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State of Ohio
Environmental Protection Agency

Division of Surface Water

Biological and Water Quality Study of the Olentangy River, Whetstone Creek and Select Tributaries, 2003-2004

Crawford, Delaware, Franklin, Marion and Morrow Counties

Pycnopsyche **caddisfly larva**

Largemouth bass, Olentangy River

Whetstone Creek, Morrow County

Smallmouth bass, Whetstone Creek

December 22, 2005

Bob Taft, Governor
Joseph P. Koncelik, Director

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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. 1987a. 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. 1987b. 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. 1989b. 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., Ecol. Assess. Sect., Columbus, Ohio.

Ohio Environmental Protection Agency. 1989c. 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, the following new publications by the Ohio EPA have become available. These publications should also be consulted as they represent the latest information and analyses used by the 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 may be obtained by writing to:

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Copies of this report are located on the Ohio EPA internet web page (www.epa.state.oh.us/dsw/document_index/psdindx.html) or may be available on CD 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 4-5 watersheds study areas with an aggregate total of 250-300 sampling sites.

The 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], Water Quality Permit Support Documents [WQPSDs]), and are eventually 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]).

Hierarchy of Indicators
A carefully conceived ambient monitoring approach, using cost-effective indicators consisting 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 includes a hierarchical continuum from administrative to true environmental indicators (Figure 1). 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

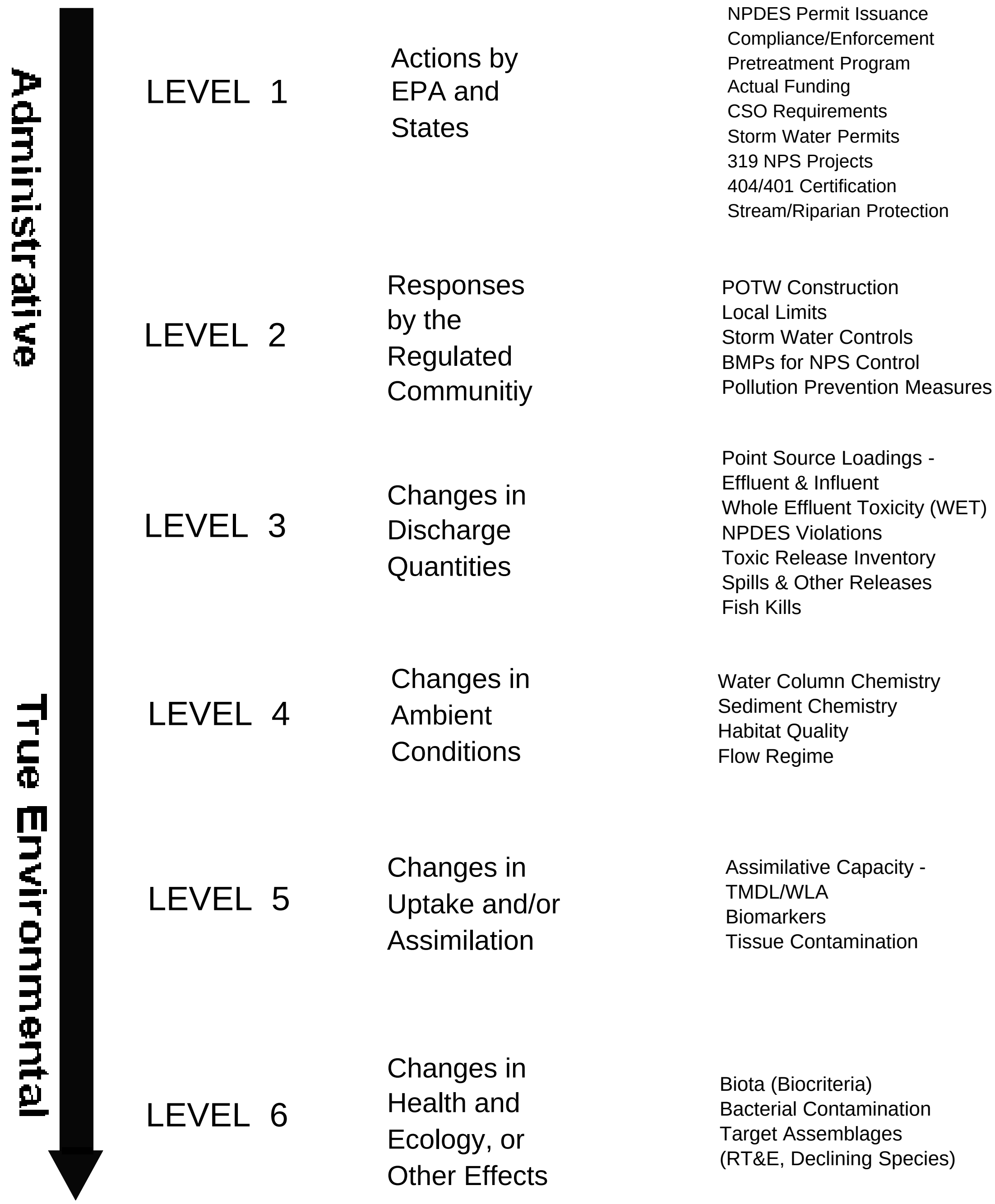


Figure 1. Hierarchy of administrative and environmental indicators which can be used for water quality management activities such as monitoring and assessment, reporting, and the evaluation of overall program effectiveness. This is patterned after a model developed by the U.S. EPA.

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 recreation 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 or subbasin scale is a biological and water quality report. These reports then provide the foundation for aggregated assessments such as the Integrated Water Quality Monitoring and Assessment Report (305[b] and 303[d]), the Ohio Nonpoint Source Assessment, and other technical bulletins.

Ohio Water Quality Standards: Designated Aquatic Life Use

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. 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) *Cold-water 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 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 can be having a water depth of at least one meter over an area of at least 100 square feet or, lacking this, where frequent human contact is a reasonable expectation. If a water body does not meet either criterion, the SCR use applies. The attainment status of PCR and SCR is determined using bacterial indicators (*e.g.,* fecal coliform, *E. coli)* and the criteria for each are specified in the Ohio WQS.

Attainment of recreation uses are evaluated based on monitored bacteria levels. The Ohio Water Quality Standards state that all waters should be free from any public health nuisance associated with raw or poorly treated sewage (Administrative Code 3745-1-04, Part F). Additional criteria (Administrative Code 3745-1-07) apply to waters that are designated as suitable for full body contact such as swimming (PCR- primary contact recreation) or for partial body contact such as wading (SCR- secondary contact recreation). These standards were developed to protect human health, because even though fecal coliform bacteria are relatively harmless in most cases, their presence indicates that the water has been contaminated with fecal matter.

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 AWS and 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.

MECHANISMS FOR WATER QUALITY IMPAIRMENT

The following paragraphs describe the various causes of impairment that were encountered during the Olentangy River and Whetstone Creek study. While these 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, negatively impacts biological communities by limiting the complexity of living spaces available to aquatic organisms. Consequently, fish and macroinvertebrate communities are not as diverse. Indirect impacts include agricultural activities such as the removal of trees and shrubs adjacent to streams (described throughout this report as riparian vegetation) and field tiling to facilitate drainage. Urbanization impacts include removal of riparian trees, influx of stormwater run off, straightening and piping of stream channels, and riparian vegetation removal. Following a rain event, most of the water is quickly removed from tiled fields or urban settings 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. Riparian vegetation aids in nutrient uptake, may decrease run-off rate into streams, and helps keep soil in place. Erosion impacts channelized streams more severely due to the lack of a riparian buffer to slow runoff, trap sediment and stabilize banks. Deep trapezoidal channels lack a functioning flood plain and therefore cannot expel sediment as would occur during flood events along natural watercourses. Additionally, the confinement of flow within an artificially deep channel accelerates the movement of water downstream, exacerbating flooding of neighboring properties.

The lack of water movement under low flow conditions can exacerbate degradation 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. Conversely, oxygen concentrations can become supersaturated during the day, due to abnormally high amounts of photosynthesis, causing gas bubble stress to both fish and invertebrate communities. Oxygen is also used by bacteria that consume dead organic matter. Nutrient enrichment promotes 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.

Siltation and 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 facilitated 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 obligate 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.

Nutrient Enrichment

The element of greatest concern is phosphorus because it is critical for plant growth and 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 on-site wastewater 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 is most often 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. Phosphorus input from urban stormwater is more of a concern if combined sewer overflows are involved. Phosphorus load 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 (Miltner and Rankin, 1998). 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, livestock waste, 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 enters streams as a component of fertilizer and manure run-off and wastewater effluent. 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 wastewater treatment plants. Under these conditions, bacteria first convert ammonia to nitrite and then to nitrate. Nitrate can then be reduced by bacteria through the de-nitrification process 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

High concentrations of either fecal coliform bacteria or *Escherichia coli* (*E. coli*) in a lake or stream may indicate contamination with human pathogens. 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 infect humans. 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. Potential waterborne viruses that are a concern include polio, hepatitis A, and encephalitis. Disease causing parasitic 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 on-lot wastewater 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 as it may seep into field tiles or travel overland during precipitation events.

Bacteria criteria for the recreational use 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 can cause skin irritation, 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.

Sediment chemistry results are evaluated by Ohio EPA 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 natural streams in Central Ohio do not contain a lot of fine grained sediment and samples often consist mostly of sand. Fine grained sediments are deposited in flood plains of natural streams during periods of high flow. 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).

NONPOINT SOURCE POLLUTION IMPACTS AND REMEDIATION PROJECTS

Nonpoint sources of pollution to a water resource are a direct function of surrounding land use. All land use contributes to nonpoint sources of pollution that impair Ohio watersheds. Land uses influence water resources by affecting stream flow, stream habitat, nutrient enrichment, and siltation. The Olentangy River watershed contains two main land uses that affect water quality. In the Upper Olentangy, Middle Olentangy and Whetstone Creek portion of the watershed, agriculture comprises approximately 66% of the land area. The land use in the lower Olentangy is dominated by urbanized areas. Urban and agricultural land use are sources of nonpoint source pollution as they may increase habitat alteration, nutrient enrichment, siltation and flow alteration which are detailed in the previous section. Nonpoint source pollution and land use impacts on water resources in the entire Olentangy River and Whetstone Creek watersheds include the following.

A. Impacts to Aquatic Life
- Failure to attain aquatic life uses set in Ohio Water Quality Standards
- Fish and wildlife kills due to spills
- Sedimentation impairment to in-stream habitat for fish and macroinvertebrates

B. Impacts to Drinking Water
- Nitrate concentrations sometimes exceed drinking water standards
- Seasonally elevated herbicide concentrations
- High concentrations of suspended solids during precipitation events
- Odor and taste concerns due to algae blooms resulting from enriched systems

C. Impacts to Recreational Use
- Primary and Secondary Contact Recreation Uses limited by high bacteria events
- Fish consumption advisory for the Olentangy River and Whetstone Creek watersheds
- Aesthetic impairment from sediment and algal blooms

D. Impacts from Agricultural Land Use
- Habitat degradation from channelization, channel 'cleaning' and unrestricted livestock access
- Nutrient enrichment and siltation from tile drainage and crop cultivation
- Siltation from barren fields
- Accelerated movement of water from tile drainage through straightened channels to downstream landowners resulting in flooding

E. Impacts from Urban Land Use
- Impervious surfaces cause accelerated delivery and runoff volume to the river perpetuating flooding
- Failing on-site wastewater treatment systems
- Contaminated stormwater runoff
- Combined Sewer Overflows (CSOs)
- Sanitary Sewer Overflows (SSOs)

- Elimination or destructive modifications to stream channels through development of property

Local Watershed Groups

There are two local watershed groups within the Olentangy watershed. The Olentangy Watershed Alliance's (OWA) mission is to work in partnership with farming, urban and other local communities to understand, appreciate and responsibly use the Olentangy River, its tributaries and watershed. OWA focuses on the portions of the Olentangy watershed that flow through Crawford, Delaware, Marion, Morrow, and Richland counties. Current activities and news about OWA is available on their website: www.olentangyriver.org. Friends of the Lower Olentangy (FLOW) is the watershed group active in the lower Olentangy watershed. FLOW is a grassroots organization dedicated to educating people about the importance of the lower Olentangy watershed. FLOW focuses on the lower portion of the Olentangy watershed, from the Delaware Reservoir to the mouth of the Olentangy River. Current activities and news about FLOW is available on their website: www.olentangywatershed.org.

Stream Restoration and other Conservation Efforts

Multiple sources of funding have supported landowner and local officials in planning projects for restoring water quality throughout the watershed. In agricultural areas, the traditional USDA "farm bill" programs have provided incentives for farmers to install conservation best management practices such as buffer strips through the Conservation Reserve Program (CRP), and livestock waste facilities or exclusion fencing through the Environmental Quality Incentives Program (EQIP). Since 2004, there has been funding available for the Scioto River Watershed Conservation Reserve Enhancement Program (CREP). The Scioto CREP is a farmer/landowner-implemented agricultural environmental stewardship program that will compensate landowners to change their land use along streams from detrimental agricultural activities to conservation-oriented uses.

The goal of the CREP is to create 70,000 acres of filter strips, riparian buffers, wildlife habitat, wetlands, and tree plantings to reduce sediment and nutrient runoff into the Scioto River and its tributaries, including the Olentangy watershed. As a result it hopes to improve biodiversity in the entire watershed. Participants in CREP will enroll for 15 years and receive 15 annual payments from USDA-FSA. Additional bonus incentives are available for planting warm season grasses and restoring wetlands. Additional funds may be available in your local area. In addition, cost-share funding is available for controlled drainage water management, livestock fencing, and livestock watering systems when enrolled with certain CREP practices. More information on the Scioto CREP can be found on the Ohio Department of Natural Resources (ODNR) website link http://www.dnr.state.oh.us/soilandwater/sciotocrep/default.htm

Historically, there have not been any Section 319 grants for nonpoint source implementation projects in the upper Olentangy watershed. However, there is currently an application pending for Section 319 funding to be subgranted to ODNR for a 3 year project to implement some demonstration practices that align modern drainage practices with CREP management practices to address nutrient, sediment, habitat alteration and hydromodification impairments in the upper Olentangy watershed. The project focus area will be the Olentangy mainstem (05060001-110), Whetstone Creek (05060001-100) and Flat Run (05060001-090) in Morrow, Marion and Crawford Counties. The grant of $411,000 is from a USEPA fund for unspent monies from previous Section 319 grant cycles. The project is expected to begin in 2005.

The high amount of agricultural practices affecting water quality throughout the Whetstone Creek basin and the upper and middle Olentangy basins indicates that changes to existing practices are necessary to improve water quality. Increase in quality riparian corridors and cessation of cleaning activities are two changes which may improve water quality. The programs above may help improve practices to reduce the negative influence of agricultural practices.

Biological and Water Quality Study of the Olentangy River, Whetstone Creek and Select Tributaries 2003-2004

Crawford, Delaware, Franklin, Marion and Morrow Counties

State of Ohio Environmental Protection Agency
Division of Surface Water
Lazarus Government Center
122 South Front Street
Columbus, Ohio 43215

INTRODUCTION

The Olentangy River watershed is located in central Ohio in portions of Crawford, Delaware, Franklin, Marion, and Morrow counties. The mainstem of the river is approximately 93 miles long and flows from the east side of Galion; west and then south through agricultural land surrounding Caledonia, past Claridon, and Waldo before entering Delaware Lake. Downstream from Delaware Lake, the mainstem flows through the City of Delaware and areas of suburban development before reaching the City of Columbus. The mainstem joins the Scioto River in downtown Columbus. A list of the mainstem and tributary sites evaluated in this study are found in Table 1.

Ambient biological, water column chemical and sediment sampling was conducted in the study area primarily from June to October 2003. Excessive rainfall and dam releases required additional sampling to be conducted primarily in the lower Olentangy basin, below Delaware dam, during June-October 2004.

Objectives of the study were to:

1) Monitor and assess the chemical, physical and biological integrity of the water bodies within the Olentangy River and Whetstone Creek study area,

2) Assess the physical conditions in streams listed in the study plan to identify their potential to support aquatic biological communities,

3) Characterize the amount of aquatic resource degradation attributable to various land uses including agricultural practices, rural development, suburban community development, and urban expansion,

4) Evaluate the biological potential to support the WWH use designation in any subsequently identified candidate WWH stream,

5) Determine any aquatic impacts from known point sources including the Mount Gilead, Cardington, Galion, Richland Road and Swiss Village MHP wastewater treatment plants (WWTPs), and from unsewered communities.

The findings of this evaluation may factor into regulatory actions taken by the Ohio EPA (e.g., NPDES permits, Director's Orders, or the Ohio Water Quality Standards (OAC 3745-1)), and may eventually be 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] report).

SUMMARY

A thumbnail characterization of this watershed would note the distinct variety of cultural landscapes seen from the headwaters to the confluence with the Scioto. The reaches and tributaries within Crawford, Marion and Morrow counties drain strongly agricultural landscapes of the Eastern Corn Belt, interspersed with small to medium towns and or villages. Delaware County's watershed townships dramatically transition from a dominant agricultural landscape north of the City of Delaware to the rapidly and intensely developing tracts seen downstream and along the U.S. 23 corridor. This corridor of contrasting development yet intense natural beauty (the steep forested ravines that ladder the river's east flank) extends southward to the Franklin county line. Here the watershed corridor begins to show an older and more densely populated landscape, draining the nearly "built out" towns and neighborhoods of Worthington, Upper Arlington, Clintonville, Ohio State University, Harrison West, Victorian Village, Short North and the Arena District.

Aquatic Life Use Attainment Status

Four Watershed Assessment Units (WAUs) comprise the Olentangy River watershed. The 2003-2004 Olentangy River and Whetstone Creek study area included portions of these four WAUs. Two of the WAUs are identical to the hydrologic unit code (HUC) boundaries established by the USGS. The Upper Olentangy Watershed Assessment Unit (UOWAU) and the Whetstone Creek Watershed Assessment Unit (WCWAU) correspond to the hydrologic unit codes 050600001-090 and 050600001-100, respectively. The Middle Olentangy Watershed Assessment Unit (MOWAU) corresponds primarily with hydrologic unit code 050600001-110, which extends from below the confluence of Flat Run (RM 59.28) to below the confluence of Delaware Run (RM 25.71). However, for the purposes of this report, the lower boundary of the MOWAU was set to below the confluence of Brondige Run (RM 38.13) to match the boundary created by Delaware Lake and the line between the Ohio EPA Northwest and Central District offices. Therefore, the Lower Olentangy Watershed Assessment Unit (LOWAU) is similar to the hydrologic unit code 050600001-120, except that the northern boundary is below the confluence with Brondige Run (RM 38.13), not Delaware Run (RM 25.71).

Heavy rains and frequent dam releases during the 2003 field season impeded fish sampling efforts and therefore additional sampling occurred during 2004 primarily in the lower Olentangy basin, south of the Delaware dam. Between the two field seasons, a total of 62,087 fish were collected representing 68 species and 11 hybrids. The state threatened bluebreast darter was identified at several sites in 2004, while one special interest species, river redhorse, was collected in 2004. Numerically predominant fish species included bluntnose minnows (20.5%), creek chub (12.2%), and stoneroller minnow (9.9%). Species that dominated in biomass included common carp (42.4%) and golden redhorse (10.5%).

During the 2003-2004 field sampling, an assessment of aquatic life uses occurred at 74 sites ranging in drainage area from 0.4 mi^2 to 543 mi^2 (Table 1). The Aquatic Life Use Attainment table (Table 2) provides biological metric scores along with causes and sources of impairment for each impaired site. Thirty-four (45.95%) of the sites fully met either the currently designated or the recommended aquatic life use. Twenty-three (31.08%) of the sites partially met and seventeen (22.97%) of the sites were not attaining their designated or recommended use (Table 2). The primary sources leading to impairment were high intensity agricultural land use activities, failing on-site wastewater treatment systems and several WWTPs in the watershed north of the Delaware dam, while a combination of urbanization effects, failing on-site wastewater treatment systems and dams were the primary sources of impairment below the Delaware dam. One stream, Wahalla Hollow, was determined to have Primary Headwater Habitat (PHWH) characteristics. Since Ohio currently does not have PHWH aquatic life uses at this time, an aquatic life use assessment was not completed on this stream.

Historical data for the upper portion of the Olentangy basin indicates that the Galion area, including its WWTP, continue to influence water quality and biological communities for several miles downstream. The age of the infrastructure for the community is a concern, as infiltration has been identified as a primary cause of bypasses and wet weather releases. Tributary streams south of Galion and near Marion suffer from channel excavation and cleaning activities (riparian vegetation removal, channel deepening and widening, etc.) associated with the facilitation of agriculture drainage. Data collected from the Olentangy mainstem reflects this, as fish community performance decreased near Marion. Increased participation in agricultural Best Management Practices (BMPs) including alternatives to traditional channel techniques and improvement of riparian corridors could benefit this portion of the watershed. Downstream from Delaware Reservoir, development pressures are depressing water quality throughout the EWH portion of the Olentangy mainstem. In this area, efforts should be focused on improving construction BMPs, obtaining conservation easements and improving storm water control measures. Additional urban influences continue to affect water quality in the lower portion of the Olentangy basin through Columbus.

Similar to the Olentangy River, Whetstone Creek continues to show impairment from WWTPs. The fish community in Whetstone Creek downstream from Cardington is performing below EWH expectations, significantly below results from 1994. Improvements to WWTPs, attention to agricultural practices, and protection of existing riparian corridors are imperative to improve biological performance in the Whetstone Creek basin. The lower quality habitat conditions of Whetstone Creek downstream from Mt. Gilead decreases the ability of the stream to ameliorate the effects of the various pollutants: nutrients, siltation and solids from the various point and nonpoint sources. Best management practices must be implemented along with improved sewage treatment to reduce impairment in Whetstone Creek.

Detailed descriptions of historical trends are provided within each WAU summary below.

Recreation Use Attainment Status

The recreation use attainment status throughout each WAU was assessed by bacterial sampling. Results from the sampling indicate elevated bacterial levels throughout each WAU, potentially impairing the designated or recommended recreation use. Each WAU summary provides detailed results from the sampling season.

As mentioned previously, fecal coliform bacteria are associated with warm blooded animals and therefore human and animal sources exist throughout the Olentangy watershed. In the UOWAU, the Galion WWTP, several permitted and unpermitted package wastewater treatment plants, mobile home parks (MHPs) and on-lot home sewage treatment systems contribute to *E.* coli and fecal coliform bacteria exceedances recorded. Tomahawk Ditch in the MOWAU has historical bacterial problems associated with the unsewered community of Waldo. Urban sources of bacteria in the LOWAU include numerous CSOs and SSOs throughout the greater Columbus metropolitan area. In the Whetstone Creek basin, direct effluent violations were noted from both the Mt. Gilead and Cardington WWTPs.

Animal sources are usually more intermittent, as manure enters a stream via runoff associated with rainfall. However, if domestic livestock have direct access to streams, the effects on water quality are much greater. Each WAU (except the LOWAU) had livestock operations which provided cattle unrestricted access to streams. Allowing livestock to enter streams provides bacteria a direct route to stream systems. Water quality could improve throughout the study area north of Delaware Reservoir by fencing livestock out of streams and by implementing proper manure management practices.

Public Water Supplies

Water Quality Standards (WQS) established for the public water supply beneficial use (OAC 3745-1-33) currently apply within 500 yards of an intake and for all publicly owned lakes. Ohio EPA is developing new assessment methodology for this beneficial use which will focus assessments on source water contaminants not effectively removed through conventional treatment methods. Impaired source waters may contribute to increased human health risk or treatment costs. Key source water quality concerns related to the Public Drinking Water Supply (PDWS) use in the Olentangy Basin include elevated nitrate and pesticides. Water systems in the basin rely on additional offline storage and ground water dilution to manage source water quality.

Public water systems must meet standards specified in the Safe Drinking Water Act (SDWA) including specific contaminant levels in the finished treated water. These treated water quality standards are defined as Maximum Contaminant Levels (MCLs) and represent the maximum allowable level of a contaminant that may be present without posing a high risk of health effects. Most of the surface water quality standards for protection of the public drinking water supply (PDWS) beneficial use are referred to as drinking water standards and are defined as chemical criteria equivalent to the SDWA MCLs.

There are three public water systems directly served by surface water sources within the Olentangy River Basin. The City of Galion's intake is on an impounded section of Rocky Fork and the City of Delaware and Del-Co Water Company (Del-Co) maintain intakes on the Olentangy River. Four locations were sampled at least six times from June-August 2003 in order to assess the PWS beneficial use. The locations were monitored for herbicides in addition to this survey's baseline chemical parameters. Rocky Fork was sampled six times at the Ammans Reservoir spillway, just downstream from the Galion intake. The Olentangy was sampled 15 times between April and December, 2003 at RM 32.10 in close proximity to the City of Delaware intakes. Eight samples were collected on the Olentangy River at RM 19.4 located about a mile upstream from the Del-Co Water Company intake. The Olentangy River was also sampled six times just upstream from the confluence with the Scioto River at RM 0.93 in order to assess a potential intake location for the City of Columbus who currently maintains an intake on the Scioto River just upstream from the confluence with the Olentangy River.

Ohio Water Quality Standards (WQS) criteria established for the PWS use (OAC 3745-1-33) currently apply within 500 yards of an intake. Ohio EPA is developing new assessment methodology for this beneficial use and several water quality criteria will likely be revised. Assessments will focus on source water contaminants not effectively removed through conventional treatment methods that if present in the water source may lead to increased human health risk or increased treatment costs. Key source water quality concerns for drinking water use in the Olentangy basin are elevated nitrate and pesticides (especially atrazine). Water systems in the basin rely on additional offline storage and ground water dilution to manage source water quality.

As required by the Safe Drinking Water Act, Ohio EPA completed Drinking Water Source Assessments for these water systems in 2003. These reports delineate source water protection areas, inventory potential contaminant sources, and recommend protective strategies. Key information from the reports is summarized in Table 3 below; however, additional information and copies of the reports are available by contacting the Ohio EPA Division of Drinking and Ground Waters at (614) 644-2752 or by visiting the Division's web site at http://www.epa.state.oh.us/ddagw/pdu/swap.html.

Table 3. Chemical sampling results of selected sites within the Olentangy basin, 2003.

Olentangy River Basin			
Sample Location	**Associated Water System**	**Nitrate-Nitrite Range (mg/l)**	**Atrazine Mean/Maximum (μg/l)**
Rocky Fork at Crawford Morrow Line Road (RM 0.41)	Galion	1.79 / 4.89	1.31 / 3.34
Main Road Downstream USGS Gauge @ RM 32.10	Delaware	4.22 / 7.50	--
Hyatts Road @ RM 18.22	Del-Co	3.49 / 7.25	--
State Route 750 @ RM 15.00	Del-Co	--	1.32 (single sample)
Goodale Avenue @ RM 0.93	Columbus	3.08 / 6.75	--

Galion

The City of Galion operates a community public water system that serves a population of approximately 11,340 people through 5,024 service connections. A community public water system is defined as a system that regularly supplies drinking water from its own sources to at least 15 service connections used by year-round residents of the area or regularly serves 25 or more people throughout the entire year. The water treatment system obtains its water from Rocky Fork, a tributary to the Olentangy River. Water is pumped from the impounded stream (Ammans Reservoir) to two above ground reservoirs. The system's treatment capacity is approximately 4.0 million gallons per day, but current average production is 1.2 million gallons per day. The City's treatment processes include coagulation, sedimentation, lime softening, carbon dioxide stabilization, filtration, and disinfection. Carbon is fed seasonally at the intake eight months of the year for taste and odor issues and pesticide removal.

Source water protection efforts for the City of Galion should focus on controlling agricultural runoff from crop fields and runoff from cattle grazing pastures, with particular attention to sources of pesticides, nitrates, phosphorus, and microorganisms. This can be accomplished via educational efforts. County extension agents are an excellent resource for assisting the agricultural community with controlling agricultural runoff, and staff from local and county health offices can instruct homeowners in proper maintenance of their home wastewater treatment systems.

Water quality data was collected at two sites on Rocky Fork, within the Galion Corridor Management Zone (CMZ). The site at Crawford Morrow Line Road (RM 0.4) was actually at the spillway from the Ammans Reservoir, which serves as a source of drinking water for Galion. If the spillway was inactive, samples were collected adjacent to the Galion water treatment plant pump house. There were no violations of the Ohio WQS criteria (OAC 3745-1) at either site, although bacterial concentrations were elevated at both sites on one sampling date. These higher concentrations may have been related to a storm/runoff event. Also, though there is no clearly defined relationship between levels of total recoverable iron and soluble iron in water, it may be worth noting that levels of total recoverable iron in some samples were two to eight times greater than the criterion for soluble iron established for the protection of human health. Herbicide samples were also collected at the Crawford Morrow Line Road site on all sampling dates. In one sample, the level of atrazine detected slightly exceeded water quality criteria set at 3.0 μg/l but the result is qualified as estimated.

City of Delaware

The City of Delaware water treatment plant is located just north of the City of Delaware and serves approximately 28,000 persons through 9,300 service connections. The City of Delaware uses surface water taken via two separate intakes on the Olentangy River just south of Delaware Reservoir. Supplemental source water is provided by two well fields. The wells are used approximately eight months out of the year triggered by elevated levels of atrazine, nitrate and turbidity in the surface water. The City of Delaware treatment capacity is approximately 6 million gallons per day, but current average production is about 3.7 million gallons per day.

As recommended in the Drinking Water Source Assessment Report, the City of Delaware should establish and maintain a working relationship with the Delaware Soil and Water Conservation District (SWCD) staff. Considerable effort should be aimed at controlling nonpoint sources of pollution such as pesticides, nitrate and fecal bacteria. It is apparent from reviewing chemical data that pesticides, including atrazine, are present (at least in low detectable levels) in the finished water, and incoming nitrate concentrations are high enough that they must be diluted with well water for much of the year. During high flow events, animal feedlots may also introduce certain pathogens (i.e. *Cryptosporidia* sp.) that are difficult to remove with typical water treatment practices. There is federal grant money available through the Ohio EPA to support projects aimed at controlling such potential agricultural sources of contamination.

For the Drinking Water Source Assessment all available chemical and biological water quality data collected from the streams in the protection area, and sampling results from finished water reported to Ohio EPA by the public water supplier were evaluated to characterize water quality. Sampling results from finished water reported to Ohio EPA by the City of Delaware were screened for inorganic compounds, synthetic organic compounds (SOCs), and volatile organic compounds (VOCs). Nutrients, including nitrates, were present in the finished water. Nitrate-nitrite (as N) and nitrates (as N) were detected in 63 of 71 and 76 of 84 samples, respectively; only two results exceeded the

10 mg/l drinking water MCL. The surface water quality criterion for nitrate in these waters is also 10 mg/l.

Baseline pesticide screening began as early as 1987 when finished water was screened for commonly used pesticides. Irregular screening for these compounds continued through 1995. In 1996, pesticide sampling was more consistent with a sampling scheme that targeted spring and winter run-off. Several pesticide compounds were detected including acetochlor, alachlor (Lasso), atrazine, cyanazine (Bladex), metolachlor, metribuzin (Sencor) and simazine. Of these, atrazine, metolachlor and simazine were most commonly detected in the finished water. These chemicals are mostly used for selective control of annual grasses and broadleaf weeds in agricultural settings for growing corn and soy beans. Simazine is also used for non-selective weed control in industrial areas, fairways, lawns and similar applications. Overland runoff and seepage into agricultural drainage systems are two likely transport mechanisms carrying these pesticides into the Olentangy River and eventually into the surface water intakes. Atrazine was detected 42 times in 55 samples. Of those 42 detections, 12 exceeded the Maximum Contaminant Level (MCL), which is the maximum allowable level of a contaminant in public drinking water.

Metolachlor and simazine were also significant detections, although almost all concentrations were below the MCL. Unlike acute chemicals of concern (i.e. nitrates), the drinking water criteria for pesticides are based on the running annual average as it relates to the MCLs for each compound. In other words, one high value does not necessarily put the City of Delaware into non-compliance. The running annual average calculation includes values from the previous three quarters.

Both nitrate and pesticides are detected in the finished water throughout the summer months. This potentially results from the intake proximity to an impounded reservoir where the water is pooled and retention time is lengthened. Nitrate and pesticides seem to persist in the reservoir all summer long, requiring the City of Delaware to mix surface water with ground water for dilution purposes. Results of the sampling conducted on the Olentangy River at RM 32.10 are summarized in the preceding table. Nitrate averaged 4.22 mg/l with a maximum of 7.50 mg/l. All detections were below the finished drinking water criterion of 10 mg/l.

Del-Co Water Company

Del-Co operates a community public water system that serves a total population of approximately 90,600 people. Del-Co Water Co. operates four water treatment plants: the Olentangy Plant, the Alum Creek Plant, the Old State Plant, and the East Knox Plant. The Del-Co Olentangy Plant, located in Liberty Township, southern Delaware County, provides drinking water for approximately 37,600 people through more than 12,545 service connections. Total plant design capacity is 7.2 million gallons per day, but average daily production is 3.2 million gallons per day. The raw water is processed through a series of four upground reservoirs. Four ground water wells at the Olentangy

Plant Wellfield can be pumped directly to the upground reservoirs to supplement surface water levels. Total reservoir capacity is 710 million gallons. Treatment consists of potassium permanganate for disinfection and to enhance settling; ferric chloride and lime addition for softening; carbon dioxide addition for recarbonation; caustic soda for pH adjustment; fluoride for dental health; and chlorine gas for disinfection.

Source water contaminants of concern that may be present in the Olentangy River in the vicinity of the Del-Co intake include:

- Microbes such as bacteria and viruses which are commonly associated with sewage treatment plants, on-site wastewater treatment systems and agricultural operations;
- Inorganic contaminants such as metals and salts that may be naturally occurring or result from storm water runoff, industrial or domestic discharge, oil and gas production, mining, or farming;
- Pesticides and herbicides, which typically result from agricultural operations, urban storm water run-off and residential uses (lawn and garden care);
- Organic chemical contaminants, including synthetic organic compounds (SOCs) and volatile organic compounds (VOCs), which can be by-products of industrial processes, leaking underground storage tanks, urban storm water runoff and septic systems; and
- Radioactive contaminants, which can be naturally occurring or the result of oil and gas production and mining activities.

The Del-Co Olentangy Plant has conducted extensive sampling for these pollutants in the drinking water (finished or treated water). These sampling results have been screened for potential water quality concerns. A review of the previous sampling conducted by Del-Co Olentangy Plant for treated water indicates detections for several pesticides including atrazine (detected in 33 of 35 samples), metolachlor (detected in 6 of 36 samples) and cyanazine (detected in 4 of 9 samples). The highest atrazine detection was 2.73 μg/l, which is below both the water quality criterion and the drinking water MCL, which are both set at 3.0 μg/l. No other pesticide or herbicide samples exceeded 50% of its finished drinking water criterion. Extensive treated water sampling for nitrate has also been conducted. From 1984 to 2001, nitrate was detected in 145 of 161 samples. The maximum detected level of nitrate was 3.30 mg/L.

Results of the sampling conducted on the Olentangy River at RM 19.40 on raw water are summarized in the preceding table. Nitrate averaged 3.49 mg/l with a maximum of 7.25 mg/l. All detections were below the MCL of 10 mg/l. Pesticide sampling conducted south of the Del-Co intake on the Olentangy River at RM 15.00 (State Route 750) indicated low levels of atrazine, simazine and metolachlor and several other compounds at levels below the MCL (e.g. atrazine standard is 3.0 mg/l).

The Del-Co Water Company is encouraged to partner with other Olentangy River watershed stakeholders to develop a local effort utilizing these strategies for protecting this drinking water resource. This could include establishing a source water assessment and protection (SWAP) committee. Del-Co should also review existing watershed protection activities and opportunities for involvement underway by the two existing watershed groups in the Olentangy River watershed.

Vicinity of City of Columbus Dublin Road Plant Intake
The City of Columbus maintains an intake on the Scioto River just upstream from the confluence with the Olentangy River but is considering adding an intake on the Olentangy in the same vicinity. A sampling location was included in the survey at Olentangy River RM 0.93 to assess source water for a potential intake. Nitrate averaged 3.08 mg/l with a maximum of 6.75 mg/l. Concentrations for this contaminant appear similar to other locations within the watershed.

Chemical Water Quality
Physical, chemical, and bacterial measurements were completed at 76 sites. Each site had at least six sets of grab samples collected at roughly two-week intervals during the field season. Several Olentangy River and Whetstone Creek mainstem sites had extra bacteria samples collected in July so the PCR use could be assessed. Results that violated WQS criteria codified in Ohio Administrative Code (OAC) Chapter 3745-1 are detailed within each WAU summary.

The primary chemical causes of concern identified throughout the Olentangy basin were bacteria, nutrient enrichment (phosphorus and nitrate), and total suspended solids (TSS). Bacterial results are briefly discussed under the Recreation Use Attainment Status section above, and detailed within each WAU. Variability among the chemicals of concern was noted between each WAU and may be associated with changes in land use.

Nutrient enrichment within the upper Olentangy mainstem was attributed primarily to the Galion WWTP, as the highest nitrate-nitrite levels throughout the UOWAU were collected downstream from the Galion WWTP. Suspended solids began to deviate from background conditions downstream from Galion and increased through rural areas. Improvements in agricultural practices could address this concern.

Tributary streams in the MOWAU were found to contain considerably higher nitrate-nitrite levels than tributary streams sampled in the UOWAU. Many streams within the MOWAU area are maintained for agricultural practices, increasing the rate of run-off and resulting in high levels of nutrient deposition into receiving waters. Phosphorus and nitrate-nitrite levels were also above target values throughout the Olentangy mainstem in this area.

Total phosphorus and organic nitrogen concentrations in the lower Olentangy River indicated nutrient enrichment. Urban sources, such as CSOs, SSOs, along with non-point sources including golf courses and stormwater runoff are responsible for these elevated concentrations. High concentrations of TSS were also identified as a concern in the LOWAU. Rapid development in the Delaware County area is the likely cause of excessively high TSS values noted in the Olentangy River mainstem.

Nutrient enrichment within Whetstone Creek was attributable to the two WWTPs and field tile drainage. Though nutrient enrichment has decreased over time in the Whetstone Creek mainstem, TSS has dramatically increased. Fish community indices reflected unstable dynamics, indicating current water quality concerns must be addressed or declines in overall stream health may occur.

Sediment Quality

Sediment sampling was conducted at four Whetstone Creek sites within the WCWAU and seven Olentangy River mainstem sites within the LOWAU. Total organic carbon (TOC) was the only parameter above reference value collected in Whetstone Creek sediments. TOC concentrations in sediments did not appear to influence bottom dwelling organisms in Whetstone Creek.

In the Olentangy River, TOC was elevated above background conditions at two sites. Phosphorus concentrations above the Lowest Effect Level (LEL) were noted at two other sites. The LEL indicates a level of contamination which has no effect on the majority of sediment dwelling organisms. Contamination in sediments that exceed the LEL may negatively affect sediment dwelling organisms. Heavy metals, including cadmium, copper, chromium, lead and zinc were discovered at concentrations above ecoregional reference values upstream from the 5th Avenue dam.

Fish Tissue

Throughout the state of Ohio there is a limit of no more than one meal per week of any sport fish due to mercury contamination. For the Olentangy River basin, there is an additional advisory of one meal per month for smallmouth bass ≥12 inches. This advisory is specific for the Olentangy River from State Route 95 (Claridon) to the mouth (Scioto River) and covers portions of Delaware, Marion and Franklin counties. For additional information related to the Fish Consumption Advisory, please see the 2005 Ohio Sport Fish Consumption Advisory homepage at:
http://www.epa.state.oh.us/dsw/fishadvisory/index.html.

Spills

Twenty spills resulting in discharges to streams were reported from 1994-2004 within the study area. Sources of the spills varied and included swimming pool chemicals, lime sludge, asphalt sealant, Safe Cure 1000 (concrete curing compound), diesel fuel, sewage, vinegar, manure, septic discharges and water from a house fire. A manure release on Shaw Creek in April 2001 affected 9.5 miles of stream and resulted in an estimated kill of 31,964 fish. Details regarding each event are provided within its corresponding WAU report.

Restoration and Protection Actions

Restoration and protection actions occur at many levels throughout the study area and are commonly associated with the predominant land use: rural, developing and urban reaches. The rural landscapes of the Olentangy watershed have access to Federal programs such as the Scioto CREP directed by NRCS staff in the county agricultural offices. This and similar initiatives address erosion which causes soil particles to enter the stream system, likely carrying nutrients, herbicides and insecticides. The programs may subsidize the planting of trees and warm summer grasses which hold top soils and provide benefits for nearby streams including: shade, organic material as leaf fall, removal of chemical compounds such as nutrients via uptake by plants, woody debris, and habitat for birds and terrestrial fauna.

NRCS staff from the watershed's dominantly agricultural counties note that conservation tillage and no-till has been decreasing over a period of years for corn fields. They observe that this is due to the insulation effect on soils by corn crop residues (lowering soil temperatures) and also by the perception that corn vegetative residues increase the number of slugs. In contrast, no-till and conservation till with wheat and soybeans appears to be increasing over the last decade.

Marion County NRCS staff indicate little or no growth among livestock operations in the watershed. Other NRCS staff observed that perception or expectation of development in agricultural townships discourages landowners from investing in livestock operation expansions. In Delaware and Morrow counties, enrollment for the Scioto CREP program is reported to be active, with a backlog of registrations in Delaware county.

Purchase of high quality riparian lands is occurring in the watershed's most intensely developing reaches. Ravine properties at Camp Lazarus and Big Run, both within Delaware County, were secured in 2004 through the Ohio EPA Water Resource Restoration Sponsorship Program (WRRSP).

Dam removals frequently improve chemical water quality and restore historical fish migration routes. Since 2003, ONDR has removed two dams on the Olentangy River within Delaware County. The City of Delaware in conjunction with ODNR, Ohio EPA and ODOT will remove five additional dams in 2005. The City of Columbus has contracted a feasibility study to investigate the potential removal of an additional five low-head dams within Franklin County.

The largest dam within the LOWAU, an 8 foot structure impounding nearly 1.5 miles of the Olentangy River above Fifth Avenue is proposed for removal. In 2005 a consortium of the City of Columbus, Ohio State University and FLOW were crafting a draft proposal for funding the dam's removal and restoration of the upstream reach to Dodgridge Avenue. A portion of the funding will be provided by the City of Columbus as a Supplemental Environmental Project (SEP). A SEP is defined as a project jointly agreed to by an entity and the Ohio EPA performed instead of paying an administrative penalty for violations of environmental laws. During this same period, City of Columbus staff were re-surveying the dam area, locating utility lines, and examining the dam for its structural properties.

Recent watershed planning covers the entire watershed. The landscapes and reaches of the upper Olentangy watershed are addressed in a watershed plan under development in 2005 by OSU faculty under contract to the City of Delaware. This plan (funded by a 319 grant) focuses on agricultural runoff and drainage within this heavily agricultural portion of the study area. The plan will include recommendations for a variety of drainage and Best Management Practices (BMPs) that may include relatively new approaches to field drainage. For areas south of Delaware, ODNR and Ohio EPA formally endorsed the watershed plan produced under the coordination and direction of FLOW in 2005.

Currently, U.S. EPA Region 5 is reviewing a proposal for installation of demonstration BMPs in the Marion County portion of the watershed. The proposal, submitted by ODNR, suggests installation of two stage channel drainage ways as demonstration projects on a number of suitable sites.

Two watershed coordinators presently work in the Olentangy study area. The lower watershed coordinator is sponsored by FLOW and works from FLOW's office in Columbus. The focus of this coordinator's work has been completion of the watershed plan and public education efforts within Columbus and near watershed communities (i.e. Worthington). A second watershed coordinator works from the Morrow County Soil and Water Conservation Offices in Mount Gilead. The work here has focused on the agricultural community and the issues of drainage and BMPs that may protect the Olentangy River system. In June, 2005, this coordinator was interacting with upper watershed farmers to learn which BMPs they would be willing to implement. This effort directly supports the Upper Olentangy watershed plan.

Table 1. Biological sampling locations throughout the Olentangy River and Whetstone Creek basins, 2003-2004.

River Mile	Drainage (mi^2)	Location
OLENTANGY RIVER		
89.3	9.0	Edward Street
86.1	12.2	Upstream Galion WWTP
86.0	12.2	Galion WWTP mix zone
85.9	12.2	Hosford Road (Polk TE 163)
85.2	12.4	Monnett New Winchester Road (CCR 19)
79.7	39.0	Shearer Road (Whetstone TR 87)
74.0	50.0	Monnett-Chapel Road (Whetstone TR 34)
68.1	58.0	Crawford Marion Line Road
63.4	67.0	Lyons Road (Tully TR 196)
56.6	142.0	Roberts Road
54.7	157.0	State Route 95
50.1	174.0	State Highway 529
45.5	181.0	St. James Road (Marion CR 141)
40.8	234.0	Waldo Fulton Road (Marion CR 140)
32.1	393.0	Main Road
28.1	409.0	Panhandle Road
27.5	411.0	Adjacent Hudson Road, opposite Law Road
24.5	433.0	Below Delaware WWTP
19.4	455.0	Hyatts Road
15.0	483.0	SR 750, upstream OECC WWTP
12.4	491.0	Mt. Air
7.8	519.0	Kenny Park
3.9	535.0	Dodridge Avenue
2.1	540.0	Upstream 5th Avenue dam
1.8	540.0	Downstream 5th Avenue dam
0.9	543.0	Goodale Ave. exit from SR 315 N
ROCKY FORK		
2.9	8.7	Atkinson Road (Morrow CR 38)
0.4	10.9	Crawford Morrow Line Road
MUD RUN		
6.7	7.7	Monnett-Chapel Road (Whetstone TR 34)
2.7	17.0	Morral-Kirkpatrick Road (Marion CR 67)
FLAT RUN		
12.6	8.9	State Highway 288 (Morrow Co.)
7.3	14.4	State Highway 309
0.6	40.9	West Canaan Road (Canaan TR 60)
THORN RUN (TRIBUTARY TO FLAT RUN RM 0.56)		
1.1	9.3	Marion-Williamsport Road (Morrow CR 61)

Table 1 (continued)		
BEE RUN		
4.9	1	Marion CR34
0.3	6.8	Caledonia Mud Pike
OTTER CREEK		
1.1	8.3	State Highway 95
GRAVE CREEK		
3.2	9.3	State Highway 529 (or Marion Cardington)
1.4	11.3	Firstenberger Road (Marion CR 148)
0.8	16.7	State Route 98
RIFFLE CREEK (TRIBUTARY TO GRAVE CREEK RM 0.21)		
4.4	10.2	Marion Edison Road
1.4	15.8	Firstenberger Road (Marion CR 148)
QUQUA CREEK		
4.6	6.8	Owens Road (Marion CR 108)
0.1	17.1	State Highway 98
BRONDIGE RUN		
0.6	12.0	State Highway 229 (Delaware Co.)
WHETSTONE CREEK		
30.5	7.5	Downstream Candlewood Lake
29.3	8.4	W. Point-Galion Road
28.1	19.0	Marion-Williamsport Road
25.5	26.0	McKibben Road
22.4	34.0	State Route 61
21.7	35.0	Loren Road
21.6	36.0	Mt. Gilead WWTP mix zone
21.5	36.0	Downstream Mt. Gilead WWTP
18.2	40.0	Bennett Road
13.7	49.0	Cardington WWTP Mix Zone
13.5	49.0	Downstream Cardington WWTP
9.2	62.0	Waldo-Fulton-Chesterville Road
2.6	113.0	State Route 229
TRIBUTARY TO WHETSTONE CREEK RM 33.71		
0.4	2.0	State Route 19 (West Point-Belleville Road)
SHAW CREEK		
13.2	11.8	Thatcher Road
10.6	14.8	S. Canaan Road
5.2	21.1	State Route 529
1.6	26.0	Beatty Road
CLAYPOLE RUN		
1.2	3.8	Prospect-Mt. Vernon Rd

Table 1 (continued)		
MITCHELL RUN		
0.2	5.4	Delaware-Cardington Road
BIG RUN		
0.1	6.1	Cardington Western Road
SAMS CREEK		
1.4	7.8	Sunfish Road
EAST BRANCH WHETSTONE CREEK		
0.4	6.3	Mt. Gilead-West Point Road
INDIAN RUN		
0.9	4.0	Horseshoe Road
NORRIS RUN		
1.3	5.8	Penry Road
SUGAR RUN		
1.3	3.5	State Route 42
MILL RUN		
0.2	1.8	Near mouth
DEEP RUN		
0.1	0.6	Owenfield Drive
OLENTANGY TRIBUTARY RM 20.71		
0.2	2.4	Near Camp Lazarus
LEWIS CENTER TRIBUTARY		
0.1	5.7	Taggart Road
TURKEY RUN		
0.7	2.3	Shattuck Avenue
Wahalla Hollow		
0.1	0.4	Adjacent Wahalla Road
Glen Echo Ravine		
1.0	0.5	Glen Echo Park

Table 2. Aquatic life use attainment status for stations sampled in the Olentangy River basin based on data collected July-October 2003. Data collected in 2004 is indicated by the value being in *italics*. Mix zone samples are in **bold** and are listed simply to indicate biological response to effluent discharge. Sites in non attainment are also in **bold**. The Index of Biotic Integrity (IBI), Modified Index of well being (MIwb), and Invertebrate Community Index (ICI) are scores based on the performance of the biotic community. The Qualitative Habitat Evaluation Index (QHEI) is a measure of the ability of the physical habitat to support a biotic community. Threats to water quality identified during the course of the study are listed under Causes and Sources.

River Mile Fish/Invertebrate	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes	Sources
Olentangy River		*WWH*					
89.3[H]/89.3	49	NA	MG[ns]	84.0	FULL	Low DO and possible undocumented spills[1]	Upstream package plants and possible undocumented spills[1]
86.1[H]/86.1	38[ns]	NA	34[ns]	58.5	FULL		
86.0/85.94 Mix Zone	**24**		**LowF/P**			**Fish avoidance response Toxicity to invertebrates**	**Galion WWTP**
85.9[H]/--	38[ns]	NA	-	79.0	(FULL)		
85.2[H]/84.5	37[ns]	NA	46	82.5	FULL		
79.7[W]/79.7	34*	7.8[ns]	42	69.5	PARTIAL	Nutrients, cadmium('94) and siltation	Galion WWTP and agricultural activities (cattle in stream)
74.0[W]/74.0	40	7.2*	Low F*	57.5	PARTIAL	Siltation, channelization	Agricultural activities
68.1[W]/68.0	33*	7.7*	30*	58.0	**NON**	Nutrients, siltation and habitat alteration	Livestock in stream, riparian cover removal
63.4[W]/63.5	45	7.3*	40	57.5	PARTIAL	Nutrient enrichment, Siltation	Agricultural activities
56.6[W]/58.8	*38[ns]*	*6.9**	44	*37.0*	PARTIAL	Siltation, Habitat alteration, Nutrient enrichment	Livestock in stream
54.8[W]/54.7	36[ns]	7.3*	VG	77.5	PARTIAL	Nutrient enrichment, Siltation	Lack of centralized wastewater treatment in Claridon

River Mile Fish/Invertebrate	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes	Sources
Olentangy River (continued)			*WWH*				
50.1[W]/50.3	38[ns]	8.2[ns]	48	84.5	FULL		
45.5[W]/45.5	40	8.0[ns]	52	84.5	FULL		
40.8[B]/41.0	35*	7.8[ns]	46	64.0	PARTIAL	Impounded, Siltation	Delaware Dam
32.1[B]/32.1	*42*	*10.2*	40	*66.0*	FULL		
28.1[W]/28.2	*36[ns]*	*6.2**	28*	*55.5*	PARTIAL	Impounded, Siltation	Panhandle Road Dam
27.5[W]/27.4	*40*	*8.1[ns]*	44	*76.5*	FULL		
24.5[W]/24.5	*42*	*9.1*	50	*75.5*	FULL		
		EWH					
19.4[W]/19.5	*45**	*9.0[ns]*	50	*89.0*	PARTIAL	Nutrient enrichment, Siltation	Urbanization
15.0[W]/14.9	*46[ns]*	*9.1[ns]*	46	*81.5*	FULL		
12.4[B]/13.2	*50*	*9.9*	50	*72.5*	FULL		
		WWH					
7.8[W]/7.3	*48[ns]*	*9.1[ns]*	48	*83.0*	FULL		
3.9[B]/4.0	*50*	*10.3*	44	*71.0*	FULL		
		MWH					
2.1[B]/2.1	*38*	*7.5*	10*	*32.5*	**NON**	Flow alteration	Impoundment
		WWH					
1.8[W]/1.8	*45*	*7.1**	40	*76.0*	PARTIAL	Nutrient enrichment	CSOs, urban runoff

River Mile Fish/Invertebrate	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes	Sources
Olentangy River (continued)			*WWH*				
0.9[B]/0.6	*40*	*9.0*	40	*78.5*	FULL		
Rocky Fork (RM 84.84)		*Undesignated / WWH Recommended*					
2.9[H]/2.9	36[ns]	NA	MG[ns]	74.0	FULL		
0.4[H]/0.4	34*	NA	P*	75.0	**NON**	Channel modifications, flow alteration from reservoir and nutrient enrichment	Below Ammans PWS reservoir
Mud Run (RM 62.44)		*MWH*					
6.7[H]/6.7	30	NA	F	35.0	FULL	Channelization, Siltation	Maintained by County Engineer, Agricultural activities
2.7[H]/2.6	40	NA	MG	38.0	FULL	Channelization	Maintained by County Engineer
Flat Run (RM 59.28)		*WWH*					
12.6[H]/12.7	42	NA	G	57.0	FULL		
7.3[H]/7.3	49	NA	E	85.0	FULL		
0.6[W]/0.6	50	9.1	52	72.5	FULL		
Thorn Run (Tributary to Flat Run RM 0.56) *WWH*							
1.1[H]/1.1	42	NA	MG[ns]	58.5	FULL	Channel modifications, Embeddedness	Agricultural activities
Bee Run (RM 57.6)		*Undesignated / WWH Recommended*					
4.9[H]/2.4	38[ns]	NA	Low F*	33.0	PARTIAL	Siltation, nutrient enrichment Channel modifications	No buffers, historically maintained Agricultural activities

River Mile Fish/Invertebrate	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes	Sources
Bee Run (RM 57.6)		*Undesignated / WWH Recommended*					
0.3^H/0.3	38^{ns}	NA	F*	59.0	PARTIAL	Siltation	
Otter Creek (RM 55.42)		*WWH*					
1.1^H/1.1	38^{ns}	NA	MG^{ns}	44.0	FULL	Channel modifications	
Grave Creek (RM 45.35)		*MWH*					
3.2^H/3.2	28	NA	<u>P</u>*	42.0	**NON**	Channelization, Nutrient enrichment	Maintained by County Engineer
		WWH					
1.4^H/1.4	31*	NA	F*	44.5	**NON**	Channelization	Marion WWTP, Maintained by County Engineer
0.8/0.1	*39^{ns}*	*7.4**	48	*81.0*	PARTIAL	Nutrient enrichment	Failing on-site wastewater systems
Riffle Creek (Tributary to Grave Creek RM 0.21) *MWH*							
4.4^H/4.4	<u>26</u>	NA	F	34.5	FULL	Channelization, Siltation	Maintained by County Engineer
		WWH					
1.4^H/1.4	31*	NA	MG^{ns}	53.5	PARTIAL	Siltation, habitat alteration	Agricultural activities with historical channelization
QuQua Creek (RM 41.32)		*MWH*					
4.6^H/4.6	<u>22</u>*	NA	Low F*	29.0	**NON**	Channelization, nutrient enrichment	Marion County Petitioned Stream
		WWH					
0.1^H/0.2	44	NA	F*	75.0	PARTIAL	Nutrient enrichment	

River Mile Fish/Invertebrate	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes	Sources
Brondige Run (RM 38.13) *WWH*							
--/0.6	--	NA	F*	73.5	**NON**	Nutrient enrichment, siltation, impounded	Agricultural activities, Delaware Dam
Whetstone Creek (RM 36.07) *EWH*							
30.5[H]/30.5	50	NA	F*	78.5	PARTIAL	Nutrient enrichment, elevated temp. (25.0C)	Candlewood Lake and associated housing
29.3[H]/29.3	43*	NA	MG*	73.0	**NON**	Nutrient enrichment	Candlewood Lake WWTP
28.1[H]/28.1	48	NA	E	80.0	FULL		
25.5[W]/25.5	46[ns]	9.0[ns]	52	74.5	FULL		
22.4[W]/22.4	50	9.0[ns]	48	72.0	FULL		
21.7[W]/21.8	50	8.1*	50	66.5	PARTIAL	Natural?	MIwb influenced by abnormal seasonal rainfall?
21.6/21.58 Mix Zone	**36**	**6.0**	**MG/ MG**			**Fish avoidance response**	**Avoidance of effluent discharged from Mt. Gilead WWTP**
21.5[W]/21.5	41*	8.6*	46	68.0	PARTIAL	Nutrient enrichment	Mt. Gilead WWTP
18.2[W]/18.3	*54*	*8.6**	40*	*72.5*	PARTIAL	Embedded substrates	
13.65/13.68 Mix Zone	**46/28**	**9.1/ 6.5**	**MG/F**			**Fish avoidance response during higher stream flow**	**Effluent discharged to flow upst. which speeds dilution at low flow; not effective during higher flows.**
13.5[W]/12.8	45*	8.4*	52	64.5	PARTIAL	Nutrient enrichment, poor riparian corridor	Cardington WWTP, historical urbanization
9.2[W]/9.0	*40**	*8.8**	50	*69.5*	PARTIAL	Nutrient enrichment	Agricultural activities, livestock in stream

River Mile Fish/Invertebrate	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes	Sources
Whetstone Creek (RM 36.07) *EWH*							
2.6[B]/2.7	36*	8.7*	56	61.5	PARTIAL	Siltation, Impounded	Delaware Reservoir
Tributary to Whetstone Creek RM 33.71 *Undesignated / WWH and CWH Recommended*							
0.4[H]/0.4	40	NA	F*	56.5	PARTIAL	Agricultural runoff	Agricultural activities
E. Branch Whetstone Creek (Tributary to Whetstone Creek RM 28.29) *WWH/ Recommended CWH in addition to WWH*							
0.4[H]/0.4	45	NA	E	78.0	FULL		
Sams Creek (Tributary to Whetstone Creek RM 23.30) *WWH*							
1.4[H]/1.4	44	NA	E	66.5	FULL		
Big Run (Tributary to Whetstone Creek RM 12.75) *WWH*							
0.1[H]/0.1	34*	NA	Low F*	64.0	**NON**	Siltation, Upstream channel modifications	Agricultural impacts exacerbated by intermittent stream flow
Shaw Creek (Tributary to Whetstone Creek RM 8.47) *WWH*							
13.2[H]/13.2	40	NA	G	39.5	FULL	Channel modifications, Nutrient enrichment	
10.6[H]/10.6	38[ns]	NA	MG[ns]	52.5	FULL	Channel modifications, Nutrient enrichment	
5.2[W]/5.2	*36*[ns]	NA	MG[ns]	*66.0*	FULL	Nutrient enrichment, Siltation, Poor riparian cover	Failing on-site wastewater systems, Agricultural activities
1.6[W]/1.5	*38[ns]*	*8.2[ns]*	42	*69.5*	FULL		
Mitchell Run (Tributary to Whetstone Creek RM 8.1) *WWH*							
0.2[H]/0.2	42	NA	MG[ns]	72.0	FULL	Nutrient enrichment	Upstream agricultural activities

River Mile Fish/Invertebrate	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes	Sources
Claypole Run (Tributary to Whetstone Creek RM 3.27) *WWH*							
1.2[H]/1.2	39[ns]	NA	Low F*	54.0	PARTIAL	Nutrient enrichment, siltation, bacteria	Home on-site wastewater discharges, Channel modifications
Indian Run (RM 35.28) *WWH*							
0.9[H]/0.9	36[ns]	NA	MG[ns]	69.0	FULL	Nutrient enrichment	Agricultural activities
Norris Run (RM 32.18) *WWH*							
1.3[H]/1.3	23*	NA	Low F*	62.0	**NON**	Habitat alteration, Nutrient enrichment and Siltation	Riparian removal, Urbanization
Sugar Run (RM 26.97) *WWH*							
1.3[H]/1.3	29*	NA	Low F*	69.0	**NON**	Siltation, nutrient enrichment	Urban influences
Mill Run (RM 25.17) *WWH*							
0.9[H]/0.7	37[ns]	NA	P*	68.0	**NON**	Nutrient enrichment	Urban influences
Tributary to Olentangy River RM 20.71 *Undesignated / WWH Recommended*							
0.2[H]/0.1	16*	NA	MG[ns]	52.5	**NON**	Isolation, impassable upstream or downstream	Upstream of large waterfall and downstream of several dams
Tributary to the Olentangy River RM 18.19 *WWH*							
0.1[H]/0.1	27*	NA	F*	68.0	**NON**	Nutrient enrichment, bacteria	On-site wastewater systems, urbanization
Deep Run (RM 15.8) *WWH*							
1.1[H]/0.5	22*	NA	F*	48.0	**NON**	Watershed modifications, nutrient enrichment, bacteria	Urbanization

River Mile Fish/Invertebrate	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes	Sources
Turkey Run (RM 5.82) *WWH*							
0.7[H]/0.7	20*	NA	Low F*	55.0	**NON**	Nutrient enrichment	Urban runoff, golf course runoff
Wahalla Hollow (RM 4.6) *Undesignated / PHWH Recommended*							
0.9[H]/1.0	12	NA	P	57.5	**NA**	Nutrient enrichment	SSOs, urban runoff
Glen Echo Ravine (RM 4.1) *Undesignated / WWH Recommended*							
1.0[H]/0.9	14*	NA	P*	60.0	**NON**	Nutrient enrichment, bacteria	SSOs, urban runoff

Ecoregion Biocriteria: Eastern Corn Belt Plain

	IBI			MIwb			ICI		
Site Type	WWH	EWH	MWH	WWH	EWH	MWH	WWH	EWH	MWH
Headwaters	40	50	24				36	46	22
Wading	40	50	24	8.3	9.4	4.0	36	46	22
Boat	42	48	24	8.5	9.6	4.0	36	46	22

H - Headwater site.
W - Wading site.
B - Boat site.
a - MIwb is not applicable (NA) to headwater streams with drainage areas ≤ 20 mi^2.
b - A narrative evaluation of the qualitative sample based on attributes such as EPT taxa richness, number of sensitive taxa, and community composition was used when quantitative data was not available or considered unreliable due to sampling considerations. VP=Very Poor, P=Poor, LF=Low Fair, F=Fair, MG=Marginally Good, G=Good, VG=Very Good, E=Exceptional.
c - Attainment status is given for both existing and proposed use designations.
ns - Nonsignificant departure from biocriteria (≤4 IBI or ICI units, or ≤0.5 MIwb units).
* - Indicates significant departure from applicable biocriteria (>4 IBI or ICI units, or >0.5 MIwb units). Underlined scores are in the Poor or Very Poor range.
1 – A fish kill was noted here during a sampling event in 2003. Though a source was not identified, it could have been a result of discharges from the upstream package plants, or some type of dumped waste. See UOWAU Report section of this report for additional information.

RECOMMENDATIONS

Current and recommended aquatic life, water supply and recreation uses are presented in Table 4. A number of the tributary streams evaluated in this study were originally assigned aquatic life use designations in the 1978 and 1985 Ohio WQS based largely on best professional judgment, while others were left undesignated. The current biological assessment methods and numerical criteria did not exist then. This study, as an objective and robust evaluation of beneficial uses, is precedent setting in comparison to the 1978 and 1985 designations. Several sub-basin streams have been evaluated for the first time using a standardized biological approach as part of this study. Ohio EPA is obligated by a 1981 public notice to review and evaluate all aquatic life use designations outside of the WWH use prior to basing any permitting actions on the existing, unverified use designations. Thus, some of the following aquatic life use recommendations constitute a fulfillment of that obligation.

Five small tributaries to the Olentangy River and one small tributary to Whetstone Creek were sampled for the first time by Ohio EPA during this study. Bee Run, Rocky Fork, an unnamed tributary to Whetstone Creek at RM 33.71, an unnamed tributary to the Olentangy River at RM 20.71, and Glen Echo Ravine were all identified as having the potential to support WWH communities and have, thus, been recommended for WWH aquatic life use designations. Biological sampling within the unnamed tributary to Whetstone Creek at RM 33.71 indicated the presence of five cool/coldwater macroinvertebrate taxa and redside dace, a cool/coldwater fish species. Therefore, a CWH aquatic life use designation in addition to the WWH aquatic life use designation is recommended for this stream. Wahalla Hollow did not have sufficient features to support a fish community and has a drainage area of less than one square mile. The most appropriate classification for Wahalla Hollow would involve a Primary Headwater Habitat (PHWH) designation. At this time, Ohio does not have PHWH aquatic life use designations available for these small streams. Therefore, Wahalla Hollow will remain undesignated.

East Branch of Whetstone Creek is currently designated a WWH stream and this use was confirmed during the 2003 survey. In addition to the ability to support WWH fauna, survey results indicate this stream may support CWH communities as three cool/coldwater macroinvertebrate taxa and both redside dace and mottled sculpin, cool/coldwater fish species, were collected. Therefore, the East Branch of Whetstone Creek is recommended for dual aquatic life use designations of WWH and CWH.

Improvements may be made to water quality throughout the study area by addressing the causes and sources identified within the aquatic life use attainment table (Table 2). The causes and sources associated with agricultural practices may be addressed by improving riparian buffers, proper fertilizer and pesticide application, and ceasing of traditional ‘cleaning’ of streams. Funding opportunities should be sought to improve agricultural practices and could include any of the above listed improvements. Urbanization impairments could be addressed through a combination of regulatory, educational and funding actions including improvements at each WWTP, management of failing septic systems, advances in storm water management, controlled development and alternatives to traditional stream channelization and riparian removal.

Table 4. Waterbody use designations for the Olentangy River and Whetstone Creek basins. Designations based on Ohio EPA biological field assessments appear as a plus sign (+). Designated use based on the 1978 water quality standards appear as an asterisk (*). 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 a circle (o). A delta (Δ) indicates a new recommendation based on the findings of this report.

Water Body Segment	Use Designations													Comments
		Aquatic Life Habitat						Water Supply			Recreation			
	SRW	WWH	EWH	MWH	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR	
Olentangy river - Delaware reservoir (RM 32.3) to Old Winter Rd. (RM 20.4)	*	+							+	+		+		
- at RM 31.23	*	+						o	+	+		+		
- at RM 31.02	*	+						o	+	+		+		
- Old Winter Rd. to I-270 (RM 11.6)	*		+						+	+		+		
- at RM 18.19	*		+					o	+	+		+		
- I-270 to st. rte. 161 (RM 9.7)	*	+							+	+		+		
- Adena brook (RM 5.9) to the Dodridge St. dam (RM 4.0)				+					+	+		+		ECBP ecoregion - impounded
- adjacent Tuttle park (RM 3.4) to the Fifth Ave. dam (RM 1.9)				+					+	+		+		ECBP ecoregion - impounded
- Conrail railroad crossing (RM 0.5) to the mouth				+					+	+		+		ECBP ecoregion - impounded
- at RM 0.2				+				o	+	+		+		
- all other segments		+							+	+		+		
Glen Echo Ravine		Δ										Δ		

Water Body Segment	Use Designations													Comments
		Aquatic Life Habitat						Water Supply			Recreation			
	SRW	WWH	EWH	MWH	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR	
Turkey run (Olentangy river RM 5.82)		+							+	+			+	
Big run (Adena brook)		+							+	+		*		
Bill Moose creek (Olentangy river RM 7.82)		+								+			+	
Turkey run		*							*	*		*		
Kempton run (Olentangy river RM 8.59)		+								+			+	
Rush run		+							+	+			+	
Linworth run (Olentangy river RM 9.9)		+								+			+	
Bartholomew run		+							+	+			+	
Deep run		*+							*+	*+		*+		
Unnamed tributary (Olentangy river RM 18.19)		+							+	+			+	
Unnamed tributary (Olentangy river RM 20.71)		Δ							Δ	Δ		Δ		
Weiser run		*							*	*		*		
Kingsbury run		*							*	*		*		
Mill run		*+							*+	*+		*+		
Delaware run		+							+	+		+		
Sugar run		*+							*+	*+		*+		
Clear run		*							*	*		*		

Water Body Segment	Use Designations													Comments
		Aquatic Life Habitat						Water Supply			Recreation			
	SRW	WWH	EWH	MWH	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR	
Horseshoe run		+							+	+			+	
Norris run		*+							*+	*+		*+		
Indian run		*+							*+	*+		*+		
Whetstone creek - headwaters to St. Rte. 229 (RM 2.6)			+						+	+		+		
- all other segments		+							+	+		+		
Claypole run		*+							*+	*+		*+		
Mitchell run		*+							*+	*+		*+		
Shaw creek		+							+	+		+		
Mud run		*							*	*		*		
Big run		*+							*+	*+		*+		
Pugh ditch		*							*	*		*		
Sams creek		*+							*+	*+		*+		
Tributary to Whetstone Creek RM 33.71		Δ				Δ			Δ	Δ		Δ		
East branch		*+				Δ			*+	*+		*+		
Brondige run		*+							*+	*+		*+		
Norton run		*							*	*		*		
Qa Qua creek (aka Cauquaw run) - headwaters to RM 3.7				+					+	+			+	ECBP ecoregion - channel modification

Water Body Segment	Use Designations: SRW	Aquatic Life Habitat: WWH	EWH	MWH	SSH	CWH	LRW	Water Supply: PWS	AWS	IWS	Recreation: BW	PCR	SCR	Comments
| | | | | | | |														
- all other segments		+							+	+		+		
Mack ditch (Cauquaw run RM 5.3)							+		*	*			+	Small drainageway maintenance
Laucher and Berringer ditch (Mack ditch RM 0.86)							+		*	*			+	Small drainageway maintenance
Grave creek - headwaters to RM 2.4				+					+	+			+	ECBP ecoregion - channel modification
- all other segments		+							+	+			+	
Riffle creek - headwaters to RM 4.0				+					+	+			+	ECBP ecoregion - channel modification
- all other segments		+							+	+			+	
Ulsh ditch				+					+	+			+	ECBP ecoregion - channel modification
Clendenon ditch				+					+	+			+	ECBP ecoregion - channel modification
Ruehrmond ditch		*							*	*		*		
McKibben ditch		*							*	*		*		
Beaver run		*							*	*		*		
Muskrat ditch		*							*	*		*		
Otter creek		*+							*+	*+		*+		
Mud river		*							*	*		*		
Flat run		+							+	+		+		
Thorn run		*+							*+	*+		*+		

Water Body Segment	Use Designations													Comments
		Aquatic Life Habitat						Water Supply			Recreation			
	SRW	WWH	EWH	MWH	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR	
Noblet drain		*							*	*		*		
Mud run		*							*	*		*		
Mud run				+					+	+			+	ECBP ecoregion - channel modification
Bee Run		Δ							Δ	Δ		Δ		
Zimmerman ditch (Olentangy river RM 81.2)				+					+	+			+	ECBP ecoregion - channel modification
Rocky fork (Olentangy river RM 84.84) - at RM 0.6		Δ						o	Δ	Δ		Δ		
Shoemaker ditch (Olentangy river RM 88.5)							+		+	+			+	Small drainageway maintenance

SRW = state resource water; WWH = warmwater habitat; EWH = exceptional warmwater habitat; MWH = modified warmwater habitat; SSH = seasonal salmonid habitat; CWH = coldwater habitat; LRW = limited resource water; PWS = public water supply; AWS = agricultural water supply; IWS = industrial water supply; BW = bathing water; PCR = primary contact recreation; SCR = secondary contact recreation.

METHODS

All physical, chemical, 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), The Qualitative Habitat Evaluation Index (QHEI): Rationale, Methods, and Application (Rankin 1989, 1995) for aquatic habitat assessment, and the Ohio EPA Sediment Sampling Guide and Methodologies (Ohio EPA 2001). Sampling locations are listed in Table 1.

Determining Use Attainment Status

Use attainment status is a term describing the degree to which environmental indicators are either above or below criteria specified by the Ohio Water Quality Standards (WQS; Ohio Administrative Code 3745-1). Assessing aquatic use attainment status involves a primary reliance on the Ohio EPA biological criteria (OAC 3745-1-07; Table 7-15). These are confined to ambient assessments and apply to rivers and streams outside of mixing zones. Numerical biological criteria are based on multimetric biological indices including the IBI and MIwb, indices measuring the response of the fish community, and the ICI, which indicates the response of the macroinvertebrate community. Three attainment status results are possible at each sampling location - full, partial, or non-attainment. Full attainment means that all of the applicable indices meet the biocriteria. Partial attainment means that one or more of the applicable indices fails to meet the biocriteria. Non-attainment means that none of the applicable indices meet the biocriteria or one of the organism groups reflects poor or very poor performance. An aquatic life use attainment table (Table 2) is constructed based on the sampling results and is arranged from upstream to downstream and includes the sampling locations indicated by river mile, the applicable biological indices, the use attainment status (*i.e.,* full, partial, or non), the Qualitative Habitat Evaluation Index (QHEI), and a sampling location description.

Habitat Assessment

Physical habitat was evaluated using the 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 reflect habitat conditions which have the ability to support exceptional warmwater faunas.

Sediment and Surface Water Assessment

Fine grain sediment samples were collected in the upper 4 inches of bottom material at each location using decontaminated stainless steel scoops and excavated using nitrile gloves. Decontamination of sediment sampling equipment followed the procedures outlined in the Ohio EPA sediment sampling guidance manual (Ohio EPA 2001). Sediment grab samples were homogenized in stainless steel pans (material for VOC analysis was not homogenized), transferred into glass jars with teflon® lined lids, placed on ice (to maintain $4^{o}C$) in a cooler, and shipped to an Ohio EPA contract lab. Sediment data is reported on a dry weight basis. Surface water samples were collected, preserved and delivered in appropriate containers to either an Ohio EPA contract lab or the Ohio EPA Division of Environmental Services. Surface water samples were evaluated using comparisons to Ohio Water Quality Standards criteria, reference conditions, or published literature. Sediment evaluations were conducted using guidelines established in MacDonald *et al.* (2000) and Ohio Specific Reference Values (2003).

Recreational Use Assessment

Recreation use attainment was assessed by using fecal coliform and *E. coli* bacteria as test organisms. Their presence indicates that the water has been contaminated with feces from warm blooded animals. Counts are reported in colony forming units (CFU)/100 ml. To determine if criteria codified in OAC 3745-1-07 are met, a minimum of five samples must be collected within any 30-day period during the recreation season (May 1-October 15). Rules for the PCR use state that the fecal coliform geometric mean shall not exceed 1000 and not more than 10% of the samples shall exceed 2000 and that the *Escherichia coli* geometric mean shall not exceed 126 and not more than 10% of the samples shall exceed 298.

Macroinvertebrate Community Assessment

Macroinvertebrates were collected from artificial substrates and from the natural habitats. The artificial substrate collection provided quantitative data and consisted of a composite sample of five modified Hester-Dendy multiple-plate samplers colonized for six weeks. At the time of the artificial substrate collection, a qualitative multihabitat composite sample was also collected. This sampling effort consisted of an inventory of all observed macroinvertebrate taxa from the natural habitats at each site with no attempt to quantify populations other than notations on the predominance of specific taxa or taxa groups within major macrohabitat types (e.g., riffle, run, pool, margin). Detailed discussion of macroinvertebrate field and laboratory procedures 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).

Fish Community Assessment

Fish were sampled using pulsed DC electrofishing methods. Fish were processed in the field, and included identifying each individual to species, counting, weighing, and recording any external abnormalities. 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

WATERSHED ASSESSMENT UNIT REPORTS

As mentioned previously, four WAUs comprise the Olentangy River watershed. Two of the WAUs are identical to the HUC boundaries established by the USGS. The UOWAU and the WCWAU correspond to the hydrologic unit codes 050600001-090 and 050600001-100, respectively. The MOWAU corresponds primarily with hydrologic unit code 050600001-110, which extends from below the confluence of Flat Run (RM 59.28) to below the confluence of Delaware Run (RM 25.71). However, for the purposes of the this report, the lower boundary of the MOWAU was set to below the confluence of Brondige Run (RM 38.13) to match the boundary created by Delaware Lake and the line between Ohio EPA Northwest and Central District offices. Likewise, the LOWAU is similar to the hydrologic unit code 050600001-120, except that the chemistry portion has northern boundary below the confluence with Brondige Run (RM 38.13), not Delaware Run (RM 25.71).

Upper Olentangy Watershed Assessment Unit *(UOWAU)*

The UOWAU corresponds to HUC #05060001-090 and covers the drainage area from the origin of the Olentangy River (RM 93.0) to below the confluence of Flat Run (RM 59.28). A schematic of the area is presented in Figure 2. Fish and macroinvertebrate populations and stream habitat conditions were evaluated at 16 sites (Figure 3). The index scores for each site and their biological attainment status are presented in Table 5 and attainment status for each site is symbolized in Figure 4. Physical, chemical, and bacterial measurements were done at 21 sites. Each site had at least six sets of grab samples collected at roughly two week intervals during the field season. Mainstem sites had extra bacteria samples collected in July so the recreation use could be assessed. Results that violated water quality criteria codified in OAC Chapter 3745-1 are summarized in Table 6.

Aquatic Life Use Attainment Status and Trends

The overall UOWAU aquatic life use attainment score was 35. An overall attainment score of 0 would reflect 0 sites meeting designated or recommended aquatic life uses in the WAU while a score of 100 would reflect all sites meeting designated or recommended aquatic life uses. This attainment score was calculated according to the protocol and procedures established in the most recent Integrated Water Quality Monitoring and Assessment Report, which can be accessed at:
http://www.epa.state.oh.us/dsw/tmdl/index.html

Biological impairment in the UOWAU was almost exclusively limited to the Olentangy River below Galion. The Rocky Fork below Ammans Reservoir was the only tributary site of eight evaluated that was not in full attainment. Water quality impairment to some degree was documented at every site and the most common causes were nutrient enrichment and bacterial contamination. Habitat and flow conditions were sufficient in most instances to overcome degradation to aquatic life from nutrient enrichment.

