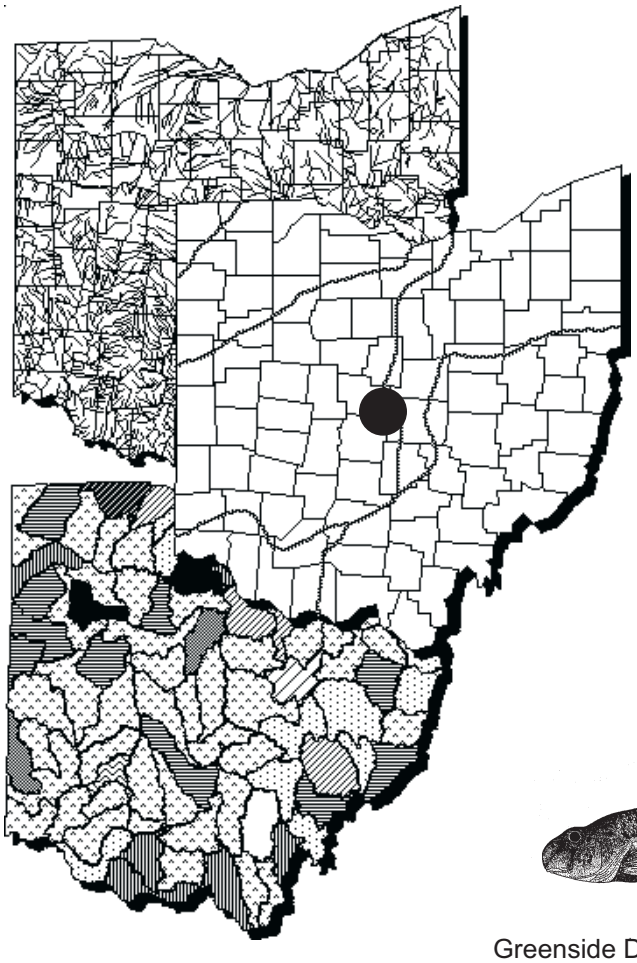
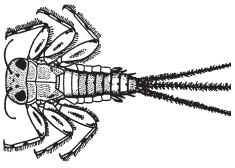
State of Ohio
Environmental Protection Agency

Ecological Assessment
Division of Surface Water

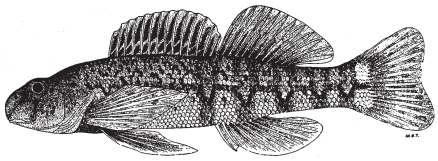
Biological and Water Quality Study of the Big Walnut Creek Basin 2000

Delaware, Fairfield, Franklin, Licking, Morrow, and Pickaway Counties, Ohio





Mayfly *(Stenonema)*



Greenside Darter *(Etheostoma blennioides)*

November 26, 2003

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Governor, State of Ohio
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Biological and Water Quality Study of the Big Walnut Creek Basin 2000

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OEPA Technical Report DSW/EAS 2003-11-10

prepared by

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NOTICE TO USERS

Ohio EPA incorporated biological criteria into the Ohio Water Quality Standards (WQS; Ohio Administrative Code 3745-1) regulations in February 1990 (effective May 1990). These criteria consist of numeric values for the Index of Biotic Integrity (IBI) and Modified Index of Well-Being (MIwb), both of which are based on fish assemblage data, and the Invertebrate Community Index (ICI), which is based on macroinvertebrate assemblage data. Criteria for each index are specified for each of Ohio's five ecoregions (as described by Omernik 1987), and are further organized by organism group, index, site type, and aquatic life use designation. These criteria, along with the existing chemical and whole effluent toxicity evaluation methods and criteria, figure prominently in the monitoring and assessment of Ohio's surface water resources.

The following documents support the use of biological criteria by outlining the rationale for using biological information, the methods by which the biocriteria were derived and calculated, the field methods by which sampling must be conducted, and the process for evaluating results:

Ohio Environmental Protection Agency. 1987. Biological criteria for the protection of aquatic life: Volume I. The role of biological data in water quality assessment. Div. Water Qual. Monit. & Assess., Surface Water Section, Columbus, Ohio.

Ohio Environmental Protection Agency. 1987. Biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters. Div. Water Qual. Monit. & Assess., Surface Water Section, Columbus, Ohio.

Ohio Environmental Protection Agency. 1989. Addendum to Biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters. Div. Water Qual. Plan. & Assess., Ecological Assessment Section, Columbus, Ohio.

Ohio Environmental Protection Agency. 1989. Biological criteria for the protection of aquatic life: Volume III. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities. Div. Water Quality Plan. & Assess., Ecol. Assess. Sect., Columbus, Ohio.

Ohio Environmental Protection Agency. 1990. The use of biological criteria in the Ohio EPA surface water monitoring and assessment program. Div. Water Qual. Plan. & Assess., Ecol. Assess. Sect., Columbus, Ohio.

Rankin, E.T. 1989. The qualitative habitat evaluation index (QHEI): rationale,methods, and application. Div. Water Qual. Plan. & Assess., Ecol. Assess. Sect., Columbus, Ohio.

Since the publication of the preceding guidance documents new publications by Ohio EPA have become available. The following publications should also be consulted as they represent the latest information and analyses used by Ohio EPA to implement the biological criteria.

DeShon, J.D. 1995. Development and application of the invertebrate community index (ICI), pp. 217-243. in W.S. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Risk-based Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Rankin, E. T. 1995. The use of habitat assessments in water resource management programs, pp. 181-208. in W. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Yoder, C.O. and E.T. Rankin. 1995. Biological criteria program development and implementation in Ohio, pp. 109-144. in W. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Yoder, C.O. and E.T. Rankin. 1995. Biological response signatures and the area of degradation value: new tools for interpreting multimetric data, pp. 263-286. in W. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Yoder, C.O. 1995. Policy issues and management applications for biological criteria, pp. 327-344. in W. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Yoder, C.O. and E.T. Rankin. 1995. The role of biological criteria in water quality monitoring, assessment, and regulation. Environmental Regulation in Ohio: How to Cope With the Regulatory Jungle. Inst. of Business Law, Santa Monica, CA. 54 pp.

These documents and this report can be obtained by writing to:

Ohio EPA, Division of Surface Water
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1685 Westbelt Drive
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This evaluation and report was possible only with the assistance of the study team, many full and part time field staff, and the chemistry analyses provided by the Ohio EPA Division of Environmental Services. Property owners who permitted access for sampling are also acknowledged for their cooperation.

Copies of this report are located on the Ohio EPA internet web page (www.epa.state.oh.us) or may be available from:

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FOREWORD

What is a Biological and Water Quality Survey?

A biological and water quality survey, or "biosurvey", is an interdisciplinary monitoring effort coordinated on a waterbody specific or watershed scale. This effort may involve a relatively simple setting focusing on one or two small streams, one or two principal stressors, and a handful of sampling sites or a much more complex effort including entire drainage basins, multiple and overlapping stressors, and tens of sites. Each year Ohio EPA conducts biosurveys in 4-6 different study areas with an aggregate total of 350-400 sampling sites.

Ohio EPA employs biological, chemical, and physical monitoring and assessment techniques in biosurveys in order to meet three major objectives: 1) determine the extent to which use designations assigned in the Ohio Water Quality Standards (WQS) are either attained or not attained; 2) determine if use designations assigned to a given water body are appropriate and attainable; and 3) determine if any changes in key ambient biological, chemical, or physical indicators have taken place over time, particularly before and after the implementation of point source pollution controls or best management practices. The data gathered by a biosurvey is processed, evaluated, and synthesized in a biological and water quality report. Each biological and water quality study contains a summary of major findings and recommendations for revisions to WQS, future monitoring needs, or other actions which may be needed to resolve existing impairment of designated uses. While the principal focus of a biosurvey is on the status of aquatic life uses, the status of other uses such as recreation and water supply, as well as human health concerns, are also addressed.

The findings and conclusions of a biological and water quality study may factor into regulatory actions taken by Ohio EPA (*e.g.*, NPDES permits, Director's Orders, the Ohio Water Quality Standards [OAC 3745-1]), and are eventually incorporated into Water Quality Permit Support Documents (WQPSDs), State Water Quality Management Plans, the Ohio Nonpoint Source Assessment, and the Ohio Water Resource Inventory (305[b] report).

Hierarchy of Indicators

A carefully conceived ambient monitoring approach, using cost-effective indicators comprised of ecological, chemical, and toxicological measures, can ensure that all relevant pollution sources are judged objectively on the basis of environmental results. Ohio EPA relies on a tiered approach in attempting to link the results of administrative activities with true environmental measures. This integrated approach is outlined in Figure 1 and includes a hierarchical continuum from administrative to true environmental indicators. The six "levels" of indicators include: 1) actions taken by regulatory agencies (permitting, enforcement, grants); 2) responses by the regulated community (treatment works, pollution prevention); 3) changes in discharged quantities (pollutant loadings); 4) changes in ambient conditions (water quality, habitat); 5) changes in uptake and/or assimilation (tissue contamination, biomarkers, wasteload allocation); and, 6) changes in health, ecology, or other effects (ecological condition, pathogens). In this process the results of administrative activities (levels 1 and 2) can be linked to efforts to improve water quality (levels 3, 4, and 5) which should translate into

the environmental "results" (level 6). Thus, the aggregate effect of billions of dollars spent on water pollution control since the early 1970s can now be determined with quantifiable measures of environmental condition.

Superimposed on this hierarchy is the concept of stressor, exposure, and response indicators. *Stressor* indicators generally include activities which have the potential to degrade the aquatic environment such as pollutant discharges (permitted and unpermitted), land use effects, and habitat modifications. *Exposure* indicators are those which measure the effects of stressors and can include whole effluent toxicity tests, tissue residues, and biomarkers, each of which provides evidence of biological exposure to a stressor or bioaccumulative agent. *Response* indicators are generally composite measures of the cumulative effects of stress and exposure and include the more direct measures of community and population response that are represented here by the biological indices which comprise Ohio's biological criteria. Other response indicators could include target assemblages, *i.e.*, rare, threatened, endangered, special status, and declining species or bacterial levels which serve as surrogates for the recreational uses. These indicators represent the essential technical elements for watershed-based management approaches. The key, however, is to use the different indicators *within* the roles which are most appropriate for each.

Describing the causes and sources associated with observed impairments revealed by the biological criteria and linking this with pollution sources involves an interpretation of multiple lines of evidence including water chemistry data, sediment data, habitat data, effluent data, biomonitoring results, land use data, and biological response signatures within the biological data itself. Thus the assignment of principal causes and sources of impairment represents the association of impairments (defined by response indicators) with stressor and exposure indicators. The principal reporting venue for this process on a watershed scale is a biological and water quality report. These reports then provide the foundation for aggregated assessments such as the Ohio Water Resource Inventory (305[b] report), the Ohio Nonpoint Source Assessment, and other technical bulletins.

Ohio Water Quality Standards: Designated Aquatic Life Uses

The Ohio Water Quality Standards (WQS; Ohio Administrative Code 3745-1) consist of designated uses and chemical, physical, and biological criteria designed to represent measurable properties of the environment that are consistent with the goals specified by each use designation. Use designations consist of two broad groups, aquatic life and non-aquatic life uses. In applications of the Ohio WQS to the management of water resource issues in Ohio's rivers and streams, the aquatic life use criteria frequently result in the most stringent protection and restoration requirements, hence their emphasis in biological and water quality reports. Also, an emphasis on protecting for aquatic life generally results in water quality suitable for all uses.

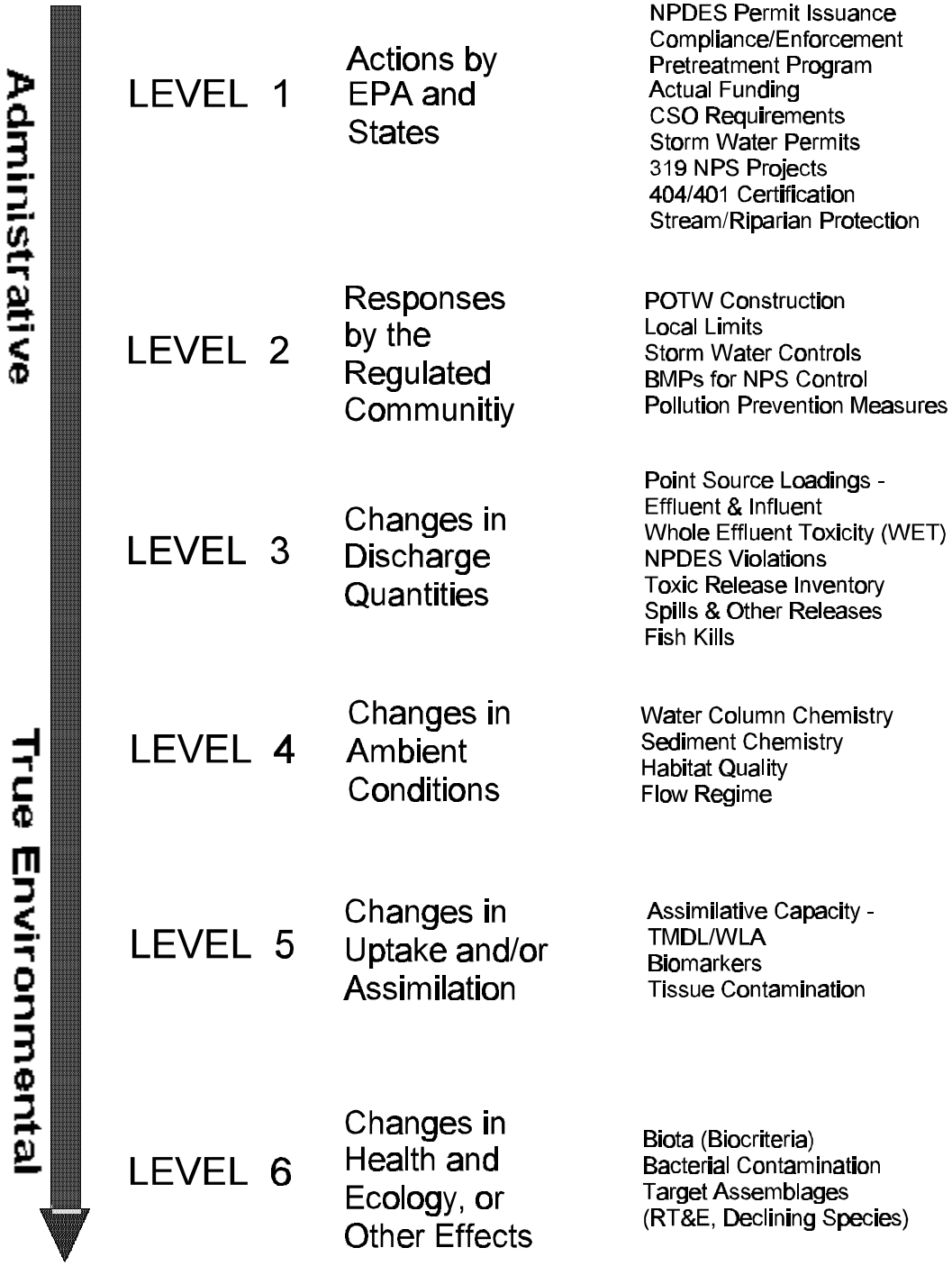

Figure 1. Hierarchy of administrative and environmental indicators which can be used for water quality management activities such as monitoring and assessment, reporting, and the evaluation of overall program effectiveness. This is patterned after a model developed by the U.S. EPA.

The five different aquatic life uses currently defined in the Ohio WQS are described as follows:

1) *Warmwater Habitat (WWH)* - this use designation defines the "typical" warmwater assemblage of aquatic organisms for Ohio rivers and streams; *this use represents the principal restoration target for the majority of water resource management efforts in Ohio.*

2) *Exceptional Warmwater Habitat (EWH)* - this use designation is reserved for waters which support "unusual and exceptional" assemblages of aquatic organisms which are characterized by a high diversity of species, particularly those which are highly intolerant and/or rare, threatened, endangered, or special status (*i.e.*, declining species); *this designation represents a protection goal for water resource management efforts dealing with Ohio's best water resources.*

3) *Coldwater Habitat (CWH)* - this use is intended for waters which support assemblages of cold water organisms and/or those which are stocked with salmonids with the intent of providing a put-and-take fishery on a year round basis which is further sanctioned by the Ohio DNR, Division of Wildlife; this use should not be confused with the Seasonal Salmonid Habitat (SSH) use which applies to the Lake Erie tributaries which support periodic "runs" of salmonids during the spring, summer, and/or fall.

4) *Modified Warmwater Habitat (MWH)* - this use applies to streams and rivers which have been subjected to extensive, maintained, and essentially permanent hydromodifications such that the biocriteria for the WWH use are not attainable *and where the activities have been sanctioned and permitted by state or federal law;* the representative aquatic assemblages are generally composed of species which are tolerant to low dissolved oxygen, silt, nutrient enrichment, and poor quality habitat.

5) *Limited Resource Water (LRW)* - this use applies to small streams (usually <3 mi.^{2} drainage area) and other water courses which have been irretrievably altered to the extent that no appreciable assemblage of aquatic life can be supported; such waterways generally include small streams in extensively urbanized areas, those which lie in watersheds with extensive drainage modifications, those which completely lack water on a recurring annual basis (*i.e.*, true ephemeral streams), or other irretrievably altered waterways.

Chemical, physical, and/or biological criteria are generally assigned to each use designation in accordance with the broad goals defined by each. As such the system of use designations employed in the Ohio WQS constitutes a "tiered" approach in that varying and graduated levels of protection are provided by each. This hierarchy is especially apparent for parameters such as dissolved oxygen, ammonia-nitrogen, temperature, and the biological criteria. For other parameters such as heavy metals, the technology to construct an equally graduated set of criteria has been lacking, thus the same water quality criteria may apply to two or three different use designations.

Ohio Water Quality Standards: Non-Aquatic Life Uses

In addition to assessing the appropriateness and status of aquatic life uses, each biological and water quality survey also addresses non-aquatic life uses such as recreation, water supply, and human health concerns as appropriate. The recreation uses most applicable to rivers and streams are the Primary Contact Recreation (PCR) and Secondary Contact Recreation (SCR) uses. The criterion for designating the PCR use is simply having a water depth of at least one meter over an area of at least 100 square feet or where canoeing is a feasible activity. If a water body is too small and shallow to meet either criterion the SCR use applies. The attainment status of PCR and SCR is determined using bacterial indicators (*e.g.*, fecal coliforms, *E. coli)* and the criteria for each are specified in the Ohio WQS.

Water supply uses include Public Water Supply (PWS), Agricultural Water Supply (AWS), and Industrial Water Supply (IWS). Public Water Supplies are simply defined as segments within 500 yards of a potable water supply or food processing industry intake. The Agricultural Water Supply (AWS) and Industrial Water Supply (IWS) use designations generally apply to all waters unless it can be clearly shown that they are not applicable. An example of this would be an urban area where livestock watering or pasturing does not take place, thus the AWS use would not apply. Chemical criteria are specified in the Ohio WQS for each use and attainment status is based primarily on chemical-specific indicators. Human health concerns are additionally addressed with fish tissue data, but any consumption advisories are issued by the Ohio Department of Health are detailed in other documents.

Causes of Resource Quality Impairment

The following paragraphs are provided to present the varied causes of impairment that are encountered during stream studies. While the various perturbations are presented under separate headings, it is important to remember that they are often interrelated and cumulative in terms of the detrimental impact that can result.

Habitat and Flow Alterations

Habitat alteration, such as channelization, impacts biological communities directly by limiting the complexity of living spaces available to aquatic organisms. Consequently, fish and macroinvertebrate communities are not as diverse. Indirect impacts include the removal of riparian trees and field tiling to facilitate drainage. Following a rain event, most of the water is quickly removed from tiled fields rather than filtering through the soil, recharging groundwater, and reaching the stream at a lower volume and more sustained rate. As a result, small streams more frequently go dry or become intermittent.

Tree shade is important because it limits the energy input from the sun, moderates water temperature, and limits evaporation. Removal of the tree canopy further degrades conditions because it eliminates an important source of coarse organic matter essential for a balanced ecosystem. Erosion impacts channelized streams more severely due to the lack of a riparian buffer zone to slow runoff, trap sediment and stabilize banks. Additionally, deep trapezoidal channels lack

a functioning flood plain and therefore cannot expel sediment as would occur during flood events along natural watercourses.

The lack of water movement under low flow conditions can exacerbate impacts from organic loading and nutrient enrichment by limiting reaeration of the stream. The amount of oxygen soluble in water decreases as temperature increases. This is one reason why tree shade is so important. The two main sources of oxygen in water are diffusion from the atmosphere and plant photosynthesis. Turbulence at the water surface is critical because it increases surface area and promotes diffusion, but channelization eliminates turbulence produced by riffles, meanders, and debris snags. Plant photosynthesis produces oxygen, but at night, respiration reverses the process and consumes oxygen. Oxygen is also used by bacteria that decay dead organic matter. Nutrient enrichment can promote the growth of nuisance algae that subsequently dies and serves as food for bacteria. Under these conditions, oxygen can be depleted unless it is replenished from the air.

Sedimentation

Whenever the natural flow regime is altered to facilitate drainage, increased amounts of sediment are likely to enter streams either by overland transport or increased bank erosion. The removal of wooded riparian areas furthers the erosional process. Channelization keeps all but the highest flow events confined within the artificially high banks. As a result, areas that were formerly flood plains and allowed for the removal of sediment from the primary stream channel no longer serve this function. As water levels fall following a rain event, interstitial spaces between larger rocks fill with sand and silt and the diversity of available habitat to support fish and macroinvertebrates is reduced. Silt also can clog the gills of both fish and macroinvertebrates, reduce visibility thereby excluding site feeding fish species, and smother the nests of lithophilic fishes. Lithophilic spawning fish require clean substrates with interstitial voids in which to deposit eggs. Conversely, pioneering species benefit. They are generalists and best suited for exploiting disturbed and less heterogeneous habitats. The net result is a lower diversity of aquatic species compared with a typical warmwater stream with natural habitats.

Sediment also impacts water quality, recreation, and drinking water. Nutrients absorbed to soil particles remain trapped in the watercourse. Likewise, bacteria, pathogens, and pesticides which also attach to suspended or bedload sediments become concentrated in waterways where the channel is functionally isolated from the landscape. Community drinking water systems address these issues with more costly advanced treatment technologies.

Nutrients

The element of greatest concern is phosphorus because it critical for plant growth and it is often the limiting nutrient. The form that can be readily used by plants and therefore can stimulate nuisance algae blooms is orthophosphate (PO_4^{-3}). The amount of phosphorus tied up in the nucleic acids of food and waste is actually quite low. This organic material is eventually converted to orthophosphate by bacteria. The amount of orthophosphate contained in synthetic detergents is a great concern however. It was for this reason that the General Assembly of the State of Ohio

enacted a law in 1990 to limit phosphorus content in household laundry detergents sold in the Lake Erie drainage basin to 0.5 % by weight. Inputs of phosphorus originate from both point and nonpoint sources. Most of the phosphorus discharged by point sources is soluble. Another characteristic of point sources is they have a continuous impact and are human in origin, for instance, effluents from municipal sewage treatment plants. The contribution from failed home sewage treatment systems can also be significant, especially if they are concentrated in a small area. The phosphorus concentration in raw waste water is generally 8-10 mg/l and after secondary treatment is generally 4-6 mg/l. Further removal requires the added cost of chemical addition. The most common methods use the addition of lime or alum to form a precipitate, so most phosphorus (80%) ends up in the sludge. A characteristic of phosphorus discharged by nonpoint sources is that the impact is intermittent and associated with stormwater runoff. Most of this phosphorus is bound tightly to soil particles and enters streams from erosion, although some comes from tile drainage. Urban stormwater is more of a concern if combined sewer overflows are involved. The impact from rural stormwater varies depending on land use and management practices and includes contributions from livestock feedlots and pastures and row crop agriculture. Crop fertilizer includes granular inorganic types and organic types such as manure or sewage sludge. Pasture land is especially a concern if the livestock have access to the stream. Large feedlots with manure storage lagoons create the potential for overflows and accidental spills. Land management is an issue because erosion is worse on streams without any riparian buffer zone to trap runoff. The impact is worse in streams that are channelized because they no longer have a functioning flood plain and cannot expel sediment during flooding. Oxygen levels must also be considered, because phosphorus is released from sediment at higher rates under anoxic conditions.

There is no numerical phosphorus criterion established in the Ohio Water Quality Standards, but there is a narrative criterion that states phosphorus should be limited to the extent necessary to prevent nuisance growths of algae and weeds (Administrative Code, 3745-1-04, Part E). Phosphorus loadings from large volume point source dischargers in the Lake Erie drainage basin are regulated by the National Pollutant Discharge Elimination System (NPDES). The permit limit is a concentration of 1.0 mg/l in final effluent. Research conducted by the Ohio EPA indicates that a significant correlation exists between phosphorus and the health of aquatic communities (Association Between Nutrients, Habitat, and Aquatic Biota in Ohio Rivers and Streams, MAS/1999-1-1). It was concluded that biological community performance in headwater and wadeable streams was highest where phosphorus concentrations were lowest. It was also determined that the lowest phosphorus concentrations were associated with the highest quality habitats, supporting the notion that habitat is a critical component of stream function. The report recommends WWH criteria of 0.08 mg/l in headwater streams (<20 mi^2 watershed size), 0.10 mg/l in wadeable streams (>20-200 mi^2) and 0.17 mg/l in small rivers (>200-1000 mi^2).

Organic Enrichment and Low Dissolved Oxygen

The amount of oxygen soluble in water is low and it decreases as temperature increases. This is one reason why tree shade is so important. The two main sources of oxygen in water are diffusion from the atmosphere and plant photosynthesis. Turbulence at the water surface is critical because it

increases surface area and promotes diffusion. Drainage practices such as channelization eliminate turbulence produced by riffles, meanders, and debris snags. Although plant photosynthesis produces oxygen by day, it is consumed by the reverse process of respiration at night. Oxygen is also consumed by bacteria that decay organic matter, so it can be easily depleted unless it is replenished from the air. Sources of organic matter include poorly treated waste water, sewage bypasses, and dead plants and algae.

Dissolved oxygen criteria are established in the Ohio Water Quality Standards to protect aquatic life. The minimum and average limits are tiered values and linked to use designations (Administrative Code 3745-1-07, Table 7-1).

Ammonia

Ammonia gas (NH_3) readily dissolves in water to form the compound ammonium hydroxide (NH_4OH). In aquatic ecosystems an equilibrium is established as ammonia shifts from a gas to undissociated ammonium hydroxide to the dissociated ammonium ion (NH_4^{+1}). Under normal conditions (neutral pH 7 and 25°C) almost none of the total ammonia is present as gas, only 0.55% is present as ammonium hydroxide, and the rest is ammonium ion. Alkaline pH shifts the equation toward gaseous ammonia production, so the amount of ammonium hydroxide increases. This is important because while the ammonium ion is almost harmless to aquatic life, ammonium hydroxide is very toxic and can reduce growth and reproduction or cause mortality.

The concentration of ammonia in raw sewage is high, sometimes as much as 20-30 mg/l. Treatment to remove ammonia involves gaseous stripping to the atmosphere, biological nitrification and de-nitrification, and assimilation into plant and animal biomass. The nitrification process requires a long detention time and aerobic conditions like that provided in extended aeration treatment plants. Under these conditions, bacteria first convert ammonia to nitrite (*Nitrosomonas*) and then to nitrate (*Nitrobacter*). Nitrate can then be reduced by the de-nitrification process (*Pseudomonas*) and nitrogen gas and carbon dioxide are produced as by-products.

Ammonia criteria are established in the Ohio Water Quality Standards to protect aquatic life. The maximum and average limits are tiered values based on sample pH and temperature and linked to use designations (Administrative Code 3745-1-07, Tables 7-2 through 7-8).

Metals

Metals can be toxic to aquatic life and hazardous to human health. Although they are naturally occurring elements many are extensively used in manufacturing and are by-products of human activity. Certain metals like copper and zinc are essential in the human diet, but excessive levels are usually detrimental. Lead and mercury are of particular concern because they often trigger fish consumption advisories. Mercury is used in the production of chlorine gas and caustic soda and in the manufacture of batteries and fluorescent light bulbs. In the environment it forms inorganic salts, but bacteria convert these to methyl-mercury and this organic form builds up in the tissues of fish. Extended exposure can damage the brain, kidneys, and developing fetus. The Ohio Department of

Health (ODH) issued a statewide fish consumption advisory in 1997 advising women of child bearing age and children six and under not to eat more than one meal per week of any species of fish from waters of the state because of mercury. Lead is used in batteries, pipes, and paints and is emitted from burning fossil fuels. It affects the central nervous system and damages the kidneys and reproductive system. Copper is mined extensively and used to manufacture wire, sheet metal, and pipes. Ingesting large amounts can cause liver and kidney damage. Zinc is a by-product of mining, steel production, and coal burning and used in alloys such as brass and bronze. Ingesting large amounts can cause stomach cramps, nausea, and vomiting.

Metals criteria are established in the Ohio Water Quality Standards to protect human health, wildlife, and aquatic life. Three levels of aquatic life standards are established (Administrative Code 3745-1-07, Table 7-1) and limits for some elements are based on water hardness (Administrative Code 3745-1-07, Table 7-9). Human health and wildlife standards are linked to either the Lake Erie (Administrative Code 3745-1-33, Table 33-2) or Ohio River (Administrative Code 3745-1-34, Table 34-1) drainage basins. The drainage basins also have limits for additional elements not established elsewhere that are identified as Tier I and Tier II values.

Bacteria

Bacteria levels in streams are a concern because of human health. People can be exposed to contaminated water while wading, swimming, and fishing. Fecal coliform bacteria are relatively harmless in most cases, but their presence indicates that the water has been contaminated with feces from a warm-blooded animal. Although intestinal organisms eventually die off outside the body, some will remain virulent for a period of time and may be dangerous sources of infection. This is especially a problem if the feces contained pathogens or disease producing bacteria and viruses. Reactions to exposure can range from an isolated illness such as skin rash, sore throat, or ear infection to a more serious wide spread epidemic. Some types of bacteria that are a concern include *Escherichia*, which cause diarrhea and urinary tract infections, *Salmonella*, which cause typhoid fever and gastroenteritis (food poisoning), and *Shigella*, which cause severe gastroenteritis or bacterial dysentery. Some types of viruses that are a concern include polio, hepatitis A, and encephalitis. Disease causing microorganisms such as cryptosporidium and giardia are also a concern.

Since fecal coliform bacteria are associated with warm-blooded animals, there are both human and animal sources. Human sources, including effluent from sewage treatment plants or discharges by home sewage treatment systems, are a more continuous problem. Bacterial contamination from combined sewer overflows are associated with wet weather events. Animal sources are usually more intermittent and are also associated with rainfall, except when domestic livestock have access to the water. Large livestock farms store manure in holding lagoons and this creates the potential for an accidental spill. Liquid manure applied as fertilizer is a runoff problem if not managed properly and it sometimes seeps into field tiles.

Bacteria criteria are established in the Ohio Water Quality Standards to protect human health. The

maximum and average limits are tiered values and linked to use designation, but only apply during the May 1-October 15 recreation season (Administrative Code 3745-1-07, Table 7-13). The standards also state that streams must be free of any public health nuisance associated with raw or poorly treated sewage during dry weather conditions (Administrative Code 3745-1-04, Part F).

Sediment Contamination

Chemical quality of sediment is a concern because many pollutants bind strongly to soil particles and are persistent in the environment. Some of these compounds accumulate in the aquatic food chain and trigger fish consumption advisories, but others are simply a contact hazard because they cause skin cancer and tumors. The physical and chemical nature of sediment is determined by local geology, land use, and contribution from manmade sources. As some materials enter the water column they are attracted to the surface electrical charges associated with suspended silt and clay particles. Others simply sink to the bottom due to their high specific gravity. Sediment layers form as suspended particles settle, accumulate, and combine with other organic and inorganic materials. Sediment is the most physically, chemically, and biologically reactive at the water interface because this is where it is affected by sunlight, current, wave action, and benthic organisms. Assessment of the chemical nature of this layer can be used to predict ecological impact.

The Ohio EPA evaluation of sediment chemistry results are evaluated using a dual approach, first by ranking relative concentrations based on a system developed by Ohio EPA (1996) and then by determining the potential for toxicity based on guidelines developed by MacDonald et al. (2000). The Ohio EPA system was derived from samples collected at ecoregional reference sites. Classes are grouped in ranges that are based on the median analytical value (non-elevated) plus 1 (slightly elevated), 2 (elevated), 4 (highly elevated), and 8 (extremely elevated) inter-quartile values. The MacDonald guidelines are consensus based using previously developed values. The system predicts that sediments below the threshold effect concentration (TEC) are absent of toxicity and those greater than the probable effect concentration (PEC) are toxic.

Sediment samples collected by the Ohio EPA are measured for a number of physical and chemical properties. Physical attributes included % particle size distribution (sand $60 µ, silt 5-59 µ, clay #4 µ), % solids, and % organic carbon. Due to the dynamics of flowing water, most streams do not contain a lot of sediment and samples often consist mostly of inert sand. This scenario changes if the stream is impounded by a dam or channelized. Chemical attributes included metals, volatile and semi-volatile organic compounds, pesticides, and poly-chlorinated biphenyls (PCBs).

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Delaware, Fairfield, Franklin, Licking, Morrow, and Pickaway Counties, Ohio

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Division of Surface Water
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INTRODUCTION

Ambient biological, water column chemical and sediment sampling was conducted in the Big Walnut Creek basin from June to October 2000 as part of the five-year basin approach for monitoring, assessment, and the issuance of National Pollution Discharge Elimination System (NPDES) permits and to facilitate a Total Maximum Daily Load (TMDL) assessment. This study area included over 73 miles of the Big Walnut Creek beginning in the headwaters (RM 73.6) and extending to US 23, downstream from Columbus, Ohio. Sub-watersheds within the study area included Alum Creek and Blacklick Creek. Where possible, tributary streams with at least 4 mi^2 of drainage were sampled.

Specific objectives of this evaluation were to:

1) Monitor and assess the chemical, physical and biological integrity of the streams within the 2000 Big Walnut Creek study area;

2) Characterize the consequences of various land uses on water quality within the Big Walnut Creek watershed;

3) Evaluate the influence of the Tussing Road and Blacklick Estates wastewater treatment plants (WWTPs) and unsewered communities;

4) Evaluate the potential impacts from spills, nonpoint source pollution (NPS), and habitat alterations on the receiving streams; and

5) Determine the attainment status of the current designated Warmwater Habitat (WWH) and Exceptional Warmwater Habitat (EWH) aquatic life uses and other non-aquatic use designations and recommend changes where appropriate.

6) Evaluate undesignated streams and assign the appropriate aquatic life use and other non-aquatic

use designations.

The findings of this evaluation factor into regulatory actions taken by the Ohio EPA (*e.g.*, NPDES permits, Director's Orders, the Ohio Water Quality Standards [OAC 3745-1], Water Quality Permit Support Documents [WQPSDs]) and are incorporated into State Water Quality Management Plans, the Ohio Nonpoint Source Assessment and the biennial Integrated Water Quality Monitoring and Assessment Report (305[b] and 303[d]).

SUMMARY

Aquatic Life Use Attainment Status

A summary of monitoring results and the attainment status of current or recommended aquatic life uses in the Big Walnut Creek study area can be found in Table 1. Biological, physical habitat, and surface water chemistry information was collected from 114 stations in 46 streams. Of these, 52 were in FULL attainment, 19 were PARTIAL, 39 were NON, two were in mixing zones, and two stations were located in primary headwater stream reaches.

Big Walnut Creek Mainstem

The study area included 15 stations on the Big Walnut Creek mainstem from the headwaters at Cardington-East Rd. (RM 73.6) to near its confluence with the Scioto River at US 23 (RM 1.7) downstream from Columbus, Ohio. Eleven stations were in FULL attainment of their existing or recommended aquatic life use designation, one was PARTIAL, and three were NON.

Fair biological communities in the headwaters of Big Walnut Creek down to Prospect-Mt. Vernon Rd. (RM 66.6) were impacted by channel modifications (especially at RM 72.5/73.6), siltation (heavy at 72.5/73.6 and moderate at downstream areas), stream dewatering (probably from agricultural drainage systems), and nutrient enrichment from agricultural activities. Exceedences of fecal coliform (as high as 26,000/100 ml at RM 66.6) and E. coli (as high as 17,000/100 ml at RM 66.6) were indications of livestock manure runoff and possibly failing home sewage treatment systems.

The biological communities improved into the good to very good range by Chambers Rd. (RM 60.0) and remained in FULL attainment of the WWH aquatic life use downstream to the upper reaches of Hoover Reservoir. However, elevated nutrients (ammonia at RM 54.6 and phosphorus at RM 61.9) and bacteria (RM 61.9) may have been caused by the hydraulic overflows from the Village of Marengo WWTP (RM 65.8) during rain events or indications of moderate agricultural runoff and possibly failing home sewage treatment systems.

The biological community performance decline downstream from Hoover Reservoir at RM 37.2 was attributed to the effects of the reservoir's hypolimnetic release. The fish and macroinvertebrate communities improved into the good to exceptional range by SR 161 (RM 34.9) and remained in

FULL attainment of the designated aquatic life uses until its confluence with the Scioto River. Elevated nutrients at RMs 37.2 and 34.9, high bacterial counts from RMs 37.2 to 27.0 (E. coli as high as 23,000/100 ml at RM 28.3 and fecal coliform as high a 20,000/100 ml at RM 28.3), and sediment contamination throughout this section (metals, PAHs, and pesticides) were indications of runoff from surrounding suburban areas.

Biological community performance in Big Walnut Creek has remained about the same or slightly improved compared to previous sampling. Surface water chemistry sampling demonstrated an improvement downstream from the Marengo WWTP, the Sunbury WWTP (via Prairie Run), and the Columbus Airport tributary. An area that declined in 2000 was downstream from Rocky Fork Big Walnut Creek with increased mean bacterial counts and total suspended solids.

Big Walnut Creek Tributaries Upstream from Hoover Reservoir

Biosurvey sampling was conducted at 37 stations in 19 streams that are tributaries to Big Walnut Creek upstream from Hoover Reservoir. Of these, 16 stations were in FULL attainment of their existing or recommended aquatic life use designation, five were PARTIAL, 15 were NON, and one was located in a primary headwater stream segment.

The biological community was primarily impacted by very low to intermittent stream flow in Reynolds Run (RM 0.7), Long Run (RM 3.6), Sugar Creek (RM 0.1), and Culver Creek (RM 4.5). These stations had adequate flow in mid July when fish sampling was conducted but were characterized by very low to intermittent flow by mid September when the macroinvertebrate sampling was conducted. In addition, Reynolds Run (RM 0.7) was also impacted by channelization and the removal of the woody riparian corridor, and Culver Creek (RM 4.5) was impacted by water quality impairments (low D.O. and elevated nutrients), probably from home sewage treatment systems and agricultural runoff.

The upper portions of North Fork Rattlesnake Creek and East Fork Rattlesnake Creek were impacted by water quality impairments (low D.O. in the E. Fk. and high nutrients in both) from land application of chicken manure generated by Buckeye Egg Farm's Croton facility in addition to channelization, livestock runoff, and possibly failing home sewage treatment systems. The lower portions of East Fork Rattlesnake Creek and South Fork Rattlesnake Creek were impacted by runoff from the construction of the Rattlesnake Ridge Golf Club. The water column of both streams became turbid brown downstream from the golf course construction during sampling in September with heavy siltation at the South Fork station downstream from Longshore Rd. (RM 0.2).

West Branch Little Walnut Creek (RM 1.5) was impacted by water quality impairments (low D.O., elevated nutrients, high bacterial counts) apparently from failing home sewage treatment systems and agricultural activities. Butler Run was impacted primarily by channelization, siltation, and the removal of the woody riparian corridor.

Duncan Run was impacted by channelization and siltation, especially in the upper reach, along with

elevated nutrients and high bacterial counts from agricultural activities and failing home sewage treatment systems.

Minor Big Walnut Creek Tributaries Downstream from Hoover Reservoir

Biosurvey sampling was conducted at 12 stations in eight streams that are minor tributaries (including Rocky Fork) to Big Walnut Creek downstream from Hoover Reservoir. Of these, two stations were in FULL attainment of their existing or recommended aquatic life use designation, two were PARTIAL, seven were NON, and one was located in a primary headwater stream.

McKenna Creek is a small suburban stream that was apparently impacted by failing home sewage treatment systems and urban runoff. Biological results (macroinvertebrate) reflected fair resource quality.

Rocky Fork Big Walnut Creek was impacted primarily from runoff and siltation from increasing land development in the basin and from poorly treated sewage from failing home sewage treatment systems and several small package plants. The biological communities in the upper part of Rocky Fork were performing as bad or worse than any time since the initial study in 1991 (Ohio EPA 1992). Sugar Run and Rose Run were showing varying degrees of impact from land development in the New Albany area.

The "Columbus Airport Tributary" was impacted by channelization, removal of the woody riparian corridor, runoff from Port Columbus International Airport including the persistent spillage of large quantities of airplane deicing solution (ethylene glycol), and sediment contamination (metals, PAHs). The resource quality is similar to the 1996 survey results (Ohio EPA 1997) except for the detection in the sediment sample of six PAHs in excess of the threshold effect concentration or the probable effect concentration.

The Mason Run basin is highly urbanized. The headwaters of Mason Run originate in an industrial area and then flow through a section that is highly modified including an underground culvert from RMs 3.4 to 1.9. The fair to poor biological communities reflected the negative impacts from habitat alterations, flow alterations, and polluted runoff from the upstream urban areas. The resource quality has declined since the 1996 survey (Ohio EPA 1998a) when at least the fish community was meeting WWH expectations.

Alum Creek Mainstem

The study area included 13 stations on the Alum Creek mainstem from the headwaters at Cardington-East Rd. (RM 56.3) to near its confluence with Big Walnut Creek at Williams Rd. (RM 0.8/0.7). Seven stations were in FULL attainment of their existing or recommended aquatic life use designation, five were PARTIAL, and one was NON.

The biological communities in Alum Creek upstream from Alum Creek Lake were generally performing in the good to exceptional range. The station upstream from the West Branch Alum

Creek (RM 42.9) had the best physical stream habitat (QHEI=89.0) of any segment in the entire survey, with a complete absence of modified attributes. The station downstream from the West Branch Alum Creek (RM 42.6) had the highest diversity of EPT taxa (24), a measure of the diversity of pollution sensitive macroinvertebrate taxa, and the highest ICI score of any station in the study. The fair fish community at SR 529 (RM 55.3) was attributed to the negative effects of channel modifications. Elevated nutrient concentrations associated with a rain event, especially in the upper reaches, and high bacterial counts throughout this part of Alum Creek indicated the presence of intermittent and chronic stressors potentially impacting the biological communities.

The biological communities in Alum Creek 4.3 miles downstream from Alum Creek Lake fully met WWH expectations for the IBI and ICI biocriteria but only marginally met for the MIwb. At Schrock Rd. (RM 19.8) the macroinvertebrate community declined into the fair range. Heavy siltation noted at the station, presumably from upstream construction, may have been a major cause of this decline. Communities continued to be impacted downstream to Refugee Rd. (RM 3.8). Much of this stretch flows through highly urbanized parts of Columbus. The stream channel in several places is channelized and impounded which slows down stream flow, reducing reaeration of the stream and creating monotonous habitat that is unsuitable for many stream organisms. Additional stressors present within this reach include urban runoff, the Alum Creek storm tank discharge, and numerous minor SSOs. Indications of water quality impairments in this area were at least one exceedence of the maximum Secondary Contact Recreation criterion for E. coli at each station, elevated nutrients throughout this area, and contaminated sediments (PAHs, cadmium) at Refugee Rd. The biological communities were fully meeting the WWH expectations at Williams Rd. (RM 0.8/0.7). The Huber Ridge WWTP discharge was not specifically evaluated in this study, but did not appear to have an obvious impact on the biology or water chemistry in Alum Creek.

The biological results from 2000 show a similar trend to the 1996 survey (Ohio EPA 1999a) with the exception of lower macroinvertebrate performance downstream from Westerville and the Huber Ridge WWTP. Water sampling results from the current study documented decreases in mean fecal coliform counts and 5-day biochemical oxygen demand in the lower Alum Creek compared to 1996.

Alum Creek Tributaries Upstream from Alum Creek Lake

Biosurvey sampling was conducted at nine stations in four streams that were tributaries to Alum Creek upstream from Alum Creek Lake. Of these, four stations were in FULL attainment of their existing or recommended aquatic life use designation, two were PARTIAL, and three were NON.

Biological communities in West Branch Alum Creek, Turkey Run, and Big Run were impacted to varying degrees by low flows, channel modifications, siltation, organic enrichment, high nutrients, and high bacterial counts from agricultural activities. The biological communities in West Branch Alum Creek improved into the good to exceptional range by Worthington-New Haven Rd. (RM 0.5). The Ashley WWTP discharge (RM 4.55) was not specifically evaluated in this study, but did not appear to have an obvious impact on the biology or water chemistry in West Branch Alum Creek.

Alum Creek Tributaries Downstream from Alum Creek Lake

Biosurvey sampling was conducted at seven stations in five streams that were tributaries to Alum Creek downstream from Alum Creek Lake. Of these, two stations were in FULL attainment of their existing or recommended aquatic life use designation, one was PARTIAL, and four were NON.

Biological communities in Spring Run, "West Spring Run", and Kilbourne Run were impacted to varying degrees by channel modifications, organic enrichment, high bacterial counts, low flow, and siltation from urbanization of the surrounding watershed. The tributary to Alum Creek at RM 25.50 was supporting an exceptional headwater fish community; however, very high bacterial counts and water quality impairments (BOD_5, Total Suspended Solids, Ammonia, Total Kjeldahl Nitrogen) indicated this stream is threatened by unrestricted livestock access to the stream upstream from the collection site. Bliss Run was contaminated with very high bacterial counts; however, since aquatic communities were not sampled, it was not possible to assess its aquatic life use attainment status.

Blacklick Creek Mainstem

The study area included 13 stations on the Blacklick Creek mainstem from the headwaters at Walnut St. (RM 27.1) to near its confluence with Big Walnut Creek at Hamilton Rd. (RM 2.6). Seven stations were in FULL attainment of their existing or recommended aquatic life use designation, one was PARTIAL, three were NON, and two were in WWTP mixing zones.

The biological communities in the headwaters of Blacklick Creek were severely impacted by failing home sewage treatment systems. Both the fish and macroinvertebrate communities were in poor condition at this station and the water quality was likewise highly degraded with very high bacterial counts, low D.O. concentrations, and very high BOD_5 and nutrient concentrations. In addition to home sewage treatment systems, Hendren Farms (250 dairy cows) has recently been having problems with manure spillage into Blacklick Creek near Central College Rd. (RM 26.0). Sediment sampling at Morse Rd. (RM 22.4) found one PAH in excess of the threshold effect concentration and five PAHs in excess of the probable effect concentration. The biological communities gradually improved downstream until the WWH use was fully attained at Havens Rd. (RM 20.4).

The Jefferson Township Wengert Rd. WWTP (RM 18.10) was not specifically evaluated during this study. The WWH aquatic life use was fully attained upstream and downstream from the discharge, however, an unusually high relative predominance of pollution facultative and tolerant macroinvertebrate organisms observed on the natural substrates and increases in elevated nutrient concentrations recorded downstream from the WWTP discharge at Broad St. (RM 16.6) suggested a mild impact from the WWTP. This WWTP is scheduled to be closed and the collection system tied into the Columbus sewage system in 2004.

Biological and water chemistry sampling in the vicinity of the Fairfield County - Tussing Rd. WWTP (RM 11.15) indicated only a mild impact from the WWTP discharge. Biological communities upstream from the discharge were in FULL attainment of the WWH aquatic life use. The samples within the mixing zone did not indicate any significant toxicity from the discharge. Sampling outside

the mixing zone and immediately downstream revealed a mild impact to the macroinvertebrate community. The aquatic life use attainment status remained FULL, however, the ICI score dropped from 48 upstream from the WWTP at RM 11.3 to 38 downstream at RM 11.0. This decline indicated mild organic/nutrient enrichment from the WWTP discharge. The macroinvertebrate community improved slightly by Refugee Rd. (RM 8.9) upstream from the Blacklick Estates WWTP discharge. The water column chemistry and bacterial sampling detected concentrations of ammonia (7.32 mg/l) and fecal coliform (25,000/100 ml) in the effluent that exceeded the permit limits. One fecal coliform count of 11,181/100 ml measured at RM 11.0 was substantially higher than any found upstream from the WWTP discharge. Elevated nutrient and demand parameter concentrations downstream from the WWTP discharge were evidence of the pollution loadings from the WWTP.

Biological and water chemistry sampling in the vicinity of the Blacklick Estates WWTP (RM 4.85) indicated only a mild to moderate impact from the WWTP discharge. Biological communities upstream from the discharge were in FULL attainment of the WWH aquatic life use. The samples within the mixing zone did not indicate any significant toxicity from the discharge. Sampling outside the mixing zone and immediately downstream revealed a moderate impact to the macroinvertebrate community resulting in a fair community (ICI=26). The fish community exhibited no decline downstream from the discharge so the attainment status was PARTIAL downstream from the Blacklick Estates WWTP. The biological communities were in FULL attainment farther downstream, upstream from Hamilton Rd. (RM 2.6). The water column chemistry and bacterial sampling did not detect any significant exceedences of water quality criteria attributable to the Blacklick Estates WWTP discharge. A fecal coliform count of 3000/100ml and E. coli counts as high as 2900/100ml collected downstream from the WWTP discharge at RM 4.6 were exceedences of the primary and secondary contact recreation criterion, respectively. However, they are not much different from collection sites upstream from the discharge. Similarly, elevated nutrient and demand parameter concentrations sampled downstream from the WWTP discharge were not dissimilar to upstream stations. Sediment chemistry sampling at RM 1.9 found concentrations of two PAHs exceeding the threshold effect concentration.

The biological results from 2000 reflected a similar trend compared to the 1996 survey (Ohio EPA 1998b) with the exception of lower macroinvertebrate performance downstream from the Blacklick Estates WWTP. The water chemistry results from the current study were similar to the 1996 survey except for increased mean fecal coliform counts downstream from the Tussing Rd. WWTP, decreased mean BOD_5 concentrations downstream from the Tussing Rd. WWTP and Blacklick Estates WWTP, and decreased mean nitrate+nitrite concentrations downstream from Blacklick Estates WWTP.

Blacklick Creek Tributaries

Biosurvey sampling was conducted at eight stations in seven streams that were tributaries to Blacklick Creek. Of these, three stations were in FULL attainment of their existing or recommended aquatic life use designation, two were PARTIAL, and three were NON.

The stations on Blacklick Creek tributaries were generally all similar in that the fish communities were meeting biocriteria benchmarks and the macroinvertebrate communities were not. Diversity of pollution sensitive macroinvertebrate taxa was relatively low and facultative or tolerant taxa were present in higher numbers than expected. Persistently high bacterial counts, mild nutrient enrichment and sedimentation at these stations were indications of the increasingly suburbanized nature of this watershed.

"Unzinger Ditch", a tributary to Blacklick Creek at RM 15.88, was not evaluated during this study, but was assessed by Ohio EPA (2001). That study found the biological communities to be in non-attainment of aquatic life uses due to stream channel modifications, toxicity associated with contaminated sediments, and nutrient enrichment from sewage. The most severe sediment contamination was found downstream from the discharge and potential runoff from the Columbus Steel Drum Company.

CONCLUSIONS AND RECOMMENDATIONS

The 2000 biological and water quality study of the Big Walnut Creek basin identified various impairments to its resource quality. These impairments can be traced to a number of anthropogenic activities and land use practices outlined below. A summary of the causes and sources of impairment by stream segment is presented in Table 2. Verifications of existing Aquatic Life Use, Public Water Supply, and Recreation use designations and new recommendations based on the findings of this study are presented in Table 3.

Agricultural and Animal Husbandry Practices

Stream channelization and removal of the woody riparian corridor in association with extensive field tile drainage was creating conditions unsuitable for healthy aquatic communities. In order to restore the resource quality to these streams, the agricultural activities should be backed away from the stream channel, the woody riparian corridor should be allowed to revegetate, and alternative engineering methods for facilitating drainage such as a two stage channel should be explored.

Livestock with unrestricted access to the stream channel creates many of the same problems as channelization with the addition of animal wastes directly entering the stream. In order to restore the resource quality to these streams, the livestock should be fenced out of the stream for most of its length to allow the natural stream and riparian habitat to reestablish.

The over application or inappropriate application of animal wastes to agricultural fields for fertilization or waste disposal was creating a highly enriched and potentially toxic conditions in certain streams. In particular, the upper portions of North Fork Rattlesnake Creek and East Fork Rattlesnake Creek were impacted by runoff from the land application of chicken manure generated by Buckeye Egg Farm's Croton facility. In order to restore the resource quality to these streams, the application time and amounts should be evaluated to prevent excessive runoff.

Home Sewage Treatment Systems

Poorly operating home sewage treatment systems were identified as one of the major contributors to the widespread occurrence of bacterial counts in excess of the maximum Primary and Secondary Contact Recreation criteria, along with elevated nutrient concentrations and oxygen demanding constituents. In order to restore the resource quality to these streams, a concerted effort should be made to inspect and repair or connect to central sewers as many of these units as possible.

Land Development and Urban Runoff

The lower Big Walnut Creek basin is either highly urbanized or rapidly suburbanizing. Suburban development often leads to stream and riparian habitat modifications and sediment runoff that impact the resource quality. Additionally, when the percentage of impervious surface in an area reaches a certain point, alterations to the hydrology and increased polluted runoff will severely impact the biological integrity of a stream (Karr & Chu 2000). In order to preserve and restore the resource quality in this basin, every effort should be made to protect the stream corridors and prevent excessive sediment runoff in rapidly developing areas and to use a combination of stormwater retention practices, both onsite and local area catchments, to slow and treat runoff whenever possible.

Municipal Sewage Collection and Treatment Systems

The wastewater treatment plants in this basin were generally doing a good job of treating sewage. However, many systems have inflow and infiltration (I/I) problems which lead to overloading of the plant, especially during wet weather. Permitted WWTPs are listed under “Pollutant Loadings: 1976-1999" along with a summary of their operational problems. In order to protect the resource quality of the streams in this basin, every effort should be made to correct the WWTPs’ I/I problems.

Impoundments

Stream channels in several places were impounded which slows down stream flow, reduces reaeration of the stream, and creates monotonous habitat that is unsuitable for many stream organisms. In addition, if the impounding structure is large enough, it will impede fish and consequently freshwater mussel migration. In particular, the lowhead dams on the lower Alum Creek were identified as contributing to the impaired biological integrity (Ohio EPA 1999). In order to restore the resource quality on the streams in this basin, the feasibility of removing unnecessary dams should be investigated.

Table 1. Aquatic life use attainment status of the Big Walnut Creek basin, June-October, 2000. The Index of Biotic Integrity (IBI), Modified Index of Well Being (MIwb), and Invertebrate Community Index (ICI) scores are based on the performance of fish (IBI, MIwb) and macroinvertebrate communities (ICI). The Qualitative Habitat Evaluation Index (QHEI) is a measure of the ability of the physical habitat to support biological communities.

River Mile Fish[a]/Invert.	IBI	MIwb	ICI[b]	QHEI	Attainment Status	Comment
Big Walnut Creek (02-100)						
			WWH Use Designation (Existing)			
72.5[E]/73.6	32*	NA	Low F*	55.5	**NON**	Cardington-East Rd.
- /70.7	-	-	F*	-	**(NON)**	Waldo-Fulton-Chesterville Rd.
66.6[D]	34*	NA	F*	58.5	**NON**	Prospect-Mt. Vernon Rd.
- /60.0	-	-	42	-	(FULL)	Chambers Rd.
54.6[D]	46	8.4	VG	73.0	FULL	Stockwell Rd.
52.4[D]/52.3	38[ns]	8.0[ns]	44	69.5	FULL	North Old 3C Rd.
49.0[E]/48.9	46	8.4	46	78.5	FULL	Dst. Sunbury
37.2[A]	32*	8.1[ns]	34[ns]	84.5	PARTIAL	Dst. Reservoir
- /34.9	-	-	40	-	(FULL)	SR 161
28.5[A]/28.3	49	10.2	40	82.0	FULL	Dst. Morse Rd. WTP, ust. airport trib.
26.7[A]/27.0	52	9.8	48	83.5	FULL	Dst. airport trib.
			EWH Use Designation (Existing)			
15.8[A]	48	10.1	46	84.5	FULL	Williams Rd.
7.1[A]/7.0[c]	48	9.5[ns]	44[ns]	83.0	FULL	SR 317
- /3.6	-	-	46	-	(FULL)	Rowe Rd., dst. Rickenbacker
1.7[A]	52	9.3[ns]	42[ns]	84.0	FULL	US 23
Castro Run (02-105) *WWH Use Designation (Existing)*						
0.4[E]/ -	36[ns]	NA	-	57.0	(FULL)	Adj. Phillips Rd.
Mill Creek (02-170) *WWH Use Designation (Existing)*						
1.3[E]/ -	40	NA	-	70.5	(FULL)	Bennington-Harmony Central Rd.
Reynolds Run (02-104) *WWH Use Designation (Existing)*						
4.9[E]/ -	28	NA	-	53.5	N/A	PHWH, Turney Center Rd.
0.7[E]	32*	NA	F*	59.0	**NON**	East Liberty North Rd.

Table 1. Continued

River Mile Fish[a]/Invert.	IBI	MIwb	ICI[b]	QHEI	Attainment Status	Comment
Long Run (02-103) *WWH Use Designation (Existing)*						
4.9[E]/ -	20*	NA	-	56.5	**(NON)**	Trimmer Rd.
3.6[E]	34*	NA	F*	69.0	**NON**	Porter Central Rd.
0.7[E]	48	NA	G	73.0	FULL	Ulery Rd.
Sugar Creek (02-102) *WWH Use Designation (Existing)*						
5.3[E]/ -	46	NA	-	71.0	(FULL)	Trimmer Rd.
0.1[E]	46	NA	F*	77.0	PARTIAL	Adj. Monkey Hollow Rd.
Culver Creek (02-101) *WWH Use Designation (Existing)*						
4.5[E]	38[ns]	NA	F*	56.5	PARTIAL	Patrick Rd.
3.3[E]	40	NA	VG	75.0	FULL	Centerburg Rd.
- /0.1	-	-	VG	-	(FULL)	Near mouth
Tributary to Culver Creek (RM 3.32) (02-336) *WWH Use Designation (Recommended)*						
0.7[E]/0.1	40	NA	G	67.0	FULL	Porter Central Rd./Fredricks Rd.
Perfect Creek (02-160) *WWH Use Designation (Existing)*						
4.7[E]/4.9	36[ns]	NA	MG[ns]	71.5	FULL	Old SR 3
1.0[E]/0.1	36[ns]	NA	VG	59.0	FULL	Near mouth
Rattlesnake Creek (02-150) *WWH Use Designation (Existing)*						
0.1[E]	37[ns]	4.9*	38	66.5	**NON**	Near mouth
North Fork Rattlesnake Creek (02-151) *WWH Use Designation (Existing)*						
5.8[E]/ -	32*	NA	-	41.0	**(NON)**	Foundation Rd. (E)
4.8[E]/ -	40	NA	-	58.5	(FULL)	North County Line Rd.
3.4[E]	30*	NA	G	37.5	PARTIAL	Hartford Rd. (East Crossing)
1.7[E]/0.1	40	NA	G	59.5	FULL	Near mouth
East Fork Rattlesnake Creek (02-152) *WWH Use Designation (Existing)*						
4.2[E]/ -	12*	NA	-	48.5	**(NON)**	Tagg Rd.
- /1.2	-	-	Low F*	-	**(NON)**	Dent Rd.
0.2[E]	38[ns]	NA	Low F*	56.0	PARTIAL	SR 605

Table 1. Continued

River Mile Fish[a]/Invert.	IBI	MIwb	ICI[b]	QHEI	Attainment Status	Comment
South Fork Rattlesnake Creek (02-153) *WWH Use Designation (Existing)*						
3.7[E]/3.0	44	NA	MG[ns]	59.5	FULL	Ross Rd./Dent Rd.
0.5[E]/0.2	24*	NA	F*	53.0	**NON**	Longshore Rd.
Prairie Run (02-125) *WWH Use Designation (Existing)*						
0.7[E]/0.4	44	NA	F*	51.0	PARTIAL	Ust. Sunbury WWTP
Little Walnut Creek (02-140) *WWH Use Designation (Existing)*						
- /9.4	-	-	G	-	(FULL)	Blue Church Rd.
7.4[E]	46	NA	G	66.5	FULL	Dst. E. Br. L Walnut Cr.
3.2[E]/4.7	30*	6.4*	28*	62.0	**NON**	Ust. Cheshire Rd./US 36 & SR 37
Tributary to Little Walnut Creek (RM 9.5) (02-341) *WWH Use Designation (Recommended)*						
1.5[E]/ -	38[ns]	NA	-	68.0	(FULL)	Blue Church Rd.
Butler Run (02-141) *WWH Use Designation (Existing)*						
1.2[E]	20*	NA	F*	45.0	**NON**	Wilson Rd.
East Branch Little Walnut Creek (02-142) *WWH Use Designation (Existing)*						
0.4[E]/ -	38[ns]	NA	-	73.0	FULL	Rosecrans Rd.
West Branch Little Walnut Creek (02-143) *WWH Use Designation (Existing)*						
- /1.5	-	-	F*	-	**(NON)**	Twigg-Hupp Rd.
Duncan Run (02-124) *WWH Use Designation (Existing)*						
- /9.0	-	-	Low F*	-	**(NON)**	Robins Rd.
- /7.3	-	-	F*	-	**(NON)**	Green-Cook Rd.
5.0[E]/ -	30*	NA	-	57.5	**(NON)**	Duncan Run Rd.
- /2.7	-	-	Low F*	-	**(NON)**	Harlem Rd.
Trib. to Big Walnut Creek (RM 32.6) (02-334) *WWH Use Designation (Recommended)*						
0.2[E]/ -	34*	NA	-	58.5	**(NON)**	Off Cherry Bottom Rd.

Table 1. Continued

River Mile Fish[a]/Invert.	IBI	MIwb	ICI[b]	QHEI	Attainment Status	Comment
McKenna Creek (Trib. to B. Walnut Cr. (RM 29.65)) (02-347)						
WWH Use Designation (Recommended)						
- /0.2	-	-	F*	-	**(NON)**	Cherry Bottom Rd.
Rocky Fork (02-123)						
WWH Use Designation (Existing)						
10.2[E]	32*	NA	F*	60.0	**NON**	Ust. Walnut St., ust. trib.
7.1[D]	38[ns]	NA	MG[ns]	60.0	FULL	Old SR 161
5.9[D]	28*	NA	F*	73.5	**NON**	Thompson Rd.
EWH use Designation (Existing)						
3.3[D]/3.2	36*	7.4*	50	66.0	PARTIAL	Clark State Rd.
1.1[E]/1.0	46[ns]	8.6*	46	81.0	PARTIAL	Hamilton Rd.
Sugar Run (02-260) *WWH Use Designation (Existing)*						
0.7[E]	38[ns]	NA	MG[ns]	66.5	FULL	Old SR 161
Rose Run (02-252) *WWH Use Designation (Existing)*						
0.5[E]/ -	32*	NA	-	55.5	**(NON)**	Harlem Rd.
Trib. to Big Walnut Creek (RM 27.29) (02-280) *WWH Use Designation (Recommended)*						
0.2[E]	26*	NA	P*	53.5	**NON**	Dst. Columbus Airport
Trib. to Big Walnut Creek (RM 27.25) (02-335) *Potential PHWH Use Designation*						
0.1[E]/ -	12	NA	-	54.5	NA	Dst. Columbus Airport
Mason Run (02-122) *WWH Use Designation (Existing)*						
1.4[E]/0.5	28*	NA	P*	55.5	**NON**	Petzinger Rd./Refugee Rd.
Alum Creek (02-110)						
WWH Use Designation (Existing)						
56.3[E]/ -	46	NA	-	47.5	(FULL)	Cardington East Rd.
55.3[E]	32*	NA	G	62.5	PARTIAL	SR 529
- /51.5	-	-	VG	-	(FULL)	Phillips Rd.
49.9[E]	56	NA	VG	83.0	FULL	Prospect-Mt. Vernon Rd.
45.5[D]/ -	47	7.3*	-	71.0	(PARTIAL)	East Liberty Rd.

Table 1. Continued

River Mile Fish[a]/Invert.	IBI	MIwb	ICI[b]	QHEI	Attainment Status	Comment
Alum Creek (02-110) (Continued)						
42.9[D]	48	8.5	48	89.0	FULL	Ust. W. Br. Alum Cr.
- /42.6	-	-	54	-	(FULL)	Dst. W. Br. Alum Cr.
22.1[D]/22.4	43	8.0[ns]	46	70.5	FULL	Adj. Cleveland Ave.
19.8[D]	42	8.2[ns]	28*	79.5	PARTIAL	Schrock Rd.
13.4[D]/13.5	38[ns]	7.6*	32[ns]	79.0	PARTIAL	Innis Park
- /7.6	-	-	24*	-	**(NON)**	Wolf Park
2.7[A]/3.8	39[ns]	9.2	28*	86.5	PARTIAL	Ust. Watkins Rd./Refugee Rd.
0.8[A]/0.7	42	8.9	46	73.0	FULL	Williams Rd.
Bunker Run (02-121) *WWH Use Designation (Existing)*						
1.8[E]	42	NA	G	75.0	FULL	South Woodbury Rd.
West Branch Alum Creek (02-118) *WWH Use Designation (Existing)*						
12.3[E]/ -	36[ns]	NA	-	50.0	(FULL)	Waldo-Fulton-Chesterville Rd.
9.9[E]/9.4	30*	NA	Low F*	47.5	**NON**	Waldo-Fulton Rd./Kilbourne Rd.
8.7[E]	40	NA	F*	48.5	PARTIAL	Westfield-Fulton Rd.
3.3[E]	54	NA	MG[ns]	75.5	FULL	Shoemaker Rd.
0.6[D]/0.5	51	8.7	50	72.0	FULL	Worthington-New Haven Rd.
Turkey Run (02-119) *WWH Use Designation (Existing)*						
3.7[E]/3.6	32*	NA	Low F*	57.0	**NON**	Pompey Rd.
0.1[E]	34*	NA	VG	74.0	PARTIAL	Piper Rd.
Big Run (02-112) *WWH Use Designation (Existing)*						
4.8[E]/2.7	34*	NA	F*	57.5	**NON**	From Jumper Rd./US36-SR37
Tributary to Alum Creek (RM 25.50) (02-338) *WWH Use Designation (Recommended)*						
0.2[E]/ -	52	NA	-	63.0	(FULL)	Africa Rd.
Tributary to Alum Creek (RM 23.47) (02-337) *WWH Use Designation (Recommended)*						
0.8[E]/ -	40	NA	-	64.0	(FULL)	Africa Rd.

Table 1. Continued

River Mile Fish[a]/Invert.	IBI	MIwb	ICI[b]	QHEI	Attainment Status	Comment
Spring Run (Trib. to Alum Creek (RM 17.22)) (02-276)						
WWH Use Designation (Recommended)						
6.0[E]/5.4	24*	NA	VP*	26.0	**NON**	Maxtown Rd./Blue Heron Rd.
3.7[E]	28*	NA	P*	59.0	**NON**	Walnut St.
0.2[E]	44	NA	F*	58.0	PARTIAL	Buenos Aires Rd.
"West Spring Run" (Trib. to Alum Creek (RM 17.15)) (02-240)						
WWH Use Designation (Recommended)						
0.4[E]/ -	20*	NA	-	60.0	**(NON)**	SR 3
Kilbourne Run (Trib. to Alum Cr. (RM 16.34)) (02-297)						
WWH Use Designation (Recommended)						
0.4[E]/ -	28*	NA	-	66.0	**(NON)**	Westerville Rd.
Blacklick Creek (02-130) *WWH Use Designation (Existing)*						
27.1[E]	20*	NA	P*	53.5	**NON**	Walnut St.
24.7[E]	34*	NA	Low F*	76.0	**NON**	SR 161
22.4[E]/23.0	32*	NA	F*	70.5	**NON**	Morse Rd.
20.4[E]	46	NA	G	63.0	FULL	Havens Rd.
16.6[D]	44	8.7	44	70.0	FULL	Broad St.
13.7[D]	46	8.5	MG[ns]	71.5	FULL	Main St.
11.3[D]	39[ns]	8.0[ns]	48	76.5	FULL	Ust Tussing Rd. WWTP
11.14[D]/11.10	*40*	*7.0*	*F/F*	*NA*	*NA*	*Tussing Rd. WWTP mixing zone*
11.0[D]	44	8.6	38	70.0	FULL	Dst. Tussing Rd. WWTP
8.8[D]/8.9	46	9.4	40	70.5	FULL	Refugee Rd.
4.83[D]	*39*	*8.5*	*F/F*	*NA*	*NA*	*Blacklick Estates WWTP mix zone*
4.6[D]/4.5	46	8.9	26*	69.0	PARTIAL	Dst. Blacklick Estates WWTP
2.6[D]	43	8.4	42	78.0	FULL	Ust. Hamilton Rd.
Dysar Run (Trib. to Blacklick Cr. (RM 14.64)) (02-281) *WWH Use Designation (Existing)*						
3.0[E]/2.1[c]	40	NA	F*	49.0	PARTIAL	Railroad bridge/Waggoner Rd.
1.9[E]/1.6	42	NA	P*	68.0	**NON**	SR 16
Tributary to Dysar Run (RM 1.67) (02-342) *WWH Use Designation (Recommended)*						
0.2[E]/ -	42	NA	-	52.0	(FULL)	Waggoner Rd.

