntnose minnow	-0.01	<0.01	0.05	0.20	0.45
Creek chub	-0.01	-0.06	1.04	0.41	1.84
White sucker	-0.03	-	-	-	-0.02
Creek chubsucker	-	-0.04	-<0.01	-	0.40
Spotted sucker	0.17	-	-	-	-
Golden redhorse	-	-	-	-	0.04
Yellow bullhead	-0.07	0.06	0.58	0.13	0.11
Channel catfish	-0.01	-	-	-	-
Pirate perch	-0.01	-	-	-0.01	0.01
Blackspotted topminnow	0.20	0.44	0.50	0.53	0.59
Western mosquitofish	0.07	0.17	0.21	0.14	<0.01
Brook silverside	-<0.01	-	-	-	-
Green sunfish	0.33	0.81	1.91	0.97	0.48
Warmouth	0	-	-	-0.02	
Bluegill	0.73	1.25	0.06	-0.04	0.24
Longear sunfish	6.33	6.41	3.36	0.31	3.08
Spotted bass	-1.23	-0.15	-0.01	-	-
Largemouth bass	0.01	-0.08	0.02	0	0.01
Slough darter	-	-	0	-0.01	-<0.01
Logperch	-	-	-	-	-0.17
Blackside darter	-	-	-	-	0.01
Total production	9.13	15.79	12.57	3.14	13.15

[a]BBK = Big Bayou Creek kilometer, LUK = Little Bayou Creek kilometer, MAK = Massac Creek kilometer.

[b]Common names according to the American Fisheries Society (Robins et al. 1991).

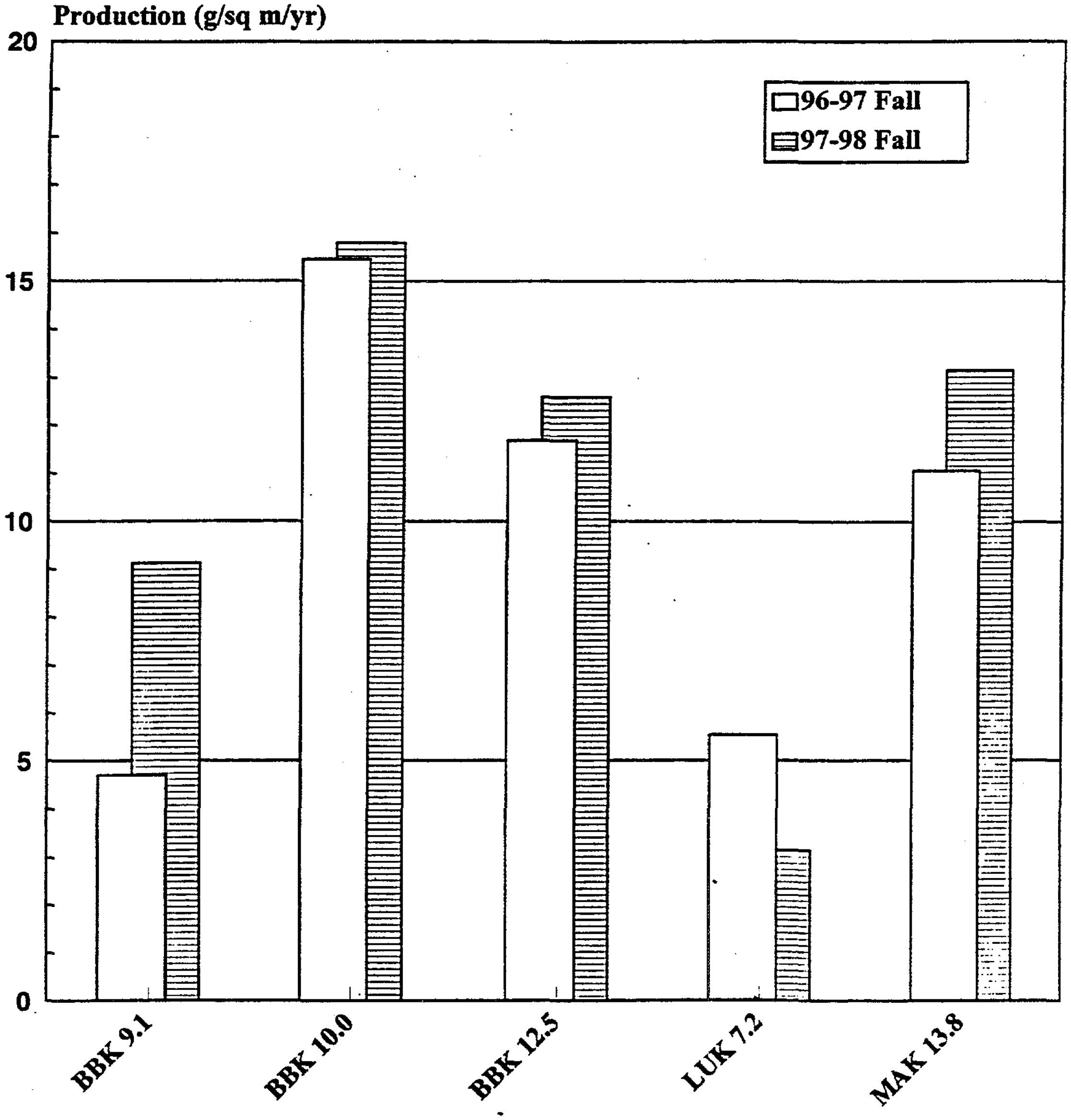


Fig. 5.3. Total annual production (in grams per m^2 per year) of fish communities for Big Bayou Creek, Little Bayou Creek, and Massac Creek based on a September to September (fall) interval for 1996 to 1997 and for 1997 to 1998. BBK = Big Bayou Creek kilometer; LUK = Little Bayou Creek kilometer; MAK = Massac Creek kilometer.

Table 5.6. Species composition, number of specimens, and catch per unit effort of the qualitative fish sampling conducted in a tributary (OLT 0.1) to Big Bayou Creek, above and below a seep from a landfill, September 14, 1998

Species[a]	Above seep[b]	Below seep[c]
Cyprinidae		
Central stoneroller (*Campostoma anomalum*)	187	293
Golden shiner (*Notemigonus chrysoleucas*)	2	-
Bluntnose minnow (*Pimephales notatus*)	-	4
Creek chub (*Semotilus atromaculatus*)	15	92
Catostomidae		
Creek chubsucker (*Erimyzon oblongus*)	1	-
Ictaluridae		
Yellow bullhead (*Ameiurus natalis*)	7	13
Aphredoderidae		
Pirate perch (*Aphredoderus sayanus*)	-	1
Cyprinodontidae		
Blackspotted topminnow (*Fundulus olivaceus*)	29	13
Poeciliidae		
Western mosquitofish (*Gambusia affinis*)	23	4
Centrarchidae		
Green sunfish (*Lepomis cyanellus*)	56	52
Bluegill (*L. macrochirus*)	1	1
Longear sunfish (*L. megalotis*)	17	-
Largemouth bass (*Micropterus salmoides*)	3	-
TOTAL SPECIMENS	342	473
TOTAL SPECIES	11	9
CATCH/UNIT EFFORT[d]	12.3	15.8

[a]Common and scientific names according to the American Fisheries Society (Robins et al.1991).

[b]One electrofisher used for 51 m and 28 min.

[c]One electrofisher used for 64 m and 30 min.

[d]Catch per unit effort is number of fish per minute of electrofishing.

Data indicated that the effects on the fish community were greatest just downstream from the Paducah Site at BBK 10.0. The fish community at this site had less than half the species richness of MAK 13.8 (Figs. 5.1 and 5.2); there were no sensitive species, and only one benthic insectivore species. Density, biomass, and production at BBK 10.0 were similar to or higher than those at the reference site (Figs 5.2 and 5.3). The limited species richness and high values for abundance/production indicate an enriched condition that favors tolerant species in competition with less tolerant species. Although the fish community at BBK 10.0 is abundant, the shortcomings in fish diversity were substantial.

The fish community at BBK 9.1 in 1998 was similar to past years. Species richness was higher than the historic means at BBK 9.1 but within the range of fall samples, and species composition measures were comparable to MAK 13.8, except for darters and benthic insectivores. Density was within the past levels for the site, but slightly less than that at MAK 13.8. Biomass was higher than in other recent fall samples (Fig. 5.2). Productivity estimates increased in fall samples (Fig 5.3) continuing the trend seen in spring production estimates from low points in 1994–95 (Ryon 1998). This increasing production indicates some moderation of impacts on recruitment success for the fish community at BBK 9.1. Whether the impacts were a natural phenomenon (e.g., floods washing any egg nests or low prey densities limiting juvenile growth) or a Paducah Site phenomenon (e.g., PCB or mercury levels reducing egg viability) cannot be determined from these data.