Longitudinal plots of IBI scores versus river miles for select years are provided in Figure 5. Fish community performance in the Olentangy River is similar to the results of the 1994 survey. While improvements have occurred at the Galion WWTP over time, it continues to be a source of noticeable impairment to biological communities in the UOWAU. Fish community performance met ecoregional expectations, though index scores were lower around Galion as compared to a 1994 survey. Infiltration and inflow from the aged Galion collection system resulted in flows to the WWTP which exceeded the design capacity on 344 days in 2003. These issues should be addressed in the near future to ensure that water quality is not further degraded.

Macroinvertebrate community performance in the Olentangy River has not changed since the 1994 survey (Figure 6). However, there was some improvement upstream and downstream from Galion since the 1979 survey. In particular, the EPT and sensitive taxa diversity were very low upstream and downstream from the Galion WWTP in 1979. It is noteworthy that the sensitive taxa diversity at the station immediately upstream from the Galion WWTP has not improved since the 1979 survey. This trend highlights the need to further investigate and correct the sources of impairment in the Galion area.

Recreation Use Attainment Status

Recreation impairment was widespread throughout the UOWAU. Sources of bacteria included both point sources, such as package plants and SSOs, and nonpoint sources such as livestock and failing home sewage disposal systems. Details regarding these sources are contained below.

Spills

Six spills were reported to ODNR between 1994-2004 for the UOWAU (Figure 7). The spills were investigated by ODNR for possible impacts to wildlife. The largest spill was reported by the Galion WWTP when approximately 6,000-8,000 gallons of lime sludge spilled from a broken gasket into the Olentangy River in 1998.

Failing sewage disposal systems from several homes have resulted in two reports of spills into a tributary to Rocky Fork just south of Galion. Considering that Rocky Fork leads to the Ammans public water supply reservoir, attention should be given to improving the home sewage disposal systems in this area.

One spill was attributed to hog manure having been spread on fields which then drained into tile and entered Mud Run. Manure releases may result in fish kills as several processes occur. High ammonia is toxic to both macroinvertebrates and fish. In addition, the high nutrients and bacteria present may use up all the dissolved oxygen in the water column, suffocating aquatic organisms. The UOWAU is approximately 66% agricultural lands. In all likelihood, many more releases of this type occur in the watershed than what is reported. Increased awareness of proper manure handling techniques may help alleviate these types of releases.

The remaining reported spills included a diesel fuel release from Elliot Machine Works, Inc. in Galion and a fish kill determined to be related to temperature change in a small reservoir along an Olentangy tributary east of Galion.

Ecoregion, Soils and Topography

The upper Olentangy watershed is located at the extreme eastern boundary of the Eastern Corn Belt Plain (ECBP) ecoregion. The ECBP ecoregion in this part of central Ohio is characterized by high lime till plain; primarily a broad, nearly level till plain with local end moraines of glacial deposits of the Wisconsinan age. The historical natural tree land cover consisted of beech forests in the upper watershed and scattered elm-ash swamp forests in the poorly drained areas of the lower watershed.

Soils in this part of the ECBP ecoregion are clayey to loamy, high lime glacial till with widespread areas of Pewamo, Blount and Glynwood series in Marion County. The headwaters of the Olentangy River originate in Crawford County, where the soils are predominantly Pewamo and Bennington, with Cardington series along the floodplains of streams. Soils are relatively fertile, easily eroded by water and wind, and are considered prime farm lands especially if artificially drained for agricultural crop production. Soil capability for onsite household sewage treatment is classified as “severe” with all soil types exhibiting slow percolation, and seasonal wetness or ponding limitations. Failing home septic systems contribute to nutrient and bacteria impairment in the watershed. The low gradient streams and runoff of agricultural sediment and fertilizers has affected stream chemistry and turbidity in the upper and middle portions of the watershed (USGS, 1997).

Current land use is predominantly agricultural crop and livestock production. The National Land Cover Dataset for the UOWAU indicates the predominant land use is agriculture (66.2%) primarily in the form of row crop and livestock production. Pasture and forested land cover 16.3% and 13.7% of the watershed, respectively, with another 2.7% for urban and residential land use. The remaining 1.1% of land is split evenly between wetlands and green space (USGS-NLCD, 1992).

According to the Census of Agriculture, land in agricultural use for either row crop or livestock production has been steadily declining since 1980. The number of farms has decreased, as has the number of animals per livestock operation. In isolated areas, the acres in crop production may have remained steady due to minor increases in farm size per operation. There is one Concentrated Animal Feeding Operation (CAFO), Albright Farms, with 4200 hogs located in the UOWAU. The decrease of land in crop production is due to suburban development, and may also be reflected in land that has been taken out of agricultural production for conservation practices such as permanent wildlife or riparian easements, other buffer practices, or wetland and floodplain restorations (USDA, 1997; OSU Extension, 2002).

Causes and sources of impairment
A flow schematic of the tributaries and significant point sources is found in Figure 2.

Point sources of pollution include insufficiently treated wastewater and separate sewer overflows from the City of Galion. Galion is a major source of organic and nutrient enrichment with the highest levels of phosphorus and nitrates encountered during the study. Galion's sewer overflows also contributed to bacteria impairments in the river. Caledonia operates a WWTP with a permitted discharge to the river approximately 25 miles downstream from Galion.

Other point sources of treated wastewater discharges from publicly owned and commercial facilities are listed in Table 7. NPDES permits have also been issued for industrial and construction stormwater sources as listed in Table 8. Small villages and unincorporated areas without any wastewater collection or treatment contribute to the bacteria and recreation impairments and nutrient enrichment of the river. Several unsewered areas include Blooming Grove, Westmoor Subdivision, Sugar Grove Lake, Iberia, and Climax. In addition, the unsewered area of homes in Morrow County along State Route 19 at Crawford Morrow Line Road negatively impacts Rocky Fork and Ammans Reservoir, which is the drinking water supply for the City of Galion.

Nonpoint sources from agricultural land use include crop and livestock production. Sediment in agricultural runoff was noted in most streams, and was further aggravated in places where livestock had access and trampled the banks of the streams. The use of fertilizer on artificially drained crop land is reflected as an adverse impact for this assessment unit. Nitrates, which dissolve easily in water and leach through the soil, are collected in drainage tile, and were highest in the Mud Run subwatershed. Although the stream is not used for public drinking water, the nitrate levels were high enough to be a concern for livestock watering. Habitat modification was most noted in Mud Run, Shumaker Ditch, and QuQua Creek which are maintained by county engineers in Marion and Crawford counties.

Table 5. Attainment Table for the Upper Olentangy Watershed Assessment Unit (UOWAU) based on data collected in 2003. Mix zone samples are in **bold**. Sites in non attainment are also in **bold**. The Index of Biotic Integrity (IBI), Modified Index of well being (MIwb), and Invertebrate Community Index (ICI) are scores based on the performance of the biotic community. The Qualitative Habitat Evaluation Index (QHEI) is a measure of the ability of the physical habitat to support a biotic community. Threats to water quality identified during the course of the study are listed under Causes and Sources.

River Mile Fish/Invertebrate	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes	Sources
Olentangy River		*WWH*					
89.3[H]/89.3	49	NA	MG[ns]	84.0	FULL	Low DO and possible undocumented spills[1]	Upstream package plants and possible undocumented spills[1]
86.1[H]/86.1	38[ns]	NA	34[ns]	58.5	FULL		
86.0/85.94 Mix Zone	**24**		**LowF/P**			**Fish avoidance response Toxicity to Invertebrates**	**Galion WWTP**
85.9[H]/--	38[ns]	NA	-	79.0	(FULL)		
85.2[H]/84.5	37[ns]	NA	46	82.5	FULL		
79.7[W]/79.7	34*	7.8[ns]	42	69.5	PARTIAL	Nutrients, cadmium('94) and siltation	Galion WWTP and agricultural activities (cattle in stream)
74.0[W]/74.0	40	7.2*	Low F*	57.5	PARTIAL	Siltation, channelization	Agricultural activities
68.1[W]/68.0	33*	7.7*	30*	58.0	**NON**	Nutrients, siltation and habitat alteration	Livestock in stream, riparian cover removal
63.4[W]/63.5	45	7.3*	40	57.5	PARTIAL	Nutrient enrichment, Siltation	Agricultural activities
Rocky Fork (RM 84.84) *Undesignated / WWH Recommended*							
2.9[H]/2.9	36[ns]	NA	MG[ns]	74.0	FULL		
0.4[H]/0.4	34*	NA	P*	75.0	**NON**	Channel modifications, flow alteration from reservoir and nutrient enrichment	Below Ammans PWS reservoir

River Mile Fish/Invertebrate	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes	Sources
Mud Run (RM 62.44) *MWH*							
6.7[H]/6.7	30	NA	F	35.0	FULL	Channelization, Siltation	Maintained by County Engineer, Agricultural activities
2.7[H]/2.6	40	NA	MG	38.0	FULL	Channelization	Maintained by County Engineer
Flat Run (RM 59.28) *WWH*							
12.6[H]/12.7	42	NA	G	57.0	FULL		
7.3[H]/7.3	49	NA	E	85.0	FULL		
0.6[W]/0.6	50	9.1	52	72.5	FULL		
Thorn Run (Tributary to Flat Run RM 0.56) *WWH*							
1.1[H]/1.1	42	NA	MG[ns]	58.5	FULL	Channel modifications, Embeddedness	Agricultural activities

Ecoregion Biocriteria: Eastern Corn Belt Plain

	IBI			MIwb			ICI		
Site Type	WWH	EWH	MWH	WWH	EWH	MWH	WWH	EWH	MWH
Headwaters	40	50	24				36	46	22
Wading	40	50	24	8.3	9.4	4.0	36	46	22
Boat	42	48	24	8.5	9.6	4.0	36	46	22

H - Headwater site.
W - Wading site.
B - Boat site.
a - MIwb is not applicable to headwater streams with drainage areas $\leq$ 20 mi^2.
b - A narrative evaluation of the qualitative sample based on attributes such as EPT taxa richness, number of sensitive taxa, and community composition was used when quantitative data was not available or considered unreliable due to sampling considerations. VP=Very Poor, P=Poor, LF=Low Fair, F=Fair, MG=Marginally Good, G=Good, VG=Very Good, E=Exceptional
c - Attainment status is given for both existing and proposed use designations.
ns - Nonsignificant departure from biocriteria ($\leq$4 IBI or ICI units, or $\leq$0.5 MIwb units).
* - Indicates significant departure from applicable biocriteria (>4 IBI or ICI units, or >0.5 MIwb units). Underlined scores are in the Poor or Very Poor range.
1 – A fish kill was noted here during a sampling event in 2003. Though a source was not identified, it could have been a result of discharges from the upstream package plants, or some type of dumped waste. See UOWAU section of this report for additional information.

Table 6. Violations of Ohio WQS criteria (OAC 3745-1) for chemical, physical, and bacterial parameters in the UOWAU in 2003. Plain text river miles indicate 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. Parameter units are #/100 ml for bacteria and μg/l for metals. Shaded areas are tributary streams and the river mile listed is the location of the confluence.

Waterbody	**NPDES Discharge**	**Biological Attainment**	**QHEI**	**River Mile**	**Parameter**	**Code**
Olentangy River and Tributaries (HUC 05060001-090) WWH, AWS, IWS, PCR						
-Unnamed Tributary				90.04		
	Swiss Village WWTP			*0.30*		
--(RM 0.08 U)					*E. coli* F. coliform	e e
		FULL	84.0	89.25	*E. coli* F. coliform	c, d c, d
		FULL	58.5	86.00	*E. coli* F. coliform	c, d c, d
	Galion WWTP			*85.96*		
		FULL	79.0	85.94	*E. coli* F. coliform copper cadmium	c, d c, d b b
- Rocky Fork				84.84		
--(RM 2.85 U)		FULL	74.0		*E. coli* F. coliform	e e
--(RM 0.41PWS)		NON	75.0		*E. coli*	e
		PARTIAL	82.5	84.48	*E. coli* F. coliform	a, b a, b
-Hooker Dapper Ditch				81.18		
--Zimmerman Ditch MWH, AWS, IWS, SCR				<u>0.30</u>		
	Spring Valley WWTP			*1.30*		
--(RM 0.29)					*E. coli* F. coliform	e e
		PARTIAL	69.5	79.66	*E. coli* F. coliform	c, d c, d

Waterbody	NPDES Discharge	Biological Attainment	QHEI	River Mile	Parameter	Code
		PARTIAL	57.5	74.00	*E. coli* F. coliform	c, d c, d
		NON	58.0	68.11	*E. coli* F. coliform copper	c, d c, d b
-Unnamed Tributary				65.60		
	Marathon Ashland Pipeline					
-Shumaker Ditch				63.89		
	General Mills Operations, Inc.			*1.92*		
--(RM 0.37 U)					*E. coli* F. coliform	e e
		PARTIAL	57.5	63.36	*E. coli* F. coliform	c, d c, d
-Mud Run MWH, AWS, IWS, SCR				62.44		
--(RM 6.56)		FULL	35.0		*E. coli* F. coliform	e e
--(RM 2.65)		FULL	38.0		*E. coli*	e
	Caledonia WWTP			*59.70*		
-Flat Run WWH, AWS, IWS, PCR				59.28		
--(RM 12.62)		FULL	57.0			
	Glen Gery Corp.			*8.24* *7.90*		
--(RM 7.26)		FULL	85.0			
--(RM 0.55)		FULL	72.5			
--Thorn Run WWH, AWS, IWS, PCR				0.56		
--Unnamed Tributary				8.85		
	Specialty Fertilizer Products			*1.20*		
--(RM 8.75)						
--(RM 1.11)		FULL	58.5			

a violates the aquatic life protection criterion outside mixing zone 24 hr. average
b violates the aquatic life protection criterion outside mixing zone minimum/maximum
c violates the primary contact recreation 30 day geometric mean
d violates the primary contact recreation 30 day maximum
e violates the secondary contact recreation maximum

Table 7. Facilities regulated by an Individual NPDES permit in the UOWAU.

Facility Name	**Ohio EPA Permit No.**	**Receiving Stream**	**River Mile**	**Wastewater Type and Treatment System**
Swiss Village MHP	2PR00099-001	Unnamed Tributary Olentangy River	0.3 90.04	sanitary 8,000 gpd package plant
Galion WWTP	2PD00030-001	Olentangy River	85.96	sanitary/industrial 2.7 mgd extended aeration
Spring Valley MHP	2PY00023-001	Zimmerman Ditch Hooker-Dapper Ditch Olentangy River	1.30 0.30 81.18	sanitary 10,000 gpd package plant
Marathon Ashland Pipeline	2IG00028-001	Unnamed Tributary Olentangy River	 65.60	storm/hydrostatic test water containment dike
General Mills Operations, Inc.	2IH00106-001	Shumaker Ditch Olentangy River	1.92 63.89	sanitary/process 1,500 gpd package plant
Caledonia WWTP	2PA00035-001	Olentangy River	59.70	sanitary 120,000 gpd package plant
Glen Gery Corp., Iberia Plant	2IJ00074-001	Flat Run Olentangy River	7.90 59.28	process/storm/groundwater series of settling ponds
Glen Gery Corp., Iberia Plant	2IJ00074-002	Flat Run	8.24	sanitary 2,000 gpd package plant
Specialty Fertilizer Prod.	4IF00100-002	Unnamed Tributary Thorn Run Flat Run	 8.85 0.56	sanitary 2,000 gpd package plant
Specialty Fertilizer Prod.	4IF00100-003, 005, 006, 007	Unnamed Tributary		stormwater

Table 8. Facilities regulated by a General NPDES permit in the UOWAU.

Facility Name	Ohio EPA Permit Number	Receiving Stream	Wastewater Type
Galion, Inc.	2GR00180	Olentangy River	industrial stormwater
Flick Packaging	2GG00212	Olentangy River	industrial stormwater
A & G Manufacturing, Inc.	2GR00090	Olentangy River	industrial stormwater
A & G Manufacturing, Inc.	2GR00091	Olentangy River	industrial stormwater
A & G Manufacturing, Inc.	2GR00089	Olentangy River	industrial stormwater
McClain E-Z Pack, Inc.	2GR00111	Olentangy River	industrial stormwater
K & B Products, Inc.	2GG00103	Olentangy River	industrial stormwater
Carter Machine Co., Plant #1	2GR00219	Olentangy River	industrial stormwater
Carter Machine Co., Plant #2	2GR00237	Olentangy River	industrial stormwater
Carter Machine Co., Plant #5	2GR00218	Rocky Fork	industrial stormwater
Ferro Graphics, Inc.	2GR00144	Olentangy River	industrial stormwater
Elliot Machine Works, Inc.	2GR00536	Olentangy River	industrial stormwater
City of Galion	2GR00548	Olentangy River	industrial stormwater
Peco II, Inc.	2GR00195	Olentangy River	industrial stormwater
Komatsu Dresser, Plant #1	2GR00317	Olentangy River	industrial stormwater
Komatsu Dresser, Plant #2	2GR00316	Olentangy River	industrial stormwater
Galion Auto Wrecking, Inc.	2GG00261	Olentangy River	industrial stormwater
General Mills Operations, Inc.	2GR00173	Shumaker Ditch	industrial stormwater
Glen Gery Corp., Iberia	2GG00197	Flat Run	industrial stormwater
Glen Gery Corp., Caledonia	2GG00085	Olentangy River	industrial stormwater
American Lumber Co.	4GR00134	Flat Run Tributary	industrial stormwater
Iberia Elementary School	4GS00004	Flat Run Tributary	small sanitary
C&DD Acquisitions, Ltd.	4GC00277	Thorn Run	construction stormwater

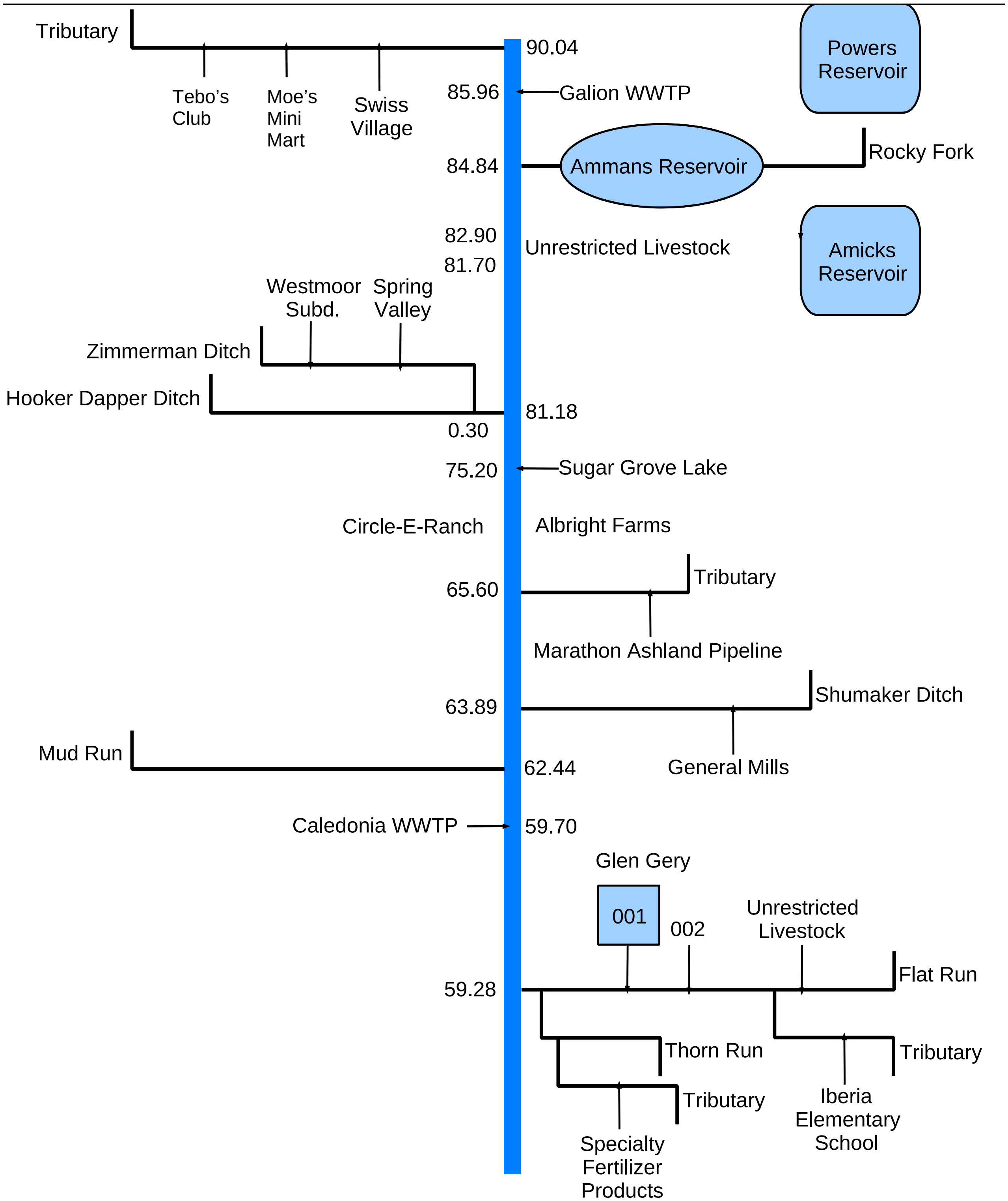


Figure 2. Schematic of the UOWAU (HUC 0506001-090).

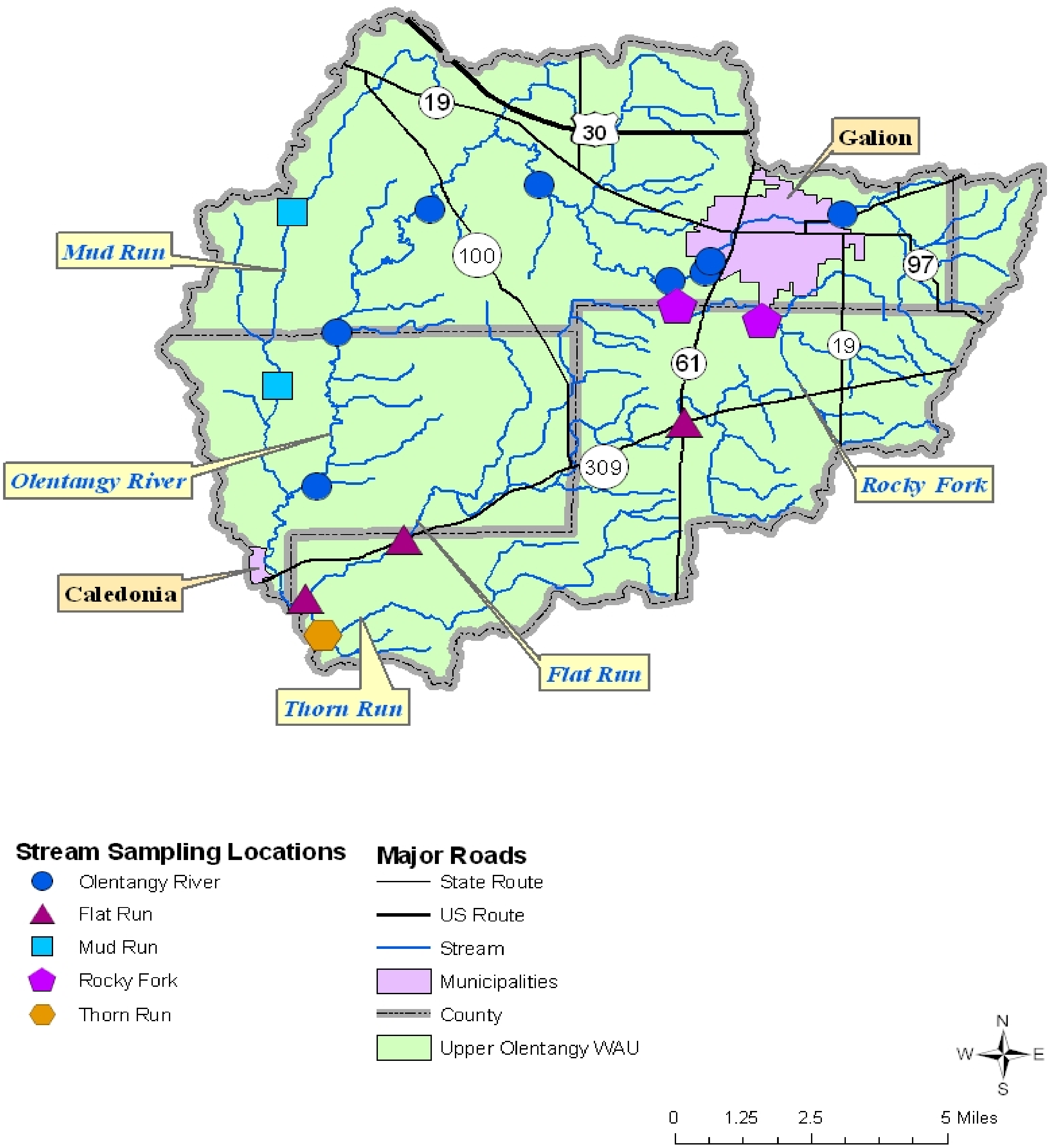


Figure 3. Biological, habitat and water quality sampling locations in the UOWAU, 2003.

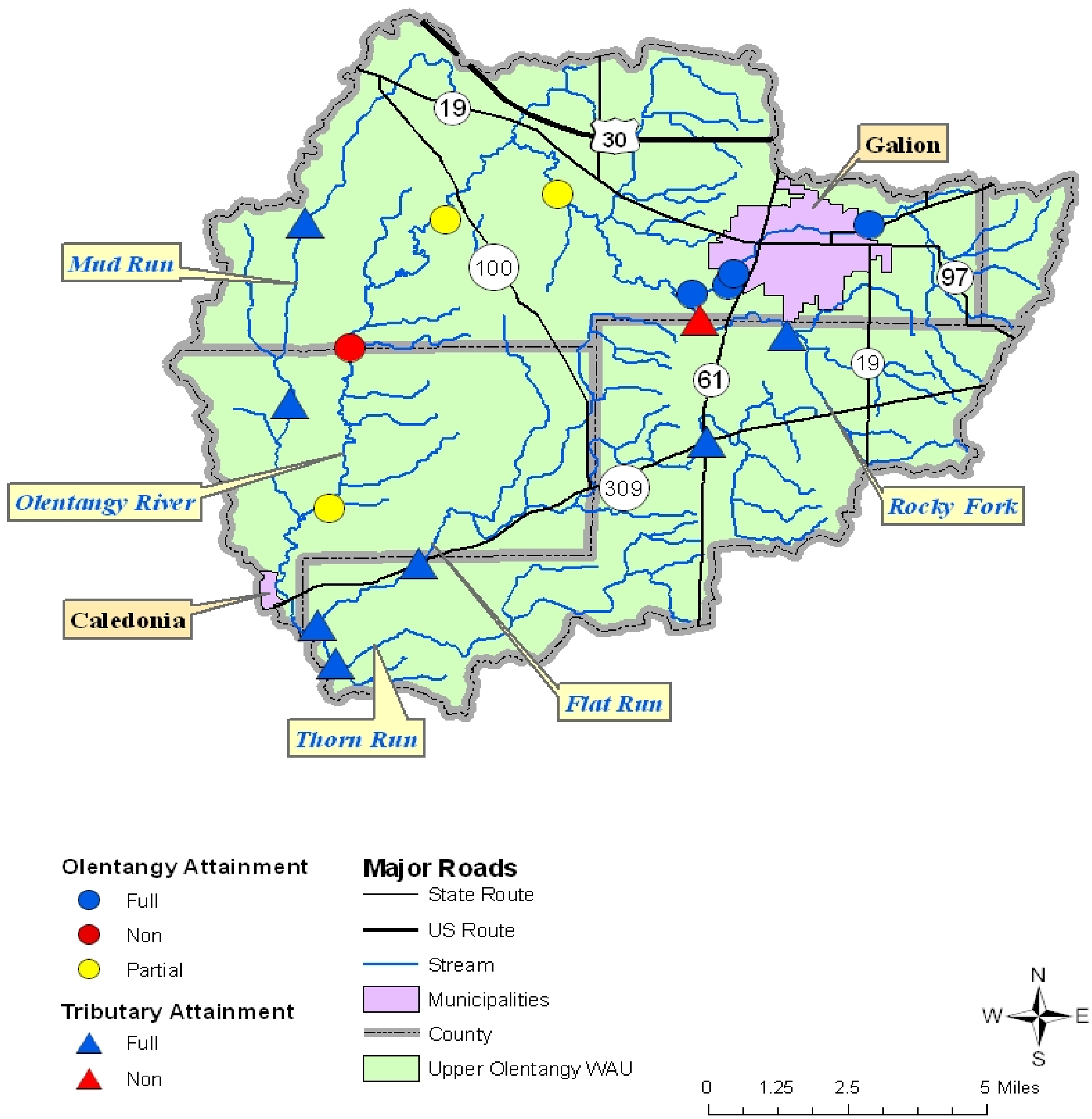


Figure 4. Attainment status of sampling locations in the UOWAU based on 2003 data.

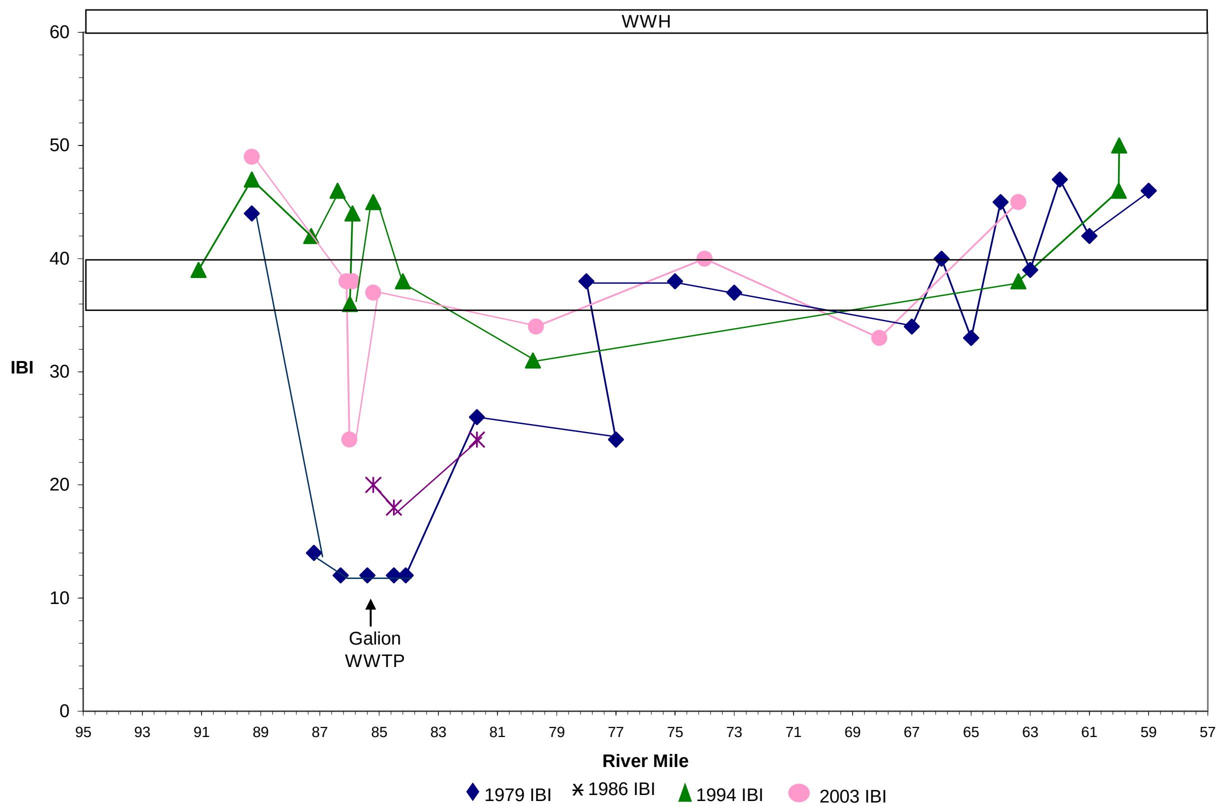


Figure 5. Longitudinal trend of the IBI from selected sites in the UOWAU, 1979-2003.

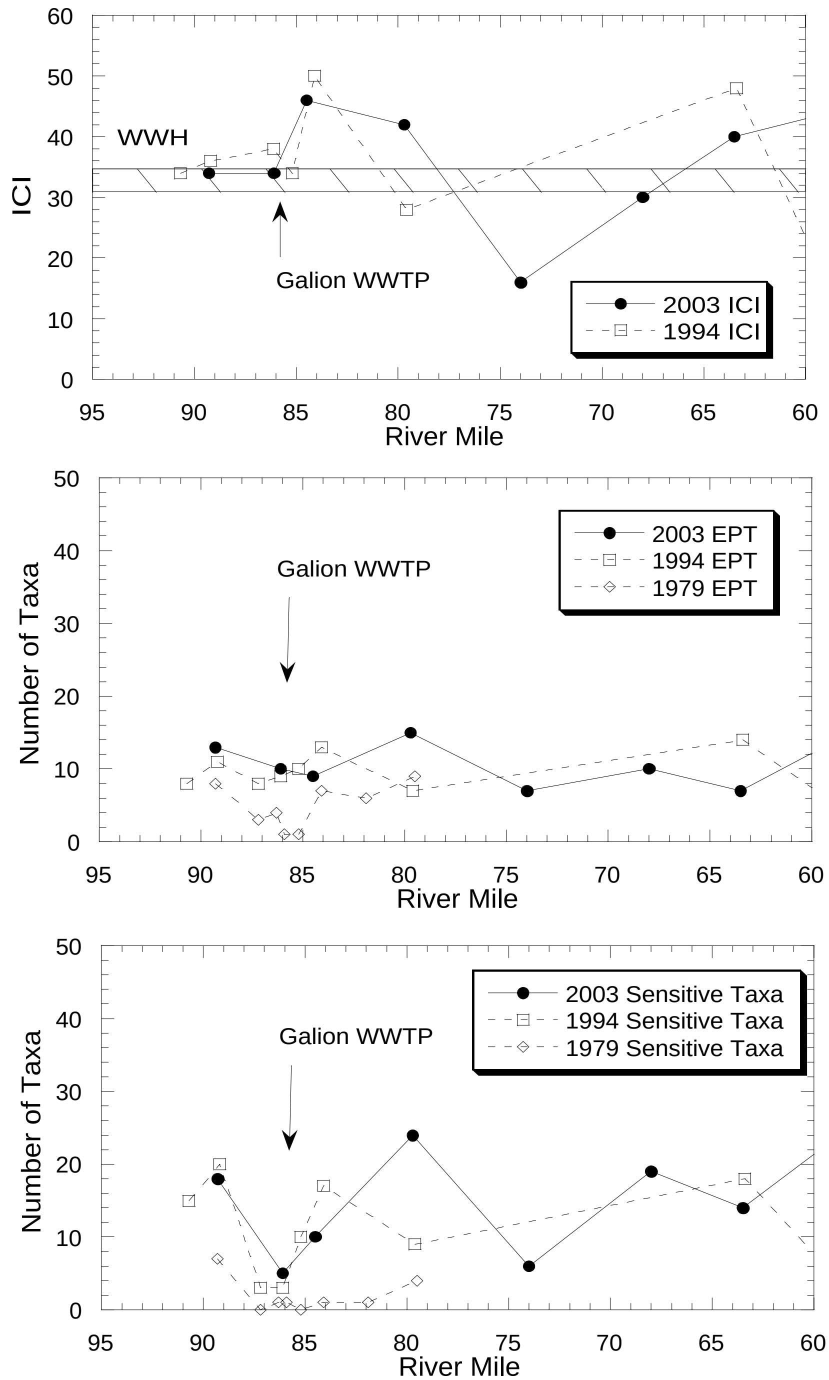


Figure 6. Longitudinal trend of the Invertebrate Community Index (ICI), total EPT, and total pollution sensitive taxa in the upper Olentangy River, 1979-2003.

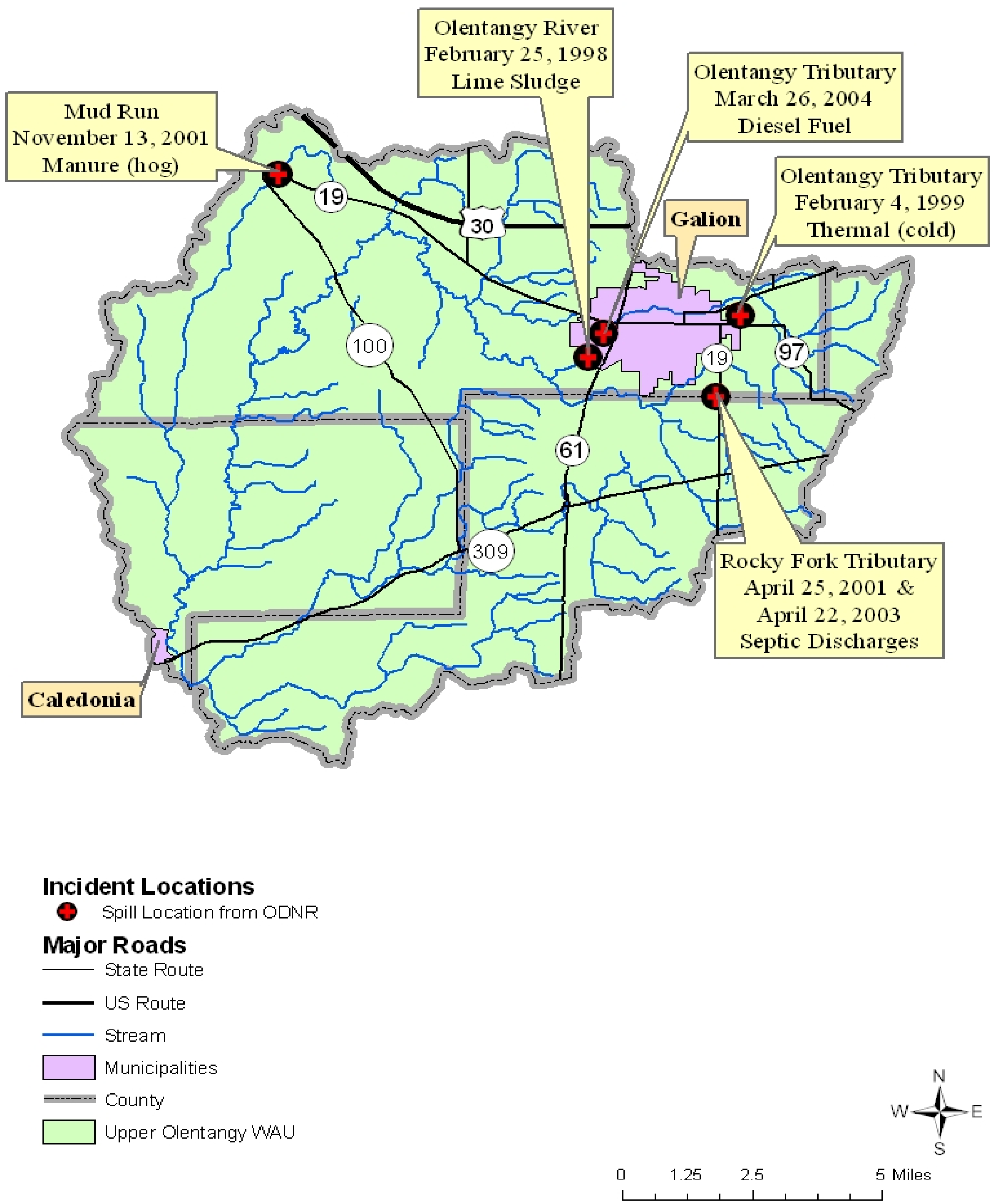


Figure 7. Spills and related fish kills reported to Ohio Department of Natural Resources (ODNR) from 1994-2004 for the UOWAU.

Chemical Water Quality

U.S. EPA has mandated that states adopt nutrient criteria as nutrients are consistently identified as a cause of impairment. The Ohio EPA has elected to develop a set of tiered criteria specific to aquatic life use designation and stream size rather than adopt federally promulgated values based on a reference site approach. While the agency hopes to have formal rules adopted by 2008, interim target values based on the association between biological index scores and use attainment status are considered reliable guidelines (Ohio EPA, 1999). Size categories were divided by drainage area (mi^2) and waters are defined as headwater (area ≤20), wadeable (20>area≤200), small river (200>area≤1000), or large river (area >1000).

The relationship between phosphorus and biological index scores has been found to be statistically significant (Ohio EPA, 1999). Targets for WWH that correspond to the size classes above are 0.08, 0.10, 0.17, and 0.30 mg/l, respectively. Targets for MWH that correspond to the size classes above are 0.34, 0.28, 0.25, and 0.32 mg/l, respectively. The relationship between nitrate-nitrite and biological index scores is not as strong. Biological degradation was not observed until median nitrate-nitrite values exceeded 3-4 mg/l, but target values were set much lower since mitigating factors such as good quality habitat may have masked the effects. Targets for WWH that correspond to the size classes above are 1.0, 1.0, 1.5, and 2.0 mg/l, respectively. Targets for MWH that correspond to the size classes above are 1.0, 1.6, 2.2, and 2.4 mg/l, respectively.

Several sites had strontium concentrations detected above tier II aquatic life guidelines established for the Ohio River basin (OAC 3745-1-34). These values are not adopted as criteria because little information is available about the toxicity of strontium. Nearly all of the elevated levels were measured in channelized streams like Mud Run, Zimmerman Ditch, and Shumaker Ditch where soil erosion and field tile drainage are common. A total of 24 of 128 values (19%) exceeded the outside mixing zone average.

Olentangy River

The upper segment of the Olentangy River begins at Crawford Morrow Line Road (RM 93.0) and ends below the confluence of Flat Run (RM 59.28) and drains about 134 mi^2. It is designated as WWH and PCR based on the results of a previous field assessment. Eight sites were sampled to evaluate biological, chemical, and bacterial conditions.

Most land in the watershed is used for crop and livestock production except for a few residential areas and scattered woodlots. The City of Galion is in the upper end of the segment and has a population of about 12,000. The Galion WWTP discharges to the Olentangy River at RM 85.96. The Village of Caledonia is in the lower portion of the segment and has a population of about 528. The Caledonia WWTP discharges to the Olentangy River at RM 59.70.

Water contaminated with feces can potentially contain many different types of disease causing bacteria and viruses. People can be exposed to these pathogens while wading, swimming, skiing, canoeing, and fishing. Reactions can range from an isolated illness such as skin rash, sore throat, or ear infection to a more serious epidemic. Bacteria that are a concern include *Escherichia*, which causes diarrhea and urinary tract infections, *Salmonella*, which causes typhoid fever and gastroenteritis (food poisoning), and *Shigella*, which causes severe gastroenteritis or bacterial dysentery. Viruses that are a concern include hepatitis A and encephalitis. Disease causing microorganisms such as *Cryptosporidium* and *Giardia* are also a concern.

Recreation use impairment was documented for the entire segment. Counts for both bacterial parameters violated their respective geometric mean and maximum values at all eight sites (Table 6). Fecal coliform results are summarized for the July 7-August 4 use evaluation period (Figure 8) and for the June 2-August 27 field season (Figure 9). Counts peaked in two distinct areas, upstream from the Galion WWTP (RM 86.00) and at Shearer Road (RM 79.66). The geometric means computed over the field season are slightly less, but the pattern from site to site is the same. Counts were considerably higher after rain events, suggesting a nonpoint source influence.

The main sources of recreational impairment are package WWTPs, home sewage treatment systems, separate sanitary sewer overflows, and livestock. In the area above Galion the main concern is several package WWTPs near the State Route 61 and State Route 309 intersection. An inspection was done at these facilities on December 8, 2004. The businesses at Moe's Mini Mart and Tebo's Restaurant were found to be closed and the plants did not appear to be operating. Neither of these facilities was regulated by an NPDES permit, but if they reopen an application will be required. The plant at Swiss Village which serves a mobile home park and hotel was inoperable and out of service. This facility has a history of non-compliance, poor operation and permit violations. In addition to these package plants, the Village of Blooming Grove at the Olentangy River headwaters is a possible source from failed home sewage treatment systems.

Within the Galion service area, the functional ability of the sewage collection system is a problem due to its age, even though sewers are 100% separate. The collection system is near capacity and easily becomes overloaded from excessive infiltration and inflow. Infiltration into the system comes from groundwater seeping through joints either by rainfall percolating through the soil or because the lines are buried below the water table. Inflow comes from storm sewer cross connections, residential sump pumps, and gutter down spouts. When the volume of water in the system exceeds capacity it can cause manholes to overflow. Some of these discharge directly into the Olentangy River. This problem was noted during a previous study done in 1994 when evidence of overflows was documented at manholes in the Fairview Avenue (RM 88.20) area (Ohio EPA, 1996). This situation is also monitored by the city and overflows from several manholes were reported on March 14, 2003. Another overflow was reported on August 13, 2003 when a tree limb fell and broke a sewer line. Other potential sources of bacteria are home sewage treatment systems on Brookview Road, which is located next to the Galion WWTP.

In the area downstream from Galion, failed home sewage systems were a problem in several areas, including at the State Route 19 and Crawford Morrow Line Road intersection and at the Westmoor Subdivision. The package WWTP at Spring Valley mobile home park is outdated and does not have disinfection facilities. These sources are discussed in more detail in the tributary stream text below. Livestock manure also contributes to the bacteria load in this reach, especially in areas adjacent to pastures. Several of these farms do not restrict livestock from either crossing the river or using it for watering. This was noted in the Olentangy River at Taylor Road (RM 84.10), Iberia Road (RM 82.90), and Galion New Winchester Road (RM 81.70).

Further downstream the Crawford County Health Department considers Sugar Grove Lake a public health nuisance because of poor sanitation. On September 12, 2003 the Ohio EPA issued a Permit to Install (PTI) for a 10,000 gpd package plant here, but the plant never went on-line because of a problem with the grant intended to fund the project. Other areas served by home sewage systems that might be a problem include the villages of New Winchester, Martel, and Iberia. Sources from livestock are a concern in this reach too. Albright Farms is a CAFO located on Goldsmith Road near Crawford Marion Line Road. It is approved to produce up to 4,200 hogs under permit # 08-015 NW. Most of the manure produced here is land applied on adjacent fields. The Circle-E-Ranch is also in this area and raises a variety of livestock, including longhorn cattle and horses.

The main causes of impairment are nutrients, siltation, and habitat and flow alteration. Biological impairment was documented below the Galion WWTP based on criteria codified in OAC 3745-1-07. Low dissolved oxygen is not an impairment, but this parameter is still a concern because of diurnal fluctuations and supersaturated conditions below the Galion WWTP. An example of this was recorded by a continuous monitor deployed at Hosford Road (RM 85.94) from September 16-18, 2003 (Figure 10). The saturation values during this sequence ranged from 74.4-125.5%. Supersaturation can cause gas bubbles to form on the external surfaces of aquatic organisms and block the flow of water across the gills. As the disease progresses, it causes bubbles to form behind the eyes (pop-eyed) and in blood. This can restrict or stop blood flow, damage tissues, and eventually cause mortality. No dissolved oxygen violations were documented in any measurements taken from either grab samples or continuous monitors. This was probably because mitigating factors like good habitat, flow, and an intact tree canopy mask the enrichment by improving the assimilation of nutrients. The threat of low dissolved oxygen impairment exists if one of these factors is lost. A summary of data collected from continuous monitors deployed in the UOWAU is presented in Table 9.

The sources of biological impairment include the Galion WWTP, urban stormwater, home sewage systems, crop and livestock production, and hydromodification (channelization and removal of riparian vegetation). Stream litter in the Galion area might be another source of impairment, especially at Edwards Street (RM 89.25). Leaking fluids from junk automobile parts and home appliances dumped here might be toxic to aquatic life. Several times during the summer, the carcasses of filleted fish were noted here, too. While this is probably no more than a nuisance, it might cause oxygen demand problems under certain circumstances. A small fish kill was documented here by Ohio EPA staff during the summer of 2003, but there was nothing obvious in the water chemistry to indicate a cause. Litter was also a problem here when this area was last studied in 1994, so it might be necessary to step up enforcement or install a fence and warning signs as a deterrent.

To control phosphorus loadings in the Lake Erie watershed, limits were imposed on major dischargers in conjunction with a phosphate detergent ban enacted in 1990 (House Bill 491). Since the Olentangy River is located in the Ohio River watershed, Galion does not have permit limits for phosphorus and is only required to monitor levels once per month. The Ohio EPA is seriously considering statewide phosphorus limits because of a federal mandate to meet nutrient criteria and a strong correlation with biological attainment. Regulated facilities normally have a concentration limit of 1.0 mg/l. All six Galion effluent samples collected by the Ohio EPA during the 2003 survey exceeded 1.0 mg/l, with a median value of 2.36 mg/l and maximum of 3.45 mg/l. These results are comparable to those obtained in 1994, with a median value of 2.66 mg/l and maximum of 2.91 mg/l. Self monitoring data can be statistically summarized using the Liquid Effluents Analysis Processing System (LEAPS). The median load rate (50^{th} percentile) during the 1984-2003 time period ranged anywhere from 14-28 kg/day (Figure 11). A slight increase in loadings has occurred in recent years, likely due to an increase in flows. Treatment to remove phosphorus is normally accomplished by adding lime or alum to bind with the phosphate and form a precipitate. This ultimately increases the volume of sludge produced. If this type of treatment was implemented at the Galion WWTP, it would be necessary to first upgrade sludge handling facilities because the current system is already undersized.

Data indicate that the Galion WWTP is the major source of nutrient enrichment in the Olentangy River. Phosphorus levels measured upstream from the WWTP either met or were below target values, but those downstream surpassed target for the next 23 miles (Figure 12). All of the samples tested in the Olentangy River below the Galion WWTP had phosphorus levels that surpassed their respective target values. A total of 40 separate samples were collected in this reach and the concentrations ranged from 0.13-2.01 mg/l with a median value of 0.26 mg/l. Similar conditions were exhibited in the Olentangy River between the 1994 and 2003 study periods (Figure 13). The ratio of dissolved, or soluble reactive phosphorus (SRP), to total phosphorus measured in the river also points to the Galion WWTP as the source. High SRP values in the 95% range are associated with point sources, while values in the 10-20% range are associated with nonpoint sources (Baker, 1996). This relationship exists because most of the total phosphorus in wastewater effluent is soluble and most from nonpoint runoff is attached to soil particles and in particulate form. Survey sites that had both parameters measured are presented in Table 10, along with the calculated % SRP. The Galion WWTP had a median % SRP value = 95.

Nitrate in surface water is a human health issue as well as an aquatic life concern. High levels of nitrate can be harmful to babies and the developing fetus because it reduces the oxygen carrying capacity of blood. It is for this reason that drinking water consumption advisories are issued when nitrate levels in raw water supplies exceed 10.0 mg/l. Sewage treatment plants are designed to convert organic nitrogen and ammonia into nitrate. This is considered favorable for a couple of reasons. Organic enrichment in a stream can cause a dissolved oxygen sag because the bacteria that perform the decomposition process consume oxygen from the water column. Under certain environmental conditions, ammonia is directly toxic to aquatic life because it builds up in gill tissue and blood. Treatment to convert these forms of nitrogen requires a long detention time and aerobic conditions (aeration tanks) so that bacteria can complete the nitrification process. Most treatment plants do not have the advanced tertiary treatment required to convert nitrate into nitrogen gas, carbon dioxide, and water. This requires a carbon source and anaerobic conditions so that bacteria can complete the de-nitrification process. As a result, wastewater effluents often have high nitrate levels.

Nitrate-nitrite levels in rural areas were more frequently above target than those for phosphorus. This is because nitrate passes easily through soil and can enter a stream through field drainage tiles, while phosphorus binds tightly to soil particles. Concentrations in agricultural areas are usually highest in the spring after fertilizer applications are completed, especially following storm events. Levels usually taper off during the summer as loadings decrease and the nutrient is assimilated. Below a large volume point source discharge there is not as much seasonal variation. The highest nitrate-nitrite levels documented in the UOWAU were in the Olentangy River downstream from the Galion WWTP (Figure 14). A similar pattern is seen when comparing results from the 1994 and 2003 study periods, with a spike in concentration below the Galion WWTP and gradual leveling off (Figure 15). About 6 miles below the discharge at Shearer Road (RM 79.66), the median concentration was 3.86 mg/l in 2003 and 4.21 mg/l in 1994. However, there was a significant decrease directly below the discharge at Hosford Road (85.94), with a median concentration of 6.0 mg/l in 2003 and 10.8 mg/l in 1994.

Sewage collection and treatment has been provided in Galion since 1911. The activated sludge system currently in operation was placed into service in 1984 after a major upgrade was completed. As raw sewage enters the plant, it is cleaned of large debris by mechanical bar screens and then lifted by screw pumps so it can flow by gravity into grit tanks. This is followed by a sequence of pre-aeration, primary settling, activated sludge aeration, and secondary settling. After final settling the wastewater enters a 2.8 MG polishing lagoon followed by a 6.2 MG bypass lagoon where it is disinfected with chlorine and finally de-chlorinated before being discharged to the Olentangy River at RM 85.96. Sludge is treated by a gravity thickener, anaerobic digesters, de-watered with a belt filter press, mixed with fly ash and cement kiln dust in an alkaline mixer, and marketed as N-Viro product. The city has a pre-treatment program which was approved by the Ohio EPA in 1985. There are about 38 industrial users of which 4 are considered categorical (metal finishers). The plant can complete tertiary treatment up to 2.7 MGD, secondary treatment up to 6.8 MGD, and primary treatment up to 8.5 MGD. Anything above the hydraulic capacity is bypassed to the disinfection lagoon and blends with treated waste. This diminishes effluent quality because the bypass contains organic matter that consumes oxygen and releases ammonia when digested. The subsequent release of nutrients stimulates algae blooms in the summer and increases suspended solids.

The Galion collection system is a problem because of the age of the infrastructure, even though sewers are 100% separate. While most of the system was constructed from 1930-1960, some portions were built as long ago as 1908 (Olentangy interceptor). The plant consistently operates above its design capacity because of excessive infiltration and inflow. Flow exceeded the design rate on 344 days in 2003 (Rick Kent, Superintendent, Galion Dept. of Public Works, personal communication). The hydraulic capacity was exceeded on 10 days, mostly during the summer months. This corresponds with the time period that the biological and water quality study was conducted (June 1-Sept. 30). The median flow rate during this time was 3.8 MGD and the maximum rate measured was 11.8 MGD on September 27. The impact from infiltration and inflow was exacerbated by above average rainfall amounts experienced the last few years. While the average precipitation is about 38 inches per year, rainfall has measured 50, 55, and 51 inches from 2000-2003 (Rick Kent, personal communication).

Galion is making an effort to improve operation of the plant and rehabilitate the collection system. Many storm sewer cross connections and down spout drains have been eliminated over the years and some grout repairs have been made. A septic discharge to the Olentangy River above Columbus Street (RM 87.99) documented in 1994 was eliminated with the installation of a lift station in 2000. An engineering firm has recently been contracted to perform a stress test and hydraulic analysis at the plant. Several storm water projects are being implemented to install tiles large enough to eliminate sump pumps from the sanitary system. The first of these eliminated about 60 homes with storm water connections. Other possible alternatives to consider include a storm flow equalization basin, blending storm flows within the plant, or a plant expansion.

Effluent samples collected by Ohio EPA and self monitoring data submitted by Galion during the study period were evaluated for permit compliance. Suspended solids was the only pollutant of concern that indicated problems. This is likely because of algae blooms in the disinfection lagoon. This parameter is collected as a 24 hour composite and run 3 times per month. The concentration and load is limited by daily maximum (18 mg/l, 184 kg/day) and monthly average (12 mg/l, 123 kg/day). Permit violations documented during the June-September study period include the monthly load 4 times, the monthly concentration 3 times, and the daily load in 8 of 12 samples. None of the

Ohio EPA samples exceeded the 18 mg/l daily limit, but several samples (4 of 6) were above the 12 mg/l monthly limit. Bioassay testing done over the years has demonstrated that the Galion WWTP effluent is not toxic. No acute toxicity was observed in any of the screening bioassays done in conjunction with permit renewal cycles in 1990, 1994, 1998, and 2004 (two tests each year).

Urban stormwater mobilizes a variety of pollutants, including sediment, nutrients, metals, and organic matter. A good example of this was documented in the Olentangy River at Galion on July 21, 2003. A major downpour started at 0930 hrs. and lasted for 15-20 minutes. The storm was intense enough to cause some street flooding. The river was still flowing clear and normal after the rain subsided and a sample was collected at 0955 hrs. above the Galion WWTP (RM 86.00). Test results included a BOD of 3.1 mg/l, suspended solids of 8 mg/l, copper of <10 µg/l, cadmium of 0.4 µg/l, and lead of <2 µg/l. By the time a sample was collected at 1015 hrs. from Hosford Road (RM 85.94) the river had become a muddy torrent. Test results included a BOD of 18 mg/l, suspended solids of 328 mg/l, copper of 47 µg/l, cadmium of 24.2 µg/l, and lead of 19.1 µg/l. These were the highest levels measured for these pollutants during the entire study period.

Metals in the Olentangy River below Galion, especially cadmium, were considered a major problem in 1994 (Ohio EPA, 1996). Conditions have improved enough since then that cadmium and other metals were not identified as a cause of impairment in 2003 (Figure 16). Results indicate that metals are still a threat, so future monitoring should be done to ensure that the decreasing trend continues. The cadmium and copper values associated with the July 21 storm mentioned above are considered violations of the OMZM criteria. Low level cadmium in the 0.2-1.0 µg/l range was still detected in the Olentangy River as far downstream as Lyons Road (RM 63.36) and concentrations in sediment were above the ecoregional reference value (0.90 mg/kg) at Monnett New Winchester Road (RM 84.48) and Shearer Road (RM 79.66), with values of 4.63 mg/kg and 0.954 mg/kg, respectively. Concentrations of cadmium, lead, and zinc in sediment at Monnett New Winchester Road were also above the threshold effect guidelines for toxicity (MacDonald, 2000). So little sediment is present here that it probably has very little ecological impact (Table 12).

Survey data indicates that the cadmium concentration in effluent from the Galion WWTP has decreased. Samples tested in 2003 had a median concentration of 5.9 µg/l and a maximum of 8.2 µg/l. In comparison, samples tested in 1994 had a median concentration of 10.6 µg/l and a maximum of 15.1 µg/l. The highest levels measured in the river in 2003 were below the Galion urban area and associated with stormwater. Potential sources of metals in urban runoff include soil from two closed metal plating facilities. These were the Galion Plating Corp. located at 343 South East Street and the Southside Plating Corp. located at 963 Edwards Street. Testing has documented contaminated soils at these sites, but no clean up has been done at either facility. There are several active industrial facilities in Galion with general stormwater permits that could contribute as well (Table 8).

Suspended solids concentrations start to deviate from background levels below Galion and continue to increase through rural areas (Figure 17). The background level was established using the median value determined from samples collected at reference sites in the ECBP ecoregion. This value was 7 mg/l for headwater streams and 14 mg/l for wadeable streams (Ohio EPA, 1999). An impact from siltation would be expected under the present conditions. The settling of suspended particles fills the interstitial spaces between larger rocks and thereby reduces the diversity of available habitat. Very high concentrations were documented in samples collected after storm events in July, with a maximum of 328 mg/l. This suggests that the majority of suspended matter enters the river during these high flow events.

Severe erosion problems were noticed in a few cases. One was below Taylor Road (RM 84.10) and another was below Galion New Winchester Road (RM 81.70). These locations are not far downstream from the Galion municipal area. Urban areas cause a change in natural hydrology patterns since impervious surfaces do not allow water to slowly percolate through the soil. This coupled with down spouts and sump pumps draining into the storm sewer system result in flash flows during storm events. Increased volume flows generally leads to increased erosion as the stream attempts to adapt its channel to accommodate the changes in volume and speed of runoff.

Row crop and livestock production are common land uses in the rural areas below Galion. The cultivation of land makes it more susceptible to erosion and therefore increased siltation, while the application of fertilizers and manure can lead to nutrient enrichment. Base trampling from livestock destabilizes stream banks and makes them highly susceptible to erosion. This activity was noted in the Olentangy River at Taylor Road (RM 84.10), Iberia Road (RM 82.90), Galion New Winchester Road (RM 81.70), and Crawford Marion Line Road (RM 68.11). A peak in suspended solids coincides with the location of farms that employ this practice. Livestock also deposit feces into the stream that causes organic enrichment and increased bacterial contamination. This problem can be effectively managed by excluding livestock from streams with a system of fences, man made crossings, and upland watering troughs. These types of "best management practices" are eligible for Section 319 grant funds.

Channelization and removal of riparian vegetation along the river has a definite negative impact in certain areas. The river was straightened many years ago through Galion to facilitate installation of sewers and to control flood water (i.e., speed its movement downstream). Other segments further downstream have had alterations to remove bends and speed the movement of water. This is evident in the low QHEI scores at Monnett-Chapel Road (RM 74.00), Crawford Marion Line Road (RM 68.11), and Lyons Road (RM 63.36).

Galion Airport Tributary

This unnamed stream drains an area of about 2 mi^2 and is confluent with the Olentangy River at RM 90.04. It does not have use designations assigned because it is not named on any topographic maps and consequently was never listed in the Ohio WQS. Most land in the watershed is used for residential and commercial purposes. No biological sampling was completed, but chemical water quality was tested at Nazor Road (RM 0.08) to evaluate package plants serving Tebo's Restaurant, Moe's Mini Mart, and the Swiss Village MHP. During an inspection done on December 8, 2004 the restaurant and mini mart were both found to be closed. Of the three package plants, the Swiss Village system is the only one with an NPDES permit. Since it is a small plant (<10,000 gpd) they are only required to conduct effluent monitoring once per quarter during the months of March, June, August, and December. Records for 2003 indicate that permit violations for ammonia and $cBOD_5$ were documented at the facility during all months except June.

A negative impact from the package WWTPs is evident in the chemical water quality as well as by the presence of nuisance algae. Although no violations were documented for ammonia, it was detected in all of the samples collected. Organic and nutrient enrichment are a concern too, especially phosphorus. Most of the concentrations exceeded the WWH target for headwater streams and one exceeded the MWH target. This stream had the second highest median phosphorus value (0.15 mg/l) among all tributary streams monitored in the UOWAU (Figure 18). Concentrations of bacteria were elevated and violated SCR criteria on several occasions, indicating that disinfection of effluent at the package WWTPs might be deficient (Table 6).

Rocky Fork

Rocky Fork drains an area of about 11 mi^2 and is confluent with the Olentangy River at RM 84.84. At this time, it is only designated as a PWS, but WWH and PCR uses will be recommended based on results of the 2003 survey. Most land in the watershed is used for crop production except for a few residential areas. A dam near the mouth forms Ammans Reservoir and this lake is used to supply drinking water for Galion. Water from the lake is pumped into Powers and Amicks above ground reservoirs for storage before entering the water treatment plant.

Septic conditions were documented in a branch of the Rocky Fork at Crawford Morrow Line Road and State Route 19. The source is failed home sewage systems from several houses along the highway. A complaint from a downstream land owner was investigated by Crawford County Wildlife Officer Mr. Ron Ollis and a pollution report was filed on April 22, 2003. Officer Ollis contacted Ms. Jacqueline Ward, Director of Environmental Health for the Crawford County Health Dept. regarding the complaint. The Morrow County Health Dept. was subsequently informed of the situation because the homes are actually located in that county. Immediate action is needed as Rocky Fork drains into Ammans Reservoir, which is the source of drinking water for Galion.

During the 2003 survey two sites were sampled to evaluate chemical and biological conditions. The site at Atkinson Road (RM 2.85) was considered in full attainment of the recommended biological criteria and the site at Crawford Morrow Line Road (RM 0.41) was considered in nonattainment. Water quality was generally good at both sites and the biological impairment documented was mainly due to the habitat and flow alterations caused by the dam. Additional testing was done to assess levels of pesticides at the Ammans Reservoir spillway since this is a public drinking water supply. Two sets of samples were collected during each of the months of June, July, and August. The compounds tested are primarily used as herbicides in crop production areas and the results are presented in Table 11. The most commonly detected compounds were atrazine (4 of 6), metolachlor (5 of 6), and simazine (2 of 6), especially during June and July. Concentrations ranged anywhere from below the quantitation limit (non detect) to a maximum of 3.34 µg/l for atrazine, 1.66 µg/l for metolachlor, and 0.63 µg/l for simazine.

Zimmerman Ditch

Zimmerman Ditch drains an area of about 2 mi^2 and is confluent with Hooker Dapper Ditch at RM 0.30 and subsequently the Olentangy River at RM 81.18. It is designated as MWH and SCR based on a previous field assessment. Although it is not maintained, it is not likely to recover from prior channelization. Land in the watershed is a mix of residential and agricultural, including crop production and some pasture. The Spring Valley MHP is the only point source in the watershed and discharges at RM 1.30. This package WWTP is outdated, does not disinfect its effluent, and frequently violates NPDES permit limits. Spring Valley entered into a Consent Order (Case # 01-CV-0436) with the Ohio Attorney General on May 22, 2003 to comply with water pollution control laws.

Westmoor Subdivision is located on the west side of Galion in Polk Township and contains about 140 homes. The Crawford County Health Dept. along with local residents have complained for many years about pollution problems caused by failed home sewage treatment systems. The Ohio EPA issued Directors Final Findings and Orders (DFFOs) to the Crawford County Commissioners as long ago as July 16, 1980 to improve sanitation. The problem was not resolved because negotiations between the county and Galion to extend sanitary sewers fell through. Sampling was done by the Ohio EPA in 1994 and again in 2003 to document that a public health nuisance still exists. This information was used to support new draft DFFOs issued on October 26, 2004.

Though no biological sampling was done on Zimmerman Ditch, chemical water quality was tested at Iberia Road (RM 0.29) to evaluate the sources of raw and poorly treated sewage. Chemical results indicate significant nutrient enrichment exists, especially phosphorus. Concentrations ranged from 0.16-0.32 mg/l and the median value of 0.22 mg/l was the highest among all tributary streams monitored in the UOWAU (Figure 18). None of the values surpassed the target of 0.34 mg/l established for MWH headwater streams. Bacteria counts violated SCR criteria on several occasions. Results for fecal coliform bacteria ranged from 1100->10000 cfu/100 ml and were above the SCR criterion (5000 cfu/100 ml) in 3 of 6 samples. Results for *E. coli* ranged from 460->10000 cfu/100 ml and were above the SCR criterion (576 cfu/100 ml) in 5 of 6 samples.

Shumaker Ditch

Shumaker Ditch drains an area of about 2 mi^2 and is confluent with the Olentangy River at RM 63.89. It does not have use designations assigned because it is not named on any topographic maps and consequently was never listed in the Ohio WQS. It is channelized and maintained for drainage by the Marion County Engineers office. Most land in the watershed is used for crop production, but residential and industrial uses are present in the Village of Martel. General Mills discharges sanitary and process water at RM 1.92 from its bulk bakery and flour mix plant. Martel does not have central sewage collection and treatment facilities.

No biological sampling was performed, but chemical water quality was tested at Timpson Road (RM 0.37) to evaluate pollution from home sewage treatment systems. While nutrient enrichment was evident, bacteria counts only violated SCR criteria on a few occasions. Results for fecal coliform ranged from 280-5800 cfu/100 ml and were above the SCR criterion (5000 cfu/100 ml) in 1 of 6 samples. Results for *E. coli* ranged from 80-3700 cfu/100 ml and were above the SCR criterion (576 cfu/100 ml) in 2 of 6 samples.

Mud Run

Mud Run drains an area of about 18 mi^2 and is confluent with the Olentangy River at RM 62.44. It is designated as MWH and SCR based on a previous field assessment. It was channelized in 1975 and is maintained by the Crawford County Engineers. Spot excavations were noted in the stream channel during 2003 and mowing and spraying are performed on a regular basis. Most land in the watershed is used for crop production.

Two sites were sampled to evaluate chemical and biological conditions. The sites at Monnett-Chapel Road (RM 6.56) and Morral-Kirkpatrick Road (RM 2.65) were both considered in full attainment of the MWH use designation. However, the widespread use of agricultural fertilizers and the impact from drainage practices were reflected in the chemical water quality. When compared to other tributaries in the UOWAU, Mud Run had the highest median and maximum nitrate values (Figure 19). Concentrations at RM 6.56 ranged from 0.16-8.80 mg/l, with a median value of 5.02 mg/l; and concentrations at RM 2.65 ranged from 0.15-8.80 mg/l, with a median value of 5.06 mg/l. This is because field tiles are common in the watershed and nitrate passes easily through soil. Phosphorus levels were generally elevated only after storm events when suspended solids were the highest because phosphorus binds tightly to soil particles. No buffer zone is present to trap soil that erodes off cultivated fields and thereby reduce the amount of phosphorus entering the stream. Iron concentrations were also elevated during storm events and surpassed the agricultural water supply (AWS) criterion of 5000 mg/l in 2 of 6 samples at both sites. This becomes a concern if the stream is used for watering livestock or irrigation.

Flat Run

Flat Run drains an area of about 40 mi^2 and is confluent with the Olentangy River at RM 59.28. It is designated as WWH and PCR based on a previous field assessment. Most land in the watershed is used for crop and livestock production. Cattle were observed in the stream near State Route 309 in Iberia (RM 11.3). The Village of Iberia is the only residential area and is served by home sewage systems. Point sources in the watershed include a package plant at the Iberia Elementary School and process and sanitary wastewater from the Glen Gery Corp. Iberia brick plant.

Three sites were sampled to evaluate chemical and biological conditions. The sites at State Route 288 (RM 12.62), State Route 309 (RM 7.26), and West Canaan Road (RM 0.55) were all considered in full attainment of the biological criteria. However, nutrient enrichment is a concern in this stream. Of the 18 samples collected at the three sites, a total of 9 had phosphorus values that surpassed the background target. Concentrations at RM 12.62 ranged from 0.03-0.15 mg/l, with a median value of 0.08 mg/l; concentrations at RM 7.26 ranged from 0.03-0.16 mg/l, with a median value of 0.10 mg/l; and concentrations at RM 0.55 ranged from 0.04-0.20 mg/l, with a median value of 0.08 mg/l. The confluence of Thorn Run seems to have a negative influence on water quality at West Canaan Road (RM 0.55). For example, nitrate concentrations increased from a median of 2.08 mg/l to 2.92 mg/l. The deleterious effects on water quality arising from livestock operations and home sewage treatment systems in Iberia are evident in the bacteria results at State Route 306 (RM 7.26). Results for fecal coliform bacteria ranged from 410-25000 cfu/100 ml and were above the PCR criterion (2000 cfu/100 ml) in 3 of 6 samples. Results for *E. coli* bacteria ranged from 160-5500 cfu/100 ml and were above the PCR (298 cfu/100 ml) in 6 of 6 samples.

Thorn Run

Thorn Run drains an area of about 10 mi^2 and is confluent with Flat Run at RM 0.56. It was assigned WWH and PCR uses in 1978 that were not based on the results of a field assessment. Most land in the watershed is used for crop and livestock production. Specialty Fertilizer Products is located in the headwaters and operates a package plant to treat sanitary waste and has four stormwater tiles. This facility manufactures a variety of nitrogen, phosphorus, and potassium fertilizers. It is open year round, but peak operation runs from January-May. All tiles discharge to an unnamed tributary confluent with Thorn Run at RM 8.85. The Village of Climax is the only residential area and is served by home sewage systems.

A site at Marion-Williamsport Road (RM 1.11) was sampled to evaluate chemical and biological conditions and was considered in full attainment of the biological criteria based on the field verified WWH aquatic life use. However, livestock observed in the stream here pose a threat to its future status. This site had the second highest nitrate levels of tributaries in the UOWAU (Figure 19). Concentrations ranged from 0.31-7.40 mg/l, with a median value of 4.47 mg/l. Chemical sampling was also conducted at West Point Bellville Road (RM 8.75) to evaluate chemical conditions and impacts from Specialty Fertilizer Products. Based on the data, this facility is not having a significant impact on water quality.

Table 9. Summary of hourly dissolved oxygen measurements (mg/l) recorded by continuous monitors deployed in the UOWAU.

Stream	River Mile	Hours	Mean	Median	Minimum	Maximum
July 8-10, 2003						
Olentangy River	85.94	41	7.53	7.80	6.14	8.28
Olentangy River- A	84.48	47	7.71	7.72	7.06	8.56
Olentangy River- B	84.48	48	8.06	8.06	7.35	9.02
Olentangy River	74.00	48	6.33	6.13	5.90	7.48
Olentangy River	68.11	47	5.76	5.65	5.32	6.52
July 29-31, 2003						
Olentangy River	68.11	48	6.80	6.76	6.59	7.14
Rocky Fork	5.9	49	6.05	5.95	5.29	7.78
Rocky Fork	3.1	30	9.47	9.18	7.28	12.46
September 16-18, 2003						
Olentangy River	87.00	52	7.05	6.85	5.47	9.20
Olentangy River	85.94	49	8.42	7.72	6.87	10.94
Olentangy River	84.48	49	8.03	7.60	7.06	9.84
Olentangy River	79.66	49	7.29	7.33	6.36	8.09
Olentangy River	74.00	49	6.74	6.72	6.00	7.44
Olentangy River	68.11	49	7.22	6.91	6.60	8.38
Flat Run	0.55	48	7.42	7.04	6.33	9.23

Table 10. Total phosphorus, dissolved phosphorus, and % SRP values calculated for the UOWAU in 2003.

Date (mm/dd)	06/02	06/16	07/07	07/21	08/04	08/18
Olentangy River upstream Galion WWTP (RM 86.00)						
total phosphorus (mg/l)	0.02	0.07	0.06	0.17	0.11	0.08
dissolved phosphorus (mg/l)	0.01	0.05	-	0.04	0.07	0.03
SRP ratio (%)	50	71	-	24	64	38
Galion WWTP Effluent (RM 85.96)						
total phosphorus (mg/l)	1.90	1.12	3.27	2.83	1.11	3.45
dissolved phosphorus (mg/l)	1.80	0.91	-	3.87	0.97	3.47
SRP ratio (%)	95	81	-	137	87	101
Olentangy River at Crawford Marion Line Road (RM 68.11)						
total phosphorus (mg/l)	0.10	0.13	0.23	0.26	0.19	0.20
dissolved phosphorus (mg/l)	0.10	0.10	-	0.23	0.15	0.18
SRP ratio (%)	100	77	-	88	79	90
Flat Run at West Canaan Road (RM 0.55)						
total phosphorus (mg/l)	0.05	0.04	0.10	0.20	0.12	0.06
dissolved phosphorus (mg/l)	0.03	0.02	0.09	0.13	0.09	0.05
SRP ratio (%)	60	50	90	65	75	83
Thorn Run at West Point Bellville Road (RM 8.75)						
total phosphorus (mg/l)	0.06	0.03	0.17	0.10	0.10	0.07
dissolved phosphorus (mg/l)	0.04	0.02	0.15	0.10	0.07	0.05
SRP ratio (%)	67	67	88	100	70	71

Table 11. Levels of herbicides (µg/l) at the Ammans Reservoir spillway (trade name in parenthesis) in 2003. Values preceded by a < were below the quantitation limit.

Rocky Fork at Crawford Morrow Line Road- RM 0.41						
date (mm/dd)	06/03	06/17	07/08	07/22	08/05	08/19
Acetochlor (Harness)	<0.21	0.65	<0.21	<0.21	<0.21	<0.21
Alachlor (Lasso)[1]	<0.21	<0.22	<0.21	<0.21	<0.21	<0.21
Atrazine (AAtrex)[2]	1.86[J]	3.34[J]	1.82[J]	0.44[J]	<0.21	<0.21
Butachlor (Lambast)	<0.21	<0.22	<0.21	<0.21	<0.21	<0.21
Cyanazine (Bladex)	<0.21	<0.24	<0.21[UJ]	<0.21	<0.21	<0.20
Metolachlor (Dual)	1.66	1.60	0.91	0.62	0.38	<0.21
Metribuzin (Sencor)	<0.21	<0.22	<0.21	<0.21	<0.21	<0.21
Pentachlorophenol (Pentacon)[3]	<5.1	<5.6	<5.1	<5.1	<5.1	<5.1
Propachlor (Ramrod)	<0.21	<0.22	<0.21	<0.21	<0.21	<0.21
Simazine (Princep)[4]	0.63[J]	0.48[J]	<0.21	<0.21[UJ]	<0.21	<0.21

1 Safe Drinking Water Act MCL= 2.0 µg/l
2 Safe Drinking Water Act MCL= 3.0 µg/l
3 Safe Drinking Water Act MCL= 1.0 µg/l
4 Safe Drinking Water Act MCL= 4.0 µg/l

J compound positively identified, but the value is estimated
UJ compound below the quantitation limit and the quantitation limit is estimated

Table 12. Metal concentrations (mg/kg) in sediment collected from the Olentangy River in 2003. Results are compared to Ohio reference values (Ohio EPA, 2003) and toxicity guidelines presented by MacDonald et al. (2000). Values preceded by a < were below the quantitation limit.

Olentangy River at Monnett New Winchester Road- RM 84.48								
Al	**Ba**	**Ca**	**Cr**	**Cu**	**Fe**	**Pb**	**Mg**	**Mn**
18100	127	19100	32	25.1	18000	42 [b]	6580	226
Ni	**K**	**Na**	**Sr**	**Zn**	**Hg**	**As**	**Cd**	**Se**
<27	4640	<3310	46	135[b]	0.066	9.47	4.63 [a b]	<1.32
Olentangy River at Shearer Road- RM 79.66								
Al	**Ba**	**Ca**	**Cr**	**Cu**	**Fe**	**Pb**	**Mg**	**Mn**
16300	89.7	6550	18	10.2	14200	<23	3200	326
Ni	**K**	**Na**	**Sr**	**Zn**	**Hg**	**As**	**Cd**	**Se**
<23	4060	<2910	31	62.8	<0.03	8.03	0.954 [a]	<1.16

a exceeds either ecoregion (ECBP) or statewide reference value (Pb, Hg)
b exceeds threshold effect concentration
c exceeds probable effect concentration

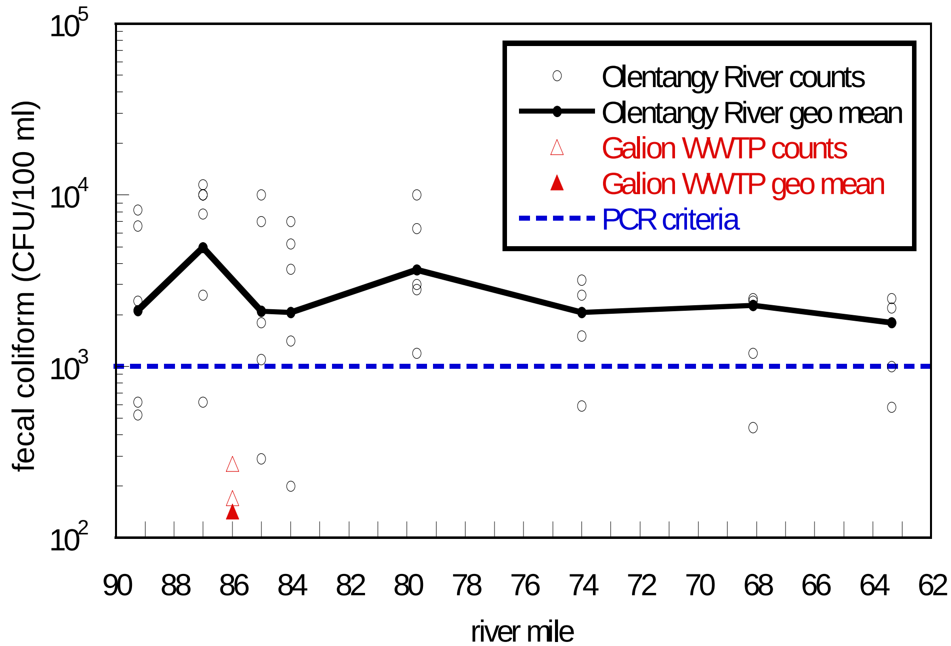


Figure 8. Fecal coliform bacteria counts in the upper Olentangy River in 2003 during the 30 day recreation use assessment period (July 7-August 4) plotted against the Primary Contact Recreation criterion.