Table 1. Continued

River Mile Fish[a]/Invert.	IBI	MIwb	ICI[b]	QHEI	Attainment Status	Comment
French Run (Trib. to Blacklick Cr. (RM 13.66)) (02-290) *WWH Use Designation (Existing)*						
0.6[E]/0.7	48	NA	F*	55.0	PARTIAL	Waggoner Rd.
North Branch French Run (Trib. to French Run (RM 0.33)) (02-291) *EWH Use Designation (Existing)*						
- /0.2	-	-	MG[*]	-	(**NON**)	Behind French Run Elem. Sch.
"Lees Creek" (Trib. to Blacklick Cr. (RM 11.25)) (02-288) *WWH Use Designation (Existing)*						
0.3[E]/ -	48	NA	-	73.5	(FULL)	Ust. SR 256
Tributary to Blacklick Creek (RM 10.36) (02-287) *WWH Use Designation (Existing)*						
0.2[E]/ -	42	NA	-	70.0	(FULL)	Dst. SR 256
"Powell Ditch" (Trib. to Blacklick Cr. (RM 6.50)) (02-286) *WWH Use Designation (Existing)*						
0.8[E]/0.9	36[ns]	NA	P*	49.5	**NON**	Dst. Brice

Ecoregion Biocriteria: Eastern Cornbelt Plains Ecoregion

INDEX - Site Type	WWH	EWH	MWH
IBI - Headwater	40	50	24
IBI - Wading	40	50	24
IBI - Boat	42	48	24
MIwb - Wading	8.3	9.4	6.2
MIwb - Boat	8.5	9.6	5.8
ICI	36	46	22

* Significant departure from ecoregion biocriterion; poor and very poor results are underlined.
ns Nonsignificant departure from biocriterion (#4 IBI or ICI units, #0.5 MIwb units).
a Fish sampling methods: A=Boat, D=Wading, E=Longline.
b Narative evaluation based on qualitative macroinvertebrate sample (E=Exceptional, VG=Very Good, G=Good, F=Fair, Low F=Low Fair, P=Poor, and VP=Very Poor).
c Macroinvertebrate sample was collected in 2001 and may be replacing a 2000 sample.

Table 2. Causes and sources of impairment in the Big Walnut Creek basin.

Watershed Stream Segment [Upper River Mile/Lower River Mile]	**Aquatic Life Use Designation**	**Attainment Status (Miles)**			**Causes of Impairment [1]**	**Sources of Impairment [1]**
		Full	Partial	NON		
Watershed: [05060001 130], Big Walnut Creek (headwaters to Hoover Dam)						
Big Walnut Creek (Headwaters to Reynolds Run) [RM 73.60-62.76]	WWH			10.84	Flow alteration-H Habitat alteration-H Siltation-H,M,S Nutrients-M,S Pathogens-S Organic enrichment-S	Nonirrigated crop prod.-H Channelization-H Range land-S Home sewage treatment syst.-S
Big Walnut Creek (Reynolds Run to Culver Cr.) [RM 62.76-53.35]	WWH	9.41				
Big Walnut Creek (Culver Cr. to L. Walnut Cr.) [RM 53.35-46.95]	WWH	6.4				
Castro Run [RM 2.3-0.0]	WWH	0.9				
Mill Creek [RM 2.2-0.0]	WWH	2.2				
Reynolds Run [RM 5.5-0.0]	WWH			1.0	Habitat alteration-H Flow alteration-H Pathogens-M Siltation-M Ammonia-S	Channelization-H Nonirrigated crop prod.-H Removal of riparian veg.-M Range land-M Home sewage treatment syst.-S
Long Run [RM 6.4-0.0]	WWH	2.15		2.75	Flow alteration-H Pathogens-S	Nonirrigated crop prod.-H Range land-S

Table 2. Causes and sources of impairment in the Big Walnut Creek basin.

Watershed Stream Segment [Upper River Mile/Lower River Mile]	**Aquatic Life Use Designation**	**Attainment Status (Miles)**			**Causes of Impairment [1]**	**Sources of Impairment [1]**
		Full	Partial	NON		
Sugar Creek [RM 8.0-0.0]	WWH	1.0	1.0		Flow alteration-H Pathogens-S	Nonirrigated crop prod.-H
Culver Creek [RM 7.5-0.0]	WWH	3.9	1.1		Flow alteration-H Organic enrichment-H Nutrients-M Ammonia-M Pathogens-S	Nonirrigated crop prod.-H Home sewage treatment syst.-M
Trib. to Culver Cr. (RM 3.32) [RM 6.06-0.0]	WWH	1.0				
Perfect Creek [RM 7.0-0.0]	WWH	5.0				
Rattlesnake Creek [RM 4.5-0.0]	WWH			1.0	Flow alteration-H Metals-M,S	Source unknown
N. Fk. Rattlesnake Creek [RM 7.0-0.0]	WWH	3.75	1.55	0.7	Habitat alteration-H Nutrients-H Siltation-M Ammonia-M Organic enrichment-M Pathogens-S	Channelization-H Septage disposal-H Nonirrigated crop prod.-S

Table 2. Causes and sources of impairment in the Big Walnut Creek basin.

Watershed Stream Segment [Upper River Mile/Lower River Mile]	**Aquatic Life Use Designation**	**Attainment Status (Miles)**			**Causes of Impairment [1]**	**Sources of Impairment [1]**
		Full	Partial	NON		
E. Fk. Rattlesnake Creek [RM 5.7-0.0]	WWH		0.7	4.0	Habitat alteration-H Organic enrichment-H Ammonia-H Nutrients-H Siltation-H Suspended solids-H Pathogens-S	Channelization-H Septage disposal-H Range grazing-riparian-H Land development-H Home sewage treatment syst.-H
S. Fk. Rattlesnake Creek [RM 6.5-0.0]	WWH	2.1		2.1	Siltation-H Suspended solids-M Nutrients-S Pathogens-S	Land development-H Range grazing-upland-M
Prairie Run [RM 3.6-0.0]	WWH		0.5		Habitat alteration-H Siltation-H Pathogens-M	Channelization-H Urban runoff-H
Little Walnut Creek [RM 11.5-0.0]	WWH	3.85		6.05	Flow alteration-H Cause Unknown-H	Dam construction-H Source unknown-H
Trib. to L. Walnut Cr. (RM 9.5) [RM 3.05-0.0]	WWH	1.0				
Butler Run [RM 2.0-0.0]	WWH			1.0	Habitat alteration-H Siltation-H organic enrichment-S Pathogens-S	Channelization-H Nonirrigated crop prod.-H Removal of riparian veg.-M Range land-M
E. Br. L. Walnut Creek [RM 1.8-0.0]	WWH	0.9				

Table 2. Causes and sources of impairment in the Big Walnut Creek basin.

Watershed Stream Segment [Upper River Mile/Lower River Mile]	**Aquatic Life Use Designation**	**Attainment Status (Miles)**			**Causes of Impairment [1]**	**Sources of Impairment [1]**
		Full	Partial	NON		
W. Br. L. Walnut Creek [RM 4.4-0.0]	WWH			3.8	Organic enrichment-H Ammonia-M,S Nutrients-M Pathogens-M,S	Home sewage treatment syst.-H Agriculture-H
Duncan Run [RM 10.6-0.0]	WWH			9.5	Habitat alteration-H Siltation-H Pathogens-H,M,S Nutrients-M	Channelization-H Home sewage treatment syst.-H Removal of riparian veg.-M Nonirrigated crop prod.-M Range land-M
Watershed: [05060001 140], Big Walnut Creek (downstream Hoover Dam to upstream Alum Creek); Blacklick Creek						
Big Walnut Creek (Hoover Res. Dam to Rocky Fork) [RM 37.6-28.3]	WWH	7.75	1.55		Thermal modifications-H Ammonia-S Nutrients-S Pathogens-S	Ust. impoundment-H Urban runoff-S
Big Walnut Creek (Rocky Fork to Alum Cr.) [RM28.30-15.31]	WWH-EWH	13.0				
Trib. to B. Walnut Cr. (RM 32.6) [RM 2.69-0.0]	WWH			1.0	Unknown-H	Unknown-H Urban runoff-S
McKenna Creek [RM 3.16-0.0]	WWH			1.0	Pathogens-H Nutrients-H Suspended solids-S Ammonia-S	Urban runoff-H Home sewage treatment syst.-H

Table 2. Causes and sources of impairment in the Big Walnut Creek basin.

Watershed Stream Segment [Upper River Mile/Lower River Mile]	**Aquatic Life Use Designation**	**Attainment Status (Miles)**			**Causes of Impairment [1]**	**Sources of Impairment [1]**
		Full	Partial	NON		
Rocky Fork [RM 13.0-0.0]	WWH-EWH	2.15	4.6	3.95	Pathogens-H,S Siltation-M Nutrients-M Ammonia-S Habitat alterations-S Metals-M	Home sewage treatment syst.-H,M Land development-H Range land-M Package plants-M Contaminated sediments-M
Sugar Run [RM 5.83-0.0]	WWH	1.0				
Rose Run [RM 3.4-0.0]	WWH			1.0	Habitat alterations-H Flow alterations-S Siltation-S	Channelization-H Land development-H Urban runoff-M
Trib. to B. Walnut Cr. (RM 27.29) [RM 4.0-0.0]	WWH			1.0	Flow alteration-H Habitat alteration-H Pathogens-M Priority organics-M Metals-H,M,S Organic enrichment-S Ammonia-S Nutrients-S Siltation-S	Land development-H Urban Runoff-H Channelization-M Removal of riparian veg.-H Contaminated sediments-H
Trib. to B. Walnut Cr. (RM 27.25) [RM 0.13-0.0]	PHWH					
Mason Run [RM 1.9-0.0]	WWH			1.0	Flow alteration-H Habitat alteration-M Siltation-M Pathogens-M	Land development-H Urban runoff-H Channelization-M

Table 2. Causes and sources of impairment in the Big Walnut Creek basin.

Watershed Stream Segment [Upper River Mile/Lower River Mile]	**Aquatic Life Use Designation**	**Attainment Status (Miles)**			**Causes of Impairment [1]**	**Sources of Impairment [1]**
		Full	Partial	NON		
Blacklick Creek [RM 28.0-0.0]	WWH	17.5	3.9	6.6	Ammonia-H Nutrients-H Organic enrichment-H Pathogens-M Siltation-M Priority organics-M	Home sewage treatment syst.-H Minor muni. point source-H Manure lagoons-M Contaminated sediments-M Land development-M
"Unzinger Ditch" **Trib. to Blacklick Cr. (RM 15.88)** [RM 1.1-0.0]	LRW-WWH			1.1	Contaminated sediment-H Nutrient enrichment-H Habitat alterations-H	Industrial site runoff-H Raw sewage discharge-H Channelization-H
Dysar Run [RM 4.98-0.0]	WWH		1.15	1.85	Siltation-H Pathogens-S Metals-S Priority organics-S Organic enrichment-S Habitat alterations-S	Land development-H Urban runoff-M Home sewage treatment syst.-S Channelization-S Contaminated sediments-S
Trib. to Dysar Run (RM 1.67) [RM 1.88-0.0]	WWH	0.7				
French Run [RM 5.28-0.0]	WWH		1.0		Siltation-H Pathogens-M	Land Development-H Urban runoff-H Home sewage treatment syst.-M
N. Br. French Run [RM 3.8-0.0]	EWH			1.0	Unknown-H Pathogens-M	Unknown-H Urban runoff-M Home sewage treatment syst.-M

Table 2. Causes and sources of impairment in the Big Walnut Creek basin.

Watershed Stream Segment [Upper River Mile/Lower River Mile]	**Aquatic Life Use Designation**	**Attainment Status (Miles)**			**Causes of Impairment [1]**	**Sources of Impairment [1]**
		Full	Partial	NON		
"Lees Creek" **Trib. to Blacklick Cr. (RM 11.25)** [RM 4.28-0.0]	WWH	0.8				
Trib. to Blacklick Cr. (RM 10.36) [RM 3.62-0.0]	WWH	0.8				
"Powell Ditch" **Trib. to Blacklick Cr. (RM 6.50)** [RM 3.43-0.0]	WWH			1.0	Habitat alterations-H Siltation-M Pathogens-M	Land development-H Urban runoff-H Home sewage treatment syst.-M Removal of riparian veg.-M
Watershed: [05060001 150], Alum Creek (headwaters to Alum Creek Dam)						
Alum Creek (Headwaters to W. Br. Alum Cr.) [RM 56.3-42.8]	WWH	10.1	3.4		Habitat alteration-H Unknown cause-H Siltation-M Organic enrichment-M Ammonia-M Nutrients-M Pathogens-S	Removal of riparian veg.-H Unknown source-H Channelization-M Nonirrigation crop prod.-M
Alum Creek (W. Br. Alum Cr. to Alum Creek Lake Dam) [RM 42.8-26.7]	WWH (RM 42.80-39.50)	3.3				
Bunker Run [RM 2.5-0.0]	WWH	2.3				

Table 2. Causes and sources of impairment in the Big Walnut Creek basin.

Watershed Stream Segment [Upper River Mile/Lower River Mile]	**Aquatic Life Use Designation**	**Attainment Status (Miles)**			**Causes of Impairment [1]**	**Sources of Impairment [1]**
		Full	Partial	NON		
W. Br. Alum Creek [RM 12.3-0.0]	WWH	1.95	8.55	1.80	Flow alteration-H Habitat alteration-H Siltation-M Organic enrichment-M Nutrients-M Pathogens-S Metals-S Ammonia-S	Nonirrigated crop prod.-H Channelization-H Range land-M
Turkey Run [RM 7.0-0.0]	WWH		1.9	2.9	Flow alteration-H Nutrients-M Organic enrichment-M Pathogens-S	Nonirrigated crop prod.-H Range land-M
Big Run [RM 4.8-0.0]	WWH			2.6	Nutrients-H Siltation-M Organic enrichment-M Pathogens-S	Nonirrigated crop prod.-H Pasture land-M
Watershed: [05060001 160], Big Walnut Creek (Alum Creek to mouth); Alum Creek (downstream Alum Creek Dam to mouth)						
Big Walnut Creek (Alum/Blacklick Cr. to Scioto R.) [RM 15.3-0.0]	EWH	15.3				
Alum Creek (Alum Creek Dam to Columbus Boundary) [RM 26.7-19.9]	WWH	6.8				

Table 2. Causes and sources of impairment in the Big Walnut Creek basin.

Watershed Stream Segment [Upper River Mile/Lower River Mile]	**Aquatic Life Use Designation**	**Attainment Status (Miles)**			**Causes of Impairment [1]**	**Sources of Impairment [1]**
		Full	Partial	NON		
Alum Creek (Columbus Boundary to Big Walnut Creek) [RM 19.9-0.0]	WWH	2.25	17.65		Siltation-H Organic enrichment-H Flow alteration-H Direct habitat alteration-H Ammonia-M Cadmium-M Priority organics-M Pathogens-S	Land development-H Urban runoff-H Impoundment-H Channelization-H Storm sewers-M
Trib. to Alum Cr. (RM 25.50) [RM 2.8-0.0]	WWH	0.7				
Trib. to Alum Cr. (RM 23.47) [RM 3.8-0.0]	WWH	1.3				
Spring Run [RM 7.2-0.0]	WWH		1.95	4.05	Habitat alterations-H Pathogens-M Siltation-S Organic enrichment-S Ammonia-S	Urban runoff-H Channelization-H
W. Spring Run [RM 3.1-0.0]	WWH			3.1	Habitat alterations-H Flow alterations-H	Urban runoff-H Channelization-H Natural-M
Kilbourne Run [RM 2.64-0.00]	WWH			1.0	Organic enrichment-H Pathogens-M Siltation-S	Urban runoff-H

1 The magnitude (i.e. relative contribution) of the cause or source of impairment is estimated as follows: H-High magnitude, M-moderate magnitude, S-Slight magnitude, T-identifies a threat.

Table 3. Waterbody use designations for the Big Walnut Creek basin. Designations based on the 1978 and 1985 water quality standards appear as asterisks (*). Designations based on Ohio EPA biological field assessments appear as a plus sign (+). Designations based on the 1978 and 1985 standards for which results of a biological field assessment are now available are displayed to the right of existing markers. Designated uses based on results other than Ohio EPA biological data are marked with an circle (o). A delta ( )) indicates a new recommendation based on the findings of this report.

Water Body Segment	Use Designations												
		Aquatic Life Habitat						Water Supply			Recreation		
	SRW	WWH	EWH	MWW	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR
Big Walnut Creek													
Williams Rd. (RM 15.8) to the mouth			+						+	+		+	
Delaware-Morrow county line to Hoover Res.	*	+							+	+		+	
Hoover Reservoir			*					o	+	+		+	
At RM 32.64		+						o	+	+		+	
At RM 51.4		+						o	+	+		+	
All other segments		+							+	+		+	
Alum Creek													
Headwaters to Alum Creek Res. (RM 39.0)	*	+							+	+		+	
At RM 26.60		+						o	+	+		+	
At RM 21.20		+						o	+	+		+	
All other segments		+							+	+		+	
Kilbourn Run (Trib. to Alum Creek (RM 16.34))													
Entire length		)							)	)		)	
"West Spring Run" (Trib. to Alum Creek (RM 17.15))													
Entire length		)							)	)		)	
Spring Run (Trib. to Alum Creek (RM 17.22))													
Entire length		)							)	)		)	
Tributary to Alum Creek (RM 23.47)													
Entire length		)							)	)		)	
Tributary to Alum Creek (RM 25.50)													
Entire length		)							)	)		)	
Big Run													
Entire length		*/+							*/+	*/+		*/+	

Water Body Segment	Use Designations												
		Aquatic Life Habitat						Water Supply			Recreation		
	SRW	WWH	EWH	MWW	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR
West Branch Alum Creek													
At RM 5.57		+						o	+	+		+	
All other segments		+							+	+		+	
Turkey Run													
Entire length		*/+							*/+	*/+		*/+	
Bunker Run													
Entire length		*/+							*/+	*/+		*/+	
Blacklick Creek													
Entire length		+							+	+		+	
"Powell Ditch" (Trib. to Blacklick Creek (RM 6.50))													
Entire length		+							+	+		+	
Tributary to Blacklick Creek (RM 10.36)													
Entire length		+							+	+		+	
Tributary to Blacklick Creek (RM 11.25)													
Entire length		+							+	+		+	
French Run (Trib. to Blacklick Creek (RM 13.66))													
Entire length		+							+	+		+	
North Branch French Run (Trib. to French Run (RM 0.33))													
Entire length			+						+	+		+	
Dysar Run (Trib. to Blacklick Creek (RM 14.64))													
Entire length		+							+	+		+	
Tributary to Dysar Run (RM 1.67)													
Entire length		)							)	)		)	
Mason Run													
Headwaters to Fifth Ave. (RM 6.1)							+		+	+		+	
Fifth Ave. to I-70 (RM 1.9)				+					+	+		+	
I-70 to mouth		+							*/+	*/+		*/+	
Tributary to Big Walnut Creek (RM 27.29)													
Entire length		)							)	)		)	
Rocky Fork													

Water Body Segment	Use Designations												
		Aquatic Life Habitat						Water Supply			Recreation		
	SRW	WWH	EWH	MWW	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR
Headwaters to US 62 (RM 5.1)	+	+							+	+		+	
US 62 to Gahanna (RM 1.5)	+		+						+	+		+	
Gahanna (RM 1.5) to the mouth			+						+	+		+	
Rose Run													
Entire length		+							+	+		+	
Sugar Run													
Entire length		+							+	+		+	
McKenna Creek (Trib. to Big Walnut Creek (RM 29.65))													
Entire length		)							)	)		)	
Tributary to Big Walnut Creek (RM 32.60)													
Entire length		)							)	)		)	
Duncan Run													
At RM 0.68		*/+						o	*/+	*/+		*/+	
All other segments		*/+							*/+	*/+		*/+	
Little Walnut Creek													
Entire length		*/+							*/+	*/+		*/+	
Butler Run													
Entire length		*/+							*/+	*/+		*/+	
East Branch Little Walnut Creek													
Entire length		*/+							*/+	*/+		*/+	
Tributary to Little Walnut Creek (RM 9.5)													
Entire length		)							)	)		)	
West Branch Little Walnut Creek													
Entire length		*/+							*/+	*/+		*/+	
Prairie Run													
Entire length		+							+	+		)	+
Rattlesnake Creek													
Entire length		+							+	+		*/+	

Water Body Segment	Use Designations												
		Aquatic Life Habitat						Water Supply			Recreation		
	SRW	WWH	EWH	MWW	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR
North Fork Rattlesnake Creek													
Entire length		+							+	+		*/+	
East Fork Rattlesnake Creek													
Entire length		+							+	+		*/+	
South Fork Rattlesnake Creek													
Entire length		+							+	+		*/+	
Perfect Creek													
Entire length		+							+	+		*/+	
Culver Creek													
Entire length		+							+	+		*/+	
Tributary to Culver Creek (RM 3.32)													
Entire length		)							)	)		)	
Sugar Creek													
Entire length		+							+	+		*/+	
Long Run													
Entire length		+							+	+		*/+	
Reynolds Run													
Entire length		+							+	+		*/+	
Mill Creek													
Entire length		+							+	+		*/+	
Castro Run													
Entire length		+							+	+		*/+	

STUDY AREA DESCRIPTION

Setting

Big Walnut Creek rises in Morrow County approximately 1.25 miles southeast of Mt. Gilead and immediately south of U.S. Route 42. The stream flows due south across Morrow County, entering Delaware County south of Pagetown. Continuing due south, it enters the Hoover Reservoir at Galena. Big Walnut Creek reappears south of the reservoir dam, flowing through Gahanna, thence to the east of the Port Columbus International Airport before bisecting the communities of Whitehall and Reynoldsburg. The stream turns southwest, flowing to the confluence with the Scioto River approximately .25 mile south of the Pickaway County line. The elevation of Big Walnut Creek at its source is 1165 feet. Elevation at its confluence with the Scioto River is 667 feet. Average gradient for the mainstem is 7.0 feet/mile. The land area drained by the Big Walnut system is 556.7 square miles. This study area included the entire mainstem and selected tributaries between its source and confluence. The very largest portion of the watershed, upstream of the reservoir, lies to the east of the mainstem. With the exception of Prairie Run, all notable tributaries above the reservoir enter Big Walnut Creek from higher elevations to the east. Downstream of the reservoir, tributaries enter the mainstem from both east and west. Two major tributaries, Alum Creek and Blacklick Creek conjoin with Big Walnut at Three Rivers Park. Three tributaries included in the study area exceeded an average gradient of 40 ft./mile. They are: Bunker Run - 44.4 ft./mile; Light Creek - 43.1 ft./mile, and East Branch of the Little Walnut -101.1 ft./mile. This latter stream rises on the Broadway Moraine, west of the mainstem.

Climate

The study area climate is one of cold winters and warm summers with precipitation through the year, enabling forest growth and crop production. The interaction of contrasting air masses from source regions north and south are largely responsible for the area's weather phenomena. Winter brings dry and cold continental (cP) air masses from Canada. Summer sees more frequent, moist maritime tropical (mT) air masses from the Gulf of Mexico. The interaction of these contrasting air masses may produce both violent thunderstorms (and tornados) with heavy precipitation or more lengthy and gentle precipitation events. The Koppen-Geiger climate code for the study area is Cfa - "Warm temperate climate, mean temperature of coldest month 64.4 degrees F down to 26.6 degrees F; sufficient precipitation in all months, warmest month mean over 71.6 degrees F" (Strahler, 1963).

Watershed climate statistics from the Delaware and Franklin County portions of the Big Walnut study area are quite similar. The total average annual precipitation recorded in Delaware County for the years 1961 - 1990 was 37.23 inches. Of this total, 21.71 inches (58%) normally falls in April through September. An average of 41 thunderstorms occurs throughout the year, with most appearing in July. In late summer and fall large hurricane systems originating in the Caribbean and

moving north along the East Coast may extend into central Ohio, bringing moist air and rain to the Big Walnut Creek watershed.

Ecoregions

With small exception, the study area lies within the Loamy High Lime Till Plains of the Eastern Corn Belt ecoregion. This sub-ecoregion is characterized by till plains of level to rolling terrain with low gradient streams, ground moraines, end moraines and glacial outwash features. Soils are derived from loamy, limey glacial deposits of the Wisconsin age. In general, these soils show better drainage characteristics and more natural fertility than Easter Corn Belt soils encountered north of the Morrow County line (Omernik & Gallant, 1988).

Geology

The Illinoisan and Wisconsin glacial periods strongly influenced the land forms, soil types, and stream substrates of the study area. Terminal and ground moraines are both present in the Big Walnut watershed. The Powell Moraine extends generally northeast from Powell to Sunbury and then along the west side of Big Walnut Creek to the Morrow County line (Soil Survey of Delaware County). The constituents of glacial depositional features and study area substrates also reflect the Mississippian system sedimentary bedrock which underlies the Big Walnut watershed. Bedford Shale, Berea Sandstone, Sunbury Shale, and Cuyahoga Sandstone are present and visibly exposed as alternating beds in both the Big Walnut and Rocky Fork Creek corridors. Similar glaciofluvial deposits are present in the Big Walnut system. They appear in lower level substrates below recent alluvium and on stream terraces. Large amounts of rounded shale fragments and some sandstone fragments are present along Alum Creek and Big Walnut Creek (Soil Survey of Delaware County).

Soils

The interaction of bedrock geology, climate, slope-topography, flora, fauna, and the passage of time produced the soils of the Big Walnut Creek study area. Within the Franklin County portion of the Big Walnut system, the Bennington - Pewamo association, formed in glacial tills, predominates both east and west of the flood plain proper. Upstream of the Delaware County line, the Bennington-Pewamo association continues on upland areas to the Big Walnut's source in Morrow County. The Bennington soils are seen on flats, low knolls and ridges while the Pewamo soils are found in depressions and concavities of the landscape.

Land use on the Bennington - Pewamo association is limited by seasonal wetness, ponding, slow or moderately slow permeability, and low strength. Tiles and surface drains are commonly used. The Soil Survey of Franklin County notes that both Bennington and Pewamo soils are severely limited for sanitary facilities because of their slow permeability, seasonal wetness, and low strength. The survey states that in areas of this association, "Sanitary facilities should be connected to central

sewers and treatment facilities".

Within the flood plain corridors, the most commonly observed association is the Medway-Genesee-Sloan formed in moderately textured recent alluvium. Each of these soils has a silt loam surface layer and high available water capacity. The Medway soils occur in broad areas of the flood plain. Narrow strips of Genesee soil are seen adjacent to streams while the Sloan soils are encountered in depressions. Flooding hazard and seasonal wetness are the chief land use limitations of this soil association. County soil surveys observe that Medway, Genesee, and Sloan soils are severely limited for sanitary facilities due to frequent flooding, wetness and or slow permeability.

South of Three Rivers Park and to the confluence, Big Walnut Creek flows between areas of the Crosby-Kokomo-Celina soil association. Due to limitations posed by seasonal wetness and slow permeability, The Soil Survey of Franklin County recommends that "Sanitary facilities should be connected to central sewers and treatment facilities, wherever possible".

The erosion potential of Big Walnut watershed soils is partly a function of soil structure, permeability and the percentage of silt, sand and organic matter. One measure of erosion which takes these factors into account is Factor K, one of six used in the Universal Soil Loss Equation (USLE) to predict the average annual rate of soil loss by sheet and rill erosion in tons per acre per year. The values of K range from 0.05 to 0.69. The higher the value the more susceptible is the soil to sheet and rill erosion. The highest K values within the Big Walnut watershed are associated with the Bennington soils (.43) which are predominant on extensive upland areas in Franklin, Delaware, and Morrow counties, and the Crosby soils (.43) which flank Alum Creek (west of the flood plain, downstream from Bexley) and Big Walnut Creek, downstream of Three Rivers Park.

Table 4. Stream characteristics and identified pollution sources within the 2003 Big Walnut Creek study area.

Stream	Length (Miles)	Average Fall (Feet/Mile)	Drainage Area (Square Miles)	Non-point Source Pollution Categories	Point Sources
Big Walnut Creek					
	74.2	7.0	556.7	urban runoff storm sewers sanitary sewers construction sites surface runoff home sewage tr. syst.	Marengo WWTP Galena WWTP Columbus Hap Cremean WTP Columbus Parsons Ave. WTP
Alum Creek					
	55.8	7.4	200.7	urban runoff storm sewers sanitary sewers construction sites surface runoff channelization in place pollutants home sewage tr. syst.	Westerville WTP Delaware Co. Alum Ck. WWTP Ohio-American Water.Huber -Ridge WTP Ohio-American Water Huber -Ridge WWTP ASARCO (via American Ditch)
West Branch Alum Creek					
	11.8	7.7	29.64	crop production livestock pasture oil-gas production	Ashley WTP Ashley WWTP
Turkey Run					
	7.0	11.4	11.26	crop production livestock pasture oil-gas production	
Bunker Run					
	2.5	44.4	4.72	crop production livestock pasture oil-gas production	
Big Run					

	3.4	16.8	10.54	urban storm sewers sanitary sewers construction sites surface runoff	
Bliss Run					
	1.5	28.7	2.64	urban storm sewers sanitary sewers construction sites surface runoff	
Rocky Fork					
	13.0	22.8	28.06	storm sewers sanitary sewers construction sites surface runoff home sewage tr. syst.	Westerville Estates MHP WWTP Taylor Estates MHP WWTP Windrush MHP WWTP via trib.
Long Run					
	6.4	26.1	7..56	crop production livestock pasture urban channelization	
Castro Run					
	2.3	35.6	3.04	crop production livestock pasture	
Mill Creek					
	2.2	37.7	6.58	crop production livestock pasture	
Light Creek					
	3.5	43.1	2.56	crop production livestock pasture	
Reynolds Run					

5.5	33.5	6.12	crop production livestock pasture

Little Walnut Creek

11.5	24.8	32.06	crop production urban storm sewers sanitary sewers construction sites surface runoff industrial land treatment home sewage tr. syst.

East Branch Little Walnut

1.8	101.1	2.00	crop production urban storm sewers sanitary sewers construction sites surface runoff

West Branch Little Walnut

4.4	9.7	6.10	crop production urban storm sewers sanitary sewers construction sites surface runoff

Butler Run

2.0	13.5	5.52	urban storm sewers sanitary sewers construction sites surface runoff

Sugar Creek

8.0	25.3	7.30	crop production livestock pasture urban

Perfect Creek

7.0	20.6	8.90	crop production urban storm sewers sanitary sewers construction sites surface runoff	Morning View Care C. WWTP

Rattlesnake Creek (length includes N. Fork)

9.7	18.1	21.22	crop production urban sanitary sewers storm sewers construction sites surface runoff	

East Fork Rattlesnake Creek

4.5	19.5	3.80	crop production urban sanitary sewers storm sewers construction sites surface runoff	

South Fork Rattlesnake Creek

3.5	12.3	7.02	crop production urban sanitary sewers storm sewers construction sites surface runoff	

North Fork Rattlesnake Creek

6.7	13.1	12.20	crop production urban storm sewers sanitary sewers construction sites surface runoff	

Prairie Run

3.6	20.5	4.42	urban	Sunbury WTP via storm sewer

			storm sewers	Sunbury WWTP
			sanitary sewers	
			construction sites	
			surface runoff	
			industrial land treatment	
Culver Creek				
7.5	24.7	12.96	crop	
			livestock	
			pasture	
			urban	
Duncan Run				
10.6	28.3	16.86	crop production	Lake of the Woods WTP
			urban	
			storm sewers	
			sanitary sewers	
			construction sites	
			surface runoff	
			home sewage tr. syst.	
Mason Run				
7.0	10.4	12.40	urban	
			storm sewers	
			sanitary sewers	
			construction sites	
			surface runoff	
Blacklick Creek				
25.5	15.5	61.3	crop production	JWSD Wengert Rd. WWTP
			urban	(via trib)
			sanitary sewers	Tussing Road WWTP
			storm sewers	Blacklick Estates WWTP
			construction	American Electric Power
			surface runoff	
			channelization	
			stream bank modification	
			bridge construction	
			home sewage tr. syst.	

Nonpoint Source Issues

Traveling upstream in the study area from Franklin County into Delaware County, nonpoint sources transition from typically urban impervious surface runoffs and aged combined sewer systems to runoff from a rapidly developing, yet still predominantly rural - agricultural landscape.

Land use changes within the study area over the past decade partially reflect changes in population, economic activity, and agricultural practices. Between the census years of 1990 and 1999, the population of Franklin County increased from 961,438 to an estimated 1,027,821 residents - an increase of 7%. Delaware County increased from 66,929 in 1990 to an estimated 103,679 residents - an of increase of 55%.

In contrast to Delaware County, the Franklin County portion of the watershed is highly urbanized or rapidly suburbanizing. Agricultural practices or lands are gradually becoming not a significant source of nonpoint source pollutants. Of greater weight are surface runoffs from an extensive road and highway network, overflows of combined sanitary-storm sewer systems, poorly treated discharges from home sewage treatment systems, urban runoff (from driveways, parking lots, roofs, home and lawns) and the likely improper disposal and leakage into storm drains and tributaries of home, business and small industry by-products including paints, lawn and garden chemicals, restaurant greases, soaps, cleaning products, vehicle lubricants and cleaning solvents.
The sanitary sewer system for the City of Columbus consists of both combined and separate sewers. There is one permitted regulator discharge and relief structure overflow in the system known as a combined storm and sanitary sewer overflow (CSO) that discharge to Alum Creek at RM 7.00. There are 25 documented sanitary sewer relief locations in the lower Alum Creek watershed. These “relief”sewers constitute separate sanitary sewer overflows (SSOs) and are designed to discharge directly to a storm sewer or open waterway when the level in the “relief” sewer reaches a certain elevation.

Dramatic increases in automobile and truck registration accompanies increased need for additional roads, lane expansions, driveways, parking and other impervious surfaces in the watershed. Between the years 1990 and 1999, motor vehicle registrations increased markedly in both Delaware and Franklin Counties (Table 5).

Table 5. Increase in registered cars and light trucks, Franklin and Delaware Counties, 1990 - 1999.

	DELAWARE			FRANKLIN		
Year	**Cars**	**Trucks**	**All**	**Cars**	**Trucks**	**All**
1990	43,144	8,655	51,799	624,922	62,433	687,355
1999	79,272	14,557	93,829	812,009	95,783	907,792
Increase	84%	68%	81%	30%	53%	32%

METHODS

All chemical, physical, and biological field, laboratory, data processing, and data analysis methodologies and procedures adhere to those specified in the Manual of Ohio EPA Surveillance Methods and Quality Assurance Practices (Ohio Environmental Protection Agency 1989a) and Biological Criteria for the Protection of Aquatic Life, Volumes I-III (Ohio Environmental Protection Agency 1987a, 1987b, 1989b, 1989c), and The Qualitative Habitat Evaluation Index (QHEI): Rationale, Methods, and Application (Rankin 1989, 1995) for aquatic habitat assessment. Chemical, physical and biological sampling locations are listed in Table 6.

Table 6. Sampling locations in the Big Walnut Creek study area, 2000 (C - conventional water chemistry, E - effluent water chemistry, S - sediment, D - Datasonde® continuous monitors, M - macroinvertebrates, F - fish).

Stream River Mile	Type of Sampling	Latitude/Longitude	Landmark	USGS 7.5 minute Quadrangle M
Big Walnut Creek (02-100)				
73.6	C,M	40°29'50"/82°48'11"	Cardington-East Rd.	Marengo
72.5	F	40°28'49"/82°47'58"	Cardington-Chesterville Rd.	Marengo
70.7	C,M	40°27'41"/82°48'15"	Waldo-Fulton-Chesterville Rd.	Marengo
66.6	C,S,M,F	40°24'47"/82°48'19"	Prospect-Mt. Vernon Rd.	Marengo
61.9	C	40°22'27"/82°48'46"	West Liberty-Mt. Vernon Rd.	Olive Green
60.0	M	40°20'17"/82°49'04"	Chambers Rd.	Olive Green
54.6	C,M,F	40°16'53"/82°50'00"	Stockwell Rd.	Olive Green
52.4	C,D,F	40°15'28"/82°50'33"	North Old 3C Rd.	Olive Green
52.3	M	40°15'24"/82°50'33"	North Old 3C Rd.	Olive Green
49.0	C,S,F	40°13'37"/82°51'47"	Dst. Sunbury	Sunbury
48.9	M	40°13'21"/82°52'10"	Dst. Sunbury	Sunbury
37.2	C,M,F	40°06'11"/82°53'02"	Dst. Hoover Reservoir	NE Columbus
34.9	C,S,D,M	40°04'45"/82°53'33"	SR 161	NE Columbus
28.5	F	40°00'55"/82°52'39"	Dst. Morse Rd. WTP	NE Columbus
28.3	C,M	40°00'44"/82°52'34"	Dst. Morse Rd. WTP	NE Columbus
27.0	C,S,M	39°59'47"/82°51'57"	Dst. airport tributary	Reynoldsburg

Table 6. Sampling locations in the Big Walnut Creek study area, 2000 (C - conventional water chemistry, E - effluent water chemistry, S - sediment, D - Datasonde® continuous monitors, M - macroinvertebrates, F - fish).

Stream River Mile	Type of Sampling	Latitude/Longitude	Landmark	USGS 7.5 minute Quadrangle M
26.7	F	39°59'41"/82°51'38"	Dst. airport tributary	Reynoldsburg
15.8	C,S,M,F	39°52'58"/82°54'56"	Williams Rd.	SE Columbus
7.1	C,D,F	39°49'58"/82°59'32"	SR 317	Lockbourn
7.0	M	39°49'55"/82°59'36"	SR 317	Lockbourn
3.7	C	39°48'40"/82°58'30"	Rowe Rd.	Lockbourn
3.6	M	39°48'37"/82°58'32"	Rowe Rd.	Lockbourn
1.7	C,S,M,F	39°48'26"/82°59'41"	US 23	Lockbourn
Castro Run (02-105)				
0.4	C,F	40°25'53"/82°47'52"	Adj. Phillips Rd.	Marengo
Mill Creek (02-170)				
1.6	C	40°23'32"/82°47'04"	Kanable Rd.	Marengo
1.3	F	40°23'38"/82°47'21"	Bennington-Harmony Central Rd.	Marengo
Light Creek (02-171)				
0.1	C	40°23'31"/82°47'05"	Ust. Kanable Rd.	Marengo
Reynolds Run (02-104)				
4.9	F	40°22'06"/82°45'47"	Turney Center Rd.	Olive Green
0.7	C,M,F	40°21'45"/82°48'24"	East Liberty North Rd.	Olive Green
Long Run (02-103)				
4.9	F	40°20'48"/82°46'32"	Trimmer Rd.	Olive Green
4.3	C	40°20'48"/82°46'57"	SR 656	Olive Green
3.6	C,M,F	40°20'25"/82°47'36"	Porter Central Rd.	Olive Green
0.7	C,M,F	40°19'31"/82°48'43"	Ulery Rd.	Olive Green
Sugar Creek (02-102)				
5.3	C,F	40°19'36"/82°46'35"	Trimmer Rd.	Olive Green
0.1	C,M,F	40°17'11"/82°49'29"	Adj. Monkey Hollow Rd.	Olive Green
Culver Creek (02-101)				
4.5	C,M,F	40°17'38"/82°48'13"	Patrick Rd.	Olive Green
3.3	C,M,F	40°16'56"/82°48'22"	Centerburg Rd.	Olive Green
0.1	C,M	40°16'05"/82°50'15"	Near mouth	Olive Green
Tributary to Culver Creek (RM 3.32) (02-336)				
0.7	F	40°17'17"/82°47'52"	Porter Central Rd.	Olive Green
0.1	C,M	40°16'57"/82°48'21"	Fredricks Rd.	Olive Green
Perfect Creek (02-160)				
6.3	C	40°16'08"/82°46'15"	Dst. tributary	Olive Green
4.9	M	40°15'57"/82°47'06"	Old SR 3	Olive Green
4.7	F	40°15'59"/82°47'15"	Old SR 3	Olive Green
0.1	C,S,M,F	40°13'38"/82°48'49"	Near mouth	Olive Green
Rattlesnake Creek (02-150)				
0.1	C,D,M,F	40°15'38"/82°51'40"	Near mouth	Sunbury
North Fork Rattlesnake Creek (02-151)				
5.8	F	40°14'44"/82°44'22"	Foundation Rd (East)	Sunbury
4.8	C,F	40°14'38"/82°45'13"	North County Line Rd.	Sunbury
3.4	C,M,F	40°14'46"/82°46'17"	Hartford Rd. (East Crossing)	Sunbury
1.7	F	40°14'24"/82°47'23"	Adj. SR 605	Sunbury

Table 6. Sampling locations in the Big Walnut Creek study area, 2000 (C - conventional water chemistry, E - effluent water chemistry, S - sediment, D - Datasonde® continuous monitors, M - macroinvertebrates, F - fish).

Stream River Mile	Type of Sampling	Latitude/Longitude	Landmark	USGS 7.5 minute Quadrangle M
0.1	C,M	40°13'29"/82°47'51"	Near mouth	Sunbury
East Fork Rattlesnake Creek (02-152)				
4.2	F	40°13'41"/82°44'18"	Tagg Rd.	Johnstown
3.1	C	40°13'42"/82°45'16"	North County Line Rd.	Sunbury
1.2	M,F	40°13'02"/82°46'53"	Dent Rd.	Sunbury
0.2	C,M,F	40°13'22"/82°47'40"	SR 6.5	Sunbury
South Fork Rattlesnake Creek (02-153)				
3.7	C,F	40°12'32"/82°46'48"	Ross Rd.	Sunbury
3.0	M	40°12'41"/82°46'52"	Dent Rd.	Sunbury
0.5	F	40°13'23"/82°48'37"	Longshore Rd.	Sunbury
0.2	M	40°13'22"/82°47'40"	Longshore Rd.	Sunbury
0.1	C	40°13'31"/82°48'44"	Longshore Rd.	Sunbury
Prairie Run (02-125)				
0.7	F	40°14'10"/82°51'42"	Ust. Sunbury WWTP	Sunbury
0.4	C,M	40°13'57"/82°51'42"	Ust. Sunbury WWTP	Sunbury
Little Walnut Creek (02-140)				
10.2	C	40°18'29"/82°51'15"	Adj. Wilson Rd.	Olive Green
9.4	C,M	40°18'28"/82°51'58"	Blue Church Rd.	Olive Green
7.4	C,M,F	40°17'24"/82°52'48"	Dst. E. Br. L. Walnut Cr.	Kilbourne
4.7	M	40°15'53"/82°54'03"	US 36/SR 37	Kilbourne
3.2	F	40°14'50"/82°53'48"	Ust. Cheshire Rd.	Galena
1.4	C,S	40°13'33"/82°53'13"	SR 3	Galena
Tributary to Little Walnut Creek (RM 9.5) (02-341)				
1.5	F	40°19'32"/82°51'57"	Blue Church Rd.	Olive Green
Butler Run (02-141)				
1.2	C,M,F	40°16'54"/82°53'45"	Wilson Rd.	Kilbourne
East Branch Little Walnut Creek (02-142)				
0.4	F	40°17'19"/82°52'28"	Rosecrans Rd.	Olive Green
0.05	C	40°17'23"/82°52'47"	Carter Corner Rd.	Kilbourne
West Branch Little Walnut Creek (02-143)				
3.3	C	40°20'15"/82°53'19"	Kilbourne Rd.	Kilbourne
1.5	M	40°18'48"/82°53'11"	Twigg-Hupp Rd.	Kilbourne
0.8	C	40°18'27"/82°52'56"	Clark Rd.	Kilbourne
Duncan Run (02-124)				
9.0	C,M	40°08'42"/82°45'46"	Robins Rd.	Sunbury
7.3	C,M	40°09'37"/82°46'41"	Green-Cook Rd.	Sunbury
5.0	F	40°09'24"/82°48'24"	Duncan Run Rd.	Sunbury
2.7	C,S,M	40°09'03"/82°50'26	Harlem Rd.	Sunbury
Tributary to Big Walnut Creek (RM 32.60) (02-334)				
0.2	F	40°03'55"/82°53'21"	Off Cherry Bottom Rd.	NE Columbus
McKenna Creek (Trib. to B. Walnut Cr. (RM 29.65)) (02-347)				
0.2	C,M	40°01'53"/82°52'33"	Cherry Bottom Rd.	NE Columbus
Rocky Fork (02-123)				
11.4	C	40°07'30"/82°49'29"	Schleppi Rd.	Sunbury

Table 6. Sampling locations in the Big Walnut Creek study area, 2000 (C - conventional water chemistry, E - effluent water chemistry, S - sediment, D - Datasonde® continuous monitors, M - macroinvertebrates, F - fish).

Stream River Mile	Type of Sampling	Latitude/Longitude	Landmark	USGS 7.5 minute Quadrangle M
10.2	C,M,F	40°06'58"/82°49'58"	Ust. Walnut St., ust. tributary	New Albany
7.1	C,S,M,F	40°04'45"/82°50'37"	Old SR 161	New Albany
5.9	C,D,M,F	40°03'49"/82°50'28"	Thompson Rd.	New Albany
3.3	C,F	40°01'59"/82°50'24"	Clark State Rd.	New Albany
3.2	M	40°01'50"/82°50'20"	Clark State Rd.	New Albany
1.1	C,S,D,F	40°01'17"/82°51'47"	Hamilton Rd.	New Albany
1.0	M	40°01'17"/82°51'53"	Hamilton Rd.	New Albany
Sugar Run (02-260)				
3.1	C	40°05'45"/82°48'45"	SR 605	New Albany
0.7	C,S,M,F	40°04'48"/82°50'06"	Old SR 161	New Albany
Rose Run (02-252)				
0.5	C,F	40°44'22"/82°49'55"	Harlem Rd.	New Albany
Tributary to Big Walnut Creek (RM 27.29) (02-280)				
0.2	C,S,M,F	39°59'58"/82°52'28"	Dst. Columbus Airport	Reynoldsburg
Tributary to Big Walnut Creek (RM 27.25) (02-335)				
0.1	F	39°59'52"/82°52'15"	Dst Columbus Airport	Reynoldsburg
Mason Run (02-122)				
1.4	F	39°55'29"/82°54'40"	Petzinger Rd.	SE Columbus
0.5	C,M	39°54'57"/82°53'26"	Refugee Rd.	SE Columbus
Alum Creek (02-110)				
56.3	C,F	40°29'47"/82°50'33"	Cardington East Rd.	Marengo
55.3	C,M,F	40°28'57"/82°50'33"	SR 529	Marengo
52.9	C	40°27'28"/82°50'10"	Power line crossing	Marengo
51.5	M	40°26'09"/82°50'44"	Phillips Rd.	Marengo
49.9	C,M,F	40°25'07"/82°51'08"	Prospect-Mt. Vernon Rd.	Marengo
45.5	F	40°22'23"/82°53'06"	West Liberty East Rd.	Kilbourne
42.9	C,M,F	40°21'27"/82°55'13"	Ust. W. Br. Alum Cr.	Kilbourne
42.6	M	40°21'16"/82°55'25"	Dst. W. Br. Alum Cr.	Kilbourne
39.45	C,D	40°19'48"/82°57'20"	SR 521	Kilbourne
22.4	M	40°08'10"/82°57'07"	Adj. Cleveland Ave.	Galena
22.1	C,F	40°58'05"/82°56'55"	Adj. Cleveland Ave.	Galena
19.8	C,D,M,F	40°06'35"/82°56'21"	Schrock Rd.	NE Columbus
13.5	M	40°02'26"/82°56'02"	Innis Park	NE Columbus
13.4	C,F	40°02'07"/82°56'00"	Innis Park	NE Columbus
7.6	M	39°57'42"/82°56'28"	Wolf Park	SE Columbus
3.8	C,S,M	39°55'03"/82°55'31"	Refugee Rd.	SE Columbus
2.7	F	39°54'20"/82°55'10"	Watkins Rd	SE Columbus
0.8	F	39°53'17"/82°54'55"	Williams Rd.	SE Columbus
0.7	C,M	39°53'15"/82°54'50"	Williams Rd.	SE Columbus
Tributary to Alum Creek (RM 54.44)				
0.6	C	40°28'54"/82°49'29"	Worthington-New Haven Rd.	Marengo
Bunker Run (02-121)				
1.8	C,M,F	40°23'39"/82°51'13"	South Woodbury Rd.	Marengo
West Branch Alum Creek (02-118)				

Table 6. Sampling locations in the Big Walnut Creek study area, 2000 (C - conventional water chemistry, E - effluent water chemistry, S - sediment, D - Datasonde® continuous monitors, M - macroinvertebrates, F - fish).

Stream River Mile	Type of Sampling	Latitude/Longitude	Landmark	USGS 7.5 minute Quadrangle M
12.3	F	40°28'30"/82°53'34"	Waldo-Fulton-Chesterville Rd.	Ashley
9.9	C,F	40°26'57"/82°53'46"	Waldo-Fulton Rd.	Ashley
9.4	M	40°26'45"/82°54'26"	Kilbourne Rd.	Ashley
8.7	C,M,F	40°26'12"/82°54'31"	Westfield-Fulton Rd.	Ashley
3.3	C,M,F	40°23'32"/82°56'15"	Shoemaker Rd.	Ashley
0.6	C,D,F	50°21'47"/82°55'22"	Worthington-New Haven Rd.	Kilbourne
0.5	M	40°21'47"/82°55'37"	Worthington-New Haven Rd.	Kilbourne
Turkey Run (02-119)				
4.8	C,D	40°25'17"/82°53°25"	Prospect-Mt. Vernon Rd.	Ashley
3.7	F	40°24'44"/82°53'58"	Pompey Rd.	Ashley
3.6	M	40°24'40"/82°54'00"	Pompey Rd.	Ashley
1.7	C	40°23'37"/82°55'03"	Ashley-West Liberty Rd.	Ashley
0.1	M,F	40°22'52"/82°56'24"	Piper Rd.	Ashley
Tributary to Alum Creek (RM 40.48)				
0.2	C	40°29'35"/82°57'13"	North Old State Rd.	Kilbourne
Tributary to Alum Creek (RM 38.75)				
0.3	C	40°19'29"/82°57'29"	North Old State Rd.	Kilbourne
Big Run (02-112)				
4.8	F	40°33'25"/82°53'30"	From Jumper Rd.	Kilbourne
2.7	C,D,M	40°33'25"/82°53'30"	US 36-SR 37	Kilbourne
Tributary to Alum Creek (RM 25.50) (02-338)				
0.2	C,F	40°10'30"/82°57'14"	Africa Rd.	Galena
Tributary to Alum Creek (RM 23.47) (02-337)				
0.8	C,F	40°09'11"/82°56'36"	Africa Rd.	Galena
Spring Run (Tributary to Alum Creek (RM 17.22)) (02-276)				
6.0	F	40°08'32"/82°53'22"	Maxtown Rd.	Galena
5.4	M	40°08'16"/82°53'34"	Blue Heron Rd.	Galena
3.7	C,M,F	40°07'13"/82°53'52"	Walnut St.	NE Columbus
0.2	C,M,F	40°05'01"/82°54'58"	Buenos Aires Rd.	NE Columbus
"West Spring Run" (Tributary to Alum Creek (RM 17.15)) (02-240)				
0.4	F	40°04'45"/82°55'38"	SR 3	NE Columbus
0.1	C	40°04'52"/82°55'17"	Castro Park	NE Columbus
Kilbourne Run (Tributary to Alum Creek (RM 16.34)) (02-297)				
0.4	C,F	40°04'13"/82°55'48"	Westerville Rd.	NE Columbus
Bliss Run (02-111)				
0.6	C	39°56'40"/82°55'41"	Roosevelt Ave.	SE Columbus
Blacklick Creek (02-130)				
27.1	C,M,F	40°06'40"/82°46'22"	Walnut St.	New Albany
24.7	C,M,F	40°44'47"/82°47'05"	SR 161	New Albany
23.0	M	40°03'42"/82°47'48"	Morse Rd.	New Albany
22.4	C,S,F	40°03'09"/82°48'11"	Morse Rd.	New Albany
20.4	C,M,F	40°01'48"/82°48'45"	Havens Rd.	New Albany
16.6	C,D,M,F	39°59'01"/82°48'43"	Broad St.	Reynoldsburg
13.7	C,M,F	39°57'24"/82°48'14"	Main St.	Reynoldsburg

Table 6. Sampling locations in the Big Walnut Creek study area, 2000 (C - conventional water chemistry, E - effluent water chemistry, S - sediment, D - Datasonde® continuous monitors, M - macroinvertebrates, F - fish).

Stream River Mile	Type of Sampling	Latitude/Longitude	Landmark	USGS 7.5 minute Quadrangle M
11.3	C,S,M,F	39°55'45"/82°47'37"	Ust. Tussing Rd. WWTP	Reynoldsburg
11.15	E	39°55'41"/82°47'30"	Tussing Rd. WWTP effluent	Reynoldsburg
11.14	F	39°55'44"/82°47'31"	Tussing Rd. WWTP mixing zone	Reynoldsburg
11.10	M	39°55'39"/82°47'29"	Tussing Rd. WWTP mixing zone	Reynoldsburg
11.05	C	39°55'36"/82°47'23"	Tussing Rd. WWTP mixing zone	Reynoldsburg
11.0	C,M,F	39°55'35"/82°47'22"	Dst. Tussing Rd. WWTP	Reynoldsburg
8.9	M	39°54'43"/82°48'31"	Refugee Rd.	Reynoldsburg
8.8	C,F	39°54'14"/82°48'32"	Refugee Rd.	Reynoldsburg
4.85	E	39°53'43"/82°51'32"	Blacklick Estates WWTP effluent	Reynoldsburg
4.83	M,F	39°53'43"/82°51'32"	Blacklick Estates WWTP mixing zone	Reynoldsburg
4.80	C	39°53'42"/82°51'33"	Blacklick Estates WWTP mixing zone	Reynoldsburg
4.6	C,F	39°53'35"/82°51'40"	Dst. Blacklick Estates WWTP	Reynoldsburg
4.5	M	39°53'30"/82°51'42"	Dst. Blacklick Estates WWTP	Reynoldsburg
2.6	M,F	39°52'33"/82°52'36"	Ust. Hamilton Rd.	SE Columbus
1.9	C,S,D	39°52'23"/82°52'30"	Hamilton Rd.	Lockbourne
Swisher Creek (Tributary to Blacklick Creek (RM 20.93)) (02-293)				
1.3	C	40°02'34"/82°47'15"	Clark State Rd.	New Albany
Dysar Run (Tributary to Blacklick Creek (RM 14.64)) (02-281)				
3.0	C,F	39°59'49"/82°47'15"	Railroad bridge	Reynoldsburg
2.1	M	39°59'23"/82°47'31"	Waggoner Rd.	Reynoldsburg
1.9	F	39°59'10"/82°47'34"	SR 16	Reynoldsburg
1.6	C,S,D,M	39°59'00"/82°47'27"	SR 16	Reynoldsburg
Tributary to Dysar Run (RM 1.67) (02-342)				
0.2	F	39°59'04"/82°47'29"	Waggoner Rd.	Reynoldsburg
French Run (Tributary to Blacklick Creek (RM 13.66)) (02-290)				
0.7	C,M	39°57'22"/82°47'37"	Waggoner Rd.	Reynoldsburg
0.6	F	39°57'22"/82°47'42"	Waggoner Rd.	Reynoldsburg
North Branch French Run (Tributary to French Run (RM 0.33)) (02-291)				
0.2	C,M	39°57'32"/82°47'52"	Behind French Run Elem. School	Reynoldsburg
Tributary to Blacklick Creek (RM 12.89) (02-289)				
0.3	C	39°56'48"/82°47'43"	Graham Rd.	Reynoldsburg
"Lees Creek" (Tributary to Blacklick Creek (RM 11.25)) (02-288)				
0.3	C,F	39°55'50"/82°47'17"	SR 256	Reynoldsburg
Tributary to Blacklick Creek (RM 10.36) (02-287)				
0.2	C,F	39°55'16"/82°47'04"	SR 256	Reynoldsburg
"Powell Ditch" (Tributary to Blacklick Creek (RM 6.50) (02-286)				
0.9	M	39°54'50"/82°49°59"	Adj. to Brice Rd.	Reynoldsburg
0.8	F	39°54'50"/82°49°59"	Adj. to Brice Rd.	Reynoldsburg
0.5	C	39°54'37"/82°50°06"	Adj. to Brice Rd.	Reynoldsburg
Tributary to Big Walnut Creek (RM 12.75)				
0.2	C	39°52'01"/82°56'08"	Alum Creek Dr.	Lockbourn

Determining Use Attainment Status

The attainment status of aquatic life uses (*i.e.*, full, partial, and non-attainment) is determined by using the biological criteria codified in the Ohio Water Quality Standards (WQS; Ohio Administrative Code [OAC] 3745-1-07, Table 7-15). These are confined to ambient assessments and apply to rivers and streams outside of mixing zones. The biological community performance measures used include the Index of Biotic Integrity (IBI) and Modified Index of Well-Being (MIwb), based on fish community characteristics, and the Invertebrate Community Index (ICI) which is based on macroinvertebrate community characteristics. The IBI and ICI are multimetric indices patterned after an original IBI described by Karr (1981) and Fausch *et al.* (1984). The ICI was developed by Ohio EPA (1987b) and further described by DeShon (1995). The MIwb is a measure of fish community abundance and diversity using numbers and weight information and is a modification of the original Index of Well-Being originally applied to fish community information from the Wabash River (Gammon 1976; Gammon *et al.* 1981).

Performance expectations for the principal aquatic life uses in the Ohio WQS (Warmwater Habitat [WWH], Exceptional Warmwater Habitat [EWH], and Modified Warmwater Habitat [MWH]) were developed using the regional reference site approach (Hughes *et al.* 1986; Omernik 1987). This fits the practical definition of biological integrity as the biological performance of the natural habitats within a region (Karr and Dudley 1981). Attainment of the aquatic life use is FULL if all three indices (or those available) meet the applicable biocriteria, partial if at least one of the indices does not attain and performance is fair, and non-attainment if all indices fail to attain or any index indicates poor or very poor performance. Partial and non-attainment indicate that the receiving water is impaired and does not meet the designated use criteria specified by the Ohio WQS. Index scores and corresponding narrative evaluations for the are based on expectations in the Eastern Corn Belt Plain (Table 7)

Habitat Assessment

Physical habitat was evaluated using the Qualitative Habitat Evaluation Index (QHEI) developed by the Ohio EPA for streams and rivers in Ohio (Rankin 1989, 1995). Various attributes of the habitat are scored based on the overall importance of each to the maintenance of viable, diverse, and functional aquatic faunas. The type(s) and quality of substrates, amount and quality of instream cover, channel morphology, extent and quality of riparian vegetation, pool, run, and riffle development and quality, and gradient are some of the habitat characteristics used to determine the QHEI score which generally ranges from 20 to less than 100. The QHEI is used to evaluate the characteristics of a stream segment, as opposed to the characteristics of a single sampling site. As such, individual sites may have poorer physical habitat due to a localized disturbance yet still support aquatic communities closely resembling those sampled at adjacent sites with better habitat, provided water quality conditions are similar. QHEI scores from hundreds of segments around the state have indicated that values greater than 60 are *generally* conducive to the existence of warmwater faunas whereas scores less than 45 generally cannot support a warmwater assemblage consistent with the WWH biological criteria. Scores greater than 75 frequently typify habitat conditions which have the ability to support exceptional warmwater faunas.

Table 7. Biological metric scores and corresponding narrative evaluations for the Eastern Corn Belt Plains ecoregion. Minimum scores for attainment of the WWH criteria (bold), MWH (underlined) and EWH (italics) are also provided. The marginally good range represents nonsignificant departure of the WWH aquatic life use. The very good range corresponds with nonsignificant departure of the EWH aquatic life use.

Eastern Corn Belt Plains						
IBI			**MIwb**		**ICI**	**Narrative Evaluation**
Headwater	Wading	Boat	Wading	Boat	All	
50-60	*50*-60	*48*-60	$*9.4*	$*9.6*	*46*-60	Exceptional
46-49	46-49	44-47	8.9-9.3	9.1-9.5	42-44	Very Good
40-45	**40**-45	**42**-43	**8.3**-8.8	**8.5**-9.0	**36**-40	Good
36-39	36-39	38-41	7.8-8.2	8.0-8.4	32-34	Marginally Good
28-35	28-35	26-37	5.9-(6.2) 7.7	6.4-7.9	14-(22) 30	Fair
18-(24) 27	18-(24) 27	16-(24) 25	4.5-5.8	5.0-(5.8) 6.3	8-12	Poor
12-17	12-17	12-15	0-4.4	0-4.9	<8	Very Poor

Macroinvertebrate Community Assessment

Macroinvertebrates were sampled quantitatively, from the larger stream sites, using multiple-plate, artificial substrate samplers (modified Hester/Dendy) in conjunction with a qualitative assessment of taxa inhabiting the available natural substrates. The smaller stream sites were sampled using the qualitative method only. Qualitative macroinvertebrate sampling consisted of an inventory of the taxa at a sampling station with an attempt to field estimate predominant populations. An assessment of the status of the macroinvertebrate community was made based on best professional judgement utilizing sample attributes such as taxa richness, EPT (Ephemeroptera - mayfly, Plecoptera - stonefly, and Trichoptera - caddisfly) richness, diversity and predominance of sensitive taxa, and the predominance of tolerant taxa.

Fish Community Assessment

Fish were sampled once or twice at each site using pulsed DC electrofishing methods. Discussion of the fish community assessment methodology used in this report is contained in Biological Criteria for the Protection of Aquatic Life: Volume III, Standardized Biological Field Sampling and Laboratory Methods for Assessing Fish and Macroinvertebrate Communities (Ohio EPA 1989b).

Causal Associations

Using the results, conclusions, and recommendations of this report requires an understanding of the methodology used to determine the use attainment status and assigning probable causes and sources of impairment. The identification of impairment in rivers and streams is straightforward - the

numerical biological criteria are used to judge aquatic life use attainment and impairment (partial and non-attainment). The rationale for using the biological criteria, within a weight of evidence framework, has been extensively discussed elsewhere (Karr *et al.* 1986; Karr 1991; Ohio EPA 1987a,b; Yoder 1989; Miner and Borton 1991; Yoder 1991; Yoder 1995). Describing the causes and sources associated with observed impairments relies on an interpretation of multiple lines of evidence including water chemistry data, sediment data, habitat data, effluent data, land use data, and biological results (Yoder and Rankin 1995). Thus the assignment of principal causes and sources of impairment in this report represent the association of impairments (based on response indicators) with stressor and exposure indicators. The reliability of the identification of probable causes and sources is increased where many such prior associations have been identified, or have been experimentally or statistically linked together. The ultimate measure of success in water resource management is the restoration of lost or damaged ecosystem attributes including aquatic community structure and function. While there have been criticisms of misapplying the metaphor of ecosystem "health" compared to human patient "health" (Suter 1993), in this document we are referring to the process for evaluating biological integrity and causes or sources associated with observed impairments, not whether human health and ecosystem health are analogous concepts.

RESULTS AND DISCUSSION

Pollutant Loadings: 1976-1999

Monthly effluent loadings are reported to the Ohio EPA by all NPDES (National Pollutant Discharge Elimination System) permitted entities. Third-quarter (July-September) monthly operating report (MOR) data describe the quantity and character of pollutant loadings through the period of record for each discharger.

There are around 30 different permitted wastewater treatment facilities in the Big Walnut Creek watershed. Most of these facilities are small WWTPs, termed "package plants", discharging from 2,000 up to 100,000 gpd.

The term "package plant" is used to describe a wastewater treatment system consisting of a prefabricated steel or concrete tank that is divided into an aeration chamber and settling chamber or clarifier. Most package plants are preceded by some type of pretreatment, which removes untreatable matter, including plastics, rags, rocks, wood, etc. Occasionally, flow equalization tanks are also included. The package treatment system is generally followed with effluent polishing and disinfection either by chlorination (followed by dechlorination) or ultraviolet light. Sometimes the plant will have a sludge holding tank.

The pretreatment devices in a package plant are generally one or two of the following - a trash trap (tank that has an outlet opening that is smaller than the inlet and is in the lower 1/3 of the tank), a bar screen (rack of bars in front of the package plant inlet- usually 1-2"apart), and/or a comminutor (grinds the trash into small pieces).

A flow equalization tank assists in providing the package plant with a steady flow, hopefully over an entire day since water use and wastewater generation varies within a day. A constant flow of sewage is essential for the microbiological fauna to have a "steady state," thus ensuring effective breakdown of organic material in the sewage. Consistent flow facilitates excellent effluent quality.

When working properly, the aeration chamber encourages 90% of the breakdown of organic material by injecting large volumes of air into the water. This provides the oxygen required to facilitate aerobic breakdown of the wastes by the microfauna (bacteria and other single and multi-celled organisms). Carbon-based oxygen demanding substances (measured by cBOD testing) are broken down first via the activity of bacteria and protozoans. If enough detention time is provided in the aeration tank, breakdown of nitrogenous wastes (ammonia) will also occur. As the waste is "eaten" by the different microfauna, these same organisms multiply.

The following chamber in the tank is the settling chamber, also termed a clarifier. Its function is to allow for an area of quiescence for the settling of the microfauna (also known as sludge or biosolids) by gravity. Some of the settled organisms are then pumped back to the aeration chamber to resume consumption of the raw wastewater components. Relatively clear water is decanted over the top of a barrier or weir and moves onto the next stage of treatment, usually polishing and/or disinfection. If the system has been upgraded, a sludge holding tank will be present to store excess biosolids. When this tank fills, the "sludge" is dried or dewatered and taken to a landfill or directly removed to a larger WWTP for digestion and processing.

Polishing treatment generally consists of sand filtration or a polishing pond. Both function to remove light weight "sludge" that did not settle in the clarifier. The treated wastewater then flows to a small disinfection tank. Disinfection (destruction of remaining microfauna in the wastewater) is generally achieved by chlorination (tablet or liquid bleach) and followed at the outlet of the tank with dechlorination (tablet or liquid). Occasionally, ultraviolet light will be used to provide disinfection making dechlorination unnecessary; however this is uncommon in package plants.

These "package plants" combine to account for approximately 5.55% of the wastewater flow, 3.99% of the $cBOD_5$ loading, 29.3% of the ammonia loading, and 12.8% of the suspended solids loading discharged to the Big Walnut watershed (Fig. 2). Many of these package plants are not properly maintained and operated, hence the disproportionate percentage of ammonia and suspended solids loadings coming from these facilities when compared with flow.

Village of Marengo WWTP (Big Walnut Creek RM 65.80)

The Village of Marengo operates a package WWTP designed to treat up to 0.038 MGD of domestic sewage. Wasted sludge is hauled to the Galion WWTP for disposal. This community is unique in that residences have individual septic tanks that discharge to the common sanitary sewer. Many of the septic tanks have failed or damaged gaskets at the inlet or outlet pipes which allow for significant inflow and infiltration (I/I) into the sewer system. There have been instances of flows exceeding

0.100 MGD for up to 6 consecutive days or peak flows in excess of 0.450 MGD (well over 10 times the design). NPDES permit violations for the period January 2000 through September 2002 included ammonia, $cBOD_5$, and total suspended solids. Over 21 violations were noted during this period.

Galena WWTP (Big Walnut Creek RM 48.28)

The Galena WWTP was designed to treat 0.080 MGD of sewage. The treatment train consists of a trash trap, flow equalization, extended aeration, clarification (both tank and upflow fixed media), surface sand filters, ultraviolet light disinfection, and post aeration. Wasted sludge is stored in an aerated holding tank prior to delivery to another facility for treatment and disposal.

The village has intermittent problems with excessive concentrations of phosphorus and subsequent violation of their permit limits for phosphorus. Phosphorus removal is facilitated by the addition of ferric chloride to the last part of the extended aeration treatment.

Additionally, precipitation events cause a couple of problems with the plant. First, during high flows, water from Big Walnut Creek fills the effluent pipe raising the water level at the effluent weir causing a false high flow reading and therefore, a false permit violation. Second, there are indications of I/I problems in the collection system.

There were 25 recorded NPDES permit violations over the time period beginning on January 1, 2000 and ending July 1, 2002. The majority of these violations were for phosphorus with others including suspended solids, low pH, dissolved oxygen, and ammonia.

Morning View Care Center WWTP (Perfect Creek RM 4.40)

The Morning View Care Center WWTP consists of a pair of trash traps followed by two package plants set up in parallel (one of 7,500 gpd design and one of 3,000 gpd design for a total capacity of 10,500 gpd), sand filtration, and chlorination/dechlorination. From January 1, 2001 through June 30, 2002 there were 16 violations of the NPDES permit for this facility, most for suspended solids or dissolved oxygen. Inspection reports revealed that the age of the facility was a concern and that timely replacement of equipment was necessary for continued operation of the plant. The presence of debris and trash in the stream near the outfall was also a concern noted in the inspection.