The fish community at LUK 7.2 was similar to the BBK 12.5 reference in terms of species richness (Fig 5.1). Biomass also remained at the mean levels of previous sampling (Table 5.3), but densities were low. The lower abundance is a continuation of a trend first seen in 1996. The general decline in density at LUK 7.2 appears linked to a decline in richness and abundance of the cyprinids (minnows) at the site. Comparisons of density trends from 1991–95 v 1996–98, show a decline of 2.5- to 5-fold for red minnow (*Cyprinella lutrensis*), central stoneroller, bluntnose minnow (*Pimephales notatus*), and creek chub (*Semotilus atromaculatus*) at this site. These declines were combined with a general disappearance in recent samples of other cyprinids, such as the suckermouth minnow (*Phenacobius mirabilis*), ribbon shiner (*Lythrurus fumeus*), and redfin shiner (*Lythrurus umbratilis*), which were last collected at LUK 7.2 in fall 1995, fall 1995, and fall 1996 respectively. Also, the mean number of cyprinids declined between 1991–95 and 1996–98 from 7.0 to 5.6 minnow species/sample at LUK 7.2; comparisons of the same periods at BBK 12.5 did not indicate any change in mean minnow species/sample. Although these are all minnow species, common life history traits that might explain their concurrent declines are not apparent. The group includes species that are sensitive (ribbon shiner) and tolerant (red minnow) to stressors, that are benthic insectivore (suckermouth minnow) and generalist (creek chub) feeders, and that reproduce by nest-building (creek chub and central stoneroller), using other species nests (redfin and red minnows), and scattering eggs without further attention (suckermouth minnow). The only common link may be in where reproduction commonly occurs, in riffle habitats. If flow patterns and/or levels of sedimentation have changed so that the quantity and quality of the riffle have declined, that may explain the lower abundance or absence of these species. For example, the removal of upstream beaver dams in recent years may have allowed more downstream transport of fine sediments. Unlike conditions in Big Bayou Creek sites, productivity continued to decline in 1998 (Fig 5.3). If declines in abundance continue, additional losses of species may occur suggesting a far more substantial impact than indicated to date at LUK 7.2.

Monitoring of the fish communities associated with Paducah Site streams indicated some depressed conditions, but did not specifically identify causative agents. The impacts were more evident at sites closest to the plant, which suggests that the Paducah Site activities may be the cause. The low species richness, lack of sensitive species or declines in abundance may be caused by poor water quality or may reflect degraded habitat. Also, as previously identified, temperature extremes may also be a factor that could be impacting fish communities (Roy et al. 1996).

6. REFERENCES

APHA (American Public Health Association, American Water Works Association and Water Pollution Control Federation). 1989. Standard Methods for the Examination of Water and Wastewater, 17th ed. Washington, D.C.

Birge, W. J., T. S. Short, and J. E. Lauth. 1990. Biological Monitoring Program for the Paducah Gaseous Diffusion Plant: Three-year report. University of Kentucky, Lexington, Kentucky.

Birge, W. J., D. Price, D. P. Keogh, J. A. Zuiderveen, and M. D. Kercher. 1992. Biological Monitoring Program for the Paducah Gaseous Diffusion Plant. Annual Report for Study Period, October 1990 through March 31, 1992. University of Kentucky, Lexington, Kentucky, Kentucky.

Carle, F. L. and M. R. Strub. 1978. A new method for estimating population size from removal data. Biometrics 34:621-630.

CH2M Hill. 1991. Results of the Site Investigation, Phase I, at the Paducah Gaseous Diffusion Plant, Kentucky, KY/ER-4, Paducah Gaseous Diffusion Plant, Paducah, Kentucky.

D'Appolonia. June 1983. Final Report, Groundwater Monitoring Program, PGDP, Paducah, Kentucky, Project 82-1397, ESO 15603, Paducah Gaseous Diffusion Plant, Paducah, Kentucky.

EPA (Environmental Protection Agency). 1991. Methods for the determination of metals in environmental samples. EPA-600/4-91-010. Environmental Monitoring Systems Laboratory, U.S. EPA, Cincinnati, Ohio.

Etnier, D. A. and W. C. Starnes. 1993. The Fishes of Tennessee. The University of Tennessee Press, Knoxville, Tennessee.

Garman, G. C., and T. F. Waters. 1983. Use of the size-frequency (Hynes) methods to estimate annual production of a stream fish population. Can. J. Fish. Manag. 6:176-182.

GeoTrans, Inc. 1990. Numerical Modeling of Groundwater Flow at the Paducah Gaseous Diffusion Plant, Phase I and II. Sterling, Kentucky.

Jones, V. W., S. E. Knaus, and G. Belcher. 1997. Paducah Site annual environmental report for 1996. KY/EM-206. Lockheed Martin Energy Systems, Inc., Paducah, Kentucky.

Karr, J. R., K. D. Fausch, P. L. Angermeier, P. R. Yant, and I. J. Schlosser. 1986. Assessing biological integrity in running waters: A method and its rationale. Illinois Natural History Survey Special Publication 5.

Karr, J. R. 1987. Biological monitoring and assessment: a conceptual framework. Environ. Manag. 11:249-256.

KDOW (Kentucky Division of Water). 1996. Procedures to facilitate alternative permit limits. Kentucky Department of Environmental Protection. Frankfort, Kentucky.

Kornegay, F. C., D. C. West, V. W. Jones, and C. M. Horak. 1994. Paducah Gaseous Diffusion Plant Annual Site Environmental Report for 1993. ES/ESH-53; KY-ERWM-18. Environmental, Safety, and Health Compliance and Environmental Staffs, Lockheed Martin Energy Systems, Inc., Oak Ridge, Tennessee, and Paducah, Kentucky.

KSNPC (Kentucky State Nature Preserves Commission). 1996. Rare and extirpated plants and animals of Kentucky. Trans. Ky. Acad. Sci. 57(2):69-91.

Kszos, L. A., S. M. Adams, T. L. Ashwood, B.G. Blalock, M. S. Greeley, Jr., R. L. Hinzman, J. M. Loar, M. J. Peterson, M. G. Ryon, B. A. Shoemaker, J. G. Smith, and G. R. Southworth. 1993. Biological Monitoring and Abatement Program for the Oak Ridge K-25 Site. K/EM-24/R2. Oak Ridge K-25 Site, Oak Ridge, Tennessee.

Kszos, L. A. (ed). 1994. Report on the Biological Monitoring Program at Paducah Gaseous Diffusion Plant, December 1990 to November 1992. ORNL/TM-12338/R1. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Kszos, L. A., R. L. Hinzman, M. J. Peterson, M. G. Ryon, J. G. Smith, and G. R. Southworth. 1994. Report on the Biological Monitoring Program at Paducah Gaseous Diffusion Plant, December 1992 to December 1993. ORNL/TM-12716. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Kszos, L. A. (ed). 1996a. Report on the Biological Monitoring Program at Paducah Gaseous Diffusion Plant, December 1993 to December 1994. ORNL/TM-12942. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Kszos, L. A. (ed). 1996b. Report on the Biological Monitoring Program at Paducah Gaseous Diffusion Plant, January–December 1995. ORNL/TM-13190. Oak Ridge National Laboratory, Oak Ridge, TN.

Kszos, L. A., A. J. Stewart, L. F. Wicker, L. E. Roberson, T. L. Phipps, and A. M. Gonzalez. 1996. Quality Assurance Program, Toxicology Laboratory, Environmental Sciences Division. QAP-X-ES-002, Rev.1, Oak Ridge National Laboratory. Oak Ridge, Tennessee.

Kszos, L. A.(ed). 1997. Report on the Biological Monitoring Program at Paducah Gaseous Diffusion Plant January–December 1996. ORNL/TM-13377. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Kszos, L. A., M. J. Peterson, M. G. Ryon, J. G. Smith, and G. R. Southworth. 1998. Report on the Biological Monitoring Program at Paducah Gaseous Diffusion Plant January-December 1997. ORNL/TM-13592. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Lee, D. S., C. R. Gilbert, C. H. Hocutt, R. E. Jenkins, D. E. McAllister, and J. R. Stauffer, Jr. 1980. Atlas of North American Freshwater Fishes. North Carolina Biological Survey Publication 1980-12, North Carolina State Museum of Natural History, North Carolina.

