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OAK RIDGE NATIONAL LABORATORY

MARTIN MARIETTA

ENVIRONMENTAL SCIENCES DIVISION

Report on the Biological Monitoring Program at Paducah Gaseous Diffusion Plant December 1992 to December 1993

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R. L. Hinzman
M. J. Peterson
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Environmental Sciences Division
Publication No. 4262

December 1994

MANAGED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

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DISCLAIMER

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ACRONYMS

ANOVA	analysis of variance
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
HC	Humphrey Creek
HINDS CR	Hinds Creek
IC	inhibition concentration
ICP	inductively coupled plasma spectroscopy
IRIS	Integrated Risk Information System
KDOW	Kentucky Division of Water
KPDES	Kentucky Pollutant Discharge Elimination System
LUK	Little Bayou Creek kilometer
MAK	Massac Creek kilometer
MMES	Martin Marietta Energy Systems, Inc.
MMUS	Martin Marietta Utility Systems, Inc.
MS-222	tricaine methanesulfonate
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

RGA	regional gravel aquifer
SAS	statistical analysis system
TU	toxicity unit(s)
TU_c	chronic toxicity unit(s)
USEC	United States Enrichment Corporation
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Service
UV	ultraviolet light
WKWMA	West Kentucky Wildlife Management Area

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EXECUTIVE SUMMARY

On September 24, 1987, the Commonwealth of Kentucky Natural Resources and Environmental Protection Cabinet issued an Agreed Order that required the development of a Biological Monitoring Program (BMP) for the Paducah Gaseous Diffusion Plant (PGDP). The PGDP BMP was implemented in 1987 by the University of Kentucky. Research staff of the Environmental Sciences Division (ESD) at Oak Ridge National Laboratory (ORNL) served as reviewers and advisers to the University of Kentucky. Beginning in fall 1991, ESD added data collection and report preparation to its responsibilities for the PGDP BMP. The goals of BMP are to (1) demonstrate that the effluent limitations established for PGDP 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 health and environmental impacts, (3) document the effects of pollution abatement facilities on stream biota, and (4) recommend any program improvements that would increase effluent treatability. In September 1992, a renewed Kentucky Pollutant Discharge Elimination System (KPDES) permit was issued to PGDP. As of this writing, a new Agreed Order is in draft form. The renewed permit requires toxicity monitoring of continuous and intermittent outfalls on a quarterly basis. A BMP is not required in either the draft Agreed Order or the renewed permit; however, biological monitoring of the U.S. Department of Energy (DOE) facilities at PGDP is required under draft DOE Order 5400.1. Data collected under BMP will also be used to support three studies proposed in the draft Agreed Order.

The BMP for PGDP consists of three major tasks: (1) effluent and ambient toxicity monitoring, (2) bioaccumulation studies, and (3) ecological surveys of stream communities (i.e., benthic macroinvertebrates and fish). This report includes ESD activities occurring from December 1992 to December 1993, although activities conducted outside this time period are included as appropriate.

Study Area

PGDP is located in the western part of the Ohio River basin. Surface drainage from PGDP enters Big Bayou Creek and Little Bayou Creek which are two small tributaries to the

Ohio River. Big Bayou Creek is a perennial stream with a drainage basin extending from ~4 km south of PGDP to the Ohio River. Part of its 14.5-km course flows along the western boundary of the plant. 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 PGDP. Four continuously flowing outfalls (001, 006, 008, and 009) discharge to Big Bayou Creek. Outfalls 002, 010, 011, and 012 are combined at the C617 pond and discharged via Outfall 011 into Little Bayou Creek. Effluent from Outfalls 013, 015, 016, 017, and 018 regularly discharge into Big Bayou and Little Bayou creeks when it rains.

Prior to ORNL's initiation of the instream monitoring task, a site selection study was conducted in early December 1990. This study included visits to 24 potential reference stream sites located in the vicinity of PGDP, but outside its boundaries, and 5 stream sites adjacent to the boundaries of PGDP. Based on the site visits, biota surveys, and previous work conducted by the University of Kentucky, five stream sites were included in the Ambient Toxicity Monitoring and Instream Monitoring tasks.

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 routinely sampled to assess the ecological health of the stream and to evaluate ambient toxicity. Three additional sites (BBK 2.8, LUK 9.0, and LUK 4.3) were sampled as part of the bioaccumulation monitoring task. Toxicity monitoring and benthic macroinvertebrate sampling were conducted quarterly, and fish community and bioaccumulation sampling were conducted twice annually: in the spring and fall. KPDES outfalls evaluated for effluent toxicity included 001, 004, 006, 008, 009, 011, 013, 015, 016, 017, and 018.

Toxicity Monitoring

Ceriodaphnia and fathead minnow toxicity tests of effluents from the continuously flowing outfalls (001, 004, 006, 008, 009, and 011), the intermittently flowing outfalls (013, 015, 016, 017, and 018), and ambient sites (BBK 12.5, BBK 10.0, BBK 9.1, LUK 7.2, and MAK 13.8) were conducted quarterly beginning in October 1991. As required by the KPDES permit renewed in September 1992, quarterly tests continued at all of the outfalls listed above except outfall 004, for which testing was discontinued after October 1992. Tests with

Ceriodaphnia and fathead minnows were typically conducted concurrently. The 25% inhibition concentrations (IC25; that concentration causing a 25% reduction in fathead minnow growth or *Ceriodaphnia* survival compared with the control) were determined for each test. The higher the TU_c, the more toxic an effluent. The chronic toxicity unit rating (TU_c=100/IC25) is required as a compliance endpoint in the renewed permit (September 1992 to present). Because Little Bayou and Big Bayou creeks have been determined to have a low flow of zero, a TU_c rating of > 1.0 would be considered a noncompliance and an indicator of potential instream toxicity.

During 1993, no toxicity was evident in effluent samples from outfalls 001, 006, or 011. Only outfall 008 had a TU_c rating significantly above 1.0, and a follow-up test demonstrated that the toxicity was transient. Results from tests of intermittently flowing outfalls were similar in 1993 to those in 1991–1992. Effluent samples were not toxic to *Ceriodaphnia* but did reduce fathead minnow growth. Outfall 018 ranked as the most toxic of all those tested. Outfall 018 is located adjacent to an active landfill and contained the highest concentrations of total suspended solids compared with the other intermittent outfalls. Removing the suspended particles from the outfall 018 effluent increased fathead minnow survival, but did not change growth. Additional tests will be conducted in 1994 to further evaluate minnow survival and growth in filtered effluent from outfall 018. Over all of the ambient tests conducted during October 1991 to October 1993, there was no evidence of consistent chronic toxicity to fathead minnows of *Ceriodaphnia*; and there were only 4 times out of a 108 possible outcomes for which a significant reduction in any endpoint was observed. The lack of toxicity at the ambient sites is consistent with the lack of toxicity in the continuously flowing outfalls. The influence of effluent from outfall 001 on the water chemistry of Big Bayou Creek was shown by the large increase in hardness, conductivity, and pH at the ambient site immediately downstream from the outfall (BBK 9.1). However, changes in water chemistry did not affect minnow survival and growth or *Ceriodaphnia* survival and reproduction in the laboratory tests.

Bioaccumulation

The objectives of the bioaccumulation monitoring were (1) to continue polychlorinated biphenyl (PCB) tracking studies in fish from Big Bayou Creek and Little Bayou Creek; (2) to confirm previously observed elevated mercury concentrations in fish in Big Bayou Creek and evaluate mercury concentrations in fish from the top trophic level; and (3) to conduct screening analyses to detect other contaminants that might be of concern to consumers of fish from these streams.

Longear sunfish and spotted bass were collected for PCB and mercury analysis from Big Bayou Creek, Little Bayou Creek, and Massac Creek during October 1992 and April/March 1993. Hinds Creek (Anderson County, Tennessee) served as a source of uncontaminated reference fish. PCB contamination was again evident in longear sunfish collected from both Big Bayou and Little Bayou creeks. Mean PCB concentrations in sunfish from sites downstream of PGDP discharges exceeded concentrations in fish from the reference sites. The highest mean PCB concentration occurred in fish from the site in Little Bayou Creek immediately downstream from outfall 011. In Big Bayou Creek, the highest mean PCB concentration was found in fish from BBK 9.1, below outfall 001; but fish from BBK 10.0 also contained similar PCB concentrations. For both creeks there was a strong downstream gradient in PCB contamination in sunfish. The continued year to year association between degree of contamination and proximity to outfalls suggests that the pattern of contamination is sustained by continuing low level contamination of waters discharged to the creeks, rather than the result of residual PCB contamination in sediments of the creeks themselves. Continued regular monitoring of PCB concentrations in fish are needed to detect any consistent trend over time.

In 1993, average mercury concentrations in longear sunfish from sites in Big Bayou Creek below PGDP were similar and exceeded concentrations in local reference site fish, as was the case in 1992. The slightly elevated concentrations of mercury in fish from Big Bayou Creek below PGDP may be a result of mercury in PGDP effluents, but they may also be a consequence of differences in the biogeochemical processing of mercury downstream from the plant. Predatory game fish (spotted bass) collected in Big Bayou Creek in October 1992 contained mercury concentrations approaching the 1 μg/g FDA[*] limit. Bass averaged 0.7 μg/g mercury, with two of eight fish containing 1 μg/g. Such concentrations are not unexpected given the concentrations observed in sunfish, which are likely to be eaten by bass. Mercury

[*]U.S. Department of Agriculture Food and Drug Administration.

concentrations in fish from Kentucky reference sites were again roughly double those observed in fish from a reference site in east Tennessee.

Concentrations of metals measured in fillets of longear sunfish from Big Bayou Creek and Little Bayou Creek are typical of those observed in previous monitoring and generally differ little (with several exceptions) from concentrations observed in fish from the Tennessee reference site. Concentrations of As, Cd, Cu, Pb, Se, and Zn were similar to or lower than the national geometric mean concentrations observed for whole body analyses of fish in the U.S. Fish and Wildlife Service (USFWS) National Contaminant Biomonitoring Program. Concentrations of Sb, Cd, Cr, Ni, Se, and Ag were well below screening levels used in the Environmental Protection Agency (EPA) Integrated Risk Information System (IRIS). Beryllium and arsenic were not detected in PGDP fish (beryllium detection limit was at the IRIS screening level; arsenic detection limit was 10× screening level). Those metals for which IRIS screening levels are not published (Cu, Pb, Tl, U, and Zn) were found at concentrations similar to or lower than typically occur in food such as marine fish or mammalian muscle (Bowen 1979). Concentrations of uranium in fish from Little Bayou Creek are consistent with the observed elevated concentrations of uranium in this creek, but were lower in 1993 than in the 1992 sampling.

Ecological 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, 1992, and March and September 1993. Qualitative sampling at one site in Little Bayou Creek was conducted during the same dates.

Data on the fish communities of Big Bayou Creek and Little Bayou Creek indicated a slight but noticeable degradation in the communities downstream of PGDP compared with reference streams. Data indicated that the impact of PGDP on the fish community was greatest just downstream from the plant at BBK 10.0. The fish community at this site had a low mean and total species richness, with no sensitive species and an abundance of tolerant species. Fish density at BBK 10.0 was similar to or higher than that at the reference site, with a correspondingly high biomass. Compared with previous sampling (Ryon 1994a), BBK 10.0 has experienced a slight decline in species richness, and biomass since 1991. Overall, the fish community at BBK 10.0 has demonstrated shortcomings. The fish community at BBK 9.1 showed a level of impact similar to that seen at BBK 10.0. Mean and total species richness were low, but more sensitive species were found at BBK 9.1 than at BBK 10.0, and tolerant species were common and abundant. Density was less than or equal to the reference site, with high biomass values in 1992. Temporal trends indicate that biomass and species richness were generally declining, especially in 1993. This decline is similar to that observed at BBK 10.0. The fish community at LUK 7.2 was similar to the reference site with, perhaps, some species deficiencies. The mean and total species richness values were higher than the reference site while density and biomass were lower. Since 1991, species richness and biomass have increased slightly, which is suggestive of improvement. Whether this trend continues or is a reflection of sample variation may possibly be determined during the next monitoring period. The fish community at LUK 4.3 did not appear to be unduly affected. Species richness was comparable to that found in earlier sampling (Ryon 1994a), particularly in terms of sensitive species. The community was well represented in most families and significant absences in feeding guilds were not demonstrated. The relative abundance and catch-per-effort data were lower than prior samples (Ryon 1994a), but still at similar levels. Thus, the community at LUK 4.3 appeared to be no more stressed than in previous samplings.

Benthic samples were collected at quarterly intervals from three sites in Big Bayou Creek, one site in Little Bayou Creek, and at one offsite reference station (Massac Creek) beginning in September 1991. Preliminary benthic macroinvertebrate community data for Big Bayou Creek and Little Bayou Creek showed distinct site differences which may be indicative of the effect of facility effluents. All sites, including the reference sites, were comprised of large proportions of taxa that were tolerant of at least moderately polluted conditions. Greater community balance at BBK 12.5, a reference site on Big Bayou Creek, suggested that if any stress existed at this site, it was minimal. The relative abundances of some of the major taxonomic groups at BBK 10.0 and BBK 12.5 differed substantially, while the community at BBK 9.1 was more similar to that observed at BBK 12.5, suggesting that conditions at BBK 10.0 had been affected. However, the presence of a large number of pollution-tolerant, hydropsychid caddisflies at BBK 9.1 suggested water quality at this site remained somewhat impaired relative to BBK 12.5. The composition and structure of the macroinvertebrate communities at BBK 9.1 and BBK 10.0 strongly suggested that they had been affected by increased siltation and nutrient enrichment. However, other factors such as elevated temperatures and excess concentrations of metals may have also affected the invertebrate communities at these sites as well.

Chironomids numerically dominated the macroinvertebrate community at LUK 7.2, while the Ephemeroptera were virtually absent, suggesting that the site had been at least moderately affected by the plant. In addition to poor water quality associated with effluent discharges, poor habitat quality may also be a possible factor contributing to the depauperate macroinvertebrate community at LBK 7.2. A more extensive data base that includes sample collections over several seasons and years should help provide a better understanding of the ecological conditions at this site as well as those at sites in Big Bayou Creek.

1. INTRODUCTION

On September 24, 1987, the Commonwealth of Kentucky Natural Resources and Environmental Protection Cabinet issued an Agreed Order that required the development of a Biological Monitoring Program (BMP) for the Paducah Gaseous Diffusion Plant (PGDP). A plan for the biological monitoring of the receiving streams (Little Bayou Creek and Big Bayou Creek) was prepared by the University of Kentucky (Birge et al. 1987), reviewed by staff at PGDP 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 PGDP 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 goals of the BMP are to (1) evaluate the acceptability of PGDP effluents under the Kentucky Pollutant Discharge Elimination System (KPDES) regulatory program, (2) characterize their potential health and environmental impacts, and (3) make recommendations on any changes necessary to improve effluent discharges. The PGDP 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 the Oak Ridge K-25 Site, 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 PGDP BMP. Data resulting from BMP conducted by the University of Kentucky were presented in a 3-year draft report issued in December 1990 (Birge et al. 1990) and an annual 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 PGDP 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, (3) guiding plans for remediation, and (4) protecting human health. For example, BMP revealed the accumulation of polychlorinated biphenyls (PCBs) in fish from selected reaches of the Bayou watershed, a finding that prompted issuance of a fish consumption advisory for Little Bayou Creek by the Kentucky Department for Environmental Protection. Continuation of the program will also provide a data base that can be used to determine the adequacy and efficacy of remedial actions that are implemented and to detect any new or unsuspected toxicants that are released in effluents.

In September 1992, a renewed KPDES permit was issued to PGDP. As of this writing, a new Agreed Order is in draft form. The renewed permit requires toxicity monitoring of continuous and intermittent outfalls on a quarterly basis. A BMP is not required in either the draft Agreed Order or the renewed permit. However, biological monitoring of the DOE facilities at PGDP, at Oak Ridge, Tennessee, and at Portsmouth, Ohio, is required under DOE Order 5400.1. Data collected under BMP will also be used to support three studies proposed in the draft Agreed Order: (1) temperature variability and instream effects of elevated temperature from outfalls 001 and 011; (2) influence of effluent pH on instream pH; and (3) development of site-specific metal limits for outfalls.

The BMP for PGDP consists of three major tasks: (1) effluent and ambient toxicity monitoring, (2) bioaccumulation studies, and (3) ecological surveys of stream communities (e.g., benthic macroinvertebrates and fish). This report includes ESD activities occurring from December 1992 to December 1993, although activities conducted outside this time period are included as appropriate.

2. DESCRIPTION OF STUDY AREA[1]

2.1 SITE DESCRIPTION *(R. L. Hinzman)*

The PGDP is owned by the United States Department of Energy (DOE). Production facilities are leased to the United States Enrichment Corporation (USEC) and are managed by Martin Marietta Utility Systems, Inc. (MMUS). The environmental restoration and waste management activities are managed by Martin Marietta Energy Systems, Inc. (MMES). The plant was constructed in 1951 and is an active uranium enrichment facility consisting of a diffusion cascade and extensive support facilities (Kornegay et al. 1992a). The uranium enrichment gaseous diffusion process involves more than 1800 stages with operations housed in 5 buildings covering ~300 ha. Including support facilities, the plant has ~ 30 permanent buildings located on a 1385-ha site (Oakes et al. 1987). Support facilities include a steam plant, four electrical switchyards, four sets of cooling towers, a chemical cleaning and decontamination facility, water and wastewater treatment plants, a chromium reduction facility, maintenance and laboratory facilities, and two active landfills. Several inactive facilities are also located on the site. Currently, the Paducah cascade processes are being used for the enrichment of uranium up to 2% ^{235}U. This product is then transferred to the Portsmouth (Ohio) Gaseous Diffusion Plant for further enrichment (Oakes et al. 1987). Most of the uranium produced is used for national defense and commercial reactors in the United States and abroad.

2.1.1 Land Use

The area surrounding PDGP is mostly rural, with residences and farms surrounding the plant. Immediately adjacent to PGDP is the West Kentucky Wildlife Management Area (WKWMA), 2821 ha comprising natural habitat, state-maintained forage crops, and ponds, for use by hunters and fishermen. About 20 of the 35 ponds support fishing, and ~ 200 deer are harvested annually.

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[1]Sections 2.1 and 2.2 contain large excerpts from: T. G. Jett, Surface Water, Section 4. pp 4.3–4.13. *IN* Kornegay et al. 1993. Paducah Gaseous Diffusion Plant Environmental Report for 1992. ES/ESH-22/V3. Oak Ridge National Laboratory. Oak Ridge, Tenn.

The population within the 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).

2.1.2 Geohydrology

PGDP is located in the Jackson Purchase region of western Kentucky. It lies in the northern margin of the Mississippi Embayment portion of the Gulf Coastal Plain Province. The Mississippi Embayment was a large sedimentary trough, oriented roughly north-south, which existed during the Cretaceous and Tertiary periods. The sedimentary sequence overlying the Mississippian age bedrock in the vicinity of PGDP consists mainly of fine- to medium-grained clastic materials, including (from youngest to oldest) a basal gravel (i.e., Tuscaloosa Formation) or rubble zone, the McNary Formation, the Porters Creek Clay, and undifferentiated Eocene sands.

Following deposition of the embayment sediments, the embayment was either uplifted and/or sea level lowered, resulting in the development of an erosional surface that truncated the sediments. Subsequently, during the late Tertiary and Quaternary periods, a unit designated as the Continental Deposits was laid down in the region. The Continental Deposits have been interpreted as originally being deposited in an alluvial fan that covered most of the Jackson Purchase region (Olive 1980). The Continental Deposits have been informally divided into a lower gravel region and an upper silt or clay unit; each unit varies in thickness from 0 to 32 m. The clay facies are believed to consist of discontinuous fine sand lenses enclosed by clay; however, this interpretation is based on limited data, and the degree of interconnectedness of the interbedded sand lenses cannot be verified at this time (Kornegay et al. 1992a). Immediately overlying the Continental Deposits, Pleistocene loess (originating as windblown material generated by glacial activity) was deposited in a layer of variable thickness (3–10 m). Recent Ohio River alluvial deposits occur at lower elevations along the river's floodplain.

Current understanding of local groundwater hydrology in the vicinity of PGDP is dominated by the recognized importance of the Continental Deposits. This unit is termed the regional gravel aquifer (RGA) and is the uppermost aquifer underlying most of PGDP and the contiguous area north. This groundwater flow system is primarily developed in Pleistocene sands and gravels of the lower member of the Continental Deposits, ~ 13 to 33 m beneath PGDP. The Continental Deposits rest upon terraces cut by the ancestral Tennessee and Tennessee-Ohio rivers. Terrace escarpments occurring under the south end of PGDP form the southern limit of the RGA.

Groundwater flow in the loess and the upper member of the Continental Deposits is primarily oriented downward because of the interbedded sand and gravel lenses and the significantly lower potentiometric surface of the RGA. Within the RGA, flow is directed north, discharging into the Ohio River. The hydrology of the RGA was first investigated by the U. S. Geological Service (USGS) in the mid 1960s. Results of these studies indicated that the gravel is saturated over most of its areal extent in the region of the plant, and wells completed within it are reported to be capable of producing yields of up to 3790 L/min. For a more detailed description of the geohydrology of the area, see Kornegay et al. 1992a; CH2M Hill 1991; D'Appolonia 1983; TERRAN 1990; GeoTrans 1990.

2.1.3 Surface Water

PGDP 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 (Fig. 2.1). Surface drainage from PGDP is two small tributaries of the Ohio River, Big Bayou Creek and Little Bayou Creek. These streams meet ~ 4.8 km north of the site and discharge to the Ohio River at kilometer 1524, which is ~ 56 km upstream of the confluence of the Ohio and Mississippi Rivers (Fig. 2.2). PGDP 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 PGDP to the Ohio River; part of its 14.5 km course flows along the western boundary of the plant. 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 plant. 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 PGDP operations can constitute about 85% of the normal flow in Big Bayou Creek and 100% in Little Bayou Creek. During the dry season which

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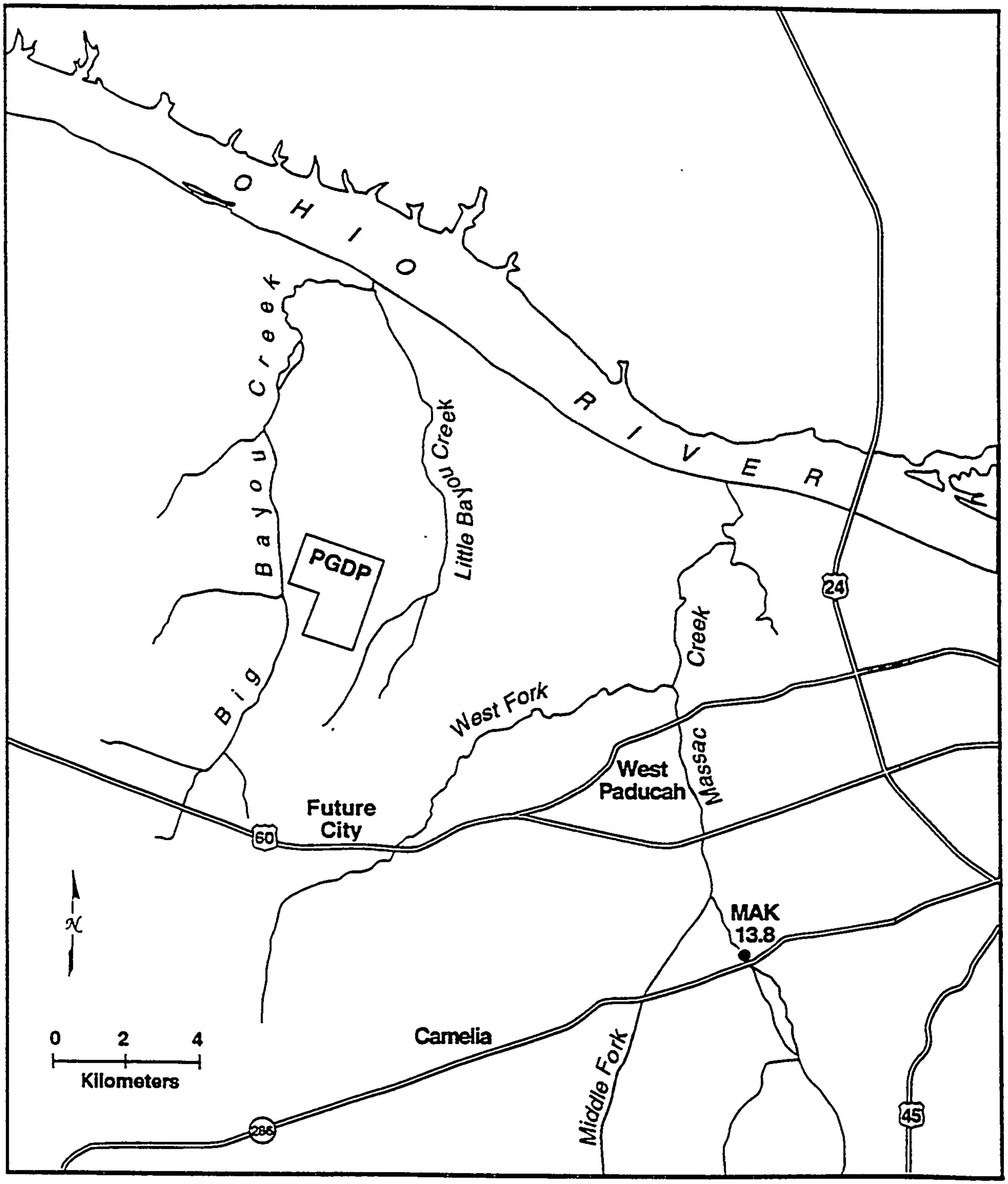

Fig. 2.1. Map of Paducah Gaseous Diffusion Plant (PGDP) in relation to the geographic region. The reference site for PGDP biological monitoring activities is located on Massac Creek at kilometer (MAK) 13.8.

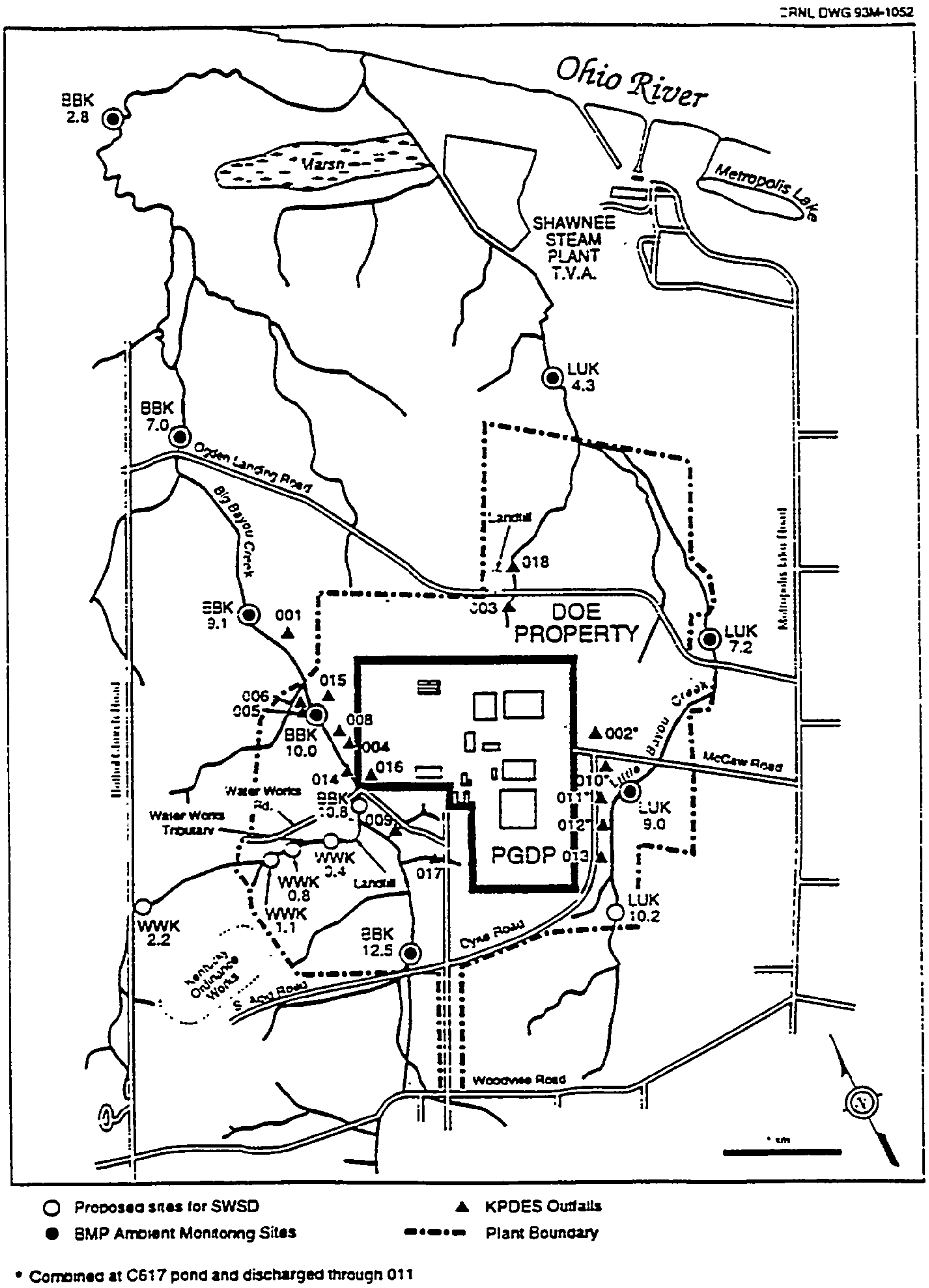

Fig. 2.2. Location of Biological Monitoring Program (BMP) sites and Kentucky Pollutant Discharge Elimination System (KPDES) permitted outfalls for the Paducah Gaseous Diffusion Plant (PGDP). BBK = Big Bayou Creek kilometer; LUK = Little Bayou Creek kilometer; WWK = Water Works Tributary kilometer; T.V.A. = Tennessee Valley Authority; DOE = Department of Energy.

extends from summer to early fall, no-flow conditions may occur in the upper section of Little Bayou Creek (Birge et al. 1992). Precipitation in the region averages about 120 cm per year. 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.

The majority of effluents at PGDP consist 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. Routine monitoring activities provide data to quantify total discharges to surface water in order to demonstrate compliance with federal, state, and DOE requirements. Monitoring also assists with evaluating the effectiveness of effluent treatment and control programs.

2.2 WATER QUALITY AND PGDP EFFLUENTS *(R. L. Hinzman)*

The Clean Water Act is currently administered for PGDP by the Kentucky Division of Water (KDOW) through the KPDES Wastewater Discharge Permitting Program. A National Pollutant Discharge Elimination System (NPDES) permit (KY0004049), issued by Region IV of the U. S. Environmental Protection Agency (EPA), became effective February 15, 1975. The NPDES permit was revised February 4, 1977, and expired in 1980. Although PGDP had applied for a new permit, no system was in place at KDOW to replace the NPDES permit and a new permit could not be issued. PGDP operated under the original 1975 NPDES permit until the state of Kentucky issued the KPDES permit (KY0004049). On November 5, 1986, the state permit was adjudicated because the permit limits were not achievable. As part of the negotiations associated with the adjudication process, an Agreed Order was proposed that included interim limits while a biological monitoring study was conducted at PGDP. The KPDES permit expired in October 1991; however, monitoring continues under the KPDES Agreed Order. By submitting permit renewal documents in May 1991, PGDP complied with regulations that allow the continued discharge of wastewater under the auspices of the expired permit. KDOW issued KPDES Permit No. KY0004049 to PGDP in September 1992. This permit became effective November 1, 1992, and is enforced by the KDOW. At the request of PGDP, the state of Kentucky granted a stay of permit limits for pH, metals, and temperature in

October 1992. PGDP is working with KDOW to approve an Agreed Order concerning the establishment of final limits for these parameters. All other conditions stated in the permit are in effect (Kornegay et al. 1993).

Monitoring of 17 individual outfalls is conducted in accordance with the KPDES Agreed Order. Table 2.1 lists all outfalls and their contributing processes; Fig. 2.2 shows the location of the outfalls. Eight of the 17 outfalls 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 011 continuously to Little Bayou Creek. These combined discharges averaged ~ 15×10^6 L/d and 1.8×10^6 L/d to Big Bayou Creek and Little Bayou Creek respectively.

Summary statistics (mean, maximum, minimum, and the number of observations) for KPDES chemical parameters for 1993 observed at each outfall are given in Appendix A (Tables A.1 to A.15). Water quality in the outfalls was characterized by occasional increases in concentrations of some metals. Metals of concern include Cd, Cu, Pb, Ni, and Zn. Maximum values for one or more of these metals have exceeded EPA water quality criteria at most outfalls in 1992 and 1993 (EPA 1986). PGDP and KDOW have agreed that PGDP will conduct a study to determine whether alternative metal limits are justified based on concentrations of dissolved metals in the outfalls; current limits are based on concentrations of total metals. KDOW will review the information developed to determine metal limits. Maximum pH levels exceeded water quality criteria at several outfalls in 1992 and at outfalls 001, 006, and 011 in 1993. PGDP has met the interim limit for pH (6.0–10.5), however, the permit limit currently under negotiation is 6.0–9.0 and would have been exceeded at several outfalls. However, instream pH measurements have been within the limits set by the permit (see Sect. 3.2). KDOW is reviewing the instream pH data collected by PGDP to determine whether in-stream monitoring of pH would be an acceptable option for PGDP to pursue. PGDP is exploring engineering controls for temperature at outfalls 001 and 011; these controls may enable PGDP to meet permit limits for temperature at these sites. In addition, ESD staff are conducting a temperature study to evaluate the effects of elevated temperatures on the biota of Big Bayou and Little Bayou creeks. Mean hardness values at Outfall 001 were about twice as high in 1992 and 1993 than in previous years (Table 5.3 in Birge et al. 1992). A discussion of current instream water quality monitoring occurs in Sect. 3.2 of this report. Discussions of previous water quality monitoring efforts can be found in Birge et al. 1992.

Table 2.1. Kentucky Pollutant Discharge Elimination System (KPDES) permitted outfalls at Paducah Gaseous Diffusion Plant

Location[a]	Discharge source	Flow[b]	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	6.2±4.3	Recirculating cooling water blowdown treatment effluent, coal-pile runoff, once-through cooling water, surface runoff, roof and floor drains, treated uranium solutions, sink drains
002	C-360, C-637, C-337-A	0.4±0.6	Once through cooling water, roof and floor drains, sink drains, extended aeration sewage treatment system
003	North edge of plant	2.8	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	1.5±0.2	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	NM[c]	Water treatment plant sludge, sand filter backwash, laboratory sink drains
006	C-611 secondary lagoon	2.7±1.1	Water treatment plant sludge, sand filter backwash, laboratory sink drains from outfall 005
007	Outfall eliminated	NM[c]	
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	4.5±3.2	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	1.7±4.6	Surface drainage, roof and floor drains, condensate, once-through cooling water, sink drains
010	C-531, C-331	0.3±0.3	Switchyard runoff, roof and floor drains, condensate, sink drains
011	C-340, C-533, C-532, C-315, C-333, C-331	0.5±0.5	Once-through cooling water, roof and floor drains, switchyard runoff, condensate, sink drains
012	C-633, C-533, C-333-A	0.6±1.2	Roof, floor, and sink drains, condensate, surface runoff, extended aeration sewage treatment system
013	Southeast corner of the plant	5.3±8.1	Surface runoff
014	C-611 U-shaped sludge lagoon	NM[c]	Sand filter backwash, sanitary water
015	West central plant areas	1.5±3.7	Surface runoff
016	Southwest corner of the plant	4.7±6.3	Surface runoff
017	Extreme south area of the plant	0.8±1.8	Surface runoff
018	Landfill at north of plant	4.97[d]	Surface runoff

[a]Numeral indicates outfall designation. Locations also identified in Fig. 2.2 of this report.
[b]Mean discharge in millions of liters per day ± 1 standard deviation.
[c]NM = Not monitored
[d]Mean value based on 11 KPDES measurements for 1993, see Table A-15.
Note: This table was taken from Kornegay et al. 1993 (Paducah Gaseous Diffusion Plant Environmental Report for 1992. ES/ESH-36. Oak Ridge National Laboratory, Oak Ridge, Tennessee) and Birge et al. 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).

Flow from the north/south diversion ditch is normally channeled through Outfall 001 by a lift station that pumps the effluent through the C-616 full-flow lagoon. However, during rainfalls with flows that have maximum daily averages greater than a 10-year occurrence interval, the lift station overflows to Outfall 003. This is the only time that Outfall 003 is monitored. Outfall 005 is not monitored regularly because its effluent flows into the C-611 secondary lagoon. Outfall 006, the C-611 secondary lagoon, is monitored for the same parameters as those required for Outfall 005. Outfall 007, a septic field for the C-611 water treatment plant, is not permitted to discharge. Monitoring of Outfall 014 occurs only when the C-611 sludge lagoon is dredged (i.e., every 2 or 3 years), and the filter backwash is discharged to the outfall.

Corrective measures have been taken to reduce the number of KPDES noncompliances at PGDP. Emphasis has been placed on erosion control at construction sites, effluent ditches, and landfills. A best management practices plan for the control of suspended solids, prepared in 1991, details measures taken to prevent erosion and investigates erosion-related problems and corrective measures. The plan was submitted to and approved by the KDOW. The Plant Effluent Chlorine and Temperature Control Project became operational in October 1991, providing common lagoon (C-617) for outfalls 002, 010, 011, and 012. This lagoon, designed to contain effluent from the outfall except during heavy rainfall, provides sodium thiosulfate feed for chlorine removal and increased holding time for temperature reduction. In addition, sodium thiosulfate feed stations were installed permanently at outfalls 009 and 004. Once-through cooling water that originally flowed through Outfall 001 is now routed through the C-616 full-flow lagoon to allow for chlorine dissipation. In response to temperature noncompliances, leaking steam traps in several buildings were repaired or replaced and temperature noncompliances ceased.

In 1993 the chromium based inhibitor was replaced with a phosphate based inhibitor at the chromium reduction facility. This change could affect the nature of wastewater at Outfall 001.

Dredging of the sludge lagoon at the C-611 water treatment plant was initiated in September 1993. Currently the clarifier bottoms are being discharged directly into the full flow lagoon for settling. This change has not resulted in permit violations, but changes in water quality at Outfall 006 may be detected as a result of this action. The sludge lagoon will be returned to service sometime in late 1994.

2.3 DESCRIPTION OF STUDY SITES *(J. G. Smith, M. J. Peterson, and M. G. Ryon)*

Three 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 station on Massac Creek (Fig. 2.1), Massac Creek kilometer (MAK) 13.8, were routinely sampled to assess the ecological health of the stream and to evaluate ambient toxicity. A summary of the site locations is given in Table 2.2. Three additional sites (BBK 2.8, LUK 9.0, and LUK 4.3; Fig 2.2) were sampled as part of the bioaccumulation monitoring task. Hinds Creek in East Tennessee also served as a reference site for the bioaccumulation monitoring task. A description of the sampling locations for the bioaccumulation monitoring is provided in Sect. 4. Site selection and sampling locations for the ecological monitoring studies are described below. Ambient toxicity monitoring sites were chosen to correspond with those used for ecological monitoring. Biological monitoring activities conducted through December 1993 are outlined in Table 2.3. Toxicity monitoring and benthic macroinvertebrate sampling were conducted quarterly, and fish community and

Table 2.2. Locations and names of sampling sites included in Paducah Gaseous Diffusion Plant Biological Monitoring Program for the Instream Monitoring Task

Current Site Name[a]	Location[b]	Former Name/Site[c]
Big Bayou Creek		
BBK 12.5	~200 m downstream of bridge on South Acid Road	BB1
BBK 10.0	~50 m upstream of Outfall 006	BB4
BBK 9.1	~25 m upstream of flume at gaging station at Bobo Road	BB7
Little Bayou Creek		
LUK 7.2	~110 m downstream of bridge on Route 358	LB3
Massac Creek		
MAK 13.8	~40 m upstream of bridge on Route 62, 10 km SE of PGDP	Not sampled

[a]Site names are based on stream name and distance of the site from the mouth of the stream. For example, BB7 is designated as Big Bayou Creek Kilometer (BBK) 9.1 and is located 9.1 km upstream of the mouth; LUK = Little Bayou Creek kilometer; and MAK = Massac Creek kilometer.

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

[c]Site designations formerly used by the University of Kentucky.

Table 2.3. Sampling schedule for the four components of the Biological Monitoring Program at Paducah Gaseous Diffusion Plant for January–December 1993

Month	Toxicity monitoring	Benthic macroinvertebrates	Fishes	Bioaccumulation
Jan.				
Feb.	X			
Mar.		X	X	
Apr.				X
May	X			X[b]
June		X	X[a]	
July				
Aug.	X			
Sept.		X	X	X
Oct.	X			
Nov.				
Dec.		X		

[a]Qualitative survey of Massac Creek watershed.
[b]Big Bayou Creek kilometer 2.8 only.

bioaccumulation sampling were conducted twice annually (in the spring and fall). KPDES outfalls at which effluents were evaluated for toxicity included 001, 004, 006, 008, 009, 011, 013, 015, 016, 017, and 018.

Prior to ORNL's initiation of the instream monitoring task for the PGDP BMP, a site selection study was conducted in early December 1990. This study included visits to 24 potential reference stream sites located in the vicinity of PGDP but outside its boundaries (see Table 2.4 in Kszos et al. 1994), and 5 stream sites adjacent to the boundary of PGDP: LUK 7.2, LUK 4.3, BBK 12.5, BBK 9.1, and the tributary draining Outfall 003. The site selection study also involved the collection of qualitative benthic macroinvertebrate and fish samples at some of the sites to aid in final site selection (Tables 2.5 and 2.6 in Kszos et al. 1994). Because these samples were qualitative, the results served primarily to document which taxa were present at these sites at the time of the survey. However, these qualitative data did provide some minimal information on the relative health of each stream sampled and, thus, helped in making final site selections.

Based on the site visits, biota surveys, and previous work conducted by the University of Kentucky (Birge et al. 1990), five stream sites were included in the instream monitoring task of the BMP. A list of the selected sites and a summary of their locations are given in Table 2.2; their locations in relation to the PGDP are shown in Fig. 2.1 and Fig. 2.2. Final sampling locations within each selected site were made in June 1991 during a habitat characterization study. This study included measurements of vegetative cover, bank structure, channel morphology, substrate and cover variables, and flow conditions. Pertinent results of this study for each site are presented in sections 2.3.1–2.3.3 and Table 2.7 in Kszos et al. 1994.

3. TOXICITY MONITORING

L. A. Kszos

The toxicity monitoring task for BMP consists of two subtasks. The first measures the toxicity of effluents as required by the KPDES permit. The second monitors ambient water toxicity of three sites in Big Bayou Creek, one site in Little Bayou Creek, and one reference site in Massac Creek. The effluent toxicity data are presented in Sect. 3.1; the ambient toxicity data are presented in Sect. 3.2.

3.1 EFFLUENT TOXICITY

3.1.1 Introduction

The EPA supports the use of aquatic test organisms to determine the chronic toxicity of a test water (Weber et al. 1989). Toxicity monitoring at PGDP uses the Cladoceran (*Ceriodaphnia dubia*) Survival and Reproduction Test (hereinafter referred to as the *Ceriodaphnia* test) and the Fathead Minnow (*Pimephales promelas*) Larval Survival and Growth Test (hereinafter referred to as the fathead minnow test; Weber et al. 1989) concurrently to characterize the toxicity of the continuous and intermittent effluents that discharge into Big Bayou and Little Bayou creeks. These two tests are EPA-approved for use in the KPDES program to estimate (1) the chronic toxicity of effluents collected at the end of the discharge pipe and tested with a standard dilution water; (2) the toxicity of receiving water downstream from or within the influence of the outfall; and (3) the effects of multiple discharges on the quality of the receiving water (Weber et al. 1989). These tests are also part of the Biological Monitoring and Abatement Programs at ORNL, the Oak Ridge K-25 Site, and the Oak Ridge Y-12 Plant.

The ESD Toxicology Laboratory at ORNL began evaluating the toxicity of continuous and intermittent outfalls at PGDP in October 1991. As required by a draft Agreed Order, *Ceriodaphnia* and fathead minnow tests were conducted quarterly. In September 1992, a renewed KPDES permit was issued to PGDP. Under the requirements of this permit, *Ceriodaphnia* and fathead minnow tests were continued on a quarterly basis. Toxicity tests of Outfall 004 were not required in the renewed KPDES permit, thus tests were discontinued for this outfall after October 1992.

3.1.2 Materials and Methods

Toxicity tests of effluents from the continuously flowing outfalls (001, 006, 008, 009, and 011) and the intermittently flowing outfalls (013, 015, 016, 017, and 018) were conducted according to the schedule shown in Table 3.1. This report includes all tests conducted from 1991 to 1993 by ESD. Most of the outfalls have been evaluated nine times.

Prior to September 1992, tests of the continuously flowing outfalls were conducted using seven consecutive, daily grab samples collected at the KPDES discharge points. Subsequent tests used seven 24-h composite samples as required by the renewed KPDES permit. Samples from the continuously flowing outfalls were collected by personnel from ESD and transported to a nearby offsite laboratory. The intermittently flowing outfalls are rainfall dependent; thus, tests were conducted using one grab sample. Samples from the intermittently flowing outfalls were collected by personnel from PGDP, refrigerated, and shipped to ESD using 24-h delivery. All samples were collected and delivered according to established chain-of-custody procedures (Kszos et al. 1989). Time of collection, water temperature, and arrival time in the laboratory were recorded.

Tests with *Ceriodaphnia* and fathead minnows were typically conducted concurrently following procedures outlined in Weber et al. (1989) and Kszos et al. (1989). These tests are static-renewal tests, meaning that test water is replaced daily for 6 or 7 consecutive days. The fathead minnow test consists 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 d, the larvae were dried and weighed to obtain an estimate of growth. The *Ceriodaphnia* test consists 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 day of a test, subsamples of each effluent were routinely analyzed for pH, conductivity, alkalinity, water hardness, and total residual and free chlorine (Kszos et al. 1989). A subsample of each sample was also acidified and saved for metal analyses by Inductively Coupled Plasma spectroscopy (ICP).

During the May 1993 test, subsamples of effluent from 016 and 018 were filtered through glass microfiber filters (1.2 μm) to remove suspended solids. Fathead minnow tests were then

Table 3.1. Summary of toxicity test dates for continuous and intermittent outfalls

Outfall	Test Date
001, 006, 008, 009, 011	October 24-31, 1991
	February 13-20, 1992
	May 21-28, 1992
	August 13-20, 1992
	October 22-29, 1992
	February 11-18, 1993
	May 20-27, 1993
	August 19-16, 1993
	October 14-21, 1993
	December 2-9, 1993[a]
013, 015, 016, 017, 018	December 27, 1991 - January 3, 1992
	March 20-27, 1992
	June 26 - July 3, 1992[b]
	September 22-29, 1992[c]
	September 29 - October 6, 1992[d]
	November 13-20, 1992
	January 6-13, 1993
	May 4-11, 1993
	September 16-23, 1993
	November 16-23, 1993

[a]Outfall 008, fathead minnow only
[b]Outfall 016 was not tested due to lack of flow
[c]Fathead minnow only
[d]*Ceriodaphnia* only

conducted using nontreated and filtered effluent samples. The amount of suspended solids in the effluent was measured by filtering a known volume of effluent through a pre-dried, pre-weighed filter.

A linear interpolation method (Weber et al. 1989) was used to determine the 25% inhibition concentration (IC25, that concentration causing a 25% reduction in fathead minnow growth or *Ceriodaphnia* survival compared to a control). A computer program (ICp Calculation Program, release 1.0) distributed by the EPA (Environmental Research Laboratory, Duluth, Minnesota) and provided by KDOW was used for the calculation. The chronic toxicity unit (TU_c=100/IC25) is required as a compliance endpoint in the renewed permit (September 1992 to present). The higher the TU_c, the more toxic an effluent. Because Little Bayou and Big Bayou creeks have been determined to have a low flow of zero, a $TU_c > 1.0$ would be considered a noncompliance and an indicator of potential instream toxicity.

3.1.3 Results

3.1.3.1 Continuously flowing outfalls 001, 004, 006, 008, 009, and 011

A summary of the TU_cs for all toxicity tests conducted during 1991–93 are provided in Table 3.2. For tests conducted to date, effluent from Outfall 011 exceeded the permit limit of $TU_c > 1.0$ for one test (February 1992). Outfalls 001, 006, and 008 each exceeded the permit limit twice. The two exceedences (one for fathead minnows and one for *Ceriodaphnia*) for Outfall 006 occurred in February 1992; no toxicity has been observed for the past 6 tests. Outfalls 001 and 008 each had one exceedence in 1992 and one in 1993. The exceedence for Outfall 001 during 1993 was only slightly above the permit limit (TU_c = 1.09). In October 1993, the TU_c for Outfall 008 with fathead minnows was high (4.08), but a follow-up test conducted in December resulted in a $TU_c < 1.0$.

A summary of water quality parameters for each outfall is provided in Table 3.3. The pH of the effluent samples ranged from a minimum of 6.8 (Outfall 006) to a maximum of 9.2 (Outfall 006). Effluent from Outfall 006 had the highest mean pH (8.62). Mean alkalinity ranged from 34 (Outfall 001) to 55 (Outfall 009). Mean hardness and conductivity were highest in effluent from Outfall 001 (403 mg/L and 1266 μS/cm respectively). Mean hardness at the remaining outfalls ranged from 77 to 87 mg/L and mean conductivity was approximately 240 μS/cm.