Wyandot Golf Course WWTP (Unnamed Trib. to Culver Creek RM ~5.00)

The Wyandot Golf Course is located at 3032 Columbus Road in Hilliar Township, Knox County. This business has a small package WWTP designed to treat up to 0.001 MGD. The NPDES permit for this facility became effective May 1, 2002. Presently, monthly self-monitoring reports have not been submitted by the entity as required.

Village of Sunbury WWTP (Prairie Run RM 0.27)

The Village of Sunbury WWTP is designed to treat 0.50 MGD of domestic wastewater. The plant is comprised of manual bar screens, influent retention, comminutors, influent pumping, grit removal, extended aeration, clarification, chlorine disinfection/dechlorination, and post aeration. The two former effluent polishing lagoons are now used for influent flow equalization due to the large amount of inflow and infiltration in the collection system. Monthly average flows are nearly 94% of capacity. The Village of Sunbury accounts for the following known point source loadings to the Big Walnut Creek watershed: 6.2% of the wastewater flow, 8.51% of the total suspended solids, and 33.5% of the $cBOD_5$ and minimal ammonia (Fig. 2). There is a concern for groundwater contamination from these unlined lagoons in addition to the overall age of the plant and the collection system. A permit-to-install (PTI) for closure of the lagoons will be required following construction of the new WWTP.

From July 2001 through June 2002 there were 42 violations of NPDES permit limits. Most of the violations were for ammonia (daily versus annual loadings noted above), $cBOD_5$, and suspended solids. Additionally, the three lift stations in the collection system do not have operable autodialers or audio-visual alarms making it difficult for the Village to monitor overflows or faulty operation of these lift stations.

The Village has submitted a PTI application to Ohio EPA to build a new plant with expanded capacity. This PTI is currently under review. Collection system work is ongoing, but hampered by lack of funding support, so the I/I problems persist and will not improve without substantial investment of resources.

Village of Sunbury WTP (Prairie Run RM 1.43 via storm sewer)

The Village of Sunbury operates a 1.3 MGD capacity water treatment facility that provides drinking water to the village. The NPDES permit authorizes the discharge of decant water from the lime/caustic sludge lagoon. Current permit reporting reveals zero discharge from the lagoons for the period of September 2001 through August 2002. Lagoon decant water is currently directed to the sanitary sewer along with filter backwash water.

Buckeye Egg Farm - Layer Site #3 (E. Fork Rattlesnake Creek via Unnamed Ditch)

Buckeye Egg Farm - Layer Site #3 is located at 11651 Clover Valley Road, Hartford Township, Licking County. This facility was permitted to discharge treated sanitary wastewater along with water plant filter backwash water to the East Fork of Rattlesnake Creek via a ditch. This discharge has been eliminated since these wastewaters are now directed to existing 2-stage settling and storage lagoons primarily used to store egg wash water prior to land application. Wastewater is land applied by spray irrigation.

Lake of the Woods WTP (Duncan Run RM 0.80)

This water treatment plant services a small subdivision. Raw water is obtained from Hoover Reservoir and treated with ferric chloride and caustic soda prior to settling and filtration. Chlorine is added following filtration and the water is then piped to customers at a rate of up to 0.100 MGD. Waste sludge from the clarifier and filter backwash is directed to a lagoon system where the sludge settles and decant water is discharged to Duncan Run. Recently, the sludge from these lagoons was removed and applied to a nearby plot of ground. The operators were informed through an inspection letter that this was not appropriate and that the facility needed to prepare a sludge management plan to address sludge use or disposal.

Delaware County-Hoover Woods Subdivision WWTP (Unnamed Tributary RM ~1.00 to Big Walnut Creek-Hoover Reservoir RM 43.24)

This package WWTP is designed to treat up to 0.026 MGD of domestic wastewater. On average, the plant treats about 0.010 MGD. The treatment train consists of typical package plant components with ultraviolet disinfection and ferric chloride addition for phosphorus removal. Sludge is stored in an aerated holding tank prior to transport to another Delaware County facility for treatment and disposal. Four "weekly" violations of NPDES permit limits were noted for suspended solids and $cBOD_5$ during 2000.

Leo Yassenoff Camp WWTP (Hoover Reservoir RM 38.80)

The Leo Yassenoff Camp is a summer day camp for children operated from June through August. The WWTP is a package type plant which has a capacity of 7,200 gpd. This facility has ongoing problems with violations of their NPDES permit. Flow monitoring requirements are ignored and monthly operating reports are not submitted with any regularity. When reports are submitted, there are violations of many limits including chlorine residual, dissolved oxygen, fecal coliform bacteria, and suspended solids. This facility also operates without the weekly supervision from a state-certified Class I operator as required in the permit.

City of Columbus-Hap Cremean WTP (Big Walnut Creek RM 32.63)

This facility treats around 75 MGD of water obtained from Big Walnut Creek to produce potable water for the Columbus metropolitan area. The NPDES permit for this facility allows wastewater discharge from up to 4 outfalls although there has been no discharge from this facility since 1992 according to monthly operating reports. Currently, all sludges and wastewater produced at this facility are pumped about 12 miles west via pipeline to a quarry on McKinley Avenue. The three sludge storage lagoons located at the plant are used for emergency purposes only, in case the pipeline fails.

Lucent Technologies (Unnamed Trib. RM 1.15-1.08 to Big Walnut Creek RM 24.17)

This facility assembles communications equipment. Process wastewater, sanitary wastewater, and cooling tower blowdown water are all routed to the sanitary sewer. This company formerly had an individual NPDES permit for the discharge of non-contact cooling water, air conditioning condensate water, and storm water. The facility currently has coverage under the general storm water permit for the air conditioning condensate and storm water. Flow volume is precipitation dependent and may range from 0.40 MGD to 1.30 MGD for each of 2 outfalls. Review of self monitoring reports for the period January 2000 through September 2002 revealed a single violation of pH for May 2001. An August 2002 compliance inspection revealed satisfactory operation and maintenance.

Westerville Estates MHP WWTP (Rocky Fork Creek RM 11.35)

The Westerville Estates WWTP services a mobile home park licensed to contain up to 297 mobile homes. The WWTP is designed to treat 0.070 MGD of domestic sewage via an influent pump station, extended aeration and clarification in two parallel treatment trains, dosing tank, surface sand filtration, ultraviolet disinfection, and post aeration. Upgrades to the plant were installed from 1999-2001 and included an additional clarifier, dosing station, sand filter, ultraviolet disinfection, and a sludge holding tank.

Sixty-five violations of the NPDES permit were recorded for the facility from January 2001 to July 2002. Ammonia, dissolved oxygen, cBOD5, and suspended solids limits were all violated with regularity during this time. Excessive inflow and infiltration continue to plague this facility causing routine carryover of biosolids from the clarifier into the sand filters which must be cleaned with high frequency to avoid loss of solids to the stream. A compliance schedule to address the problems in the collection system has not been adequately addressed by the facility. Sludge wasting, storage, and hauling also has not been adequately documented and may be done infrequently due to loss of solids from the clarifier during high flow.

Franklin County-Taylor Estates WWTP (Rocky Fork Creek RM 10.09)

The Franklin County Taylor Estates WWTP services a small subdivision of approximately 50 homes. The treatment train at the 0.025 MGD plant consists of an influent lift station, twin extended aeration tanks and clarifiers, a dosing tank, surface sand filtration, chlorination/dechlorination, and post aeration. An aerated sludge holding tank is used to store wasted sludge prior to disposal with the City of Columbus. Operation and maintenance appears adequate.

Nineteen violations of the NPDES permit were reported by Franklin County to Ohio EPA via monthly operating reports for the time period January 1, 2000 through May 30, 2002. Most of these were for dissolved oxygen or suspended solids. To correct the lack of dissolved oxygen, a post aeration system was installed as of June 2002. Occasional high flows are observed at the plant

indicating probable sources of inflow or infiltration, however the facility generally complies with its permit.

Windrush Creek WWTP (Unnamed Tributary RM ~1.20 to Rocky Fork Creek RM 1.85)

The Jefferson Water and Sewer District (JWSD) owns and operates the Windrush Creek WWTP located in Franklin County. This plant is designed to treat 0.040 MGD of domestic sewage. The treatment process includes a raw sewage lift station, aeration tank clarifier, slant plate settlers, chlorination, and effluent pumping. Wasted sludge is held in an aerated holding tank prior to delivery to the South Bloomfield WWTP for disposal.

The NPDES permit for this facility required the abandonment of the plant by July 1, 1999. This has not occurred as yet and may not occur until October 2003. This is a violation of their permit. Some 20 other violations of the NPDES permit were recorded between January 1, 2000 and June 30, 2002. Chlorine residual, $cBOD_5$, and suspended solids were the most numerous violations. Sludge deposits were also noted in the creek during the last inspection performed in August 2002. Inflow and infiltration into the collection system is a major problem at this facility and, in spite of statements from the JWSD saying that I/I has been significantly reduced, continue to impair operations.

Village of Ashley WWTP (West Branch Alum Creek RM 4.55)

The Village of Ashley operates a WWTP designed to treat an average of 0.190 MGD of domestic sewage. Recent upgrades performed in 1999 have facilitated compliance with the NPDES permit. Treatment consists of a hydrosieve static screen, orbal oxidation ditch, circular clarifiers, rapid sand filters, and ultraviolet disinfection. Wasted sludge is aerobically digested and dewatered in reed filter beds. The village accounts for 2.78% of the flow, 2.41% of the ammonia, and 1.86% of the $cBOD_5$ point source loadings to the Big Walnut Creek watershed.

Significant inflow and infiltration during wet weather is common. Flows up to 0.85 MGD may occur causing noncompliance with the NPDES permit. Most of the 35 violations of permit limits from January 1, 2001 to June 30, 2002 involved excessive suspended solids with $cBOD_5$ and ammonia violations also evident. Plans for reducing I/I have been requested from the village, but remain forthcoming.

Delaware County-County Home WWTP (Unnamed Trib RM 1.47 to Alum Creek RM 38.75)

This package WWTP is designed to treat up to 0.020 MGD of domestic wastewater. Ultraviolet radiation is used in place of chlorination for disinfection, but in all other ways, this plant is the typical package plant design. The County Home is no longer in use, so the only discharge to the plant comes from the Hickory Knoll Early Childhood Center School where teachers and students number under 100. The WWTP is significantly underloaded and, in many instances, there is no discharge from the plant. Operation and maintenance practices at this plant are satisfactory. Only 3 NPDES

permit violations were noted from July 2000 through June 2002, 2 for ammonia and 1 for fecal coliform bacteria.

Del-Co-Water Co. (Unnamed Trib RM ~1.00 to Alum Creek RM 26.13)

The Del-Co-Water Company operates the Old State Water Plant as a peak demand plant which supplements production of potable water at the Del-Co-Water Alum Creek plant. The Old State Water Plant does not operate continuously, but only when high demand warrents. During March through November of 2002, the plant only operated a total of 80 days. The plant is designed to process around 4 MGD of potable water but operates at around 1 MGD when operating. Although this facility carries a permit to discharge supernatant water from settling lagoons, no discharge has ever occurred from this facility. Liquid water softening sludge is removed from the lagoons and land applied to farm fields as a soil pH amendment in accordance with Ohio EPA regulations.

City of Westerville WTP (Alum Creek RM 21.18)

The City of Westerville operates a water treatment plant that provides treated, potable water to the city at a rate up to 7.5 MGD. Average water usage is around 4.0 MGD. Water is removed from Alum Creek, treated in a lime softening and filtration process, chlorinated, and fluoridated. The lime sludge produced from treatment is conveyed to one of three settling lagoons. Filter backwash water is stored in a fourth lagoon. Filter backwashing occurs 3-5 days per week. All four lagoons discharge to a common pipe linked to outfall 001. Depending on the water level, lime sludge storage lagoons may or may not discharge decant water. The average flow from 001 is around 0.062 MGD to an unnamed tributary of Alum Creek.

There were six violations of the NPDES permit for total suspended solids for this facility from January 2000 through June 2002. Lime sludge solids were also noted on the creek bottom during the latest inspection and facility personnel indicated that there was a spill of lime sludge in May 2002 and that some clean up was performed. Further remediation was recommended to remove sludge still present in the creek as noted in the inspection report.

Delaware County Alum Creek WWTP (Alum Creek RM 20.20)

This facility is new and began operations in June 2001. The WWTP is designed to treat up to 10 MGD of wastewater but is averaging only around 22% to 23% capacity (2.2-2.3 MGD). Treatment includes mechanical fine screens, extended aeration, clarification, tertiary filtration (via traveling bridge filters), ultraviolet disinfection, and post aeration. The discharge pipe runs some 6,700 meters to Alum Creek downstream of the City of Westerville water intake. Wasted sludge is aerobically digested, dewatered using a belt filter press, and land applied.

The facility has been in compliance with NPDES permit limits with the exception of some initial violations during plant start-up (the first month of operation) and a minor dissolved oxygen violation

in October 2001. Loadings from this plant were taken from 2001 data and compared with 1999 data from other facilities. According to this comparison, the Alum Creek WWTP comprises 30.3% of the flow, 19.2% of the suspended solids, 41.3% of the ammonia, and 13.3% of the $cBOD_5$ point source loadings to the Big Walnut Creek watershed.

Ohio-American Water Company Huber Ridge WTP (Alum Creek RM 17.85)

The Ohio-American Water Company operates the Huber Ridge water treatment and distribution facility with an average wastewater flow of 0.09 MGD. Wastewater flow consists mainly of off specification water from the reverse osmosis treatment process and can contain anywhere from 3000 mg/l to 4400 mg/l dissolved solids. Wastewater may also contain an insignificant amount of red water (iron) filter backwash water although most of this wastewater goes to the sanitary sewer. There were no NPDES permit violations for this facility.

Ohio-American Water Company Huber Ridge WWTP (Alum Creek RM 17.50)

Ohio-American Water Company operates the Huber Ridge WWTP which is designed to treat up to 1.03 MGD of domestic wastewater. The current treatment train consists of a raw sewage lift station, comminutor, extended aeration, clarification, chlorination/dechlorination, and post aeration. Wasted sludge is aerobically digested, dewatered via belt filter press and landfilled. This WWTP accounts for approximately 18.2% of the flow, 26.4% of the suspended solids, 12.1% of the ammonia, and 23.9% of the $cBOD_5$ point source loadings to the Big Walnut Creek watershed.

Monthly operating reports showed 9 permit violations over the period January 2001 to June 2002 and flow readings over that same period indicated some possible problems with inflow and infiltration. A few plant bypass events also were indicative of I/I problems. The plant bypass cap required removal 3 times in the last 3 years, twice in 2000 and once in 2002 (through July). Plant operation and maintenance practices are generally good and the facility will be examining their I/I situation more thoroughly in the near future. A compliance sampling inspection revealed appropriate effluent concentrations and comparable results for most parameters when comparing the facility lab versus the EPA lab.

Certified Oil (Unnamed Tributary to Alum Creek RM ~20.00)

Certified Oil Company operates a gas station at 5323 Westerville Road, Franklin County, Ohio. This facility operates a groundwater treatment system to remediate groundwater contaminated with petroleum hydrocarbons. A pump and treat system was installed in 1991 and includes 3 wells from which water is pumped to an air stripper unit followed by an LEL drum and two activated carbon cylinders. Treated groundwater is currently used to operate toilets on site with water going to the sanitary sewer after use. This facility currently has a general permit for petroleum related corrective action; thus, the NPDES permit is no longer required.

ASARCO (Alum Creek RM 9.45 via American Ditch)

The ASARCO property is a former zinc smelting facility that has been closed. The site was closed using a remedial action plan approved through the Ohio EPA Division of Emergency and Remedial Response. All of the zinc smelting facilities have been removed from the site and the site capped with geosynthetic material and clay cap. A grass ground cover dons the surface of the clay cap.

Flow from this site is sporadic and rainfall dependent. The highest recorded flow for the time period January 2000 through June 2002 was 2.8 MGD. American Ditch and Alum Creek downstream of American Ditch are believed to have contaminated sediments caused by past discharges from the ASARCO facility. The compliance schedule in the new NPDES permit requires ASARCO to submit a study and monitoring plan documenting and delineating contamination from zinc and cadmium in these areas. This plan was submitted March 1, 2003 and is currently under review.

Jefferson Water and Sewer District, Wengert Road WWTP (Unnamed Tributary RM 0.10 to Blacklick Creek RM 18.10)

The Wengert Road WWTP consists of grit and solids removal, small-scale flow equalization, extended aeration, clarification, Dynasand® tertiary sand filtration, ultraviolet disinfection, and post aeration. Wasted sludge is held in an aerated holding tank prior to hauling to the South Bloomfield WWTP for disposal. The WWTP is designed to accommodate 0.18 MGD of domestic sewage. The monthly average flow for the period September 2001 through August 2002 was 0.176 MGD.

This facility contributes approximately 2.11% of the wastewater flow and 1.84% of the suspended solids, 1.36% of the $cBOD_5$, and over 5.32% of the ammonia-N loading to the Big Walnut Creek watershed (Fig. 3). Flows have been increasing over time with the accompanying geometric increases in 95th percentile loadings of cBOD, suspended solids, ammonia-N, and phosphorus (Fig. 4). This is a classical example of periodic hydraulic overloading of the plant. This is further documented by noting the number of days that the flow was in excess of the design capacity of the plant. For the period January 2001 to August 2002 a total of 181 out of 608 days exhibited daily flow above the design capacity. Hydraulic overloading occurs nearly 30% of the time and is indicative of a serious problem. Twenty-six violations of NPDES permit limits were recorded for this facility between January 1, 2000 to August 31, 2002, most for suspended solids. Biosolids were also noted in the receiving tributary and in Blacklick Creek during the August 2002 inspection. Operation and maintenance performed at this facility are marginal at best and unsatisfactory at worst as noted in the August 2002 inspection report. Acute toxicity was not apparent in effluent samples obtained in October 2000.

As of June 2003 this facility is in the process of connecting to the Columbus sanitary sewer system. The sewage plant will be decommissioned and the discharge to Blacklick Creek will cease.

Columbus Steel Drum Company (Unzinger Ditch to Blacklick Creek RM 17.85)

Columbus Steel Drum, located in Gahanna, Ohio, reconditions and recycles 55-gallon steel drums. Facility processes include heat oxidation, stripping, caustic washing, shot blasting, and painting. All process-related wastewater is discharged (after pretreatment) to the sanitary sewer system. The NPDES permit for this facility covers strictly stormwater runoff and is thus precipitation dependent.

Runoff from the site is polluted from contact with contaminated soils, leaking drums awaiting reconditioning, and air deposition from processes with inadequate air pollution controls. The current permit contains limits for oil and grease, free cyanide, cadmium, copper, zinc, and pH. Monitoring is required for chemical oxygen demand (COD), suspended solids, and lead as well as organic compounds. Permit violations for oil and grease, zinc, copper, cyanide, cadmium, and pH regularly occur. High detections of COD and organic compounds in runoff confirm contaminant escape as do high concentrations of metals and organic compounds in tributary sediments downstream of the discharge point. The company has been referred to the Ohio Attorney General for these permit violations.

By Willow Mobile Home Park (Unnamed Trib. RM 1.90 to Blacklick Creek RM 12.89)

The By Willow MHP WWTP is located at 8450 E. Main Street, Reynoldsburg, Ohio. The facility operates a package WWTP designed to treat 3,800 gpd. Currently, the park is undergoing depopulation in expectation of closing sometime in 2003. The Kroger Company has an option to buy the property and erect a store on the site. The NPDES permit for this facility became effective August 1, 2002 and contains a compliance schedule requiring connection to a nearby sanitary sewer with subsequent decommissioning of the package plant.

Modern Mobile Home Park (Unnamed Trib. RM 1.15 to Blacklick Creek RM 12.89)

The Modern MHP is located at 8910 E. Main Street in Etna Township, Licking County. The park has about 25 trailers. The package WWTP is designed to treat 3,600 gpd. An NPDES permit has not yet been issued to this facility but is currently under review. Discharge occurs to a roadside ditch which flows into an unnamed tributary to Blacklick Creek.

Fairfield County, Tussing Road WWTP (Blacklick Creek RM 11.15)

The Tussing Road WWTP consists of an influent pumping station, mechanically cleaned bar screens, extended aeration, clarification, ultraviolet disinfection, and cascade post-aeration. Wasted sludge is aerobically digested and dewatered by a belt filter press prior to land application. The Tussing Road WWTP contributes 16.6% of the wastewater flow to the Big Walnut Creek watershed. Suspended solids, $cBOD_5$, and ammonia-N loadings are 12.5%, 11.3%, and 9.62%, respectively, of the total WWTP loading to the Big Walnut Creek watershed (Fig. 3).

Median effluent flows have risen steadily to nearly 1 MGD with 95th percentile flows sometimes up to 1.5 MGD or more (Fig. 5). High flows to the plant and age-related equipment failures have resulted in some extraordinary loadings of suspended solids, cBOD, and ammonia-N discharged to the creek. Although these seem to occur infrequently, they still impact the chemical water quality in the creek and provide stresses to the biological communities. County officials recognize these problems and have submitted a PTI application to upgrade and expand the plant. The application is currently under review by Ohio EPA. Eighteen permit violations have been noted during the period January 2000 through July 2002 mostly for excess ammonia concentrations or loadings. Operation and maintenance at this facility are satisfactory as noted in the July 2002 inspection report. Acute toxicity was not apparent in effluent samples obtained in March 2001.

Ohio-American Water Company Blacklick Estates WWTP (Blacklick Creek RM 4.85)

The Blacklick Estates WWTP consists of an influent pumping station, grit removal, step-feed extended aeration, clarification, chlorine disinfection, dechlorination, and post-aeration. Wasted sludge is aerobically digested, dewatered via belt filter press and landfilled. The design capacity for this plant is 1.20 MGD. This facility contributes nearly 14.1% of the wastewater flow, 18.8% of the suspended solids, 10.8% of the $cBOD_5$ and much less than 1% of the ammonia loadings to the Big Walnut Creek watershed (Fig. 3). Flows to the plant have remained stable at nearly 1 MGD with loadings for suspended solids, cBOD, and ammonia-N all decreasing or remaining stable (Fig. 6). Loading for nitrate+nitrite-N have increased, peaking in 1997. This is indicative of the removal of ammonia via nitrification. Operation and maintenance practices at this plant are satisfactory. Acute toxicity was not apparent in effluent samples obtained in March 2001.

There were 17 violations of the NPDES permit for this facility, mostly for ammonia (daily versus annual loadings noted above) from January 2000 through June 2002 with most occurring in 2000 and 2001. Complete compliance was noted in the 2002 self-monitoring results.

American Electric Power (Blacklick Creek RM 3.05)

The NPDES permitted discharge from this facility consists of non-contact cooling water used for building cooling and some stormwater. After use, non-contact cooling water is discharged to a retention pond prior to entering Blacklick Creek. The creek has changed course recently and now cuts through a corner of the retention pond. This facility was in compliance with the permit at the time of the inspection. AEP is responsible for approximately 4.12% of the total known point source flow in the Big Walnut Creek watershed.

Big Walnut Sand and Gravel, Inc. (Big Walnut Creek RM 12.62)

Big Walnut Sand and Gravel, Inc. excavates, processes and sells sand and gravel products for construction purposes. Discharge from this facility only arises during pumping to lower the lake level of the quarry so that the dredge may operate efficiently. Discharge occurs on an as needed

basis and up to 1.01 MGD is the maximum discharge that can be effected. Surface pumping occurs at the opposite end of the quarry from dredging operations so as to limit discharge of suspended solids.

City of Columbus-Parsons Avenue WTP (Big Walnut Creek RM 8.80)

The Parsons Avenue water plant obtains raw water from a well field for treatment and distribution to the Columbus metro area. Up to 29 MGD of water may be treated in any one day. There has never been a discharge coming from the plant as long as the facility has been in operation. Decant water from the sludge settling lagoons is recirculated to an inactive lagoon and not discharged to the creek.

Rickenbacker Port Authority (Unnamed Trib. to the Ohio Canal RM 4.20)

This entity coordinates the operation of a military and commercial air freight terminal used by various tenants. The discharges from this facility are all precipitation-based. Storm water may come into contact with various materials used on site, particularly deicing agents used on aircraft and runways (e.g., glycol, various salts) during freezing conditions. Petroleum related materials (jet fuel, lubricating oils) may also drain into storm sewers and find their way into the creek. Only one outfall discharges to the Big Walnut Creek watershed. All other drainage is directed to the Walnut Creek watershed. There were no violations of NPDES permit limits for the period January 2000 through September 2002; however, self-monitoring efforts by this facility are marginal and require more diligent implementation by the entity.

Ohio Air National Guard (Unnamed Trib. to the Ohio Canal RM 4.20)

The Ohio Air National Guard, 121st Air Refueling Wing owns and operates a facility at the Rickenbacker Airport which provides support and fueling services to flying units of the Air National Guard. The NPDES permit covers the discharge of storm water runoff associated with the fuel storage complex. Runoff is treated via an oil-water separator prior to discharge to a ditch that leads to an unnamed tributary to the old Ohio Canal outlet to Big Walnut Creek. Runoff from other areas of this facility are not currently under permit, but may be permitted in the near future. A single violation of the pH permit limit of 9.0 was noted in June 2001.

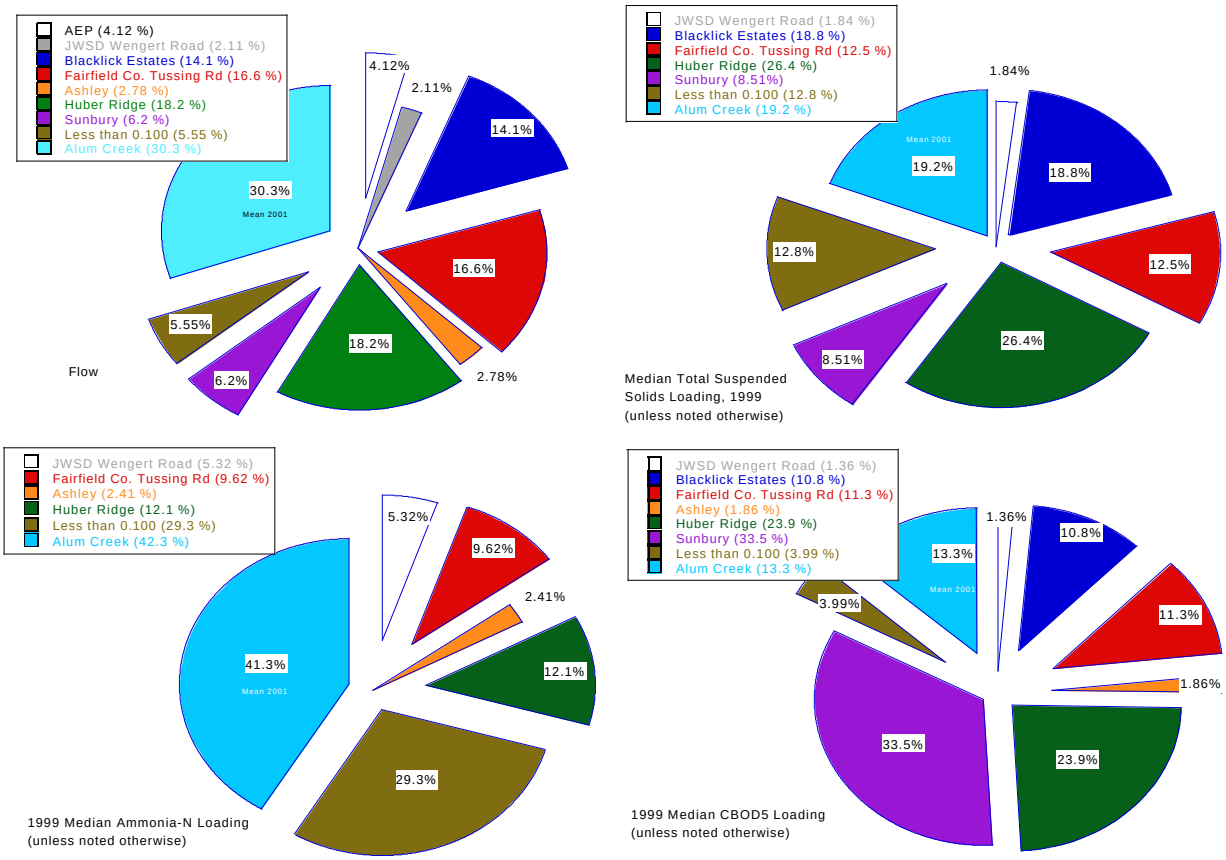

Figure 2. Proportion of flow and Total Suspended Solids, Ammonia-N, and $cBOD_5$ loadings for the principal known point source dischargers into the Big Walnut Creek basin.

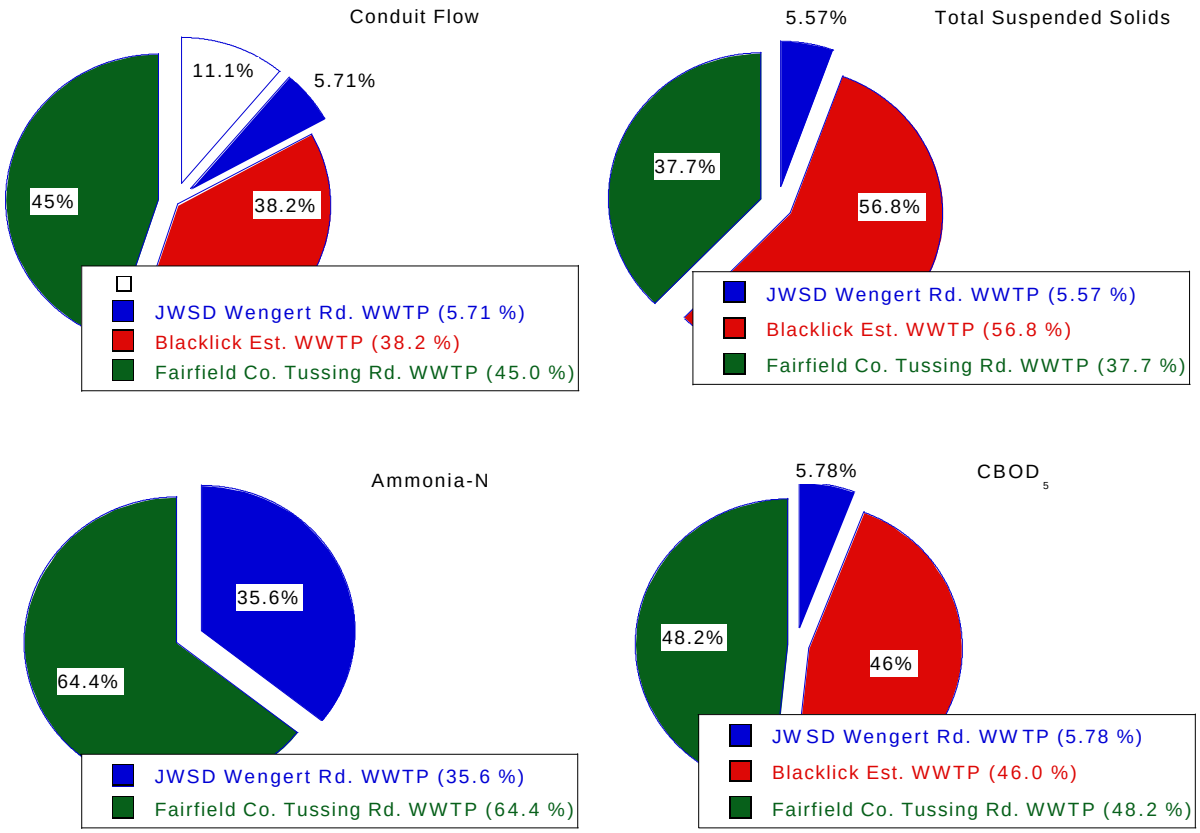

Figure 3. Proportion of flow and Total Suspended Solids, Ammonia-N, and $cBOD_5$ loadings for the principal known point source dischargers into Blacklick Creek.

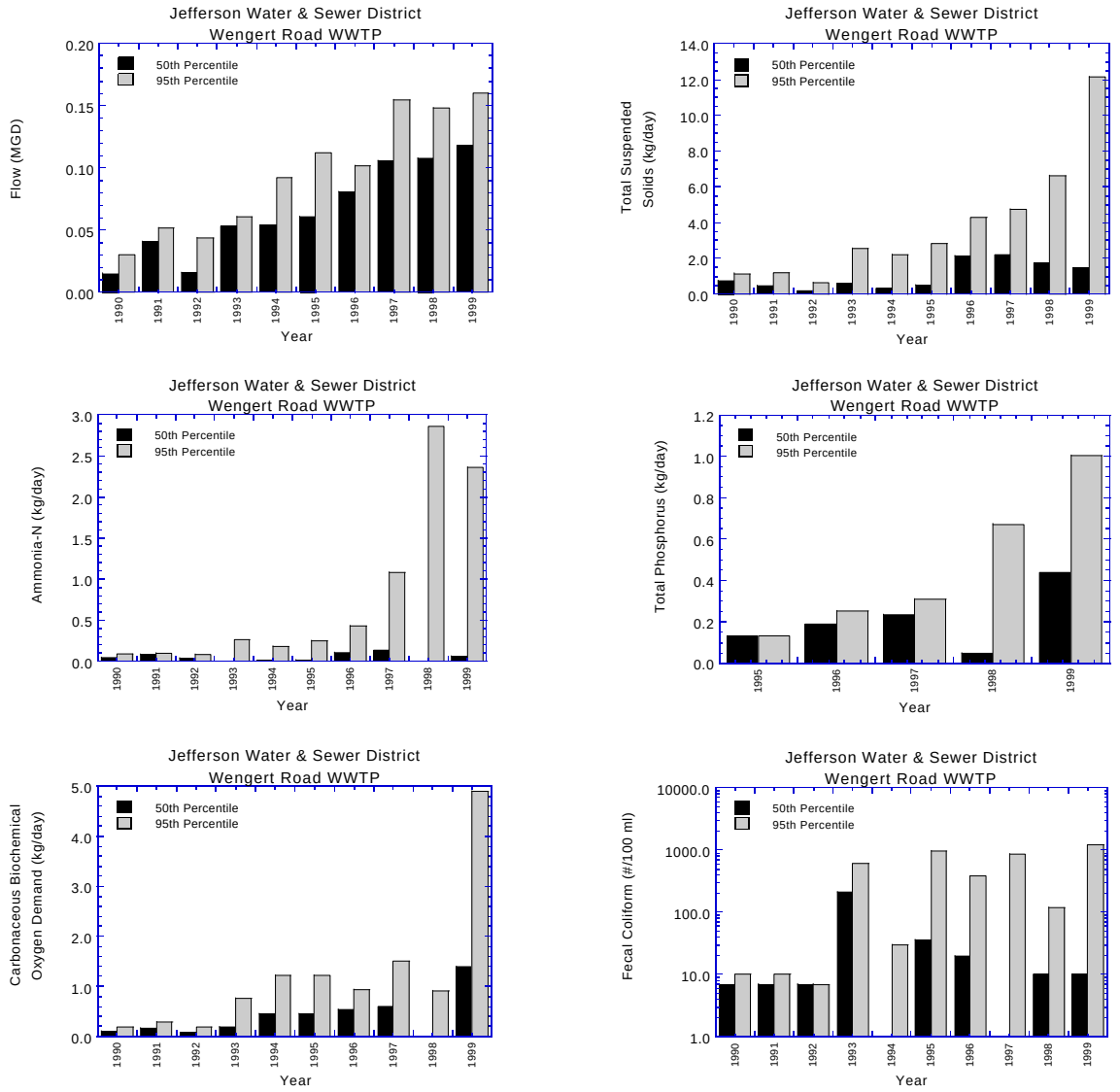

Figure 4: Third-quarter median and 95th percentile conduit flow (MGD) and pollutant loads (kg/day) of Total Suspended Solids, Ammonia-Nitrogen, Total Phosphorus, five-day carbonaceous Biochemical Oxygen Demand, and Fecal Coliform bacteria counts from the Jefferson Water and Sewer District, Wengert Road WWTP, 1990-1999.

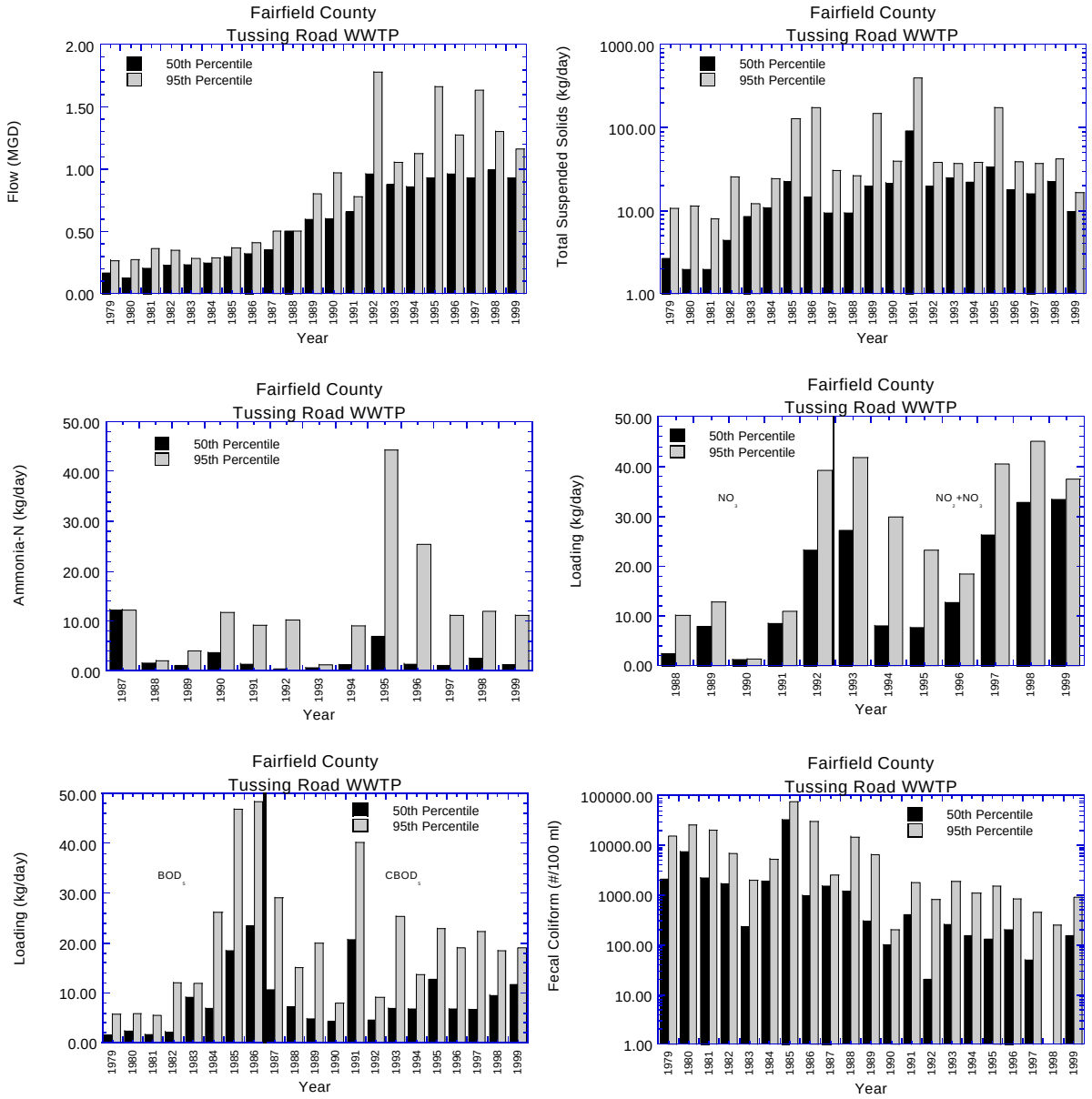

Figure 5. Third-quarter median and 95th percentile conduit flow (MGD) and pollutant loads (kg/day) of Total Suspended Solids, Ammonia-Nitrogen, Nitrate+Nitrite-N, five-day carbonaceous Biochemical Oxygen Demand, and Fecal Coliform bacteria counts from the Fairfield County, Tussing Road WWTP, 1979-1999.

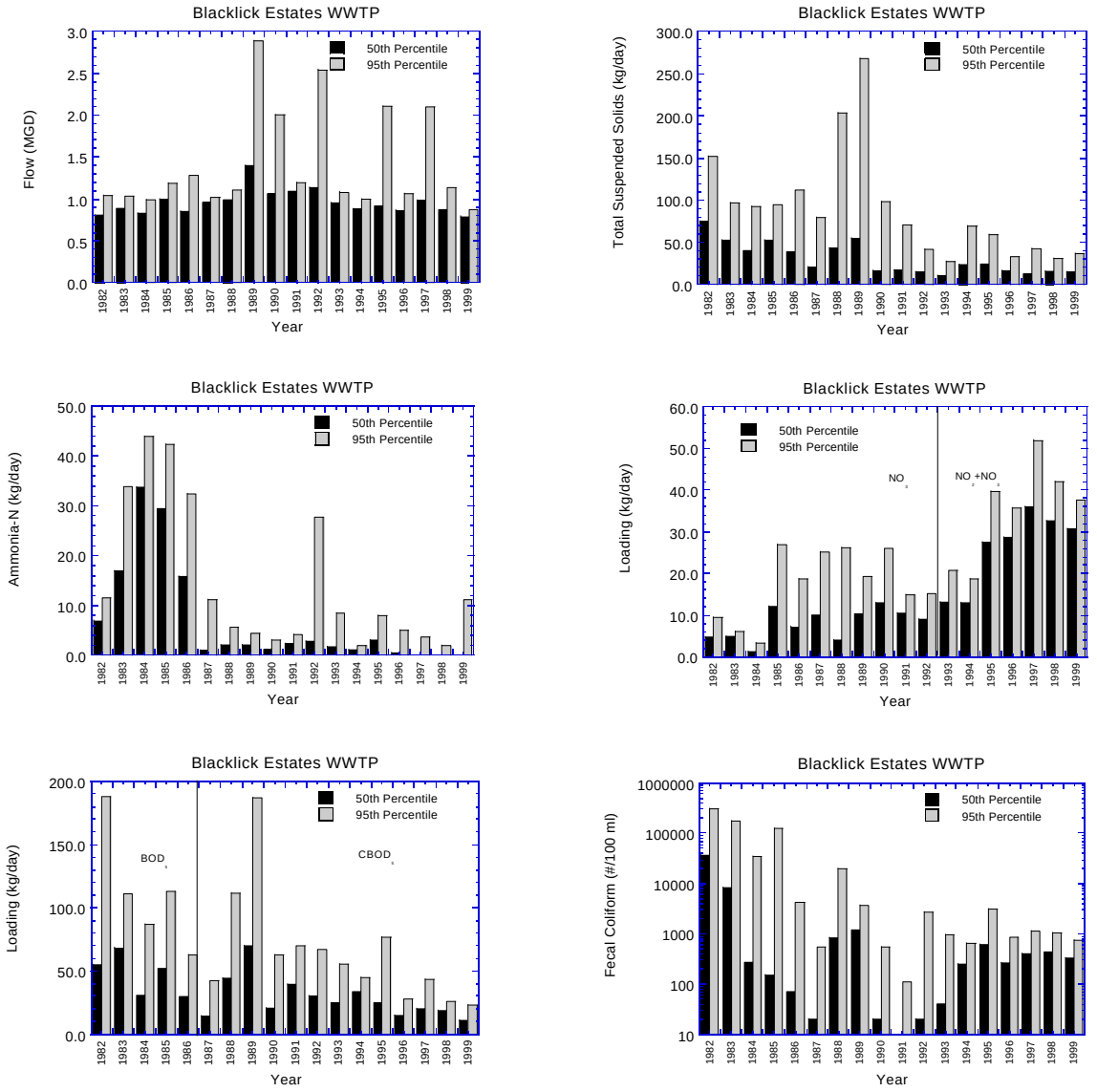

Figure 6. Third-quarter median and 95th percentile conduit flow (MGD) and pollutant loads (kg/day) of Total Suspended Solids, Ammonia-Nitrogen, Nitrate+Nitrite-N, five-day carbonaceous Biochemical Oxygen Demand, and Fecal Coliform bacteria counts from the Blacklick Estates WWTP, 1982-1999.

Pollutant Spills and Unauthorized Releases

In addition to NPDES permit violations and Ohio WQS criteria exceedences, a review of the Ohio EPA Division of Emergency and Remedial Response (DERR) Release Reporting System (RRS) database revealed 37 spills to the Big Walnut Creek basin in 2000 (Table 8). This list should be considered only a small fraction of the pollutants that are spilled into the basin on a regular basis. Sewage from municipal collection and treatment facilities, ethylene glycol from the Columbus Airport Authority and petroleum products from miscellaneous spills appear to be the most substantial materials reported.

Table 8. Summary of pollutants spilled into the Big Walnut Creek basin reported to the Ohio EPA Division of Emergency and Remedial Response in 2000.

Date	Entity	Material	Amount	Waterway
1/04/2000	Westerville WWTP	Sewage	Unknown	Alum Cr.
1/07/2000	Columbus Airport Authority	Ethylene glycol	Unknown	B. Walnut Cr.
1/10/2000	Ameritech	Gasoline Waste water (gas contaminated)	0.1 gal. 450 gal.	Alum Cr. via storm sewer
2/25/2000	John A. Madden Trucking Inc.	Diesel fuel	100 gal.	Alum Cr. Trib.
2/28/2000	American Showa Inc.	Hydraulic oil	300 gal.	L. Walnut Cr. Trib.
2/28/2000	Lucent Technologies	Waste water	70,000 gal.	B. Walnut Cr.
3/14/2000	Schneiner National	Diesel fuel	15 gal.	Alum Cr. Trib. Pond
3/22/2000	Citizen Utilities Co.	Sewage	Unknown	Spring Run
3/29/2000	John E. Salter	Gasoline	194 gal.	Blacklick Cr.
3/31/2000	Quality Golf	Material-gray	Unk.	Perfect Cr.
4/03/2000	Davey Tree Expert Co.	Pendimethalin mix	275 gal.	Alum Cr. Trib.
4/04/2000	Citizen Utilities Co.	Sewage	Unknown	Alum Cr.
4/26/2000	Citizen Utilities Co.	Sewage	10,000 gal.	Spring Run
5/02/2000	Claycraft Brick Plant No. 2	Heavy metals	Unknown	B. Walnut Cr. Trib.
5/17/2000	Anheuser-Busch, Inc.	Beer, waste beer	Unknown	Alum Cr. Trib.
6/09/2000	Sunbury Pump WWTP	Sewage	7,000 gal.	Drainage ditch
6/14/2000	Place to Place Transportation	Diesel fuel	50 gal.	Alum Cr. Trib.
6/19/2000	Alboher Development Co.	Muddy water	Unknown	B. Walnut Cr.
7/25/2000	Fishburn Producing	Crude oil	500 gal.	Alum Cr. Trib.
7/25/2000	Fishburn Producing	Crude oil	500 gal.	Alum Cr. Trib.
8/17/2000	Columbus Airport Authority	Ethylene glycol	550 gal.	B. Walnut Cr.
9/11/2000	Columbus WWTP	Sewage	Unknown	Alum Cr.
9/25/2000	Huber Ridge WWTP	Sewage	Unknown	Alum Cr.
9/25/2000	Columbus Airport Authority	Jet fuel	50 gal.	B. Walnut Cr. via SS

Date	Entity	Material	Amount	Waterway
9/27/2000	Glory Transportation	Diesel Fuel	100 gal.	B. Walnut Cr. Trib.
10/01/2000	Unknown	Red material	Unknown	B. Walnut Cr.
10/04/2000	MGR Construction	Sewage	Unknown	Alum Cr. via SS
10/09/2000	Hoover Bridge WWTP	Sewage	Unknown	Alum Cr.
10/30/2000	Hoggy's Restaurant	Grease	Unknown	Rocky Fork
10/31/2000	Consolidated Freightways Corp.	Diesel fuel	75 gal.	Alum Cr. Trib.
11/04/2000	William Ringler Hog Farm	Hog manure	Unknown	W. Br. Alum Cr.
11/08/2000	City of Whithall	Black material	Unknown	B. Walnut Cr. Trib.
11/28/2000	Columbus Airport Authority	Etheylene glycol	660 gal.	B. Walnut Cr. via SS
12/12/2000	Cooper Power Systems, Inc.	Transformer oil	55 gal.	Alum Cr.Trib. via SS
12/18/2000	Huber Ridge WWTP	Sewage	Unknown	Alum Cr.
12/20/2000	Columbus Airport Authority	Etheylene glycol	1,600 gal.	B. Walnut Cr.
12/27/2000	Columbus Sewers and Drains	Sewage	Unknown	Alum Cr.

Chemical Water Quality

Between June and September 2000, five grab samples of water were taken at each of 117 sites within the Big Walnut Creek watershed. The effort included samples from 113 ambient sites, 2 WWTP effluent sites, and 2 mixing zones. Samples were collected, preserved, and analyzed for a variety of pollutants following the protocols specified in the Manual of Ohio EPA Surveillance Methods and Quality Assurance Practices (Ohio EPA 1989a) Analytical results for the field and laboratory parameters are presented in Appendix Table A (provided upon request). Various longitudinal plots of this data are found in the figures below.

Sampling stations in the Big Walnut Creek watershed were chosen to provide information concerning ambient water quality. The sampling scheme chosen was based on a geometric progression of drainage areas with more sampling sites at smaller drainage area locales and fewer sites at larger drainage area locales (Table 6). Sample results were evaluated to determine impacts from land use practices in the watershed and to determine instantaneous exceedences of criteria listed in the Ohio Water Quality Standards (OAC 3745-1). Exceedences were based on designated or assigned Exceptional Warmwater Habitat (EWH), Warmwater Habitat (WWH), or Modified Warmwater Habitat (MWH) aquatic life uses, Primary or Secondary Contact Recreation (PCR or SCR) uses, and Agricultural and Industrial Water Supply (AWS or IWS) uses; exceedences are summarized in Table 9.

Despite advanced methods of treating wastes used in the United States, contaminated waters still cause illness via contact through direct consumption, via swimming and wading, and consumption of contaminated fish and shellfish. Commonly used tools intended to protect the public from

waterborne pathogens identify contaminated waters, but cannot distinguish between human and animal sources of contamination. This limitation makes for difficulty in correcting pollution problems and in maintaining clean waters in urbanized areas.

Big Walnut Creek Mainstem (WWH, EWH)

Chemical water quality in the Big Walnut Creek mainstem was generally good, improving with distance downstream. Water quality impacts resulting from bacterial contamination were common and nearly stream-wide (Table 9); some of these were related to a rain event in mid-June. The headwater portion of Big Walnut Creek from RM 73.60 through RM 66.60 showed the greatest degradation from bacteria. Fecal coliform bacteria regularly exceeded the maximum Primary Contact Recreation (PCR) criterion. *E. coli* values typically exceeded the maximum Secondary Contact Recreation (SCR) criterion. Moving downstream, the reach beginning at RM 61.90 showed little improvement in bacterial contamination from the headwater areas upstream. This site may be influenced by hydraulic overflows from the Village of Marengo WWTP during rain events. However, beginning at RM 54.60, a marked improvement in bacterial contamination was noted until the reach just downstream of Gahanna and the Port Columbus International Airport where bacterial contamination was again excessive. The EWH designated reach of Big Walnut Creek (beginning at Williams Road, RM 15.80) exhibited few bacterial exceedences.

Evaluation of mean temperature in Big Walnut Creek showed a gradual increase when moving downstream. Wider variability in temperatures was noted upstream with variation decreasing moving downstream (Fig. 8). This is likely due to a larger proportion of cooler groundwater input to the creek in the headwater reaches keeping temperatures lower. As drainage area and flow volume increases, temperature variability decreases, but the mean value increases nearly 5 degrees Celsius when compared with headwater areas. This may be due to reduction of riparian shading as the stream becomes wider and impounded at Hoover Reservoir (allowing more sunlight to impact the surface), loss of riparian corridor, increased urbanization (the urban "heat island"), as well as a lower percentage of groundwater comprising total stream flow.

Instantaneous evaluation of dissolved oxygen showed only one data point below the WWH criterion at only one site in the headwaters at RM 73.60 (Table 9, Fig. 8). All other instantaneous readings were well above the minimum and mean WWH and EWH criteria.

Nutrients (largely ammonia and phosphorus but also including organic nitrogen) and suspended solids were more concentrated in the headwater areas (RM 73.60 through RM 66.60) than in downstream sections (except directly downstream of Hoover Reservoir) (Table 10, Fig. 9). Mean ammonia concentrations were the highest found in the mainstem, often exceeding the 95th percentile of background ecoregional reference concentrations at RM 73.60 (Fig. 9). Total phosphorus, TKN, and nitrite were also present in significant quantities, often in excess of the 75th percentile of background reference. Total phosphorus detections over background reference median were prevalent from the headwaters downstream to RM 54.60 where they began to dissipate. Suspended

solids concentrations were well above 75th percentile background reference values in most cases, with some even higher than the 90th and 95th percentiles. The uppermost 2 sites showed the highest mean suspended solids concentrations in the mainstem. Elevated concentrations of suspended solids are likely one cause of substrate embeddedness in this area of the stream. Headwater areas were definitely impaired by excess nutrients compared with background ecoregional reference concentrations.

Nitrogen-based nutrient (except TKN) and suspended solids concentrations were attenuated upstream of Hoover Reservoir but increased again downstream of the dam (Table 10, Fig. 9). The reach from RM 28.30 to the mouth showed noticeably fewer instances of suspended solids and nutrients above the median background ecoregional reference than the headwater areas.

Metals concentrations in Big Walnut Creek never exceeded Water Quality Standards criteria; however, there were large fluctuations in longitudinal mean concentrations of some metals including manganese, iron, aluminum, strontium, sodium, and overall hardness (Fig. 10). These concentrations of metals did not influence chemical water quality.

Diel Dissolved Oxygen Study-Big Walnut Creek

Diel dissolved oxygen patterns were evaluated at 3 locations on the Big Walnut Creek mainstem, RM 52.40, RM 34.90, and RM 7.10. Each site was assessed 2 or 3 times during the summer for approximately 48 consecutive hours. The WWH or EWH minimum criterion for dissolved oxygen was never violated during the survey period except in mid August at RM 52.40 where one value dipped below 4.0 mg/l (Figs. 11,12). The cause for this single violation is unknown. Typical diel fluctuations were also noted at each site and supersaturated conditions were rarely present.

Water Column Organics-Big Walnut Creek

Three sites were sampled for organic constituents in the water column on the Big Walnut Creek mainstem. The alpha (α) and gamma (γ) forms of benzene hexachloride (BHC) were the only contaminants detected (Table 11) in the water column. The site at RM 1.70 exhibited a value for γ-BHC (aka Lindane) which exceeded the standard for the protection of aquatic life outside the mixing zone. Sources for this material are unknown but may be linked to various agricultural practices as this insecticide is under restricted use as a seed and soil treatment.

Table 9. Exceedences of Ohio EPA Warmwater Habitat (WWH) and Exceptional Warmwater Habitat (EWH) water quality criteria (OAC 3745-1) for chemical/physical parameters in the Big Walnut Creek study area, 2000. Plain text river miles indicate Warmwater Habitat, boldface river miles are designated Exceptional Warmwater Habitat, effluent discharges are in italic print, undesignated streams have a letter U following the river mile, and areas designated Modified Warmwater Habitat are underlined (Units are #/100 ml for bacteria, µg/l for metals, cyanide and pesticides, and mg/l for all other parameters).

River/Stream	NPDES Discharge	River Mile	Parameter	(Value) code
Big Walnut Creek		73.60	Dissolved Oxygen Fecal Coliform E. coli	(3.27)‡‡ (2800, 2900, 3550)• • (955, 2200, 2950, 4300)• • •
		70.70	Fecal Coliform E. coli	(2100)• • (300, 530)• •, (1080, 1400)• • •
		66.60	Fecal Coliform E. coli	(26000)• • • (800, 2600, 17000)• • •
		61.90	Fecal Coliform E. coli	(2600, 3100)• • (1120, 2000, 2700, 3100)• • •
		54.60	E. coli	(415)• •
		52.40	E. coli	(340)• •
		49.00	None	
		37.20	Fecal Coliform E. coli	(2500)• • (2500)• • •
		34.90	E. coli	(600, 1500)• • •
		28.30	Fecal Coliform E. coli	(20000)• • • (370, 520)• •, (1500, 23000)• • •
		27.00	Fecal Coliform E. coli	(2000)• • (405, 430, 560)• •, (2800)• • •
		15.80	E. coli	(330)• •
		7.10	E. coli	(405)• •
		3.70	None	
		1.70	E. coli	(395)• •
Alum Creek		56.30	Fecal Coliform E. coli	(18500)• • • (315, 425, 510)• • (2700, 27500)• • •

River/Stream	NPDES Discharge	River Mile	Parameter	(Value) code
		55.30	Fecal Coliform E. coli	(2000)• •, (25500)• • • (680, 790, 905, 2100, 22500)• • •
		52.90	E. coli	(330, 350)• •, (1030)• • •
		49.90	E. coli	(360)• •, (610)• • •
		42.90	E. coli	(300)• •, (964)• • •
		39.45	E. coli	(300, 430)• •, (800)• • •
		22.10	E. coli	(300, 340, 430)• •, (1000)• • •
	Delaware County Alum Creek WWTP)	20.80	No discharge during survey period	
		19.80	E. coli	(340)• •, (1200)• • •
		13.40	Fecal Coliform E. coli	(5259)• • • (310)• •, (730, 4400)• • •
		3.80	Fecal Coliform E. coli	(3300)• • (530, 1110)• • •
		0.70	E. coli	(360, 460, 490)• •
West Branch Alum Creek		9.90	Fecal Coliform E. coli	(10000)• • • (460)• •, (945, 1240, 11000)• • •
		8.70	Dissolved Oxygen Copper Fecal Coliform E. coli	(3.38)‡‡ (23)** (8000)• • • (350, 490)• •, (690, 9360)• • •
		3.30	Zinc Fecal Coliform E. coli	(583)** (2400)• • (300, 320)• •, (1300)• • •
		0.60	E. coli	(600, 918, 918)• • •
Turkey Run		4.80	Dissolved Oxygen Fecal Coliform E. coli	(4.41)‡, (2.90, 3.57)‡‡ (2000)• • (370, 590)• •, (1100, 1210, 1500)• • •
		1.70	Fecal Coliform E. coli	(2000)• • (550)• •, (740)• • •
Unnamed Tributary to Alum Creek @ RM 54.44		0.60U	Dissolved Oxygen Fecal Coliform E. coli	(2.52, 3.90)‡‡ (2700, 3000)• •, (7546)• • • (610, 760, 2400, 3100, 6500)• • •
Bunker Run		1.80	Fecal Coliform E. coli	(2400)• •, (5400)• • • (320)• •, (640, 2700, 8270)• • •

River/Stream	NPDES Discharge	River Mile	Parameter	(Value) code
Unnamed Tributary to Alum Creek @ RM 40.48		0.20U	Fecal Coliform E. coli	(3050)• • (500, 575, 590)• •, (987, 2300)• • •
Unnamed Tributary to Alum Creek @ RM 38.75		0.30U	E. coli	(340, 380)• •, (630, 690, 690)• • •
Big Run		2.70	Dissolved Oxygen Fecal Coliform E. coli	(3.42)‡‡ (3000, 3900)• • (1200, 1700, 2400, 2900)• • •
Unnamed Tributary to Alum Creek @ RM 25.50		0.20U	Fecal Coliform E. coli	(3300)• •, (5250, 21000, 31000)• • • (455, 590)• •, (3000, 18000, 29000)• • •
Unnamed Tributary to Alum Creek @ RM 23.47		0.80U	E. coli	(320, 410, 440)• •, (620, 650)• • •
Spring Run		3.70U	Fecal Coliform E. coli	(8273, 27000)• • • (730, 1040, 2500, 8910, 25000)• • •
		0.20U	Fecal Coliform E. coli	(2300)• •, (8818, 11000)• • • (360)• •, (818, 7200, 9640)• • •
West Spring Run		0.10U	Copper Fecal Coliform E. coli	(12)** (9000, 55000)• • • (1600, 10100, 35000)• • •
Kilbourne Run		0.40U	Fecal Coliform E. coli	(4000)• •, (10000)• • • (710, 7400, 10300)• • •
Bliss Run		0.60	Fecal Coliform E. coli	(2600, 4100)• •, (17000, 55000)• • • (450)• •, (2400, 2500, 11200, 54500)• • •
Rocky Fork Big Walnut Creek		11.40	Dissolved Oxygen E. coli	(2.91)‡‡ (400, 540)• •
		10.20	E. coli	(700, 730, 2000)• • •
		7.10	Fecal Coliform E. coli	(2600)• •, (8455)• • • (710, 730, 1750, 3300)• • •
		5.90	Fecal Coliform E. coli	(9000)• • • (480)• •, (1000, 1500)• • •
		3.30	E. coli	(540)• •, (1500)• • •
		1.10	Fecal Coliform E. coli	(26000)• • • (370)• •, (14400)• • •

River/Stream	NPDES Discharge	River Mile	Parameter	(Value) code
Rose Run		0.50	E. coli	(809, 873, 1000, 1700, 2000)• • •
Sugar Run		3.10	None	
		0.70	E. coli	(360, 540)• •, (660, 740)• • •
Long Run		4.30	E. coli	(400, 520)• •, (740)• • •
		3.60	E. coli	(410, 460)• •, (700, 1300)• • •
		0.70	E. coli	(340)• •, (620)• • •
Castro Run		1.10	E. coli	(415)• •
Mill Creek		1.60	Fecal Coliform E. coli	(53000, 60000)• • • (500)• •, (2000, 80000, 92000)• • •
Light Creek		0.10	E. coli	(380)• •, (1400, 1600)• • •
Reynolds Run		0.70	Fecal Coliform E. coli	(2900, 4700)• • (710, 750, 4500)• • •
Little Walnut Creek		10.20	E. coli	(300, 310)• • •
		9.40	Dissolved Oxygen Fecal Coliform E. coli	(3.60)‡‡ (2600)• • (350, 370)• •, (1900)• • •
		7.40	E. coli	(300, 310, 350)• •
		1.40	E. coli	(300)• •
East Branch Little Walnut Creek		0.05	Fecal Coliform E. coli	(3500)• • (500)• •, (3200)• • •
West Branch Little Walnut Creek		3.30	Dissolved Oxygen Fecal Coliform E. coli	(0.40, 2.27, 2.83)‡‡ (2100, 2700,)• •, (12000, 41000)• • • (1700, 4300, 17000, 33000)• • •
		0.80	Dissolved Oxygen E. coli	(2.85)‡‡ (450, 470)• •, (800)• • •
Butler Run		1.20	Dissolved Oxygen E. coli	(3.95)‡‡ (360)• •, (680, 790)• • •
Sugar Creek		5.30	Dissolved Oxygen E. coli	(2.72, 3.92)‡‡ (310, 380, 420)• •
		0.10	E. coli	(320, 330)• •
Perfect Creek		6.30	Dissolved Oxygen E. coli	(2.45)‡‡ (520)• •

River/Stream	NPDES Discharge	River Mile	Parameter	(Value) code
		0.10	E. coli	(310, 500)• •
Rattlesnake Creek		0.10	E. coli	(370)• •
East Fork Rattlesnake Creek		3.10	Dissolved Oxygen Fecal Coliform E. coli	(1.41, 3.16)‡‡ (2700)• • (2000, 3000)• • •
		0.20	Fecal Coliform E. coli	(2600)• • (600, 600, 1600, 2800, 4400)• • •
South Fork Rattlesnake Creek		3.70	E. coli	(360)• •, (750, 900)• • •
		0.10	E. coli	(720, 2600)• • •
North Fork Rattlesnake Creek		4.80	Fecal Coliform E. coli	(3100)• • (600, 1100, 1700)• • •
		3.40	E. coli	(300, 555)• •, (630, 1700)• • •
		0.10	Dissolved Oxygen E. coli	(2.81)‡‡ (360, 470, 480, 520)• •, (964)• • •
Prairie Run		0.40	E. coli	(500, 510, 590)• •, (936, 1000)• • •
	Sunbury WWTP	0.35??	Not analyzed	
Culver Creek		4.50	Dissolved Oxygen E. coli	(2.60, 2.06)‡‡ (500, 510, 590)• •, (936, 1000)• • •
		3.30	Fecal Coliform E. coli	(2300)• • (410, 590)• •, (1600, 2000)• • •
		0.10	Dissolved Oxygen Fecal Coliform E. coli	(3.44)‡‡ (2000)• • (1240)• • •
Unnamed Tributary to Culver Creek @ RM 3.32		0.10	Fecal Coliform E. coli	(2000, 3200)• •, (5900)• • • (370)• •, (1330, 2100, 2900, 3000)• • •
Duncan Run		9.00	E. coli	(450)• •, (1070)• • •
		7.30	Fecal Coliform E. coli	(2800)• • (320, 430)• •, (1290)• • •
		2.70	Fecal Coliform E. coli	(14300)• • • (370, 410)• •, (14500)• • •

River/Stream	NPDES Discharge	River Mile	Parameter	(Value) code
McKenna Creek		0.20U	Fecal Coliform E. coli	(2050, 3800)• • (320, 380, 515)• •, (2300, 2800)• • •
Unnamed Tributary to Big Walnut Creek @ RM 27.29		0.20U	Fecal Coliform E. coli	(2400, 4400)• •, (8000)• • • (1000, 2300, 2600, 6450)• • •
Mason Run		0.50	Fecal Coliform E. coli	(2500, 2700)• • (380, 440)• •, (918, 1060, 2300)• • •
Unnamed Tributary to Big Walnut Creek @ RM 12.74		0.20U	E. coli	(500, 540)• •, (1040)• • •
Blacklick Creek		27.10	Dissolved Oxygen Total Dissolved Solids Fecal Coliform E. coli	(1.50, 2.99)‡‡ (1830, 3320, 3810) **k** (3000)• •, (11818, 21000, 26000)• • • (2000, 7100, 9000, 15000, 20000)• • •
		24.70	E. coli	(1000)• • •
		22.40	E. coli	(300, 440)• •
		20.40	E. coli	(300, 320, 360, 400)• •
		16.60	E. coli	(350, 520)• •, (1700)• • •
		13.70	E. coli	(500)• •, (800, 1020, 2000, 3000)• • •
		11.30	Fecal Coliform E. coli	(2900)• •, (7000)• • • (440)• •, (1160, 2100, 4000)• • •
	Tussing Road WWTP	11.10	Ammonia Fecal Coliform	(7.32) **;** (25000) **;**
	Mixing Zone	11.05		
		11.00	Fecal Coliform E. coli	(8000, 11182)• • • (340)• •, (780, 3300, 5600)• • •
		8.80	E. coli	(580)• •, (650, 2700, 6000)• • •
	Blacklick Estates WWTP	4.83	None	
	Mixing Zone	4.80		

River/Stream	NPDES Discharge	River Mile	Parameter	(Value) code
		4.60	Fecal Coliform E. coli	(3000)• • (470, 530)• •, (2900)• • •
		1.90	E. coli	(400, 400)• •, (750, 8000)• • •
Swisher Creek		1.30	Dissolved Oxygen E. coli	(1.20)‡‡ (320, 330, 410)• •
North Branch French Run		**0.20**	Fecal Coliform E. coli	(3800)• • (1040, 1110, 2100, 3400)• • •
French Run		0.70	Fecal Coliform E. coli	(3500, 3600, 4000)• •, (5000)• • • (1060, 1400, 2800, 4200, 4500)• • •
Unnamed Tributary to Blacklick Creek @ RM 12.89		0.30	Fecal Coliform E. coli	(4900)• • (330)• •, (1120, 3800)• • •
Lees Creek		0.30	E. coli	(770, 1170, 1190)• • •
Powell Ditch		0.50	Fecal Coliform E. coli	(2800)• •, (5600)• • • (310, 340)• •, (3100, 3100, 6000)• • •
Dysar Run		3.00	Fecal Coliform E. coli	(2000, 3000)• • (500)• •, (1000, 1300, 2000)• • •
		1.60	E. coli	(510)• •
Unnamed Tributary to Blacklick Creek @ RM 10.36		0.20	Fecal Coliform E. coli	(11000)• • • (300)• •, (610, 1020, 2900, 11000)• • •

*	exceedence of numerical criteria for prevention of chronic toxicity [Chronic Aquatic Conc. (CAC)].
**	exceedence of numerical criteria for prevention of acute toxicity [Acute Aquatic Conc. (AAC)].
***	exceedence of numerical criteria for prevention of acute toxicity inside the mixing zone [i.e., Final Acute Value (FAV)].
‡c	exceedence of the mean exceptional warmwater habitat or warmwater habitat dissolved oxygen criterion (EWH = 6.0 mg/l, WWH = 5.0 mg/l).
‡‡	exceedence of the minimum exceptional warmwater habitat or warmwater habitat dissolved oxygen criterion (EWH = 5.0 mg/l, WWH = 4.0 mg/l).
kc	exceedence the maximum Total Dissolved Solids criterion of 1500 mg/l
• •	exceedence of the maximum Primary Contact Recreation criterion (E. coli 298/100 ml, Fecal coliform 2000/100mL).
• • •	exceedence of the maximum Secondary Contact Recreation criterion (E. coli 576/100 ml, Fecal coliform 5000/100 ml).
;Ë	exceedence of NPDES permit limitation.