Leonard, P. M. and D. J. Orth. 1986. Application and testing of an Index of Biotic Integrity in small, coldwater streams. Trans. Am. Fish. Soc. 115:401-414.

Lewis, P. A., D. J. Klemm, J. M. Lazorchak, T. J. Norberg-King, W. H. Peltier, and M. A. Heber (eds). 1994. Short-term methods for estimating the chronic toxicity of effluents and receiving waters to freshwater organism (third edition). EPA/600/4-91/002. Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio.

Loar, J. M., S. M. Adams, L. J. Allison, J. M. Giddings, J. F. McCarthy, G. R. Southworth, J. G. Smith, and A. J. Stewart. 1989. The Oak Ridge Y-12 Plant Biological Monitoring and Abatement Program for East Fork Poplar Creek. ORNL/TM-10265. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Loar, J. M., S. M. Adams, L. J. Allison, B. G. Blaylock, H. L. Boston, M. A. Huston, B. L. Kimmel, J. T. Kitchings, C. R. Olsen, J. G. Smith, G. R. Southworth, A. J. Stewart, and B. T. Walton. 1991. Oak Ridge National Laboratory Biological Monitoring and Abatement Program for White Oak Creek Watershed and the Clinch River. ORNL/TM-10370. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

MacFayden, A. 1948. The meaning of productivity in biological systems. J. Anim. Ecol. 17:75–80.

Miller, D. L., P. M. Leonard, R. M. Hughes, J. R. Karr, P. B. Moyle, L. H. Schrader, B. A. Thompson, R. A. Daniels, K. D. Fausch, G. A. Fitzhugh, J. R. Gammon, D. B. Halliwell, P. L. Angermeier, and D. J. Orth. 1988. Regional application of an Index of Biotic Integrity for use in water resource management. Fisheries 13(5):12-20.

Mills, M. R., G. Bech, J. Brumley, S. M. Call, J. Grubs, R. Houp, L. Metzmeier, and K. Smathers. 1993. Methods for Assessing Biological Integrity of Surface Waters. Kentucky Department for Environmental Protection, Division of Water, Frankfort, Kentucky.

Norberg-King, T. J. 1993. A linear interpolation method for sublethal toxicity: The inhibition concentration (ICp) approach. Version 2.0. National Effluent Toxicity Assessment Center Technical Report 03-93, Environmental Research Laboratory, Duluth, Minnesota.

Ohio EPA (Environmental Protection Agency). 1988. Biological Criteria for the Protection of Aquatic Life: Volume II. Users Manual for Biological Field Assessment of Ohio Surface Streams. Ohio Environmental Protection Agency, Division of Water Quality Monitoring and Assessment, Columbus, Ohio.

Omerik, J. M. 1987. Annuals of the Association of American Geographers. Ecoregions of the Conterminous United States. 77:118–125.

Peterson, M. J. 1997. Memorandum to V. W. Jones, Paducah Gaseous Diffusion Plant. Analysis of stream fish near the Paducah Gaseous Diffusion Plant (PGDP) for assessing ecological risk. Dated September 20, 1997. Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Phipps, T. L., and L. A. Kszos. 1996. Bioavailability study for the Paducah Gaseous Diffusion Plant. ORNL/TM-13258. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Railsback, S. F., B. D. Holcomb, and M. G. Ryon. 1989. A Computer Program for Estimating Fish Population Sizes and Annual Productions Rates. ORNL/TM-11061. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Robins, C. R., R. M. Bailey, C. E. Bond, J. R. Brooker, E. A. Lachner, R. N. Lea, and W. B. Scott. 1991. Common and Scientific Names of Fishes of the United States and Canada. 5th Edition. American Fisheries Society Spec. Pub. 20. Bethesda, Maryland.

Roy, W. K., M. G. Ryon, R. L. Hinzman, J. G. Smith, J. J. Beauchamp, M. R. Smith, B. A. Carrico, R. P. Hoffmeister, M. K. McCracken, and R. A. Norman. 1996. Thermal Discharges from Paducah Gaseous Diffusion Plant Outfalls: Impacts on Stream Temperatures and Fauna of Little Bayou and Big Bayou Creeks. ORNL/TM-13183. Oak Ridge National Laboratory. Oak Ridge, Tennessee.

Ryon, M. G. 1994. Fishes. In: L. A. Kszos et al. Report on the Biological Monitoring Program at Paducah Gaseous Diffusion Plant, December 1992 to December 1993. ORNL/TM-12716. Oak Ridge National Laboratory. Oak Ridge, Tennessee.

Ryon, M. G. 1996. Fishes. In: L. A. Kszos 1996. Report on the Biological Monitoring Program at Paducah Gaseous Diffusion Plant, January–December 1995. ORNL/TM-13190. Oak Ridge National Laboratory. Oak Ridge, Tennessee.

Ryon, M. G. 1997. Fishes. In: L. A. Kszos 1997. Report on the Biological Monitoring Program at Paducah Gaseous Diffusion Plant, January–December 1996. ORNL/TM-13377. Oak Ridge National Laboratory. Oak Ridge, Tennessee.

Ryon, M. G. and B. A. Carrico. 1998. Distributional Records for Fishes of the Coastal Plain Province, Ballard and McCracken Counties, in Western Kentucky. Trans. KY Acad. Sci. 59 (1):

Ryon, M. G. 1998. Fishes. In: L. A. Kszos et al. Report on the Biological Monitoring Program at Paducah Gaseous Diffusion Plant, January–December 1997. ORNL/TM-13592. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Ryon, M. G. 1999. Biological Monitoring and Abatement Program (BMAP) Fish Community Studies, Standard Operating Procedures. QAP-X-90-ES-0607, Rev. 01. Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Sample, B. E. 1997. Memorandum to C. S. Jones, Paducah Gaseous Diffusion Plant. Screening of available ecological risk data for wildlife at the Paducah Gaseous Diffusion Plant (PGDP). Dated October 9, 1997. Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tenn.

TERRAN. 1990. Aquifer assessment report-groundwater monitoring phase II. C-404 Aquifer Testing Program. ESO 16749. Kettering, Ohio.

U.S. Department of Commerce, Bureau of the Census. April 1991. 1990 Census of Population and Housing Public Law 94-171 Data. Washington, D.C.

Weber, C. I. (ed.). 1993. Methods for measuring the acute toxicity of effluents and receiving waters to freshwater and marine organisms. EPA/600/4-90/027F. Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio.

Appendix A

RAINFALL

Table A.1. Daily precipitation for 1998 in Paducah, Kentucky

Month	Day	Precipitation (cm)
January	3	0.025
	5	2.286
	6	1.118
	7	1.905
	8	0.381
	11	0.051
	12	0.025
	14	0.152
	15	0.432
	16	0.000
	17	0.051
	18	0.254
	22	1.092
February	5	0.025
	6	0.076
	10	0.127
	11	1.981
	16	2.438
	17	4.267
	18	0.406
	22	0.076
	26	2.667
March	3	0.025
	5	0.203
	6	0.051

Table A.1 (continued)

Month	Day	Precipitation (cm)
	7	1.118
	8	0.533
	9	0.076
	11	0.051
	15	0.356
	16	0.432
	17	0.533
	18	0.914
	19	2.769
	20	0.203
	31	1.676
April	3	0.940
	7	0.102
	8	0.965
	13	1.295
	15	0.025
	16	3.835
	20	0.864
	21	0.432
	27	2.083
	28	1.143
	29	0.965
	30	1.092
May	1	0.051
	2	1.245
	3	0.178
	6	2.667
	7	1.600

Table A.1 (continued)

Month	Day	Precipitation (cm)
	9	0.076
	21	0.813
	25	0.483
	26	0.559
	31	0.533
June	4	5.486
	5	1.067
	8	0.914
	9	10.058
	10	1.473
	11	0.178
	12	0.991
	14	0.737
	19	1.626
	20	0.432
	21	0.991
	29	3.073
	30	0.864
July	3	7.137
	7	0.051
	10	0.381
	11	0.711
	14	0.940
	15	0.838
	24	0.254
	26	0.838
	27	0.102
	29	0.864

Table A.1 (continued)

Month	Day	Precipitation (cm)
	30	8.306
August	6	0.610
	7	4.547
	8	2.413
	11	0.432
	12	0.000
September	15	0.025
	16	0.152
	17	0.051
	20	0.076
October	2	0.406
	3	0.025
	5	0.838
	6	8.255
	7	5.156
	13	0.025
	18	1.219
	19	0.025
	26	0.025
	30	0.025
November	2	0.127
	7	0.381
	8	0.076
	10	1.219
	19	1.219
	20	0.965
	30	0.203
December	2	0.025

Table A.1 (continued)

Month	Day	Precipitation (cm)
	4	1.575
	5	0.051
	6	0.025
	7	0.356
	8	0.229
	9	0.025
	12	0.737
	13	0.127
	19	0.330
	20	0.025
	21	2.210
	24	0.102
	30	0.025

Note: Only days with measurable precipitation are shown.