Table 3.2. Results of effluent toxicity tests for outfalls 001, 006, 008, 009, and 011

Outfall	Test Date	Chronic Toxicity Units (TU_c)[a]	
		Fathead Minnow	*Ceriodaphnia*
001	October 1991	ND[b]	<1
	February 1992	<1	<1
	May 1992	ND[b]	4.5
	August 1992	<1	<1
	October 1992	<1	<1
	February 1993	<1	<1
	May 1993	<1	<1
	August 1993	<1	<1
	October 1993	<1	1.09
006	October 1991	ND[b]	<1
	February 1992	1.39	1.56
	May 1992	ND[b]	<1
	August 1992	<1	<1
	October 1992	<1	<1
	February 1993	<1	<1
	May 1993	<1	I[d]
	June 1993	NT[c]	<1
	August 1993	<1	<1
	October 1993	<1	<1
008	October 1991	ND[b]	<1
	February 1992	9.77	<1
	May 1992	ND[b]	<1
	August 1992	<1	<1
	October 1992	<1	<1
	February 1993	<1	<1
	May 1993	<1	I[d]
	June 1993	NT[c]	<1
	August 1993	<1	<1
	October 1993	4.08	<1
	December 1993	<1	NT[c]
009	October 1991	ND[b]	<1
	February 1992	7.87	<1
	May 1992	<1	<1
	August 1992	<1	<1
	October 1992	2.16	1.05
	February 1993	<1	<1
	May 1993	<1	I[d]
	June 1993	NT[c]	<1
	August 1993	<1	<1
	October 1993	<1	<1

Table 3.2 (continued)

Outfall	Test Date	Chronic Toxicity Units (TU_c)[a]	
		Fathead Minnow	*Ceriodaphnia*
011	October 1991	ND[b]	<1
	February 1992	7.69	<1
	May 1992	ND[b]	<1
	August 1992	<1	<1
	October 1992	<1	<1
	February 1993	<1	<1
	May 1993	<1	<1
	August 1993	<1	<1
	October 1993	<1	<1

[a]Chronic toxicity unit = 100/IC25; IC25 = the concentration causing a 25% reduction in fathead minnow growth or *Ceriodaphnia* reproduction. IC = inhibition concentration.

[b]ND = not determined.

[c]NT = not tested.

[d]I = Invalid test due to low reproduction in the control water.

Table 3.3. Summary of water chemistry analyses of full-strength samples from continuously flowing effluents, 1991–1993

Sample	pH (Standard Units)	Alkalinity (mg/L as $CaCO_3$)	Hardness (mg/L as $CaCO_3$)	Conductivity (μS/cm)
Outfall 001				
Mean (± SD)	8.21 (0.57)	34.3 (10.7)	402.6 (131.0)	1266.0 (383.7)
Range	7.40–9.54	23–85	134–680	489–1867
n	63	63	63	63
Outfall 006				
Mean (± SD)	8.92 (0.49)	48.6 (16.7)	86.5 (27.1)	240.2 (44.8)
Range	6.80–9.72	30–88	50–204	163–329
n	69	69	69	69
Outfall 008				
Mean (± SD)	7.44 (0.19)	36.2 (10.0)	76.6 (14.4)	269.7 (44.8)
Range	6.90–8.20	23–63	50–112	177–461
n	75	75	75	75
Outfall 009				
Mean (± SD)	7.69 (0.27)	54.7 (28.6)	83.9 (24.2)	250.0 (113.4)
Range	7.10–8.37	32–233	44–210	116–1020
n	69	69	69	69
Outfall 011				
Mean (± SD)	7.81 (0.28)	37.2 (9.5)	78.2 (14.6)	239.9 (34.8)
Range	7.40–9.15	23–62	52–110	168–330
n	63	63	63	63

Results of the metal analyses conducted by ESD are not yet available. KPDES data are available in Appendix A. Because toxicity is rarely observed for the effluents, ESD will no longer collect metal data.

3.1.3.2 Intermittently flowing outfalls 013, 015, 016, 017, and 018

A summary of the TU_cs for all toxicity tests conducted during 1991–93 is provided in Table 3.4. Although PGDP does not have a compliance limit for the intermittent outfalls, $TU_c > 1.0$ was used as a benchmark. For all tests conducted, only effluent from outfall 013 was toxic to *Ceriodaphnia* and only during one test (January 1993). No toxicity to *Ceriodaphnia* was observed for any of the other outfalls during any test. As in 1992, fathead minnows continued to be more sensitive than *Ceriodaphnia* to the effluents. For tests conducted to date, effluents from outfalls 015, 016, and 017 each had a $TU_c > 1.0$ for fathead minnows three times. Outfall 018 had a $TU_c > 1.0$ for fathead minnows four times and outfall 013 had a $TU_c > 1.0$ for fathead minnows six times (Table 3.4). The average TU_cs for outfalls 013, 015, 016, 017, and 018 were 2.3, 4.4, 1.7, 11.1, and 9.2. Filtering the effluent samples from 016 and 018 improved fathead minnow survival by 15 to 22% (Table 3.5) when compared with the nonfiltered samples. The difference was largest for outfall 018, which also contained the highest concentration of suspended solids (0.04 g/L compared with 0.01 g/L for outfall 016). Mean growth was not higher in the filtered effluent than in the nonfiltered effluent (Table 3.5)

Ranking the outfalls provided a means to determine which outfall was the most toxic. Each outfall was ranked in terms of frequency of $TU_c > 1.0$ (5 = highest frequency and 1 = lowest frequency) and by mean TU_c for fathead minnows (5 = highest mean and 1 = lowest mean). The ranks were then summed to obtain an overall ranking (Table 3.6). Outfall 018 did not rank the highest in either frequency or mean TU_c, but had the highest sum rank (8). Outfalls 013 and 017 tied with a sum rank of 7. Outfall 013 had the highest rank in terms of frequency and Outfall 017 had the highest rank in terms of mean TU_c.

A summary of water quality parameters for each outfall is provided in Table 3.7. In general, water from the intermittent outfalls had higher alkalinity and hardness than the continuous outfalls. Mean alkalinity ranged from 55 to 121 mg/L and mean hardness ranged from 103 to 178 mg/L. Minimum pH ranged from 6.91 to 7.75 and maximum pH ranged from 7.96 to 8.27. Mean conductivity ranged from 202 to 349μS/cm.

Table 3.4. Results of effluent toxicity tests for Outfalls 013, 015, 016, 017, and 018

Outfall	Test Date	Chronic toxicity unit (TU_c)[a]	
		Fathead minnow	*Ceriodaphnia*
013	December 1991	<1	<1
	March 1992	5.82	<1
	June 1992	1.02	<1
	September 1992	<1	<1
	November 1992	1.96	<1
	January 1993	<1	6.99
	May 1993	1.3	<1
	September 1993	1.39	<1
	November 1993	<1	<1
015	December 1991	<1	<1
	March 1992	7.91	<1
	June 1992	<1	<1
	September 1992	<1	ND[b]
	November 1992	<1	<1
	January 1993	1.52	<1
	May 1993	3.62	<1
	September 1993	<1	<1
	November 1993	<1	<1
016	December 1991	<1	<1
	March 1992	1.74	<1
	September 1992	<1	<1
	November 1992	1.32	<1
	January 1993	2.04	<1
	May 1993	<1	<1
	September 1993	<1	<1
	November 1993	<1	<1
017	December 1991	ND[b]	<1
	March 1992	4.54	<1
	June 1992	<1	<1
	September 1992	5.01	<1
	November 1992	<1	<1
	January 1993	<1	<1
	May 1993	23.8	<1
	September 1993	<1	<1
	November 1993	<1	<1
018	December 1991	<1	<1
	March 1992	5.27	<1
	June 1992	<1	<1
	September 1992	<1	<1
	November 1992	1.43	<1
	January 1993	8.47	<1
	May 1993	21.7	<1
	September 1993	<1	<1
	November 1993	<1	<1

[a]Chronic toxicity unit = 100/IC25; IC25 = the concentration causing a 25% reduction in fathead minnow growth or *Ceriodaphnia* reproduction. IC = inhibition concentration.

[b]ND = not determined.

Table 3.5. Comparison of fathead minnow survival and growth in filtered (1.2 μm) and nonfiltered water from outfalls 016 and 018

Sample	Treatment[a]	Mean Survival (%)	Mean Growth (± SD) (mg)
Control	N	95.0	0.40 (0.04)
016	N	80.0	0.45 (0.03)
	F	95.0	0.36 (0.04)
018	N	70.0	0.35 (0.07)
	F	92.5	0.39 (0.07)

Note: Effluent samples were collected on May 3, 1993. Toxicity tests were conducted during May 5-12, 1993.

[a]N = none; F = filtered.

Table 3.6. Ranking of intermittent outfalls based upon frequency of chronic toxicity unit (TU_c) > 1.0 and mean TU_c for nine tests

Outfall	Frequency of TU_c > 1.0	Rank[a] of Frequency (TU_c > 1)	Mean TU_c	Rank of Mean TU_c	Sum of Ranks
013	6	5	2.3	2	7
015	3	2	4.4	3	5
016	3	2	1.7	1	3
017	3	2	11.1	5	7
018	4	4	9.2	4	8

[a]Highest rank = 5; lowest rank = 1.

Table 3.7. Summary of water chemistry analyses of full-strength samples from intermittently flowing effluents, 1991–1993

Sample	pH (Standard units)	Alkalinity (mg/L as $CaCO_3$)	Hardness (mg/L as $CaCO_3$)	Conductivity (µS/cm)
Outfall 013				
Mean (± SD)	7.44 (0.30)	54.7 (15.2)	155.6 (116.2)	303.7 (221.5)
Range	6.91–7.96	28–81	42–360	84–704
n	10	10	10	10
Outfall 015				
Mean (± SD)	7.73 (0.27)	85.3 (25.5)	136.9 (30.3)	288.6 (65.2)
Range	7.20–8.16	42–119	76–182	153–368
n	9	9	9	9
Outfall 016				
Mean (± SD)	7.85 (0.28)	98.8 (22.4)	173.4 (102.7)	334.2 (194.9)
Range	7.35–8.20	60–122	72–446	138–856
n	10	10	10	10
Outfall 017				
Mean (± SD)	7.97 (0.16)	120.8 (22.8)	177.8 (42.8)	349.0 (85.6)
Range	7.75–8.27	70–146	92–230	175–466
n	10	10	10	10
Outfall 018				
Mean (± SD)	7.75 (0.27)	57.1 (13.4)	102.9 (41.6)	201.5 (79.2)
Range	7.23–8.13	36–79	52–162	98–337
n	11	11	11	11

3.1.4 Discussion

3.1.4.1 Continuously flowing outfalls

During 1993, no toxicity was evident in effluent samples from 001, 006, or 011. In October 1993, Outfall 001 had a TU_c of 1.09 for *Ceriodaphnia* which is 0.09 units above the compliance endpoint (TU_c = 1.0). Only effluent from Outfall 008 had a TU_c significantly above 1.0, and a follow-up test demonstrated that the toxicity was transient. Thus, during 1993, there was no evidence of consistent toxicity in any of the continuously flowing outfalls.

3.1.4.2 Intermittently flowing outfalls

Toxicity test results in 1993 were similar to those for 1991–92. Effluent samples were not toxic to *Ceriodaphnia* but did reduce fathead minnow growth. After ranking the outfalls, Outfall 018 was identified as the most toxic. This outfall is located adjacent to an active landfill on the northeast side of PGDP (Fig. 2-2) and is located on a tributary to Little Bayou Creek. It also contained the highest amount of total suspended solids (maximum 204 g/L, Appendix A) compared with the other intermittent outfalls. Removing the suspended solids from the 018 effluent increased survival of fathead minnows but did not change minnow growth. This indicates that suspended solids may directly (e.g. deposition on gill surfaces) or indirectly (e.g., contaminant desorption from particles) reduce the survival of the minnows. Additional tests will be conducted in 1994 to further evaluate minnow survival and growth in filtered effluent from 018. A special study will also be conducted in 1994 to determine site-specific metal criteria for many of the outfalls. This study is a requirement of the current draft Agreed Order and will include a determination of the concentrations of dissolved and total metals in each effluent.

3.2 AMBIENT TOXICITY

3.2.1 Introduction

Ambient toxicity monitoring at PGDP employed the *Ceriodaphnia* and fathead minnow tests described in Sect. 3.1. Toxicity monitoring was incorporated into BMP in order to (1) evaluate area source contributions to stream toxicity, (2) characterize patterns of toxicity in Big Bayou and Little Bayou creeks, (3) document changes in water quality attributable to changes in operations at PGDP, and (4) provide data to evaluate whether the effluent limitations established for PGDP protect and maintain the use of Big Bayou and Little Bayou creeks for growth and propagation of fish and other aquatic life. The sites chosen for testing on Big Bayou Creek were selected to bracket area and point source discharges into the creeks and to correspond closely to those selected as instream monitoring study sites. The site chosen on Little Bayou Creek is downstream of all PGDP continuous discharges. The following discussion includes all tests conducted during 1991–93.

3.2.2 Materials and Methods

Ambient toxicity was evaluated using the fathead minnow test and the *Ceriodaphnia* test as described in Sect. 3.1 for continuously flowing outfalls with the following exceptions: (1) no dilutions were tested, and (2) each test used seven consecutive, daily grab samples of stream water. For eight tests, a subsample of each ambient water sample was exposed to ultraviolet (UV) light for a 15-min period in a Lifegard® model QL25TH water treatment device. The unit contained a 25-W UV light source (254 nm wavelength) shielded from direct contact with the water by a quartz tube. The water samples were then evaluated for toxicity using fathead minnows.

Three ambient sites on Big Bayou Creek (BBK 12.5, BBK 10.0, and BBK 9.1; Fig. 2.2), one site on Little Bayou Creek (LUK 7.2, Fig. 2.2), and one site on Massac Creek (MAK 13.8, Fig. 2.1) were evaluated for toxicity. These sites are the same as those selected for the ecological monitoring component of BMP (Sect. 5). Nine tests were conducted on a quarterly basis from October 1991 to October 1993. Water sampling and water chemistry analyses were conducted as described for continuously flowing outfalls in Sect. 3.1.2.

All data analyses were accomplished as in Sect. 3.1.2 with the exception of those described in the following section. Significant differences in *Ceriodaphnia* survival among sites for all tests were evaluated using the General Linear Models (GLM) procedure in SAS (SAS 1985a, 1985b). Because significant differences existed from test to test in *Ceriodaphnia* reproduction and fathead minnow survival and growth, the GLM procedure was inappropriate for separating differences among all sites. Thus, separate GLM analyses (followed by a separation of means using Tukey's Studentized Range Test) were conducted for each test period. Fathead minnow growth and *Ceriodaphnia* reproduction were also summarized by comparing the outcome for each site to the outcome in the reference site, MAK 13.8. First, the data were normalized by calculating the growth or reproduction for each site as a percentage of the growth or reproduction for the reference site in the corresponding test. A frequency distribution of that percentage was then plotted. Unless otherwise noted, statements of significance (probability) are based on $p = 0.05$.

3.2.3 Results

Mean survival and growth of fathead minnows for each site and test are provided in Appendix B (Table B.1). The frequency distribution of fathead minnow survival is provided in Figures 3.1 and 3.2. In 66% of the tests conducted, mean survival of minnows was between 80 and 100%. In 12 to 27% of the tests conducted, mean survival of minnows was between 60 and 80%. For BBK 12.5, BBK 10.0, BBK 9.1, and LUK 7.2, survival was <60% in 12% (1 of 9) of the tests conducted. A comparison among sites for each test period showed that during the February 1992 test period, survival at LUK 7.2 was significantly lower than survival at the remaining sites. No difference was found for the remaining test periods. A comparison of minnow survival in nontreated water vs UV-treated water showed that survival was significantly higher in the UV-treated water from LUK 7.2 (GLM; $p = 0.007$) and BBK 9.1 (GLM; $p = 0.02$).

The frequency distribution of fathead minnow growth at each site as a percentage of growth at MAK 13.8 is shown in Figures 3.3 and 3.4. For Big Bayou Creek sites, approximately 10 to 20% of the tests with nontreated water had growth equal to 75% of the growth at MAK 13.8. In the remaining tests of nontreated water from Big Bayou Creek sites, minnow growth was ≥100% of the growth at MAK 13.8. Minnow growth in nontreated water from Little Bayou Creek was ≥100% of the growth at MAK 13.8. A comparison among sites for each test period showed that during the May 1992 test period, growth at BBK 10.0 and BBK 9.1 was significantly lower than growth at reference site MAK 13.8. During the February 1993 test period, growth at BBK 10.0 was significantly lower than growth at all other sites. No difference was found for the remaining test periods. Treating the water with UV altered the frequency distribution of growth slightly (Figs. 3.3 and 3.4), but a comparison of growth in nontreated water vs UV-treated water showed that there was no significant difference (GLM; $p > 0.05$) in growth at any site.

Mean survival and reproduction of *Ceriodaphnia* for each site and test are provided in Appendix B (Table B.2). *Ceriodaphnia* survival for all sites and tests was ≥80% except during October 1991 when survival for BBK 9.1 was 70%. The frequency distribution of *Ceriodaphnia* reproduction is shown in Figures 3.5 and 3.6. For all sites, approximately 10

ORNL-DWG 94-14143

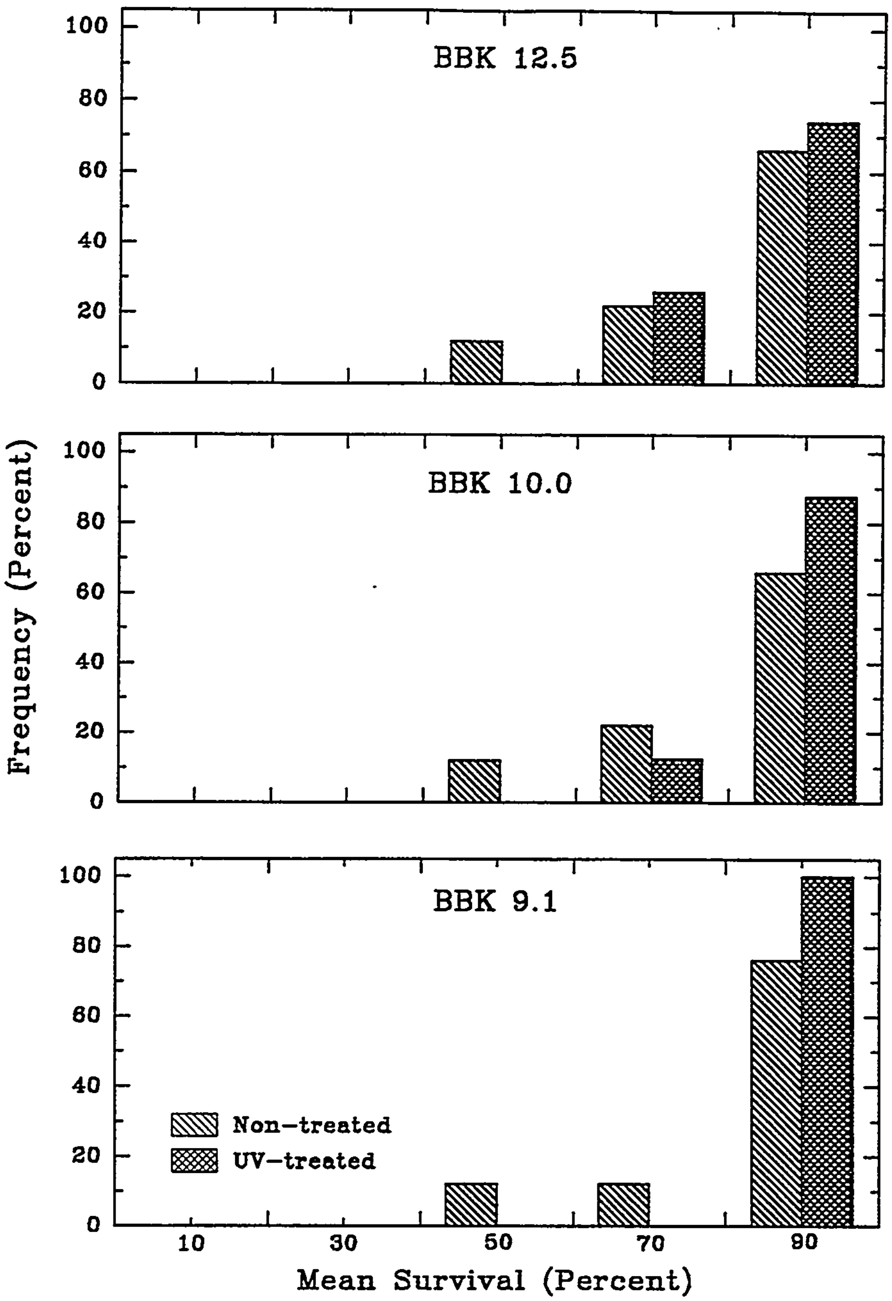

Figure 3.1. Frequency distribution of fathead minnow survival at Big Bayou Creek sites. BBK = Big Bayou Creek kilometer.

ORNL-DWG 94-14144

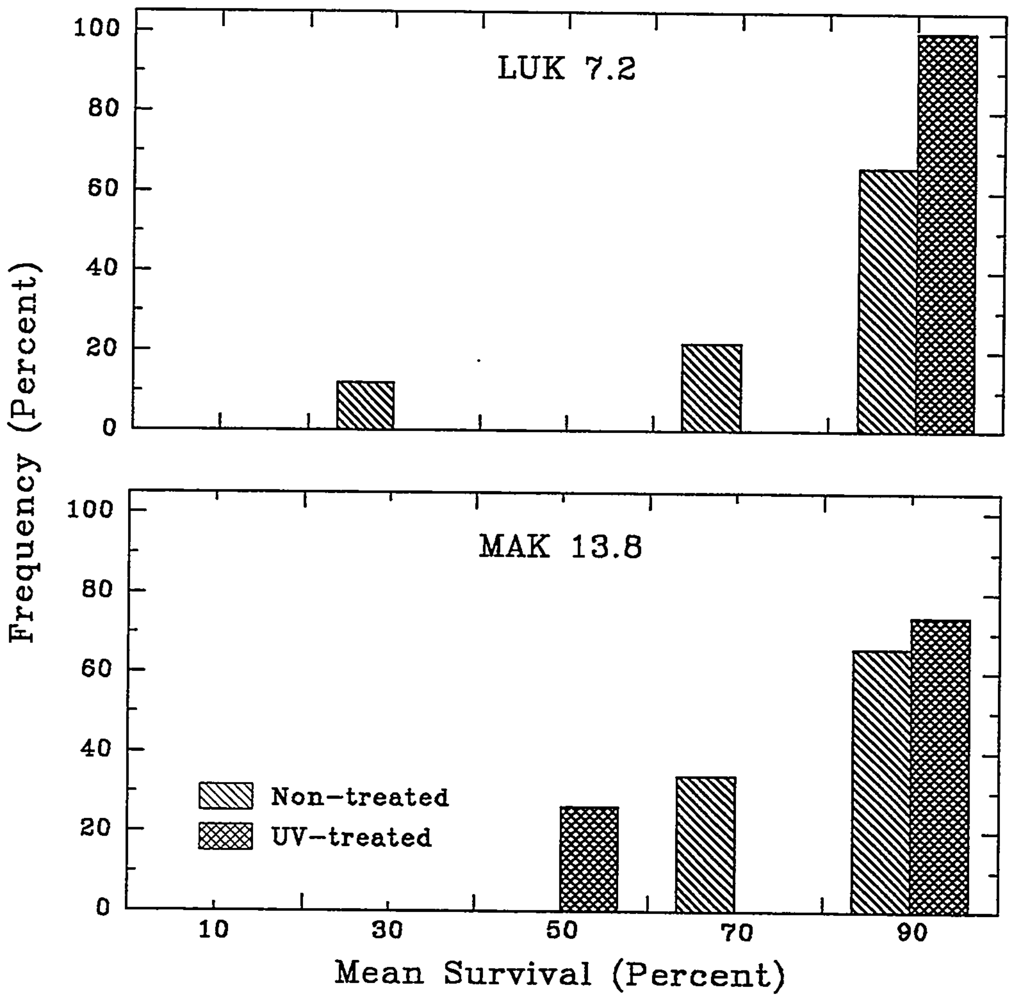

Figure 3.2. Frequency distribution of fathead minnow survival at one site on Little Bayou Creek and one site on Massac Creek. LUK = Little Bayou Creek kilometer, MAK = Massac Creek kilometer.

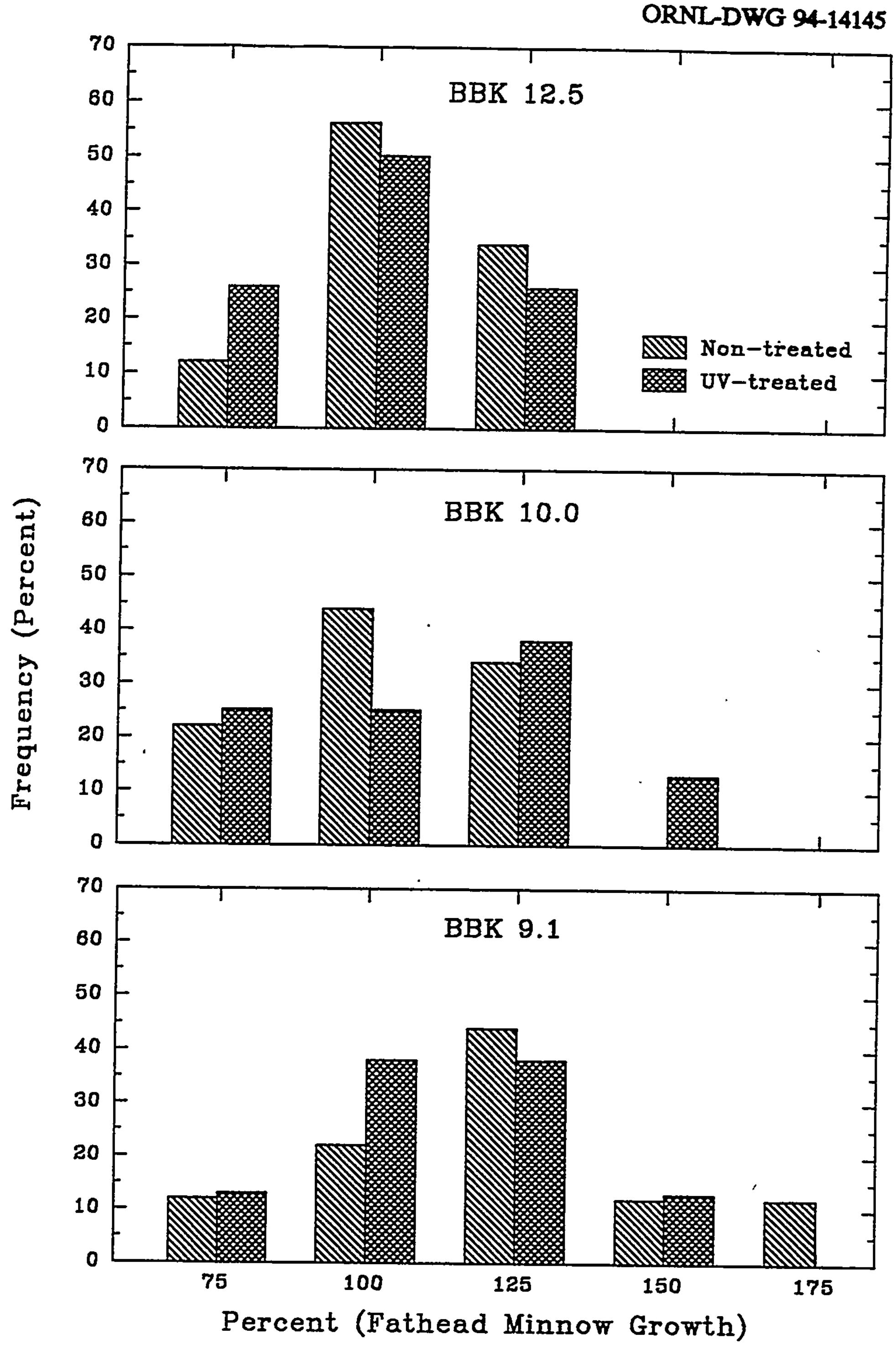

Figure 3.3. Frequency distribution of fathead minnow growth at Big Bayou Creek sites expressed as a percentage of growth at the reference site, Massac Creek at kilometer 13.8. BBK = Big Bayou Creek kilometer.

ORNL-DWG 94-14146

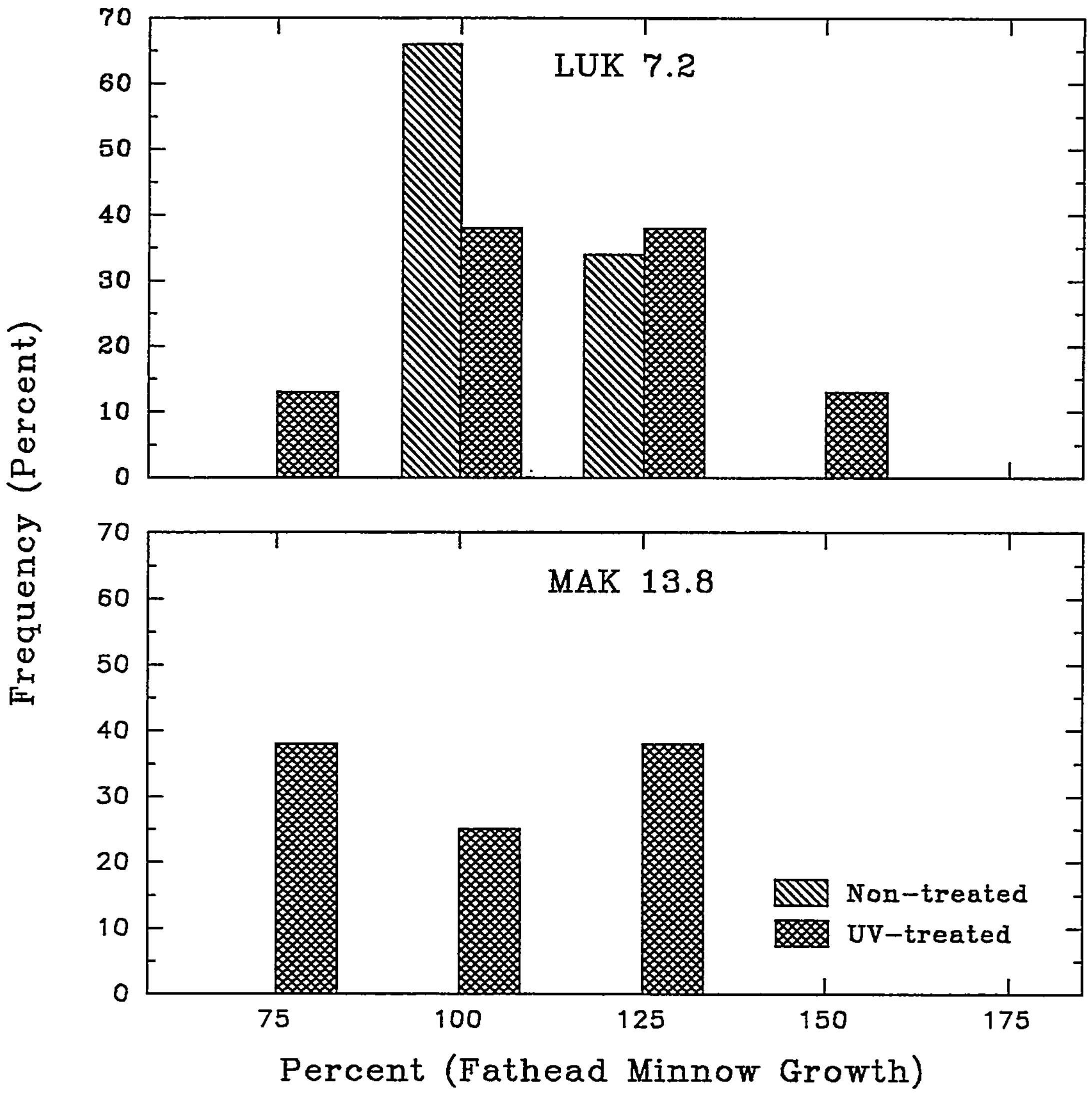

Figure 3.4. Frequency distribution of fathead minnow growth for Little Bayou Creek site and UV-treated Massac Creek site expressed as a percentage of growth at the reference site, Massac Creek at kilometer (MAK) 13.8. LUK = Little Bayou Creek kilometer.

ORNL-DWG 94-14147

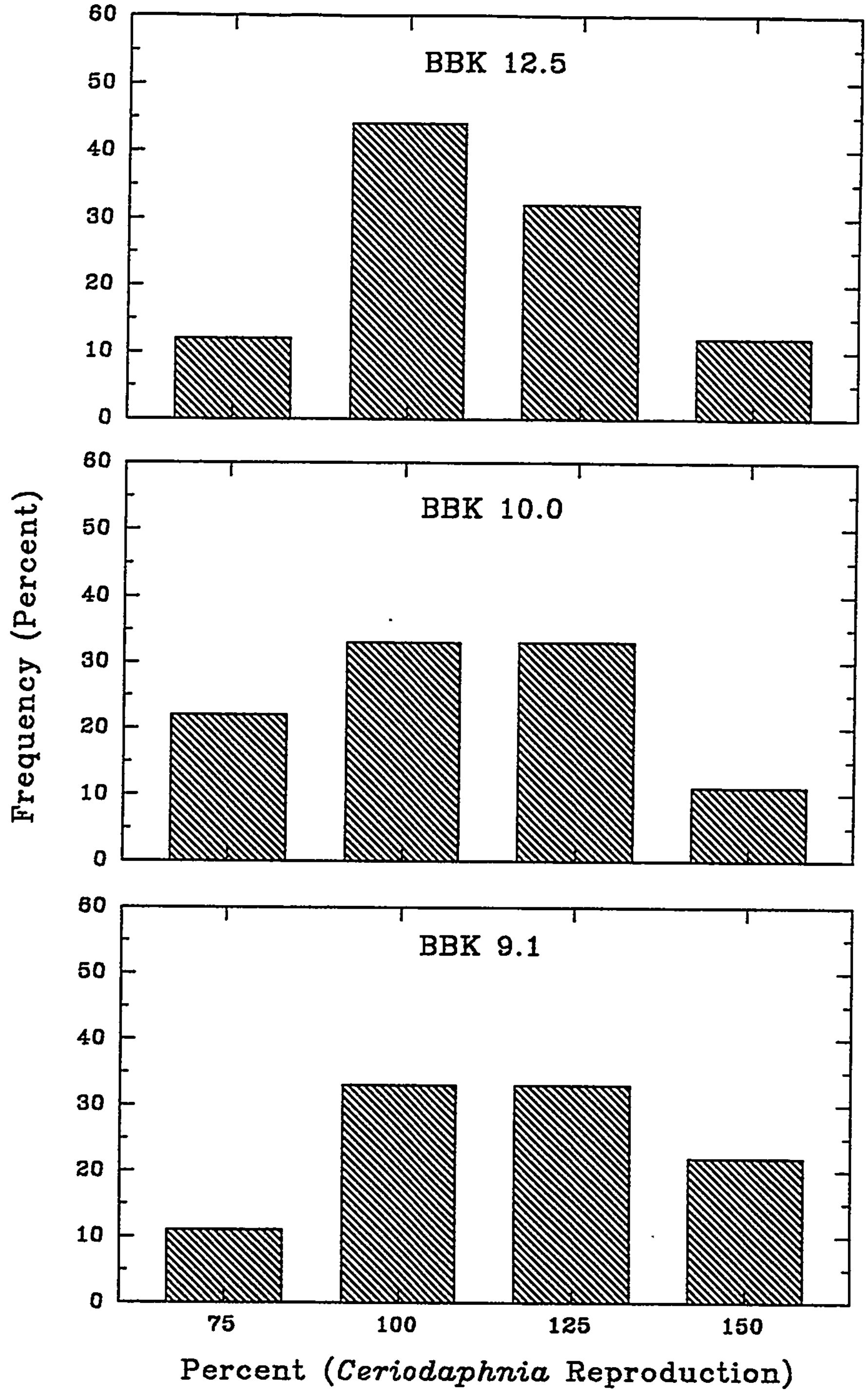

Figure 3.5. Frequency distribution of *Ceriodaphnia* reproduction for Big Bayou Creek sites expressed as a percentage of reproduction at the reference site Massac Creek at kilometer 13.8. BBK = Big Bayou Creek kilometer.

ORNL-DWG 94-14148

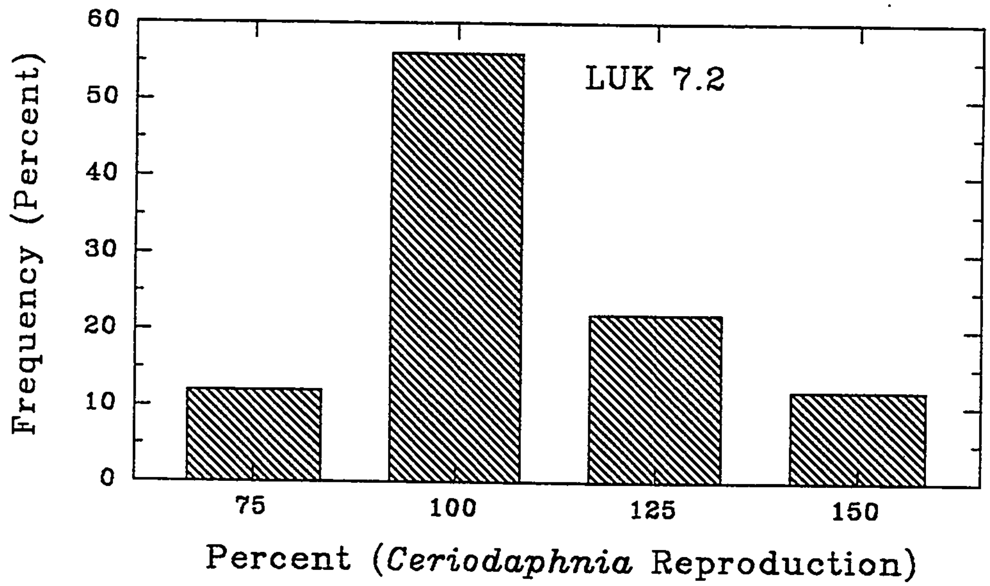

Figure 3.6. Frequency distribution of *Ceriodaphnia* reproduction for a Little Bayou Creek site expressed as a percentage of growth at the reference site, Massac Creek kilometer 13.8.

ORNL-DWG 94-14167

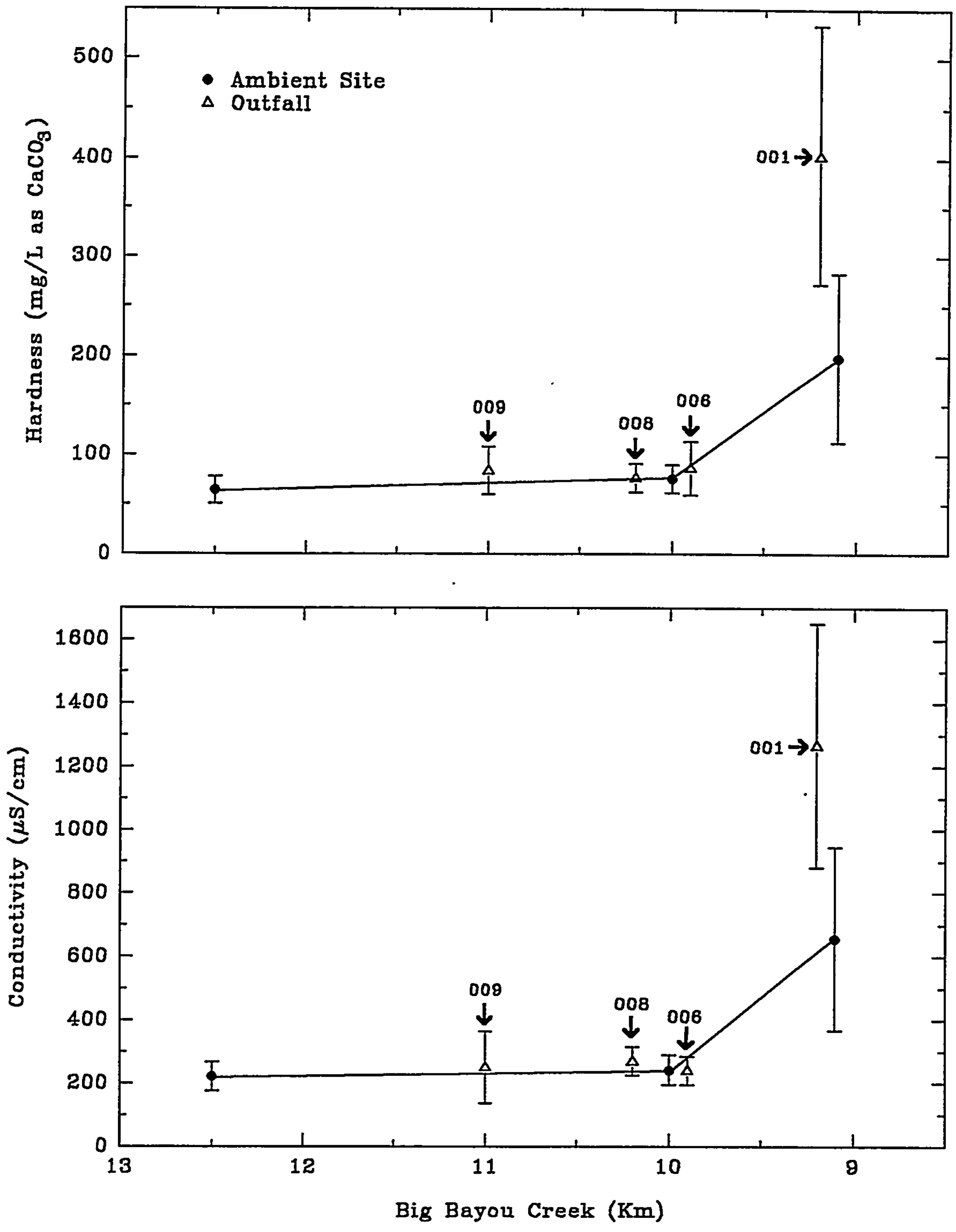

Figure 3.7. Summary of hardness and conductivity (mean ±SD) at Big Bayou Creek sites. Mean (±SD) value of continuously flowing outfalls is also shown.

ORNL-DWG 94-14168

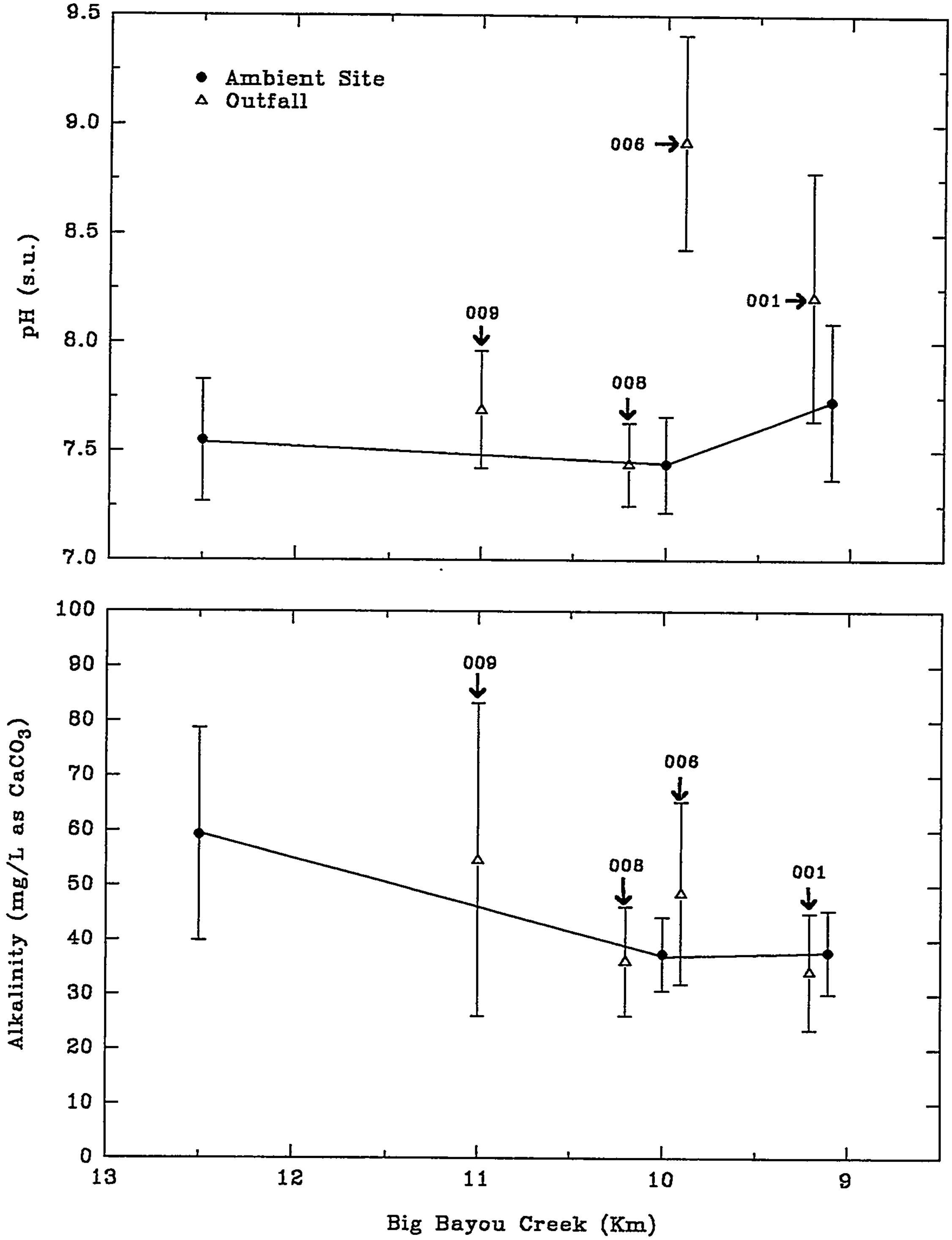

Figure 3.8. Summary of pH and alkalinity (mean ±SD) at Big Bayou Creek sites. Mean (±SD) value of continuously flowing outfalls is also shown.

Table 3.8. Mean water chemistry (n = 63) measured at each site and comparison of means (Tukey's Studentized Range test)

Parameter	Site[a]				
	BBK 12.5	BBK 10.0	BBK 9.1	LUK 7.2	MAK 13.8
Conductivity (µS/cm)					
Mean	221	241	657	266	136
Comparison	B	B	A	B	C
Hardness (mg/L as $CaCO_3$)					
Mean	64	76	198	81	51
Comparison	BC	B	A	B	C
pH (s.u.)					
Mean	7.55	7.44	7.73	7.54	7.37
Comparison	B	BC	A	B	C
Alkalinity (mg/L as $CaCO_3$)					
Mean	59	37	38	47	36
Comparison	A	C	C	B	C

Note: Sites with the same letter are not significantly different.

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

3.2.4 Discussion

In none of the tests conducted during October 1991 to October 1993 was there any evidence of consistent chronic toxicity to fathead minnows or *Ceriodaphnia.* For all tests conducted, there were only 4 times out of a 108 possible outcomes (3 test sites × 9 tests × 4 test endpoints) for which fathead minnow survival or growth, or *Ceriodaphnia* survival or reproduction, were significantly reduced. The frequency distributions of fathead minnow growth and *Ceriodaphnia* survival and reproduction (expressed as a percentage at MAK 13.8) show that these parameters are rarely lower than at the reference site. The lack of toxicity at the ambient sites is consistent with the lack of toxicity in the continuously flowing outfalls. Ambient tests of Big Bayou, Little Bayou, and Massac creeks, using UV-treated water, showed that UV treatment significantly improved survival in BBK 9.1 and LUK 7.2; however, growth was not significantly affected. Because high survival was evident for nontreated water from all sites and survival was not improved at all sites, particularly the reference sites, it is unclear whether the improvement in survival was really caused by the destruction of a natural pathogen as proposed in Kszos et al. (1994).

The influence of effluent from Outfall 001 on the water chemistry of Big Bayou Creek was shown by the large increase in hardness, conductivity, and pH at the ambient site immediately downstream (BBK 9.1). However, the changes in water chemistry did not affect minnow survival or growth or *Ceriodaphnia* survival or reproduction in the laboratory tests.

3.3 SUMMARY

During 1991–93, there was no evidence of consistent toxicity in any of the continuously flowing outfalls. Outfall 001 had the highest mean conductivity and hardness and the lowest alkalinity of any of the continuously flowing outfalls. Outfall 006 had the highest mean pH of any of the continuously flowing outfalls. Effluent samples from the intermittent outfalls were not toxic to *Ceriodaphnia* but did reduce fathead minnow growth. Ranking the outfalls identified Outfall 018 as the most toxic. Additional tests will be conducted in 1994 to further evaluate minnow survival and growth in filtered effluent from 018.

After all tests of ambient water conducted during October 1991 to October 1993, there was no evidence of consistent chronic toxicity to fathead minnows or *Ceriodaphnia.* For all tests conducted, there were only 4 times out of a 108 possible outcomes (3 test sites × 9 tests × 4 test endpoints) for which fathead minnow survival or growth, or *Ceriodaphnia* survival or reproduction, were significantly reduced. The influence of effluent from Outfall 001 on the water chemistry of Big Bayou Creek was evident in the 3-fold increase in conductivity and hardness between BBK 10.0 and BBK 9.1.

Because there has been no evidence of *consistent* chronic toxicity to fathead minnows or *Ceriodaphnia* at any of the ambient sites, it is appropriate to change this portion of the monitoring program. However, while it is especially important to conduct toxicity tests when instream toxicity is demonstrated, it is also important to maintain a database that demonstrates the lack of toxicity. Thus, future toxicity tests will be conducted on a quarterly basis at sites BBK 12.5, BBK 9.1, LUK 7.2, and MAK 13.8 with fathead minnows only. No UV treatment will be used and ICP samples will not be collected. Because the toxicity monitoring task is the only task during which routine chemistry measurements are taken over several days on a quarterly basis, water chemistry measurements will continue to be taken at all five ambient sites.

4. BIOACCUMULATION

G. R. Southworth and M. J. Peterson

4.1 INTRODUCTION

Bioaccumulation monitoring conducted to date as part of the Biological Monitoring Plan at PGDP identified PCB contamination in fish in Big Bayou Creek and Little Bayou Creek as major concerns (Birge et al. 1990,1992; Kszos et al. 1994). Mercury concentrations in fish from Big Bayou were found to be higher in fish collected downstream from PGDP discharges than in fish from an upstream site (Birge et al. 1990, 1992; Kszos et al. 1994), but the difference was not large, and mercury concentrations in fish were well below both the Food and Drug Administration (FDA) limit (FDA 1984) and the human health EPA risk assessment guidelines (EPA 1990). Concentrations of various metals in fish from Big Bayou Creek and Little Bayou Creek were well below levels of concern for human consumption.

The objectives of the 1992 bioaccumulation monitoring were (1) to continue PCB tracking studies in fish from Big Bayou Creek and Little Bayou Creek, (2) to confirm earlier reports of elevated mercury concentrations in fish in Big Bayou Creek and evaluate mercury concentrations in fish from the top trophic level, and (3) conduct screening analyses to detect other contaminants in fish from these streams that may be of concern to consumers.