Table 10. Comparison of background ecoregional reference nutrient and demand parameter concentrations with those found in the Big Walnut Creek study area, 2000. Comparisons are made to Eastern Corn Belt Plains (ECBP) ecoregion background 50th percentile (normal print), 75th (*italic print*), 90th (underlined), and 95th percentile (**boldface**) values for headwaters (HW), wadeable (W), and small river reference sites (SR). Units are mg/l for all parameters. Sample size, n = 5 unless otherwise stated. **E** = Exceptional Warmwater Habitat.

River/Stream	River Mile **STORET Code**	Parameter(s)	Value(s)
Big Walnut Creek	73.60 **V05G05** HW	Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(**94**, *41, 21, 18, 17*) (**0.54, 0.22, 0.19**, 0.11, *0.09*) (4.82, *2.37*) (**0.11**, *0.04*, *0.03*, 0.02, 0.02) (1.24, 0.57, 0.57, 0.52, 0.42) (*0.19*, *0.19*, *0.16*, *0.11*, *0.08*)
	70.70 **V05G06** HW	Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(57, *39, 39, 39, 36*) (*0.09, 0.07, 0.05*) (*2.48*, 1.42) (**0.11**, 0.02, 0.02) (*0.96*, 0.53, 0.42) (*0.17*, *0.15*, *0.12*, *0.10*, *0.08*)
	66.60 **V05S06** HW	Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(*33*, *26*, *22*, 13, 12) (*0.07*, *0.06*, *0.06*, *0.05*) (2.05, 1.96) (0.05, 0.02, 0.02) (*0.81*, *0.69*, 0.57, 0.55) (*0.11*, *0.08*, 0.07, 0.07, 0.05)
	61.90 **V05W02** W	Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(*49*) (*0.09*, *0.07*) (2.31, 1.86, 1.53) (*0.04*) (*0.79*, *0.70*, *0.66. 0.61*) (**0.41**, 0.11, 0.07, 0.07, 0.07)
	54.60 **V05G07** W	Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(**0.27**, *0.057*) (2.74, 0.95) (*0.04*) (*0.77*, *0.73*, *0.62*, *0.62*, 0.57) (0.10, 0.09, 0.07)

River/Stream	River Mile **STORET Code**	Parameter(s)	Value(s)
	52.40 **V05S03** W	Total Suspended Solids Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(18) (1.93, 0.89) (0.02, 0.02) (*0.63*, *0.62*, 0.59, 0.55, 0.50) (0.09)
	49.00 **V05S01** W	Ammonia Nitrate+Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(*0.05*) (2.34, 1.35, 0.93) (*0.69*, *0.63*, 0.54) (0.07)
	37.20 **V05S47** W	Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen	(15) (**0.18, 0.18**, 0.14, 0.11) (*2.82*, 2.25, 1.91, 1.54, 1.13) (**0.09**, **0.08**, 0.07, 0.05) (*0.82*, *0.75*, *0.66*, *0.64*, *0.63*)
	34.90 **V05G08** W	Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen	(0.12, 0.11, *0.09*, *0.07*) (2.66, 2.21, 2.04, 1.58, 1.22) (0.07, 0.06, 0.05, *0.04*, *0.04*) (*0.79*, *0.68*, 0.59, 0.59, 0.53)
	28.30 **V05S45** SR	Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(*60*) (*0.06*, *0.06*) (2.51, 2.29) (0.02) (0.71) (0.09)
	27.00 **V05S44** SR	Nitrate+Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(1.94, 1.70) (0.66) (0.09, 0.07)
	15.80 **V05S41 E** SR	Ammonia Nitrite	(*0.06*, *0.06*, *0.05*) (0.02)
	7.10 **V05G09 E** SR	Total Suspended Solids Ammonia Nitrite	(38) (*0.07*, *0.05*, *0.05*) (0.02, 0.02)
	3.70 **V05S40 E** SR	Total Suspended Solids Nitrite	(31) (0.02)
	1.70 **600890 E** SR	Total Suspended Solids Ammonia	(34) (*0.05*, *0.05*)

Table 11. Water column organic compounds collected in the Big Walnut Creek study area during July-September, 2000. **AT**=Airport Tributary, **RF1**=Rocky Fork at RM 7.1, **RF2**=Rocky Fork at RM 1.1, **LWC**=Little Walnut Creek at RM 9.4, **RC**=Rattlesnake Creek at RM 0.1, **AC1**=Alum Creek at RM 0.7, **AC2**=Alum Creek at RM 13.4, **BC1**=Blacklick Creek at RM 1.9, **BC2**=Blacklick Creek at RM 13.7, **BW1**=Big Walnut Creek at RM 1.7, **BW2**=Big Walnut Creek at RM 15.8, **BW3**=Big Walnut Creek at RM 61.9. **Boldface** print indicates that the value exceeds the standard for protection of aquatic life outside the mixing zone. Blank spaces indicate that the compound was not detected in the sample. Units=µg/l.

Big Walnut Creek and Tributaries Water Organics											
Analyte	**AT**	**RF1**	**RF2**	**LWC**	**AC1**	**AC2**	**BC1**	**BC2**	**BW1**	**BW2**	**BW3**
α-BHC		0.011	0.011	0.011				0.012		0.010	0.012
δ-BHC			0.0091								
γ-BHC	0.0072						0.007		**0.010**	0.0069	
Dieldrin					**0.0078**	**0.0084**		**0.0075**			
Endosulfan		**0.0055**		**0.0081**							

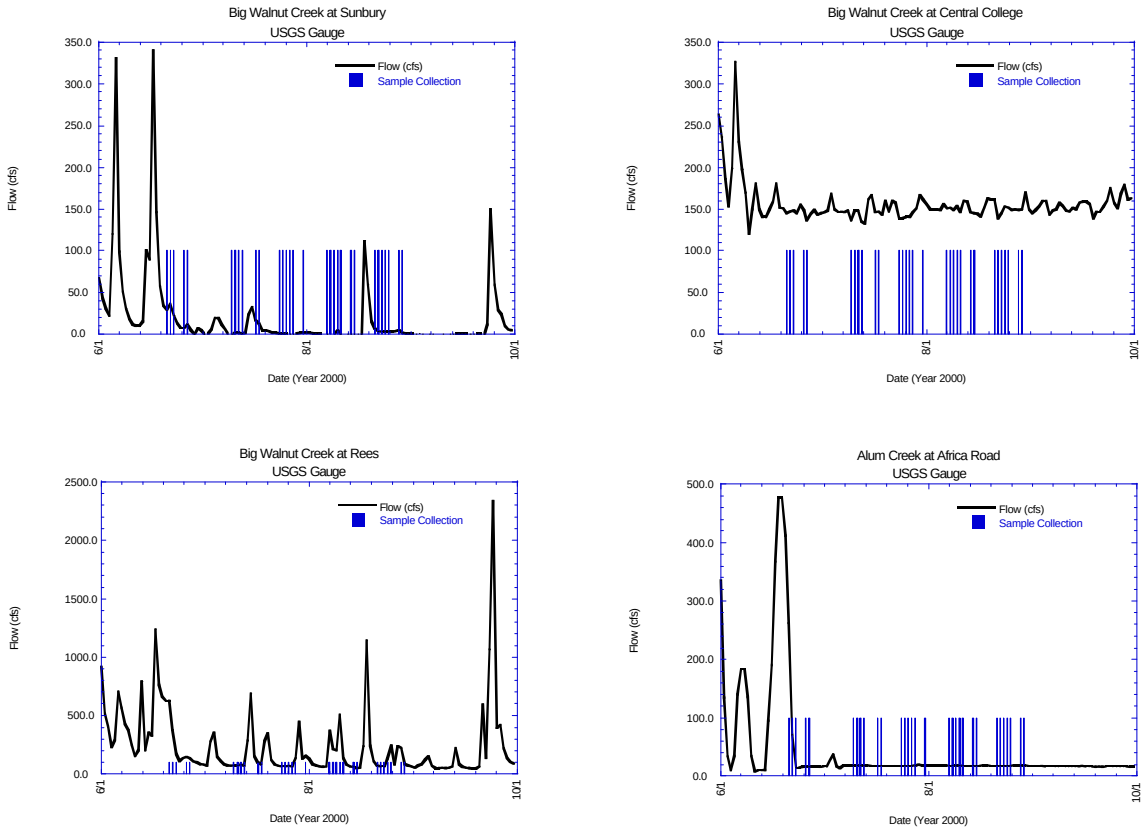

Figure 7. Flow hydrographs for Big Walnut Creek at Sunbury (RM 50.3), Central College Rd. (RM 37.2), and Rees Rd. (RM 10.8) and for Alum Creek at Africa Rd. (RM 26.3) June thru September, 2000.

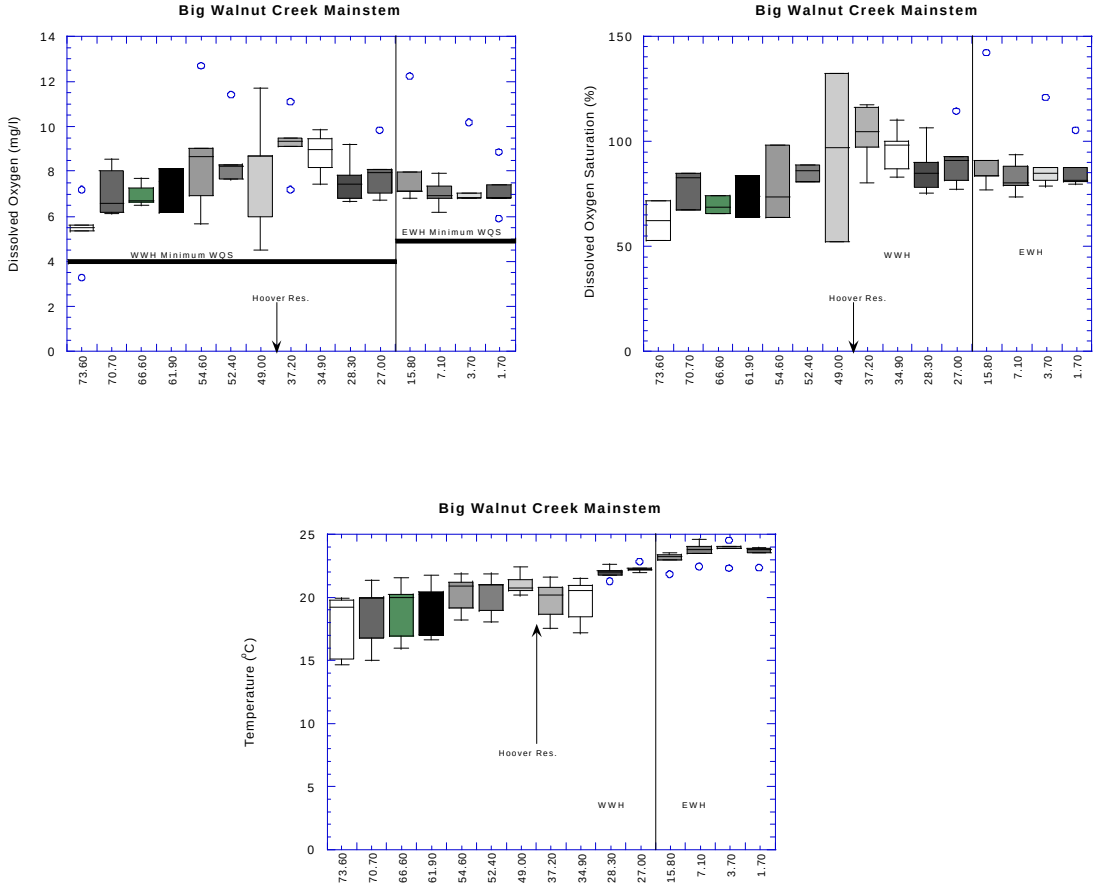

Figure 8. Box plots of Dissolved Oxygen concentrations, Dissolved Oxygen Percent Saturation, and Temperature in Big Walnut Creek, 2000.

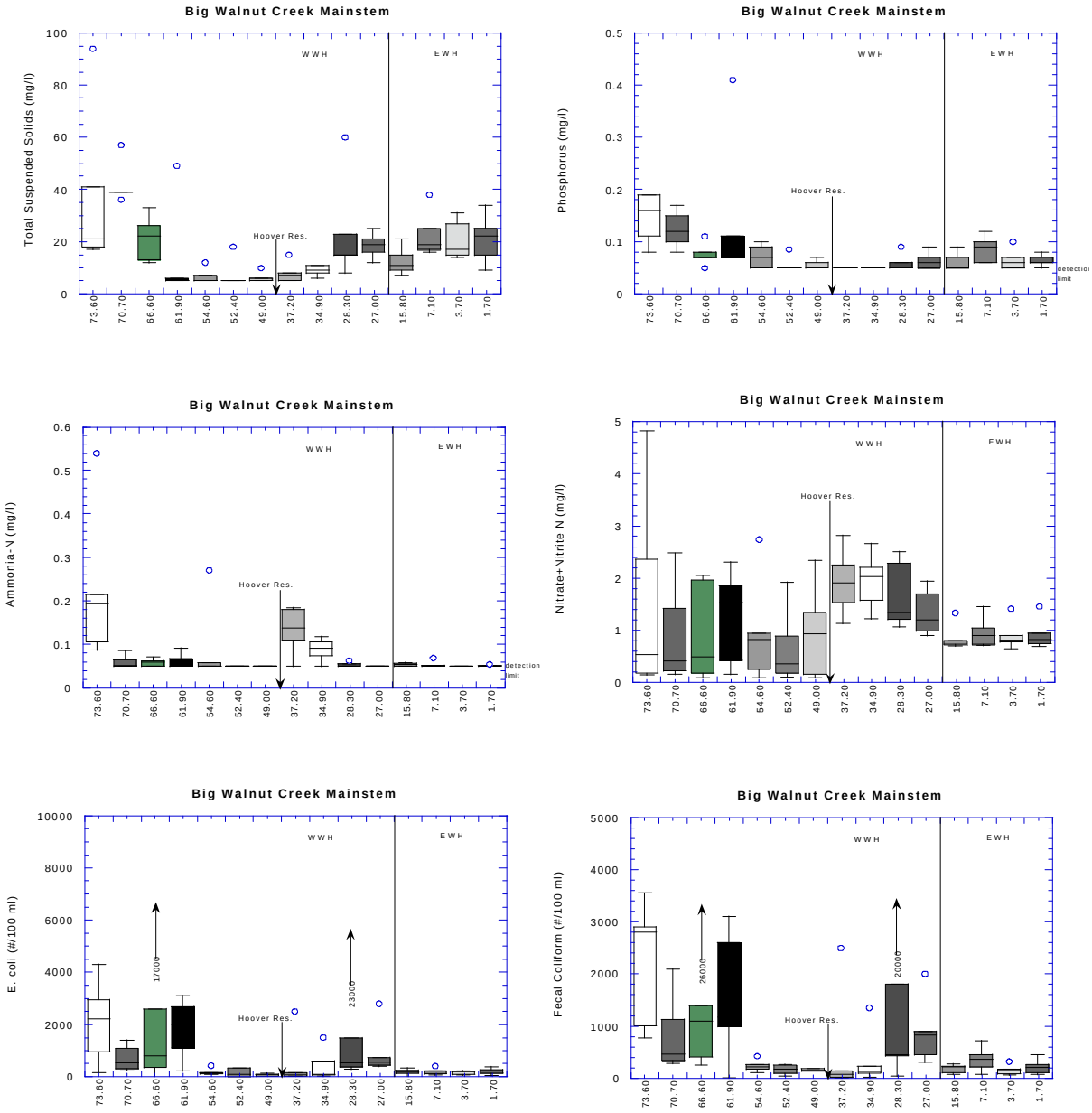

Figure 9. Box plots of Total Suspended Solids, Total Phosphorus, Ammonia-Nitrogen, Nitrite+Nitrate-Nitrogen, E. coli, and Fecal Coliform for Big Walnut Creek, 2000.

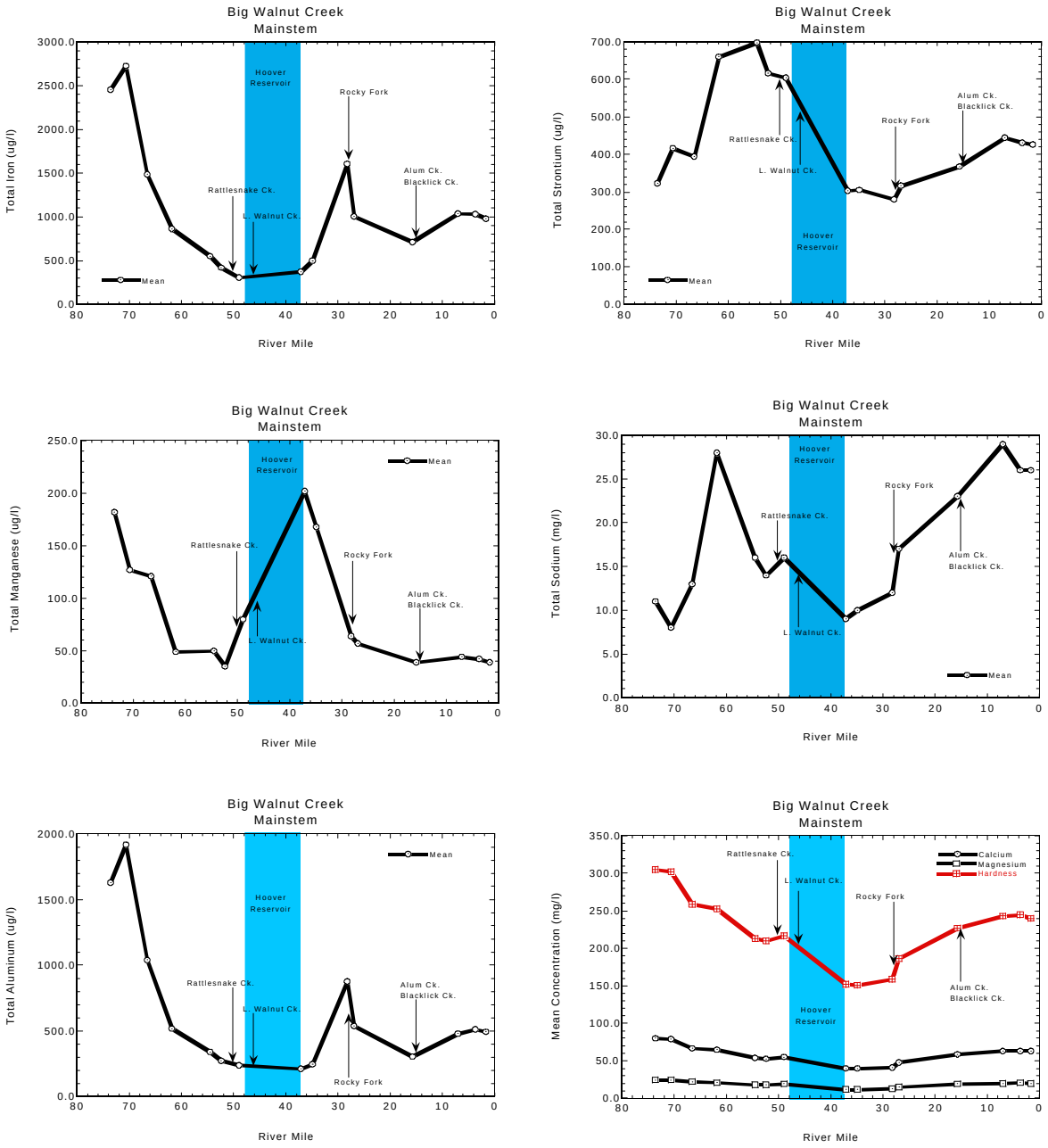

Figure 10. Mean longitudinal concentrations of selected metals from Big Walnut Creek, 2000.

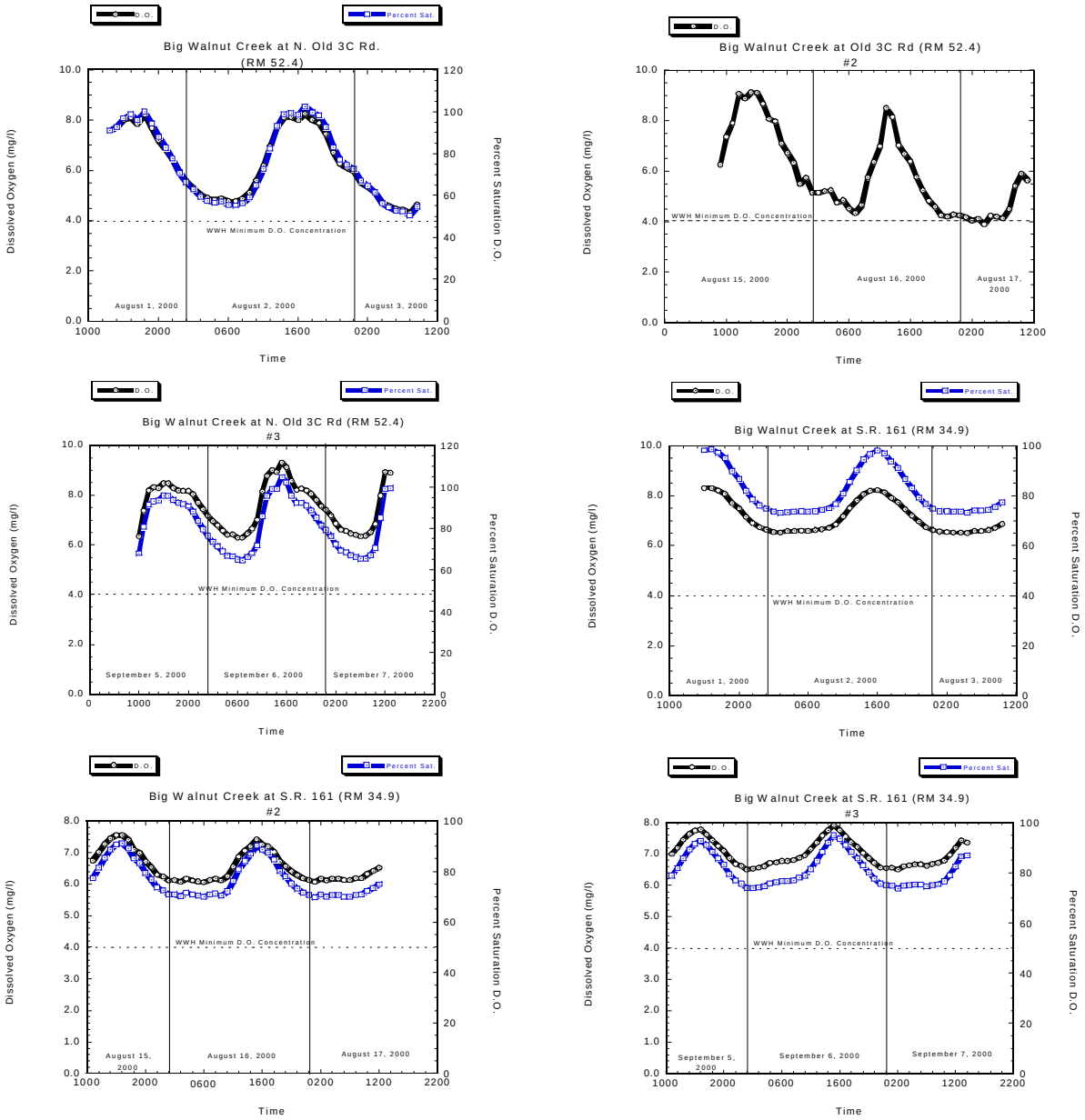

Figure 11. Diel Dissolved Oxygen concentrations and Dissolved Oxygen Percent Saturation at Old 3C Rd. (RM 52.4) and SR 161 (RM 34.9) on Big Walnut Creek, 2000.

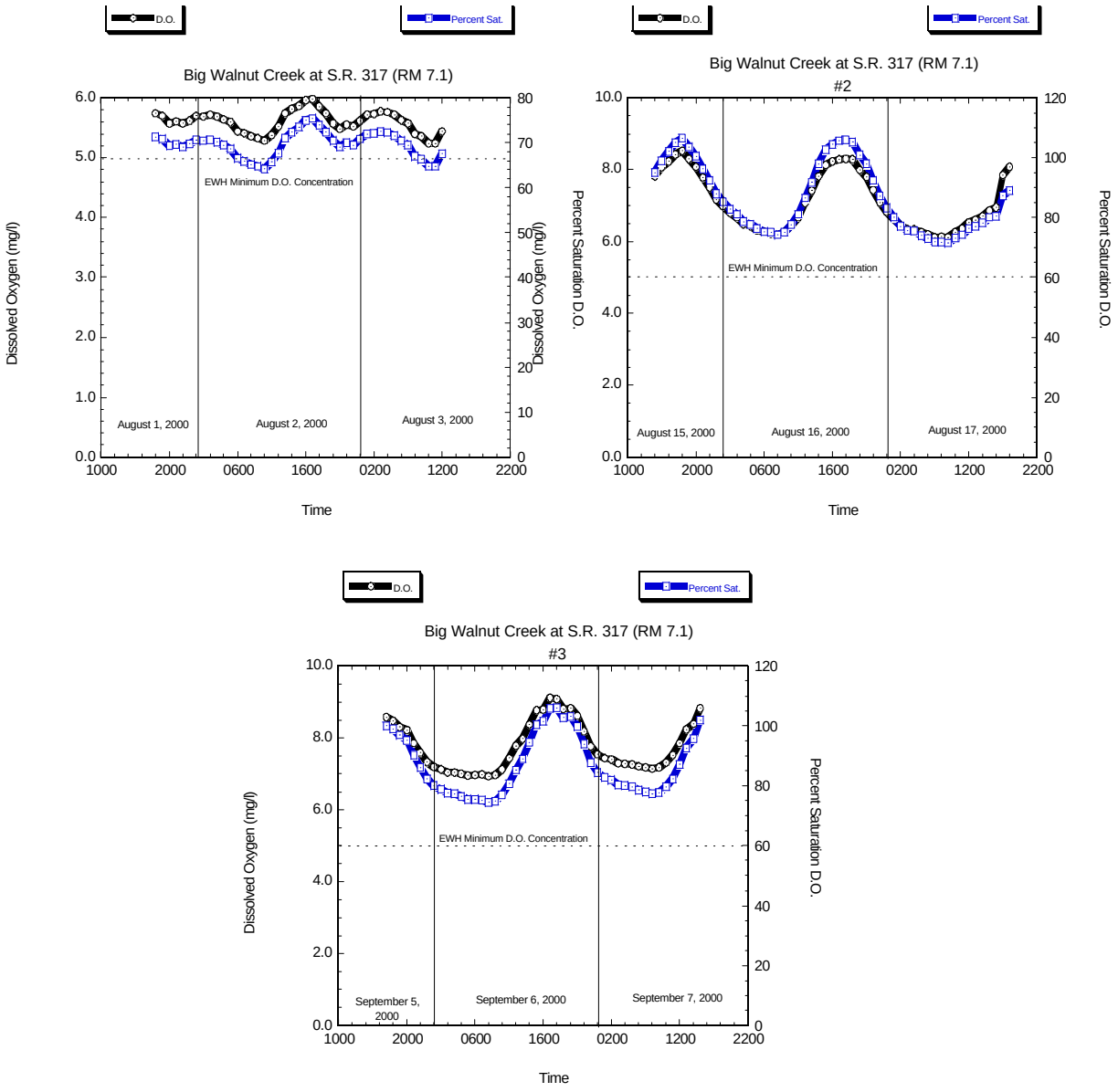

Figure 12. Diel Dissolved Oxygen concentrations and Dissolved Oxygen Percent Saturation at SR 317 (RM 7.1) on Big Walnut Creek, 2000.

Big Walnut Creek Tributaries

Rocky Fork Creek (WWH, EWH)

Rocky Fork Creek was evaluated at 6 locations for chemical water quality. The Warmwater Habitat water quality criterion minimum for dissolved oxygen was violated at RM 11.40 (Table 9). Oxygen depletion noted on July 12, 2000 in this upstream reach was probably an artifact of a concurrent high concentration of chemical oxygen demand (COD, 237 mg/l) discovered instream (Fig. 13). Since biochemical oxygen demand was undetected, an oxygen demanding chemical contaminant of some kind is likely draining into the creek via some kind of dumping or an in-home business (e.g., a beauty

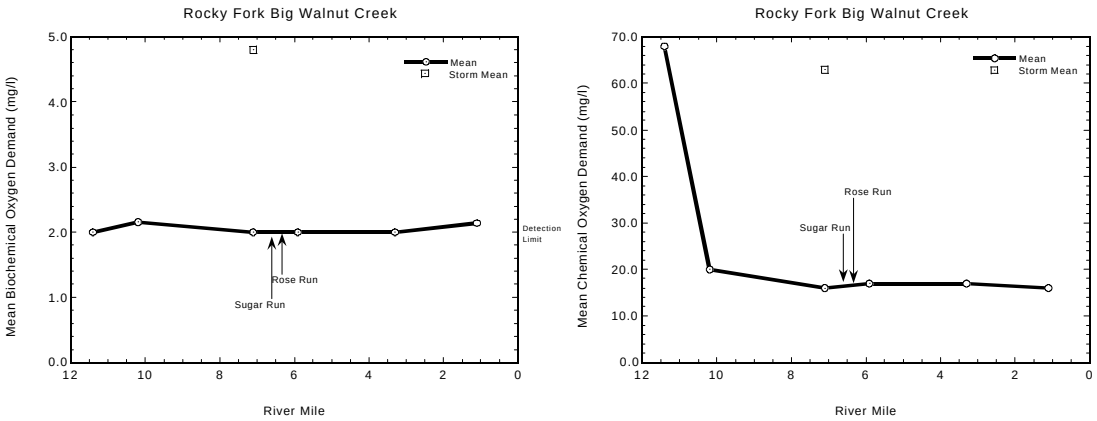

Figure 13. Mean five day Biochemical Oxygen Demand and Chemical Oxygen Demand in Rocky Fork Big Walnut Creek, 2000.

salon, photographic studio, or car repair shop) discharging intermittently, possibly through a home sewage treatment system. Further investigation is warranted to determine the source of this contamination.

Bacterial exceedences were more widespread, affecting all sites to some extent (Table 9). Mean bacterial concentrations were low upstream, rose steadily by RM 7.10, then fell, and eventually spiked upwards at RM 1.10 (Fig. 14). Failing home sewage treatment systems are likely the major source of the bacteria in addition to several small package WWTPs including Westerville Estates, Taylor Estates, and Windrush Creek. Agricultural sources are likely contributing to this problem in the rural portion of the upper watershed. Storm sampling efforts during the survey also revealed high concentrations of bacteria contaminating the stream during runoff events (Fig. 18). The three WWTPs mentioned above certainly contributed to this phenomenon as they all have I/I problems in their collection systems which, in turn, cause hydraulic overloading and washout of bacteria and

solids at the plants.

Adverse effects from nutrients appeared to be limited to the upper three sites, but Rocky Fork exhibited the effects of nutrient enrichment throughout its length even though concentrations of nutrients in the water column attenuated with increasing distance downstream. Evidence of the effects of nutrient enrichment in downstream areas included the presence of large blooms of filamentous algae and supersaturated dissolved oxygen concentrations (Fig. 14). Total phosphorus concentrations were nearly all greater than the 75th percentile for background ecoregional reference at the three upstream sites, with many in excess of the 90th percentile (Table 12). Ammonia, nitrate+nitrite, and TKN concentrations were also excessive at RM 10.20 and probably emanated from the package WWTPs as well as home sewage treatment systems discharges and suburban runoff from continued development in the watershed.

Mean total suspended solids concentrations were moderate to low throughout the Rocky Fork watershed during dry weather. However, precipitation events produced some extremely high concentrations in the water column most likely due to runoff and bank erosion as revealed by storm event sampling at RM 7.10 (Table 12). Increasing development of the watershed is changing the flow dynamics of Rocky Fork resulting in extremes of flow (e.g. higher high flows during runoff events and lower low flows during dry periods) and increased erosive forces acting on the stream banks.

Rose Run (WWH)

Rose Run was evaluated for chemical water quality at a single location near the mouth (RM 0.50). No violations of chemical water quality criteria were noted although bacterial exceedences for *E. coli* were evident for all 5 sampling runs (Table 9). This was likely due to poorly operating home sewage treatment systems. Nutrient enrichment was not visually evident at this site, although dissolved oxygen concentrations were found to be supersaturated at times and total phosphorus values were all in excess of the backgroundreference median for this area. Nitrogen-based nutrients and suspended solids were not elevated at this site. Continued development in the small watershed most likely contributed to these problems.

Sugar Run (WWH)

Chemical water quality was evaluated in Sugar Run at two locations during the 2000 survey. There were no water quality criteria exceedences found at RM 3.10. Bacterial exceedences for *E. coli* were evident in 4 of 5 samples obtained at RM 0.70. Dissolved oxygen concentrations were well within water quality norms at each site (Fig. 16).

Nutrient enrichment appears problematic in Sugar Run, especially in the upstream reach (RM 3.10) where organic nitrogen (TKN) concentrations exceeded the median reference background in every sample and total phosphorus concentrations exceeded the 90th percentile of background in 80% of

the samples (Table 12). Total suspended solids also exhibited elevated concentrations with 3 of 5 samples greater than the 75th percentile of background. The site at RM 0.70 showed less evidence of enrichment as nutrients were found in lower concentrations and detected less often than at RM 3.10. Agricultural inputs of nutrients as well as bacteria are likely sources of contamination in the upper watershed as well as ongoing development and suburbanization of the watershed.

Long Run (WWH)

Chemical water quality sampling was conducted at three sites along the length of Long Run during the 2000 survey. The upper two sites on Long Run (RM 4.30, RM 3.60) exhibited moderate to heavy impact from bacteria and nutrients, particularly ammonia (Tables 9, 12). Total suspended solids concentrations at RM 3.60 were among the highest found during the survey in the larger tributaries of Big Walnut Creek (Fig. 16). Agricultural practices were the likely sources of contamination in this rural area. Chemical water quality impacts at RM 0.70 was limited to bacterial contamination from *E. coli*. Nutrients and suspended solids concentrations at RM 0.70 were well below median background reference concentrations for this ecoregion.

Castro Run (WWH)

Chemical water quality in Castro Run was characterized by low levels of bacteria but high concentrations of suspended solids and nutrients at the single location evaluated during the survey. Bacterial contamination was limited to one detection of *E. coli* exceeding the Primary Contact Recreation criterion (Table 9). Total suspended solids concentrations exceeded the 75th percentile of background reference in all 5 samples, with two of these in excess of the 90th percentile (Table 12). Nutrients in the forms of ammonia, organic nitrogen (TKN), and total phosphorus were also well above median values in most cases with most values exceeding the 75th percentile for background. Oxygen demanding substances were also present with chemical oxygen demand and biochemical oxygen demand both displaying high concentrations. Dissolved oxygen concentrations ranged just above the minimum WWH criterion although saturation was under 60% in all cases.

Sources of this degradation were most likely agricultural operations and observed results may have been related to application of inorganic fertilizers and/or organic manure with subsequent runoff into the creek. Low level bacterial contamination seems to preclude heavy impacts from individual home sewage treatment systems.

Mill Creek (WWH)

Mill Creek exhibited degraded chemical water quality at the single location evaluated during the survey (RM 1.60). Exceedences were noted for total dissolved solids on two separate occasions in addition to many instances of bacterial contamination (Table 9). Total suspended solids, biochemical oxygen demand, ammonia, other nitrogenous compounds, conductivity, and total phosphorus were also elevated, sometimes severely (Table 12, Appendix A). Dissolved oxygen concentrations were

found in normal ranges (Fig. 16). Since biological communities were not evaluated in Mill Creek, it is difficult to infer the degree of aquatic life use impairment. However, based on land uses in this watershed, chemical water quality degradation may have resulted from agricultural operations as well as discharges of brine associated with oil and gas pumping.

Light Creek (WWH)

Light Creek showed far less chemical water quality impacts than its receiving stream Mill Creek. Bacterial exceedences were apparent (Table 9), but muted and less numerous as were concentrations of nutrients and suspended solids (Table 12). Oxygen demanding substances were not found in substantial quantities and dissolved oxygen concentrations were found in a normal range throughout the survey period (Fig. 16). Since biological communities were not evaluated in Light Creek, it was difficult to infer the degree, if any, of aquatic life use impairment.

Reynolds Run (WWH)

Reynolds Run showed chemical water quality impacts similar to many of the headwater streams found in this drainage. Bacterial contamination in excess of recreational water quality criteria were noted in about 60% of the samples (Table 9). Analysis for chemical oxygen demand revealed one of the highest individual readings among small streams in the survey (73 mg/l). Organic nitrogen, total phosphorus, ammonia, and nitrates were also evident at elevated concentrations (Table12). Dissolved oxygen concentrations were within normal ranges (Fig. 16). Sources of pollution may have been associated with agricultural practices as well as home sewage treatment systems. Chemical oxygen demand spikes did not appear to cause declines in the dissolved oxygen concentrations in the stream.

Little Walnut Creek (WWH)

Chemical water quality was evaluated at four locations along the length of Little Walnut Creek. A single violation of the water quality criterion for dissolved oxygen was noted at RM 9.40. On this occasion, dissolved oxygen registered 3.60 mg/l which was well under the WWH minimum criterion of 4 mg/l (Table 9). Additionally, bacterial exceedences were noted at each site at least once with the majority of the excursions showing *E. coli* contamination.

Organic and nutrient enrichment were prevalent at RM 1.40 (just upstream of the influence of Hoover Reservoir) as were suspended solids (Table 12). Mean total suspended solids more than tripled compared with upstream locales (Fig. 15). Less intense organic and nutrient enrichment was noted at RM 10.20. Negligible concentrations of most nutrients and oxygen demanding substances were noted at RM 9.40 and RM 7.40. The only exception to this was organic nitrogen found above background reference median levels in each sample taken at RM 7.40. The major sources of nutrient enrichment in this rural watershed were likely agricultural with contributions from failing home sewage treatment systems.

East Branch Little Walnut Creek (WWH)

Water chemistry was evaluated at the mouth (RM 0.05) of East Branch Little Walnut Creek. Bacterial contamination from *E. coli* and fecal coliform bacteria exceeded recreational water quality criteria only infrequently (Table 9). Total suspended solids and total phosphorus concentrations were each somewhat elevated at this site but nitrogen-based nutrients were not (Table 12). Interestingly, sulfate concentrations were elevated over most other tributaries which could have been an artifact of nearby oil extraction operations.

Branch Little Walnut Creek (WWH)

Chemical water quality was examined at two sites on West Branch Little Walnut Creek. Both sites showed violations of the Water Quality Standards criterion for dissolved oxygen, with 60% of the tests under the 4 mg/l minimum criterion at RM 3.30 as were 20% of the tests at RM 0.80 (Table 9). The majority of the tests also revealed exceedences of bacterial criteria for both *E. coli* and fecal coliform bacteria.

The upstream site at RM 3.30 showed the most serious contamination. Bacterial ranges were far in excess of most small tributaries in this basin (Fig. 16). Dissolved oxygen values were well below both the mean criterion of 5 mg/l and the minimum of 4 mg/l. Organic and nutrient enrichment were excessive as were concentrations of suspended solids (Table 12). Contamination of this type likely resulted from a combination of heavily modified channel with low flow and numerous home sewage treatment systems, some of which were not properly operated or maintained.

Downstream, contamination was much less apparent, but still present, and likely due to the situation upstream. Elevated concentrations of ammonia and TKN along with depleted dissolved oxygen concentrations indicated continued degradation, but conditions were less severe compared to that found upstream. Sulfate concentrations also ranged widely and peaked at the second highest concentrations found in the survey (602 mg/l) possibly due to oil and gas mining in the area.

Butler Run (WWH)

A single chemical sampling location on Butler Run revealed WWH Water Quality Standards criteria violations for minimum dissolved oxygen and bacterial exceedences for *E. coli* (Table 9). Light to moderate nutrient enrichment was also evident with the detection of excess nitrates and TKN (Table 12). Total suspended solids concentrations were all greater than the 75th percentile for background reference which may have been an artifact of channelization and riparian destruction. Agricultural sources of pollution are likely responsible for nutrient enrichment and bacterial inputs. Dissolved oxygen violations were likely the result of poor riffle development (due to channelization) as well as effects from enrichment.

Sugar Creek (WWH)

Chemical water quality sampling was performed at two sites on Sugar Creek. The upstream site at RM 5.30 exhibited WWH Water Quality Standards criterion violations for mean and minimum dissolved oxygen (Table 9, Fig. 16). Exceedences of Primary Contact Recreation criterion for *E. coli* were also noted at both sites (Table 9). Nutrient enrichment was not a decisive factor at either site although nutrients, especially ammonia, were found in moderate concentrations in the upstream samples (Table 12). Based on the prevailing land use, agricultural sources of pollution were likely responsible for lessened chemical water quality.

Perfect Creek (WWH)

Water chemistry sampling was conducted on Perfect Creek at RM 6.30 and RM 0.10. A single Water Quality Standards criterion violation for dissolved oxygen was noted at RM 6.30. Recreational criterion exceedences for *E. coli* bacteria were noted in only a few instances. The site at RM 6.30 was sampled a total of 4 times as one aborted sampling run revealed only intermittent pools and no surface flow. Both sites exhibited similar concentrations of nutrients and showed moderate enrichment from total phosphorus and organic nitrogen (TKN). The Morning View Care Center WWTP did not appear to exacerbate nutrient enrichment in Perfect Creek although agricultural sources of pollution were likely responsible for the measured nutrient enrichment.

Culver Creek (WWH)

Chemical water quality was evaluated at three locations on Culver Creek. Exceedences of Water Quality Standards criteria for *E. coli* and fecal coliform bacteria were noted in nearly all samples obtained from the two upstream locations (RM 4.50, RM 3.30) and during one sampling event at the mouth (RM 0.10), a noticeable longitudinal decline (Table 9, Fig. 15). Violations of WWH minimum Water Quality Standards criterion for dissolved oxygen were noted at RM 4.50 and RM 0.10. Excessive nutrient enrichment was evident at RM 4.50 with ammonia, nitrite, TKN, and total phosphorus values often exceeding the 95th percentile of background reference (Table 12). Nutrient enrichment declined sharply at RM 3.30 and remained moderately low at the mouth. Nutrient enrichment, low dissolved oxygen, and bacterial contamination may be artifacts of poor flow characteristics and discharge from home sewage treatment systems as well as agricultural runoff.

Unnamed Tributary to Culver Creek at RM 3.32 (WWH recommended)

Water quality criteria identified for the Warmwater Habitat use designation apply to water bodies not assigned an aquatic life use designation. This headwater stream was evaluated for chemical water quality at the mouth (RM 0.10). Bacterial exceedences of Water Quality Standards criteria were noted in every sample (Table 9). Dissolved oxygen concentrations were all above mean and minimum WWH criteria. Nutrient enrichment consisted of mostly organic nitrogen greater than median background reference values and one detection of ammonia greater than the 95th percentile

of background reference (Table 12). Neither suspended solids nor biochemical oxygen demand was significantly elevated. A small package WWTP located at the Wyandot Golf Course located five miles upstream, may have influenced these results slightly. Overall, chemical water quality appeared good. The chemical information gathered during the study supports the recommended WWH use designation for this waterbody based on biological community sampling results.

Rattlesnake Creek (WWH)

The mainstem of Rattlesnake Creek was evaluated for chemical water quality at one point near the mouth (RM 0.10). Bacterial exceedences were limited to a single incidence of elevated *E. coli* (Table 9) and nutrient enrichment was moderate compared with other tributary streams in the Big Walnut watershed and Rattlesnake Creek tributaries (Table 12). Sources of nutrients and bacteria are likely from upstream sources found in the tributaries discussed below.

East Fork Rattlesnake Creek (WWH)

Chemical water quality was analyzed in East Fork Rattlesnake Creek at two locations. The site at RM 3.10 exhibited two Water Quality Standards violations of the WWH minimum dissolved oxygen criterion and several exceedences of bacterial criteria (Table 9). The site at RM 0.20 exhibited only exceedences of bacterial criteria, mostly for *E. coli*.

Nutrient and organic enrichment was prevalent at both sites. Ammonia, nitrite, nitrate, organic nitrogen, and total phosphorus were all extremely high at RM 3.10 with most values exceeding the 95th percentile compared to background reference data (Table 12). Additionally, this site also showed elevated biochemical oxygen demand (Fig. 17) and total suspended solids were found above median background reference in all cases.

Nutrient enrichment was somewhat less prevalent at RM 0.20 although many values were still in excess of the 75th percentile of background reference data. Evidence of organic enrichment was present in the form of high biochemical oxygen demand and total suspended solids.

The primary source of nutrient enrichment in the upstream areas was chicken manure over-application to fields in this subwatershed and the subsequent migration of manure and constituents to the creek from saturated fields. Nitrates and inorganic forms of phosphorus are especially mobile. The manure was generated by Buckeye Egg Farm's Croton facility. Organic enrichment and suspended solids found at the mouth were due to similar circumstances upstream at RM 3.10 and nearby malfunctioning home sewage treatment systems.

South Fork Rattlesnake Creek (WWH)

Chemical water quality sampling occurred at two locations on South Fork Rattlesnake Creek (RM 3.70 and RM 0.10). South Fork Rattlesnake Creek was not as overwhelmed with nutrients and

oxygen-demanding substances as was the East Fork. Most of the South Fork drainage, while agricultural, was outside of the influence of Buckeye Egg Farm manure applications. Bacterial exceedences were still present, however, as were some serious acute pollution events (Table 9).

The site at RM 3.70 was relatively unaffected by nutrient pollution in all but one instance where nitrate concentrations exceeded the 90th percentile for background reference in late June (Table 12), although bacterial exceedences were apparent in 3 of 5 samples (Table 9). Sampling at the mouth (RM 0.10) revealed moderately increased nutrient and organic enrichment compared with upstream samples. A single sampling event on August 29, 2000, revealed some extraordinary values for total suspended solids and nitrite at RM 0.10. A precipitation event with subsequent contaminated runoff may have been a large factor in this pollutant spike and an indicator of contamination from agricultural stormwater runoff.

North Fork Rattlesnake Creek (WWH)

Chemical water quality was evaluated at three locations on North Fork Rattlesnake Creek. Special storm-event sampling was also performed at RM 3.40 during precipitation incidents in addition to regular sampling. Samples obtained from RM 4.80 showed moderate contamination from bacteria (Table 9) and heavy, but infrequent, contamination from nutrients (Table 12). Nitrogen-based nutrients exhibited the highest concentrations with many values exceeding the 95th percentile of background reference. Elevated total phosphorus concentrations were also noted in 40% of the samples.

Water quality sampling conducted at RM 3.40 showed similar contamination from bacteria and nutrients as samples taken from RM 4.80. *E. coli* exceedences were noted in 80% of the samples and nitrogenous constituents dominated the nutrient samples. The presence of ammonia and nitrite at concentrations above the 95th percentile of background reference was particularly startling. Total phosphorus concentrations were also elevated in all samples obtained from this location. Storm sampling at RM 3.40 revealed intermittent contamination from oxygen-demanding substances, suspended solids, and nutrients. Median values for TKN, nitrate+nitrite, ammonia, and total phosphorus were among the highest noted during storm sampling conducted at five different sites in the Big Walnut watershed (Fig. 18). Interestingly, the concentration ranges of bacteria found instream exhibited low variability and the lowest medians of the five storm sites. Mean bacterial contamination did not increase precipitously during storm events but remained near the mean for the site.

Water quality sampling at RM 0.10 revealed a single violation of the minimum WWH criterion for dissolved oxygen in addition to exceedences for *E. coli* in all samples (Table 9). Nutrient enrichment at this locale was less severe when compared with upstream sites, but still apparent (Table 12). Nutrient enrichment and perhaps even bacterial contamination seemed to arise from manure over-application on agricultural fields by Buckeye Egg Farm, Croton facility.

Prairie Run (WWH)

Prairie Run water chemistry was evaluated at a single location just upstream of the Sunbury WWTP outfall at RM 0.40. Bacterial exceedences from *E. coli* were apparent in every sample (Table 9) although the range of *E. coli* concentrations was narrower compared with many other headwater streams (Fig. 17). Total suspended solids and nutrient concentrations were also less than that of most small tributary streams (Table 12) indicating that nutrient enrichment was not problematic in Prairie Run upstream of the WWTP. The Sunbury WTP discharge at RM 1.43 did not appear to affect water chemistry in Prairie Run during the summer of 2000.

Duncan Run (WWH)

Water quality sampling was conducted in Duncan Run at three locations including RM 9.00, RM 7.30, and RM 2.70. Fewer bacterial exceedences were noted at RM 9.00 than at the two downstream sites (Table 9). Mean concentrations of total suspended solids at RM 9.00 were nearly double those found at the two downstream sites. Nutrient concentrations appeared moderate but consistent along the length of Duncan Run (Table 12). Total phosphorus and organic nitrogen (TKN) were consistently above background reference median concentrations at every location with the site at RM 7.30 exhibiting the highest concentration ranges (all above the 75th percentile). Nutrient and bacterial enrichment likely resulted from a combination of agricultural runoff and malfunctioning home sewage treatment systems.

McKenna Creek (WWH recommended)

McKenna Creek is a small undesignated, headwater stream draining suburban Gahanna, Ohio. Chemical water quality sampling was performed at one location near the mouth of the stream at RM 0.20. Water quality criteria identified for the Warmwater Habitat use designation apply to water bodies like McKenna Creek that have not been assigned an aquatic life use designation. Wet weather sampling was also performed during three rain events over the summer of 2000. Bacterial exceedences for *E. coli* were found for each sampling event, and for fecal coliform bacteria in 40% of the samples (Table 9). Nutrient concentrations in McKenna Creek were typically below the background reference median value during normal flow although there was one instance of an excessive concentration of total phosphorus (Table 12). Sampling during precipitation events yielded much more contamination from suspended solids, ammonia, nitrite, and phosphorus, demonstrating that runoff events do not necessarily dilute pollutant concentrations, but actually increase pollutant loadings. Ongoing suburban development coupled with increased impervious surface in the watershed are causing the chemical impacts in this stream. Flow is now highly variable and flashy during storm events causing severe bank erosion in unforested areas within subdivisions. A City of Gahanna ordinance forbidding mowing near the creek bank is not regularly obeyed by many homeowners hindering stabilization efforts and exacerbating bank erosion and suspended solids loadings. Contaminated runoff from streets, rooftops, and lawns also contributed to chemical impairment.

Unnamed Tributary to Big Walnut Creek at RM 27.29 (WWH)

This small headwater tributary drains the grounds of the Port Columbus International Airport. Bacterial exceedences for fecal coliform and *E. coli* were found in about 60% of the samples (Table 9). Nutrient enrichment was extreme with all samples exceeding the 95th percentile of background reference for ammonia and nitrite (Table 12). Concentrations of TKN and nitrate+nitrite were also well above background reference conditions and in most cases, significantly greater than other small tributaries in the Big Walnut basin. Organic enrichment was also present as evidenced by the presence of oxygen demanding substances revealed by 5-day biochemical oxygen demand testing as well as chemical oxygen demand testing. Both tests revealed significant oxygen demand in this headwater stream (Fig. 17) compared with other streams in the basin. BOD_5 concentrations exceeded the 75th percentile of background reference in 4 of 5 instances. This may be due to ongoing contributions of glycol-based deicing products and urea salts arising from surrounding soils and sediments contaminated during past freezing precipitation events. The airport authority currently operates a program to collect aircraft deicing materials to prevent their further release to the environment.

Mason Run (WWH)

Mason Run was evaluated for chemical water quality at a single location 0.50 mile from the mouth. Bacterial exceedences were noted for *E. coli* in all samples and for fecal coliform in 40% of the samples (Table 9). Nutrient enrichment was moderate with 4 of 5 samples for ammonia in excess of the 90th percentile of background reference as well as a significant presence of nitrate+nitrite and total phosphorus (Table 12). Urban runoff and developmental pressures are significant contributors to chemical impairment in Mason Run.

Unnamed Tributary to Big Walnut Creek at RM 12.74 (Undesignated)

Water quality criteria identified for the Warmwater Habitat use designation applies to this waterbody not yet assigned an aquatic life use designation. Chemical water quality was evaluated on this small headwater stream at RM 0.20 and revealed moderate amounts of bacterial contamination (Table 9) and little in the way of nutrient pollution (Table 12). Developmental pressures and watershed hardening were evident from extensive erosion of the stream bed and banks. Since biological communities were not evaluated in this tributary, it is difficult to infer the degree, if any, of aquatic life use impairment.

Diel Dissolved Oxygen Study-Big Walnut Creek Tributaries

Rattlesnake Creek

Diel dissolved oxygen patterns were evaluated at RM 0.10 in Rattlesnake Creek. Typical diel fluctuations were noted at the site. The WWH minimum criterion for dissolved oxygen was never

violated during the survey period although the nighttime lows for August 2-3 and August 16-17 came close to the limit (Fig. 20). Excessively supersaturated conditions were not observed although oxygen saturation did, at times, seem low with wide variability (roughly between 50% and 110%).

Rocky Fork Creek

Diel dissolved oxygen patterns were evaluated at two sites on Rocky Fork Creek at RM 5.90 and RM 1.10 (Fig. 19). Each site was evaluated three times during the summer. Typical diel fluctuations were noted at each site with significant supersaturation (nearly 140%) noted during the period of August 1-3, 2001 at RM 5.90. Nutrient enrichment is generally the cause of supersaturated conditions. This was the only significant instance of supersaturation noted in Rocky Fork during the survey period. The WWH minimum criterion for dissolved oxygen was never violated during any of the survey periods.

Water Column Organics-Big Walnut Creek Tributaries

Three minor tributary streams were sampled for organic constituents during this survey including one site on the Airport Tributary, two sites on Rocky Fork, and one site on Little Walnut Creek. Contaminants detected at these sites included those listed in Table 11. Of these, endosulfan was detected at concentrations exceeding the WQS criterion for the protection of aquatic life outside the mixing zone at RM 7.10 in Rocky Fork and RM 9.40 in Little Walnut. Endosulfan is a widely used chlorinated hydrocarbon pesticide that has many uses for the control of insects and mites on fruits, nuts, vegetables, grains, ornamentals, and timber. Isomers of Lindane were found in Rocky Fork and Little Walnut Creek whereas Lindane itself was detected in the Airport Tributary. None of these detections exceeded WQS criteria.

Table 12. Comparison of ecoregional reference background nutrient and demand parameter concentrations with those found in the Big Walnut Creek study area, 2000. Comparisons are made to Eastern Corn Belt Plains (ECBP) ecoregion background 50th percentile (normal print), 75th *(italic print)*, 90th (underlined), and 95th (**boldfaced**) percentile values for headwaters, wadeable, and small river reference sites. Units are mg/l for all parameters. Sample size, n = 5 unless otherwise stated. **E** = Exceptional Warmwater Habitat. HW = headwater, W = wadeable.

River/Stream	River Mile **STORET Code**	Parameter(s)	Value(s)
Rocky Fork Big Walnut Creek	11.40 **V05G70** HW	Total Suspended Solids Ammonia Tot. Kjeldahl Nitrogen Phosphorus	(*15*, 9) (*0.06*) (*0.79*, *0.79*, 0.56, 0.47, 0.41) (**1.18**, 0.26, 0.24, *0.11*)
	10.20 **V05S39** HW	BOD_5 Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(*2.8*) (*24*, 9, 7) (**0.22**, 0.13, 0.12, *0.10*, *0.05*) (*2.79*, 1.55, 1.51, 1.31) (0.07) (*0.75*, *0.74*, *0.68*, 0.50, 0.48) (0.33, 0.31, 0.31, 0.28, 0.25)
	7.10 **V05S38** HW	BOD_5 Total Suspended Solids Ammonia Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(*2.2*) (*23*, 10) (0.10, *0.09*, *0.06*, *0.06*, *0.05*) (*0.04*) (0.59) (*0.15*, *0.08*, 0.06)
	7.10 storm **V05S38** HW n=4	BOD_5 Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(**13.0**) (**1920**, **196**, *23*, 12) (0.12, 0.11, 0.10, *0.08*) (4.69, 1.06) (**0.61**, **0.14**, 0.06, *0.04*) (*0.82*, *0.75*, 0.52, 0.48) (0.33, *0.14*, *0.08*, 0.06)
	5.90 **V05P11** HW	Total Suspended Solids Ammonia Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(*21*, 7) (0.13, 0.12, *0.07*) (*0.05*) (0.57, 0.52, 0.47) (*0.16*, 0.07, 0.06, 0.05)
	3.30 **V05G10 E** W	Ammonia Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(*0.06*) (*0.03*) (0.53) (*0.13*, 0.11)

River/Stream	River Mile **STORET Code**	Parameter(s)	Value(s)
	1.10 **V05S34 E** W	BOD_5 Total Suspended Solids Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(*2.7*) (**126**) (**0.10**) (0.50) (0.24, 0.08)
Rose Run	0.50 **V05S25** HW	Total Suspended Solids Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(8) (0.03) (0.43) (*0.10*, *0.09*, 0.07, 0.07, 0.05)
Sugar Run	3.10 **V05G38** HW	BOD_5 Total Suspended Solids Ammonia Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(4.2) (67, 57, *27*, 8) (0.15) (**0.13**) (*0.82*, 0.57, 0.55, 0.52, 0.50) (0.23, 0.22, 0.22, 0.21, *0.18*)
	0.70 **V05P10** HW	Total Suspended Solids Ammonia Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(*20*, *18*, 12) (*0.08*, *0.08*, *0.06*) (*0.03*) (0.53, 0.40) (*0.12*, 0.05, 0.05)
Long Run	4.30 **V05G34** HW	BOD_5 Total Suspended Solids Ammonia Nitrate+Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(*2.1*) (12, 9) (0.12, 0.10, *0.08*, *0.06*) (1.62) (*0.66*, *0.61*, 0.59, 0.41) (*0.10*)
	3.60 **V05G29** HW	BOD_5 Total Suspended Solids Ammonia Tot. Kjeldahl Nitrogen Phosphorus	(*2.0*) (*25*, *23*, *14*) (0.12, *0.09*, *0.09*, *0.08*) (*0.83*, 0.57) (*0.16*)
	0.70 **V05G30** HW		No exceedence
Castro Run	1.10 **V05G37** HW	BOD_5 Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(**5.6**, 3.8, *2.2*) (**127**, 53, *31*, *23*, *22*) (**0.19**, 0.11, *0.06*, *0.05*) (1.05) (*0.03*, 0.02) (*0.93*, *0.73*, 0.57, 0.52) (*0.13*, *0.11*, *0.08*, *0.08*, *0.08*)

River/Stream	River Mile **STORET Code**	Parameter(s)	Value(s)
Mill Creek	1.60 **V05G35** HW	BOD_5 Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(4.7, 4.7) (62, *14*, 7) (**1.58**, 0.15) (*3.21*, *2.62*, *2.24*, 1.46, 1.14) (**0.24**, **0.10**) (**3.26**, 1.14, *0.78*, 0.53) (**0.65**, 0.27, *0.10*, 0.06, 0.05)
Light Creek	0.10 **V05G36** HW	Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(*18*, *16*, 12, 8, 7) (*0.08*, *0.08*, *0.06*, *0.06*) (1.32) (0.02) (0.70, 0.58, 0.47) (*0.14*, 0.06, 0.05)
Reynolds Run	0.70 **V05G31** HW	BOD_5 Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(4.7, *3.3*) (11) (**0.22**, 0.12, 0.11) (*3.02*, *2.62*) (0.05, 0.02) (1.66, 0.95, 0.55, 0.48, 0.40) (0.26, 0.25, 0.07)
Little Walnut Creek	10.20 **V05G59** HW	BOD_5 Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(3.8, *2.0*) (0.10, *0.09*) (*2.33*) (*0.04*, 0.03) (*0.68*, 0.46, 0.46, 0.45, 0.45) (*0.15*, 0.07)
	9.40 **V05G11** HW	Nitrate+Nitrite Phosphorus	(1.72) (0.05)
	7.40 **V05G12** HW	Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(*0.06*, *0.06*) (2.02) (0.02) (*0.64*, 0.51, 0.47, 0.43, 0.40) (0.07, 0.05)
	1.40 **V05G13** W	BOD_5 Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(**9.4**, **6.1**, **4.6**) (22, 21, 15, 15) (*0.09*, *0.07*) (1.45, 0.98) (0.07, 0.06, *0.03*) (1.04, *0.83*, 0.50) (0.08, 0.07)

River/Stream	River Mile **STORET Code**	Parameter(s)	Value(s)
E. Branch Little Walnut Creek	0.05 **V05G60** HW	Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(*35*, 13, 8) (0.13) (1.64) (0.02) (0.43, 0.41) (*0.11*, 0.06, 0.06, 0.05, 0.05)
W. Branch Little Walnut Creek	3.30 **V05G61** HW	BOD_5 Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(**8.0**, 4.5, 4.0, *2.1*) (*24*, *21*, *17*, *16*) (**2.07**, **0.72**, **0.68**, **0.33**) (**6.53**) (0.05, *0.04*, *0.03*) (**2.99**, **1.82**, **1.46**, *0.76*, 0.56) (0.41, 0.27, *0.19*, *0.09*)
	0.80 **V05G15** HW	BOD_5 Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(*2.8*) (**0.25**, 0.16, 0.12, *0.07*) (*3.46*) (*0.03*) (*0.77*, *0.75*, *0.65*, 0.58, 0.54) (*0.08*)
Butler Run	1.20 **V05G14** HW	BOD_5 Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(*3.2*) (49, *27*, *27*, *22*, *18*) (*0.05*) (5.44, 1.08) (0.07, 0.06) (*0.65*, *0.63*, 0.45) (*0.08*)
Sugar Creek	5.30 **V05G32** HW	Total Suspended Solids Ammonia Tot. Kjeldahl Nitrogen Phosphorus	(11, 8) (*0.09*, *0.08*, *0.08*, *0.06*) (0.47, 0.45) (0.06)
	0.10 **V05G28** HW	Tot. Kjeldahl Nitrogen	(0.48)
Perfect Creek	6.30 **V05G33** HW n=4	BOD_5 Total Suspended Solids Nitrate+Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(*2.1*) (10) (*3.68*) (*0.72*, *0.66*, *0.60*, 0.52) (*0.11*, 0.07, 0.07, 0.05)

River/Stream	River Mile **STORET Code**	Parameter(s)	Value(s)
	0.10 **V05G23** HW	Total Suspended Solids Nitrate+Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(*22*, 12) (**6.02**, 1.40) (*0.74*, *0.69*, 0.40) (*0.17*, *0.11*, *0.10*, *0.10*, *0.10*)
Rattlesnake Creek	0.10 **V05G19** W	Total Suspended Solids Nitrate+Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(9) (*4.30*, 1.05) (*0.82*, *0.62*) (0.09, 0.08, 0.07, 0.07)
E. Fork Rattlesnake Creek	3.10 **V05G63** HW	BOD_5 Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(**4.8**, 4.6, *2.7*, *2.0*) (*20*, *14*, 11, 11, 7) (**5.54**, **4.54**, **2.86**, **0.37**, 0.12) (**14.60**, **13.20**, **7.20**, *4.11*, 1.07) (**2.21**, **1.08**, **1.06**, **0.16**, **0.12**) (**8.77**, **8.31**, **6.02**, **2.25**, 1.20) (**0.79**, **0.43**, **0.43**, 0.40, *0.17*)
	0.20 **V05G21** HW	BOD_5 Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(**16.1**, **12.0**, **5.9**) (**198**, **169**, **76**, **74**, *25*) (*0.07*, *0.07*, *0.06*) (1.94) (*0.04*, *0.04*, *0.04*, *0.03*) (**1.50**, *0.92*, *0.89*, *0.70*, 0.49) (0.30, *0.14*, *0.14*, *0.12*)
S. Fork Rattlesnake Creek	3.70 **V05G81** HW	BOD_5 Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(*2.1*) (9) (*0.08*) (4.68) (0.06) (*0.80*, *0.65*, 0.48) (*0.11*, 0.05)
	0.10 **V05G22** HW	BOD_5 Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(3.6, *2.4*, *2.2*) (**155**, *16*, 11, 9) (0.11, *0.06*) (1.39) (**0.14**, *0.03*) (*0.77*, *0.72*, 0.58, 0.56, 0.46) (*0.17*, 0.05, 0.05)
N. Fork Rattlesnake Creek	4.80 **V05G62** HW	Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(**2.06**, *0.05*) (**13.20**, **6.57**, 5.42) (**0.56**, **0.10**, *0.05*) (**2.95**, *0.93*, *0.75*, *0.72*, 0.60) (*0.14*, *0.08*)

River/Stream	River Mile **STORET Code**	Parameter(s)	Value(s)
	3.40 **V05G01** HW	Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(**1.73**, **0.47**, 0.13, 0.12, *0.07*) (**11.40**, **10.20**) (**0.26**, **0.12**, 0.05) (**2.63**, **1.60**, 1.24, *0.80*, *0.64*) (0.31, *0.15*, 0.06, 0.06, 0.05)
	3.40 storm **V05G01** HW n=3	BOD_5 Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(**5.6**) (**164**, 7) (**0.78**, **0.43**, *0.06*) (**9.73**, **7.99**) (**0.24**, 0.05) (**1.61**, *0.64*, 0.58) (**0.96**, 0.06, 0.06)
	0.10 **V05G20** HW	Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(*20*) (*0.10*, *0.09*, *0.07*, *0.07*, *0.07*) (5.51, 2.18) (*0.04*, *0.03*) (*0.79*, 0.50, 0.48, 0.45) (*0.14*, 0.07, 0.06)
Prairie Run	0.40 **V05W06** HW	Total Suspended Solids Ammonia Tot. Kjeldahl Nitrogen Phosphorus	(13, 8, 7) (*0.05*) (0.45, 0.40) (*0.10*, *0.09*)
Culver Creek	4.50 **V05G26** HW	BOD_5 Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(*2.5*) (8) (**2.26**, **1.06**, **0.69**, 0.11, *0.07*) (1.31, 1.23, 1.09) (**0.27**, **0.14**, 0.05, 0.02) (**2.82**, **1.84**, **1.74**, *0.61*, 0.43) (**0.79**, **0.71**, 0.27, 0.07, 0.05)
	3.30 **V05G25** HW	Ammonia Tot. Kjeldahl Nitrogen Phosphorus	(*0.06*) (0.57, 0.51) (0.06)
	0.10 **V05G24** HW	Total Suspended Solids Nitrate+Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(9) (1.14) (0.59, 0.45, 0.43, 0.42) (0.05, 0.05, 0.05)

River/Stream	River Mile **STORET Code**	Parameter(s)	Value(s)
Unnamed Tributary to Culver Creek	0.10 **V05G27** HW	BOD_5 Total Suspended Solids Ammonia Tot. Kjeldahl Nitrogen Phosphorus	(*2.2*) (7) (**0.27**, *0.07*) (*0.96*, 0.55, 0.55, 0.50, 0.49) (*0.13*)
Duncan Run	9.00 **V05G18** HW	BOD_5 Total Suspended Solids Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(4.4) (*21*, 8, 7) (*2.98*) (0.05, *0.04*) (*0.90*, *0.62*, 0.58, 0.54, 0.50) (*0.10*, *0.08*, 0.05, 0.05)
	7.30 **V05G17** HW	BOD_5 Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(*3.1*) (5.00, 1.81) (**0.17**, *0.04*, *0.04*) (*0.92*, *0.82*, *0.72*, *0.68*, *0.64*) (**1.02**, *0.14*, *0.12*, *0.10*, *0.08*)
	2.70 **V05G16** HW	BOD_5 Total Suspended Solids Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(*2.1*) (12) (*2.87*) (*0.03*, 0.02) (*0.70*, 0.57, 0.56, 0.45, 0.40) (*0.15*, *0.11*, 0.06, 0.05, 0.05)
McKenna Creek	0.20 **V05G04** HW	Total Suspended Solids Phosphorus	(7) (**0.58**, 0.05)
	0.20 storm **V05G04** HW n=3	BOD_5 Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(3.6) (**282**, *52*, *37*) (**0.30**, 0.16, 0.10) (1.10) (**0.10**, 0.06, *0.03*) (*0.87*, *0.74)* (*0.20*, *0.13*, 0.05)
Columbus Airport Tributary	0.20 **V05W40** HW	BOD_5 Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen	(**5.4**, **4.9**, 3.9, *2.2*) (**1.76**, **1.28**, **0.58**, **0.53**, **0.51**) (*4.46*, *3.01*, *2.94*) (**0.63**, **0.41**, **0.30**, **0.25**, **0.14**) (**2.1**, **1.64**, **1.48**, 1.25, *0.82*)

River/Stream	River Mile **STORET Code**	Parameter(s)	Value(s)
Mason Run	0.50 **V05P17** HW	Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(0.18, 0.13, 0.12, 0.10) (1.61, 1.48, 0.18) (0.02) (0.58) (*0.12*, *0.10*, *0.08*, *0.08*)
Unnamed Tributary to Big Walnut Creek	0.20 **V05G57** HW	Phosphorus	(0.05)

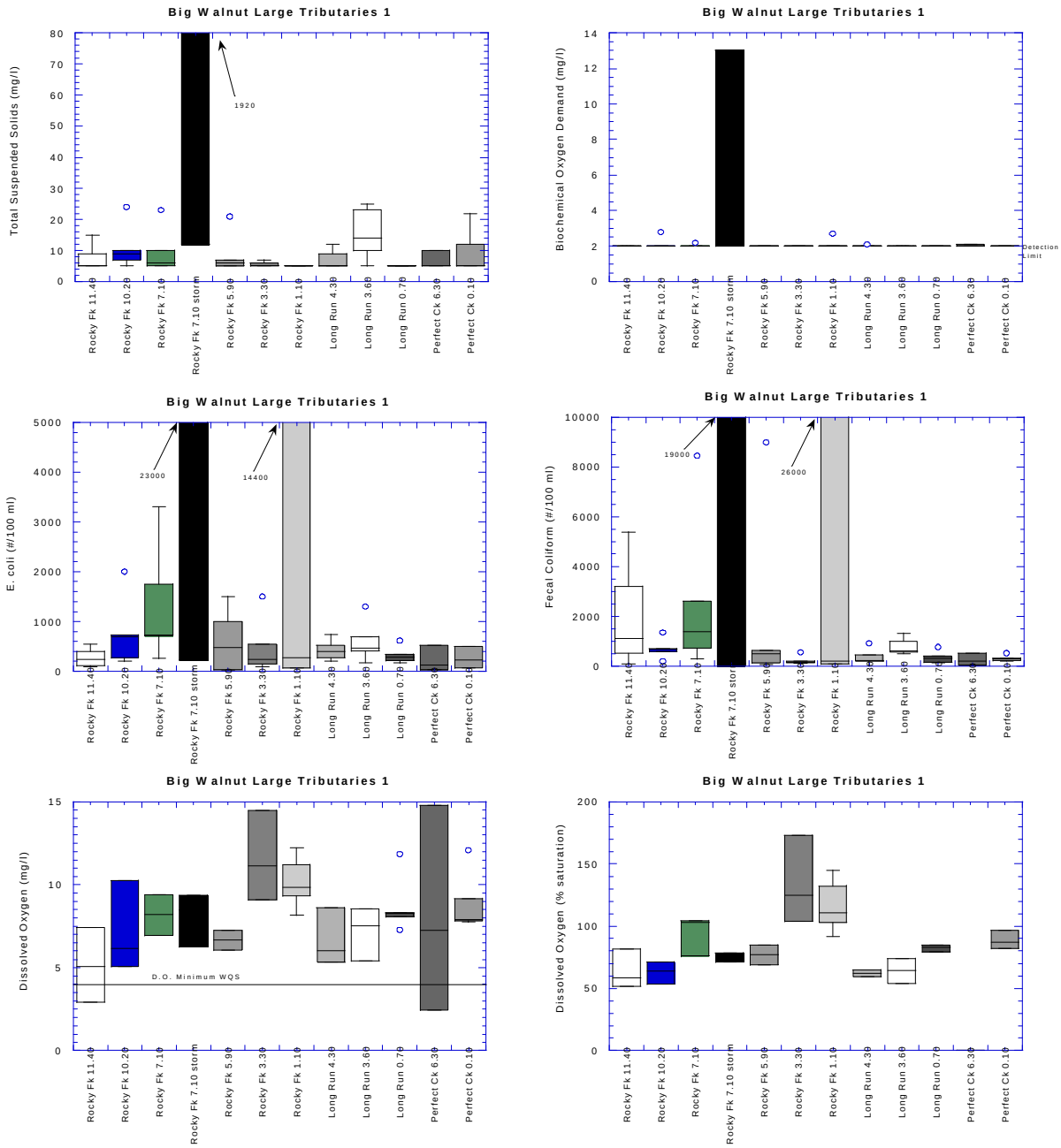

Figure 14. Box plots of Total Suspended Solids, Biochemical Oxygen Demand, E. coli, Fecal Coliform, Dissolved Oxygen, and Dissolved Oxygen Percent Saturation in selected large Big Walnut Creek tributaries, 2000.