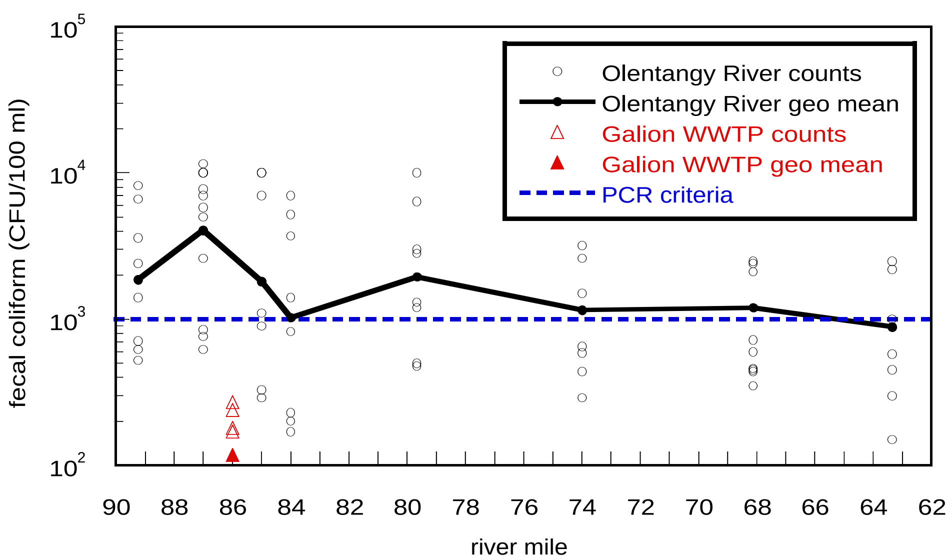


Figure 9. Fecal coliform bacteria counts in the upper Olentangy River in 2003 during the entire field season (June 2-August 27) plotted against the Primary Contact Recreation criterion.

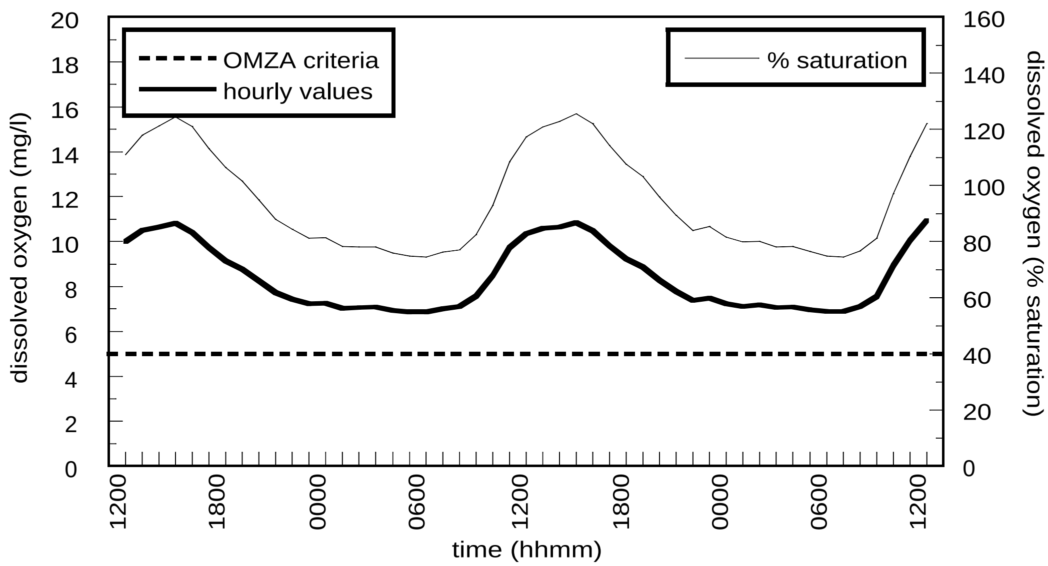


Figure 10. Hourly dissolved oxygen measurements obtained in the Olentangy River at Hosford Road (RM 85.94) from Sept. 16-18, 2003.

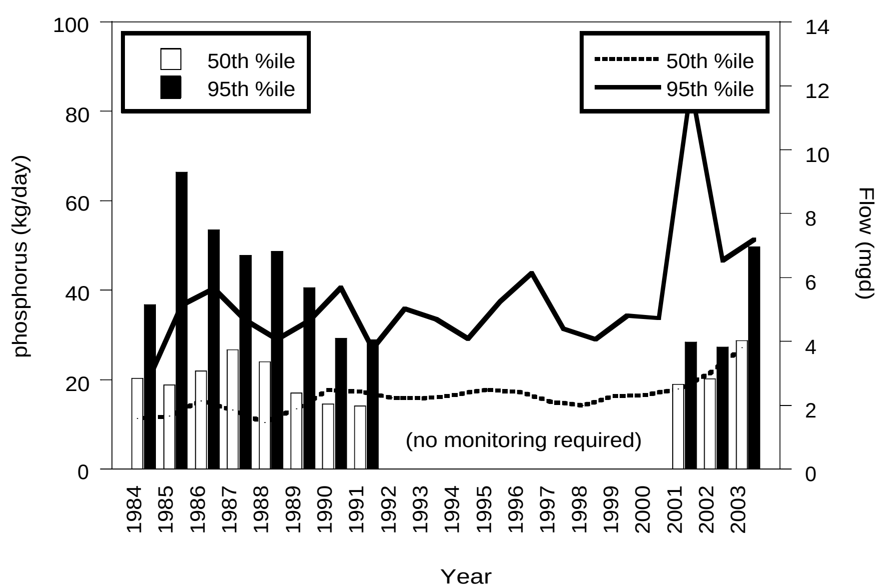


Figure 11. Annual phosphorus loadings at the Galion WWTP from 1984-2003.

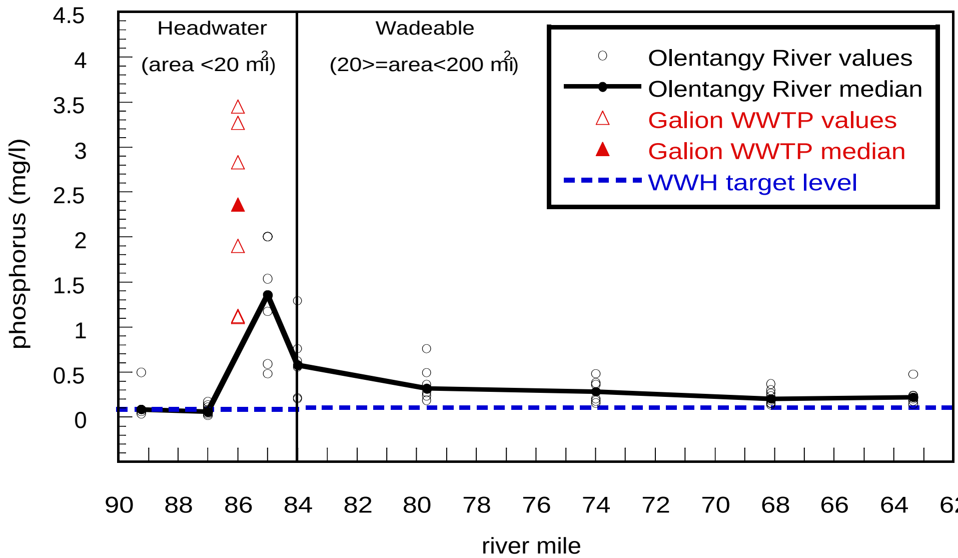


Figure 12. Phosphorus concentration in the upper Olentangy River in 2003 plotted against the target level. Target increases from 0.08 to 0.10 mg/l at the transition from a headwater stream to a wadeable stream (RM 84.48) (Ohio EPA, 1999).

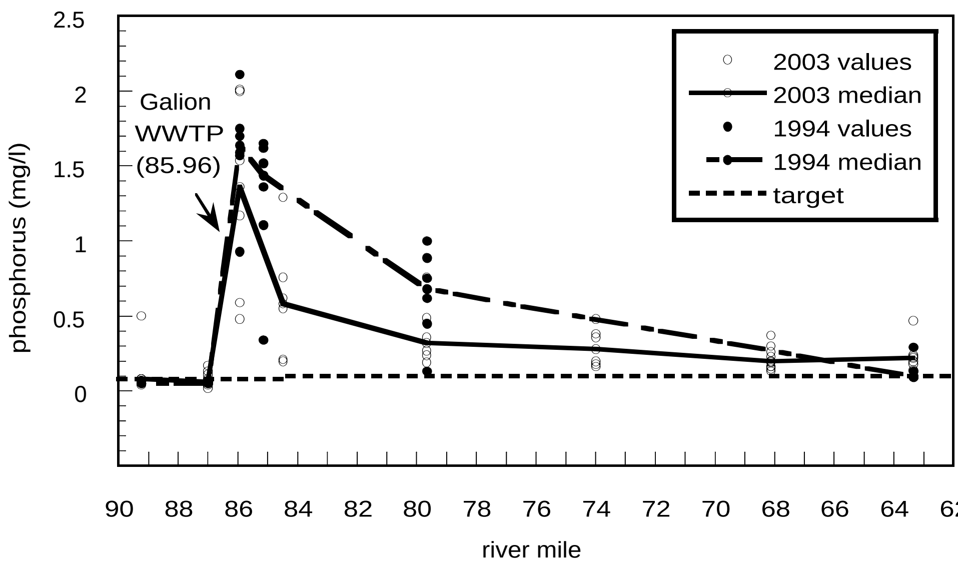


Figure 13. Trend in phosphorus concentration in the upper Olentangy River.

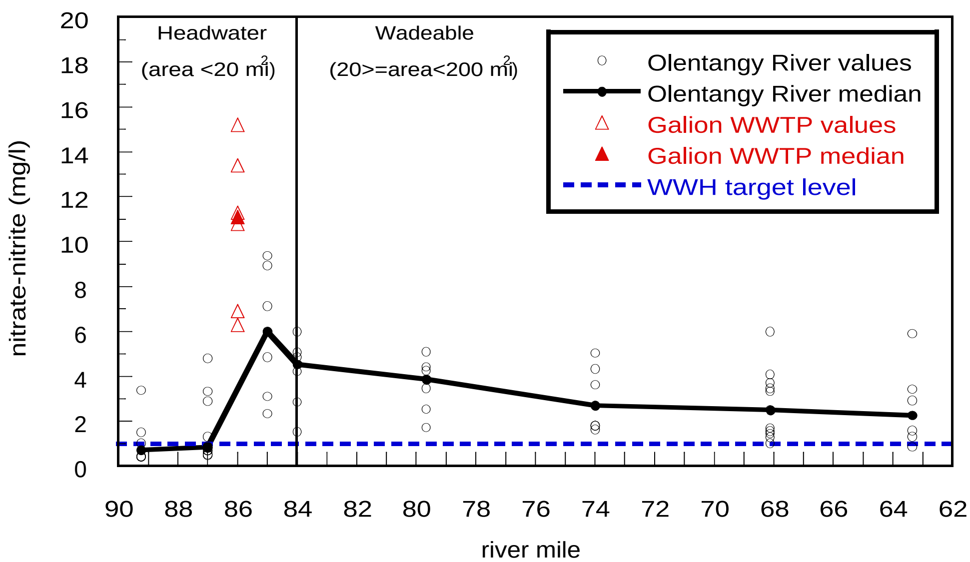


Figure 14. Nitrate-nitrite concentration in the upper Olentangy River in 2003 plotted against the target level. Target is 1.0 mg/l for both headwater and wadeable streams (Ohio EPA, 1999).

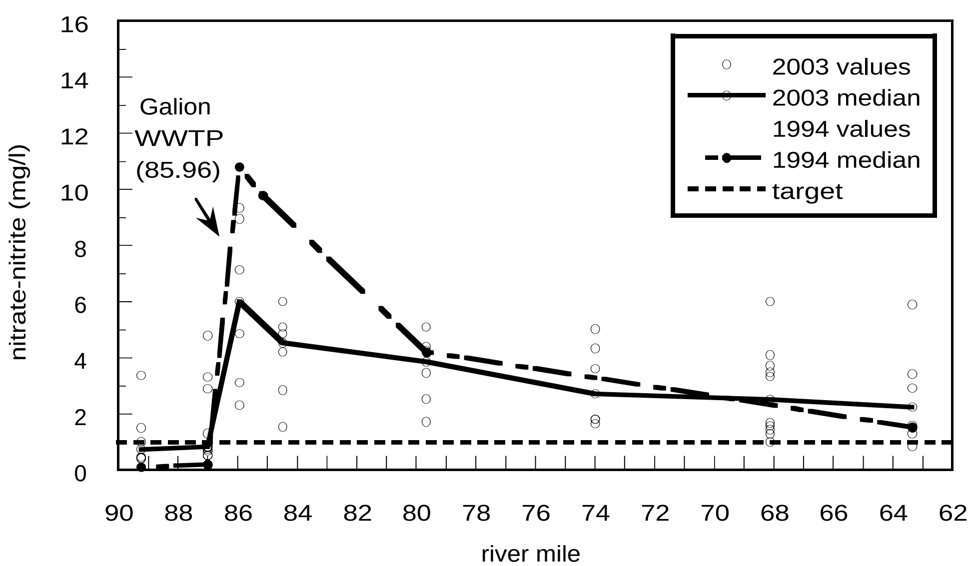


Figure 15. Trend in nitrate-nitrite concentration in the upper Olentangy River.

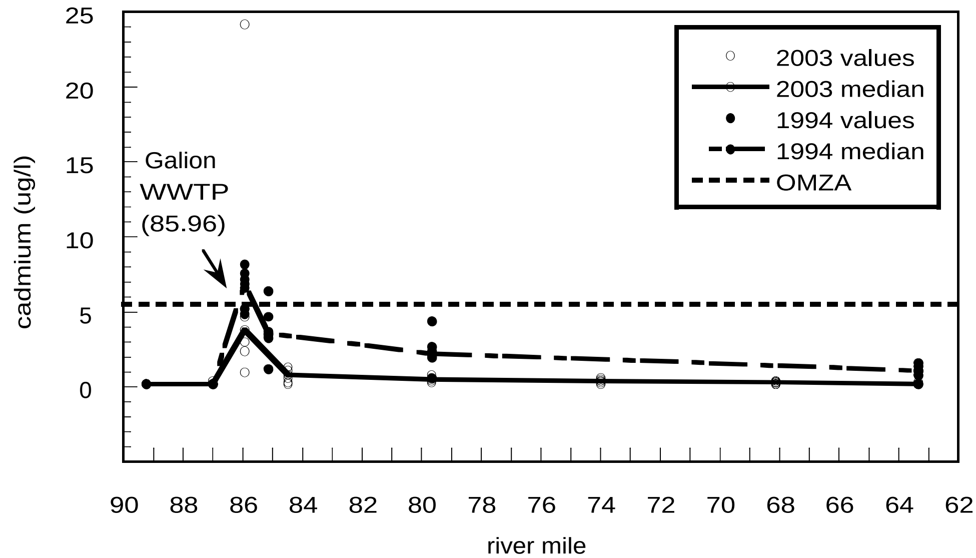


Figure 16. Trend in cadmium concentration in the upper Olentangy River. The outside mixing zone average (OMZA) criterion was calculated using the median hardness value of data pooled from both years (n=92).

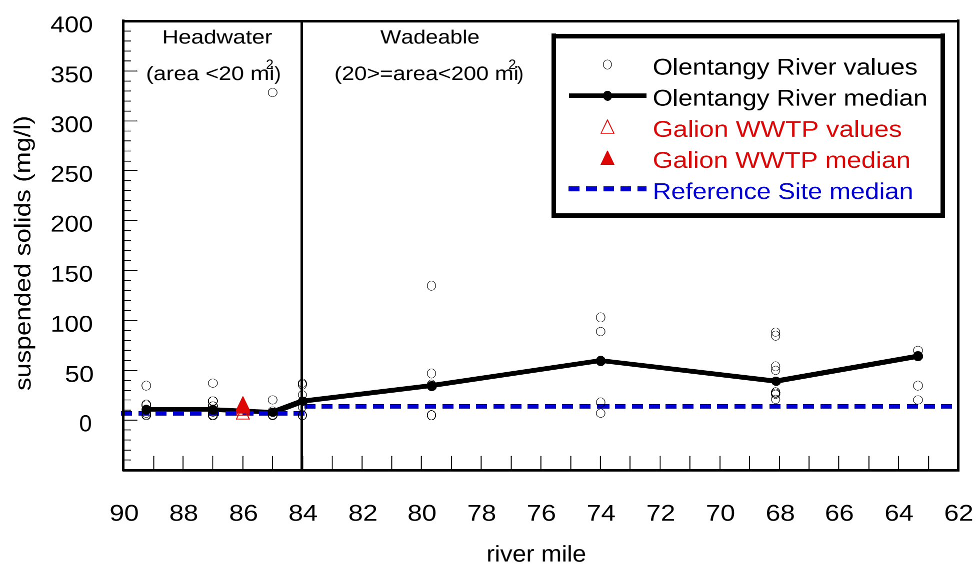


Figure 17. Suspended solids concentration in the upper Olentangy River in 2003 plotted against the background value. Background increases from 7 to 14 mg/l at the transition from a headwater stream to a wadeable stream at Monnett New Winchester Road (RM 84.48).

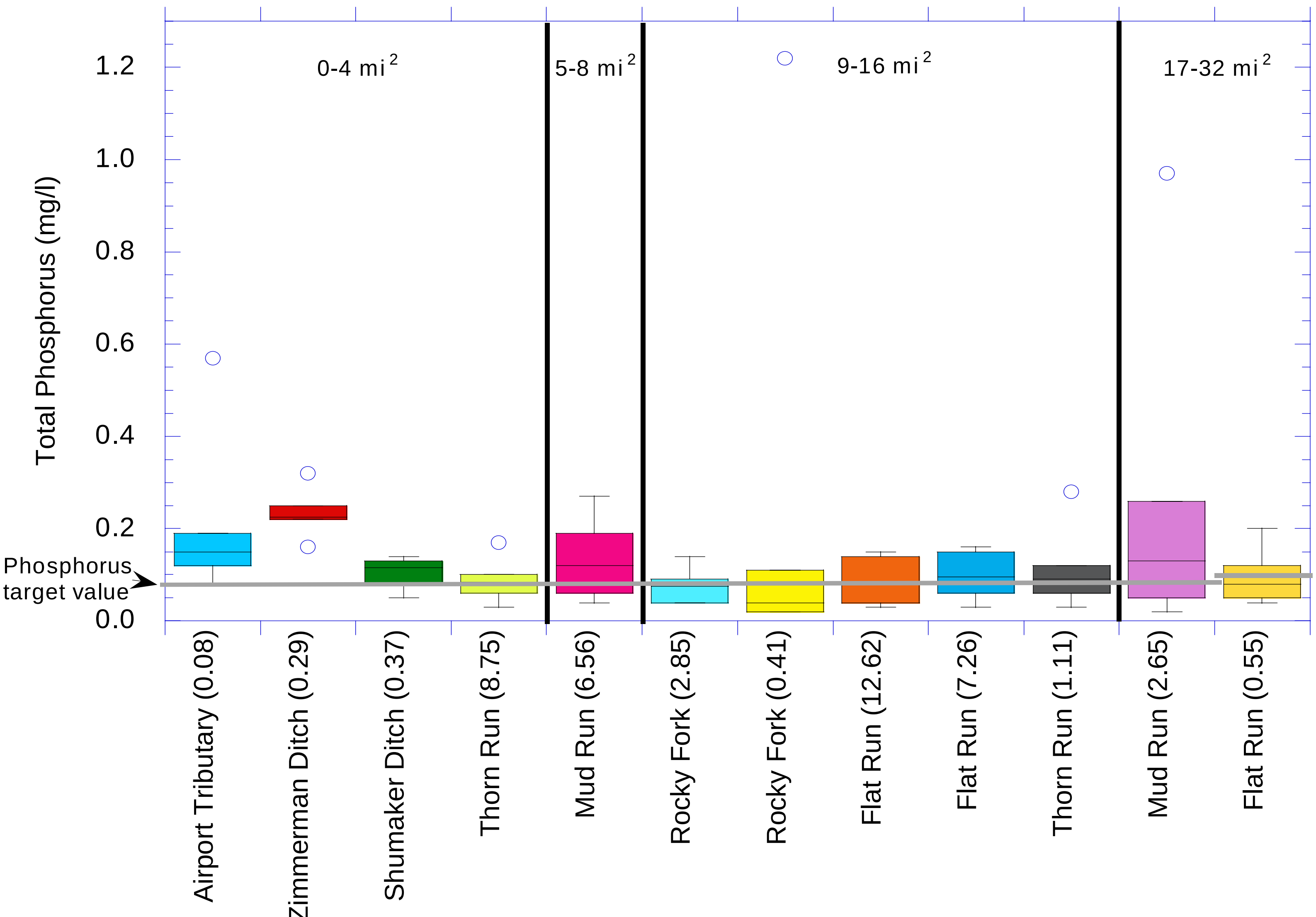


Figure 18. Summary of phosphorus measurements at tributary sites within the UOWAU in 2003. Values are below the WWH targets of 0.08 for headwater streams (≤20mi^2) and 0.10 for wadeable streams (20>and≤200mi^2).

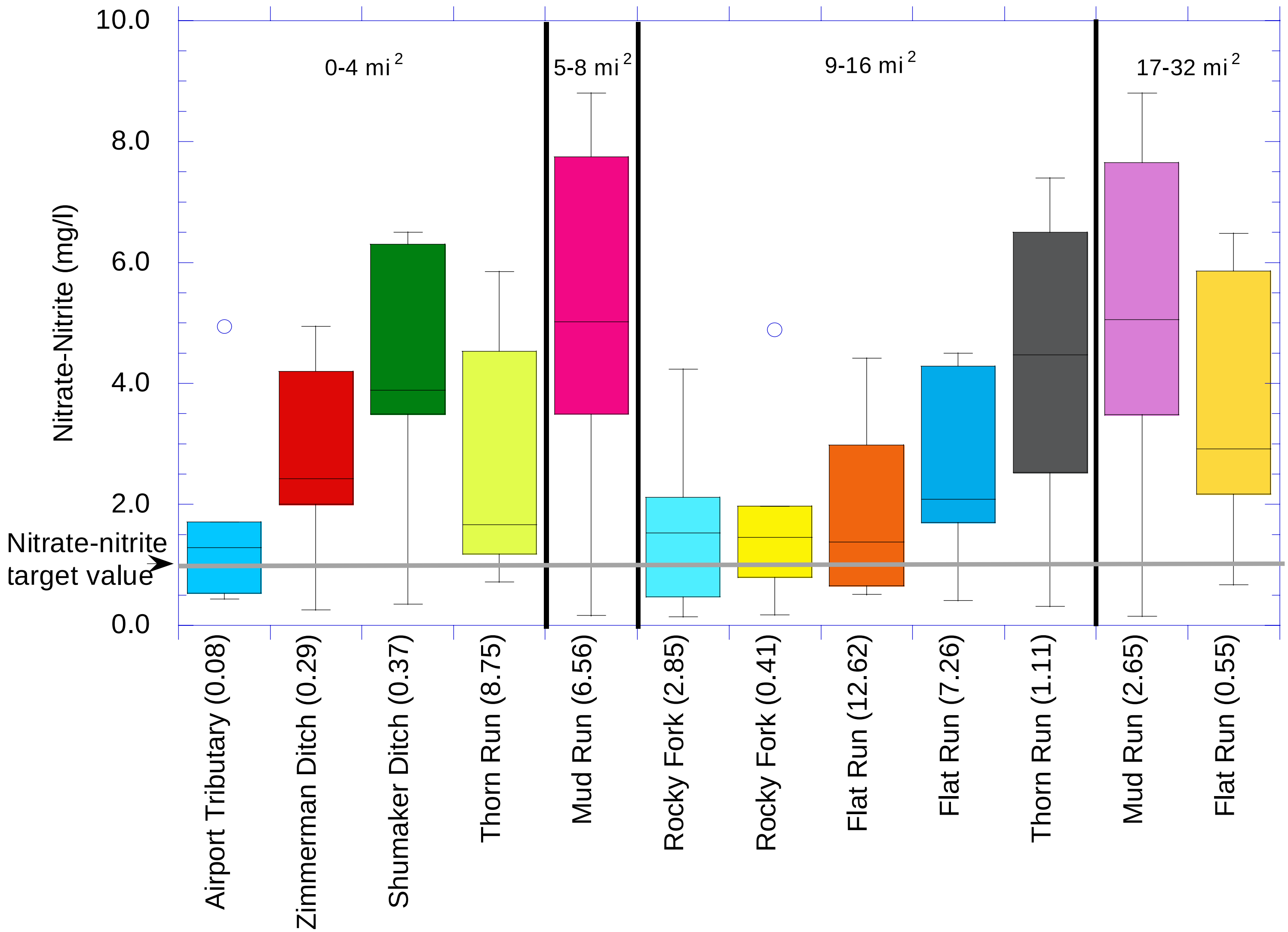


Figure 19. Summary of nitrate-nitrite measurements at tributary sites within the UOWAU in 2003. Values are above the WWH target of 1.0 for headwater streams (≤20mi^2) and for wadeable streams (20>and≤200mi^2).

Physical Habitat

The physical habitat of 16 locations within the UOWAU was evaluated with the QHEI. As Figure 20 shows, the majority of sites scored within the fair to very good range. The only sites that scored less than fair were the two sites located on Mud Run which scored in the poor range. Mud Run is designated MWH due to maintenance activities by the county engineer.

The average QHEI = 68.3 (range of 57.5 to 84.0) for mainstem sites while the average QHEI = 61.9 (range of 35.0 to 85.0) for the tributaries. Though the majority of habitat conditions indicate the ability of streams within the UOWAU to support WWH communities, extenuating influences, including the Galion WWTP and agricultural activities, adversely affected biological performance.

Olentangy River

Streambed materials of the upper reach of the Olentangy River, from Edward Street (RM 89.25) to Lyons Road (RM 63.4) developed primarily from tills. Sand, silt, cobble, boulder, and gravel were noted as predominant substrate types, though areas of hardpan, artificial substrates (concrete), and bedrock were also noted. Silt and embedded substrate increased in a downstream direction from normal and moderate amounts in the headwaters to moderate and heavy siltation with moderate and extensive embeddedness downstream. Moderate to extensive amounts of habitat were provided by undercut banks, overhanging vegetation, shallows, rootmats, deep pools (>70cm), rootwads, boulders and woody debris at the majority of sites in the upper reach. However, only sparse amounts of habitat including shallows, boulders and overhanging vegetation were found at the site upstream from the Galion WWTP (RM 86.0). Both of the sites upstream and downstream from the Galion Wastewater Treatment Plant showed evidence of past channelization, with the upstream site having little sinuosity with fair development and low stability and the downstream site exhibiting low sinuosity with fair to good development and moderate stability. In contrast, the remaining sites within the upper reach appeared to have recovered from channelization activities. Moderate to high sinuosity, with good development and moderate to high stability was noted in the headwaters while fair to good development with low stability was observed further downstream. Deep pools, shallows and eddies were accompanied by currents from slow to fast throughout most sites except for the site upstream of the Galion wastewater treatment plant and the stretch of mainstem from Monnett-Chapel Road (RM 74.0) to Lyons Road (RM 63.4) which exhibited predominantly slow to moderate flows.

Outside of the stream channel, wooded areas provided a quality riparian buffer near the site at Edward Street (RM 89.3). Upstream from the Galion WWTP, no riparian buffers were present between the WWTP on the left descending bank and the combination of residential homes and the wastewater treatment plant on the right descending bank. Downstream from the Galion WWTP and near Monnett-New Winchester Road (RM 84.4), riparian buffers ranged from very narrow (<5m) to moderate (10-50m) depth, with residential land use predominating at the former site and a mixture of residential and forested use at the latter. Further downstream, buffers decreased from wide (>50m) adjacent to forest and occasional residential areas near Shearer Road (RM 79.7) to nonexistent and very narrow (<5m) as land use intensified to open pastures, residential areas and crops.

The diversity of aquatic habitat combined with the strong channel development and varied currents in the majority of the upper portion of the mainstem resulted in QHEI scores ranging primarily between 79.0 and 84.0 (x = 81.8). However, the urbanized section of stream near the Galion WWTP scored a 58.5 due to the lack of riparian buffers, recent channelization and low quality habitat. As land use intensified further downstream, habitat quality decreased. The average QHEI was 60.6 (range of 57.5 – 69.5) from Shearer Road (RM 79.7) to Lyons Road (RM 63.4).

Rocky Fork

Rocky Fork was evaluated from Atkinson Road (RM 2.9) to County Road 8 (RM 0.4). The streambed appeared to originate from tills, as the primary substrates present were gravel and sand in the upper reach and cobble and boulders in the lower reach. All four substrate types were present throughout each stream reach, with hardpan also observed in the upper reach. Asphalt was noted in the lower reach. Silt was present in normal to moderate amounts, while embedded substrates were evident in normal amounts. Logs, undercut banks, boulders, overhanging vegetation, shallows, rootwads and rootmats provided moderate amounts of instream cover. The upper reach appeared free from channelization as high sinuosity with good development and low to moderate stability was dominant. In contrast, the lower reach appeared to be slowly recovering from relocation and channelization activities associated with the dam for Ammans Reservoir.

Outside of the stream channel, wide (>50m) buffers extended adjacent to forested and residential areas along the upper reach, though areas of moderate erosion were noted along each bank. Moderate (10-50m) buffers extended adjacent to forested areas along the lower reach, though no buffers were apparent along a portion of the stream adjacent to one home. The mixtures of land use and buffer quality with diverse substrates and instream cover resulted in QHEI scores of 74.0 for the upper reach and 75.0 for the lower reach.

Mud Run

Mud Run was evaluated near Monnett-Chapel Road (RM 6.7) and Morral-Kirkpatrick Road (RM 2.7). The Mud Run streambed appeared to originate from glacial tills as noted by their occasional presence in the stream, though sand and silt were the dominant substrate types. Gravel and occasional areas of cobble were intermixed with the sand and silt, though the silt and sand were loose enough to easily sink an individual's leg 30-60cm when attempting to walk throughout the majority of the stream. This moderate to heavy amount of silt resulted in moderate to extensive embeddedness of the underlying substrates. Sparse amounts of instream cover were provided by undercut banks, overhanging vegetation, shallows, aquatic macrophytes and occasional deep pools

(>70cm). The stream channel has not recovered from recent channelization as evidenced by low to nonexistent sinuosity, poor to fair channel development and low stability.

The riparian zone was dominated by row cropping extended to nearly the stream's edge, with only small mowed areas along the stream edge providing any buffer. A septic discharge was noted near the bridge along Monnett-Chapel Road (RM 6.7) and field drain tiles were observed along Mud Run near Morral-Kirkpatrick Road (RM 2.7). The inability of the stream to recover from past channelization activities and current land use practices resulted in QHEI scores ranging from 35.0 to 38.0 (x=36.5). The low QHEI scores reflect the poor habitat of Mud Run resulting from agricultural activities in the area.

Flat Run

The physical habitat of Flat Run was evaluated between State Route 288 (RM 12.6) to County Road 60 (RM 0.5). Glacial tills appeared to be the substrate source for the streambed of Flat Run, though the upper reach near State Route 288 (RM 12.6) exhibited bedrock as the dominant substrate with only occasional areas of sand, cobble and boulder providing additional habitat niches. Silt and embedded substrates were present in normal amounts. Instream cover was present in moderate amounts and included undercut banks, overhanging vegetation, shallows, rootmats and boulders. No woody debris or deep pools were present. The upper reach appeared to have recovered from past channelization as low sinuosity, good development and low to moderate stability were apparent. Currents were slow to moderate throughout the upper reach, with moderately stable riffles and runs exhibiting low embeddedness. Residential lawns extended to the stream banks, providing no riparian buffer from surface water run-off. However, trees present within the yards did provide some shading to the upper reach.

While the upper reach may be characterized as a bedrock channel with suburban influences, the lower reach from State Route 309 (RM 7.3) to County Road 60 (RM 0.5) was a more diverse system exhibiting fewer modified traits. The dominant substrate types consisted of sand, cobble and boulders which were intermixed with gravel, hardpan and bedrock. The diverse substrate types provided numerous interstitial spaces for aquatic organisms. Silt and embedded substrates were present in normal amounts. Moderate to extensive amounts of instream cover were provided by undercut banks, overhanging vegetation, shallows, rootmats, deep pools (>70cm), rootwads, boulders, aquatic macrophytes, logs and woody debris. The lower reach appeared to have recovered from past channelization activities as moderate to high sinuosity with good development and moderate to high stability was evident. Currents ranged from slow to fast with several eddies also noted. The combination of the above attributes provided good habitat for aquatic life.

Land use and the extent of riparian buffers varied at each site in the lower reach. Near State Route 309 (RM 7.3), buffers were moderate (10-50m) to wide (>50m) adjacent to cultivated and forested areas, though buffers were nonexistent along a 25m stretch adjacent to a residential lawn. Along County Road 60 (RM 0.5), buffers were nonexistent except for occasional trees along the right descending bank adjacent to crop fields. A very narrow (5-10m) buffer of trees provided rootwads as instream habitat and shade to diffuse sunlight along the left descending bank adjacent to crop fields.

The differing land uses, buffers and habitats resulted in disparate QHEI scores between the upper and lower reaches of Flat Run. Moderate instream cover and diverse substrates combined with a lack of riparian buffers resulted in a QHEI score of 57.0 for the upper reach. The combination of diverse substrates, moderate to extensive instream cover, moderate to high sinuosity and stability and mixture of land uses and buffers resulted in QHEI scores of 72.5 and 85.0 (x=76.3) for the lower reach.

Thorn Run

Thorn Run was evaluated near Marion-Williamsport Road (RM 1.1) and appeared to originate primarily from glacial tills. Sand and cobble were the dominating substrates intermixed with gravel and silt. Silt and embedded substrates were present in moderate amounts. Sparse amounts of instream cover were provided by undercut banks, overhanging vegetation, shallows, rootmats, aquatic macrophytes and occasional logs. The stream appeared to have recovered from historical channelization as moderate sinuosity with good development was apparent. However, several cattle access areas were observed along the banks as evidenced by false banks, erosion, and siltation with accompanying low stream stability.

Outside of the stream channel, very narrow (<5m) riparian buffers extended to a mixture of old field and open pasture. The poor riparian cover, sparse instream cover and high intensity agricultural use resulted in a QHEI of 57.5.

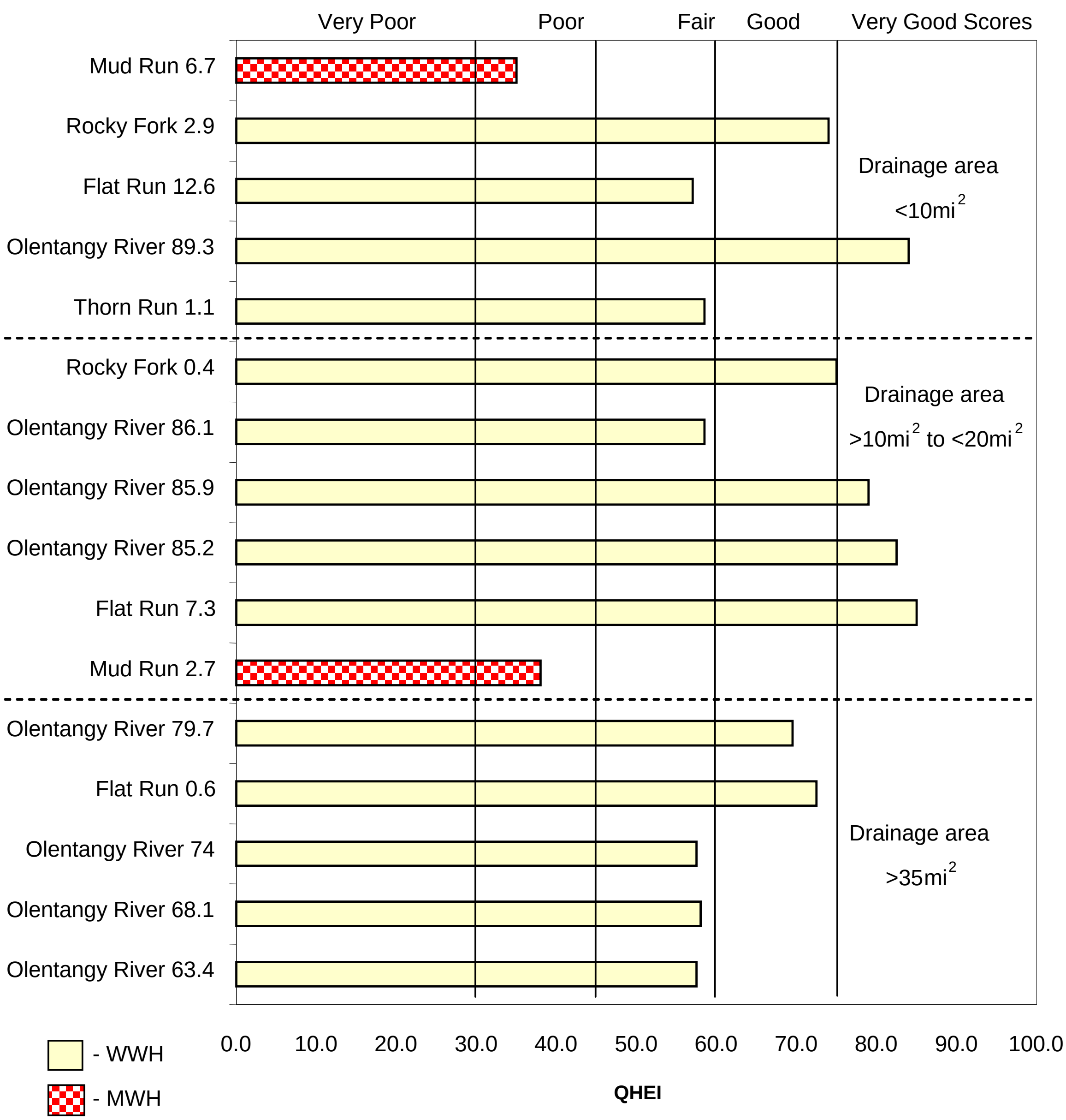


Figure 20. QHEI scores by drainage area for UOWAU. Existing or proposed aquatic life use designations were Warmwater Habitat (WWH) or Modified Warmwater Habitat (MWH). Values for Mud Run are the lowest, as it is maintained by Crawford and Marion County Engineers.

Biological Communities: Fish

The fish communities of the UOWAU were sampled at sixteen locations. The eight Olentangy River mainstem sites generally showed good correlation with habitat conditions (Figure 21). Two of the sites, Crawford-Marion Line Road (RM 68.1) and Shearer Road (RM 79.7), performed below WWH expectations though habitat conditions should have been sufficient to support WWH communities. Nutrient enrichment and siltation from surrounding agricultural land have impacted the fish communities in these areas.

Olentangy River

The fish community within the upper Olentangy River mainstem was evaluated at four sites from Edward Street (RM 89.3) to Roberts Road (RM 56.6). Community index scores and narrative evaluations ranged between very good (IBI=49) and fair (IBI=33). Several dead and dying bluntnose minnows, creek chubs, rock bass, and silver shiners were noted at the most upstream site, Edward Street (RM 89.3), on September 15, 2003. Darters were present in the riffles, though the deep pools were nearly devoid of fish. Several small package plants discharge to an unnamed tributary upstream from this site. In addition, unauthorized dumping is known to occur in this area. Though no chemical WQS violations were observed at this site during the sampling season, it is possible that the package plants and the dumping activities may be degrading water quality.

Downstream from Edwards Street, the Olentangy River flowed through the City of Galion before winding northwest through agricultural areas. Upstream from the Galion WWTP, urban influences were observed in the fish community as stoneroller minnow (39.8%) and bluntnose minnow (33.9%) were the most numerically abundant. The mixing zone at the Galion WWTP (RM 86.0) was sampled to see if avoidance by aquatic organisms occurs. It was not considered a community evaluation site. Fish avoided the mix zone of the Galion WWTP. Downstream from the Galion WWTP, tolerant fish species comprised the majority of the community as green sunfish (24.8%), bluntnose minnow (20.1%), and creek chub (10.1%) were 3 of the 4 most abundant species by number.

The Olentangy River flowed through agricultural and rural areas downstream from Galion. MIwb values for the sites were in the fair (MIwb=7.8) to marginally good range (MIwb=7.8) with an average MIwb=7.5, reflecting the lower quality habitat available to fish within this reach. The lower quality habitat occurred as a result of agricultural activities including livestock access to streams, field tile drainage and the removal of riparian cover.

Even in areas where habitat was sufficient to support WWH communities, near Crawford-Marion Line Road (RM 68.1) and Shearer Road (RM 79.7), fish communities performed below expectations (Figure 21). Nutrient enrichment from agricultural activities and the Galion WWTP may be attributable to the less than WWH performance of these fish communities.

Rocky Fork

Rocky Fork was sampled at two sites, one site near Atkinson Road (RM 2.9) and the other below Ammans Reservoir (RM 0.4). Community indices and narrative evaluations ranged from fair (IBI=34) to marginally good (IBI=36). Though the fish communities performed similarly at both sites, the lower reach was likely influenced by the flow alterations and nutrient enrichment from the reservoir. Three species comprised 84.4% of the population sampled at the lower site, while five species comprised 79.7% of the population at the upstream site. Stoneroller minnow comprised 47.6% of the population at the lower site, suggesting nutrient enrichment from the reservoir was influencing the fish community.

Mud Run

The fish community of Mud Run was sampled at two locations between Monnet-Chappel Road (RM 6.7) and Morral-Kirkpatrick Road (RM 2.7). Despite the fact that Mud Run is maintained by the Crawford County Engineer's Office, the community indices and narrative evaluations ranged from fair (IBI=30) to good (IBI=40). Tolerant fish species decreased in abundance in a downstream direction as six tolerant species comprised 55% of the community at the upstream site and six tolerant species comprised only 31.8% of the community at the downstream site.

Flat Run

Three sites were sampled along Flat Run from State Highway 22 (RM 12.6) to West Canaan Road (RM 0.6). Community indices and narrative evaluations increased in a downstream direction from good (IBI=42) to exceptional (IBI=50). The increase in fish community scores reflected improved habitat conditions as QHEI scores increased from 57.0 at the most upstream site to an average of 78.8 downstream. Though the sites sampled on Flat Run had similar drainage areas to the two sites sampled on Mud Run, the improved habitat conditions on Flat Run resulted in improved biological diversity within the fish community (Figure 20). Though no intolerant species were observed at the most upstream site, common intolerant species including silver shiner, banded darter and stonecat madtom were noted downstream. The total number of species collected increased from 15 to 26 in a downstream direction as habitat quality improved.

Thorn Run

One site was sampled along Thorn Run near Marion-Williamsport Road (RM 1.1). The fish community sampled was characterized as good (IBI=42). A total of twenty species were collected at this site. One common intolerant species, the banded darter, and five moderately intolerant species were collected, though they only comprised 4% of the total population. Though some channel modifications were noted, existing conditions support a WWH fish community.

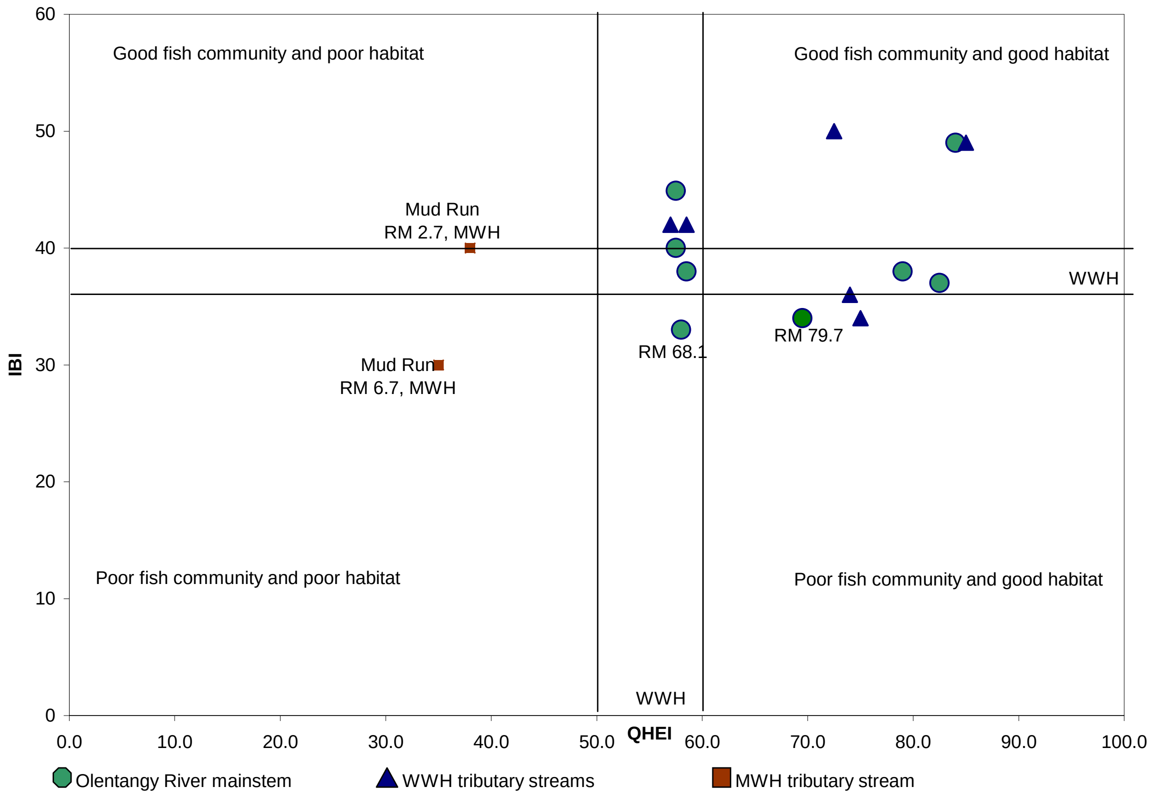


Figure 21. IBI versus QHEI scores for the UOWAU. Two Olentangy River mainstem sites performed below WWH expectations, even though habitat conditions were sufficient to support WWH communities.

Biological Communities: Macroinvertebrates

Macroinvertebrate communities were evaluated at 15 stations and one mixing zone in the UOWAU (Table 13). The community performance was evaluated as exceptional at three stations, very good at one, good at two, marginally good at five, fair at two, low fair at one, and poor at one. The Galion WWTP mixing zone was sampled twice with evaluations of low fair and poor. The station with the highest total mayfly (Ephemeroptera), stonefly (Plecoptera), and caddisfly (Trichoptera) taxa richness (EPT) was on Flat Run at SR 309 (RM 7.3) with 21 taxa. The station with the highest number of total sensitive taxa was on Flat Run at West Canaan Road (RM 0.6) with 33. Two sensitive taxa that are not commonly collected were the mayfly *Acerpenna macdunnoughi* in Flat Run (RM 12.7) and the midge *Eukiefferiella devonica* group in Flat Run (RM 7.3).

The Olentangy River at the upstream border of Galion (RM 89.3) was evaluated as marginally good (MG). Silt accumulation on the natural substrates was noted and may have contributed to the moderate impact at this station. The site (RM 86.1) upstream from the Galion WWTP (RM 86.0) received an ICI evaluation of marginally good (ICI=34). However, both the EPT and sensitive taxa diversity declined and the predominance of tolerant taxa increased compared to the upstream station (Figure 22, Table 13). The invertebrate community was probably impacted by habitat modifications (i.e., channelization, the removal of the forested riparian buffer), nutrient enrichment (as evidenced by excessive growths of filamentous algae), and probable urban runoff from Galion. Two tolerant midges (*Cricotopus bicinctus* and *Cricotopus sylvestris* group) found in low to moderate abundance at this station are tolerant of toxic conditions which suggests a source of toxic pollution within Galion. Invertebrate communities evaluated within the Galion WWTP mixing zone (RM 85.94) on 16 July and 27 August were assessed as low fair and poor, respectively. Very low diversity of EPT and sensitive taxa along with high abundance of midges (including the toxicity tolerant taxa *Cricotopus bicinctus*, *Cricotopus sylvestris* group, and *Parachironomus "hirtalatus"*) indicated a toxic impact. Downstream communities tended to improve until the station at Monnet Chappel Road (RM 74.0) where the stream was channelized with only fine grained sediments and no riffle habitat. EPT and sensitive taxa diversity declined markedly at this station and the EPT and to a lesser extent the sensitive taxa diversity remained depressed at the next downstream two stations (Figure 22). The stream channel at the stations sampled from Monnet Chappel Road to Lyons Road (RM 63.6) was channelized with virtually no riffle development. Stream channel habitat improved by the first station in the next downstream assessment unit at SR 746 (RM 58.8). This resulted in substantial increases in EPT and sensitive taxa diversity.

Rocky Fork

The community sampled in Rocky Fork (RM 2.9) upstream from the Ammans Reservoir was evaluated as marginally good (MG). The EPT diversity was fairly high (16); however, depressed diversity and predominance of sensitive taxa (15) was an indication of community imbalance. Downstream from the reservoir the community (RM 0.4) declined into the poor range, with very low EPT (3) and sensitive taxa (1) diversity and high predominance of facultative taxa. The community performance at this station was likely depressed by low stream flow discharging from the reservoir, nutrient enrichment as evidenced by heavy filamentous algae growth, and a channelized stream channel.

Mud Run

Mud Run is a highly channelized stream that flows through intensively row-cropped areas and has been designated MWH. The invertebrate communities were impaired by the stream habitat modifications and runoff associated with the surrounding agricultural activities. However, the community achieved the expectations of the MWH aquatic life use designation.

Flat Run

Flat Run was the only stream in this assessment unit that was consistently meeting or exceeding biological expectations for macroinvertebrate performance. This stream had the highest EPT (21 at RM 7.3) and sensitive taxa (33 at RM 0.6) diversity recorded for the assessment unit and had the only infrequently collected sensitive taxa in the unit. Evaluations ranged from good (G) at RM 12.7 to exceptional at RM 7.3 and 0.6; the RM 0.6 site scored an ICI of 52.

Thorn Run

The community sampled in Thorn Run (RM 1.1) was evaluated as marginally good (MG). EPT diversity (14) was marginally meeting WWH expectations but the diversity and abundance of sensitive taxa were depressed. Channel modifications and embedded substrates were likely contributing to the slightly to moderately impaired macroinvertebrate community.

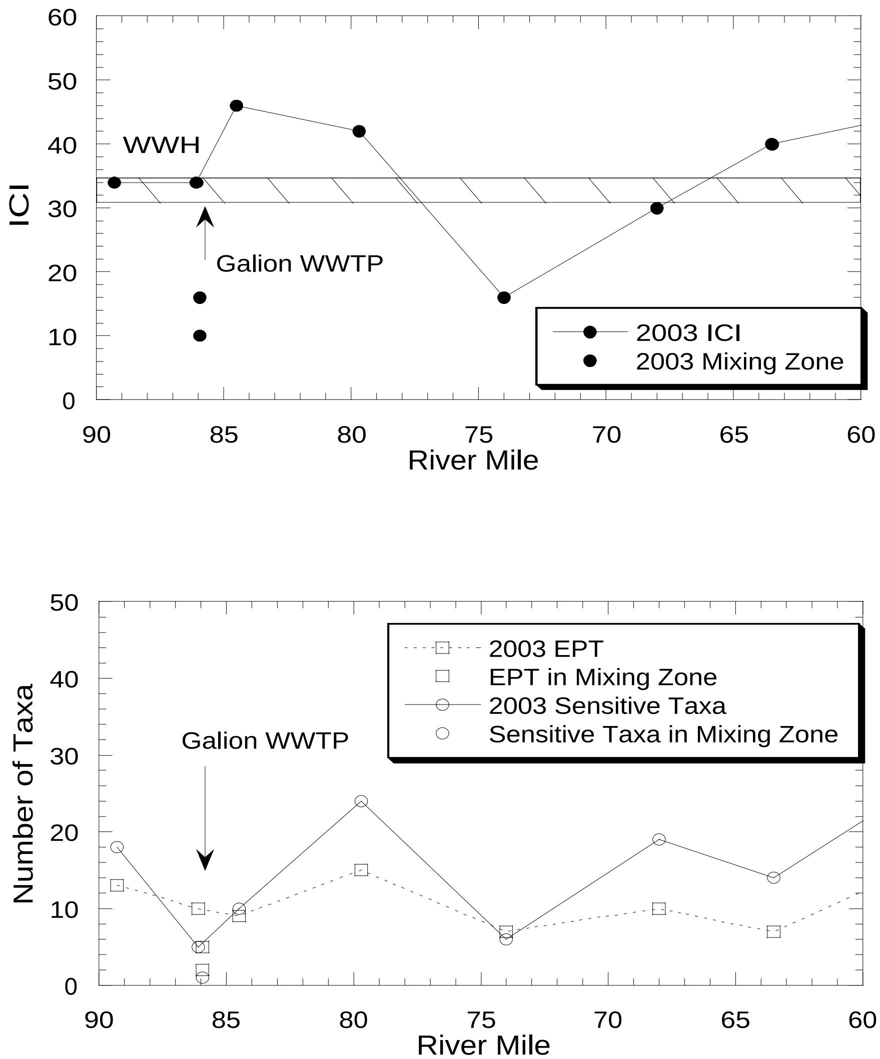


Figure 22. Longitudinal trend of the Invertebrate Community Index (ICI), total EPT, and total sensitive taxa in the upper Olentangy River, 2003.

Table 13. Summary of macroinvertebrate data collected from artificial substrates (quantitative sampling) and natural substrates (qualitative sampling) in the upper Olentangy River study area, July to September, 2003.

Stream RM	Dr. Ar. (sq. mi.)	Data Codes	Qual. Taxa	EPT Ql. / Total	Sensitive Taxa Ql. / Total	Density Ql. / Qt.	Predominant Organisms on the Natural Substrates With Tolerance Category(ies) in Parentheses	ICI	Narrative Evaluation
Olentangy River (02-400)									
89.3	9.0	-	53	13 / -	18 / -	L-M / -	Hydropsychid caddisflies (F)	-	Marg. Good
86.1	12.2	-	40	8 / 10	4 / 5	M-H / 902	Midges (F,MT), hydropsychid caddisflies (F)	34	Marg. Good
85.94 A	12.2	21	30	5 / -	1 / -	H / -	Midges (F,MT,VT)	-	Low Fair
85.94 B	12.2	21	23	2 / -	1 / -	H / -	Midges (F,T), hydropsychid caddisflies (F)	-	Poor
84.5	24	-	37	9 / 9	7 / 10	H / 1487	Hydropsychid caddisflies (F), flatworms (F), water penny beetle larva (MI)	46	Exceptional
79.7	39	-	40	13 / 15	16 / 24	L-M / 995	Baetid mayflies (F,I), hydropsychid caddisflies (F), midges (MI)	42	Very Good
74.0	50	-	27	7 / -	6 / -	M / -	midges (F,MI)	-	Low Fair
68.0	58	-	28	6 / 10	8 / 19	L-M / 166	Midges (F,MI)	30	Fair
63.5	67	-	16	2 / 7	6 / 14	L-M / 182	Midges (MI), hydropsychid caddisflies (F)	40	Good
Rocky Fork (02-466)									
2.9	8.7	-	46	16	15	L-M	Midges (F,MI), hydropsychid caddisflies (F)	-	Marg. Good
0.4	10.9	-	20	3	1	M	Flatworms (F), midges (F)	-	Poor
Mud Run (02-429)									
6.7	7.7	-	38	9	6	L-M	Hydropsychid caddisflies (F), *Elimia* smails (MI), heptageniid mayflies (F)	-	Fair

Stream RM	Dr. Ar. (sq. mi.)	Data Codes	Qual. Taxa	EPT Ql. / Total	Sensitive Taxa Ql. / Total	Density Ql. / Qt.	Predominant Organisms on the Natural Substrates With Tolerance Category(ies) in Parentheses	ICI	Narrative Evaluation
2.6	17.0	-	32	13	10	L-M	Hydropsychid caddisflies (F), baetid mayflies (F,I)	-	Marg. Good
Flat Run (02-425)									
12.7	8.9	-	53	15	21	L-M	Blackflies (F), hydropsychid caddisflies (F), midges (MI)	-	Good
7.3	14.4	-	52	21	26	L-M	Hydropsychid caddisflies (F), mayflies (MI), midges (F,MI)	-	Exceptional
0.6	40.9	-	49	10 / 20	16 / 33	Low / 237	Midges (MI)	52	Exceptional
Thorn Run (02-426)									
1.1	9.3	-	50	14	14	L-M	Hydropsychid caddisflies (F), heptageniid mayflies (F), *Stenelmis* riffle beetles (F)	-	Marg. Good

RM: River Mile.
Dr. Ar.: Drainage Area
Data Codes: 21=Mixing Zone Sample.
Sensitive Taxa: Taxa listed on the Ohio EPA Macroinvertebrate Taxa List as MI (moderately intolerant) or I (intolerant).
Ql.: Qualitative sample collected from the natural substrates.
Qt.: Quantitative sample collected on Hester-Dendy artificial substrates, density is expressed in organisms per square foot.
Qualitative sample relative density: L=Low, M=Moderate, H=High.
Tolerance Categories: VT=Very Tolerant, T=Tolerant, MT=Moderately Tolerant, F=Facultative, MI=Moderately Intolerant, I=Intolerant

***Middle Olentangy Watershed Assessment Unit** (MOWAU)*

The MOWAU primarily corresponds to HUC 050600001-110, which extends from below the confluence of Flat Run (RM 59.28) to below the confluence of Delaware Run (RM 25.71). However, for the purposes of this report, the lower boundary of the MOWAU was set below the confluence of Brondige Run (RM 38.13) to match the boundary created by Delaware Lake and the line between Ohio EPA Northwest and Central District offices. A schematic of the area is presented in Figure 23.

Fish and macroinvertebrate communities and stream habitat conditions were evaluated at five Olentangy mainstem sites and 14 tributary sites (Figure 24). The index scores for each site and their biological attainment status are presented in Table 15 while Figure 25 provides the biological attainment status by location. Chemical, physical and bacterial measurements were completed at 18 sites. Each site had at least six sets of grab samples collected at roughly two week intervals during the field season. Mainstem sites had extra bacteria samples collected in July so the recreation use could be assessed. Results that violated Ohio WQS criteria codified in OAC Chapter 3745-1 are summarized in Table 16.

Aquatic Life Use Attainment Status and Trends

The WAU spatial attainment score corresponds to HUC codes. As mentioned previously, the data analysis sections of this report have the boundary for the middle Olentangy basin ending below Brondige Run (RM 38.13), though the HUC boundary extends to below Delaware Run (RM 25.71). However, the HUC boundary was used to determine the attainment scores.

The overall WAU aquatic life use attainment score was 46. An overall attainment score of 0 would reflect 0 sites meeting designated or recommended aquatic life uses in the WAU while a score of 100 would reflect all sites meeting designated or recommended aquatic life uses. This attainment score was calculated according to the protocol and procedures established in the most recent Integrated Water Quality Monitoring and Assessment Report, which can be accessed at:
http://www.epa.state.oh.us/dsw/tmdl/2004IntReport/2004OhioIntegratedReport.html

Biological impairment on the Olentangy mainstem within the MOWAU was primarily from nutrient enrichment in the upper portion and impoundment from dams in the lower portion. Indian Run and Otter Creek were the only tributaries in full attainment. Bee Run, Grave Creek, Riffle Creek, QuQua Creek and Brondige Run were all impaired by agricultural activities including channelization, nutrient enrichment and siltation. Norris Run and Sugar Run were impaired due to urban influences including siltation, nutrient enrichment and habitat alteration.

The fish communities of the MOWAU were previously sampled in 1994. Longitudinal plots of IBI and MIwb versus river mile for 1994 and 2003 are presented in Figure 26.

Primarily the plots show that fish community performance improves in a downstream direction as it flows through less developed areas, until it nears Marion. This may be attributable to ditch cleaning practices in the area and increased urbanization activities.

Macroinvertebrate community performance in the Olentangy River since 1988 is illustrated in Figure 27. Community performance in the upper part of this assessment unit has improved since 1994. The communities downstream from Delaware Lake have remained similar. A decline was observed downstream from Delaware Lake (at RM 32.1/32.0), a depressed community was sampled in the Panhandle Road Dam pool (RM 28.2/28.4), and exceptional communities were found downstream from that impoundment (RM 27.4/27.5/27.9).

Recreation Use Attainment Status

Recreation use impairment was documented for the entire Olentangy River mainstem within the MOWAU. Package WWTPs plants, home sewage treatment systems and livestock were found to be the primary sources of the impairment. Specific details regarding these sources are contained under the Chemistry Water Quality section (p. 109).

Spills

One spill was reported to ODNR and Ohio EPA between 1994-2004 for the MOWAU (Figure 28). The draining of a pond on the OSU Marion campus changed the color of Grave Creek to a dark blue-green in August 2003. No immediate affects to the biological community was noted.

Ecoregion, Soils, and Topography

The 11-digit HUC for this portion of the Olentangy watershed covers the drainage area from the Olentangy River below the confluence with Flat Run (RM 59.28) to below the confluence of Delaware Run (RM 25.71). For this technical support document, the lower boundary of the MOWAU was set below the confluence of Brondige Run (RM 38.13) to match the line between Ohio EPA Northwest and Central District offices and the boundary created by Delaware Lake.

The MOWAU is located at the extreme eastern boundary of the ECBP ecoregion. The ECBP ecoregion in this part of central Ohio is characterized by high lime till plain; this is primarily a broad, nearly level till plain with local end moraines of glacial deposits of the Wisconsonian age. The historical natural forest cover consisted of beech in the upper area and scattered elm-ash swamp in the poorly drained areas.

Soils in this part of the ECBP ecoregion are clayey to loamy, high lime glacial till with widespread areas of Pewamo, Blount and Glynwood series in Marion County. Soils are relatively fertile, easily eroded by water and wind, and are considered prime farm land especially if artificially drained for crop production. Soil capability for onsite household sewage treatment is classified as “severe” with all soil types exhibiting slow percolation, and seasonal wetness or ponding limitations. Failing home septic and leach bed systems contribute to nutrient and bacteria impairment throughout the MOWAU watershed. Low gradient streams coupled with agricultural runoff containing sediment and fertilizers has negatively affected stream water quality in the MOWAU (USGS, 1997).

Current land use is predominantly agricultural crop and livestock production with increasing areas of urban land use in Delaware County. The National Land Cover Dataset for the middle assessment unit indicates the predominant land use is agriculture (66.2%) including row crop and livestock production. Pasture and forested land cover 16.3% and 13.7%, respectively, of the watershed with another 2.7% for urban and residential land use. The remaining 1.1% of land is split evenly between wetlands and green space (USGS-NLCD, 1992).

According to the Census of Agriculture in 2002, land in agricultural use for either row crop or livestock production has been steadily declining since 1980. The number of farms has decreased, as has the number of animals per livestock operation. In isolated areas, the acres in crop production may have remained steady due to minor increases in farm size per operation. The decrease of land in crop production is due to suburban development, and may also be reflected in land that has been taken out of agricultural production for conservation practices such as permanent wildlife or riparian easements, other buffer practices, or wetland and floodplain restorations (USDA, 1997; OSU Extension, 2002).

Causes and sources of impairment

A flow schematic of the tributaries and significant point sources located in this subwatershed can be found in Figure 23.

Point sources in the MOWAU include the Marion County wastewater treatment plants for Sewer District 7, which discharges to Grave Creek, and Sewer District 5A which discharges to QuQua Creek. Other sources of treated wastewater discharges from publicly owned and commercial facilities are listed in Table 18. NPDES permits have also been issued for industrial and construction stormwater sources as listed in Table 19.

Small villages and unincorporated areas without any wastewater collection or treatment contribute to the bacteria and recreation impairments of the river. Unsewered areas include Waldo, Denmark and Claridon. The Village of Waldo, in Marion County, is discharging poorly treated sewage from homes into village storm sewers and causing a public health nuisance in Tomahawk Ditch. This becomes a greater public health issue when Tomahawk flows into Delaware Lake which has a marina, campground and public swimming beach. Riffle Creek is impacted by package plants upstream in Ulsh Ditch and by contaminated sediments in the vicinity of the former Marion Engineering Depot, an army installation operated by the Army Corps of Engineers for about 19 years in the mid 1900s.

Nonpoint sources from agricultural land use include crop and livestock production. Sediment in agricultural runoff was noted in most streams, and was further aggravated in places where livestock had access and trampled the banks of the streams. The use of fertilizer on artificially drained crop land is reflected as an adverse impact in the study data for this assessment unit. Nitrates which leach through the soil, are picked up in tile drainage and flow directly into streams. Brondige Run had the highest nitrate levels in the MOWAU. Habitat degradation is noted in streams that are recovering from channelization and those that are regularly maintained. The Marion County engineer's office maintains Grave Creek, Ulsh Ditch, Bee Run, QuQua Creek, and Tomahawk Ditch. Riffle Creek and Otter Creek appear to be maintained by individual landowners in those watersheds.

Alteration of the flow, or hydromodification of the river, is observed in two dam locations. There is one low head dam adjacent to Kings Mill golf course that impounds riverine habitat for approximately ½ mile of the river upstream from Saint James Road. The second dam, Delaware Lake dam, impounds approximately 8 miles of the Olentangy River.

Table 14. Attainment Table for the Middle Olentangy Watershed Assessment Unit (MOWAU) based on data collected in 2003-2004. Data collected in 2004 is indicated by the value being in *italics*. Sites in non attainment are in **bold**. The Index of Biotic Integrity (IBI), Modified Index of well being (MIwb), and Invertebrate Community Index (ICI) are scores based on the performance of the biotic community. The Qualitative Habitat Evaluation Index (QHEI) is a measure of the ability of the physical habitat to support a biotic community. Threats to water quality identified during the course of the study are listed under Causes and Sources.

River Mile Fish/Invertebrate	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes	Sources
Olentangy River		*WWH*					
56.6[W]/58.8	*38[ns]*	*6.9**	44	*37.0*	PARTIAL	Siltation, Habitat alteration, Nutrient enrichment	Livestock in stream
54.8[W]/54.7	36[ns]	7.3*	VG	77.5	PARTIAL	Nutrient enrichment, Siltation	Lack of centralized wastewater treatment in Claridon
50.1[W]/50.3	38[ns]	8.2[ns]	48	84.5	FULL		
45.5[W]/45.5	40	8.0[ns]	52	84.5	FULL		
40.8[B]/41.0	35*	7.8[ns]	46	64.0	PARTIAL	Impounded, Siltation	Delaware Dam
Bee Run (RM 57.6)	*Undesignated / WWH Recommended*						
4.9[H]/2.4	38[ns]	NA	Low F*	33.0	PARTIAL	Siltation, nutrient enrichment Channel modifications	No buffers, historically maintained Agricultural activities
0.3[H]/0.3	38[ns]	NA	F*	59.0	PARTIAL	Siltation	
Otter Creek (RM 55.42)		*WWH*					
1.1[H]/1.1	38[ns]	NA	MG[ns]	44.0	FULL	Channel modifications	
Grave Creek (RM 45.35)		*MWH*					
3.2[H]/3.2	28	NA	P*	42.0	**NON**	Channelization, Nutrient enrichment	Maintained by County Engineer

River Mile Fish/Invertebrate	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes	Sources
Grave Creek (RM 45.35) (continued) *WWH*							
1.4[H]/1.4	31*	NA	F*	44.5	**NON**	Channelization	Marion WWTP, Maintained by County Engineer
0.8/0.1	*39[ns]*	*7.4**	48	*81.0*	PARTIAL	Nutrient enrichment	Failing septic systems
Riffle Creek (Tributary to Grave Creek RM 0.21) *MWH*							
4.4[H]/4.4	26	NA	F	34.5	FULL	Channelization, Siltation	Maintained by County Engineer
		WWH					
1.4[H]/1.4	31*	NA	MG[ns]	53.5	PARTIAL	Siltation, habitat alteration	Agricultural activities with historical channelization
QuQua Creek (RM 41.32) *MWH*							
4.6[H]/4.6	22*	NA	Low F*	29.0	**NON**	Channelization, nutrient enrichment	Marion County Petition Stream
		WWH					
0.1[H]/0.2	44	NA	F*	75.0	PARTIAL	Nutrient enrichment	
Brondige Run (RM 38.13) *WWH*							
--/0.6	--	NA	F*	73.5	**NON**	Nutrient enrichment, siltation, impounded	Agricultural activities, Delaware dam

Ecoregion Biocriteria: Eastern Corn Belt Plain

	IBI			MIwb			ICI		
Site Type	WWH	EWH	MWH	WWH	EWH	MWH	WWH	EWH	MWH
Headwaters	40	50	24				36	46	22
Wading	40	50	24	8.3	9.4	4.0	36	46	22
Boat	42	48	24	8.5	9.6	4.0	36	46	22

H - Headwater site.
W - Wading site.
B - Boat site.
a - MIwb is not applicable to headwater streams with drainage areas ≤ 20 mi^2.
b - A narrative evaluation of the qualitative sample based on attributes such as EPT taxa richness, number of sensitive taxa, and community composition was used when quantitative data was not available or considered unreliable due to sampling considerations. VP=Very Poor, P=Poor, LF=Low Fair, F=Fair, MG=Marginally Good, G=Good, VG=Very Good, E=Exceptional
c - Attainment status is given for both existing and proposed use designations.
ns - Nonsignificant departure from biocriteria (≤4 IBI or ICI units, or ≤0.5 MIwb units).
* - Indicates significant departure from applicable biocriteria (>4 IBI or ICI units, or >0.5 MIwb units). Underlined scores are in the Poor or Very Poor range.

Table 15. Violations of Ohio WQS criteria (OAC 3745-1) for chemical, physical, and bacterial parameters in the Olentangy River and tributaries (MOWAU) 2003. Plain text river miles indicate 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. Parameter units are #/100 ml for bacteria. Shaded areas are tributary streams and the river mile listed is the location of the confluence.

Waterbody	NPDES Discharge	Biological Attainment	QHEI	River Mile	Parameter	Code
Olentangy River and Tributaries (HUC 05060001-110) WWH, AWS, IWS, PCR						
		PARTIAL	40.5	58.85	*E. coli* F. coliform	a,b a,b
-Unnamed Tributary				57.80		
	United Mobile Homes WWTP					
-Bee Run				57.60		
--(RM 4.9 U)		PARTIAL	33.0			
--(RM 0.3 U)		PARTIAL	59.0			
-Otter Creek WWH, AWS, IWS, PCR				55.42		
--(RM 1.10)		FULL	44.0			
		PARTIAL	77.5	54.74	*E. coli* F. coliform	a,b a,b
	River Bend Corp. WWTP			*52.90* *52.80*		
		FULL	84.5	50.14	*E. coli* F. coliform	a,b a,b
		FULL	84.5	45.55	*E. coli* F. coliform	a,b a,b
-Grave Creek MWH, AWS, IWS, SCR				45.35		
--(RM 3.18)		NON	42.0			
	Marion Co. Sewer Dist. #7 WWTP			*3.16*		
--(RM 1.40)		PARTIAL	44.5			
WWH, AWS, IWS, SCR						

Waterbody	NPDES Discharge	Biological Attainment	QHEI	River Mile	Parameter	Code
--(RM 0.03)		FULL	76.0		*E. coli*	c
-Riffle Creek MWH, AWS, IWS, SCR				0.21		
--(RM 4.47)		FULL	34.5		*E. coli*	c
WWH, AWS, IWS, SCR						
--(RM 1.44)		NON	53.5		*E. coli*	c
-Ulsh Ditch MWH, AWS, IWS, SCR				4.50		
	Blue Willow WWTP			*4.15*		
	Verizon WWTP			*4.05*		
--(RM 2.92)						
-QuQua Creek MWH, AWS, IWS, SCR						
--(RM 5.78)					*E. coli*	c
	Marion Co. Sewer Dist. #5A WWTP			*5.50*		
--(RM 4.62)		PARTIAL	29.0		*E. coli* F. coliform	c c
WWH, AWS, IWS, PCR						
--(RM 0.12)		FULL	75.0			
		PARTIAL	57.5	40.76	*E. coli* F. coliform	a,b a,b
-Unnamed Tributary				40.41		
	Duchess WWTP					
--(RM 0.28 U)					*E. coli* F. coliform	c c
-Brondige Run WWH, AWS, IWS, PCR				38.13		
--(RM 0.60)		NON	73.5			

a violates the primary contact recreation 30 day geometric mean
b violates the primary contact recreation 30 day maximum
c violates the secondary contact recreation maximum

Table 16. Facilities regulated by an Individual NPDES permit in the MOWAU.

Facility Name	Ohio EPA Permit No.	Receiving Stream	River Mile	Wastewater Type and Treatment System
United Mobile Homes	2PY00015-001	Unnamed Tributary Olentangy River	 57.80	sanitary 30,000 gpd package plant
River Bend Corp.	2PR00189-001	Olentangy River	52.80	sanitary 5,000 gpd package plant
River Bend Corp.	2PR00189-002	Olentangy River	52.90	sanitary 7,500 gpd package plant
Marion County Sewer Dist. 7	2PJ00002-001	Grave Creek Olentangy River	3.16 45.35	sanitary 1.75 mgd oxidation ditch
Blue Willow Mobile Home Park	2PR00039-001	Ulsh Ditch Riffle Creek Grave Creek	4.15 4.50 0.21	sanitary 15,000 gpd package plant
Verizon North	2PR00115-001	Ulsh Ditch	4.05	sanitary 25,000 gpd package plant
Marion County Sewer Dist. 5A	2PG00035-001	QuQua Creek Olentangy River	5.50 41.32	sanitary 100,000 gpd package plant
Waldo Duchess	2PR00062-001	Unnamed Tributary Olentangy River	 40.41	sanitary 1,500 gpd package plant

Table 17. Facilities regulated by a General NPDES permit in the MOWAU.

Facility Name	Ohio EPA Permit Number	Receiving Stream	Description
Inland Paperboard & Packaging	2GR00393	Grave Creek	industrial stormwater
Sika Corp.	2GR00302	Grave Creek	industrial stormwater
Semco, Inc.	2GR00027	Grave Creek	industrial stormwater
Hildreth Manufacturing	2GR00467	Grave Creek	industrial stormwater
Anheuser Busch Recycling Corp.	2GG00130	Grave Creek	industrial stormwater
Vigortone Ag Products, Inc.	2GG00257	Grave Creek	industrial stormwater
Todco	2GR00267	Grave Creek Trib.	industrial stormwater
Brontel Bearing Bronze Co.	2GG00140	Riffle Creek	industrial stormwater
Jerrod Industries	2GC00126	Riffle Creek	construction stormwater
Ohio State University, Marion	2GC00207	Grave Creek	construction stormwater
BGZ Associates, Inc.	2GC00195	Grave Creek Trib.	construction stormwater
Safe Sites Environmental, Inc.	2GU00006	Grave Creek	petroleum corrective action
BP Products of N. America, Inc.	2GU00003	Tomahawk Ditch	petroleum corrective action

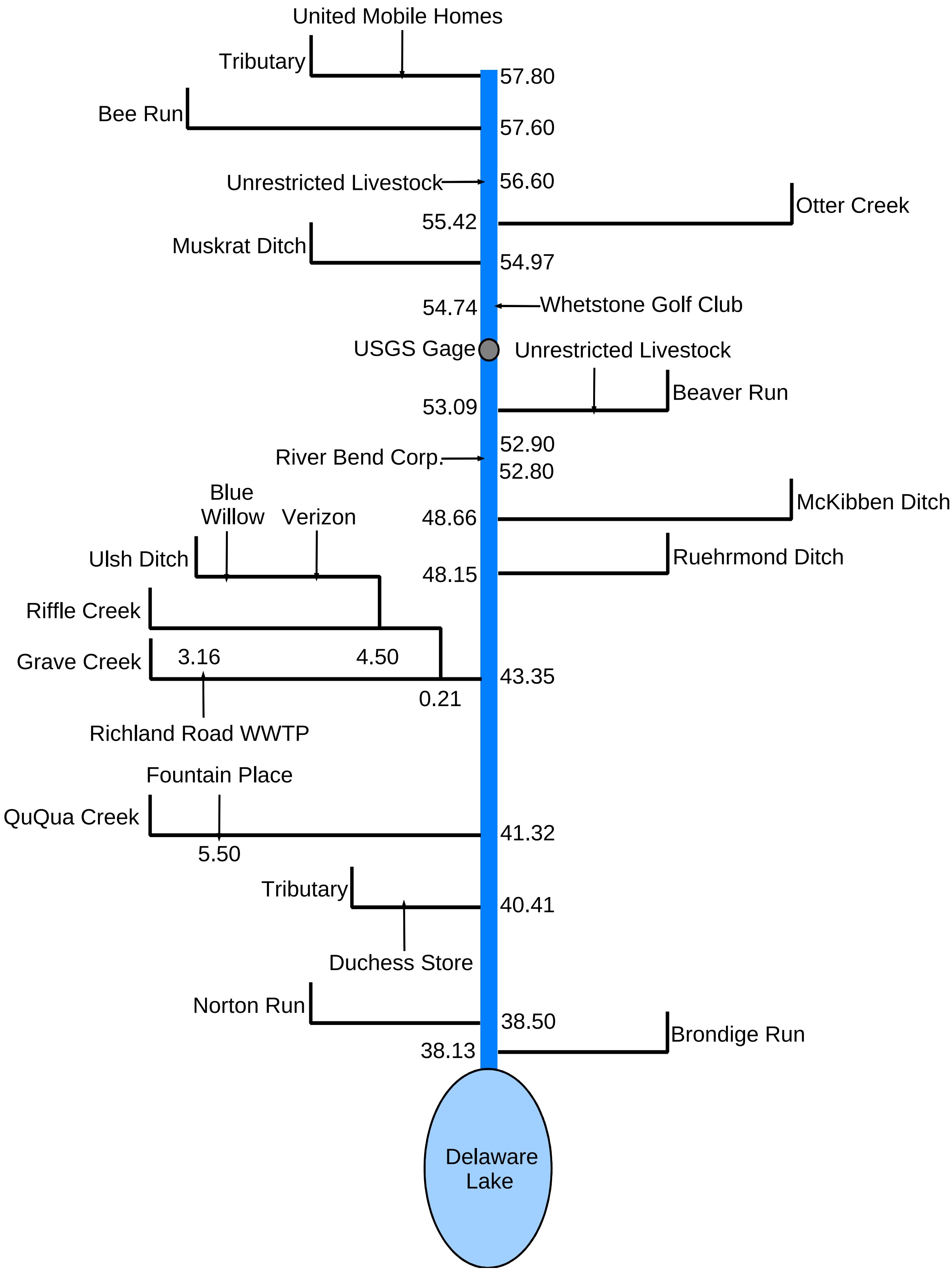


Figure 23. Schematic of the MOWAU (HUC 0506001-110).