4.2 STUDY SITES

Longear sunfish (*Lepomis megalotis*) were collected for PCB analysis at BBK 12.5 (the upstream reference site on Big Bayou Creek), BBK 10.0, BBK 9.1, and BBK 2.8 on Big Bayou Creek below PGDP, and LUK 9.0 and LUK 4.3 on Little Bayou Creek (Fig 2.2). Longear sunfish were also taken for mercury analysis at BBK 12.5, BBK 10.0, BBK 9.1, BBK 2.8, and MAK 13.8 (local reference site, Fig. 2.1). Hinds Creek in Anderson County, Tennessee, served as a source of uncontaminated reference fish. This stream has been used as a reference site for monitoring programs conducted at DOE facilities in Oak Ridge since 1985, and concentrations of various metals and organic contaminants in fish from this site are well characterized. Longear sunfish were also sampled from LUK 7.2 and BBK 9.1 for contaminant screening analyses. Larger fish (spotted bass, *Micropterus punctulatus*, and carp, *Cyprinus carpio*), were collected, when present, from BBK 9.1 and LUK 4.3. (Carp were absent from both sites in the 1992/1993 sampling; spotted bass were also absent from LUK 4.3.) The length of stream sampled at each site varied with the degree of difficulty in obtaining fish but was held to less than or equal to 1000 m. The site at BBK 10.0 was constrained to the reach between PGDP outfalls 008 and 006 (Fig. 2.2). The BBK 9.1 site encompassed the reach from BBK 9.1 up to Outfall 001 (Fig. 2.2). Larger fish (carp and bass) require large pools and deeper water. Because such habitat is scarce at sites in Big Bayou Creek close to PGDP, a 1000-m reach below BBK 9.1 containing such habitat was used for collection.

In Little Bayou Creek, the very sharp decrease in PCB contamination in fish between LUK 9.0 and LUK 7.2 (LB2 and LB3 in Birge et al. 1990, 1992) required that collections be confined to a relatively short reach near LUK 9.0, even though expanding the reach downstream would have made it possible in order to obtain larger fish of a single species. This site was restricted to approximately 250 m from Outfall 011 downstream to LUK 9.0. The downstream site included 1000 m centered at LUK 4.3. Fish for contaminant screening analyses were collected from BBK 9.1 and from LUK 7.2.

4.3 MATERIALS AND METHODS

Concentrations of contaminants that accumulate in sunfish provide an effective monitor of temporal and spatial changes in contamination within stream fishes, but do not provide a direct estimate of the maximum concentrations that may be present in stream biota. Larger, older, fattier fish, such as carp, catfish, and black bass (*Micropterus spp.*) accumulate several times higher contaminant concentrations under the same exposure conditions (Southworth 1990). Although concentrations in these larger species can be inferred from concentrations in sunfish, direct measurement provides a more reliable estimate.

Fish were collected by backpack electrofishing. Eight fish were taken from each site for PCB and mercury analysis, and four fish were taken for screening analyses. Collections of sunfish and larger fish (spotted bass) for PCB and mercury (bass only) monitoring were made on October 13-14, 1992, in Big Bayou Creek (BBK 9.1) and Little Bayou Creek (LUK 4.3). Eight longear sunfish were obtained at all sites. Collections of sunfish were restricted whenever possible to fish of a size large enough to be taken by sport fishermen 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 sources. High fish densities at most sites enabled the collection of eight specimens of sunfish ≥35 g at all sites except LUK 9.0 (the site closest to PGDP where habitat is extremely limited). No carp were found in either Big Bayou Creek or Little Bayou Creek; therefore eight spotted bass were taken at BBK 9.1 as a substitute. Neither species was found in Little Bayou Creek. Spotted bass are abundant in Big Bayou Creek downstream from PGDP, and the fish attain large enough size to make the creek an attractive sport fishing resource. This species is probably the most likely species in the creek to be eaten in significant numbers by anglers.

Longear sunfish were collected in Big Bayou Creek and Little Bayou Creek on April 26-27, 1993, as part of routine twice yearly monitoring of PCB concentrations in this species. Fish were also taken for mercury analysis at BBK 12.5, BBK 10.0, BBK 9.1, LUK 7.2, and MAK 13.8 (local reference site) on April 26-27, 1993, and Hinds Creek in Tennessee on May 5, 1993. Floodwaters of the Ohio River inundated the lower site on Big Bayou Creek (BBK 2.8) in April 1993, therefore sunfish were collected at that site on May 27, 1993. 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 the next day. 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 on dry ice (if processed on site) or in a standard freezer at -15° C. For larger fish (bass), fillets were wrapped and labeled as were sunfish samples, but at a later date, the frozen fillets were partially thawed, cut into 2- to 4-cm pieces, and homogenized by passing each sample three times through a hand meat grinder. A 25-g sample of the ground tissue was wrapped in heavy duty aluminum foil, labeled, frozen, and submitted to ORNL Analytical Chemistry Division for PCB analyses. Any remaining tissue from fillets of sunfish or larger fish was wrapped in foil, labeled, and placed in the freezer for short-term archival storage.

PCB/pesticide determinations in fish were conducted by capillary column gas chromatography/electron capture detection (GC/ECD) using a method based on EPA procedure PPB 12/83 (EPA 1984), which involves homogenizing the sample in anhydrous sodium sulfate, extraction with methylene chloride, cleanup using column chromatography, and GC/ECD. When pesticide screening was not needed (PCBs only), analyses were conducted using a modification to this method in which sulfuric acid partitioning is used as a cleanup step to destroy lipids (Mid-America Group, 1989). 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). Arsenic, cadmium, chromium, copper, lead, nickel, selenium, silver, vanadium, and uranium concentrations in fish were measured by inductively coupled plasma/mass spectrometry (EPA 1991, procedures 200.3, 200.8). Concentrations of zinc were measured by inductively coupled plasma/optical emission spectrometry (EPA 1991, procedure 200.11). Radionuclides were detected by gamma scintillation spectrometry.

Quality assurance was maintained 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. Results are summarized in Appendix C.

Statistical evaluaions of data were made using SAS procedures and software (SAS 1985a, 1985b) for ANOVA, Tukey's Multiple Comparison Test, and the calculation of mean, standard error, and standard deviation. Tests for homogeneity of variance among various data groups were conducted using Levene's test on untransformed and $\log_e$-transformed variables (Sokal and Rohlf 1981). Dunnett's Test was used to compare means of various groups with controls (Zar 1984). All comparisons were conducted using alpha=0.05.

4.4. RESULTS

4.4.1. PCBs

Fall 1992

Results of PCB analyses of sunfish collected from Big Bayou Creek and Little Bayou Creek in October 1992 are presented in Table 4.1, C.1, and Fig 4.1. Fish from Big Bayou Creek contained relatively similar concentrations of PCBs, decreasing with distance from 0.3 to 0.4 μg/g between BBK 9.1 and BBK 10.0, and up to 2.0 μg/g at BBK 2.8. Although low, mean PCB concentrations in sunfish from all sites in Big Bayou Creek exceeded reference site concentrations (Dunnetts test, $\log_e$-transformed data). PCB concentrations in sunfish from Little Bayou Creek near PGDP were much higher, averaging 1.03 μg/g. The mean concentration dropped sharply with distance downstream, averaging only 0.15 μg/g at BBK 4.3. Composition of the PCB mixtures found in sunfish resembled Aroclor 1254 and 1260 at most sites, with less chlorinated constituents (Aroclor 1248) occurring in samples from LUK 9.0, BBK 10.0 and BBK 9.1

Spotted bass from Big Bayou Creek averaged (± SE) 0.16 ± 0.03 μg/g PCBs, about the same as longear sunfish. Concentrations in the eight fish ranged from 0.08 to 0.35 μg/g, primarily as highly chlorinated materials similar to Aroclor 1260 (Table C.1). Although it was expected that bass would contain higher concentrations than sunfish because of their higher

Table 4.1. Mean concentrations of polychlorinated biphenyls in longear sunfish from streams near Paducah Gaseous Diffusion Plant, October 1992

Measured in micrograms per gram wet weight

Site	Mean	SE	Range	*n*	Tukey group[a]	Dunnett's test[b]
BBK 12.5	0.04	0.003	BLD[c]	8	D	ref
BBK 10.0	0.33	0.074	0.06–0.63	8	A,B	S
BBK 9.1	0.38	0.055	0.04–0.65	8	A,B	S
BBK 2.8	0.20	0.057	0.07–0.53	8	B,C	S
LUK 9.0	1.03	0.31	0.27–2.97	8	A	S
LUK 4.3	0.15	0.05	0.03–0.37	8	B,C,D	S
Hinds Cr[d]	0.05	0.007	BLD[c]	6	C,D	ref

Note: BBK = Big Bayou Creek kilometer; LUK = Little Bayou Creek kilometer; Hinds Cr = Hinds Creek, a reference site (ref) located in Anderson County, Tennessee.

[a]Groups separated by results of Tukey's Multiple Comparison Test on $\log_e$-transformed data. Mean concentrations are similar at sites having the same letter grouping, $p < 0.05$.

[b]Results of one-tailed Dunnett's Test for comparing group means with a reference site mean using $\log_e$-transformed data. Data from HindsCr and BBK 12.5 were pooled to compute the reference site mean (ref). S indicates statistically significant difference, $p < 0.05$.

[c]Values below the limit of detection were assumed to equal 0.5 times the detection limit for computational purposes. Detection limits varied from sample to sample depending on sample size and lipid interferences, generally detection limit was 0.04–0.10 µg/g. BLD indicates below limit of detection.

[d]Redbreast sunfish, *Lepomis auritus.*

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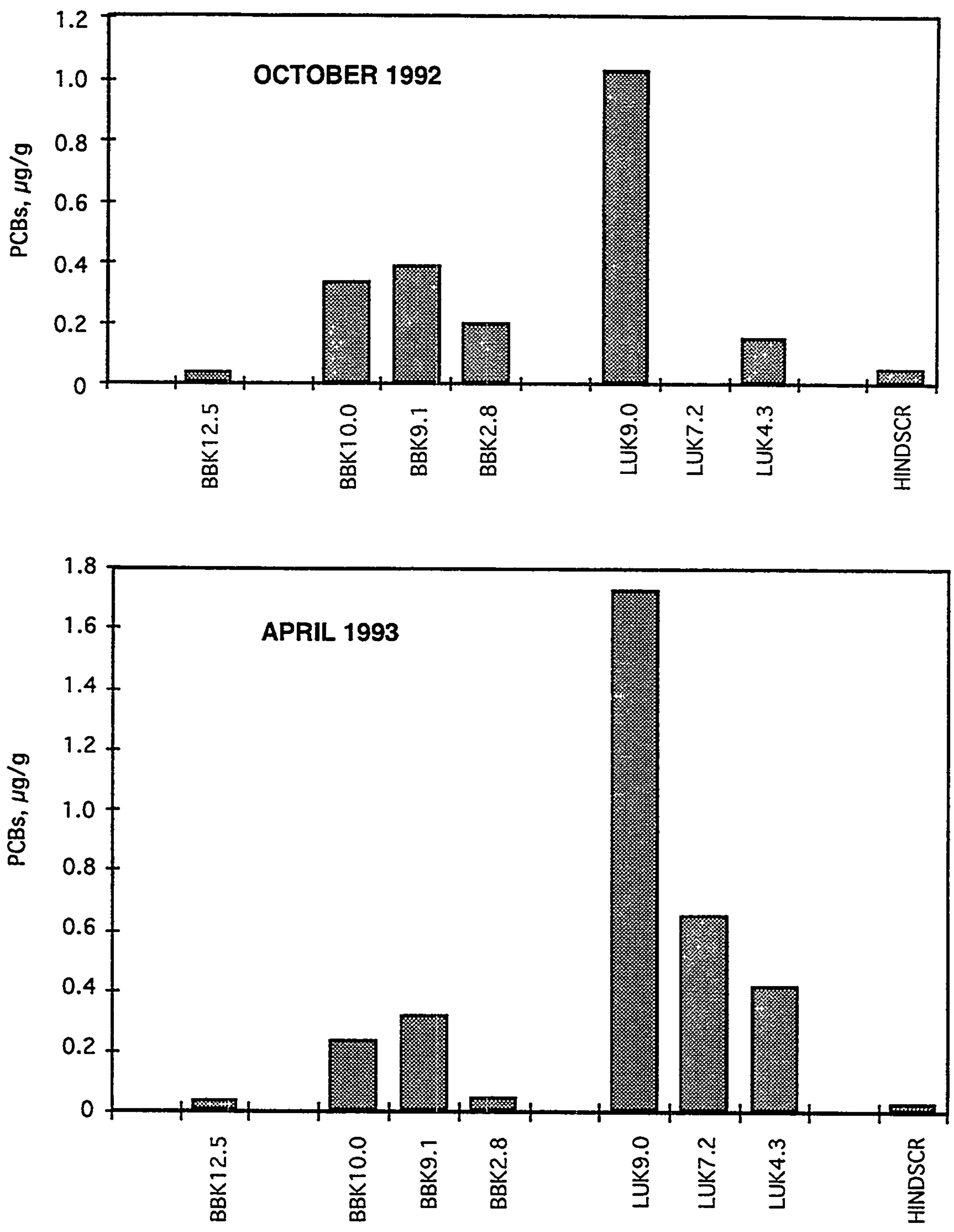

Fig. 4.1. Mean concentrations of polychlorinated biphenyls (PCBs) in fillets of longear sunfish from Big Bayou Creek and Little Bayou Creek near Paducah Gaseous Diffusion Plant, October 1992 and April 1993. Hinds Creek (HINDSCR) and Big Bayou Creek kilometer (BBK) 12.5 are reference sites. LUK = Little Bayou Creek kilometer.

trophic position, the similarity in lipid content between the two species in Big Bayou Creek may partially explain why PCB concentrations in bass were not higher.

Spring 1993

In spring 1993, PCB contamination was again evident in longear sunfish collected from both Big Bayou Creek and Little Bayou Creek (Table 4.2, Fig. 4.1, Table C.1). Statistical comparison (Dunnett's test) of mean concentrations in fish from sites downstream from PGDP discharges with the mean concentration in fish from reference sites [Hinds Creek in Tennessee and Big Bayou Creek above all PGDP discharges (BBK 12.5)] indicated that mean PCB concentrations in sunfish exceeded the reference site mean at all sites in Big Bayou Creek and Little Bayou Creek downstream from PGDP (Table 4.2). The constituents of the PCB mixtures extracted from fish most closely resembled commercial mixtures Aroclor 1254 and 1260. Lower chlorinated PCBs were found in abundance only in fish from LUK 9.0.

Table 4.2. Mean concentrations of polychlorinated biphenyls (PCBs) in longear sunfish from streams near Paducah Gaseous Diffusion Plant, April/May 1993

Measurements given in micrograms per gram wet weight

Site	Mean	SE	Range	n	Tukey group[a]	Dunnett's test[b]
BBK 12.5	0.04	0.005	BLD[c]	8	C	ref
BBK 10.0	0.24	0.035	0.12–0.38	8	B	S
BBK 9.1	0.33	0.060	0.08–0.77	12	B	S
BBK 2.8	0.05	0.015	0.01–0.10	8	C	S
LUK 9.0	1.73	0.54	0.37–4.53	8	A	S
LUK 7.2	0.65	0.15	0.34–1.00	4	A,B	S
LUK 4.3	0.42	0.11	0.10–1.02	8	B	S
Hinds Cr[d]	0.03	0.003	BLD	6	C	ref

Note: BBK = Big Bayou Creek kilometer; LUK = Little Bayou Creek kilometer; Hinds Cr = Hinds Creek, a reference site (ref) located in Anderson County, Tennessee.

[a]Groups separated by results of Tukey's Multiple Comparison Test on $\log_e$-transformed data. Mean concentrations are similar at sites having the same letter grouping, $p < 0.05$.

[b]Results of one-tailed Dunnett's Test for comparing group means with a reference site mean using $\log_e$-transformed data. Data from HindsCr and BBK 12.5 were pooled to compute the reference site mean (ref). S indicates statistically significant difference, $p < 0.05$.

[c]Values below the limit of detection were assumed to equal 0.5 times the detection limit for computational purposes. Detection limits varied from sample to sample depending on sample size and lipid interferences, generally the detection limit was 0.04–0.10 μg/g. BLD indicates below the limit of detection.

[d]Redbreast sunfish, *Lepomis auritus*.

As was the case in all previous sampling (Birge et al. 1990, 1992, Kszos et al. 1994), the highest mean concentration occurred in fish from the site in Little Bayou Creek immediately downstream from Outfall 011 (LUK 9.0). The level of contamination in sunfish from Little Bayou Creek declined substantially farther downstream at LUK 4.3, a pattern also observed consistently in previous monitoring (Birge et al. 1990, 1992; Kszos et al. 1994). In Big Bayou Creek, the highest mean PCB concentration was found in fish from BBK 9.1, below Outfall 001, but fish from BBK 10.0 also contained PCB contamination (Table 4.2, Fig. 4.1.). As was the case in Little Bayou Creek, PCB concentrations in sunfish were much lower farther downstream (BBK 2.8). Statistical comparisons of differences in mean PCB concentrations among sites (Tukey's test, log_e-transformed data) discriminated LUK 9.0, the site having the highest PCB contamination, from all sites in Big Bayou Creek and LUK 4.3 (Table 4.2). PCB contamination was not evident in longear sunfish from lower Big Bayou Creek in spring 1993, although fish from this site did contain above background concentrations of PCBs in previous monitoring. The absence of contamination may be related to the extended period of flooding in spring 1993 at this site, during which Big Bayou Creek fish populations may have exchanged with Ohio River populations.

Mean concentrations of PCBs in sunfish varied considerably among sampling periods in previous monitoring in Big Bayou Creek and Litle Bayou Creek, with no apparent temporal trend or pattern (Birge et al. 1990, 1992; Kszos et al. 1994). Generally, when higher PCB concentrations were observed in sunfish, lower chlorinated constituents (Aroclor 1248) were present in substantial proportions, and PCBs were detected in aqueous effluent samples. Results of the October 1992 and April 1993 sampling reaffirm the variable nature of PCB contamination in stream sunfish, and suggest that inputs are continuing to both Big Bayou and Little Bayou creeks from PGDP discharges or contaminated sediments in the immediate vicinity of those discharges. The strong downstream gradient in PCB contamination in sunfish, along with the close association between degree of contamination and proximity to outfalls demonstrated to be PCB sources in the past, suggests that the pattern of contamination is sustained by continuing low level contamination of waters discharged to the creeks, rather than a result of residual PCB contamination in sediments of the creeks themselves. PCB residues in upstream ditch or pond sediments could act as primary continuing sources, or various in-plant sources of fugitive PCBs may continue to contribute concentrations below levels detectable in aqueous phase monitoring. PCB concentrations of about 0.3 μg/g in fish having 1% lipids would imply PCB concentrations of roughly 0.03 µg/L in ambient water (using concentration factor =10,000 from EPA 1990).

4.4.2 Mercury

Mercury concentrations in fish from Big Bayou Creek were found to be somewhat higher downstream from PGDP than upstream in previous monitoring (Birge et al. 1990, 1992, Kszos et al. 1994). Fish from all sites contained concentrations of mercury that appeared to be elevated relative to reference sites in East Tennessee.

The results of mercury monitoring in longear sunfish in April 1993 confirmed the findings of previous studies (Birge et al. 1992, Kszos et al. 1994) that concentrations in fish from Big Bayou Creek were somewhat higher downstream from PGDP than upstream (Table 4.3, Fig 4.2, Table C.1). Mean mercury concentrations in sunfish were similar to those observed previously, ranging from a maximum of 0.37 µg/g at BBK 9.1 to 0.10 µg/g at BBK 12.5, upstream from PGDP. Previous sampling (Birge et al. 1992, Kszos et al. 1994) suggested that background or reference site concentrations of mercury in streams near PGDP were elevated relative to concentrations of mercury typical of fish from uncontaminated streams in East Tennessee; therefore a second local reference site, Massac Creek, was sampled to help determine the appropriate reference concentration. The mean concentration of mercury in redbreast sunfish from Hinds Creek were again lower than those observed at any site in Big Bayou Creek or in Massac Creek (Table 4.3). Statistical comparison of mean mercury concentrations in fish from Big Bayou Creek, Massac Creek, and Hinds Creek (Tukey's Test) indicated that the Hinds Creek fish differed significantly from all sites except BBK 12.5 (Table 4.3). Mercury concentrations in fish from Big Bayou Creek sites below PGDP were similar. Because mercury concentrations in both Kentucky reference sites were similar, and much different from the Tennessee reference site, data from the two Kentucky sites (BBK 12.5 and Massac Creek) were combined as a local reference collection for comparison with Big Bayou Creek sites below PGDP. Dunnett's test indicated that mean mercury concentrations in fish from all sites in Big Bayou Creek downstream from PGDP exceeded that in local reference site fish again in 1993.

Although some previous monitoring indicated that mercury was not elevated in fish from Little Bayou Creek (Birge et al. 1992), mercury concentrations in four fish taken from LUK 7.2 in 1992 as part of screening studies varied considerably, with two fish containing low

Table 4.3. Mean concentrations of total mercury in longear sunfish from streams near Paducah Gaseous Diffusion Plant, April 1993

Measured in micrograms per gram wet weight

Site	Mean	SE	Range	*n*	Tukey group[a]	Dunnett's test[b]
BBK 12.5	0.10	0.01	0.06–0.15	8	C,D	ref
BBK 10.0	0.22	0.05	0.12–0.53	8	B	S
BBK 9.1	0.37	0.03	0.28–0.51	8	A	S
BBK 2.8	0.23	0.02	0.15–0.31	8	A,B	S
LUK 7.2	0.08	0.01	0.06–0.10	8	D	NS
Massac Cr	0.16	0.02	0.08–0.24	8	B,C	ref
HindsCr[c]	0.06	0.01	0.03–0.09	6	D	excluded

Note: BBK = Big Bayou Creek Kilometer; LUK = Little Bayou Creek kilometer; Massac Cr = Massac Creek; Hinds Cr = Hinds Creek, a reference site (ref) located in Anderson County, Tennessee.

[a]Groups separated by results of Tukey's Multiple Comparison Test on $\log_e$-transformed data. Mean concentrations are similar at sites having the same letter grouping, $p < 0.05$.

[b]Results of one-tailed Dunnett's Test for comparing group means with a local reference site mean (ref) using $\log_e$-transformed data. Data from Massac Creek and BBK 12.5 were pooled to compute the reference site mean. S indicates statistically significant difference, $p < 0.05$. NS indicates no significant difference.

[c]Redbreast sunfish, *Lepomis auritus*.

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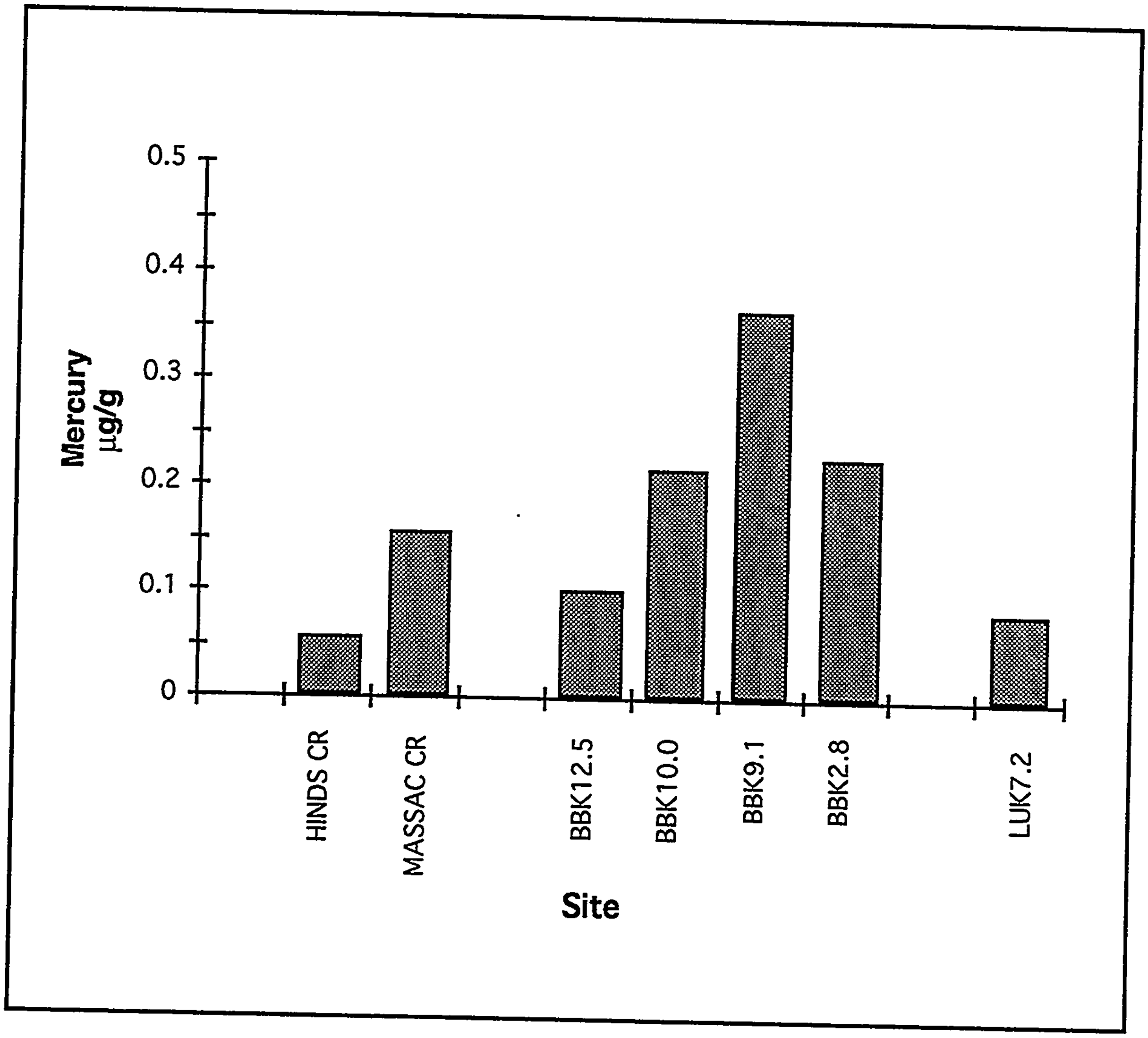

Fig. 4.2. Mean concentrations of total mercury in fillets of longear sunfish from Big Bayou Creek and Little Bayou Creek near Paducah Gaseous Diffusion Plant, April 1993. Hinds Creek (Hinds Cr) is a reference site in Anderson Co., Tennessee; Massac Creek (Massac Cr) and Big Bayou Creek at kilometer (BBK) 12.5 are reference sites near Paducah, Kentucky. LUK = Little Bayou Creek kilometer.

concentrations and two containing concentrations typical of Big Bayou Creek fish. A more extensive collection of fish was analyzed from Little Bayou Creek in 1993 to more conclusively evaluate mercury levels in fish there. Results indicated no mercury contamination (Fig 4.2, Tables 4.3, C.1).

Because the bioaccumulation of methylmercury by fish is predominantly a food chain mediated process, 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. Mercury concentrations in spotted bass from BBK 9.1 averaged 0.71 ± 0.08 μg/g (range, 0.44–1.0 μg/g). Thus, two fish in the collection equalled the FDA action level (1 μg/g), and one other exceeded 0.9 μg/g. Such concentrations are not unexpected given concentrations of about 0.4 μg/g in sunfish, which probably provide a reasonable estimate of mercury concentrations in bass food organisms.

Mercury concentrations in fish are not closely related to mercury concentrations in ambient water. East Fork Poplar Creek in Oak Ridge, Tenessee, is highly contaminated with mercury. Aqueous total mercury concentrations exceed 1 μg/L in the headwaters (Kornegay et al. 1992b). However, mercury concentrations in redbreast sunfish from that creek average close to 1 mg/kg (Kornegay et al. 1992b), only a little more than twice the level typical of Big Bayou Creek sunfish. Fish from relatively pristine lakes in Canada and the upper midwest USA can have fish that exceed 1 mg/kg mercury despite very low (<10 ng/L) concentrations of mercury in water. The slightly elevated concentrations of mercury in fish from Big Bayou Creek below PGDP may be a result of mercury in PGDP effluents, but they may also be a consequence of differences in the biogeochemical processing of mercury downstream from the plant. The bioaccumulation of mercury is a complex process, in which inorganic mercury is converted to methylmercury by microorganisms, and the methylmercury is then accumulated via food chain processes. Mercury concentrations in fish would be affected by factors that alter the rate at which naturally occurring mercury is converted to methylmercury or by changes in food chain structure that induce fish at some locations to feed on more highly contaminated prey. Naturally occurring mercury appears to be more bioavailable in streams near PGDP than in some other parts of the country (Lowe et al. 1985). Thus, it is possible that elevated mercury concentrations in fish in Big Bayou Creek are a consequence of changes in water chemistry or invertebrate community structure downstream from PGDP.

Resolution of questions about the source of elevated mercury in Big Bayou Creek fish is likely to be difficult and expensive, involving ultra-trace analyses of part-per-trillion concentrations of methylmercury in water. The concentrations found in longear sunfish are well below the FDA limit of 1 mg/kg. However, sampling of spotted bass (*Micropterus punctulatus*) in Big Bayou Creek does indicate a substantial difference in concentrations between this species and sunfish. Mercury concentrations in bass approach levels that are of concern for human consumption. Mercury concentrations in spotted bass from the local reference site, Massac Creek, will be measured in spring 1994 to help evaluate the extent to which mercury concentrations in Big Bayou Creek bass reflect background levels.

4.4.3 Screening studies

4.4.3.1 Metals

Concentrations of metals measured in fillets of longear sunfish from Big Bayou Creek and Little Bayou Creek are listed in Tables 4.4 and C.2. Levels are typical of those observed in previous monitoring (Birge et al. 1990, Kszos et al. 1994), and generally differ little (with several exceptions) from concentrations observed in fish from the Hinds Creek, Tennessee, reference site. Concentrations of As, Cd, Cu, Pb, Se, and Zn were lower than the national geometric mean concentrations (Table 4.4) observed for whole body analyses of fish in the U.S. Fish and Wildlife Service National Contaminant Biomonitoring Program (Lowe et al. 1985) as would be expected in uncontaminated fillets. Concentrations of Sb, Cd, Cr, Ni, Se, and Ag were well below screening levels used in the EPA Integrated Risk Information System (IRIS) (EPA 1990). Beryllium was not detected in PGDP fish. (Beryllium detection limit was at the IRIS screening level; arsenic, for which the detection limit was 10× screening level, was found at concentrations near the limit of detection in two samples.) Those metals for which IRIS screening levels are not published (Cu, Pb, Tl, U, and Zi) were found at concentrations similar to or lower than typically occur in food such as marine fish or mammalian muscle (Bowen 1979).

Selenium appeared to be somewhat higher in PGDP fish than in Hinds Creek fish in 1993; but, in the past, selenium concentrations in Hinds Creek have typically been around 0.5 ug/g. The latter concentrations are similar to those observed in fish from Big and Little Bayou creeks. Concentrations of zinc were somewhat higher in PGDP fish than in Hinds Creek fish, but were not atypical of many sites (Lowe et al. 1985).

Table 4.4. Mean metal concentrations in longear sunfish from streams at Paducah Gaseous Diffusion Plant, April 1993

	Site				
Metal	BBK 9.1	LUK 7.2	Hinds Cr[a]	NCBP[b]	EPA[c]
Antimony	<0.02	<0.02	<0.02	NS	43.1
Arsenic	<0.05-0.06[d]	<0.05-0.06[d]	<0.05	0.16	0.006
Beryllium	<0.003	<0.003	<0.003	NS	0.0025
Cadmium	<0.02	<0.02	<0.02	0.04	10.8
Chromium	<0.05-0.24[d]	<0.05±0.09[d]	0.05-0.12[d]	NS	10,800
Copper	0.25±0.02	0.26±0.01	0.23±0.02	0.86	ND
Lead	<0.02	<0.02-0.05[d]	<0.10-0.82[d]	0.19	ND
Nickel	0.10±0.02	0.15±0.04	0.28±0.05	NS	2.15
Selenium	0.39±0.05	0.52±0.04	0.28±0.05	0.46	5.4
Silver	<0.04	<0.04	0.04	NS	2.48
Thallium	<0.02	<0.02	<0.02	NS	ND
Uranium	<0.003	<0.003-0.006[e]	<0.003	NS	ND
Zinc	11.7±1.1	8.6±0.9	4.8±0.5	25.6	ND

Note: N=4 except where noted. If ≥50% of results are below detection limit, range is given. NS=not sampled, ND=not determined. Measurements are in micrograms per pram wet weight, ±1SE.

[a]Reference stream, Anderson Co., Tennessee; n=2.

[b]Mean concentration of metals in whole body fish collected for the National Contaminant Biomonitoring Program (NCBP) (Lowe et al. 1985. National Contaminant Biomonitoring Program: Concentrations of seven elements in freshwater fish, 1978-1981. Arch. Environ. Contam. Toxicol. 14:363-388).

[c]Environmental Protection Agency Integrated Risk Information System screening levels (EPA 1990. Region IV Toxic Substances Spreadsheet. U.S. Environmental Protection Agency, Region IV, Atlanta, Georgia. July 1990. Unpublished memeo).

[d]Single value exceeded detection limit.

[e]Two values exceeded detection limit.

Measurement of detectable concentrations of uranium (Table 4.4) in fish from Little Bayou Creek is consistent with the observed elevated concentrations of uranium in this creek (Kornegay et al. 1992a) and the results of 1992 monitoring of fish (Kszos et al. 1994). In the 1992 monitoring, uranium concentrations in Little Bayou Creek sunfish were both higher and more consistently detected than in the 1993 sampling. Uranium has a low bioconcentration factor, consequently concentrations in fish would be expected to fluctuate rapidly in response to changing aqueous phase concentrations. Thus, uranium measurements in fish provide little time averaging of exposure, and variation in yearly measurements cannot be used to infer long term trends in exposure.

4.4.3.2 Chlorinated pesticides

No chlorinated pesticides were detected in fish from Big Bayou Creek or Little Bayou Creek (Table C.3). These results are consistent with previous monitoring (Kszos et al. 1994).

4.4.3.3 Radionuclides

Gamma spectroscopy of fish samples had not been completed at the time of report preparation. Results will be reported in the following quarterly report.

5. ECOLOGICAL MONITORING STUDIES

5.1 FISHES *(M. G. Ryon)*

5.1.1 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 over other 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. Monitoring of fish communities has been used by the Biological Monitoring and Abatement Program (BMAP) in ESD for receiving streams at ORNL (Loar 1991), K-25 Site (Loar et al. 1992; Ryon 1993a), the Portsmouth, Ohio, facility (Ryon, M. G., Environmental Sciences Division, ORNL, unpublished data), and the Y-12 Plant (Loar and Smith 1989; Ryon 1992a; Southworth et al. 1992), with some programs operational since 1984. Changes in the fish communities in these systems have indicated recovery (Ryon 1989) as well as documented impacts (Ryon 1990, 1993b).

The initial objectives of the instream fish monitoring task were (1) to characterize spatial and temporal patterns in the distribution and abundance of fishes in Little Bayou and Big Bayou creeks and (2) to document the effects of PGDP operations on fish community structure and function.

5.1.2 Study Sites

Quantitative sampling of the fish community was conducted at five sites. Three sites are located on Big Bayou Creek (BBK 12.5, BBK 10.0, and BBK 9.1; Fig. 2.2), one on Little Bayou Creek (LUK 7.2, Fig. 2.2), and one offsite reference station 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. A qualitative sampling site (LUK 4.3) was established to evaluate the fish community in this area in response to earlier concerns of possible PGDP impacts (see Ryon 1994a).

5.1.3 Materials and Methods

Quantitative sampling of the fish populations at four sites in the Bayou watershed (BBK 12.5, BBK 10.0, BBK 9.1, and LUK 7.2) and at one site in a reference stream, Massac Creek (MAK 13.8), was conducted by electrofishing on September 13–16, 1992, March 1, 22, 24–26, 1993, and September 13–17, 1993. Data from these samples were used to estimate species richness, population size (numbers and biomass per unit area), and calculate annual production. Fish sampling sites either overlapped or were within 100 m of the sites included in the benthic macroinvertebrate monitoring task. Qualitative fish sampling was conducted by electrofishing on September 15, 1992, March 24, 1993, and September 15, 1993. Data from these samples were used to determine the species richness and number of specimens (relative abundance) based on sampling a known length of stream. All field sampling was conducted according to standard operating procedures (Ryon 1992b).

5.1.3.1 Quantitative field sampling procedures

All stream sampling was conducted using two or three Smith-Root Model 15A backpack electrofishers, depending on stream size. Each unit can deliver up to 1200 V of pulsed direct current in order 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 five to nine 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 in 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 based on the weighed individuals were used to estimate missing weight data.

After processing fish from all passes, the fish were allowed to fully recover from the anesthesia and returned to the stream. Any additional mortality that occurred as a result of processing was noted at that time. Following completion of fish sampling, the length, mean width, mean depth, and pool:riffle ratio of the sampling reach were measured at each site.

5.1.3.2 Qualitative field sampling procedures

Qualitative sampling involved electrofishing a limited length of stream for one pass and collecting all stunned fish. A five-person sampling team electrofished upstream for approximately 1 h using two Smith-Root Model 15A backpack electrofishers. Sampling always started at the same stream location and proceeded through a known length of stream. Stunned fish were netted, placed in buckets, and given to a two- to three-person shore crew for processing. The shore crew counted and identified all specimens; easily identifiable species were immediately released downstream from the sampling crew. Species that were more difficult to identify were preserved in 10% formaldehyde and taken to the ESD laboratory for positive identification. The duration of the electrofishing effort (in minutes) and the length of stream (in meters) sampled were recorded.

5.1.3.3 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). Qualitative samples were compared using total number of species and specimens and the relative abundance of the specimens. Relative abundance of species was rated as follows: 1 specimen = rare, 2 to 20 specimens = uncommon, 21 to 100 specimens = common, and >100 specimens = abundant.

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 spring 1992 and spring 1993 sampling dates.

5.1.4 Results

The physical parameters of the sample sites showed some differences between the September 1992 (fall) and March 1993 (spring) samples (Table 5.1). All sites were deeper and wider in spring than in fall samples, similar to the pattern seen in spring 1992 and fall 1991 (Ryon 1994a). The spring samples were collected during a very rainy period, which resulted in above average water levels at all sites.

Table 5-1. Lengths, mean width, mean depth, surface area, and pool to riffle ratio of fish sampling sites in Big Bayou Creek, Little Bayou Creek, and a reference stream (Massac Creek) for September 1992, March 1993, and September 1993

Site[a]	Length (m)	Mean width (m)	Mean depth (cm)	Surface area (m^2)	Pool; riffle ratio
			September 1992		
BBK 9.1	89	6.2	18.0	552	0:6
BBK 10.0	100	4.1	17.0	410	1:2
BBK 12.5	111	5.9	13.2	655	3:4
LUK 7.2	107	3.5	6.5	375	0:6
MAK 13.8	101	4.4	22.9	444	1:7
			March 1993		
BBK 9.1	95	7.7	27.5	732	0:8
BBK 10.0	90	8.4	33.5	756	0:1
BBK 12.5	100	7.1	14.7	710	3:5
LUK 7.2	109	4.0	11.1	436	0:7
MAK 13.8	102	6.4	27.8	653	4:1
			September 1993		
BBK 9.1	98	6.6	21.6	647	0:8
BBK 10.0	97	5.3	12.9	514	1:8
BBK 12.5	98	5.9	10.0	578	4:2
LUK 7.2	112	3.4	8.7	381	1:2
MAK 13.8	100	3.9	14.8	390	2:1

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

5.1.4.1 Quantitative sampling

Species richness and composition. A total of 33 fish species were found at the 5 sites on Big Bayou Creek, Little Bayou Creek, and Massac Creek (Table 5.2) for the September 1992, March 1993, and September 1993 samples. BBK 9.1 and BBK 10.0 had 21 and 15 species for the 3 sampling seasons, compared to 30 species at the reference stream, MAK 13.8. The LUK 7.2 site had 20 species during the 3 sampling seasons, while the comparable reference site, BBK 12.5 had 18 species. Mean species richness for MAK 13.8, BBK 9.1, and BBK 10.0 was 21.7, 14.3, and 10.7 respectively (Table 5.3). At LUK 7.2 and BBK 12.5, the mean richness was 17.7 and 14.7 respectively. At most sites, species richness was higher in the September samples than in March 1993. However, at BBK 9.1, species richness declined from September 1992 to September 1993 with a drop of eight species (Table 5.3). The core species assemblage at all sites included central stoneroller (*Campostoma anomalum*), creek chub (*Semotilus atromaculatus*), yellow bullhead (*Ameiurus natalis*), blackspotted topminnow (*Fundulus olivaceus*), creek chubsucker (*Erimyzon oblongus*), green sunfish (*Lepomis cyanellus*), and longear sunfish (*L. megalotis*). Seven species were judged to be sensitive to water quality and/or habitat degradation (see Karr et al. 1986; Ohio EPA 1987, 1988) and seven were rated as tolerant to such conditions (Appendix D, Table D.1).

The lowest site on Big Bayou Creek, BBK 9.1, had several species which are more common in larger streams including gizzard shad (*Dorosoma cepedianum*) and white crappie (*Pomoxis annularis*). These species were not taken at upstream Big Bayou Creek sites. BBK 9.1 had high numbers of cyprinid (seven), catostomid (three), and centrarchid (six) species. The number of sensitive species (three) was half the number of species tolerant (six) of habitat degradation and/or pollution. Hybrid sunfish were also found during all three surveys. The fish community composition at BBK 9.1 included representatives of all trophic levels. Piscivores or top carnivores included two species, largemouth bass (*Micropterus salmoides*), and spotted bass (*M. punctulatus*). Benthic insectivores, a feeding guild that can reflect impacts on the benthic macroinvertebrate community (Miller et al. 1988), were represented by two species. Generalist feeders, species that are capable of switching easily between food items and therefore can be more successful in streams exposed to a variety of stresses (Leonard and Orth 1986), included a total of eight species.

BBK 10.0 had low numbers of cyprinid (four) and catostomid species (two) and the same number of centrarchid species (six) as BBK 9.1. However, there were no sensitive species and

Table 5.2. Species composition of quantitative samples in Big Bayou Creek, Little Bayou Creek, and a reference stream, Massac Creek, September 1992, March 1993, and September 1993

Species[b]	Sites[a]				
	BBK 9.1	BBK 10.0	BBK 12.5	LUK 7.2	MAK 13.8
Clupeidae					
Gizzard shad (*Dorosoma cepedianum*)	1[c]	0	0	0	1
Cyprinidae					
Central stoneroller (*Campostoma anomalum*)	3	3	3	3	3
Goldfish (*Carassius auratus*)	0	0	0	0	1
Red shiner (*Cyprinella lutrensis*)	3	2	3	3	1
Hybrid shiner (*Cyprinella X*)[d]	0	0	1	0	1
Steelcolor shiner (*Cyprinella whipplei*)[d]	2	0	0	0	3
Mississippi silvery minnow (*Hybognathus nuchalis*)	0	0	0	0	1
Ribbon shiner (*Lythrurus fumeus*)[d]	1	0	2	3	2
Redfin shiner (*Lythrurus umbratilis*)[d]	2	0	2	3	3
Golden shiner (*Notemigonus crysoleucas*)	0	0	1	2	0
Suckermouth minnow (*Phenacobius mirabilis*)	1	1	2	3	2
Bluntnose minnow (*Pimephales notatus*)	0	0	3	3	3
Creek chub (*Semotilus atromaculatus*)	2	2	3	3	3
Catostomidae					
White sucker (*Catostomus commersoni*)	1	1	2	0	3
Creek chubsucker (*Erimyzon oblongus*)	3	2	3	3	3
Spotted sucker (*Minytrema melanops*)	1	0	0	0	1
Black redhorse (*Moxostoma duquesnei*)	0	0	0	0	1
Golden redhorse (*Moxostoma erythrurum*)	0	0	0	0	3
Ictaluridae					
Black bullhead (*Ameiurus melas*)[d]	1	0	0	0	0
Yellow bullhead (*Ameiurus natalis*)	3	2	3	3	3
Esocidae					
Grass pickerel (*Esox americanus vermiculatus*)	0	0	0	0	1
Aphredoderidae					
Pirate perch (*Aphredoderus sayanus*)	0	0	0	3	2
Cyprinodontidae					
Blackspotted topminnow (*Fundulus olivaceus*)	3	3	3	3	3
Poeciliidae					
Western mosquitofish (*Gambusia affinis*)	2	2	1	3	2

Table 5.2 (continued)

Species[b]	Sites[a] BBK 9.1	BBK 10.0	BBK 12.5	LUK 7.2	MAK 13.8
Centrarchidae					
Green sunfish (*Lepomis cyanellus*)	3	3	3	3	3
Warmouth (*Lepomis gulosus*)	0	1	1	3	2
Bluegill (*Lepomis macrochirus*)	3	3	3	1	3
Longear sunfish (*Lepomis megalotis*)	3	3	3	3	3
Hybrid sunfish	3	3	2	0	0
Spotted bass (*Micropterus punctulatus*)	3	3	3	1	3
Largemouth bass (*Micropterus salmoides*)	1	2	0	1	2
White crappie (*Pomoxis annularis*)	1	0	0	0	0
Percidae					
Bluntnose darter (*Etheostoma chlorosomum*)[d]	0	0	0	0	1
Slough darter (*Etheostoma gracile*)	0	0	0	3	1
Blackside darter (*Percina maculata*)[d]	0	0	0	0	2
TOTAL SPECIES	21	15	18	20	30

[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 (Robbins et al. 1991. Common and scientific names of fishes from the United States and Canada. Fifth Edition. American Fisheries Society Special Publication 20. Bethesda, MD).

[c]Numbers represent the number of sampling periods ($n = 3$) that a given species was collected at the site and a '0' indicates that the species was not collected.

[d]Species identification confirmed by Dr. David A. Etnier, Department of Zoology, University of Tennessee.

Table 5.3. Total fish density, biomass, and species richness for September 1992, March 1993, and September 1993 at sampling site in Big Bayou Creek, Little Bayou Creek, and a reference stream, Massac Creek

Density measured as individuals per square meter, biomass as grams per square meter

	Sites[a]				
Sampling periods	BBK 9.1	BBK 10.0	BBK 12.5	LUK 7.2	MAK 13.8
September 1992					
Density	2.47	5.57	2.46	6.06	3.99
Biomass	33.38	31.21	15.08	5.85	15.28
Species richness	19	13	15	17	21
March 1993					
Density	1.13	1.80	2.79	1.63	1.51
Biomass	23.45	8.81	12.39	6.64	7.47
Species richness	13	9	15	17	21
September 1993					
Density	2.60	6.21	6.90	4.54	3.21
Biomass	12.33	22.73	14.32	7.8	18.46
Species richness	11	10	14	19	23
Means 1992–1993					
Density	2.07	4.53	4.05	4.08	2.90
Biomass	23.05	20.92	13.93	6.76	13.74
Species richness	14.3	10.7	14.7	17.7	21.7

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

five tolerant species. Hybrid sunfish were taken in all samples. The trophic composition of the community at BBK 10.0 included two piscivores (the bass species), only two benthic insectivores, and six generalist feeders.

Compared to the MAK 13.8 reference, the two lower Big Bayou Creek sites showed some degradation. The reference site had higher numbers of cyprinid (ten), catostomid (five), and percid (three) species, with the same level of centrarchid species (six). MAK 13.8 also had more sensitive species (seven), slightly lower numbers of tolerant species (six), but did have hybrid minnows. Trophically, MAK 13.8 had more piscivore species (three), including the grass pickerel (*Esox americanus vermiculatus*), than the Big Bayou Creek sites. The reference had more generalist feeders (nine) than the Big Bayou Creek sites but also had four times as many benthic insectivores (eight).

The LUK 7.2 site maintained high levels of cyprinid (eight) and centrarchid (six) species with one catostomid. LUK 7.2 had four tolerant species with only one sensitive species. Hybrid sunfish were not found at the site. The trophic composition of the fish community at LUK 7.2 included two piscivores, four benthic insectivores, and five generalist feeders. By comparison, the BBK 12.5 reference site had similar numbers of cyprinid (eight), centrarchid (five), and catostomid (two) species. The number of sensitive species was the same (one), with a higher number of tolerant species (five). Hybrid sunfish and minnows were also found at the site. Trophically, the fish community at BBK 12.5 reflected the headwater influence, with six generalist feeders, two piscivores, and only two benthic insectivores. In headwater habitats, generalist feeders have a decided advantage because they can utilize terrestrial sources of food much easier than can benthic insectivores.

Density. Quantitative estimates of density were higher at all sites during the September samples than during the March samples (Table 5.3). This was the pattern in previous PGDP samples (Ryon 1994a) and has been the dominant pattern for the BMAP sampling conducted at the approximately 50 sites in the Oak Ridge, Tennessee, area since 1985 (Loar 1992, Ryon 1992c; Southworth et al. 1992). The higher fall density reflects recruitment of fish into the community and normally occurs at all sites, unless a substantial impact has occurred.

The highest total density values were at LUK 7.2 in September 1992 and at BBK 12.5 during both 1993 sampling seasons. Density at BBK 12.5 increased continuously from September 1992 to September 1993. The densities at BBK 9.1 were about one-half to two-thirds of the levels at BBK 10.0 but showed less variation between sampling seasons. The

MAK 13.8 reference had levels similar to BBK 10.0 in March 1993, but levels were proportionally lower in September samples (Table 5.3).

Densities of individual species varied between sites, especially among the three species with the highest values (Appendix D, Tables D.2, D.3, and D.4). During all sampling seasons at BBK 9.1 and BBK 10.0, the species present in highest or next highest numbers were the central stoneroller or longear sunfish, with a variety of species having the third highest numbers. The species at the MAK 13.8 reference site that had the highest densities were longear sunfish, and a variety of cyprinids, including bluntnose minnow (*Pimephales notatus*), central stoneroller, and ribbon shiner (*Lythurus fumeus*). The high densities of central stoneroller (a scraping herbivore) in Big Bayou Creek probably reflected greater algal growth resulting from nutrient enrichment by PGDP discharges. At LUK 7.2, the species with the highest densities were bluntnose minnow, western mosquitofish (*Gambusia affinis*), creek chub, and green sunfish (Tables D.2, D.3, and D.4). The BBK 12.5 reference site was similar to downstream Big Bayou Creek sites with highest densities for longear sunfish and central stoneroller.