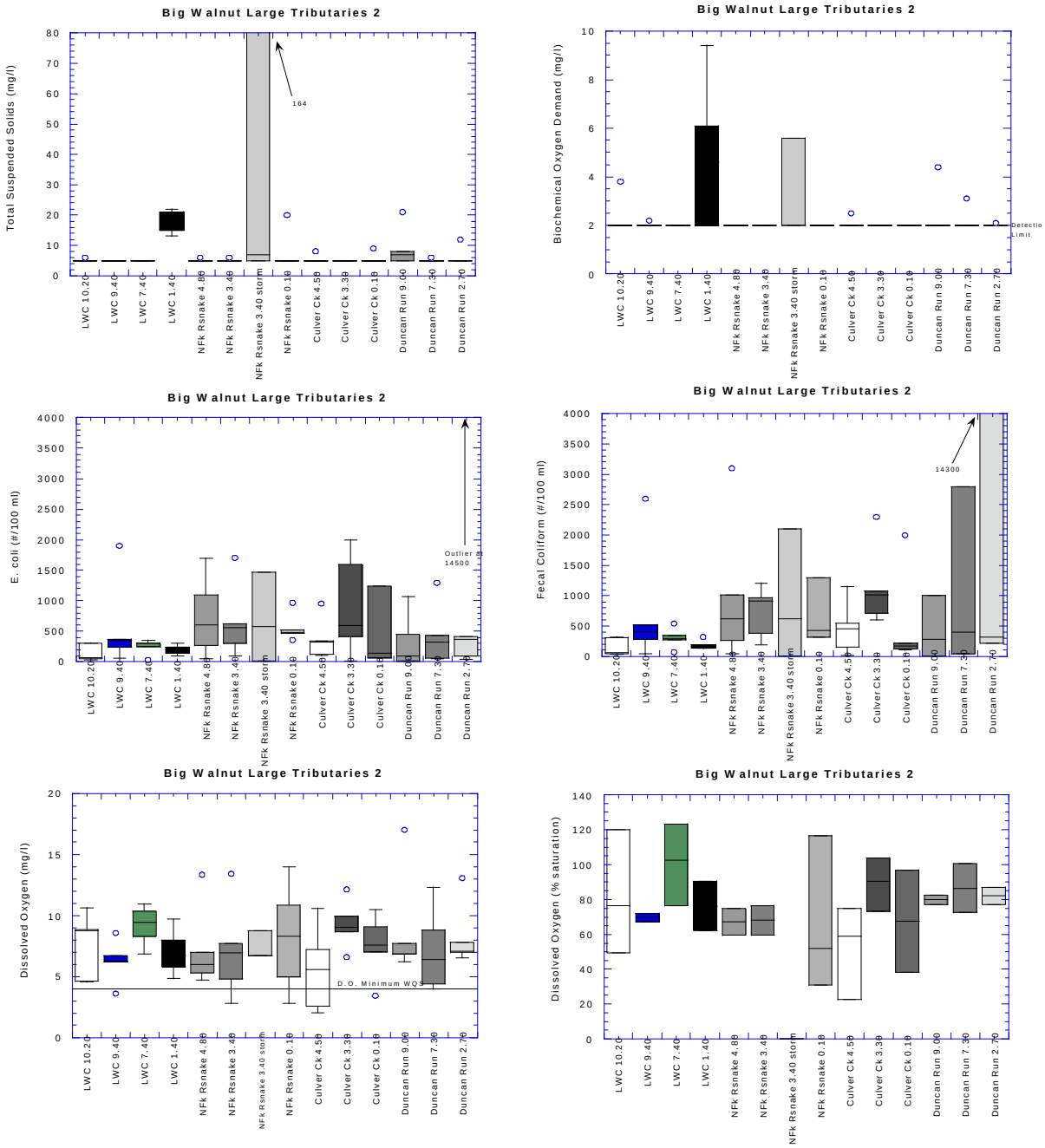

Figure 15. Box plots of Total Suspended Solids, five-day Biochemical Oxygen Demand, E. coli, Fecal Coliform, Dissolved Oxygen, and Dissolved Oxygen Percent Saturation in selected large Big Walnut Creek tributaries, 2000.

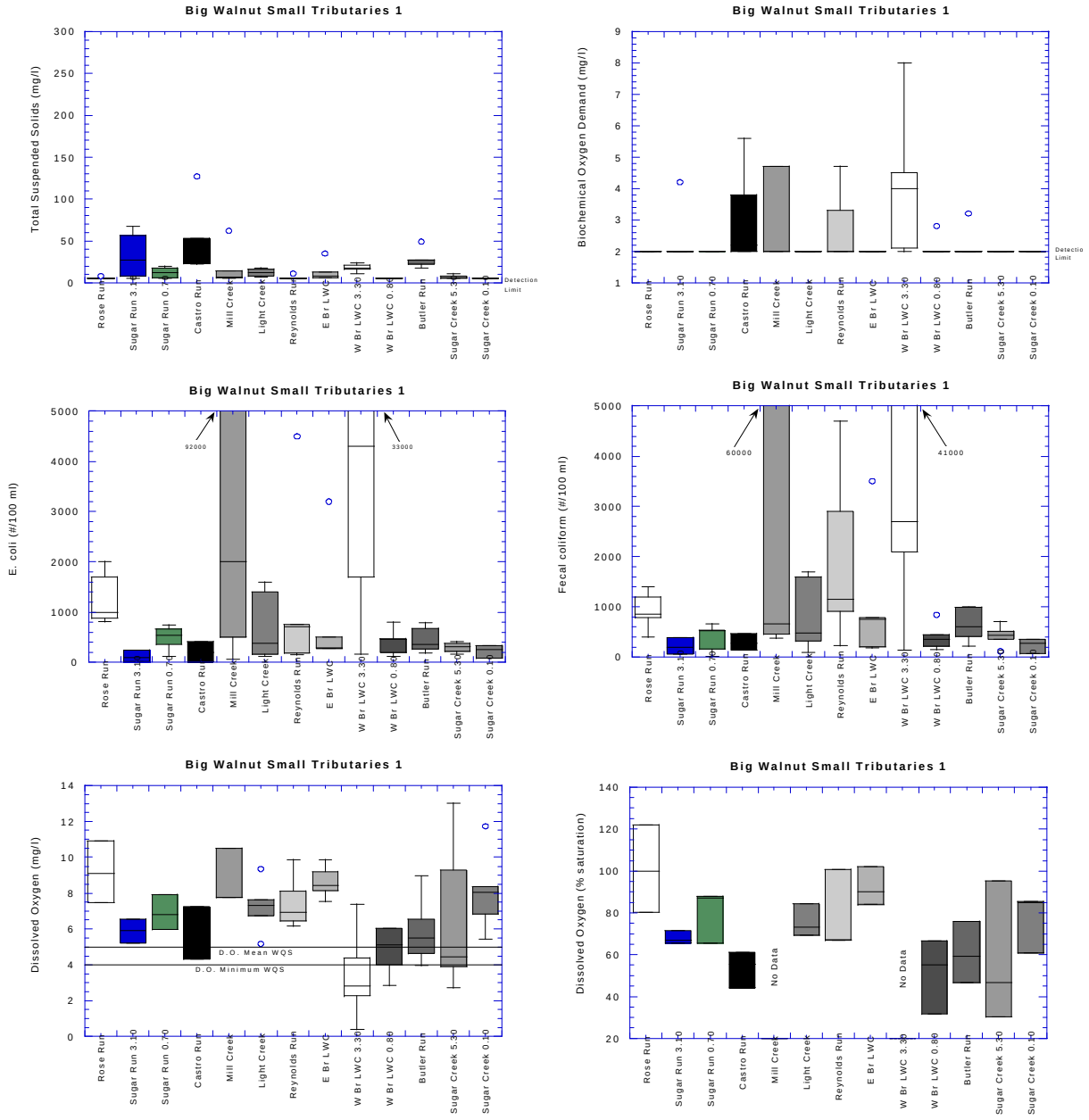

Figure 16. Box plots of Total Suspended Solids, five-day Biochemical Oxygen Demand, E. coli, Fecal Coliform, Dissolved Oxygen, and Dissolved Oxygen Percent Saturation in selected small Big Walnut Creek tributaries, 2000.

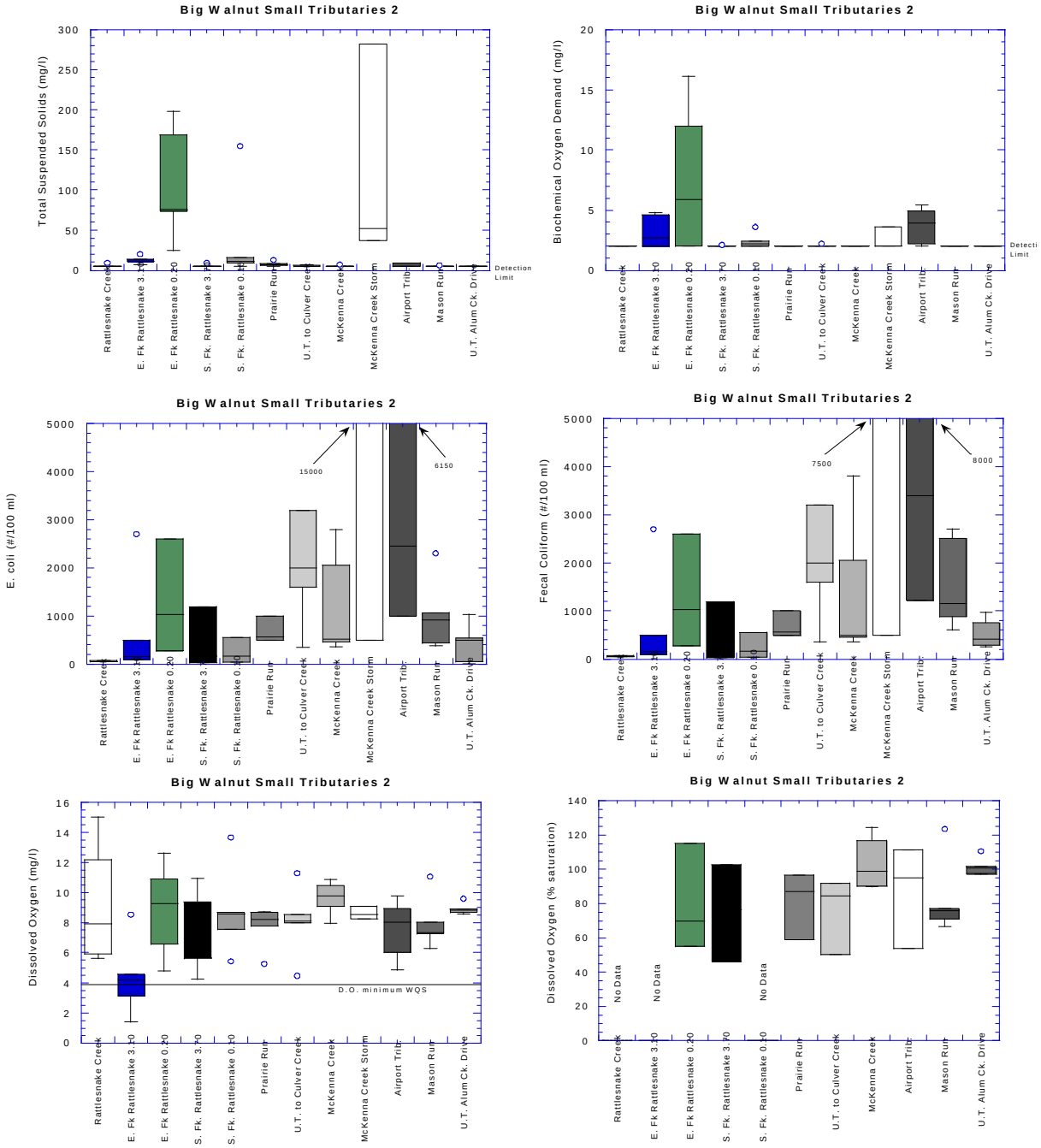

Figure 17. Box plots of Total Suspended Solids, Biochemical Oxygen Demand, E. coli, Fecal Coliform, Dissolved Oxygen, and Dissolved Oxygen Percent Saturation in selected small Big Walnut Creek tributaries, 2000.

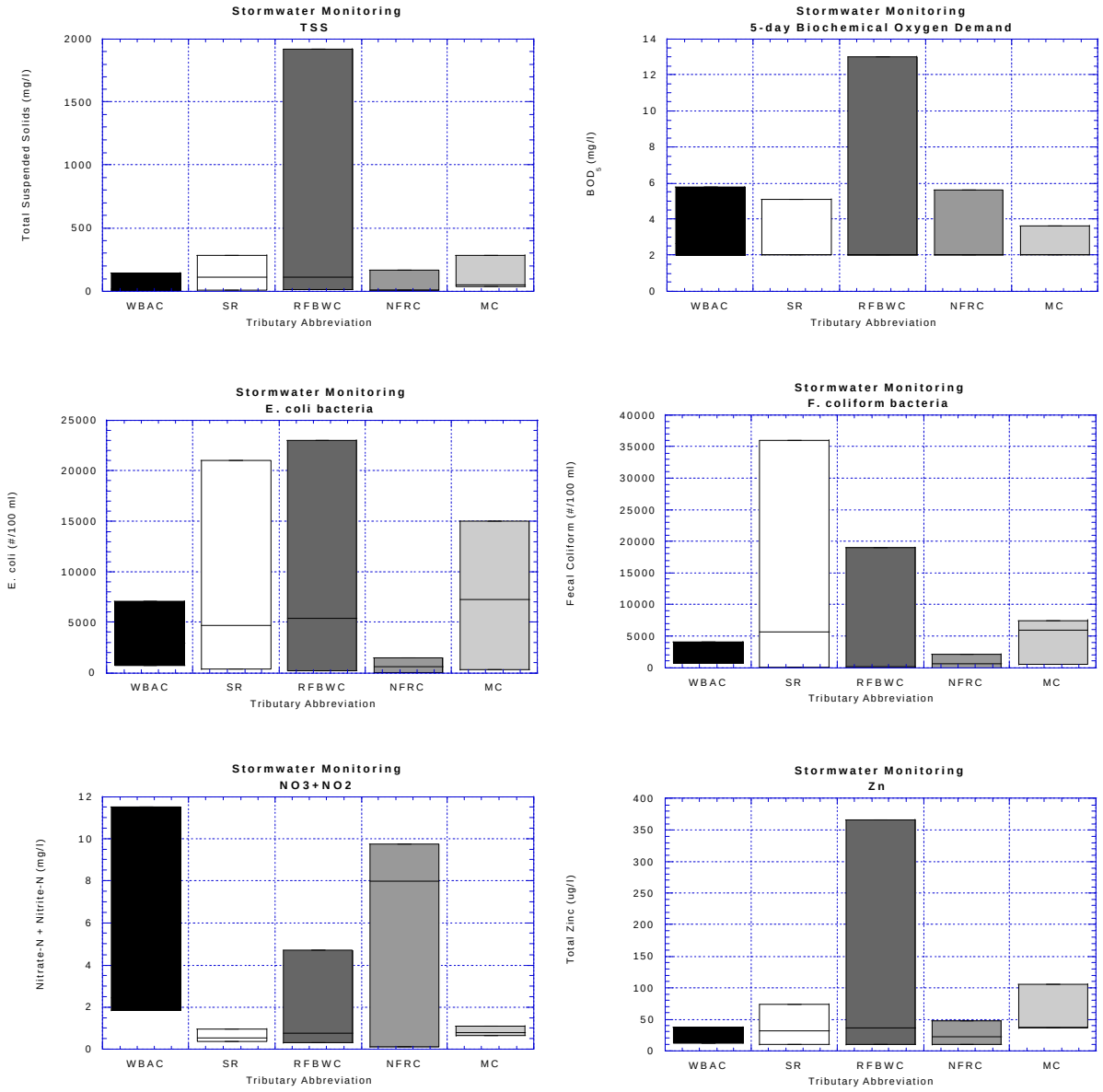

Figure 18. Box plot of Total Suspended Solids, Biochemical Oxygen Demand, E. coli, Fecal Coliform, Nitrate+Nitrite-Nitrogen, and Total Zinc during storm events in WBAC=W. Br. Alum Cr.(RM 8.7), SR=Spring Run, RFBWC=Rocky Fork Big Walnut Cr. (RM 7.1), NFRC=N. Fk. Rattlesnake Cr. (RM 3.4), and MC=McKenna Cr. (RM 0.2), 2000.

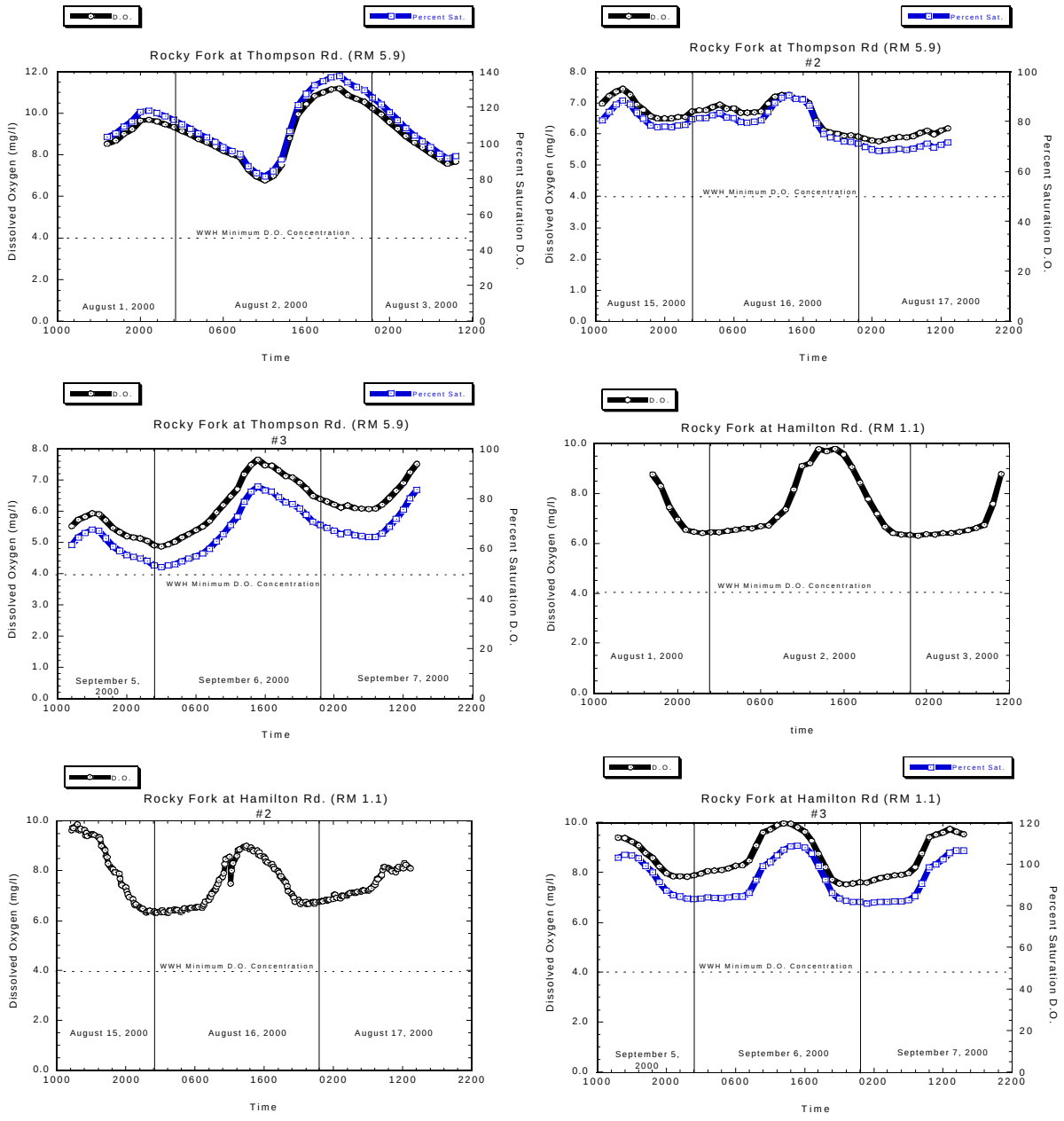

Figure 19. Diel Dissolved Oxygen concentration and Dissolved Oxygen Percent Saturation from Rocky Fork Big Walnut Creek at Thompson Rd. (RM 5.9) and Hamilton Rd. (RM 1.1), 2000.

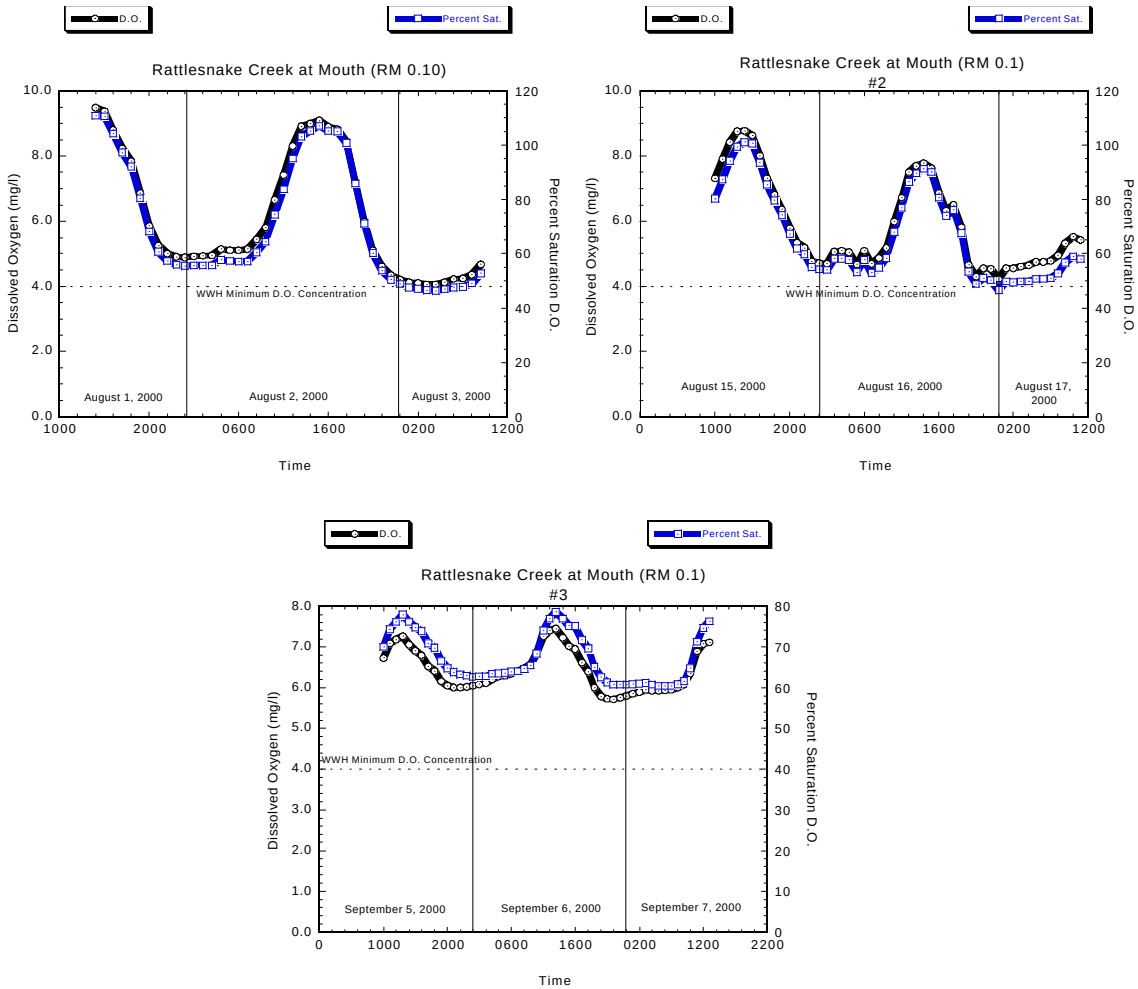

Figure 20. Diel Dissolved Oxygen concentration and Dissolved Oxygen percent saturation from Rattlesnake Creek near mouth (RM 0.1), 2000.

Alum Creek and Tributaries

Alum Creek (WWH)

Chemical water quality in Alum Creek was impacted by bacterial contamination throughout the basin. The maximum Primary Contact Recreation (PCR) criteria for fecal coliform and *E. coli* bacteria were exceeded at each site at least once, if not more often (Table 9). No other water quality criteria were exceeded during the survey period. Additionally, mean concentrations of fecal coliform

bacteria exceeded the PCR criterion in the headwaters of Alum Creek (Fig. 21). The average concentration of *E. coli* bacteria also exceeded the PCR criterion throughout the length of the creek (Fig. 21).

Excessive concentrations of suspended solids and nutrient enrichment were also apparent in Alum Creek. There were some distinct differences in stations evaluated above Alum Creek Lake when compared to stations downstream of the reservoir. At upstream sites (RM 56.30 to RM 39.45), concentrations of suspended solids in excess of the 95th percentile of background reference were measured (Table 13). Nutrient enrichment also was evident with concentrations of ammonia, nitrate+nitrite, TKN and BOD exceeding the 95th percentile of background. This overabundance of nutrients and solids resulted from a storm event (Fig. 7) and gives some indication of the magnitude with which runoff can cause acute nutrient and solids pollution. In most instances, this event overshadowed nutrient concentrations during normal flow periods. Phosphorus was the exception to this as it appeared regularly at concentrations above the median background reference value for this ecoregion, indicating a more chronic problem. Likely sources of pollution from runoff events included agricultural inputs from both field tile drainage and animal husbandry operations.

Suspended solids and nutrient concentrations downstream of Alum Creek Lake (RM 22.10 to RM 0.70) appeared less influenced by the storm event than upstream. However, chronic nutrient pollution was evident at each site evaluated below the dam. Suspended solids, nitrate+nitrite, and ammonia were the major nutrients present (Table 13). Ammonia was particularly evident at RM 3.80, exceeding the 95th percentile background reference value in 4 of 5 instances. Phosphorus was not a chronic problem in this reach as opposed to the reach upstream of the dam. Numerous sewer system overflows and old landfills exist along the lower reaches of Alum Creek. These likely were instrumental in causing the chemical impairment detected in the urbanized lower sections of the river.

West Branch Alum Creek (WWH)

Water samples were obtained in West Branch Alum Creek at four different sampling locations during the survey period and were analyzed for many chemical constituents. All four sites showed moderate contamination from bacteria, especially *E. coli* (Table 9). The site at RM 8.70 also exhibited a single WQS violations of the minimum dissolved oxygen criterion and an exceedence of the numerical criterion for prevention of acute toxicity for copper. The location at RM 3.30 showed a similar single exceedence of the numerical criterion for prevention of acute toxicity although it was for zinc. Sources of these metals are unknown, but may be related to some small-scale business activity with an intermittent direct discharge to the creek (e.g., an auto repair facility or welding operation).

Mean concentrations of bacteria showed dramatic declines from upstream to downstream (Fig. 22). Nutrients and suspended solids concentrations ranged from high during storm events to low or moderate during dry weather. Storm event sampling performed on June 21 at RM 8.70 revealed some extraordinary concentrations of pollutants including BOD_5, suspended solids, ammonia,

nitrate+nitrite and TKN all in excess of the 95th percentile of background reference (Table 14). This particular event was the heaviest precipitation of the summer in this part of the basin (Fig. 7) and resulted in increased loadings of pollutants to the watershed in spite of dilution. This particular rain event was also noted at the other sites evaluated and showed similar high concentrations of pollutants, especially BOD_5, suspended solids and nitrate+nitrite. Of all the sites evaluated for storm runoff, mean nitrate+nitrite concentrations on West Branch Alum Creek were second only to those on North Fork Rattlesnake Creek (Fig. 18). The site at RM 0.60 seemed least affected by nutrients of the sites evaluated on West Branch Alum Creek. Prevalent land use suggested that agricultural sources may be the cause of the majority of the nutrient enrichment.

Turkey Run (WWH)

Chemical water quality in Turkey Run was evaluated at two locations. The site at RM 4.80 was impacted by low dissolved oxygen concentrations and elevated bacterial concentrations (Table 9). Also, excessive suspended solids and nutrient concentrations were present. Suspended solids concentrations were all greater than the 75th percentile for background reference (Table 14). Ammonia concentrations were greater than the 90th percentile in two cases and greater than the 75th percentile in two cases, both during normal flow. An acutely elevated concentration of nitrates (greater than the 95th percentile) was noted on one occasion, likely due to a precipitation event. Organic nitrogen was also chronically elevated; however, phosphorus and BOD were elevated on only two occasions over the survey period.

Potential water quality impacts at RM 1.70 were significantly less than the upstream site. Bacterial concentrations were still elevated, but to a lesser frequency, and dissolved oxygen concentrations were all above the 4 mg/l minimum criterion (Table 9, Fig. 23). Suspended solids were also reduced compared with RM 4.80 as were concentrations of ammonia (Table 14). A single acute concentration of nitrates was recorded similar to RM 4.80, again likely due to a precipitation event. Total phosphorus was the only nutrient that showed an increase at this site compared with the upstream locale. Based on prevailing land use, agricultural operations are the likely sources of nutrient enrichment in Turkey Run. Elevated suspended solids concentrations are likely caused by lack of riparian cover in many areas which aggravates bank erosion and dispersal of fine soil particles.

Unnamed Tributary to Alum Creek at RM 54.44 (Undesignated)

Chemical water quality problems were discovered in this headwater stream. Water quality criteria identified for the Warmwater Habitat use designation apply to water bodies not assigned an aquatic life use designation. WQS criteria violations were noted for dissolved oxygen on two occasions and exceedences of bacterial criteria were noted in all samples (Table 9). Chronic nutrient enrichment was also apparent as were chronic elevated concentrations of suspended solids (Table 14). Water quality degradation may be the result of drainage from the unsewered community of Fulton. Since biological communities were not evaluated in this small creek it is difficult to infer the degree, in any,

of aquatic life use impairment.

Bunker Run (WWH)

Bunker Run was evaluated for chemical water quality at RM 1.80. Potential water quality impacts included exceedences of bacterial water quality criteria in most of the samples (Table 9). Dissolved oxygen measurements were all well above minimum criteria, but did not reflect supersaturated conditions. Nutrient enrichment did not seem to be a chronic problem in Bunker Run although sampling conducted during a storm event revealed high concentrations of many nutrients and other pollutants including nitrates, ammonia, nitrite, and suspended solids, evidence of pollution from rural runoff sources (Table 14).

Unnamed Tributary to Alum Creek at RM 40.48 (Undesignated)

Chemical water quality was evaluated at RM 0.20 in the headwater stream. Water quality criteria identified for the Warmwater Habitat use designation apply to water bodies not assigned an aquatic life use designation. Bacterial exceedences were observed in every sample (Table 9). Dissolved oxygen measurements were all well above minimum criteria but did not reflect supersaturated conditions. Nutrient enrichment was not problematic although separate samples did show elevated nitrates (during a rain event) and ammonia (during dry weather) (Table 14) which may be evidence of an intermittent acute problem. Since biological communities were not evaluated in this small creek it is difficult to infer the degree, in any, of aquatic life use impairment.

Unnamed Tributary to Alum Creek at RM 38.75 (Undesignated)

Chemical water quality sampling was performed on this undesignated headwater stream during the summer of 2000. Water quality criteria identified for the Warmwater Habitat use designation apply to this waterbody since it is currently not assigned an aquatic life use designation. Water quality criteria exceedences for *E. coli* were noted in all 5 samples (Table 9). Dissolved oxygen concentrations were found in the normal range and not supersaturated. Nutrient concentrations for all parameters were below the background reference median for the most part except for a single nitrate+nitrite value greater than the 95th percentile that was observed during a rain event, one nitrite value, and two TKN values (Table 14). Total suspended solids concentrations were above the 75th percentile of background in 3 of 5 samples. Since biological communities were not evaluated in this small creek it is difficult to infer the degree, in any, of aquatic life use impairment.

Big Run (WWH)

Big Run was evaluated for chemical water quality at RM 2.70 (upstream of the influence of the reservoir). A violation of the minimum dissolved oxygen WQS croterion was noted on one occasion (Table 9). Bacterial exceedences were evident in most samples for *E. coli*. Nutrient enrichment was notable with the presence of ammonia and organic nitrogen above median background reference

concentrations in most samples in addition to extreme concentrations of nitrate+nitrite during two sampling events and high nitrite concentrations on one occasion (Table 14). Agricultural uses and growing development of this watershed are likely causes of these chemical water quality problems.

Unnamed Tributary to Alum Creek at RM 25.50 (Undesignated)

Chemical water quality was evaluated on this small tributary at RM 0.20. Water quality criteria identified for the Warmwater Habitat use designation apply to this stream since it is not assigned an aquatic life use designation. Fecal coliform and/or *E. coli* bacterial exceedences were noted in all samples (Table 9). Both organic and nutrient enrichment were excessive at times in this tributary with BOD_5, ammonia, and TKN values well in excess of the 95th percentile of background reference on three occasions (Table 14). Total suspended solids concentrations were also extremely elevated in 3 of the 5 samples. The most direct cause of this enrichment was witnessed on 3 occasions, with a herd of cattle noted in the creek upstream of the sampling locale. Elevated BOD_5, TKN, suspended solids, and total phosphorus were directly linked to the presence of the herd in the creek. Elevated ammonia concentrations seemed unaffected by the presence or absence of the cattle and may be influenced by some other source of pollution. An average water temperature of 16.64 ^{o}C (about 2 degrees below similar headwater streams nearby) along with consistent flow suggests that this stream may be influenced by groundwater flow and, therefore, harbor cool water species.

Unnamed Tributary to Alum Creek at RM 23.47 (Undesignated)

Chemical water quality was evaluated in this stream downstream of the Westerville Reservoir at RM 0.80. Water quality criteria identified for the Warmwater Habitat use designation apply to water bodies not assigned an aquatic life use designation. Exceedences of the WQS criterion for *E. coli* were noted in each sample (Table 9). Nutrient enrichment in this creek consisted of elevated ammonia, nitrite, and TKN. Ammonia values exceeded the 90th percentile for background reference (Table 14). Nitrite and TKN concentrations surpassed the 75th percentile of background. Evidence of organic enrichment was sparse and included only two detections of BOD_5 instream. Suspended solids were not detected above the background median. The presence of unsewered subdivisions and semi-public sewage treatment systems may be sources of bacteria and nutrients in the stream.

Spring Run (WWH)

Spring Run was evaluated for chemical water quality at two locations during the survey. Bacterial exceedences of WQS criteria were evident at RM 3.70 in every sample and at RM 0.20 in 4 of 5 samples (Table 9). Nutrient and organic enrichment at RM 3.70 was mostly limited to a single storm event, although TKN, ammonia, and BOD_5 were also detected during dry weather sampling (Table 14). Chemical detection of nutrient parameters was limited at the mouth and appeared directly related to a storm event; however, evidence of nutrient enrichment was apparent via the presence of excessively supersaturated dissolved oxygen conditions found during the majority of the sampling season (Fig. 23). Large amounts of suspended solids were noted during the storm event likely due

to urban runoff and bank erosion.

West Spring Run (Undesignated)

West Spring Run is a tributary to Alum Creek on the opposite bank from Spring Run. Water chemistry was examined at one location on the stream at RM 0.10. Water quality criteria identified for the Warmwater Habitat use designation apply to this waterbody which does not have an assigned aquatic life use designation. Chemical water quality in West Spring Run nearly mimicked Spring Run. Bacterial exceedences were evident in the majority of the samples (Table 9). Nutrient enrichment and elevated suspended solids were not noticeable except during precipitation and subsequent elevated flows (Table 14).

Kilbourne Run (WWH)

Chemical water quality sampling in Kilbourne Run was limited to three samples. Two sampling visits revealed isolated pools with no surface flow so samples were not obtained. Of the three successful samples, all revealed contamination from bacteria exceeding the PCR water quality criteria (Table 9). Nutrient enrichment was limited to total phosphorus during dry weather (Table14). Other nutrients were present in concentrations greater than background reference medians during wet weather. Total suspended solids concentrations were excessive during wet weather, likely due to urban runoff and bank erosion (Fig. 23).

Bliss Run (WWH)

Water in Bliss Run was heavily contaminated with bacteria, both fecal coliform and *E. coli*, during the 2000 survey (Table 9, Fig. 23). Enrichment was also very evident with the presence of ammonia, moderate concentrations of nitrates, and high concentrations of total phosphorus (Table 14). Nitrite, TKN, BOD_5, and elevated zinc concentrations (mean of 133 : m/l) also were present and indicative of degraded chemical water quality due to urban runoff. Since biological communities were not evaluated in Bliss Run, it was not possible to determine the attainment status of the designated WWH aquatic life use.

Diel Dissolved Oxygen Study-Alum Creek and Tributaries

Alum Creek

Diel dissolved oxygen patterns were evaluated at two sites on Alum Creek at RM 39.50 and RM 19.80. Each site was evaluated three times during the summer. The site at State Route 521 (RM 39.50) did not exhibit the typical diel pattern for oxygen concentration (Fig. 24). At this site, the pattern was irregular although the WWH WQS criterion for dissolved oxygen was not violated during any of the three survey periods. The irregularity was likely due to the semi-impounded nature of the site which is occasionally affected by the pool level in Alum Creek Lake. The site at Schrock

Road (RM 19.80) showed regular diel fluctuations in dissolved oxygen, typical of a stream environment. Dissolved oxygen concentrations at RM 19.80 were always greater than the WWH minimum criterion of 4.0 mg/l.

West Branch Alum Creek

Diel dissolved oxygen concentrations were evaluated on two occasions in the West Branch Alum Creek near the mouth (RM 0.50). The analysis performed between July 25, 2000 and July 27, 2000 showed wide diel swings in oxygen concentrations varying from highly supersaturated (nearly 160%) to about 60% saturation although the minimum criterion for WWH was not violated (Fig. 25). This is indicative of nutrient enrichment and high algal primary productivity. The evaluation done between August 15, 2000 and August 17, 2000 showed wide variation in oxygen concentrations once again, but at much less saturation and with violations of the WWH minimum dissolved oxygen criterion. This could be related to low summer flow resulting in poor reaeration rates as well as oxygen demand from organic/nutrient enrichment.

Turkey Run

Diel dissolved oxygen patterns were evaluated at RM 4.80 in Turkey Run. Typical diel fluctuations were noted at the site during the August and September evaluations; however, the July analysis proved to be somewhat irregular (Fig. 25). The WWH minimum criterion for dissolved oxygen was violated several times mostly during the September sampling event. Excessively supersaturated conditions were not observed although oxygen saturation did, at times, seem low with wide variability, roughly between 45% and 115% during the August Datasonde® deployment. September data showed even lower saturation levels dropping below 36%. The prsence of channel modifications have negatively affected riffle presence and quality and, therefore, the aeration potential of these features, a likely cause of low saturation and poor dissolved oxygen concentrations instream.

Big Run

Diel dissolved oxygen patterns were evaluated twice at RM 2.70 in Big Run in July and September, 2000. Both sampling events showed an irregular diel pattern with some results exhibiting violations of the WWH dissolved oxygen minimum criterion of 4.0 mg/l (Fig. 26). A single “spike” of supersaturated conditions occurred during the July evaluation and may be cause for concern regarding nutrient enrichment. These symptoms corresponded to causes and sources of chemical water quality degradation discussed in the chemical water quality section of this report.

Water Column Organics-Alum Creek

Two sites were evaluated for organic constituents in water (RM 13.40 and RM 0.70). Both sites were contaminated with dieldrin at concentrations greater than the criterion for the protection of

aquatic life outside the mixing zone (Table 11). Dieldrin is a broad range organochlorine insecticide used in a variety of situations to control insect pests. Manufacture of this insecticide has been discontinued since 1991. Water column contamination in Alum Creek may arise from disposal in the many old landfills along the creek and past applications of this persistent insecticide in the Columbus metropolitan area. No other organic compounds were detected at these sites.

Table 13. Comparison of ecoregional reference background nutrient and demand parameter concentrations with those found in the Big Walnut Creek study area, 2000. Comparisons are made to Eastern Corn Belt Plains (ECBP) ecoregion background 50th percentile (median) (Normal print), 75th (*Italic print*), 90th (Underlined), and 95th (**Boldfaced**) percentile values for headwaters, wadeable, and small river reference sites. Units are mg/l for all parameters. Sample size, n = 5 unless otherwise stated. **(** = Exceptional Warmwater Habitat. HW = headwater, W = wadeable, SR = small river

River/Stream	River Mile **STORET Code**	Parameter(s)	Value(s)
Alum Creek	56.30 **V05G38** HW	BOD_5 Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(**7.0**) (**82**, *14*, 11) (**0.39**) (**7.14**) (**0.27**) (**1.65**) (0.22, 0.06)
	55.30 **V05G39** HW	BOD_5 Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(**7.3**) (**216**, *19*, 10) (**0.41**, 0.10, *0.05*, *0.05*) (**7.53**) (**0.27**) (**1.65**) (0.21, 0.06, 0.05)
	52.90 **V05G40** HW	Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(**115**, 12, 11, 8, 8) (*0.07*) (*3.35*, 1.02) (0.08) (0.49) (*0.12*, *0.10*, *0.09*, *0.08*, 0.06)
	49.90 **V05G41** HW	Total Suspended Solids Nitrate+Nitrite Phosphorus	(12) (2.00) (0.06, 0.06, 0.05)
	42.90 **V05G42** W	Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(**92**) (*0.09*) (5.40, 1.36) (0.07, 0.02) (*0.71*, 0.58) (0.12, 0.11)
	39.45 **V05G43** W	Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(15) (*0.05*) (*4.48*, 1.82) (*0.02*) (**2.89**, 0.62) (*0.13*, 0.07, 0.07)

River/Stream	River Mile **STORET Code**	Parameter(s)	Value(s)
	22.10 **V05W25** W	Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen	(*49*, *43*, *32*, 21, 16) (*0.08*, *0.08*, *0.08*, *0.07*, *0.06*) (2.21, 2.16, 2.06, 1.98, 1.89) (*0.05*, *0.04*, *0.04*, *0.04*, *0.04*) (0.54)
	19.80 **V05W24** W	Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite	(**103**, *34*, 27, 26) (*0.09*, *0.09*, *0.09*, *0.07*, *0.07*) (2.24, 1.84, 1.56, 1.49) (0.06, *0.04*, *0.04*, *0.03*, *0.03*)
	13.40 **V05S17** W	BOD_5 Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(*2.2*) (*45*, 20, 19) (*0.06*, *0.06*) (2.09, 1.35, 1.30, 1.22, 1.12) (*0.03*, *0.03*, *0.02*, *0.02*, *0.02*) (0.56) (*0.15*, 0.07)
	3.80 **V05W21** W	Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(26, 17, 17) (**0.31**, **0.25**, **0.23**, **0.21**, 0.12) (1.48, 0.91) (0.05, 0.05, *0.04*, *0.04*, *0.02*) (*0.68*, *0.67*, 0.53) (0.08)
	0.70 **V05G44** W	Ammonia Nitrate+Nitrite Nitrite Phosphorus	(0.12, 0.11, *0.08*, *0.06*) (1.51, 0.86) (0.05, *0.03*, *0.03*, *0.03*, *0.02*) (0.08)

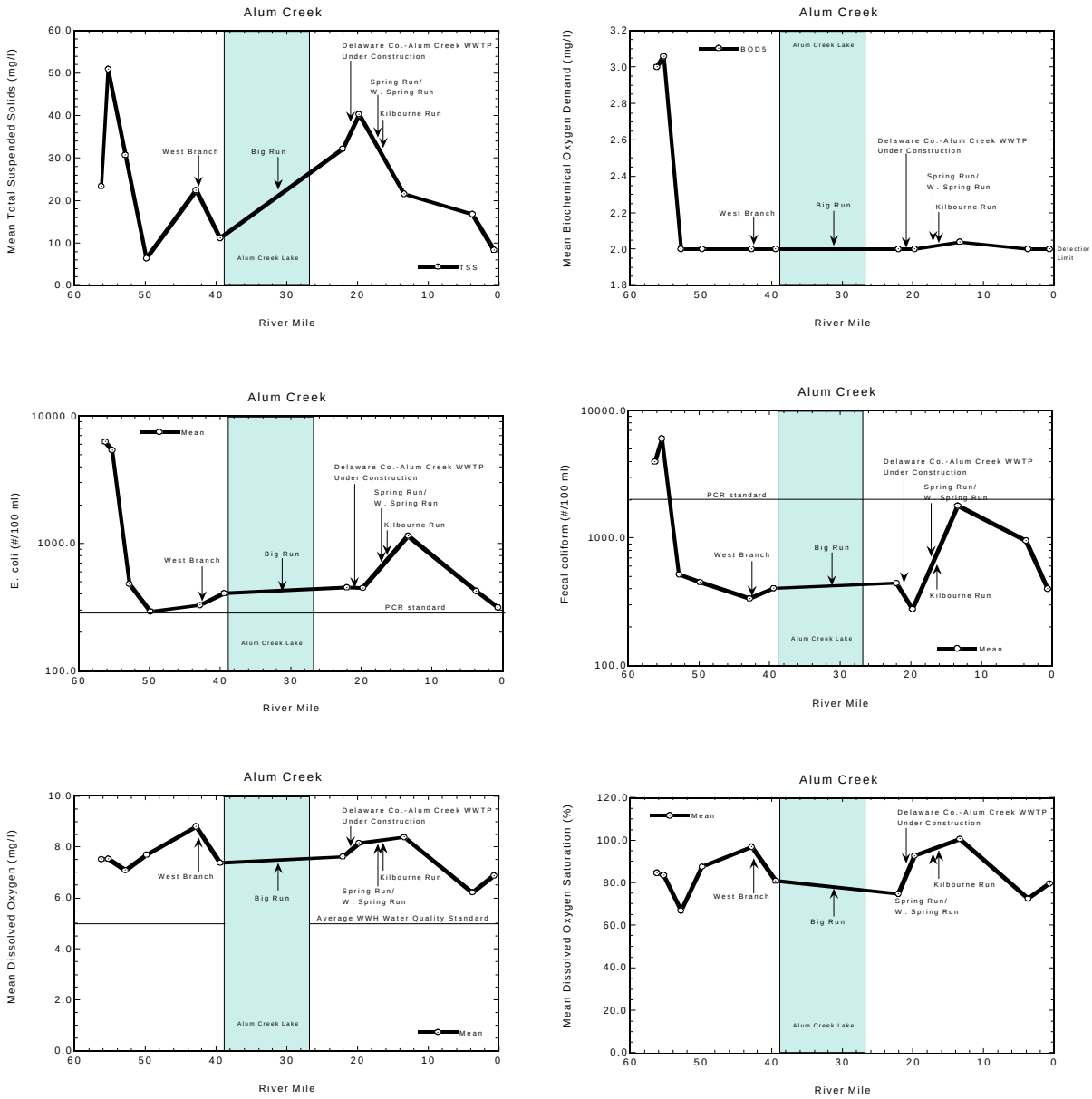

Figure 21. Longitudinal plots of mean Total Suspended Solids, Biochemical Oxygen Demand, E. coli, Fecal Coliform, Dissolved Oxygen, and Dissolved Oxygen Percent Saturation in Alum Creek, 2000.

Table 14. Comparison of ecoregional reference background nutrient and demand parameter concentrations with those found in the Big Walnut Creek study area, 2000. Comparisons are made to Eastern Corn Belt Plains (ECBP) ecoregion background 50th percentile (median) (Normal print), 75th (*Italic print*), 90th (Underlined), and 95th (**Boldfaced**) percentile values for headwaters, wadeable, and small river reference sites. Units are mg/l for all parameters. Sample size, n = 5 unless otherwise stated. **(** = Exceptional Warmwater Habitat. HW = headwater, W = wadeable.

River/Stream	River Mile **STORET Code**	Parameter(s)	Value(s)
West Branch Alum Creek	9.90 **V05G47** HW	BOD_5 Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(**4.9**, *2.1*) (**274**, *34*, *30*) (0.12, *0.06*, *0.05*) (**7.04**, *4.26*) (**0.23**) (1.10, *0.64*, 0.45, 0.40) (0.22, *0.09*)
	8.70 **V05G03** HW	BOD_5 Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(**5.3**) (**614**) (0.11, *0.05*) (**6.40**, 1.78) (**0.31**) (*0.99*, 0.56, 0.44, 0.44, 0.42) (0.27, *0.08*, *0.08*)
	8.70 storm **V05G03** HW	BOD_5 Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(**5.8**, *3.3*) (**143**, *29*, 7) (**0.44**, *0.08*, *0.07*) (**11.50**, *2.92*, 1.92, 1.85) (**0.22**, 0.07, *0.04*) (**2.08**, *0.64*, 0.50, 0.48) (*0.20*, *0.10*, 0.07)
	3.30 **V05G48** HW	Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(53) (*0.08*) (5.56, 2.08, 1.86, 1.83, 1.74) (0.08) (*0.76*, *0.69*, *0.61*, *0.60*, 0.48)
	0.60 **V05W30** W	Total Suspended Solids Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(19) (5.61, 1.69, 1.00) (*0.03*) (0.92, 0.52, 0.52) (0.26, 0.09, 0.09, 0.08, 0.07)

River/Stream	River Mile **STORET Code**	Parameter(s)	Value(s)
Turkey Run	4.80 **V05G49** HW	BOD_5 Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(*2.4*, *2.2*) (*39*, *26*, *24*, *22*, *18*) (0.17, 0.14, *0.08*, *0.06*) (**8.21**, 1.38) (0.08, *0.05*) (*0.84*, *0.65*, 0.52, 0.49) (*0.11*, *0.08*)
	1.70 **V05G50** HW	Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(*24*) (*0.07*, *0.05*) (**6.22**) (0.07) (0.57, 0.55, 0.53) (*0.13*, *0.11*, *0.10*)
Unnamed Tributary to Alum Creek @ RM 54.44	0.60 **V05G52** HW	BOD_5 Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(3.6, *3.0*, *2.9*) (54, *39*, *26*, *24*, *23*) (**0.19**, 0.11, *0.09*, *0.07*) (**9.21**, 2.18, 1.05) (**0.13**, *0.05*, *0.03*) (1.18, 0.49, 0.43, 0.40) (*0.14*, *0.12*, *0.10*)
Bunker Run	1.80 **V05G51** HW	BOD_5 Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(*2.4*) (**82**, *40*) (0.15) (5.69) (**0.10**) (*1.01*) (*0.12*, *0.09*)
Unnamed Tributary to Alum Creek @ RM 40.48	0.20 **V05G46** HW	Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(0.16) (**11.80**) (*0.04*) (*0.67*, 0.50) (*0.11*)
Unnamed Tributary to Alum Creek @ RM 38.75	0.30 **V05G45** HW	Total Suspended Solids Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen	(*18*, *17*, *16*) (**10.60**) (0.05) (0.54, 0.50)

River/Stream	River Mile **STORET Code**	Parameter(s)	Value(s)
Big Run	2.70 **V05G68** HW	Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(*15*) (0.16, *0.07*, *0.07*, *0.07*) (**19.60**, **14.40**) (**0.110**) (*0.75*, *0.63*, 0.55, 0.43) (*0.09*, *0.08*)
Unnamed Tributary to Alum Creek @ RM 25.50	0.20 **V05G67** HW	BOD_5 Total Suspended Solids Ammonia Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(**30**, **23**, **12.8**) (**563**, **424**, **141**) (**0.33**, **0.31**, **0.26**, **0.26**, 0.13) (0.07, 0.07, 0.05) (**6.54**, **3.75**, **3.03**) (0.27, *0.17*, *0.10*)
Unnamed Tributary to Alum Creek @ RM 23.47 aka Westerville Reservoir Trib.	0.80 **V05G66** HW	BOD_5 Ammonia Nitrite Tot. Kjeldahl Nitrogen	(*2.5*, *2.1*) (0.17, 0.16, 0.16, 0.16, 0.10) (0.06, *0.04*, *0.03*, *0.03*, *0.03*) (*0.99*, *0.87*, *0.84*, *0.73*, *0.62*)
Spring Run	3.70 **V05G64** HW	BOD_5 Total Suspended Solids Ammonia Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(**4.8**, *2.8*) (**105**) (**0.30**, 0.16) (*0.03*, *0.03*) (*0.76*, *0.71*, 0.51, 0.46, 0.44) (*0.11*)
	0.20 **V05G02** HW	BOD_5 Total Suspended Solids Ammonia Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(4.5) (56) (0.16) (*0.04*) (*0.70*, 0.48) (*0.09*)
West Spring Run	0.10 **V05G65** HW	BOD_5 Total Suspended Solids Ammonia Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(**5.8**, *2.6*) (**203**) (**0.23**) (0.05) (*0.71*, 0.44) (*0.20*)
Kilbourne Run	0.10 **V05G69** HW n=3	BOD_5 Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(**5.0**) (**224**) (0.15) (1.21) (0.07) (0.50) (*0.17*, *0.16*, *0.10*)

River/Stream	River Mile **STORET Code**	Parameter(s)	Value(s)
Bliss Run	0.60 **V05G71** HW	BOD_5 Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(3.7, *3.2*) (*31*) (0.11, *0.09*, *0.09*, *0.06*, *0.05*) (*3.13*, *2.85*, 2.20, 2.08, 1.30) (0.08, 0.05) (*0.67*, *0.65*, 0.41) (0.41, 0.34, 0.31, 0.28, 0.25)

Normal print values exceed the 50th percentile background
Italic print values exceed the *75th* percentile background
Underlined values exceed the 90th percentile background
Boldfaced values exceed the **95th** percentile background

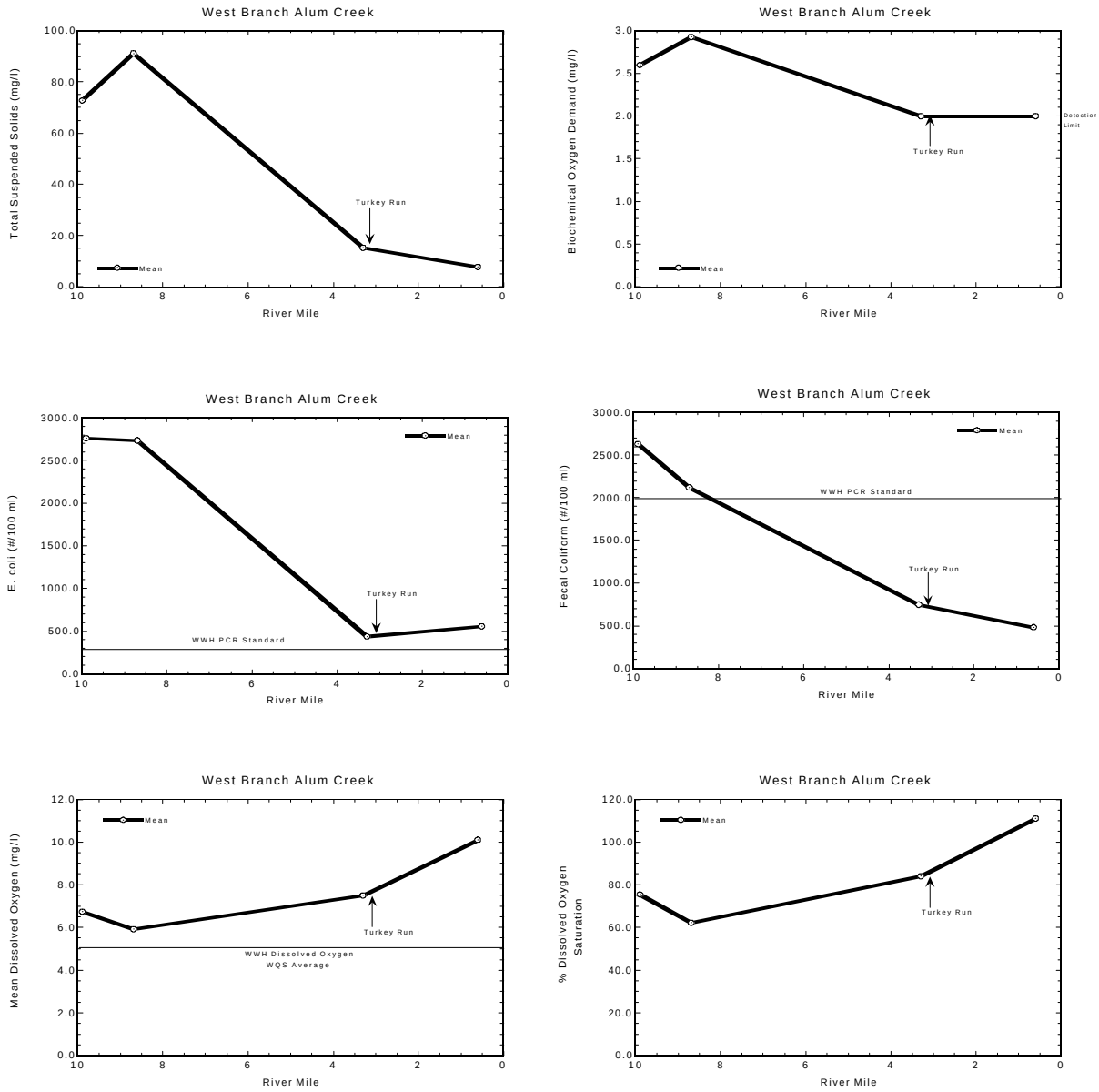

Figure 22. Longitudinal plots of mean Total Suspended Solids, Biochemical Oxygen Demand, E. coli, Fecal Coliform, Dissolved Oxygen, and Dissolved Oxygen Percent Saturation in West Branch Alum Creek, 2000.

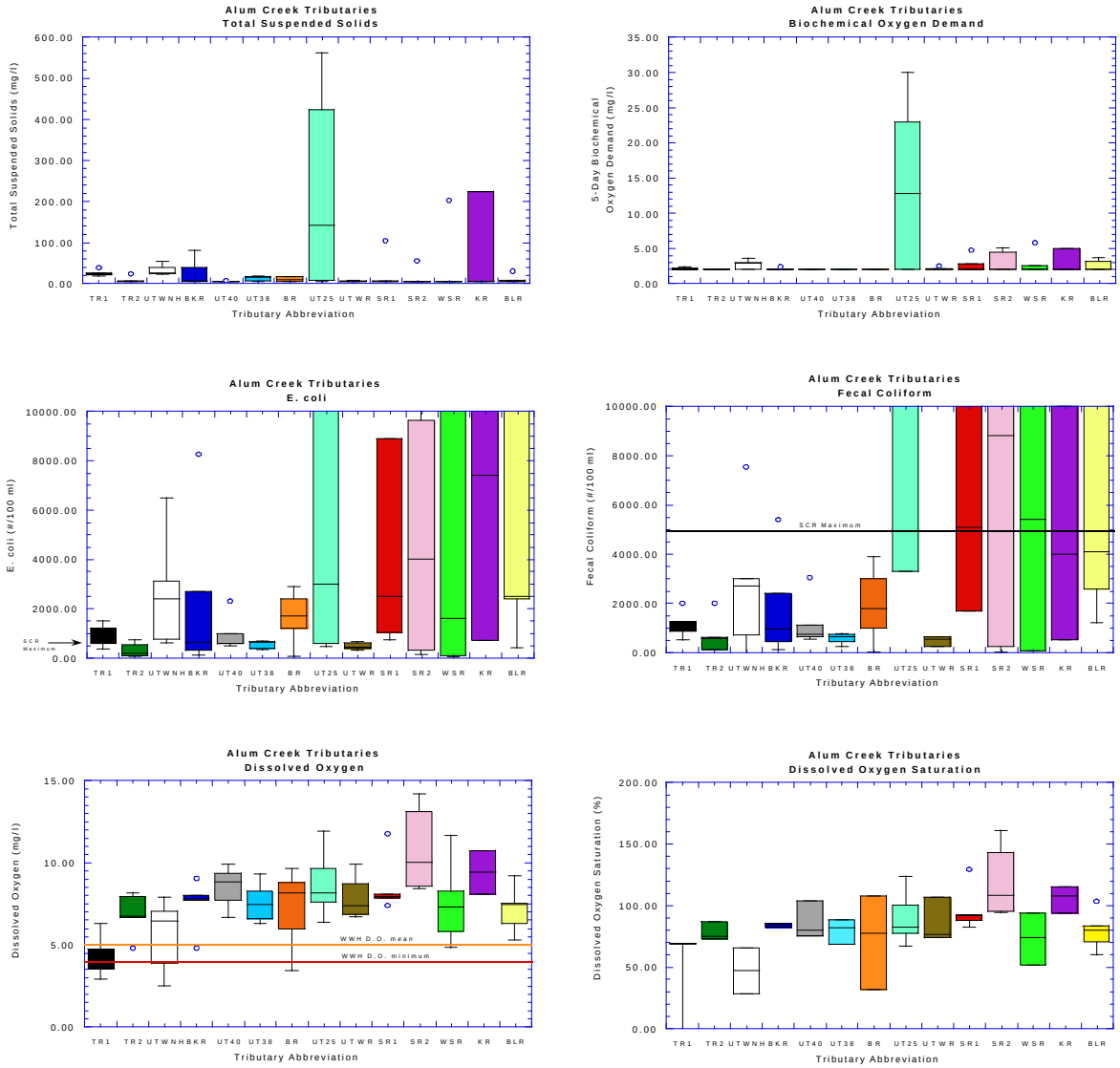

Figure 23. Box plots of Total Suspended Solids, Biochemical Oxygen Demand, E. coli, Fecal Coliform, Dissolved Oxygen, and Dissolved Oxygen Percent Saturation in TR1=Turkey Run (RM 4.8), TR2=Turkey Run (RM 1.7), UTWNH=Unnamed Trib. to Alum Cr. at RM 54.44 (RM 0.6), BKR=Bunker Run (RM 1.8), UT40=Unnamed Trib. at 40.48 (RM 0.2), UT38=Unnamed Trib. at RM 38.75 (RM 0.3), BR=Big Run (RM 2.7), UT25=Unnamed Trib. at RM 25.50 (RM 0.2), UTWR=Unnamed Trib. at RM 23.47 (RM 0.8), SR1=Spring Run (RM 3.7), SR2=Spring Run (RM 0.2), WSR=West Spring Run (RM 0.1), KR=Kilbourne Run (RM 0.1), and BLR=Bliss Run (RM 0.6), 2000.

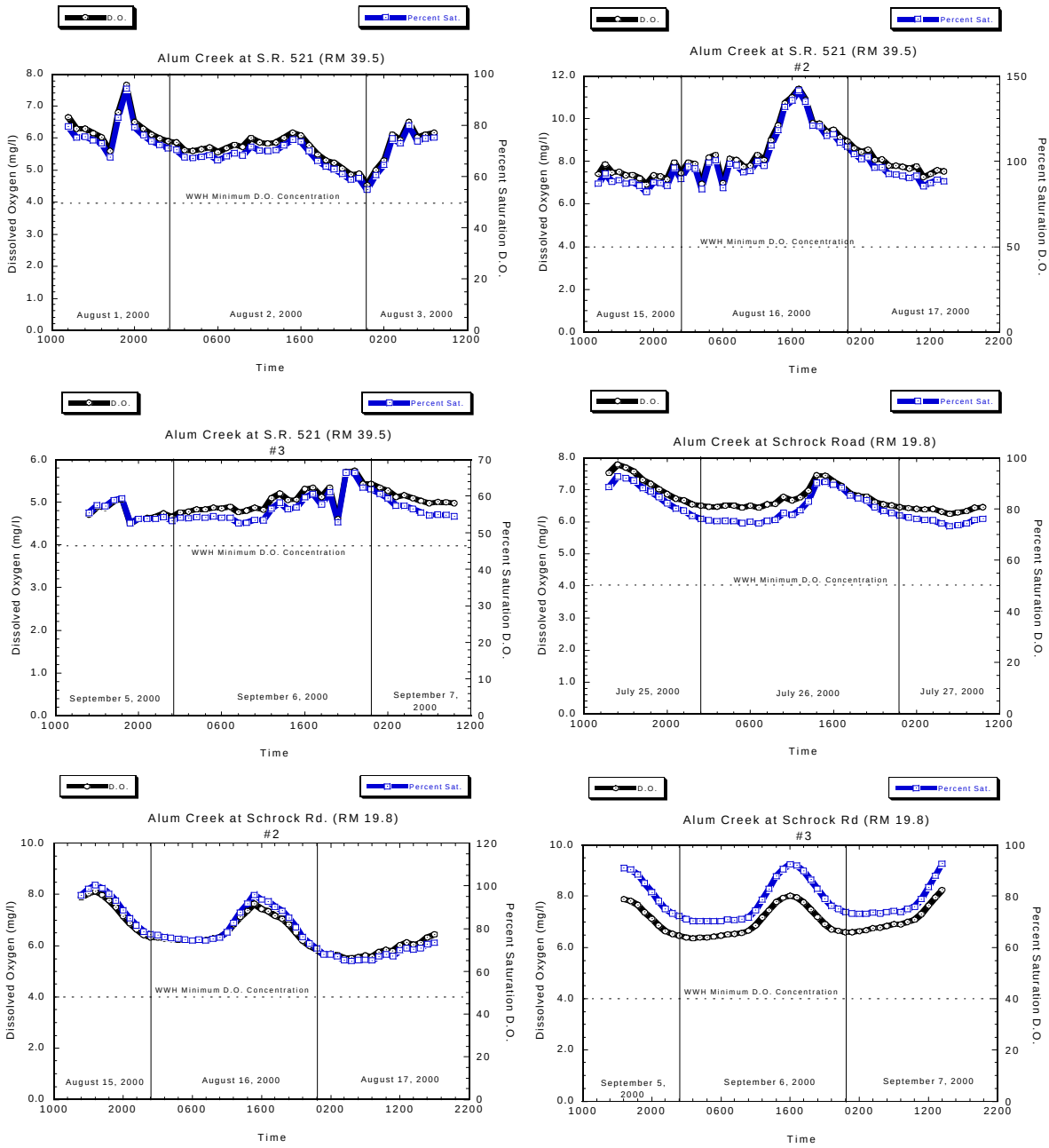

Figure 24. Diel Dissolved Oxygen concentrations and Dissolved Oxygen Percent Saturation in Alum Creek at SR 521 (RM 39.5) and Schrock Rd. (RM 19.8), 2000.