Source: Midwestern Climate Center, Champaign, IL, Station ID156110, Barkley Regional Airport, Paducah National Weather Service.

Appendix B

TOXICITY TEST SUMMARIES PROVIDED TO THE KENTUCKY DIVISION OF WATER

Continuous Outfalls

Table B.1. Results of a *Pimephales promelas* chronic toxicity test conducted 01/27/98–02/03/98 using effluent from Outfall 001

	Percent surviving (day)							Dry weight	
Test solution	1	2	3	4	5	6	7	Total	Mean
Control	100	100	100	100	100	100	100	40	0.659
100% Effluent	100	100	100	100	95.0	87.5	85.0	40	0.628
50% Effluent	100	100	100	100	100	100	100	40	0.658
25% Effluent	100	100	100	100	97.5	97.5	97.5	40	0.692
12% Effluent	100	100	100	100	100	97.5	97.5	40	0.648
6% Effluent	100	100	100	100	100	100	100	40	0.646

IC_{25} Value: > 100%	Calculated TU_c value: < 1.0
95% Confidence limits: NA UL: LL: UL = Upper limit LL = Lower limit	Permit limits: NA If acute test, method used to determine LC_{50} and confidence limit values: NA

Table B.2. Results of a *Pimephales promelas* chronic toxicity test conducted 04/28/98–05/05/98 using effluent from Outfall 001

	Percent surviving (day)							Dry weight	
Test solution	1	2	3	4	5	6	7	Total	Mean
Control	100	100	100	100	97.5	97.5	97.5	40	0.533
100% Effluent	100	100	100	100	100	100	100	40	0.731
50% Effluent	100	100	100	100	100	95.0	95.0	40	0.663
25% Effluent	100	100	100	97.5	97.5	97.5	97.5	40	0.645
12% Effluent	100	100	100	100	100	100	100	40	0.693
6% Effluent	100	100	100	100	100	100	100	40	0.647

IC_{25} value: > 100%	Calculated TU_c value: < 1.0
95% Confidence limits: NA	Permit limits: NA
UL: LL: UL = Upper limit LL = Lower limit	If acute test, method used to determine LC_{50} and confidence limit values: NA

Table B.3. Results of a *Pimephales promelas* chronic toxicity test conducted 08/11–18/98 using effluent from Outfall 001

	Percent surviving (day)							Dry weight	
Test solution	1	2	3	4	5	6	7	Total	Mean
Control	100	100	100	97.5	97.5	95.0	95.0	40	0.484
100% Effluent	100	100	100	97.5	92.5	87.5	85.0	40	0.534
50% Effluent	100	100	100	100	100	95.0	95.0	40	0.580
25% Effluent	100	100	100	97.5	97.5	97.5	90.0	40	0.524
12% Effluent	100	100	100	100	95.0	92.5	87.5	40	0.458
6% Effluent	100	100	100	100	95.0	92.5	92.5	40	0.493

IC_{25} Value: > 100%	Calculated TU_c value: < 1.0
95% Confidence limits: NA UL: LL: UL = Upper limit LL = Lower limit	Permit limits: NA If acute test, method used to determine LC_{50} and confidence limit values: NA

Table B.4. Results of a *Pimephales promelas* chronic toxicity test conducted 11/10–17/98 using effluent from Outfall 001

	Percent surviving (day)							Dry weight	
Test solution	1	2	3	4	5	6	7	Total	Mean
Control	100	100	100	100	100	97.5	97.5	40	0.613
100% Effluent	100	100	100	100	100	100	100	40	0.744
50% Effluent	100	100	100	100	100	100	100	40	0.703
25% Effluent	100	100	100	100	100	100	100	40	0.724
12% Effluent	100	100	100	100	100	100	100	40	0.693
6% Effluent	100	100	100	100	100	100	100	40	0.687

IC_{25} Value: > 100%	Calculated TU_c value: < 1.0
95% Confidence limits: NA	Permit limits: NA
UL: LL: UL = Upper limit LL = Lower limit	If acute test, method used to determine LC_{50} and confidence limit values: NA

Table B.5. Results of a *Ceriodaphnia dubia* chronic toxicity test conducted 01/27/98–02/03/98 using effluent from Outfall 001

	Percent surviving (day)							Number of young	
Test solution	1	2	3	4	5	6	7	Total	Mean
Control	100	100	100	100	100	100	100	10	26.1
100% Effluent	100	100	100	100	100	100	100	10	27.2
50% Effluent	100	100	100	100	100	100	100	10	23.6
25% Effluent	100	100	100	100	100	100	90	10	17.9
12% Effluent	100	100	100	100	100	100	100	10	21.0
6% Effluent	100	100	100	100	100	100	100	10	28.3

IC_{25} Value: > 100%	Calculated TU_c value: < 1.0
95% Confidence limits: NA	Permit limits: TU_c = 1.0
UL: LL: UL = Upper limit LL = Lower limit	If acute test, method used to determine LC_{50} and confidence limit values: NA

Table B.6. Results of a *Ceriodaphnia dubia* chronic toxicity test conducted 04/28/98–05/04/98 using effluent from Outfall 001

	Percent surviving (day)							Number of young	
Test solution	1	2	3	4	5	6	7	Total	Mean
Control	100	100	100	100	100	100	100	10	25.9
100% Effluent	100	100	100	100	100	100	100	10	29.5
50% Effluent	100	100	100	100	100	100	100	10	27.9
25% Effluent	100	100	100	100	100	100	100	10	27.1
12% Effluent	100	100	100	100	100	100	100	10	27.5
6% Effluent	100	100	100	100	100	100	100	10	22.5

IC_{25} Value: > 100%	Calculated TU_c value: < 1.0 Permit limits: TU_c = 1.0
95% Confidence limits: NA UL: LL: UL = Upper limit LL = Lower limit	If acute test, method used to determine LC_{50} and confidence limit values: NA

Table B.7. Results of a *Ceriodaphnia dubia* chronic toxicity test conducted 08/11–18/98 using effluent from Outfall 001

	Percent surviving (day)							Number of young	
Test solution	1	2	3	4	5	6	7	Total	Mean
Control	100	100	100	100	100	100	100	9[a]	25.3
100% Effluent	100	100	100	100	100	100	100	9[a]	29.3
50% Effluent	100	100	100	100	100	100	100	9[a]	28.0
25% Effluent	100	100	100	100	100	100	100	9[a]	26.7
12% Effluent	100	100	100	100	100	100	100	9[a]	26.9
6% Effluent	100	100	100	100	100	100	100	9[a]	25.9

IC_{25} Value: > 100%	Calculated TU_c value: < 1.0
95% Confidence limits: NA	Permit Limits: TU_c = 1.0
UL: LL: UL = Upper limit LL = Lower limit	If acute test, method used to determine LC_{50} and confidence limit values: NA

[a] Unhealthy siblings from a single adult were inadvertently used at test initiation; therefore, percent surviving and mean number of offspring were based on 9 replicates.

Table B.8. Results of a *Ceriodaphnia dubia* Chronic toxicity test conducted 11/10–16/98 using effluent from Outfall 001

	Percent surviving (day)							Number of young	
Test solution	1	2	3	4	5	6	7	Total	Mean
Control	100	100	100	100	100	100	100	10	30.1
100% Effluent	100	100	100	100	100	100	100	10	33.8
50% Effluent	100	100	100	100	100	100	100	10	34.0
25% Effluent	100	100	100	100	100	100	100	10	32.0
12% Effluent	100	100	100	100	100	100	100	10	31.3
6% Effluent	100	100	100	100	100	100	100	10	31.2

IC_{25} Value: > 100%	Calculated TU_c value: < 1.0
95% Confidence limits: NA UL: LL: UL = Upper limit LL = Lower limit	Permit limits: TU_c = 1.0 If acute test, method used to determine LC_{50} and confidence limit values: NA

Intermittent Outfalls

Table B.9. Results of a Pimephales promelas chronic toxicity test conducted 01/07–14/98 using effluent from Outfall 015

	Percent surviving (day)							Dry weight	
Test solution	1	2	3	4	5	6	7	Total	Mean
Control.	100	97.5	97.5	95.0	92.5	92.5	92.5	40	0.436
100% Effluent	100	100	100	97.5	95.0	92.5	92.5	40	0.544
50% Effluent	100	100	100	90.0	90.0	90.0	87.2	39[a]	0.502
25% Effluent	100	100	100	97.5	97.5	97.5	97.5	40	0.531
12% Effluent	100	100	100	92.5	92.5	92.5	92.5	40	0.543
6% Effluent	100	100	92.5	87.5	87.5	87.5	87.5	40	0.425
IC_{25} Value: > 100%				Calculated TU_c value: < 1.0					
95% Confidence limits: NA				Permit limits: NA					
UL: LL: UL = Upper limit LL = Lower limit				If acute test, method used to determine LC_{50} and confidence limit values: NA					

[a]One test organism was missing on Day 7; therefore, percent surviving and mean growth were based on 39 test organisms.