Biomass. Unlike the density estimates, quantitative estimates of total fish biomass were not consistently higher in September samples than in March samples (Table 5.3). The highest biomass levels were at BBK 9.1 and BBK 10.0. Compared with MAK 13.8, mean fish biomass was as much as 3 times greater at the lower Big Bayou Creek sites. Mean fish biomass at LUK 7.2 was as much as 260% lower than the mean fish biomass at the BBK 12.5 reference site.

Each site was evaluated for the species that constituted the two highest biomass values during each sample period. The longear sunfish species contributed the highest or next highest biomass at every site except LUK 7.2 (Tables D.5, D.6, and D.7). Other fish species that were among the two highest biomass contributors included central stoneroller, or spotted sucker (*Minytrema melanops*) at BBK 9.1; central stoneroller at BBK 10.0; black redhorse (*Moxostoma duquesnei*) or golden redhorse (*M. erythrurum*) at MAK 13.8; and central stoneroller or yellow bullhead at BBK 12.5. At LUK 7.2, the two highest biomass contributors varied among the creek chub, green sunfish, or western mosquitofish.

Production. Production values were calculated for the spring 1992 to spring 1993 period at all sites. Total production (in grams per square meter per year) was highest in Big Bayou

Table 5.4. Fish annual production in Big Bayou Creek, Little Bayou Creek, and a reference stream, Massac Creek, March 1992 to March 1993

Measured in grams per square meter per year

	Sites[a]				
Species[b]	BBK 9.1	BBK 10.0	BBK 12.5	LUK 7.2	MAK 13.8
Central stoneroller	1.36	11.69	2.87	0.25	0.08
Red shiner	<0.01	0.02	0.06	0.07	-
Steelcolor shiner[c]	-	-0.04	0.02	-	0.34
Ribbon shiner	<0.01	-	0	0	0.01
Redfin shiner[c]	0	-	<0.01	0.03	0.12
Golden shiner	-	-	-	-0.01	-
Suckermouth minnow	0.18	0.01	0.01	0.14	-0.02
Bluntnose minnow	-	-	0.69	1.41	0.95
Fathead minnow	-	-	<0.01	-	-
Creek chub	0.01	-0.55	0.23	0.61	-0.03
White sucker	1.49	-	0.02	-	0.01
Creek chubsucker	0.03	0.01	0.02	0.02	0.04
Black redhorse	-	-	-	-	0.37
Golden redhorse	-	-	-	-	1.62
Yellow bullhead	1.08	-0.02	1.31	0.18	0.28
Pirate perch	-	-	-	0.35	0.05
Blackspotted topminnow	-0.01	0.01	0.96	0.47	0.25
Western mosquitofish	-	0	-	0.02	0.02
Green sunfish	0.29	1.97	1.45	0.70	0.29
Warmouth	-	-	0	-0.06	-0.06
Bluegill	1.78	0.40	1.71	-	-0.04
Longear sunfish	11.22	2.91	6.47	0.55	2.66
Redear sunfish	0.50	-	-	-	-
Hybrid sunfish	0.67	0.61	0.89	-	-
Spotted bass	0.13	0.49	-0.06	-	0.57
Largemouth bass	0.10	-	0.11	-	-0.09
White crappie	0.17	-	-	-	-

Table 5.4 (continued)

Species[b]	Sites[a]				
	BBK 9.1	BBK 10.0	BBK 12.5	LUK 7.2	MAK 13.8
Bluntnose darter	-	-	-	-	<0.01
Slough darter	<0.01	<0.01	0	0.06	-
Blackside darter	-	-	-	-	0.04
Total production	19.00	17.51	16.76	4.79	7.46

[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 (Robbins et al. 1991. Common and scientific names of fishes from the United States and Canada. Fifth Edition. American Fisheries Society Special Publication 20. Bethesda, Maryland).

[c]Species identification confirmed by Dr. David A. Etnier, Department of Zoology, University of Tennessee.

Creek, increasing downstream (Table 5.4). The production at BBK 9.1 and BBK 10.0 was more than twice that at the reference site, MAK 13.8. The principal difference between production at BBK 9.1 and MAK 13.8 was the tremendously high levels for centrarchids, especially longear sunfish at BBK 9.1. At BBK 10.0, the higher production was dominated by the contribution of the central stoneroller. A further difference between MAK 13.8 and Big Bayou Creek sites was the contribution of sensitive species (2.38 $g \cdot m^{-2} \cdot year^{-1}$) at MAK 13.8, whereas they were virtually absent at the Big Bayou Creek sites. Production at LUK 7.2 was only a third of that found at BBK 12.5 (Table 5.4). A ten-fold difference in production of central stoneroller, longear sunfish, and yellow bullhead accounted for the majority of the disparity. The higher level of production at BBK 9.1 and BBK 10.0 might be expected given the other signs of enrichment; however, the overall high production throughout the Big Bayou Creek system was unexpected.

The production found in these streams was within the range of production values found in warmwater streams of the southeastern U.S., including production estimates generated by similar methods at Oak Ridge monitoring sites (Table 5.5). Estimates of production in southeastern reference streams varied from 2.02 to 27.12 $g \cdot m^{-2} \cdot year^{-1}$ compared to 7.46 to 16.76 $g \cdot m^{-2} \cdot year^{-1}$ at PGDP area reference streams. Similarly, production at sites downstream of plant discharges ranged from 3.06 to 27.38 $g \cdot m^{-2} \cdot year^{-1}$ in the southeast vs 4.79 to 19.0 $g \cdot m^{-2} \cdot year^{-1}$ in Big Bayou Creek watershed.

5.1.4.2 Qualitative sampling

During qualitative sampling conducted on lower Little Bayou Creek at LUK 4.3, a total of 26 species were collected, with 20-21 species in each sample (Table 5.6). These totals were similar to species richness values generated by earlier qualitative samples at this site (Ryon 1994a). Species found only during the qualitative sampling included spotfin shiner (*Cyprinella spiloptera*) and common carp (*Cyprinus carpio*). The surveys yielded a considerable number of cyprinid (12) and centrarchid (5) species, although the number of catostomids (1) were low for the stream size and available habitat.

The qualitative samples were also evaluated for relative abundance of the species based on sampling a known area (131–190 m) with a limited effort (74-89 min). The most abundant species were longear sunfish and bluntnose minnow. Species rated as common included Mississippi silvery minnow (*Hybognathus nuchalis*), ribbon shiner, green sunfish, and

Table 5.5. Annual production (P) rates of fish communities in warmwater streams in the southeastern United States

Stream/State	Stream order	Sample year	P (grams wet wt·m^{-2}·year^{-1}	Reference[a]
J. Carpenter Br, Kentucky	1st	1967–1968	8.55	Lotrich 1973
Clemmons Ck, Kentucky	2nd	1967–1968	10.55	
	3rd		7.72	
Steeles Run, Kentucky	2nd	1970–1971	12.0	Small 1975[b]
	2nd		15.8	
	3rd		3.7	
	3rd		2.7	
Guys Run, Virginia	2nd	1979–1980	2.84	Neves and Pardue 1983
	2nd		3.16	
	2nd		3.96	
Mitchell Br, Tennessee	2nd[c]	1987–1988	3.06	Ryon 1994
	2nd[c]	1988–1989	4.73	
	2nd[c]	1989–1990	6.85	
East Fork Poplar Cr, Tennessee	1st[c]	1989–1990	16.71	M. G. Ryon, Environmental Sicences Division (ESD), Oak Ridge National Laboratory (ORNL) unpublished data
	1st[c]	1990–1991	27.38	
	4th[c]	1989–1990	2.29	
	4th[c]	1990–1991	5.57	
Brushy Fork, Tennessee	4th	1989–1990	4.84	
	4th	1990–1991	4.44	
White Oak Creek, Tennessee	2nd	1992–1993	4.33	E.M. Schilling, ESD, ORNL, unpublished data
	2nd[c]		17.11	
	3rd[c]		12.78	
	4th[c]		3.65	
Fifth Creek, Tennessee	1st	1992–1993	27.12	
	1st[c]		4.01	
Melton Branch, Tennessee	2nd	1992–1993	2.02	
	3rd[c]		6.93	

[a]References cited in this table are listed in Chapter 6 of this report.
[b]Production for benthic species only; values converted from dry weight using conversion factor in Waters (1977).
[c]Sample site is associated with industrial effluent.

Table 5.6. Species composition, number of specimens, relative abundance and catch per unit effort of the qualitative fish sampling conducted on Little Bayou Creek, September 1992 to September 1993

Species[a]	Sept 15, 1992[b]	March 24, 1993[c]	Sept 15, 1993[d]
Clupeidae			
Gizzard shad (*Dorosoma cepedianum*)			2 (UC)
Cyprinidae			
Central stoneroller (*Campostoma anomalum*)		6 (UC)	3 (UC)
Red shiner (*Cyprinella lutrensis*)	11 (UC)	10 (UC)	
Spotfin shiner (*Cyprinella spiloptera*)[e]	1 (R)	6 (UC)	
Steelcolor shiner (*Cyprinella whipplei*)[e]	7 (UC)	4 (UC)	
Hybrid shiner (*C. spiloptera X C. whipplei*)[e]	1 (R)	1 (R)	
Common carp (*Cyprinus carpio*)			1 (R)
Mississippi silvery minnow (*Hybognathus nuchalis*)	40 (C)	36 (C)	4 (UC)
Ribbon shiner (*Lythrurus fumeus*)[e]	47 (C)	22 (C)	5 (UC)
Redfin shiner (*Lythrurus umbratilis*)[e]	19 (UC)	16 (UC)	2 (UC)
Golden shiner (*Notemigonus crysoleucas*)[e]			2 (UC)
Suckermouth minnow (*Phenacobius mirabilis*)	3 (UC)	2 (UC)	
Bluntnose minnow (*Pimephales notatus*)	207 (A)	75 (C)	32 (C)
Creek chub (*Semotilus atromaculatus*)	59 (C)	16 (UC)	1 (R)
Catostomidae			
Creek chubsucker (*Erimyzon oblongus*)		5 (UC)	2 (UC)
Ictaluridae			
Yellow bullhead (*Ameiurus natalis*)	9 (UC)	4 (UC)	5 (UC)
Esocidae			
Grass pickerel (*Esox americanus vermiculatus*)			1 (R)
Aphredoderidae			
Pirate perch (*Aphredoderus sayanus*)	7 (UC)	1 (UC)	2 (UC)
Cyprinodontidae			
Blackspotted topminnow (*Fundulus olivaceus*)	81 (C)	39 (C)	82 (C)
Poeciliidae			
Western mosquitofish (*Gambusia affinis*)	18 (UC)		9 (UC)
Centrarchidae			
Green sunfish (*Lepomis cyanellus*)	62 (C)	15 (UC)	38 (C)
Warmouth (*Lepomis gulosus*)	11 (UC)	5 (UC)	10 (UC)
Bluegill (*Lepomis macrochirus*)	19 (UC)	5 (UC)	43 (C)
Longear sunfish (*Lepomis megalotis*)	168 (A)	74 (C)	113 (A)
Hybrid sunfish (*Lepomis*)			2 (UC)
Spotted bass (*Micropterus punctulatus*)	5 (UC)	1 (R)	10 (UC)
Percidae			
Bluntnose darter (*Etheostoma chlorosomum*)[e]	1 (R)	6 (UC)	2 (UC)
Slough darter (*Etheostoma gracile*)	1 (R)	1 (R)	
TOTAL SPECIMENS	780	350	371
TOTAL SPECIES	20	21	21
CATCH/UNIT EFFORT[f]	4.4	2.4[g]	2.5[g]

Note: Relative abundance is defined as rare (R) 1 specimen; uncommon (UC) 2-20 specimens; common (C) 21-99 specimens; and abundant (A) >99 specimens.

[a]Species identifications were performed in the field and/or confirmed in the laboratory on preserved specimens collected during the surveys. Common and scientific names according to the American Fisheries Society (Robins et al. 1991. Common and scientific names of fishes from the United States and Canada. Fifth Edition. American Fisheries Society Special Publication 20. Bethesda, Md).

[b]Two electrofishers used for 190 m and 89 min.

[c]Two electrofishers used for 170 m and 74 min.

[d]Two electrofishers used for 131 m and 74 min.

[e]Species identification were confirmed by Dr. David A. Etnier, Department of Zoology, University of Tennessee.

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

[g]Catch per unit effort was affected by higher than normal water levels and associated elevations in turbidity.

blackspotted topminnow. The total catch for each sample was 780, 350, and 371 fish for September 1992, March 1993, and September 1993 respectively. The catch per unit effort (number fish per minute electrofished) ranged from 2.4 to 4.4. Although these numbers are lower than numbers found in earlier qualitative estimates (Ryon 1994a), they do suggest that there was a resident fish community at the LUK 4.3 site. No stronger influence from PGDP was indicated at this site than was indicated further upstream.

5.1.5 Discussion

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

Data indicated that the effects on the fish community were greatest just downstream from PGDP at BBK 10.0. The fish community at this site had a low mean and total species richness in comparison with MAK 13.8. There were no sensitive species, while tolerant species were more abundant here than at the reference site. The number of benthic insectivores were low, although other feeding guilds were similar to levels seen at MAK 13.8. Hybrid sunfish were found during all sampling seasons, which indicated some reproductive stress. Density at BBK 10.0 was similar to or higher than that at the reference site, with a correspondingly high biomass. Compared to previous sampling (Ryon 1994a), BBK 10.0 has experienced a slight decline in species richness and biomass since 1991 (Fig 5.1). The declining trend may be a result of sample variation which could reverse with further sampling. If a reversal does not occur, the decline may suggest greater impacts than seen in earlier sampling at this site. Overall the fish community at BBK 10.0 has demonstrated shortcomings.

The fish community at BBK 9.1 showed signs of impact similar to the level seen at BBK 10.0. Mean and total species richness were lower than at MAK 13.8. Although there were fewer sensitive species and at lower densities at BBK 9.1 than at MAK 13.8, more sensitive species were found at BBK 9.1 than at BBK 10.0. The tolerant species were common and abundant. Similar to findings from BBK 10.0, hybrid sunfish were found during all sampling seasons. Density was less than or equal to that at MAK 13.8, and the biomass values were high in 1992. Temporal trends indicate that biomass and species richness were generally declining (Fig 5.1), especially in 1993. This decline is similar to that at BBK 10.0.

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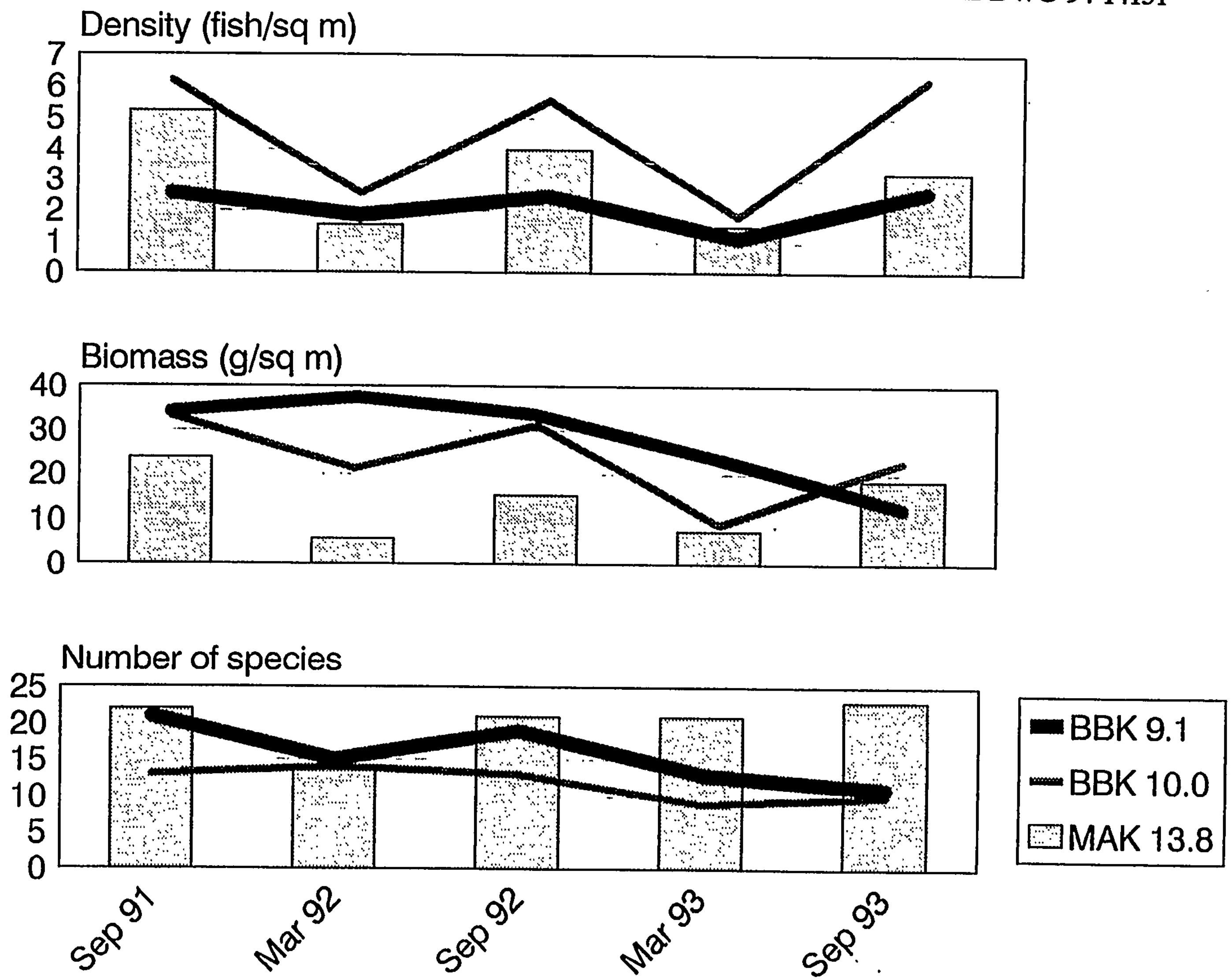

Fig. 5.1. Species richness, biomass, and density of fish at Big Bayou Creek sites and a reference site, Massac Creek. BBK = Big Bayou Creek kilometer; MAK = Massac Creek kilometer.

The fish community at LUK 7.2 was similar to the BBK 12.5 reference, with perhaps some species deficiencies. The mean and total species richness values were higher than those of the reference site with slightly fewer catostomid species. Density and biomass were lower than at BBK 12.5. Since 1991, species richness and biomass have increased slightly (Fig 5.2). The increase in species and slight increase in more sensitive species is suggestive of improvement. Whether this trend continues or is a reflection of sample variation may be determined with future monitoring.

The downstream qualitative site, LUK 4.3, did not appear to be unduly affected. Species richness was comparable (Fig 5.3) to that found in earlier sampling (Ryon 1994a), particularly in terms of sensitive species. The community was well represented in all families, except perhaps Catostomidae, and significant absences in feeding guilds were not demonstrated. The relative abundance and catch-per-effort data were lower than prior samples (Ryon 1994a), but still at similar levels (Fig 5.3). Thus, the community at LUK 4.3 appeared to be no more stressed than previously.

Monitoring of the fish communities associated with PGDP streams indicated some depressed conditions but did not specifically identify causative agents. The greatest impacts occurred at sites closest to the plant, which suggests that PGDP effluents may be the cause. The low species richness and lack of sensitive species may be caused by poor water quality or may reflect degraded habitat conditions. Biomass and density respond quickly to improvements in degraded conditions and it will be important to follow changes in these parameters, particularly at the most stressed sites. After changes in density, the return of sensitive species or changes in proportions of feeding guilds (e.g., an increase in benthic insectivores) would signal an improvement in water quality.

5.2 BENTHIC MACROINVERTEBRATES *(J. G. Smith)*

5.2.1 Introduction

Benthic macroinvertebrates are those organisms that are large enough to be seen without the aid of magnification and that live on or among the substrate particles of flowing and non-flowing bodies of water. The limited mobility and relatively long life spans (a few months to more than a year) of most taxa make them ideal for use in evaluating the ecological effects of

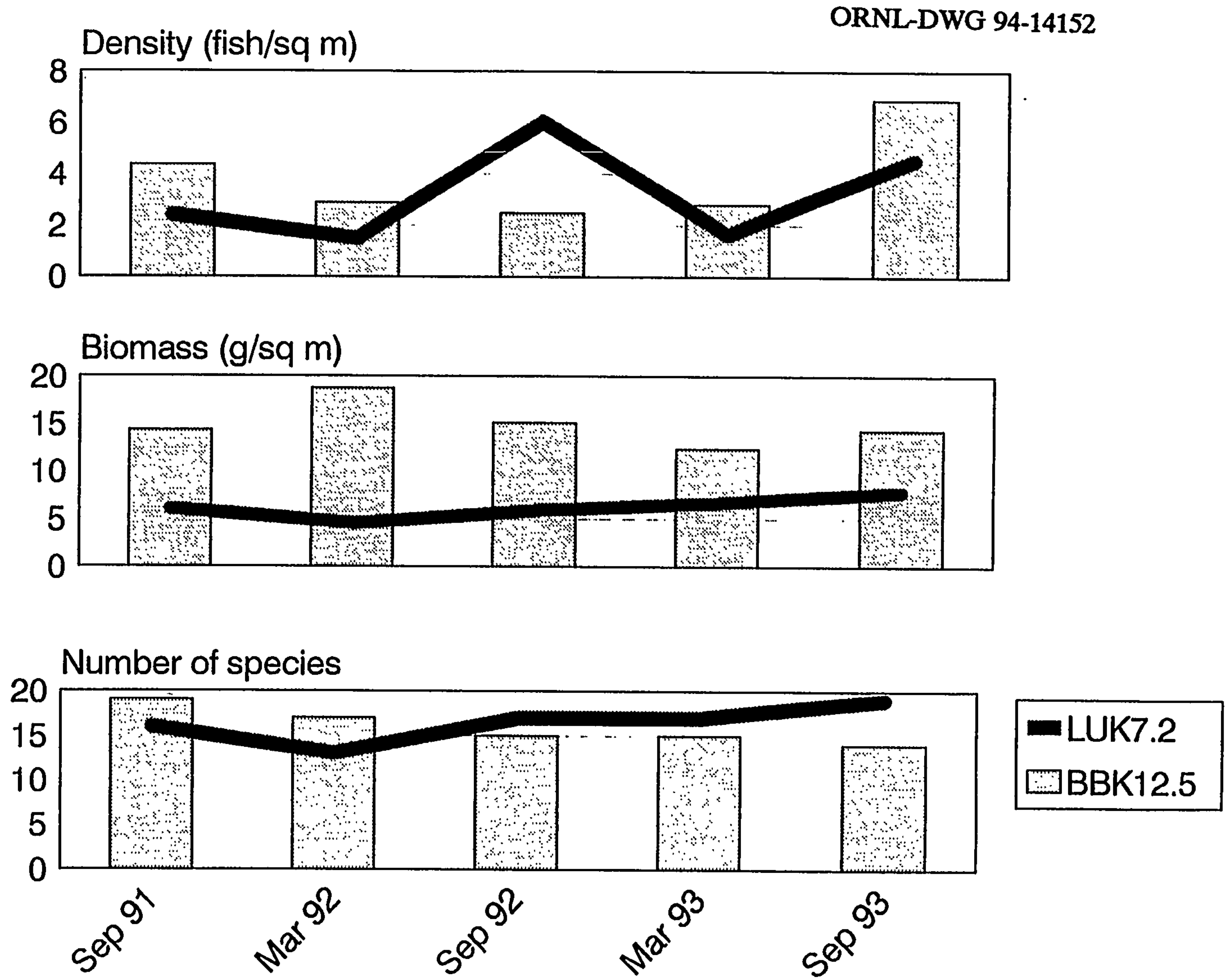

Fig. 5.2. Species richness, biomass, and density of fish at Little Bayou Creek site at kilometer (LUK) 7.2 and reference site, Big Bayou Creek at kilometer (BBK) 12.5.

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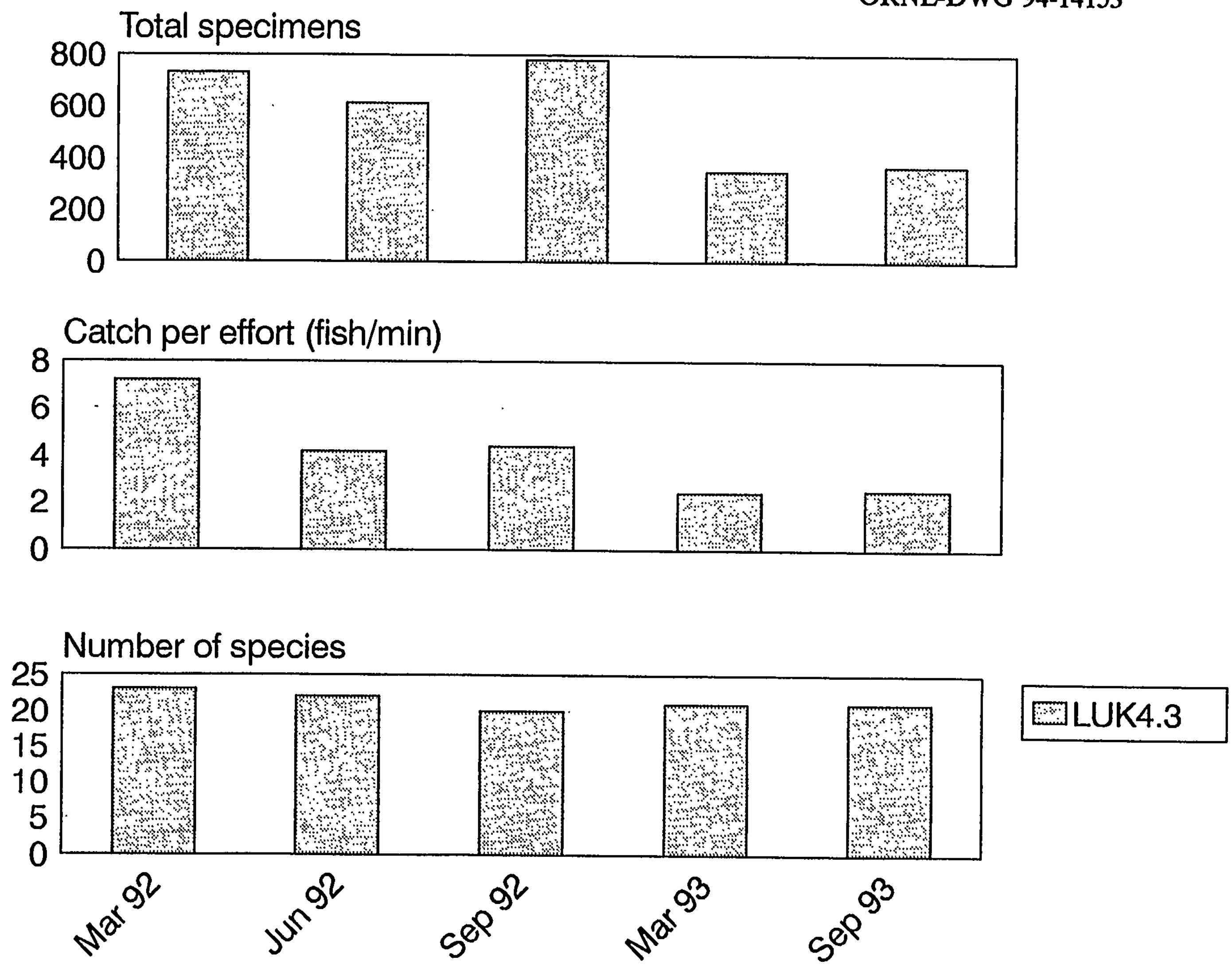

Fig. 5.3. Species richness, catch per effort, and total specimens of fish at Little Bayou Creek qualitative site at kilometer (LUK) 4.3.

effluent discharges to streams (Platts et al. 1983). Thus, the composition and structure of the benthic macroinvertebrate community reflects the relatively recent past and can be considerably more informative than methods that rely solely on water quality analyses, but ignore the potential synergistic effects often associated with complex effluents.

The initial objectives of the benthic macroinvertebrate monitoring task were to characterize the benthic macroinvertebrate community and assist in evaluating the ecological health of the two streams that receive effluent discharges from PGDP, including Big Bayou Creek and Little Bayou Creek. After satisfying the initial objectives, changes in the benthic macroinvertebrate community will then be followed to help evaluate and document the effectiveness of pollution abatement activities, and to determine whether any changes in operations at PGDP have any effects as well. This report presents the results of samples collected in September 1991 only, ORNL's first collection period for the BMAP. Thus, these results provide only a preliminary step in characterizing the benthic macroinvertebrate community and assisting in the evaluation of the ecological conditions of the streams. These results also provide the first step in building a baseline data base that is needed for following changes in the streams as they occur.

5.2.2 Materials and Methods

Beginning in September 1991, benthic macroinvertebrate samples were collected at quarterly intervals from three sites in Big Bayou Creek (BBK 9.1, BBK 10.0, and BBK 12.5) and one site in Little Bayou Creek (LUK 7.2); BBK 12.5 served as a reference site for LUK 7.2 and both downstream sites on Big Bayou Creek (Fig. 2.2). One site on Massac Creek (MAK 13.8), located off of the PGDP Reservation, served as an additional reference site (Fig. 2.1).

Three random, quantitative samples were collected from a permanently marked riffle at each site with a Surber bottom sampler (0.09 m^2 or 1 ft^2) fitted with a 363-μm-mesh collection net. All samples were placed in prelabeled, polyurethane-coated, glass jars and preserved in ~80% ethanol; the ethanol was replaced with fresh ethanol within 7 days of collection. Further details on the collection, storage, and maintenance of benthic macroinvertebrate samples may be found in Smith (1992a).

Supplemental information on water quality and stream characteristics was recorded at the time of sampling. Temperature, conductivity, dissolved oxygen, and pH were measured with an Horiba Model U-7 Water Quality Checker. Water depth, location within the riffle area (distance from permanent headstakes on the stream bank), visual determination of relative stream velocity (very slow, slow, moderate, or fast), and substrate type (visual determination) based on a modified Wentworth particle size scale (Loar et al. 1985) were recorded for each sample. These data are used only where needed for observational support. All measurements and data for water quality and stream characteristics were obtained in accordance with established quality assurance (QA) procedures (Smith 1992).

Samples were washed in the laboratory in a U. S. Standard No. 60-mesh (250-µm-mesh) sieve. Small aliquots of the sample were removed from the sieve, placed into a white tray containing water, and then the organisms were removed from the sample debris. This was repeated until the entire sample was sorted. Finally, the removed organisms were identified to the lowest practical taxon and enumerated. Further details of the laboratory procedures followed to process benthos samples may be found in Wojtowicz and Smith (1992).

Data were managed and computer analyzed primarily with Statistical Analysis System software and procedures (SAS 1985a, 1985b).

5.2.3 Results

5.2.3.1 Taxonomic composition and abundance

A checklist of the benthic macroinvertebrate taxa collected in September 1991 from Big Bayou Creek, Little Bayou Creek, and Massac Creek is presented in Appendix E, Table E.1. The five sites sampled had comparatively diverse invertebrate communities, with most sites having at least one or more taxa within each of the major taxonomic groups represented. However, there were a few notable differences and absences in taxonomic composition. No Odonata (dragonflies and damselflies) were collected from BBK 9.1, whereas one to three taxa were collected from each of BBK 12.5, LUK 7.2, and MAK 13.8, and six to nine taxa (three could not be identified beyond order or family) were collected from BBK 10.0. Only one taxon within the Ephemeroptera (mayflies) was collected at LUK 7.2, while two or more were collected from each of the other four sites. Finally, no Plecoptera (stoneflies) were collected from any site.

Considerable differences in average densities existed among sites (Fig. 5.4). Highest densities were observed in Big Bayou Creek at BBK 9.1 and BBK 10.0 where the number of invertebrates per 0.1 m^2 were approximately 2.5 times to 5.0 times higher than at the reference

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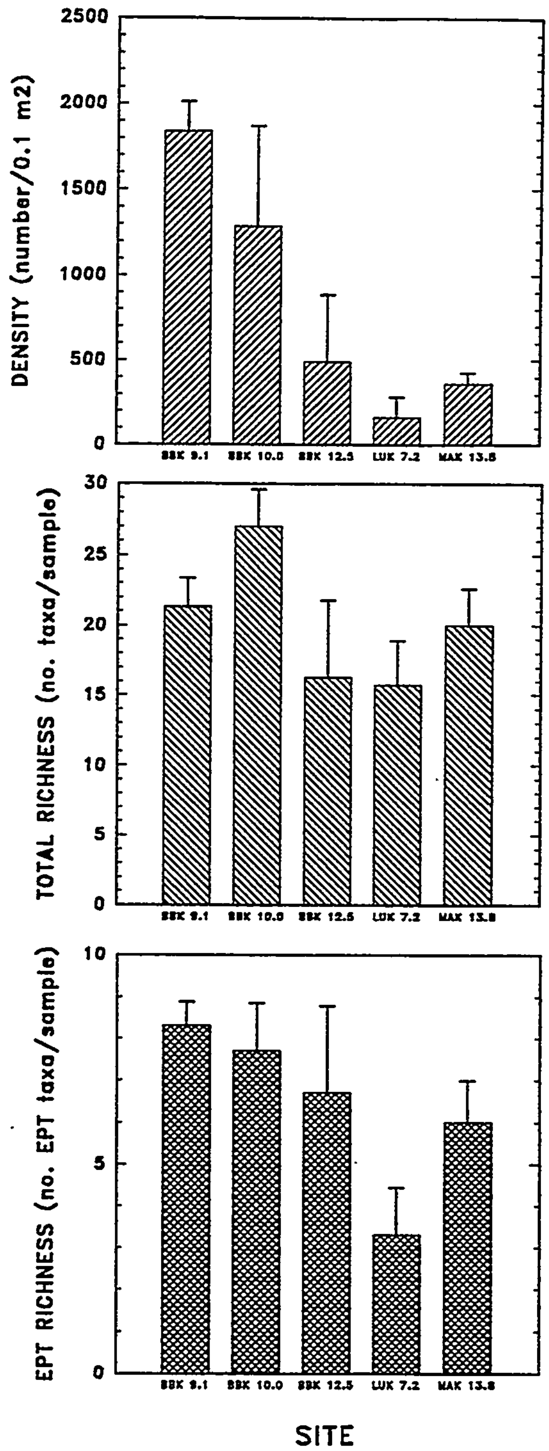

Fig. 5.4. Mean total density, mean total richness, and mean richness of the Ephemeroptera, Plecoptera, and Trichoptera (EPT richness) of the benthic macroinvertebrate communities in Big Bayou Creek, Little Bayou Creek, and Massac Creek, September 1991. Verticle bars represent ± 1SD. BBK = Big Bayou Creek kilometer; LBK = Little Bayou Creek kilometer; MAK = Massac Creek kilometer.

sites (BBK 12.5 and MAK 13.8). This contrasted with LUK 7.2 where the density was about one-half to one-third the densities observed at BBK 12.5 and MAK 13.8.

The major differences among sites in the taxa numerically dominating the community were related primarily to three major groups: Trichoptera, Ephemeroptera, and Chironomidae (Fig. 5.5). At BBK 9.1 and BBK 12.5, Trichoptera accounted for approximately 40% of the total density, and at LUK 7.2 and MAK 13.8 they accounted for at least 10% of the total density. This contrasts with BBK 10.0 where this group accounted for less than 3% of the total density. BBK 10.0 was dominated primarily by Ephemeroptera, which made up about 66% of the total density. Ephemeroptera were also prominent at BBK 9.1, BBK 12.5, and MAK 13.8, comprising 9% to 25% of the total density. However, Ephemeroptera were virtually absent from LUK 7.2. Also notable was the numerical dominance of Chironomidae at LUK 7.2 and MAK 13.8, where they comprised ≥ 60% of the density; chironomids made up only about 15% or less of the communities at Big Bayou Creek sites. Differences among sites in the "Other Taxa" (Fig. 5.5) were largely attributable to the relative abundances of Coleoptera and/or Planariidae. For example, Planariidae accounted for 10% and 17.4% of the total density at BBK 9.1 and BBK 12.5, respectively, and Coleoptera accounted for 14.5% and 15.6% at BBK 12.5 and LUK 7.2 respectively.

Further differences among the sites were evident upon closer examination of the composition of the Ephemeroptera and Trichoptera (Fig. 5.6). A majority of the Ephemeroptera at both BBK 12.5 and BBK 9.1 were of a single taxon, *Baetis*. However, two additional taxa, *Tricorythodes* and *Caenis*, also occurred in relatively high numbers at BBK 9.1; the number of *Caenis* occurring at BBK 12.5 was small and no *Tricorythodes* were collected. Also notable were the large number of *Caenis* at BBK 10.0, the virtual absence of mayflies other than *Baetis* at MAK 13.8, and the virtual absence of Ephemeroptera from LUK 7.2.

The majority of Trichoptera at BBK 9.1, BBK 10.0, and MAK 13.8 were taxa within the family Hydropsychidae, although the *Chimarra* were also abundant at BBK 9.1 (Fig. 5.6). Most of the Trichoptera collected at BBK 12.5 were *Chimarra*, whereas Trichoptera were numerically unimportant at LUK 7.2.

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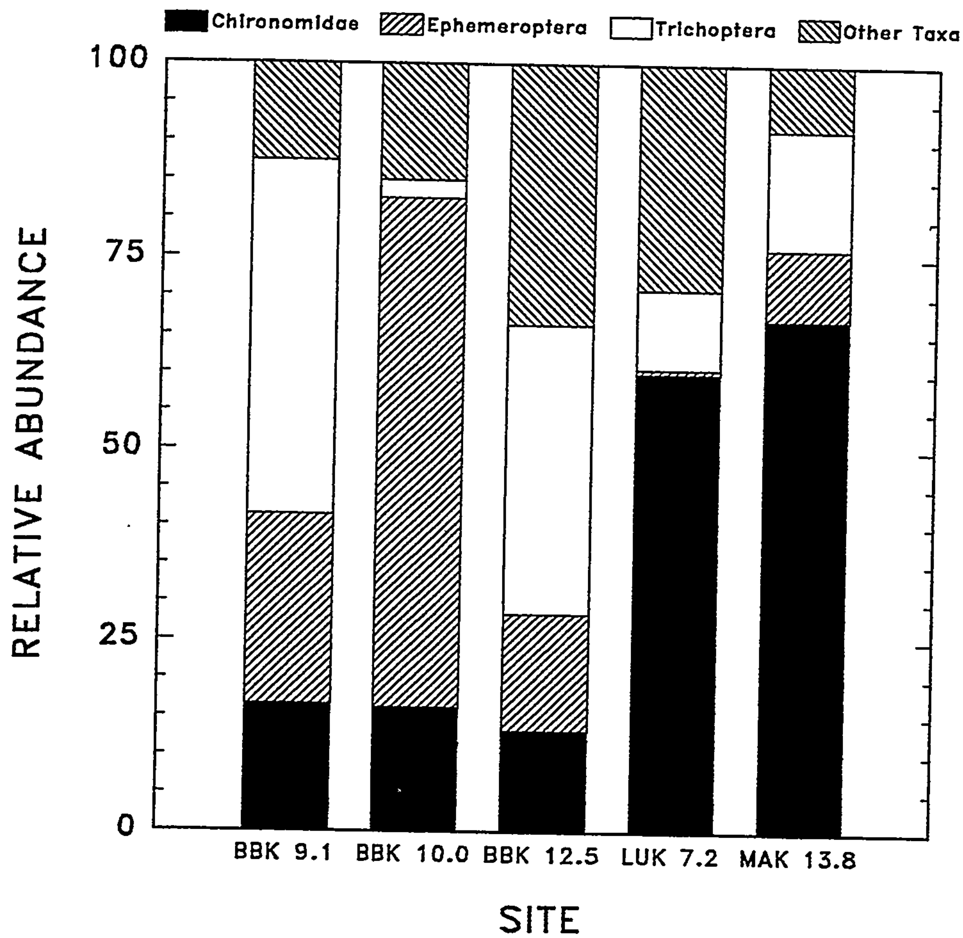

Fig. 5.5. Mean relative abundance (i.e., percent density) of selected benthic macroinvertebrate taxa in Big Bayou Creek, Little Bayou Creek, and Massac Creek, September 1991. BBK = Big Bayou Creek kilometer; LBK = Little Bayou Creek kilometer; MAK = Massac Creek kilometer.

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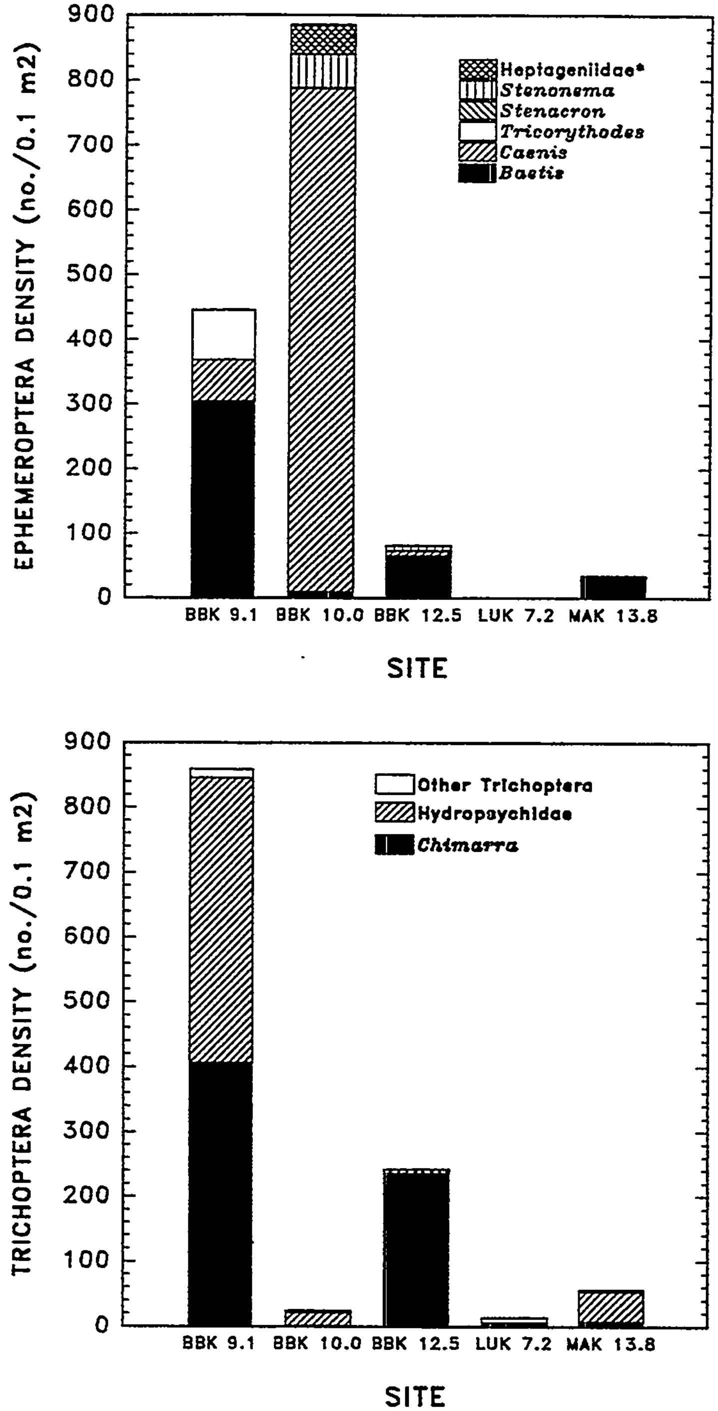

Fig. 5.6. Mean densities of the Ephemeroptera and Tricoptera taxa in Big Bayou Creek, Little Bayou Creek, and Massac Creek, September 1991. *The Heptageniidae are composed of unidentified specimens and may include *Stenacron* or *Stenonema*. BBK = Big Bayou Creek kilometer; LBK = Little Bayou Creek kilometer; MAK = Massac Creek kilometer.

5.2.3.2 Taxonomic richness

Differences among sites in mean total taxonomic richness (i.e., total number of taxa per sample) were not as substantial as those observed for density (Fig. 5.4). The highest mean richness value was observed at BBK 10.0 where the number of taxa collected per sample was approximately six more than at the other four sites. The largest difference among the sites occurred between BBK 10.0 and LUK 7.2, with richness differing by a factor of only 1.8 times. Richness at the remaining four sites differed by no more than five taxa per sample.

Except for LUK 7.2, differences among sites in the combined richness of Ephemeroptera, Plecoptera, and Trichoptera (i.e., the number of EPT taxa per sample or EPT richness) were even less pronounced than those for total richness (Fig. 5.4). The average number of EPT taxa per sample at LUK 7.2 was at least half that observed at the other four sites; differences at the other four sites were no greater than two EPT taxa per sample.

5.2.4 Discussion

Benthic macroinvertebrate community data from only a single sampling period do not provide a data base extensive enough to fully evaluate the ecological health of a stream, except where stress or environmental degradation are substantial. However, even though probable differences in sampling and processing techniques and the level of taxonomic identification do not allow direct comparisons to be made with previous studies of Big Bayou Creek and Little Bayou Creek (Birge et al. 1990, 1992), the general spatial patterns exhibited by the invertebrate communities during these earlier studies help provide some insight into the patterns exhibited during the current study.

In previous studies of Big Bayou Creek and Little Bayou Creek, considerable spatial differences and temporal variability were observed in the benthic macroinvertebrate communities of Big Bayou Creek (Birge et al. 1990, 1992); poor benthic invertebrate habitat in Little Bayou Creek did not allow meaningful evaluation of the condition of the invertebrate community of this stream (Birge et al. 1990). Spatial differences in Big Bayou Creek were attributed to possible effects of discharges from outfalls 001 through 009, and to differences in instream habitat that, relative to BBK 12.5 (BB1), included a less stable substrate from BBK 10.0 (BB4) downstream to BBK 9.1 (BB7). Temporal differences were attributed to a combination of increased precipitation which resulted in increased flows, and to improvements in water quality downstream of Outfall 008. It was hypothesized that the increased flows may have increased scouring and/or increased dilution of the effluents, with the former adversely affecting the invertebrates and the latter allowing some recovery. Based on results obtained from October 1987 through July 1991, Birge et al. (1992) concluded that those sites located downstream of the outfalls, beginning at Outfall 009, were slightly to moderately impacted with the greatest impact, occurring in the midreaches between Outfall 008 to immediately below Outfall 001.

In the current study, both obvious and subtle differences were evident among the sites. Macroinvertebrate densities appeared to be excessively high at BBK 9.1 and BBK 10.0 and relatively low at LUK 7.2. In contrast, site differences in total richness were not as extensive; and, except for LUK 7.2, site differences in EPT richness were also less than those exhibited by density. Birge et al (1990, 1992) also observed that site differences for density were generally larger than those for total richness (Fig. 5.7); they did not, however, evaluate site differences on the basis of EPT richness.

The Big Bayou Creek sites were dominated primarily by either ephemeropterans (BBK 10.0) or a combination of ephemeropterans and trichopterans (BBK 9.1 and BBK 12.5), although the occurrence of relatively large number of Planariidae and Coleoptera at BBK 12.5 as well, gave this site the appearance of a more evenly balanced community (Fig. 5.5 and Section 5.2.3.1). In contrast, LUK 7.2 was dominated mostly by chironomids and, to a lesser extent, the Coleoptera; Ephemeroptera were virtually absent from this site. Interestingly, the reference site, MAK 13.8, was also dominated by chironomids. In general, as the level of stress or impact increases, the proportion of a few taxa such as Chironomidae also increases (e.g., Hynes 1974; Wiederholm 1984). Because of the dominance of chironomids at MAK 13.8, the stability of this site as a reference will be evaluated in greater detail in future reports.

Good water quality and relatively undisturbed streams generally favor groups such as the Ephemeroptera, Trichoptera, and Plecoptera (Hynes 1974, Lenat 1988, Wiederholm 1984). Although Ephemeroptera or Trichoptera were the dominant or codominant taxa at most of the sites in the present study, most of the taxa occurring at these sites are often tolerant of silty and/or enriched conditions. For example, hydropsychid caddisflies are often found in large numbers in areas recovering from organically enriched conditions (Wiederholm 1984). Some species of *Baetis* are able to take advantage of the large amount of food produced (i.e., algae) under conditions simulating enrichment (e.g., clearcutting with subsequent increased growth of

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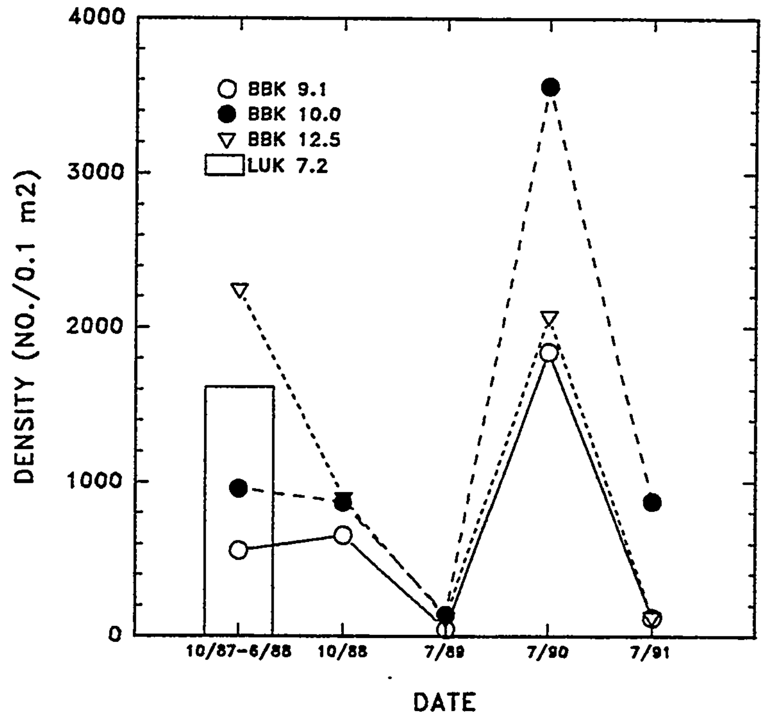

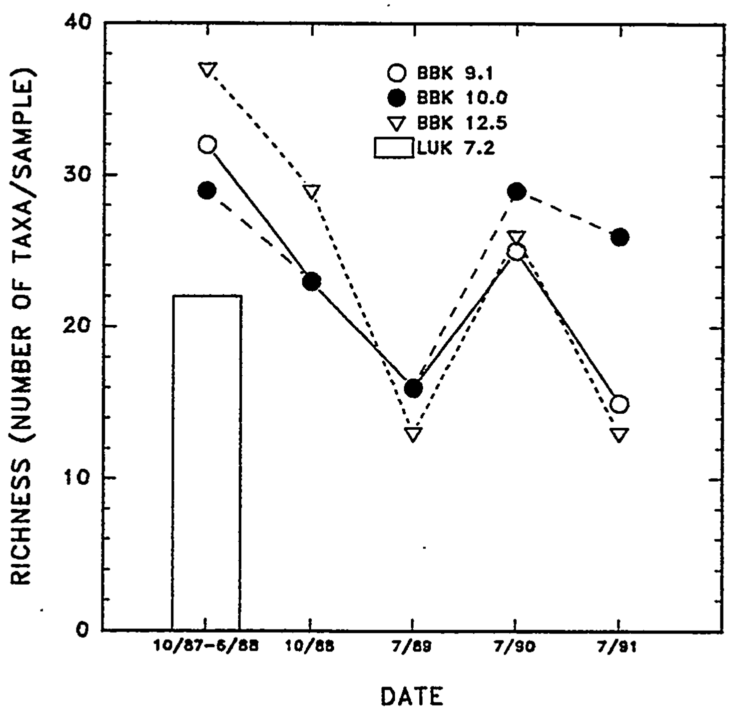

Fig. 5.7. Mean total density and mean total richness of benthic macroinvertebrates communities in Big Bayou Creek and Little Bayou Creek, October 1987–July 1991. The data were adapted from Birge et al. (1990, 1992; complete citations are provided in Sect. 6.0). BBK = Big Bayou Creek kilometer; LBK = Little Bayou Creek kilometer.

algae due to increased sunlight), and some species are also able to tolerate some silt (Noel et al. 1986, Wiederholm 1984). Some species of *Caenis* are tolerant of considerable pollution (Edmunds et al. 1976), and most species that are likely to occur in the Paducah area are more likely to be tolerant of organically rich and silty conditions (Provonsha 1990). Finally, no Plecopterans were collected from any site during the first collection period. Birge et al. (1990, 1992) also found this group to be relatively rare in Big Bayou Creek and Little Bayou Creek.