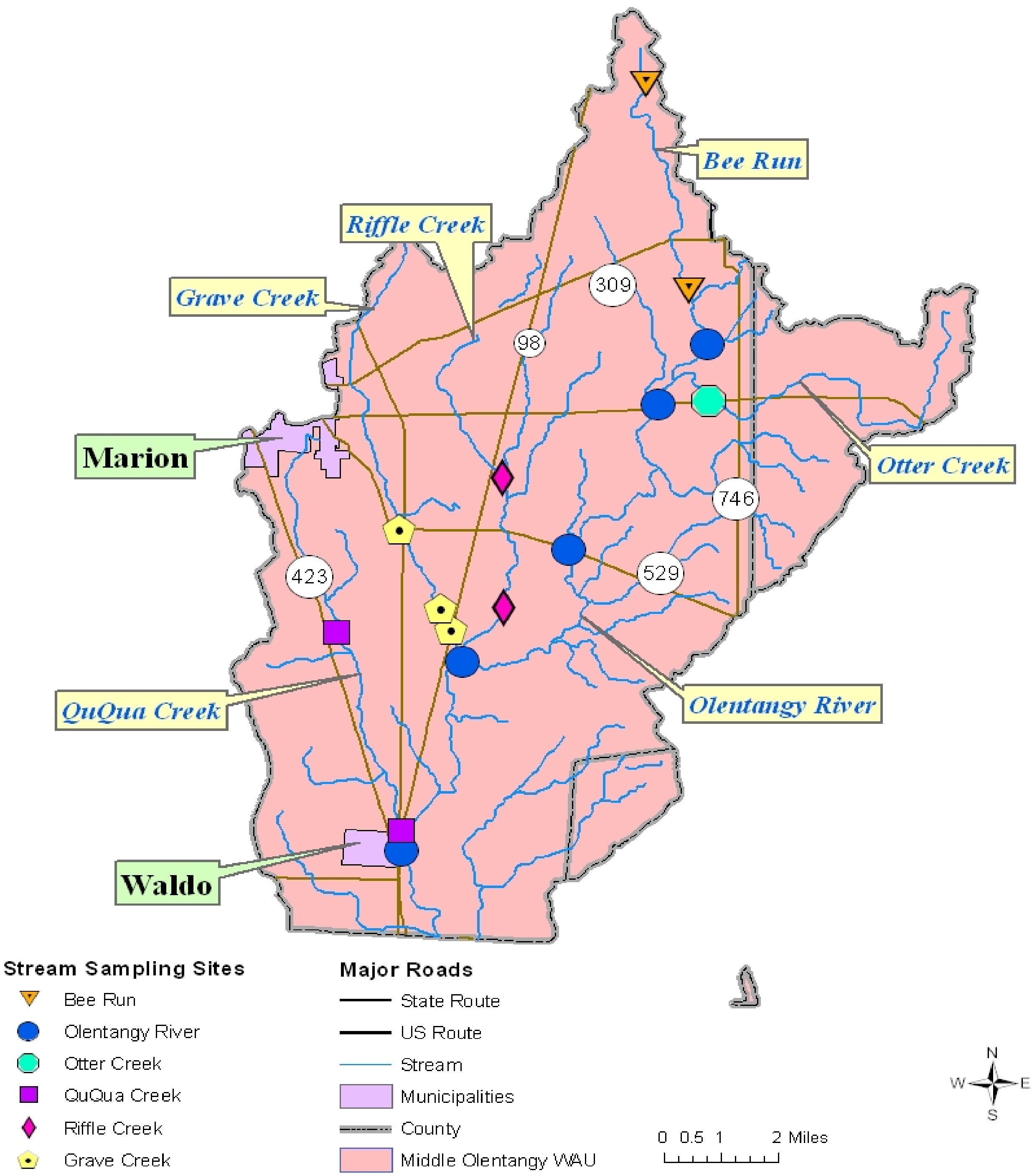


Figure 24. Biological, habitat and water quality sampling locations throughout the MOWAU, 2003-2004.

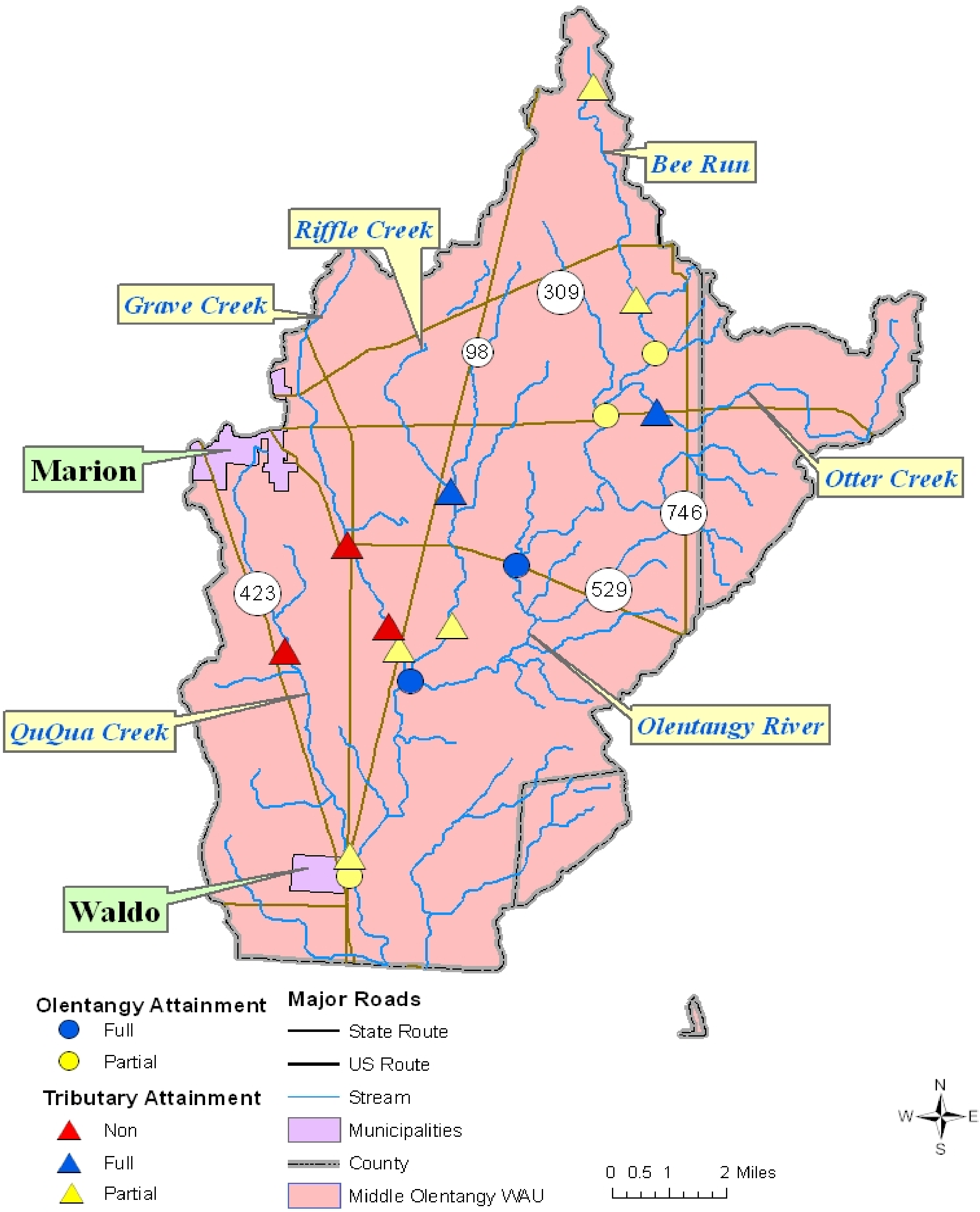
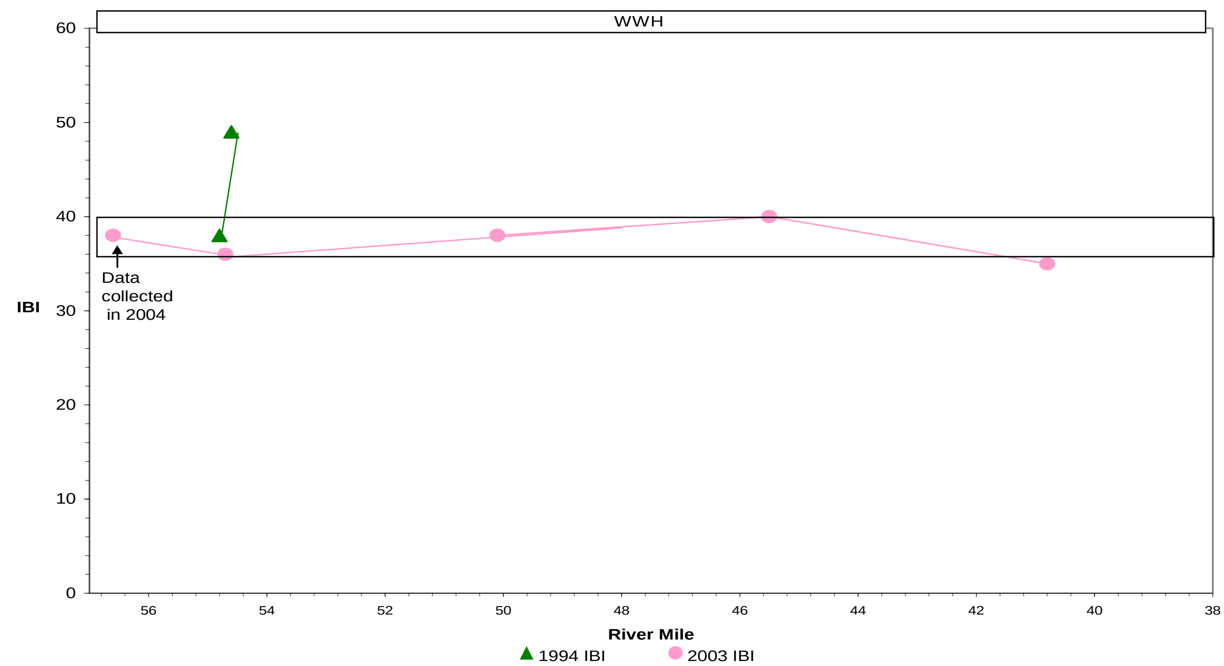


Figure 25. Attainment status of sampling locations throughout the MOWAU, 2003-2004.



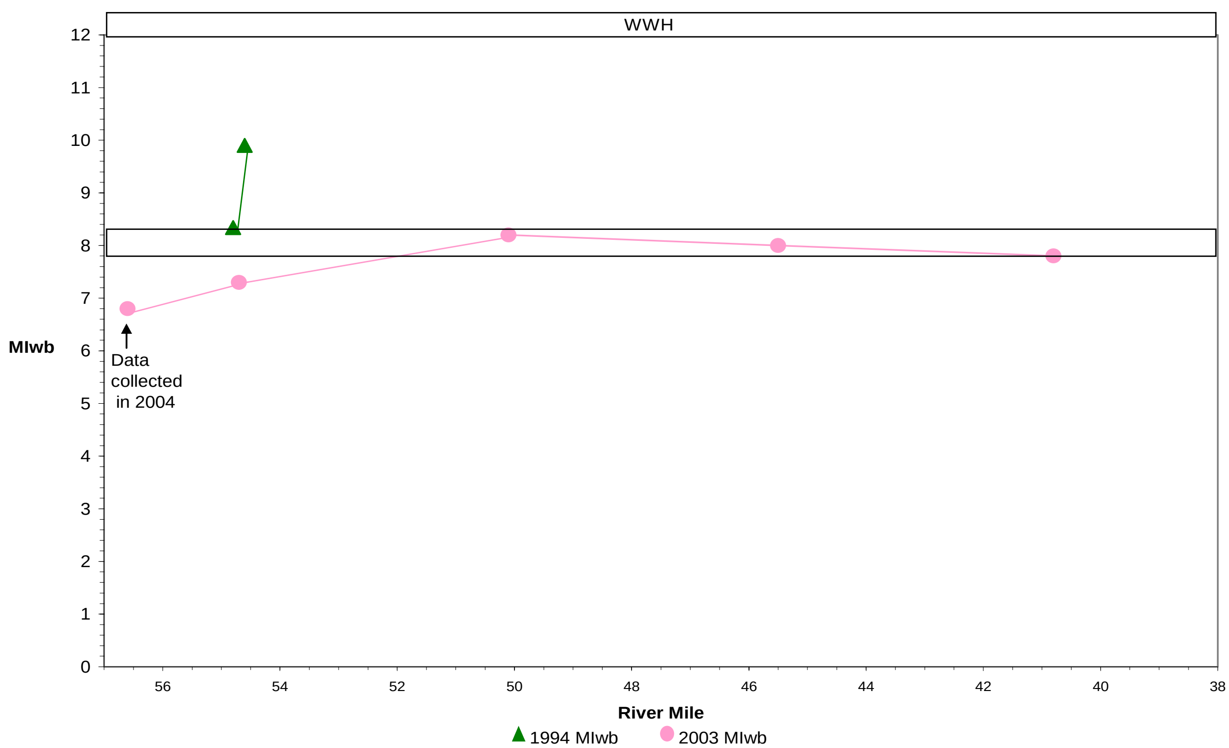


Figure 26. Longitudinal plots of IBI and MIwb for the MOWAU from 1994 and 2003.

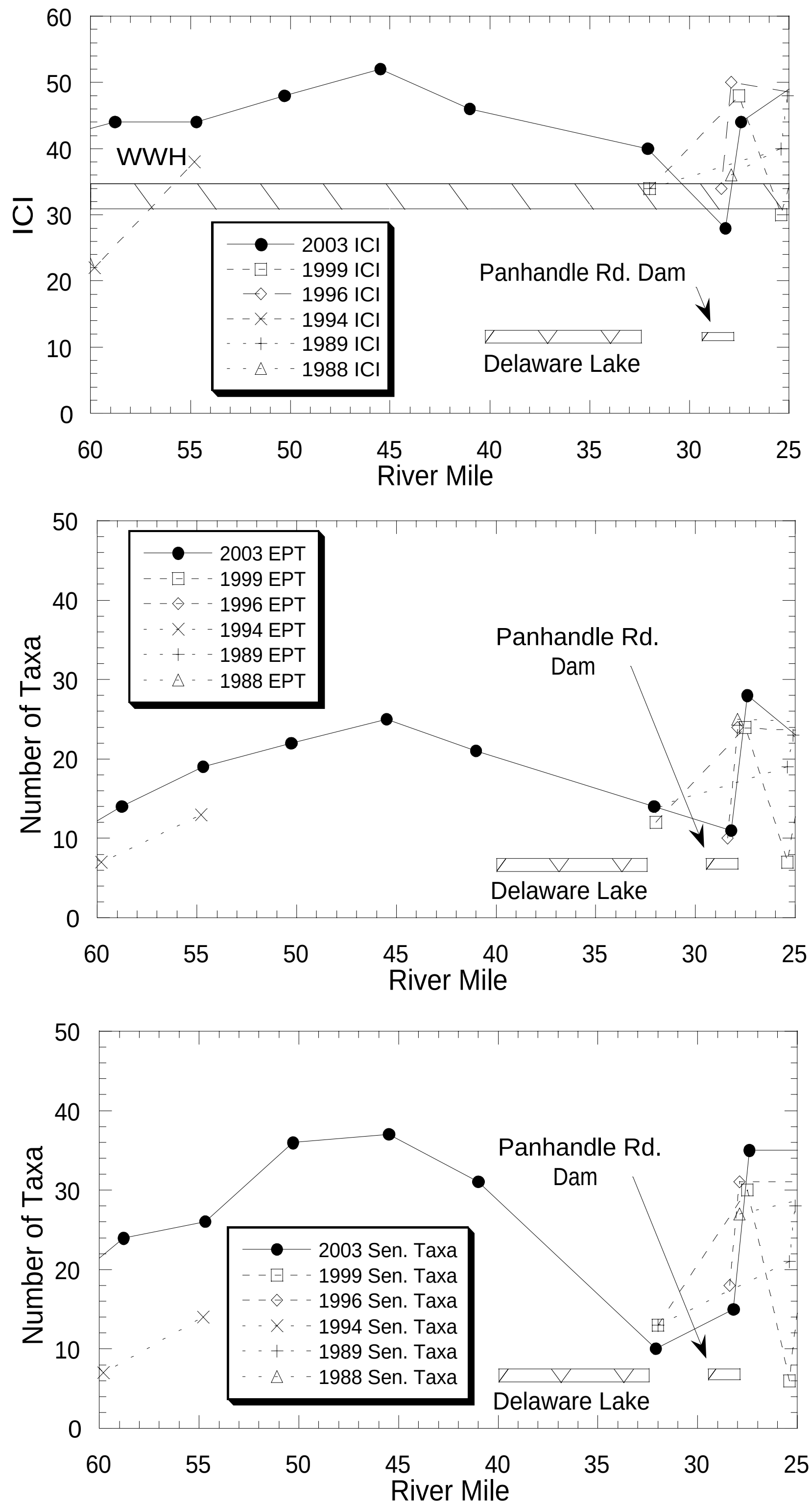


Figure 27. Longitudinal trend of the Invertebrate Community Index (ICI), total EPT, and total pollution sensitive taxa in the middle Olentangy River, 1988-2003.

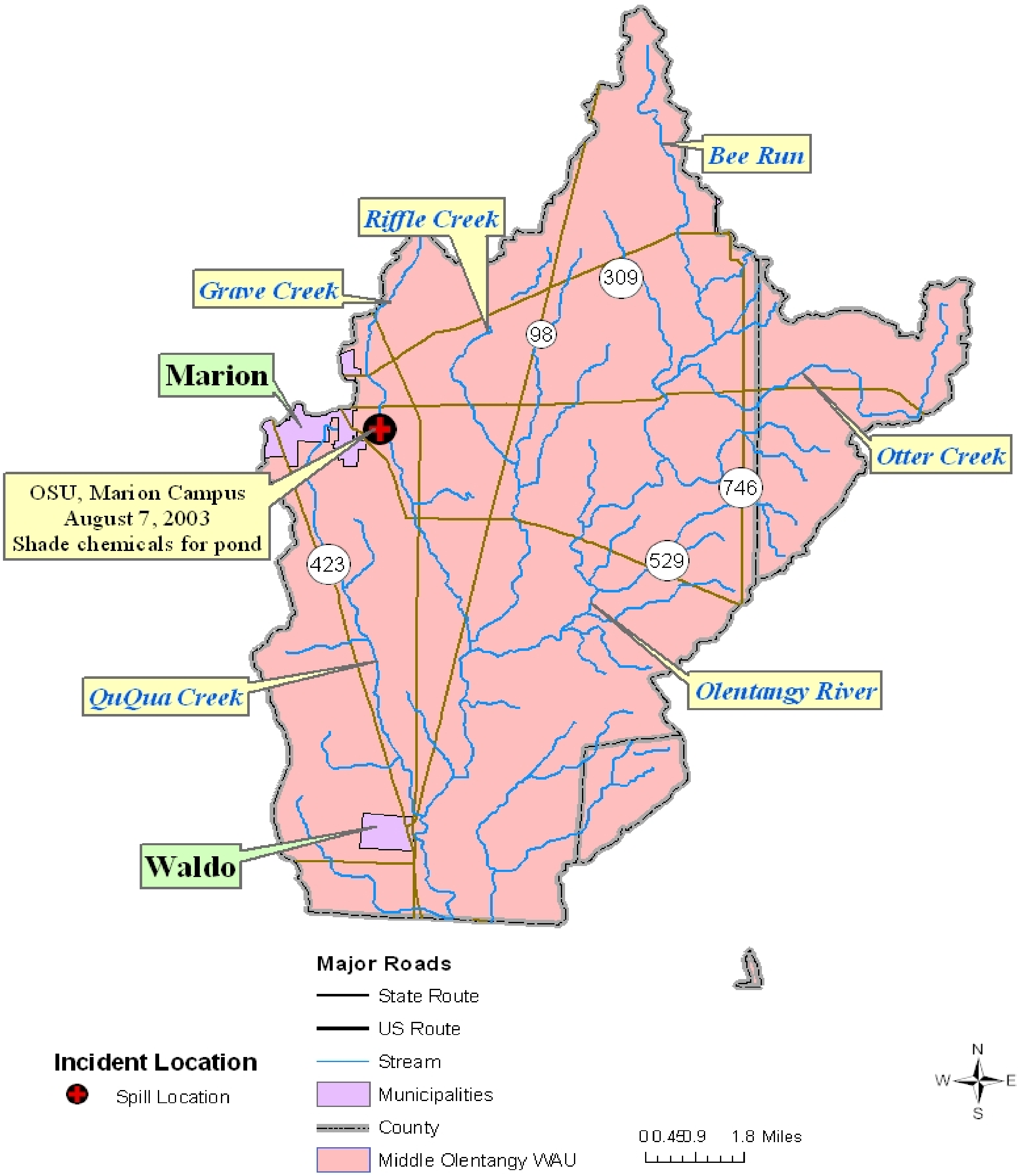


Figure 28. Spills reported to Ohio Department of Natural Resources (ODNR) from 1994-2004 for the MOWAU.

Chemical Water Quality

A schematic of the area is presented in Figure 23. Physical, chemical, and bacterial measurements were done at 18 sites. Results that violated WQS criteria codified in (OAC) Chapter 3745-1 are summarized in Table 15. Each site had at least six sets of grab samples collected at roughly two week intervals during the summer (June-August). All mainstem sites had extra bacteria samples collected in July so the recreation use could be assessed.

Biological impairment in the MOWAU was more widespread than in the UOWAU. While the Olentangy River mainstem showed improvement, all of the tributaries except Otter Creek had some degree of impairment. The most common cause of water quality impairment was nutrient enrichment. In most instances, habitat and flow conditions were not sufficient to overcome the impairment. Recreation use impairment was widespread because of elevated bacteria levels.

The same causes of impairment were consistently identified throughout the MOWAU. These included habitat and flow alterations, excessive nutrients, siltation, and bacterial contamination. The main sources of impairment were hydromodification (channelization and removal of riparian vegetation), crop and livestock production, point sources, and home sewage systems. Point sources located in the watershed are listed by Individual NPDES permit in Table 16 and General NPDES permit in Table 17. Those that have a significant impact are discussed in the text.

Many streams in the MOWAU were channelized in the past to facilitate drainage in crop production areas. Some are under petition and maintained by the county, including Grave Creek and QuQua Creek. Streams under maintenance or those considered to have little chance for recovery after being assessed in the field are usually designated as MWH. The Ohio EPA has found that many of these ditches do not even attain the MWH criteria codified in OAC 3745-1. While the need to drain agricultural land to maximize crop yields is important it does not justify ignoring Clean Water Act goals. It might be necessary to consider different methods for facilitating drainage in the future. Natural and two stage channel designs address both water quality and water quantity concerns by facilitating drainage in a self-maintaining channel and providing better habitat conditions and consequently increasing assimilation of pollution, thereby improving chances of attainment.

Nitrate-nitrite levels in tributary streams within the MOWAU are considerably higher than those within the UOWAU. The median value in the MOWAU was 5.16 mg/l (n=72), with a maximum of 16.6 mg/l and the median value in the UOWAU was 2.31 mg/l (n=72), with a maximum of 8.80 mg/l. This can probably be attributed to drainage practices in crop production areas. Traditional techniques designed to quickly remove water after a storm (e.g., tile drainage for fields) result in higher levels of nitrate because it passes easily through soil.

Several streams in the MOWAU had strontium concentrations detected above tier II aquatic life values established for the Ohio River basin (OAC 3745-1-34). These values are not adopted as criteria and are considered guidelines only because little information is available about the toxicity of strontium. A total of 48 of 105 values (46%) exceeded the outside mixing zone average.

Olentangy River

The middle segment of the Olentangy River begins below the confluence of Flat Run (RM 59.28) and ends below the confluence of Brondige Run (RM 38.13) and drains a total of about 250 mi^2. It is designated as WWH and PCR based on the results of a previous field assessment. Most land in the watershed is used for crop and livestock production except for a few residential areas and some scattered woodlots. The City of Marion is the largest urban area present and has a population of about 38,600, although a large part drains into the Scioto River watershed. A total of 5 sites were sampled to evaluate biological, chemical, and bacterial conditions.

Recreational use attainment was assessed by using fecal coliform and *E. coli* as test organisms. Their presence indicated that the water had been contaminated with feces from warm blooded animals. Counts are reported in colony forming units (CFU)/100 ml. To determine if criteria codified in OAC 3745-1-07 are met a minimum of five samples must be collected within any 30 day period during the recreation season (May 1-October 15). Rules for PCR state that the fecal coliform geometric mean should not exceed 1000 and not more than 10% of the samples should exceed 2000 cfu/100ml and that the *E. coli* geometric mean should not exceed 126 cfu/100ml and not more than 10% of the samples should exceed 298 cfu/100ml.

Water contaminated with feces can potentially contain many different types of disease causing bacteria and viruses. People can be exposed to these pathogens while wading, swimming, skiing, canoeing, and fishing. Reactions can range from an isolated illness such as a skin rash, sore throat, or ear infection to a more serious 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 hepatitis A and encephalitis. Disease causing microorganisms such as cryptosporidium and giardia are also a concern.

Recreation impairment was documented for the entire segment. Counts for both test organisms violated their respective geometric mean and maximum values at all five sites (Table 15). Fecal coliform results are summarized for the July 9-August 6, 2003 use evaluation period (Figure 29) and for the June 4-September 4, 2003 field season (Figure 30). There is not much variation in geometric mean values from site to site. The geometric means are slightly less when computed over the field season, but the pattern is the same. Counts were considerably higher after rain events, suggesting a nonpoint influence.

The main sources of recreation impairment are package plants, home sewage systems, and livestock. Ditching practices in the area have also reduced the capacity of these streams to assimilate waste loads. The package plant at United Mobile Homes has a history of poor operation and permit violations. This facility discharges to an unnamed tributary confluent with the Olentangy River at RM 57.80. Failed home sewage systems are a known problem in Waldo and are discussed in more detail under Tomahawk Ditch. Other areas served by home sewage systems that might be a problem include the villages of Climax and Denmark. Livestock manure contributes to the bacteria load in areas susceptible to runoff from pastures or where it is land applied as a crop fertilizer. Livestock that cross streams to access pastures or use them for watering is a significant issue. This activity was noted in the Olentangy River at Roberts Road (RM 56.60) and in Beaver Run at Salem Road (RM 1.00).

In addition to recreational impairment, biological impairment was documented in the upper end of the segment, but full biological attainment was met prior to where the river is impounded by Delaware Lake. The main causes of aquatic life impairment are nutrients, siltation, and habitat and flow alteration. No violations were documented for dissolved oxygen, probably because mitigating factors like good habitat, flow, and a fairly intact tree canopy mask the enrichment impact by improving the assimilation of nutrients. This parameter is considered threatened because the loss of one of these factors could trigger a violation.

Concentrations of phosphorus (Figure 31) and nitrate-nitrite (Figure 32) in this segment were consistently above background. Although levels at the upper end were close to background values, substantial increases occurred between State Route 95 (RM 54.74) and State Route 529 (RM 50.14). The median total phosphorus value increased from 0.12 to 0.19 mg/l and the median nitrate-nitrite value increased from 2.68 to 4.01 mg/l. Sources in this reach include package WWTPs, home sewage treatment systems, and crop and livestock production areas. The Whetstone Golf Club and River Bend Corporation both have package WWTPs that discharge to the river on a seasonal basis. The plant serving the golf club is just downstream from the State Route 95 bridge and is not under permit, so no information is available regarding its performance. The golf club also diverts water from the river for irrigation purposes and it is likely that any runoff contains nutrients from fertilizer applications. River Bend Corporation is a campground and recreation area open from April through October and the resort operates two package WWTPs. The north plant (outfall 002) discharges to the Olentangy River at RM 52.90 and the south plant (outfall 001) discharges at RM 52.80. During the 2003 season, the north plant violated NPDES permit limits for ammonia in July and the south plant violated fecal coliform limits in July and September.

The Village of Claridon borders the Olentangy River at State Route 95. Individual home sewage treatment systems are used here since central sewage collection and treatment is not provided. The operating efficiency and maintenance condition of these systems is unknown. Marion County recently extended a sanitary sewer line from the Richland

Road WWTP to serve the new River Valley High School and Middle School complex. This is only about 1 mile west of the village, so it would be feasible to extend this line to Claridon and eliminate these systems. There are also many homes along Whetstone River Road in rural Claridon Township with property adjacent to the river that may have problems.

Much of the land adjacent to the river in this segment is used for crop production. The cultivation of land makes it more susceptible to erosion and subsequently leads to siltation problems in the river. This is especially true after heavy rains in areas that lack a riparian buffer and where conservation tillage is not employed. This erosion contributes to nutrient enrichment as well because phosphorus contained in fertilizer tends to attach to soil particles. Field tile drainage also leads to nutrient enrichment because nitrate passes easily through soil into the water table. Another source of impairment is livestock with unrestricted access to streams. Their movements damage habitat and destabilize banks, making them more susceptible to erosion. These animals also introduce organic matter, nutrients, and pathogens to the water. Cattle were observed wading in the Olentangy River at Roberts Road (RM 56.60) and in Beaver Run at Salem Road (RM 1.00). The land adjacent to both of these streams is used as pasture. Beaver Run is confluent with the Olentangy River at RM 53.09 and this is the area where a spike in nutrient levels was documented. Sources like this can be eliminated by excluding livestock with a system of fences and man made crossings if needed. If the stream is used for livestock watering it can be replaced with an upland watering system. These types of “best management practices” are eligible for Section 319 grant funds.

Levels of suspended solids in this segment were consistently above background (Figure 33). The background concentration was established using the median value determined from samples collected at reference sites in the ECBP ecoregion. This value was 14 mg/l for wadeable streams and 28 mg/l for small rivers (Ohio EPA, 1999). The median values at individual sites ranged from 38 to 58 mg/l, so the impairment was fairly consistent from site to site. Very high concentrations were documented in samples collected during floods in July, with a maximum of 386 mg/l. This suggests that the majority of suspended matter enters the river during these high flow events due to bank and bed erosion in areas without riparian corridors. A negative impact on aquatic life from siltation would be expected under the present conditions. The settling of suspended particles fills the interstitial spaces between larger rocks and thereby reduces the diversity of available habitat.

There are several areas where habitat and flow alteration affect conditions in this segment. Most riparian vegetation has been removed between Roberts Road (RM 56.60) and the confluence of Bee Run (RM 57.60) and it appears that the river channel might have been straightened along this reach. There is a low head dam at RM 45.68 just above Saint James Road and adjacent to the Kings Mill golf course. The pool created by this dam impounds about ½ mile of the river. The Delaware Lake dam has a much greater influence on the Olentangy River. The dam is located at RM 32.30 and the headwaters of the lake extend to about State Route 229 (RM 38.40), but the river is still impounded as far upstream as Waldo Fulton Road (RM 40.76).

Bee Run

Bee Run drains an area of about 7 mi^2 and confluences with the Olentangy River at RM 57.60. It does not have assigned use designations, but WWH is recommended based on results of the 2003 survey. Most land in this small watershed is used for crop production and the stream was channelized in the past, a fact reflected in the low QHEI score of 33.0 in the modified section.

Otter Creek

Otter Creek drains an area of about 9 mi^2 and confluences with the Olentangy River at RM 55.42. It was assigned WWH and PCR uses in 1978 that were not based on the results of a field assessment. Most land in the watershed is used for crop production and the stream was channelized, a fact reflected in the low QHEI score of 44.0. It is not maintained by the county, but might be maintained by individual landowners. A wooded riparian corridor is present in the lower 2 miles of stream, but above this point there is virtually no buffer. The Village of Denmark is in the headwaters and sewage is treated by individual home systems.

A site was sampled at State Route 95 (RM 1.10) to evaluate aquatic life and water quality conditions and it was found to be in full attainment of the biological criteria. Water quality was generally good, but elevated nutrient concentrations and bacteria counts are a concern. Total phosphorus surpassed background reference conditions in 4 of 6 samples with concentrations ranging from 0.04-0.11 mg/l (Figure 34). A wooded floodplain present in the lower 2 miles of stream likely sequesters some phosphorus by promoting the settling of sediments during high water conditions. The median nitrate-nitrite concentration of 6.22 mg/l was the fourth highest of twelve tributary sites tested within the MOWAU (Figure 35). Fecal coliform values ranged from 300-3,000 cfu/100 ml and *E. coli* levels ranged from 30->2,200 cfu/100 ml.

Grave Creek

Grave Creek drains an area of about 29 mi^2 and is confluent with the Olentangy River at RM 45.35. It was petitioned and channelized in 1969 and is maintained by the Marion County Engineers from Firstenberger Road (RM 1.40) to its origin at Likens Road (RM 9.4). It was partially rerouted to accommodate the expansion of a Wal-Mart store at 1546 Marion Mt. Gilead Road, Marion, OH. It is designated as WWH from the mouth (RM 0.0) to about 1 mile above Firstenberger Road (RM 2.4) and MWH above that point. The entire length is designated as SCR because it is shallow. Most land in the watershed is used for crop production except for areas within the Marion municipal limits. The Marion sewage collection system has a lift station and bypass that overflows to Grave Creek at State Route 95 (RM 5.6). Cross connections between the sanitary and storm sewers are suspected in this area too. The Marion County Sewer Dist. 7 WWTP (a.k.a. Richland Road) discharges to Grave Creek at RM 3.16.

Three sites were sampled to evaluate aquatic life and water quality conditions. The site at State Route 529 (RM 3.18) was in non attainment of the MWH biological criteria and the site at Firstenberger Road (RM 1.40) was in non attainment of the WWH biological criteria. The site at Whetstone River Road (RM 0.03) was in full attainment of the WWH biological criteria. This is an improvement from 1994 when organic enrichment and nutrients from the Richland Road WWTP caused impairment. Based on an evaluation of the bacteria data the SCR use is not impaired anywhere within this stream.

The causes of impairment in Grave Creek are habitat and related flow alteration and nutrient enrichment. The main sources are hydromodification, crop production, and the Richland Road WWTP. The effects of channelization and removal of riparian vegetation are reflected in the QHEI scores. In general, sites with scores >60 are able to meet WWH criteria and sites with scores >45 are able to meet MWH criteria. Scores in the maintained section were 42.0 at State Route 529 (RM 3.18) and 44.5 at Firstenberger Road (RM 1.40). In the natural section at Whetstone River Road (RM 0.03) the score was 76.0.

The Richland Road WWTP was originally constructed in 1973 as an activated sludge system. Due to rapid development in the service area and excessive infiltration and inflow in the collection system, the plant eventually became over loaded. This resulted in frequent permit violations and excessive organic and nutrient enrichment in Grave Creek downstream of the discharge. The plant was replaced with the present system in 1995. It consists of manual and mechanical bar screens, a grit chamber, Orbal oxidation ditch aeration tank, secondary settling tanks, chlorination, and de-chlorination. Sludge is treated by a series of aerobic digesters and gravity thickeners, de-watered with a belt press, and stored for land application. The plant is designed to treat 1.75 MGD and has a peak hydraulic capacity of 4.0 MGD. The collection system consists of 100% separate sewers and has 1 lift station with no bypass or overflow.

Effluent samples collected by Ohio EPA and self monitoring data submitted by the facility during the study period were evaluated for permit compliance. No violations were documented and many results were actually below reporting limits. Self monitoring data summarized in the Liquid Effluents Analysis Processing System (LEAPS) was used to evaluate pollutant loading trends. Annual discharge rates for phosphorus and $cBOD_5$ are displayed in Figures 36 and 37, respectively. There is a significant reduction in organic pollutant loadings after the plant upgrade in 1995. Rates have remained relatively stable even though the hydraulic load has increased substantially in recent years due to sewer extensions. Bioassay testing completed by the Ohio EPA over the years to evaluate toxicity has had mixed results. There was 100% *Ceriodaphnia dubia* mortality in all effluents and in the Grave Creek mixing zone in February 1999, but subsequent tests done in March 1999 and March and April 2004 had no acute toxicity.

Nutrient enrichment is a problem in Grave Creek because it is difficult for a modified stream with such a small drainage area to assimilate a large volume of wastewater.

There are no permit limits for phosphorus at the Richland Road WWTP because it is in the Ohio River drainage basin. Results from Ohio EPA tests indicate that the 1.0 mg/l level was exceeded in 2 of 6 samples. The phosphorus target in Grave Creek was surpassed in 11 of 12 samples collected in the WWH segment.

Riffle Creek

Riffle Creek drains an area of about 18 mi^2 and is confluent with Grave Creek at RM 0.21. Much of the headwaters were channelized in 1946 and even though it is not maintained by the county, it is slow to recover because of low gradient and landowner maintenance. It is designated as WWH from the mouth (RM 0.0) to about ½ mile below Marion Edison Road (RM 4.0) and MWH above this point. The entire length is designated as SCR because it is too shallow for full body contact. Most land in the watershed is used for crop production except for the Marion Industrial Complex located in the headwaters. This area is now used mainly for warehouse storage, but it was the location of the former Marion Engineering Depot. This depot operated as a military installation for about 19 years and was used to handle and store heavy engineering equipment. The compound trichloroethylene was used as a solvent to de-grease metal parts here and resulted in some soil contamination.

Two sites were sampled to evaluate aquatic life and water quality conditions. The site at Marion Edison Road (RM 4.47) was considered in full attainment of the MWH biological criteria and the site at Firstenberger Road (RM 1.44) was considered in non attainment of the WWH biological criteria. The sources of impairment include hydromodification, crop production, and package WWTPs in Ulsh Ditch. Nitrate-nitrite values surpassed the target values in almost all instances, while elevated phosphorus concentrations were confined to the WWH segment. The source of these nutrients was probably a combination of runoff from crop production areas and wastewater effluent discharged to Ulsh Ditch.

Contaminated sediments are a concern in Riffle Creek based on sampling conducted in 1998 (Ohio EPA 2000, Technical Report MAS/1999-12-6). Elevated concentrations of metals and polynuclear aromatic hydrocarbons (PAH) were documented, especially in the upper reaches. The source of these contaminants is probably the former Marion Engineering Depot. After the depot ceased operation part of the property was sold and used as a building site for River Valley Schools. This complex was eventually closed amidst concerns for the health of its students. Some of this property was scheduled to undergo a cleanup starting in January 2005. This U.S. Army Corps of Engineers project removed about 9,500 cubic yards of contaminated soil and was completed during the summer of 2005. Additional portions of the Marion Engineering Depot south of the River Valley schools is scheduled for clean-up by the Army Reserves in late 2005 – early 2006.

Ulsh Ditch

Ulsh Ditch drains an area of about 3 mi^2 and is confluent with Riffle Creek at RM 4.50. It was channelized in the 1940's and is maintained by the Marion County Engineers. The stream is a sub-surface pipe above Marion-Williamsport Road (RM 4.2). It is designated as MWH and SCR based on the results of a previous survey. Land in the watershed is used mostly for crop and livestock production, but some is used for commercial and residential purposes. The Blue Willow mobile home park and Verizon business complex have package WWTPs that discharge at RM 4.15 and 4.05, respectively.

A site was evaluated at Roberts Road (RM 2.92) to test water quality conditions and any potential impact from the two package WWTPs. The plants appear to be functioning as designed based on discharge data (BOD_5, ammonia, suspended solids, and bacterial levels). Most of the ditch is clogged with aquatic vegetation because of nutrient enrichment exacerbated by channelization and the open canopy.

QuQua Creek

QuQua Creek drains an area of about 17 mi^2 and conlfuences with the Olentangy River at RM 41.32. It was petitioned and channelized in 1949 and is maintained by the Marion County Engineers from Newmans Cardington Road (RM 2.8) to its origin. Consequently, it is designated as WWH and PCR from the mouth (RM 0.0) to about 1 mile below Owens Road (RM 3.7) and MWH and SCR above that point. Land use is predominantly crop production except for areas within the Marion municipal limits. The Marion County Sewer District 5A WWTP (a.k.a. Fountain Place) discharges at RM 5.50. This is a 100,000 gal/day package plant that serves a mobile home park.

Two sites were sampled to evaluate aquatic life and water quality conditions. The site at Owens Road (RM 4.62) was considered in non attainment of the MWH biological criteria and the site at State Route 98 (RM 0.12) was considered in partial attainment of the WWH biological criteria. The sources of impairment include hydromodification, crop production, and the Fountain Place WWTP. QuQua Creek was hydromodified again in 2003, a fact reflected in the QHEI score of 29.0 at Owens Road (RM 4.62). A score of 41.5 was obtained when habitat was evaluated at this site in 1998 (Ohio EPA Technical Report MAS/1999-12-6). In contrast, the site at State Route 98 (RM 0.12) had a QHEI score of 75.0, an area that did not receive attentions of the county backhoe. Additional water quality testing was done at Somerlot Hoffman Road (RM 5.78) to evaluate the Fountain Place WWTP. Based on BOD_5 measurements, the plant does not promote organic enrichment in the creek, although there was evidence of modest nutrient enrichment. The median phosphorus concentration of 0.18 mg/l was the third highest of twelve tributary sites tested within the MOWAU (Figure 34). An increase in bacterial concentrations indicated that there might be a problem with disinfection at this facility. The median fecal coliform count increased from 1,400 to 1850 cfu/100 ml and the median Escherichia coliform count increased from 805 to 1,000 cfu/100 ml.

Tomahawk Ditch

Tomahawk Ditch drains an area of about 2 mi^2 and is confluent with the Olentangy River at RM 40.41. It does not have assigned use designations because it is not named on any topographic maps and consequently was never listed in the Ohio water quality standards. The headwaters are sub-surface tile and maintained by the Marion County Engineers.

A site was sampled at US Route 23 (RM 0.38) in the Village of Waldo to evaluate water quality conditions and determine if a public health nuisance exists because of poorly treated sewage. Waldo is a community with a population of about 350 located in southern Marion County. Home sewage treatment systems are used because municipal sewage collection and treatment is not provided by the village. Many of these systems are old and have been illegally connected to storm sewers to prevent sewage from backing up in yards and basements. Replacement of these failed systems is often not a viable option because of small lot sizes and poorly drained soils. This problem has been an issue between the village, Ohio EPA, and the Marion County Health Department since the mid-1970's. In November 2005, Director's Final Findings and Orders were issued to the Village of Waldo requiring them to determine the most feasible way to correct the unsanitary conditions in Tomahawk Ditch. The plan must be completed within 18 months and may include, but is not limited to, building a centralized wastewater treatment system, connecting to existing sewers and directing the sewage flow to the nearest regional treatment plant, utilizing land application for wastewater disposal, constructing controlled discharge lagoons or limiting the discharge by using constructed wetlands.

A public health nuisance was documented in Tomahawk Ditch based on criteria codified in OAC 3745-1-04 (F). Fecal coliform levels ranged from 3,900-27,000 cfu/100 ml and *E. coli* levels ranged from 700->10,000 cfu/100 ml. Concentrations of ammonia, nitrate-nitrite, and phosphorus were also high enough to cause concern for aquatic life. The median concentrations for both phosphorus and nitrate-nitrite were the highest of twelve tributary sites tested in the MOWAU (Figures 34 and 35, respectively). Nitrate-nitrite was detected as high as 13.9 mg/l and phosphorus ranged from 0.22-0.77 mg/l. A septic odor was often noticed here too, a characteristic of anaerobic decomposition of organic matter that produces hydrogen sulfide gas.

This problem is more than just a local health issue because Tomahawk Ditch flows into Delaware Lake. Delaware State Park is located here and services provided include a marina, campground, and public swimming beach. The park is required to monitor bacteria concentrations at the beach during the recreation season. These must fall below bathing water criteria codified in OAC 3745-1-07, Table 7-13.

Brondige Run

Brondige Run drains an area of about 12 mi^2 and is confluent with the Olentangy River at RM 38.13. The existing WWH and PCR use designations were assigned in 1978 and are not based on the results of a field assessment. Land in the watershed is used mostly for crop production except for the portion that lies within the Delaware State Park Wildlife Area.

A site was sampled at State Route 229 (RM 0.60) to evaluate aquatic life and water quality conditions. This reach was in non attainment of the biological criteria. The sources of impairment include extensive hydromodification in the headwaters, the Delaware Lake flood pool at the mouth, and crop production. Water quality was generally good except for a problem with nutrient enrichment. Brondige Run had the highest maximum nitrate-nitrite concentration measured in the MOWAU of 16.6 mg/l. The median value of 6.30 mg/l was the third highest of twelve tributary sites (Figure 35) and 5 of 6 results surpassed background reference conditions. This indicated pollution from field tile drainage and fertilizer runoff. Total phosphorus concentrations were less problematic however, 4 of 6 results still surpassed background conditions and concentrations ranged from 0.06-0.21 mg/l (Figure 34). The wooded floodplain present in the lower 2.5 miles of stream probably assimilates a considerable amount of phosphorus laden sediment.

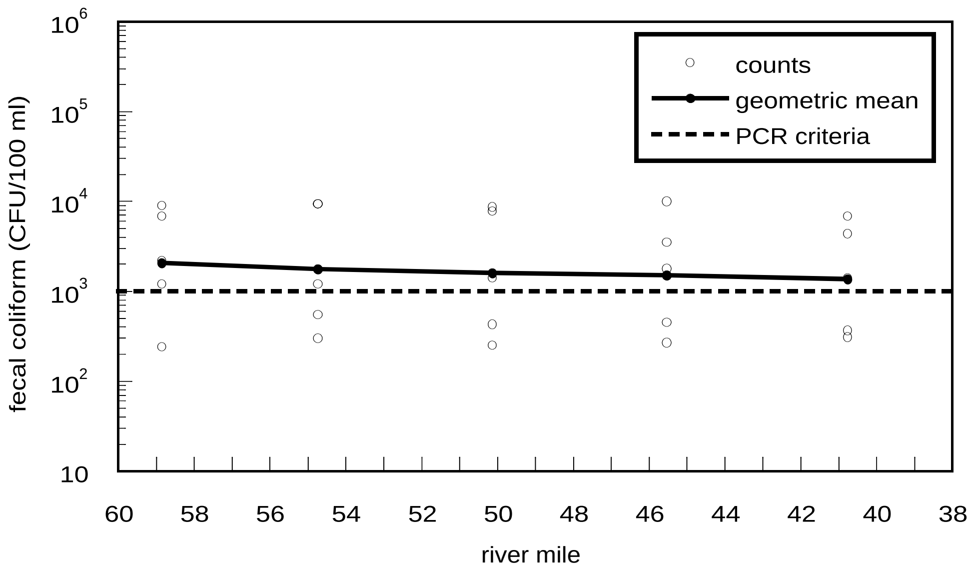


Figure 29. Fecal coliform counts in the middle Olentangy River in 2003 during the 30 day recreation use assessment period (July 9-August 6) plotted against the primary contact recreation criterion.

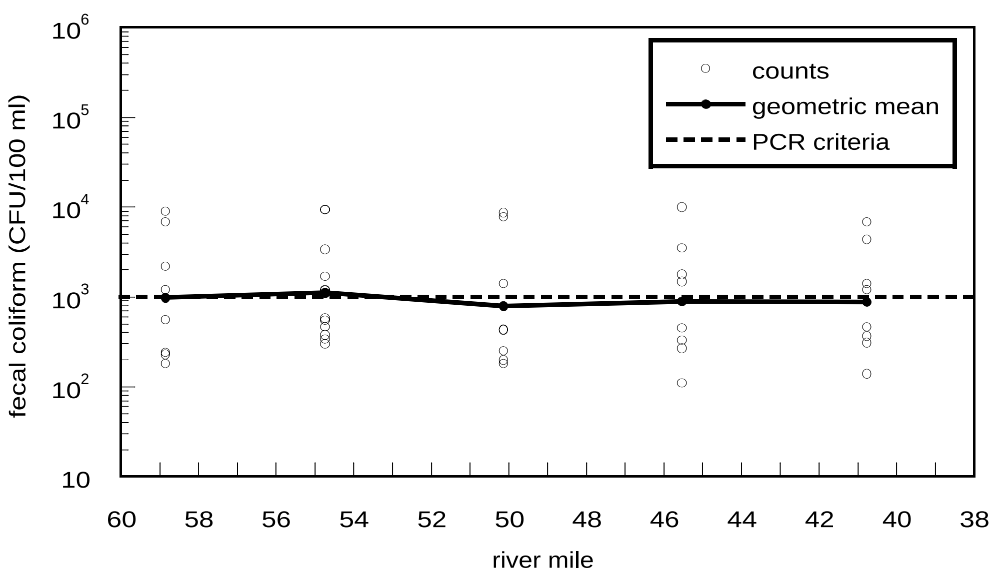


Figure 30. Fecal coliform counts in the middle Olentangy River in 2003 during the entire field season (June 2-September 4) plotted against the primary contact recreation criterion.

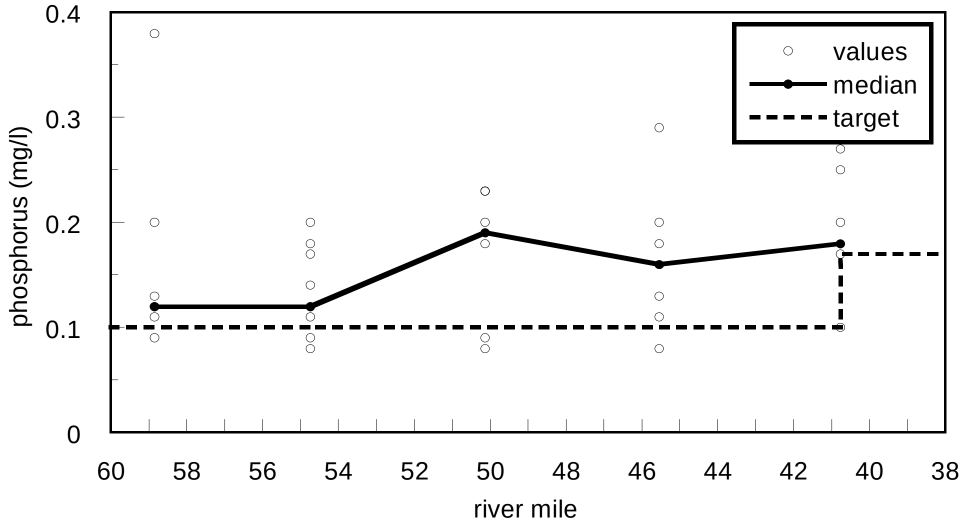


Figure 31. Phosphorus concentrations in the middle Olentangy River in 2003 plotted against the target level. The target increases from 0.10 to 0.17 mg/l at the transition from a wadeable stream to a small river (RM 40.76).

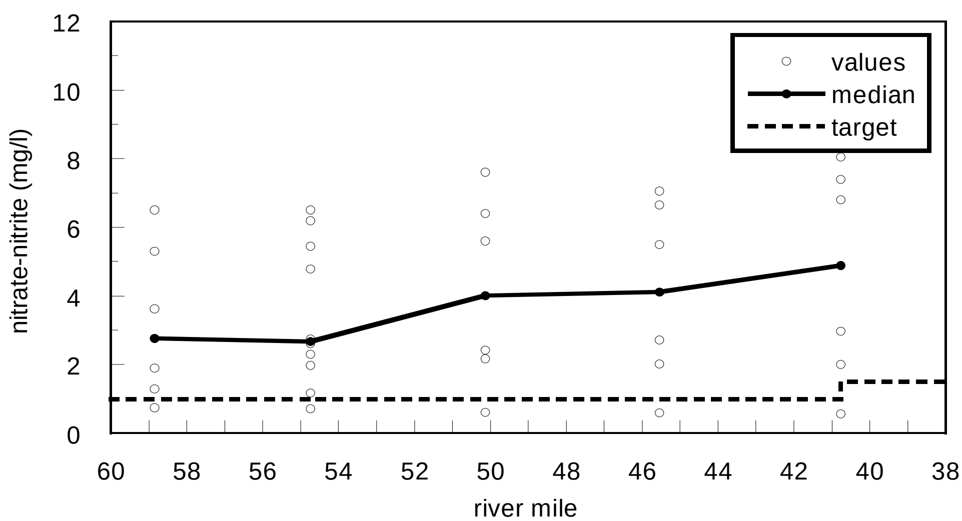


Figure 32. Nitrate-nitrite concentrations in the middle Olentangy River in 2003 plotted against the target level. The target increases from 1.00 to 1.50 mg/l at the transition from a wadeable stream to a small river (RM 40.76).

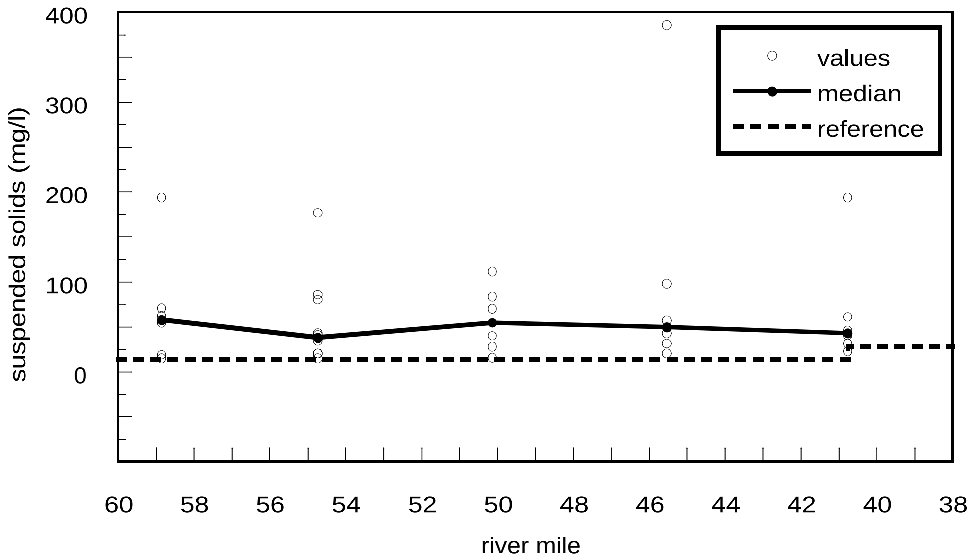


Figure 33. Suspended solids concentration in the middle Olentangy River in 2003 plotted against the background value. Background increases from 14 to 28 mg/l at the transition from a wadeable stream to a small river (RM 40.76).

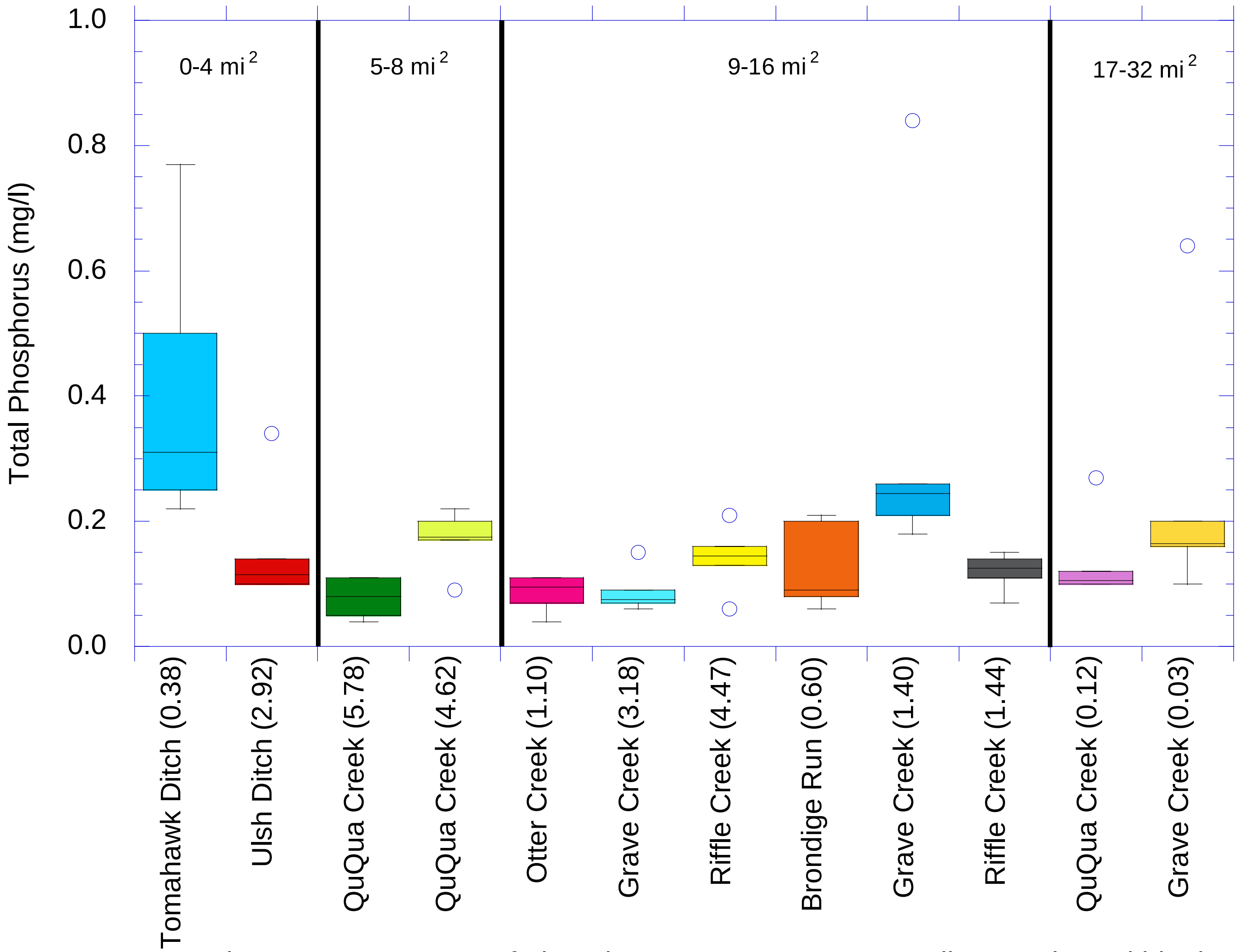


Figure 34. Summary of phosphorus measurements at tributary sites within the MOWAU in 2003.

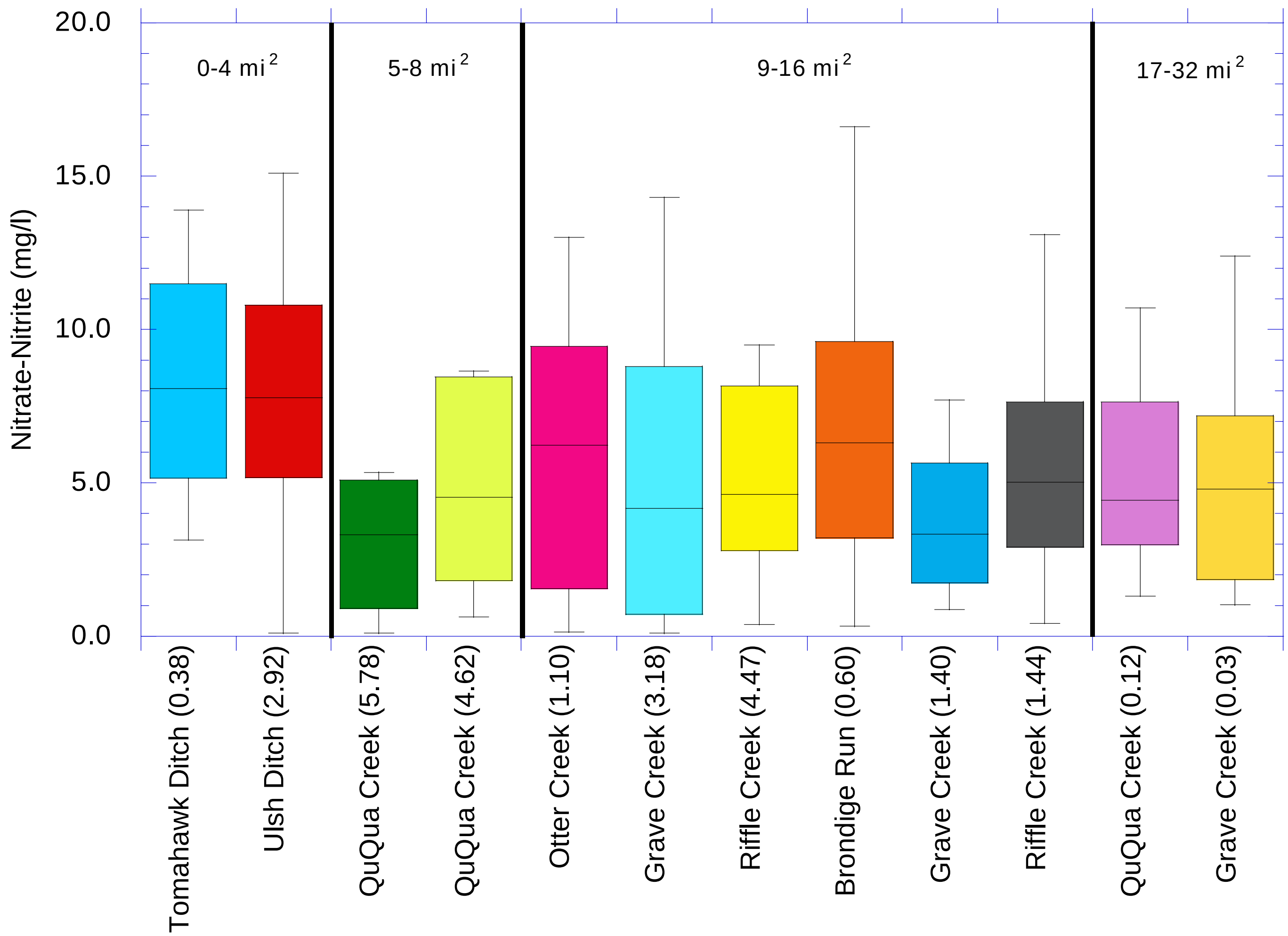


Figure 35. Summary of nitrate-nitrite measurements at tributary sites within the MOWAU in 2003.

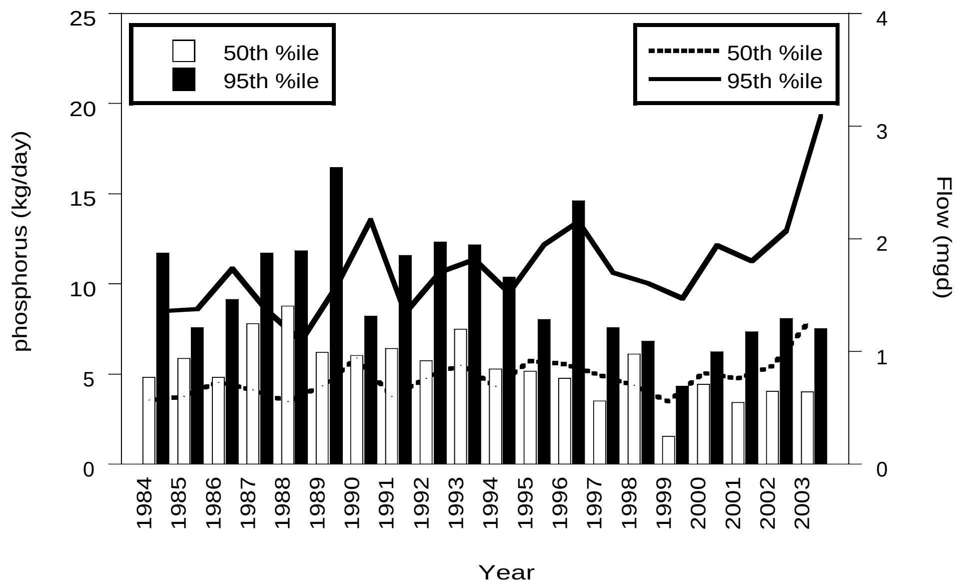


Figure 36. Annual phosphorus loadings at the Richland Road WWTP from 1984-2003.

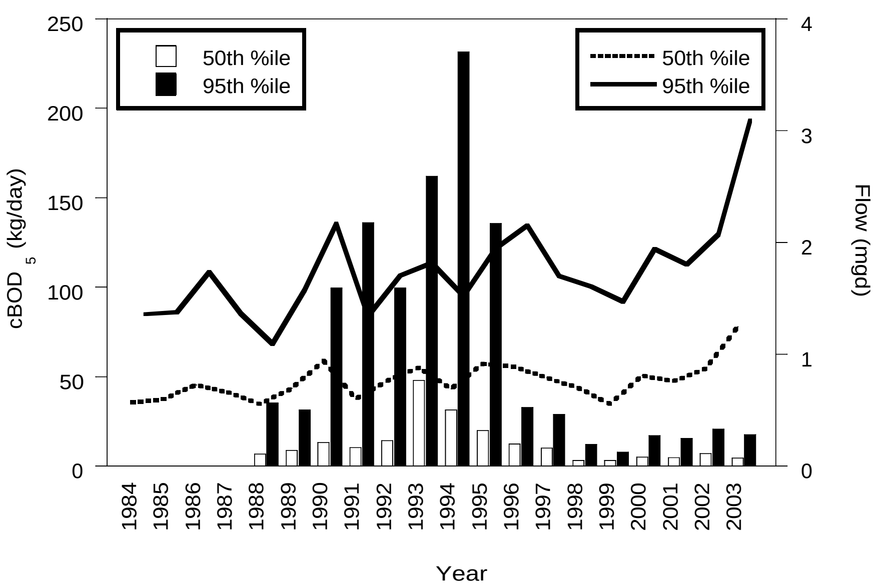


Figure 37. Annual $cBOD_5$ loadings at the Richland Road WWTP from 1984-2003.

Physical Habitat

The physical habitat of 16 sites within the MOWAU was evaluated with the QHEI (Figure 38). One mainstem site scored in the poor range as a result of habitat destruction by unrestricted livestock access to the stream and one site scored within the fair range as a result of being impounded by a dam. The remaining mainstem sites scored in the good to very good range. The average QHEI was 69.9 for mainstem sites with a range of values from 37.0 to 84.5.

In addition to the mainstem sites, fourteen sites were sampled among nine tributaries. Channelization and maintenance activities resulted in 43% of the tributary sites scoring in the very poor to poor range. These activities affect the quality of habitat available to aquatic organisms and thereby biological performance. Altered hydrologic regimes and increased sediment and nutrient loads also occur as a result of these activities, affecting biological performance further downstream. The average QHEI was 54.9 for tributary sites with a range of values from 29.0 to 81.0. The lower average QHEI scores for the tributary sites reflect aquatic habitat destruction as a result of agricultural activities throughout the MOWAU.

Olentangy River

Similar to the upper reach, streambed substrate in the middle reach of the Olentangy River from Roberts Road (RM 56.6) to Fulton Road (RM 40.8) developed primarily from glacial tills. Boulders, bedrock, concrete, cobble, hardpan, silt, gravel and sand were present throughout the middle section of the Olentangy River, though silt, sand and hardpan dominated the substrates from Shearer Road (RM 79.7) to Roberts Road (RM 58.9), while gravel, sand, cobble and boulders with slabs dominated the stream bed from State Route 95 (RM 54.7) to Fulton Road (RM 40.8). In the upper portion of this reach, moderate to heavy amounts of silt caused moderate to extensive embeddedness of the substrates, smothering interstitial spaces available for aquatic organisms.

In contrast, the lower portion of the middle reach contained silt in normal to moderate amounts with substrates embedded in normal to moderate amounts leaving interstitial spaces intact for aquatic life. Moderate amounts of instream cover were provided throughout the middle reach by undercut banks, overhanging vegetation, shallows, rootmats, deep pools (>70cm), rootwads, boulders, logs, and aquatic vegetation. The majority of the middle reach of the Olentangy River appeared to have recovered from or showed no evidence of past channelization. Most areas exhibited low to moderate amounts of sinuosity with fair to good channel development and moderate to high stability. However, evidence of recent channelization was evident near Roberts Road (RM 56.6), as the stream here was very straight with false banks on both sides, fair development and low stability.

Outside of the stream channel, land use shifts from high intensity uses to less intense uses in a downstream direction. In the upper portion of the middle reach, high intensity land uses including open pastures, and residential uses dominated the landscape, though a few forested areas were also observed. The buffers adjacent to these uses were predominantly nonexistent to narrow (5-10m) for the agricultural and residential areas, while the buffers were moderate (10-50m) to wide (>50m) for the lower intensity land uses. In contrast, the lower portion of the middle reach was dominated by forests, old fields and a smattering of residential homes. Buffers throughout this area were predominantly in the moderate (10-50m) to wide (>50m) range.

The relationship of land use intensity to water quality is exemplified throughout the middle reach. The upper portion of the middle reach was dominated by areas of higher intensity land use, narrow buffers, poor channel development and more embedded substrates resulting in a QHEI score of 37.0 near Roberts Road (RM 56.6). In contrast, the remainder of the middle reach was dominated by lower intensity land use with more extensive buffers, better channel development and stability, and less embedded substrates. QHEI scores throughout the remaining portion of the middle reach ranged between 64.0 - 84.5 (mean was 75.3).

Bee Run

The physical habitat of Bee Run was evaluated near Marseilles-Galion Road (RM 4.9) and downstream of County Road 310 (RM 0.3). Though Bee Run substrates appeared to have originated from glacial tills throughout the areas evaluated, historical and continuing maintenance activities in the upper reach resulted in a vastly different habitat than the lower reach. Silt was the predominant substrate type, though occasional areas of detritus and sand were observed. Stepping into the stream channel resulted in sinking from ankle depth to mid-thigh depth (up to 80cm) in silt, though the water itself was only about 6 inches deep. The buried substrates diminished any available bottom habitat so only silt tolerant macroinvertebrates were present. The shallow water and absent riparian cover yielded moderate amounts of instream cover via overhanging vegetation, shallows, undercut banks, aquatic macrophytes and occasional pieces of woody debris. The maintained features of the stream included a straight channel with very low sinuosity, poor development and low stability. A residential home with a mowed lawn was present adjacent to the stream along the left descending bank, while row crops were present within several feet of the right descending bank. The maintained upper reach exhibited poor development, high silt and poor habitat resulting in a QHEI score of 33.0 indicating the poor potential of the stream to support diverse biological communities.

In contrast to the upper reach, the lower reach contained gravel as the dominant substrate type with areas of hardpan, silt and sand also observed. Silt was present in normal amounts, and substrates were embedded in normal to moderate amounts. Sparse to moderate amounts of instream cover was provided by undercut banks, overhanging vegetation, shallows, rootwads, and woody debris. High sinuosity with fair to good development and moderate stability were observed as the stream was recovering from past channelization. Narrow (5-10m) riparian buffers were present adjacent to an old pasture. The lower reach is still recovering from historical channelization and received a QHEI score of 59.0.

Otter Creek

The physical habitat of Otter Creek was evaluated near State Route 95 (RM 1.1) and the stream substrate was found to originate primarily from glacial tills. Otter Creek is currently under county maintenance, similar to many other streams in the upper Olentangy watershed. Sand and silt were the dominant substrate types, though several areas of gravel, cobble and boulder were also observed. A boot sucking sludge created by the heavy silt deposits would sink an individual's leg 5-12 inches as when attempting to walk through the stream. Coarse substrates were embedded in moderate to extensive amounts, limiting the interstitial spaces available for aquatic life. Sparse amounts of cover were available for aquatic organisms and were limited to undercut banks, overhanging vegetation, shallows, boulders and a few logs. The channel appeared to be recovering from past channelization, with low sinuosity, fair channel development and low stream stability observed.

Outside of the stream channel, wooded riparian buffers were nonexistent as residential lawns extended to the stream channel on the left descending bank, though an old field provided a lower intensity use adjacent to the residential homes. Along the right descending bank, narrow (5-10m) riparian buffers extended to residential areas. The combination of narrow to no-existent riparian buffers, along with high siltation and sparse cover resulted in a QHEI score of 44.0. The maintenance activities practiced along Otter Creek have severely disrupted habitat thereby limiting its ability to support WWH communities.

Grave Creek

The physical habitat of Grave Creek was evaluated between State Route 529 (RM 3.2) and State Route 98 (RM 0.8). The upper portion of Grave Creek, from Firstenberger Road (RM 1.4) to Likens Road (RM 9.6), has been maintained by the Marion County Engineer's Office since 1969. The upper reach from State Route 529 (RM 3.2) to Firstenberger Road (RM 1.4) appeared to have substrate origins of sandstone and tills, though recent maintenance activities had sand and silt as the dominant substrate types with only a few areas of gravel and rock rip-rap near bridges to provide substrate diversity. Silt and embedded substrates were present in moderately heavy to extensive amounts, embedding coarse substrates and limiting habitat for aquatic life. Thick algal growth suggested nutrient enrichment from adjacent agricultural lands. Sparse to moderate amounts of instream cover were provided mainly by overhanging vegetation, and aquatic macrophytes though occasional deep pools (>70cm), undercut banks, and shallows provided some refuge for aquatic organisms. Little to no sinuosity was observed as the stream had poor to fair development and low stability due to the recent modification including snagging, relocation and canopy removal. Currents were mainly slow to moderate, though a few eddies were observed.

Outside of the stream channel, nonexistent to narrow (5-10m) riparian buffers extended to a mixture of land uses including fenced pasture, residential homes, row cropping, and a wastewater treatment plant. The QHEI score for the upper reach ranged between 42.0

and 44.5 reflecting the diminished capacity of the upper reach to support WWH communities as a result of degraded habitat caused by channelization activities.

While the upper reach showed the lasting detrimental effects hydromodification can have on a stream's physical habitat, the lower reach exhibited qualities depicting how, given time and space, a stream can begin to recover from channelization activities to reestablish more functional habitat for aquatic life. The substrates of the lower reach near Firstenberger Road (RM 0.3) originated primarily from glacial tills, and though cobble was the dominant substrate type, it was intermixed with boulders, gravel, sand and bedrock. Silt was present in normal amounts. Embeddedness was also typical, though not extensive. Moderate amounts of instream cover were provided by overhanging vegetation, shallows, rootmats, rootwads, boulders, aquatic macrophytes and woody debris. The stream appeared to have recovered from past channelization as moderate sinuosity, good development and moderate stability were observed. Currents ranged from slow to fast, with cobble riffles providing adequate interstitial spaces with low embeddedness.

Outside the stream channel, moderate (10-50m) buffers extended to a mixture of low density residential areas and forest. The low intensity land use and moderate buffers combined with the diversity of substrates and instream cover resulted in a QHEI score of 76.0 for the lower reach. In general, QHEI scores >70 indicate the potential of a stream to support EWH communities. However, the poor habitat conditions observed in the upper reach lessen the likelihood that the stream could currently support even a WWH community. If the upper reach would be allowed to heal from the past channelization activities, the stream could increase its potential to support both WWH and EWH communities.

Riffle Creek

The physical habitat of Riffle Creek was evaluated near Marion-Edison Road (RM 4.4) and Firstenberger Road (RM 1.4). While Riffle Creek appeared to have originated from glacial tills, sand and silt were the only substrates noted in the upper reach near Marion-Edison Road (RM 4.4). The heavy amount of silt resulted in extensively embedded substrates, severely limiting the amount of interstitial spaces for aquatic organisms. Very sparse amounts of instream cover were provided by shallows, rootmats, aquatic macrophytes and occasional backwaters. This reach has not recovered from recent channelization activities as evidenced by the near absence of sinuosity, development and the unstable channel. Moderate erosion of the stream banks was noted and likely occurred as a result of bank shaping and relocation. Outside of the upper reach, very narrow (<5m) to narrow (5-10m) riparian buffers were noted adjacent to fields of corn and soybean. The maintained channel of the upper reach with its high intensity land use received a QHEI score of 34.5.

Similar to the upper reach, the lower reach of Riffle Creek had sand as a dominant substrate, though areas of silt, hardpan, and gravel were also noted. Silt was present in moderate amounts leaving substrates moderately embedded. Overhanging vegetation, shallows, deep pools (>70cm), rootwads, boulders, aquatic macrophytes, and woody debris provided moderate amounts of instream cover in the lower reach. The lower reach of Riffle Creek appeared to be recovering from channelization activities as moderate amounts of sinuosity with good development and moderate stability were noted. Very narrow (<5m) buffers extended beyond the stream channel to row crops along the right descending bank, while narrow (5-10m) buffers extended beyond the stream channel along the left descending bank to residential homes.

In contrast, the mixed intensity of land use and less maintained characteristics of the lower reach resulted in a QHEI score of 53.5. The differences in QHEI scores along Riffle Creek exemplify the effects of agricultural maintenance activities on habitat quality.