Table B.10. Results of a *Pimephales promelas* chronic toxicity test conducted 01/07–14/98 using effluent from Outfall 017

	Percent surviving (day)							Dry weight	
Test solution	1	2	3	4	5	6	7	Total	Mean
Control	100	100	100	100	100	97.5	97.5	40	0.542
100% Effluent	100	100	100	100	97.5	97.5	97.5	40	0.615
50% Effluent	97.5	97.5	97.5	97.5	97.5	97.5	97.5	40	0.654
25% Effluent	100	100	100	100	100	100	100	40	0.640
12% Effluent	100	100	100	97.1	97.1	97.1	97.1	35[a]	0.681
6% Effluent	100	97.5	97.4	94.9	94.9	94.9	94.9	39[b]	0.574

IC_{25} Value: > 100%	Calculated TU_c value: < 1.0
95% Confidence limits: NA	Permit limits: NA
UL: LL: UL = Upper limit LL = Lower limit	If acute test, method used to determine LC_{50} and confidence limit values: NA

[a]On Day 4, five larvae were inadvertently killed when a beaker was spilled; therefore, percent surviving and mean growth were based on 35 test organisms.

[b]One test organism was missing on Day 3; therefore, percent surviving and mean growth were based on 39 test organisms.

Table B.11. Results of a *Pimephales promelas* chronic toxicity test conducted 01/07–14/98 using effluent from Outfall 018

	Percent surviving (day)							Dry weight	
Test solution	1	2	3	4	5	6	7	Total	Mean
Control	100	100	100	100	100	97.5	97.5	40	0.465
100% Effluent	100	100	97.5	97.5	97.5	97.5	95.0	40	0.591
50% Effluent	100	100	100	97.5	97.5	97.5	97.5	40	0.546
25% Effluent	100	100	100	100	100	100	100	40	0.579
12% Effluent	100	100	100	100	100	100	100	40	0.559
6% Effluent	100	100	97.5	97.5	97.5	97.5	92.5	40	0.515

IC_{25} Value: > 100%	Calculated TU_c value: < 1.0
95% Confidence limits: NA	Permit limits: NA
UL: LL: UL = Upper limit LL = Lower limit	If acute test, method used to determine LC_{50} and confidence limit values: NA

Table B.12. Results of a *Pimephales promelas* acute toxicity test conducted 04/29/98 – 05/01/98 using effluent from Outfall 015

	Percent surviving		Total alive
Test solution	24 H	48 H	
Control	100	97.5	39
100% Effluent	100	100	40
50% Effluent	100	100	40
25% Effluent	100	97.5	39
12% Effluent	100	100	40
6% Effluent	100	100	40
LC_{50} Value: > 100%		Calculated TU_a value: < 1.0	
95% Confidence limits: NA		Permit limits: NA	
UL: LL: UL = Upper limit LL = Lower limit		If acute test, method used to determine LC_{50} and confidence limit values: NA	

Table B.13. Results of a *Pimephales promelas* acute toxicity test conducted 04/29/98–05/01/98 using effluent from Outfall 017

	Percent surviving		Total alive
Test solution	24 H	48 H	
Control	100	100	40
100% Effluent	100	97.5	39
50% Effluent	100	97.5	39
25% Effluent	100	100	40
12% Effluent	100	100	40
6% Effluent	100	100	40
LC_{50} Value: > 100%		Calculated TU_a value: < 1.0	
95% Confidence limits: NA		Permit limits: NA	
UL: LL: UL = Upper limit LL = Lower limit		If acute test, method used to determine LC_{50} and confidence limit values: NA	

Table B.14. Results of a *Pimephales promelas* acute toxicity test conducted 04/24–26/98 using effluent from Outfall 019

	Percent surviving		Total alive
Test solution	24 H	48 H	
Control	97.5	97.5	39
100% Effluent	92.5	92.5	37
50% Effluent	97.5	97.5	39
25% Effluent	100	100	40
12% Effluent	100	100	40
6% Effluent	97.5	97.5	39
LC_{50} Value: > 100%		Calculated TU_a value: < 1.0	
95% Confidence limits: NA		Permit limits: NA	
UL: LL: UL = Upper limit LL = Lower limit		If acute test, method used to determine LC_{50} and confidence limit values: NA	

Table B.15. Results of a *Pimephales promelas* acute toxicity test conducted 07/15–17/98 using effluent from Outfall 015

	Percent surviving		Total alive
Test solution	24 H	48 H	
Control	100	100	40
100% Effluent	80	80	38
50% Effluent	100	100	40
25% Effluent	100	97.5	39
12% Effluent	100	100	40
6% Effluent	100	100	40
LC_{50} Value: > 100%		Calculated TU_a value: < 1.0	
95% Confidence limits: NA		Permit limits: NA	
UL: LL: UL = Upper limit LL = Lower limit		If acute test, method used to determine LC_{50} and confidence limit values: NA	

Table B.16. Results of a *Pimephales promelas* acute toxicity test conducted 07/15–17/98 using effluent from Outfall 017

	Percent surviving		Total alive
Test solution	24 H	48 H	
Control	100	100	40
100% Effluent	100	90.0	36
50% Effluent	100	100	40
25% Effluent	100	97.5	39
12% Effluent	100	100	40
6% Effluent	100	100	40
LC_{50} Value: > 100%		Calculated TU_a value: < 1.0	
95% Confidence limits: NA		Permit limits: NA	
UL: LL: UL = Upper limit LL = Lower limit		If acute test, method used to determine LC_{50} and confidence limit values: NA	

Table B.17. Results of a *Pimephales promelas* acute toxicity test conducted 08/11–13/98 using effluent from Outfall 019

	Percent surviving		Total alive
Test solution	24 H	48 H	
Control	100	100	40
100% Effluent	100	97.5	39
50% Effluent	100	100	40
25% Effluent	97.5	97.5	39
12% Effluent	100	100	40
6% Effluent	100	95.0	38
LC_{50} Value: > 100%		Calculated TU_a value: < 1.0	
95% Confidence limits: NA		Permit limits: NA	
UL: LL: UL = Upper limit LL = Lower limit		If acute test, method used to determine LC_{50} and confidence limit values: NA	

Table B.18. Results of a *Pimephales promelas* acute toxicity test conducted 10/07–09/98 using effluent from Outfall 015

	Percent surviving		Total alive
Test solution	24 H	48 H	
Control	100	100	40
100% Effluent	95.0	92.5	37
50% Effluent	97.5	97.5	39
25% Effluent	92.5	92.5	37
12.5% Effluent	100	100	40
6.25% Effluent	92.5	92.5	37
LC_{50} Value: > 100%		Calculated TU_a value: < 1.0	
95% Confidence limits: NA		Permit limits: 1.0	
UL: LL: UL = Upper limit LL = Lower limit		If acute test, method used to determine LC_{50} and confidence limit values: NA	

Table B.19. Results of a *Pimephales promelas* acute toxicity test conducted 10/07–09/98 using effluent from Outfall 017

	Percent surviving		Total alive
Test solution	24 H	48 H	
Control	92.5	92.5	37
100% Effluent	89.7[a]	89.7[a]	35
50% Effluent	100	100	40
25% Effluent	95.0	95.0	38
12.5% Effluent	95.0	95.0	38
6.25% Effluent	90.0	87.5	35
LC_{50} Value: > 100%		Calculated TU_a value: < 1.0	
95% Confidence limits: NA		Permit limits: 1.0	
UL: LL: UL = Upper limit LL = Lower limit		If acute toxicity test, method used to determine LC_{50} and confidence limit values: NA	

[a]One fathead minnow larvae was missing on day 1; therefore, percent surviving is based on 39 test organisms.