5.2.5 Summary and Conclusions

Preliminary data on the benthic macroinvertebrate communities of Big Bayou Creek and Little Bayou Creek showed distinct site differences, which may be indicative of impact. All sites, including the reference sites, were composed of large proportions of taxa tolerant of at least moderately polluted conditions. Greater community balance appeared to exist at BBK 12.5 as evidenced by more evenly apportioned abundances of the major taxonomic groups, suggesting that any stress existing at this site may be minimal. The relative abundances of some of the major taxonomic groups at BBK 10.0 and BBK 12.5 differed substantially, while the community at BBK 9.1 was more similar to that observed at BBK 12.5, suggesting that BBK 10.0 was impacted. This is in agreement with Birge et al. (1990, 1992) who suggested impacts in Big Bayou Creek were greatest at those sites upstream of BBK 9.1 (or BB7). However, the presence of a large number of pollution-tolerant hydropsychid caddisflies at BBK 9.1 suggested that water quality at this site remained somewhat impaired compared with BBK 12.5. The composition and structure of the macroinvertebrate communities at BBK 9.1 and BBK. 10.0 suggested that they were likely impacted by siltation and nutrient enrichment. The presence of high levels of nutrients is also suggested by the finding of the fish community studies in which high densities and biomass of central stonerollers were found at BBK 9.1 and BBK 10.0 (Ryon 1994a). However, other factors such as elevated temperatures and excess concentrations of metals may be impacting the invertebrate communities at these sites as well.

The absence of mayflies and the dominance of chironomids at LUK 7.2 suggested moderate impact. The relatively close proximity of this site to Outfall 011 make the effluents from this outfall a primary factor that may be contributing to this impact. However, as Birge et al. (1990) observed, poor benthic invertebrate habitat already existed in Little Bayou Creek, which could also be an important factor contributing to the occurrence of a depauperate benthic community at this site. The riffle area in the vicinity of LUK 7.2 was not extensive, and the substrate was generally dominated by clay with only sparse areas of gravel and rubble. A more extensive data base that includes sample collections over several seasons and years should help provide a better understanding of the ecological conditions at this site as well as those in Big Bayou Creek.

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Appendix A
SUMMARY STATISTICS AND INTERIM LIMITS FOR WATER QUALITY PARAMETERS AT KPDES PERMITTED OUTFALLS

Table A.1. Summary statistics for Kentucky Pollutant Discharge Elimination System Permit water quality parameters at Outfall 001 for 1993

Analysis	(Units)	Maximum	Minimum	Average	Count
Conventional Parameters					
Ammonia as nitrogen	(mg/L)	<0.2500	<0.2500	<0.2500	2
BOD	(mg/L)	<5.0000	<5.0000	<5.0000	2
Bromide	(mg/L)	<1.0000	<1.0000	<1.0000	2
Chloride	(mg/L)	66.0000	58.0000	62.0000	53
Chlorine, total residual	(mg/L)	0.0500	<0.0200	<0.0415	2
COD	(mg/L)	8.0000	8.0000	8.0000	5
Color	(units)	13.0000	11.0000	12.0000	55
Cyanide	(mg/L)	<0.0200	<0.0200	<0.0200	2
Fecal Coliform	(Co/100mL)	500.0000	0.3900	0.4250	54
Flow	(MLD)	62.8	<11.0000	<305.4000	2
Fluoride	(mg/L)	0.4600	1.9000	8.0000	25
Hardness as $CaCO_3$	(mg/L $CaCO_3$)	530.0000	120.0000	364.2037	2
Hexavalent Chromium	(mg/L)	0.0200	<0.0100	<0.0104	54
Nitrate-nitrite	(mg/L)	2.3000	2.0000	2.1500	2
Oil and grease	(mg/L)	<5.0000	<5.0000	<5.0000	2
pH	(SU)	9.8000	7.3000	8.5115	2
Specific conductance	(μmhos/cm)	1740.0000	542.0000	1328.4510	2
Sulfate	(mg/L)	270.0000	237.0000	253.5000	2
Sulfide	(mg/L)	<1.0000	<1.0000	<1.0000	2
Sulfite	(mg/L)	<3.0000	<3.0000	<3.0000	51
Surfactants	(mg/L)	<0.0800	<0.0800	<0.0800	2
Temperature	(C)	36.7000	5.6000	20.7000	2
Total organic carbon	(mg/L)	6.0000	5.0000	5.5000	60
Total organic nitrogen	(mg/L)	0.9600	0.8200	0.8900	54
Total suspended solids	(mg/L)	48.0000	<4.0000	<16.3889	51
TOX	(μg/L)	504.0000	90.0000	217.4706	55
Metals					
Aluminum	(mg/L)	2.6900	0.1760	0.6820	26
Antimony	(mg/L)	<0.0600	<0.0600	<0.0600	2
Arsenic	(mg/L)	<0.0050	<0.0050	<0.0050	2
Barium	(mg/L)	0.0270	0.0250	0.0260	2
Beryllium	(mg/L)	<0.0050	<0.0050	<0.0050	2
Boron	(mg/L)	0.7130	0.7040	0.7085	2
Cadmium	(mg/L)	0.0190	<0.0100	<0.0103	26
Chromium	(mg/L)	<0.0500	<0.0500	<0.0500	12
Cobalt	(mg/L)	<0.0500	<0.0500	<0.0500	2
Copper	(mg/L)	0.1680	<0.0100	<0.0173	26
Iron	(mg/L)	1.9500	0.0590	0.4488	26
Lead	(mg/L)	<0.2000	<0.0500	<0.1888	26
Magnesium	(mg/L)	19.2000	18.2000	18.7000	2
Manganese	(mg/L)	0.0480	0.0410	0.0445	2
Mercury	(mg/L)	<0.0002	<0.0002	<0.0002	2
Molybdenum	(mg/L)	<0.0500	<0.0500	<0.0500	2
Nickel	(mg/L)	0.4650	<0.0500	<0.0660	26
Phosphorus (P)	(mg/L)	0.4700	0.1400	0.2485	54
Selenium	(mg/L)	<0.0050	<0.0050	<0.0050	2
Silver	(mg/L)	<0.0300	<0.0300	<0.0300	2
Thallium	(mg/L)	<0.0440	<0.0440	<0.0440	2
Tin	(mg/L)	<5.0000	<5.0000	<5.0000	2
Titanium	(mg/L)	<0.0500	<0.0500	<0.0500	2
Zinc	(mg/L)	0.1450	<0.0050	<0.0197	26

Table A.1 (continued)

Analysis	(Units)	Maximum	Minimum	Average	Count
Organics					
1,1,1-Trichloroethane	(µg/L)	<10.0000	<10.0000	<10.0000	4
1,1,2,2-Tetrachloroethane	(µg/L)	<10.0000	<10.0000	<10.0000	4
1,1,2-Trichloroethane	(µg/L)	<10.0000	<10.0000	<10.0000	4
1,1-Dichloroethane	(µg/L)	<10.0000	<10.0000	<10.0000	4
1,1-Dichloroethene	(µg/L)	<10.0000	<10.0000	<10.0000	4
1,2-Dichloroethane	(µg/L)	<10.0000	<10.0000	<10.0000	4
1,2-Dichloroethene	(µg/L)	<10.0000	<10.0000	<10.0000	4
1,2-Dichloropropane	(µg/L)	<10.0000	<10.0000	<10.0000	4
2-Chloroethyl vinyl	(µg/L)	<10.0000	<10.0000	<10.0000	2
2-Chlorophenol	(µg/L)	<10.0000	<10.0000	<10.0000	2
2-Nitrophenol	(µg/L)	<50.0000	<50.0000	<50.0000	2
2,3,7,8-Tetrachlorodibenzene P-dioxin	(µg/L)	<0.0007	<0.0007	<0.0007	2
2,4-Dichlorophenol	(µg/L)	<10.0000	<10.0000	<10.0000	2
2,4-Dimethylphenol	(µg/L)	<50.0000	<50.0000	<50.0000	2
2,4-Dinitrophenol	(µg/L)	<10.0000	<10.0000	<10.0000	2
2,4,6-Trichlorophenol	(µg/L)	<10.0000	<10.0000	<10.0000	4
4-Chloro-3-methylphenol	(µg/L)	<10.0000	<10.0000	<10.0000	2
4-Nitrophenol	(µg/L)	<50.0000	<50.0000	<50.0000	2
4,6-Dinitro-2-methylphenol	(µg/L)	<50.0000	<50.0000	<50.0000	2
Acetone	(µg/L)	<1000.0000	<1000.0000	<1000.0000	14
Acrolein	(µg/L)	<100.0000	<100.0000	<100.0000	4
Acrylonitrile	(µg/L)	<100.0000	<100.0000	<100.0000	4
Benzene	(µg/L)	<10.0000	<10.0000	<10.0000	2
Bromodichloromethane	(µg/L)	<10.0000	<10.0000	<10.0000	4
Bromoform	(µg/L)	<10.0000	<10.0000	<10.0000	4
Bromomethane	(µg/L)	<10.0000	<10.0000	<10.0000	4
Carbon tetrachloride	(µg/L)	<10.0000	<10.0000	<10.0000	4
Chlorobenzene	(µg/L)	<10.0000	<10.0000	<10.0000	4
Chloroethane	(µg/L)	<10.0000	<10.0000	<10.0000	4
Chloroform	(µg/L)	10.0000	<5.0000	<7.5000	4
Chloromethane	(µg/L)	<10.0000	<10.0000	<10.0000	4
Cis-1,3-dichloropropene	(µg/L)	<10.0000	<10.0000	<10.0000	4
Dibromochloromethane	(µg/L)	<10.0000	<10.0000	<10.0000	4
Ethylbenzene	(µg/L)	<10.0000	<10.0000	<10.0000	2
Isopropanol	(µg/L)	<1000.0000	<1000.0000	<1000.0000	14
Methylene Chloride	(µg/L)	<10.0000	<10.0000	<10.0000	4
PCB	(µg/L)	<10.0000	<10.0000	<10.0000	4
Pentachlorophenol	(µg/L)	<50.0000	<50.0000	<50.0000	2
Phenol	(µg/L)	<10.0000	<10.0000	<10.0000	2
Tetrachloroethene	(µg/L)	<0.1000	<0.0100	<0.0936	14
Toluene	(µg/L)	<10.0000	<10.0000	<10.0000	2
Trans-1,3-dichloropropene	(µg/L)	<10.0000	<10.0000	<10.0000	4
Trichloroethene	(µg/L)	<10.0000	<1.0000	<2.8000	20
Vinyl chloride	(µg/L)	<10.0000	<10.0000	<10.0000	4
Xylene	(µg/L)	<10.0000	<10.0000	<10.0000	4

Table A.1 (continued)

Analysis	(Units)	Maximum	Minimum	Average	Count
Radionuclides					
% U-235	(Wt %)	1.8840	0.3590	0.5653	39
Dissolved alpha	(pCi/L)	91.1000	-23.4000	13.2151	2
Dissolved beta	(pCi/L)	143.0000	7.0000	55.2453	2
Gross alpha	(pCi/L)	3.6000	0.5000	2.0500	2
Gross beta	(pCi/L)	29.0000	21.0000	25.0000	2
Neptunium-237	(pCi/L)	0.4000	0.0000	0.2000	3
Plutonium-239	(pCi/L)	0.0000	0.0000	0.0000	3
Rad alpha	(pCi/ml)	<1.0000	<1.0000	<1.0000	1
Rad beta	(pCi/ml)	<1.0000	<1.0000	<1.0000	53
Rad screen	(pCi/ml)	<1.0000	<1.0000	<1.0000	53
Suspended alpha	(pCi/L)	10.4000	-9.2000	0.3472	56
Suspended beta	(pCi/L)	80.0000	-7.0000	5.9434	1
Technetium-99	(pCi/L)	99.0000	2.0000	28.7500	2
Thorium-230	(pCi/L)	0.4000	0.4000	0.4000	78
Total radium	(pCi/L)	1.6000	1.0000	1.3000	53
Uranium	(mg/L)	0.2000	0.0020	0.0319	53

Table A.2. Summary statistics for Kentucky Pollutant Discharge Elimination System Permit water quality parameters at Outfall 002 for 1993

Analysis	(Units)	Maximum	Minimum	Average	Count
Conventional Parameters					
Ammonia as nitrogen	(mg/L)	<0.2500	<0.2500	<0.2500	1
BOD	(mg/L)	<5.0000	<5.0000	<5.0000	1
Bromide	(mg/L)	<1.0000	<1.0000	<1.0000	1
Chloride	(mg/L)	8.0000	8.0000	8.0000	1
Chlorine, total residual	(mg/L)	<0.0500	<0.0200	<0.0425	12
COD	(mg/L)	29.0000	29.0000	29.0000	1
Color	(units)	37.0000	37.0000	37.0000	1
Cyanide	(mg/L)	<0.0200	<0.0200	<0.0200	1
Fluoride	(mg/L)	0.1300	0.1300	0.1300	1
Hardness as $CaCO_3$	(mg/L $CaCO_3$)	115.0000	50.0000	75.5833	12
Fecal Coliform	(Co/100mL)	>3000.0000	3000.0000	3000.0000	1
Flow	(MLD)	17.7100	<0.0040	<3.2200	13
Oil and grease	(mg/L)	<5.0000	<5.0000	<5.0000	12
pH	(SU)	9.8000	7.3000	7.7333	12
Surfactants	(mg/L)	<0.0800	<0.0800	<0.0800	1
Temperature	(C)	28.9000	7.8000	19.1000	12
Total suspended solids	(mg/L)	34.0000	6.0000	19.0000	12
Nitrate-nitrite	(mg/L)	0.5500	0.5500	0.5500	1
Sulfate	(mg/L)	21.0000	21.0000	21.0000	1
Sulfide	(mg/L)	<1.0000	<1.0000	<1.0000	1
Sulfite	(mg/L)	<3.0000	<3.0000	<3.0000	1
Total organic carbon	(mg/L)	4.0000	4.0000	4.0000	1
Total organic nitrogen	(mg/L)	0.5500	0.5500	0.5500	1
Metals					
Aluminum	(mg/L)	2.7500	0.2200	1.1468	12
Antimony	(mg/L)	<0.0600	<0.0600	<0.0600	1
Arsenic	(mg/L)	<0.0050	<0.0050	<0.0050	1
Barium	(mg/L)	0.0320	0.0320	0.0320	1
Beryllium	(mg/L)	<0.0050	<0.0050	<0.0050	1
Boron	(mg/L)	0.0052	0.0052	0.0052	1
Cadmium	(mg/L)	0.0240	<0.0100	<0.0112	12
Chromium	(mg/L)	<0.0500	<0.0500	<0.0500	12
Cobalt	(mg/L)	<0.0500	<0.0500	<0.0500	1
Copper	(mg/L)	0.0270	<0.0100	<0.0128	12
Iron	(mg/L)	2.3400	0.1400	0.9421	12
Lead	(mg/L)	<0.2000	<0.2000	<0.2000	12
Magnesium	(mg/L)	1.9900	1.9900	1.9900	1
Manganese	(mg/L)	0.0310	0.0310	0.0310	1
Mercury	(mg/L)	<0.0002	<0.0002	<0.0002	1
Molybdenum	(mg/L)	<0.0500	<0.0500	<0.0500	1
Nickel	(mg/L)	<0.0500	<0.0500	<0.0500	12
Phosphorus(P)	(mg/L)	0.4700	0.1600	0.2650	12
Selenium	(mg/L)	<0.0050	<0.0050	<0.0050	1
Silver	(mg/L)	<0.0300	<0.0300	<0.0300	1
Thallium	(mg/L)	<0.0560	<0.0560	<0.0560	1
Tin	(mg/L)	<5.0000	<5.0000	<5.0000	1
Titanium	(mg/L)	<0.0500	<0.0500	<0.0500	1
Zinc	(mg/L)	0.0390	0.0100	0.0294	12

Table A.2 (continued)

Analysis	(Units)	Maximum	Minimum	Average	Count
Organics					
1,1,1-Trichloroethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
1,1,2,2-Tetrachloroethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
1,1,2-Trichloroethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
1,1-Dichloroethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
1,1-Dichloroethene	(µg/L)	<1.0000	<1.0000	<1.0000	1
1,2-Dichloroethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
1,2-Dichloropropane	(µg/L)	<1.0000	<1.0000	<1.0000	1
2,3,7,8-Tetrachlorodibenzene P-dioxin	(µg/L)	<0.0007	<0.0007	<0.0007	1
2,4,6-Trichlorophenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
2,4-Dichlorophenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
2,4-Dimethylphenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
2,4-Dinitrophenol	(µg/L)	<50.0000	<50.0000	<50.0000	1
2-Chloroethyl vinyl	(µg/L)	<1.0000	<1.0000	<1.0000	1
2-Chlorophenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
2-Nitrophenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
4,6-Dinitro-2-methylphenol	(µg/L)	<50.0000	<50.0000	<50.0000	1
4-Chloro-3-methylphenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
4-Nitrophenol	(µg/L)	<50.0000	<50.0000	<50.0000	1
Pentachlorophenol	(µg/L)	<50.0000	<50.0000	<50.0000	1
Phenol	(µg/L)	<10.0000	<5.0000	<7.5000	2
Acrolein	(µg/L)	<5.0000	<5.0000	<5.0000	1
Acrylonitrile	(µg/L)	<5.0000	<5.0000	<5.0000	1
Benzene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Bromodichloromethane	(µg/L)	J0.6000	0.6000	0.6000	1
Bromoform	(µg/L)	<1.0000	<1.0000	<1.0000	1
Bromomethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
Carbon tetrachloride	(µg/L)	<1.0000	<1.0000	<1.0000	1
Chlorobenzene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Chloroethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
Chloroform	(µg/L)	2.0000	2.0000	2.0000	1
Chloromethane	(µg/L)	7.0000	7.0000	7.0000	1
Cis-1,3-dichloropropene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Dibromochloromethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
Dichlorodifluoromethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
Ethylbenzene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Methylene Chloride	(µg/L)	<1.0000	<1.0000	<1.0000	1
PCB	(µg/L)	<0.1000	<0.1000	<0.1000	11
Tetrachloroethene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Toluene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Trans-1,2-dichloroethene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Trans-1,3-dichloropropene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Trichloroethene	(µg/L)	<1.0000	<1.0000	<1.0000	13
Trichlorofluoromethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
Vinyl chloride	(µg/L)	<1.0000	<1.0000	<1.0000	1
Radionuclides					
% U-235	(wt%)	0.6590	0.5410	0.6000	2
Gross alpha	(pCi/L)	0.0000	0.0000	0.0000	1
Gross beta	(pCi/L)	4.0000	4.0000	4.0000	1
Neptunium-237	(pCi/L)	0.8000	-0.1000	0.2571	7
Plutonium-239	(pCi/L)	0.2000	0.0000	0.0429	7
Rad screen	(pCi/mL)	<1.0000	<1.0000	<1.0000	1
Suspended alpha	(pCi/L)	1.6000	-4.4000	-1.4000	7
Suspended beta	(pCi/L)	12.0000	-7.0000	0.0000	7
Technetium-99	(pCi/L)	17.0000	6.0000	10.4000	5
Thorium-230	(pCi/L)	0.7000	0.0000	0.3800	5
Total radium	(pCi/L)	0.8000	0.8000	0.8000	1
Uranium	(mg/L)	0.0040	<0.0010	<0.0021	7
Dissolved alpha	(pCi/L)	8.8000	-3.2000	0.6857	7
Dissolved beta	(pCi/L)	16.0000	1.0000	7.0000	7

Table A.3. Summary statistics for Kentucky Pollutant Discharge Elimination System Permit water quality parameters at Outfall 004 for 1993

Analysis	(Units)	Maximum	Minimum	Average	Count
Conventional Parameters					
Ammonia as nitrogen	(mg/L)	0.3900	0.3900	0.3900	1
BOD	(mg/L)	14.0000	<5.0000	<7.7200	25
Bromide	(mg/L)	<1.0000	<1.0000	<1.0000	1
Chloride	(mg/L)	21.0000	21.0000	21.0000	1
Chlorine, total residual	(mg/L)	<0.0500	<0.0500	<0.0500	1
COD	(mg/L)	8.0000	8.0000	8.0000	1
Color	(units)	18.0000	18.0000	18.0000	1
Cyanide	(mg/L)	<0.0200	<0.0200	<0.0200	1
Fecal Coliform	(co/100mL)	340.0000	<1.0000	<19.0000	25
Flow	(MLD)	1.6800	1.0900	1.3000	25
Fluoride	(mg/L)	0.1800	0.1800	0.1800	1
Hardness as $CaCO_3$	(mg/L$CaCO_3$)	86.0000	86.0000	86.0000	1
Nitrate-nitrite	(mg/L)	2.7000	2.7000	2.7000	1
Oil and grease	(mg/L)	<5.0000	<5.0000	<5.0000	1
pH	(SU)	9.7000	6.8000	7.4800	25
Sulfate	(mg/L)	55.0000	55.0000	55.0000	1
Sulfide	(mg/L)	<1.0000	<1.0000	<1.0000	1
Sulfite	(mg/L)	<3.0000	<3.0000	<3.0000	1
Surfactants	(mg/L)	0.0900	0.0900	0.0900	1
Temperature	(C)	28.3000	28.3000	28.3000	1
Total organic carbon	(mg/L)	4.0000	4.0000	4.0000	1
Total organic nitrogen	(mg/L)	0.7300	0.7300	0.7300	1
Total suspended solids	(mg/L)	4.0000	4.0000	4.0000	1
Metals					
Aluminum	(mg/L)	0.1480	0.1480	0.1480	1
Antimony	(mg/L)	<0.0600	<0.0600	<0.0600	1
Arsenic	(mg/L)	<0.0050	<0.0050	<0.0050	1
Barium	(mg/L)	0.0170	0.0170	0.0170	1
Beryllium	(mg/L)	<0.0050	<0.0050	<0.0050	1
Boron	(mg/L)	0.2730	0.2730	0.2730	1
Cadmium	(mg/L)	<0.0100	<0.0100	<0.0100	1
Chromium	(mg/L)	<0.0500	<0.0500	<0.0500	1
Cobalt	(mg/L)	<0.0500	<0.0500	<0.0500	1
Copper	(mg/L)	0.0120	0.0120	0.0120	1
Iron	(mg/L)	0.1660	0.1660	0.1660	1
Lead	(mg/L)	<0.2000	<0.2000	<0.2000	1
Magnesium	(mg/L)	7.2800	7.2800	7.2800	1
Manganese	(mg/L)	0.0130	0.0130	0.0130	1
Mercury	(mg/L)	<0.0002	<0.0002	<0.0002	1
Molybdenum	(mg/L)	<0.0500	<0.0500	<0.0500	1
Nickel	(mg/L)	<0.0500	<0.0500	<0.0500	1
Phosphorus (P)	(mg/L)	0.9200	0.9200	0.9200	1
Selenium	(mg/L)	<0.0050	<0.0050	<0.0050	1
Silver	(mg/L)	<0.0300	<0.0300	<0.0300	1
Thallium	(mg/L)	<0.0440	<0.0440	<0.0440	1
Tin	(mg/L)	<5.0000	<5.0000	<5.0000	1
Titanium	(mg/L)	<0.0500	<0.0500	<0.0500	1
Zinc	(mg/L)	0.0250	0.0250	0.0250	1

Table A.3 (continued)

Analysis	(Units)	Maximum	Minimum	Average	Count
Organics					
1,1-Dichloroethane	(µg/L)	<10.0000	<10.0000	<10.0000	2
1,1-Dichloroethene	(µg/L)	<10.0000	<10.0000	<10.0000	2
1,1,1-Trichloroethane	(µg/L)	<10.0000	<10.0000	<10.0000	2
1,1,2-Trichloroethane	(µg/L)	<10.0000	<10.0000	<10.0000	2
1,1,2,2-Tetrachloroethane	(µg/L)	<10.0000	<10.0000	<10.0000	2
1,2-Dichloroethane	(µg/L)	<10.0000	<10.0000	<10.0000	2
1,2-Dichloroethene	(µg/L)	<10.0000	<10.0000	<10.0000	2
1,2-Dichloropropane	(µg/L)	<10.0000	<10.0000	<10.0000	2
2-Chloroethyl vinyl	(µg/L)	<10.0000	<10.0000	<10.0000	2
2-Chlorophenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
2-Nitrophenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
2,3,7,8-Tetrachlorodibenzene P-dioxin	(µg/L)	<0.0007	<0.0007	<0.0007	1
2,4-Dichlorophenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
2,4-Dimethylphenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
2,4-Dinitrophenol	(µg/L)	<50.0000	<50.0000	<50.0000	1
2,4,6-Trichlorophenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
4-Chloro-3-methylphenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
4-Nitrophenol	(µg/L)	<50.0000	<50.0000	<50.0000	1
4,6-Dinitro-2-methylphenol	(µg/L)	<50.0000	<50.0000	<50.0000	1
Acrolein	(µg/L)	<100.0000	<100.0000	<100.0000	2
Acrylonitrile	(µg/L)	<100.0000	<100.0000	<100.0000	2
Benzene	(µg/L)	<10.0000	<10.0000	<10.0000	1
Bromodichloromethane	(µg/L)	<10.0000	<10.0000	<10.0000	2
Bromoform	(µg/L)	<10.0000	<10.0000	<10.0000	2
Bromomethane	(µg/L)	<10.0000	<10.0000	<10.0000	2
Carbon tetrachloride	(µg/L)	<10.0000	<10.0000	<10.0000	2
Chlorobenzene	(µg/L)	<10.0000	<10.0000	<10.0000	2
Chloroethane	(µg/L)	<10.0000	<10.0000	<10.0000	2
Chloroform	(µg/L)	Ja34.0000	5.0000	19.5000	2
Chloromethane	(µg/L)	<10.0000	<10.0000	<10.0000	2
Cis-1,3-dichloropropene	(µg/L)	<10.0000	<10.0000	<10.0000	2
Dibromochloromethane	(µg/L)	<10.0000	<10.0000	<10.0000	2
Ethylbenzene	(µg/L)	<10.0000	<10.0000	<10.0000	1
Methylene Chloride	(µg/L)	<10.0000	<10.0000	<10.0000	2
Pentachlorophenol	(µg/L)	<50.0000	<50.0000	<50.0000	1
Phenol	(µg/L)	<10.0000	<5.0000	<7.5000	2
Tetrachloroethene	(µg/L)	<10.0000	<10.0000	<10.0000	2
Toluene	(µg/L)	<10.0000	<10.0000	<10.0000	1
Trans-1,3-dichloropropene	(µg/L)	<10.0000	<10.0000	<10.0000	2
Trichloroethene	(µg/L)	<10.0000	<10.0000	<10.0000	2
Vinyl chloride	(µg/L)	<10.0000	<10.0000	<10.0000	2
Xylene	(µg/L)	<10.0000	<10.0000	<10.0000	2
Radionuclides					
Gross alpha	(pCi/L)	0.3000	0.3000	0.3000	1
Gross beta	(pCi/L)	14.0000	14.0000	14.0000	1
Rad alpha	(pCi/ml)	<1.0000	<1.0000	<1.0000	2
Rad beta	(pCi/ml)	<1.0000	<1.0000	<1.0000	2
Total radium	(pCi/L)	0.7000	0.7000	0.7000	1

Table A.4. Summary statistics for Kentucky Pollutant Discharge Elimination System Permit water quality parameters at Outfall 006 for 1993

Analysis	(Units)	Maximum	Minimum	Average	Count
Conventional Parameters					
Ammonia as nitrogen	(mg/L)	<0.2500	<0.2500	<0.2500	1
BOD	(mg/L)	<5.0000	<5.0000	<5.0000	1
Bromide	(mg/L)	<1.0000	<1.0000	<1.0000	1
Chloride	(mg/L)	13.0000	13.0000	13.0000	1
Chlorine, total residual	(mg/L)	<0.0500	<0.0200	<0.0413	52
COD	(mg/L)	5.0000	5.0000	5.0000	1
Color	(units)	21.0000	21.0000	21.0000	1
Cyanide	(mg/L)	<0.0200	<0.0200	<0.0200	1
Fecal Coliform	(Co/100mL)	18.0000	18.0000	18.0000	1
Flow	(MLD)	8.6700	0.9800	2.6800	54
Fluoride	(mg/L)	0.1400	0.1400	0.1400	1
Hardness as $CaCO_3$	(mg/L$CaCO_3$)	132.0000	51.0000	88.7170	53
Nitrate-nitrite	(mg/L)	<0.0100	<0.0100	<0.0100	1
Oil and grease	(mg/L)	<5.0000	<5.0000	<5.0000	53
pH	(SU)	10.5000	7.6000	9.0358	53
Sulfate	(mg/L)	45.0000	45.0000	45.0000	1
Sulfide	(mg/L)	<1.0000	<1.0000	<1.0000	1
Sulfite	(mg/L)	<3.0000	<3.0000	<3.0000	1
Surfactants	(mg/L)	<0.0800	<0.0800	<0.0800	1
Temperature	(C)	33.9000	8.3000	23.5000	12
Total organic carbon	(mg/L)	4.0000	4.0000	4.0000	1
Total organic nitrogen	(mg/L)	0.7100	0.7100	0.7100	1
Total suspended solids	(mg/L)	42.0000	<4.0000	<14.8113	53
Turbidity	(NTU)	20.0000	6.0000	11.6000	22
Metals					
Aluminum	(mg/L)	0.9960	0.2470	0.4800	25
Antimony	(mg/L)	<0.0600	<0.0600	<0.0600	1
Arsenic	(mg/L)	<0.0050	<0.0050	<0.0050	1
Barium	(mg/L)	0.0220	0.0220	0.0220	1
Beryllium	(mg/L)	<0.0050	<0.0050	<0.0050	1
Boron	(mg/L)	0.3080	0.3080	0.3080	1
Cadmium	(mg/L)	0.0230	<0.0100	<0.0105	25
Chromium	(mg/L)	<0.0500	<0.0500	<0.0500	25
Cobalt	(mg/L)	<0.0500	<0.0500	<0.0500	1
Copper	(mg/L)	0.0140	<0.0100	<0.0102	25
Iron	(mg/L)	2.0200	0.0850	0.6118	25
Lead	(mg/L)	<0.2000	<0.0600	<0.1944	25
Magnesium	(mg/L)	8.8600	8.8600	8.8600	1
Manganese	(mg/L)	0.0400	0.0400	0.0400	1
Mercury	(mg/L)	<0.0002	<0.0002	<0.0002	1
Molybdenum	(mg/L)	<0.0500	<0.0500	<0.0500	1
Nickel	(mg/L)	<0.0500	<0.0500	<0.0500	25
Phosphorus (P)	(mg/L)	0.3100	<0.0500	<0.1047	53
Selenium	(mg/L)	<0.0050	<0.0050	<0.0050	1
Silver	(mg/L)	<0.0300	<0.0300	<0.0300	1
Thallium	(mg/L)	<0.0440	<0.0440	<0.0440	1
Tin	(mg/L)	<5.0000	<5.0000	<5.0000	1
Titanium	(mg/L)	<0.0500	<0.0500	<0.0500	1
Zinc	(mg/L)	0.0300	<0.0050	<0.0105	25

Table A.4 (continued)

Analysis	(Units)	Maximum	Minimum	Average	Count
Organics					
1,1-Dichloroethane	(µg/L)	<10.0000	<10.0000	<10.0000	2
1,1-Dichloroethene	(µg/L)	<10.0000	<10.0000	<10.0000	2
1,1,1-Trichloroethane	(µg/L)	<10.0000	<10.0000	<10.0000	2
1,1,2,2-Tetrachloroethane	(µg/L)	<10.0000	<10.0000	<10.0000	2
1,1,2-Trichloroethane	(µg/L)	<10.0000	<10.0000	<10.0000	2
1,2-Dichloroethane	(µg/L)	<10.0000	<10.0000	<10.0000	2
1,2-Dichloroethene	(µg/L)	<10.0000	<10.0000	<10.0000	2
1,2-Dichloropropane	(µg/L)	<10.0000	<10.0000	<10.0000	2
2-Chloroethyl vinyl	(µg/L)	<10.0000	<10.0000	<10.0000	2
2-Chlorophenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
2-Nitrophenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
2,3,7,8-Tetrachlorodibenzene P-dioxin	(µg/L)	<0.0007	<0.0007	<0.0007	1
2,4-Dichlorophenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
2,4-Dimethylphenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
2,4-Dinitrophenol	(µg/L)	<50.0000	<50.0000	<50.0000	1
2,4,6-Trichlorophenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
4-Chloro-3-methylphenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
4-Nitrophenol	(µg/L)	<50.0000	<50.0000	<50.0000	1
4,6-Dinitro-2-methylphenol	(µg/L)	<50.0000	<50.0000	<50.0000	1
Acrolein	(µg/L)	<100.0000	<100.0000	<100.0000	2
Acrylonitrile	(µg/L)	<100.0000	<100.0000	<100.0000	2
Benzene	(µg/L)	<10.0000	<10.0000	<10.0000	1
Bromodichloromethane	(µg/L)	<10.0000	<10.0000	<10.0000	2
Bromoform	(µg/L)	<10.0000	<10.0000	<10.0000	2
Bromomethane	(µg/L)	<10.0000	<10.0000	<10.0000	2
Carbon tetrachloride	(µg/L)	<10.0000	<10.0000	<10.0000	2
Chlorobenzene	(µg/L)	<10.0000	<10.0000	<10.0000	2
Chloroethane	(µg/L)	<10.0000	<10.0000	<10.0000	2
Chloroform	(µg/L)	J10.0000	<5.0000	<7.5000	2
Chloromethane	(µg/L)	<10.0000	<10.0000	<10.0000	2
Cis-1,3-dichloropropene	(µg/L)	<10.0000	<10.0000	<10.0000	2
Dibromochloromethane	(µg/L)	<10.0000	<10.0000	<10.0000	2
Ethylbenzene	(µg/L)	<10.0000	<10.0000	<10.0000	1
Methylene Chloride	(µg/L)	14.0000	<10.0000	<12.0000	2
PCB	(µg/L)	0.2000	<0.0100	<0.1008	13
Pentachlorophenol	(µg/L)	<50.0000	<50.0000	<50.0000	1
Phenol	(µg/L)	<10.0000	<5.0000	<7.5000	2
Tetrachloroethene	(µg/L)	<10.0000	<10.0000	<10.0000	2
Toluene	(µg/L)	<10.0000	<10.0000	<10.0000	1
Trans-1,3-dichloropropene	(µg/L)	<10.0000	<10.0000	<10.0000	2
Trichloroethene	(µg/L)	<10.0000	<10.0000	<10.0000	2
Vinyl chloride	(µg/L)	<10.0000	<10.0000	<10.0000	2
Xylene	(µg/L)	<10.0000	<10.0000	<10.0000	2
Radionuclides					
Gross alpha	(pCi/L)	1.2000	1.2000	1.2000	1
Gross beta	(pCi/L)	3.0000	3.0000	3.0000	1
Rad alpha	(pCi/ml)	<1.0000	<1.0000	<1.0000	7
Rad beta	(pCi/ml)	<1.0000	<1.0000	<1.0000	7
Total radium	(pCi/L)	0.3000	0.3000	0.3000	1

Table A.5. Summary statistics for Kentucky Pollutant Discharge Elimination System Permit water quality parameters at Outfall 008 for 1993

Analysis	(Units)	Maximum	Minimum	Average	Count
Conventional Parameters					
Ammonia as nitrogen	(mg/L)	0.2500	0.2500	0.2500	1
BOD	(mg/L)	<5.0000	<5.0000	<5.0000	1
Bromide	(mg/L)	<1.0000	<1.0000	<1.0000	1
Chloride	(mg/L)	19.0000	19.0000	19.0000	1
Chlorine, total residual	(mg/L)	<0.0500	<0.0200	<0.0421	53
COD	(mg/L)	<5.0000	<5.0000	<5.0000	1
Color	(units)	14.0000	14.0000	14.0000	1
Cyanide	(mg/L)	<0.0200	<0.0200	<0.0200	1
Fecal Coliform	(Co/100mL)	2000.0000	2000.0000	2000.0000	1
Flow	(MLD)	96.8960	1.5800	4.6300	56
Fluoride	(mg/L)	0.1900	0.1900	0.1900	1
Hardness as $CaCO_3$	(mg/L$CaCO_3$)	96.0000	38.0000	70.6226	53
Nitrate-nitrite	(mg/L)	2.1000	2.1000	2.1000	1
Oil and grease	(mg/L)	<5.0000	<5.0000	<5.0000	57
pH	(SU)	8.6000	5.9000	7.5358	53
Sulfate	(mg/L)	62.0000	62.0000	62.0000	1
Sulfide	(mg/L)	<1.0000	<1.0000	<1.0000	1
Sulfite	(mg/L)	<3.0000	<3.0000	<3.0000	1
Surfactants	(mg/L)	<0.0800	<0.0800	<0.0800	1
Temperature	(C)	33.3000	6.7000	21.1000	54
Total organic carbon	(mg/L)	3.0000	3.0000	3.0000	1
Total organic nitrogen	(mg/L)	0.6800	0.6800	0.6800	1
Total suspended solids	(mg/L)	20.0000	<4.0000	<6.3396	53
Metals					
Aluminum	(mg/L)	1.3400	0.1150	0.2615	25
Antimony	(mg/L)	<0.0600	<0.0600	<0.0600	1
Arsenic	(mg/L)	<0.0050	<0.0050	<0.0050	1
Barium	(mg/L)	0.0140	0.0140	0.0140	1
Beryllium	(mg/L)	<0.0050	<0.0050	<0.0050	1
Boron	(mg/L)	0.2930	0.2930	0.2930	1
Cadmium	(mg/L)	0.1160	<0.0100	<0.0142	25
Chromium	(mg/L)	<0.0500	<0.0500	<0.0500	25
Cobalt	(mg/L)	<0.0500	<0.0500	<0.0500	1
Copper	(mg/L)	0.1620	<0.0100	<0.0166	25
Iron	(mg/L)	1.1600	0.1080	0.2524	25
Lead	(mg/L)	0.2590	<0.0500	<0.1908	25
Magnesium	(mg/L)	6.7500	6.7500	6.7500	1
Manganese	(mg/L)	0.0120	0.0120	0.0120	1
Mercury	(mg/L)	<0.0002	<0.0002	<0.0002	1
Molybdenum	(mg/L)	<0.0500	<0.0500	<0.0500	1
Nickel	(mg/L)	0.1520	<0.0500	<0.0541	25
Phosphorus (P)	(mg/L)	1.3400	0.2200	0.6545	53
Selenium	(mg/L)	<0.0050	<0.0050	<0.0050	1
Silver	(mg/L)	<0.0300	<0.0300	<0.0300	1
Thallium	(mg/L)	<0.0440	<0.0440	<0.0440	1
Tin	(mg/L)	<5.0000	<5.0000	<5.0000	1
Titanium	(mg/L)	<0.0500	<0.0500	<0.0500	1
Zinc	(mg/L)	0.1270	<0.0050	<0.0265	25

Table A.5 (continued)

Analysis	(Units)	Maximum	Minimum	Average	Count
Organics					
1,1,1-Trichloroethane	(μg/L)	<10.0000	<10.0000	<10.0000	2
1,1,2,2-Tetrachloroethane	(μg/L)	<10.0000	<10.0000	<10.0000	2
1,1,2-Trichloroethane	(μg/L)	<10.0000	<10.0000	<10.0000	2
1,1-Dichloroethane	(μg/L)	<10.0000	<10.0000	<10.0000	2
1,1-Dichloroethene	(μg/L)	<10.0000	<10.0000	<10.0000	2
1,2-Dichloroethane	(μg/L)	<10.0000	<10.0000	<10.0000	2
1,2-Dichloroethene	(μg/L)	<10.0000	<10.0000	<10.0000	2
1,2-Dichloropropane	(μg/L)	<10.0000	<10.0000	<10.0000	2
2,3,7,8-Tetrachlorodibenzene P-dioxin	(μg/L)	<0.0007	<0.0007	<0.0007	1
2,4,6-Trichlorophenol	(μg/L)	<10.0000	<10.0000	<10.0000	1
2,4-Dichlorophenol	(μg/L)	<10.0000	<10.0000	<10.0000	1
2,4-Dimethylphenol	(μg/L)	<10.0000	<10.0000	<10.0000	1
2,4-Dinitrophenol	(μg/L)	<50.0000	<50.0000	<50.0000	1
2-Chloroethyl vinyl	(μg/L)	<10.0000	<10.0000	<10.0000	2
2-Chlorophenol	(μg/L)	<10.0000	<10.0000	<10.0000	1
2-Nitrophenol	(μg/L)	<10.0000	<10.0000	<10.0000	1
4,6-Dinitro-2-methylphenol	(μg/L)	<50.0000	<50.0000	<50.0000	1
4-Chloro-3-methylphenol	(μg/L)	<10.0000	<10.0000	<10.0000	1
4-Nitrophenol	(μg/L)	<50.0000	<50.0000	<50.0000	1
Acrolein	(μg/L)	<100.0000	<100.0000	<100.0000	2
Acrylonitrile	(μg/L)	<100.0000	<100.0000	<100.0000	2
Benzene	(μg/L)	<10.0000	<10.0000	<10.0000	1
Bromodichloromethane	(μg/L)	<10.0000	<10.0000	<10.0000	2
Bromoform	(μg/L)	<10.0000	<10.0000	<10.0000	2
Bromomethane	(μg/L)	<10.0000	<10.0000	<10.0000	2
Carbon tetrachloride	(μg/L)	<10.0000	<10.0000	<10.0000	2
Chlorobenzene	(μg/L)	<10.0000	<10.0000	<10.0000	2
Chloroethane	(μg/L)	<10.0000	<10.0000	<10.0000	2
Chloroform	(μg/L)	17.0000	5.0000	11.0000	2
Chloromethane	(μg/L)	<10.0000	<10.0000	<10.0000	2
Cis-1,3-dichloropropene	(μg/L)	<10.0000	<10.0000	<10.0000	2
Dibromochloromethane	(μg/L)	<10.0000	<10.0000	<10.0000	2
Ethylbenzene	(μg/L)	<10.0000	<10.0000	<10.0000	1
Methylene Chloride	(μg/L)	J10.0000	<9.0000	<9.5000	2
PCB	(μg/L)	<0.1000	<0.1000	<0.1000	13
Pentachlorophenol	(μg/L)	<50.0000	<50.0000	<50.0000	1
Phenol	(μg/L)	<10.0000	<5.0000	<7.5000	2
Tetrachloroethene	(μg/L)	<10.0000	<10.0000	<10.0000	2
Toluene	(μg/L)	<10.0000	<10.0000	<10.0000	1
Trans-1,3-dichloropropene	(μg/L)	<10.0000	<10.0000	<10.0000	2
Trichloroethene	(μg/L)	10.0000	<1.0000	<2.2000	15
Vinyl chloride	(μg/L)	<10.0000	<10.0000	<10.0000	2
Xylene	(μg/L)	<10.0000	<10.0000	<10.0000	2

Table A.5 (continued)

Analysis	(Units)	Maximum	Minimum	Average	Count
Radionuclides					
% U-235	(Wt%)	0.7020	0.4850	0.5913	3
Dissolved alpha	(pCi/L)	16.9000	-3.5000	6.1667	3
Dissolved beta	(pCi/L)	60.0000	2.0000	22.3333	3
Gross alpha	(pCi/L)	0.6000	0.6000	0.6000	1
Gross beta	(pCi/L)	4.0000	4.0000	4.0000	1
Neptunium-237	(pCi/L)	0.2000	-0.6000	-0.2000	2
Plutonium-239	(pCi/L)	0.0000	0.0000	0.0000	2
Rad alpha	(pCi/ml)	<1.0000	<1.0000	<1.0000	13
Rad beta	(pCi/ml)	<1.0000	<1.0000	<1.0000	13
Suspended alpha	(pCi/L)	0.0000	-6.9000	-4.2667	3
Suspended beta	(pCi/L)	3.0000	1.0000	1.6667	3
Technetium-99	(pCi/L)	37.0000	7.0000	18.0000	6
Thorium-230	(pCi/L)	0.3000	0.3000	0.3000	1
Total radium	(pCi/L)	0.7000	0.7000	0.7000	1
Uranium	(mg/L)	0.0190	0.0010	0.0080	13

Table A.6. Summary statistics for Kentucky Pollutant Discharge Elimination System Permit water quality parameters at outfall 009 for 1993

Analysis	(Units)	Maximum	Minimum	Average	Count
Conventional Parameters					
Ammonia as nitrogen	(mg/L)	0.3200	0.3200	0.3200	1
BOD	(mg/L)	<5.0000	<5.0000	<5.0000	1
Bromide	(mg/L)	<1.0000	<1.0000	<1.0000	1
Chloride	(mg/L)	19.0000	19.0000	19.0000	1
Chlorine, total residual	(mg/L)	<0.0500	<0.0200	<0.0421	53
COD	(mg/L)	9.0000	9.0000	9.0000	1
Color	(units)	22.0000	22.0000	22.0000	1
Cyanide	(mg/L)	<0.0200	<0.0200	<0.0200	1
Fecal Coliform	(Co/100mL)	<500.0000	<500.0000	<500.0000	1
Flow	(MLD)	>13.250	0.3860	1.1100	56
Fluoride	(mg/L)	0.1800	0.1800	0.1800	1
Hardness as $CaCO_3$	(mg/LCO_3)	112.0000	16.0000	76.1132	53
Nitrate-nitrite	(mg/L)	1.2000	1.2000	1.2000	1
Oil and grease	(mg/L)	11.2000	<5.0000	<5.1148	54
pH	(SU)	9.5000	6.9000	8.0226	53
Sulfate	(mg/L)	42.0000	42.0000	42.0000	1
Sulfide	(mg/L)	<1.0000	<1.0000	<1.0000	1
Sulfite	(mg/L)	<3.0000	<3.0000	<3.0000	1
Surfactants	(mg/L)	<0.0800	<0.0800	<0.0800	1
Temperature	(C)	31.1000	3.9000	17.3600	54
Total organic carbon	(mg/L)	4.0000	4.0000	4.0000	1
Total organic nitrogen	(mg/L)	0.7300	0.7300	0.7300	1
Total suspended solids	(mg/L)	51.0000	<4.0000	<9.6792	53
Turbidity	(NTU)	6.0000	6.0000	6.0000	1
Metals					
Aluminum	(mg/L)	1.5000	0.2140	0.5541	25
Antimony	(mg/L)	<0.0600	<0.0600	<0.0600	1
Arsenic	(mg/L)	<0.0050	<0.0050	<0.0050	1
Barium	(mg/L)	0.0340	0.0340	0.0340	1
Beryllium	(mg/L)	<0.0050	<0.0050	<0.0050	1
Boron	(mg/L)	0.2610	0.2610	0.2610	1
Cadmium	(mg/L)	0.0470	<0.0100	<0.0115	25
Chromium	(mg/L)	<0.0500	<0.0500	<0.0500	27
Cobalt	(mg/L)	<0.0500	<0.0500	<0.0500	1
Copper	(mg/L)	0.0150	<0.0100	<0.0103	25
Iron	(mg/L)	1.4100	0.1050	0.6232	25
Lead	(mg/L)	<0.2000	<0.0500	<0.1884	25
Magnesium	(mg/L)	5.3900	5.3900	5.3900	1
Manganese	(mg/L)	0.1030	0.1030	0.1030	1
Mercury	(mg/L)	<0.0002	<0.0002	<0.0002	1
Molybdenum	(mg/L)	<0.0500	<0.0500	<0.0500	1
Nickel	(mg/L)	<0.0500	<0.0500	<0.0500	25
Phosphorus (P)	(mg/L)	0.4800	0.0800	0.2200	53
Selenium	(mg/L)	<0.0050	<0.0050	<0.0050	1
Silver	(mg/L)	<0.0300	<0.0300	<0.0300	1
Thallium	(mg/L)	<0.0440	<0.0440	<0.0440	1
Tin	(mg/L)	<5.0000	<5.0000	<5.0000	1
Titanium	(mg/L)	<0.0500	<0.0500	<0.0500	1
Zinc	(mg/L)	0.2580	<0.0050	<0.0376	25

Table A.6 (continued)