QuQua Creek

The physical habitat of QuQua Creek was evaluated from Owens Road (RM 4.6) to State Route 98 (RM 0.1). While the entire stream appeared to originate from tills and sandstone, two major differences in regulating authority over the stream have resulted in diverse stream systems. The upper portion of QuQua Creek, from near Benzler Lust Road (RM 4.0) to Laura Drive (RM 9.0) in the City of Marion, was ‘cleaned’ by petition through the Marion County Engineer’s office between spring 2002 and spring 2003. Manipulation of streams for drainage purposes is often referred to as ‘cleaning’ by Ohio county officials and engineers as it involves removal of substrates, woody debris, logs, sinuosity, floodplain and vegetation from a stream and riparian area to increase drainage for agricultural purposes.

Figure 39. Algae present in QuQua Creek (RM 4.6).

The results of these activities in QuQua Creek near Owens Road (RM 4.6) resulted in a channel with gravel and sand as the only substrate types present. Silt was present in normal to moderate amounts though substrates were moderately to extensively embedded, limiting the amount of interstitial spaces available for aquatic organisms. Instream cover was nearly absent with only sparse amounts of shallow areas providing any instream cover. The recent channelization activities left the stream with none to low sinuosity, poor development and low stability.

The stream was very uniform in cross-section, and nearly trapezoidal in configuration. Channelization techniques including bank shaping, dredging, canopy removal, relocation and snagging were all evident. No buffers were present adjacent to the high intensity row cropping along the stream, increasing the amount of sunlight available to the excessive nutrients in the stream. This resulted in excessive algal production (Figure 39). Removal of vegetation and reshaping of the stream resulted in increased erosion as moderate bank erosion was noted throughout the upper reach (Figure 40).

Figure 40. Evidence of recent channelization activities increasing bank erosion in QuQua Creek (RM 4.6).

In contrast to the upper reach, the lower portion of QuQua Creek, near State Route 98 (RM 0.1), is restricted from development as part of the controlled floodway for Delaware reservoir, which is under national Federal Emergency Management and Agency (FEMA) control (Figure 41). According to Marion county officials, this is the only reason the lower portion of QuQua Creek was not channelized along with the upper reach. The lower portion of the stream was last channelized in 1946 according to Marion County Officials.

Figure 41. Intact riparian corridor and natural appearance of QuQua Creek near State Route 98 (RM 0.12).

The lower reach of QuQua Creek was dominated by cobble, though areas of sand, gravel and boulders were also noted. The amount of silt present ranged from none to normal, while substrates were embedded in normal amounts, providing interstitial spaces for aquatic organisms. Moderate amounts of instream cover was provided by undercut banks, overhanging vegetation, shallows, rootmats, rootwads, boulders, aquatic macrophytes and woody debris. The channel appeared to be recovering from past channelization activities as it exhibited none to low sinuosity with fair to good development and moderate stability. Currents velocities ranged from slow to fast with several eddies noted, while riffles varied in stability from large boulders to gravel and sand riffles that appeared to shift with larger flows. Wide (>50m) riparian buffers provided shade, floodplain access, nutrient removal, and stream bank stability along the forested areas of either bank. Erosion was none to little throughout the lower portion of QuQua Creek.

The QHEI score for the recently channelized upper portion of QuQua Creek was 29.0, reflecting the diminished habitat quality and impaired nature of the stream. The lower portion of QuQua Creek received a QHEI score of 75.0, depicting the improved habitat conditions.

Brondige Run

The physical habitat of Brondige Run was evaluated north of State Route 229 (RM 0.7). The primary substrate origin appeared to be glacial tills. The dominant substrate types, cobble and gravel, were intermixed with boulders and sand. Silt and embedded substrates were present in normal to moderate amounts. Moderate instream cover was provided by undercut banks, overhanging vegetation, shallows, rootmats, rootwads, boulders, and logs. The stream appeared free from hydromodification and exhibited moderate to high sinuosity, good development, and moderate stability. Flow velocities ranged from slow to fast. Debris in trees and along banks provided evidence of flows 4' above the flow stage observed. Since Brondige Run drains into Delaware Reservoir, it is likely that the stream was impounded by the reservoir in 2003.

Adjacent to the stream channel, wide (>50m) riparian buffers extended along a forested area on the left descending bank while moderate (10-50m) buffers extended along a scrubby old field on the right descending bank. The combination of low intensity land use with extensive buffers and diverse instream habitat resulted in a QHEI score of 73.5.

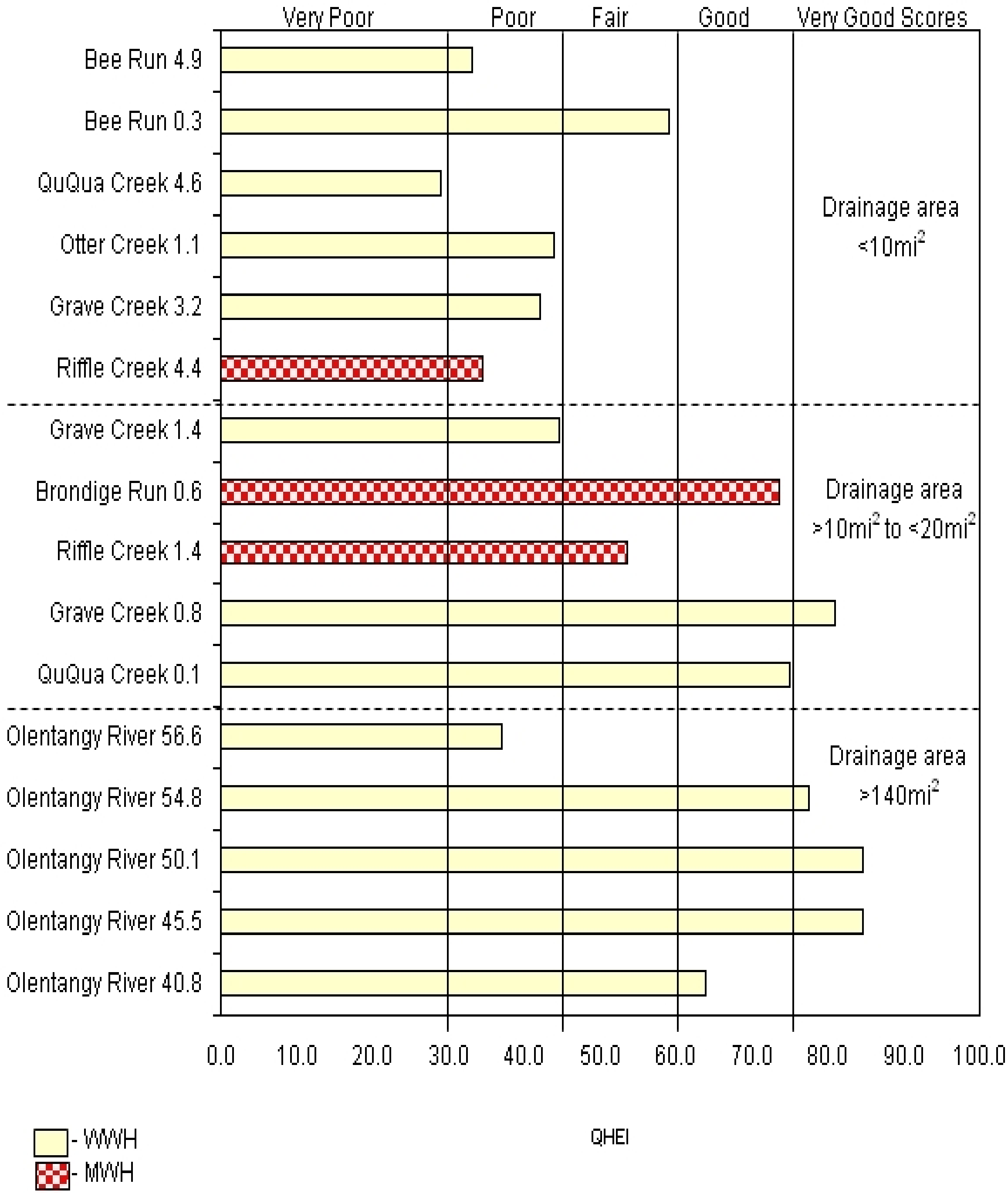


Figure 38. QHEI scores by drainage area for MOWAU. Existing or proposed aquatic life use designations were warmwater habitat (WWH) or modified warmwater habitat (MWH). Tributary sites scoring in the very poor and poor range have been maintained by county engineers (MWH) or by private landowners (Bee Run 4.9). Mainstem sites predominantly scored in the good to very good range except for where livestock had direct access to the stream (RM 56.6) or where the area was impounded by a dam (RM 28.1).

Biological Communities: Fish

The fish communities of the MOWAU were sampled in 15 locations. The five Olentangy River mainstem sites primarily showed good correlation with habitat conditions (Figure 42). Two of the mainstem sites, Crawford-Marion Line Road (RM 68.1) and Shearer Road (RM 79.7), performed below WWH expectations though habitat conditions should have been sufficient to support WWH communities. Nutrient enrichment and siltation from surrounding agricultural land have impaired the fish communities in these areas.

The effect of stream habitat on fish community performance is clearly presented by the two sites from QuQua Creek displayed in Figure 42. The upstream site at RM 4.6 was maintained by the Marion County Engineers in 2002-2003. The removal of riparian cover, straightening of the channel and decimation of instream habitat has affected the habitat available to aquatic life, resulting in an IBI score of 22 for the fish community. In contrast, the downstream site at RM 1.4 is protected by a flood easement for Delaware Reservoir. The treed riparian cover, clean substrates and diversity of habitat features provides beneficial habitat for the fish community, resulting in the highest IBI score (IBI=44) for the MOWAU.

Olentangy River

The fish communities of the Olentangy River were sampled in six locations throughout the MOWAU from Roberts Road (RM 56.6) to Fulton Road (RM 40.8). Community indices and narrative evaluations ranged from fair (MIwb=6.9) to good (IBI=40). The fish community scores reflected the various conditions present within the MOWAU.

The fish community near Roberts Road (RM 56.6) where livestock had access to the historically channelized stream compromised only 19 species, 4 less than any other mainstem site within the MOWAU. No common intolerant species were collected, and only two darter species, blackside darter and johnny darter were found at the site.

Habitat conditions generally improved downstream, as the average QHEI score increased from a 37.0 at Roberts Road (RM 56.6) to 82.2 from State Route 95 (RM 54.8) to St. James Road (RM 45.5). The improved habitat conditions resulted in higher diversity, as total species collected ranged from 26 to 28 species. The total number of darter species present also increased in this reach, as greenside darters, rainbow darters, fantail darters, logperch darters and banded darters were collected in addition to the johnny darters and blackside darters. Though habitat conditions improved, nutrient enrichment from the lack of centralized wastewater treatment in Claridon influenced community performance as tolerant species, predominantly bluntnose minnows (42.25% and 47.25%, respectively) comprised 45.4% of the total population by number near State Route 95 (RM 54.8) and 48.6% of the total population by number near State Highway 529 (RM 50.1).

The most downstream site in the MOWAU, Waldo Fulton Road (RM 40.8) was characterized as fair (IBI=35) due to impoundment by Delaware reservoir. No intolerant species were collected and simple lithophils comprised only an average of 7% of the community present.

Bee Run

The fish community of Bee Run was sampled in two locations between Marseilles Galion Road (RM 4.9) and near the mouth (RM 0.3). Based on the community indices and narrative evaluations, the fish community was evaluated as marginally good (IBI=38). No intolerant species were collected at either location, and the maintained channelized section near Marseilles Galion Road (RM 4.9) had only 10 species present, half of them were considered highly tolerant. In contrast, the less maintained downstream site exhibited higher diversity with a total of 16 species collected although 5 of the 16 were still considered highly tolerant. During the summer of 2003, the Marion County Engineer began designing plans to hydromodify Bee Run. Though attempts have been made to encourage alternative designs to the trapezoidal ditch cleaning similar to the work conducted on QuQua Creek, the project will likely go forward in a similar fashion. Therefore, it is likely that the water quality and biological communities of Bee Run will become more impaired in the future.

Otter Creek

The fish community of Otter Creek was sampled near State Highway 95 (RM 1.1). Community indices and narrative evaluations indicated stream as marginally good (IBI=38) conditions. While Otter Creek performed within WWH ranges, ongoing channel modifications threaten the ability of this stream to continue to support WWH communities. Twenty species of fish were collected during sampling, but tolerant species comprised 63.3% of the population by number, and no intolerant species were collected.

Figure 43. Failing septic system along Grave Creek RM 0.8.

Grave Creek

The maintained portion of Grave Creek was evaluated between State Highway 529 (RM 3.2) and Firstenberger Road (RM 1.4). A third sample of Grave Creek was completed near State Route 98 (RM 0.8). Fish community indices and narrative evaluations ranged from fair (IBI=28) in the maintained portion of Grave Creek to marginally good (IBI=39) near State Route 98. Channelization activities in the upper portion contributed to the low scores, while failing household sewage treatment systems degraded water quality in the lower reach (Figure 43).

Riffle Creek

Riffle Creek was sampled in two locations between Marion Edison Road (RM 4.4) and Firstenberger Road (RM 1.4). Community indices and narrative evaluations ranged from poor (IBI=26) to fair (IBI=31). Riffle Creek is maintained by the County Engineer for much of its length, and the low fish community scores reflect the severely modified habitat available to aquatic life. Within the maintained portion of Riffle Creek, 7 of the 14 species collected were considered highly tolerant of degraded conditions. No intolerant species were collected. Tolerant species comprised 93% of the relative number of individuals collected in the maintained section. Though habitat conditions were improved in the unmaintained portion, historical channel modifications and high intensity surrounding land use limited the ability of the stream to support WWH communities. A total of 22 species were collected within the unmaintained portion of Riffle Creek, though tolerant individuals still comprised 68% of the relative number of individuals.

QuQua Creek

The recently maintained portion of QuQua Creek was sampled near Owens Road (RM 4.6) while the unmaintained portion of QuQua Creek was evaluated near State Highway 98 (RM 0.1). Fish community indices and narrative evaluations for the sites were poor (IBI=22) in the maintained portion of the stream and good (IBI=44) in the unmaintained portion of the stream. As discussed in the habitat section of this report, recent 'cleaning' activities in QuQua Creek have destroyed habitat required for the fish community to meet water quality criteria. Only 5 species of fish were collected in the maintained portion of QuQua Creek. A total of 88% of the relative number of individuals collected in the maintained portion of QuQua Creek are considered tolerant of degraded conditions. In contrast, 18 species with were collected in the unmaintained portion of QuQua Creek with tolerant species comprising only 14% of the catch. This unmaintained area fully met WWH criteria for fish as listed in the WQS.

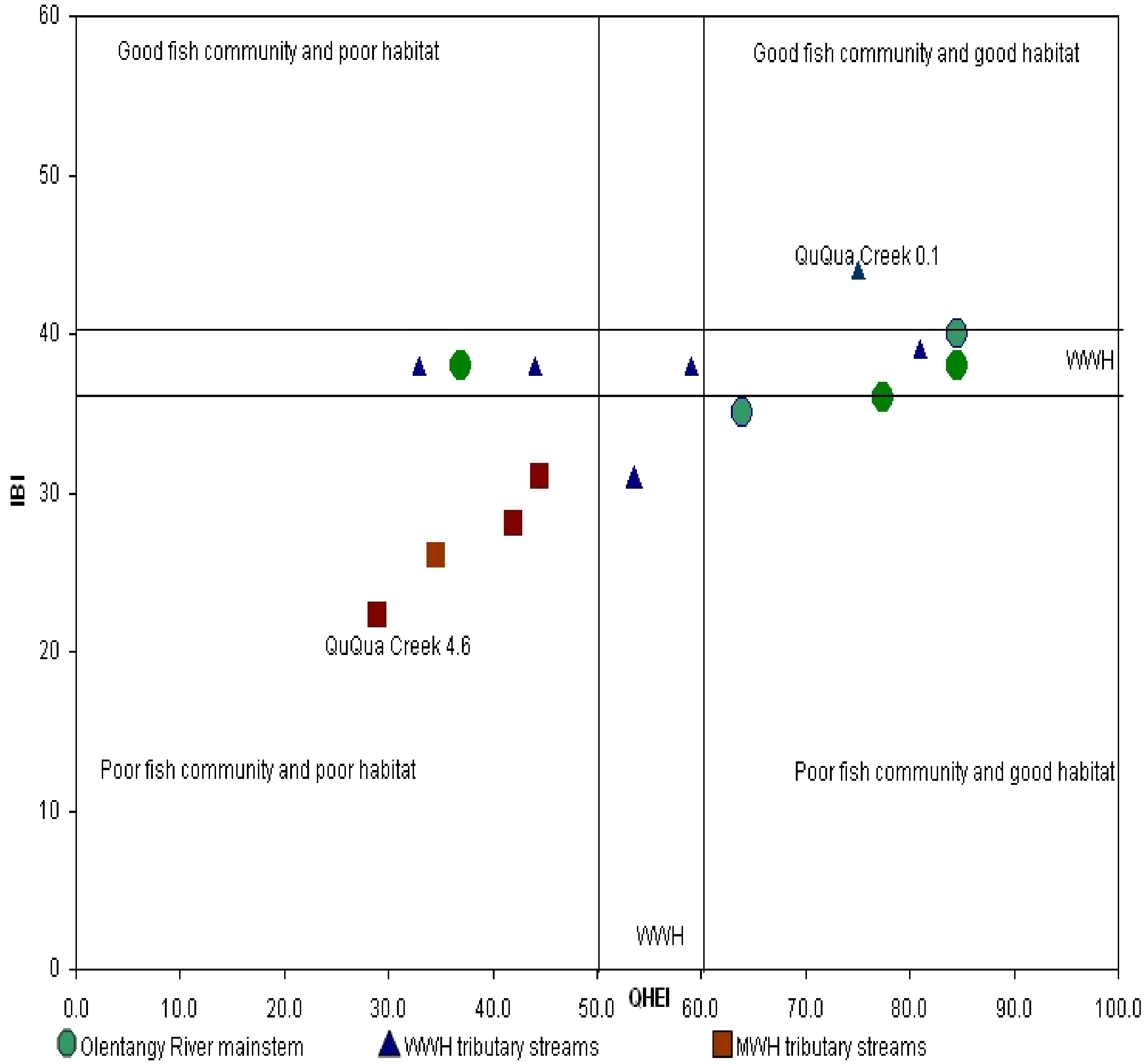


Figure 42. IBI versus QHEI for the fish sampling sites within the MOWAU. QuQua Creek shows the strong relationship between habitat and fish community performance at both ends of the spectrum.

Biological Communities: Macroinvertebrates

Macroinvertebrate communities were evaluated at 22 stations in the MOWAU (Table 18). The community performance was evaluated as exceptional at four stations, very good at three, good at one, marginally good at one, fair at eight, low fair at four, and poor at one. The station with the highest total EPT taxa was on the Olentangy River adjacent to Hudson Road (RM 27.4) with 28 taxa. The station with the highest number of total sensitive taxa was on the Olentangy River at St. James Road (RM 45.5) with 37. Sensitive taxa found in this assessment unit which are noteworthy because they are not commonly collected were the mayflies *Serratella deficiens* in the Olentangy River (RM 27.4) and *Ephoron leukon* in the Olentangy River (RM 45.5), the stonefly *Agnetina capitata* complex in the Olentangy River (RMs 50.3, 45.5, 41.0, 27.4), the caddisflies *Hydropsyche venularis* in the Olentangy River (RMs 45.5, 32.1) and *Macrostemum zebratum* in the Olentangy River (RM 27.4) and the midge *Polypedilum (Cerobregma) ontario* in the Olentangy River (RM 27.4).

The Olentangy River macroinvertebrate communities sampled in this assessment unit upstream from Delaware Lake were meeting or exceeding the expectations for the WWH aquatic life use designation (Figure 44). In fact, the stations at SR 529 (RM 50.3) and St. James Road (RM 45.5) were even supporting exceptional communities. The St. James Road station was the highest performing station on the Olentangy River upstream from Delaware Lake with the highest ICI, EPT, sensitive taxa diversity, and number of uncommon sensitive taxa (3). Downstream from Delaware Lake the community upstream from Main Road (RM 32.1) maintained a good ICI but declined in EPT and sensitive taxa diversity and had increased abundance of facultative flatworms, indicating community imbalance. This station was likely impacted by the Delaware Lake discharge and possibly the low-head dam located immediately upstream from the station. The station (RM 28.2) located within the Panhandle Road Dam impoundment was impaired by the pooled condition as expected. The caddisfly *Macrostemum zebratum*, a good indicator of medium to large high quality rivers, was found all four years that the station downstream from the Panhandle Road Dam was sampled. The station sampled adjacent to Hudson Road (RM 27.4) was performing at a level comparable to the best station upstream from Delaware Lake in terms of EPT and sensitive taxa diversity and number of uncommon sensitive taxa (4). This is the most upstream station on the river were the caddisfly *Macrostemum zebratum* was collected, which is a good indicator of medium to large high quality rivers.

The macroinvertebrate communities sampled in Bee Run, Otter Creek, Grave Creek, Riffle Creek, and QuQua Creek were all impaired by hydromodification and various degrees of siltation and nutrient enrichment. Excessive algae growth, an indication of nutrient enrichment, was observed in Grave Creek (RM 3.2) and QuQua Creek (RM 4.6). Low EPT and sensitive taxa diversity along with reduced dominance of sensitive taxa and increased numbers of facultative and tolerant taxa were indications of community impairment. Grave and QuQua Creek additionally originate in the City of Marion and may be marred by urban runoff. The Marion County WWTP discharges to Grave Creek

(RM 3.16) and was not noticeably impacting the macroinvertebrate community located at RM 1.4, where it improved to fair compared to poor upstream from the WWTP at RM 3.2.

The stations on Brondige Run (RM 0.6) and Indian Run (RM 0.9) were located within the area of maximum inundation by Delaware Lake for flood control. Both of these sites were free flowing when sampled. Brondige Run was the more likely of the two to be impounded. Brondige Run did not meet WWH expectations and Indian Run was just barely meeting expectations for macroinvertebrate community performance in a WWH stream. Brondige Run had embedded substrates and large quantities of sand and silt covering rocks in the pool habitat. This is an indication of excessive siltation. Indian Run had excessive moss growth in the riffle habitat, which indicates excessive nutrient enrichment.

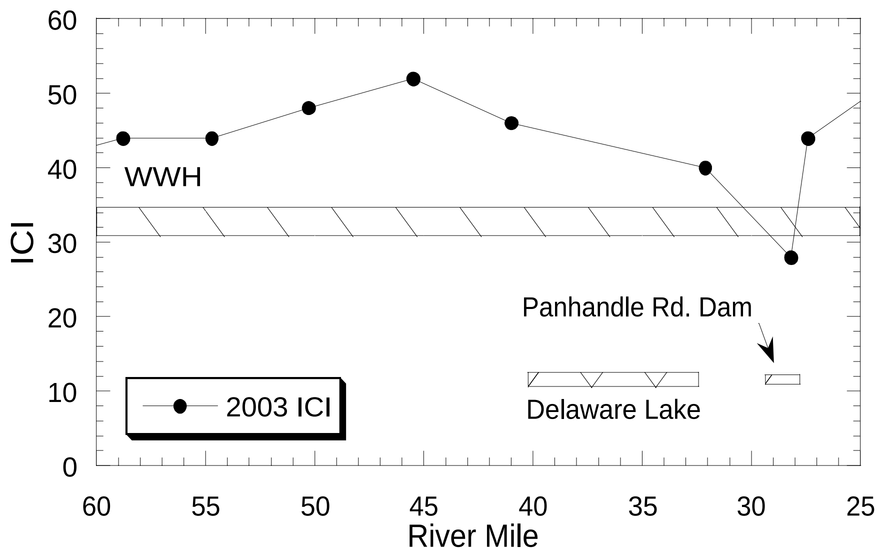
The macroinvertebrate communities from Norris Run and Sugar Run were both evaluated as low fair. Low EPT and sensitive taxa diversity along with reduced numbers of sensitive taxa and increased predominance of facultative and tolerant taxa were indications of community impairment. Norris Run was sampled in a residential area and was likely impacted by poorly treated domestic sewage. Sugar Run was sampled in a more remote area but may also be impacted by poorly treated sanitary wastes.

Table 18. Summary of macroinvertebrate data collected from artificial substrates (quantitative sampling) and natural substrates (qualitative sampling) in the MOWAU study area, July to September, 2003.

Stream RM	Dr. Ar. (sq. mi.)	Data Codes	Qual. Taxa	EPT Ql. / Total	Sensitive Taxa Ql. / Total	Density Ql. / Qt.	Predominant Organisms on the Natural Substrates With Tolerance Category(ies) in Parentheses	ICI	Narrative Evaluation
Olentangy River (02-400)									
58.8	134	-	40	11 / 14	18 / 24	M-H / 622	Midges (MI)	44	Very Good
54.7	157	-	63	19 / -	26 / -	M / -	Hydropsychid caddisflies (F), fingernail clams (F), *Elimia* snails (MI)	-	Very Good
50.3	174	-	50	20 / 22	23 / 36	M / 182	*Stenelmis* riffle beetles (F)	48	Exceptional
45.5	181	-	55	20 / 25	29 / 37	H / 1090	Baetid mayflies (F,I), hydropsychid caddisflies (F,MI), blackflies (F), *Stenelmis* riffle beetles (F)	52	Exceptional
41.0	234	-	41	15 / 21	17 / 31	L-M / 1255	Hydropsychid caddisflies (F,MI), Midges (MI), *Petrophila* moth larvae (I)	46	Exceptional
32.1	393	-	31	10 / 14	7 / 10	L-M / 1828	Hydropsychid caddisflies (F,MI), midges (F,MI), flatworms (F)	40	Good
28.2	409	2,8	30	6 / 11	7 / 15	L / 643	Scuds (F), midges (T)	28	Fair
27.4	411	-	65	27 / 28	30 / 35	M / 1631	Hydropsychid caddisflies (F,MI,I), midges (F,MI), *Petrophila* moth larvae (I)	44	Very Good
Bee Run (02-470)									
2.4		-	45	5	6	L-M	Midges (F,MI)	-	Low Fair
0.3	6.8	-	42	7	11	Low	Hydropsychid caddisflies (F), midges (F,MI), sow bugs (F)	-	Fair
Otter Creek (02-423)									
1.1	8.3	-	54	14	14	L-M	Hydropsychid caddisflies (F), mayflies (F,MI), flatworms (F), blackflies (F)	-	Marg. Good

Stream RM	Dr. Ar. (sq. mi.)	Data Codes	Qual. Taxa	EPT Ql. / Total	Sensitive Taxa Ql. / Total	Density Ql. / Qt.	Predominant Organisms on the Natural Substrates With Tolerance Category(ies) in Parentheses	ICI	Narrative Evaluation
Grave Creek (02-418)									
3.2	9.3	-	29	3	6	Moderate	Flatworms (F), midges (F,MI)	-	Poor
1.4	11.3	-	36	9	8	L-M	Midges (MI)	-	Fair
0.1	28.5	-	39	8 / 10	12 / 24	M / 574	Blackflies (F), baetid mayflies (F)	48	Exceptional
Riffle Creek (02-432)									
4.4	10.2	-	50	9	8	Low	Caddisflies (F), midges (F,MI), baetid mayflies (MI), blackflies (F)	-	Fair
1.4	15.8	-	43	13	13	L-M	Hydropsychid caddisflies (F), midges (F), baetid mayflies (F)	-	Marg. Good
QuQua Creek (02-417)									
4.6	6.8	-	47	7	4	M-H	Midges (MT,F), blackflies (F)	-	Low Fair
0.2	17.1	-	35	8	6	L-M	Blackflies (F), hydropsychid caddisfleis (F), midges (MT,F,MI)	-	Fair
Brondige Run (02-415)									
0.6	~12.0	-	28	7	7	L-M	Hydropsychid caddisflies (F)	-	Fair
Indian Run (02-414)									
0.9	4.0	-	44	12	14	L-M	Midges (F,MI), baetid mayflies (F,I)	-	Marg. Good
Norris Run (02-413)									
1.3	5.8	-	37	5	5	Moderate	Blackflies (F)	-	Low Fair
Sugar Run (02-410)									
1.3	3.5	-	41	8	9	Moderate	Blackflies (F), sow bugs (F)	-	Low Fair

RM: River Mile.
Dr. Ar.: Drainage Area
Data Codes: 2=Dam Pool, 8=Non-Detectable Current.
Ql.: Qualitative sample collected from the natural substrates.
Sensitive Taxa: Taxa listed on the Ohio EPA Macroinvertebrate Taxa List as MI (moderately intolerant) or I (intolerant).
Qt.: Quantitative sample collected on Hester-Dendy artificial substrates, density is expressed in organisms per square foot.
Qualitative sample relative density: L=Low, M=Moderate, H=High.
Tolerance Categories: VT=Very Tolerant, T=Tolerant, MT=Moderately Tolerant, F=Facultative, MI=Moderately Intolerant, I=Intolerant



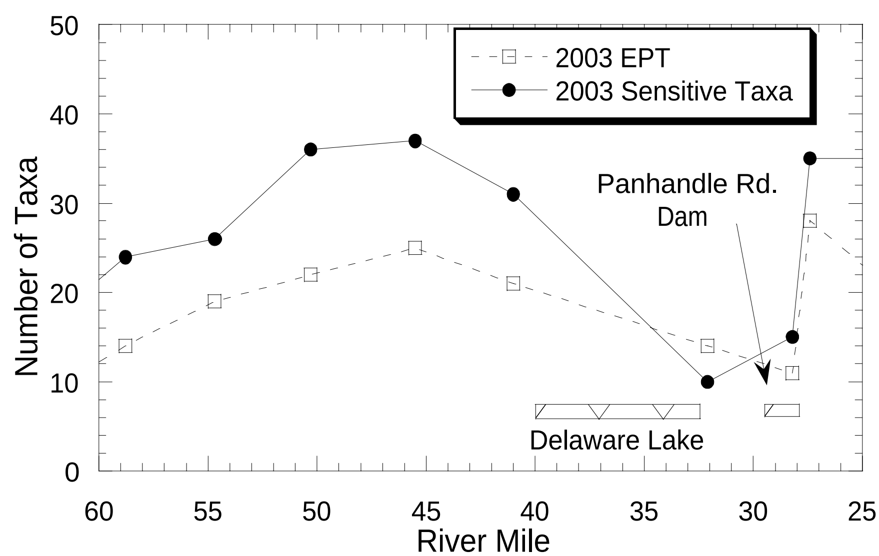


Figure 44. Longitudinal trend of the Invertebrate Community Index (ICI), total EPT, and total sensitive taxa in the middle Olentangy River, 2003.

Whetstone Creek Watershed Assessment Unit (WCWAU)

The WCWAU matches the boundaries of the USGS hydrologic unit #05060001-100 which encompasses the drainage area beginning with the headwaters of Whetstone Creek and ending at the mouth of Whetstone Creek at Delaware Lake. Water chemistry, biological, and habitat assessments were conducted at 23 sites in 2003 including the Whetstone Creek mainstem and tributaries, such as Shaw Creek (Figure 45). The index scores for each site and their biological attainment status are discussed below (Figure 46 and Table 19).

General water chemistry grab samples containing demand parameters, dissolved materials, bacteria, and total recoverable metals were collected 6 times during the period of June through September 2003. Two additional sampling events were added in July solely to evaluate 30-day geometric mean bacterial concentrations to establish attainment status of recreational uses. Four sites on the mainstem of Whetstone Creek were also evaluated for sediment chemistry and organic water chemistry. Surface water chemistry grab sample results exhibiting violations of WQS criteria codified in OAC Chapter 3745-1 are summarized in Table 20.

Aquatic Life Use Attainment Status and Trends

The overall WAU aquatic life use attainment score was 21. An overall attainment score of 0 would reflect 0 sites meeting designated or recommended aquatic life uses in the WAU while a score of 100 would reflect all sites meeting designated or recommended aquatic life uses. This attainment score was calculated according to the protocol and procedures established in the most recent Integrated Water Quality Monitoring and Assessment Report, which can be accessed at:
http://www.epa.state.oh.us/dsw/tmdl/index.html

Figure 46 depicts the attainment status of each sampling location throughout the WCWAU. Big Run was the only Whetstone Creek tributary in non attainment, which occurred as a result of agricultural activities. Only two tributaries were in partial attainment of their designated WWH use, Whetstone Creek tributary at 33.71 and Claypole Run. Channel modifications and nutrient enrichment from on-lot sewage treatment discharges have negatively affected Claypole Run while agricultural activities have impaired the Whetstone Creek tributary at 33.71. The remaining tributary sites were in full attainment.

The Whetstone Creek mainstem was in partial and non attainment near Candlewood Lake, but then improved to full attainment before reaching Mt. Gilead. The effects of the Mt. Gilead WWTP and Cardington WWTP are clearly depicted on the map, as the remaining portion of the Whetstone Creek mainstem never reaches full attainment downstream of Mt. Gilead. In addition, tributaries that are impaired by agricultural activities, such as Big Run, also contribute to the problems noted in Whetstone Creek.

Preservation and restoration efforts should address both point and non-point sources of pollution present in WCWAU.

Biological impairment in Whetstone Creek stemmed mainly from nutrient enrichment contributed by agribusiness, the Mt. Gilead WWTP, and the Cardington WWTP. The lower 2.6 miles of Whetstone Creek is periodically impounded by Delaware Reservoir. The East Branch of Whetstone Creek, Sams Creek, Shaw Creek and Mitchell Run were all in full attainment of their designated aquatic life use. Agricultural activities influenced the water quality of Big Run and a Tributary to Whetstone Creek (RM 33.71) leading to biological impairments of these streams. Nutrient enrichment and siltation from channel modifications and failing septic systems led to impairment of Claypole Run.

Longitudinal plots of IBI and MIwb versus river mile for 1984, 1994 and 2003 are presented in Figure 47. The plots show that fish community performance increased significantly between 1984 and 1994, likely due to the1985-1986 upgrade of the Mt. Gilead WWTP. Since 1994, fish community performance as measured by the IBI has slightly decreased downstream of Mt. Gilead WWTP and Cardington WWTP. The MIwb shows a marked decrease between 1994 and 2003. The drop in scores begins just upstream of Mt. Gilead and encompasses the remainder of the mainstem. The drop in MIwb scores throughout Whetstone Creek is disturbing, as it is sensitive to the uneven distribution of individuals and biomass within community assemblages.

Uneven distribution of individuals, such as finding fish representing only a few age classes, may occur as a result of toxic spills and/or fish kills. However, no reports of fish kills or spills have been reported for the Whetstone Creek basin since prior to 1998. These events may be occurring and simply go unreported.

The shift in biomass assemblages may also be attributed to changes in water quality affecting the environment available to aquatic organisms. For instance, there has been a significant increase in TSS throughout Whetstone Creek since 1994. This may increase the embeddness of substrates and reduce water clarity. This could diminish or eliminate fish species requiring clean substrates for spawning and also sight feeding species.

Macroinvertebrate community health upstream from the Mt. Gilead WWTP has apparently improved since the 1984 and 1994 surveys (Figure 48). There continued to be a decline in community diversity downstream from Mt. Gilead to Cardington and then community diversity started to improve.

While chemical results from this survey generally indicate improvements in nutrient and organic enrichment from past surveys, it showed increases in mean TSS. Increase in solids concentrations can occur from stream modifications and erosion caused by agricultural activities, WWTP bypasses and overflows, and run-off from development. Nutrient and organic enrichment were noted downstream of the Candlewood Lake WWTP, Mt. Gilead WWTP and Cardington WWTP. Improvements to these facilities and their sewage collection systems will likely decrease the amount of organic enrichment, TSS and nutrients entering the stream.

Recreation Use Attainment Status

Recreation impairment was noted throughout Whetstone Creek Basin. The main channel of Whetstone Creek exhibited violations of bacterial standards at nearly 62% of the sites evaluated during the survey. Only the upper and lower portions of the mainstem seemed unaffected by bacterial pollution.

Bacterial contamination appeared to emanate from several sources including municipal wastewater collection and treatment systems at the Mt. Gilead WWTP, the wastewater treatment plant at Cardington, municipal stormwater runoff, contaminated discharges from on-site wastewater treatment systems and agribusiness (e.g., uncontrolled runoff from feedlots, unrestricted access of livestock to creeks and streams, over application or untimely application of manure to fields).

Spills

All of the spills reported to ODNR between 1994-2004 for the WCWAU were related to manure releases (Figure 49). A broken seal on an irrigation sprayer caused manure to seep over land and into drain tiles, affecting 1.9 miles of Big Run. Manure applied onto fields drained into tiles affecting 0.17 miles of a tributary to Whetstone Creek (RM 6.98). The largest manure spill occurred with a lagoon overflow at Harper Crest Dairy, affecting 9.55 miles of Shaw Creek.

As the majority of land use in the WCWAU is in agricultural production, it is not surprising that all of the spills are related to these activities. It is likely that numerous unreported spills occur each year. Emphasis should be placed on proper manure handling techniques and best management practices related to agricultural activities to reduce the number and effect of spills in the future.

Ecoregion, Soils and Topography

Whetstone Creek drains more landscape within the Olentangy watershed than any other tributary to the mainstem (115 mi^2). Some portions of its riparian corridor are arguably the finest remaining in the Olentangy both in width and length of contiguous forest cover.

Whetstone Creek originates in north central Ohio, flowing southwesterly across Morrow County and discharging to the Delaware Reservoir, where its waters mix with the Olentangy River. Prior to the reservoir impoundment, it flowed directly to the Olentangy River. Elevation at the headwaters of Whetstone Creek is 1295 feet; the elevation at the confluence with the reservoir is 893 feet, resulting in a mean gradient of 11.5 feet/mile. Shaw Creek is the main tributary to the Whetstone and drains 30 mi^2 as it enters the Whetstone at RM 8.47.

As part of the Olentangy system, Whetstone Creek lies with the ECBP ecoregion and shows a glaciated topography of flat to gently rolling landforms including kames, eskers, and moraines. Igneous glacial erratics are found along with prairie potholes, which are few in number in the downstream portions of the Olentangy watershed. Climate characteristics within the Whetstone watershed are similar if not identical to those of the Olentangy overall; with localized weather variation.

Soils here are partly a product of the glaciation. Parent materials in the western portion of Morrow County consist of high lime glacial drift with the resultant soils lightly colored, poorly drained and generally fertile. The predominant soil groups are the Blount series on the uplands and the poorly drained Pewamos in depressions and low areas. These soils are susceptible to high rates of erosion.

Whetstone watershed plant communities reflect poorly drained soils. Green and white ash, sycamore, cottonwood, hackberry, box elder, pin oak, swamp white oak, burr oak and black ash are common over story species. Other oaks (red), hickories and black walnut are present on well drained soils. The chinkapin (sweet oak) and redbud are found in areas of limestone. Shrubs include paw-paws, black haw and arrowwood in open settings with sumac, hawthorns, black cherry and crab apple in areas which are reverting towards climax forest (pers. comm. Harold Bower, ODNR Division of Forestry).

Land use changes within this sub watershed reflect changes in population, economic activity, and agricultural practices. Between the census years 1980 and 1990, the population of Morrow County increased from 26,476 to 27,749, an increase of 5.1% or 0.5% per year. By 2000, county population had increased to 31,628, an increase of 14% or 1.4% per year. Increasing population raises demand for housing, commercial activity, primary and secondary education, employment and many other needs which may translate to building and change of land use. In June of 2000 county planning agency staff indicated that new construction was primarily single lot homes.

Causes and sources of impairment

Point sources of pollution include insufficient wastewater treatment from the Candlewood Lake WWTP, Mt. Gilead WWTP, and Cardington WWTP. Each facility contributes excessive nutrients, organic enrichment and TSS to Whetstone Creek. Candlewood Lake WWTP is hydraulically overloaded, with an average daily flow of 84,200 gpd when the design average treatment capacity is 15,000gpd. Similarly, the Mt. Gilead WWTP has a design average treatment capacity of 0.474 mgd and yet had an average daily flow of 0.59 mgd, significantly over the design average. The Cardington WWTP maintained an average daily flow of 0.43 mgd, which was below the design average treatment capacity of 0.5 mgd. However, the maximum flow recorded during 2003 was 2.31 mgd. Wet weather bypasses from these plants, in addition to poorly treated wastes, inhibited biological attainment throughout Whetstone Creek.

Nonpoint sources of pollution include a mixture of urban and agricultural issues. Increased housing developments have changed land use, resulted in the straightening of stream channels and decreased riparian corridors, compromising the ability of streams to assimilate pollutants. Failing septic systems contribute excessive nutrients and organics into streams. Agricultural activities that degrade streams include unrestricted livestock access to streams, channelization and removal of riparian corridors on tributary streams, and artificial drainage of fields.

Table 19. Aquatic life use attainment status for stations sampled in the WCWAU based on data collected July-October 2003. The Index of Biotic Integrity (IBI), Modified Index of well being (MIwb), and Invertebrate Community Index (ICI) are scores based on the performance of the biotic community. The Qualitative Habitat Evaluation Index (QHEI) is a measure of the ability of the physical habitat to support a biotic community. Threats to water quality identified during the course of the study are listed under Causes and Sources.

River Mile Fish/Invertebrate	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes	Sources
Whetstone Creek (RM 36.07) *EWH*							
30.5[H]/30.5	50	NA	F*	78.5	PARTIAL	Nutrient enrichment, elevated temp. (25.0C)	Candlewood Lake and associated housing
29.3[H]/29.3	43*	NA	MG*	73.0	**NON**	Nutrient enrichment	Candlewood Lake WWTP
28.1[H]/28.1	48	NA	E	80.0	FULL		
25.5[W]/25.5	46[ns]	9.0[ns]	52	74.5	FULL		
22.4[W]/22.4	50	9.0[ns]	48	72.0	FULL		
21.7[W]/21.8	50	8.1*	50	66.5	PARTIAL	Natural?	MIwb influenced by abnormal seasonal rainfall?
21.6/21.58 Mix Zone	**36**	**6.0**	**MG/ MG**			**Avoidance occurs**	**Avoidance of effluent discharged from WWTP**
21.5[W]/21.5	41*	8.6*	46	68.0	PARTIAL	Nutrient enrichment	Mt. Gilead WWTP
18.2[W]/18.3	*54*	*8.6**	40*	*72.5*	PARTIAL	Embedded substrates	
13.65/13.68 Mix Zone	**46/28**	**9.1/ 6.5**	**MG/F**			**Avoidance occurs during higher flow**	**Effluent discharged to flow upst. which speeds dilution at low flow; not effective during higher flows.**
13.5[W]/12.8	45*	8.4*	52	64.5	PARTIAL	Nutrient enrichment, poor riparian corridor	Cardington WWTP, historical urbanization

River Mile Fish/Invertebrate	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes	Sources
Whetstone Creek (RM 36.07) (Continued) *EWH*							
9.2[W]/9.0	*40**	*8.8**	50	*69.5*	PARTIAL	Nutrient enrichment	Agricultural activities, livestock in stream
2.6[B]/2.7	36*	8.7*	56	61.5	PARTIAL	Siltation, Impounded	Delaware Reservoir
Tributary to Whetstone Creek RM 33.71 *Undesignated / WWH and CWH Recommended*							
0.4[H]/0.4	40	NA	F*	56.5	PARTIAL	Agricultural runoff	Agricultural activities
E. Branch Whetstone Creek (Tributary to Whetstone Creek RM 28.29) *WWH / CWH Recommended in addition to WWH*							
0.4[H]/0.4	45	NA	E	78.0	FULL		
Sams Creek (Tributary to Whetstone Creek RM 23.30) *WWH*							
1.4[H]/1.4	44	NA	E	66.5	FULL		
Big Run (Tributary to Whetstone Creek RM 12.75) *WWH*							
0.1[H]/0.1	34*	NA	Low F*	64.0	**NON**	Siltation, Upstream channel modifications	Agricultural impacts exacerbated by intermittent stream flow
Shaw Creek (Tributary to Whetstone Creek RM 8.47) *WWH*							
13.2[H]/13.2	40	NA	G	39.5	FULL	Channel modifications, Nutrient enrichment	
10.6[H]/10.6	38[ns]	NA	MG[ns]	52.5	FULL	Channel modifications, Nutrient enrichment	
5.2[W]/5.2	*36*[ns]	NA	MG[ns]	*66.0*	FULL	Nutrient enrichment, Siltation, Poor riparian cover	Failing septic systems, Agricultural activities

River Mile Fish/Invertebrate	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes	Sources
Shaw Creek (Tributary to Whetstone Creek RM 8.47) (continued) *WWH*							
1.6[W]/1.5	*38[ns]*	*8.2[ns]*	42	*69.5*	FULL		
Mitchell Run (Tributary to Whetstone Creek RM 8.1) *WWH*							
0.2[H]/0.2	42	NA	MG[ns]	72.0	FULL	Nutrient enrichment	Upstream agricultural activities
Claypole Run (Tributary to Whetstone Creek RM 3.27) *WWH*							
1.2[H]/1.2	39[ns]	NA	Low F*	54.0	PARTIAL	Nutrient enrichment, siltation, bacteria	Home septic discharges, Channel modifications

Ecoregion Biocriteria: Eastern Corn Belt Plain

	IBI			MIwb			ICI		
Site Type	WWH	EWH	MWH	WWH	EWH	MWH	WWH	EWH	MWH
Headwaters	40	50	24				36	46	22
Wading	40	50	24	8.3	9.4	4.0	36	46	22
Boat	42	48	24	8.5	9.6	4.0	36	46	22

H - Headwater site.
W - Wading site.
B - Boat site.
a - MIwb is not applicable to headwater streams with drainage areas ≤ 20 mi^2.
b - A narrative evaluation of the qualitative sample based on attributes such as EPT taxa richness, number of sensitive taxa, and community composition was used when quantitative data was not available or considered unreliable due to current velocities less than 0.3 fps flowing over the artificial substrates. VP=Very Poor, P=Poor, LF=Low Fair, F=Fair, MG=Marginally Good, G=Good, VG=Very Good, E=Exceptional
c - Attainment status is given for both existing and proposed use designations.
ns - Nonsignificant departure from biocriteria (≤4 IBI or ICI units, or ≤0.5 MIwb units).
* - Indicates significant departure from applicable biocriteria (>4 IBI or ICI units, or >0.5 MIwb units). Underlined scores are in the Poor or Very Poor range.

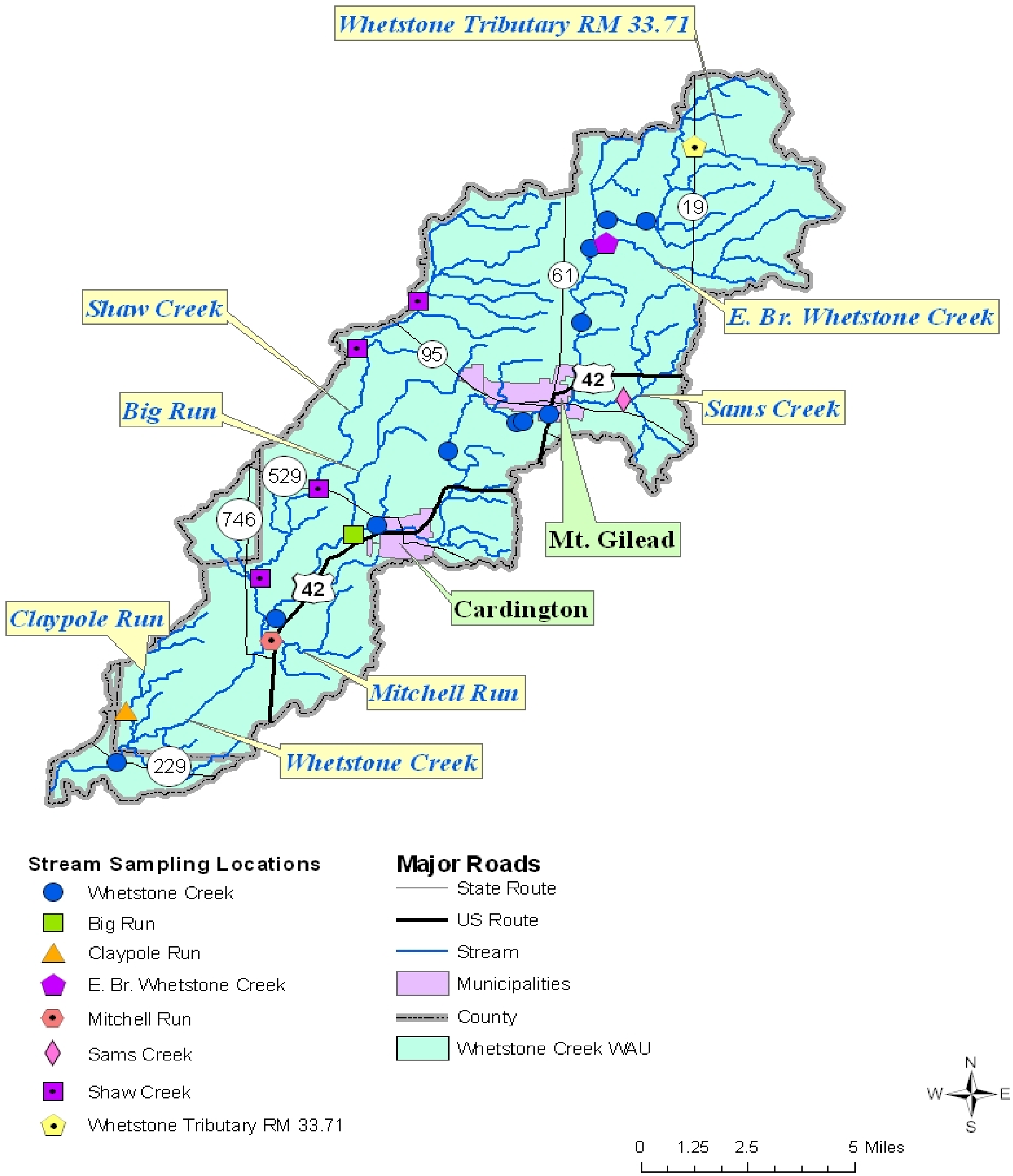


Figure 45. Biological sampling locations for WCWAU 2003.

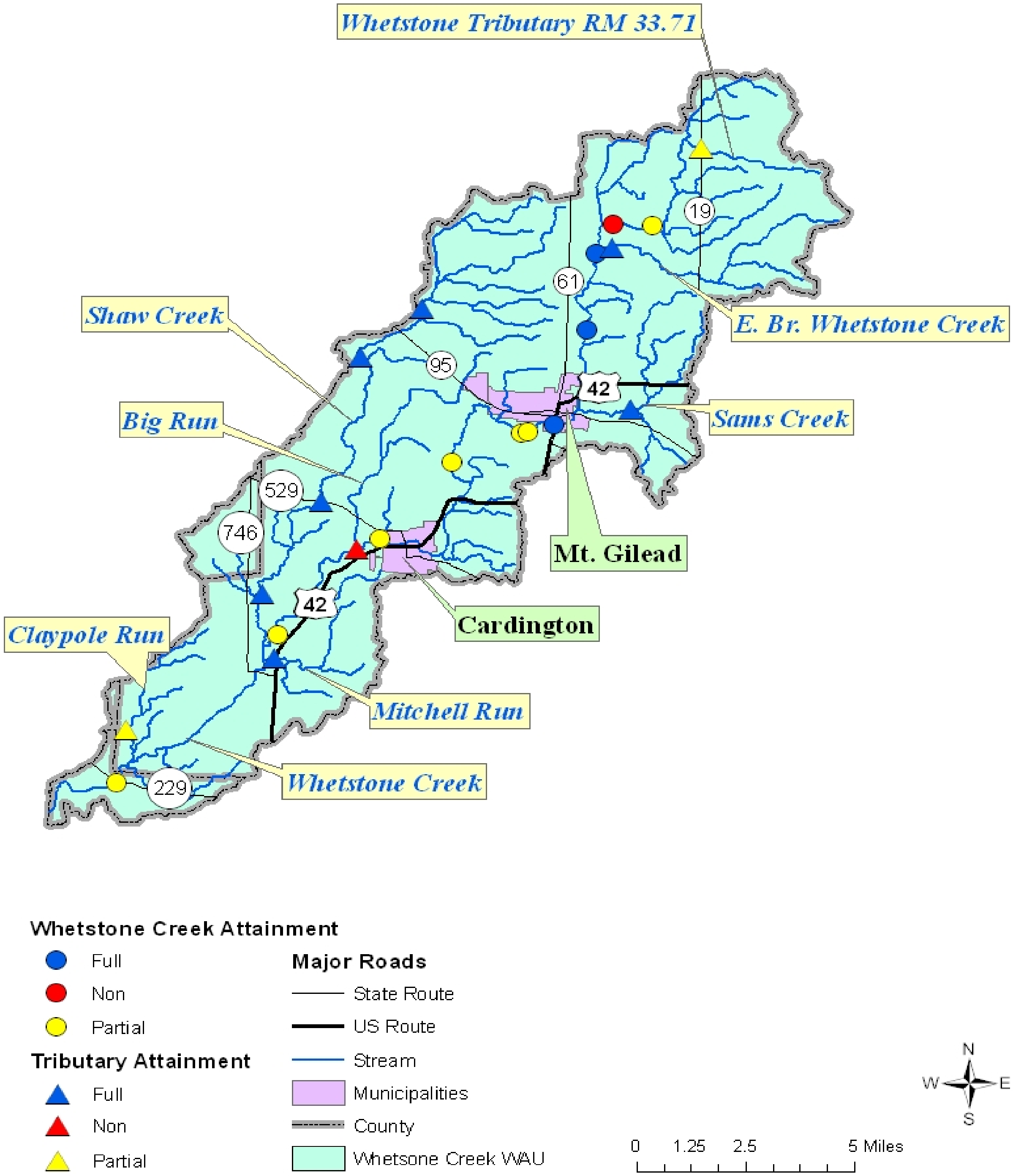
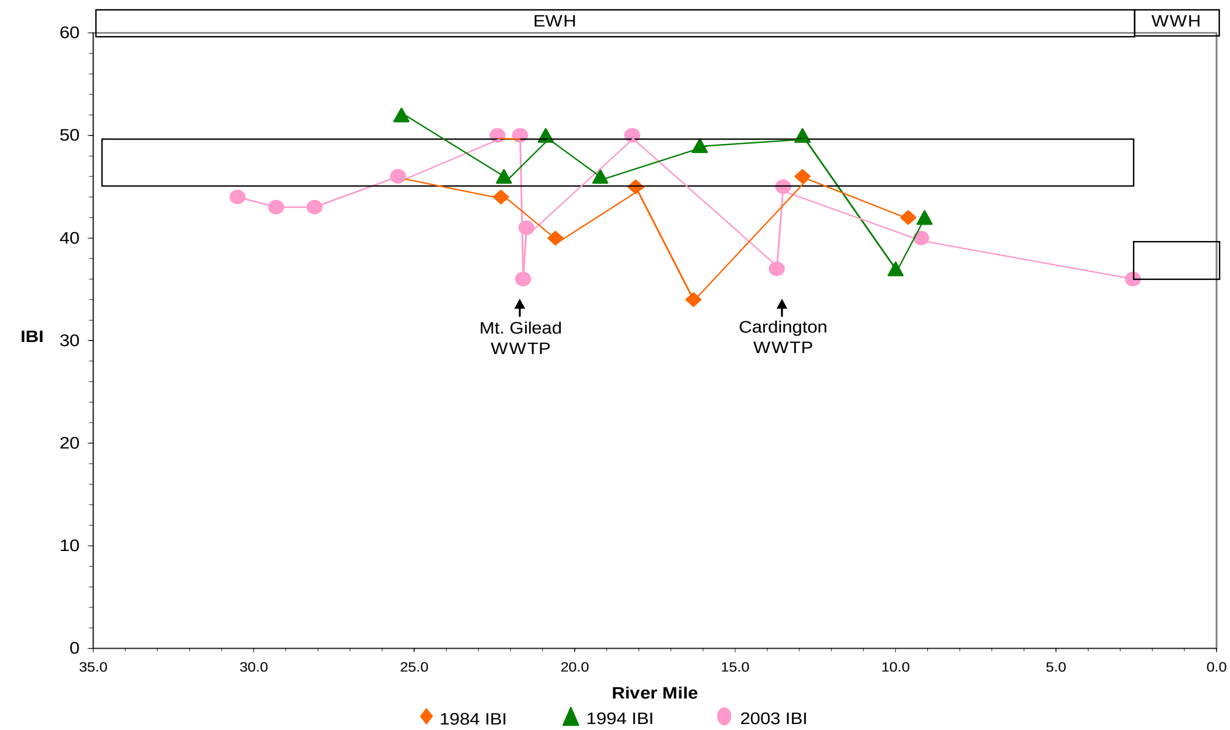


Figure 46. Attainment status of biological sampling sites in the WCWAU based on data from 2003.



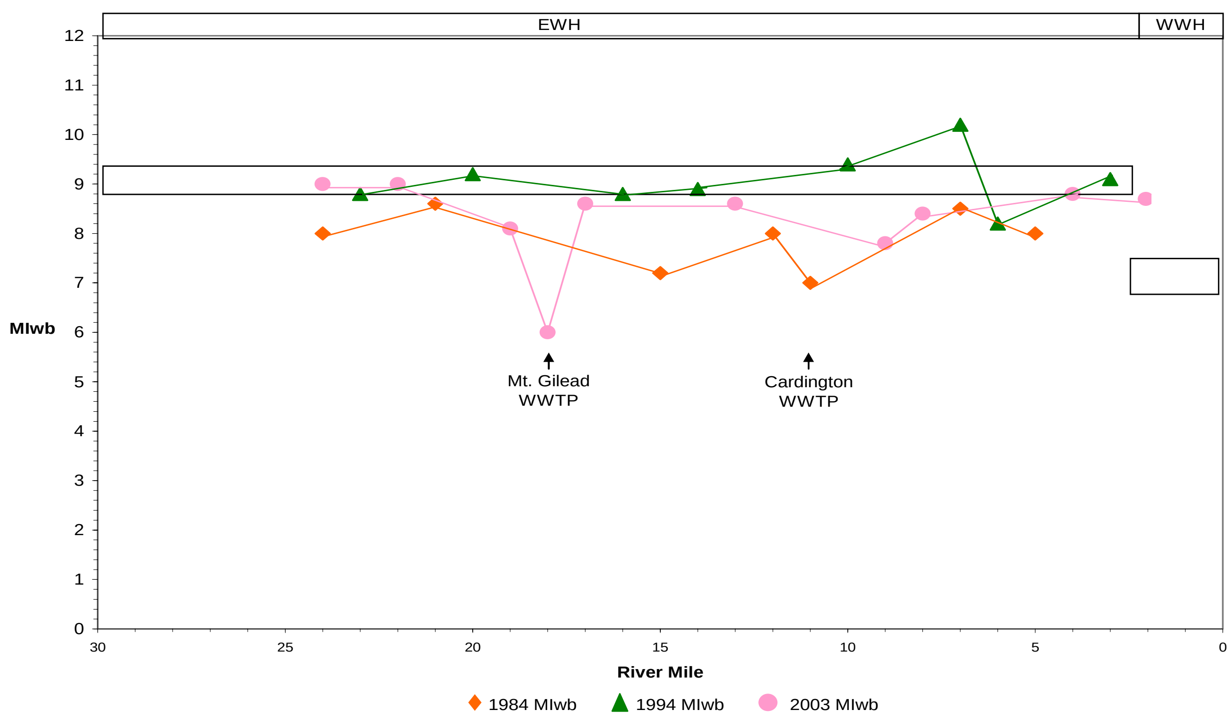
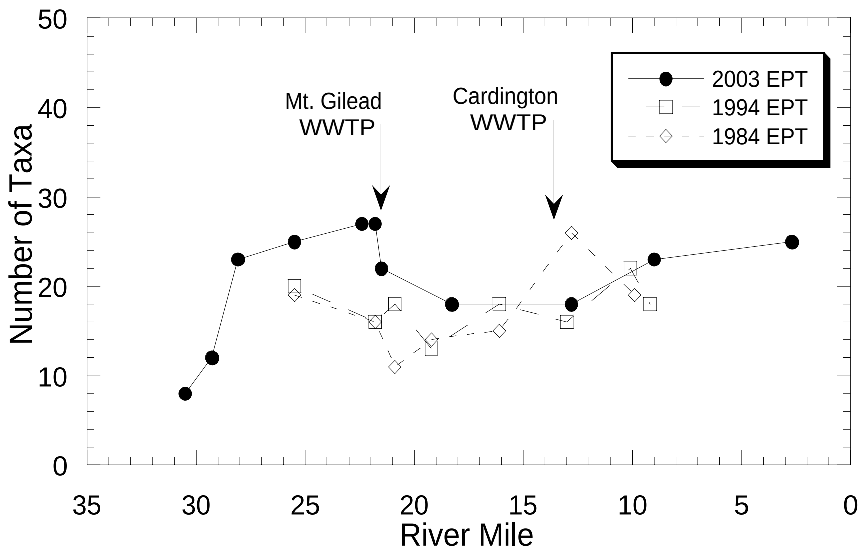


Figure 47. Longitudinal plots of IBI and MIwb for Whetstone Creek from 1984, 1994 and 2003.



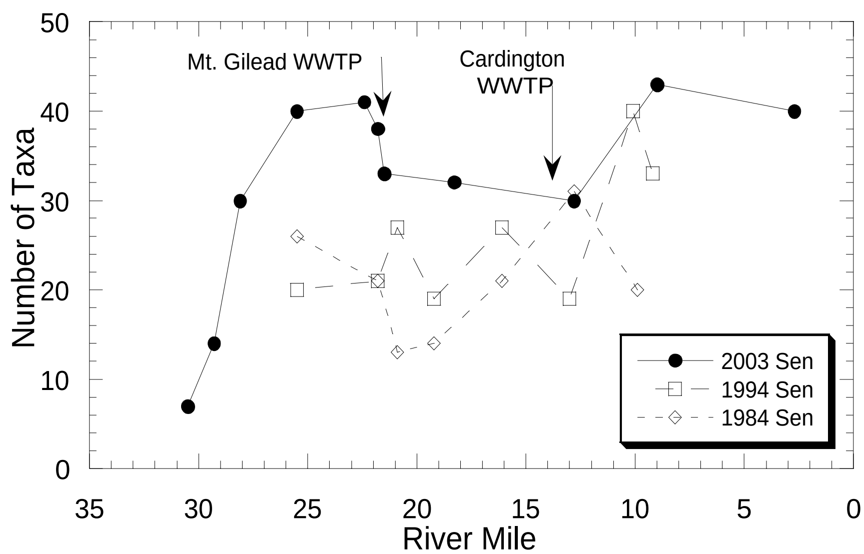


Figure 48. Longitudinal trend of the total EPT and total sensitive taxa in Whetstone Creek. 1984-2003.

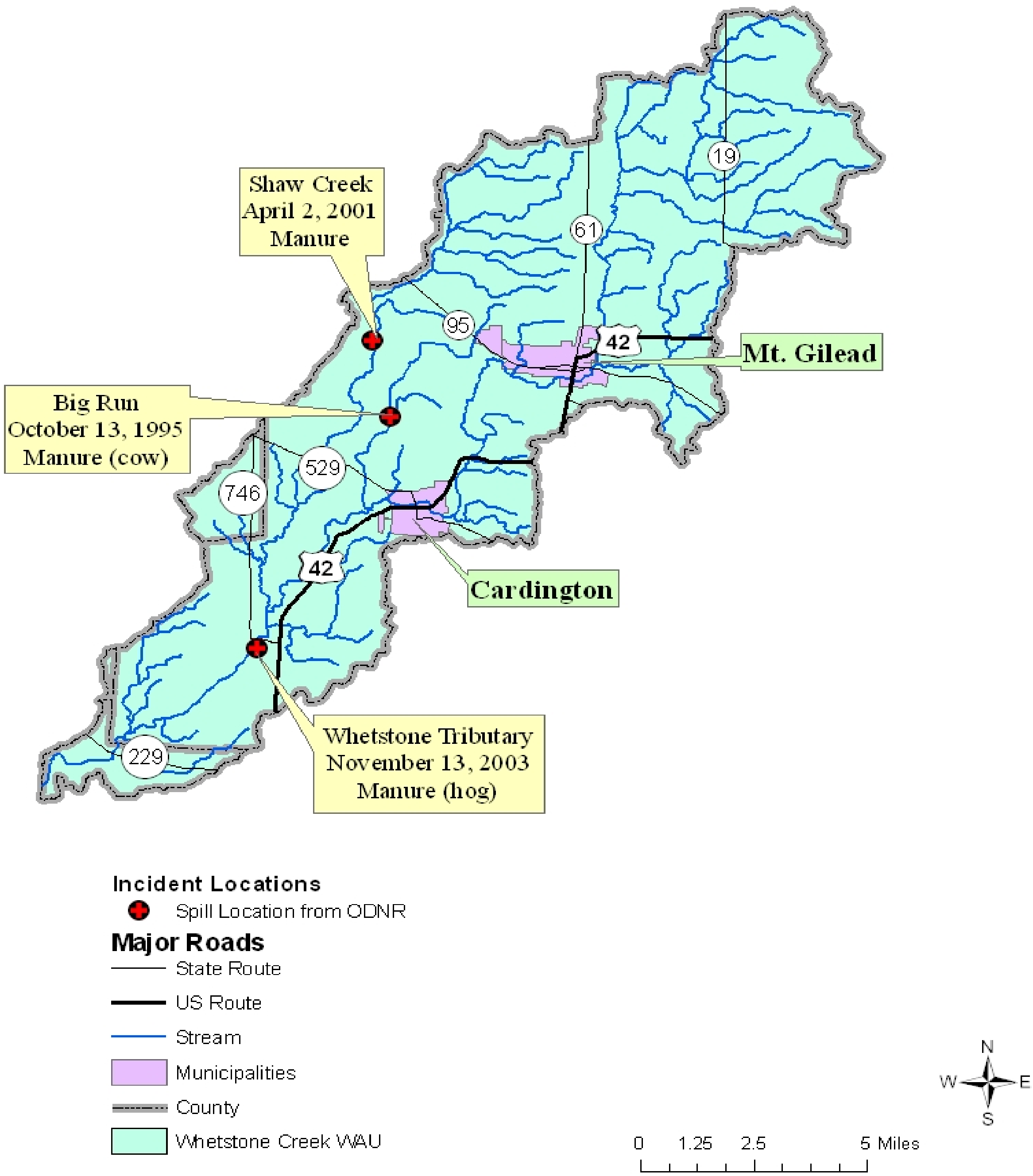


Figure 29. Spills reported to ODNR between 1994-2004 for the WCWAU.

Chemical Water Quality

Whetstone Creek

The main channel of Whetstone Creek exhibited violations of bacterial standards at nearly 62% of the sites evaluated during the survey (Table 19). The geometric mean concentrations of both *E. coli* and fecal coliform bacteria were found to be in violation of the Ohio Water Quality Standards at 8 of the 13 sites on the Whetstone Creek mainstem (Figures 50 and 51). Additionally, maximum values for each of these bacterial parameters were violated at these same sites (Table 19). Only the upper and lower portions of the mainstem did not have violations of bacterial standards.

Bacterial contamination appeared to emanate from several sources including municipal wastewater collection and treatment systems at Mt. Gilead WWTP, the wastewater treatment plant at Cardington, municipal stormwater runoff, contaminated discharges from on-site wastewater treatment systems and agribusiness.

Both nutrient and organic enrichment posed problems in Whetstone Creek as well. The areas immediately downstream of three municipal wastewater treatment facilities (Candlewood Lake, Mt. Gilead, and Cardington) revealed significant organic and nutrient enrichment (Table 21) which inhibited attainment in the biological community (Table 19). The monitoring site on Whetstone Creek downstream of the Candlewood Lake WWTP (RM 29.3) showed noticeably higher concentrations of ammonia-N, total phosphorus, and TKN compared with most other streams of the same drainage area (Figures 52, 53, and 54) and one of the highest median suspended solids concentrations (greater than 20 mg/l) of this size drainage (Figure 55). Longitudinal graphs of the Whetstone Creek mainstem provide further evidence of enrichment from both the Candlewood Lake WWTP and the Mt. Gilead WWTP (Figures 56, 57, and 58). Additionally, fish were observed to avoid the mixing zones adjacent to the discharge points of both the Mt. Gilead and Cardington WWTPs indicating potential effluent toxicity.

Nutrient enrichment was also evidenced by elevated concentrations of nitrate+nitrite and TKN (Table 21). Elevated nitrate+nitrite concentrations were attributed to both point source WWTPs and farm field tile drainage (Figure 59). Suspended solids concentrations were also higher than background, especially during storm events and high water, and were likely caused by excessive stream bank erosion enhanced by hydromodification, riparian disruption, and unrestricted livestock access to the stream (Figure 60). High suspended solids concentrations were attributed to hydraulic overloading of point sources.

Mean daytime dissolved oxygen concentrations never fell below 7 mg/l in the entire mainstem easily meeting the EWH average standard of 6 mg/l (Figure 61). There was a small noticeable oxygen sag downstream of the Mt. Gilead WWTP discharge undoubtedly caused by wet weather hydraulic overloading of the plant (Figure 62).

Several organic chemicals were found in the water column during sampling events at four stations in Whetstone Creek. Those organic chemicals detected are listed in Table 22. None of the chemicals were found at concentrations that would cause concern for human health or aquatic life.

Figure 62. Mt. Gilead wet weather discharge.

Water Quality Trends

Trends analysis revealed generally improved conditions in Whetstone Creek during 2003 versus past surveys. This was especially noticeable downstream of the Mt. Gilead and Cardington WWTPs. Nutrient enrichment decreased significantly (Figures 63, 64, and 65). Both mean biochemical oxygen demand and mean ammonia concentrations were also much reduced (Figures 66 and 67). Dissolved oxygen mean concentrations were greatly improved compared to previous surveys (Figure 68). These improvements may be directly linked to enhanced treatment at both the Mt. Gilead and Cardington WWTPs, although both plants still suffer from problems, especially during wet weather. One disturbing trend existed showing increased mean concentrations of suspended solids, well above the 1994 survey results (Figure 69). Increases in solids concentrations are likely the result of stream modifications and erosion caused by agricultural activities, WWTP bypasses and overflows caused by wet weather, and development.

Sediments

Sediment samples were obtained from 4 different sites on the mainstem of Whetstone Creek. Total organic carbon (TOC) was the only parameter above reference values (Table 23). TOC contaminated sediment did not appear to cause problems for the benthos in the Whetstone Creek watershed.

Point Sources

Candlewood Lake WWTP **-** The Candlewood Lake WWTP was originally constructed in 1980 with a design average treatment capacity of 15,000 gpd. The existing plant consists of two facultative lagoons which are operated in series. Four surface aerators were added to the lagoons in 1995. The lagoons were deepened to a total depth of 5'8" in 1996 to improve the treatment efficiency. Since 1980, the Candlewood Lake development has continued to grow without a commensurate expansion of their WWTP. The existing plant is hydraulically overloaded (average daily flow 84,200 gpd) which has resulted in chronic noncompliance with the effluent loading limits contained in the effective NPDES permit.

Candlewood Lake recently completed construction of a new wastewater treatment plant that is now functioning. The new plant is designed for an average daily flow of 300,000 gpd and will meet tertiary treatment limits (i.e., nutrient removal). The treatment train consists of flow equalization, extended aeration, clarification, rapid sand filtration, ultraviolet disinfection and post aeration.

Cardington WWTP - The Cardington WWTP has a design average treatment capacity of 0.5 Million Gallons per Day (MGD). The wet stream process at the facility includes an influent lift station, comminution, screening, aerated grit removal, extended aeration, clarification, chlorine disinfection, post aeration and dechlorination. Solids handling consists of aerobic digestion, dewatering with sludge drying beds, sludge storage and land application. The average daily flow at outfall 001, for the time period between January - December 2003 was 0.43 MGD. The maximum flow during this period of record was 1.35 MGD.

Mt. Gilead WWTP - The Mount Gilead WWTP is a conventional activated sludge plant designed to treat an average daily flow of 0.474 MGD. Unit processes at the plant include influent bar screens, a comminutor, primary settling, extended aeration, final clarification, chlorination, dechlorination and post aeration. Solids are treated through anaerobic (sludge from primary settling) and aerobic digestion (sludge from secondary settling) followed by sand drying beds or liquid land application. The average daily flow at outfall 001, for the time period between January - December 2003 was 0.59 MGD, significantly over the design average. The maximum flow during this period of record was 2.31 MGD.

Unnamed Tributary to Whetstone Creek at RM 33.71

This headwater tributary exhibited both organic and nutrient enrichment as well as contamination from bacteria. However, daytime dissolved oxygen concentrations were very good. One-third of the samples obtained in this small stream were greater than the 95^{th} percentile of background for BOD_5, TSS, and ammonia (Table 24). Nitrates, phosphorus, and TKN values were also noticeably above median background concentrations (Table 21).

Comparisons of other small undesignated tributary streams (0-4 mi^2) demonstrated that this creek had a median dissolved oxygen value of over 8 mg/l, comparing favorably to other streams of this size in the Olentangy watershed (Figure 70). Daytime dissolved oxygen concentrations ranged from around 7 mg/l to over 11 mg/l, well above WWH water quality standards. Saturation levels were appropriate with median saturation just below 90% (Figure 71).

Bacteria and suspended solids concentrations varied widely in this stream with median values below background for TSS or secondary contact (bacteria) concentrations (Figures 72, 73 and 74). Bacterial contamination was evident and violated both primary and secondary contact standards for geometric mean fecal coliform and *E. coli* bacteria

(Table 19, Figure 75). The ultimate designation of this stream as primary or secondary contact recreation is addressed in another section of this report. Suspended solids were of great concern in this tributary during high flow with values exceeding 200 mg/l (Table 20). These were among the highest collected in the survey.

A source of pollution for this tributary may include the unsewered community of West Point. During the summer of 2003, odors were apparent in this small crossroads town and there are several ditches and a storm sewer running through the community with many houses with small lots for septic and leach field systems. This situation certainly has the potential to contribute pollutants to this tributary and will be studied further.

East Branch Whetstone Creek

East Branch Whetstone Creek has a drainage area of over 6 mi^2 and discharges to Whetstone Creek at RM 28.29. This creek was in non-attainment for primary contact bacteriological standards (Table 19, Figure 75).

Nutrient enrichment was not as pronounced as that found in other similarly sized tributaries (4-8 mi^2). Both nitrate+nitrite and TKN exhibited median concentrations very similar to background values (Figures 76 and 77). However, total phosphorus concentrations were all found to be above background median values (Table 20, Figure 78) and raise concern. Suspended solids concentrations were elevated concurrent with rainfall events although the median concentration was well below background (Figure 79).

Daytime dissolved oxygen concentrations were excellent, among the highest median values for a 4 mi^2 to 8 mi^2 tributary (Figure 80), and well above the WWH water quality minimum criterion of 4 mg/l. Median oxygen saturation was nearly 100% (Figure 71) with no supersaturation.

Sam's Creek

Sam's Creek encompasses a drainage of nearly 8 mi^2 and discharges to Whetstone Creek at RM 23.30. At RM 1.40, this creek was in non-attainment for primary contact recreational standards (Table 19, Figure 75).

Modest nutrient enrichment was evident in Sam's Creek with most concentrations of ammonia, TKN, nitrate+nitrite, and total phosphorus found in excess of median background values (Table 20). However, these values were less variable than in most of the other Whetstone Creek tributary streams (nitrate+nitrite, see Figure 81). The median concentration of total suspended solids was greater than the background median, possibly indicative of an emerging problem, although the values seen in Sam's Creek compared favorably with other tributaries of similar drainage (Figure 79).

Daytime dissolved oxygen concentrations never dipped below 8 mg/l in Sam's Creek (Figure 80) and were well above the WWH water quality minimum of 4 mg/l. Dissolved oxygen saturation showed a median value just below 100%, exceeding saturation only twice during the survey (Table 1 in the Appendix). This mild, intermittent condition provided evidence of minor nutrient enrichment.

Big Run

Big Run drains slightly more than 6 mi^2 and discharges to Whetstone Creek at RM 12.75. The sampling point at the mouth of this creek was in non-attainment for primary contact recreational standards for both the geometric mean (Figure 75) and maximum bacterial value (Table 19).

Nutrient enrichment was apparent and comparable with other tributaries of similar drainage area (Figures 77 and 78). Big Run had by far the largest range of nitrate+nitrite concentrations (Figure 76) with 2 values exceeding 10 mg/l. Five of 6 total phosphorus concentrations were found to be greater than the background median (Table 20). Noticeable concentrations of ammonia and TKN were also present in Big Run (Table 20). Total suspended solids concentrations exceeded median background values in half of the six samples perhaps revealing an ongoing problem when taken in conjunction with nutrient enrichment and non-attainment in the biological community (Table 20).

Daytime dissolved oxygen concentrations were well above WWH standards with median concentrations around 9 mg/l. Nutrient enrichment was confirmed by 3 daytime samples revealing supersaturated conditions in Big Run (Table 1 in the Appendix).

Shaw Creek

Shaw Creek drains approximately 30 mi^2 and is the largest tributary in the Whetstone Creek watershed, discharging to Whetstone Creek at RM 8.47. All four sites evaluated on Shaw Creek were in non-attainment for primary contact bacteriological standards, both geometric mean (Table 19, Figure 75) and maximum values (Table 19).

Enriched conditions prevailed along the length of Shaw Creek. The two uppermost sites appeared to be organically enriched. Three BOD_5 values (25% of the total of 12) were found to be greater than the 90^{th} percentile of background and provided evidence of intermittent organic enrichment in the upper half of the drainage (Table 20). Nutrient enrichment was apparent at each of the 4 sampling locations. Total phosphorus values exceeded the background median in 83% of the samples, likewise nitrate+nitrite results exceeded the background median in 58% of the samples (33% of the total number of samples were above the 90^{th} percentile). The lower 3 sites also revealed some conspicuous values for ammonia. Ten of the 18 samples (56%) transcended the 75^{th} percentile for background (Table 20). Supersaturated conditions fro daytime dissolved oxygen observed at 3 of the sites support the conclusion that this stream was nutrient enriched (Figure 82).

Total suspended solids concentrations exceeded median background values in nearly 71% of the samples with 4 samples (nearly 17%) exceeding the 95^{th} percentile (Table 20,

Figure 83). In this rural area, suspended solids combined with enriched conditions indicate pollution from agricultural sources. Daytime dissolved oxygen concentrations never fell below minimum water quality criteria (Figure 84).

Mitchell Run

Mitchell Run is a small headwater stream which drains approximately 5.4 mi^2 and discharges to Whetstone Creek at RM 8.10. Water samples were obtained 0.2 mile from the mouth. This stream fails to meet the primary contact recreational standards for both maximum and geometric mean concentrations of bacteria (Table 19, Figure 75).