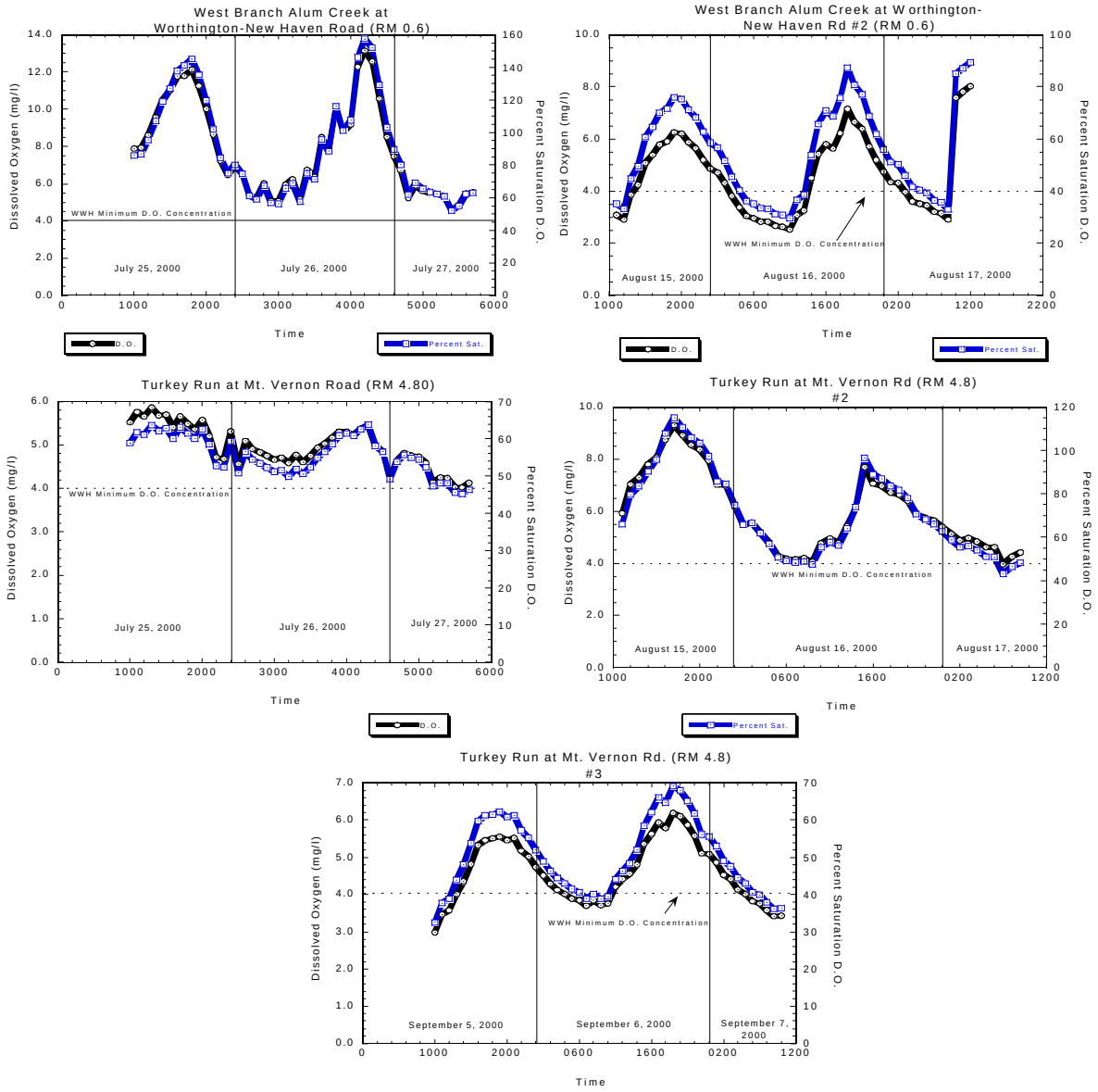

Figure 25. Diel Dissolved Oxygen concentrations and Dissolved Oxygen Percent Saturation in West Branch Alum Creek at Worthington-New Haven Rd. (RM 0.6) and Turkey Run at Mt. Vernon Rd. (RM 4.8), 2000.

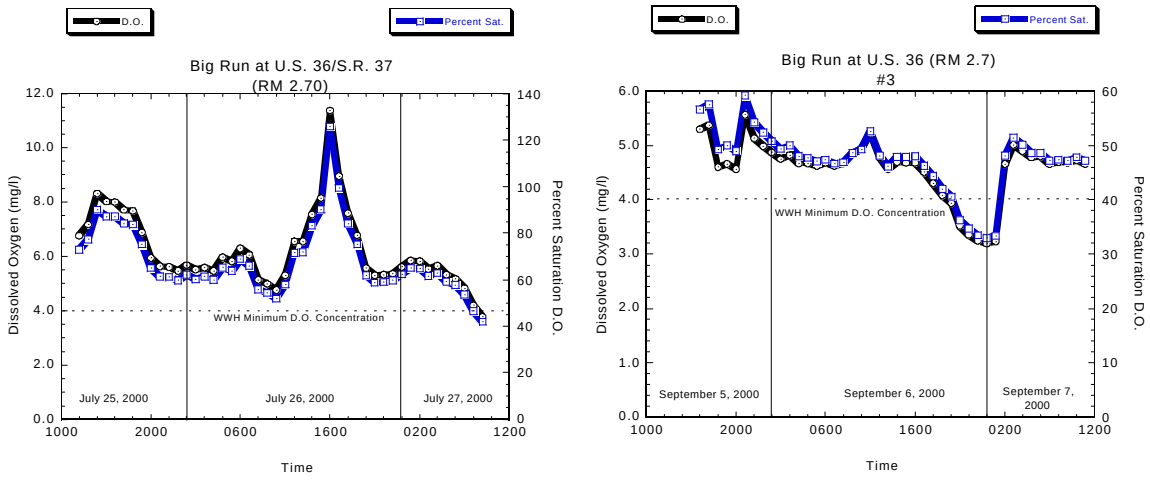

Figure 26. Diel Dissolved Oxygen concentrations and Dissolved Oxygen Percent Saturation in Big Run at US 36/SR 37 (RM 2.7), 2000.

Blacklick Creek and Tributaries

Blacklick Creek (WWH)

Chemical water quality problems in Blacklick Creek included bacterial contamination, depleted dissolved oxygen, and dissolved solids exceedences of Water Quality Standards criteria. Bacterial exceedences were found along the entire length of Blacklick Creek for both fecal coliform bacteria and *E. coli* (Table 9). Bacterial contamination was the most severe at RM 27.10 due to failing home sewage treatment systems. Moving downstream, bacterial problems eased with fewer exceedences at RMs 24.70 and 22.40. However, the number of bacterial exceedences then increased and remained consistent throughout the rest of the mainstem, mostly due to the presence of *E. coli* which exceeded the Primary Contact Recreation maximum criterion.

Dissolved oxygen exceedences in Blacklick Creek were confined to the uppermost headwater site at RM 27.10 (Table 9, Fig. 27). With numerous failing home sewage treatment systems discharging poorly treated sewage to the creek at this point, the creek cannot assimilate the sewage. This results in the observed low dissolved oxygen and high bacterial counts in addition to excessive nutrient enrichment (Tab. 15). Oxygen demanding wastes were mostly assimilated upon reaching RM 24.70 (Fig. 27). Mean dissolved oxygen concentrations recovered quickly moving downstream with a brief dip at RM 20.40 (cause unknown). The upward trend continued until just downstream of the Tussing Road WWTP. A significant decline in dissolved oxygen concentrations was noted

downstream of the Tussing Road WWTP outfall with recovery beginning to occur as the stream reached the Blacklick Estates WWTP discharge. Further depletion of dissolved oxygen was noted at RM 1.90.

Ammonia, nitrates, and phosphorus concentrations were excessive at times in the headwaters (RM 27.10) due to the aforementioned home discharges. Nutrient levels moderated at the site downstream (RM 22.40); however, supersaturated dissolved oxygen conditions were also evident with a median oxygen saturation near 115% and a range between about 100% to around 135% (Fig. 27). This is indicative of high primary productivity (nutrients removed from the water to produce algal biomass). Nutrient concentrations were low to moderate throughout the reach from RM 20.40 to RM 11.30 although supersaturated oxygen concentrations with the associated algal productivity existed at RM 16.60 (see also the Diel Dissolved Oxygen Study below), RM 13.70, and RM 11.30. Nutrient concentrations increased abruptly downstream of the Tussing Road WWTP and remained elevated at the last sampling site at RM 1.90. Both the Tussing Road WWTP and Blacklick Estates WWTP contribute significant loadings of nitrates and phosphorus to the creek. The Tussing Road WWTP also infrequently contributes appreciable concentrations of ammonia during plant breakdowns or upsets. Oxygen saturation remained in a normal range throughout the rest of the mainstem.

A noteworthy increase in mean suspended solids indicated impacts from development in the watershed including the tributaries French Run, Lees Creek, Dysar Run, Unnamed Tributaries at RM 12.89 and RM 10.36, and Powell Ditch. The Tussing Road WWTP as well as the Blacklick Estates WWTP also provided some contributions to the increase in suspended solids due to irregularities in treatment at times during the summer.

Swisher Creek (WWH)

Chemical water quality was evaluated in Swisher Creek at RM 1.30. A single WQS violation of the dissolved oxygen minimum criterion was noted during the survey in addition to three exceedences of the *E. coli* criterion (Table 9). Nutrient enrichment was indicated by elevated total phosphorus concentrations in every sample as well as occasional detections of TKN and nitrate+nitrite in excess of background reference median values (Table 16). Since biological communities were not evaluated in Swisher Creek it was not possible to determine the attainment status of the designated WWH aquatic life use.

French Run (WWH)

French Run was characterized by a site at RM 0.70 where water quality samples were collected. Exceedences of bacterial WQS criteria were found in every sample (Table 9) and this stream was one of the most bacterially contaminated of the Blacklick Creek tributaries (Fig. 28). Nutrients, except for phosphorus, were not detected above median background reference concentrations. Only 3 of 5 samples showed detections for phosphorus above median background levels (Table 16).

Moderate to low concentrations of total suspended solids were detected in 40% of the samples. Development in this watershed has directly influenced chemical water quality conditions.

North Branch French Run (EWH)

Samples to assess chemical water quality were collected from North Branch French Run at RM 0.20 near the mouth. Bacterial WQS criteria were exceeded in most samples, primarily due to high amounts of *E. coli* (Table 9). Nutrient concentrations were not problematic other than three detections of total phosphorus that were above background reference median values (Table 16).

Unnamed Tributary to Blacklick Creek at RM 12.89 (WWH)

Chemical water quality assessment was performed at RM 0.30 on this headwater stream. Moderate bacterial contamination was present in the form of elevated concentrations of *E. coli* (Table 9). Nutrient enrichment was apparent with elevated concentrations of total phosphorus present in all samples and two instances of nitrate+nitrite above the background reference median (Table16, Fig. 28). Total suspended solids concentrations were elevated only during a single storm event. Two small package WWTPs located upstream may heve exacerbated the bacteria and nutrient enrichment noted in this creek. Development in this watershed also directly influenced chemical water quality. Since biological communities were not evaluated in this tributary, it was not possible to determine the attainment status of the WWH aquatic life use.

Lees Creek

Water quality problems in Lees Creek were mainly limited to moderate concentrations of *E. coli* bacteria noted on three occasions (Table 9). However, nutrient enrichment was inferred via observation of mean oxygen saturations of around 115% even though actual concentrations of nutrients were low (Fig. 28). Consistently supersaturated conditions typically mean algal overpopulation due to nutrient enrichment and high light conditions from an open channel. Algal blooms were directly observed during water quality sampling of this modified stretch of the creek. Low nutrient concentrations indicated that nutrients were either utilized as soon as they become available, or that the nutrient excesses were intermittent. The intermittent nature of the enrichment was further substantiated by the single high concentration of TKN noted instream during the sampling effort (Table 16). Total suspended solids concentrations were also moderately elevated with 3 of 5 samples exhibiting values in excess of background reference median concentrations. Ongoing development in this watershed directly influenced chemical water quality conditions.

Powell Ditch (WWH)

Chemical water quality was evaluated in Powell Ditch at one location (RM 0.50). Bacterial WQS criteria were exceeded in every sample (Table 9). Nutrient enrichment was not a major issue although a slight to moderate problem from suspended solids was apparent (Table 16).

Dysar Run (WWH)

Dysar Run was assessed for chemical water quality at two locations (RMs 3.00 and 1.60). The site at RM 3.00 was impacted by contamination from *E. coli* and fecal coliform bacteria (Table 9) in addition to moderate concentrations of total phosphorus, TKN and suspended solids (Table 16). Bacterial contamination attenuated greatly at RM 1.60 where only a single exceedence was noted. Nutrient enrichment and impacts from suspended solids were also diminished compared with the upstream site. Dissolved oxygen data revealed supersaturated conditions at each location and confirmed algal overproduction noted during visual inspection of the creek (Figs. 28, 30). Development in this watershed directly influenced chemical water quality conditions.

Unnamed Tributary to Blacklick Creek at RM 10.36 (WWH)

This unnamed tributary was impacted by bacterial exceedences of WQS criteria (Table 9). Nutrient enrichment was not apparent either through chemical analysis or via visual evidence of algal overproduction (Table 16). Adequate riparian shading is likely a factor in this regard. Excessive suspended solids were noted during one sampling event following precipitation. Development in this watershed directly influenced chemical water quality conditions.

Diel Dissolved Oxygen Study-Blacklick Creek

Diel dissolved oxygen patterns were evaluated at two locations in the Blacklick Creek subbasin at RMs 16.60 (Broad St.) and 1.90 (Hamilton Rd.). Each site was assessed three times during the summer, July 25-27, 2000, August 15-17, 2000, and September 5-7, 2000. The WWH minimum criterion for dissolved oxygen (4 mg/l) was never violated during the survey period at either site. However, the site at RM 16.60 exhibited wide diel fluctuations in dissolved oxygen concentrations (Fig. 29). Each assessment revealed supersaturation of 140 to 150%. The large variability in dissolved oxygen concentrations was indicative of substantial primary productivity at this site which, in turn, meant nutrient enrichment and little or no riparian shading. The station at RM 1.90 exhibited no supersaturation. Diel fluctuations were narrower and more normal when compared to the upstream site.

Dysar Run at RM 1.60 (Broad St.) was also evaluated for diel dissolved oxygen patterns over the same three time periods as the Blacklick Creek sites (Fig. 30). Dissolved oxygen concentrations never fell below the WWH minumum criterion of 4 mg/l during the evaluation periods. Critically high supersaturated conditions were observed during only the evaluation done in September. Values over 150% were noted, again a symptom of severe algal overproduction from an open canopy (missing riparian buffer) and nutrient enrichment.

Water Column Organics-Blacklick Creek

Water samples were obtained from Blacklick Creek at two sites in September 2000 and evaluated

for organic constituents. The sample taken at RM 13.70 was found to contain both alpha-BHC and dieldrin (Table 11). The site at RM 1.90 showed only gamma-BHC, also known as Lindane. Dieldrin concentrations found at RM 13.70 exceeded the Ohio River basin water quality standards for the protection of aquatic life (7.5 : g/l versus the standard of 5.0 : g/l). Sources for this material were unknown.

Table 15. Comparison of background nutrient and demand parameter concentrations with those found in the Big Walnut Creek study area, 2000. Comparisons are made to Eastern Corn Belt Plains (ECBP) ecoregion background 50th percentile (median) (Normal print), 75th (*Italic print*), 90th (Underlined), and 95th (**Boldfaced**) percentile values for headwaters, wadeable, and small river sites. Units are mg/l for all parameters. Sample size, n = 5 unless otherwise stated. HW = headwater, W = wadeable, SR = small river.

River/Stream	River Mile **STORET Code**	Parameter(s)	Value(s)
Blacklick Creek	27.10 **V05S33** HW	BOD_5 Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(**26.0**, **17.4**, **14.0**, 3.4) (*17*, *16*, 8) (**11.30**, **7.21**, **3.82**, 0.17, 0.12) (**8.16**, *4.59*, 2.13, 1.80, 1.21) (**1.43**, **1.26**, **0.59**, **0.15**, 0.05) (**18.00**, **11.60**, **5.73**, 1.22, *0.95*) (**5.40**, **4.09**, **3.15**, 0.27, 0.22)
	24.70 **V05G54** HW	BOD_5 Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(4.7, *2.3*, *2.1*) (63, 10) (0.10, *0.09*, *0.09*, *0.08*) (*3.47*, *3.08*) (**0.10**, **0.10**) (1.12, 1.06, *0.94*, *0.76*, *0.74*) (0.21, *0.18*, *0.15*, *0.10*, *0.08*)
	22.40 **V05W36** HW	BOD_5 Total Suspended Solids Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(*2.5*) (*15*, 10) (1.82) (*0.03*) (*0.72*, 0.59, 0.48) (*0.16*, *0.09*, *0.08*, 0.05)
	20.40 **V05S31** HW	Total Suspended Solids Tot. Kjeldahl Nitrogen Phosphorus	(8) (0.53) (*0.12*, 0.07, 0.05)
	16.60 **V05S30** HW	BOD_5 Nitrate+Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(*2.8*) (1.38, 1.62, 1.70, 1.76, 1.88) (0.58, 0.47, 0.43) (*0.16*, *0.12*, *0.12*, *0.09*, *0.08*)

River/Stream	River Mile **STORET Code**	Parameter(s)	Value(s)
	13.70 **V05G53** W	NA	NA
	11.30 **V05W18** W	Total Suspended Solids Nitrate+Nitrite Nitrite	(17) (0.89) (*0.03*)
	Tussing Road WWTP Mix Zone **V05W33** W	BOD_5 Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(*2.8*, *2.5*, *2.4*) (20, 14) (**1.53**, 0.12, 0.11, *0.10*, *0.09*) (**30.50**, 1.32, 1.17, 1.10) (**0.21**, **0.13**, **0.12**, **0.09**, 0.06) (**2.35**, 1.02, 0.92, *0.79*, *0.69*) (**0.84**, **0.40**, *0.21*, *0.15*)
	11.00 **V05G55** W	BOD_5 Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(3.0, *2.7*, *2.1*) (24, 22) (**1.45**, 0.11, 0.11, 0.10, *0.09*) (*3.64*, 1.28, 1.12, 1.06) (**0.20**, **0.14**, **0.11**, 0.06) (**2.21**, 1.04, 0.99, *0.71*, 0.59) (**1.00**, **0.53**, **0.48**, 0.23, *0.15*)
	8.80 **V05P15** W	Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(*36*, *33*) (0.13, *0.07*) (1.39, 1.22, 1.09, 1.02, 0.84) (0.07, 0.05, *0.03*) (*0.73*, *0.71*, 0.55) (**0.46**, **0.33**, 0.12, 0.11, 0.07)
	Blacklick Est. WWTP Mix Zone **V05G56** W	BOD_5 Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(**8.1**, **4.2**, *2.2*, *2.1*) (*41*, 24, 19, 18) (**0.48**, **0.17**, 0.11, *0.07*) (**7.06**, *4.78*, *4.69*, *4.37*, *2.80*) (**0.40**, 0.07, *0.02*, *0.02*, *0.02*) (**1.65**, **1.19**, 1.04, *0.88*, *0.67*) (**1.08**, **1.02**, **1.00**, **0.93**, **0.51**)
	4.60 **V05S14** W	BOD_5 Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(*2.3*, *2.1*) (63, 15) (0.11, *0.09*, *0.07*, *0.05*) (*3.42*, *2.84*, 1.48, 1.17, 0.89) (0.05, 0.05, *0.02*) (*0.73*, *0.73*, *0.64*, 0.53) (**0.58**, **0.55**, 0.29, *0.13*, 0.09)

River/Stream	River Mile **STORET Code**	Parameter(s)	Value(s)
	1.90 **V05W31** W	BOD_5 Total Suspended Solids Ammonia Nitrate+Nitrite Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(*2.8*) (**126**, 23, 21, 18, 15) (**0.15**, 0.14, 0.12, 0.11, *0.07*) (1.70, 1.54, 1.48, 1.03, 0.89) (**0.09**, 0.06, *0.05*, *0.04*, *0.03*) (0.5) (0.28, 0.27, 0.26, *0.21*, *0.15*)

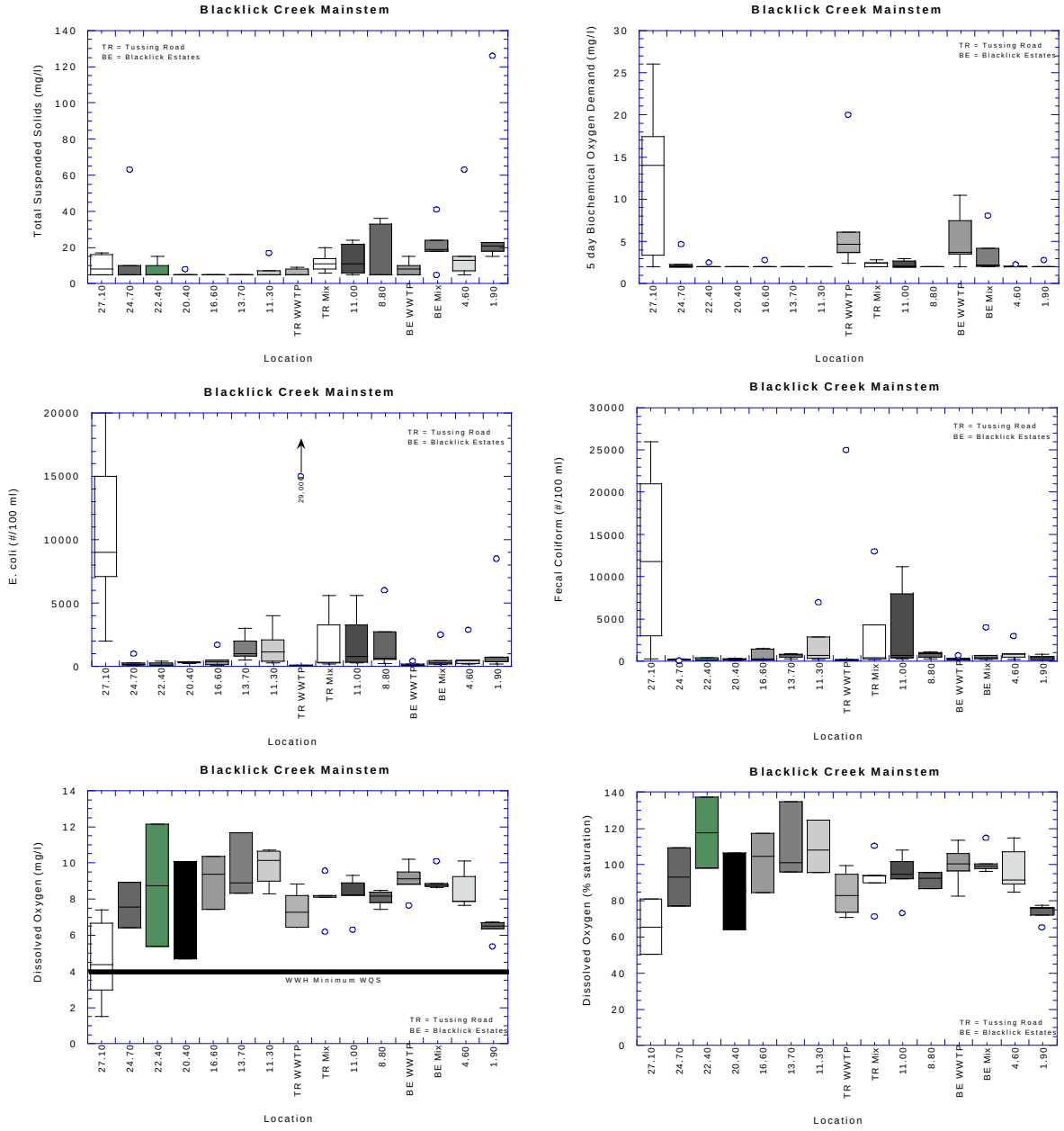

Figure 27. Box plots of Total Suspended Solids, five-day Biochemical Oxygen Demand, E. coli, Fecal Coliform, Dissolved Oxygen, and Dissolved Oxygen Percent Saturation in Blacklick Creek, 2000.

Table 16. Comparison of background nutrient and demand parameter concentrations with those found in the Big Walnut Creek study area, 2000. Comparisons are made to Eastern Corn Belt Plains (ECBP) ecoregion background 50th percentile (median) (Normal print), 75th (*Italic print*), 90th (Underlined), and 95th (**Boldfaced**) percentile values for headwaters, wadeable, and small river sites. Units are mg/l for all parameters. Sample size, n = 5 unless otherwise stated. **(** = Exceptional Warmwater Habitat, HW = headwater, W = wadeable.

River/Stream	River Mile **STORET Code**	Parameter(s)	Value(s)
Swisher Creek	1.30 **V05G80** HW	Total Suspended Solids Nitrate+Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(*25*) (2.08, 0.90) (*1.02*, *0.63*, *0.61*, 0.59) (0.28, 0.22, *0.10*, *0.10*, *0.10*)
North Branch French Run	0.20 **V05G17E** HW	Phosphorus	(0.07, 0.06, 0.05)
French Run	0.70 **V05G76** HW	Total Suspended Solids Phosphorus	(*17*, 7) (*0.10*, 0.05, 0.05)
Unnamed Tributary to Blacklick Creek @ RM 12.89	0.30 **V05G75** HW	Total Suspended Solids Nitrate+Nitrite Phosphorus	(*40*) (1.94, 1.01) (*0.19*, *0.16*, *0.14*, *0.14*, *0.11*)
Lees Creek	0.30 **V05G74** HW	Total Suspended Solids Tot. Kjeldahl Nitrogen	(*15*, 10, 10) (**4.56**)
Powell Ditch	0.50 **V05G72** HW	BOD_5 Total Suspended Solids Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(*2.5*) (*16*, 10, 8) (*0.04*) (0.45, 0.41) (0.07, 0.05)
Dysar Run	3.00 **V05G78** HW	BOD_5 Total Suspended Solids Ammonia Nitrate+Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(**5.7**) (*36*, *36*, *27*, 8, 7) (*0.10*, *0.07*) (0.85) (*0.72*, *0.67*, 0.56, 0.43) (*0.15*, *0.08*, 0.07, 0.06, 0.05)
	1.60 **V05G79** HW	Total Suspended Solids Nitrite Tot. Kjeldahl Nitrogen Phosphorus	(*19*, 11, 10) (*0.03*) (0.45, 0.41) (*0.13*, 0.05, 0.05)
Unnamed Tributary to Blacklick Creek @ RM 10.36	0.30 **V05G73** HW	Total Suspended Solids Nitrite Phosphorus	(**256**, 9) (*0.04*) (*0.14*, 0.07, 0.05)

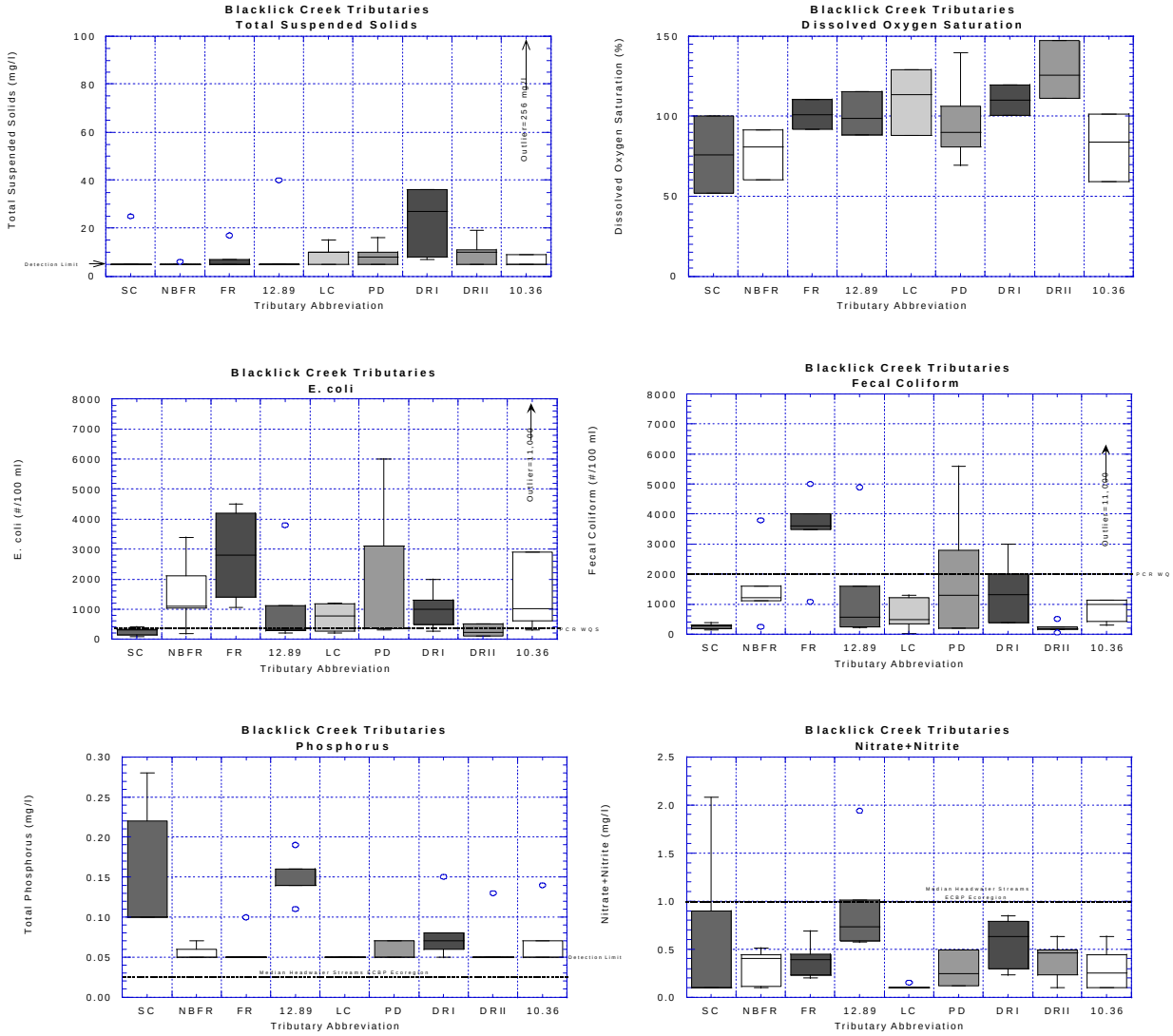

Figure 28. Box plots of Total Suspended Solids, Dissolved Oxygen Percent Saturation, E. coli, Fecal Coliform, Total Phosphorus, and Nitrate+Nitrite-Nitrogen in the Blacklick Creek tributaries: SC=Swisher Cr. at RM 1.3, NBFR=N. Br. French Run at RM 0.2, FR=French Run at RM 0.7, 12.89=Trib. to Blacklick Cr. (RM 12.89) at RM 0.3, LC=Lees Cr. at RM 0.3, PD=Powell Ditch at RM 0.5, DRI=Dysar Run at RM 3.0, DRII=Dysar Run at RM 1.6, and 10.36=Trib. to Blacklick Cr. (RM 10.36) at RM 0.3, in 2000.

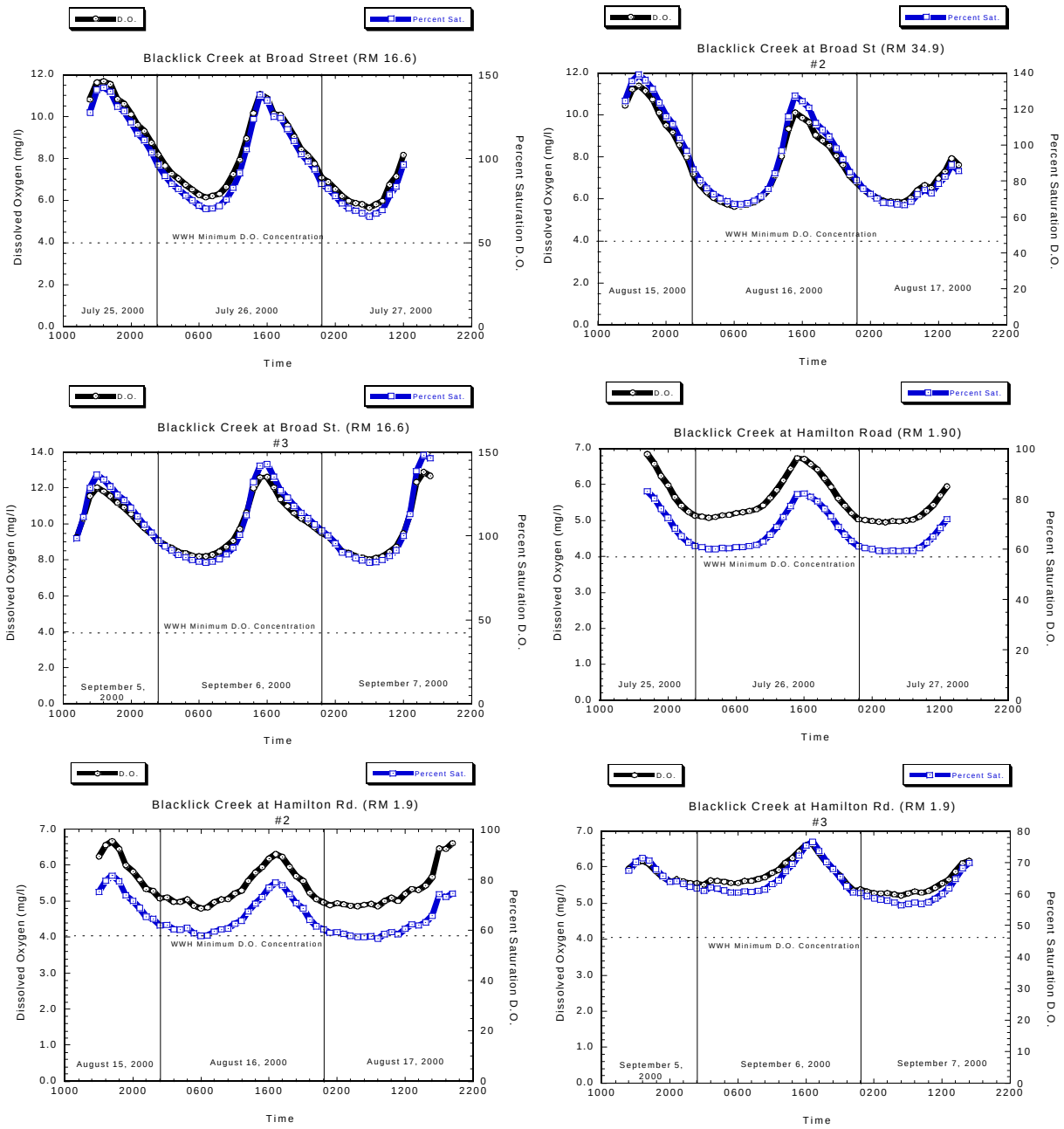

Figure 29. Diel Dissolved Oxygen concentrations and Dissolved Oxygen Percent Saturation in Blacklick Creek at Broad Street (RM 16.6) and Hamilton Rd. (RM 1.9), 2000.

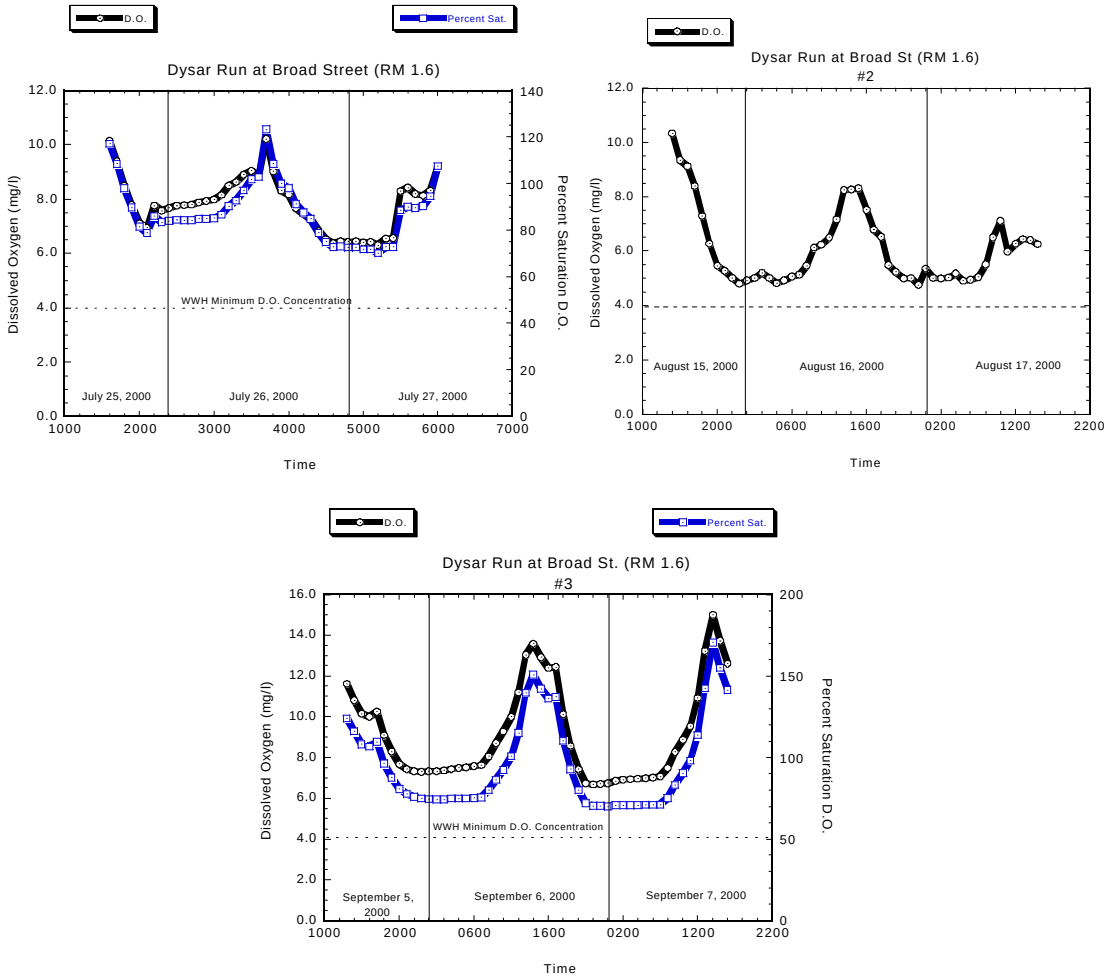

Figure 30. Diel Dissolved Oxygen concentrations and Dissolved Oxygen Percent Saturation in Dysar Run at Broad Street (RM 1.6), 2000.

Sediment Chemistry

Sediment samples were obtained directly from the rivers and creeks of the study area from locations instream where sediments had been freshly deposited and not yet consolidated. Samples were collected and analyzed for a variety of metals, pesticides, PCBs, and volatile/semi-volatile organic compounds. Concentrations of metals were compared with reference area conditions within Ohio and categorized therein as ranging from not elevated up to extremely elevated. Certain metals and organic compounds (including pesticides and PCBs) were evaluated using consensus-based Sediment

Quality Guidelines developed by MacDonald, 2000. Values below the threshold effect concentration (TEC) are not expected to show adverse effects on sediment-dwelling organisms. Values above the probable effect concentration (PEC) are likely to show negative effects on sediment-dwelling organisms while values greater than the TEC, but less than the PEC are less clear as to their impact.

Big Walnut Creek Mainstem

Sediment samples were collected from six sites on the Big Walnut Creek mainstem. The uppermost sites at RMs 66.60 and 49.00 showed minor contamination from metals and organic compounds. Table 17 shows slightly elevated concentrations of cadmium, chromium, and zinc along with elevated concentrations of aluminum and barium at RM 66.60. Mercury was also detected. Organic constituents included very low levels of acetone and acetophenone (Table 18). The site at RM 49.00, downstream of Sunbury, exhibited only slightly elevated concentrations of aluminum along with acetone. Impairment of the benthic or fish communities due to sediment contamination was not apparent at these sites (Table 1).

Sediment contamination increased in a downstream direction. The site at State Route 161 (RM 34.90), downstream from Hoover Reservoir, showed increased contamination from metals including slightly elevated concentrations of arsenic, cadmium, and chromium along with highly elevated aluminum and extremely elevated concentrations of barium and manganese (Table 17). Mercury was also detected. Threshold effect concentrations (TEC as defined by MacDonald, 2000) of fluoranthene and pyrene (two polycyclic aromatic hydrocarbons or PAHs) were also detected along with acetone (Table 18). Impairment of the benthic macroinvertebrate community due to sediment contamination was not apparent at this site (Table 1).

Further increases in sediment contaminants were noted at Hamilton Road(RM 27.00) downstream of Port Columbus International Airport. Slightly elevated concentrations of chromium, iron, and manganese were noted as were elevated concentrations of aluminum, arsenic, barium, cadmium, copper, and zinc (Table 17). Cadmium, lead, and zinc were notable as they were greater than the probable effect concentration (PEC, MacDonald, 2000). Mercury was also detected. Organic contaminants in the form of PAHs (Table 18) were also present. Chrysene, fluoranthene, and pyrene all exceeded the PEC and benz[a]anthracene, benzo[a]pyrene, phenanthrene, and total PAHs all exceeded the TEC (Ibid). Impairment of the benthic or fish communities due to sediment contamination was not apparent at this site. In fact, the fish and macroinvertebrate indicies for this reach were the highest found in the survey, all in the exceptional range.

The site with the greatest relative sediment contamination in Big Walnut Creek was found at Williams Road (RM 15.80). Extremely elevated concentrations of cadmium were detected along with highly elevated concentrations of aluminum, barium, and zinc, and elevated concentrations of arsenic, chromium, copper, and lead (Table 17). Slightly elevated concentrations of iron, manganese, and nickel were also found. Cadmium, lead, and zinc exceeded the TEC (MacDonald, 2000). PAHs, pesticides and PCBs were present in the sediments at this site. PAH compounds

exceeding the PEC included benz[a]anthracene, benzo[a]pyrene, chrysene, fluoranthene, phenanthrene, pyrene, and total PAHs (Table 18). Fluoranthene was also found to exceed the PEC, however, the predictive PEC calculated in MacDonald (2000) was found to be unreliable. The pesticides, 4-4' DDD, gamma chlordane, and alpha chlordane were all found to be greater than the TEC. Total PCBs were also in excess of the TEC. In spite of the relatively significant level of sediment pollution, impairment of the benthic or fish communities due to sediment contamination was very slight (macroinvertebrate) or not apparent (fish). The macroinvertebrate and fish communities were in very good to exceptional condition respectively (Table 1).

The most downstream sediment monitoring site occurred at U.S. 23 (RM 1.70). Both metals and organic compounds were found in sediments in varying concentrations (Tables 17, 18). Extremely elevated concentrations of aluminum were discovered along with highly elevated concentrations of barium, cadmium, chromium, copper, and zinc. Elevated concentrations of arsenic, iron, manganese, and nickel were also noted along with slightly elevated concentrations of lead. Mercury was also detected. Cadmium, copper, lead, and zinc concentrations were greater than the TEC as published in MacDonald, 2000. Organic contaminants observed at this site included the pesticide methoxychlor and the plasticizer bis(2-ethylhexyl)phthalate and several PAHs. Benzo[a]pyrene, fluoranthene, phenanthrene, and total PAHs were found to be greater than the TEC while chrysene and pyrene exceeded the PEC. The effects of these contaminants in the sediments may have contributed to the nonattainment of the macroinvertebrate community at this site (Table 1). Fish community attainment seemed unaffected by sediment contamination although fish tissue results from 1996 did show mercury, certain pesticides, and PCBs in fillet samples.

Sediment contamination in Big Walnut Creek was slight in upper stream reaches. Below Hoover Reservoir, contamination increased moving downstream to Williams Road. The site at U.S. 23, while contaminated, was less impacted than the site at Williams Road. Contamination is likely due to the urban nature of the lower watershed with sources ranging from diffuse runoff, old leaking landfills, industrial operations (past and present) or/and historical disposal of materials directly into the creek and its tributaries.

Big Walnut Creek Tributaries

Rocky Fork

Rocky Fork sediment was evaluated at two different sites (RMs 7.10 and 1.10). Metals contamination was found at both sites, however, organic compounds were not found at either site (Table 20).

The site at RM 7.10 exhibited extremely elevated concentrations of aluminum, barium, and chromium; highly elevated concentrations of arsenic, cadmium, copper, iron, and zinc; and elevated concentrations of manganese and nickel (Table 19). Lead was below laboratory detection in the sample; however, the laboratory detection level was above the concentration deemed slightly

elevated. Cadmium, copper, and zinc also exceeded the consensus-based TEC (MacDonald, 2000) while nickel exceeded the consensus-based PEC (MacDonald, 2000). Nutrients concentrations in the sediment were also evaluated. Both ammonia and phosphorus were found. Phosphorus was found to be highly elevated when compared to the guidelines published by Kelly and Hite (1984). Sediment contamination found at this site did not appear to negatively impact the biological communities (Table 1).

The Hamilton Road site (RM 1.10) was characterized by extremely elevated concentrations of aluminum; highly elevated concentrations of arsenic, barium, and chromium; elevated concentrations of cadmium, copper, iron, and manganese; and slightly elevated concentrations of lead and zinc (Table 19). Nickel was below laboratory detection in the sample; however, the laboratory detection level was above the concentration deemed slightly elevated. Copper and lead exceeded the consensus-based TEC (MacDonald, 2000). Impairment of the benthic or fish communities due to sediment contamination was not apparent at this site (Table 1).

Airport Tributary

Both metals and organic compounds were found to contaminate the sediments of this small tributary draining the Port Columbus International Airport. Samples were obtained near the confluence with Big Walnut Creek. Extremely elevated levels of copper along with highly elevated concentrations of aluminum, barium, and cadmium were noted as were elevated concentrations of chromium and zinc (Table 19). Slightly elevated concentrations of arsenic and iron were also discovered. Organic compounds found in the sediments included the volatile compound acetone as well as PAHs, many of which exceeded the TEC or PEC (Table 20) as stated in MacDonald (2000). Biological community impairment may be linked to contaminated sediments found at this site (Table 1).

Sugar Run

Sediments from Sugar Run near the mouth (RM 0.7) were found to be contaminated with metals and organic compounds. Metals contamination included extremely elevated concentrations of aluminum, barium, and manganese; highly elevated concentrations of arsenic, cadmium, chromium, and iron; and elevated concentrations of copper, nickel and zinc (Table 19). Cadmium, lead, and zinc exceeded the consensus-based TEC (MacDonald, 2000) while nickel exceeded the consensus-based PEC (MacDonald, 2000). The only organic contaminant discovered in Sugar Run consisted of fluoranthene above the TEC (MacDonald, 2000) as noted in Table 20. Nutrients, in the form of ammonia and phosphorus, were also evaluated. Ammonia was present at slightly above detection levels and phosphorus was found at slightly elevated concentrations according to guidelines published by Kelly and Hite (1984). Sediment contamination did not appear to impair biological communities at this site (Table 1).

Little Walnut Creek

Sediments taken from Little Walnut Creek at RM 1.40 were only contaminated with metals. Highly elevated concentrations of aluminum were detected as were elevated concentrations of arsenic, barium, cadmium, and chromium (Table 19). Slightly elevated concentrations of copper, iron, nickel, and zinc were also found. No metals exceeded the TEC or PEC (MacDonald, 2000) in Little Walnut Creek.

Duncan Run

Sediments obtained from Duncan Run at RM 2.70 were free from organic contamination (Table 20) although metals contamination was apparent (Table 19). Highly elevated concentrations of aluminum were present along with elevated amounts of arsenic, barium, and chromium. Cadmium, iron, manganese, nickel, and zinc were slightly elevated above reference conditions. No metals were found to exceed the TEC or PEC in Duncan Run at RM 2.70.

Rattlesnake Creek

Rattlesnake Creek sediment samples were collected from a site near the mouth (RM 0.10). The sample was free from organic contamination (Table 20) although metals contamination was present (Table 19). Extremely elevated concentrations of aluminum were present as were highly elevated concentrations of barium, cadmium, and chromium. Elevated concentrations of copper, iron, and zinc were also discovered along with slightly elevated concentrations of arsenic and lead. Nickel was undetected in the sample, although the detection level was greater than the elevated reference guideline. Cadmium, lead, and zinc all exceeded the TEC found in MacDonald (2000). Fish community impairment in Rattlesnake Creek may have been linked to the contaminated sediment (Table 1).

Alum Creek

Alum Creek sediment samples were obtained from the site at RM 3.80. Both metals and organic contaminants were detected in the sample. Highly elevated concentrations of cadmium along with elevated concentrations of aluminum, barium, chromium, copper, lead, and zinc were discovered, as well as slightly elevated concentrations of arsenic (Table 19). Cadmium, lead, and zinc all exceeded the TEC found in MacDonald (2000). Organic contaminants found in Alum Creek consisted of pesticides, PCBs, and PAHs. 4-4' DDD and chlordane isomers were above the TEC as was fluoranthene. Benz[a]anthracene, benzo[a]pyrene, chrysene, phenanthrene, pyrene, and total PAHs were all greater than the PEC (Table 20). Macroinvertebrate community impairment may have been associated with the sediment contamination at this site (Table 1).

Blacklick Creek

Sediment samples were obtained from three separate sites on the Blacklick Creek mainstem and one site on a tributary stream (Dysar Run). The upstream site on the Blacklick Creek mainstem (RM 22.40) contained slightly elevated concentrations of arsenic, cadmium, chromium, copper and zinc. Elevated concentrations of barium were also found as well as highly elevated levels of aluminum (Table 19). Polycyclic aromatic hydrocarbons (PAHs) were also detected in sediments at this site as were 3&4-methylphenol and toluene (Table 20). Acetone and 2-butanone were also detected in the sample; however these compound were also found in the trip blank indicating contamination. Total PAHs exceeded the PEC whereas several individual PAH compounds exceeded the TEC or PEC.

Sediments obtained from Blacklick Creek at RM 11.30 contained slightly elevated concentrations of copper, iron, manganese, and zinc along with elevated concentrations of arsenic, barium, cadmium, and chromium as well as highly elevated concentrations of aluminum (Table 19). Zinc concentrations exceeded the TEC. The only organic compound detected at this site was the plasticizer, bis(2-ethylhexyl)phthalate (Table 20). Impairment of the macroinvertebrate community due to sediment contamination was not evident (Table 1).

Slightly elevated concentrations of arsenic, cadmium, chromium, copper, and zinc along with elevated concentrations of barium and highly elevated concentrations of aluminum were detected in sediments obtained from Blacklick Creek near the mouth at RM 1.90 (Table 19). Total PAHs were detected at concentrations above the TEC as were two individual PAH compounds (Table 20). Impairment of the macroinvertebrate community due to sediment contamination was not apparent at the nearby upstream site (Table 1).

Dysar Run

Sediments collected from Dysar Run at RM 1.60 showed slightly elevated concentrations of cadmium, copper, and zinc; elevated concentrations of arsenic, iron, and manganese; highly elevated concentrations of barium and chromium; and extremely elevated concentrations of aluminum (Table 19). Zinc exceeded the TEC. Total PAHs exceeding the TEC were also detected as were two individual PAH compounds (Table 20). Acetone was also detected in the sample. Sediment contamination at this site may have been limiting macroinvertebrate community quality as evidenced by a poor qualitative evaluation (Table 1).

Generally, sediment contamination was limited to more developed areas of the watershed. In some cases, the availability of good habitat and clean water were enough to overcome any effects of contaminated sediments, although some areas appeared to show biological degradation due to contamination. Certain metals, particularly aluminum, were found at high to extreme concentrations when compared with background, but are already abundant in the earth's crust and typically unavailable to organisms at neutral pH values typically found in streams. Organic contamination was

generally relegated to PAHs and likely due to the extensive use of these compounds to construct and repair roads, driveways, and rooftops.

Table 17. Results of chemical/physical sediment quality sampling conducted in the Big Walnut Creek study area during July-September, 2000. Parameters in *italic* have no established guideline for comparison. Underlined values indicate concentrations below the method detection limit. NA means not analyzed. Parameters noted with a * are compared with the Illinois guidelines published by Kelly and Hite, 1984. All other parameters are compared with Ohio EPA sediment reference guidelines. Descriptive guidelines are as follows: Not elevated, slightly elevated (j), elevated(Z), highly elevated(~), extremely elevated(;). Shaded boxes exceed the consensus-based threshold effect concentration (TEC) published in MacDonald, 2000.

Big Walnut Creek Mainstem Sediments							
		River Mile					
Analyte	Units	66.6	49.0	34.9	27.0	15.8	1.7
Solids	%	*49.5*	*53.7*	*52.3*	*51.3*	*47.4*	*36.6*
pH	S.U.	*7.32*	*7.55*	*7.71*	*7.59*	*7.2*	*7.4*
METALS							
Aluminum	mg/kg	22100 Z	14900 j	25000 ~	21700 Z	29600 ~	46400 ;
Arsenic	mg/kg	7.2	8.17	13 j	13.7 Z	16.3 Z	20.5 Z
Barium	mg/kg	143 Z	83.6	377 ;	178 Z	247 ~	278 ~
Cadmium	mg/kg	0.653 j	0.484	0.687 j	1.07 Z	1.86 ;	1.76 ~
Calcium	mg/kg	*8080*	*5880*	*3890*	*17900*	*20700*	*34700*
Chromium	mg/kg	24.9 j	19.6	25.9 j	24.3 j	35 Z	45 ~
Copper	mg/kg	17.5	13.1	16.8	28.8 Z	31.5 Z	40.8 ~
Iron	mg/kg	18500	19300	20400	22500 j	27000 j	32700 Z
Lead	mg/kg	31	26.1	25.9	35.8	82 Z	49 j
Magnesium	mg/kg	*3370*	*3270*	*3240*	*8310*	*10700*	*15600*
Manganese	mg/kg	252	268	2290 ;	357 j	362 j	593 Z
Nickel	mg/kg	26.9	26.1	25.9	26.8	33 j	43 Z
Mercury*	mg/kg	0.055	0.0401	0.04	0.0564	0.056	0.087
Potassium	mg/kg	*5390*	*3270*	*6480*	*6390*	*8580*	*12100*
Selenium	mg/kg	*1.35*	*1.31*	*1.35*	*1.28*	*1.64*	*1.91*
Sodium	mg/kg	*3370*	*3270*	*3240*	*3200*	*3580*	*4340*
Strontium	mg/kg	*52.5*	*44.4*	*44.1*	*50.5*	*57*	*82*
Zinc	mg/kg	105 j	74.5	84.9	147 Z	378 ~	230 ~

Table 18. Results of chemical/physical sediment quality sampling conducted in the Big Walnut Creek study area during July-September, 2000. Blank spaces indicate that the compound was not detected in the sample. Parameters noted with underlining exceed the threshold effect concentration (TEC), those in boldface exceed the probable effect concentration (PEC), and those in italics were not evaluated (MacDonald, 2000).

Big Walnut Creek Mainstem Sediments							
		River Mile					
Analyte	Units	66.6	49.0	34.9	27.0	15.8	1.7
Solids	%	49.6	53.4	33.3	52.4	56.2	46.5
TOC	%	2.8	2	4.5	3.5	3	3
Acetone	mg/kg	*0.0828*	*0.111*	*0.21*			
4-4' DDD	µg/kg					8.2	
Methoxychlor	µg/kg						*12.8*
Alpha-chlordane [a]	µg/kg					7.84	
Gamma-chlordane [a]	µg/kg					12.4	
PCB-1260	µg/kg					125	
bis(2-ethylhexyl) phthalate	mg/kg					*0.83*	*0.94*
Acetophenone	mg/kg	*0.75*					
Benz[a]anthracene	mg/kg				0.81	**1.9**	
Benzo[a]pyrene	mg/kg				0.92	**2.2**	1
Benzo[b]fluoranthene	mg/kg				*1.3*	*2.7*	*1.5*
Benzo[ghi]perylene	mg/kg				*0.84*	*2*	*1.1*
Benzo[k]fluoranthene	mg/kg				*1.2*	*2.5*	*1.2*
Chrysene	mg/kg				**1.5**	**3.2**	**1.6**
Dibenz[ah]anthracene	mg/kg					*0.8*	
Fluoranthene	mg/kg			1.6	2.5*	5.8*	2.6*
Indeno[123cd]pyrene	mg/kg				*0.9*	*2.2*	*1.2*
Phenanthrene	mg/kg				0.97	**2.8**	0.92
Pyrene	mg/kg			1.3	**2**	**4.6**	**2**
Total PAHs	mg/kg	0	0	2.9	12.94	**30.7**	13.12

* Exceeds PEC, but PEC found to be unreliable.
[a] Compared with values for total chlordane.

Table 19. Results of chemical/physical sediment quality sampling conducted in the Big Walnut Creek study area during July-September, 2000. Parameters in *italic* have no established guideline for comparison. Underlined values indicate concentrations below the method detection limit. Parameters noted with an * are compared with the Illinois guidelines published by Kelly and Hite, 1984. Most other parameters are compared with Ohio EPA sediment reference guidelines. Descriptive guidelines are as follows: Not elevated, slightly elevated (**j**), elevated(**Z**), highly elevated(**~**), extremely elevated(**;**). Shaded boxes exceed the consensus-based threshold effect concentration (TEC) published in MacDonald, 2000. Shaded boxes with bold print exceed the consensus-based probable effect concentration (PEC) found in MacDonald, 2000. Units are: Solids-%, pH-S.U., everything else-mg/kg.

Big Walnut Creek Tributaries Sediments												
Analyte	**AT**	**RF1**	**RF2**	**SR**	**LWC**	**DR**	**RC**	**AC**	**BC1**	**BC2**	**BC3**	**DyR**
Solids	*54.5*	*25.6*	*36.8*	*41.7*	*49.8*	*54.6*	*28.7*	*50.9*	*51.1*	*46.3*	*51.1*	*44.0*
pH	*7.38*	*7.08*	*7.53*	*7.1*	*7.28*	*7.44*	*7.29*	*7.54*	*7.4*	*7.4*	*7.4*	*7.15*
Ammonia	NA	*63.7*	NA	*23.7*	*25.7*	*23.5*	*24.4*	NA	NA	NA	NA	*36.7*
T-Phosphorus*	NA	1730 **~**	NA	765 **j**	742 **j**	696 **j**	1080 **Z**	NA	NA	NA	NA	762 **j**
Aluminum	25400 **~**	63600 **;**	38800 **;**	53800 **;**	32800 **~**	32300 **~**	42900 **;**	20200 **Z**	23200 **~**	24800 **~**	23200 **~**	39400 **;**
Arsenic	10.5 **j**	30.5 **~**	27 **~**	27.5 **~**	13.7**Z**	14.6**Z**	11.8 **j**	11.2 **j**	12.1 **j**	13.7**Z**	12.1 **j**	15.9**Z**
Barium	244 **~**	415 **;**	296 **~**	370 **;**	182**Z**	206**Z**	268 **~**	144**Z**	152**Z**	161**Z**	152**Z**	233 **~**
Cadmium	1.15 **~**	1.46 **~**	0.941**Z**	1.43 **~**	0.965 **Z**	0.594 **j**	1.25 **~**	1.33 **~**	0.715 **j**	0.962**Z**	0.715 **j**	0.647 **j**
Calcium	*9690*	*25600*	*35900*	*8650*	*9160*	*13100*	*5530*	*30100*	*20200*	*58400*	*20200*	*20800*
Chromium	28.4**Z**	66.6 **;**	39.8 **~**	51.9 **~**	34.5**Z**	33.2**Z**	46.4 **~**	28.2**Z**	25 **j**	28.8**Z**	25 **j**	39.3 **~**
Copper	80.3 **;**	46.1 **~**	36.9**Z**	28.3**Z**	20.4 **j**	19.4	27.6**Z**	32.1**Z**	20.9 **j**	25.2 **j**	20.9 **j**	26.2 **j**
Iron	23700 **j**	54900 **~**	39700**Z**	51600 **~**	27000 **j**	23900 **j**	29100 **Z**	21000	21400	23800 **j**	21400	28700 **Z**
Lead	27.7	51.2 **j**	50.5 **j**	37.7	28.2	29.7	48.7 **j**	76**Z**	27	36.0	27	30.8
Magnesium	*4850*	*14100*	*11600*	*7080*	*5640*	*6220*	*5530*	*11800*	*8770*	*10800*	*8770*	*7700*
Manganese	264	566**Z**	591**Z**	1640 **;**	261	369 **j**	228	263	307	399 **j**	307	650**Z**
Mercury*	0.0478	0.124	0.0642	0.0624	0.0526	0.0456	0.0932	0.096	0.048	0.068	0.048	0.0496
Nickel	27.7	**58.9Z**	38.8 **j**	**58.2Z**	28.9 **j**	31.1 **j**	44.2**Z**	26.2	27	36 **j**	27	30.8 **j**
Potassium	*7620*	*16600*	*12600*	*14900*	*8450*	*8980*	*11100*	*6550*	*6750*	*6290*	*6750*	*10000*
Selenium	*1.38*	*2.56*	*1.94*	*1.57*	*1.41*	*1.38*	*2.21*	*1.31*	*1.35*	*1.80*	*1.35*	*1.54*
Sodium	*3460*	*6400*	*4850*	*3930*	*3520*	*3460*	*5530*	*3270*	*3370*	*4500*	*3370*	*3850*
Strontium	*38.8*	*110*	*105*	*79.4*	*66.9*	*46.3*	*75.2*	*70.7*	*61*	*115*	*61*	*57.8*
Zinc	217**Z**	255 **~**	128 **j**	148**Z**	118 **j**	108 **j**	171**Z**	197**Z**	109 **j**	143 **j**	109 **j**	132 **j**

AT=Airport Tributary, **RF1**=Rocky Fork at RM 7.1, **RF2**=Rocky Fork at RM 1.1, **SR**=Sugar Run at RM 0.7, **LWC**=Little Walnut Creek at RM 1.4, **DR**=Duncan Run at RM 2.7, **RC**=Rattlesnake Creek at RM 0.1, **AC**=Alum Creek at RM 3.8, **BC1**=Blacklick Creek at RM 22.4, **BC2**=Blacklick Creek at RM 11.3, **BC3**=Blacklick Creek at RM 1.9, **DyR**=Dysar Run at RM 1.6.

Table 20. Results of chemical/physical sediment quality sampling conducted in the Big Walnut Creek

study area during July-September, 2000. **AT**=Airport Tributary, **RF1**=Rocky Fork at RM 7.1, **RF2**=Rocky Fork at RM 1.1, **SR**=Sugar Run at RM 0.7, **LWC**=Little Walnut Creek at RM 1.4, **DR**=Duncan Run at RM 2.7, **RC**=Rattlesnake Creek at RM 0.1, **AC**=Alum Creek at RM 3.8, **BC1**=Blacklick Creek at RM 22.4, **BC2**=Blacklick Creek at RM 11.3, **BC3**=Blacklick Creek at RM 1.9, **DyR**=Dysar Run at RM 1.6. Blank spaces indicate that the compound was not detected in the sample. Parameters noted with underlining exceed the threshold effect concentration (TEC), those in boldface exceed the probable effect concentration, and those in italics were not evaluated (PEC, MacDonald, 2000). Parameters with a subscript b were detected in the field blank.

Big Walnut Creek Tributaries Sediments													
Analyte	Units	**AT**	**RF1**	**RF2**	**SR**	**LWC**	**DR**	**RC**	**AC**	**BC1**	**BC2**	**BC3**	**DyR**
Solids	%	50.9	46.8	50.9	57.6	47.8	58.3	31.6	53.9	40.3	46.3	NA	48.6
TOC	%	3	2.2	2.4	1.9	2.4	2.4	4.4	4	2.7	3	1	2.7
Acetone	mg/kg	*0.0766*								*0.72$_b$*			*0.123*
2-Butanone	mg/kg									*1.6$_b$*			
Toluene	mg/kg									*0.6*			
4-4' DDD	µg/kg								8.28				
Alpha-chlordane	µg/kg								19.7				
Gamma-chlordane	µg/kg								20.8				
Trans-nonachlor	µg/kg								11.6				
PCB-1260	µg/kg								37.9				
bis(2-ethylhexyl) phthalate	mg/kg								*1.8*		*1.2*		
3&4 Methylphenol	mg/kg									*2*			
Benz[a]anthracene	mg/kg	**1.1**							**3.3**	**1.5**			
Benzo[a]pyrene	mg/kg	1.3							**3.2**	**1.8**			
Benzo[b]fluoranthene	mg/kg	*2.4*							*4.4*	*2*		*0.84*	
Benzo[ghi]perylene	mg/kg	*1.2*							*2.7*	*1.6*			
Benzo[k]fluoranthene	mg/kg	*1.3*							*2.8*	*2.2*			
Chrysene	mg/kg	**2.3**							**4.8**	**2.6**		0.82	
Dibenz[ah]anthracene	mg/kg								*1.1*				
Fluoranthene	mg/kg	3.2			0.87				8.9	4.9		1.5	1.1
Indeno[123cd]pyrene	mg/kg	*1.4*							*3*	*1.8*			
Phenanthrene	mg/kg	0.96							**4.2**	**2.2**			
Pyrene	mg/kg	**2.5**							**7.2**	**3.8**			0.84
Total PAHs	mg/kg	17.7	0	0	0.87	0	0	0	**45.6**	**24.4**	0	3.16	1.94

Chemical Water Quality Changes 1981-2000

Chemical water quality trends were evaluated in each of the 3 major tributaries of Big Walnut creek as well as the mainstem. Dissolved oxygen, 5-day biochemical oxygen demand, total suspended solids, fecal coliform bacteria, ammonia, nitrate+nitrite, and total phosphorus were all examined.

Big Walnut Creek

Dissolved oxygen concentrations in the upper watershed showed increases over previous survey work in Big Walnut Creek, especially in the vicinity of the Marengo WWTP and the confluence with Prairie Run (Sunbury WWTP) (Fig. 33). Continued improvements are needed at the Sunbury WWTP as dissolved oxygen values reflected a decline in Big Walnut Creek downstream of the confluence with Prairie Run. Values in the lower part of the watershed were similar to previous survey data with mean D.O. values between 7 and 8 mg/l. Trends in biochemical oxygen demand were lower throughout the basin (Fig. 31). Upgrades to the Marengo, Sunbury, and Galena WWTPs in the last two decades have virtually eliminated detectable organic enrichment from the mainstem, although dissolved oxygen readings (noted above) still show an impact from Sunbury and Prairie Run.

Total suspended solids trends showed a general lessening of concentrations compared to previous surveys; however, the area downstream of the confluence with Rocky Fork showed an increase compared with 1996 and 1991 data, indicative of the large amount of development in that subwatershed (Fig. 31).

Bacterial concentrations as measured by fecal coliform testing showed some variability compared with survey results from previous years. Mean fecal coliform bacteria concentrations were elevated above 1982 levels in the upper watershed, likely due to rural sources (i.e., agriculture, poorly operating home sewage treatment systems). Values remained similar to previous surveys until the site downstream of Rocky Fork where there was another large increase over past results (Fig. 31), followed by a decreasing trend downstream to the mouth. Rocky Fork appears to be contributing significant bacterial contamination to the mainstem (see later discussion below).

Mean concentrations of total phosphorus and ammonia were generally similar to those found in the past (Fig. 32). Mean concentrations of nitrate+nitrite were noticeably elevated compared with previous surveys (Fig. 32).

Alum Creek

Average dissolved oxygen concentrations generally trended higher in 2000 than during previous survey efforts. No impacts were noted from the Huber Ridge WWTP which had a negative influence on the creek in 1986 but which has since been upgraded (Fig. 36). The Alum Creek combined sewer overflow from the City of Columbus continues to negatively influence dissolved oxygen concentrations in Alum Creek farther downstream. Biochemical oxygen demand showed a downward trend in the watershed where comparisons were available (Fig. 34).

Mean total suspended solids concentrations in upstream reaches (above RM 12.00) showed higher concentrations in this latest survey than in 1996 (Fig. 34). Intensive agricultural uses in the rural areas combined with developmental pressures nearer the Columbus metropolitan area are likely causes of this increased trend.

Bacterial trends definitely show lower concentrations compared with previous survey results, especially in the lower watershed downstream of RM 21.00 (Fig. 34). Total phosphorus trended lower and ammonia concentrations were similar compared to previous survey data (Fig. 35). Mean nitrate+nitrite concentrations were significantly greater than past measurements in most cases (Fig. 35).

Blacklick Creek

Trends in dissolved oxygen concentrations have generally increased and remained stable since 1996 (Fig. 39). Improved treatment at the Blacklick Estates WWTP provided marked improvement to the D.O. in the downstream reach of Blacklick Creek since 1986. Negative impacts from malfunctioning and closely-spaced home sewage treatment systems still plague the headwaters. This same trend was observed with biochemical oxygen demand (Fig. 37).