Analysis	(Units)	Maximum	Minimum	Average	Count
Organics					
1,1-Dichloroethane	(μg/L)	<10.0000	<10.0000	<10.0000	2
1,1-Dichloroethene	(μg/L)	<10.0000	<10.0000	<10.0000	2
1,1,1-Trichloroethane	(μg/L)	<10.0000	<10.0000	<10.0000	2
1,1,2,2-Tetrachloroethane	(μg/L)	<10.0000	<10.0000	<10.0000	2
1,2-Dichloroethane	(μg/L)	<10.0000	<10.0000	<10.0000	2
1,2-Dichloroethene	(μg/L)	<10.0000	<10.0000	<10.0000	2
1,2-Dichloropropane	(μg/L)	<10.0000	<10.0000	<10.0000	2
1,1,2-Trichloroethane	(μg/L)	<10.0000	<10.0000	<10.0000	2
2-Chloroethyl vinyl	(μg/L)	<10.0000	<10.0000	<10.0000	2
2-Chlorophenol	(μg/L)	<10.0000	<10.0000	<10.0000	1
2-Nitrophenol	(μg/L)	<10.0000	<10.0000	<10.0000	1
2,3,7,8-Tetrachlorodibenzene P-dioxin	(μg/L)	<0.0007	<0.0007	<0.0007	1
2,4-Dichlorophenol	(μg/L)	<10.0000	<10.0000	<10.0000	1
2,4-Dimethylphenol	(μg/L)	<10.0000	<10.0000	<10.0000	1
2,4-Dinitrophenol	(μg/L)	<50.0000	<50.0000	<50.0000	1
2,4,6-Trichlorophenol	(μg/L)	<10.0000	<10.0000	<10.0000	1
4-Chloro-3-methylphenol	(μg/L)	<10.0000	<10.0000	<10.0000	1
4-Nitrophenol	(μg/L)	<50.0000	<50.0000	<50.0000	1
4,6-Dinitro-2-methylphenol	(μg/L)	<50.0000	<50.0000	<50.0000	1
Acrolein	(μg/L)	<100.0000	<100.0000	<100.0000	2
Acrylonitrile	(μg/L)	<100.0000	<100.0000	<100.0000	2
Benzene	(μg/L)	<10.0000	<10.0000	<10.0000	1
Bromodichloromethane	(μg/L)	<10.0000	<10.0000	<10.0000	2
Bromoform	(μg/L)	<10.0000	<10.0000	<10.0000	2
Bromomethane	(μg/L)	<10.0000	<10.0000	<10.0000	2
Carbon tetrachloride	(μg/L)	<10.0000	<10.0000	<10.0000	2
Chlorobenzene	(μg/L)	<10.0000	<10.0000	<10.0000	2
Chloroethane	(μg/L)	<10.0000	<10.0000	<10.0000	2
Chloroform	(μg/L)	<10.0000	<10.0000	<10.0000	2
Chloromethane	(μg/L)	<10.0000	<10.0000	<10.0000	2
Cis-1,3-dichloropropene	(μg/L)	<10.0000	<10.0000	<10.0000	2
Dibromochloromethane	(μg/L)	<10.0000	<10.0000	<10.0000	2
Ethylbenzene	(μg/L)	<10.0000	<10.0000	<10.0000	1
Methylene Chloride	(μg/L)	<10.0000	<10.0000	<10.0000	2
PCB	(μg/L)	<0.1000	<0.0100	<0.0931	13
Pentachlorophenol	(μg/L)	<50.0000	<50.0000	<50.0000	1
Phenol	(μg/L)	<10.0000	<5.0000	<7.5000	2
Tetrachloroethene	(μg/L)	<10.0000	<10.0000	<10.0000	2
Toluene	(μg/L)	<10.0000	<10.0000	<10.0000	1
Trans-1,3-dichloropropene	(μg/L)	<10.0000	<10.0000	<10.0000	2
Trichloroethane	(μg/L)	<10.0000	<10.0000	<10.0000	1
Trichloroethene	(μg/L)	<10.0000	<1.0000	<2.2000	15
Vinyl chloride	(μg/L)	<10.0000	<10.0000	<10.0000	2
Xylene	(μg/L)	<10.0000	<10.0000	<10.0000	2

Table A.6 (continued)

Analysis	(Units)	Maximum	Minimum	Average	Count
		Radionuclides			
% U-235	(Wt%)	0.3810	0.3810	0.3810	1
Dissolved Alpha	(pCi/L)	6.5000	-4.2000	-4.2000	3
Dissolved Beta	(pCi/L)	28.0000	7.0000	7.0000	3
Gross alpha	(pCi/L)	0.6000	0.6000	0.6000	1
Gross beta	(pCi/L)	6.0000	6.0000	6.0000	1
Neptunium-237	(pCi/L)	0.2000	0.1500	0.1000	2
Plutonium-239	(pCi/L)	0.0000	0.0000	0.0000	2
Rad alpha	(pCi/ml)	<1.0000	<1.0000	<1.0000	8
Rad beta	(pCi/Ml)	<1.0000	<1.0000	<1.0000	8
Suspended alpha	(pCi/L)	0.0000	-3.9000	-6.9000	3
Suspended beta	(pCi/L)	0.0000	-1.0000	-0.3333	3
Technetium-99	(pCi/L)	26.0000	7.0000	17.0000	6
Thorium-230	(pCi/L)	0.4000	0.4000	0.4000	1
Total radium	(pCi/L)	1.6000	1.6000	1.6000	1
Uranium	(mg/L)	0.0060	<0.0010	<0.0026	13

Table A.7. Summary statistics for Kentucky Pollutant Discharge Elimination System Permit water quality parameters at Outfall 010 for 1993

Analysis	(Units)	Maximum	Minimum	Average	Count
Conventional Parameters					
Ammonia as nitrogen	(mg/L)	<0.2500	<0.2500	<0.2500	1
BOD	(mg/L)	<5.0000	<5.0000	<5.0000	1
Bromide	(mg/L)	<1.0000	<1.0000	<1.0000	1
Chloride	(mg/L)	7.0000	7.0000	7.0000	1
Chlorine, total residual	(mg/L)	<0.0500	<0.0200	<0.0408	13
COD	(mg/L)	30.0000	30.0000	30.0000	1
Color	(units)	39.0000	39.0000	39.0000	1
Cyanide	(mg/L)	<0.0200	<0.0200	<0.0200	1
Fecal Coliform	(Co/100mL)	>3000.0000	3000.0000	3000.0000	1
Flow	(MLD)	9.6500	<0.0030	<2.5000	15
Fluoride	(mg/L)	0.2500	0.2500	0.2500	1
Hardness as $CaCO_3$	(mg/LCaO_3)	56.0	82.6	92313	1
Nitrate-nitrite	(mg/L)	0.8600	0.8600	0.8600	13
Oil and grease	(mg/L)	8.8000	<5.0000	<5.2923	13
pH	(SU)	9.9000	7.2000	8.0308	1
Sulfate	(mg/L)	20.0000	20.0000	20.0000	1
Sulfide	(mg/L)	<1.0000	<1.0000	<1.0000	1
Sulfite	(mg/L)	<3.0000	<3.0000	<3.0000	1
Surfactants	(mg/L)	<0.0800	<0.0800	<0.0800	13
Temperature	(C)	23.3300	7.2200	16.1500	1
Total organic carbon	(mg/L)	5.0000	5.0000	5.0000	1
Total organic nitrogen	(mg/L)	0.6600	0.6600	0.6600	13
Total suspended solids	(mg/L)	55.0000	<4.0000	<19.6154	
Metals					
Aluminum	(mg/L)	3.0400	0.3020	1.3595	11
Antimony	(mg/L)	<0.0600	<0.0600	<0.0600	1
Arsenic	(mg/L)	<0.0050	<0.0050	<0.0050	1
Barium	(mg/L)	0.0330	0.0330	0.0330	1
Beryllium	(mg/L)	<0.0050	<0.0050	<0.0050	1
Boron	(mg/L)	0.0103	0.0103	0.0103	1
Cadmium	(mg/L)	<0.0100	<0.0100	<0.0100	11
Chromium	(mg/L)	<0.0500	<0.0500	<0.0500	11
Cobalt	(mg/L)	<0.0500	<0.0500	<0.0500	1
Copper	(mg/L)	0.0160	<0.0100	<0.0105	11
Iron	(mg/L)	3.5000	0.1290	1.2282	11
Lead	(mg/L)	<0.2000	<0.2000	<0.2000	11
Magnesium	(mg/L)	2.5600	2.5600	2.5600	1
Manganese	(mg/L)	0.0400	0.0400	0.0400	1
Mercury	(mg/L)	<0.0002	<0.0002	<0.0002	1
Molybdenum	(mg/L)	<0.0500	<0.0500	<0.0500	1
Nickel	(mg/L)	0.0570	<0.0500	<0.0506	11
Phosphorus (P)	(mg/L)	0.7900	0.1300	0.2846	13
Selenium	(mg/L)	<0.0050	<0.0050	<0.0050	1
Silver	(mg/L)	<0.0300	<0.0300	<0.0300	1
Thallium	(mg/L)	<0.0560	<0.0560	<0.0560	1
Tin	(mg/L)	<5.0000	<5.0000	<5.0000	1
Titanium	(mg/L)	0.0290	0.0290	0.0290	1
Zinc	(mg/L)	0.0710	0.0160	0.0337	11

Table A.7 (continued)

Analysis	(Units)	Maximum	Minimum	Average	Count
Organics					
1,1-Dichloroethane	(μg/L)	<1.0000	<1.0000	<1.0000	1
1,1-Dichloroethene	(μg/L)	<1.0000	<1.0000	<1.0000	1
1,1,1-Trichloroethane	(μg/L)	<1.0000	<1.0000	<1.0000	1
1,1,2-Trichloroethane	(μg/L)	<1.0000	<1.0000	<1.0000	1
1,1,2,2-Tetrachloroethane	(μg/L)	<1.0000	<1.0000	<1.0000	1
1,2-Dichloroethane	(μg/L)	<1.0000	<1.0000	<1.0000	1
1,2-Dichloropropane	(μg/L)	<1.0000	<1.0000	<1.0000	1
2-Chloroethyl vinyl	(μg/L)	<1.0000	<1.0000	<1.0000	1
2-Chlorophenol	(μg/L)	<10.0000	<10.0000	<10.0000	1
2-Nitrophenol	(μg/L)	<10.0000	<10.0000	<10.0000	1
2,3,7,8-Tetrachlorodibenzene P-dioxin	(μg/L)	<0.0007	<0.0007	<0.0007	1
2,4-Dichlorophenol	(μg/L)	<10.0000	<10.0000	<10.0000	1
2,4-Dimethylphenol	(μg/L)	<10.0000	<10.0000	<10.0000	1
2,4-Dinitrophenol	(μg/L)	<50.0000	<50.0000	<50.0000	1
2,4,6-Trichlorophenol	(μg/L)	<10.0000	<10.0000	<10.0000	1
4-Chloro-3-methylphenol	(μg/L)	<10.0000	<10.0000	<10.0000	1
4-Nitrophenol	(μg/L)	<50.0000	<50.0000	<50.0000	1
4,6-Dinitro-2-methylphenol	(μg/L)	<50.0000	<50.0000	<50.0000	1
Acrolein	(μg/L)	<5.0000	<5.0000	<5.0000	1
Acrylonitrile	(μg/L)	<5.0000	<5.0000	<5.0000	1
Benzene	(μg/L)	<1.0000	<1.0000	<1.0000	1
Bromodichloromethane	(μg/L)	1.0000	1.0000	1.0000	1
Bromoform	(μg/L)	<1.0000	<1.0000	<1.0000	1
Bromomethane	(μg/L)	<1.0000	<1.0000	<1.0000	1
Carbon tetrachloride	(μg/L)	<1.0000	<1.0000	<1.0000	1
Chlorobenzene	(μg/L)	<1.0000	<1.0000	<1.0000	1
Chloroethane	(μg/L)	<1.0000	<1.0000	<1.0000	1
Chloroform	(μg/L)	3.0000	3.0000	3.0000	1
Chloromethane	(μg/L)	<1.0000	<1.0000	<1.0000	1
Cis-1,3-dichloropropene	(μg/L)	<1.0000	<1.0000	<1.0000	1
Dibromochloromethane	(μg/L)	<1.0000	<1.0000	<1.0000	1
Dichlorodifluoromethane	(μg/L)	<1.0000	<1.0000	<1.0000	1
Ethylbenzene	(μg/L)	<1.0000	<1.0000	<1.0000	1
Methylene Chloride	(μg/L)	<1.0000	<1.0000	<1.0000	1
PCB	(μg/L)	<0.1000	<0.1000	<0.1000	9
Pentachlorophenol	(μg/L)	<50.0000	<50.0000	<50.0000	1
Phenol	(μg/L)	<10.0000	<5.0000	<7.5000	2
Tetrachloroethene	(μg/L)	<1.0000	<1.0000	<1.0000	1
Toluene	(μg/L)	<1.0000	<1.0000	<1.0000	1
Trans-1,2-dichloroethene	(μg/L)	<1.0000	<1.0000	<1.0000	1
Trans-1,3-dichloropropene	(μg/L)	<1.0000	<1.0000	<1.0000	1
Trichloroethene	(μg/L)	<1.0000	<1.0000	<1.0000	10
Trichlorofluoromethane	(μg/L)	<1.0000	<1.0000	<1.0000	1
Vinyl chloride	(μg/L)	<1.0000	<1.0000	<1.0000	1

Table A.7 (continued)

Analysis	(Units)	Maximum	Minimum	Average	Count
		Radionuclides			
% U-235	(Wt%)	0.5500	0.2310	0.3300	10
Dissolved alpha	(pCi/L)	23.3000	3.3000	11.6000	8
Dissolved beta	(pCi/L)	50.0000	3.0000	24.8750	8
Gross alpha	(pCi/L)	3.4000	3.4000	3.4000	1
Gross beta	(pCi/L)	7.0000	7.0000	7.0000	1
Neptunium-237	(pCi/L)	1.0000	-0.5000	0.1000	4
Plutonium-239	(pCi/L)	0.1000	0.0000	0.0250	4
Rad screen	(pCi/mL)	<1.0000	<1.0000	<1.0000	1
Suspended alpha	(pCi/L)	4.1000	0.2000	1.3875	8
Suspended beta	(pCi/L)	24.0000	-7.0000	6.3750	8
Technetium-99	(pCi/L)	116.0000	0.0000	37.8182	11
Thorium-230	(pCi/L)	1.2000	0.5000	0.8500	2
Total radium	(pCi/L)	1.1000	1.1000	1.1000	1
Uranium	(mg/L)	0.0360	0.0080	0.0213	11

Table A.8. Summary statistics for Kentucky Pollutant Discharge Elimination System Permit water quality parameters at Outfall 011 for 1993

Analysis	(Units)	Maximum	Minimum	Average	Count
Conventional Parameters					
Ammonia as nitrogen	(mg/L)	<0.2500	<0.2500	<0.2500	1
BOD	(mg/L)	<5.0000	<5.0000	<5.0000	1
Bromide	(mg/L)	<1.0000	<1.0000	<1.0000	1
Chloride	(mg/L)	17.0000	17.0000	17.0000	1
Chlorine, total residual	(mg/L)	<0.0500	<0.0200	<0.0419	48
COD	(mg/L)	<5.0000	<5.0000	<5.0000	1
Color	(units)	11.0000	11.0000	11.0000	1
Cyanide	(mg/L)	<0.0200	<0.0200	<0.0200	1
Fecal Coliform	(Co/100mL)	500.0000	<5.0000	<169.6667	6
Flow	(MLD)	7.4600	0.5900	1.9900	52
Fluoride	(mg/L)	0.1700	0.1700	0.1700	1
Hardness as $CaCO_3$	(mg/L $CaCO_3$)	109.0000	48.0000	75.9184	49
Nitrate-nitrite	(mg/L)	1.2000	1.2000	1.2000	1
Oil and grease	(mg/L)	<5.0000	<5.0000	<5.0000	49
pH	(SU)	9.5000	7.2000	8.2592	49
Sulfate	(mg/L)	56.0000	56.0000	56.0000	1
Sulfide	(mg/L)	<1.0000	<1.0000	<1.0000	1
Sulfite	(mg/L)	<3.0000	<3.0000	<3.0000	1
Surfactants	(mg/L)	<0.0800	<0.0800	<0.0800	1
Temperature	(C)	35.0000	8.3300	22.6300	49
Total organic carbon	(mg/L)	3.0000	3.0000	3.0000	1
Total organic nitrogen	(mg/L)	1.2000	1.2000	1.2000	1
Total suspended solids	(mg/L)	58.0000	<4.0000	<10.8163	49
Metals					
Aluminum	(mg/L)	0.9400	0.1630	0.3567	23
Antimony	(mg/L)	<0.0600	<0.0600	<0.0600	2
Arsenic	(mg/L)	<0.0050	<0.0050	<0.0050	2
Barium	(mg/L)	0.0220	0.0100	0.0160	2
Beryllium	(mg/L)	<0.0100	<0.0050	<0.0075	2
Boron	(mg/L)	0.2770	0.2770	0.2770	1
Cadmium	(mg/L)	<0.0100	<0.0100	<0.0100	24
Calcium	(mg/L)	19.0000	19.0000	19.0000	1
Chromium	(mg/L)	<0.0500	<0.0500	<0.0500	24
Cobalt	(mg/L)	<0.0500	<0.0500	<0.0500	2
Copper	(mg/L)	0.0110	<0.0100	<0.0101	24
Iron	(mg/L)	8.3800	0.1170	0.6502	24
Lead	(mg/L)	0.2040	<0.0600	<0.1943	24
Magnesium	(mg/L)	6.9100	6.4800	6.6950	2
Manganese	(mg/L)	3.5500	0.0230	1.7865	2
Mercury	(mg/L)	<0.0002	<0.0002	<0.0002	2
Molybdenum	(mg/L)	<0.0500	<0.0500	<0.0500	1
Nickel	(mg/L)	<0.0500	<0.0500	<0.0500	24
Phosphorus (P)	(mg/L)	0.8400	0.1400	0.3767	49
Potassium	(mg/L)	<2.0000	<2.0000	<2.0000	1
Selenium	(mg/L)	<0.0050	<0.0050	<0.0050	2
Silver	(mg/L)	<0.0300	<0.0300	<0.0300	2
Thallium	(mg/L)	<0.0440	<0.0440	<0.0440	1
Tin	(mg/L)	<5.0000	<5.0000	<5.0000	1
Titanium	(mg/L)	<0.0500	<0.0500	<0.0500	1
Zinc	(mg/L)	0.0450	<0.0050	<0.0209	24

Table A.8 (continued)

Analysis	(Units)	Maximum	Minimum	Average	Count
Organics					
1,1,1-Trichloroethane	(μg/L)	<10.0000	<10.0000	<10.0000	2
1,1,2,2-Tetrachloroethane	(μg/L)	<10.0000	<10.0000	<10.0000	2
1,1,2-Trichloroethane	(μg/L)	<10.0000	<10.0000	<10.0000	2
1,1-Dichloroethane	(μg/L)	<10.0000	<10.0000	<10.0000	2
1,1-Dichloroethene	(μg/L)	<10.0000	<10.0000	<10.0000	2
1,2-Dichloroethane	(μg/L)	<10.0000	<10.0000	<10.0000	2
1,2-Dichloroethene	(μg/L)	<10.0000	<10.0000	<10.0000	2
1,2-Dichloropropane	(μg/L)	<10.0000	<10.0000	<10.0000	2
2,3,7,8-Tetrachlorodibenzene P-dioxin	(μg/L)	<0.0007	<0.0007	<0.0007	1
2,4,6-Trichlorophenol	(μg/L)	<10.0000	<10.0000	<10.0000	1
2,4-Dichlorophenol	(μg/L)	<10.0000	<10.0000	<10.0000	1
2,4-Dimethylphenol	(μg/L)	<10.0000	<10.0000	<10.0000	1
2,4-Dinitrophenol	(μg/L)	<50.0000	<50.0000	<50.0000	1
2-Chloroethyl vinyl	(μg/L)	<10.0000	<10.0000	<10.0000	2
2-Chlorophenol	(μg/L)	<10.0000	<10.0000	<10.0000	1
2-Nitrophenol	(μg/L)	<10.0000	<10.0000	<10.0000	1
4,6-Dinitro-2-methylphenol	(μg/L)	<50.0000	<50.0000	<50.0000	1
4-Chloro-3-methylphenol	(μg/L)	<10.0000	<10.0000	<10.0000	1
4-Nitrophenol	(μg/L)	<50.0000	<50.0000	<50.0000	1
Pentachlorophenol	(μg/L)	<50.0000	<50.0000	<50.0000	1
Phenol	(μg/L)	<10.0000	<5.0000	<7.5000	2
Acrolein	(μg/L)	<100.0000	<100.0000	<100.0000	2
Acrylonitrile	(μg/L)	<100.0000	<100.0000	<100.0000	2
Benzene	(μg/L)	<10.0000	<10.0000	<10.0000	1
Bromodichloromethane	(μg/L)	<10.0000	<10.0000	<10.0000	2
Bromoform	(μg/L)	<10.0000	<10.0000	<10.0000	2
Bromomethane	(μg/L)	<10.0000	<10.0000	<10.0000	2
Carbon tetrachloride	(μg/L)	<10.0000	<10.0000	<10.0000	2
Chlorobenzene	(μg/L)	<10.0000	<10.0000	<10.0000	2
Chloroethane	(μg/L)	<10.0000	<10.0000	<10.0000	2
Chloroform	(μg/L)	<10.0000	<10.0000	<10.0000	2
Chloromethane	(μg/L)	<10.0000	<10.0000	<10.0000	2
Cis-1,3-dichloropropene	(μg/L)	<10.0000	<10.0000	<10.0000	2
Dibromochloromethane	(μg/L)	<10.0000	<10.0000	<10.0000	2
Ethylbenzene	(μg/L)	<10.0000	<10.0000	<10.0000	1
Methylene Chloride	(μg/L)	<10.0000	<10.0000	<10.0000	2
PCB	(μg/L)	0.2000	<0.1000	<0.1083	12
Tetrachloroethene	(μg/L)	<10.0000	<10.0000	<10.0000	2
Toluene	(μg/L)	<10.0000	<10.0000	<10.0000	1
Trans-1,3-dichloropropene	(μg/L)	<10.0000	<10.0000	<10.0000	2
Trichloroethene	(μg/L)	14.0000	<1.0000	<4.4667	15
Vinyl chloride	(μg/L)	<10.0000	<10.0000	<10.0000	2
Xylene	(μg/L)	<10.0000	<10.0000	<10.0000	2

Table A.8 (continued)

Analysis	(Units)	Maximum	Minimum	Average	Count
		Radionuclides			
% U-235	(Wt%)	0.7850	0.1240	0.2659	53
Dissolved alpha	(pCi/L)	27.3000	-6.1000	10.1588	34
Dissolved beta	(pCi/L)	50.0000	-6.0000	11.6471	34
Gross alpha	(pCi/L)	7.0000	5.4000	6.2000	2
Gross beta	(pCi/L)	9.0000	9.0000	9.0000	2
Neptunium-237	(pCi/L)	0.2000	-0.2000	0.0000	2
Plutonium-239	(pCi/L)	0.1000	0.0000	0.0500	2
Rad alpha	(pCi/ml)	<1.0000	<1.0000	<1.0000	3
Rad beta	(pCi/ml)	<1.0000	<1.0000	<1.0000	3
Suspended alpha	(pCi/L)	5.6000	<-7.4000	<-0.5412	34
Suspended beta	(pCi/L)	101.0000	-4.0000	7.8235	34
Technetium-99	(pCi/L)	32.0000	<0.0000	<9.7963	54
Thorium-230	(pCi/L)	0.3000	0.3000	0.3000	1
Total radium	(pCi/L)	0.9000	0.9000	0.9000	1
Uranium	(mg/L)	0.0740	0.0040	0.0330	54

Table A.9. Summary statistics for Kentucky Pollutant Discharge Elimination System Permit water quality parameters at Outfall 012 for 1993

Analysis	(Units)	Maximum	Minimum	Average	Count
Conventional Parameters					
Ammonia as nitrogen	(mg/L)	<0.2500	<0.2500	<0.2500	1
BOD	(mg/L)	<5.0000	<5.0000	<5.0000	1
Bromide	(mg/L)	<1.0000	<1.0000	<1.0000	1
Chloride	(mg/L)	8.0000	8.0000	8.0000	1
Chlorine, total residual	(mg/L)	<0.0500	<0.0100	<0.0392	12
COD	(mg/L)	35.0000	35.0000	35.0000	1
Color	(units)	72.0000	72.0000	72.0000	1
Cyanide	(mg/L)	<0.0200	<0.0200	<0.0200	1
Fecal Coliform	(Co/100mL)	>3000.0000	3000.0000	3000.0000	1
Flow	(MLD)	13.8500	<0.0080	<3.8100	12
Fluoride	(mg/L)	0.2900	0.2900	0.2900	1
Hardness as $CaCO_3$	(mg/L$CaCO_3$)	180.0000	60.0000	110.5455	11
Nitrate-nitrite	(mg/L)	0.7900	0.7900	0.7900	1
Oil and grease	(mg/L)	<5.0000	<5.0000	<5.0000	10
pH	(SU)	7.7000	6.9000	7.4000	11
Sulfate	(mg/L)	21.0000	21.0000	21.0000	1
Sulfide	(mg/L)	<1.0000	<1.0000	<1.0000	1
Sulfite	(mg/L)	<3.0000	<3.0000	<3.0000	1
Surfactants	(mg/L)	<0.0800	<0.0800	<0.0800	1
Temperature	(C)	26.1100	7.2200	16.2100	11
Total organic carbon	(mg/L)	7.0000	7.0000	7.0000	1
Total organic nitrogen	(mg/L)	0.9500	0.9500	0.9500	1
Total suspended solids	(mg/L)	30.0000	<4.0000	<14.4545	11
Metals					
Aluminum	(mg/L)	1.8000	0.1210	0.8377	11
Antimony	(mg/L)	<0.0600	<0.0600	<0.0600	1
Arsenic	(mg/L)	<0.0050	<0.0050	<0.0050	1
Barium	(mg/L)	0.0560	0.0560	0.0560	1
Beryllium	(mg/L)	<0.0050	<0.0050	<0.0050	1
Boron	(mg/L)	0.0159	0.0159	0.0159	1
Cadmium	(mg/L)	<0.0100	<0.0100	<0.0100	11
Chromium	(mg/L)	<0.0500	<0.0500	<0.0500	12
Cobalt	(mg/L)	<0.0500	<0.0500	<0.0500	1
Copper	(mg/L)	0.0130	<0.0100	<0.0103	11
Iron	(mg/L)	1.7600	0.2000	0.8119	11
Lead	(mg/L)	<0.2000	<0.2000	<0.2000	11
Magnesium	(mg/L)	3.3200	3.3200	3.3200	1
Manganese	(mg/L)	0.0390	0.0390	0.0390	1
Mercury	(mg/L)	<0.0002	<0.0002	<0.0002	1
Molybdenum	(mg/L)	<0.0500	<0.0500	<0.0500	1
Nickel	(mg/L)	0.1270	<0.0500	<0.0570	11
Phosphorus (P)	(mg/L)	0.3100	0.1200	0.2060	10
Selenium	(mg/L)	<0.0050	<0.0050	<0.0050	1
Silver	(mg/L)	<0.0300	<0.0300	<0.0300	1
Thallium	(mg/L)	<0.0560	<0.0560	<0.0560	1
Tin	(mg/L)	<5.0000	<5.0000	<5.0000	1
Titanium	(mg/L)	<0.0500	<0.0500	<0.0500	1
Zinc	(mg/L)	0.1000	<0.0050	<0.0536	11

Table A.9 (continued)

Analysis	(Units)	Maximum	Minimum	Average	Count
Organics					
1,1-Dichloroethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
1,1-Dichloroethene	(µg/L)	Ja0.5000	0.5000	0.5000	1
1,1,1-Trichloroethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
1,1,2-Trichloroethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
1,1,2,2-Tetrachloroethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
1,2-Dichloroethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
1,2-Dichloropropane	(µg/L)	<1.0000	<1.0000	<1.0000	1
2-Chloroethyl vinyl	(µg/L)	<1.0000	<1.0000	<1.0000	1
2-Chlorophenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
2-Nitrophenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
2,3,7,8-Tetrachlorodibenzene P-dioxin	(µg/L)	<0.0007	<0.0007	<0.0007	1
2,4-Dichlorophenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
2,4-Dimethylphenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
2,4,6-Trichlorophenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
2,4-Dinitrophenol	(µg/L)	<50.0000	<50.0000	<50.0000	1
4-Chloro-3-methylphenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
4-Nitrophenol	(µg/L)	<50.0000	<50.0000	<50.0000	1
4,6-Dinitro-2-methylphenol	(µg/L)	<50.0000	<50.0000	<50.0000	1
Acrolein	(µg/L)	<1.0000	<1.0000	<1.0000	1
Acrylonitrile	(µg/L)	<1.0000	<1.0000	<1.0000	1
Benzene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Bromodichloromethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
Bromoform	(µg/L)	<1.0000	<1.0000	<1.0000	1
Bromomethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
Carbon Tetrachloride	(µg/L)	<1.0000	<1.0000	<1.0000	1
Chlorobenzene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Chloroethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
Chloroform	(µg/L)	1.0000	1.0000	1.0000	1
Chloromethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
Cis-1,3-dichloropropene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Dibromochloromethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
Dichlorodifluoromethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
Ethylbenzene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Methylene Chloride	(µg/L)	<1.0000	<1.0000	<1.0000	1
PCB	(µg/L)	<0.1000	<0.1000	<0.1000	10
Pentachlorophenol	(µg/L)	<50.0000	<50.0000	<50.0000	1
Phenol	(µg/L)	<10.0000	<5.0000	<7.5000	2
Tetrachloroethene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Toluene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Trans-1,2-dichloroethene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Trans-1,3-dichloropropene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Trichloroethene	(µg/L)	<1.0000	<1.0000	<1.0000	11
Trichlorofluoromethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
Vinyl chloride	(µg/L)	<1.0000	<1.0000	<1.0000	1

Table A.9 (continued)

Analysis	(Units)	Maximum	Minimum	Average	Count
		Radionuclides			
% U-235	(Wt%)	0.9980	0.3710	0.6618	4
Dissolved alpha	(pCi/L)	12.4000	-10.6000	1.2000	8
Dissolved beta	(pCi/L)	22.0000	-2.0000	5.7500	8
Gross alpha	(pCi/L)	5.1000	5.1000	5.1000	1
Gross beta	(pCi/L)	6.0000	6.0000	6.0000	1
Neptunium-237	(pCi/L)	0.7000	-0.2000	0.3250	4
Plutonium-239	(pCi/L)	0.0000	0.0000	0.0000	4
Rad screen	(pCi/mL)	<1.0000	<1.0000	<1.0000	1
Suspended alpha	(pCi/L)	3.4000	-9.0000	-2.7625	8
Suspended beta	(pCi/L)	20.0000	-5.0000	4.2500	8
Technetium-99	(pCi/L)	24.0000	0.0000	9.8571	7
Thorium-230	(pCi/L)	1.1000	0.4000	0.6667	3
Total radium	(pCi/L)	1.0000	1.0000	1.0000	1
Uranium	(mg/L)	0.0090	0.0040	0.0055	8

Table A.10. Summary statistics for Kentucky Pollutant Discharge Elimination System Permit water quality parameters at Outfall 013 for 1993

Analysis	(Units)	Maximum	Minimum	Average	Count
Conventional Parameters					
Ammonia as nitrogen	(mg/L)	<0.2500	<0.2500	<0.2500	2
BOD	(mg/L)	<5.0000	<5.0000	<5.0000	2
Bromide	(mg/L)	<1.0000	<1.0000	<1.0000	2
Chloride	(mg/L)	6.0000	6.0000	6.0000	2
Chlorine, total residual	(mg/L)	<0.0500	<0.0100	<0.0367	3
COD	(mg/L)	35.0000	25.0000	30.0000	2
Color	(units)	80.0000	80.0000	80.0000	2
Cyanide	(mg/L)	<0.0200	<0.0200	<0.0200	2
Fecal Coliform	(Co/100mL)	>3000.0000	1200.0000	2100.0000	2
Flow	(MLD)	14.1000	0.1900	3.7800	11
Fluoride	(mg/L)	0.6600	0.6400	0.6500	2
Hardness as $CaCO_3$	(mg/L$CaCO_3$)	352.0000	57.0000	138.3846	13
Nitrate-nitrite	(mg/L)	1.0000	1.0000	1.0000	2
Oil and grease	(mg/L)	<5.0000	<5.0000	<5.0000	17
pH	(SU)	8.2000	6.6000	7.5727	11
Specific conductance	(μmhos/cm)	448.0000	137.0000	248.0000	6
Sulfate	(mg/L)	62.0000	58.0000	60.0000	2
Sulfide	(mg/L)	<1.0000	<1.0000	<1.0000	2
Sulfite	(mg/L)	<3.0000	<3.0000	<3.0000	2
Surfactants	(mg/L)	<0.0800	<0.0800	<0.0800	2
Temperature	(C)	23.9000	23.9000	23.9000	1
Total organic carbon	(mg/L)	8.0000	7.0000	7.5000	2
Total organic nitrogen	(mg/L)	0.9900	0.9400	0.9650	2
Total suspended solids	(mg/L)	45.0000	4.0000	21.4615	13
TOX	(μg/L)	42.0000	8.0000	16.3333	6
Metals					
Aluminum	(mg/L)	6.0000	0.1700	1.9690	13
Antimony	(mg/L)	<0.0600	<0.0600	<0.0600	2
Arsenic	(mg/L)	<0.0050	<0.0050	<0.0050	2
Barium	(mg/L)	0.0630	0.0470	0.0550	2
Beryllium	(mg/L)	<0.0050	<0.0050	<0.0050	2
Boron	(mg/L)	0.0291	0.0291	0.0291	2
Cadmium	(mg/L)	<0.0100	<0.0100	<0.0100	13
Chromium	(mg/L)	<0.0500	<0.0500	<0.0500	14
Cobalt	(mg/L)	<0.0500	<0.0500	<0.0500	2
Copper	(mg/L)	<0.0100	<0.0100	<0.0100	13
Iron	(mg/L)	3.9200	0.1370	1.4734	13
Lead	(mg/L)	<0.2000	<0.2000	<0.2000	13
Magnesium	(mg/L)	6.3200	6.2300	6.2750	2
Manganese	(mg/L)	0.0190	0.0060	0.0125	2
Mercury	(mg/L)	<0.0002	<0.0002	<0.0002	2
Molybdenum	(mg/L)	<0.0500	<0.0500	<0.0500	2
Nickel	(mg/L)	<0.0500	<0.0500	<0.0500	13
Phosphorus (P)	(mg/L)	0.2700	0.2700	0.2700	2
Selenium	(mg/L)	<0.0050	<0.0050	<0.0050	2
Silver	(mg/L)	<0.0300	<0.0300	<0.0300	2
Thallium	(mg/L)	<0.0560	<0.0560	<0.0560	2
Tin	(mg/L)	<5.0000	<5.0000	<5.0000	2
Titanium	(mg/L)	<0.0500	<0.0500	<0.0500	2
Zinc	(mg/L)	0.0410	0.0090	0.0162	13

Table A.10 (continued)

Analysis	(Units)	Maximum	Minimum	Average	Count
Organics					
1,1,1-Trichloroethane	(µg/L)	<1.0000	<1.0000	<1.0000	2
1,1,2,2-Tetrachloroethane	(µg/L)	<1.0000	<1.0000	<1.0000	2
1,1,2-Trichloroethane	(µg/L)	<1.0000	<1.0000	<1.0000	2
1,1-Dichloroethane	(µg/L)	<1.0000	<1.0000	<1.0000	2
1,1-Dichloroethene	(µg/L)	<1.0000	<1.0000	<1.0000	2
1,2-Dichlorobenzene	(µg/L)	<1.0000	<1.0000	<1.0000	2
1,2-Dichloroethane	(µg/L)	<1.0000	<1.0000	<1.0000	2
1,2-Dichloropropane	(µg/L)	<1.0000	<1.0000	<1.0000	2
1,3-Dichlorobenzene	(µg/L)	<1.0000	<1.0000	<1.0000	2
1,4-Dichlorobenzene	(µg/L)	<1.0000	<1.0000	<1.0000	2
2,3,7,8-Tetrachlorodibenzene P-dioxin	(µg/L)	<0.0007	<0.0007	<0.0007	2
2,4,6-Trichlorophenol	(µg/L)	<10.0000	<10.0000	<10.0000	2
2,4-Dichlorophenol	(µg/L)	<10.0000	<10.0000	<10.0000	2
2,4-Dimethylphenol	(µg/L)	<10.0000	<10.0000	<10.0000	2
2,4-Dinitrophenol	(µg/L)	<50.0000	<50.0000	<50.0000	2
2-Chloroethyl vinyl	(µg/L)	<1.0000	<1.0000	<1.0000	2
2-Chlorophenol	(µg/L)	<10.0000	<10.0000	<10.0000	2
2-Nitrophenol	(µg/L)	<10.0000	<10.0000	<10.0000	2
4,6-Dinitro-2-methylphenol	(µg/L)	<50.0000	<50.0000	<50.0000	2
4-Chloro-3-methylphenol	(µg/L)	<10.0000	<10.0000	<10.0000	2
4-Nitrophenol	(µg/L)	<50.0000	<50.0000	<50.0000	2
Acrolein	(µg/L)	<1.0000	<1.0000	<1.0000	2
Acrylonitrile	(µg/L)	<1.0000	<1.0000	<1.0000	2
Benzene	(µg/L)	<1.0000	<1.0000	<1.0000	2
Bromodichloromethane	(µg/L)	<1.0000	<1.0000	<1.0000	2
Bromoform	(µg/L)	<1.0000	<1.0000	<1.0000	2
Bromomethane	(µg/L)	<1.0000	<1.0000	<1.0000	2
Carbon tetrachloride	(µg/L)	<1.0000	<1.0000	<1.0000	2
Chlorobenzene	(µg/L)	<1.0000	<1.0000	<1.0000	2
Chloroethane	(µg/L)	<1.0000	<1.0000	<1.0000	2
Chloroform	(µg/L)	<1.0000	<1.0000	<1.0000	2
Chloromethane	(µg/L)	<1.0000	<1.0000	<1.0000	2
Cis-1,3-dichloropropene	(µg/L)	<1.0000	<1.0000	<1.0000	2
Dibromochloromethane	(µg/L)	<1.0000	<1.0000	<1.0000	2
Ethylbenzene	(µg/L)	<1.0000	<1.0000	<1.0000	2
Methylene Chloride	(µg/L)	1.0000	<1.0000	<1.0000	2
PCB	(µg/L)	<0.1000	<0.1000	<0.1000	12
Pentachlorophenol	(µg/L)	<50.0000	<50.0000	<50.0000	2
Phenol	(µg/L)	<10.0000	<5.0000	<7.5000	4
Tetrachloroethene	(µg/L)	<1.0000	<1.0000	<1.0000	2
Toluene	(µg/L)	<1.0000	<1.0000	<1.0000	2
Trans-1,2-dichloroethene	(µg/L)	<1.0000	<1.0000	<1.0000	2
Trans-1,3-dichloropropene	(µg/L)	<1.0000	<1.0000	<1.0000	2
Trichloroethene	(µg/L)	<1.0000	<1.0000	<1.0000	13
Trichlorofluoromethane	(µg/L)	<1.0000	<1.0000	<1.0000	2
Vinyl chloride	(µg/L)	<1.0000	<1.0000	<1.0000	2

Table A.10 (continued)

Analysis	(Units)	Maximum	Minimum	Average	Count
		Radionuclides			
% U-235	(Wt%)	0.2000	0.2000	0.2000	1
Dissolved alpha	(pCi/L)	5.8000	-3.1000	3.6400	5
Dissolved beta	(pCi/L)	28.0000	3.0000	15.0000	5
Gross alpha	(pCi/L)	1.0000	-1.2000	-0.1000	2
Gross beta	(pCi/L)	6.0000	5.0000	5.5000	2
Neptunium-237	(pCi/L)	0.5000	-0.5000	-0.0600	5
Plutonium-239	(pCi/L)	0.0000	0.0000	0.0000	5
Rad alpha	(pCi/ml)	<1.0000	<1.0000	<1.0000	3
Rad beta	(pCi/ml)	<1.0000	<1.0000	<1.0000	3
Suspended alpha	(pCi/L)	6.5000	-1.8000	0.7600	5
Suspended beta	(pCi/L)	5.0000	-2.0000	1.8000	5
Technetium-99	(pCi/L)	25.0000	6.0000	15.5000	2
Thorium-230	(pCi/L)	1.5000	0.1000	0.7000	3
Total radium	(pCi/L)	1.2000	0.6000	0.9000	2
Uranium	(mg/L)	0.0040	0.0010	0.0028	5

Table A.11. Summary statistics for Kentucky Pollutant Discharge Elimination System Permit water quality parameters at Outfall 014 for 1993

Analysis	(Units)	Maximum	Minimum	Average	Count
		Conventional Parameters			
Chlorine, total residual	(mg/L)	<0.0500	<0.0500	<0.0500	19
Flow	(MLD)	1.0900	0.4100	0.7100	19
Hardness as $CaCO_3$	(mg/L$CaCO_3$)	97.0000	53.0000	78.5000	18
Oil and grease	(mg/L)	<5.0000	<5.0000	<5.0000	19
pH	(SU)	8.7000	6.1000	7.2105	4
Temperature	(C)	30.0000	17.8000	25.6000	10
Total suspended solids	(mg/L)	19.0000	<4.0000	<8.0526	19
Turbidity	(NTU)	12.0000	3.3000	7.6700	10
		Metals			
Aluminum	(mg/L)	0.6000	<0.1000	<0.2658	10
Cadmium	(mg/L)	<0.0100	<0.0100	<0.0100	10
Chromium	(mg/L)	<0.0500	<0.0500	<0.0500	8
Copper	(mg/L)	<0.0100	<0.0100	<0.0100	10
Iron	(mg/L)	2.3800	0.1590	1.0800	10
Lead	(mg/L)	<0.2000	<0.2000	<0.2000	10
Nickel	(mg/L)	<0.0500	<0.0500	<0.0500	10
Zinc	(mg/L)	0.0300	<0.0050	<0.0114	10
		Organics			
PCB	(μg/L)	<0.1000	<0.1000	<0.1000	5
		Radionuclides			
Dissolved alpha	(pCi/L)	0.5000	-4.5000	-2.0000	2
Dissolved beta	(pCi/L)	6.0000	-2.0000	2.0000	2
Suspended alpha	(pCi/L)	0.0000	-10.1000	-6.4000	2
Suspended beta	(pCi/L)	0.0000	-3.0000	-2.0000	2
Uranium	(mg/L)	<0.0010	<0.0010	<0.0010	2

Table A.12. Summary statistics for Kentucky Pollutant Discharge Elimination System Permit water quality parameters at Outfall 015 for 1993.

Analysis	(Units)	Maximum	Minimum	Average	Count
Conventional Parameters					
Ammonia as nitrogen	(mg/L)	<0.2500	<0.2500	<0.2500	1
BOD	(mg/L)	6.0000	6.0000	6.0000	1
Bromide	(mg/L)	<1.0000	<1.0000	<1.0000	1
Chloride	(mg/L)	86.0000	86.0000	86.0000	1
Chlorine, total residual	(mg/L)	<0.0500	<0.0500	<0.0500	1
COD	(mg/L)	40.0000	40.0000	40.0000	1
Color	(units)	150.0000	150.0000	150.0000	1
Cyanide	(mg/L)	<0.0200	<0.0200	<0.0200	1
Fecal Coliform	(Co/100mL)	>3000.0000	3000.0000	3000.0000	1
Flow	(MLD)	7.9900	0.0600	2.1700	11
Fluoride	(mg/L)	0.3400	0.3400	0.3400	1
Hardness as $CaCO_3$	(mg/L$CaCO_3$)	307.0000	94.0000	155.9091	11
Nitrate-nitrite	(mg/L)	0.2700	0.2700	0.2700	1
Oil and grease	(mg/L)	5.6000	<5.0000	<5.0545	11
pH	(mg/L)	8.2000	7.3000	7.6818	11
Sulfate	(SU)	36.0000	36.0000	36.0000	1
Sulfide	(mg/L)	<1.0000	<1.0000	<1.0000	1
Sulfite	(mg/L)	<3.0000	<3.0000	<3.0000	1
Surfactants	(mg/L)	<0.0800	<0.0800	<0.0800	1
Temperature	(mg/L)	23.9000	23.9000	23.9000	1
Total organic carbon	(C)	14.0000	14.0000	14.0000	1
Total organic nitrogen	(mg/L)	1.5000	1.5000	1.5000	1
Total suspended solids	(mg/L)	66.0000	7.0000	20.8182	11
Metals					
Aluminum	(mg/L)	2.1000	0.3260	1.1347	11
Antimony	(mg/L)	<0.0600	<0.0600	<0.0600	1
Arsenic	(mg/L)	<0.0050	<0.0050	<0.0050	1
Barium	(mg/L)	0.0390	0.0390	0.0390	1
Beryllium	(mg/L)	<0.0050	<0.0050	<0.0050	1
Boron	(mg/L)	0.0461	0.0461	0.0461	1
Cadmium	(mg/L)	<0.0100	<0.0100	<0.0100	11
Chromium	(mg/L)	<0.0500	<0.0500	<0.0500	11
Cobalt	(mg/L)	<0.0500	<0.0500	<0.0500	1
Copper	(mg/L)	0.0130	<0.0100	<0.0103	11
Iron	(mg/L)	2.1600	0.2450	0.9685	11
Lead	(mg/L)	<0.2000	<0.2000	<0.2000	11
Magnesium	(mg/L)	8.1700	8.1700	8.1700	1
Manganese	(mg/L)	<0.0050	<0.0050	<0.0050	1
Mercury	(mg/L)	<0.0002	<0.0002	<0.0002	1
Molybdenum	(mg/L)	<0.0500	<0.0500	<0.0500	1
Nickel	(mg/L)	<0.0500	<0.0500	<0.0500	11
Phosphorus (P)	(mg/L)	0.4600	0.4600	0.4600	1
Selenium	(mg/L)	<0.0050	<0.0050	<0.0050	1
Silver	(mg/L)	<0.0300	<0.0300	<0.0300	1
Thallium	(mg/L)	<0.0560	<0.0560	<0.0560	1
Tin	(mg/L)	<5.0000	<5.0000	<5.0000	1
Titanium	(mg/L)	<0.0500	<0.0500	<0.0500	1
Zinc	(mg/L)	0.0860	0.0080	0.0213	11

Table A.12 (continued)

Analysis	(Units)	Maximum	Minimum	Average	Count
Organics					
1,1,1-Trichloroethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
1,1,2,2-Tetrachloroethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
1,1,2-Trichloroethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
1,1-Dichloroethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
1,1-Dichloroethene	(µg/L)	<1.0000	<1.0000	<1.0000	1
1,2-Dichlorobenzene	(µg/L)	<1.0000	<1.0000	<1.0000	1
1,2-Dichloroethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
1,2-Dichloropropane	(µg/L)	<1.0000	<1.0000	<1.0000	1
1,3-Dichlorobenzene	(µg/L)	<1.0000	<1.0000	<1.0000	1
1,4-Dichlorobenzene	(µg/L)	<1.0000	<1.0000	<1.0000	1
2-Chloroethyl vinyl	(µg/L)	<1.0000	<1.0000	<1.0000	1
2-Chlorophenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
2-Nitrophenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
2,3,7,8-Tetrachlorodibenzene P-dioxin	(µg/L)	<0.0007	<0.0007	<0.0007	1
2,4-Dichlorophenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
2,4-Dimethylphenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
2,4-Dinitrophenol	(µg/L)	<50.0000	<50.0000	<50.0000	1
2,4,6-Trichlorophenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
4-Chloro-3-methylphenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
4-Nitrophenol	(µg/L)	<50.0000	<50.0000	<50.0000	1
4,6-Dinitro-2-methylphenol	(µg/L)	<50.0000	<50.0000	<50.0000	1
Acrolein	(µg/L)	<1.0000	<1.0000	<1.0000	1
Acrylonitrile	(µg/L)	<1.0000	<1.0000	<1.0000	1
Benzene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Bromodichloromethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
Bromoform	(µg/L)	<1.0000	<1.0000	<1.0000	1
Bromomethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
Carbon tetrachloride	(µg/L)	<1.0000	<1.0000	<1.0000	1
Chlorobenzene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Chloroethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
Chloroform	(µg/L)	<1.0000	<1.0000	<1.0000	1
Chloromethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
Cis-1,3-dichloropropene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Dibromochloromethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
Ethylbenzene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Methylene Chloride	(µg/L)	<1.0000	<1.0000	<1.0000	1
PCB	(µg/L)	<0.1000	<0.1000	<0.1000	10
Pentachlorophenol	(µg/L)	<50.0000	<50.0000	<50.0000	1
Phenol	(µg/L)	<10.0000	<5.0000	<7.5000	2
Tetrachloroethene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Toluene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Trans-1,2-dichloroethene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Trans-1,3-dichloropropene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Trichloroethene	(µg/L)	<1.0000	<1.0000	<1.0000	11
Trichlorofluoromethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
Vinyl chloride	(µg/L)	<1.0000	<1.0000	<1.0000	1

Table A.12 (continued)

Analysis	(Units)	Maximum	Minimum	Average	Count
		Radionuclides			
% U-235	(Wt%)	0.4910	0.1490	0.3123	8
Dissolved alpha	(pCi/L)	241.3000	8.7000	87.2000	4
Dissolved beta	(pCi/L)	200.0000	23.0000	84.7500	4
Gross alpha	(pCi/L)	13.9000	13.9000	13.9000	1
Gross beta	(pCi/L)	45.0000	45.0000	45.0000	1
Neptunium-237	(pCi/L)	0.4000	0.0000	0.1750	4
Plutonium-239	(pCi/L)	0.0000	0.0000	0.0000	4
Rad alpha	(pCi/ml)	<1.0000	<1.0000	<1.0000	2
Rad beta	(pCi/ml)	<1.0000	<1.0000	<1.0000	2
Suspended alpha	(pCi/L)	13.5000	0.2000	5.1750	4
Suspended beta	(pCi/L)	140.0000	7.0000	42.5000	4
Technetium-99	(pCi/L)	50.0000	28.0000	36.3333	3
Thorium-230	(pCi/L)	3.6000	0.7000	2.1500	2
Total radium	(pCi/L)	2.2000	2.2000	2.2000	1
Uranium	(mg/L)	1.0000	0.0200	0.2013	8

Table A.13. Summary statistics for Kentucky Pollutant Discharge Elimination System Permit water quality parameters at Outfall 016 for 1993