Table B.20. Results of a *Ceriodaphnia dubia* acute toxicity test conducted 01/07–09/98 using effluent from Outfall 015

	Percent surviving		Total alive
Test solution	24 H	48 H	
Control	100	100	24
100% Effluent	100	100	24
50% Effluent	100	100	24
25% Effluent	100	100	24
12% Effluent	100	100	24
6% Effluent	100	100	24
LC_{50} Value: > 100%		Calculated TU_a value: < 1.0	
95% Confidence limits: NA		Permit limits: NA	
UL: LL: UL = Upper limit LL = Lower limit		If acute toxicity test, method used to determine LC_{50} and confidence limit values: NA	

Table B.21. Results of a *Ceriodaphnia dubia* acute toxicity test conducted 01/07–09/98 using effluent from Outfall 017

	Percent surviving		Total alive
Test solution	24 H	48 H	
Control	100	95.8	23
100% Effluent	95.8	95.8	23
50% Effluent	100	100	24
25% Effluent	100	100	24
12% Effluent	100	100	24
6% Effluent	100	100	24
LC_{50} Value: > 100%		Calculated TU_a value: < 1.0	
95% Confidence limits: NA		Permit limits: NA	
UL: LL: UL = Upper limit LL = Lower limit		If acute toxicity test, method used to determine LC_{50} and confidence limit values: NA	

Table B.22. Results of a *Ceriodaphnia dubia* acute toxicity test conducted 01/07–09/98 using effluent from Outfall 018

	Percent surviving		Total alive
Test solution	24 H	48 H	
Control	100	100	24
100% Effluent	100	100	24
50% Effluent	100	100	24
25% Effluent	100	100	24
12% Effluent	100	100	24
6% Effluent	100	100	24
LC_{50} Value: > 100%		Calculated TU_a value: < 1.0	
95% Confidence limits: NA		Permit limits: NA	
UL: LL: UL = Upper limit LL = Lower limit		If acute toxicity test, method used to determine LC_{50} and confidence limit values: NA	

Table B.23. Results of a *Ceriodaphnia dubia* acute toxicity test conducted 04/29/98–05/01/98 using effluent from Outfall 015

	Percent surviving		Total alive
Test solution	24 H	48 H	
Control	100	100	23[a]
100% Effluent	100	100	24
50% Effluent	100	100	24
25% Effluent	100	100	24
12% Effluent	100	100	24
6% Effluent	100	100	24
LC_{50} Value: > 100%		Calculated TU_a value: < 1.0	
95% Confidence limits: NA		Permit limits: NA	
UL: LL: UL = Upper limit LL = Lower limit		If acute toxicity test, method used to determine LC_{50} and confidence limit values: NA	

[a]One test organism was missing on Day 1; therefore, percent surviving was based on 23 test organisms.

Table B.24. Results of a *Ceriodaphnia dubia* acute toxicity test conducted 04/29/98–05/01/98 using effluent from Outfall 017

	Percent surviving		Total alive
Test solution	24 H	48 H	
Control	100	100	24
100% Effluent	95.8	95.8	23
50% Effluent	100	100	24
25% Effluent	100	100	24
12% Effluent	100	100	24
6% Effluent	100	100	23[a]
LC_{50} Value: > 100%		Calculated TU_a value: < 1.0	
95% Confidence limits: NA		Permit limits: NA	
UL: LL: UL = Upper limit LL = Lower limit		If acute toxicity test, method used to determine LC_{50} and confidence limit values: NA	

[a]One test organism was missing on Day 1; therefore, percent surviving was based on 23 test organisms.

Table B.25. Results of a *Ceriodaphnia dubia* acute toxicity test conducted 04/24–26/98 using effluent from Outfall 019

	Percent surviving		Total alive
Test solution	24 H	48 H	
Control	100	95.8	23
100% Effluent	100	100	24
50% Effluent	100	100	24
25% Effluent	100	100	24
12% Effluent	95.8	95.8	23
6% Effluent	100	100	24
LC_{50} Value: > 100%		Calculated TU_a value: < 1.0	
95% Confidence limits: NA		Permit limits: NA	
UL: LL: UL = Upper limit LL = Lower limit		If acute toxicity test, method used to determine LC_{50} and confidence limit values: NA	

Table B.26. Results of a *Ceriodaphnia dubia* acute toxicity test conducted 07/15–17/98 using effluent from Outfall 015

	Percent surviving		Total alive
Test solution	24 H	48 H	
Control	100	95.8	23
100% Effluent	100	100	24
50% Effluent	100	100	24
25% Effluent	100	100	24
12% Effluent	100	100	24
6% Effluent	100	100	24
LC_{50} Value: > 100%		Calculated TU_a value: < 1.0	
95% Confidence limits: NA		Permit limits: NA	
UL: LL: UL = Upper limit LL = Lower limit		If acute toxicity test, method used to determine LC_{50} and confidence limit values: NA	

Table B.27. Results of a *Ceriodaphnia dubia* acute toxicity test conducted 07/15–17/98 using effluent from Outfall 017

	Percent surviving		Total alive
Test solution	24 H	48 H	
Control	100	100	24
100% Effluent	70.8	70.8	17
50% Effluent	100	100	24
25% Effluent	100	100	24
12% Effluent	100	100	24
6% Effluent	100	100	24
LC_{50} Value: > 100%		Calculated TU_a value: < 1.0	
95% Confidence limits: NA		Permit limits: NA	
UL: LL: UL = Upper limit LL = Lower limit		If acute toxicity test, method used to determine LC_{50} and confidence limit values: NA	

Table B.28. Results of a *Ceriodaphnia dubia* acute toxicity test conducted 08/11–13/98 using effluent from Outfall 019

	Percent surviving		Total alive
Test solution	24 H	48 H	
Control	100	100	24
100% Effluent	100	100	24
50% Effluent	100	100	24
25% Effluent	100	100	24
12% Effluent	100	100	24
6% Effluent	100	100	24
LC_{50} Value: > 100%		Calculated TU_a value: < 1.0	
95% Confidence limits: NA		Permit limits: NA	
UL: LL: UL = Upper limit LL = Lower limit		If acute toxicity test, method used to determine LC_{50} and confidence l limit values: NA	

Table B.29. Results of a *Ceriodaphnia dubia* acute toxicity test conducted 10/07–09/98 using effluent from Outfall 015

	Percent surviving		Total alive
Test solution	24 H	48 H	
Control	100	100	24
100% Effluent	100	100	24
50% Effluent	100	100	24
25% Effluent	100	100	24
12.5% Effluent	100	100	24
6.25% Effluent	100	100	24
LC_{50} Value: > 100%		Calculated TU_a value: < 1.0	
95% Confidence limits: NA		Permit limits: 1.0	
UL: LL: UL = Upper limit LL = Lower limit		If acute toxicity test, method used to determine LC_{50} and confidence limit values: NA	

Table B.30. Results of a *Ceriodaphnia dubia* acute toxicity test conducted 10/07–09/98 using effluent from Outfall 017

	Percent surviving		Total alive
Test solution	24 H	48 H	
Control	100	100	24
100% Effluent	0	0	0
50% Effluent	91.7	91.7	22
25% Effluent	100	100	24
12.5% Effluent	100	100	24
6.25% Effluent	100	100	24
LC_{50} Value: 66.74%		Calculated TU_a value: 1.50	
95% Confidence limits:		Permit limits: 1.0	
UL: 72.17% LL: 61.72% UL = Upper limit LL = Lower limit		If acute toxicity test, method used to determine LC_{50} and confidence limit values: Spearman-Karber Method Version 1.5	

Table B.31. Results of a *Ceriodaphnia dubia* acute toxicity test conducted 12/22–24/98 using effluent from Outfall 017

	Percent surviving		Total alive
Test solution	24 H	48 H	
Control	100	95.8	23
100% Effluent	0	0	0
50% Effluent	37.5	37.5	9
25% Effluent	100	100	24
12.5% Effluent	100	100	24
6.25% Effluent	100	95.8	23
LC_{50} Value: 46.10%		Calculated TU_a value: 2.17	
95% Confidence limits:		Permit limit: 1.0	
UL: 52.90% LL: 40.18% UL = Upper limit LL = Lower limit		If acute toxicity test, method used to determine LC_{50} and confidence limit values: Spearman-Karber Method Version 1.5	

Appendix C

RESULTS OF ANALYSES OF FISH SAMPLES

Table C.1 Concentrations of mercury and PCBs in individual fish collected from Little Bayou Creek and Big Bayou Creek.

See table footnote for explanations of parameters measured.