Nutrient enriched conditions prevailed in Mitchell Run with 67% of the values for nitrate+nitrite exceeding the 75^{th} percentile for background (Table 20). Ammonia and TKN were also inflated over background conditions in most of the samples (Table 20). Total phosphorus values were found to be excessive with all concentrations exceeding the 75^{th} percentile and over half greater than the 90^{th} percentile (Table 20). In fact, Mitchell Run had the highest actual concentration and highest median concentration of phosphorus for any WWH 4-8mi^2 tributary stream in the entire Whetstone Creek watershed (Figure 78). Daytime dissolved oxygen saturation disclosed supersaturated conditions at times in Mitchell Run providing further evidence of significant nutrient enrichment (Figure 71).

Additionally, median concentrations of suspended solids were greater than any other 4-8 mi^2 WWH tributary stream in the Whetstone Creek watershed (Figure 79). High to moderate riffle embeddedness noted instream combined with a moderately good invertebrate community may be artifacts of the presence of excessive solids in the streambed.

Daytime dissolved oxygen concentrations found in Mitchell Run were significantly greater than the minimum water quality criterion of 4 mg/l. Median values of dissolved oxygen were well over 8.5 mg/l (Figure 80) and supersaturated at times as noted above.

Claypole Run

Claypole Run drains approximately 3.8 mi^2 of the Whetstone Creek watershed, discharging to the parent stream at RM 3.27. This small headwater stream failed to meet primary contact recreational standards for bacteria for both geometric mean and maximum values (Table 19, Figure 75).

In most water chemistry categories, Claypole Run was very similar to Mitchell Run. Nutrient enrichment was significant with high values recorded for ammonia, nitrate+nitrite, TKN, and total phosphorus. Ammonia concentrations were above the 75^{th} percentile in 5 of 6 instances (Table 20). Fifty percent of the nitrate+nitrite values exceeded the 95^{th} percentile for background and all of the values for TKN and total phosphorus exceeded the background median with most in excess of the 75^{th} percentile (Table 20). Intermittent dissolved oxygen supersaturation provided additional evidence of nutrient enrichment (Table 2 in the Appendix). Daytime dissolved oxygen concentrations recorded in Claypole Run were significantly greater than the minimum water quality criterion of 4 mg/l and similar to those found in Mitchell Run. Median values of dissolved oxygen were nearly 9.5 mg/l (Figure 70) and comparable to other streams of similar drainage area in this watershed. Median total suspended solids concentrations were the highest among WWH streams of 104 mi^2 drainage (Figure 74) and were largely due to channelization, riparian disturbance, and influence from upstream silt loading.

Table 20. Violations of Ohio EPA Warmwater Habitat (WWH) and Exceptional Warmwater Habitat (EWH) water quality criteria (OAC 3745-1) for chemical/physical parameters in the WCWAU, 2003. 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. Shaded areas are tributary streams to Whetstone Creek and the river mile listing is the location of the confluence with Whetstone Creek.

Waterbody	NPDES Discharge	Biological Attainment	QHEI	River Mile	Parameter	Code
Whetstone Creek and Tributaries (HUC 05060001-100) EWH, AWS, IWS, PCR						
-Unnamed Trib (RM 0.42U)		PARTIAL	56.5	**33.71**	E. coli F. coliform	d d
		PARTIAL	78.5	**30.52**		
	Candlewood Lake WWTP			*30.49*		
		NON	73.0	**29.33**		
-E. Br. Whetstone Creek (RM 0.40) WWH, AWS, IWS, PCR		FULL	78.0	**28.29**	E. coli F. coliform	b,c b,c
		FULL	80.0	**28.10**	E. coli F. coliform	b,c b,c
		FULL	74.5	**25.50**	E. coli F. coliform	b,c b,c
-Sams Creek (RM 1.40) WWH, AWS, IWS, PCR		FULL	66.5	**23.30**	E. coli F. coliform	b,c b,c
				23.10		
		FULL	72.0	**22.43**	E. coli F. coliform	b,c b,c
		PARTIAL	66.5	**21.71**	E. coli F. coliform	b,c b,c
	Mt. Gilead WWTP			*21.60*	F. coliform	a
	Mix Zone	Avoidance	NA	**21.57**		
		NON	68.0	**21.53**	E. coli F. coliform	b,c b,c
		FULL	64.0	**18.20**	E. coli F. coliform	b,c b,c
	Cardington WWTP			*13.70*	F. coliform	a
	Mix Zone	Avoidance	NA	**13.69**		

Waterbody	NPDES Discharge	Biological Attainment	QHEI	River Mile	Parameter	Code
		PARTIAL	39.5	**13.20**	NA	
				12.88	E. coli F. coliform	b,c b,c
-Big Run (RM 0.01) WWH, AWS, IWS, PCR		NON	64.0	**12.75**	E. coli F. coliform	b,c b,c
		PARTIAL	69.0	**9.17**		
-Shaw Creek WWH, AWS, IWS, PCR				**8.47**		
--(RM 13.20)		PARTIAL	39.5		E. coli F. coliform	b,c b,c
--(RM 10.60)		FULL	52.5		E. coli F. coliform	b,c b,c
--(RM 5.20)		NON	61.5		E. coli F. coliform	b,c b,c
--(RM 1.56)		FULL	68.5		E. coli F. coliform	b,c b,c
-Mitchell Run (RM 0.20) WWH, AWS, IWS, PCR		FULL	72.0	**8.10**	E. coli F. coliform	b,c b,c
-Claypool Run (RM 1.20) WWH, AWS, IWS, PCR		PARTIAL	54.0	**3.27**	E. coli F. coliform	b,c b,c
		PARTIAL	61.5	**2.55**		

a violates an NPDES permit limit.
b violates the primary contact recreation 30 day geometric mean
c violates the primary contact recreation 30 day maximum
d violates the secondary contact recreation maximum

Table 21. Comparison of background nutrient and demand parameter concentrations with those found in the WCWAU study area, June through August 2003. Comparisons are made to Eastern Corn Belt Plains (ECBP) ecoregion background 50th percentile (plain text), 75th percentile (*italic text*), 90th percentile (underlined text), and 95th percentile (**boldface text**) values for headwaters, wadeable, and small river sites. Units are mg/l for all values. Plain text river miles indicate Warmwater Habitat, boldface river miles are designated Exceptional Warmwater Habitat, areas designated Modified Warmwater Habitat are underlined, and undesignated streams have a letter U following the river mile. Shaded areas are tributary streams to the Whetstone Creek.

River/Stream (Trib. River Mile)	QHEI	Whetstone Creek River Mile	Drainage Area (mi^2)	Parameter	Value
Whetstone Creek (HUC 05060001-100)					
U.T. to Whetstone Creek at RM 0.42 U		33.71	2.0	BOD_5 TSS NH_3 NO_2+NO_3 TKN T-P	(**6.1**, **4.8**) (**460**, **217**) (**0.627**, **0.24**) (**7.35**, *2.57*, 1.37, 1.28) (**1.74**, *0.718*, *0.68*, *0.62*, 0.53) (0.355, 0.226, *0.144*, 0.056, 0.050)
		30.52	7.5	BOD_5 TSS NH_3 NO_2+NO_3 TKN T-P	*2.7*, *2.4* *23*, *14*, 9, 9 0.155, 0.152, *0.090*, *0.081*, *0.051* 1.86, 1.70, 1.58, 1.14 *0.79*, *0.73*, *0.68*, *0.63*, *0.61*, 0.48 0.065, 0.025
		29.33	8.4	BOD_5 TSS NH_3 NO_2+NO_3 TKN T-P	4.0, *2.9*, *2.4*, *2.4*, *2.0* *30*, *27*, *22*, 9 **1.29**, **0.961**, **0.340**, **0.325**, **0.299** 1.84, 1.41, 1.14 **4.07**, **1.65**, **1.42**, 1.04, *0.79* **0.475**, 0.402, *0.150*, *0.136*, *0.092*
E. Branch Whetstone Creek (RM 0.40)		**28.29**	6.3	BOD_5 TSS NH_3 NO_2+NO_3 TKN T-P	(2.1) (67, 61) (*0.081*, *0.072*, *0.069*) (*2.55*, 1.56) (**1.66**, *0.608*, 0.52, 0.48) (**0.501**, *0.116*, *0.108*, 0.066, 0.034, 0.030)

River/Stream (Trib. River Mile)	QHEI	Whetstone Creek River Mile	Drainage Area (mi^2)	Parameter	Value
		28.10	19.0	BOD_5 TSS NH_3 NO_2+NO_3 TKN T-P	4.2, *2.4* **123**, *35*, 9 0.143, *0.092*, *0.072* *3.75*, *2.61*, 1.28, 1.24 *0.83*, *0.77*, 0.45, 0.43, 0.41 0.355, *0.161*, *0.106*, *0.102*, 0.072, 0.034
		25.50	26.0	BOD_5 TSS NH_3 NO_2+NO_3 TKN T-P	3.3, *2.4*, *2.4*, *2.1* **94**, 54, *43*, 23 0.146, *0.093*, *0.092*, *0.064* *3.89*, *2.80*, 2.50, 1.66, 1.23, 1.07 **1.57**, *0.75*, *0.72*, *0.60*, 0.41 **0.717**, *0.209*, *0.151*, *0.147*
Sams Creek (RM 1.40)		**23.30**	7.8	BOD_5 TSS NH_3 NO_2+NO_3 TKN T-P	(*2.8*) (*43*, 16, 11, 7) (0.172, *0.062*, *0.055*, *0.051*) (*2.71*, 2.00, 1.88, 1.47, 1.25, 1.07) (*0.83*, *0.69*, *0.64*, 0.52, 0.47) (*0.104*, *0.092*, 0.059, 0.055, 0.047, 0.035)
		22.43	34	BOD_5 TSS NH_3 NO_2+NO_3 TKN T-P	*2.2* 72 *0.063*, *0.051* 2.37, 1.02, 0.93 *0.62*, 0.52 0.224, 0.074
		21.71	35	BOD_5 TSS NH_3 NO_2+NO_3 TKN T-P	**7.4**, 2.4 75, *35* **0.269**, *0.051* 2.32, 0.99, 0.86, 0.84 *0.73*, *0.63*, 0.52 *0.148*, *0.145*, 0.073
		21.53	36	BOD_5 TSS NH_3 NO_2+NO_3 TKN T-P	**7.4**, **4.7**, 2.9 **83**, 23, 19, 14 0.128, *0.086*, *0.081* 2.41, 1.53, 1.31, 1.15, 1.09 *0.74*, *0.66*, *0.65*, *0.60*, 0.52 **0.599**, **0.371**, **0.322**, 0.228, 0.119, 0.102

River/Stream (Trib. River Mile)	QHEI	Whetstone Creek River Mile	Drainage Area (mi^2)	Parameter	Value
		18.20	40	BOD_5 TSS NH_3 NO_2+NO_3 TKN T-P	**4.2**, *2.0* 63 *0.076*, *0.065*, *0.051* 2.59, 1.46, 1.13, 1.10, 1.06 *0.70*, 0.58, 0.54 **0.402**, 0.280, *0.199*, *0.143*
		12.88	51	BOD_5 TSS NH_3 NO_2+NO_3 TKN T-P	*2.8* *42*, *39*, *32*, 27 *0.094*, *0.090*, *0.070*, *0.061* *3.40*, 1.83, 1.37, 1.26, 1.22, 1.07 *0.68*, *0.65*, 0.59, 0.57, 0.56, 0.54 **0.311**, 0.291, 0.225, *0.192*, 0.091, 0.080
Big Run (RM 0.01)		**12.75**	6.1	BOD_5 TSS NH_3 NO_2+NO_3 TKN T-P	(*2.6*) (*24*, *16*, 14) (0.151, *0.063*, *0.052*) (**12.2**, **10.4**, 1.28, 1.16) (*0.80*, *0.63*, 0.59, 0.52) (*0.109*, *0.084*, 0.077, 0.066, 0.062)
		9.17	62.0	TSS NH_3 NO_2+NO_3 TKN T-P	*33*, *30*, 17 *0.054*, *0.053* 3.60, 4.32, 1.04, 0.92, 0.91 0.65, 0.58, 0.57 0.288, *0.216*, *0.180*, *0.173*, 0.095, 0.073
Shaw Creek		**8.47**			
–(RM 13.20)			11.8	BOD_5 TSS NO_2+NO_3 TKN T-P	(**5.3**) (**208**, 10, 8) (5.80, 5.05, 3.51) (*0.80*, 0.56, 0.45, 0.43, 0.41) (0.268, *0.11*, 0.076, 0.048, 0.037, 0.027)
–(RM 10.60)			17.0	BOD_5 TSS NH_3 NO_2+NO_3 TKN T-P	(**4.8**, 3.8) (**396**, **91**, 12, 10, 9) (0.157, *0.094*, *0.054*) (**6.95**, 5.38, *4.27*) (*0.61*, 0.60, 0.60, 0.48) (0.297, 0.284, *0.117*, 0.04, 0.035)

River/Stream (Trib. River Mile)	QHEI	Whetstone Creek River Mile	Drainage Area (mi^2)	Parameter	Value
–(RM 5.20)				TSS NH_3 NO_2+NO_3 TKN T-P	(**83**, *43*, 28, 25, 14) (**0.232**, 0.101, *0.050*) (**8.10**, **6.90**, 2.57, 0.91) (0.95, *0.68*, 0.50) (0.091, 0.083, 0.079, 0.072)
–(RM 1.56)				TSS NH_3 NO_2+NO_3 TKN T-P	(*41*, *32*, 22, 16) (*0.074*, *0.068*, *0.056*, *0.055*) (**8.60**, **8.30**, 0.97, 0.92) (*0.72*, 0.54) (*0.136*, 0.116, 0.111, 0.098, 0.076)
Mitchell Run (RM 0.20)		**8.10**	5.4	BOD_5 TSS NH_3 NO_2+NO_3 TKN T-P	(*2.8*, *2.1*, *2.0*) (*41*, *37*, *35*, *29*, 7) (0.154, *0.064*, *0.054*, *0.052*) (**8.10**, 5.84, 5.25, *2.94*) (*0.99*, *0.90*, *0.87*, *0.79*, 0.44, 0.44) (**0.604**, 0.275, 0.21, *0.178*, *0.134*, *0.126*)
Claypool Run (RM 1.20)		**3.27**	3.8	BOD_5 TSS NH_3 NO_2+NO_3 TKN T-P	(*2.5*, *2.4*) (*43*, *34*, *16*, 13, 13) (**0.445**, 0.103, *0.098*, *0.071*, *0.066*) (**13.0**, **11.1**, **10.1**, *3.35*, 1.94) (1.33, *0.99*, *0.98*, *0.66*, 0.52, 0.42) (*0.181*, *0.144*, *0.127*, *0.101*, *0.082*, 0.046)
		2.55	113	TSS NH_3 NO_2+NO_3 TKN T-P	55, *40*, 20, 16 **0.160**, *0.063* **6.90**, **6.30**, 2.31, 1.86, 0.92 *0.79*, *0.74*, *0.64*, *0.63*, 0.59 *0.186*, *0.186*, *0.146*, *0.117*, 0.094, 0.080

Table 22. Results of chemical/physical water quality sampling conducted in the Olentangy River and WCWAU study area during July-October, 2003. **WC1** = Whetstone Creek at McKibben Road (RM 25.5, HUC 100), **WC2** = Whetstone Creek downstream Mt. Gilead WWTP (RM 21.53, HUC 100), **WC3** = Whetstone Creek at CR 11 (RM 12.88, HUC 100), **WC4** = Whetstone Creek at Waldo-Fulton-Chesterville Road (RM 9.17, HUC 100), **OR** = Olentangy River at SR 750 (RM 15.00, HUC 120). **Boldface** number 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.

Olentangy River and Tributaries Water Organics					
Analyte (mg/l)	**WC1**	**WC2**	**WC3**	**WC4**	**OR**
Atrazine	1.52	1.11_j	2.05_j	0.87	1.32
bis(2-Ethylhexyl) adipate	2.08	0.53_j	0.70_j	0.52_j	2.40_b
bis(2-Ethylhexyl) phthalate		0.58_j	0.68_j	0.54_j	2.44_b
Acetochlor			0.56_j	0.37	
Metolachlor	1.60	0.83_j	1.74_j	0.53	1.80
Simazine	1.08	0.38_j	0.36_j	0.33	1.12
a-BHC				0.0067_{uj}	
d-BHC	0.0071				0.0080
Dieldrin	0.0040_{uj}		0.0053_{uj}		0.0054_{uj}
Bromomethane	1.12				

b = Analytical result is estimated. Analyte was detected in the associated method/trip/field blank as well as in the sample.
j = The analyte was positively identified, the associated numerical value is estimated.
uj = The analyte was not detected above the sample quantification limit (QL). However, the reported QL is estimated.

Table 23. Results of chemical/physical sediment quality sampling conducted in the Whetstone Creek study area during July-September, 2003. Parameters in *italic* have no established guideline for comparison. Underlined values indicate concentrations below the method reporting limit. NA means not analyzed. Parameters noted with a ◙ are compared with the Ontario guidelines published by Persaud and Jaagumagi, 1993 (LEL = greater than the Lowest Effect Level but less than the Severe Effect Level, SEL = greater than the severe effect level). All metals parameters are compared with ecoregional (default) or statewide (noted by a subscript s) sediment reference values determined by Ohio EPA (Ohio EPA, 2003). Metals values in **boldface** and shaded are greater than the reference value.

Whetstone Creek Sediments (HUC 05060001-100)					
		River Mile			
Analyte	Units	**25.50**	**21.53**	**12.88**	**9.17**
Solids	*%*	*62.6*	*63.6*	*55.5*	*52.9*
NUTRIENTS					
TOC ◙	%	2.0_{LEL}	2.0_{LEL}	2.7_{LEL}	1.9_{LEL}
Ammonia	*mg/kg*	*41*	*NA*	*NA*	*NA*
Phosphorus ◙	mg/kg	456	NA	NA	NA
METALS					
Aluminum	mg/kg	13000	16100	17700	21600
Arsenic	mg/kg	10.4	11.4	13.5	13.2
Barium	mg/kg	81.3	99.0	135	140
Cadmium	mg/kg	0.308	0.291	0.603	0.638
Calcium	mg/kg	7410	10200	10100	8900
Chromium	mg/kg	17	18	20	22
Copper	mg/kg	8.6	16.1	13.5	15.5
Iron	mg/kg	14600	15400	19800	18600
$Lead_s$	mg/kg	22	25	25	25
Magnesium	mg/kg	3780	4470	4670	4120
Manganese	mg/kg	385	356	383	655
$Mercury_s$	mg/kg	0.036	0.032	0.042	0.039
Nickel	mg/kg	22	24	25	25
Potassium	mg/kg	3680	4040	4630	5520
Selenium	mg/kg	1.10	1.19	1.24	1.24
Sodium	*mg/kg*	*2750*	*2970*	*3110*	*3100*

Whetstone Creek Sediments (HUC 05060001-100)					
		River Mile			
Analyte	Units	**25.50**	**21.53**	**12.88**	**9.17**
Strontium	mg/kg	36	69	76	81
Zinc	mg/kg	55.5	68.1	88.5	93.3

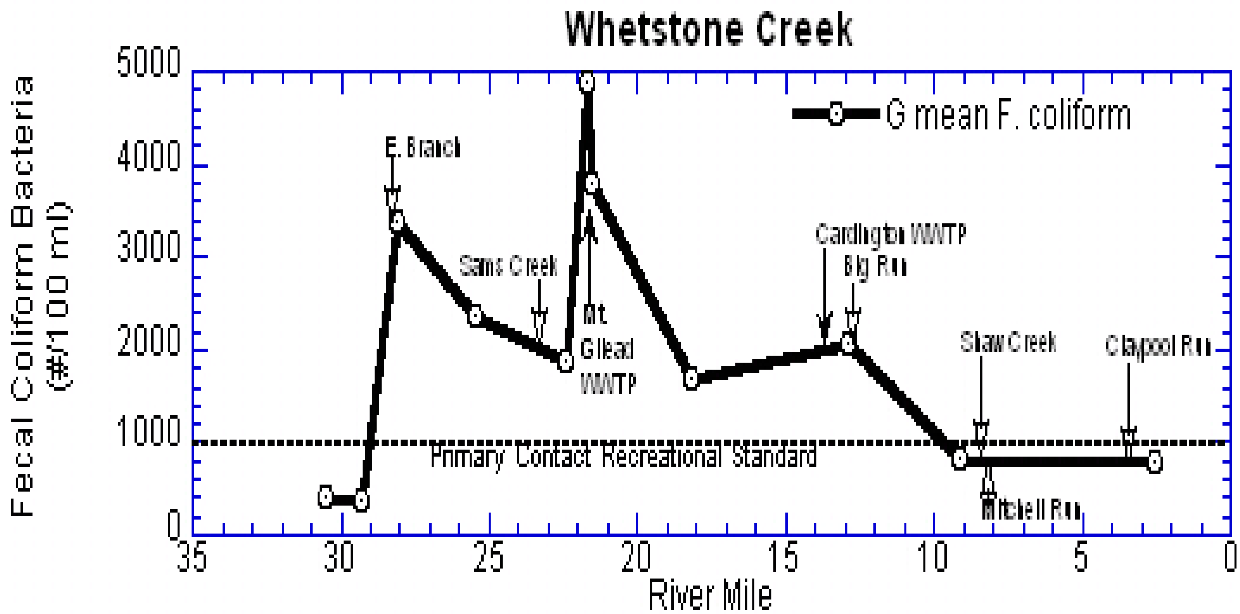


Figure 50. Geometric mean fecal coliform results for Whetstone Creek mainstem, 2003.

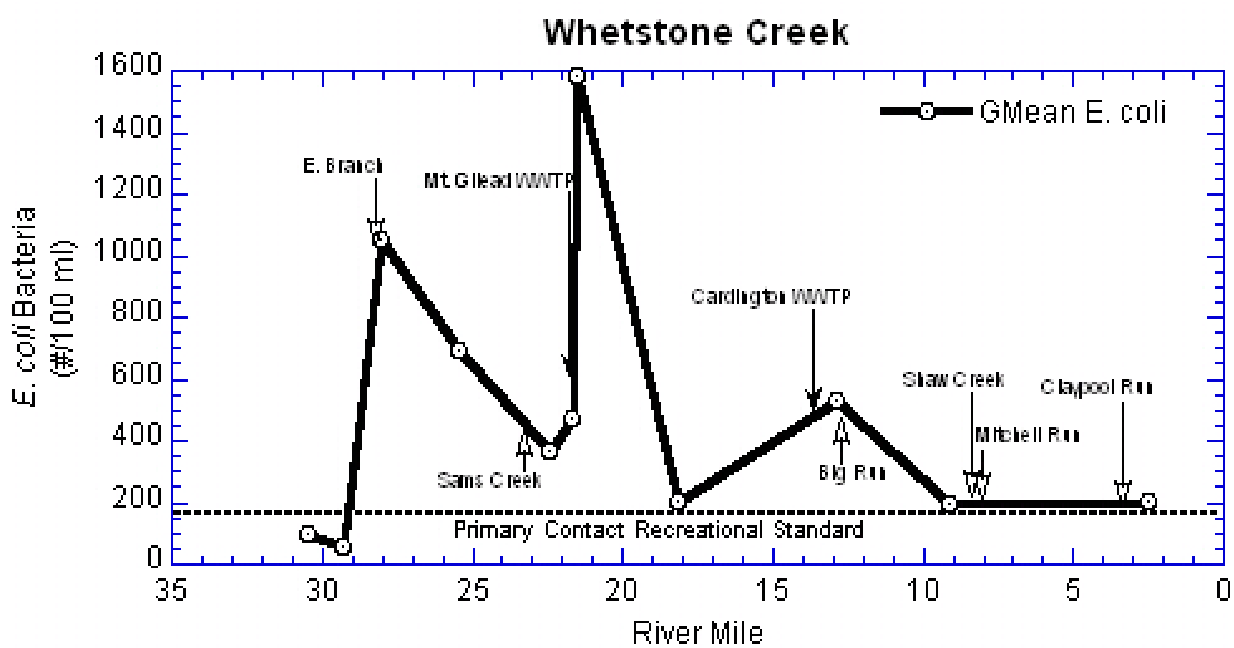


Figure 51. Geometric mean *E. coli* results for Whetstone Creek, 2003.

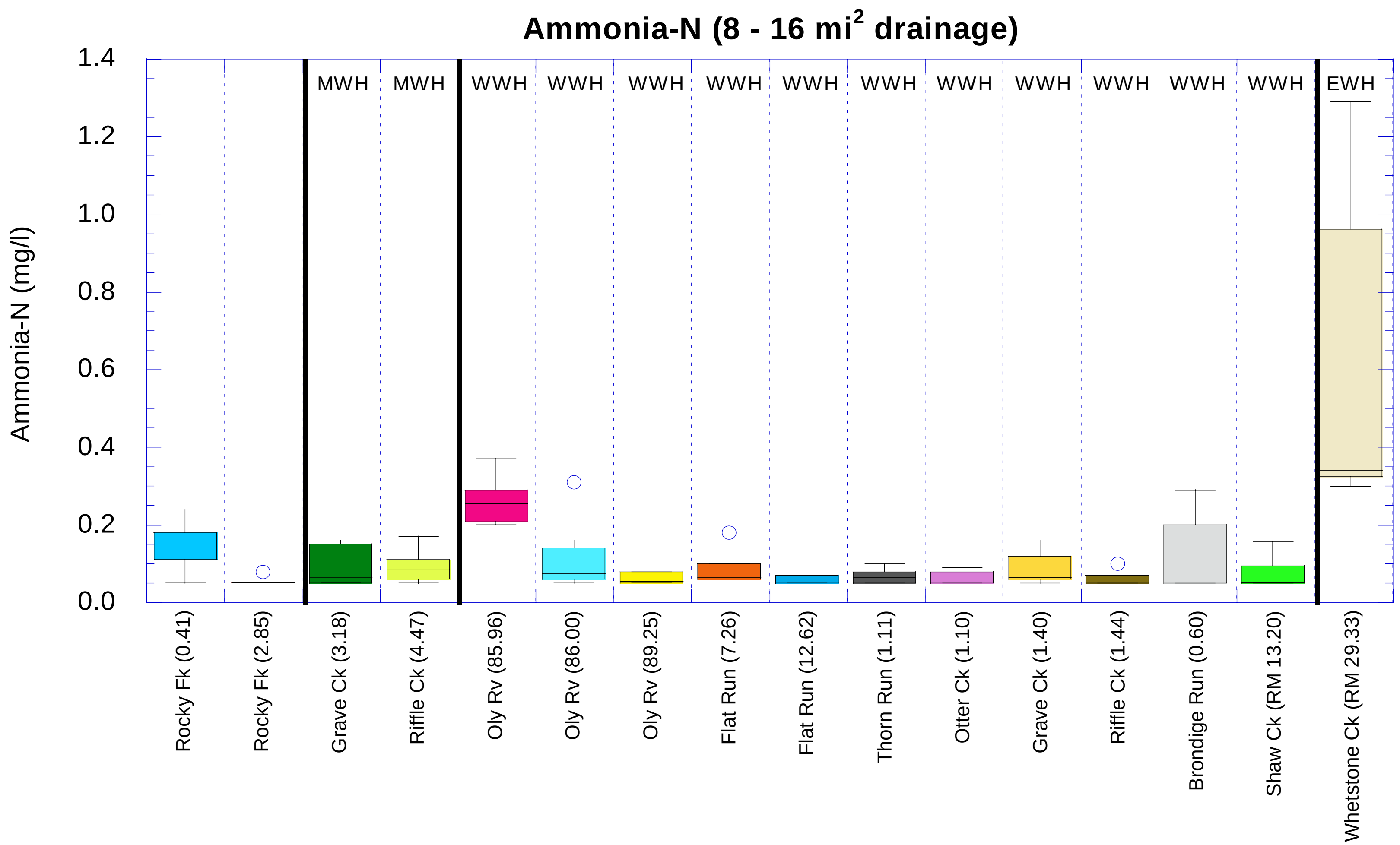


Figure 52. Ammonia-N concentrations of 8-16mi^2 drainage area sampling locations within the WCWAU, 2003.

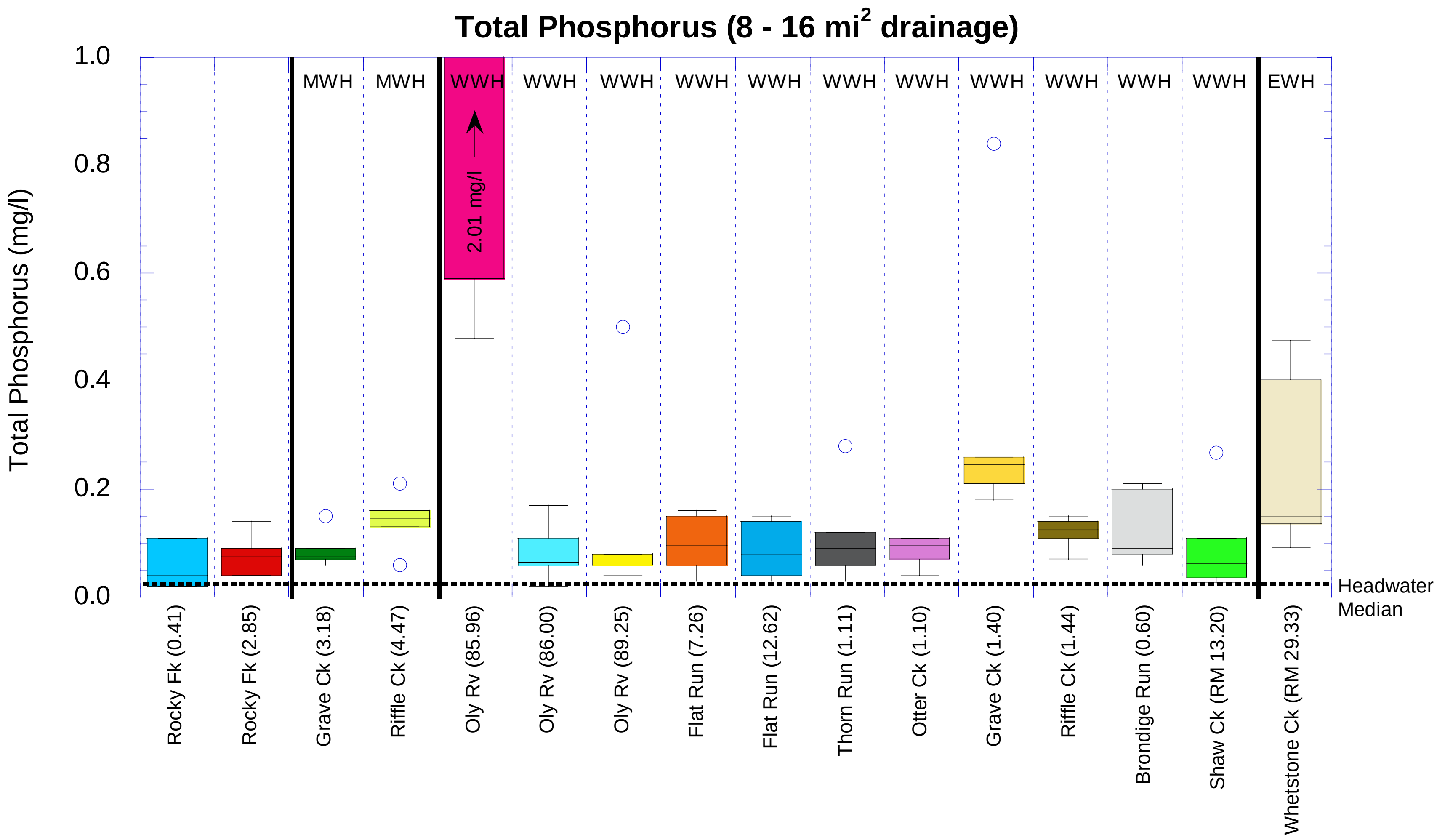


Figure 53. Total phosphorus for 8-16mi^2 drainage area sampling locations within the WSWAU, 2003.

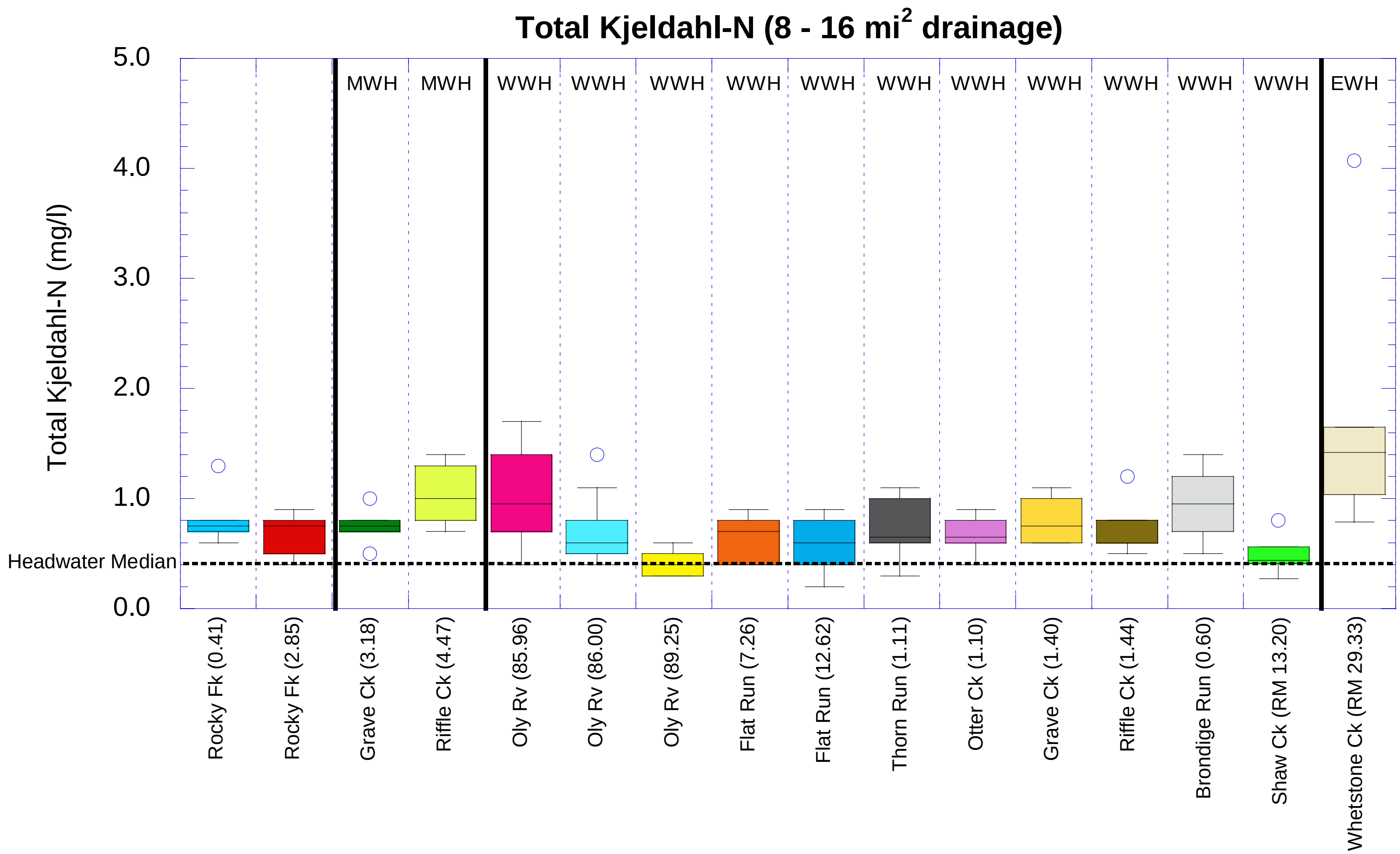


Figure 54. Total Kjeldahl-N for sampling locations with 8-16mi^2 drainage area within the WCWAU, 2003.

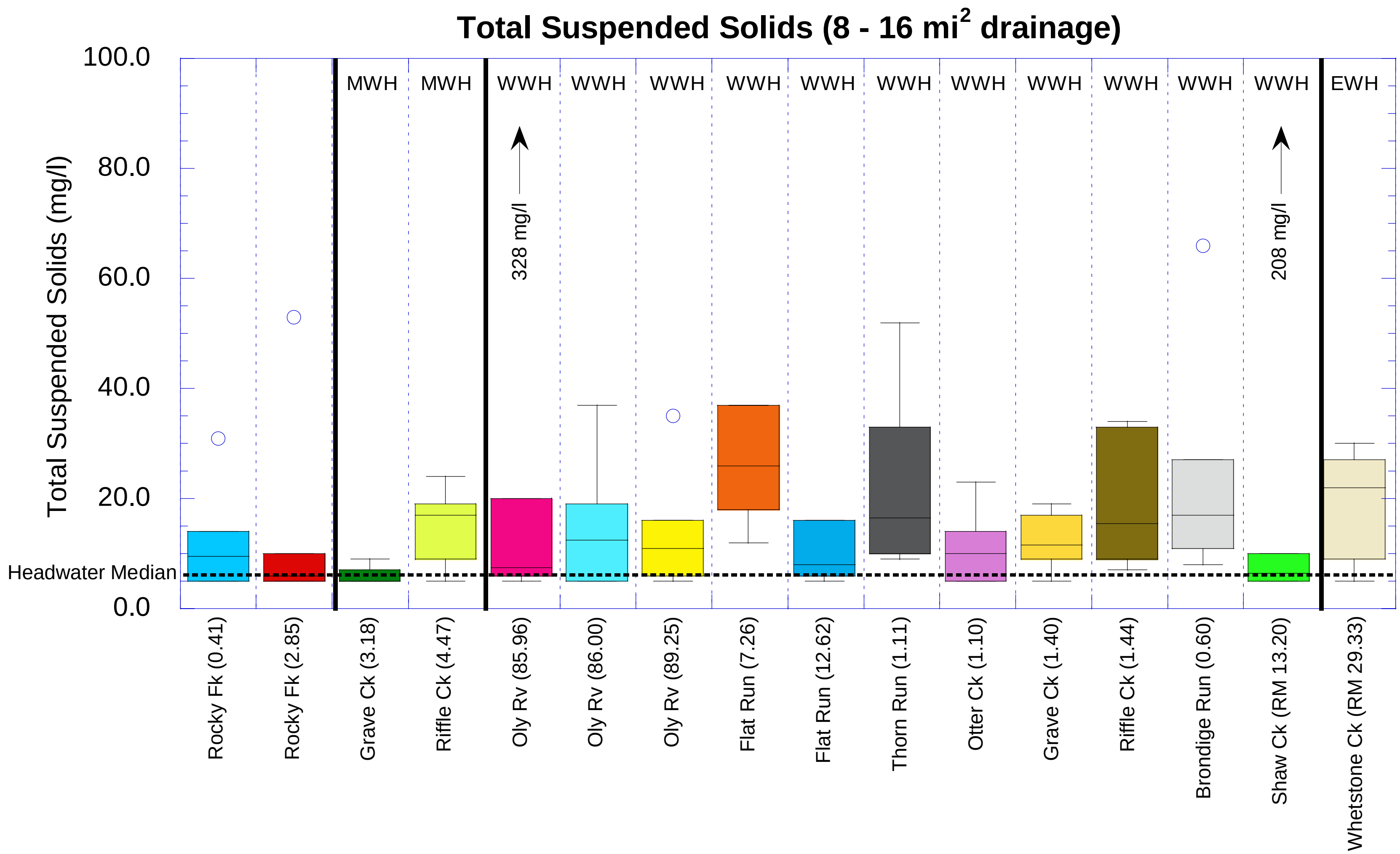


Figure 55. Total suspended solids for sampling locations with 8-16mi^2 drainage area within the WCWAU, 2003.

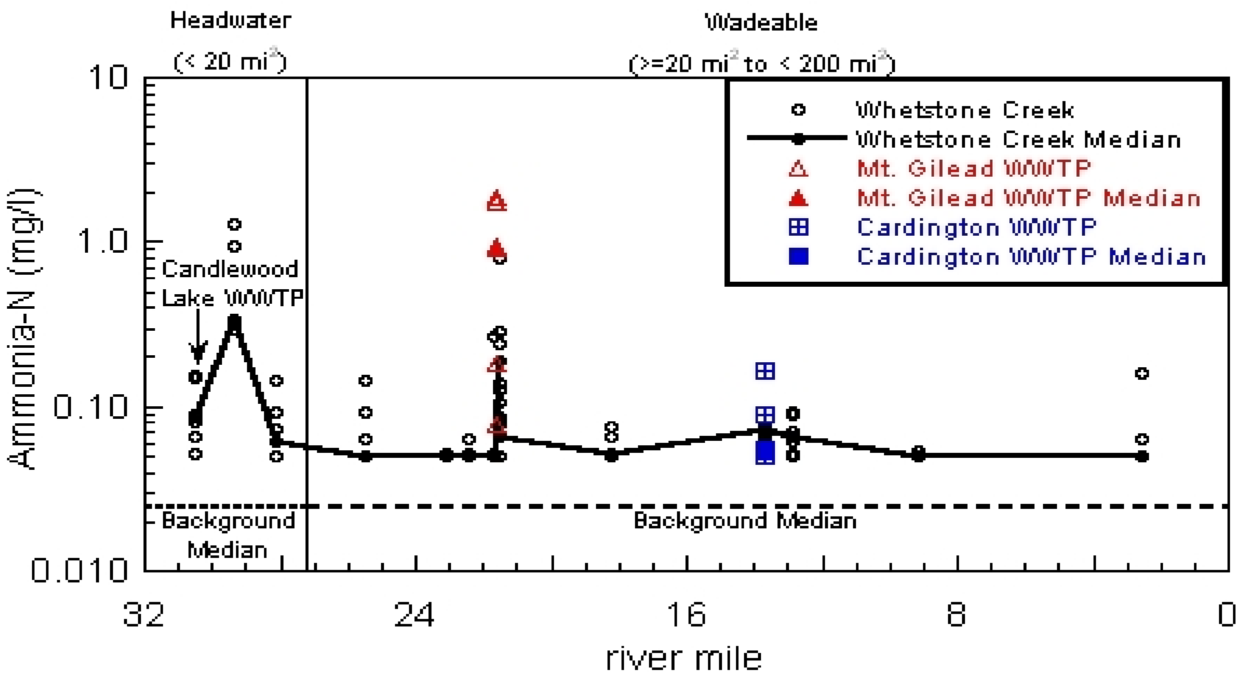


Figure 56. Ammonia-N results from the Whetstone Creek mainstem, 2003.

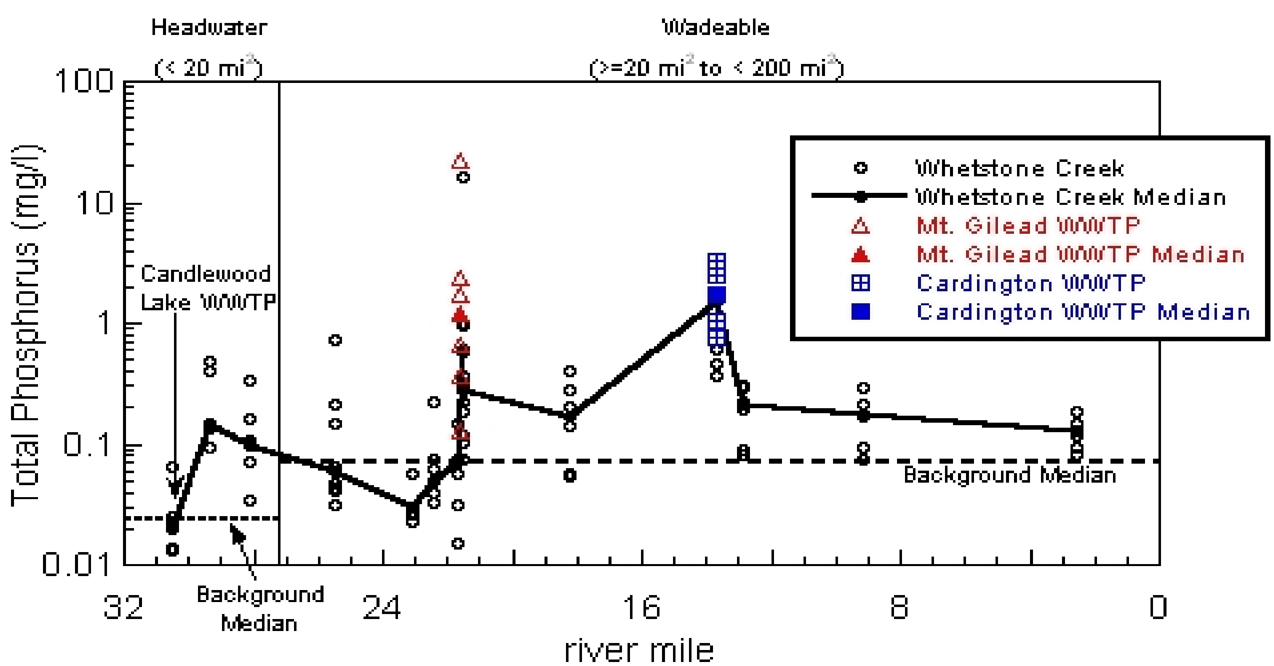


Figure 57. Phosphorus results from Whetstone Creek, 2003.

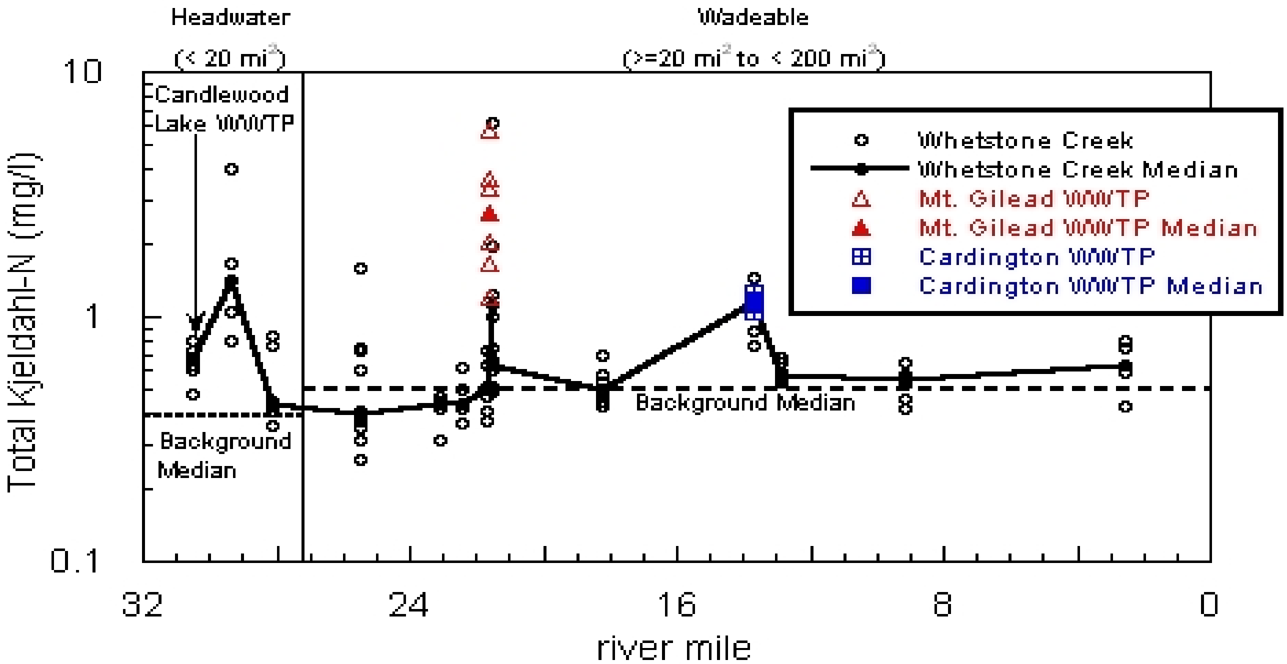


Figure 58. Total Kjeldahl-N results for Whetstone Creek, 2003.

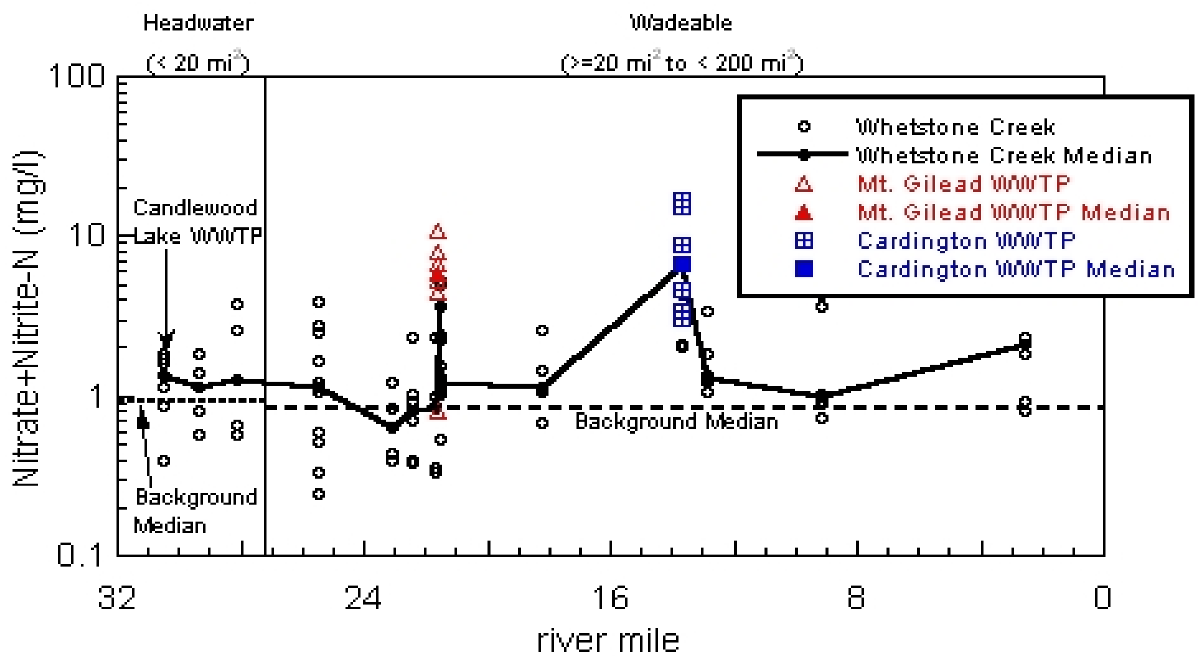


Figure 59. Nitrate+Nitrite-N results for Whetstone Creek, 2003.

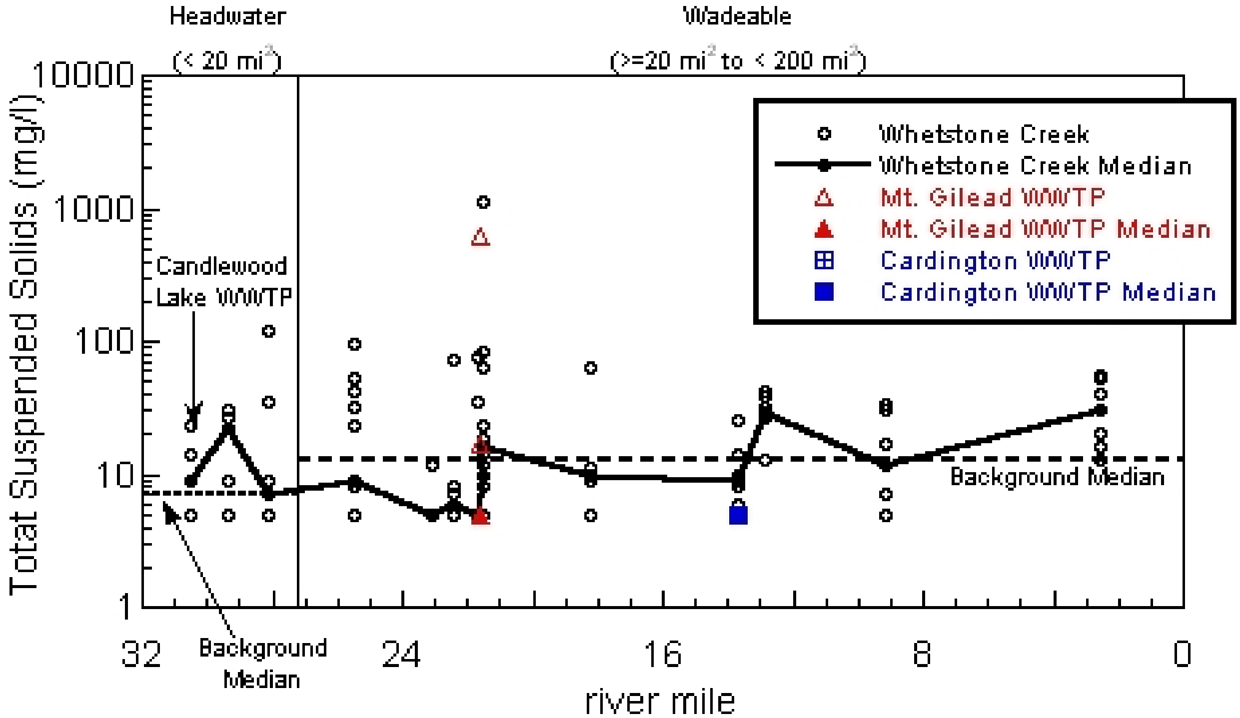


Figure 60. Total suspended solids concentrations for Whetstone Creek, 2003.

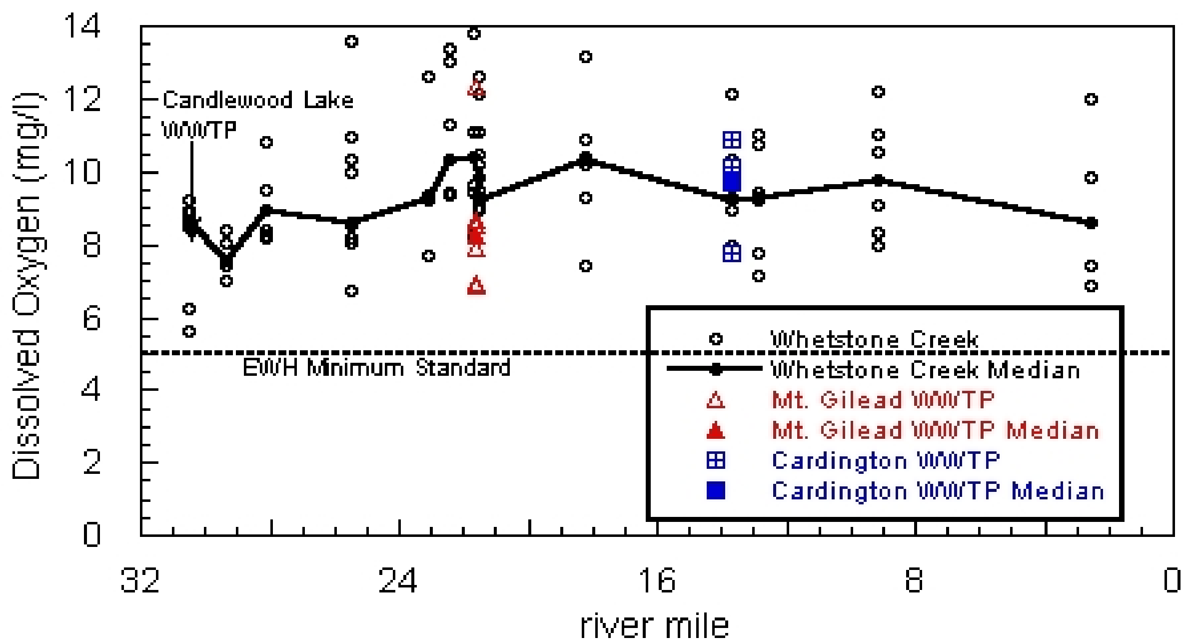


Figure 61. Dissolved oxygen concentrations for Whetstone Creek, 2003.

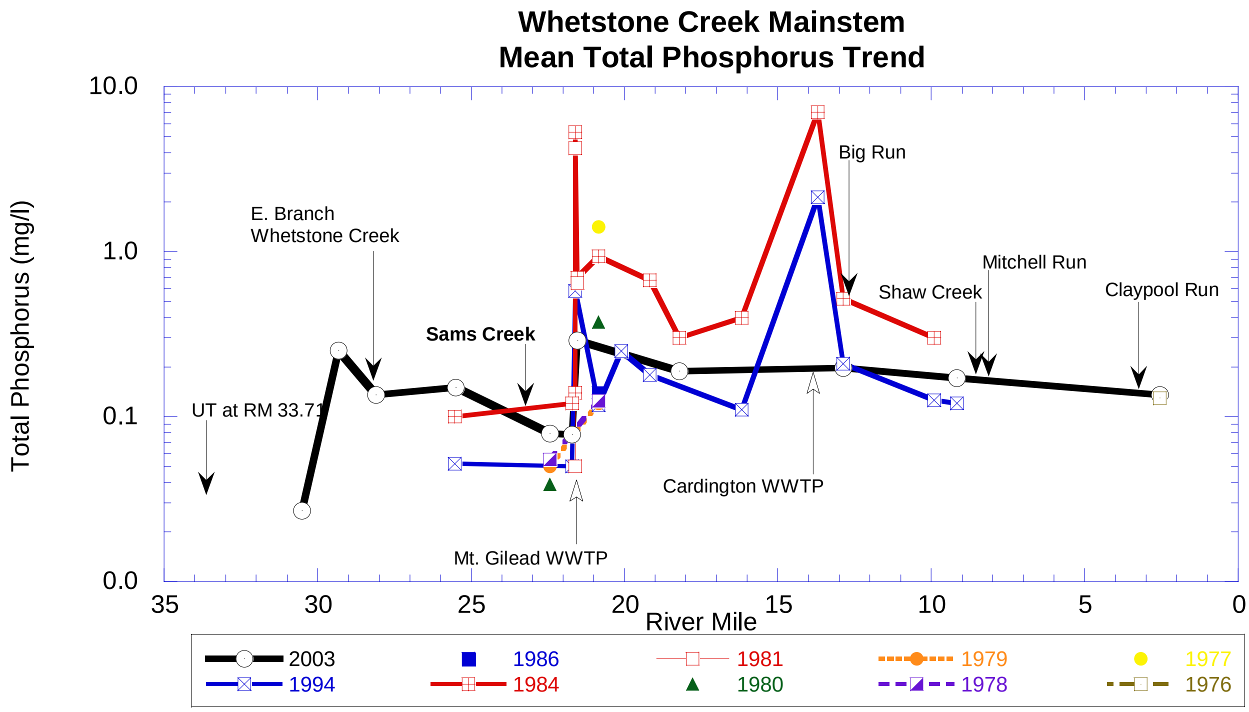


Figure 63.Total phosphorus mean values in the Whetstone Creek mainstem over time.

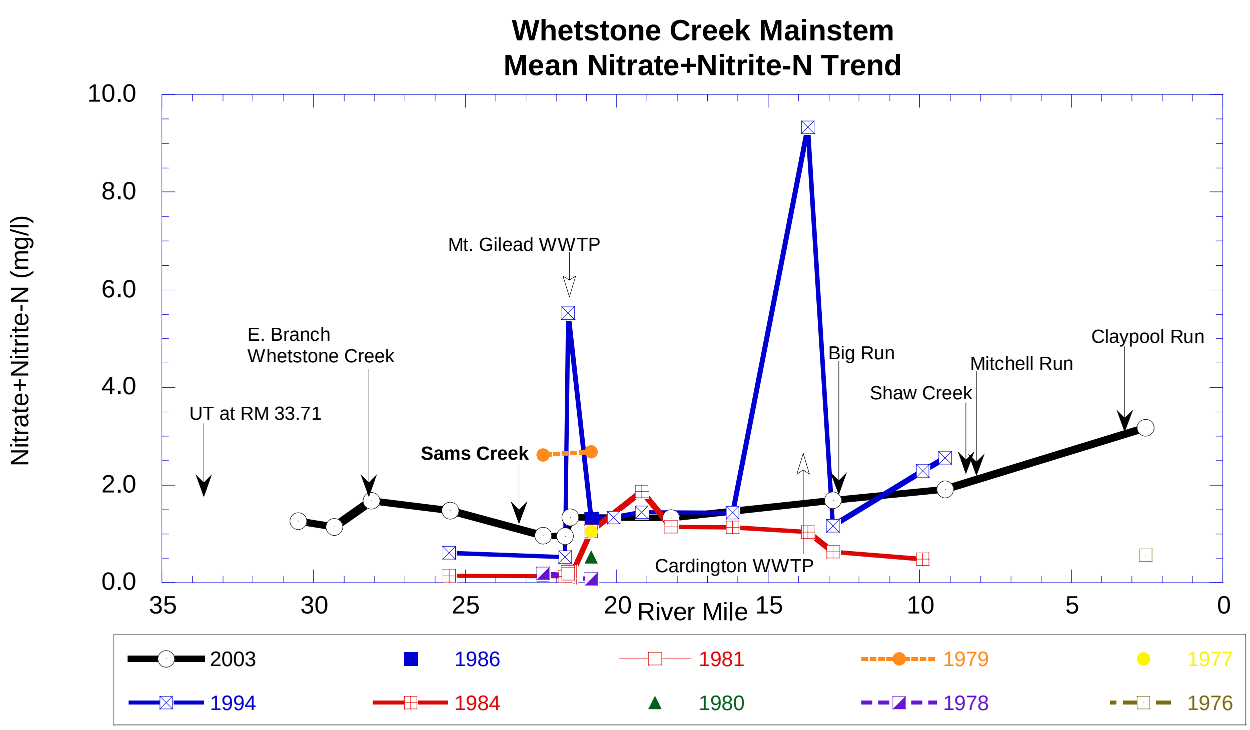


Figure 64. Nitrate-nitrite-N mean values in the Whetstone Creek mainstem over time.

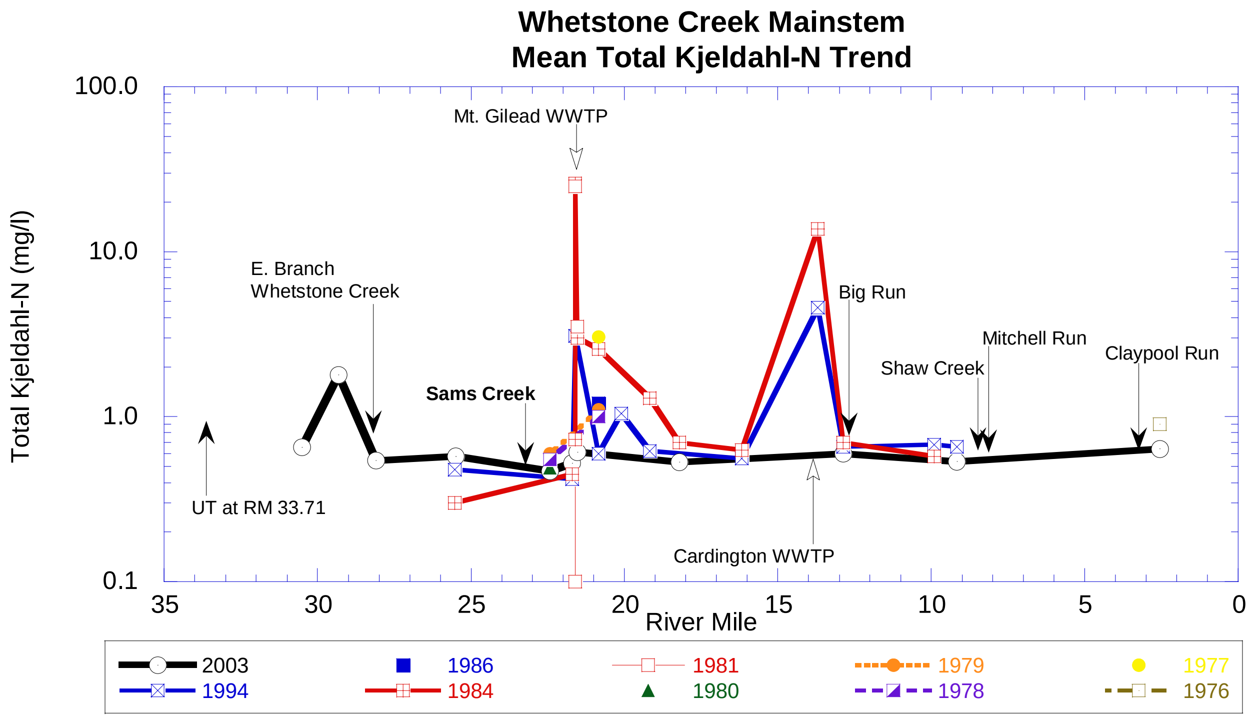


Figure 65. Total Kjeldahl-N mean values in the Whetstone Creek mainstem over time.

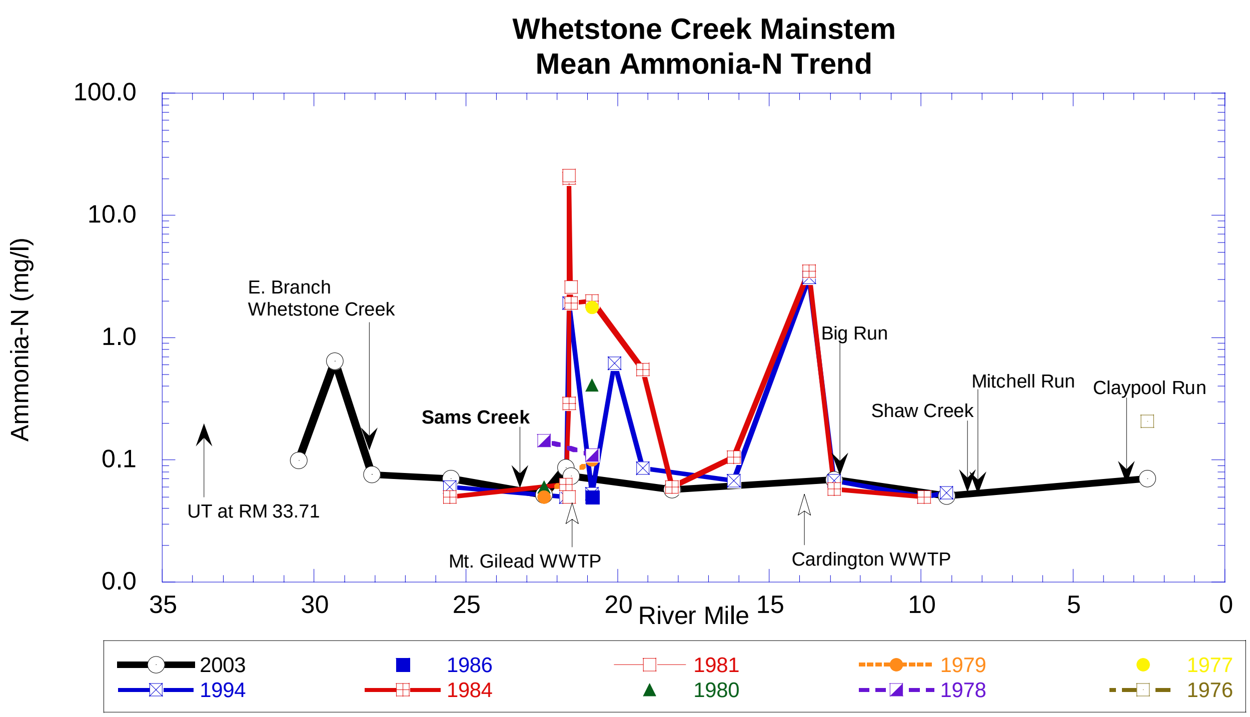


Figure 66. Ammonia-N mean values in the Whetstone Creek mainstem over time.

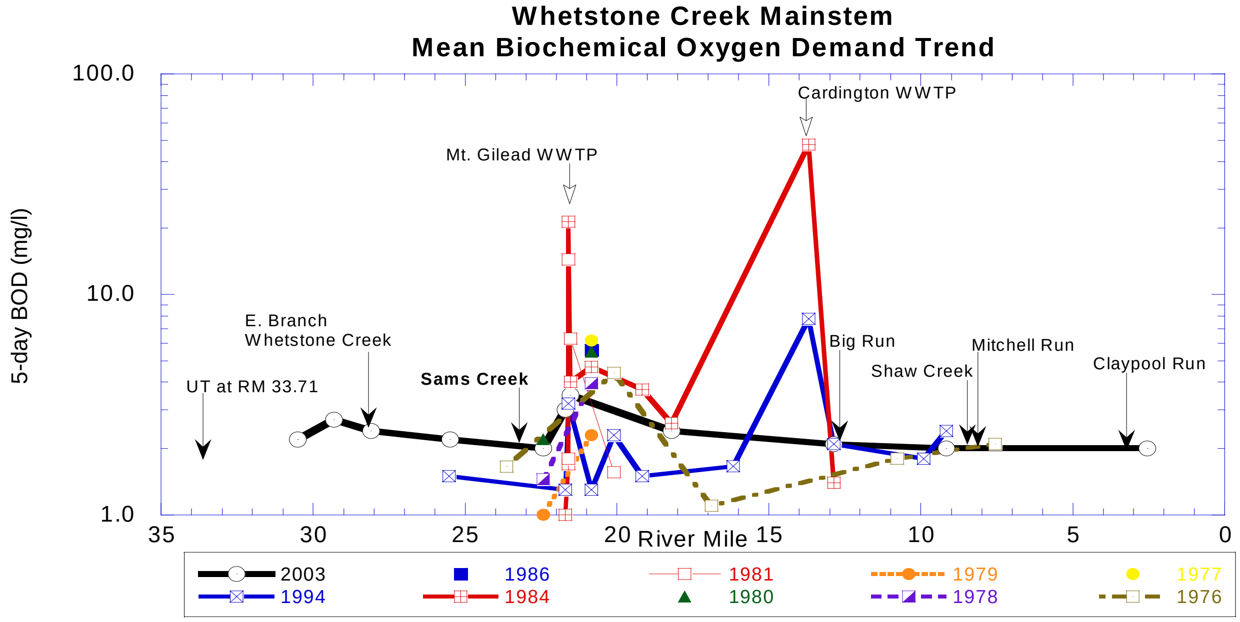


Figure 67. 5-day BOD for the Whetstone Creek mainstem over time.

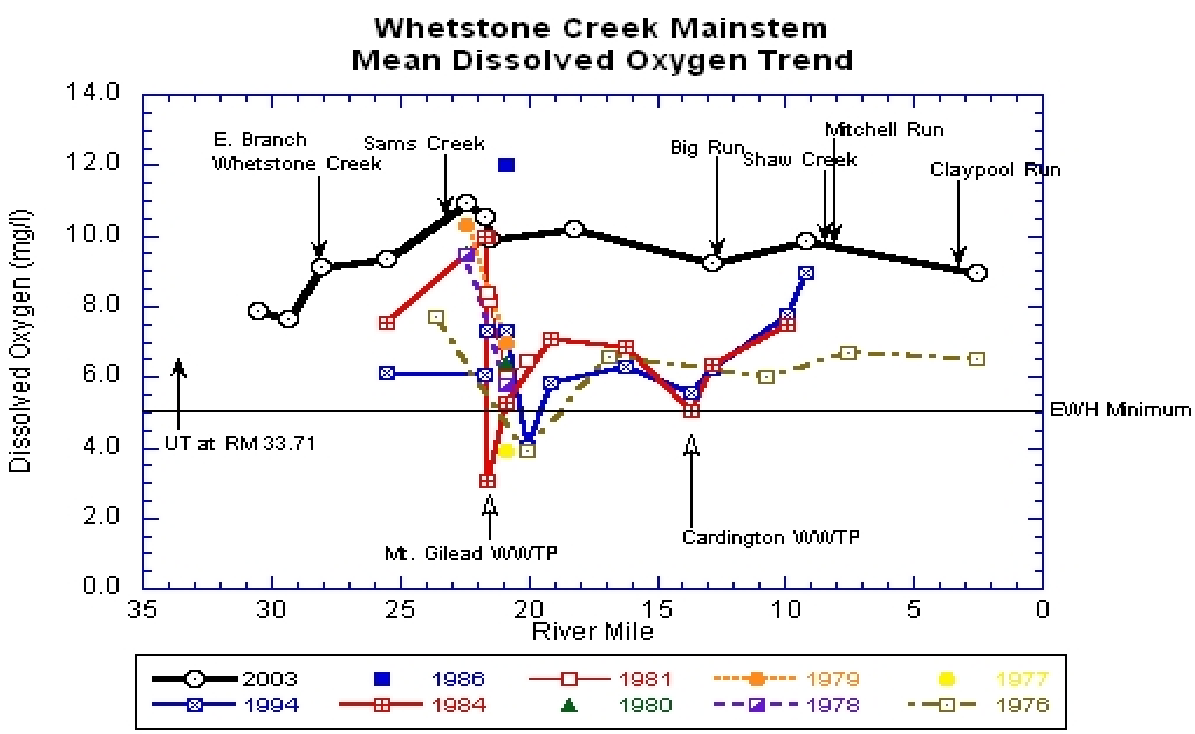


Figure 68. Dissolved oxygen concentration over time for Whetstone Creek mainstem.

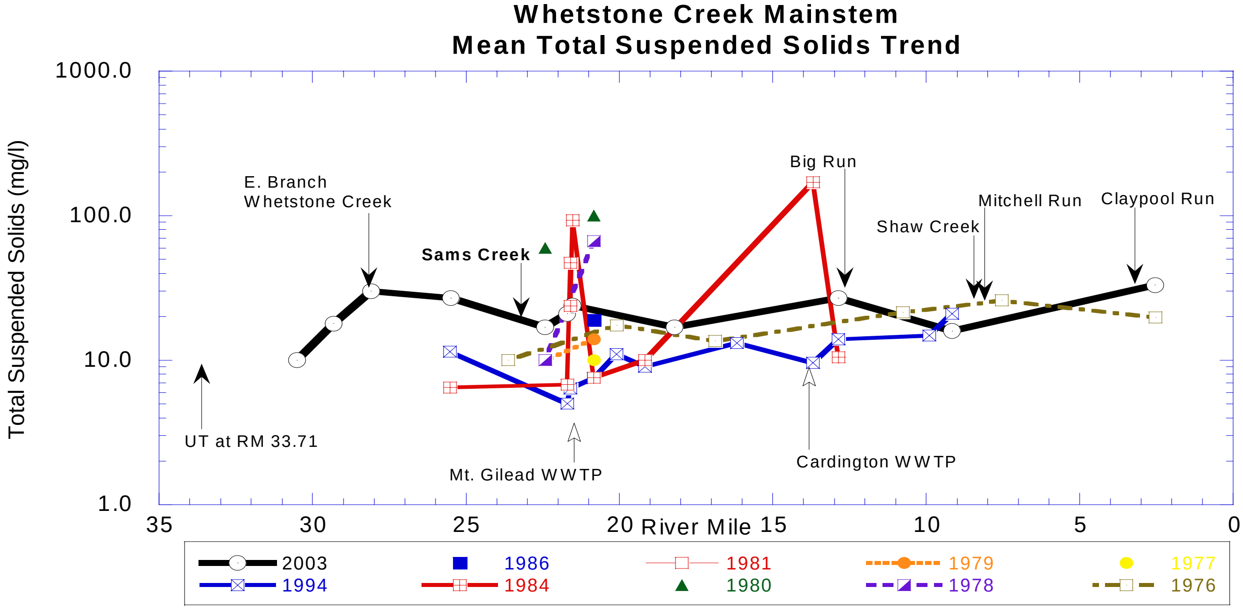


Figure 69. Historical trend of total suspended solids in the Whetstone Creek mainstem.

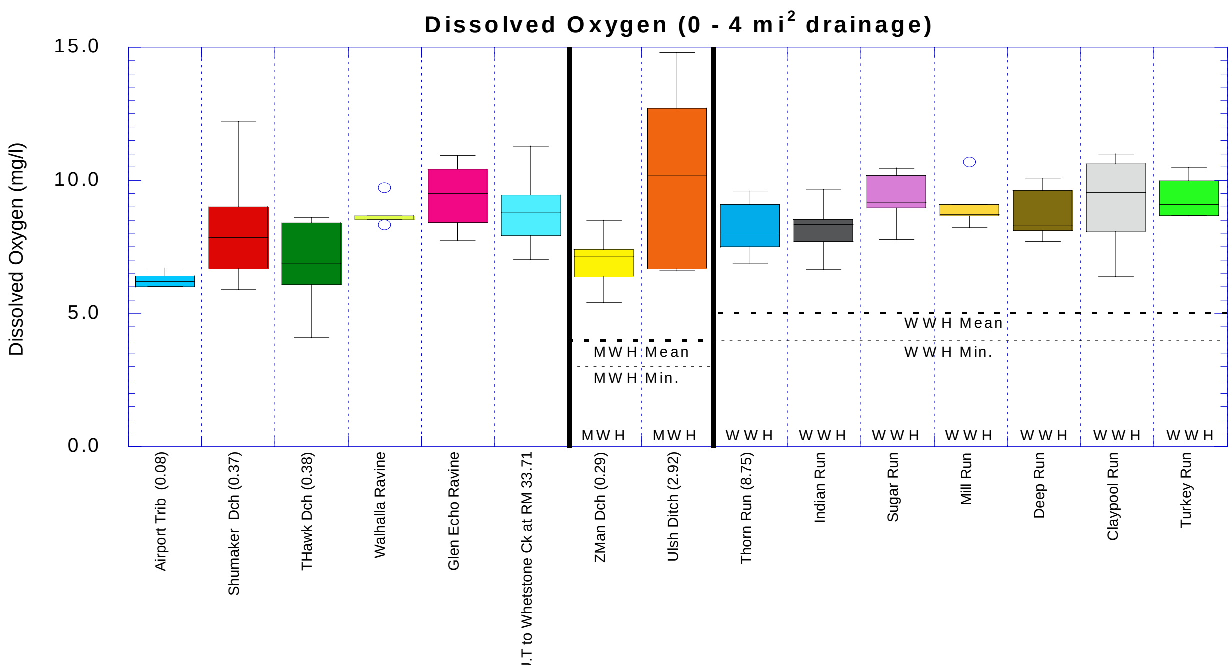


Figure 70. Dissolved oxygen concentrations for 0-4mi^2 drainage tributary streams within the entire Olentangy River study area, 2003.