Analysis	(Units)	Maximum	Minimum	Average	Count
Conventional Parameters					
Ammonia as nitrogen	(mg/L)	<0.2500	<0.2500	<0.2500	1
BOD	(mg/L)	6.0000	6.0000	6.0000	1
Bromide	(mg/L)	< 1.0000	<1.0000	<1.0000	1
Chloride	(mg/L)	9.0000	9.0000	9.0000	1
Chlorine, total residual	(mg/L)	<0.0500	<0.0500	<0.0500	1
COD	(mg/L)	40.0000	40.0000	40.0000	1
Color	(units)	160.0000	160.0000	160.0000	1
Cyanide	(mg/L)	<0.0200	<0.0200	<0.0200	1
Fecal Coliform	(Co/100mL)	>3000.0000	3000.0000	3000.0000	11
Flow	(MLD)	1.8500	0.0200	0.4700	1
Fluoride	(mg/L)	0.3000	0.3000	0.3000	11
Hardness as $CaCO_3$	(mg/L$CaCO_3$)	301.0000	86.0000	186.2727	1
Nitrate-nitrite	(mg/L)	0.7200	0.7200	0.7200	14
Oil and grease	(mg/L)	<5.0000	<5.0000	<5.0000	11
pH	(SU)	8.8000	7.0000	7.7455	1
Sulfate	(mg/L)	52.0000	52.0000	52.0000	1
Sulfide	(mg/L)	<1.0000	<1.0000	<1.0000	1
Sulfite	(mg/L)	<3.0000	<3.0000	<3.0000	1
Surfactants	(mg/L)	<0.0800	<0.0800	<0.0800	1
Temperature	(C)	23.3000	23.3000	23.3000	1
Total organic carbon	(mg/L)	14.0000	14.0000	14.0000	1
Total organic nitrogen	(mg/L)	1.7000	1.7000	1.7000	11
Total suspended solids	(mg/L)	23.0000	<4.0000	<11.3636	
Metals					
Aluminum	(mg/L)	1.4100	0.1060	0.8106	11
Antimony	(mg/L)	<0.0600	<0.0600	<0.0600	1
Arsenic	(mg/L)	<0.0050	<0.0050	<0.0050	1
Barium	(mg/L)	0.0440	0.0440	0.0440	1
Beryllium	(mg/L)	<0.0050	<0.0050	<0.0050	1
Boron	(mg/L)	0.0367	0.0367	0.0367	1
Cadmium	(mg/L)	<0.0100	<0.0100	<0.0100	11
Chromium	(mg/L)	<0.0500	<0.0500	<0.0500	11
Cobalt	(mg/L)	<0.0500	<0.0500	<0.0500	1
Copper	(mg/L)	0.0160	<0.0100	<0.0105	11
Iron	(mg/L)	1.1200	0.0470	0.5787	11
Lead	(mg/L)	<0.2000	<0.2000	<0.2000	11
Magnesium	(mg/L)	4.9200	4.9200	4.9200	1
Manganese	(mg/L)	0.0170	0.0170	0.0170	1
Mercury	(mg/L)	<0.0002	<0.0002	<0.0002	1
Molybdenum	(mg/L)	<0.0500	<0.0500	<0.0500	1
Nickel	(mg/L)	<0.0500	<0.0500	<0.0500	11
Phosphorus (P)	(mg/L)	0.6000	0.6000	0.6000	1
Selenium	(mg/L)	<0.0050	<0.0050	<0.0050	1
Silver	(mg/L)	<0.0300	<0.0300	<0.0300	1
Thallium	(mg/L)	<0.0560	<0.0560	<0.0560	1
Tin	(mg/L)	<5.0000	<5.0000	<5.0000	1
Titanium	(mg/L)	<0.0500	<0.0500	<0.0500	1
Zinc	(mg/L)	0.0510	<0.0050	<0.0215	11

Table A.13 (continued)

Analysis	(Units)	Maximum	Minimum	Average	Count
Organics					
1,1,1-Trichloroethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
1,1,2,2-Tetrachloroethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
1,1,2-Trichloroethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
1,1-Dichloroethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
1,1-Dichloroethene	(µg/L)	<1.0000	<1.0000	<1.0000	1
1,2-Dichlorobenzene	(µg/L)	<1.0000	<1.0000	<1.0000	1
1,2-Dichloroethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
1,2-Dichloropropane	(µg/L)	<1.0000	<1.0000	<1.0000	1
1,3-Dichlorobenzene	(µg/L)	<1.0000	<1.0000	<1.0000	1
1,4-Dichlorobenzene	(µg/L)	<1.0000	<1.0000	<1.0000	1
2-Chloroethyl vinyl	(µg/L)	<1.0000	<1.0000	<1.0000	1
2-Chlorophenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
2-Nitrophenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
2,3,7,8-Tetrachlorodibenzene P-dioxin	(µg/L)	<0.0007	<0.0007	<0.0007	1
2,4,6-Trichlorophenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
2,4-Dichlorophenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
2,4-Dimethylphenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
2,4-Dinitrophenol	(µg/L)	<50.0000	<50.0000	<50.0000	1
4-Chloro-3-methylphenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
4-Nitrophenol	(µg/L)	<50.0000	<50.0000	<50.0000	1
4,6-Dinitro-2-methylphenol	(µg/L)	<50.0000	<50.0000	<50.0000	1
Acrolein	(µg/L)	<1.0000	<1.0000	<1.0000	1
Acrylonitrile	(µg/L)	<1.0000	<1.0000	<1.0000	1
Benzene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Bromodichloromethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
Bromoform	(µg/L)	<1.0000	<1.0000	<1.0000	1
Bromomethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
Carbon tetrachloride	(µg/L)	<1.0000	<1.0000	<1.0000	1
Chlorobenzene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Chloroethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
Chloroform	(µg/L)	<1.0000	<1.0000	<1.0000	1
Chloromethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
Cis-1,3-dichloropropene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Dibromochloromethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
Ethylbenzene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Methylene Chloride	(µg/L)	<1.0000	<1.0000	<1.0000	1
PCB	(µg/L)	<0.1000	<0.1000	<0.1000	10
Pentachlorophenol	(µg/L)	<50.0000	<50.0000	<50.0000	1
Phenol	(µg/L)	<10.0000	<5.0000	<7.5000	2
Tetrachloroethene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Toluene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Trans-1,2-dichloroethene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Trans-1,3-dichloropropene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Trichloroethene	(µg/L)	<1.0000	<1.0000	<1.0000	11
Trichlorofluoromethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
Vinyl chloride	(µg/L)	<1.0000	<1.0000	<1.0000	1

Table A.13 (continued)

Analysis	(Units)	Maximum	Minimum	Average	Count
		Radionuclides			
% U-235	(Wt%)	0.6340	0.4260	0.5060	3
Dissolved alpha	(pCi/L)	8.3000	-1.2000	5.7000	4
Dissolved beta	(pCi/L)	17.0000	6.0000	12.0000	4
Gross alpha	(pCi/L)	0.2000	0.2000	0.2000	1
Gross beta	(pCi/L)	4.0000	4.0000	4.0000	1
Neptunium-237	(pCi/L)	0.4000	-0.2000	0.0500	4
Plutonium-239	(pCi/L)	0.0000	0.0000	0.0000	4
Rad alpha	(pCi/ml)	<1.0000	<1.0000	<1.0000	2
Rad beta	(pCi/ml)	<1.0000	<1.0000	<1.0000	2
Suspended alpha	(pCi/L)	2.0000	-1.4000	0.3750	4
Suspended beta	(pCi/L)	10.0000	-2.0000	5.5000	4
Technetium-99	(pCi/L)	5.0000	5.0000	5.0000	1
Thorium-230	(pCi/L)	0.7000	0.4000	0.5500	2
Total radium	(pCi/L)	2.2000	2.2000	2.2000	1
Uranium	(mg/L)	0.0160	0.0010	0.0083	4

Table A.14. Summary statistics for Kentucky Pollutant Discharge Elimination System Permit water quality parameters at Outfall 017 for 1993

Analysis	(Units)	Maximum	Minimum	Average	Count
Conventional Parameters					
Ammonia as nitrogen	(mg/L)	<0.2500	<0.2500	<0.2500	1
BOD	(mg/L)	<5.0000	<5.0000	<5.0000	1
Bromide	(mg/L)	< 1.0000	<1.0000	<1.0000	1
Chloride	(mg/L)	7.0000	7.0000	7.0000	1
Chlorine, total residual	(mg/L)	<0.0500	<0.0500	<0.0500	1
COD	(mg/L)	31.0000	31.0000	31.0000	1
Color	(units)	27.0000	27.0000	27.0000	1
Cyanide	(mg/L)	<0.0200	<0.0200	<0.0200	1
Fecal Coliform	(Co/100mL)	>3000.0000	3000.0000	3000.0000	12
Flow	(MLD)	8.0600	0.0800	1.6400	1
Fluoride	(mg/L)	0.4700	0.4700	0.4700	11
Hardness as $CaCO_3$	(mg/L$CaCO_3$)	202.0000	63.0000	141.4545	1
Nitrate-nitrite	(mg/L)	1.0000	1.0000	1.0000	14
Oil and grease	(mg/L)	6.1000	<5.0000	<5.0786	11
pH	(SU)	8.3000	7.2000	7.6455	1
Sulfate	(mg/L)	43.0000	43.0000	43.0000	1
Sulfide	(mg/L)	<1.0000	<1.0000	<1.0000	1
Sulfite	(mg/L)	<3.0000	<3.0000	<3.0000	1
Surfactants	(mg/L)	<0.0800	<0.0800	<0.0800	1
Temperature	(C)	23.9000	23.9000	23.9000	1
Total organic carbon	(mg/L)	5.0000	5.0000	5.0000	1
Total organic nitrogen	(mg/L)	0.7300	0.7300	0.7300	1
Total suspended solids	(mg/L)	89.0000	<4.0000	<21.7273	11
Metals					
Aluminum	(mg/L)	1.2700	0.2110	0.7485	11
Antimony	(mg/L)	<0.0600	<0.0600	<0.0600	1
Arsenic	(mg/L)	<0.0050	<0.0050	<0.0050	1
Barium	(mg/L)	0.1100	0.1100	0.1100	1
Beryllium	(mg/L)	<0.0050	<0.0050	<0.0050	1
Boron	(mg/L)	0.0360	0.0360	0.0360	1
Cadmium	(mg/L)	<0.0100	<0.0100	<0.0100	11
Chromium	(mg/L)	<0.0500	<0.0500	<0.0500	11
Cobalt	(mg/L)	<0.0500	<0.0500	<0.0500	1
Copper	(mg/L)	0.0120	<0.0100	<0.0102	11
Iron	(mg/L)	8.1800	0.2560	1.4123	11
Lead	(mg/L)	0.4250	<0.2000	<0.2205	11
Magnesium	(mg/L)	5.1100	5.1100	5.1100	1
Manganese	(mg/L)	0.1360	0.1360	0.1360	1
Mercury	(mg/L)	<0.0002	<0.0002	<0.0002	1
Molybdenum	(mg/L)	<0.0500	<0.0500	<0.0500	1
Nickel	(mg/L)	<0.0500	<0.0500	<0.0500	11
Phosphorus (P)	(mg/L)	0.1400	0.1400	0.1400	1
Selenium	(mg/L)	<0.0050	<0.0050	<0.0050	1
Silver	(mg/L)	<0.0300	<0.0300	<0.0300	1
Thallium	(mg/L)	<0.0560	<0.0560	<0.0560	1
Tin	(mg/L)	<5.0000	<5.0000	<5.0000	1
Titanium	(mg/L)	<0.0500	<0.0500	<0.0500	1
Zinc	(mg/L)	0.0700	<0.0050	<0.0199	11

Table A.14 (continued)

Analysis	(Units)	Maximum	Minimum	Average	Count
Organics					
1,1,1-Trichloroethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
1,1,2,2-Tetrachloroethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
1,1,2-Trichloroethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
1,1-Dichloroethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
1,1-Dichloroethene	(µg/L)	<1.0000	<1.0000	<1.0000	1
1,2-Dichloroethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
1,2-Dichloropropane	(µg/L)	<1.0000	<1.0000	<1.0000	1
2-Chloroethyl vinyl	(µg/L)	<1.0000	<1.0000	<1.0000	1
2-Chlorophenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
2-Nitrophenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
2,3,7,8-Tetrachlorodibenzene P-dioxin	(µg/L)	<0.0014	<0.0014	<0.0014	1
2,4-Dichlorophenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
2,4-Dimethylphenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
2,4-Dinitrophenol	(µg/L)	<50.0000	<50.0000	<50.0000	1
2,4,6-Trichlorophenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
4-Chloro-3-methylphenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
4-Nitrophenol	(µg/L)	<50.0000	<50.0000	<50.0000	1
4,6-Dinitro-2-methylphenol	(µg/L)	<50.0000	<50.0000	<50.0000	1
Acrolein	(µg/L)	<5.0000	<5.0000	<5.0000	1
Acrylonitrile	(µg/L)	<5.0000	<5.0000	<5.0000	1
Benzene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Bromodichloromethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
Bromoform	(µg/L)	<1.0000	<1.0000	<1.0000	1
Bromomethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
Carbon tetrachloride	(µg/L)	<1.0000	<1.0000	<1.0000	1
Chlorobenzene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Chloroethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
Chloroform	(µg/L)	<1.0000	<1.0000	<1.0000	1
Chloromethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
Cis-1,3-dichloropropene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Dibromochloromethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
Dichlorodifluoromethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
Ethylbenzene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Methylene Chloride	(µg/L)	<1.0000	<1.0000	<1.0000	1
PCB	(µg/L)	<0.1000	<0.1000	<0.1000	10
Pentachlorophenol	(µg/L)	<50.0000	<50.0000	<50.0000	1
Phenol	(µg/L)	<10.0000	<5.0000	<7.5000	2
Tetrachloroethene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Toluene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Trans-1,2-dichloroethene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Trans-1,3-dichloropropene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Trichloroethene	(µg/L)	<1.0000	<1.0000	<1.0000	11
Trichlorofluoromethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
Vinyl chloride	(µg/L)	<1.0000	<1.0000	<1.0000	1

Table A.14 (continued)

Analysis	(Units)	Maximum	Minimum	Average	Count
Radionuclides					
% U-235	(Wt%)	0.5530	0.4880	0.5163	3
Dissolved alpha	(pCi/L)	10.7000	-1.0000	5.4250	4
Dissolved beta	(pCi/L)	10.0000	7.0000	8.0000	4
Gross alpha	(pCi/L)	1.3000	1.3000	1.3000	1
Gross beta	(pCi/L)	4.0000	4.0000	4.0000	1
Neptunium-237	(pCi/L)	0.4000	-0.1000	0.2000	4
Plutonium-239	(pCi/L)	0.1000	0.0000	0.0750	4
Rad alpha	(pCi/ml)	<1.0000	<1.0000	<1.0000	2
Rad beta	(pCi/ml)	<1.0000	<1.0000	<1.0000	2
Rad screen	(pCi/mL)	<1.0000	<1.0000	<1.0000	1
Suspended alpha	(pCi/L)	0.9000	-1.8000	-0.0500	4
Suspended beta	(pCi/L)	4.0000	-2.0000	1.5000	4
Technetium-99	(pCi/L)	6.0000	6.0000	6.0000	1
Thorium-230	(pCi/L)	2.0000	0.1000	1.0500	2
Total radium	(pCi/L)	0.7000	0.7000	0.7000	1
Uranium	(mg/L)	0.0100	0.0040	0.0073	4

Table A.15. Summary statistics for Kentucky Pollutant Discharge Elimination System Permit water quality parameters at Outfall 018 for 1993

Analysis	(Units)	Maximum	Minimum	Average	Count
		Conventional Parameters			
Ammonia as nitrogen	(mg/L)	<0.2500	<0.2500	<0.2500	1
BOD	(mg/L)	15.0000	15.0000	15.0000	1
Bromide	(mg/L)	< 1.0000	<1.0000	<1.0000	1
Chloride	(mg/L)	12.0000	9.0000	10.5000	2
Chlorine, total residual	(mg/L)	<0.0500	<0.0500	<0.0500	1
COD	(mg/L)	51.0000	27.0000	39.0000	2
Color	(units)	280.0000	280.0000	280.0000	1
Cyanide	(mg/L)	<0.0200	<0.0200	<0.0200	1
Dissolved solids	(mg/L)	281.0000	281.0000	281.0000	1
Fecal Coliform	(Co/100mL)	>3000.0000	3000.0000	3000.0000	1
Flow	(MLD)	22.630	0.1200	4.9700	11
Fluoride	(mg/L)	0.4400	0.4400	0.4400	1
Hardness as $CaCO_3$	(mg/L$CaCO_3$)	180.0000	51.0000	96.7273	11
Nitrate-nitrite	(mg/L)	0.3800	0.3800	0.3800	1
Oil and grease	(mg/L)	<5.0000	<5.0000	<5.0000	14
pH	(SU)	8.0000	7.2000	7.6636	11
Specific conductance	(μmhos/cm)	357.0000	357.0000	357.0000	1
Temperature	(C)	22.2000	22.2000	22.2000	1
Total organic carbon	(mg/L)	20.0000	9.0000	14.5000	2
Total organic nitrogen	(mg/L)	2.6000	2.6000	2.6000	1
Total solids	(mg/L)	295.0000	295.0000	295.0000	1
Total suspended solids	(mg/L)	204.0000	14.0000	48.1818	11
Sulfate	(mg/L)	69.0000	21.0000	45.0000	2
Sulfide	(mg/L)	<1.0000	<1.0000	<1.0000	1
Sulfite	(mg/L)	<3.0000	<3.0000	<3.0000	1
Surfactants	(mg/L)	<0.0800	<0.0800	<0.0800	1
		Metals			
Aluminum	(mg/L)	13.5300	0.2750	4.1727	11
Antimony	(mg/L)	<0.0600	<0.0600	<0.0600	1
Arsenic	(mg/L)	<0.0050	<0.0050	<0.0050	1
Barium	(mg/L)	0.1120	0.1120	0.1120	1
Beryllium	(mg/L)	<0.0050	<0.0050	<0.0050	1
Boron	(mg/L)	0.0448	0.0448	0.0448	1
Cadmium	(mg/L)	<0.0100	<0.0100	<0.0100	11
Chromium	(mg/L)	<0.0500	<0.0500	<0.0500	11
Cobalt	(mg/L)	<0.0500	<0.0500	<0.0500	1
Copper	(mg/L)	0.0210	<0.0100	<0.0116	11
Iron	(mg/L)	15.0400	0.2630	4.0119	11
Lead	(mg/L)	0.4500	<0.2000	<0.2259	11
Magnesium	(mg/L)	4.8000	4.8000	4.8000	1
Manganese	(mg/L)	0.1390	0.1390	0.1390	1
Mercury	(mg/L)	<0.0002	<0.0002	<0.0002	1
Molybdenum	(mg/L)	<0.0500	<0.0500	<0.0500	1
Nickel	(mg/L)	<0.0500	<0.0500	<0.0500	11
Phosphorus (P)	(mg/L)	1.1000	1.1000	1.1000	1
Selenium	(mg/L)	<0.0050	<0.0050	<0.0050	1
Silver	(mg/L)	<0.0300	<0.0300	<0.0300	1
Thallium	(mg/L)	<0.0560	<0.0560	<0.0560	1
Tin	(mg/L)	<5.0000	<5.0000	<5.0000	1
Titanium	(mg/L)	<0.0500	<0.0500	<0.0500	1
Zinc	(mg/L)	0.0560	<0.0070	<0.0283	11

Table A.15 (continued)

Analysis	(Units)	Maximum	Minimum	Average	Count
Organics					
1,1,1-Trichloroethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
1,1,2,2-Tetrachloroethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
1,1,2-Trichloroethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
1,1-Dichloroethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
1,1-Dichloroethene	(µg/L)	<1.0000	<1.0000	<1.0000	1
1,2-Dichlorobenzene	(µg/L)	<1.0000	<1.0000	<1.0000	1
1,2-Dichloroethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
1,2-Dichloropropane	(µg/L)	<1.0000	<1.0000	<1.0000	1
1,3-Dichlorobenzene	(µg/L)	<1.0000	<1.0000	<1.0000	1
1,4-Dichlorobenzene	(µg/L)	<1.0000	<1.0000	<1.0000	1
2,3,7,8-Tetrachlorodibenzene P-dioxin	(µg/L)	<0.0007	<0.0007	<0.0007	1
2,4,6-Trichlorophenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
2,4-Dichlorophenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
2,4-Dimethylphenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
2,4-Dinitrophenol	(µg/L)	<50.0000	<50.0000	<50.0000	1
2-Chloroethyl vinyl	(µg/L)	<1.0000	<1.0000	<1.0000	1
2-Chlorophenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
2-Nitrophenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
4,6-Dinitro-2-methylphenol	(µg/L)	<50.0000	<50.0000	<50.0000	1
4-Chloro-3-methylphenol	(µg/L)	<10.0000	<10.0000	<10.0000	1
4-Nitrophenol	(µg/L)	<50.0000	<50.0000	<50.0000	1
Acrolein	(µg/L)	<1.0000	<1.0000	<1.0000	1
Acrylonitrile	(µg/L)	<1.0000	<1.0000	<1.0000	1
Benzene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Bromodichloromethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
Bromoform	(µg/L)	<1.0000	<1.0000	<1.0000	1
Bromomethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
Carbon tetrachloride	(µg/L)	<1.0000	<1.0000	<1.0000	1
Chlorobenzene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Chloroethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
Chloroform	(µg/L)	<1.0000	<1.0000	<1.0000	1
Chloromethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
Cis-1,3-dichloropropene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Dibromochloromethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
Ethylbenzene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Methylene Chloride	(µg/L)	<1.0000	<1.0000	<1.0000	1
PCB	(µg/L)	<0.1000	<0.1000	<0.1000	10
Pentachlorophenol	(µg/L)	<50.0000	<50.0000	<50.0000	1
Phenol	(µg/L)	<10.0000	<5.0000	<7.5000	2
Tetrachloroethene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Toluene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Trans-1,2-dichloroethene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Trans-1,3-dichloropropene	(µg/L)	<1.0000	<1.0000	<1.0000	1
Trichloroethene	(µg/L)	<1.0000	<1.0000	<1.0000	11
Trichlorofluoromethane	(µg/L)	<1.0000	<1.0000	<1.0000	1
Vinyl chloride	(µg/L)	<1.0000	<1.0000	<1.0000	1

Table A.15 (continued)

Analysis	(Units)	Maximum	Minimum	Average	Count
		Radionuclides			
% U-235	(Wt%)	0.8860	0.4660	0.6893	3
Dissolved alpha	(pCi/L)	27.4000	1.2000	10.1750	4
Dissolved beta	(pCi/L)	49.0000	9.0000	30.7500	4
Gross alpha	(pCi/L)	13.5000	2.9000	8.2000	2
Gross beta	(pCi/L)	82.0000	30.0000	56.0000	2
Neptunium-237	(pCi/L)	0.7000	0.0000	0.2500	4
Plutonium-239	(pCi/L)	1.1000	0.0000	0.3250	4
Rad alpha	(pCi/ml)	<1.0000	<1.0000	<1.0000	2
Rad beta	(pCi/ml)	<1.0000	<1.0000	<1.0000	2
Suspended alpha	(pCi/L)	3.8000	-0.9000	1.4000	4
Suspended beta	(pCi/L)	16.0000	-2.0000	4.7500	4
Technetium-99	(pCi/L)	61.0000	24.0000	37.6667	3
Thorium-230	(pCi/L)	1.4000	0.4000	0.9000	2
Total radium	(pCi/L)	1.3000	1.3000	1.3000	1
Uranium	(mg/L)	0.0230	0.0030	0.0102	6

Appendix B
TOXICITY TEST RESULTS AND WATER CHEMISTRY ANALYSES

Table B.1. Summary of fathead minnow survival and growth for ambient sites

Test Date	Site[a]	Treatment[b]	Mean survival (%)	Survival SD (%)	Mean growth (mg)	Growth SD (mg)
Oct. 1991	BBK 12.5	N	42.5	33.0	0.15	0.05
	BBK 10.0	N	57.5	33.0	0.16	0.04
	BBK 9.1	N	52.5	33.0	0.21	0.07
	LUK 7.2	N	95.0	5.7	0.14	0.03
	MAK 13.8	N	62.5	27.5	0.14	0.02
Feb. 1992	BBK 12.5	N	62.5	26.3	0.47	0.11
	BBK 12.5	UV	87.5	12.5	0.46	0.05
	BBK 10.0	N	80.0	18.2	0.47	0.04
	BBK 10.0	UV	95.0	5.7	0.52	0.04
	BBK 9.1	N	75.0	17.3	0.63	0.06
	BBK 9.1	UV	85.0	19.1	0.56	0.07
	LUK 7.2	N	20.0	24.4	0.46	0.18
	LUK 7.2	UV	90.0	14.1	0.52	0.03
	MAK 13.8	N	75.0	37.8	0.37	0.08
	MAK 13.8	UV	97.5	5.0	0.43	0.03
May 1992	BBK 12.5	N	90.0	8.1	0.25	0.02
	BBK 12.5	UV	97.5	5.0	0.24	0.03
	BBK 10.0	N	90.0	11.5	0.20	0.01
	BBK 10.0	UV	95.0	5.7	0.21	0.03
	BBK 9.1	N	95.0	5.7	0.21	0.04
	BBK 9.1	UV	97.5	5.0	0.33	0.02
	LUK 7.2	N	67.5	35.9	0.33	0.03
	LUK 7.2	UV	97.5	5.0	0.28	0.01
	MAK 13.8	N	65.0	26.4	0.36	0.12
	MAK 13.8	UV	95.0	10.0	0.25	0.04
Aug. 1992	BBK 12.5	N	97.5	5.0	0.62	0.07
	BBK 12.5	UV	62.5	20.6	0.46	0.07
	BBK 10.0	N	97.5	5.0	0.60	0.06

Table B.1 (continued)

Test Date	Site[a]	Treatment[b]	Mean survival (%)	Survival SD (%)	Mean growth (mg)	Growth SD (mg)
	BBK 10.0	UV	62.5	5.0	0.50	0.08
	BBK 9.1	F	97.5	5.0	0.67	0.05
	BBK 9.1	N	100.0	0.0	0.61	0.08
	BBK 9.1	UV	100.0	0.0	0.66	0.05
	LUK 7.2	F	97.5	5.0	0.63	0.06
	LUK 7.2	N	100.0	0.0	0.57	0.10
	LUK 7.2	UV	97.5	5.0	0.62	0.04
	MAK 13.8	N	92.5	9.5	0.55	0.07
	MAK 13.8	UV	95.0	5.7	0.63	0.03
Oct. 1992	BBK 12.5	N	82.5	15.0	0.37	0.09
	BBK 12.5	UV	100.0	0.0	0.46	0.03
	BBK 10.0	N	82.5	5.0	0.50	0.03
	BBK 10.0	UV	97.5	5.0	0.52	0.06
	BBK 9.1	N	97.5	5.0	0.54	0.08
	BBK 9.1	UV	100.0	0.0	0.53	0.04
	LUK 7.2	N	95.0	5.7	0.42	0.05
	LUK 7.2	UV	100.0	0.0	0.47	0.06
	MAK 13.8	N	90.0	11.5	0.41	0.02
	MAK 13.8	UV	95.0	5.7	0.45	0.02
Feb. 1993	BBK 12.5	N	65.0	10.0	0.82	0.06
	BBK 12.5	UV	95.0	10.0	0.75	0.10
	BBK 10.0	N	70.0	31.6	0.60	0.03
	BBK 10.0	UV	92.5	9.5	0.65	0.06
	BBK 9.1	N	85.0	5.7	0.90	0.12
	BBK 9.1	UV	90.0	8.1	0.70	0.08
	LUK 7.2	N	72.5	12.5	0.85	0.04
	LUK 7.2	UV	97.5	5.0	0.73	0.02
	MAK 13.8	N	95.0	10.0	0.83	0.03

Table B.1 (continued)

Test Date	Site[a]	Treatment[b]	Mean survival (%)	Survival SD (%)	Mean growth (mg)	Growth SD (mg)
	MAK 13.8	UV	45.0	51.9	0.69	0.01
May 1993	BBK 12.5	N	92.5	9.5	0.47	0.07
	BBK 12.5	UV	90.0	0.0	0.46	0.09
	BBK 10.0	N	95.0	5.7	0.51	0.05
	BBK 10.0	UV	97.5	5.0	0.45	0.06
	BBK 9.1	N	87.5	15.0	0.56	0.05
	BBK 9.1	UV	100.0	0.0	0.47	0.03
	LUK 7.2	N	97.5	5.0	0.49	0.04
	LUK 7.2	UV	95.0	5.7	0.51	0.04
	MAK 13.8	N	95.0	10.0	0.45	0.06
	MAK 13.8	UV	47.5	18.9	0.34	0.06
Aug. 1993	BBK 12.5	N	95.0	5.7	0.36	0.02
	BBK 12.5	UV	67.5	9.5	0.37	0.08
	BBK 10.0	N	95.0	10.0	0.35	0.02
	BBK 10.0	UV	97.5	5.0	0.42	0.03
	BBK 9.1	N	90.0	8.1	0.44	0.03
	BBK 9.1	UV	95.0	5.7	0.43	0.05
	LUK 7.2	N	97.5	5.0	0.45	0.13
	LUK 7.2	UV	100.0	0.0	0.43	0.03
	MAK 13.8	N	82.5	12.5	0.34	0.04
	MAK 13.8	UV	92.5	5.0	0.31	0.04
Oct. 1993	BBK 12.5	N	90.0	0.0	0.46	0.09
	BBK 12.5	UV	95.0	5.7	0.45	0.04
	BBK 10.0	N	100.0	0.0	0.39	0.09
	BBK 10.0	UV	97.5	5.0	0.48	0.05
	BBK 9.1	N	97.5	5.0	0.42	0.03
	BBK 9.1	UV	97.5	5.0	0.42	0.05
	LUK 7.2	N	92.5	5.0	0.40	0.01

Table B.1 (continued)

Test Date	Site[a]	Treatment[b]	Mean survival (%)	Survival SD (%)	Mean growth (mg)	Growth SD (mg)
	LUK 7.2	UV	92.5	5.0	0.39	0.05
	MAK 13.8	N	95.0	10.0	0.40	0.06
	MAK 13.8	UV	95.0	10.0	0.46	0.06

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

[b]N = non-treated; UV = treated with ultra violet light.

Table B.2. Summary of *Ceriodaphnia* survival and reproduction for ambient sites

Test Date	Site[a]	Survival (%)	Mean reproduction (Offspring/female)	Reproduction SD
Oct. 1991	BBK 12.5	100	38.10	10.81
	BBK 10.0	100	31.70	9.50
	BBK 9.1	70	32.43	14.39
	LUK 7.2	90	27.33	6.40
	MAK 13.8	90	43.11	2.57
Feb. 1992	BBK 12.5	100	30.90	3.11
	BBK 10.0	90	33.00	3.16
	BBK 9.1	100	32.80	3.79
	LUK 7.2	100	30.20	2.25
	MAK 13.8	90	27.33	4.82
May 1992	BBK 12.5	90	32.56	2.30
	BBK 10.0	100	30.10	8.13
	BBK 9.1	90	29.00	7.68
	LUK 7.2	100	31.00	9.78
	MAK 13.8	100	29.20	5.77
Aug. 1992	BBK 12.5	100	23.70	10.14
	BBK 10.0	100	25.60	7.73
	BBK 9.1	100	32.40	3.27
	LUK 7.2	100	29.20	3.55
	MAK 13.8	100	30.80	4.71
Oct. 1992	BBK 12.5	100	28.80	6.05
	BBK 10.0	100	28.70	7.59
	BBK 9.1	90	32.67	6.95
	LUK 7.2	100	30.60	5.23
	MAK 13.8	100	24.00	6.43
Feb. 1993	BBK 12.5	100	28.80	4.64
	BBK 10.0	100	30.50	4.12
	BBK 9.1	90	31.11	5.88
	LUK 7.2	90	30.89	3.76

Table B.2 (continued)

Test Date	Site[a]	Survival (%)	Mean reproduction (offspring/female)	Reproduction SD
	MAK 13.8	100	31.30	6.07
May 1993	BBK 12.5	90	17.25	6.23
	BBK 10.0	90	15.44	9.36
	BBK 9.1	80	17.75	8.10
	LUK 7.2	90	17.33	6.71
	MAK 13.8	100	12.33	5.98
Aug. 1993	BBK 12.5	100	20.60	7.23
	BBK 10.0	90	20.89	8.13
	BBK 9.1	100	25.70	9.50
	LUK 7.2	100	19.60	6.59
	MAK 13.8	100	19.40	7.63
Oct. 1993	BBK 12.5	100	22.60	4.48
	BBK 10.0	100	28.30	6.85
	BBK 9.1	100	29.50	7.28
	LUK 7.2	100	22.10	5.78
	MAK 13.8	100	18.80	2.74

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

Table B.3. Summary of water quality measurements taken for ambient sites (n = 7)

Parameter	Test date	Site[a]	Mean	SD	Min	Max
pH	Oct. 1991	BBK 12.5	7.57	0.15	7.38	7.83
(standard units)		BBK 10.0	7.55	0.08	7.45	7.65
		BBK 9.1	8.40	0.48	7.71	9.02
		LUK 7.2	7.62	0.11	7.48	7.79
		MAK 13.8	7.41	0.24	7.22	7.83
	Feb. 1992	BBK 12.5	7.50	0.19	7.13	7.69
		BBK 10.0	7.61	0.34	6.88	7.85
		BBK 9.1	7.77	0.27	7.17	7.92
		LUK 7.2	7.73	0.27	7.19	8.03
		MAK 13.8	7.57	0.33	6.84	7.79
	May 1992	BBK 12.5	7.80	0.15	7.49	7.95
		BBK 10.0	7.48	0.06	7.38	7.57
		BBK 9.1	7.72	0.06	7.63	7.8
		LUK 7.2	7.75	0.07	7.69	7.88
		MAK 13.8	7.49	0.14	7.32	7.67
	Aug. 1992	BBK 12.5	7.80	0.20	7.6	8.03
		BBK 10.0	7.74	0.10	7.57	7.83
		BBK 9.1	7.95	0.21	7.78	8.32
		LUK 7.2	7.69	0.11	7.52	7.86
		MAK 13.8	7.64	0.13	7.39	7.76
	Oct. 1992	BBK 12.5	7.51	0.31	6.98	7.88
		BBK 10.0	7.29	0.17	7.00	7.51
		BBK 9.1	7.54	0.09	7.45	7.67
		LUK 7.2	7.52	0.15	7.3	7.72
		MAK 13.8	7.32	0.12	7.15	7.48
	Feb. 1993	BBK 12.5	7.00	0.14	6.75	7.17
		BBK 10.0	7.28	0.12	7.11	7.45
		BBK 9.1	7.26	0.16	7.05	7.52
		LUK 7.2	7.18	0.19	6.94	7.43

Table B.3 (continued)

Parameter	Test date	Site[a]	Mean	SD	Min	Max
		MAK 13.8	7.15	0.13	7.00	7.37
	May 1993	BBK 12.5	7.54	0.15	7.35	7.7
		BBK 10.0	7.36	0.18	7.02	7.55
		BBK 9.1	7.70	0.20	7.34	7.93
		LUK 7.2	7.47	0.24	7.07	7.79
		MAK 13.8	7.28	0.13	7.11	7.42
	Aug. 1993	BBK 12.5	7.57	0.14	7.40	7.8
		BBK 10.0	7.27	0.10	7.18	7.48
		BBK 9.1	7.53	0.07	7.41	7.64
		LUK 7.2	7.44	0.11	7.24	7.57
		MAK 13.8	7.11	0.09	6.99	7.24
	Oct. 1993	BBK 12.5	7.69	0.16	7.51	7.92
		BBK 10.0	7.38	0.08	7.28	7.49
		BBK 9.1	7.72	0.07	7.58	7.78
		LUK 7.2	7.50	0.12	7.39	7.74
		MAK 13.8	7.36	0.21	7.20	7.69
Conductivity	Oct. 1991	BBK 12.5	249.86	25.82	218	281
(μS/cm)		BBK 10.0	286.43	24.34	256	319
		BBK 9.1	906.86	289.10	610	1277
		LUK 7.2	301.86	21.08	280	333
		MAK 13.8	144.86	13.41	128	167
	Feb. 1992	BBK 12.5	145.00	21.62	112	171
		BBK 10.0	174.14	26.98	126	203
		BBK 9.1	318.43	70.65	207	401
		LUK 7.2	176.71	42.78	100	217
		MAK 13.8	123.71	15.26	98	141
	May 1992	BBK 12.5	258.00	4.73	253	265
		BBK 10.0	268.71	12.74	254	291
		BBK 9.1	658.14	248.32	353	952
		LUK 7.2	297.43	14.26	278	314

Table B.3 (continued)

Parameter	Test date	Site[a]	Mean	SD	Min	Max
		MAK 13.8	138.14	6.04	130	148
	Aug. 1992	BBK 12.5	242.43	4.20	236	250
		BBK 10.0	222.14	16.43	198	250
		BBK 9.1	625.00	239.13	307	885
		LUK 7.2	238.43	25.28	203	268
		MAK 13.8	131.14	7.13	116	136
	Oct. 1992	BBK 12.5	228.71	23.21	202	261
		BBK 10.0	256.57	17.42	239	288
		BBK 9.1	893.43	172.55	706	1167
		LUK 7.2	259.00	16.48	242	287
		MAK 13.8	137.71	1.98	135	141
	Feb. 1993	BBK 12.5	146.14	36.05	111	218
		BBK 10.0	171.43	29.19	122	215
		BBK 9.1	307.57	93.67	184	455
		LUK 7.2	175.71	43.65	113	240
		MAK 13.8	132.00	9.61	120	144
	May 1993	BBK 12.5	228.00	7.33	215	238
		BBK 10.0	269.57	7.59	258	280
		BBK 9.1	861.00	146.41	640	1054
		LUK 7.2	347.29	8.58	336	360
		MAK 13.8	136.29	1.50	134	138
	Aug. 1993	BBK 12.5	257.14	9.51	242	264
		BBK 10.0	259.43	17.42	236	282
		BBK 9.1	532.00	196.36	252	793
		LUK 7.2	267.71	23.72	231	296
		MAK 13.8	131.71	10.63	114	144
	Oct. 1993	BBK 12.5	235.14	10.76	216	250
		BBK 10.0	264.14	54.28	193	317
		BBK 9.1	810.14	230.00	541	1049
		LUK 7.2	325.57	45.50	253	375

Table B.3 (continued)

Parameter	Test date	Site[a]	Mean	SD	Min	Max
		MAK 13.8	144.57	8.79	130	154
Alkalinity	Oct. 1991	BBK 12.5	75.71	8.10	64	84
(mg/L as $CaCO_3$)		BBK 10.0	43.29	4.11	38	50
		BBK 9.1	38.71	5.12	32	44
		LUK 7.2	49.71	5.77	43	56
		MAK 13.8	43.00	4.32	37	49
	Feb. 1992	BBK 12.5	29.43	5.80	20	36
		BBK 10.0	33.86	4.98	24	39
		BBK 9.1	34.14	4.56	26	40
		LUK 7.2	40.14	10.73	21	52
		MAK 13.8	25.00	2.77	21	29
	May 1992	BBK 12.5	72.86	2.61	68	76
		BBK 10.0	39.00	3.70	35	43
		BBK 9.1	33.86	1.21	33	36
		LUK 7.2	55.57	7.41	47	71
		MAK 13.8	40.00	2.16	37	43
	Aug. 1992	BBK 12.5	67.71	1.11	66	69
		BBK 10.0	33.71	2.56	30	38
		BBK 9.1	33.86	1.35	31	35
		LUK 7.2	37.43	2.82	33	41
		MAK 13.8	35.57	0.79	35	37
	Oct. 1992	BBK 12.5	53.29	11.66	33	66
		BBK 10.0	34.43	1.40	33	37
		BBK 9.1	31.71	1.50	30	34
		LUK 7.2	43.57	1.51	42	46
		MAK 13.8	36.29	1.60	34	38
	Feb. 1993	BBK 12.5	26.43	5.19	19	36
		BBK 10.0	30.29	2.75	27	33
		BBK 9.1	32.14	4.02	25	36

Table B.3 (continued)

Parameter	Test date	Site[a]	Mean	SD	Min	Max
		LUK 7.2	36.29	9.81	20	48
		MAK 13.8	27.00	2.77	22	30
	May 1993	BBK 12.5	57.14	5.90	44	61
		BBK 10.0	43.29	2.29	40	46
		BBK 9.1	46.86	4.45	41	53
		LUK 7.2	65.00	2.52	61	69
		MAK 13.8	37.71	2.21	36	42
	Aug. 1993	BBK 12.5	75.43	1.40	73	77
		BBK 10.0	32.57	1.99	30	36
		BBK 9.1	36.86	1.86	35	39
		LUK 7.2	39.71	2.21	38	44
		MAK 13.8	38.57	4.50	29	42
	Oct. 1993	BBK 12.5	75.71	1.50	74	78
		BBK 10.0	47.00	8.56	42	66
		BBK 9.1	52.00	6.68	42	64
		LUK 7.2	53.14	13.15	41	75
		MAK 13.8	43.43	3.26	40	49
Hardness	Oct. 1991	BBK 12.5	63.14	15.95	50	98
(mg/L as $CaCO_3$)		BBK 10.0	76.00	16.37	64	112
		BBK 9.1	256.57	75.47	172	346
		LUK 7.2	93.29	15.97	72	111
		MAK 13.8	50.29	16.99	40	88
	Feb. 1992	BBK 12.5	56.86	7.10	50	70
		BBK 10.0	67.43	6.60	54	74
		BBK 9.1	100.57	22.02	64	122
		LUK 7.2	66.00	12.70	50	88
		MAK 13.8	47.14	5.15	40	54
	May 1992	BBK 12.5	74.29	8.75	64	86
		BBK 10.0	80.29	9.41	70	94

Table B.3 (continued)

Parameter	Test date	Site[a]	Mean	SD	Min	Max
		BBK 9.1	198.00	77.89	100	282
		LUK 7.2	88.29	8.20	76	98
		MAK 13.8	52.00	5.89	42	58
	Aug. 1992	BBK 12.5	59.43	6.19	50	68
		BBK 10.0	65.14	8.63	56	80
		BBK 9.1	166.57	66.89	90	260
		LUK 7.2	72.29	4.54	68	80
		MAK 13.8	40.00	5.42	32	46
	Oct. 1992	BBK 12.5	73.71	9.20	60	86
		BBK 10.0	78.29	5.94	70	86
		BBK 9.1	261.14	36.48	216	324
		LUK 7.2	75.14	5.87	66	84
		MAK 13.8	49.14	6.09	38	54
	Feb. 1993	BBK 12.5	60.57	14.22	42	84
		BBK 10.0	66.57	10.56	52	80
		BBK 9.1	105.14	27.93	72	154
		LUK 7.2	64.86	12.85	48	82
		MAK 13.8	63.71	18.38	46	98
	May 1993	BBK 12.5	64.57	9.14	54	78
		BBK 10.0	92.29	21.71	76	140
		BBK 9.1	286.57	49.34	200	340
		LUK 7.2	90.86	15.57	72	120
		MAK 13.8	58.57	15.69	42	78
	Aug. 1993	BBK 12.5	57.14	5.76	50	66
		BBK 10.0	70.57	6.08	60	78
		BBK 9.1	148.86	55.82	78	228
		LUK 7.2	76.86	7.29	62	84
		MAK 13.8	45.71	6.78	38	54
	Oct. 1993	BBK 12.5	68.86	25.74	54	124
		BBK 10.0	86.29	11.28	64	100

Table B.3 (continued)

Parameter	Test date	Site[a]	Mean	SD	Min	Max
		BBK 9.1	255.14	63.70	172	328
		LUK 7.2	103.57	11.13	92	124
		MAK 13.8	50.14	12.81	38	76
Temperature (°C)	Oct. 1991	BBK 12.5	18.17	1.56	15.7	21.0
		BBK 10.0	20.94	0.55	20.0	21.6
		BBK 9.1	20.24	0.58	19.4	21.1
		LUK 7.2	20.47	0.60	19.2	20.9
		MAK 13.8	17.93	0.85	16.2	18.8
	Feb. 1992	BBK 12.5	8.30	1.13	7.0	10.6
		BBK 10.0	8.67	1.14	7.3	10.9
		BBK 9.1	8.80	0.97	7.7	10.6
		LUK 7.2	8.99	1.01	7.8	10.9
		MAK 13.8	8.10	1.13	7.0	10.4
	May 1992	BBK 12.5	17.49	2.42	14.6	20.0
		BBK 10.0	20.79	1.83	18.3	23.1
		BBK 9.1	21.53	2.06	18.6	23.8
		LUK 7.2	19.00	2.56	15.7	21.7
		MAK 13.8	18.56	2.58	15.0	21.3
	Aug. 1992	BBK 12.5	19.54	1.57	17.6	21.7
		BBK 10.0	23.76	1.55	21.5	26.1
		BBK 9.1	24.49	1.57	22.3	26.3
		LUK 7.2	21.80	1.35	20.1	23.6
		MAK 13.8	20.97	1.48	19.5	23.0
	Oct. 1992	BBK 12.5	12.97	1.03	11.4	14.4
		BBK 10.0	17.84	0.85	16.6	19.0
		BBK 9.1	15.81	1.62	12.7	17.3
		LUK 7.2	16.10	1.52	13.9	18.2
		MAK 13.8	13.66	1.15	12.4	15.0
	Feb. 1993	BBK 12.5	4.16	3.15	1.1	10.3
		BBK 10.0	5.36	3.31	1.4	10.6

Table B.3 (continued)

Parameter	Test date	Site[a]	Mean	SD	Min	Max
		BBK 9.1	5.76	3.17	1.9	10.7
		LUK 7.2	6.16	3.41	2.1	11.9
		MAK 13.8	5.11	3.07	1.8	9.4
	May 1993	BBK 12.5	15.11	1.72	13	17.5
		BBK 10.0	17.93	2.06	14.7	20.2
		BBK 9.1	18.24	2.31	13.5	20.6
		LUK 7.2	17.79	1.66	15.4	19.8
		MAK 13.8	16.36	1.79	13.8	18.9
	Aug. 1993	BBK 12.5	23.87	0.87	22.1	24.6
		BBK 10.0	27.49	0.75	26.1	28.5
		BBK 9.1	28.24	0.69	26.8	29.0
		LUK 7.2	26.27	0.86	24.6	27.4
		MAK 13.8	24.70	0.98	23.1	25.8
	Oct. 1993	BBK 12.5	15.43	2.04	12.2	17.5
		BBK 10.0	18.17	2.19	14.0	20.2
		BBK 9.1	18.06	2.32	13.8	19.8
		LUK 7.2	18.20	1.75	15.4	19.9
		MAK 13.8	16.37	1.64	13.1	18.2

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

Appendix C
CONCENTRATIONS OF CONTAMINANTS IN INDIVIDUAL FISH AND QUALITY ASSURANCE SUMMARY FOR POLYCHLORINATED BIPHENYLS ANALYSES

QUALITY ASSURANCE SUMMARY

Results of analyses of uncontaminated fish that were spiked with known concentrations of PCB standards were improved over 1992. Matrix spike recoveries averaged (± SD) 76 ± 27% (n = 13). Spike recoveries in the April 1993 samples averaged 94%, while the October 1992 samples averaged 56%. Recoveries of decachlorobiphenyl (DCBP) internal recovery standards, added to each sample prior to extraction, were similar to PCB spikes averaging 80 ± 14 % (n = 142). The mean absolute difference between duplicate samples was 0.19 ± 0.26 µg/g (n = 13). Mean coefficient of variation among duplicates was 44%. PCBs were not found in fish from uncontaminated reference sites (mean concentration <0.04 µg/g, n = 12).

Overall, the PCB results display a pattern expected from previous studies at Big and Little Bayou creeks and would not lead to any conclusions different from those made previously. Variability remains higher than desired, but not atypical of PCB analyses of biological samples.

In pesticide screening studies, matrix spike recoveries were 126% for Aroclor 1254 and 63% for gamma chlordane.

Analyses of standard reference mercury contaminated fish yielded results close to the published true value of 2.52 µg/g, averaging 2.58 ± 0.11 µg/g (n = 15). Mean absolute difference between duplicate samples was small, 0.03 ± 0.04 µg/g (n = 7), with a mean coefficient of variation of 7%. Analyses of reference site samples averaged 0.06 ± 0.03 (n = 6), a value slightly below the long term average at the Hinds Creek reference site. In screening analyses, mean (n = 4) recoveries of matrix spike additions of metals to reference site fish ranged from a low of 89% for thallium to a high of 110% for selenium, with an overall average (±SD) for all metals of 96 ± 4%.