Site	Date	Spp.	Sex	Sample	Type	Wt.	Lgt.	Hg	PCB 1248	Qual.	PCB 1254	Qual.	PCB 1260	Qual.	Lipids
LUK9.2	10/28/97	LONEAR	M	2800	R	33.0	13.2	.	0.170	U	0.410	P	0.660	=	0.6
LUK9.2	10/28/97	LONEAR	M	2801	R	28.4	11.7	.	0.096	U	0.37	P	0.200	P	1.02
LUK9.2	10/28/97	LONEAR	M	2802	R	27.9	11.4	.	0.098	U	0.21	P	0.130	P	1.72
LUK9.2	10/28/97	LONEAR	M	2803	R	26.1	11.6	.	0.120	U	0.110	JP	0.180	P	0.496
LUK9.2	10/28/97	LONEAR	M	2804	R	31.1	12.4	.	0.110	U	0.600	P	0.630	=	0.511
LUK9.2	10/28/97	LONEAR	M	2805	R	25.8	10.8	.	0.110	U	0.320	P	0.420	=	0.768
LUK9.2	10/28/97	LONEAR	M	2806	D	.	.	.	0.140	U	0.200	=	0.510	=	0.261
LUK7.2	10/28/97	LONEAR	M	2810	R	36.9	12.8	.	0.100	U	0.310	P	0.570	=	0.757
LUK7.2	10/28/97	LONEAR	M	2811	R	43.0	13.2	.	0.110	U	0.280	P	0.420	=	0.545
LUK7.2	10/28/97	LONEAR	M	2812	R	36.0	12.1	.	0.082	U	0.22	P	0.120	P	0.658
LUK7.2	10/28/97	LONEAR	M	2813	R	38.2	13.2	.	0.100	U	0.120	P	0.270	=	0.639
LUK7.2	10/28/97	LONEAR	M	2814	R	38.6	12.8	.	0.089	U	0.16	P	0.140	P	1.54
LUK7.2	10/28/97	LONEAR	M	2815	R	34.6	12.7	.	0.110	U	0.410	P	0.760	=	0.672
LUK7.2	10/28/97	LONEAR	M	2816	D	.	.	.	0.120	U	0.390	P	0.590	=	0.728
LUK4.3	10/27/97	LONEAR	M	2820	R	43.9	12.3	.	0.067	U	0.067	U	0.067	U	0.875
LUK4.3	10/27/97	LONEAR	M	2821	R	39.5	12.6	.	0.093	U	0.17	P	0.053	J	1.21
LUK4.3	10/27/97	LONEAR	M	2822	R	41.7	12.9	.	0.076	U	0.047	JP	0.130	P	0.928
LUK4.3	10/27/97	LONEAR	M	2823	R	37.6	12.4	.	0.081	U	0.12	=	0.058	J	0.912
LUK4.3	10/27/97	LONEAR	M	2824	R	49.5	12.7	.	0.073	U	0.04	J	0.071	J	0.933
LUK4.3	10/27/97	LONEAR	M	2825	R	57.9	14.5	.	0.120	U	0.053	JP	0.071	JP	0.837
LUK4.3	10/27/97	LONEAR	M	2826	D	.	.	.	0.110	U	0.120	P	0.087	J	0.488
BBK9.1	10/28/97	SPOBAS	M	2830	R	296.3	28.7	0.35	0.022	U	0.077	P	0.069	=	0.529
BBK9.1	10/28/97	SPOBAS	F	2831	R	270.9	26.9	0.33	0.026	U	0.065	P	0.078	P	0.896
BBK9.1	10/28/97	SPOBAS	M	2832	R	269.0	27.5	0.22	0.033	U	0.058	P	0.082	=	0.673
BBK9.1	10/28/97	SPOBAS	F	2833	R	143.1	22.4	0.13	0.038	U	0.068	P	0.084	=	0.582
BBK9.1	10/28/97	SPOBAS	M	2836	D	.	.	0.37	.		.		.		.
MAK13.8	10/28/97	LONEAR	F	2807	R	26.9	11.8	.	0.140	U	0.140	U	0.140	U	0.676
MAK13.8	10/28/97	LONEAR	M	2808	R	33.4	12.4	.	0.099	U	0.099	U	0.099	U	0.771
MAK13.8	10/28/97	LONEAR	M	2809	R	26.8	11.3	.	0.120	U	0.120	U	0.120	U	0.99
MAK13.8	10/28/97	LONEAR	M	2817	R	37.7	12.5	.	0.098	U	0.098	U	0.098	U	0.723
MAK13.8	10/28/97	LONEAR	M	2818	R	32.6	12.7	.	0.110	U	0.110	U	0.110	U	0.686
MAK13.8	10/28/97	LONEAR	M	2819	R	34.9	13.3	.	0.130	U	0.130	U	0.130	U	0.757
LUK4.3	5/1/98	LONEAR	F	10070	R	47.3	12.6	.	0.076	U	0.046	JP	0.06	JP	0.967
LUK4.3	5/1/98	LONEAR	M	10071	R	50.4	12.7	.	0.063	U	0.041	JP	0.037	JP	0.84
LUK4.3	5/1/98	LONEAR	M	10072	R	60.9	14.0	.	0.085	U	0.028	JP	0.096	P	0.576
LUK4.3	5/1/98	LONEAR	M	10073	R	46.4	12.7	.	0.075	U	0.06	JP	0.077	P	0.858
LUK4.3	5/1/98	LONEAR	F	10074	R	35.7	11.9	.	0.086	U	0.028	JP	0.041	JP	0.722
LUK4.3	5/1/98	LONEAR	M	10075	R	56.5	13.5	.	0.055	U	0.058	P	0.084	P	1.34
LUK4.3	5/1/98	LONEAR	M	10076	D	.	.	.	0.074	U	0.037	JP	0.079	P	0.802

Table C.1 (continued)