The trend for total suspended solids showed significantly lower concentrations over most of the length of the creek than in previous surveys (Fig. 37). Mean solids increased moving downstream, showing an increased concentration compared with a previous survey in 1996.

Fecal coliform bacteria showed similarities with past survey results in most areas of the creek. The exceptions were in the headwaters and downstream of the Fairfield County Tussing Road WWTP where bacterial counts were elevated over the 1991 and 1996 survey results (Fig. 37). These elevated bacterial concentrations provided further evidence of the pollution impacts emanating from failing home sewage treatment systems in the upper watershed and the Fairfield County Tussing Road WWTP farther downstream.

Nutrient concentrations followed similar trends in the Blacklick Creek subbasin. In most cases, different years produced similar results except for the headwater area where nutrient concentrations were excessive (Fig. 38). Moderate increases in nutrient concentrations were noted downstream of the Fairfield County Tussing Road WWTP, whereas concentrations from the Blacklick Estates WWTP were similar to or improved compared to those observed in 1996.

Rocky Fork Creek

Mean dissolved oxygen values found in the 2000 survey of Rocky Fork compared well with historical information obtained the previous decade (Fig. 42). In most cases, the 2000 data showed higher concentrations of dissolved oxygen than those found in other years. This is a positive trend in the upper portion of this subbasin, however, the lower portion of the basin experienced significantly higher concentrations of dissolved oxygen, which were probably indicative of supersaturated conditions and nutrient enrichment. Biochemical oxygen demand was only elevated

above historical values at RM 7.10, possibly due to lingering effects from the Taylor Estates WWTP (Fig. 40).

Total suspended solids averages were low or comparable with most historical information, except at RM 7.10 where the mean value was nearly 5 times higher than the data collected in 1994 (Fig. 40). Development pressures in this area may be the major cause of this spike due to construction site runoff and changes in flow dynamics causing increased bank erosion during storm flows.

Fecal coliform bacteria concentrations generally were similar over the different survey periods although the 2000 survey did reveal a spike at the site near the mouth, possibly due to the Windrush MHP WWTP (Fig. 40). Nutrient concentrations trended similarly with past data including increased concentrations upstream which attenuated downstream (Fig. 41). Nutrient reduction downstream may have been influenced by increased uptake and primary productivity inferred from supersaturated dissolved oxygen concentrations (Fig. 14).

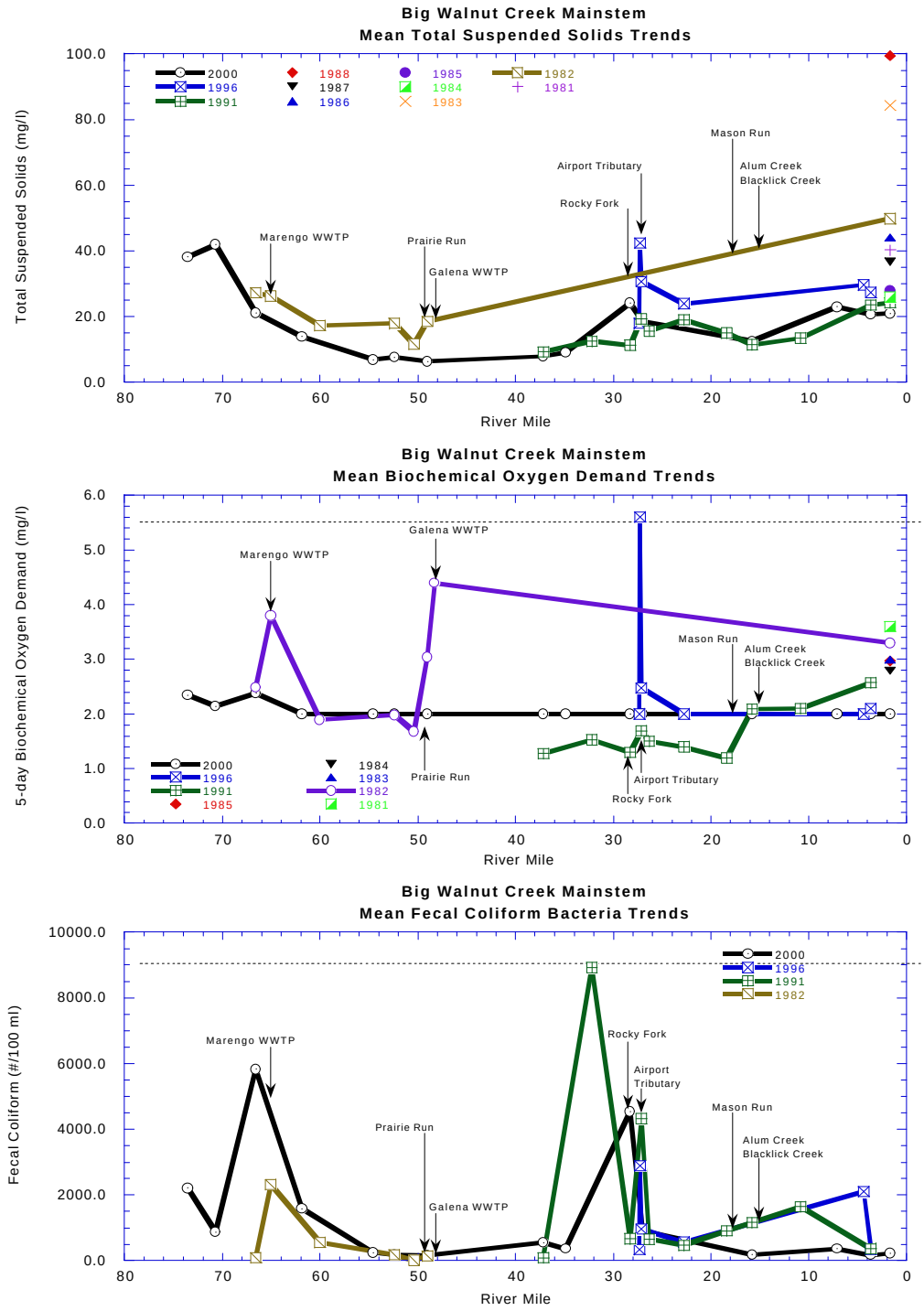

Figure 31. Longitudinal trend in mean Total Suspended Solids, Biochemical Oxygen Demand, and Fecal Coliform in Big Walnut Creek from 1981 to 2000.

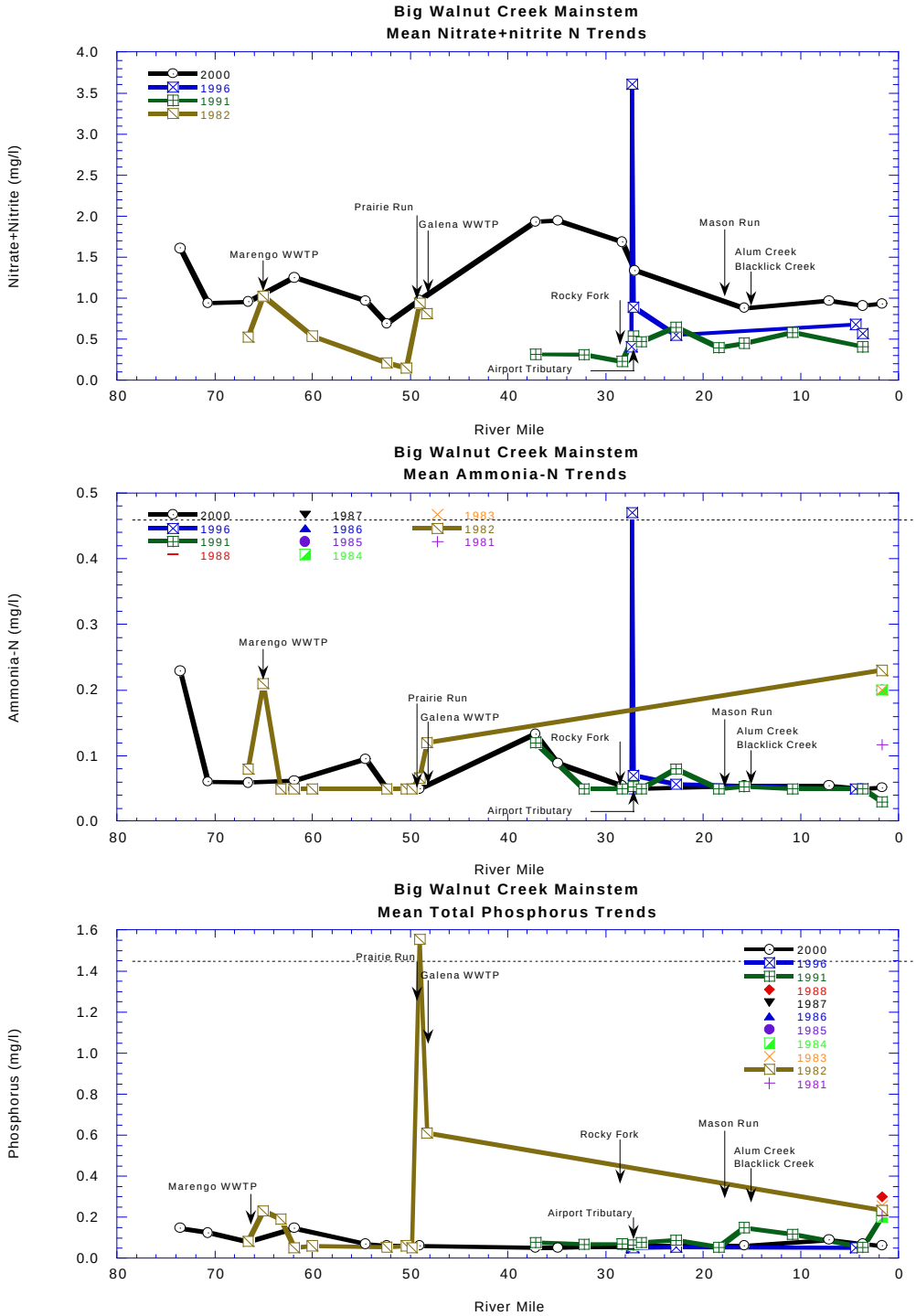

Figure 32. Longitudinal trend in mean Nitrate+Nitrite-Nitrogen, Ammonia-Nitrogen, and Total Phosphorus in Big Walnut Creek from 1981 to 2000.

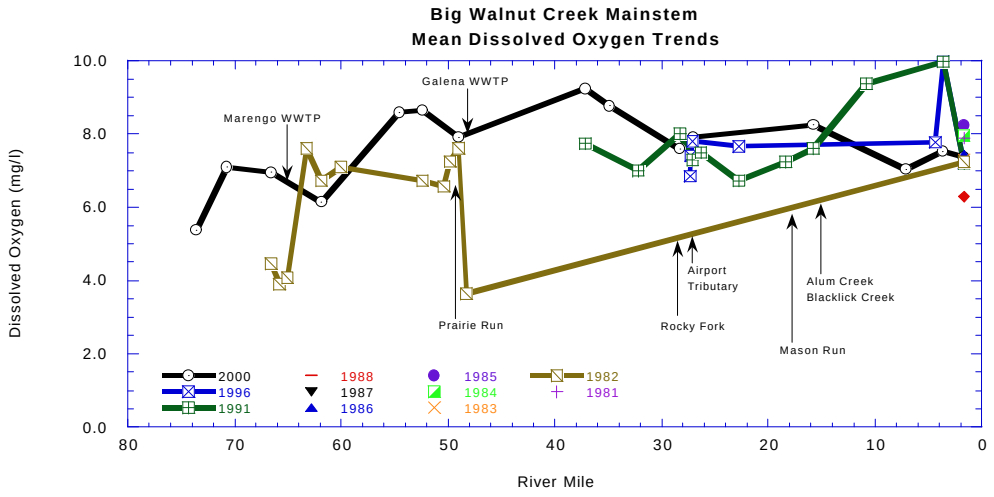

Figure 33. Longitudinal trend in mean Dissolved Oxygen in Big Walnut Creek from 1981 to 2000.

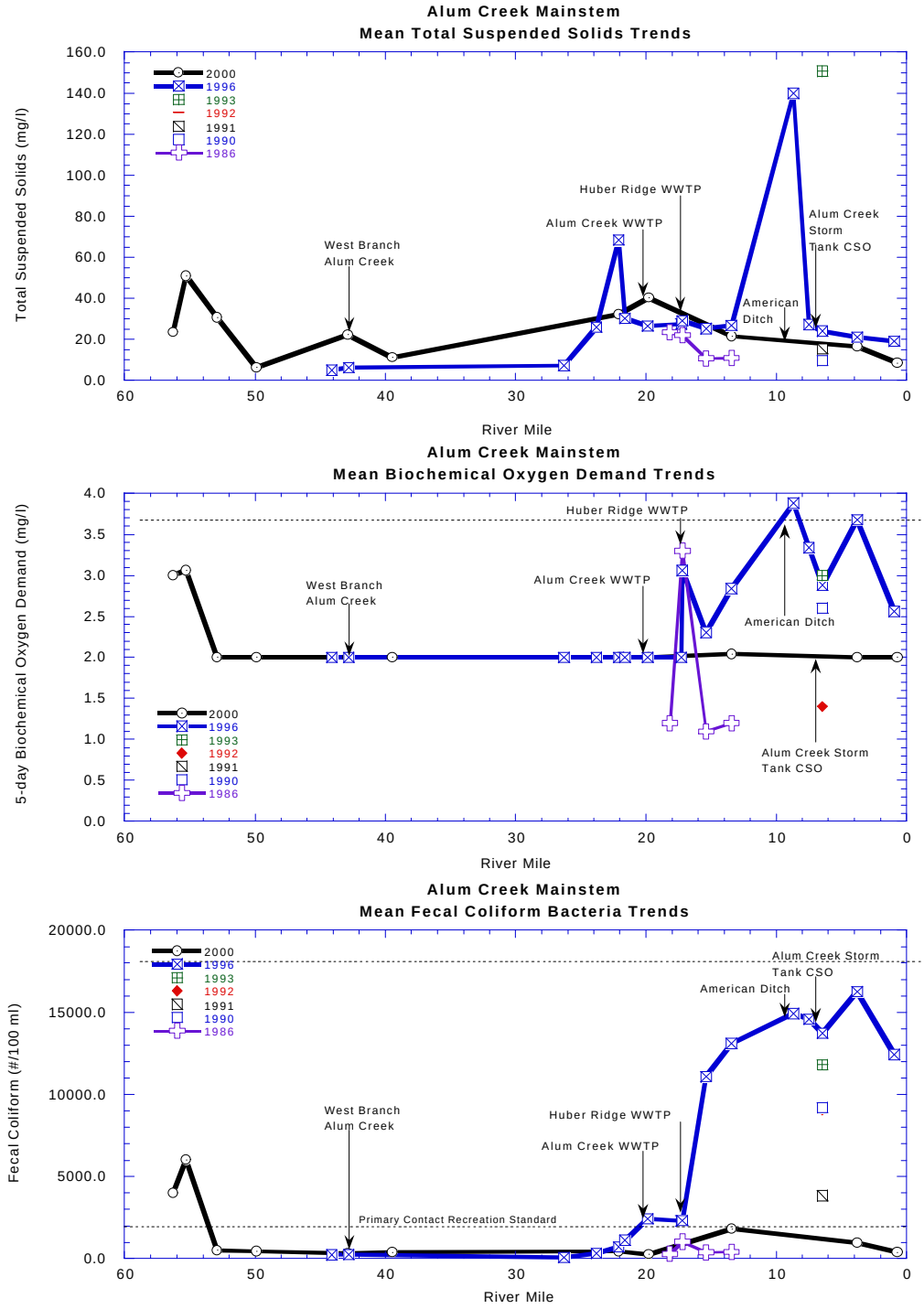

Figure 34. Longitudinal trend in mean Total Suspended Solids, Biochemical Oxygen Demand, and Fecal Coliform in Alum Creek from 1986 to 2000.

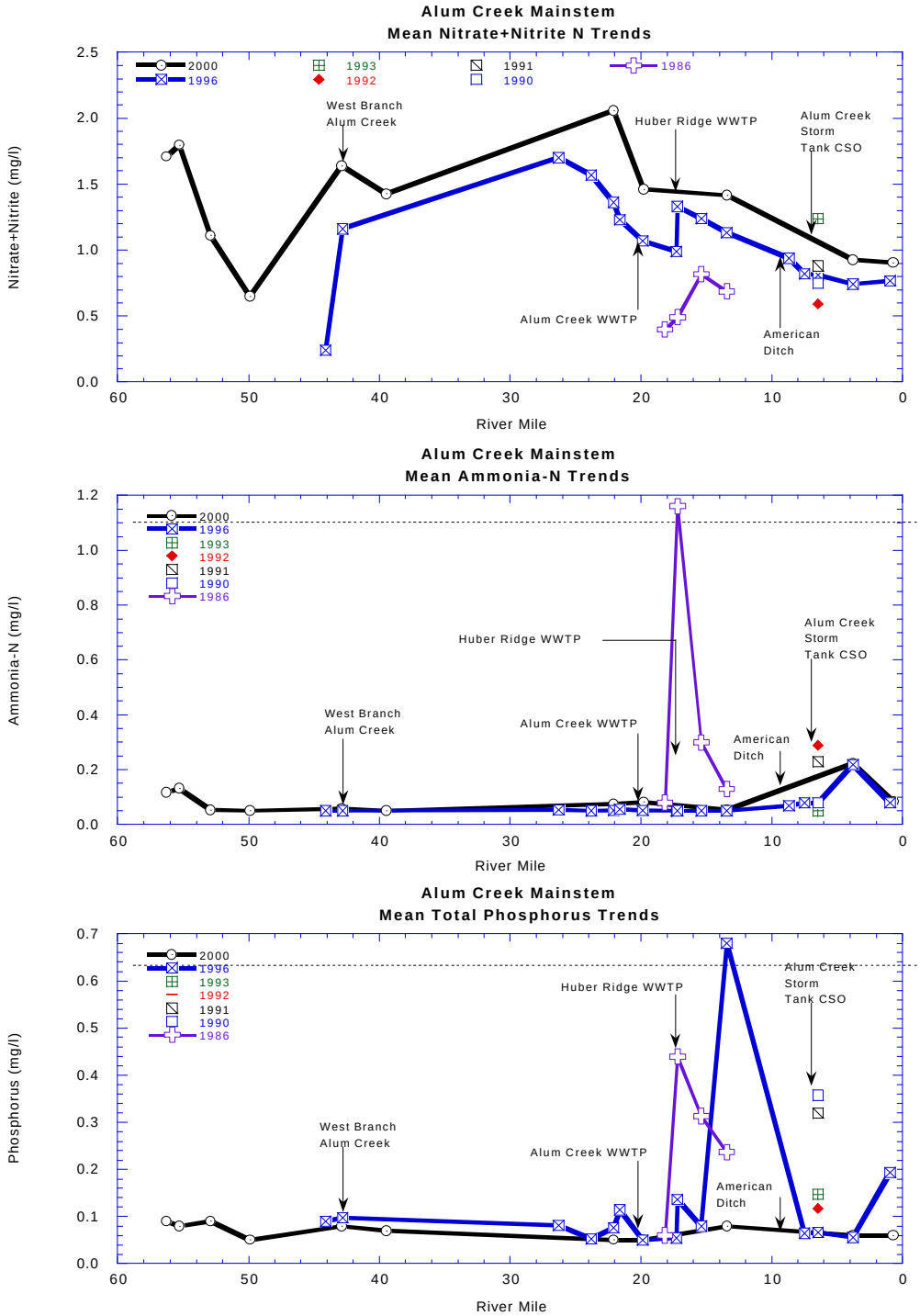

Figure 35. Longitudinal trend in mean Nitrate+Nitrite-Nitrogen, Ammonia-Nitrogen, and Total Phosphorus in Alum Creek from 1986 to 2000.

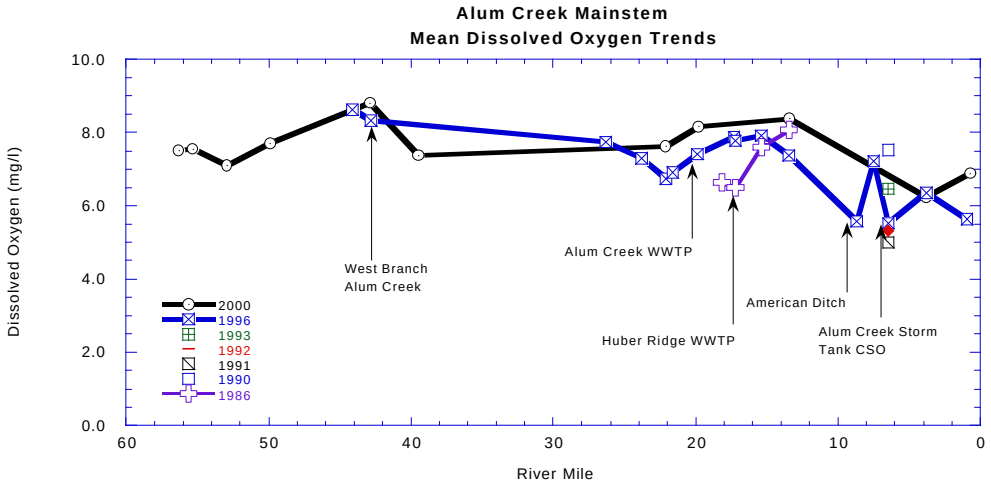

Figure 36. Longitudinal trend in mean Dissolved Oxygen in Alum Creek from 1986 to 2000.

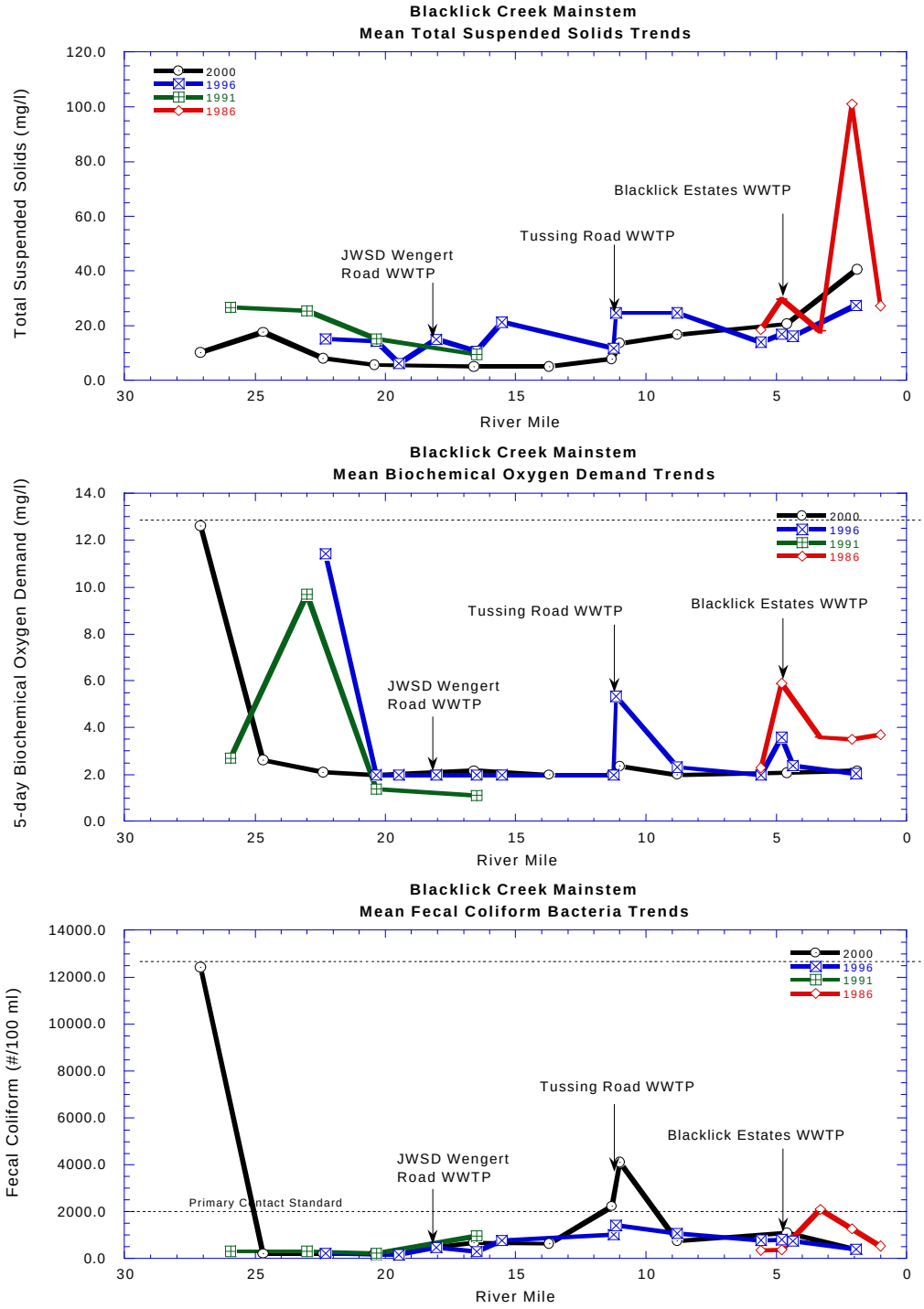

Figure 37. Longitudinal trend in mean Total Suspended Solids, Biochemical Oxygen Demand, and Fecal Coliform in Blacklick Creek from 1986 to 2000.

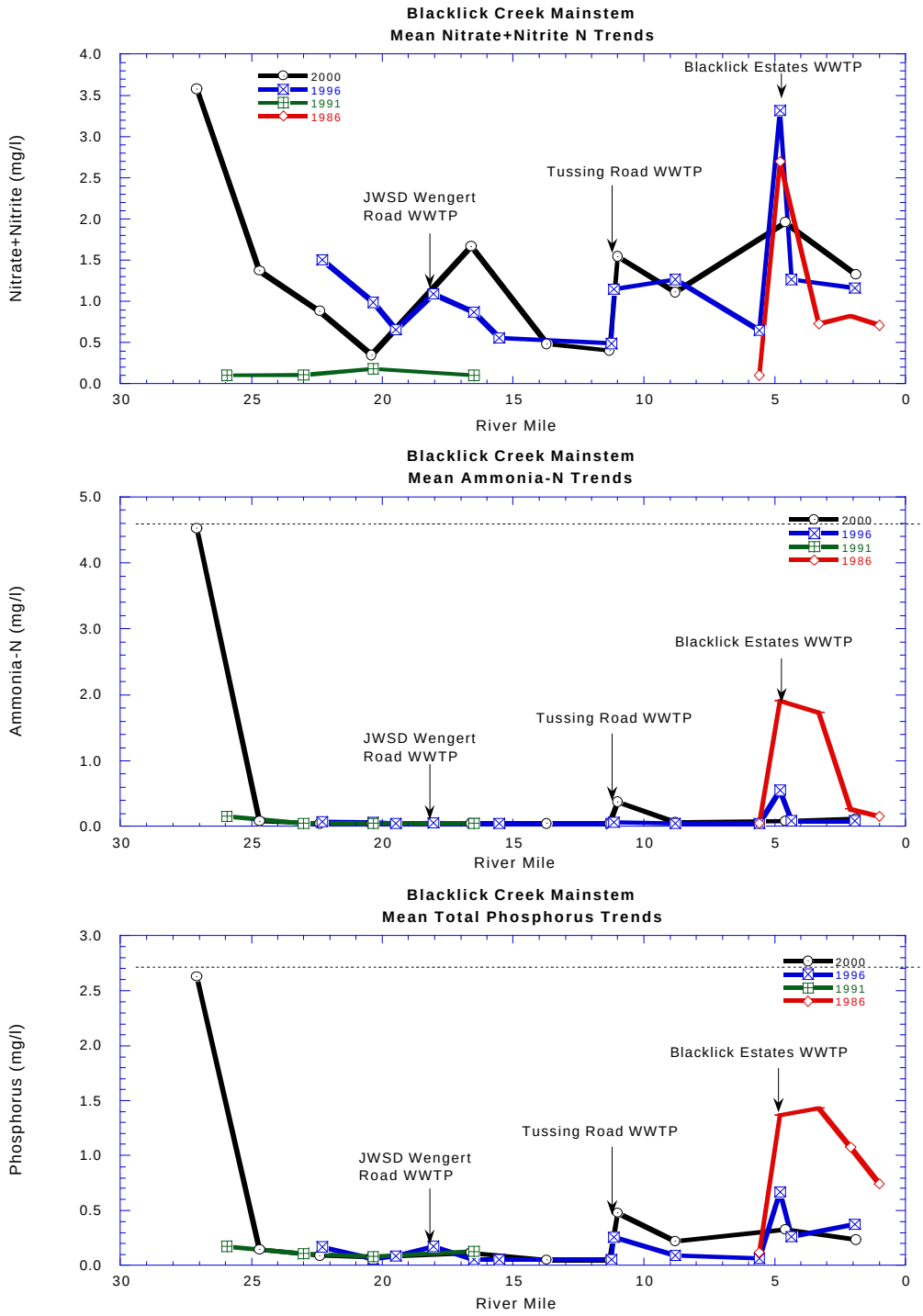

Figure 38. Longitudinal trend in mean Nitrate+Nitrite-Nitrogen, Ammonia-Nitrogen, and Total Phosphorus in Blacklick Creek from 1986 to 2000.

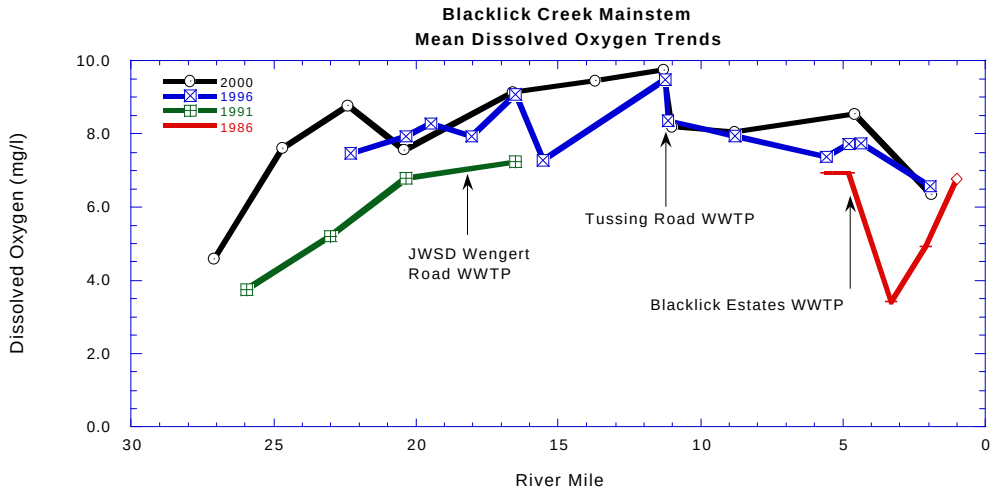

Figure 39. Longitudinal trend in mean Dissolved Oxygen in Blacklick Creek from 1986 to 2000.

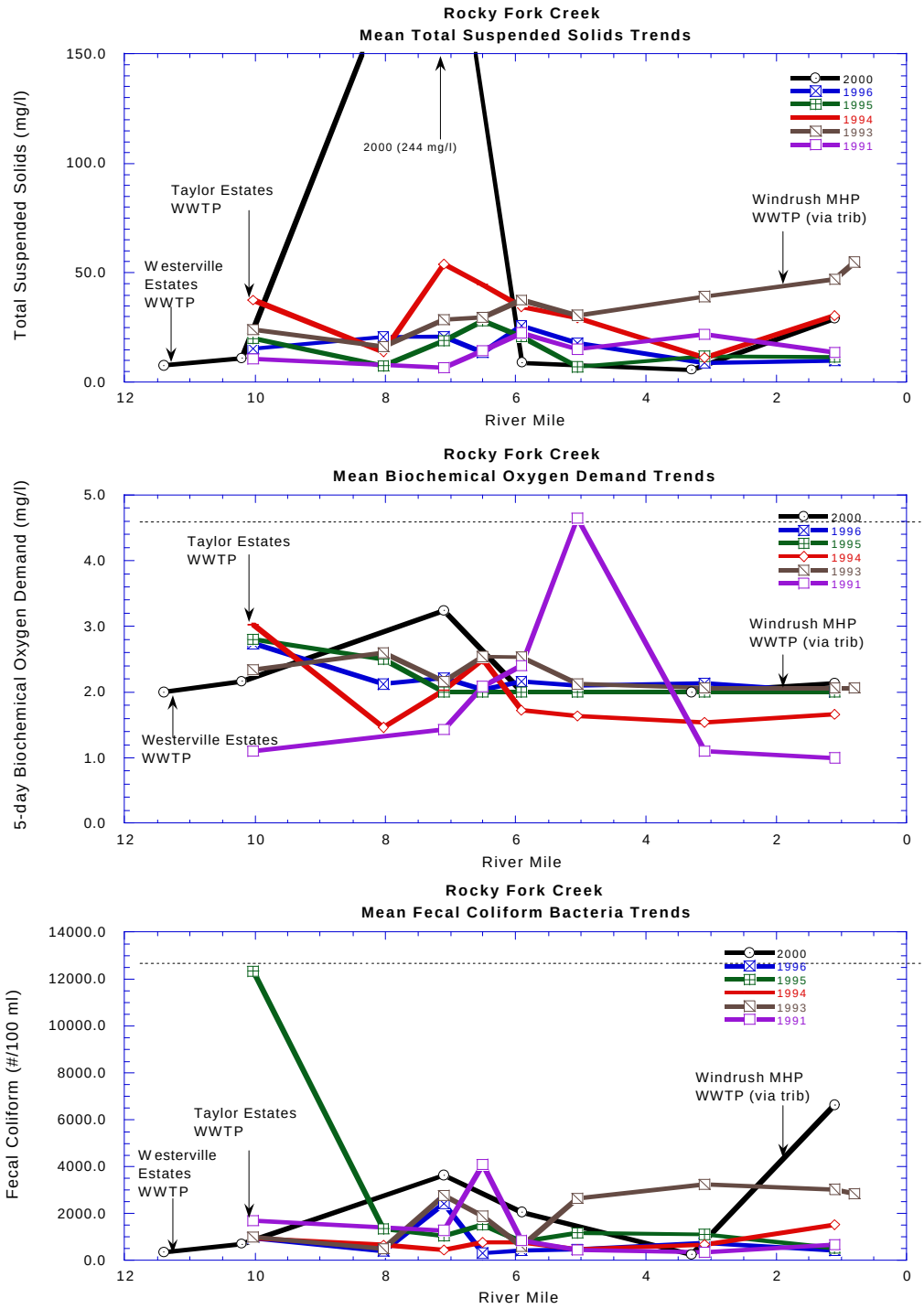

Figure 40. Longitudinal trend in mean Total Suspended Solids, Biochemical Oxygen Demand, and Fecal Coliform in Rocky Fork Big Walnut Creek from 1991 to 2000.

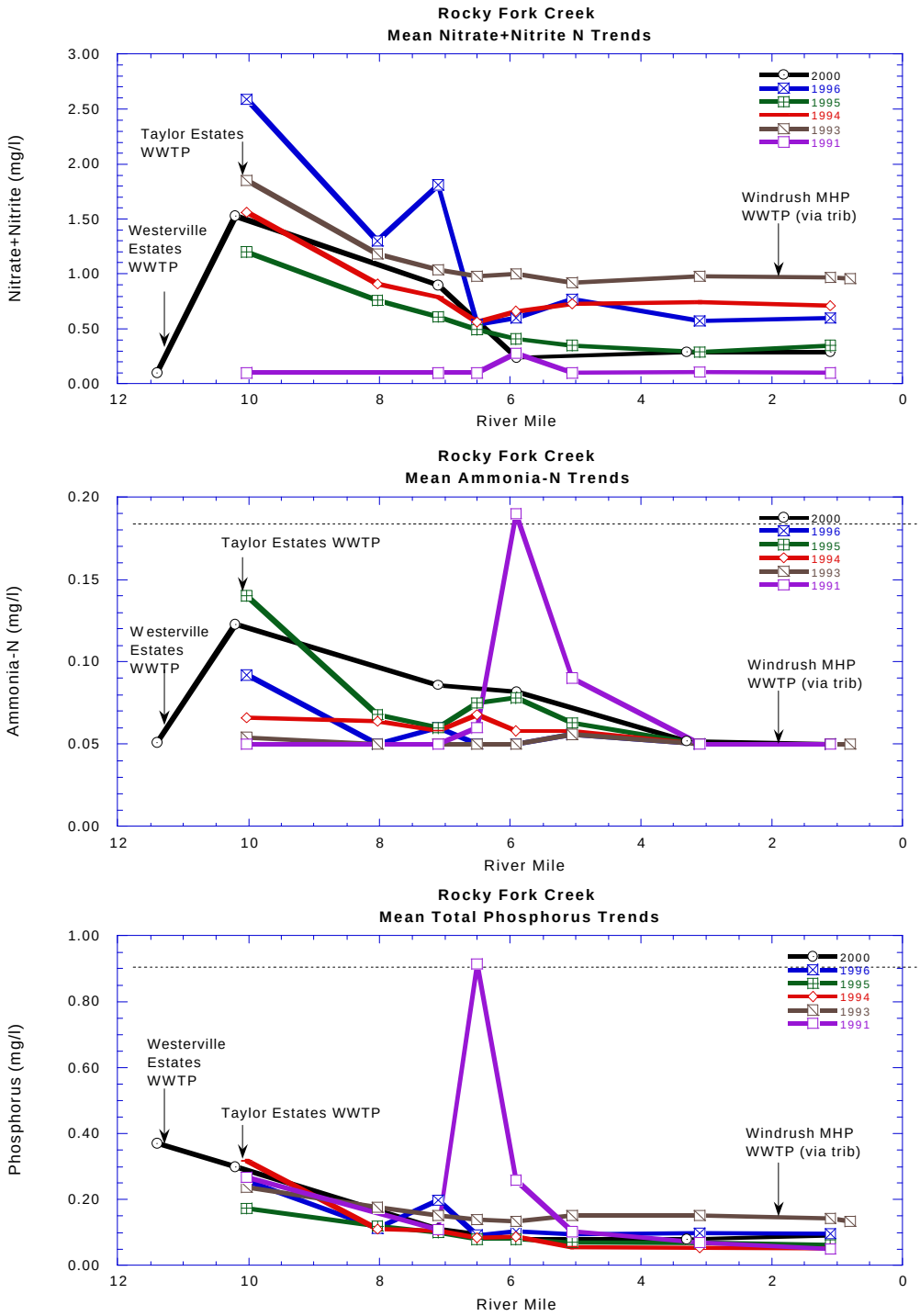

Figure 41. Longitudinal trend in mean Nitrate+Nitrite-Nitrogen, Ammonia-Nitrogen, and Total Phosphorus in Rocky Fork Big Walnut Creek from 1991 to 2000.

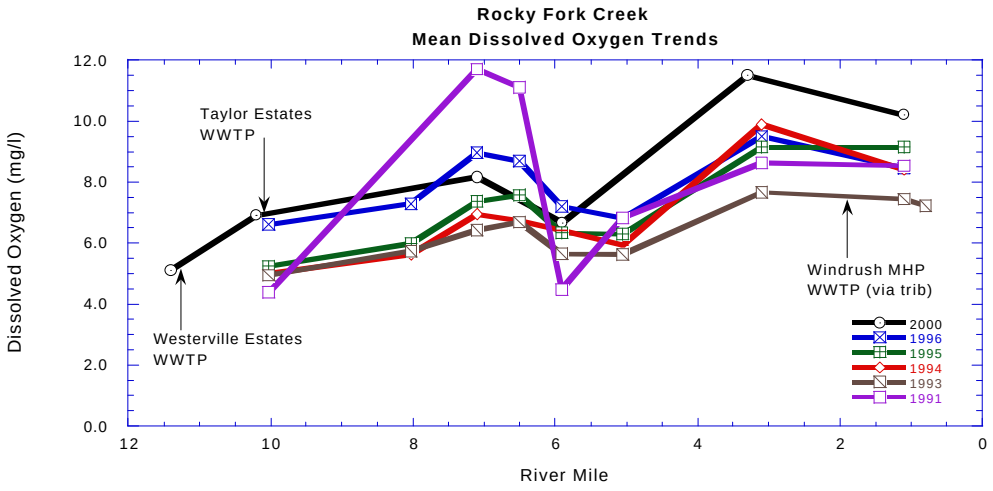

Figure 42. Longitudinal trend in mean Dissolved Oxygen in Rocky Fork Big Walnut Creek from 1991 to 2000.

Physical Habitat for Aquatic Life

Big Walnut Creek
The instream habitat and surrounding riparian zone along the Big Walnut mainstem was generally in excellent condition and fully capable of supporting a WWH fish community. The exception was the headwater reach upstream from Marengo where the stream had been historically channelized. The upper-most site (RM 72.5, Cardington Rd.) being either the most recently channelized or least recovered had the highest number of modified attributes, and the only site on the mainstem having a high-influence modified attribute (Table 21).

Modified attributes are those that reflect both direct and indirect anthropogenic modifications. Some modified attributes are associated more strongly with impaired aquatic communities than others, and therefore are considered high-influence modified attributes (Ohio EPA, 1999b). Modified attributes less strongly associated with biological impairment are said to have a moderate influence. One high influence attribute alone in any given stream reach will usually preclude an EWH fish community, and two or more prevents an EWH fish community with near certainty, and makes meeting WWH increasingly unlikely. Four or more high influence modified attributes in a reach almost always precludes WWH. Likewise an accumulation of seven or more moderate-influence attributes typically will preclude a WWH fish community. Despite the occurrence of a high-influence attribute at the Cardington Road site (RM 72.5), enough natural habitat features have become reestablished to suggest that, in the absence of further perturbations, the habitat will eventually recover to the point of being capable of supporting a WWH fish community.

Alum Creek and West Branch Alum Creek
Similar to the Big Walnut mainstem, the headwater reaches of Alum Creek and the West Branch suffered the highest number of modified attributes. Both have high-influence attributes, and both showed a higher number of modified attributes than natural attributes. However, like Big Walnut, enough natural features and stream gradient exist that recovery to WWH potential is likely in the absence of added or continued alterations.

Other than the headwaters, and downstream from Alum Creek Lake, the habitat in both creeks was excellent and fully capable of supporting EWH fish communities. The site at RM 42.9 (Meyers Rd.), having a complete absence of modified attributes, had the best habitat of any segment in the entire survey. Downstream from the reservoir, substrate and riffle embeddedness increased due to the effects of construction and stormwater runoff.

Rocky Fork Big Walnut Creek
The stream habitat throughout Rocky Fork was capable of supporting a WWH fish community, and the habitat in the lower several miles was capable of supporting EWH fish communities. Despite the generally good habitat, the influence of construction in the watershed was evident in the high number of modified habitat attributes especially at the two sites downstream from SR 161 (RMs 7.1 and 5.9) where the pool and riffle substrates were embedded and silt covered, and the total number of modified attributes equaled or exceeded natural attributes (Table 21, Fig. 43). Sugar Run and especially Rose Run have been negatively affected by construction and showed a higher proportion

of modified habitat attributes than natural ones.

Blacklick Creek

Nine of ten locations sampled in Blacklick Creek had good to excellent habitat. The one site falling short was the upper-most headwater site (RM 27.1, Walnut St) where modified attributes slightly

Figure 43. Construction in the Rocky Fork basin. Upper left, cluster development in the vicinity of Walnut Street. Upper right, a properly constructed silt fence along the bank of Sugar Run. Lower panels, new home construction lacking proper erosion controls, and encroaching on and destroying the riparian zone.

outnumbered natural ones owing mostly to limited flow. Beyond the obvious, the limited flow allowed accumulation of sediment in the stream channel, and encouraged habitat uniformity by lack of scour and deposition. The cumulative effect of suburbanization was apparent in the lower half of the creek where both pool and riffle substrates were embedded with sand and fine gravel.

The habitat quality of tributaries to Blacklick Creek varied by the amount of urbanization in their respective catchments. French Run, Powell Ditch, and the headwaters of Dysar Run had the highest ratio of modified attributes to natural ones and were also the most heavily urbanized or rapidly

urbanizing in the case of Dysar Run. The two tributaries to Blacklick entering near Tussing Road (RMs 10.36 and 11.25) had good habitat, but both were threatened by construction and suburbanization.

Upper Big Walnut Tributaries

Defining the "upper" Big Walnut as the portion of the basin north of Franklin County, that portion, when taken as a whole had relatively intact habitat as evidenced by a mean and median QHEI score of 62.0 and 59.5, respectively. These measures of central tendancy were not biased by including the mainstems of Alum Creek and Big Walnut (Θ = 61.0, median = 59.0), and followed the general pattern of the upper most headwater reaches suffering the most anthropogenic modification (Fig. 44, left panel). Although QHEI scores were evenly split between what was generally considered good to excellent habitat (i.e., QHEI $60) and fair to poor habitat, QHEI scores were skewed slightly toward better habitat, such that the 25th percentile score was . 56.0 (Fig. 44, right panel). This was further evidence for the overall habitat integrity and WWH potential for all tributaries in the upper watershed. Obviously those tributary segments scoring less than 60 should be the focus of restoration efforts.

Little Walnut Creek

Habitat quality varied widely within the Little Walnut subbasin from maintained ditch (Butler Run, West Branch) to natural stream (East Branch, Little Walnut headwater), but the habitat quality overall was good (mean QHEI = 62.0, n = 5), and natural attributes typically outnumbered modified ones. Apart from outright channelization in Butler Run and the West Branch, unrestricted livestock access was the most influential factor negatively affecting habitat in Little Walnut Creek.

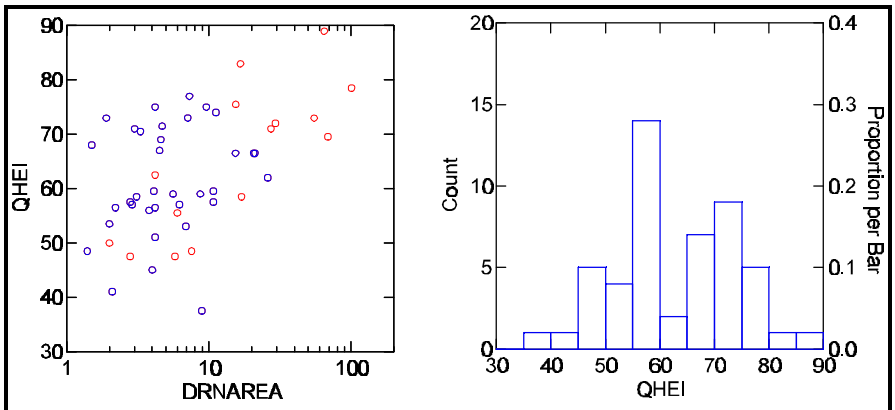

Figure 44. Left panel: Scatter plot of QHEI score on drainage area for sites sampled in the "upper" Big Walnut basin. Points colored red are from Alum Creek and West Branch Alum Creek. Right panel: Frequency distrbution of QHEI scores from the upper basin.

Rattlesnake Creek subbasin

Rattlesnake Creek and its tributaries, the North, South and East Forks, collectively had the worst habitat of any major tributary to Big Walnut Creek. Prior channelization, encroachment along riparian areas, unfenced livestock, and construction have resulted in more modified habitat attributes than natural ones at 6 of 9 sites sampled (Table 21, Fig. 45). However, a sufficient number of natural attributes existed, including cobble-gravel substrates and reasonably good channel development, to support, or potentially support, a WWH aquatic life use. The habitat in the lower portion of Rattlesnake Creek was excellent, which helped ammeliorate any downstream consequences to the mainstem of Big Walnut Creek. The habitat in the lower corridor of Rattlesnake should therefore be preserved as a near-term measure in light of the existing development pressure in its headwaters.

Figure 45. Habitat conditions in the Rattlesnake Creek subbasin of Big Walnut Creek. Clockwise from top left: sparse riparian vegetation allowing full sunlight to the stream in the North Fork; unfenced livestock in the East Fork; and construction in the South Fork.

Key QHEI Components

			WWH Attributes											MWH Attributes																		
														High Influence					*Moderate Influence*													
River Mile	QHEI	Gradient (ft/mile)	No Channelization or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrates	Good/Excellent Substrates	Moderate/High Sinuosity	Extensive/Moderate Cover	Fast Current/Eddies	Low-Normal Overall Embeddedness	Max Depth > 40 cm	Low-Normal Riffle Embeddedness	**Total WWH Attributes**	Channelized or No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse/No Cover	Max Depth < 40 cm (WD, HW)	**Total HL MWH Attributes**	Recovering Channel	Heavy/Moderate Silt Cover	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair/Poor Development	Low Sinuosity	Only 1-2 Cover Types	Intermittent and Poor Pools	No Fast Current	High/Mod. Overall Embeddedness	High/Mod. Riffle Embeddedness	No Riffle	**Total ML MWH Attributes**	**(MWH HL+1)/(WWH+1) Ratio**	**(MWH ML+1)/(WWH+1) Ratio**
(02-100) Big Walnut Creek																																		
Year: 2000																																		
72.5	**55.5**	4.08		■				■			■		3				●		1	▲	▲		▲	▲	▲			▲	▲	▲	▲	9	0.50	2.75
66.6	**58.5**	4.98	■	■			■	■		■	■		6						0				▲	▲				▲			▲	4	0.14	0.71
54.6	**73.0**	7.30	■	■		■	■	■		■	■		8						0				▲					▲		▲		3	0.11	0.44
52.4	**69.5**	20.41	■	■		■	■	■	■	■	■		9						0											▲		1	0.10	0.20
49.0	**78.5**	13.16	■	■		■	■	■		■	■	■	8						0									▲				1	0.11	0.22
37.2	**84.5**	4.42	■	■		■	■	■	■	■	■	■	9						0				▲									1	0.10	0.20
28.5	**82.0**	5.32	■	■		■	■	■		■	■		7						0									▲		▲		2	0.13	0.38
26.7	**83.5**	4.44	■	■		■	■	■	■	■	■		9						0											▲		1	0.10	0.20
15.8	**84.5**	5.29	■	■		■	■	■	■	■	■		8						0											▲		1	0.11	0.22
7.1	**83.0**	2.36	■	■		■	■	■	■	■	■		8						0											▲		1	0.11	0.22
1.7	**84.0**	5.13	■	■		■	■	■	■	■	■		8						0											▲		1	0.11	0.22
(02-101) Culver Creek																																		
Year: 2000																																		
4.5	**56.5**	18.87	■	■			■	■		■			5					●	1				▲	▲				▲			▲	4	0.33	1.00
3.3	**75.0**	12.50	■	■		■	■	■		■	■	■	8						0				▲					▲		▲		3	0.11	0.44
(02-102) Sugar Creek																																		
Year: 2000																																		
5.3	**71.0**	23.26	■	■		■	■	■		■	■		8						0									▲		▲		2	0.11	0.33
0.1	**77.0**	16.39	■	■		■	■	■		■	■		7						0									▲		▲		2	0.13	0.38
(02-103) Long Run																																		
Year: 2000																																		
4.9	**56.5**	18.18	■				■	■		■			4					●	1				▲	▲				▲	▲		▲	5	0.40	1.40
3.6	**69.0**	10.75	■	■		■	■	■			■		6						0									▲	▲	▲		3	0.14	0.57
0.7	**73.0**	19.23	■	■		■	■	■		■	■		8						0				▲					▲		▲		3	0.11	0.44
(02-104) Reynolds Run																																		
Year: 2000																																		
4.9	**53.5**	27.78	■	■			■			■			4				●	●	2				▲	▲			▲	▲			▲	5	0.60	1.60
0.7	**59.0**	23.26		■				■			■		3				●	●	2	▲			▲	▲	▲			▲	▲	▲		7	0.75	2.50
(02-105) Castro Run																																		
Year: 2000																																		
0.4	**57.0**	19.23	■	■			■	■		■	■		6						0				▲	▲				▲	▲		▲	5	0.14	0.86

Key QHEI Components

			WWH Attributes											MWH Attributes																							
														High Influence					*Moderate Influence*																		
River Mile	QHEI	Gradient (ft/mile)	No Channelization or Recovered	Bouldery/Cobble/Gravel Substrates	Silt Free Substrates	Good/Excellent Substrates	Moderate/High Sinuosity	Extensive/Moderate Cover	Fast Current/Eddies	Low-Normal Overall Embeddedness	Max Depth > 40 cm	Low-Normal Riffle Embeddedness	**Total WWH Attributes**	Channelized or No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse/No Cover	Max Depth < 40 cm (WD, HW)	**Total HI MWH Attributes**	Recovering Channel	Heavy/Moderate Silt Cover	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair/Poor Development	Low Sinuosity	Only 1-2 Cover Types	Intermittent and Poor Pools	No Fast Current	High/Mod. Overall Embeddedness	High/Mod. Riffle Embeddedness	No Riffle	**Total MI MWH Attributes**	**(MWH HI+1)/(WWH+1) Ratio**	**(MWH MI+1)/(WWH+1) Ratio**
(02-110) Alum Creek																																					
Year: 2000																																					
56.3	**47.5**	19.23		■								■	2	●			●	●	3		▲		▲	▲	▲			▲	▲	▲		7	1.33	3.67
55.3	**62.5**	8.06	■	■		■	■	■				■	6						0	▲	▲		▲	▲				▲	▲	▲		7	0.14	1.14
49.9	**83.0**	11.11	■	■		■	■	■	■	■	■		9						0												▲	1	0.10	0.20
45.5	**71.0**	13.70	■	■		■	■	■		■	■	■	8						0									▲				1	0.11	0.22
42.9	**89.0**	10.00	■	■		■	■	■	■	■	■	■	9						0													0	0.10	0.10
22.1	**70.5**	3.27	■	■		■	■	■	■		■		7						0		▲								▲	▲		3	0.13	0.50
19.8	**79.5**	6.58	■	■		■	■	■	■		■		7						0		▲		▲						▲	▲		4	0.13	0.63
13.4	**79.0**	5.95	■	■		■	■	■	■		■		7						0				▲						▲	▲		3	0.13	0.50
2.7	**86.5**	2.73	■	■		■	■	■	■	■	■		8						0												▲	1	0.11	0.22
0.8	**73.0**	2.98	■	■		■	■	■		■	■		7						0		▲		▲					▲	▲	▲		5	0.13	0.75
(02-112) Big Run																																					
Year: 2000																																					
4.8	**57.5**	10.99	■	■			■	■		■			5			●		●	2		▲		▲	▲	▲			▲	▲	▲		7	0.50	1.67
(02-118) West Branch Alum Creek																																					
Year: 2000																																					
12.3	**50.0**	10.87		■				■		■			3			●		●	2	▲			▲	▲	▲			▲	▲		▲	7	0.75	2.50
9.9	**47.5**	8.33		■				■		■	■		4			●			1	▲	▲		▲	▲	▲			▲	▲	▲	▲	9	0.40	2.20
8.7	**48.5**	5.95		■				■		■	■		4	●		●		●	3	▲			▲	▲	▲			▲	▲	▲		7	0.80	2.20
3.3	**75.5**	9.80	■	■		■	■	■		■	■		7						0		▲							▲		▲		3	0.13	0.50
0.6	**72.0**	9.43	■	■		■	■	■		■	■	■	8						0									▲				1	0.11	0.22
(02-119) Turkey Run																																					
Year: 2000																																					
3.7	**57.0**	9.62	■				■	■		■	■		5						0				▲	▲				▲			▲	4	0.17	0.83
0.1	**74.0**	10.20	■	■		■	■	■		■	■		8						0									▲			▲	2	0.11	0.33
(02-121) Bunker Run																																					
Year: 2000																																					
1.8	**75.0**	18.87	■	■		■	■	■		■	■		7						0									▲	▲	▲		3	0.13	0.50
(02-122) Mason Run																																					
Year: 2000																																					
1.4	**55.5**	16.13	■	■				■			■		4				●	●	2	▲				▲	▲			▲	▲	▲		6	0.60	1.80

Key QHEI Components

			WWH Attributes											MWH Attributes																								
														High Influence					*Moderate Influence*																			
River Mile	QHEI	Gradient (ft/mile)	No Channelization or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrates	Good/Excellent Substrates	Moderate/High Sinuosity	Extensive/Moderate Cover	Fast Current/Eddies	Low-Normal Overall Embeddedness	Max Depth > 40 cm	Low-Normal Riffle Embeddedness	**Total WWH Attributes**	Channelized or No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse/No Cover	Max Depth < 40 cm (WD, HW)	**Total HI MWH Attributes**	Recovering Channel	Heavy/Moderate Silt Cover	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair/Poor Development	Low Sinuosity	Only 1-2 Cover Types	Intermittent and Poor Pools	No Fast Current	High/Mod. Overall Embeddedness	High/Mod. Riffle Embeddedness	No Riffle	**Total MI MWH Attributes**	**(MWH HI+1)/(WWH+1) Ratio**	**(MWH MI+1)/(WWH+1) Ratio**
(02-123) Rocky Fork Big Walnut Creek																																						
Year: 2000																																						
10.2	**60.0**	10.99	■	■			■	■		■	■		6				●		1					▲	▲			▲			▲	4	0.29	0.86
7.1	**60.0**	7.87	■	■			■	■		■	■		6						0		▲		▲	▲				▲	▲	▲		6	0.14	1.00
5.9	**73.5**	10.75	■	■				■		■	■		5				●		1				▲	▲	▲			▲	▲	▲		6	0.33	1.33
3.3	**66.0**	45.45	■		■	■	■	■		■	■		8						0					▲		▲		▲		▲		4	0.11	0.56
1.1	**81.0**	24.39	■	■		■	■	■		■	■	■	8						0									▲				1	0.11	0.22
(02-124) Duncan Run																																						
Year: 2000																																						
5.0	**57.5**	24.39	■	■		■	■	■		■	■		7						0					▲				▲			▲	3	0.13	0.50
(02-125) Prairie Run																																						
Year: 2000																																						
0.7	**51.0**	17.24		■			■	■			■		4				●	●	2	▲			▲	▲	▲			▲	▲	▲		7	0.60	2.00
(02-130) Blacklick Creek																																						
Year: 2000																																						
27.1	**53.5**	16.13	■				■	■		■			4					●	1				▲	▲			▲			▲	4	0.40	1.20
24.7	**76.0**	15.87	■	■		■	■	■		■	■		8						0									▲	▲	▲		3	0.11	0.44
22.4	**70.5**	17.54	■	■		■	■	■		■	■		8				●		1						▲			▲		▲		3	0.22	0.56
20.4	**63.0**	28.57	■	■	■	■	■	■		■	■		9						0							▲		▲		▲		3	0.10	0.40
16.6	**70.0**	14.93	■	■		■	■	■		■	■		7						0									▲		▲		2	0.13	0.38
13.7	**71.5**	17.24	■	■		■	■	■		■	■		8						0									▲	▲	▲		3	0.11	0.44
11.3	**76.5**	10.31	■	■		■	■	■		■	■		7						0									▲	▲	▲		3	0.13	0.50
11.0	**70.0**	10.31	■	■		■	■	■		■	■		7						0									▲	▲	▲		3	0.13	0.50
8.8	**70.5**	13.16	■	■		■	■	■	■		■		7						0					▲					▲	▲		3	0.13	0.50
4.6	**69.0**	5.95	■	■		■	■	■	■		■		7						0										▲	▲		2	0.13	0.38
(02-140) Little Walnut Creek																																						
Year: 2000																																						
7.4	**66.5**	8.26	■	■		■	■	■		■	■		8						0		▲		▲					▲	▲	▲		5	0.11	0.67
3.2	**62.0**	4.42	■	■			■	■			■		5					●	1				▲	▲				▲	▲		▲	5	0.33	1.17
(02-141) Butler Run																																						
Year: 2000																																						
1.2	**45.0**	14.29		■							■		2	●			●	●	3	▲	▲		▲	▲	▲			▲	▲	▲		8	1.33	4.00

Key QHEI Components

River Mile	QHEI	Gradient (ft/mile)	WWH Attributes: No Channelization or Recovered	Bouldery/Cobble/Gravel Substrates	Silt Free Substrates	Good/Excellent Substrates	Moderate/High Sinuosity	Extensive/Moderate Cover	Fast Current/Eddies	Low-Normal Overall Embeddedness	Max Depth > 40 cm	Low-Normal Riffle Embeddedness	Total WWH Attributes	MWH Attributes – High Influence: Channelized or No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse/No Cover	Max Depth < 40 cm (WD, HW)	Total HL MWH Attributes	MWH Attributes – Moderate Influence: Recovering Channel	Heavy/Moderate Silt Cover	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair/Poor Development	Low Sinuosity	Only 1-2 Cover Types	Intermittent and Poor Pools	No Fast Current	High/Mod. Overall Embeddedness	High/Mod. Riffle Embeddedness	No Riffle	Total ML MWH Attributes	(MWH HL+1)/(WWH+1) Ratio	(MWH ML+1)/(WWH+1) Ratio
(02-142) East Branch Little Walnut Creek																																		
Year: 2000																																		
0.4	73.0	25.00	■	■		■	■	■		■	■		7						0				▲				▲			▲		3	0.13	0.50
(02-150) Rattlesnake Creek																																		
Year: 2000																																		
0.1	66.5	62.50	■	■			■	■		■	■		7						0					▲		▲		▲				3	0.13	0.50
(02-151) North Fork Rattlesnake Creek																																		
Year: 2000																																		
5.8	41.0	7.41		■							■		2				●	●	2	▲	▲			▲	▲	▲		▲		▲		8	1.00	3.67
4.8	58.5	7.41	■			■	■	■		■	■		6						0				▲	▲				▲			▲	4	0.14	0.71
3.4	37.5	10.00		■							■		2				●	●	2	▲	▲		▲	▲	▲	▲		▲		▲		9	1.00	4.00
1.7	59.5	12.35	■	■				■			■		4				●		1					▲	▲			▲		▲		5	0.40	1.40
(02-152) East Fork Rattlesnake Creek																																		
Year: 2000																																		
4.2	48.5	14.49	■	■				■		■			4				●		2	▲			▲	▲	▲			▲			▲	6	0.60	1.80
0.2	56.0	25.00	■	■			■	■			■		5						0		▲		▲	▲				▲		▲	▲	6	0.17	1.17
(02-153) South Fork Rattlesnake Creek																																		
Year: 2000																																		
3.7	59.5	11.36	■			■	■	■		■	■		6						0				▲					▲			▲	3	0.14	0.57
0.5	53.0	7.52	■	■			■	■			■		5						0				▲	▲				▲		▲	▲	5	0.17	1.00
(02-160) Perfect Creek																																		
Year: 2000																																		
4.7	71.5	17.24	■	■		■	■	■		■	■		8						0					▲				▲			▲	3	0.11	0.44
1.0	59.0	9.35	■	■			■	■			■		5						0		▲		▲	▲				▲		▲	▲	6	0.17	1.17
(02-170) Mill Creek																																		
Year: 2000																																		
1.3	70.5	25.00	■	■		■	■	■		■	■		7						0		▲		▲					▲		▲	▲	5	0.13	0.75
(02-240) Trib. to Alum Creek (RM 17.15)																																		
Year: 2000																																		
0.4	60.0	40.00	■	■		■	■	■			■		6				●		1	▲			▲	▲	▲			▲		▲	▲	7	0.29	1.29
(02-252) Rose Run																																		
Year: 2000																																		
0.5	55.5	22.22	■	■			■	■		■			5					●	2				▲	▲				▲		▲	▲	5	0.50	1.33

Key QHEI Components

			WWH Attributes										MWH Attributes																	
													High Influence					*Moderate Influence*												
River Mile	QHEI	Gradient (ft/mile)	No Channelization or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrates	Good/Excellent Substrates	Moderate/High Sinuosity	Extensive/Moderate Cover	Fast Current/Eddies	Low-Normal Overall Embeddedness	MaxDepth > 40 cm	Low-Normal Riffle Embeddedness	**Total WWH Attributes**	Channelized or No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse/No Cover	Max Depth < 40 cm (WD, HW)	**Total HL MWH Attributes**	Recovering Channel	Heavy/Moderate Silt Cover	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair/Poor Development	Low Sinuosity	Only 1-2 Cover Types	Intermittent and Poor Pools	No Fast Current	High/Mod. Overall Embeddedness	High/Mod. Riffle Embeddedness	No Riffle	**Total ML MWH Attributes**	**(MWH HL+1)/(WWH+1) Ratio**	**(MWH ML+1)/(WWH+1) Ratio**
(02-260) Sugar Run																																		
Year: 2000																																		
0.7	**66.5**	15.87	■	■				■			■		4			●			1	▲		▲	▲	▲			▲	▲	▲		7	0.40	1.80
(02-276) Spring Run																																		
Year: 2000																																		
6.0	**26.0**	6.76											0	●	●	●	●	●	5	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲		▲	9	6.00	*.**
3.7	**59.0**	14.29	■	■			■	■			■		5						0		▲		▲	▲				▲	▲	▲		6	0.17	1.17
0.2	**58.0**	35.71	■	■		■	■	■		■	■		8				●		1					▲				▲		▲		3	0.22	0.56
(02-280) Trib. to Big Walnut Creek (RM 27.29)																																		
Year: 2000																																		
0.2	**53.5**	25.00	■	■			■	■			■		5				●		1				▲	▲				▲	▲	▲		5	0.33	1.17
(02-281) Dysar Run																																		
Year: 2000																																		
3.0	**49.0**	45.45		■			■	■			■		4			●			1	▲			▲	▲	▲			▲	▲		▲	7	0.40	1.80
1.9	**68.0**	28.57	■	■		■	■	■			■		6						0									▲	▲	▲		3	0.14	0.57
(02-286) Powell Ditch																																		
Year: 2000																																		
0.8	**49.5**	9.71	■	■			■	■			■		5				●		1					▲		▲		▲	▲	▲		5	0.33	1.17
(02-287) Trib. to Blacklick Creek (RM 10.36)																																		
Year: 2000																																		
0.2	**70.0**	58.82	■	■		■	■	■		■	■		8						0									▲		▲		2	0.11	0.33
(02-288) Trib. to Blacklick Creek (RM 11.25)																																		
Year: 2000																																		
0.3	**73.0**	40.00	■	■		■	■	■		■	■		8						0		▲			▲				▲	▲	▲		5	0.11	0.67
(02-290) French Run																																		
Year: 2000																																		
0.6	**55.0**	50.00	■	■			■	■			■		5						0	▲				▲				▲	▲	▲		5	0.17	1.00
(02-297) Kilbourne Run																																		
Year: 2000																																		
0.4	**66.0**	40.00	■	■		■	■	■			■		6						0									▲	▲	▲		3	0.14	0.57
(02-334) Trib. to Big Walnut Creek (RM 32.60)																																		
Year: 2000																																		
0.2	**58.5**	43.48	■	■		■	■	■		■		■	7				●	●	2						▲			▲				2	0.38	0.63

Key QHEI Components

			WWH Attributes										MWH Attributes																
													High Influence					*Moderate Influence*											
River Mile	QHEI	Gradient (ft/mile)	No Channelization or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrates	Good/Excellent Substrates	Moderate/High Sinuosity	Extensive/Moderate Cover	Fast Current/Eddies	Low-Normal Overall Embeddedness	Max Depth > 40 cm	Low-Normal Riffle Embeddedness	**Total WWH Attributes**	Channelized or No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse/No Cover	Max Depth < 40 cm (WD, HW)	**Total HL MWH Attributes**	Recovering Channel	Heavy/Moderate Silt Cover	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair/Poor Development	Low Sinuosity	Only 1-2 Cover Types	Intermittent and Poor Pools	No Fast Current	High/Mod. Overall Embeddedness	High/Mod. Riffle Embeddedness	No Riffle	**Total ML MWH Attributes**	**(MWH HL+1)/(WWH+1) Ratio**	**(MWH ML+1)/(WWH+1) Ratio**
(02-335) Trib. to Big Walnut Creek (RM 27.25)																																			
Year: 2000																																			
0.1	**54.5**	125.0	■	■			■	■			■		5						0					▲				▲	▲	▲		4	0.17	0.83
(02-336) Trib. to Culver Creek (RM 3.32)																																			
Year: 2000																																			
0.7	**67.0**	17.54	■	■			■	■	■		■	■	7						0				▲	▲				▲	▲	▲		5	0.13	0.75
(02-337) Trib. to Alum Creek (RM 23.47)																																			
Year: 2000																																			
0.8	**64.0**	22.73	■	■			■	■	■			■	6						0		▲			▲				▲	▲	▲		5	0.14	0.86
(02-338) Trib. to Alum Creek (RM 25.50)																																			
Year: 2000																																			
0.2	**63.0**	40.00	■	■			■	■	■	■	■	■	8						0		▲			▲						▲		3	0.11	0.44
(02-341) Trib. to Little Walnut Creek (RM 9.5)																																			
Year: 2000																																			
1.5	**68.0**	15.87	■	■			■	■	■		■	■	7						0					▲				▲			▲	3	0.13	0.50
(02-342) Trib. to Dysar Run (RM 1.67)																																			
Year: 2000																																			
0.2	**52.0**	200.0	■	■			■	■			■		5					●	1					▲				▲			▲	3	0.33	0.83

Biological Assessment: Macroinvertebrate Communities

Big Walnut Creek

Macroinvertebrate communities were evaluated at 15 stations on Big Walnut Creek from the headwaters (RM 73.6, drainage area of ~ 5.0 mi^2) to near its confluence with the Scioto River (RM 1.7) (Table 22, Fig. 46). The invertebrate community performance ranged from exceptional (ICI=48) downstream from the airport tributary (RM 27.0) to low fair in the headwaters at Cardington-East Road (RM 73.6). The station with the highest total mayfly (Ephemeroptera), stonefly (Plecoptera), and caddisfly (Trichoptera) taxa richness (EPT), a measure of the diversity of pollution sensitive taxa, was at North Old 3C Road (RM 52.3) with 19 taxa. In particular, stoneflies are usually only found, during the summer months, at the least impacted sites. The stonefly *Acroneuria frisoni* was found at RMs 60.0, 54.6, and 3.6. Overall, the macroinvertebrate communities were evaluated as exceptional at four sites, very good at four sites, good at three sites, marginally good at one site, and fair at three sites.