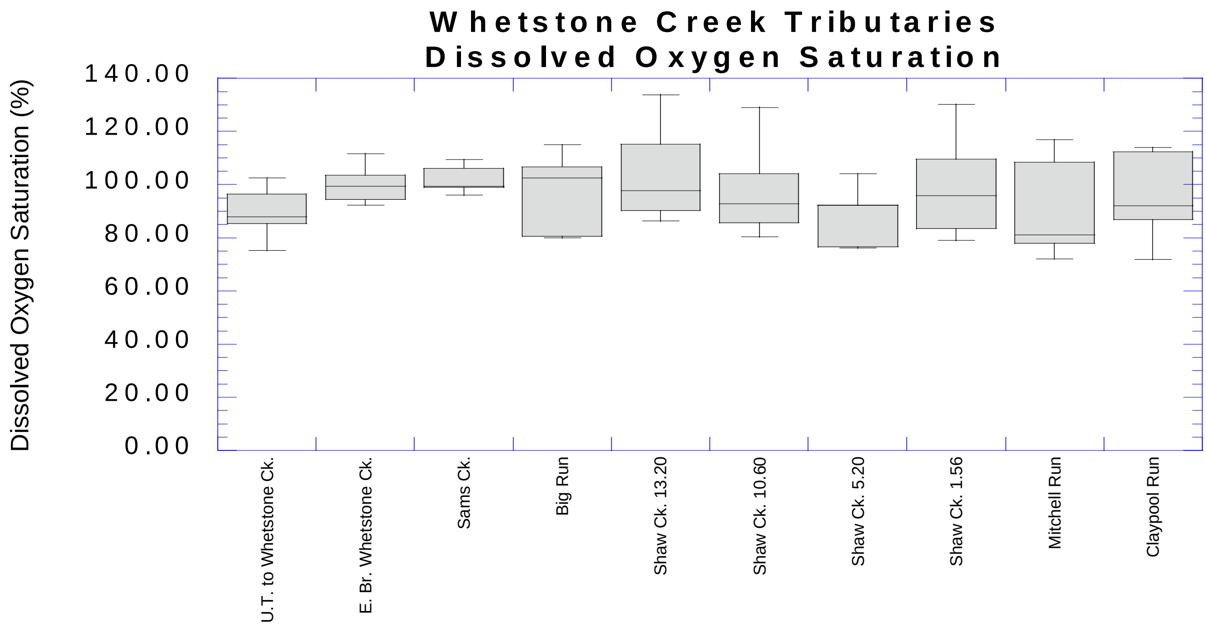


Figure 71. Dissolved oxygen concentrations for Whetstone Creek tributaries, 2003.

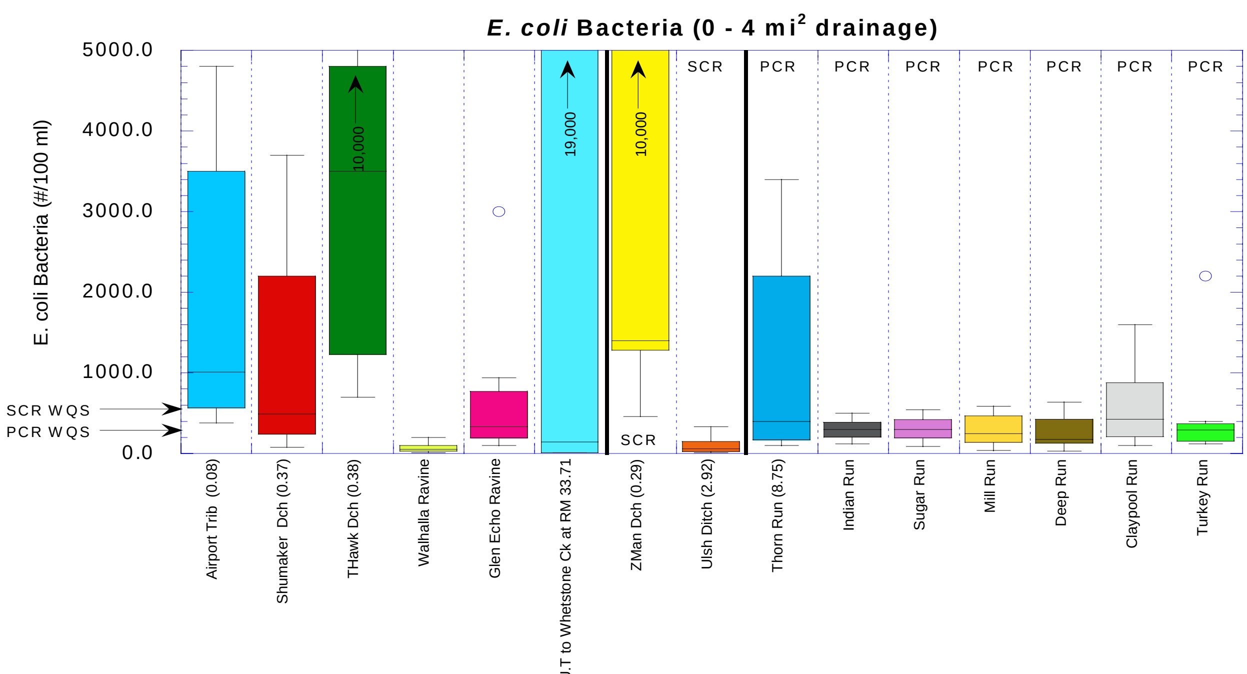


Figure 72. *E. coli* sampling results for 0-4mi^2 streams within the Olentangy basin, 2003.

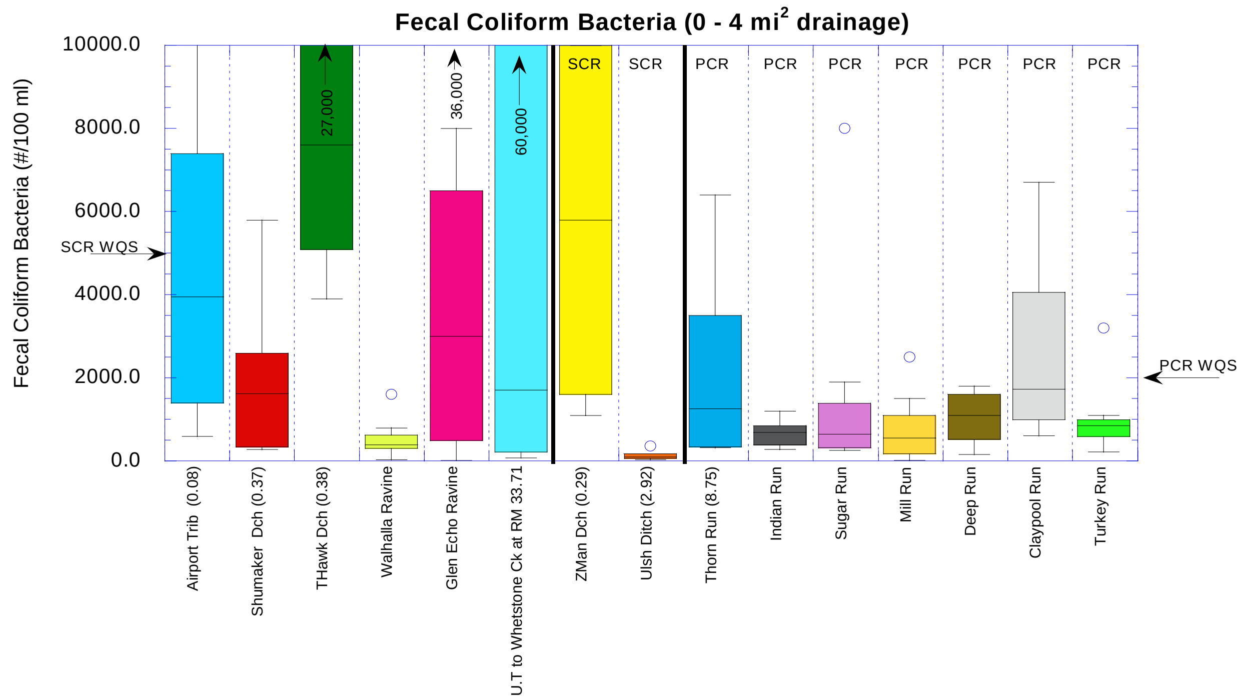


Figure 73. Fecal coliform sampling results for 0-4mi^2 streams within the Olentangy basin, 2003.

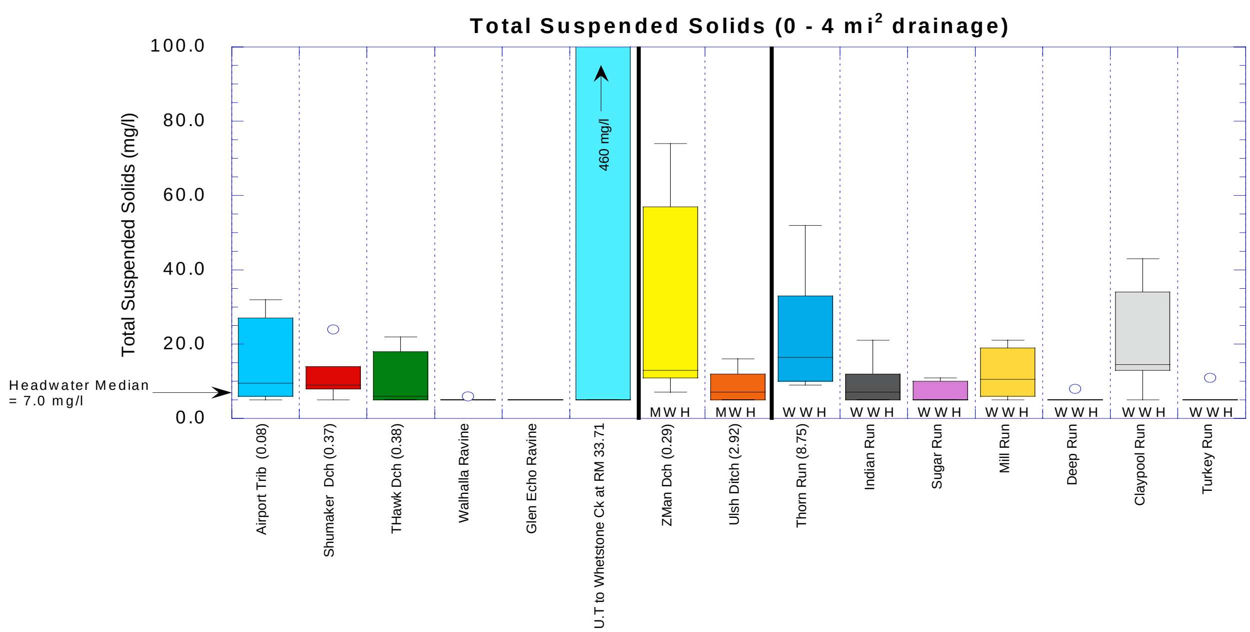


Figure 74. Total suspended solids for sampling sites with 0-4 mi^2 drainage in the Olentangy basin, 2003.

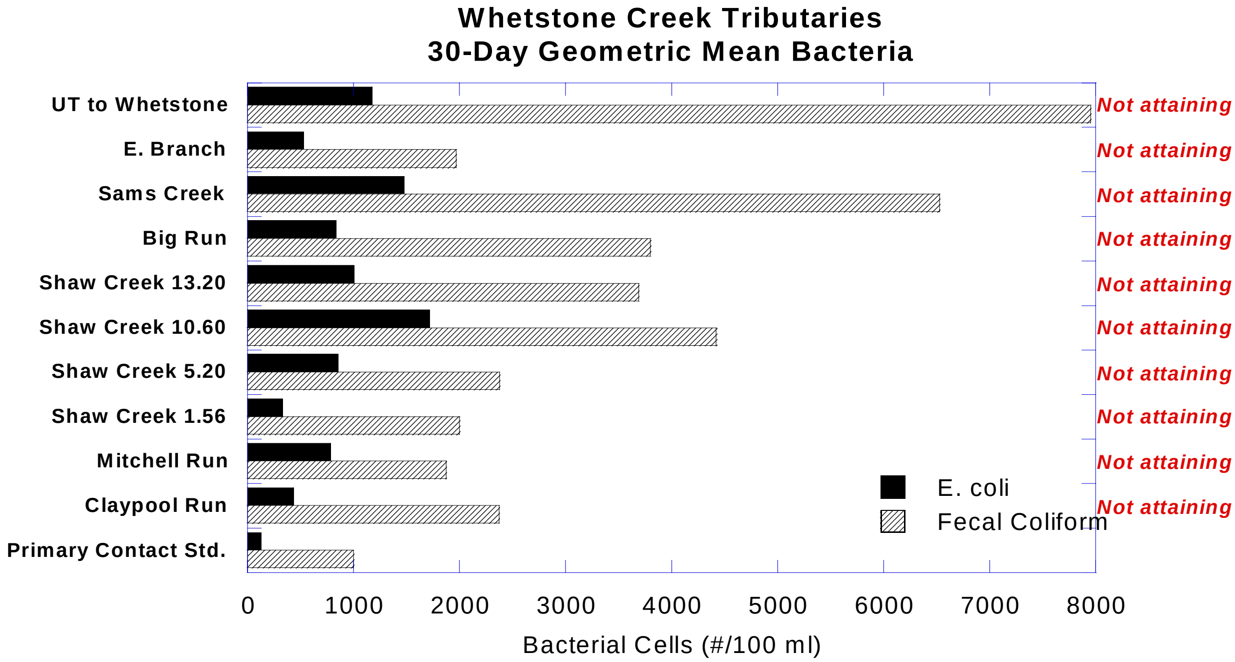


Figure 75. Attainment status for the recreational use of Whetstone Creek tributaries based on *E. coli* and fecal coliform sampling results, 2003.

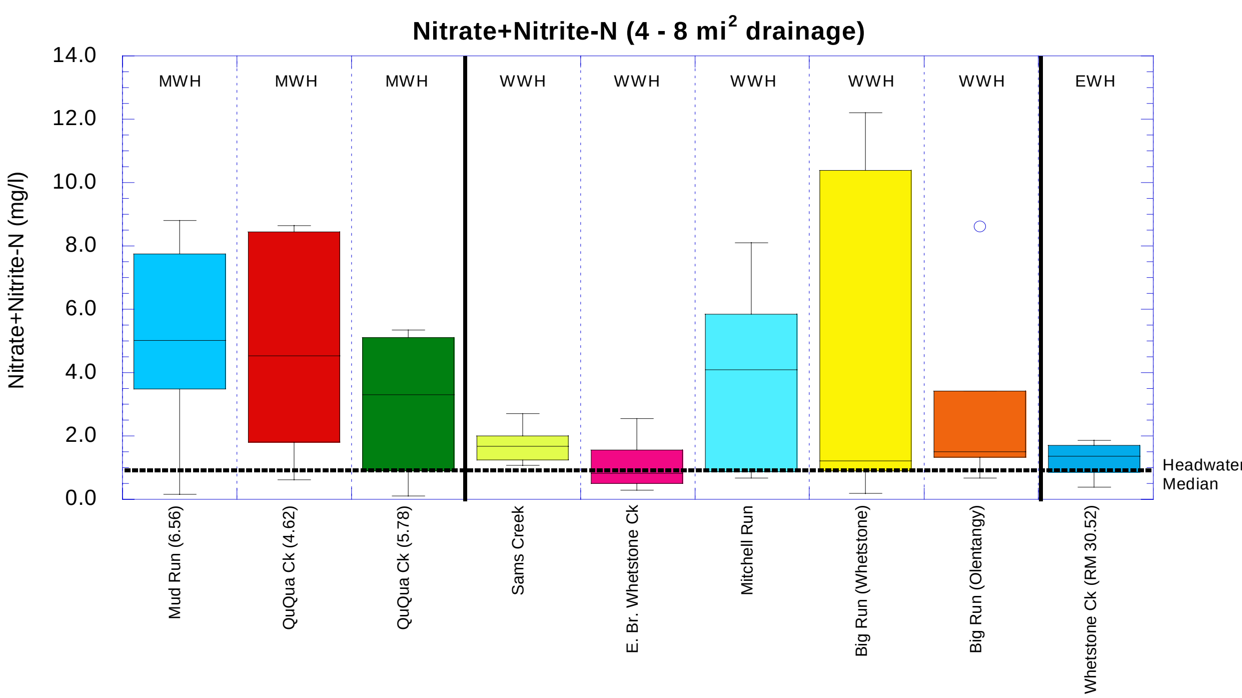


Figure 76. Nitrate-nitrite-N concentrations for 4-8mi^2 streams within the Olentangy basin, 2003.

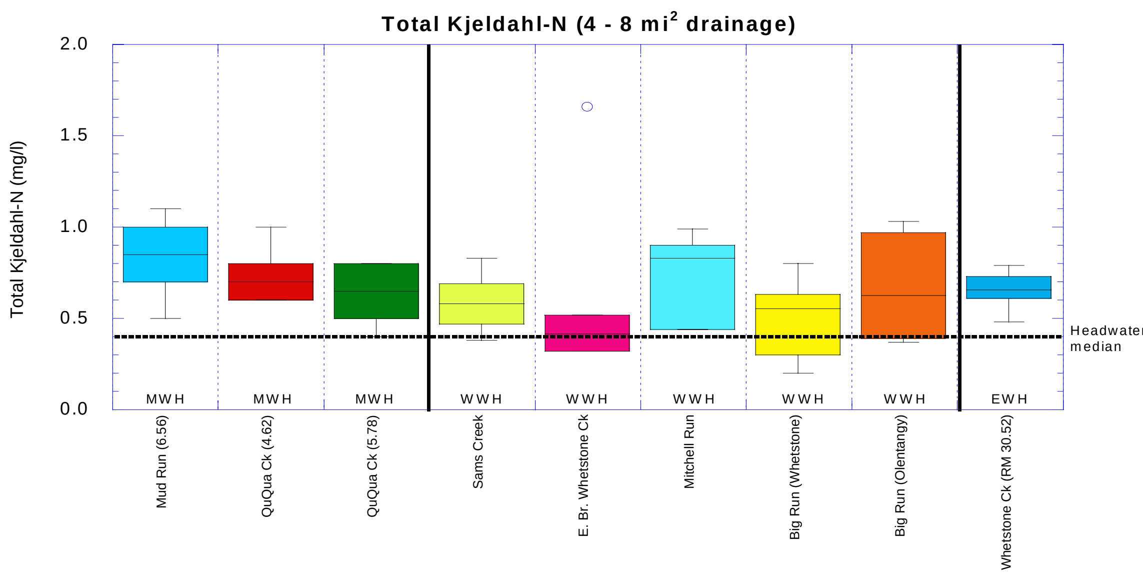


Figure 77. Total Kjeldahl-N concentrations for 4-8mi^2 streams within the Olentangy basin, 2003.

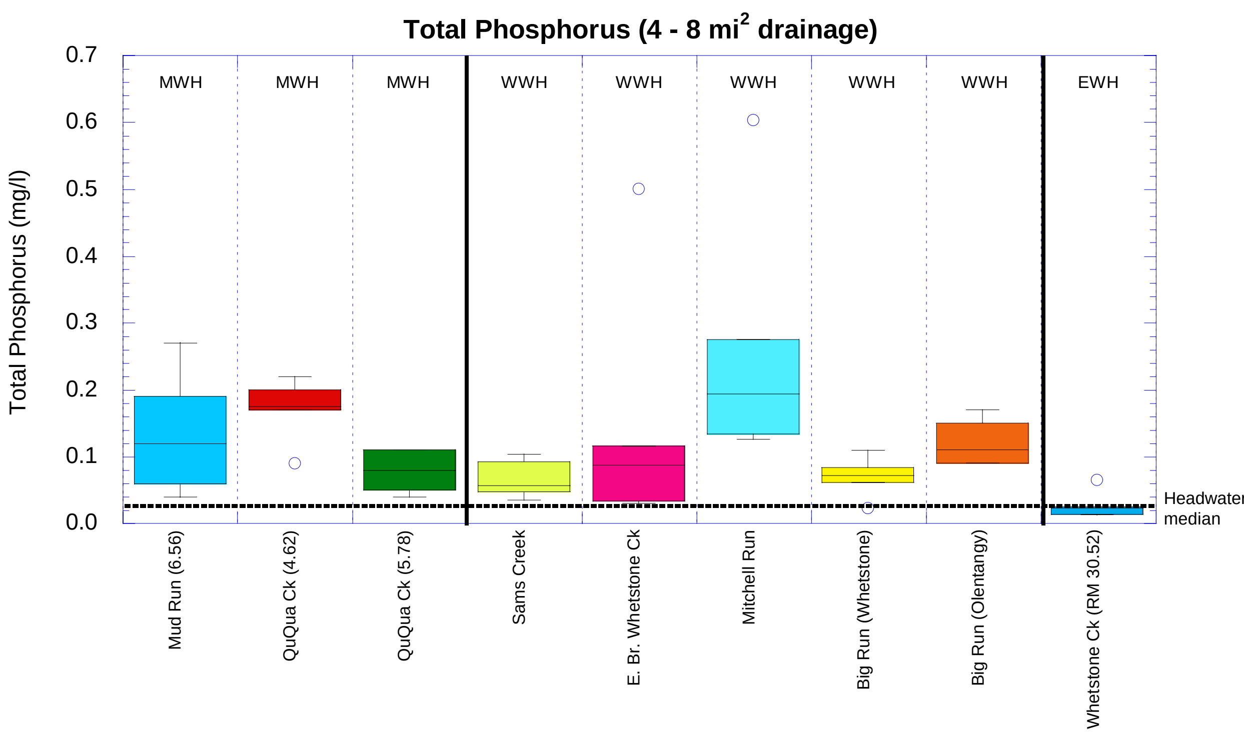


Figure 78. Total phosphorus for 4-8mi^2 drainage area streams throughout the Olentangy basin, 2003.

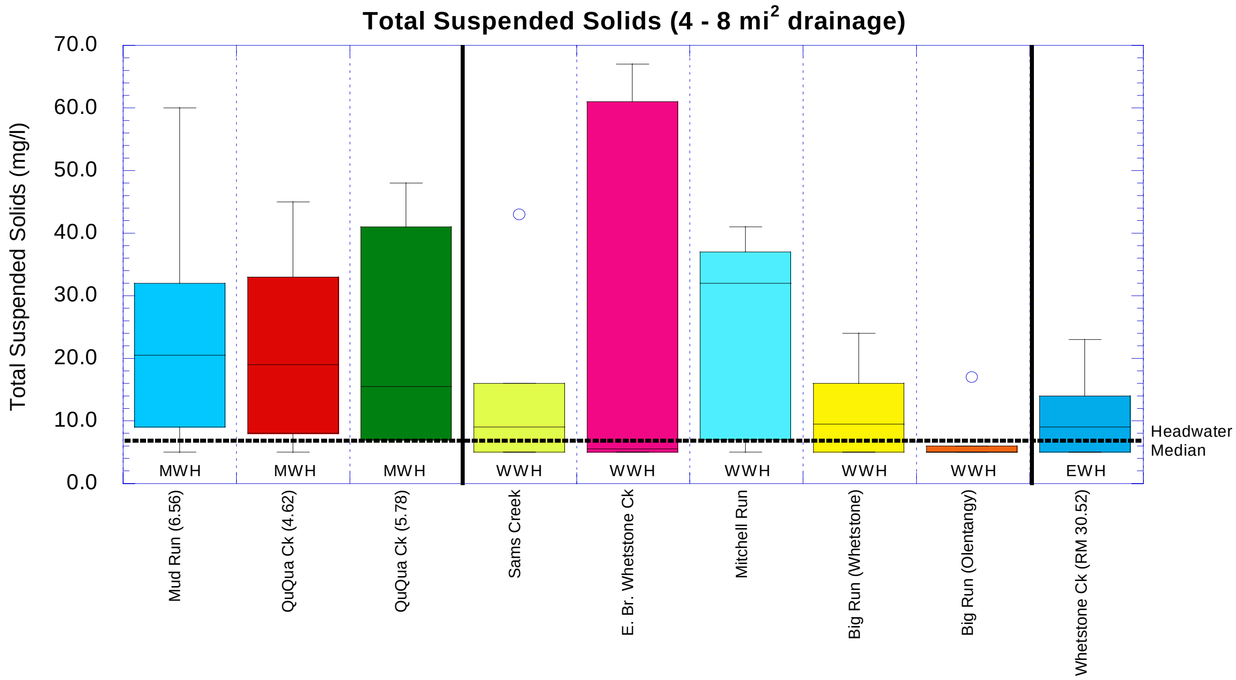


Figure 79. Total suspended solids for 4-8mi^2 drainage area streams throughout the Olentangy basin, 2003.

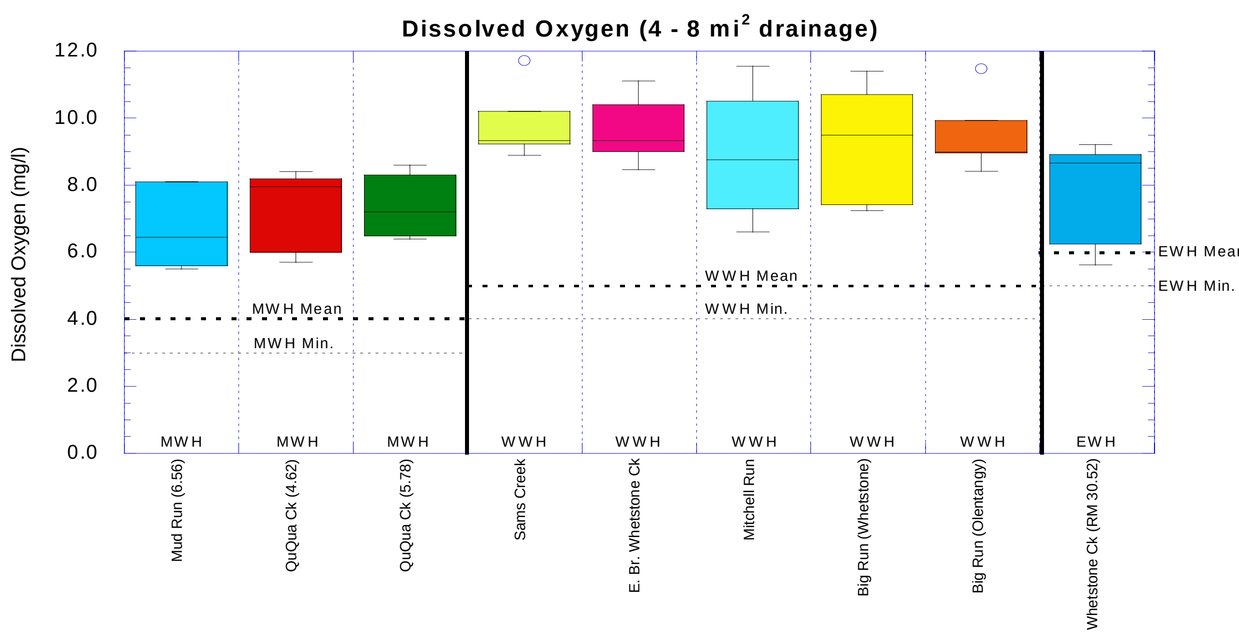


Figure 80. Dissolved oxygen concentrations for 4-8mi^2 drainage area streams within the Olentangy basin, 2003.

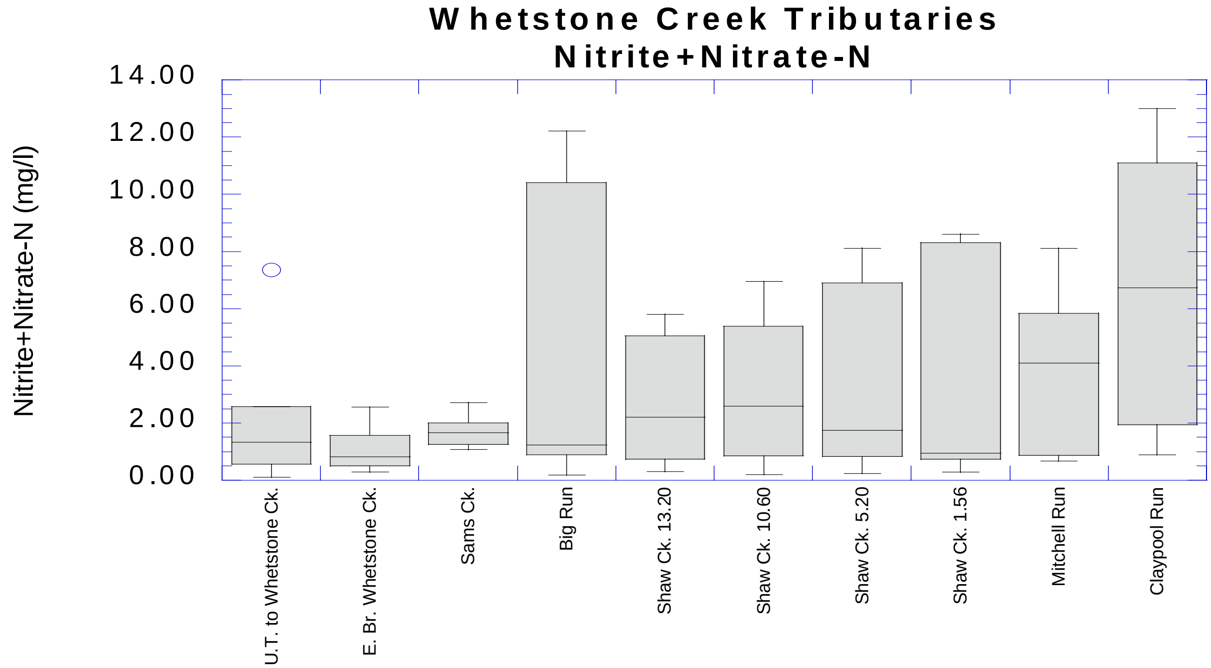


Figure 81. Nitrate-nitrite-N concentrations for tributaries within the WCWAU, 2003.

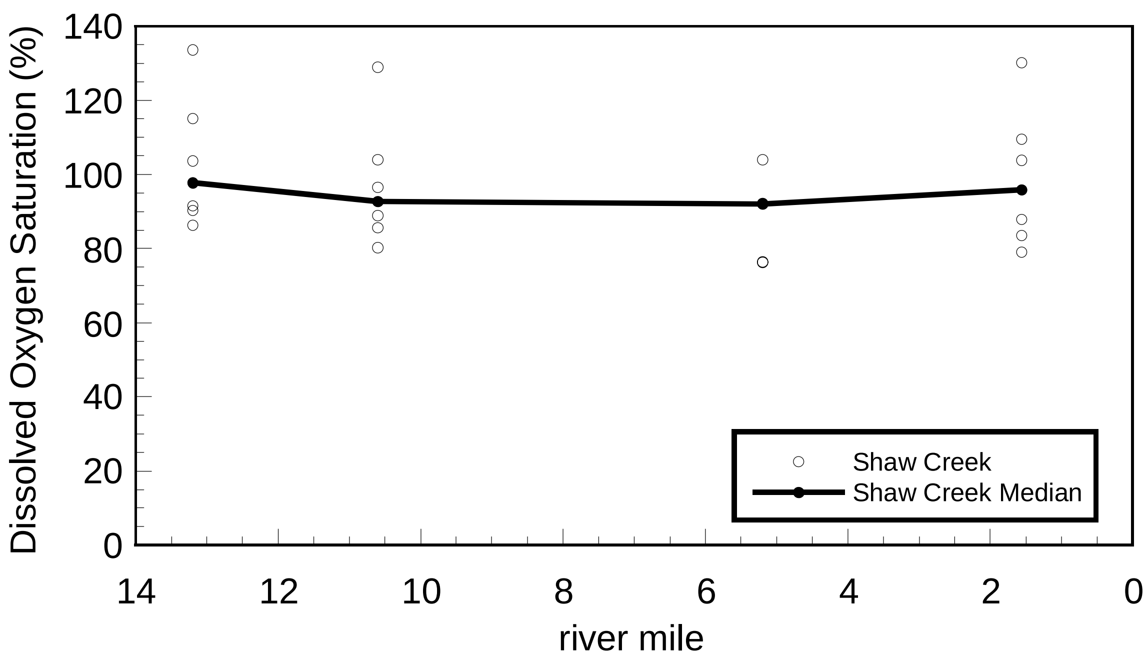


Figure 82. Dissolved oxygen saturation for Shaw Creek, 2003.

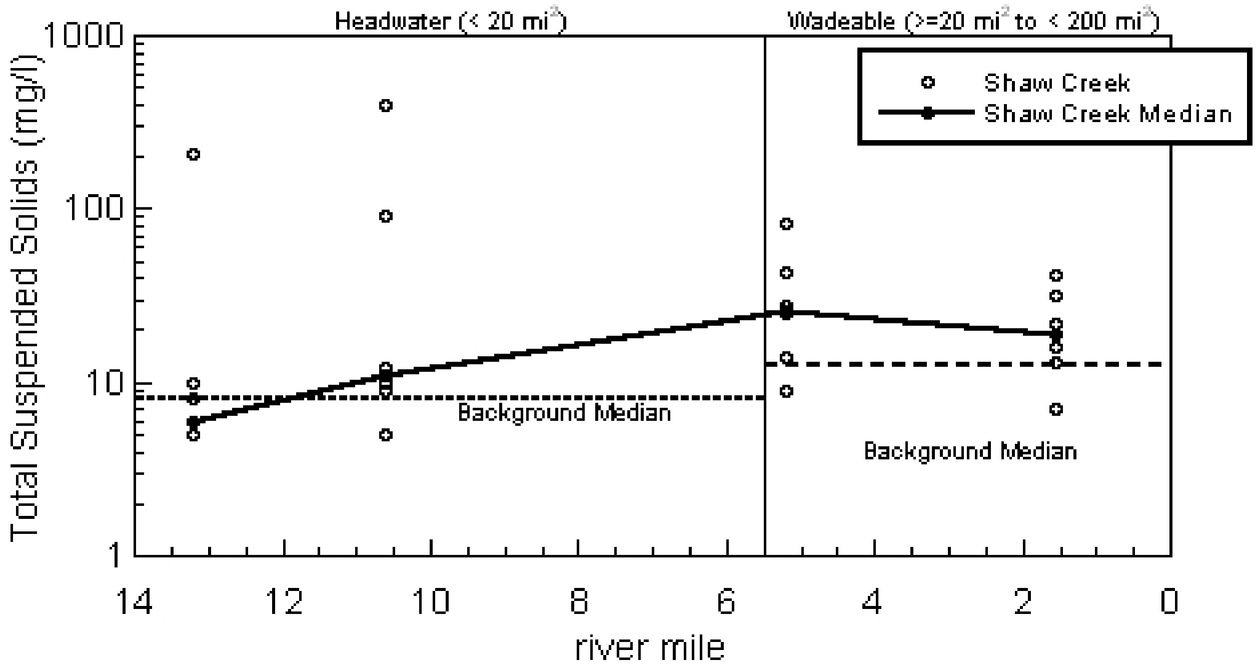


Figure 83. Total suspended solids for Shaw Creek, 2003.

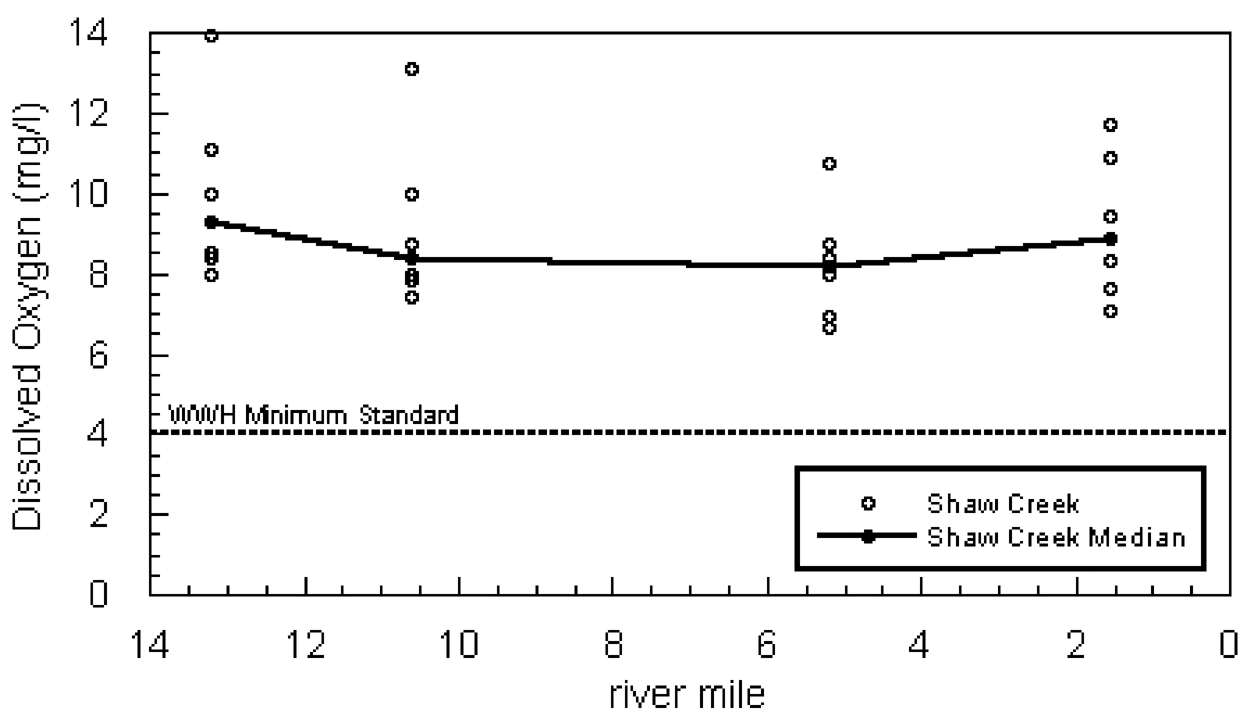


Figure 84. Dissolved oxygen concentration for Shaw Creek, 2003.

Physical Habitat

The stream physical habitat of 22 sites within the WCWAU were evaluated with QHEI. As Figure 85 shows, the majority of sites scored within the good range. The only sites that scored in the poor to fair ranges were Claypole Run, a tributary to Whetstone Creek RM 33.71 and two sites on Shaw Creek. Agricultural activities have modified the habitat in these areas, limiting their ability to support aquatic communities. The Whetstone Creek mainstem is listed as EWH, yet only two of the sites assessed scored within EWH expectations. Nutrient enrichment and siltation have decreased the quality of habitat available to aquatic organisms in Whetstone Creek.

The average QHEI was 61.9 (range of 39.5 to 78.0) for tributary sites while the average QHEI was 70.7 (range of 61.5 to 80.0) for the mainstem. For the mainstem, QHEI scores for the sites upstream of Mt. Gilead averaged 74.0, whereas downstream they averaged 68.2. This is partially attributable to the decrease in riparian width observed from upstream of Mt. Gilead downstream. Increased riparian set asides may help improve habitat quality. However, organic and nutrient enrichment from the Mt. Gilead WWTP, Cardington WWTP and surrounding agricultural activities must be addressed in order to improve conditions in Whetstone Creek.

Whetstone Creek

The upper reach of Whetstone Creek was evaluated from West Point-Galion Road (RM 30.5) to State Route 61 and State Route 42 (RM 22.4). The upper reach appeared to originate primarily from glacial tills with gravel, sand and cobble substrates dominant and intermixed with boulders, hardpan, detritus, and occasional areas of silt and concrete. Silt was present in normal to moderate amounts throughout the upper reach. However, substrates were embedded in moderate to extensive amounts at the two upper most sites, West Point-Galion Road (RM 30.5) and Mt. Gilead-West Point Road (RM 29.3) while the substrates were embedded in normal amounts from Marion-Williamsport Road (RM 28.1) to State Route 61 and State Route 42 (RM 22.4). Moderate to extensive amounts of instream cover were provided by undercut banks, overhanging vegetation, shallows, rootmats, deep pools (>70cm), rootwads, boulders, logs and woody debris. The upper two sapling locations appeared to be free from channelization with moderate sinuosity, good development and moderate stability from West-Point Galion Road (RM 30.5) to Marion-Williamsport Road (RM 28.1). The upper most site may have been influenced by dam releases from Candlewood Lake. The lower two sampling locations within this reach appeared to be recovering from past hydromodification near County Road 99 (RM 25.5) and State Route 61 and State Route 42 (RM 22.4). Low to moderate sinuosity with fair to good development and low to moderate stability were observed here.

Outside of the upper reach, riparian buffers were wide (>50m) adjacent to forested areas in the headwaters, becoming narrower (5-10m) to nonexistent adjacent to row crops, residential areas and the town of Mt. Gilead. QHEI scores ranged from 72.0 to 80.0

(x=75.6) throughout the upper reach, indicating the stream has physical habitat attributes often found in EWH streams.

The lower reach of Whetstone Creek was evaluated from Loren Road (RM 21.71) to State Route 229 (RM 2). The lower reach appeared to have originated from glacial tills and shales. Dominant substrates varied throughout the reach and included gravel and cobble, bedrock and boulders, sand and cobble, bedrock and silt, and solely bedrock. Additional substrates present throughout the lower reach included detritus, boulders with slabs and concrete blocks. Silt was present primarily in normal amounts except near State Route 229 (RM 2.0), where silt was present in moderate to heavy amounts. Similarly, substrates were embedded in normal to moderate amounts throughout the lower reach except near State Route 229 (RM 2.0) where substrates were embedded in the moderate to extensive range. The increase in silt and embedded substrates near State Route 229 (RM 2.0) is likely due to its proximity to Delaware Reservoir. The site is within the flood easement elevation of Delaware Reservoir, and flow within this area was slow to moderate, with the current barely discernible. These conditions allow the settling of silt onto the substrates within this area.

Within the stream channel of the lower reach, moderate instream cover was provided by undercut banks, overhanging vegetation, shallows, rootmats, deep pools (>70cm), rootwads, boulders, backwaters, logs and woody debris. However, near Waldo-Fulton-Chesterville Road (RM 9.2), instream cover was sparse to moderate in abundance and included only logs, boulders, rootwads, shallows, overhanging vegetation and undercut banks. Aside from the State Route 229 (RM 2.0) site, the majority of the lower reach appeared to be in various stages of recovery from past channelization activities. Sinuosity varied from none to high just as stability varied from low to high. Stream development was consistently fair to good within the lower reach, including near State Route 229 (RM 2.0).

Outside of the lower reach, buffers varied from very narrow (<5m) and narrow (5-10m) adjacent to crop fields, open pastures, residential areas and wastewater treatment plants, to moderate (10-50m) and wide (>50m) adjacent to forested areas downstream of the Mt. Gilead wastewater treatment plant (RM 21.5) and near State Route 229 (RM 2.0). Regardless of the stage of recovery from channelization or intensity of surrounding land use, the lower reach of Whetstone Creek provided diverse substrate combinations and instream cover to aquatic organisms. These qualities resulted in QHEI scores ranging between 61.5 and 69.0 (x=67.5).

Riparian widths upstream of Mt. Gilead varied greatly compared to the consistently narrow buffers present downstream. The average habitat score for the upstream section was 74 whereas the downstream section was 68.2. The difference in habitat condition hinders the ability of the stream to ameliorate the effects of the various pollutants; nutrients, siltation and solids from the upstream WWTPs and surrounding agricultural activities. Best management practices must be implemented as well as upgrades to sewage collection and treatment to reduce impairment in Whetstone Creek.

Tributary to Whetstone Creek (RM 33.71)
The unnamed tributary to Whetstone Creek was evaluated near State Route 19 (RM 0.4). Stream substrates appeared to have originated from glacial tills. Sand and gravel were the dominant substrate types, though occasional areas of cobble and hardpan were also observed. Moderate amounts of silt were present and embedded substrates reducing the interstitial spaces available for aquatic organisms. Moderate amounts of instream cover were provided by undercut banks, overhanging vegetation, shallows, rootwads, boulders, and woody debris. The stream appeared to be recovering from past channelization activities, as moderate sinuosity with fair to good development and moderate stability were evident. Moderate bank erosion was also noted along the stream channel and may have been exacerbated by the presence of several drain tiles observed.

Surrounding land uses were a combination of row crops with very narrow (<5m) buffers and residential homes with a mixture of nonexistent to narrow (5-10m) buffers. The stream was also likely affected by failing on-site sewage treatment systems, as a moderate sewage odor was noted during the sampling event. The combination of variable buffer widths with high intensity land use and moderate amounts of instream habitat and development resulted in a QHEI score of 56.5.

East Branch of Whetstone Creek
The East Branch of Whetstone Creek was evaluated near Mt. Gilead-West Point Road (RM 0.4) and the substrates appeared to have originated from tills. Sand and gravel were the predominant substrate types, though areas of cobble, and boulders were also noted. Silt and embedded substrates were present in moderate amounts, while moderate to extensive amounts of instream cover were provided by undercut banks, overhanging vegetation, shallows, pools, rootwads, boulders, and logs with woody debris. No evidence of channelization activities were present, as the stream exhibited moderate to high sinuosity with good development. However, low stability was noted in several areas where moderate to severe erosion was evident.

Outside of the stream channel, wide (>50m) riparian buffers extended adjacent to forested areas upstream of Mt. Gilead - West Point Road, while very narrow (<5m) riparian buffers extended adjacent to row crop fields. The diverse and plentiful instream cover in addition to the mixed land use and decent riparian buffer size resulted in a QHEI score of 78.0, indicating that East Branch Whetstone Creek should easily support WWH communities.

Sams Creek
The physical habitat of Sams Creek was evaluated near Sunfish Road (RM 1.4). The stream substrates appeared to have originated from glacial tills, with sand and cobble as

the dominant substrate types intermixed with areas of boulders and gravel. Silt was present in normal amounts; preserving interstitial spaces as habitat available for aquatic life. Moderate quantities of instream habitat were provided by overhanging vegetation, shallows, boulders and woody debris. The entire reach appeared to have recovered from past channelization activities, though the upper reach extended into an open cow pasture with no riparian buffers. Low to moderate sinuosity with fair to good channel development was observed as the lower portion of the stream had moderate (10-50m) buffers adjacent to woods south of Sunfish Road. The combination of diverse substrates, multiple types of instream cover and mixed intensity land use resulted in a QHEI score of 66.5.

Big Run (Tributary to Whetstone Creek RM 12.75)
Substrates in Big Run, near Cardington Western Road (RM 0.1), appeared to have originated from glacial tills. Gravel and sand were the dominant substrate types, though areas of boulders and cobble were also present. Substrates were moderately embedded with silt, significantly limiting the amount of interstitial spaces available for aquatic organisms. Moderate quantities of diverse instream cover were provided by undercut banks, overhanging vegetation, shallows, rootmats, pools, rootwads, boulders, and logs. The stream appeared to be recovering from past hydromodification as high sinuosity with good development but low to moderate stability and little to moderate amounts of bank erosion were noted. Flow through the stream channel was intermittent with dry riffles and runs separating perennial pools.

Outside of the stream channel, nonexistent to narrow (5-10m) riparian buffers were observed adjacent to hayfields while narrow (5-10m) to moderately-sized (10-50m) riparian buffers extended adjacent to residential areas. The combination of high intensity land use with diverse instream habitat resulted in a QHEI score of 64.0, indicating the stream has the potential to support WWH communities. The combination of intermittent flow and surrounding agricultural activities likely influenced the poor biological communities present.

Shaw Creek
Shaw Creek was evaluated from Thatcher Road (RM 13.2) to Beatty Road (RM 1.6). The upper reach of Shaw Creek from Thatcher Road (RM 13.2) to South Canaan Road (RM 10.6) is maintained by the County and therefore had modified physical attributes compared to the downstream reach. Substrates in the upper reach originated primarily from glacial tills. Sand, gravel and silt were the dominant substrates and were mixed with occasional areas of cobble, and boulder. Silt was present in normal to moderate amounts, though substrate embeddedness ranged from normal to extensive. Moderate amounts of instream cover increased in a downstream direction, as only undercut banks, overhanging vegetation, shallows and woody debris were available as habitat near Thatcher Road (RM 13.2), and undercut banks, overhanging vegetation, shallows, rootmats, boulders, and logs were available to organisms near South Canaan Road (RM 10.6). The lack of recovery from the maintenance activities in the upper reach was

exemplified by low sinuosity, poor to fair channel development and low stability. Outside of the upper reach, row crops extended to within several feet of the stream channel, increasing the opportunity for nutrients and soil to run-off into the stream.

In contrast to the upper reach, the portion of Shaw Creek from State Route 529 (RM 5.2) to County Road 149 (RM 1.6) appeared to be recovering from past historical channelization activities. The substrates in this section originated primarily from shale, but had bedrock, gravel and sand as the predominant substrates mixed with areas of boulders, cobble and hardpan. Silt was present in normal amounts while embedded substrates were evident in normal to moderate amounts. Instream cover was diverse and plentiful as evidenced by undercut banks, overhanging vegetation, shallows, rootmats, pools, rootwads, boulders, oxbows, aquatic macrophytes and logs. Moderate sinuosity with fair to good channel development and moderate to high stability were observed, though some canopy removal was also noted. Very narrow (<5m) to narrow (5-10m) buffers extended along the stream adjacent to residential homes, crop fields and shrub dominated old fields.

The channel modifications evident in the upper reach decreased the quality of habitat available to aquatic life resulting in a QHEI score of 39.5 for the site near Thatcher Road (RM 13.2) and a QHEI score of 52.5 for the site near South Canaan Road (RM 10.6). The improved habitat described for the lower stream sites from State Route 529 (RM 5.2) to County Road 149 (RM 1.56) scored from 61.5 to 68.5 (x=65).

Mitchell Run

The physical habitat of Mitchell Run was evaluated near Delaware-Cardington Road (RM 0.2). The stream substrates appeared to originate primarily from glacial tills. Cobble was the most dominant substrate intermixed with smaller quantities of sand, gravel and boulders. Silt and embedded substrates were present in normal amounts, providing interstitial spaces for aquatic organisms. Moderate amounts of instream cover were provided by undercut banks, overhanging vegetation, shallows, rootmats, rootwads, boulders, and occasional woody debris. The stream appeared to be recovering from past channelization activities showing high sinuosity and good development with low to moderate stability. Currents ranged from slow to fast and a few eddies were observed.

The riparian corridor was very narrow (<5m) and abutted residential homes, old fields, new fields and open pasture. Diverse substrates, instream cover and abundant interstitial spaces resulted in a QHEI score of 72.0.

Claypole Run

The physical habitat of Claypole Run was evaluated near Prospect-Mt. Vernon Road (RM 1.2). The stream substrates appeared to originate primarily from glacial tills. Silt and cobble were the dominant substrate types intermixed with sand, gravel and boulders. Large quantities of silt were present smothering the majority of substrates and severely limiting interstitial spaces available for aquatic organisms. Moderate instream cover was provided by logs, backwaters, boulders, rootwads, rootmats, overhanging vegetation, shallows and undercut banks. No evidence of channelization was apparent in the upstream portion of the zone, as it exhibited moderate sinuosity with fair development and moderate stability. However, the portion of the site downstream of Prospect-Mt. Vernon Road had not recovered from recent channelization activities as it exhibited less sinuosity with fair development and low stability with false banks and moderate erosion.

Riparian buffers ranged from nonexistent and very narrow (<5m) adjacent to row crops to very narrow (<5m) and narrow (5-10m) adjacent to residential areas. The extensive amounts of siltation and embedded substrates combined with the moderate amounts of instream cover and diverse substrate types resulted in a QHEI score of 54.0.

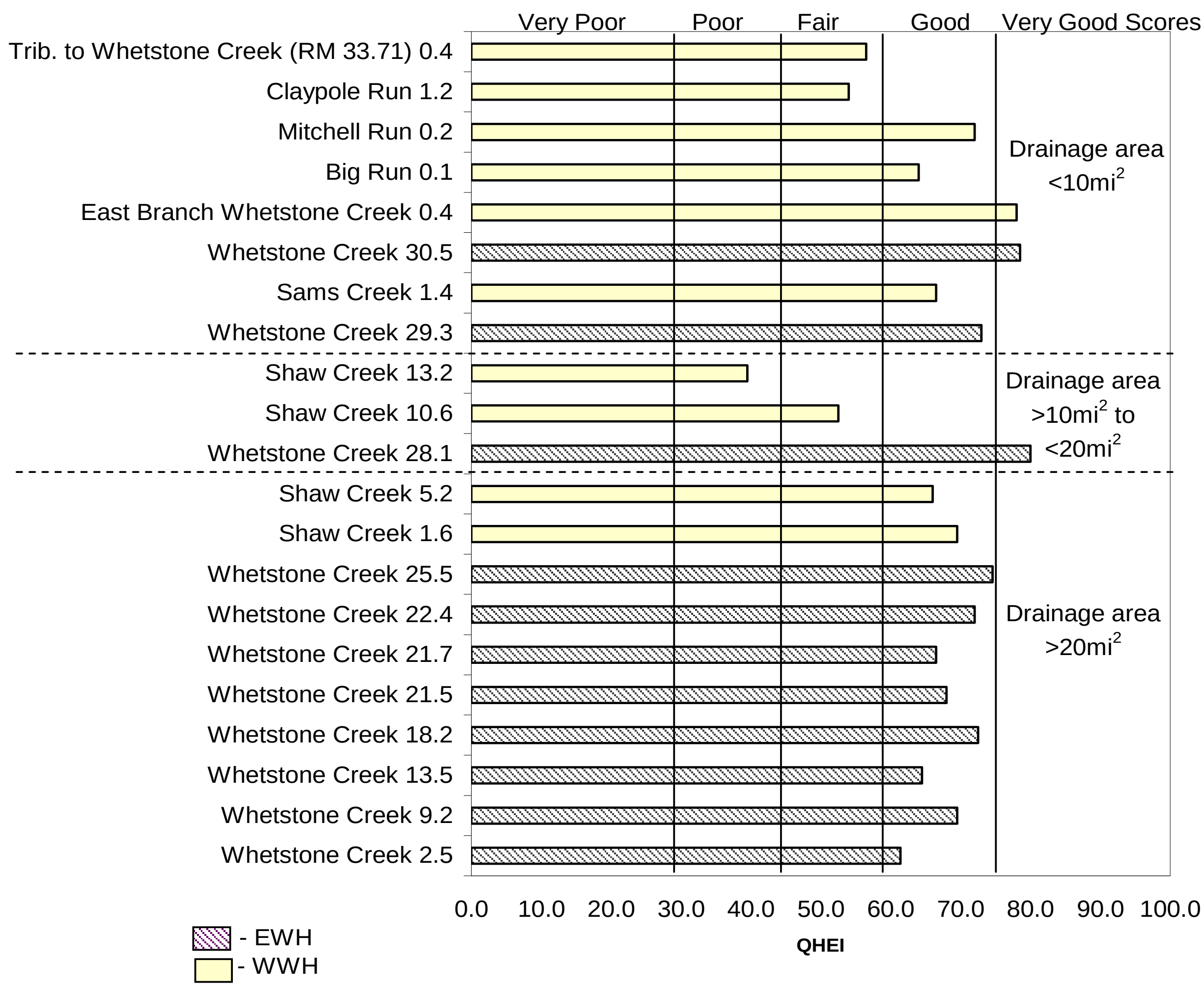


Figure 85. QHEI scores for sampling locations within the WCWAU, 2003.

Biological Communities: Fish

The fish communities of the WCWAU were evaluated at twenty-one locations. The eleven Whetstone Creek mainstem sites primarily showed good correlation with habitat conditions (Figure 86). However, habitat quality has decreased since the last study in 1994. Increased siltation and nutrient enrichment from the Mt. Gilead and Cardington WWTPs, and surrounding agricultural land uses have degraded the quality of habitat available to aquatic organisms. These changes are reflected in the fish community downstream of Mt. Gilead as the average IBI score in this reach was 43, while upstream of MT. Gilead the average IBI score was 48.

As Whetstone Creek flowed through Mt. Gilead, the fish community became less balanced. MIwb results downstream of Mt. Gilead were consistently lower in 2003 than the results obtained in 1994 (Figure 86). The lack of multiple age classes among several species of fish suggests toxic releases or spills resulting in fish kills. The imbalance of the fish populations present indicates the beginning of a possible shift from diverse, high quality fish assemblages to more tolerant communities over time. Steps must be taken to address the various pollutant sources of concerns (nutrient enrichment, total suspended solids, probable toxic releases, and siltation) before the diverse fish community is lost within Whetstone Creek.

Whetstone Creek

Fish communities in Whetstone Creek were sampled at eleven sites from upstream of the Candlewood Lake WWTP (RM 30.5) to State Route 229 (RM 2.6). Fish community indices and narrative evaluations ranged from marginally good (IBI=36) to exceptional (IBI=54). The Candlewood Lake development negatively influenced the biological fauna of the upper portion of Whetstone Creek in several ways. Elevated temperatures from the spillway and nutrient enrichment from the reservoir and the wastewater treatment plant degraded the fish community downstream of the dam. The IBI score upstream of the wastewater treatment plant (RM 30.5) was 50, which indicates the stream could support an EWH community. However, downstream of the wastewater treatment plant (RM 29.3) the IBI score dropped to 43, indicating this portion of the stream is less likely to support an EWH community. Omnivorous fish species comprised ≥38% of the species present throughout this portion of Whetstone Creek.

Biological community performance improved (IBI range of 46 to 50) as the stream flowed further south through a predominantly treed riparian corridor adjacent to agricultural fields, woodlots and scattered residential homes from Marion-Williamsport Road (RM 28.1) to State Route 61 (RM 22.4). The total percent of omnivores within this area decreased in a downstream direction, from an average of 33% at the most upstream site, to 8% near State Route 61 (RM 22.4). This trend from generalist to specialized feeders reflected improved water quality in this area.

As Whetstone Creek flowed through Mt. Gilead, the fish community became less balanced. The MIwb measures relative number, weight, and how evenly relative number and weight is distributed among species. It is sensitive to the total number and biomass of fish excluding tolerant species and to the uneven distribution of individuals and biomass within the community assemblage. The MIwb scores for the sites from State Route 61 (RM 22.4) and upstream of Mt. Gilead were very good (MIwb=9.0), while the MIwb scores from upstream of the wastewater treatment plant (RM 21.7) to Bennett Road (RM 18.2) were marginally good (MIwb=8.1) to good (MIwb=8.6). The relative numbers, age groups and proportion of intolerant and moderately intolerant species decreased as Whetstone Creek flowed through the Mt. Gilead area. Nine intolerant and moderately intolerant species (golden redhorse, northern hog sucker, silver shiner, rosefin shiner, brook silverside, smallmouth bass, longear sunfish, greenside darter and rainbow darter) comprised 31.9% of the fish community near State Route 61 (RM 22.4), while only six intolerant and moderately intolerant species (golden redhorse, northern hog sucker, silver shiner, smallmouth bass, banded darter, greenside darter and rainbow darter) were present upstream of the Mt. Gilead WWTP (RM 21.7). Fish representing multiple age groups were primarily collected near State Route 61 (RM 22.4). An increase in relative numbers of stoneroller minnows, striped shiners and bluntnose minnows indicate nutrient enrichment issues throughout Mt. Gilead. The mixing zone at the Mt. Gilead wastewater treatment plant (RM 21.6) was sampled to see if avoidance by aquatic organisms occurred, and was not considered a community evaluation site. Fish avoided contact with the mix zone of the Mt. Gilead WWTP.

Downstream of the Mt. Gilead WWTP (RM 21.5), community indices and narrative evaluations were within the good range (IBI=41 and MIwb=8.6) though results continued to indicate instability within the fish community. Stoneroller minnow (23.0%), bluntnose minnow (20.4%), and striped shiner (21.7%) comprised 65.1% of the relative number of individuals reflecting the nutrient enriched conditions of the area. As Whetstone Creek flowed further downstream, the total number of species increased to 23 including three intolerant and seven moderately intolerant species. The relative abundance of bluntnose minnow (11.7%), stoneroller minnow (9.5%) and striped shiner (8.0%) decreased near Bennett Road (RM 18.2) comprising only 29.2% of the relative number of individuals. However, few of any species present contained multiple year classes. The inability of the fish community to maintain well balanced assemblages in regards to age groups within each species demonstrates the importance of good water quality and the far reaching effects of water quality pollutants.

Within and downstream of Cardington, biological community indices and narrative evaluations ranged from fair (IBI=36 for boat site at RM 2.5) to good (IBI=45 for wading site at RM 13.5). The mixing zone at the Cardington WWTP (RM 13.7) was sampled to see if avoidance by aquatic organisms occurred, and was not considered a community evaluation site. The effluent was discharged to flow against the current which sped dilution at low flow and diminished the length of the effluent plume. Fish did avoid the mix zone of the Cardington wastewater treatment plant, especially during higher stream flows. Nutrient enrichment and less than excellent quality habitat conditions were reflected in the fish populations as tolerant species comprised 42%-50% of the individuals collected from downstream of Cardington WWTP (RM 13.5) to Waldo-Fulton-Chesterville Road (RM 9.2).

The most downstream site sampled on Whetstone Creek was adjacent to State Route 229 (RM 2.6). The flow condition at this site during the 2003 sampling season was nearly stagnant as waters from Delaware reservoir backed up into this portion of Whetstone Creek. The impounded conditions resulted in the lowest IBI score on Whetstone Creek (IBI=36). Omnivores comprised 58% of the individuals collected and round-bodied suckers comprised <4% of the individuals collected. The population collected reflected the low flow and high silt conditions observed.

Tributary to Whetstone Creek (RM 33.71)
The fish community of this stream was sampled near State Route 19 (RM 0.4). Community indices and narrative evaluations described the community as good (IBI=40). Even though the drainage area of the stream at this site was only approximately 2.0mi^2, a total of 10 fish species were collected, including the pollution intolerant redside dace.

East Branch
The East Branch of Whetstone Creek was sampled near Mt. Gilead-West Point Road (RM 0.4). Community indices and narrative evaluations characterized the fish community as good (IBI=45). Twenty-two species of fish were collected including the pollution intolerant redside dace. Though highly pollution tolerant species comprised 61% of the community, five darter species including blackside darter, greenside darter, rainbow darter, johnny darter and fantail darter were collected. In addition, six headwater species were observed, including least brook lamprey, blacknose dace, southern redbelly dace, redside dace, fantail darter, and mottled sculpin. The presence of several headwater species including those needing cool water temperatures (all daces, mottled sculpin) indicated consistent flow, probably augmented with ground water, in addition to adequate habitat and low environmental stress.

Sams Creek
Sams Creek was evaluated near Sunfish Road (RM 1.4). Community indices and narrative evaluations characterized the fish community as good (IBI=44). Sixteen species were collected incuding four darter species; johnny darter, greenside darter, rainbow darter, and fantail darter.

Big Run
The fish community of Big Run was sampled near Cardington Western Road (RM 0.1). Community indices and narrative evaluations characterize the community as fair (IBI=34). Seventeen species were collected in Big Run and 62% of the individuals collected were pollution tolerant. No headwater species were collected here reflecting the flashy nature of flow rates caused by upstream hydromodifications and degraded water quality from nutrient enrichment and siltation.

Shaw Creek

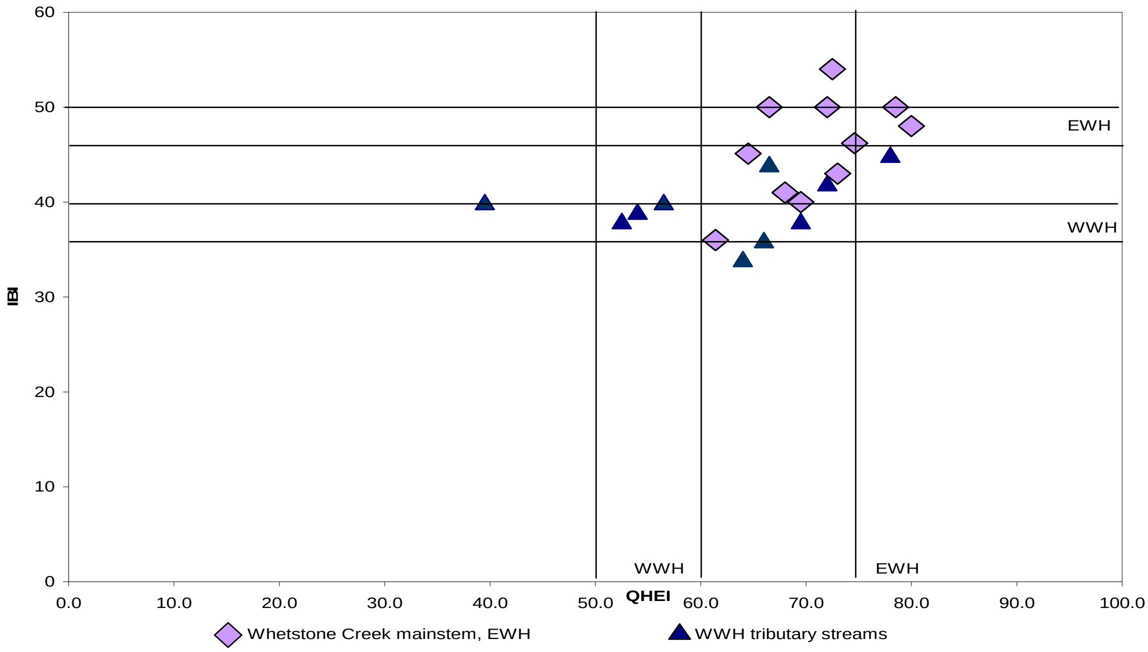
The fish community of Shaw Creek was sampled at four locations from Thatcher Road (RM 13.2) to Beatty Road (RM 1.6). Community indices and narrative evaluations characterized the fish community as marginally good (IBI=36) to good (IBI=40). Twenty-three species were collected in the headwaters, though the only common intolerant species collected was the banded darter. Seven tolerant species including white sucker, common carp, blacknose dace, creek chub, green sunfish, yellow bullhead and bluntnose minnow comprised 65.5% of the population in the headwaters reflecting the channelized conditions observed. Further downstream the combination of poor riparian cover, failing on-site sewage treatment systems and agricultural practices influenced the fish community as tolerant species continued to dominate the population at 65%.

Mitchell Run

The fish community of Mitchell Run was sampled near Delaware-Cardington Road (RM 0.2). Community indices and narrative evaluations characterized the stream as good (IBI=42). A total of twenty species were collected though eight of the species were common pollution tolerant species including creek chub, bluntnose minnow, green sunfish, blacknose dace, central mudminnow, white sucker, goldfish, and yellow bullhead. Though IBI indicated an overall good fish community and habitat was adequate, signs of nutrient enrichment were observed.

Claypole Run

Claypole Run was sampled near Prospect-Mt.Vernon Road (RM 0.2). The combination of modified habitat conditions and failing individual sewage treatment systems resulted in marginally good (IBI=39) performance by the fish community. Common tolerant individuals comprised 76.5% of the population and included white sucker, common carp, golden shiner, blacknose dace, creek chub, fathead minnow, bluntnose minnow, yellow bullhead, and green sunfish.



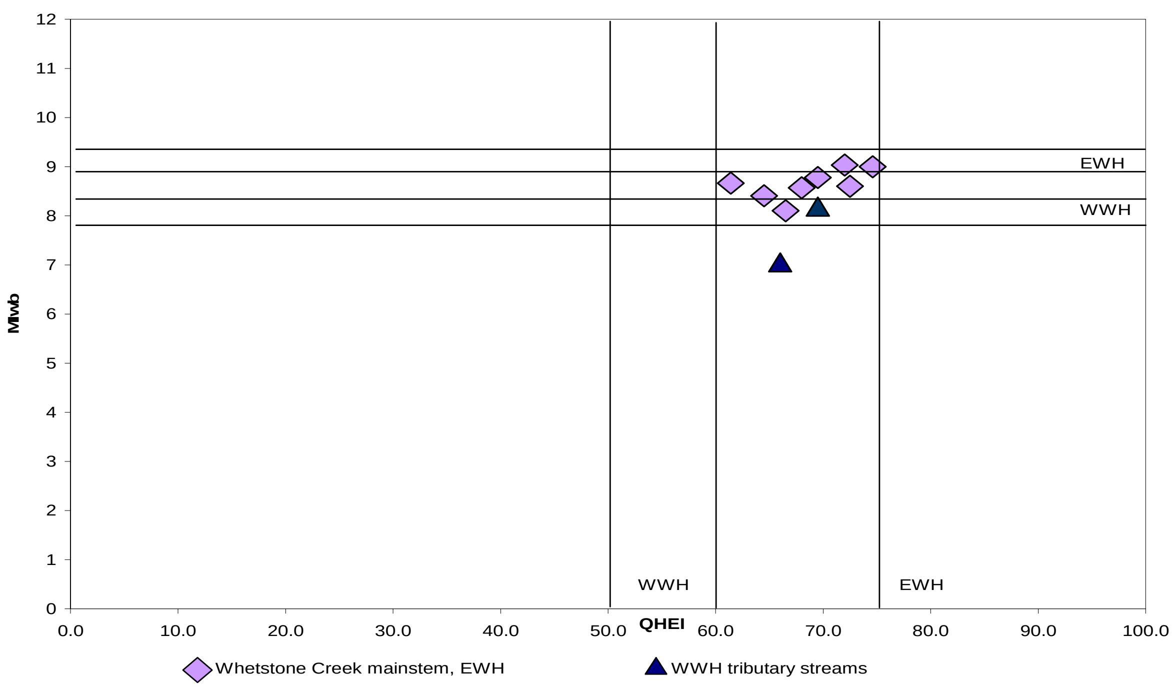


Figure 86. IBI versus QHEI and MIwb versus QHEI for fish sampling locations in the WCWAU, 2003. MIwb only applies to streams ≥20mi^2.

Biological Communities: Macroinvertebrates

Macroinvertebrate communities were evaluated at 23 stations in the Whetstone Creek assessment unit (WAU 05060001-100) (Table 24). The community performance was evaluated as exceptional at 10 stations, very good at one, good at two, marginally good at one, fair at five, low fair at two, and two mixing zone stations were sampled twice, the Mt. Gilead WWTP mixing zone was marginally good and fair and the Cardington WWTP mixing zone was fair on both passes. The stations with the highest EPT taxa richness were on Whetstone Creek at SR 61 (RM 22.4) and upstream from the Mt. Gilead WWTP (at RM 21.8) with 27 taxa. The station with the highest number of total sensitive taxa was on Whetstone Creek at Waldo-Fulton-Chesterville Road (RM 9.0) with 43 taxa. Sensitive taxa found in this assessment unit which are noteworthy because they are not commonly collected were the mayflies *Acentrella turbida* in the E. Br. Whetstone Cr. (RM 0.4), *Acerpenna macdunnoughi* in Whetstone Cr. (RM 25.5), E. Br. Whetstone Cr. (RM 0.4), and Shaw Cr. (RM 13.2), *Serratella deficiens* in Whetstone Cr. (RMs 22.4, 21.5), and *Brachycercus sp.* in Whetstone Cr. (RM 2.7); the stonefly *Agnetina capitata* complex in Whetstone Cr. (RMs 21.8, 18.3, 12.8, 9.0); the caddisflies *Psychomyia flavida* in Sams Cr. (RM 1.4), *Hydropsyche frisoni* in Whetstone Cr. (RM 2.7), *Hydropsyche venularis* in Whetstone Cr. (RMs 21.8, 21.58 A & B, 18.3, 9.0), *Macrostemum zebratum* in Whetstone Cr. (RM 2.7), *Glossosoma sp.* in E. Br. Whetstone Cr. (RM 0.4), and *Leucotrichia pictipes* in Whetstone Cr. (RM 21.8); and the midge *Nanocladius (Plecopteracoluthus) downesi* in Whetstone Cr. (RM 22.4, 21.5, 18.3, 12.8, 9.0) and E. Br. Whetstone Cr. (RM 0.4).

The upstream station on Whetstone Creek (W. Point-Galion Road, RM 30.5) was evaluated as fair due to low diversity of EPT and sensitive taxa and high predominance of facultative taxa like blackflies and flatworms (Figure 87, Table 24). This station is located downstream from Candlewood Lake and the Candlewood Lake housing development. The water temperature at this station was elevated to 25.0°C. The reservoir and housing development were having a negative impact (increased water temperature as well as organic and nutrient enrichment) on macroinvertebrate community health. Moving downstream, invertebrate assemblages gradually improved with an exceptional community observed at Marion-Williamsport Road/CR 61 (RM 28.1). There was no discernable impact to the invertebrate community from the Candlewood Lake WWTP (RM 30.5). The invertebrate communities remained exceptional for most of the entire length of the stream. However, there was a decline in community performance downstream from the Mt. Gilead WWTP (RM 21.6). The mixing zone samples (RM 21.58) were evaluated as marginally good. The first two stations downstream from the Mt Gilead WWTP exhibited declines in ICI, EPT, and sensitive taxa diversity (Figure 87), which appears to be a response to nutrient enrichment from the WWTP. The Cardington WWTP (RM 13.7) mixing zone samples (RM 13.68) were evaluated as marginally good and fair. Low numbers of EPT and low diversity of sensitive taxa accompanied by high predominance of the very pollution tolerant midge *Chironomus riparius* group were indications of degradation due to nutrient enrichment, low DO, or moderate toxicity. The station downstream from the Cardington WWTP at CR 11 (RM 12.8) realized an improved ICI score while continuing the depressed EPT and sensitive taxa diversity trend present upstream from the WWTP. The Cardington WWTP discharge may have contributed to the impact observed from the Mt. Gilead WWTP. The macroinvertebrate populations at the remaining two stations on the Whetstone Creek mainstem had nearly recovered to conditions present upstream from Mt. Gilead.

The macroinvertebrate communities evaluated in the Tributary to Whetstone Creek (RM 33.71) at RM 0.4 were evaluated as fair. Poor diversity of pollution sensitive taxa and low numbers and diversity of EPT taxa were indications of community impairment. Facultative and tolerant taxa dominated the invertebrate community. This station is in a rural area and appeared to be impacted by habitat modifications and agricultural runoff. Five cool/coldwater macroinvertebrate taxa were collected from this station which indicates the potential of this stream to be classified as a Coldwater Habitat aquatic life use.

The macroinvertebrate communities sampled from East Branch Whetstone Creek (RM 0.4) and Sams Creek (RM 1.4) were performing at an exceptional level with high diversity of EPT and sensitive taxa. These streams are supporting healthier invertebrate communities than other tributary streams in the basin due to their more intact woody riparian areas. In East Branch Whetstone Creek, three cool/coldwater macroinvertebrate taxa were collected, the caddisfly *Glossosoma sp.*, the midge *Paratanytarsus n. sp.* 1, and the dance fly *Chelifera sp.* Even though this is below the four taxa expected in a CWH stream, the presence of the two coldwater fish species, redside dace and mottled sculpin, indicates that this stream is supporting coolwater communities.

The macroinvertebrate communities sampled in Big Run (RM 0.1), Mitchell Run (RM 0.2), and Claypole Run (RM 1.2) were performing below or just barely meeting Warmwater Habitat expectations. These streams are located in rural agricultural areas and have each been modified to some extent, degrading invertebrate habitat. Runoff from nearby agribusinesses also undermines invertebrate community integrity in these streams. The smell of raw sewage at the Claypole Run station indicated pollution from poorly treated domestic sanitary wastes. All of these streams are probably impacted by varying degrees of channel modification, agricultural runoff, and poorly treated domestic sanitary wastes.

The upstream station on Shaw Creek at Thatcher Road (RM 13.2) was supporting a community that was performing at a higher level (good) than the remaining stations in terms of EPT and sensitive taxa diversity. However, high predominance of the facultative flatworms was an indication of community imbalance possibly from nutrient enrichment. This station was located in an agricultural area with extensive channel modifications similar to downstream stations. One possible explanation of the higher community performance at the upstream station in Shaw Creek would be greater groundwater recharge at that station. The water temperature on September 4 was 18.5°C, however, no cool/coldwater taxa were collected. Community performance at downstream stations gradually declined, especially the caddisfly component, except for a slight improvement at Beatty Road (RM 1.5). The two upstream stations were likely impacted by channel modifications and enrichment, while the two downstream stations were likely impacted by siltation and possibly enrichment.

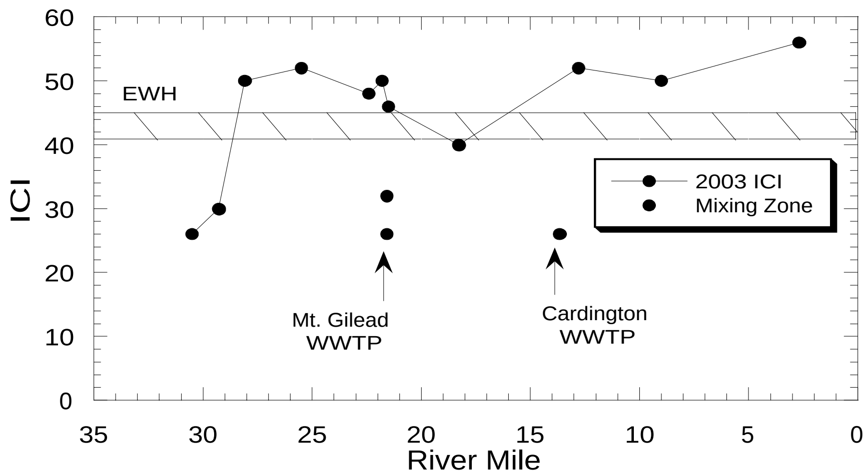
Table 24. Summary of macroinvertebrate data collected from artificial substrates (quantitative sampling) and natural substrates (qualitative sampling) in the Whetstone Creek study area, July to September, 2003.