Site	Date	Spp.	Sex	Sample	Type	Wt.	Lgt.	Hg	PCB 1248	Qual.	PCB 1254	Qual.	PCB 1260	Qual.	Lipids
LUK7.2	5/1/98	LONEAR	M	10040	R	67.2	13.5	.	0.08	U	0.065	JP	0.23	=	0.605
LUK7.2	5/1/98	LONEAR	M	10041	R	42.7	11.5	.	0.071	U	0.062	JP	0.11	=	1.02
LUK7.2	5/1/98	LONEAR	M	10042	R	48.7	12.7	.	0.065	U	0.081	P	0.24	=	0.903
LUK7.2	5/1/98	LONEAR	M	10043	R	41.9	11.8	.	0.079	U	0.088	P	0.23	P	0.708
LUK7.2	5/1/98	LONEAR	M	10044	R	37.9	11.7	.	0.095	U	0.057	JP	0.074	J	0.819
LUK7.2	5/1/98	LONEAR	M	10045	R	49.9	12.5	.	0.062	U	0.12	P	0.24	=	1.01
LUK7.2	5/1/98	LONEAR	M	10046	D	.	.	.	0.081	U	0.053	JP	0.12	P	0.694
LUK9.2	4/30/98	LONEAR	M	10010	R	26.0	10.6	.	0.11	U	0.091	JP	0.17	P	0.778
LUK9.2	4/30/98	LONEAR	F	10011	R	23.0	9.5	.	0.14	U	0.066	JP	0.18	=	1.01
LUK9.2	4/30/98	LONEAR	M	10012	R	49.9	12.2	.	0.059	U	0.092	P	0.2	=	0.955
LUK9.2	4/30/98	LONEAR	M	10013	R	43.3	12.0	.	0.075	U	0.078	P	0.24	=	1.19
LUK9.2	4/30/98	LONEAR	F	10014	R	27.5	10.2	.	0.14	U	0.16	P	0.16	=	1.19
LUK9.2	4/30/98	LONEAR	M	10015	R	40.7	11.2	.	0.073	U	0.069	P	0.12	P	0.757
MAK13.8	5/1/98	LONEAR	M	10093	R	37.1	12.2	.	0.089	U	0.089	U	0.089	U	0.552
MAK13.8	5/1/98	LONEAR	M	10094	R	38.2	12.0	.	0.096	U	0.096	U	0.096	U	0.731
MAK13.8	5/1/98	LONEAR	M	10095	R	36.2	11.8	.	0.093	U	0.093	U	0.093	U	0.841
MAK13.8	5/1/98	LONEAR	M	10086	R	38.1	11.7	.	0.091	U	0.091	U	0.091	U	1.02
MAK13.8	5/1/98	LONEAR	M	10097	R	25.4	10.5	.	0.12	U	0.062	JP	0.12	P	0.894
MAK13.8	5/1/98	LONEAR	M	10098	R	24.8	10.7	.	0.14	U	0.05	JP	0.092	JP	0.894
LUK9.2	10/27/98	LONEAR	M	10250	R	38.4	13.6	.	0.13	U	0.42	P	2	=	7.05
LUK9.2	10/27/98	LONEAR	M	10251	R	31.2	12.6	.	0.11	U	0.22	=	0.93	=	.
LUK9.2	10/27/98	LONEAR	M	10252	R	30.2	12.0	.	0.12	U	0.22	=	0.6	=	1.4
LUK9.2	10/27/98	LONEAR	M	10253	R	27.4	11.7	.	0.14	U	0.27	P	1.8	=	0.85
LUK9.2	10/27/98	LONEAR	M	10254	R	21.7	11.0	.	0.13	U	0.46	P	0.39	=	.
LUK9.2	10/27/98	LONEAR	M	10255	R	22.8	11.1	.	0.19	U	0.37	P	0.33	=	.
LUK9.2	10/27/98	LONEAR	M	10256	D	.	.	.	0.11	U	0.35	P	1.8	=	0.455
LUK7.2	10/27/98	LONEAR	M	10420	R	49.1	13.7	.	0.07	U	0.11	P	0.48	=	3.64
LUK7.2	10/27/98	LONEAR	M	10421	R	52.3	13.6	.	0.10	U	0.12	=	0.11	P	3.2
LUK7.2	10/27/98	LONEAR	M	10422	R	37.4	13.6	.	0.083	U	0.11	=	0.18	=	1
LUK7.2	10/27/98	LONEAR	M	10423	R	44.7	13.2	.	0.066	U	0.086	=	0.095	=	1.71
LUK7.2	10/27/98	LONEAR	M	10424	R	32.5	11.6	.	0.09	U	0.11	P	0.13	=	1.08
LUK7.2	10/27/98	LONEAR	M	10425	R	32.4	12.2	.	0.093	U	0.14	=	0.25	=	0.559
LUK7.2	10/27/98	LONEAR	M	10426	D	.	.	.	0.075	U	0.14	=	0.13	=	0.447
LUK4.3	10/28/98	LONEAR	M	10490	R	56.6	14.5	.	0.071	U	0.12	=	0.13	=	0.427
LUK4.3	10/28/98	LONEAR	M	10491	R	38.8	12.5	.	0.089	U	0.095	=	0.34	P	.
LUK4.3	10/28/98	LONEAR	M	10492	R	32.2	11.8	.	0.095	U	0.12	=	0.082	J	2.1
LUK4.3	10/28/98	LONEAR	M	10493	R	32.1	12.0	.	0.096	U	0.099	=	0.089	J	1.73
LUK4.3	10/28/98	LONEAR	F	10494	R	29.1	11.7	.	0.110	U	0.042	JP	0.029	J	0.852
LUK4.3	10/28/98	LONEAR	M	10495	R	38.2	13.2	.	0.090	U	0.021	JP	0.058	J	0.700
LUK4.3	10/28/98	LONEAR	M	10496	D	.	.	.	0.099	U	0.060	JP	0.074	J	0.853
BBK9.1	10/28/98	SPOBAS	F	10450	R	518.0	34.2	0.384	0.029	U	0.046	=	0.057	=	0.771
BBK9.1	10/28/98	SPOBAS	M	10452	R	422.3	31.4	0.218	0.068	P	0.150	P	0.140	=	1.990
BBK9.1	10/28/98	SPOBAS	F	10454	R	361.7	31.3	0.127	0.044	P	0.096	=	0.110	=	1.180
BBK9.1	10/28/98	SPOBAS	F	10455	R	359.0	29.0	0.166	0.050	P	0.130	P	0.140	=	1.670

Table C.1 (continued)

Site	Date	Spp.	Sex	Sample	Type	Wt.	Lgt.	Hg	PCB 1248	Qual.	PCB 1254	Qual.	PCB 1260	Qual.	Lipids
MAK13.8	10/28/98	LONEAR	M	10216	R	36.8	12.8	.	0.097	U	0.097	U	0.097	U	0.772
MAK13.8	10/28/98	LONEAR	M	10217	R	26.8	11.7	.	0.130	U	0.130	U	0.130	U	5.190
MAK13.8	10/28/98	LONEAR	M	10218	R	21.7	11.2	.	0.120	U	0.120	U	0.120	U	0.551
MAK13.8	10/28/98	LONEAR	M	10219	R	24.7	12.0	.	0.140	U	0.140	U	0.140	U	0.943
MAK13.8	10/28/98	LONEAR	M	10419	R	24.1	10.9	0.151	.		.		.		.

Table acronyms and data explanations are as follows:
Site designations: BBK = Big Bayou Creek kilometer; LUK = Little Bayou Creek kilometer; MAK = Massac Creek kilometer.
The date is when the fish sample was collected.
Species designations: LONEAR = Longear sunfish; SPOBAS = Spotted bass.
Type designations : R = regular sample; D = duplicate sample.
The weight of the fish is in grams.
The length of the fish is in centimeters.
Concentrations of Hg are reported as µg/g, wet weight.
Concentrations of all aroclors are reported as µg/g, wet weight.
Qual. desigation refers to the analytical qualifiers for the three aroclors. "U" indicates the compound was analyzed for but not detected. The sample quantitation limit is listed. (*detection limits are often estimated by using one tenth of the quantitation limit*). "J" indicates an estimated value that is below the quantitation limit. "P" indicates greater than 25% difference between the primary and secondary column results. "=" indicates the compound was detected at the concentration cited.
The lipid values are the percent lipids in that sample.
These data should be considered preliminary. It is BMAP's QA/QC policy that bioaccumulation data are not considered final until a number of additional QA/QC checks are completed and the data are entered into the Oak Ridge Environmental Information System (OREIS). Values for the fall of 1997 have changed slightly from those originally reported after final quality assurance checks and subsequent PCB recalculations.

ORNL/TM-13743

INTERNAL DISTRIBUTION

1. D. E. Fowler
2. B. K. Konetsky
3. S. W. Christensen
4. P. L. Henry
5. S. G. Hildebrand
6. G. K. Jacobs
7. P. Kanciruk
8–17. L. A. Kszos
18. J. M. Loar
19. T. E. Myrick
20. M. J. Peterson
21. W. K. Roy
22. M. G. Ryon
23. J. G. Smith
24. G. R. Southworth
25. Central Research Library
26–27. ESD Library
28–29. Laboratory Records Dept.
30. Laboratory Records, ORNL-RC

EXTERNAL DISTRIBUTION

31. D. L. Ashburn, Bechtel Jacobs Company LLC, 761 Veterans Avenue, Kevil, KY 42053
32. Bechtel Jacobs Company LLC, Document Management Center, 761 Veterans Avenue, Kevil, KY 42053
33. M. Broido, Director, Environmental Sciences Division, ER-74, Department of Energy, 19901 Germantown Road, Germantown, MD 20874
34. E. B. Bryant, Science Applications International Corporation, 301 Laboratory Road, Oak Ridge, TN 37931
35. J. E. Carter, Bechtel Jacobs Company LLC, 761 Veterans Avenue, Kevil, KY 42053
36. E. G. Cumesty, ORNL Site Manager, Department of Energy, Oak Ridge National Laboratory, P.O. Box 2008, Oak Ridge, TN 37831-6269
37. J. P. Giesy, Michigan State University, College of Natural Science, Department of Zoology, 203 Natural Science Building, East Lansing, MI 48824-1115
38. D. R. Guminski, Bechtel Jacobs Company LLC, 761 Veterans Avenue, Kevil, KY 42053
39. C. S. Jones, Bechtel Jacobs Company LLC, 761 Veterans Avenue, Kevil, KY 42053
40-49. V. W. Jones, Bechtel Jacobs Company LLC, 761 Veterans Avenue, Kevil, KY 42053
50. A. A. Lucier, National Council of the Paper Industry For Air and Stream Improvement, Inc., P.O. Box 13318, Research Triangle Park, NC 27709-3318
51. M. C. MacCracken, Director, Office of the U.S. Global Change Research Program, Code YS-1, 300 E Street, S.W., Washington, DC 20546
52. L. Robinson, Director, Environmental Sciences Institute, Florida A&M University Science Research Facility, 1520 S. Bronough Street, Tallahassee, FL 32307
53. J. M. Tiedje, University Distinguished Professor and Director, 540 Plant and Soil Sciences Building, Michigan State University, East Lansing, MI 48824
54-55. Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831