Table C.1. Concentrations of mercury and polychlorinated biphenyls in individual longear sunfish collected from Big Bayou Creek and Little Bayou Creek

Site[a]	Type[b]	Date	Spp[c]	Sex[d]	Tag[e]	Wgt[f]	Lgth[g]	Hg[h]	ΣPCB[i]	1248[j]	1254[k]	1260[l]	Lipid[m]
BBK 12.5	R	04/27/93	LNGEAR	M	4510	69.0	13.8	0.12	<0.12	<0.06	<0.12	<0.12	0.32
BBK 12.5	R	04/27/93	LNGEAR	M	4511	46.0	13.2	0.09	<0.09	<0.05	<0.09	<0.09	0.29
BBK 12.5	R	04/27/93	LNGEAR	M	4512	51.5	13.4	0.07	<0.08	<0.04	<0.08	<0.08	0.60
BBK 12.5	R	04/27/93	LNGEAR	M	4513	81.0	15.0	0.15	<0.08	<0.08	<0.16	<0.16	0.26
BBK 12.5	R	04/27/93	LNGEAR	M	4514	75.0	13.9	0.13	<0.06	<0.03	<0.06	<0.06	0.63
BBK 12.5	R	04/27/93	LNGEAR	M	4515	42.3	12.3	0.07	<0.05	<0.05	<0.10	<0.10	0.68
BBK 12.5	R	04/27/93	LNGEAR	M	4516	57.7	13.3	0.06	<0.03	<0.03	<0.06	<0.06	0.46
BBK 12.5	R	04/27/93	LNGEAR	F	4517	49.9	12.7	0.12	<0.06	<0.03	<0.06	<0.06	0.41
BBK 10.0	R	04/27/93	LNGEAR	M	4490	91.1	15.5	0.19	0.16	<0.04	0.07	0.09	0.60
BBK 10.0	R	04/27/93	LNGEAR	M	4491	39.7	12.1	0.12	0.20	<0.05	0.08	0.12	0.53
BBK 10.0	R	04/27/93	LNGEAR	M	4492	65.9	15.0	0.53	0.12	<0.03	<0.06	0.12	0.24
BBK 10.0	R	04/27/93	LNGEAR	M	4493	39.2	12.3	0.16	0.21	<0.05	0.08	0.13	0.30
BBK 10.0	R	04/27/93	LNGEAR	M	4494	41.4	12.4	0.24	0.38	<0.05	0.12	0.26	0.36
BBK 10.0	R	04/27/93	LNGEAR	M	4495	63.1	14.3	0.16	0.16	<0.03	0.04	0.12	0.58
BBK 10.0	R	04/27/93	LNGEAR	M	4496	42.1	13.0	0.12	0.28	<0.08	<0.16	0.28	0.18
BBK 10.0	R	04/27/93	LNGEAR	M	4497	35.5	12.0	0.27	0.38	<0.07	0.19	0.19	0.43
BBK 9.1	R	04/27/93	LNGEAR	M	4450	70.2	13.8	0.32	.	.	.	.	.
BBK 9.1	R	04/27/93	LNGEAR	M	4451	51.2	13.5	0.39	0.35	<0.04	0.15	0.20	0.16
BBK 9.1	R	04/27/93	LNGEAR	F	4452	54.7	13.2	0.49	0.09	<0.05	0.09	<0.09	0.35
BBK 9.1	R	04/27/93	LNGEAR	M	4453	57.2	13.6	0.28	0.13	<0.11	0.13	<0.22	0.19
BBK 9.1	R	04/27/93	LNGEAR	M	4454	47.9	13.0	.	.	.	.	.	.
BBK 9.1	R	04/27/93	LNGEAR	M	4455	57.0	13.8	0.29	0.26	<0.04	0.14	0.12	0.21
BBK 9.1	R	04/27/93	LNGEAR	M	4456	51.5	13.4	.	0.08	<0.04	0.08	<0.08	0.32
BBK 9.1	R	04/27/93	LNGEAR	M	4457	55.5	14.1	.	0.50	<0.05	0.34	0.16	0.44
BBK 9.1	R	04/27/93	LNGEAR	M	4458	48.2	12.7	0.29	0.26	<0.05	0.12	0.14	1.18
BBK 9.1	R	04/27/93	LNGEAR	F	4459	61.6	13.4	0.39	.	.	.	.	.
BBK 9.1	R	04/27/93	LNGEAR	F	4438	64.2	14.4	0.51	0.51	<0.06	0.24	0.27	0.55

Table C.1 (continued)

Site[a]	Type[b]	Date	Spp[c]	Sex[d]	Tag[e]	Wgt[f]	Lgth[g]	Hg[h]	ΣPCB[i]	1248[j]	1254[k]	1260[l]	Lipid[m]
BBK 9.1	R	04/27/93	LNGEAR	M	4453	57.2	13.6	.	0.49	0.06	0.21	0.22	0.15
BBK 9.1	R	04/27/93	LNGEAR	M	4454	47.9	13.0	.	0.20	<0.04	0.11	0.09	0.18
BBK 9.1	R	04/27/93	LNGEAR	F	4459	61.6	13.4	.	0.77	<0.04	0.40	0.37	1.06
BBK 9.1	R	04/27/93	LNGEAR	F	4437	45.5	13.0	.	0.26	<0.05	0.13	0.13	0.23
BBK 2.8	R	05/27/93	LNGEAR	F	4710	51.1	12.6	0.28	0.01	<0.04	0.01	<0.08	1.12
BBK 2.8	R	05/27/93	LNGEAR	F	4711	42.5	12.6	0.26	0.01	<0.22	<0.44	0.01	0.63
BBK 2.8	R	05/27/93	LNGEAR	M	4712	36.0	11.4	0.20	0.09	<0.30	<0.60	0.01	0.47
BBK 2.8	R	05/27/93	LNGEAR	M	4713	61.8	13.0	0.19	<0.30	<0.15	<0.30	<0.30	0.00
BBK 2.8	R	05/27/93	LNGEAR	M	4714	67.6	14.1	0.15	0.07	0.02	<0.30	0.05	0.90
BBK 2.8	R	05/27/93	LNGEAR	M	4715	48.9	12.4	0.20	0.09	0.04	<0.45	0.05	1.39
BBK 2.8	R	05/27/93	LNGEAR	F	4716	46.8	12.4	0.26	0.01	<0.22	<0.45	0.01	0.58
BBK 2.8	R	05/27/93	LNGEAR	M	4717	34.7	11.2	0.31	0.10	0.01	<0.50	0.09	1.38
LUK 9.0	R	04/27/93	LNGEAR	M	4530	37.7	12.5	.	0.72	<0.06	0.37	0.35	0.00
LUK 9.0	R	04/27/93	LNGEAR	M	4531	25.8	10.9	.	0.51	<0.09	0.31	0.20	0.20
LUK 9.0	R	04/27/93	LNGEAR	M	4532	18.5	10.0	.	0.45	0.23	0.14	0.08	0.03
LUK 9.0	R	04/27/93	LNGEAR	M	4533	20.6	10.1	.	0.37	0.14	0.18	0.05	0.03
LUK 9.0	R	04/27/93	LNGEAR	M	4534	23.1	10.4	.	1.58	0.63	0.52	0.43	0.00
LUK 9.0	R	04/27/93	LNGEAR	M	4535	20.8	10.1	.	3.01	1.25	0.92	0.84	0.38
LUK 9.0	R	04/27/93	LNGEAR	M	4536	15.5	8.8	.	2.68	1.27	0.80	0.61	0.06
LUK 9.0	R	04/27/93	LNGEAR	M	4537	17.7	9.6	.	4.53	1.94	1.44	1.15	0.08
LUK 7.2	R	04/27/93	LNGEAR	M	4520	44.5	12.4	0.10	1.01	<0.04	0.51	0.50	0.42
LUK 7.2	R	04/27/93	LNGEAR	M	4521	44.0	13.0	0.07	.	.	.	.	.
LUK 7.2	R	04/27/93	LNGEAR	M	4522	41.8	12.2	0.10	0.78	<0.04	0.44	0.29	0.29
LUK 7.2	R	04/27/93	LNGEAR	M	4523	52.9	12.5	0.07	.	.	.	.	.
LUK 7.2	R	04/27/93	LNGEAR	M	4524	47.9	12.4	0.10	0.34	0.05	0.15	0.14	0.56

Table C.1 (continued)

Site[a]	Type[b]	Date	Spp[c]	Sex[d]	Tag[e]	Wgt[f]	Lgth[g]	Hg[h]	ΣPCB[i]	1248[j]	1254[k]	1260[l]	Lipid[m]
LUK 7.2	R	04/27/93	LNGEAR	M	4525	46.8	13.1	0.06	.	.	.	.	.
LUK 7.2	R	04/27/93	LNGEAR	M	4527	35.6	11.0	0.08	0.47	<0.06	0.26	0.21	0.10
LUK 7.2	R	04/27/93	LNGEAR	M	4528	51.7	13.0	0.07	.	.	.	.	.
LUK 4.3	R	04/27/93	LNGEAR	M	4500	56.0	13.3	.	0.33	<0.04	0.09	0.24	0.42
LUK 4.3	R	04/27/93	LNGEAR	M	4501	44.8	12.0	.	1.02	<0.06	0.48	0.54	2.09
LUK 4.3	R	04/27/93	LNGEAR	M	4502	32.6	11.9	.	0.70	<0.05	0.61	0.09	0.07
LUK 4.3	R	04/27/93	LNGEAR	M	4503	34.8	11.8	.	0.24	<0.04	0.11	0.13	0.23
LUK 4.3	R	04/27/93	LNGEAR	M	4504	60.4	13.4	.	0.25	0.04	0.11	0.10	4.54
LUK 4.3	R	04/27/93	LNGEAR	M	4507	33.4	11.6	.	0.41	<0.05	0.18	0.23	0.80
LUK 4.3	R	04/27/93	LNGEAR	M	4508	38.2	11.3	.	0.29	<0.05	0.12	0.17	0.76
LUK 4.3	R	04/27/93	LNGEAR	M	4509	39.2	11.5	.	0.10	<0.07	0.05	0.05	0.16
LUK 4.3	R	04/27/93	SPBASS	M	4319	140.4	21.3	0.18	0.93	0.11	0.34	0.48	0.54
LUK 7.2	R	04/27/93	LMBASS	M	4539	140.9	20.3	0.27	0.57	<0.14	0.30	0.27	0.20
MASSAC	R	04/28/93	LNGEAR	M	4430	57.0	14.0	0.22	0.00	0.00	0.00	0.00	0.00
MASSAC	R	04/28/93	LNGEAR	M	4431	49.5	13.6	0.17	0.00	0.00	0.00	0.00	0.00
MASSAC	R	04/28/93	LNGEAR	F	4432	39.4	11.7	0.24	0.00	0.00	0.00	0.00	0.00
MASSAC	R	04/28/93	LNGEAR	M	4433	38.0	11.7	0.14	0.00	0.00	0.00	0.00	0.00
MASSAC	R	04/28/93	LNGEAR	M	4434	65.1	14.2	0.16	0.00	0.00	0.00	0.00	0.00
MASSAC	R	04/28/93	LNGEAR	M	4435	69.8	13.6	0.08	0.00	0.00	0.00	0.00	0.00
MASSAC	R	04/28/93	LNGEAR	M	4436	36.3	11.8	0.10	0.00	0.00	0.00	0.00	0.00
MASSAC	R	04/28/93	LNGEAR	M	4498	47.6	13.4	0.19	0.00	0.00	0.00	0.00	0.00
HINDSCR	R	05/05/93	REDBRE	M	4465	47.9	13.2	0.03	.	.	.	.	.
HINDSCR	R	05/05/93	REDBRE	M	4466	45.2	12.8	.	<0.07	<0.03	<0.07	<0.07	0.00
HINDSCR	R	05/05/93	REDBRE	F	4467	71.9	15.4	0.05	<0.07	<0.03	<0.07	<0.07	0.81
HINDSCR	R	05/05/93	REDBRE	F	4477	46.9	13.0	0.09	<0.05	<0.05	<0.09	<0.09	0.36

Table C.1 (continued)

Site[a]	Type[b]	Date	Spp[c]	Sex[d]	Tag[e]	Wgt[f]	Lgth[g]	Hg[h]	ΣPCB[i]	1248[j]	1254[k]	1260[l]	Lipid[m]	
HINDSCR	R	05/05/93	REDBRE	F	4476	39.7	12.5	.	<0.09	<0.05	<0.09	<0.09	0.46	
HINDSCR	R	05/05/93	REDBRE	M	4464	79.1	15.9	0.04	<0.07	0.03	0.07	0.07	0.74	
HINDSCR	R	05/05/93	REDBRE	F	4474	47.9	13.2	0.08	<0.05	<0.05	<0.10	<0.10	0.55	
HINDSCR	R	05/05/93	REDBRE	M	4485	153.0	18.5	0.09	.	.	.	.	.	
BBK 12.5	R	10/19/92	LNGEAR	M	3840	40.9	12.9	.	<0.10	<0.05	<0.10	<0.10	0.16	
BBK 12.5	R	10/19/92	LNGEAR	M	3841	41.0	13.1	.	<0.10	<0.05	<0.10	<0.10	0.13	
BBK 12.5	R	10/19/92	LNGEAR	M	3842	46.0	12.8	.	<0.09	<0.05	<0.09	<0.09	1.23	
BBK 12.5	R	10/19/92	LNGEAR	M	3843	52.6	13.9	.	<0.10	<0.05	<0.10	<0.10	0.33	
BBK 12.5	R	10/19/92	LNGEAR	M	3844	47.4	13.7	.	<0.09	<0.05	<0.09	<0.09	0.53	
BBK 12.5	R	10/19/92	LNGEAR	M	3845	84.2	16.1	.	<0.11	<0.05	<0.11	<0.11	.	
BBK 12.5	R	10/19/92	LNGEAR	M	3846	58.0	14.4	.	<0.06	<0.03	<0.06	<0.06	0.36	
BBK 12.5	R	10/19/92	LNGEAR	.	3847	72.8	14.7	.	<0.05	<0.05	<0.05	<0.05	0.68	
BBK 10.0	R	10/19/92	LNGEAR	M	3880	41.2	13.4	.	0.31	0.13	0.07	0.11	0.30	
BBK 10.0	R	10/19/92	LNGEAR	M	3881	51.4	13.5	.	0.05	<0.07	<0.07	0.05	0.36	
BBK 10.0	R	10/19/92	LNGEAR	M	3882	44.1	13.6	.	0.27	0.10	0.07	0.10	0.40	
BBK 10.0	R	10/19/92	LNGEAR	M	3883	53.5	14.1	.	0.63	0.18	0.22	0.23	0.58	
BBK 10.0	R	10/19/92	LNGEAR	F	3884	45.3	13.5	.	0.38	0.10	0.12	0.16	0.36	
BBK 10.0	R	10/19/92	LNGEAR	M	3885	49.2	13.9	.	0.06	<0.09	<0.09	0.06	0.41	
BBK 10.0	R	10/19/92	LNGEAR	M	3886	48.2	13.4	.	0.58	0.18	0.18	0.22	0.40	
BBK 10.0	R	10/19/92	LNGEAR	M	3887	42.0	12.9	.	0.35	0.12	0.10	0.13	1.00	
BBK 9.1	R	10/19/92	LNGEAR	M	3870	56.3	14.3	.	0.34	0.16	0.08	0.10	0.17	
BBK 9.1	R	10/19/92	LNGEAR	M	3871	50.4	13.8	.	0.53	0.16	0.10	0.27	0.23	
BBK 9.1	R	10/19/92	LNGEAR	M	3872	45.9	13.2	.	0.34	0.16	0.08	0.10	0.25	
BBK 9.1	R	10/19/92	LNGEAR	M	3873	56.8	15.3	.	0.41	0.14	0.12	0.15	0.21	
BBK 9.1	R	10/19/92	LNGEAR	M	3874	39.6	13.0	.	0.65	0.22	0.16	0.27	0.64	
BBK 9.1	R	10/19/92	LNGEAR	M	3875	58.0	14.2	.	0.39	0.13	0.14	0.12	0.33	

Table C.1 (continued)

Site[a]	Type[b]	Date	Spp[c]	Sex[d]	Tag[e]	Wgt[f]	Lgth[g]	Hg[h]	ΣPCB[i]	1248[j]	1254[k]	1260[l]	Lipid[m]
BBK 9.1	R	10/19/92	LNGEAR	M	3876	55.9	14.4	.	0.04	<0.05	<0.08	0.04	0.23
BBK 9.1	R	10/19/92	LNGEAR	M	3877	45.9	13.1	.	0.33	0.19	0.06	0.08	0.18
BBK 9.1	R	10/20/92	SPBASS	M	3848	333	29.2	0.60	0.08	0.005	0.015	0.08	0.41
BBK 9.1	R	10/20/92	SPBASS	M	3849	582	35.9	1.00	0.19	0.06	0.015	0.13	.
BBK 9.1	R	10/20/92	SPBASS	F	3858	334	29.0	0.55	0.11	0.005	0.015	0.11	0.55
BBK 9.1	R	10/20/92	SPBASS	F	3859	651	35.2	0.93	0.12	0.03	0.015	0.09	.
BBK 9.1	R	10/20/92	SPBASS	F	3878	708	36.1	0.61	0.11	0.04	0.015	0.07	.
BBK 9.1	R	10/20/92	SPBASS	M	3879	443	31.5	0.44	0.13	0.03	0.015	0.10	0.42
BBK 9.1	R	10/20/92	SPBASS	M	3888	433	30.6	0.58	0.15	0.02	0.015	0.13	.
BBK 9.1	R	10/20/92	SPBASS	M	3889	540	35.5	1.00	0.35	0.05	0.015	0.30	.
BBK 2.8	R	10/19/92	LNGEAR	M	3850	43.2	13.5	.	0.10	<0.05	<0.10	0.10	0.36
BBK 2.8	R	10/19/92	LNGEAR	F	3851	40.0	13.4	.	0.08	<0.05	<0.10	0.08	0.96
BBK 2.8	R	10/19/92	LNGEAR	M	3852	40.0	14.0	.	0.28	<0.05	0.09	0.19	0.32
BBK 2.8	R	10/19/92	LNGEAR	M	3853	36.3	12.9	.	0.32	0.15	0.05	0.12	0.34
BBK 2.8	R	10/19/92	LNGEAR	M	3854	39.5	13.0	.	0.07	<0.07	<0.13	0.07	0.32
BBK 2.8	R	10/19/92	LNGEAR	M	3855	35.2	13.5	.	0.07	<0.03	<0.07	0.07	0.25
BBK 2.8	R	10/19/92	LNGEAR	M	3856	36.8	12.0	.	0.18	<0.05	<0.10	0.18	0.55
BBK 2.8	R	10/19/92	LNGEAR	M	3857	42.0	13.4	.	0.53	<0.04	0.22	0.31	0.21
LUK 9.0	R	10/20/92	LNGEAR	F	3860	18.6	10.4	.	1.18	0.23	0.51	0.44	1.30
LUK 9.0	R	10/20/92	LNGEAR	M	3861	19.8	10.7	.	2.97	0.32	1.09	1.56	1.16
LUK 9.0	R	10/20/92	LNGEAR	M	3862	14.7	9.1	.	0.35	<0.10	<0.20	0.35	0.23
LUK 9.0	R	10/20/92	LNGEAR	M	3863	21.1	10.9	.	0.94	<0.07	0.50	0.44	0.87
LUK 9.0	R	10/20/92	LNGEAR	M	3864	26.5	11.5	.	1.49	<0.07	0.77	0.72	0.75
LUK 9.0	R	10/20/92	LNGEAR	M	3866	20.6	10.4	.	0.43	<0.05	0.19	0.24	0.13
LUK 9.0	R	10/20/92	LNGEAR	M	3867	16.8	10.3	.	0.27	<0.07	0.16	0.11	0.31
LUK 9.0	R	10/20/92	LNGEAR	F	3869	18.9	10.1	.	0.63	<0.05	0.33	0.30	0.24

Table C.1 (continued)

Site[a]	Type[b]	Date	Spp[c]	Sex[d]	Tag[e]	Wgt[f]	Lgth[g]	Hg[h]	ΣPCB[i]	1248[j]	1254[k]	1260[l]	Lipid[m]
LUK 4.3	R	10/20/92	LNGEAR	M	4100	31.4	11.9	.	0.35	0.09	0.13	0.13	0.12
LUK 4.3	R	10/20/92	LNGEAR	M	4101	28.9	11.5	.	0.27	0.07	0.13	0.07	0.13
LUK 4.3	R	10/20/92	LNGEAR	F	4102	37.3	13.4	.	0.05	<0.05	<0.10	0.05	0.26
LUK 4.3	R	10/20/92	LNGEAR	M	4103	30.4	11.5	.	0.37	0.13	0.10	0.14	0.30
LUK 4.3	R	10/20/92	LNGEAR	M	4104	44.6	13.6	.	0.06	<0.04	<0.09	0.06	0.11
LUK 4.3	R	10/20/92	LNGEAR	M	4105	30.8	11.8	.	<0.07	<0.04	<0.07	<0.07	0.14
LUK 4.3	R	10/20/92	LNGEAR	M	4106	25.5	11.3	.	<0.07	<0.04	<0.07	<0.07	0.23
LUK 4.3	R	10/20/92	LNGEAR	M	4107	26.6	11.5	.	0.05	<0.04	<0.09	0.05	0.20
HINDSCR	R	11/30/92	REDBRE	F	4110	32.7	12.5	.	<0.15	<0.08	<0.15	<0.15	0.51
HINDSCR	R	11/30/92	REDBRE	M	4111	57.9	16.2	.	<0.07	<0.04	<0.07	<0.07	0.24
HINDSCR	R	11/30/92	REDBRE	F	4113	43.7	14.1	.	<0.11	<0.05	<0.11	<0.11	.
HINDSCR	R	11/30/92	REDBRE	M	4115	39.5	14.0	.	<0.11	<0.05	<0.11	<0.11	0.18
HINDSCR	R	11/30/92	REDBRE	M	4116	48.3	14.8	.	<0.08	<0.04	<0.08	<0.08	0.31
HINDSCR	R	11/30/92	REDBRE	F	4121	35.2	13.4	.	<0.10	<0.05	<0.10	<0.10	0.14

[a]BBK = Big Bayou Creek kilometer; LUK = Little Bayou Creek kilometer; MAK = Massac Creek kilometer; HINDSCR = Hinds Creek.
[b]R = regular; C = reference site; D = duplicate.
[c]Spp = species, LNGEAR = Longear sunfish, *Lepomis megalotus*; REDBRE = redbreast sunfish, *Lepomis auritus*.
[d]Sex: M = male; F = female.
[e]Tag = fish identification tag number.
[f]Weight in grams.
[g]Length = total length, in centimeters.
[h]Hg = total mercury concentration, micrograms per gram wet wt.
[i]ΣPCB = sum of PCBs quantified as specific Aroclor mixtures, micrograms per gram wet wt.
[j]1248 = PCBs quantified as similar to Aroclor 1248, in micrograms per gram wet wt.
[k]1254 = PCBs quantified as similar to Aroclor 1254, in micrograms per gram wet wt.
[l]1260 = PCBs quantified as similar to Aroclor 1260, in micrograms per gram wet wt.
[m]Lipid = Lipid content of fish fillet, percentage wet weight.

Table C.2. Concentrations of metals in longear sunfish from Little Bayou Creek and Big Bayou Creek, April 1993

Site[a]	Spp	Date	Sex	Tag	Wgt (g)	Lgth (cm)	Ag	As	Be	Cd	Cr	Cu	Ni	Pb	Sb	Se	Tl	U	Zn
BBK 9.1	LONGEAR	4/27/93	M	4450	70.2	13.8	<0.04	0.06	<0.003	<0.02	<0.05	0.26	0.07	<0.02	<0.02	0.50	<0.02	<0.003	12.00
BBK 9.1	LONGEAR	4/27/93	F	4452	54.7	13.2	<0.04	<0.05	<0.003	<0.02	<0.05	0.29	<0.05	<0.02	<0.02	0.40	<0.02	<0.003	14.00
BBK 9.1	LONGEAR	4/27/93	M	4455	57.0	13.8	<0.04	<0.05	<0.003	<0.02	<0.05	0.22	<0.05	<0.02	<0.02	0.40	<0.02	<0.003	12.00
BBK 9.1	LONGEAR	4/27/93	F	4459	61.6	13.4	<0.04	<0.05	<0.003	<0.02	0.24	0.23	0.13	<0.02	<0.02	0.25	<0.02	<0.003	8.80
				Mean	60.9	13.6	<0.04	<0.05	<0.003	<0.02	0.07	0.25	0.10	<0.02	<0.02	0.39	<0.02	<0.003	11.70
				SE	3.4	0.2						0.02	0.02			0.05			1.08
LUK 7.2	LONGEAR	4/27/93	M	4521	44.0	13.0	<0.04	<0.05	<0.003	<0.02	0.36	0.25	0.14	<0.02	<0.02	0.49	<0.02	0.005	8.30
LUK 7.2	LONGEAR	4/27/93	M	4523	52.9	12.5	<0.04	0.06	<0.003	<0.02	<0.05	0.25	<0.05	<0.02	<0.02	0.58	<0.02	<0.003	8.30
LUK 7.2	LONGEAR	4/27/93	M	4525	46.8	13.1	<0.04	<0.05	<0.003	<0.02	<0.05	0.24	0.07	<0.02	<0.02	0.43	<0.02	<0.003	11.00
LUK 7.2	LONGEAR	4/27/93	M	4528	51.7	13.0	<0.04	<0.05	<0.003	<0.02	<0.05	0.28	0.23	0.05	<0.02	0.57	<0.02	0.006	6.70
				Mean	48.9	12.9	<0.04	<0.05	<0.003	<0.02	0.09	0.26	0.15	0.02	<0.02	0.52	<0.02	0.003	8.58
				SE	2.1	0.1						0.01	0.04			0.04			0.89
HINDSCR	BLUGIL	5/5/93	M	4541	60.4	14.7	<0.04	<0.05	<0.003	<0.02	0.12	0.23	0.15	0.82	<0.02	0.35	<0.02	<0.003	5.50
HINDSCR	BLUGIL	5/5/93	M	4540	77.9	15.7	<0.04	<0.05	<0.003	<0.02	<0.05	0.21	<0.05	<0.02	<0.02	0.23	<0.02	<0.003	4.70
HINDSCR	BLUGIL	5/5/93	M	4470	67.8	15.2	<0.04	<0.05	<0.003	<0.02	<0.05	0.21	<0.05	<0.02	<0.02	0.27	<0.02	<0.003	4.30
HINDSCR	BLUGIL	5/5/93	M	4473	68.0	15.0	<0.04	<0.05	<0.003	<0.02	<0.05	0.25	<0.05	<0.02	<0.02	0.26	<0.02	<0.003	4.80
				Mean	68.5	15.2	<0.04	<0.05	< 0.003	<0.02	0.05	0.23	0.05	0.21	<0.02	0.28	<0.02	<0.003	4.83
				SE	7.2	0.4						0.02				0.05			0.50

Note: Unless otherwise specified, concentrations are given in micrograms per gram, wet weight.

[a]BBK = Big Bayou Creek kilometer; LUK = Little Bayou Creek kilometer; HINDSCR = Hinds Creek.

Table C.3 Concentrations of chlorinated pesticides in longear sunfish from Big Bayou Creek and Little Bayou Creek, April 1993

Site	Date	Spp	Tag	Sex	Wgt (g)	Lgth (cm)	Dieldrin	DDE	Endosulfan I	Endosulfan II	Heptachlor epoxide	Alpha Chlordane	Gamma Chlordane	Methoxychlor	%Lipid
LUK7.2	4/27/92	LNGEAR	4520	M	44.5	12.4	ND	ND	ND	ND	ND	ND	ND	ND	0.42
LUK7.2	4/27/92	LNGEAR	4522	M	41.8	12.2	ND	ND	ND	ND	ND	ND	ND	ND	0.29
LUK7.2	4/27/92	LNGEAR	4524	M	47.9	12.4	ND	ND	ND	ND	ND	ND	ND	ND	0.56
LUK7.2	4/27/92	LNGEAR	4527	M	35.6	11.0	ND	ND	ND	ND	ND	ND	ND	ND	0.10
BBK9.1	4/27/93	LNGEAR	4553	M	57.2	13.6	ND	ND	ND	ND	ND	ND	ND	ND	0.15
BBK9.1	4/27/93	LNGEAR	4554	M	47.9	13.0	ND	ND	ND	ND	ND	ND	ND	ND	0.18
BBK9.1	4/27/93	LNGEAR	4559	F	61.6	13.4	ND	ND	ND	ND	ND	ND	ND	ND	1.06
BBK9.1	4/27/93	LNGEAR	4437	M	45.5	13.0	ND	ND	ND	ND	ND	ND	ND	ND	0.23
HINDSCR	5/6/93	BLUGIL	4466	M	45.2	12.8	ND	ND	ND	ND	ND	ND	ND	ND	0.06

COMPOUND	DETECTION LIMIT, µg/g wet wt[a]	COMPOUND	DETECTION LIMIT, µg/g wet wt[a]
ALPHA-BHC	0.005	ENDOSULFAN II	0.01
BETA-BHC	0.005	DDD	0.01
DELTA-BHC	0.005	ENDOSULFAN SULFATE	0.01
GAMMA-BHC	0.005	DDT	0.01
HEPTACHLOR	0.005	METHOXYCHLOR	0.05
ALDRIN	0.005	ENDRIN KETONE	0.01
HEPTACHLOR EPOXIDE	0.005	ALPHA CHLORDANE	0.05
ENDOSULFAN I	0.005	GAMMA CHLORDANE	0.05
DIELDRIN	0.01	TOXAPHENE	0.1
DDE	0.01		
ENDRIN	0.01		

[a]Detection limit for a 5-g sample estimated a 10% of quantitation limit. Reported estimated concentrations may be lower in some cases.

Note: Unless otherwise indicated, measurements are given in micrograms per gram wet weight; LUK = Little Bayou Creek; BBK = Big Bayouc Creek; HINDSCR = Hinds Creek.

Appendix D
SPECIES CHARACTERISTICS, DENSITY, AND BIOMASS FOR FISH COMMUNITY DATA COLLECTED FROM BIG BAYOU CREEK, LITTLE BAYOU CREEK, AND MASSAC CREEK DURING SEPTEMBER 1992, MARCH 1993, AND SEPTEMBER 1993

Table D.1. Tolerance, feeding guilds and lithophilic spawners for species found in and near the drainages of Big Bayou Creek, Little Bayou Creek, and Massac Creek

Species	Tolerance[a]	Feeding guild[b]	Lithophilic spawner[c]
Gizzard shad (*Dorosoma cepedianum*)	TOL	GEN	
Goldfish (*Carassius auratus*)	TOL	GEN	
Red shiner (*Cyprinella lutrensis*)	TOL		
Spotfin shiner (*Cyprinella spiloptera*)	TOL		
Steelcolor shiner (*Cyprinella whipplei*)	INTOL		
Common carp (*Cyprinus carpio*)	TOL	GEN	
Ribbon shiner (*Lythrurus fumeus*)	INTOL		
Sand shiner (*Notropis stramineus*)	INTOL		
Suckermouth minnow (*Phenacobius mirabilis*)		BIN	LITH
Fathead minnow (*Pimephales promelas*)	TOL	GEN	
Creek chub (*Semotilus atromaculatus*)	TOL	GEN	
White sucker (*Catostomus commersoni*)	TOL	GEN	LITH
Creek chubsucker (*Erimyzon oblongus*)		BIN	
Spotted sucker (*Minytrema melanops*)	INTOL	GEN	LITH
Black redhorse (*Moxostoma duquesnei*)	INTOL	BIN	LITH
Golden redhorse (*Moxostoma erythrurum*)	INTOL	BIN	LITH
Black bullhead (*Ameiurus melas*)	TOL	GEN	
Yellow bullhead (*Ameiurus natalis*)	TOL	GEN	
Tadpole madtom (*Noturus gyrinus*)	INTOL	BIN	
Freckled madtom (*Noturus nocturnus*)	INTOL	BIN	
Grass pickerel (*Esox americanus vermiculatus*)		PIS	
Pirate perch (*Aphredoderus sayanus*)		BIN	
Green sunfish (*Lepomis cyanellus*)	TOL		
Warmouth (*Lepomis gulosus*)		GEN	
Bluegill (*Lepomis macrochirus*)		GEN	
Longear sunfish (*Lepomis megalotis*)		GEN	
Spotted bass (*Micropterus punctulatus*)		PIS	
Largemouth bass (*Micropterus salmoides*)		PIS	

Table D.1 (continued)

Species	Tolerance[a]	Feeding guild[b]	Lithophilic spawner[c]
Mud darter (*Etheostoma asprigene*)		BIN	LITH
Bluntnose darter (*Etheostoma chlorosomum*)	INTOL	BIN	
Slough darter (*Etheostoma gracile*)		BIN	
Logperch (*Percina caprodes*)	INTOL	BIN	LITH
Blackside darter (*Percina maculata*)	INTOL	BIN	LITH

[a]Tolerant (TOL) and sensitive (INTOL) species were tentatively identified for the Paducah area using collection records and text discussions in Becker 1983, Burr and Warren 1986, Cross and Collins 1975, Etnier and Starnes 1993, Karr et al. 1986, Lee et al. 1980, Ohio EPA 1987, Ohio EPA 1988, Plfieger 1975, Robison and Buchanan 1988, Smith 1979, and Trautman 1981. Complete citations for references listed in this table may be found in Section 6 of this report.

[b]Feeding guilds are assigned to categories of interest in assessing impacts. Guilds include species that are primarily *generalists* (GEN), fish that feed on many types of food items and from many areas of the stream; *benthic insectivores* (BIN), those that eat macroinvertebrates associated with bottom substrates; and *piscivores* (PIS), fish that eat other fish.

[c]Lithophilic spawners (LITH) are species that release eggs randomly or without parental care in or onto gravel substrates. These species are especially vulnerable to siltation or low dissolved oxygen conditions.

Table D.2. Fish densities in Big Bayou Creek, Little Bayou Creek, and a reference stream, Massac Creek, September 1992

Species[b]	Sites[a]				
	BBK 9.1	BBK 10.0	BBK 12.5	LUK 7.2	MAK 13.8
Gizzard shad	0.02	-	-	-	0.02
Central stoneroller	1.36	4.00	0.74	0.49	1.85
Red shiner	0.02	0.02	0.02	0.23	-
Hybrid shiner[c]	-	-	<0.01	-	<0.01
Steelcolor shiner[c]	0.02	-	-	-	0.02
Ribbon shiner[c]	0.01	-	-	<0.01	<0.01
Redfin shiner[c]	<0.01	-	0.01	0.03	0.02
Suckermouth minnow	0.04	-	-	0.11	0.02
Bluntnose minnow	-	-	0.09	0.83	0.16
Creek chub	0.01	0.02	0.03	0.19	0.07
White sucker	-	<0.01	0.01	-	0.01
Creek chubsucker	<0.01	0.03	0.02	0.01	0.03
Spotted sucker	0.02	-	-	-	-
Golden redhorse	-	-	-	-	0.02
Black bullhead	<0.01	-	-	-	-
Yellow bullhead	0.03	0.09	0.13	0.18	0.01
Pirate perch	-	-	-	0.01	0.02
Blackspotted topminnow	0.03	0.30	0.54	0.26	0.40
Western mosquitofish	0.23	0.24	0.01	3.37	0.03
Green sunfish	0.04	0.05	0.16	0.15	0.01
Warmouth	-	-	<0.01	0.03	0.01
Bluegill	0.03	0.04	0.02	0.01	0.06
Longear sunfish	0.57	0.72	0.68	0.12	1.19
Hybrid sunfish	0.01	0.01	0.01	-	-
Spotted bass	0.03	0.04	0.01	-	0.03
Largemouth bass	-	0.01	-	-	0.01
White crappie	<0.01	-	-	-	-
Slough darter	-	-	-	0.04	-
Total Density	2.47	5.57	2.46	6.06	3.99

Note: Measurements are given in number per squre meter.

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

[b]Common and scientific names according to the American Fisheries Society (Robins et al. 1991. Common and scientific names of fishes form the United States and Canada. Fifth Edition. American Fisheries Society Special Publication 20. Bethesda, MD).

[c]Species identification confirmed by Dr. David A. Etnier, Department of Zoology, University of Tennessee.

Table D.3. Fish densities in Big Bayou Creek, Little Bayou Creek, and a reference stream, Massac Creek, March 1993

Species[b]	Sites[a]				
	BBK 9.1	BBK 10.0	BBK 12.5	LUK 7.2	MAK 13.8
Central stoneroller	0.35	1.65	1.57	0.16	0.20
Red shiner	0.01	0.01	0.09	0.08	-
Steelcolor shiner[c]	-	-	-	-	0.03
Ribbon shiner	-	-	<0.01	0.02	0.23
Redfin shiner[c]	0.01	-	0.01	0.02	0.05
Golden shiner	-	-	-	<0.01	-
Suckermouth minnow	-	0.02	<0.01	0.07	0.01
Bluntnose minnow	-	-	0.13	0.54	0.25
Creek chub	<0.01	<0.01	0.08	0.09	0.01
White sucker	<0.01	-	<0.01	-	0.02
Creek chubsucker	<0.01	-	0.01	<0.01	0.02
Black redhorse	-	-	-	-	0.01
Golden redhorse	-	-	-	-	0.01
Yellow bullhead	0.01	-	0.04	0.08	0.01
Pirate perch	-	-	-	0.06	-
Blackspotted topminnow	<0.01	0.02	0.10	0.09	0.06
Western mosquitofish	-	-	-	0.01	-
Green sunfish	0.03	0.01	0.11	0.19	0.01
Warmouth	-	-	-	0.04	<0.01
Bluegill	0.01	<0.01	<0.01	-	0.01
Longear sunfish	0.70	0.09	0.64	0.17	0.57
Hybrid sunfish	<0.01	<0.01	0.01	-	-
Spotted bass	0.02	<0.01	<0.01	-	<0.01
Largemouth bass	<0.01	-	-	-	<0.01
Bluntnose darter	-	-	-	-	<0.01
Slough darter	-	-	-	0.01	-
Blackside darter	-	-	-	-	0.01
Total density	1.13	1.80	2.79	1.63	1.51

Note: Densities expressed as number per square meter.

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

[b]Common and scientific names according to the American Fisheries Society (Robins et al. 1991. Common and scientific names of fishes form the United States and Canada. Fifth Edition. American Fisheries Society Special Publication 20. Bethesda, MD).

[c]Species identification confirmed by Dr. David A. Etnier, Department of Zoology, University of Tennessee.

Table D.4. Fish densities in Big Bayou Creek, Little Bayou Creek, and a reference stream, Massac Creek, September 1993

	Sites[a]				
Species[b]	BBK 9.1	BBK 10.0	BBK 12.5	LUK 7.2	MAK 13.8
Central stoneroller	1.42	4.71	3.18	0.70	0.33
Goldfish	-	-	-	-	<0.01
Red shiner	0.02	-	0.05	0.10	0.01
Miss. silvery minnow	-	-	-	-	0.03
Steelcolor shiner[c]	<0.01	-	-	-	0.10
Ribbon shiner[c]	-	-	<0.01	0.04	-
Redfin shiner[c]	-	-	-	0.01	0.23
Golden shiner	-	-	<0.01	<0.01	-
Suckermouth minnow	-	-	0.01	0.46	-
Bluntnose minnow	-	-	0.05	1.25	0.26
Creek chub	-	-	0.31	0.79	0.16
White sucker	-	-	-	-	0.02
Creek chubsucker	<0.01	0.01	0.17	0.02	0.11
Spotted sucker	-	-	-	-	0.01
Golden redhorse	-	-	-	-	0.06
Yellow bullhead	0.01	0.02	0.10	0.13	0.04
Grass pickerel	-	-	-	-	<0.01
Pirate perch	-	-	-	0.02	0.01
Blackspotted topminnow	0.13	0.15	0.71	0.16	0.48
Western mosquitofish	0.10	0.37	-	0.57	0.03
Green sunfish	0.10	0.21	0.14	0.14	0.18
Warmouth	-	-	-	0.01	-
Bluegill	0.09	0.10	0.05	-	0.25
Longear sunfish	0.71	0.60	2.10	0.12	0.87
Hybrid sunfish	0.01	<0.01	-	-	-
Spotted bass	0.01	0.04	0.03	0.01	0.03
Largemouth bass	-	<0.01	-	<0.01	-
Slough darter	-	-	-	0.01	<0.01
Blackside darter	-	-	-	-	<0.01
Total Density	2.60	6.21	6.90	4.54	3.21

Note: Density expressed a number of fish per square meter.

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

[b]Common and scientific names according to the American Fisheries Society (Robins et al. 1991. Common and scientific names of fishes form the United States and Canada. Fifth Edition. American Fisheries Society Special Publication 20. Bethesda, MD).

[c]Species identification confirmed by Dr. David A. Etnier, Department of Zoology, University of Tennessee.

Table D.5. Fish biomass in Big Bayou Creek, Little Bayou Creek, and a reference stream, Massac Creek, September 1992

	Sites[a]				
Species[b]	BBK 9.1	BBK 10.0	BBK 12.5	LUK 7.2	MAK 13.8
Gizzard shad	1.96	-	-	-	0.59
Central stoneroller	3.38	13.11	2.76	0.95	1.83
Red shiner	0.04	0.04	0.04	0.12	-
Hybrid shiner[c]	-	-	<0.01	-	0.01
Steelcolor shiner[c]	0.13	-	-	-	0.06
Ribbon shiner[c]	0.01	-	-	<0.01	<0.01
Redfin shiner[c]	<0.01	-	0.02	0.01	0.01
Suckermouth minnow	0.26	-	-	0.26	0.05
Bluntnose minnow	-	-	0.10	0.47	0.12
Creek chub	0.08	0.20	0.03	1.03	0.06
White sucker	-	0.04	-	-	0.77
Creek chubsucker	0.05	1.27	0.20	0.03	0.55
Spotted sucker	9.24	-	-	-	-
Golden redhorse	-	-	-	-	1.75
Black bullhead	0.15	-	-	-	-
Yellow bullhead	2.09	1.44	3.26	0.61	0.37
Pirate perch	-	-	-	0.04	0.05
Blackspotted topminnow	0.05	0.61	1.15	0.46	0.69
Western mosquitofish	0.08	0.12	0.01	1.00	0.01
Green sunfish	0.91	1.68	1.44	0.41	0.10
Warmouth	-	-	0.03	0.03	0.04
Bluegill	1.46	1.17	0.20	<0.01	0.68
Longear sunfish	10.86	10.09	5.74	0.41	6.37
Hybrid sunfish	0.50	0.17	0.06	-	-
Spotted bass	1.96	1.24	0.04	-	0.45
Largemouth bass	-	0.03	-	-	0.72
White crappie	0.17	-	-	-	-
Slough darter	-	-	-	0.02	-
Total Biomass	33.38	31.21	15.08	5.85	15.28

Note: Measurements are stated in grams of fish per square meter.

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

[b]Common and scientific names according to the American Fisheries Society (Robins et al. 1991. Common and scientific names of fishes form the United States and Canada. Fifth Edition. American Fisheries Society Special Publication 20. Bethesda, MD).

[c]Species identification confirmed by Dr. David A. Etnier, Department of Zoology, University of Tennessee.

Table D.6. Fish biomass in Big Bayou Creek, Little Bayou Creek, and a reference stream, Massac Creek, March 1993

Species[b]	Sites[a]				
	BBK 9.1	BBK 10.0	BBK 12.5	LUK 7.2	MAK 13.8
Central stoneroller	1.21	6.93	3.99	0.84	0.34
Red shiner	<0.01	0.03	0.15	0.07	-
Steelcolor shiner[c]	-	-	-	-	0.12
Ribbon shiner	-	-	<0.01	0.01	0.11
Redfin shiner[c]	<0.01	-	0.03	0.03	0.06
Golden shiner	-	-	-	0.01	-
Suckermouth minnow	-	0.15	0.01	0.25	0.03
Bluntnose minnow	-	-	0.21	0.89	0.37
Creek chub	0.03	0.02	0.27	0.92	0.02
White sucker	2.02	-	0.38	-	0.13
Creek chubsucker	0.14	-	0.03	0.01	0.13
Black redhorse	-	-	-	-	1.49
Golden redhorse	-	-	-	-	0.62
Yellow bullhead	0.07	-	0.50	0.62	0.36
Pirate perch	-	-	-	0.58	-
Blackspotted topminnow	<0.01	0.03	0.20	0.19	0.12
Western mosquitofish	-	-	-	<0.01	-
Green sunfish	0.44	0.10	1.51	1.21	0.09
Warmouth	-	-	-	0.21	0.04
Bluegill	0.27	0.01	<0.01	-	0.05
Longear sunfish	14.84	1.34	4.80	0.79	3.15
Hybrid sunfish	0.04	0.07	0.25	-	-
Spotted bass	4.32	0.13	0.06	-	0.01
Largemouth bass	0.07	-	-	-	0.22
Bluntnose dace	-	-	-	-	<0.01
Slough darter	-	-	-	0.01	-
Blackside darter	-	-	-	-	0.01
Total biomass	23.45	8.81	12.39	6.64	7.47

Note: Measurements are stated in grams of fish per square meter.

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

[b]Common and scientific names according to the American Fisheries Society (Robins et al. 1991. Common and scientific names of fishes form the United States and Canada. Fifth Edition. American Fisheries Society Special Publication 20. Bethesda, MD).

[c]Species identification confirmed by Dr. David A. Etnier, Department of Zoology, University of Tennessee.

Table D.7. Fish biomass in Big Bayou Creek, Little Bayou Creek, and a reference stream, Massac Creek, September 1993

Species[b]	Sites[a]				
	BBK 9.1	BBK 10.0	BBK 12.5	LUK 7.2	MAK 13.8
Central stoneroller	1.74	8.85	2.87	0.82	0.50
Goldfish	-	-	-	-	0.02
Red shiner	0.01	-	0.03	0.04	<0.01
Miss. silvery minnow	-	-	-	-	0.14
Steelcolor shiner[c]	<0.01	-	-	-	0.18
Ribbon shiner[c]	-	-	<0.01	0.02	-
Redfin shiner[c]	-	-	-	<0.01	0.28
Golden shiner	-	-	<0.01	<0.01	-
Suckermouth minnow	-	-	0.01	1.24	-
Bluntnose minnow	-	-	0.07	1.19	0.44
Creek chub	-	-	0.81	1.53	0.41
White sucker	-	-	-	-	0.67
Creek chubsucker	0.01	0.10	0.43	0.11	1.10
Spotted sucker	-	-	-	-	0.73
Golden redhorse	-	-	-	-	3.11
Yellow bullhead	0.70	0.42	1.83	0.97	0.50
Grass pickerel	-	-	-	-	0.18
Pirate perch	-	-	-	0.05	0.05
Blackspotted topminnow	0.17	0.22	0.77	0.23	0.61
Western mosquitofish	0.02	0.14	-	0.16	0.01
Green sunfish	1.01	2.07	1.31	0.70	0.86
Warmouth	-	-	-	0.03	-
Bluegill	1.35	1.87	0.40	-	0.80
Longear sunfish	6.59	8.18	5.69	0.63	7.09
Hybrid sunfish	0.55	0.12	-	-	-
Spotted bass	0.18	0.68	0.10	0.03	0.77
Largemouth bass	-	0.08	-	0.05	-
Slough darter	-	-	-	<0.01	<0.01
Blackside darter	-	-	-	-	0.01
Total Biomass	12.33	22.73	14.32	7.8	18.46

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

[b]Common and scientific names according to the American Fisheries Society (Robins et al. 1991. Common and scientific names of fishes form the United States and Canada. Fifth Edition. American Fisheries Society Special Publication 20. Bethesda, MD).

[c]Species identification confirmed by Dr. David A. Etnier, Department of Zoology, University of Tennessee.

Appendix E
CHECKLIST OF BENTHIC MACROINVERTEBRATE TAXA COLLECTED FROM BIG BAYOU CREEK, LITTLE BAYOU CREEK, AND MASSAC CREEK IN PADUCAH, KENTUCKY, SEPTEMBER 1991.

Table E.1. Checklist of benthic macroinvertebrate taxa collected from Big Bayou Creek, Little Bayou Creek, and Massac Creek in Paducah, Kentucky, September 1991

	SITE[a,b]				
TAXON	BBK 9.1	BBK 10.0	BBK 12.5	LUK 7.2	MAK 13.8
Turbellaria					
Planariidae	X	X	X	-	-
Nermertea	X	X	X	-	X
Nematoda	-	-	-	X	-
Oligochaeta	X	X	X	X	X
Crustacea					
Decapoda	-	-	-	-	X
Hydrachnida	X	X	-	-	-
Hygrobatidae					
Atractides	-	-	-	-	X
Hygrobates	X	X	-	-	-
Torrenticolidae					
Torrenticola	X	-	-	X	X
Oribatida	-	-	-	-	X
Insecta					
Ephemeroptera					
Baetidae					
Baetis	X	X	X	-	X
Caenidae					
Caenis	X	X	X	-	-
Heptageniidae	X	X	-	X	-
Stenacron	-	-	X	-	-
Stenonema	X	X	X	-	X
Tricorythidae					
Tricorythodes	X	X	-	-	-
Odonata	-	X	-	-	-
Anisoptera					
Gomphidae					
Progomphus	-	-	-	X	X
Libellulidae					
Miathyria	-	X	-	-	-
Macromiidae					
Macromia	-	X	-	-	-

Table E.1 (continued)

TAXON	SITE[a,b]				
	BBK 9.1	BBK 10.0	BBK 12.5	LUK 7.2	MAK 13.8
Zygoptera	-	X	-	-	-
Calopterygidae					
Calopteryx	-	-	X	X	X
Hetaerina	-	X	-	X	-
Coenagrionidae	-	X	-	-	-
Argia	-	X	-	-	-
Argiallagma	-	X	-	-	-
Enallagma	-	X	-	-	-
Megaloptera					
Corydalidae					
Corydalus cornutus	-	X	X	X	-
Trichoptera	X	-	X	X	X
Hydropsychidae	X	X	-	X	X
Cheumatopsyche	X	X	X	X	X
Hydropsyche	X	-	X	-	X
Hydroptilidae					
Hydroptila	-	-	X	X	-
Leptoceridae					
Oecetis	-	X	-	X	X
Philopotamidae					
Chimarra	X	X	X	X	X
Polycentropodidae					
Polycentropus	-	-	X	-	-
Coleoptera					
Elmidae					
Dubiraphia	-	-	-	X	-
Optioservus	-	-	-	-	X
Stenelmis	X	-	-	X	X
Hydrophilidae					
Berosus	X	X	X	X	X
Enochrus	-	X	-	-	-
Diptera					
Ceratopogonidae					
Bezzia	X	-	X	-	X
Culicoides	X	-	X	-	-
Probezzia	-	-	-	X	-

Table E.1 (continued)

TAXON	SITE[a,b] BBK 9.1	BBK 10.0	BBK 12.5	LUK 7.2	MAK 13.8
Chironomidae	X	X	X	X	X
Chironomini	X	X	X	X	X
Orthocladiinae	X	X	X	X	X
Tanypodinae	X	X	X	X	X
Tanytarsini	X	X	X	X	X
Empididae					
Chelifera	X	X	X	-	-
Hemerodromia	X	X	-	-	-
Tabanidae					
Tabanus	X	X	-	X	-
Tipulidae					
Erioptera	-	X	-	-	-
Helius	-	X	-	-	-
Tipula	-	-	X	-	-
Mollusca					
Gastropoda					
Ancylidae	-	-	-	-	X
Ferrissia fragilis	X	X	-	X	X
Lymnaeidae					
Pseudosuccinea columella	-	-	-	-	X
Physidae					
Physella	-	X	-	-	X
Planorbidae					
Micromenetus dilatatus	-	X	-	X	X
Bivalvia					
Corbiculidae					
Corbicula fluminea	X	-	-	-	-
Sphaeriidae					
Pisidium	-	-	-	X	-

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

[b]An X indicates that a taxon was collected at least once; a blank indicates that a lower level of classification (e.g., family, genus, species) was possible at one or more sites; and a hyphen indicates that the taxon was not collected or was identified to a lower level at one or more sites.

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