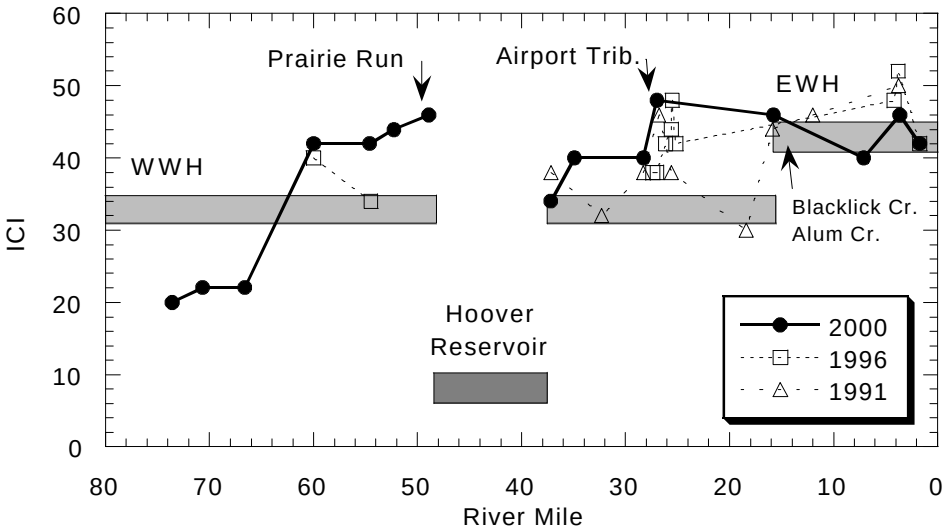

Figure 46. Longitudinal trend of the Invertebrate Community Index (ICI) in Big Walnut Creek, 1991 to 2000.

The macroinvertebrate communities analyzed at the three most upstream stations on Big Walnut Creek were not meeting expectations with low fair or fair evaluations. The communities at these stations were characterized by low EPT diversity (3-6) and predominance of facultative or tolerant taxa. The farthest upstream station at Cardington-East Road (RM 73.6) was impacted by channelization, siltation, lack of flow, removal of the woody riparian, nutrient enrichment, and low D.O. The stream channel was relatively intact at the next two stations; however, both stations were still impacted by lack of flow and the station at Waldo-Fulton-Chesterville Road (RM 70.7) was observed to have excessive amounts of silt covering larger substrates. The lack of flow within this part of Big Walnut Creek was probably the result of channelization of headwater streams and widespread use of drainage tiles in surrounding agricultural fields. The best plan to improve the

resource quality of this section would probably be to set back the agricultural and livestock operations from the stream channels and allow the woody riparian to reestablish, and to investigate and correct the sources of nutrients and pathogens entering the stream and its tributaries.

Big Walnut Creek at Chambers Road (RM 60.0) was flowing and the macroinvertebrate community was performing in the very good range with an ICI score of 42 and 18 total EPT. Community performance remained very good or exceptional to the upper reaches of Hoover Reservoir.

The community at RM 37.2, immediately downstream from the Hoover Reservoir dam (RM 37.6), declined to the marginally good range with an ICI value of 34, due primarily to declines in mayfly diversity and the relative abundance of mayflies and Tanytarsini midges. Negative community responses are often observed for short reaches below large impoundments. The community improved into the good range by SR 161 (ICI=40 at RM 34.9) and remained good to exceptional to the mouth. The station at SR 665/317 (RM 7.1) was resampled in 2001 at RM 7.0 due to the lack of riffle habitat at the original location.

The longitudinal trend of macroinvertebrate community performance in Big Walnut Creek was similar in 2000 compared to 1996 and 1991 (Fig. 46).

Big Walnut Creek Tributaries upstream from the Hoover Reservoir dam
Macroinvertebrate communities in the minor Big Walnut Creek tributaries upstream from Hoover Reservoir were evaluated at 26 stations in 15 streams. Fourteen of these stations were not achieving the aquatic life use expectations for the macroinvertebrate community. The EPT diversities were relatively low (2-8) and the communities were predominated by primarily facultative or tolerant taxa. Three stations were supporting high quality communities with relatively high numbers of EPT taxa (18). These stations were on Culver Cr. (RMs 3.3 and 0.1) and Perfect Cr. (RM 0.1). The stonefly *Acroneuria frisoni* was found at Reynolds Run (RM 0.7), Perfect Creek (RM 0.1), and Rattlesnake Creek (RM 0.1).

The stations at Reynolds Run (RM 0.7), Long Run (RM 3.6), Sugar Run (RM 0.1), and Culver Cr. (RM 4.5) were observed to be experiencing low to intermittent stream flow. The Reynolds Run station was also channelized and the woody riparian was partially denuded. Effects from the low flows at these stations could possibly be reduced if the agricultural practices in the area ceased encroachment on the stream corridor and allow the riparian vegetation to reestablish.

The community in E. Fk. Rattlesnake Cr. at Dent Rd. (RM 1.2) was impacted by upstream sources including land application of chicken manure, livestock runoff, and channelization. The station at SR 605 (RM 0.2) was further degraded by silt runoff from the construction of a golf course. The EPT dropped from five to two and organism density dropped to the point where it was hard to find macroinvertebrates. The downstream station on the S. Fk. Rattlesnake Cr. (RM 0.2) was also impacted by silt runoff from the golf course construction. The number of pollution sensitive taxa dropped from 12 at RM 3.0 to seven at RM 0.2 and the predominance of sensitive taxa also declined at the station downstream from the construction area. The water column at RM 0.2 was turbid brown with silt from the construction site and the stream substrates were heavily silt covered.

The macroinvertebrate community sampled in Prairie Run at RM 0.4 was performing at the fair level with six EPT taxa and the community predominated by pollution facultative taxa. Possible causes of impairment were siltation, channel modifications, and urban runoff.

The macroinvertebrate community in Butler Run (RM 1.2) was impacted by channelization, the removal of the woody riparian vegitation, and possibly nutrient enrichment (excessive algal growth in the pools). The community was predominated by pollution facultative taxa with only four sensitive taxa present at the site.

The West Branch Little Walnut Creek macroinvertebrate community (RM 1.5) was apparently impacted by home sewage treatment systems. Greyish, septic looking water was observed at this station. The community had relatively high numbers of pollution tolerant snails of the genus *Physella* and low diversity of EPT taxa (4).

Macroinvertebrate community performance in Little Walnut Creek declined from good at RMs 9.4 and 7.4, with 14 and 16 qualitative EPT, respectively, to fair at RM 4.7 with an ICI score of 28 and 7 qualitative EPT. The reason for the decline was unclear.

The macroinvertebrate communities sampled at three stations in Duncan Run were all performing below expectation with evaluations of fair. The qualitative EPT ranged from 4 (RM 2.7) to 6 (RM 9.0). The stream channel at the two upstream stations was channelized with the woody riparian removed. Siltation appeared to be excessive, especially at RM 9.0.

Minor Big Walnut Creek Tributaries Downstream from the Hoover Reservoir Dam

The three streams sampled in this category were not achieving the macroinvertebrate community expectations. McKenna Creek (RM 0.2) is a small urbanized stream. The EPT diversity (5 taxa) and abundance were relatively low and was represented primarily by pollution facultative taxa. The Tributary to B. Walnut Cr. (RM 27.29) is a small, channelized stream that flows adjacent to the Port Columbus International Airport. The community was predominated by pollution tolerant (*Polypedilum illinoense*) and facultative (*Conchapelopia sp.*) taxa of midges and was supporting very low EPT diversity (3 taxa) and predominance. The poor community response at this station indicated highly impaired water quality conditions in addition to impacts caused by habitat modifications. Mason Run originates in an industrial area and then flows through an underground culvert from RM 3.4 to 1.9. The macroinvertebrate community was evaluated as poor at RM 0.5 due to very low EPT taxa diversity (3) and abundance, overall low diversity (17 taxa), and relatively high predominance of pollution tolerant (oligochaete worms) and facultative (midges of the *Polypedilum scalaenum* group) taxa. Accumulations of foul-looking black solids in the slack water margins was evidence of water quality contamination.

Rocky Fork Basin

The macroinvertebrate communities sampled at the three upstream Rocky Fork stations were generally not meeting WWH expectations with the exception of old SR 161 (RM 7.1) which was marginally meeting (Fig. 47). The community sampled upstream from Walnut St. (RM 10.2)

appeared to be impacted by organic/nutrient enrichment. EPT diversity was relatively low (6) and facultative organisms like sow bugs (*Lirceus*) and flatworms (Turbellaria) were more common than expected in a healthy stream. Dark brown silt/solids were observed to be common on the streambed. The station at old SR 161 (RM 7.1) was marginally meeting WWH macroinvertebrate expectations with slightly improved EPT diversity (7) and a reduction in the predominance of the more tolerant taxa. However, heavy silt deposition observed in the pool habitat were one noted negative habitat feature. The macroinvertebrate community performance in the upper part of Rocky Fork in 2000 was the lowest of all surveys since 1991 (Fig. 47). There is no consistent trend in this data which may indicate variable impact severity during this period.

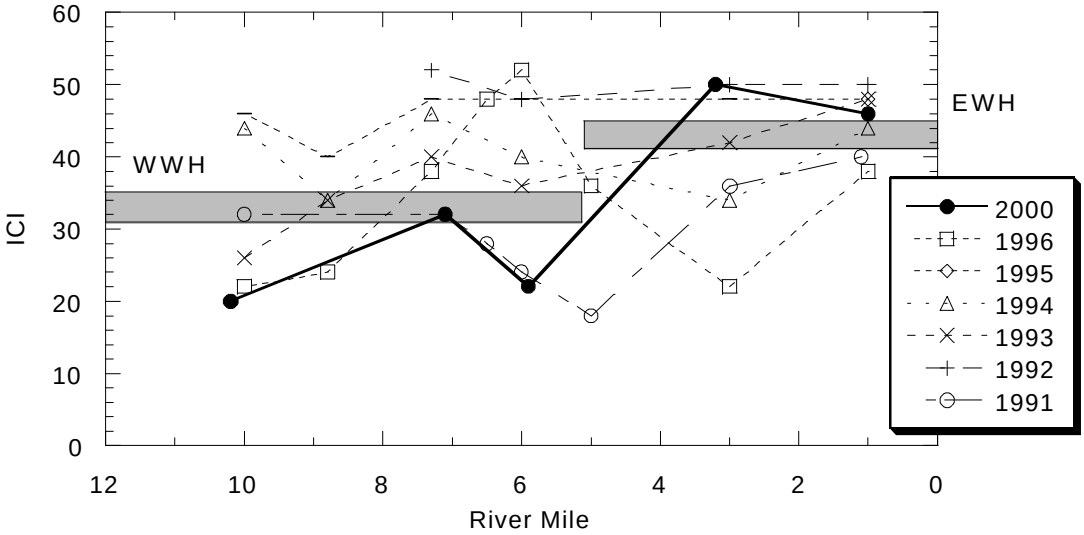

Figure 47. Longitudinal trend of the Invertebrate Community Index (ICI) in Rocky Fork, 1991 to 2000.

The two stations sampled in the lower part of Rocky Fork, within a reach designated EWH, had communities performing in the exceptional range. The macroinvertebrate community performance in the lower part of Rocky Fork was as high as it has been during the six previous surveys conducted since 1991. There is no consistent trend in this data which, similar to the upper part, may indicate variable impact severity during this period.

The macroinvertebrate community sampled in Sugar Run (RM 0.7) was only marginally meeting WWH expectations. EPT diversity was relatively low (8 taxa), number of sensitive taxa (intolerant and moderately intolerant taxa) was low (5 taxa), and the predominant taxa in riffles included pollution facultative fingernail clams and damselflies (in addition to hydropsychid caddisflies), which would not be expected in healthy, unimpacted stream communities. A lot of silt was observed in the pool habitat. The macroinvertebrate community health in Sugar Run has declined compared to a 1996 sample (RM 0.4) which supported a good community assessment (EPT=12, sensitive taxa=17, hydropsychid caddisflies predominant).

Alum Creek

Macroinvertebrate communities were evaluated at 11 stations on Alum Creek from the headwaters (RM 55.3, drainage area of 4.2 mi^2) to near its confluence with Big Walnut Creek (RM 0.7) (Table 22, Fig. 48). The macroinvertebrate community performance ranged from exceptional (ICI=54) downstream from W. Br. Alum Cr. (RM 42.6) to fair (ICI=24) in Wolf Park (RM 7.6). The station with the highest total mayfly (Ephemeroptera), stonefly (Plecoptera), and caddisfly (Trichoptera) taxa richness (EPT), a measure of the diversity of pollution sensitive taxa, was downstream from W. Br. Alum Cr. (RM 42.6) with 24 taxa. In particular, stoneflies are usually only found, during the summer months, at the least impacted sites. The stonefly *Acroneuria frisoni* was found at every station upstream from Alum Creek Lake and stoneflies of the *Neoperla clymene* complex were found at the two stations upstream and downstream from W. Br. Alum Cr. (RMs 42.9 & 42.6). Overall, the macroinvertebrate communities were evaluated as exceptional at four sites, very good at two sites, good or marginally good at two sites, and fair at three sites.

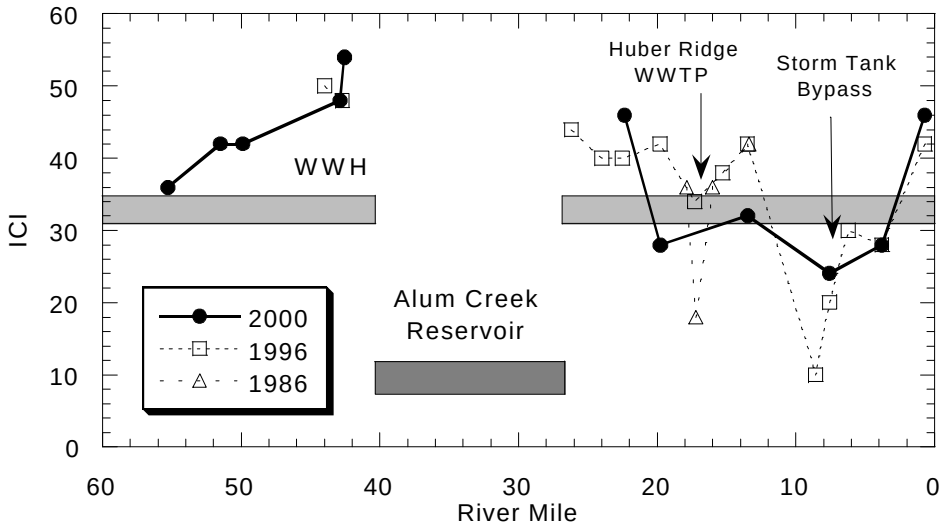

Figure 48. Longitudinal trend of the Invertebrate Community Index (ICI) in Alum Creek, 1986 to 2000.

The macroinvertebrate communities sampled upstream from Alum Creek Lake were all meeting WWH expectations. The most upstream station, sampled downstream from SR 529 (RM 55.3), was achieving good community performance. Woody riparian vegitation was removed from this station which may have contributed to the relatively lower performance. The remaining stations were performing in the very good to exceptional range with diverse and balanced communities.

Macroinvertebrate community performance downstream from Alum Creek Lake started out in the exceptional range (ICI=46) adjacent to Cleveland Ave. (RM 22.4). The community declined into the fair range (ICI=28) by Schrock Rd. (RM 19.8). Mayfly and caddisfly diversity declined and the relative abundance of tolerant taxa increased from 3.6 % upstream to 16.6 % at RM 19.8. Excessive siltation was noted as a likely cause of impairment. This station was resampled in 2001 with similar

results (ICI=30). Community performance at Innis Park (RM 13.7) improved slightly into the marginally good range (ICI=32) and then declined back into fair community performance at Wolf Park (ICI=24 at RM 7.6) and Refugee Rd (ICI=28 at RM 3.8). Mayfly and caddisfly diversity and relative abundance were low and the relative abundance of tolerant taxa (29.7% at RM 7.6, 10.5% at RM 3.8) was high at these two stations. These stations are surrounded by highly urbanized areas of Columbus. The community performance improved at Williams Rd. to the exceptional range (ICI=46 at RM 0.7). However, the high density of organisms (2269/ft^2) at this station compared to the station adjacent to Cleveland Ave. (284/ft^2) was an indication of organic/nutrient enrichment.

Low numbers of zebra mussels (*Dreissena polymorpha*) were found in Alum Creek downstream from Alum Creek Lake and in Big Walnut Creek downstream from the confluence of Alum Creek. Zebra mussels are well established in Alum Creek Lake which will continue to be a source for this introduced species in the stream channels downstream.

The overall macroinvertebrate community performance in Alum Creek was similar to the 1996 survey with the exception of the stations downstream from Westerville and Huber Ridge (Fig. 48). This decline may be due to increased development in this area.

Alum Creek Tributaries Upstream From Alum Creek Lake

The macroinvertebrate community in Bunker Run (RM 1.8) was meeting WWH expectations. The communities sampled in W. Br. Alum Cr. were highly degraded in the headwaters and gradually improved downstream until WWH expectations were fully met near the mouth. The two upstream stations (RMs 9.4 and 8.7) were heavily influenced by intermittent flow conditions; limited macroinvertebrate communities were evaluated as fair. W. Br. Alum Cr. at Shoemaker Rd. (RM 3.3) was flowing and had an improved macroinvertebrate community (marginally good). Predominance of pollution facultative flatworms in the riffle habitat was an indication of some continued impact at this station. The community improved substantially by Worthington-New Haven Rd. (RM 0.5) into the exceptional range (ICI=50). A 1996 sample at RM 0.7 yielded similar results with an exceptional macroinvertebrate community performance (ICI=52). The Turkey Run community at Pompey Rd. was performing in the low fair range with low numbers of EPT taxa (2) and sensitive taxa (3). The stream at this site was intermittent which limited the community diversity and exacerbated water quality problems. The stream at Piper Rd. (RM 0.1) was flowing and was supporting a very good macroinvertebrate community (EPT=18, 24 sensitive taxa). The macroinvertebrate community in Big Run at SR 36/37 was not meeting WWH expectations with relatively low EPT taxa diversity (6) and number of sensitive taxa (8). Stream flow was low which may have exacerbated water quality problems.

Alum Creek Tributaries Downstream From Alum Creek Lake

The macroinvertebrate communities sampled in Spring Run were highly degraded. The most upstream station at Blue Heron Rd. (RM 5.4) had a very poor community with no EPT taxa and was predominated by facultative and tolerant taxa. This station was channelized and surrounded by a housing development. The community gradually improved downstream into the fair range at Buenos Aires Dr. (RM 0.2). Habitat alterations, urban runoff, and possibly home sewage treatment systems were likely sources causing the degraded macroinvertebrate communities.

Blacklick Creek Basin

The macroinvertebrate communities in the headwaters of Blacklick Creek were highly impacted by home sewage treatment systems and livestock operations. A poor community was found at Walnut St. (RM 27.1) with low numbers of EPT taxa (2) and sensitive taxa (1) (Table 22, Fig. 49). A pipe discharging septic water was observed at this station. The station at old SR 161 (RM 24.7) was not much improved (2 EPT and 2 sensitive taxa). This part of the basin is progressively becoming more urbanized. There was gradual improvement downstream until the community was meeting WWH expectations at Havens Rd. (RM 20.4) with a good community (10 EPT taxa and 11 sensitive taxa). The community performance remained at least marginally meeting WWH expectations through the Reynoldsburg area. However, unusually high relative predominance of pollution facultative flatworms and tolerant oligochaete worms observed in the riffle habitats starting at Broad St (RM 16.6) was an indication of water quality degradation in this area. The Jefferson Twp. Wengert Rd. WWTP discharges to Blacklick Cr. at RM 18.10 and may be a contributing factor to any degradation in this area. The Fairfield Co. Tussing Rd. WWTP (RM 11.15) discharge was mildly impacting the macroinvertebrate community. The ICI score dropped from 48 upstream from the WWTP at RM 11.3 to 38 downstream at RM 11.0. The relative predominance of tolerant taxa (primarily oligochaete worms) increased downstream from the WWTP to 12.2 % compared to 3.8 % upstream. The natural substrate qualitative sample EPT diversity also declined downstream to eight taxa compared to 13 upstream. The qualitative samples taken in the Tussing Rd. WWTP mixing zone were both evaluated as fair but not reflecting a toxic response to the discharge. The community was only slightly improved by the time the Blacklick Estates WWTP discharges into Blacklick Cr. at RM 4.85. Downstream from the WWTP, the ICI score declined from the good range (40) to the fair range (26) due to declines in mayfly and caddisfly diversity and an increase in tolerant taxa (primarily oligochaete worms) from 7.4 % upstream to 23.9 % downstream. The qualitative samples taken in the Blacklick Estates WWTP mixing zone were both evaluated as fair but not reflecting a toxic response to the discharge. The community improved into the very good range (ICI=42) by Hamilton Rd. (RM 2.6).

The general longitudinal trend in macroinvertebrate community performance in Blacklick Creek in 2000 was similar to the previous sampling in 1996 except for a substantial decline downstream from the Blacklick Estates WWTP (Fig. 49). The impact from the Blacklick Estates WWTP was more severe in 1986 when the impact extended to at least RM 2.1.

The macroinvertebrate communities sampled in Dysar Run, French Creek, and Powell Ditch were not meeting WWH expectations. Diversity of EPT taxa and sensitive taxa were low and the riffle habitats were at least in part predominated by pollution facultative taxa like blackflies, *Tipula* craneflies, and flatworms. One likely source of impairment in these streams was the urbanized nature of the surounding area. The community in the N. Br. French Creek was evaluated as marginally good. Diversity of EPT taxa (9) and sensitive taxa (10) were higher than sampling locations in surounding streams but on the low end for a good community. The stream was interstitial when sampled on September 19 which may have contributed to the community's marginal performance. A sample collected at this station on August 27 yielded similar results with an ICI score of 34 (marginally good).

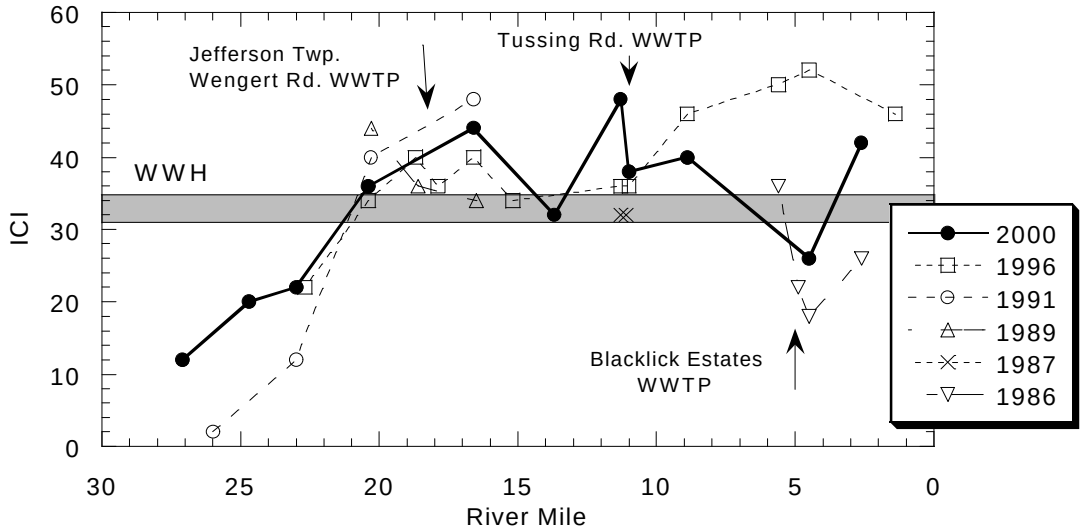

Figure 49. Longitudinal trend of the Invertebrate Community Index (ICI) in Blacklick Creek, 1986 to 2000.

Table 22. Summary of macroinvertebrate data collected from artificial substrates (quantitative sampling) and natural substrates (qualitative sampling) in the Big Walnut Creek study area, July to September, 2000.

			Quantitative Evaluation				
Stream River Mile	Density (/ft^2)	Quant. Taxa	Qual. Taxa	Qual. EPT[a]	Total EPT	ICI	Evaluation[b]
Big Walnut Creek (02-100)							
Eastern Cornbelt Plains (WWH - Existing)							
73.6	-	-	38	4	-	Low F*	Low Fair
70.7	-	-	32	6	-	F*	Fair
66.6	-	-	26	3	-	F*	Fair
60.0	85	38	37	15	18	42	Very Good
54.6	196	36	51	15	17	[30][c]	Very Good
52.3	265	40	48	14	19	44	Very Good
48.9	196	39	41	13	15	46	Exceptional
37.2	284	30	46	11	11	34[ns]	Marg. Good
34.9	448	30	42	12	16	40	Good
28.3	365	33	52	15	18	40	Good
27.0	1312	41	37	10	16	48	Exceptional
Eastern Cornbelt Plains (EWH - Existing)							
15.8	318	38	55	12	13	46	Exceptional
7.0[d]	530	30	36	16	20	44[ns]	Very Good
3.6	330	39	35	11	15	46	Exceptional
1.7	339	34	37	10	13	42[ns]	Very Good
Rattlesnake Creek (02-150) Eastern Cornbelt Plains (WWH - Existing)							
0.1	100	30	30	10	12	38	Good
Little Walnut Creek (02-140) Eastern Cornbelt Plains (WWH - Existing)							
4.7	315	40	32	7	8	28*	Fair
Rocky Fork (02-123)							
Eastern Cornbelt Plains (WWH - Existing)							
10.2	-	-	30	6	-	-	Fair
7.1	-	-	37	7	-	-	Marginally Good
5.9	-	-	38	5	-	-	Fair
Eastern Cornbelt Plains (EWH - Existing)							
3.2	492	36	44	11	13	50	Exceptional
1.0	656	55	37	12	14	46	Exceptional

Table 22. Continued

Stream River Mile	Density (/ft^2)	Quant. Taxa	Qual. Taxa	Qual. EPT[a]	Total EPT	ICI	Evaluation[b]
			Quantitative Evaluation				
Alum Creek (02-110) Eastern Cornbelt Plains (WWH - Existing)							
55.3	-	-	53	13	-	-	Good
51.5	-	-	61	19	-	-	Very Good
49.9	-	-	56	16	-	-	Very Good
42.9	198	41	67	20	23	48	Exceptional
42.6	637	42	63	22	24	54	Exceptional
22.4	284	60	49	14	18	46	Exceptional
19.8	1402	43	30	5	8	28*	Fair
13.5	1597	32	35	7	8	32[ns]	Marginally Good
7.6	628	38	25	2	5	24*	Fair
3.8	697	33	31	5	8	28*	Fair
0.7	2268	36	46	14	17	46	Exceptional
West Branch Alum Creek (02-118) Eastern Cornbelt Plains (WWH - Existing)							
0.5	291	38	61	18	22	50	Exceptional
Blacklick Creek (02-130) Eastern Cornbelt Plains (WWH - Existing)							
27.1	-	-	30	2	-	-	Poor
24.7	-	-	34	2	-	-	Low Fair
23.0	-	-	35	4	-	-	Fair
20.4	-	-	42	10	-	-	Good
16.6	405	51	49	12	12	44	Very Good
13.7	-	-	48	8	-	-	Marginally Good
11.3	866	41	47	13	13	48	Exceptional
11.10	-	-	27/30	6/6	-	-	Fair/Fair
11.0	2790	39	48	8	11	38	Good
8.9	696	47	36	8	9	40	Good
4.83	-	-	33/25	8/4			Fair/Fair
4.5	647	37	47	9	10	26*	Fair
2.6	538	42	51	12	15	42	Very Good
N. Br. French Run (Trib. to French Run (RM 0.33)) (02-291) Eastern Cornbelt Plains (EWH - Existing)							
0.2[d]	328	32	17	4	7	34*	Marginally Good

Table 22. Continued

Stream River Mile	No. Taxa	EPT[a]	I&MI Taxa[e]	Relative Density	***Qualitative Evaluation*** Predominant Organisms	Narrative Evaluation
Big Walnut Creek (02-100) Eastern Cornbelt Plains (WWH - Existing)						
73.6	38	4	1	Mod.-High	Water boatmen, scuds	Low Fair
70.7	32	6	4	Low-Mod.	Water boatmen, red midges, heptageniid mayflies	Fair
66.6	26	3	4	Low-Mod.	Beetles, water boatmen, mayflies	Fair
54.6	51	15	30	Moderate	Caddisflies, mayflies, midges	Very Good
Reynolds Run (02-104) Eastern Cornbelt Plains (WWH - Existing)						
0.7	40	7	11	Moderate	Beetles, water boatmen, snails	Fair
Long Run (02-103) Eastern Cornbelt Plains (WWH - Existing)						
3.6	36	6	9	Low-Mod.	Hydropsychid caddisflies, midges	Fair
0.7	43	14	18	Low-Mod.	Caddisflies, midges	Good
Sugar Creek (02-102) Eastern Cornbelt Plains (WWH - Existing)						
0.1	29	8	7	Low-Mod.	Crayfish, mayflies	Fair
Culver Creek (02-101) Eastern Cornbelt Plains (WWH - Existing)						
4.5	42	5	6	Moderate	Water boatmen, midges, snails	Fair
3.3	63	18	19	Mod.-High	Midges, elmid beetles, *Chimarra* caddisflies	Very Good
0.1	53	18	25	Low-Mod.	Hydropsychid caddisflies, elmid beetles	Very Good
Tributary to Culver Creek (RM 3.32) (02-336) Eastern Cornbelt Plains (WWH - Recommended)						
0.1	60	17	18	Low-Mod.	Midges	Good
Perfect Creek (02-160) Eastern Cornbelt Plains (WWH - Existing)						
4.9	52	7	12	Low-Mod.	Hydropsychid caddisflies, elmid beetles	Marginally Good
0.1	45	18	21	Low-Mod.	Hydropsychid caddisflies, elmid beetles	Very Good
North Fork Rattlesnake Creek (02-151) Eastern Cornbelt Plains (WWH - Existing)						
3.4	49	12	15	Moderate	Caddisflies, *Elimia* snails	Good
0.1	50	9	17	Moderate	Caddisflies, fingernail clams, midges	Good
East Fork Rattlesnake Creek (02-152) Eastern Cornbelt Plains (WWH - Existing)						
1.2	35	5	7	Low	Snails, hydropsychid caddisflies	Low Fair
0.2	22	2	5	Low	Snails	Low Fair
South Fork Rattlesnake Creek (02-153) Eastern Cornbelt Plains (WWH - Existing)						
3.0	36	6	12	Low	Fingernail clams, *Elimia* snails, *Helicopsyche*	Marginally Good
0.2	47	8	7	Low	Hydropsychid caddisflies	Fair
Prairie Run (02-125) Eastern Cornbelt Plains (WWH - Existing)						
0.4	36	6	7	Low	Hydroplychid caddisflies	Fair

Table 22. Continued

Stream River Mile	No. Taxa	EPT[a]	I&MI Taxa[e]	Relative Density	***Qualitative Evaluation*** Predominant Organisms	Narrative Evaluation
Little Walnut Creek (02-140) Eastern Cornbelt Plains (WWH - Existing)						
9.4	49	14	15	Moderate	Hydropsychid caddisflies, midges	Good
7.4	50	16	19	Moderate	Hydropsychid caddisflies, midges, baetid mayflies	Good
Butler Run (02-141) Eastern Cornbelt Plains (WWH - Existing)						
1.2	42	8	3	Moderate	Clams, hydropsychid caddisflies, flatworms	Fair
West Branch Little Walnut Creek (02-143) Eastern Cornbelt Plains (WWH - Existing)						
1.5	35	4	5	Low	*Physella* snails, hydropsychid caddisflies	Fair
Duncan Run (02-124) Eastern Cornbelt Plains (WWH - Existing)						
9.0	35	6	6	Low-Mod.	Scuds, beetles, odonates	Low Fair
7.3	34	5	3	Low-Mod.	Hydropsychid caddisflies	Fair
2.7	26	4	2	Low	*Tipula* craneflies, heptageniid mayflies, scuds	Low Fair
McKenna Creek (Trib. to B. Walnut Cr. (RM 29.65)) (02-347) Eastern Cornbelt Plains (WWH - Recommended)						
0.2	24	5	6	Moderate	*Elimia* snails, water pennies, heptageniid mayflies	Fair
Rocky Fork (02-123) Eastern Cornbelt Plains (WWH - Existing)						
10.2	30	6	7	Moderate	Hydropsychid caddisflies, sow bugs, flatworms	Fair
7.1	37	7	6	Low	Mayflies, hydropsychid caddiflies	Marg. Good
5.9	38	5	8	Moderate	Midges, hydropsychid caddiflies	Fair
Sugar Run (02-260) Eastern Cornbelt Plains (WWH - Existing)						
0.7	30	8	5	Low-Mod.	Fingernail clams, damselflies, baetid mayflies	Marg. Good
Tributary to Big Walnut Creek (RM 27.29) (02-280) Eastern Cornbelt Plains (WWH - Recommended)						
0.2	29	3	2	Mod.-high	Midges	Poor
Mason Run (02-122) Eastern Cornbelt Plains (WWH - Existing)						
0.5	17	3	1	Low	Baetid mayflies, oligochaete worms, leeches	Poor
Alum Creek (02-110) Eastern Cornbelt Plains (WWH - Existing)						
55.3	53	13	10	Low-Mod.	Hydropsychid caddisflies, fingernail clams, midges	Good
51.5	61	19	26	Moderate	Hydropsychid caddisflies, midges, mayflies	Very Good
49.9	56	16	22	Low-Mod.	Mayflies, hydropsychid caddisflies, fishflies	Very Good
Bunker Run (02-121) Eastern Cornbelt Plains (WWH - Existing)						
1.8	27	8	10	Low-Mod.	Caddisflies	Good

Table 22. Continued

Stream River Mile	No. Taxa	EPT[a]	I&MI Taxa[e]	Relative Density	***Qualitative Evaluation*** Predominant Organisms	Narrative Evaluation
West Branch Alum Creek (02-118) Eastern Cornbelt Plains (WWH - Existing)						
9.4	32	4	0	Low-Mod.	Midges, water boatmen	Low Fair
8.7	35	6	5	Moderate	Scuds, water boatmen	Fair
3.3	33	8	12	Moderate	Flatworms, *Chimarra* caddisflies	Marg. Good
Turkey Run (02-119) Eastern Cornbelt Plains (WWH - Existing)						
3.6	39	2	3	Moderate	Water boatmen, damselflies, midges	Low Fair
0.1	49	18	24	Moderate	Caddisflies, Mayflies	Very Good
Big Run (02-112) Eastern Cornbelt Plains (WWH - Existing)						
2.7	44	6	8	Low-Mod.	Hydropsychid caddisflies, midges, *Tipula* cranefly	Fair
Spring Run (Trib. to Alum Creek (RM 17.22) (02-276) Eastern Cornbelt Plains (WWH - Recommended)						
5.4	12	0	0	Low-Mod.	Flatworms, *Helosoma* snails, fingernail clams	Very Poor
3.7	30	1	3	Low-Mod.	Flatworms, elmid beetles, midges	Poor
0.2	28	5	8	Low	Hydropsychid caddisflies, beatid mayflies, flatworms	Fair
Blacklick Creek (02-130) Eastern Cornbelt Plains (WWH - Existing)						
27.1	30	2	1	Moderate	Fingernail clams, flatworms, midges	Poor
24.7	34	2	2	Moderate	Heptageniid mayflies, elmid beetles	Low Fair
23.0	35	4	6	Mod.-High	Elmid beetles, hydropsychid caddisflies	Fair
20.4	42	10	11	Mod.-High	Caddisflies, mayflies, Elimia snails	Good
13.7	48	8	9	Moderate	Baetid mayflies, hydropsychid caddisflies, midges	Marginally Good
11.10A	27	6	6	Mod.-High	Midges, hydropsychid caddisflies	Fair
11.10B	30	6	8	Moderate	Hydropsychid caddisflies, baetid mayflies, midges	Fair
4.83A	33	8	9	Moderate	Hydropsychid caddisflies, *Rheotanytarsus* midges	Fair
4.83B	25	4	7	Low	Hydropsychid caddisflies	Fair
Dysar Run (Trib. to Blacklick Cr. (RM 14.64)) (02-281) Eastern Cornbelt Plains (WWH - Existing)						
3.1[d]	29	4	8	Low-Mod.	Blackflies, hydropsychid caddisflies	Fair
1.6	10	0	2	Low	*Tipula* craneflies	Poor
French Run (Trib. to Blacklick Cr. (RM 13.66) (02-290) Eastern Cornbelt Plains (WWH - Existing)						
0.7	20	5	2	Low-Mod.	Flatworms, hydropsychid caddisflies	Fair
North Branch French Run (Trib. to French Run (RM 0.33)) (02-291) Eastern Cornbelt Plains (EWH - Existing)						
0.2	35	9	10	Low-Mod.	Hydropsychid caddisflies, mayflies, flatworms	Marginally Good
Powell Ditch (Trib. to Blacklick Cr. (RM 6.50)) (02-286) Eastern Cornbelt Plains (WWH - Existing)						
0.9	23	3	4	Low	Flatworms	Poor

Ecoregion Biocriteria: Invertebrate Community Index (ICI)

	WWH	EWH	MWH
Eastern Corn Belt Plains	36	46	22

[a] EPT = total Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) taxa richness.
[b] A qualitative narrative evaluation based on best professional judgement is used when quantitative data is not available to calculate the Invertebrate Community Index (ICI) scores.
[c] The artificial substrate samples were affected by insufficient current speed (< 0.3 fps), so the evaluation was based on the qualitative sample.
[d] Sample was collected in 2001 and may be replacing a 2000 sample.
e Sensitive taxa include I=intolerant taxa and MI=moderately intolerant taxa.
C Significant departure from applicable biological criterion (>4 ICI units), poor and very poor results are underlined.
ns Nonsignificant departure from applicable biological criterion (<4 ICI units).

Biological Assessment: Fish Communities

Big Walnut mainstem - downstream from Hoover Reservoir
Fish communities in Big Walnut Creek downstream from Hoover Reservior have improved since 1991 such that marginal EWH performance was realized at most sites sampled (Fig. 50). The one exception was the site immediately downstream from Hoover Reservior where the hypolimnetic release of cool reservoir water favored white suckers, a species adapted to cool water, over redhorse suckers, a warmwater species of fish. The outcome, due to the abundance of white suckers, resulted in lower than normal IBI scores, but did not indicate pollution. More importantly, the improvement evident in the remainder of the lower mainstem, though not dramatic, was significant in that several pollution intolerant species were routinely present that were rare or absent in past collections. Especially notable was the presence of streamline chubs (*Erimystax dissimilis*), a species last collected from Big Walnut in 1897. Also notable was the absence of an impact downstream from Port Columbus Airport, where, in 1996 and 1991, an impact was present.

Despite the improvements evident in 2000, performance of component metrics of the IBI reflected the fact that all the riffles were moderately embedded with small gravel, sand and silt. Evidence for this was given by lower than expected relative abundance of round-bodied suckers, simple lithophils, and number of sucker species. All three metric groups may have responded similarly to the stress, but simple lithophils are, by definition, dependent on clean rocky substrates to spawn, and are therefore the most indicative of the problem. Round-bodied suckers and sucker species in general are a subset of simple lithophils. Another problem, suggested by the elevated abundance of omnivorous fishes and the slightly elevated incidence of DELT anomalies, was either nutrient or organic enrichment. Omnivores are favored by enriched conditions, and DELTs reflect chronic sublethal stress. Sublethal stress is one consequence of enrichment. The root cause of both problems (*i.e.*, riffle embeddedness and enrichment) was likely stormwater runoff and its effect on stream hydrology and water quality.

Big Walnut mainstem - upstream from Hoover Reservoir
Fish communities sampled upstream from Hoover Reservoir in 2000 were of similar quality to those measured in 1996, 1988 and 1982 (Fig. 50), and at the two reference sites resampled in 1999 and 1998. The fish communities met expectations for WWH at all sites sampled except for the two upstream-most headwater sites where tolerant and pioneering fishes composed the majority of individuals in the samples. Embedded substrates and limited flow were the most obvious factor limiting these two sites.

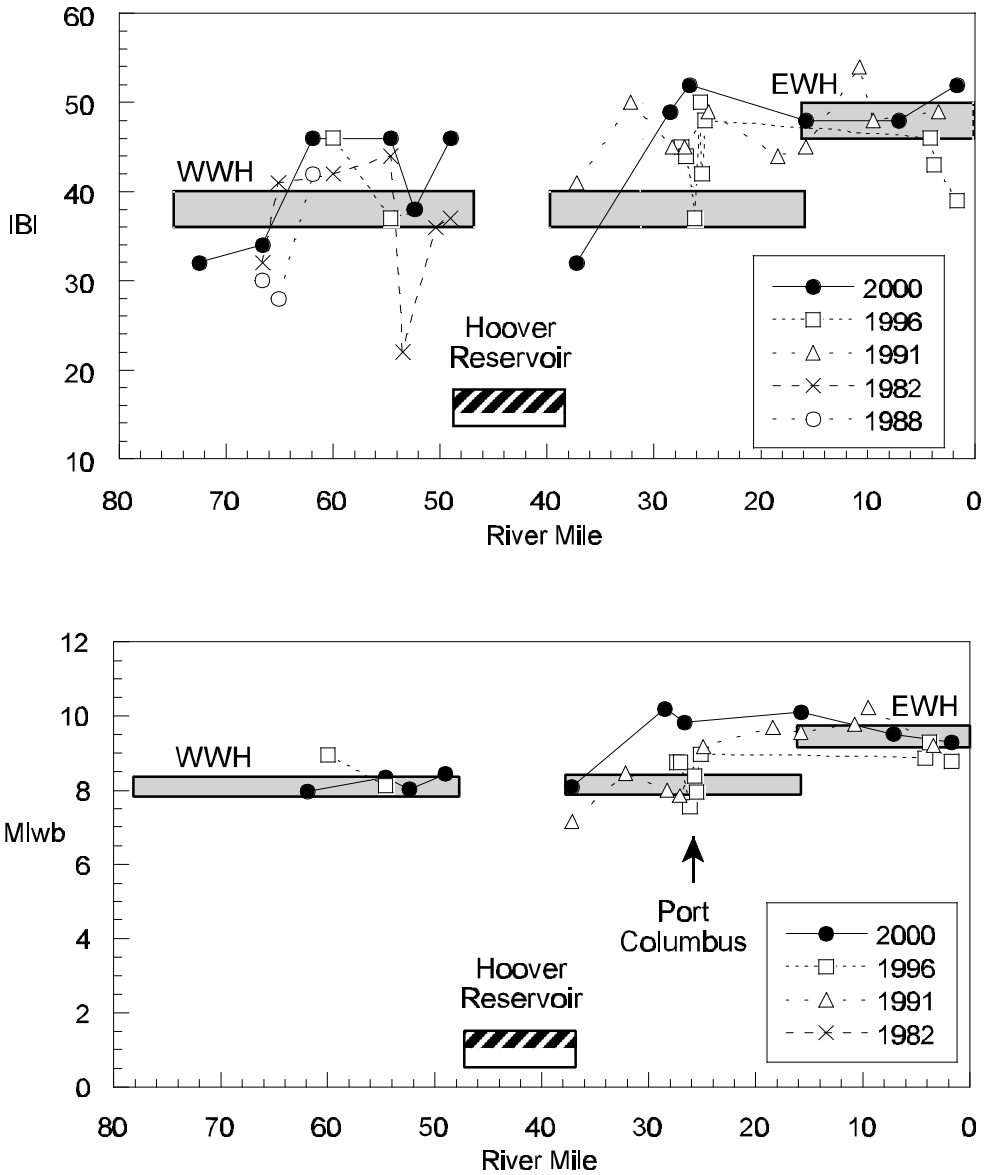

Figure 50. Mean IBI (top panel) and MIwb (bottom panel) scores for fish communities sampled from the the Big Walnut Creek mainstem, 1982 through 2000. Shaded boxes show the range of "nonsignificant departure" for the given aquatic life use criterion.

Rocky Fork Big Walnut

Fish communites in Rocky Fork have become significantly degraded as a result of land development. IBI scores from samples collected in 2000 were lower at almost every site sampled compared to 1996, 1994, 1993, 1992 and 1991 (Fig. 51), and were clearly lower on average (Fig. 52). Most telling of all was the complete absence of intolerant species at the Clark State Road site (RMs 3.1 - 3.3) in 2000 where, historically, silver shiners and hornyhead chubs were abundant (Fig. 52). Additionally, pollution sensitive species as a whole declined over the last decade from 8 species in the early 1990's to 4 species by 2000. The overall decline at Clark State Road has resulted in a loss of aquatic life use from near EWH to less than WWH.

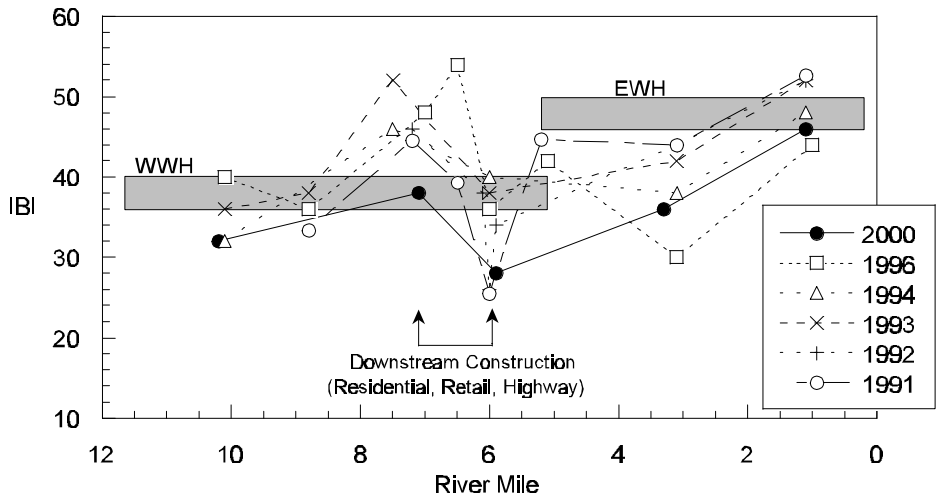

Figure 51. IBI scores for fish communities sampled in Rock Fork of Big Walnut, 1991 through 2000.

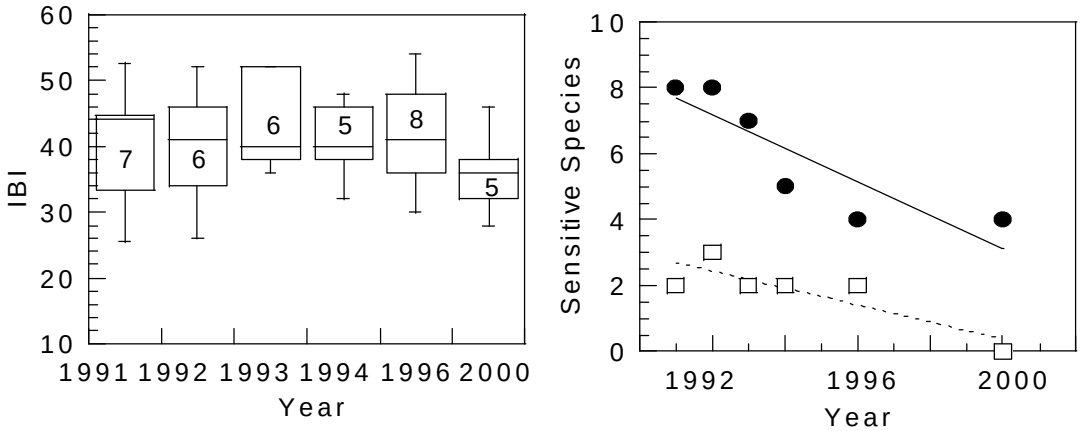

Figure 52. Left panel - IBI scores for Rocky Fork shown as box plots by year. Sample sizes are shown as numbers within respective boxes. Right panel - the number of pollution sensitive species (circles) and highly pollution intolerant species (a subset of sensitive species - squares) sampled at Clark State Road (1991 - 2000).

Blacklick Creek

On the whole, fish communities sampled in Blacklick Creek fared as well or better in 2000 compared to 1996, 1991 or 1986, especially in the lower 15 miles of the creek due to improved sewage treatment (Fig. 54). However, in the middle reach (RMs 20.4 to 16.5) the fish community was showing signs of stress from suburbanization. IBI scores within this reach were slightly lower in 2000 than those from previous years, and, though the difference in IBI scores falls within the range of variation expected between years, the number of pollution sensitive species decreased at RM 20.4, suggesting that the decline, like that seen in Rocky Fork, was real or imminent (Fig. 53).

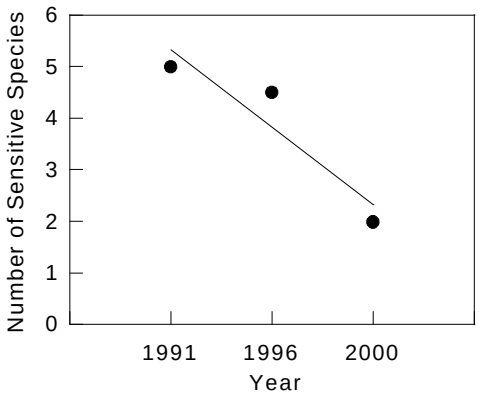

Figure 53. Number of pollution sensitive species in fish samples collected at the Havens Road site (RM 20.4) 1991, 1996 and 2000.

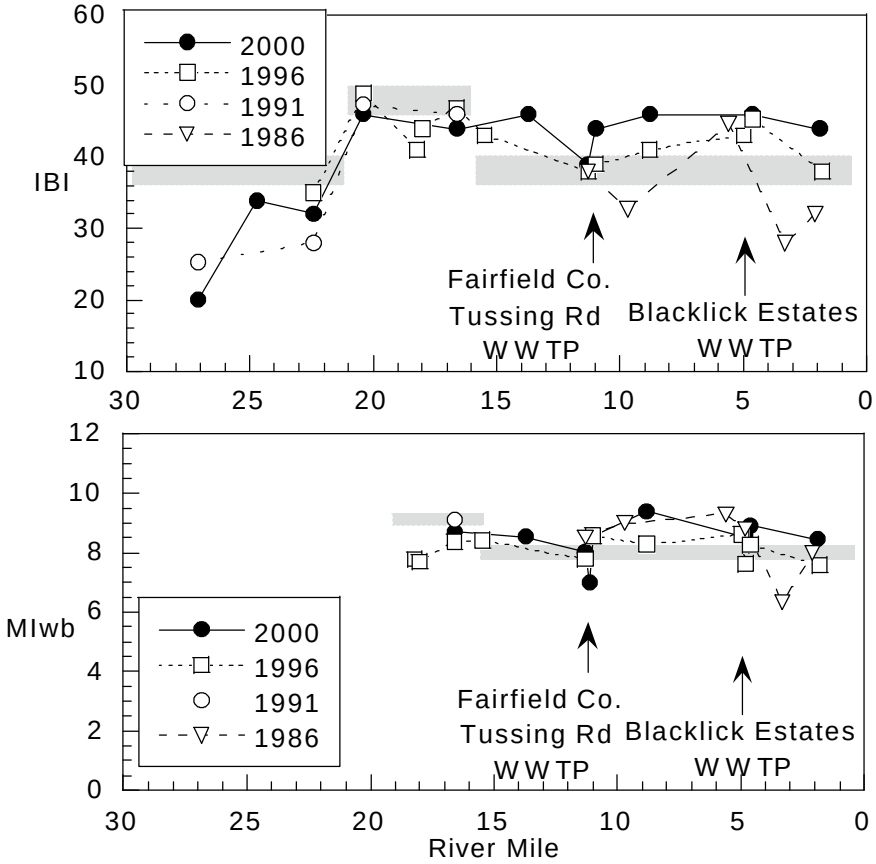

Figure 54. IBI scores (top panel) and MIwb scores (bottom panel) for fish communities sampled in Blacklick Creek, 1986 - 2000.

Alum Creek - downstream from Alum Creek Lake

Four of five sites sampled downstream from Alum Creek Lake supported fish communities meeting expectations for WWH (Fig. 55). The one exception was at RM 13.4 (Innis Road) where the mean MIwb score was slightly lower than the WWH criterion. In 1996, all three indicator groups were in nonsignificant departure of applicable criteria. The difference in scores between years fell within the range of normal interannual variability and probably did not indicate backsliding by the Huber Ridge WWTP. Also, no meaningfull difference in structural metrics was evident between years a fact further suggesting continuity.

Alum Creek - upstream from Alum Creek Lake

The reach near the confluence with the West Branch scored similarly in 1996 and 2000 (Fig. 55). The upper two most sites had been historically channelized; the site at RM 55.3 to drain a wetland. The influence of the wetland remained evident in both the stream habitat and fish community.

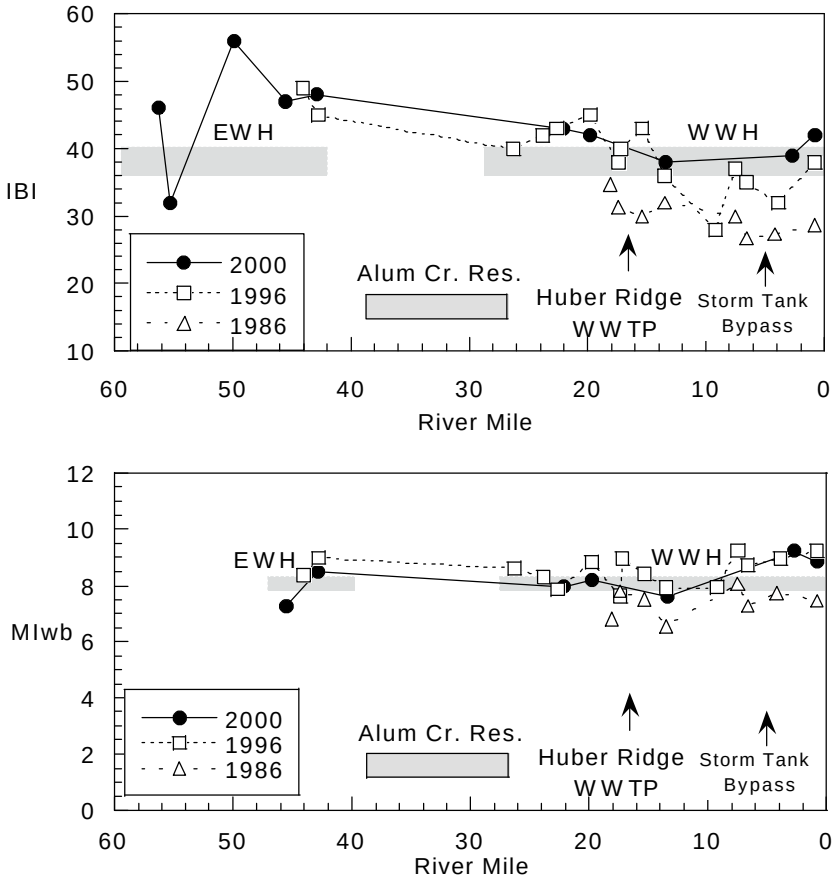

Figure 55. Plots of mean IBI scores (top panel) and mean MIwb scores (bottom panel) for fish communities sampled in Alum Creek, 1986, 1996 and 2000. Shaded boxes show the range of "nonsignificant departure" for the given aquatic life use criterion.

Little Walnut subbasin

Fish communities were sampled at five locations within the Little Walnut subbasin, two of which, Butler Run and the Little Walnut at RM 3.2, did not meet applicable WWH biological criteria. Butler Run was degraded by channelization and unfenced livestock. Little Walnut Creek at RM 3.2 was downstream from a golf course, but also within the influence of Hoover Reservior such that the fish community may have reflected the unstable flow regime.

Rattlesnake Creek

Sediment from construction, degraded habitat from historic channelization and nutrient enrichment from home sewage treatment systems and livestock were the causes and sources of impairment to fish communities within the Rattlesnake Creek subbasin. Construction impacted the lower reach of the South Fork and the Rattlesnake mainstem, and a combination of septic discharge, lawn fertilizer and rowcropping enriched the North Fork, as well as the East Fork, but with the added contribution of livestock.

Miscellaneous Tributaries

Fish community quality throughout the upper Big Walnut basin, defined *ad hoc* as the portion north of Franklin County, closely tracked habitat quality. The tendency for the headwaters to have the most degraded habitat was also reflected in the relationship between IBI scores and drainage area (Fig. 56). The obvious implications were that both restoration and, more importantly, given the rapidity of suburbanization, protection of headwaters should be the focal point of TMDL efforts in the upper watershed. The headwater tributaries containing significant reaches of high quality habitat were Alum Creek downstream from Cardington Road, West Branch Alum Creek, Long Run, Sugar Creek, Little Walnut Creek near Blue Church Road, East Fork Little Walnut, Perfect Creek, Culver Creek, Bunker Run and Mill Creek.

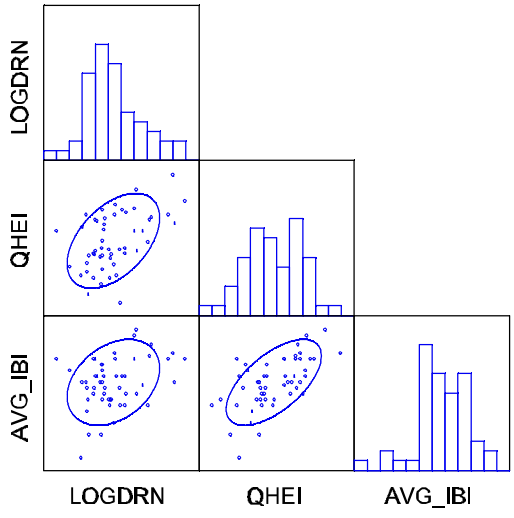

Figure 56. Scatterplot matrix of mean IBI scores, QHEI scores and drainage area (LOGDRN) for sites sampled in the upper portion of the Big Walnut basin (*i.e.*, north of Franklin County), 2000.

Table 23. Fish community summary data for samples collected from the Big Walnut study area, 2000.

Stream/ River Mile[a]	Mean Species	Cumulative Species	Relative Number	QHEI	Mean MIwb[b]	MIwb Narrative	Mean IBI	IBI Narrative
Big Walnut Creek 02-100								
72.50E	14.0	14	676	55.5	NA	NA	32	Fair
66.60D	17.0	17	730	58.5	NA	NA	34	Fair
54.60D	21.5	23	544	73.0	8.4	Good	46	Very Good
52.40D	19.0	20	1143	69.5	8.0	Marg. Good	38	M. Good
49.00E	21.5	24	1980	78.5	8.4	Good	46	Very Good
37.20A	20.5	26	700	84.5	8.1	Marg. Good	32	Fair
28.50A	25.5	31	659	82.0	10.2	Exceptional	49	Very Good
26.70A	26.0	31	687	83.5	9.8	Exceptional	52	Exceptional
15.80A	27.0	31	747	84.5	10.1	Exceptional	48	Very Good
7.10A	30.5	37	598	83.0	9.5	Very Good	48	Very Good
1.70A	26.5	35	525	84.0	9.3	Very Good	52	Exceptional
Culver Creek 02-101								
4.50E	6.0	6	224	56.5	NA	NA	38	Marg. Good
3.30E	17.0	17	626	75.0	NA	NA	40	Good
Trib to Culver Creek 02-336								
0.70E	12.0	12	750	67.0	NA	NA	40	Good
Sugar Creek 02-102								
5.30E	11.0	11	1214	71.0	NA	NA	46	Very Good
0.10E	17.0	17	418	77.0	NA	NA	46	Very Good
Long Run 02-103								
4.90E	3.0	3	28	56.5	NA	NA	20	Poor
3.60E	13.0	13	762	69.0	NA	NA	34	Fair
0.70E	16.0	16	950	73.0	NA	NA	48	Very Good
Reynolds Run 02-104								
4.90E	6.0	6	87	53.5	NA	NA	28	Fair
0.70E	14.0	14	694	59.0	NA	NA	32	Fair
Castro Run 02-105								
0.40E	9.0	9	586	57.0	NA	NA	36	Marg. Good
Mason Run 02-122								
1.40E	9.0	9	88	55.5	NA	NA	28	Fair

Table 23. Continued.

Stream/ River Mile[a]	Mean Species	Cumulative Species	Relative Number	QHEI	Mean MIwb[b]	MIwb Narrative	Mean IBI	IBI Narrative
Little Walnut Creek 02-140								
7.40E	12.0	12	1160	66.5	NA	NA	46	Very Good
3.20E	16.0	16	222	62.0	6.4	Fair	30	Fair
Trib to L Walnut 9.5 02-341								
1.50E	12.0	12	166	68.0	NA	NA	38	Marg. Good
Butler Run 02-141								
1.20E	13.0	13	674	45.0	NA	NA	20	Poor
E. Fk. L. Walnut Cr. 02-142								
0.40E	8.0	8	532	73.0	NA	NA	38	Marg. Good
Rattlesnake Creek 02-150								
0.10E	10.0	13	333	66.5	4.9	Poor	37	Marg. Good
N Fk Rattlesnake Cr. 02-151								
5.80E	9.0	9	892	41.0	NA	NA	32	Fair
4.80E	14.0	14	1200	58.5	NA	NA	40	Good
3.40E	12.0	12	628	37.5	NA	NA	30	Fair
1.70E	15.0	15	746	59.5	NA	NA	40	Good
E Fk Rattlesnake Cr. 02-152								
4.20E	0.0	0	0	48.5	NA	NA	12	Very Poor
0.20E	11.0	11	614	56.0	NA	NA	38	Marg. Good
S Fk Rattlesnake Cr. 02-153								
3.70E	13.0	13	256	59.5	NA	NA	44	Good
0.50E	11.0	11	106	53.0	NA	NA	24	Poor
Perfect Creek 02-160								
4.70E	11.0	11	754	71.5	NA	NA	36	Marg. Good
1.00E	14.0	14	590	59.0	NA	NA	36	Marg. Good
Mill Creek 02-170								
1.30E	11.0	11	518	70.5	NA	NA	40	Good
Duncan Run 02-124								
5.00E	11.0	11	1316	57.5	NA	NA	30	Fair

Table 23. Continued.

Stream/ River Mile[a]	Mean Species	Cumulative Species	Relative Number	QHEI	Mean MIwb[b]	MIwb Narrative	Mean IBI	IBI Narrative
Prairie Run 02-125								
0.70E	16.0	16	798	51.0	NA	NA	44	Good
B Walnut trib 27.29 02-280								
0.20E	11.0	11	564	53.5	NA	NA	26	Poor
B Walnut trib 32.6 02-334								
0.20E	9.0	9	324	58.5	NA	NA	34	Fair
B Walnut trib 27.25 02-335								
0.10E	0.0	0	0	54.5	NA	NA	12	Very Poor
Alum Creek 02-110								
56.30E	12.0	12	390	47.5	NA	NA	46	Very Good
55.30E	17.0	17	1458	62.5	NA	NA	32	Fair
49.90E	22.0	22	572	83.0	NA	NA	56	Exceptional
45.50D	19.5	22	1211	71.0	7.3	Fair	47	Very Good
42.90D	25.0	27	1571	89.0	8.5	Good	48	Very Good
22.10D	23.0	26	314	70.5	8.0	Marg. Good	43	Good
19.80D	24.0	29	623	79.5	8.2	Marg. Good	42	Good
13.40D	23.5	26	852	79.0	7.6	Fair	38	Marg. Good
2.70A	28.0	32	756	86.5	9.2	Very Good	39	Marg. Good
0.80A	28.0	34	597	73.0	8.9	Good	42	Good
W. Br. Alum Creek 02-118								
12.30E	8.0	8	573	50.0	NA	NA	36	Marg. Good
9.90E	9.0	9	640	47.5	NA	NA	30	Fair
8.70E	15.0	15	484	48.5	NA	NA	40	Good
3.30E	17.0	17	926	75.5	NA	NA	54	Exceptional
0.60D	25.0	28	1011	72.0	8.7	Good	51	Exceptional
Turkey Run 02-119								
3.70E	9.0	9	62	57.0	NA		32	Fair
0.10E	14.0	14	338	74.0	NA		34	Fair
Big Run 02-112								
4.80E	9.0	9	138	57.5	NA	NA	34	Fair

Table 23. Continued.

Stream/ River Mile[a]	Mean Species	Cumulative Species	Relative Number	QHEI	Mean MIwb[b]	MIwb Narrative	Mean IBI	IBI Narrative
Bunker Run 02-121								
1.80E	13.0	13	944	75.0	NA	NA	42	Good
Alum Cr. trib 23.47 02-337								
0.80E	9.0	9	326	64.0	NA	NA	40	Good
Alum Cr. trib 25.50 02-338								
0.20E	13.0	13	1568	63.0	NA	NA	52	Exceptional
Alum Cr. trib 17.15 02-240								
0.40E	2.0	2	488	60.0	NA	NA	20	Poor
Spring Run 02-276								
6.00E	6.0	6	184	26.0	NA	NA	24	Poor
3.70E	8.0	8	942	59.0	NA	NA	28	Fair
0.20E	12.0	12	1324	58.0	NA	NA	44	Good
Kilbourne Run 02-297								
0.40E	7.0	7	212	66.0	NA	NA	28	Fair
Rocky Fk. Big Walnut 02-123								
10.20E	9.0	9	648	60.0	NA	NA	32	Fair
7.10D	16.0	16	545	60.0	NA	NA	38	Marg. Good
5.90D	15.0	15	602	73.5	NA	NA	28	Fair
3.30D	15.0	18	797	66.0	7.4	Fair	36	Marg. Good
1.10E	21.5	25	1219	81.0	8.6	Good	46	Very Good
Rose Run 02-252								
0.50E	11.0	11	664	55.5	NA	NA	32	Fair
Sugar Run 02-260								
0.70E	13.0	13	1058	66.5	NA	NA	38	Marg. Good
Blacklick Creek 02-130								
27.10E	3.0	3	244	53.5	NA	NA	20	Poor
24.70E	11.0	11	226	76.0	NA	NA	34	Fair
22.40E	11.0	11	842	70.5	NA	NA	32	Fair

Table 23. Continued.

Stream/ River Mile[a]	Mean Species	Cumulative Species	Relative Number	QHEI	Mean MIwb[b]	MIwb Narrative	Mean IBI	IBI Narrative
Blacklick Creek 02-130								
20.40E	15.0	15	1970	63.0	NA	NA	46	Very Good
16.60D	19.0	19	1298	70.0	8.7	Good	44	Good
13.70D	19.5	22	1256	71.5	8.5	Good	46	Very Good
11.30D	21.0	24	2342	76.5	8.0	Marg. Good	39	Marg. Good
11.14D	*11.0*	*11*	*936*	*NA*	*7.0*	*Fair*	*40*	*Good*
11.00D	19.5	21	1479	70.0	8.6	Good	44	Good
8.80D	19.5	21	1376	70.5	9.4	Exceptional	46	Very Good
4.83D	*15.0*	*19*	*1674*	*NA*	*8.5*	*Good*	*39*	*M. Good*
4.60D	22.5	26	947	69.0	8.9	Very Good	46	Very Good
2.60D	27.7	38	515	78.0	8.4	Good	43	Good
Dysar Run 02-281								
3.00E	10.0	10	1152	49.0	NA	NA	40	Good
1.90E	13.0	13	1076	68.0	NA	NA	42	Good
Trib to Dysar 1.67 02-342								
0.20E	7.0	7	771	52.0	NA	NA	42	Good
French Run 02-290								
0.60E	16.0	16	1474	55.0	NA	NA	48	Very Good
Blacklick Trib 6.50 02-286								
0.80E	14.0	14	974	49.5	NA	NA	36	Marg. Good
Blacklick Trib 10.36 02-287								
0.20E	14.0	15	856	70.0	NA	NA	42	Good
Blacklick Trib 11.28 02-288								
0.30E	15.3	20	763	73.5	NA	NA	48	Very Good

Ecoregion Biocriteria: Eastern Cornbelt Plains

Site Type	IBI WWH	IBI EWH	IBI MWH[c]	MIwb WWH	MIwb EWH	MIwb MWH[c]
Headwaters	40	50	24	NA	NA	NA
Wading	40	50	24	8.3	9.4	5.6
Boat	40	48	24	8.5	9.6	5.7

a - Fish sampling methods: A=Boat, D=Wading, and E=Longline.

b - MIwb is not applicable to headwater streams with drainage areas <20 mi^2.

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