Stream RM	Dr. Ar. (sq. mi.)	Data Codes	Qual. Taxa	EPT Ql. / Total	Sensitive Taxa Ql. / Total	Density Ql. / Qt.	Predominant Organisms on the Natural Substrates With Tolerance Category(ies) in Parentheses	ICI	Narrative Evaluation
Whetstone Creek (02-450)									
30.5	7.5	-	43	8	7	Moderate	Midges (F), blackflies (F), flatworms (F)	-	Fair
29.3	8.4	-	44	12	14	L-M	Midges (F,MI), flatworms (F)	-	Marg. Good
28.1	19.0	-	72	23	30	L-M	Midges (F,MI), riffle beetles (F,MI), caddisflies (F,MI)	-	Exceptional
25.5	26	-	58	23 / 25	29 / 40	M / 973	Caddisflies (F,MI), midges (MI), baetid mayflies (F)	52	Exceptional
22.4	34	-	66	23 / 27	33 / 41	M / 296	Caddisflies (F,MI), midges (MI), water penny beetle larvae (MI)	48	Exceptional
21.8	35	-	68	20 / 27	26 / 38	M / 217	Caddisflies (F,MI,I), midges (F,MI), *Elimia* snails (MI)	50	Exceptional
21.58 A	36	21	51	14	19	Moderate	Midges (F,MI)	-	Marg. Good
21.58 B	36	21	41	11	15	Moderate	Midges (T,F,MI), flatworms (F)	-	Marg. Good
21.5	36	-	65	17 / 22	23 / 33	M / 959	Midges (T,F,MI), caddisflies (F,MI)	46	Exceptional
18.3	40	-	51	15 / 18	21 / 32	M / 401	Caddisflies (F,MI), midges (F,MI), baetid mayflies (F)	40	Good
13.68 A	49	21	39	10	10	L-M	Midges (T,F)	-	Marg. Good

Stream RM	Dr. Ar. (sq. mi.)	Data Codes	Qual. Taxa	EPT Ql. / Total	Sensitive Taxa Ql. / Total	Density Ql. / Qt.	Predominant Organisms on the Natural Substrates With Tolerance Category(ies) in Parentheses	ICI	Narrative Evaluation
13.68 B	49	21	30	7	8	Moderate	Red midges (T,F)	-	Fair
12.8	51	-	51	14 / 18	20 / 30	M / 2154	*Stenelmis* riffle beetles (F), *Chimarra* caddisflies (MI)	52	Exceptional
9.0	62	-	58	19 / 23	26 / 43	M-H / 322	*Petrophila* moth larvae (I), hydropsychid caddisflies (F,MI)	50	Exceptional
2.7	113	-	58	17 / 25	25 / 40	M / 426	*Rheotanytarsus* midges (MI), *Petrophila* moth larvae (I)	56	Exceptional
Trib. To Whetstone Cr. (RM 33.71) (02-467)									
0.4	2.0	-	48	6	12	L-M	Midges (MI,F,T)	-	Fair
E. Br. Whetstone Creek (02-458)									
0.4	6.3	-	61	21	29	L-M	Midges (F,MI), *Hydroptila* caddisflies (F)	-	Exceptional
Sams Creek (02-457)									
1.4	7.8	-	75	25	34	M	Midges (F,MI), hydropsychid caddisflies (F)	-	Exceptional
Big Run (02-455)									
0.1	6.1	-	28	7	7	L-M	Sow bugs (F), midges (F,MI)	-	Low Fair
Shaw Creek (02-453)									
13.2	11.8	-	63	17	19	M-H	Flatworms (F), caddisflies (F), baetid mayflies (F), midges (MI,F)	-	Good
10.6	14.8	-	57	14	13	M	*Stenelmis* riffle beetles (F), caddisflies (F), baetid mayflies (F,I), blackflies (F)	-	Marg. Good
5.2	21.1	-	42	12	12	L-M	Mayflies (F,I), hydropsychid caddisflies (F), aquatic sow bugs (F)	-	Marg. Good

Stream RM	Dr. Ar. (sq. mi.)	Data Codes	Qual. Taxa	EPT Ql. / Total	Sensitive Taxa Ql. / Total	Density Ql. / Qt.	Predominant Organisms on the Natural Substrates With Tolerance Category(ies) in Parentheses	ICI	Narrative Evaluation
1.5	26	-	33	9 / 11	9 / 16	L / 173	*Stenelmis* riffle beetles (F), water penny beetles (MI), *Elimia* snails (MI)	42	Very Good
Mitchell Run (02-452)									
0.2	5.4	-	46	11	13	L-M	Hydropsychid caddisflies (F), heptageniid mayflies (F), water penny beetles (MI), blackflies (F)	-	Marg. Good
Claypole Run (02-451)									
1.2	3.8	-	31	7	5	M	Elimia snails (MI), hydropsychid caddisflies (F)	-	Low Fair

RM: River Mile.
Dr. Ar.: Drainage Area
Data Codes: 21=Mixing Zone Sample.
Ql.: Qualitative sample collected from the natural substrates.
Sensitive Taxa: Taxa listed on the Ohio EPA Macroinvertebrate Taxa List as MI (moderately intolerant) or I (intolerant).
Qt.: Quantitative sample collected on Hester-Dendy artificial substrates, density is expressed in organisms per square foot.
Qualitative sample relative density: L=Low, M=Moderate, H=High.
Tolerance Categories: VT=Very Tolerant, T=Tolerant, MT=Moderately Tolerant, F=Facultative, MI=Moderately Intolerant, I=Intolerant



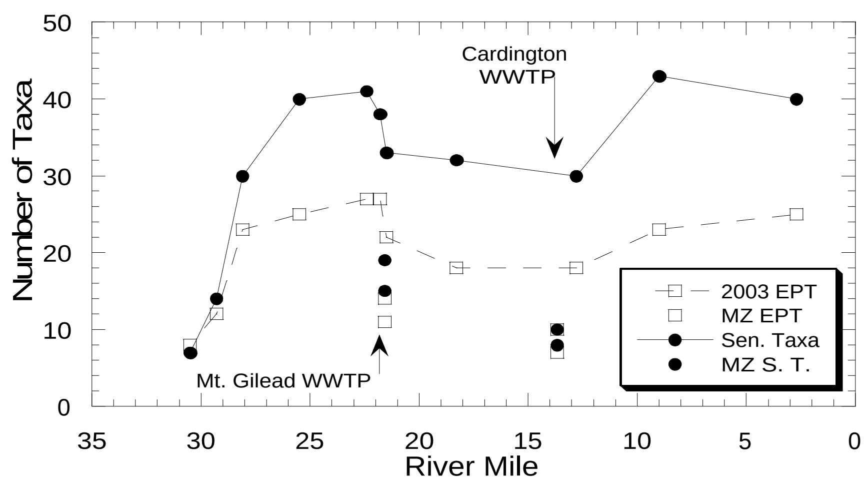


Figure 87. Longitudinal trend of the Invertebrate Community index (ICI), total EPT, and total sensitive taxa in Whetstone Creek, 2003.

Lower Olentangy Watershed Assessment Unit (LOWAU)

The HUC code for the lower Olentangy River (#05060001-120) encompasses the area from downstream the confluence of Delaware Run to the mouth. For the purposes of this report, the chemical summary for the LOWAU will correspond with the HUC code, except that the upper boundary will begin downstream of the Olentangy River confluence with Brondige Run (RM 38.13) and end at the mouth of the Olentangy River as it confluences with the Scioto River near downtown Columbus. The remaining sections will have the LOWAU correspond with the boundaries established by HUC code # 05060001-120.

Fish and macroinvertebrate communities and stream habitat conditions were evaluated at 14 sites within the LOWAU (Figure 88). The index scores for each site and their biological attainment status are presented in Table 25 while Figure 89 provides the biological attainment status by location. Water quality samples were collected at 14 sites and analyzed for a variety of chemical and bacteriological parameters. Each site had at least six sets of grab samples collected at roughly two week intervals during the field season. Mainstem sites had extra bacteria samples collected in July so the recreation use could be assessed. Results that violated water quality criteria codified in OAC Chapter 3745-1 are summarized in Table 26.

Aquatic Life Use Attainment Status and Trends

As mentioned previously, the data analysis sections of this report have the boundary for the lower Olentangy basin beginning below Brondige Run (RM 38.13), though the HUC boundary begins below Delaware Run (RM 25.71). However, the HUC boundary was used to determine the attainment scores. The WAU overall attainment score was 40. An overall attainment score of 0 would reflect 0 sites meeting designated or recommended aquatic life uses in the WAU while a score of 100 would reflect all sites meeting designated or recommended aquatic life uses. The attainment score was calculated according to the protocol and procedures established in the most recent Integrated Water Quality Monitoring and Assessment Report, which can be accessed at:
http://www.epa.state.oh.us/dsw/tmdl/Index.html

Biological impairment within the Olentangy mainstem in the LOWAU was a result of nutrient enrichment and siltation in the EWH portion (north of I-270) caused by the rapid pace of development in the surrounding watershed. The lower portion of the mainstem was impaired as a result of impoundment by low head dams and organic/nutrient enrichment from SSOs, CSOs and urban stormwater runoff. The Tributary to Olentangy River RM 20.71 was impaired as fish migration and thus recruitment is not possible due to isolation of segments by a waterfall and several dams. Wahalla Hollow, was determined to have primary headwater characteristics. Since Ohio currently does not have primary headwater aquatic life uses at this time, an aquatic life use assessment was not completed on this stream. All the remaining tributary streams assessed in the LOWAU were in non attainment of their designated aquatic life uses due primarily to nutrient enrichment from SSOs, failing on-site sewage treatment systems, altered flow regimes and urban stormwater run-off. Most of these tributaries also had modified channels and the associated problems that arise from a hardened (paved) watershed, habitat destruction and altered flow.

Longitudinal plots of IBI and MIwb community indices are presented in Figure 90. IBI scores are generally similar to those from the 1999 survey, indicating stability. However, areas previously noted in the 1999 survey as impaired or threatened remain a concern to the overall health of the Olentangy River. The Hyatts Road site (RM 19.4) is of special concern as it again performed below EWH expectations. In addition, biological community performance at the next downstream site, State Route 750/Highbanks (RM 15.0) decreased significantly, falling below EWH expectations. Thus, the cause for the decline in 1999 was not drought related, as had been hoped. Instead, it is likely a reflection of the increased development occurring throughout northern Franklin county and Delaware county. Increased impervious surfaces from development result in changes of flow regimes, increased urban run-off, increased siltation and nutrient enrichment. Steps should be taken now to reduce the effects of urbanization throughout this area. If not, future surveys may indicate a complete loss of this exceptional fish community.

Macroinvertebrate community performance in the Olentangy River from Olentangy Avenue in Delaware to Kenny Park in Columbus has remained as high as or slightly higher than previous surveys (Figure 91). Moderate declines in community performance downstream from the Delaware WWTP (RM 25.26) and the Olentangy Environmental Control Center (RM 13.39) in 1999 were not observed by the current study. The free flowing stations located within Columbus were demonstrating a remarkable improvement compared to previous years. This may be due to reductions in sanitary sewer overflows or eliminations of some discharges. Figure 92 graphs the ICI trend of the Hyatts Road station in the EWH part of the river and the station at the railroad bridge near the mouth. The Hyatts Road station has consistently performed in the exceptional range since 1983 and the station near the mouth has gradually improved from poor community evaluations in 1988 and 1991 to good in 2003.

Reaches impounded by dams, such as the 5th Avenue dam, are continually identified as a source of impairment. The removal of these dams, in combination with elimination of the numerous CSOs and SSOs in the LOWAU, would improve water quality within these reaches likely resulting in attainment of aquatic life use designations.

Recreation Use Attainment Status

Recreation impairment occurred throughout the Olentangy River mainstem. Numerous wet weather related sanitary and combined sewer overflows were noted during the surveys. Several tributaries are known to receive SSOs, which then discharge directly to the Olentangy River. Detailed descriptions of the sources of recreational use impairment are discussed below. Addressing these sources is necessary to eliminate impairment present throughout the LOWAU.

Spills

Eleven spills were reported to ODNR from 1994-2004 for the LOWAU (Figure 93). The spills were investigated by ODNR for possible harm to wildlife. More spills were reported for this WAU than any other in the study area. This is likely the result of their simply being more people present here than in the other WAUs. The type of materials reported reflects the surrounding landscape, as most are attributable to components of an urbanized environment.

The draining of a community swimming pool at Mingo Park in the City of Delaware resulted in a fish kill in the Olentangy River in September 1994. Construction activities by ODOT on US 23 in Delaware resulted in a spill of Safe Cure 1000, a chemical for curing concrete, in August 1995. The spill affected 1.75 miles of Mink Run. In 2004, Bill Moose Creek had two spills reported, one from chlorine and pool cleaner and one from an unknown source, though it was likely conveyed through storm sewers. Adena Brook also had two spills reported, one from a ruptured sewer line in 1996 and one from 4500 gallons of vinegar discharged from the Marzetti food processing company in 2001. A tributary to Adena Brook had a fish kill reported in 1999, though no source for the kill could be determined. Turkey Run received water from a house fire which caused a small fish kill in 1994. Bethel Commons Pond received cement and a color additive conveyed through a storm sewer in 1995 discharged to the sewer by a private home owner. A tributary to the Olentangy River received cement dust and chlorine from a swimming pool demolition in 2004. The one spill reported for the Olentangy River was for asphalt sealant washed into the river via a storm sewer in 2001. The City of Columbus conveys lime sludge from their Morse Road water treatment facility on the east side through a pipeline to an abandoned quarry on the west side of town. In April 2001, a rupture in the pipeline was reported as it spilled lime sludge into the Olentangy River near Bethel Road. Over 1,000 yds^3 of lime sludge was noted at the time of the report, though it appeared the pipe had burst earlier in the year.

Ecoregion, Soils and Topography

In Delaware County, the river flows along the eastern margin of the City of Delaware. Within three river miles of the city limits lie five low head dams: Panhandle Road dam, Central Avenue dam, Williams Street dam, Stratford dam and U. S. Route 23 dam. Built for a variety of purposes, but now outmoded, all five are proposed to be removed. At the time of this report, the Williams Street dam had just been removed. The Panhandle Road dam is proposed for removal in autumn 2006, while no definite date has been set for the remaining three dams. Several rapids are located between the Stratford dam and the Sandusky Street exit.

Along the above mentioned reach and downstream to approximately Home Road, Delaware limestone is exposed at numerous sites in the river’s bed. The bedrock is visible at the crossing of the U.S. Route 23 bridge at State Route 315. Where bedrock is not exposed, a substrate of unconsolidated alluvial sand, gravel and cobbles is seen as far south as the High Banks Metro Park. Here the eroding cliffs of Ohio Shale provide substrate materials. This shale substrate begins to transition past the Village of Mount Air as the river enters a different geological region indicated by a transition in substrate, river morphology and surrounding watershed landscapes.

Between Mount Air and the I-270 bridge and also downstream of the State Route 161 dam to the West North Broadway bridge, the river exhibits broad meanders, bars, islands, extensive shallow riffle zones, runs, flats and small pools flanked by a narrow yet forested riparian corridor. The substrate here consists of sands, gravel and cobbles; the products of Ice Age erosion and deposition. These materials take on prominence as one proceeds downstream in the Olentangy corridor. The watershed inventory - "A Snapshot: The State of the Lower Olentangy River Watershed in 2001" produced by Friends of the Lower Olentangy Watershed (FLOW) in 2003 reads:

> This portion of the valley, however, is broader and deeper and has been back-filled with silty alluvium and glacial outwash sand and gravel to depths as great as 120 feet below the ground surface. The thickness of the outwash valley fill increases downstream towards the mouth of the river, ranging from a thickness of 40 feet at Mt. Air to 70 feet in Clintonville to thicknesses in excess of 100 feet at the Ohio State University campus in Columbus (ODNR well logs). Public drinking water supplies in Mt. Air and Worthington Hills are from wells 40 to 55 feet deep that are screened in these glacial deposits.

The reach between I-270 and State Route 161 was extensively modified during construction of the I-270 and State Route 315 interchange. Modification included "moving" the river channel 1000 feet eastward. Evidence of this work is seen in its somewhat unnatural and linear appearance as well as the remnant rip rap "riffles", installed presumably to enhance aquatic habitat.

Downstream of State Route 161 to the Lane Avenue bridge, the Olentangy River corridor is marked by a number of parklands, cemeteries, and research facilities (Ohio State University Olentangy Wetlands Research Park) which preserve wooded riparian corridor within a densely built residential-commercial landscape. Further downstream, the river corridor of the Lane Avenue bridge divides the Ohio State University campus with its stadium, playing fields, numerous parking lots and building complexes. The corridor here exhibits fewer wooded riparian tracts as lawn and paved surfaces fill the landscape. In this reach the Fifth Avenue dam shows a strong influence as the river broadens in a long pool upstream of the dam wall (Figure 94). The FLOW inventory notes that "This stretch of the river is floored with muck, silt, and clay with locally abundant aquatic vegetation." (FLOW, 2001).

Between Kinnear Road and the confluence, the river's near west bank is dominated by extensive highway surface and rights of way. Both up and downstream of Fifth Avenue, State Route 315 strides above the river bed on massive concrete pylons while below traffic flows along Olentangy River Road within 50 yards and easy view of the river itself. From the confluence to Worthington, the Olentangy bikeway on both west and east banks affords more detailed views of the remaining forested riparian within this overall, urban-dominated watershed setting.

Extensive transportation projects including multiple bridge reconstructions (Lane Avenue, Third Avenue) and massive highway interchange complexes (Spring-Sandusky) have reshaped the river corridor south from Lane Avenue in the last 10 years. However, small banks of wooded riparian continue to flank the river and better quality substrates of cobble, gravel, sand and boulders are yet present downstream of Fifth Avenue to the confluence. While the wooded banks can be viewed from State Route 315's northern lane as one approaches Fifth Avenue, the substrates are becoming embedded with silt from stormwater run-off.

Soils of the LOWAU are products of glacial till outside of the floodplain. Associations within the flood plain showed influence of alluvium, glacial outwash and or loess deposition. North of the Franklin County line, the study area soils show a higher requirement for artificial drainage, and when eroded, contribute clayey sediments to surface waters.

The Franklin County watershed flood plains are dominated by the Med way-Genesee-Sloan soil association, formed in moderately coarse to moderately fine textured recent alluvium. East of the river corridor, the Cardington-Alexandria-Bennington soil association is found in a band between 0.25 and 0.5 miles wide, extending back from the flood plain proper. It also extends eastward into tributary ravines such as Rush Run and Adena Brook. This association is formed in medium textured and moderately fine textured glacial tills.

The Eldean-Ockley-Warsaw association extends along the southern third of the river corridor within the LOWAU. These well drained soils, formed in moderately coarse to moderately fine textured glacial outwash, alluvium or loess, are found 0.5 to 0.75 miles west of the flood plain between Grant Riverside Hospital thence south to the confluence.

Within Delaware County and north of Winter Road; the lower lime soils of the Cardington-Alexandria association are seen in the eastern tributary ravines and the Bennington-Pewamo associations of the east bank uplands are replaced by the higher lime Glenwood-Blount and Blount-Pewamo associations. The Blount-Pewamo association is one of poorly to very poorly drained soils. In the flood plain and low outwash terraces of the Olentangy and Horseshoe Run; Ross, Sloan and Scioto soils dominate. (Pers. Comm. Delaware-NRCS, 2004)

Numerous tributaries flow throughout the LOWAU. In northern Columbus, Worthington and particularly southern Delaware County, tributaries east of the Olentangy River mainstem cut steep sided ravines through black shale bedrock. Sewer lines and storm water pipe are buried in a number of these ravines - adjacent to or under the streambed itself. In urban areas, impervious surfaces from residential communities, commercial centers and roadways contribute a significant portion of the stream's flow and act as conveyors for pollutants to the Olentangy River itself. As development continues to expand in southern Delaware County, similar alterations to tributary streams and water quality are likely to occur.

The LOWAU tree species vary with soil associations, slope orientation and land use history (logging, pasturing, cultivation, development etc.). Flood plain tree species include: box elder, sycamore, green ash, willow, hackberry, buckeye, honey locust, and silver maple. Beech, maples, cherry and redbud are more commonly seen in tributary ravines such as Big Run. Oak species, walnut, hickory, and sugar maple appear on the better drained uplands. On more limey soils chinkapin oak is present.

In urban areas, some reaches of wooded riparian show extensive growth of bush honeysuckle, a nonindigenous species. Watershed and community groups in Columbus have focused on honeysuckle removal as a project activity since 2000. Garlic mustard, also nonindigenous, was observed in many urban riparian and ravine sites since 2000 (pers. comm. Harold Bower, ODNR Division of Forestry).

Similar to the other WAUs of the Olentangy watershed, the LOWAU lies within the ECBP ecoregion. Just north of the Franklin County line lies the Clayey High Lime Till Plains, a broad nearly level area containing end moraines and basins. To the south, begin the Loamy High Lime Till Plains, a subregion of level to rolling glacial till with end moraines and glacial outwash features. Other depositional features, including kames and eskers, are also present on this watershed landscape**.** Glacial erratics from bedrock formations north of Ohio are found throughout the study area, often seen piled in farm field corners. The geological parent materials and slopes of these depositional forms worked with climate, flora and fauna over time to produce the watershed's soil associations (Omernik, 1988)**.**

Causes and Sources of Impairment

The urbanized setting of the LOWAU has produced both point and nonpoint sources of pollution including CSOs and SSOs, urban stormwater runoff and altered hydrology due to the hardened watershed. These pollutants sources have been created as a result of the urbanized landscape within the LOWAU. The watershed's increasing population and accompanying land use change are facilitated by infrastructure (roads, buildings, utilities) planning, construction and maintenance projects. Construction and maintenance activities have strong <u>potential</u> to impact both mainstem and tributaries directly or indirectly through surface runoff, removal of riparian vegetation, equipment crossings, stream filling or in stream work including abutment, pylon or underground pipeline construction, and stream straightening.

Population growth in the upper portion of the LOWAU, specifically in Delaware County, was 20.7% between April 2000 to July 2003 (Table 27). Active subdivision proposals for communities within the Olentangy watershed are some of the most numerous of communities in Delaware County. Liberty Township had 965 lot proposals in 2004, the highest of any community within Delaware County (Table 28). In addition, motor vehicle registrations for Delaware County rose 21.9% from 1999 to 2002.

The Mid Ohio Regional Planning Commission's Transportation Improvement Program draft report lists projects within Delaware and Franklin counties that are slated for state fiscal years 2006 – 2009 (Table 29). These may include projects "rescheduled" for this period from previous years. A number of projects, some extensive, are within the watershed and or the riparian corridor itself. Examination of these proposed projects should extend beyond the immediate acute effects on receiving streams, but also the cumulative effect all of the projects will have on the Olentangy River mainstem and each receiving stream.

The highly urbanized setting of the LOWAU requires focus on riparian corridors, dam removals and water quality/quantity problems to improve the overall ecological health of this watershed. Purchase of high quality riparian lands is occurring in the watershed's most intensely developing reaches. Ravine properties at Camp Lazarus and Big Run, both within Delaware County, were secured in 2004 through the Ohio EPA's Water Resources Restoration Sponsorship Program (WRRSP) and will be left in a more natural state.

Dam removals frequently improve water quality and enable fish migration. Since 2003, ONDR has removed two dams on the Olentangy River within Delaware County. ODNR in conjunction with the City of Delaware, OEPA and ODOT had proposed removal of five additional dams in Delaware County. One of the dams, known as the William Street dam, was removed in November 2005. The City of Columbus has contracted a feasibility study to investigate the potential removal of an additional five low-head dams within Franklin County. The largest dam structure within the LOWAU is the Fifth Avenue dam. This 8 foot structure impounds an extensive amount of river along the OSU campus (Figure 94). In 2005 a consortium of the City of Columbus, Ohio State University and FLOW were crafting a draft proposal for funding the dam's removal and restoration of the upstream reach to Dodridge Street. During this same period, City of Columbus staff were re-surveying the dam area, locating utility lines, and examining the dam for its structural properties.

Recent watershed planning efforts for areas south of Delaware include a watershed plan produced under the coordination and direction of FLOW. ODNR and OHIO EPA formally endorsed the plan in 2005.

Table 25. Aquatic life use attainment status for stations sampled in the Olentangy basin based on data collected July-October 2003. Data collected in 2004 is indicated by the value being in *italics*. The Index of Biotic Integrity (IBI), Modified Index of well being (MIwb), and Invertebrate Community Index (ICI) are scores based on the performance of the biotic community. The Qualitative Habitat Evaluation Index (QHEI) is a measure of the ability of the physical habitat to support a biotic community. Threats to water quality identified during the course of the study are listed under Causes and Sources.

River Mile Fish/Invertebrate	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes	Sources
Olentangy River		*WWH*					
32.1[B]/32.1	*42*	*10.2*	40	*66.0*	FULL		
28.1[W]/28.2	*36*[ns]	*6.2**	28*	*55.5*	PARTIAL	Impounded, Siltation	Panhandle Road Dam
27.5[W]/27.4	*40*	*8.1*[ns]	44	*76.5*	FULL		
24.5[W]/24.5	*42*	*9.1*	50	*75.5*	FULL		
		EWH					
19.4[W]/19.5	*45**	*9.0*[ns]	50	*89.0*	PARTIAL	Nutrient enrichment, Siltation	Urbanization
15.0[W]/14.9	*46*[ns]	*9.1*[ns]	46	*81.5*	FULL		
12.4[B]/13.2	*50*	*9.9*	50	*72.5*	FULL		
		WWH					
7.8[W]/7.3	*48*[ns]	*9.1*[ns]	48	*83.0*	FULL		
3.9[B]/4.0	*50*	*10.3*	44	*71.0*	FULL		
		MWH					
2.1[B]/2.1	*38*	*7.5*	<u>10</u>*	*32.5*	**NON**	Flow alteration	Impoundment
		WWH					
1.8[W]/1.8	*45*	*7.1**	40	*76.0*	PARTIAL	Nutrient enrichment	CSOs, urban runoff

River Mile Fish/Invertebrate	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes	Sources
Olentangy River (continued) *WWH*							
0.9[B]/0.6	*40*	*9.0*	40	*78.5*	FULL		
Indian Run (RM 35.28) *WWH*							
0.9[H]/0.9	36[ns]	NA	MG[ns]	69.0	FULL	Nutrient enrichment	Agricultural activities
Norris Run (RM 32.18) *WWH*							
1.3[H]/1.3	23*	NA	Low F*	62.0	**NON**	Habitat alteration, Nutrient enrichment and Siltation	Riparian removal, Urbanization
Sugar Run (RM 26.97) *WWH*							
1.3[H]/1.3	29*	NA	Low F*	69.0	**NON**	Siltation, nutrient enrichment	Urban influences
Mill Run (RM 25.17) *WWH*							
0.9[H]/0.7	37[ns]	NA	P*	68.0	**NON**	Nutrient enrichment	Urban influences
Tributary to Olentangy River RM 20.71 *Undesignated / WWH Recommended*							
0.2[H]/0.1	16*	NA	MG[ns]	52.5	**NON**	Isolation, impassable upstream or downstream	Upstream of large waterfall and downstream of several dams
Tributary to the Olentangy River RM 18.19 *WWH*							
0.1[H]/0.1	27*	NA	F*	68.0	**NON**	Nutrient enrichment, bacteria	Septic systems, urbanization
Deep Run (RM 15.8) *WWH*							
1.1[H]/0.5	22*	NA	F*	48.0	**NON**	Watershed modifications, nutrient enrichment, bacteria	Urbanization

River Mile Fish/Invertebrate	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes	Sources
Turkey Run (RM 5.82) *WWH*							
0.7[H]/0.7	20*	NA	Low F*	55.0	**NON**	Nutrient enrichment	Urban runoff, golf course runoff
Wahalla Hollow (RM 4.6) *Undesignated / PHWH Recommended*							
0.9[H]/1.0	12	NA	P	57.5	**NA**	Nutrient enrichment	SSOs, urban runoff
Glen Echo Ravine (RM 4.1) *Undesignated / WWH Recommended*							
1.0[H]/0.9	14*	NA	P*	60.0	**NON**	Nutrient enrichment, bacteria	SSOs, urban runoff

Ecoregion Biocriteria: Eastern Corn Belt Plain

	IBI			**MIwb**			**ICI**		
Site Type	WWH	EWH	MWH	WWH	EWH	MWH	WWH	EWH	MWH
Headwaters	40	50	24				36	46	22
Wading	40	50	24	8.3	9.4	4.0	36	46	22
Boat	42	48	24	8.5	9.6	4.0	36	46	22

H - Headwater site.
W - Wading site.
B - Boat site.
a - MIwb is not applicable to headwater streams with drainage areas ≤ 20 mi^2.
b - A narrative evaluation of the qualitative sample based on attributes such as EPT taxa richness, number of sensitive taxa, and community composition was used when quantitative data was not available or considered unreliable due to current velocities less than 0.3 fps flowing over the artificial substrates. VP=Very Poor, P=Poor, LF=Low Fair, F=Fair, MG=Marginally Good, G=Good, VG=Very Good, E=Exceptional
c - Attainment status is given for both existing and proposed use designations.
ns - Nonsignificant departure from biocriteria (≤4 IBI or ICI units, or ≤0.5 MIwb units).
* - Indicates significant departure from applicable biocriteria (>4 IBI or ICI units, or >0.5 MIwb units). Underlined scores are in the Poor or Very Poor range.

Table 26. Violations of Ohio EPA Warmwater Habitat (WWH) and Exceptional Warmwater Habitat (EWH) water quality criteria (OAC 3745-1) for chemical/physical parameters in the Olentangy River study area, 2003. Plain text river miles indicate Warmwater Habitat, boldface river miles are designated Exceptional Warmwater Habitat, areas designated Modified Warmwater Habitat are underlined, and italic river miles indicate a point source discharge. Shaded areas are tributary streams to the Olentangy River and the river mile listed is the location of the confluence.

Waterbody	NPDES Discharge	Biological Attainment	QHEI	River Mile	Parameter	Code
Lower Olentangy River (HUC 05060001-120, EWH or WWH, AWS, IWS, PCR)						
-Mill Run (RM 0.17, WWH, AWS, IWS, PCR)		PARTIAL	68.0	25.71	E. coli	d
	City of Delaware WWTP			*25.26*		
				24.51	E. coli F. coliform	d d
				19.40	E. coli F. coliform	d d
-Lewis Ctr. Trib (RM 0.01, WWH, AWS, IWS, SCR)		NON	68.0	18.19		
-Deep Run (RM1.20, WWH, AWS, IWS, PCR)		NON	48.0	15.20	E. coli	d
				15.00	E. coli F. coliform	d d
	Delaware Co. OECC WWTP			*13.39*		
				11.50	E. coli F. coliform Copper	d d a, b
-Turkey Run (RM 0.70, WWH, AWS, IWS, SCR)		NON	55.0	5.82		
-Wahalla Hollow (RM 0.80 U)		NON	57.5	4.60		
-Glen Echo Ravine (RM 0.70 U)		NON	60.0	4.10	E. coli F. coliform	e e
				3.93	E. coli F. coliform	d d
				<u>2.06</u>	E. coli F. coliform	d d
				1.85	E. coli F. coliform Copper	d d a, b

Waterbody	NPDES Discharge	Biological Attainment	QHEI	River Mile	Parameter	Code
				0.93	E. coli F. coliform	c,d c,d

a violates the aquatic life protection criterion outside mixing zone 24 hr. average
b violates the aquatic life protection criterion outside mixing zone minimum/maximum
c violates the primary contact recreation 30 day geometric mean
d violates the primary contact recreation 30 day maximum
e violates the secondary contact recreation 30 day maximum

Table 27. Population change in several central Ohio counties from 2000 to 2003.

Population and Change	**Marion**	**Morrow**	**Delaware**	**Franklin**
% Change- 2000	3%	14%	64.3%	11.2%
% Change 4/2000 - 7/2003	.3%	6.1%	20.7%	1.9%
Population: 2003 est.	66,396	33,568	132,797	1.088,944

Table 28. Active subdivision proposals approved by Delaware County Regional Planning Commission in 2004**.**

Township	**Number of Lots**	**Number of Lots Non Residential**	**Acreage**
Berkshire	662	-	762.12
Berlin	276	1	291.06
Brown	-	-	-
Concord	564	6	691.37
Delaware*	-	-	-
Genoa	206	1	176.38
Harlem	16	-	88.75
Kingston	268	-	663.75
Liberty*	**438**	-	**577.27**
Marlboro*	-	-	-
Orange*	**965**	**21**	**656.01**
Oxford	-	-	-
Porter	-	-	-
Radnor	-	-	-
Scioto	23	-	95.51
Thompson	-	-	-
Trenton	13	-	55.00
Troy*	**3**	-	**9.68**

***** Townships drained by Olentangy River and or tributary streams.

Table 29. Planned transportation improvement projects throughout the LOWAU based on data from the Mid-Ohio Regional Planning Commission's Transportation Improvement Program draft report, 2003.

Olentangy Watershed:
Delaware and Franklin Counties.
Planned Transportation Improvement Projects with Identified Funding
2005 - 2009

Map I.D. Number	Location	Phase - Type	Scheduled Years, Responsible Agency	Estimated Costs
1142	Lexington Glen/SR37 Delaware Co.	DD. ROW, CON, Other	2006 - 2009 Delaware City	$855,000
752	Murphy Prkwy Ext. Powell	CON	2006 Powell	$1,500,000
974	Sawmill Pkwy Ext.	Stud, ENVIR.	2006 - 2007 Delaware City	$300,000
781	W. Orange Rd/ Rv. Delaware Co.	Bridge CON.	2007 Delaware Co.	$687,960
806	Dntwn. Delaware	Bikepath CON.	2006 Delaware City	$698,400
280	SR315 / Bartholomew Run, Delaware Co.	Bridge CON	2009 ODOT 6	$249,170
1004	Home Rd.	Widening, ROW, CON	2006 - 2007 Delaware Co.	$3,337,500
1111	SR315 @ 3rd. Ave.	Bridge deck replace. CON	2005 ODOT 6	$2,500,000
118	Grandview &. Neil Ave. Columbus	Landscaping	2004 ODOT 6	$177,000
1137	SR315, Del. Co.	Resurfacing	2005 ODOT 6	$935,000
1358	SR315 @ SR750 Del. Co.	Embankment slip PE, CON	2005-2007 ODOT 6	$1,834,000
274	Hard Rd./Linworth - Olentangy R.Rd. Cols	Widening, reconst. ROW,CON	2004-2007 Columbus	$8,800,000

Map I.D. Number	Location	Phase - Type	Scheduled Years, Responsible Agency	Estimated Costs
891	Olentangy Bikeway- I-670 bikeway	Bikeway CON	2006 Columbus	$2,000,000
1039	Morse Rd.-Indianola to Cleveland Ave.	Reconst. ROW, CON Enhancement	2005 Columbus	$10,003,000
1298	Kanawha Ave.@river	Bikeway bridge CON	2006 Columbus	$524,000
25	Convention Center, Cols.	Various CON	2004-2005 COTA	$15,004,000
632	US23 @ Penn. Ave. Delaware	Interchange, Road PE,DD,ROW, CON	2004-2007-200x Delaware City	$4,100,000
978	US23@US42 Delaware	Connector-Roadway US23 and US42 PE,DD,ROW,CON	2004-2007-200x Delaware City	$4,700,000
1303	US23@US42	Connector-Roadway US23 & US42 to US36 PLNG,, PE, ROW, CON	2004-2007-200x Delaware City	$60,700,000
974	Sawmill Prkwy. ext. Delaware	New 4 lane roadway. Bunty S.Rd.-Section Line Road Envir, DD,CON	2004-2007-200x Delaware City	$16,800,000
806	Olentangy Ave. to William St. Delaware	Bikeway upgrade CON	2006 Delaware City	$798,000
1004	Home Rd. from Liberty Rd. to Sawmill Pkwy.	Widening, grade sep. ROW,CON	2006-2007 Delaware Co.	$3,350,000
781	W.Orange Rd. @ riv.	Bridge replacement	2004 Delaware Co.	$688,000

Map I.D. Number	**Location**	**Phase - Type**	**Scheduled Years, Responsible Agency**	**Estimated Costs**
636	US36@Delaware Run Delaware	Bridge Rehabilitation ROW,CON	2006 ODOT 6	$320,000
280	SR315/Bartholomew Run	Bridge replacement CON	2004 ODOT 6	$351,000
1334	SR315,I270 US23 interchanges	Engineering-North Central Outerbelt Study PE	2005 ODOT 6	$9,900,000
1111	SR315/3rd. Ave. bridge, Columbus	Bridge deck replace. Painting CON	2005 ODOT 6	$2,500,000
155	I-670, Spring Sandusky, Columbus	Bikeway CON	2004 ODOT 6	$411,000
118	Grandview Ave-Neil Ave, SR315-Broad St. Columbus	Landscaping CON	2004 ODOT 6	$750,000

CON – Construction
DD – Detailed Design
ENVIR – Environmental Document
Other – Other phases not listed
PE – Preliminary Engineering
PLNG – Planning Study or Activity
ROW – Right-of-Way Acquisition

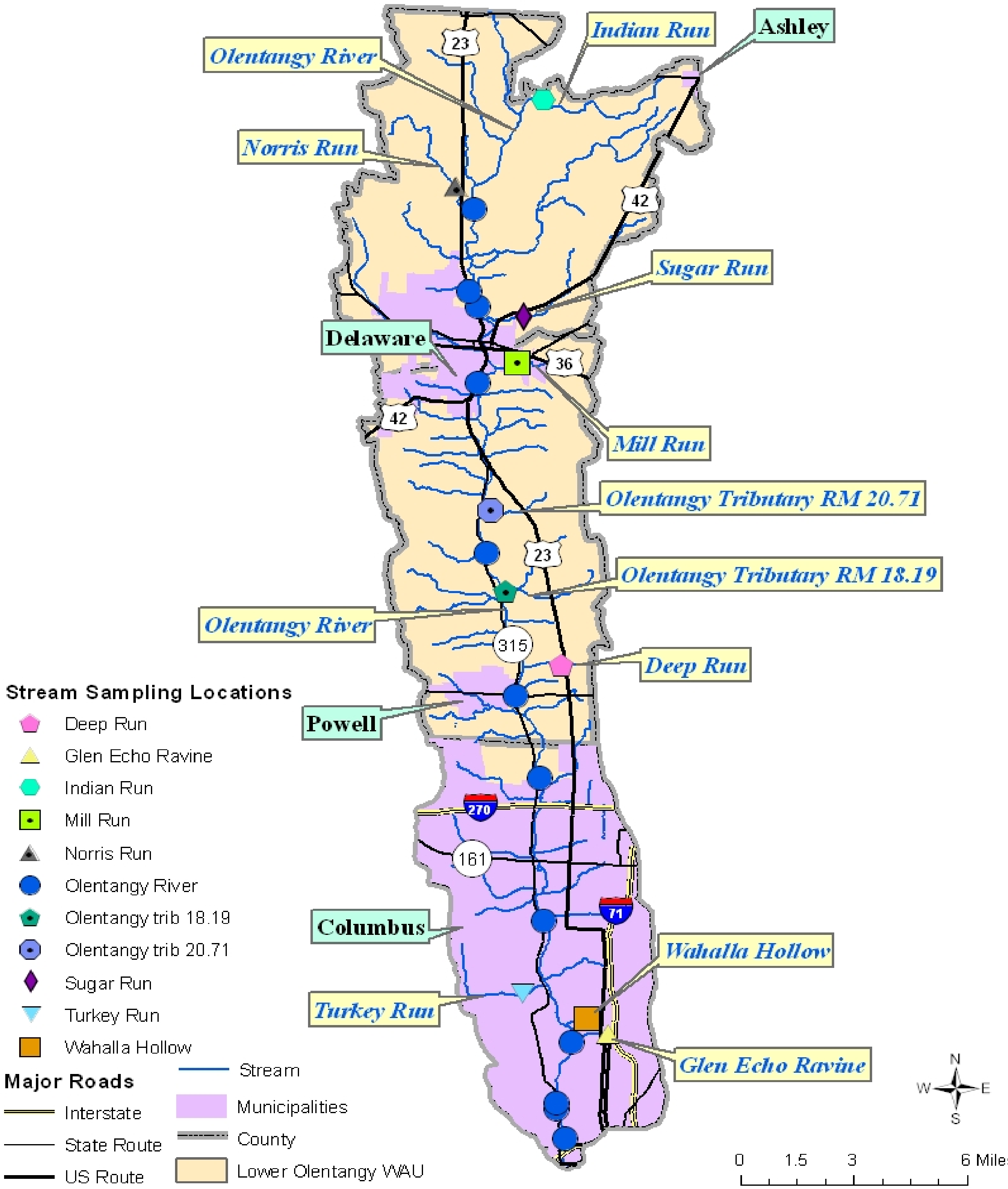


Figure 88. Biological sampling locations throughout the LOWAU, 2003-2004.

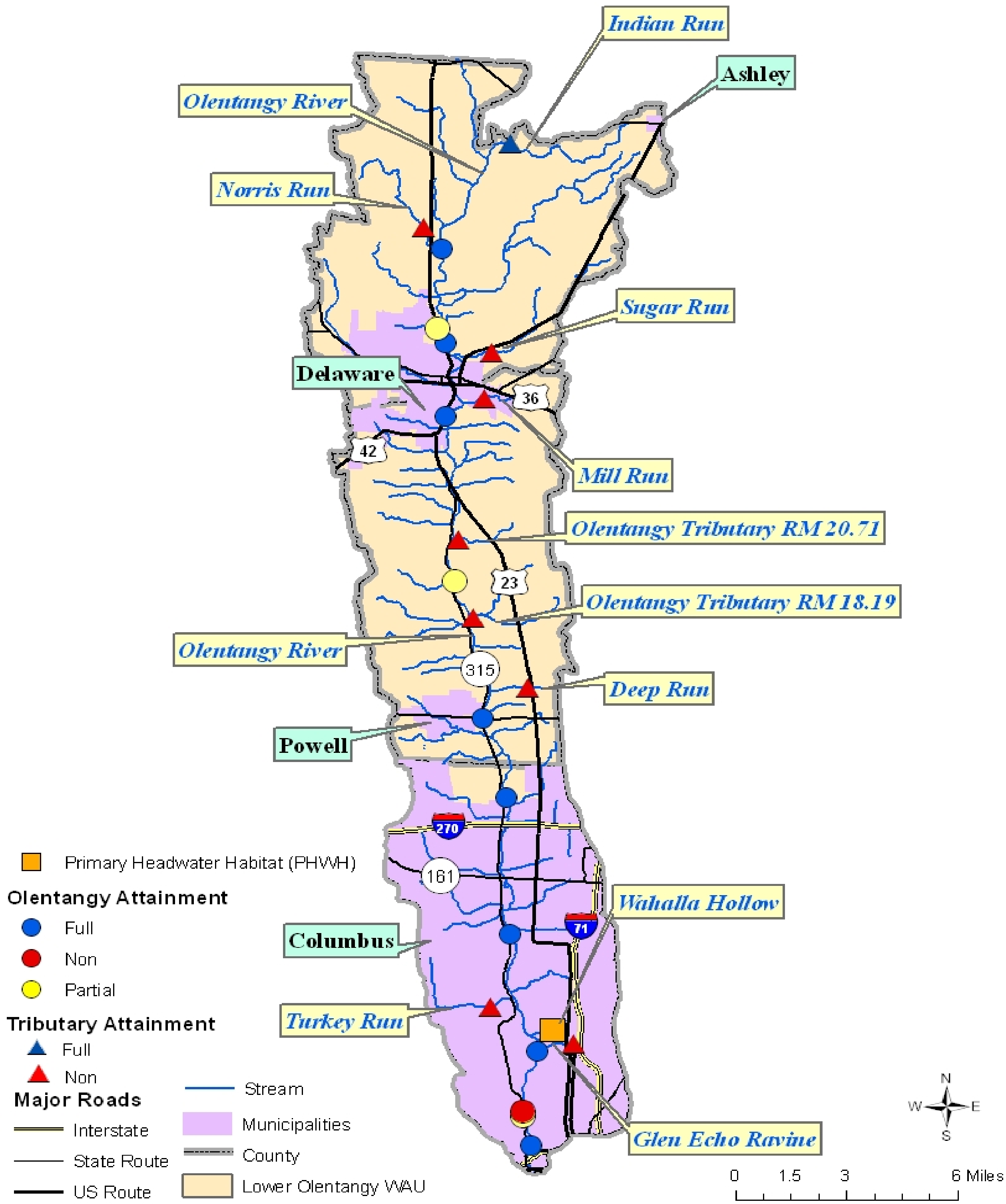
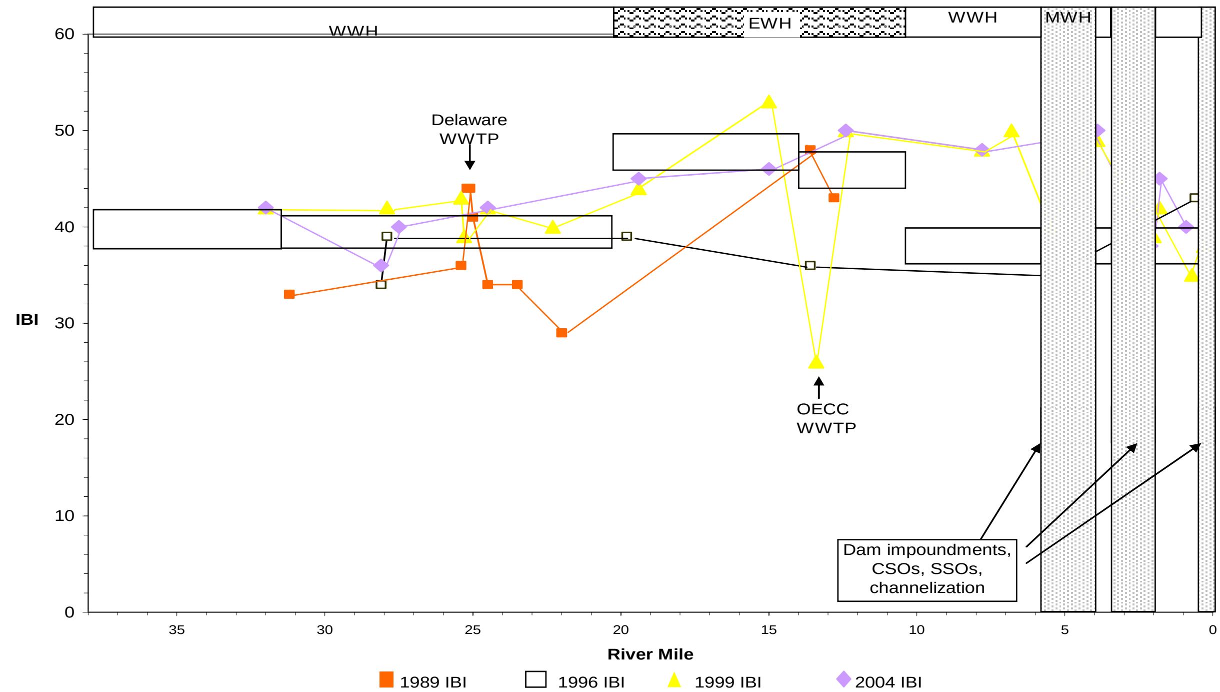


Figure 89. Biological sampling locations by attainment status for the LOWAU, 2003-2004.



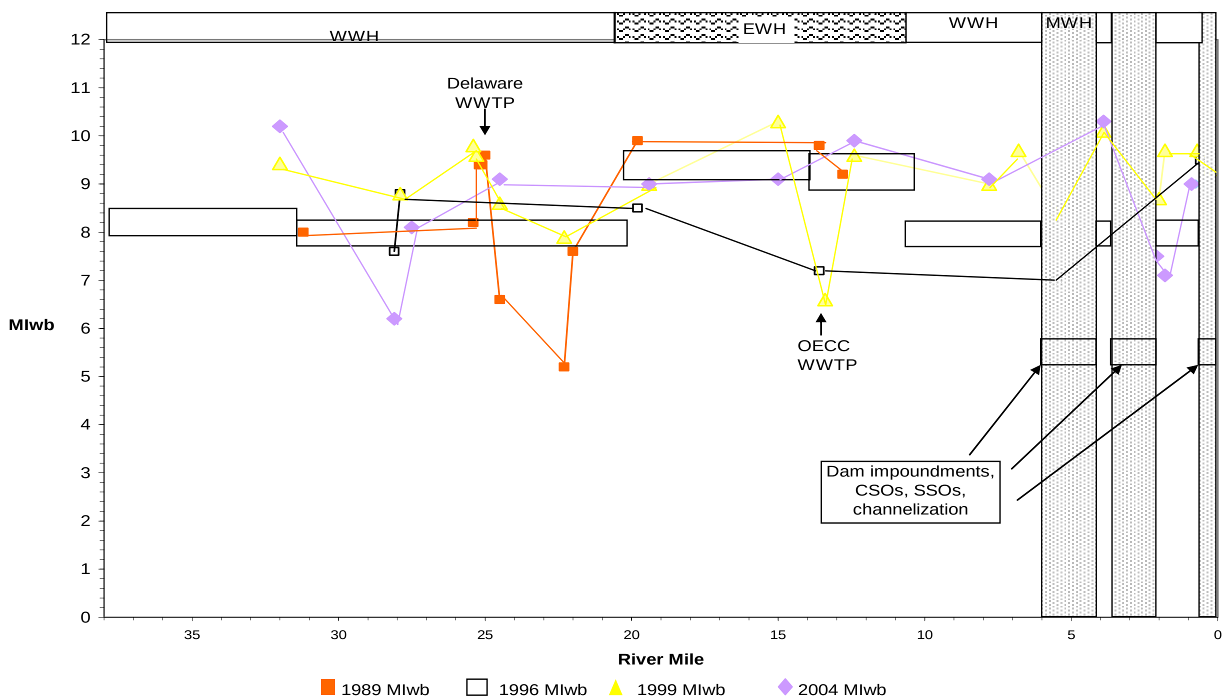


Figure 90. Longitudinal plots of IBI and MIwb for the LOWAU from 1989, 1996, 1999, and 2004.

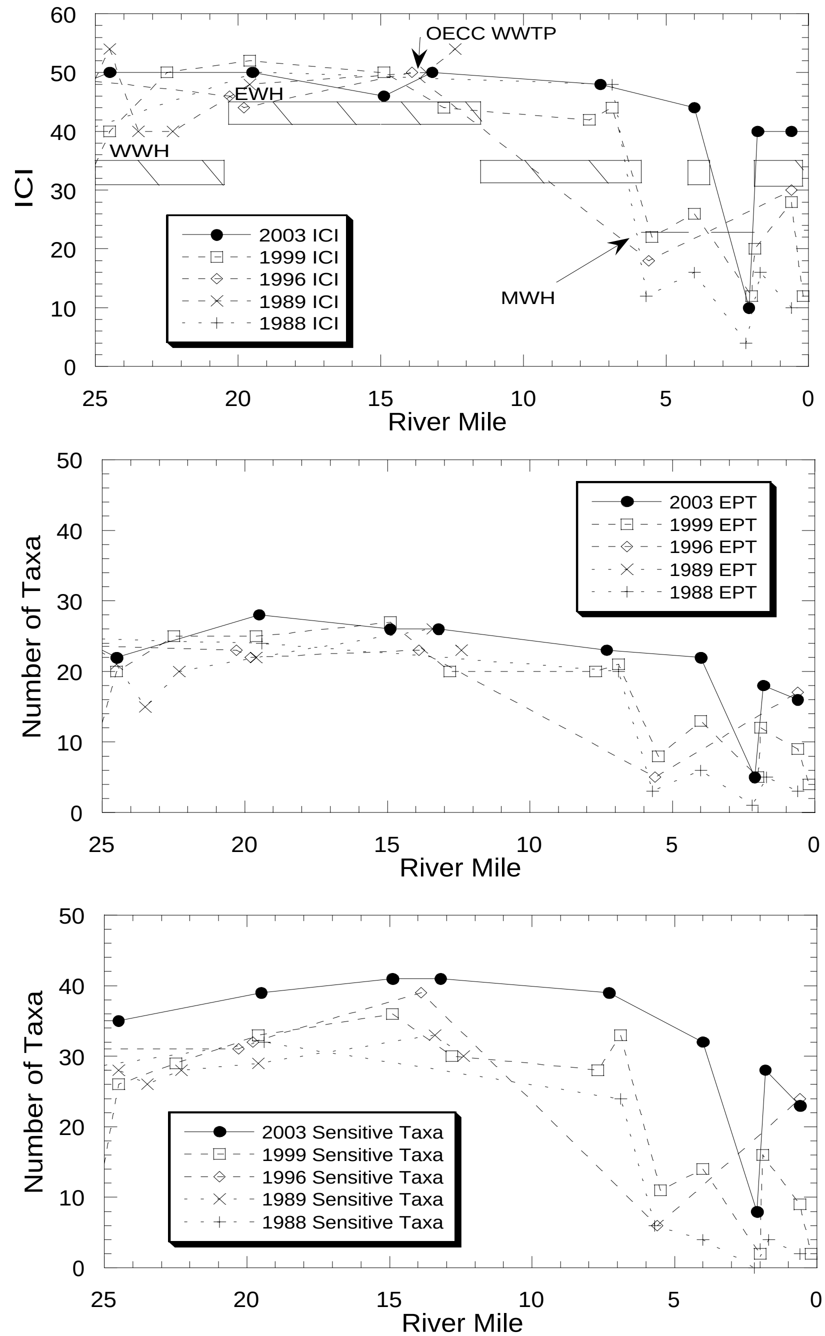


Figure 91. Longitudinal trend of the Invertebrate Community Index (ICI), total EPT, and total sensitive taxa in the lower Olentangy River, 1988-2003. The stations RM 7.3 and 4.0 were collected in 2004.

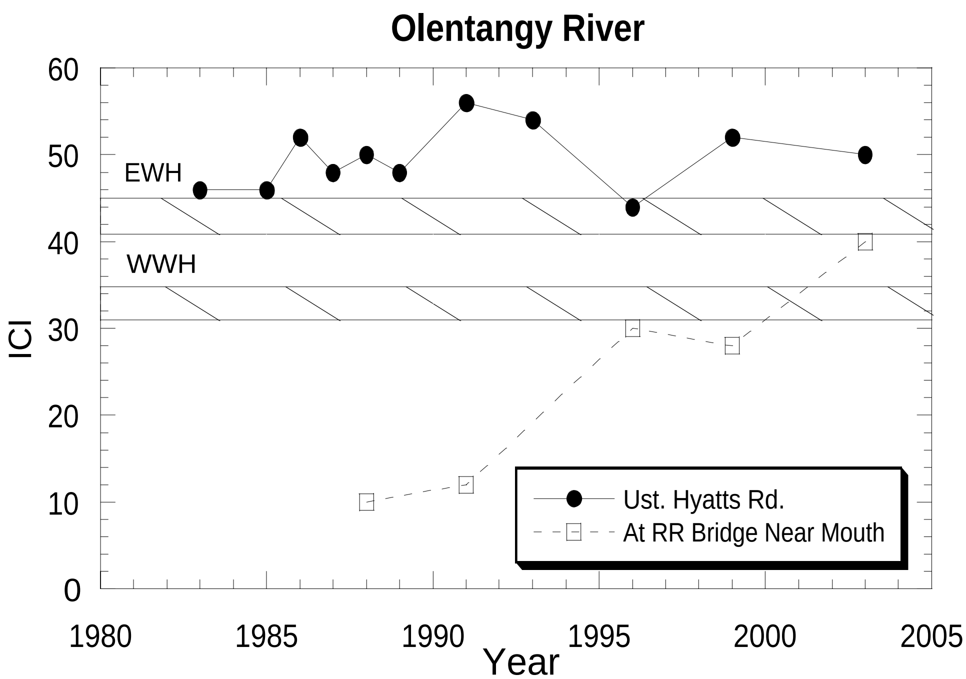


Figure 92. Yearly trend of the Invertebrate Community Index (ICI) in the lower Olentangy River at the stations upstream from Hyatts Road (RM 19.4, 19.5, 19.6, 19.8, or 20.3) and at road bridge near mouth (RM 0.6).

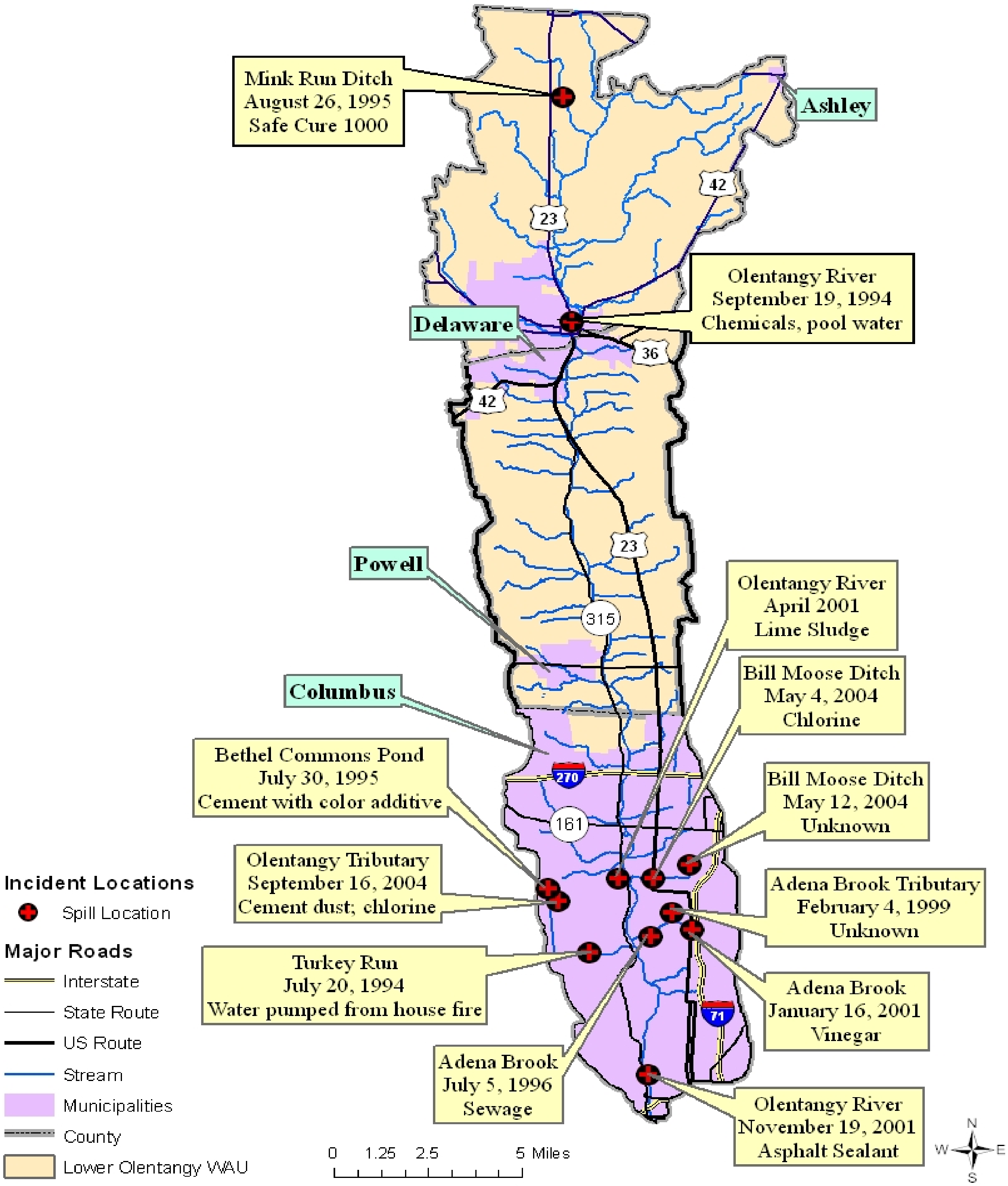


Figure 93. Spills reported to ODNR from 1994 - 2004 for the LOWAU.

Figure 94. Orthophoto of the Fifth Avenue dam pool. Notice the straight, monotonous form of the river, poor riparian buffers and high intensity urbanized landscape.

Chemical Water Quality

General water chemistry grab samples including demand parameters, dissolved materials, bacteria, and total recoverable metals were collected 6 times during the period of June through September 2003. Two additional sampling events were added in July to enable evaluation of 30-day geometric mean bacterial concentrations to determine recreational use attainment. Each site was evaluated solely for *E. coli* and fecal coliform bacteria. Seven sites were also evaluated for sediment chemistry and organic water chemistry. Surface water chemistry results detailing violations of the criteria in the Ohio Water Quality Standards are shown in Table 26.

Olentangy River

Recreational use attainment was problematic in the lower Olentangy River. Primary contact maximum standards for both *E. coli* and fecal coliform bacteria were exceeded at all mainstem sites (Table 26), although primary contact average criteria were only surpassed at the site near the mouth (Figures 95, 96). Numerous wet-weather related, sanitary and combined sewer overflows noted during the survey are likely partially responsible for this situation. Sanitary sewer overflows or WWTP bypasses discharged directly to the mainstem a minimum of 171 times from June through September 2003 (Tables 30, 31, 32, and Table 3 in Appendix). Additionally, during June through September, 2003, there were at least 38 overflows of raw sewage to tributaries or ditches flowing into the Olentangy River (Table 3 in Appendix).

Copper violations were noted at two widely separated points, RM 11.50 adjacent to parkland and State Route 315 in Worthington and at RM 1.85 downstream of the 5th Avenue dam. The source(s) of these copper violations is currently unknown.

Nutrient enrichment was evident within the lower Olentangy River. Ammonia concentrations were noticeable throughout the mainstem with most sites exhibiting concentrations greater than the 75th percentile of background for at least 4 of the 6 sample iterations (Table 31). Significantly, at least 1 sample exceeded the 95th percentile at each mainstem sampling site (Table 31). The ubiquity of ammonia in the mainstem suggests several chronic sources. As this portion of the watershed becomes more developed and less rural, this ammonia problem may intensify as aging sewerage systems become increasingly overtaxed. Chronic or subacute concentrations of ammonia (concentrations *below* Ohio WQS) and other nutrients may be linked to decreased diversity of a number of aquatic organisms, including mussels (Goudreau, Neves, and Sheehan 1993; Miltner and Rankin, 1998). Sanitary sewer overflows and WWTP bypasses are well documented in the mainstem (Table 29, 30, 31, 32 and Table 3 in Appendix) and are certainly contributing to nutrient enrichment problems noted in the lower watershed.

Nitrate+nitrite concentrations were consistently elevated in the mainstem (Figure 97). These increased concentrations result from the high solubility of nitrate in water and arise from several sources including the agricultural upper basin (via discharge from field tile drainage ultimately into Delaware Lake and then downstream through the dam) as well as WWTPs (including two major facilities City of Delaware and Delaware County OECC) and potentially urban sources including road runoff and lawn fertilizers. There are several raw water intakes along this section of the river which ultimately provide drinking water for much of Delaware County. High concentrations of nitrates in surface waters cause water treatment plants to supplement surface water with ground water to dilute the nitrate concentrations. Nutrient removal at the Delaware County OECC WWTP effectively reduces the amount of nitrates discharged to the Olentangy River by this plant by around 50-80% compared with historical concentrations (Figure 98). The current expansion for the City of Delaware WWTP is expected to include nutrient removal as well, hopefully further reducing loadings of nitrates (and other nutrients) to the lower watershed.

Both TKN (organic nitrogen) and total phosphorus concentrations in the mainstem were indicative of enrichment in the lower Olentangy River. Over 91% of the sample results showed TKN concentrations greater than the respective background median concentrations while total phosphorus values exceeded the 90^{th} percentile in over 14% of the samples (Figure 99). Both urban point (e.g., CSOs, SSOs, bypasses) and non-point sources (e.g., OSU golf course, stormwater runoff, development) are responsible for these elevated concentrations.

TSS concentrations were problematic in the lower Olentangy River as well. Each site on the mainstem revealed at least one TSS concentration above the 95^{th} percentile of background (Table 33) for a total of 24% of the samples exceeding the 95^{th} percentile. Peculiarly, the site at RM 15.00 showed an inordinate amount of contamination from TSS with 6 of 7 values above the background 75^{th} percentile. Three of seven values were above the 95^{th} percentile for background (Table 33). No other mainstem site in the lower watershed had this number and magnitude of deviations from background (Figure 100). Development continues at a rapid pace in the Delaware County area of the lower watershed and was likely one cause of this spike in TSS. Changes in the watershed resulting from development activities and dam releases are also contributing to changes in the flow dynamics of the river increasing bank and channel erosion with the accompanying increase in suspended materials.

Dissolved oxygen concentrations were found to be in good to excellent ranges throughout the lower Olentangy mainstem. Both daytime grab and Datasonde collected discrete sampling (performed every 60 minutes for approximately 48 hours) showed no violations of water quality criteria for dissolved oxygen (Figure 101).

Several different organic chemicals were found in the water column during a single sampling event in the Olentangy River at RM 15.00. Organic chemicals that were detected are shown in Table 34. None of the chemicals detected were found at concentrations that would cause concern for human or ecological health.

Nutrient and suspended solids loadings can be controlled and possibly reduced by several pathways. Diligent implementation of BMPs to control runoff and drainage tile discharge in agribusiness (especially from Concentrated Animal Feeding Operations and artificially drained cropland) and runoff from property development can positively influence the river whereas a lax and slipshod approach will produce continued, and possibly increased, degradation.

Elimination of bypasses from WWTPs and control of the number and severity of illegal discharges from combined and sanitary sewers will likely produce positive results. For example, in the City of Columbus during the period of June through September 2003, there were at least 391 sanitary sewer overflows to the lower Olentangy watershed during wet weather events (Table 3 in Appendix). Franklin County, and the City of Grandview Heights also contribute to sewer overflow problems as noted in Table 30. They are each responsible for one SSO apiece. The City of Delaware also operates an active WWTP bypass (Table 32). Reducing the frequency and magnitude of these illicit wet-weather discharges should benefit the river by reducing pollutant loads. Restrictive permit limits and nutrient removal at expanding WWTPs will also help stem nutrient overload in the lower Olentangy basin.

Analysis of chemical water quality trends showed both improvements to the lower Olentangy River mainstem and areas of increased concentrations of pollutants. Dissolved oxygen concentrations obtained in 2003 were generally higher than in 1999 and much improved in the lower 3 miles over data obtained in 1996 and 1991 (Figure 101). Some of this is likely due to the differences between the drought conditions in 1999 and the wet conditions in 2003.

Mean total phosphorus concentrations were improved in areas upstream of Columbus over those results obtained in 1989 and 1999 (Figure 99). The contribution of phosphorus from the City of Delaware WWTP has certainly decreased over the last 15 years. However, sampling sites in the lower 3 miles exhibited elevated mean concentrations of phosphorus compared with nearly all previous years' results (Figure 99). Mean concentrations of suspended solids and nitrate+nitrite were much higher than the comparison years (Figures 97 and 100) partly due to the unusually wet summer weather and the accompanying elevated river flows. Suspended solids concentrations remained relatively consistent along the length of the lower Olentangy River in past years. This was not the case in 2003 where mean concentrations increased with movement downstream (Figure 100). This same trend existed for mean bacterial concentrations. The wet weather in 2003 added nearly an order of magnitude to the bacterial contamination between RM 20.0 and RM 7.0 as compared with most of the previous sampling events (Figure 102). Overflows from the collection system in the City of Columbus directly to the Olentangy River undoubtedly contributed to some of these increases as did bypass events from the City of Delaware due to the wetter than normal weather (Tables 30, 31, 32, and Table 3 in Appendix).

Point Sources

Delaware WWTP - The Delaware WWTP has a design treatment capacity of 5.5 MGD with a discharge to the Olentangy River at RM 25.26. Wet stream processes provided at the plant include primary screening, grit removal, first stage aeration, intermediate clarification, second stage aeration, final settling, tertiary sand filtration, chlorination, dechlorination and post aeration. A flow equalization basin equipped with a bypass (outfall 002) is provided for use during wet weather. Solids handling facilities consist of aerobic digestion, a belt filter press for sludge dewatering followed by disposal at a landfill. The average daily flow at outfall 001, for the time period between January - December 2003 was 4.27 mgd. The maximum flow during this period of record was 10.28 MGD. Eleven bypass events were reported at outfall 002 during 2003 ranging in volume from 0.02 - 1.82 MGD. These bypasses resulted in a significant percentage of flow and suspended solids loadings to the river (Table 32). Delaware WWTP has broken ground on a plant expansion to increase the design average flow to 10 MGD. The upgraded facility includes primary clarification, nutrient removal, ultra-violet disinfection and the elimination of the bypass on the flow equalization basin.

Olentangy Environmental Control Center - The Olentangy Environmental Control Center has a design treatment capacity of 6.0 MGD with a discharge to the Olentangy River at RM 13.39. Wet stream process provided at the facility include comminution, single-stage extended aeration with nutrient removal, final clarification, tertiary sand filtration, ultraviolet disinfection and post-aeration. Solids handling facilities consist of aerobic digestion, gravity belt thickening and sludge storage followed by land application. The average daily flow at outfall 001, for the time period between January - December 2003 was 2.78 mgd. The maximum flow during this period of record was 8.95 mgd. It is anticipated that flows to the plant will increase significantly following completion of the Perry-Taggart interceptor sewer along the Olentangy River.

Small Wastewater Treatment Facilities **-** There are several small wastewater treatment facilities within the lower Olentangy watershed. These entities treat under 100,000 gallons of wastewater per day and are not exclusively treating sewage, but may treat such wastewater as filter backwash from the creation of potable water. Generally, the smaller sewage treatment facilities do not provide adequate treatment as they typically are poorly supported and maintained. These types of facilities contribute significant amounts of pollutants to the watershed.

Sediment Quality

Sediment samples were collected at 6 different locations on the Olentangy River mainstem. The uppermost sites at RMs 24.51 and 19.40 did not reveal any contamination above background concentrations other than TOC, which was found at concentrations above the lowest effect level (LEL) (Table 33). TOC was found above the LEL at each site evaluated. Sites at RM 15.00 and 1.85 showed phosphorus concentrations above the LEL as well (Table 35). The only site that showed evidence of contamination from heavy metals was at RM 2.06, just upstream of the 5th Avenue dam.

Cadmium, chromium, copper, lead, and zinc were discovered at concentrations above ecoregional reference values (Table 35). This pool area acts as a sediment sink, allowing the build up of contaminants.

Tributary chemical water quality

Mill Run

Mill Run discharges to the Olentangy River at RM 25.71. It drains around $2mi^2$. This stream failed to meet PCR 30-day maximum standard for *E. coli* (Table 26).

Nutrient enrichment was evident in Mill Run. Median values for nitrate+nitrite, TKN, and total phosphorus were all elevated above background median concentrations and were similar to other WWH headwater streams in the Olentangy basin (Figures 103, 104, and 105).

Total suspended solids concentrations were also notable with 67% of the values exceeding the background median. One of the sources of these nutrients and suspended materials may be a nearby foundry. Refractory bricks as well as other kinds of foundry debris were prevalent in Mill Run. Sources of bacteria may be simply runoff related.

Dissolved oxygen concentrations were found in a narrow range in Mill Run, well above the WWH minimum standard of 4 mg/l. These results were similar to other 0-4 square mile WWH streams in the Olentangy watershed (Figure 106).

Big Run

Big Run (fka Lewis Center Tributary) drains less than $8mi^2$ of the Olentangy watershed. This stream is designated as secondary contact recreation and bacteria concentrations were below the criteria for both *E. coli* and fecal coliform bacteria. There were no violations of water quality standards in this stream.

Median concentrations of nitrate+nitrite, TKN, and total phosphorus all exceeded background median concentrations for the Eastern Corn Belt Plains ecoregion and were indicative of enriched conditions (Figures 107, 108, and 109). These enriched conditions were similar to other WWH streams of this size in the Olentangy watershed and contributed to biological non-attainment (Table 24).

The median total suspended solids concentration in Big Run was below the background median value for headwater streams and the lowest value for $4\text{-}8mi^2$ drainage WWH streams in the Olentangy watershed. The shale bedrock substrate of this stream, the lack of development and the wooded riparian corridor may be responsible for the lack of suspended solids found in Big Run. The recent public purchase of forested land surrounding this stream for a park may slow further degradation to this stream, though the headwaters are currently being developed into residential subdivisions. Protection is needed due to the accelerated amounts of development in this watershed.

Dissolved oxygen concentrations were found to be well above the WWH minimum of 4 mg/l. Instream dissolved oxygen concentrations were similar to other WWH streams of this size in the Olentangy basin (Figure 110).

Deep Run

Deep Run drains a minuscule 1.1 mi^2 on the east side of the Olentangy River. This creek is designated primary contact recreation and failed to meet the 30-day maximum standard for *E. coli* bacteria (Table 26).

Nutrient enrichment and suspended solids were not nearly the problem that was apparent in other similarly-sized warmwater streams in the Olentangy watershed. Median values for TKN and total phosphorus were only slightly above background concentrations and were among the lowest values for comparable streams (Table 33, Figures 104, 105). Nitrate+nitrite concentrations were the lowest of any 0-4mi^2 WWH stream in the watershed (Figure 103). Totals suspended solids were also among the lowest values recorded for the watershed (Figure 111). All of this was somewhat surprising since Deep Run is in an area undergoing rapid development. Proper adherence to stormwater runoff regulations by developers may be benefiting the water quality of Deep Run.

Dissolved oxygen concentrations in Deep Run were well above the WWH minimum standard of 4 mg/l with a median daytime value of approximately 8.3 mg/l. The lowest daytime measurement was 7.7 mg/l (Table 2 in Appendix).

Turkey Run

Turkey Run drains 2.4mi^2 on the west side of the Olentangy River near Upper Arlington and flows through the Ohio State University golf courses. Bacterial contamination was below the water quality criteria for both *E. coli* and fecal coliform bacteria in this secondary contact recreation stream.

Concentration of nutrients found in Turkey Run were moderately elevated, especially for TKN and total phosphorus, both of which were found at concentrations well above background (Table 33, Figures 104 and 105). The nitrate+nitrite median value was also slightly elevated above the background median for this ecoregion although it was among the lowest of the WWH streams of this drainage area (Figure 103). Nutrients are likely emanating from the golf course and nearby homes as a result of fertilizer applications and are likely one cause of biological non-attainment in this stream.

Total suspended solids and dissolved oxygen were found at satisfactory concentrations in Turkey Run. Suspended solids were amongst the lowest found in a WWH stream of this size (Figure 111) and dissolved oxygen concentrations were well above the 4 mg/l minimum WWH water quality criterion. Some supersaturation was noted at scattered intervals lending credence to the presence of nutrient enrichment in Turkey Run (Table 2 in Appendix).

Sediments collected from Turkey run did not indicate the presence of contamination other than TOC above the LEL (Table 35) although most fine grained sediments (silts and clays) had been washed away by high flow events during the wet summer.

Wahalla Hollow

Wahalla Hollow drains a small ravine area on the east side of the Olentangy River within the City of Columbus. The area is heavily wooded with a number of homes built along the creek or on top of the ravine wall. There were no violations of water quality criteria noted for this undesignated stream (WWH water quality standards apply until an appropriate designation is made). Bacteria concentrations were low as were concentrations of suspended solids and daytime dissolved oxygen concentrations were more than adequate. However, monitoring did not take place during the only SSO events which occurred in September 2003 (Table 3 in Appendix).

There are two known sanitary sewer relief structures that drain to Wahalla Hollow. Examination of the data from Glen Echo Ravine (discussed below) shows that SSO events do lead to contamination from bacteria and nutrients. This stream was certainly impaired by these intermittent overflow events in addition to the urban nature of the watershed as evidenced by the poor condition of the biological communities (Table 24). Nutrient enrichment was apparent with numerous values of ammonia, nitrate+nitrite, TKN, and total phosphorus above background median concentrations (Table 33). Phosphorus concentrations were particularly elevated with all exceeding the 75th percentile, among the highest range for undesignated headwater streams (Table 33, Figure 105). Like many other Olentangy tributaries, nutrient enrichment was a contributing factor to impairment of this creek.

Glen Echo Ravine

Glen Echo Ravine is another small tributary on the eastern side of the Olentangy River which drains a ravine area in the City of Columbus. Many violations of the secondary contact maximum recreational criteria for both *E. coli* and fecal coliform bacteria were noted in this ravine stream (Table 26). According to the City of Columbus, Glen Echo Ravine can receive sanitary sewage from 10 known (there may be others that are yet undiscovered) sanitary sewer overflow structures and in the months of July, August, and September 2003, 8 of these overflows were active, some more than once (Table 30). Nutrient enrichment was also moderate to severe at times in this stream. Some of the highest ammonia and TKN values in the lower Olentangy watershed were recorded in Glen Echo Ravine. Bacterial and ammonia/TKN contamination are very likely a direct result of sewage overflow events in this watershed as were elevated nitrate+nitrite and total phosphorus values (Table 33). Biological attainment was undoubtedly inhibited in this stream due to these pollution events (Table 24).

Table 30. List of known sanitary sewer overflows within the City of Columbus (other jurisdictions are noted in italic print) sewerage system that discharge somewhere in the Olentangy River watershed. This list was updated from the 1999 Biological and Water Quality report on the lower Olentangy River (Ohio EPA, 1999).

Relief Location	Type	Receiving Stream	Notes	2003 Discharge*
MH s/s Third Ave. 490' w/o Olentangy Rv Rd	A	Olentangy River s/o Third Ave		≥10
MH s/s Third Ave. 690' w/o Olentangy Rv Rd	A	Olentangy River s/o Third Ave		≥4
MH s/s Third Ave. 290' w/o Olentangy Rv Rd	A	Olentangy River s/o Third Ave		≥6
MH Northwest Blvd & Hilo Lane	A	Olentangy River s/o Third Ave	Removed	
MH f/o 814 W. Third Ave	A	Olentangy River s/o Third Ave		≥6
MH alley n/o King Ave and w/o Star Ave	A	Olentangy River s/o King Ave		≥2
MH Third and Morning	A	Olentangy River s/o Fifth Ave		≥15
MH King Ave & alley w/o Virginia	A	Olentangy River s/o King Ave		≥6
MH Meadow Rd & Third Ave	A	Olentangy River s/o Fifth Ave		≥2
MH Third and Virginia	A	Olentangy River s/o Fifth Ave		
MH Fifth Ave & North Star	A	Olentangy River s/o Fifth Ave		≥4
MH King & North Star	A	Olentangy River s/o King Ave		≥4
MH Fifth Ave & Eastview/Kenny	A	Olentangy River s/o Fifth Ave		≥7
MH @ Urlin & Goodale (City of Grandview)	*A*	Olentangy River*, unknown location*		
MH alley n/o Hill Ave w/o Perry St	A	Olentangy River alley n/o Hill		≥3
MH Third Ave & Oxley (east)	A	Olentangy River s/o Fifth Ave		≥8
MH Third Ave & Oxley (west)	A	Olentangy River s/o Fifth Ave		≥9
MH Howey & Briarwood	A	Glen Echo Ravine w/o I-71		≥3
MH Howey & Maynard	A	Olentangy River n/o Woody Hayes Dr	New	≥8
MH Akola & alley w/o Azelda	A	Glen Echo Ravine w/o I-71	Removed	
MH Akola & alley w/o Hiawatha	A	Glen Echo Ravine w/o I-71	Removed	
MH Azelda & alley n/o Hudson	B	Olentangy River n/o Woody Hayes Dr		≥4
MH Akola & alley w/o Atwood Terrace	A	Glen Echo Ravine w/o I-71		≥1
MH Velma & alley s/o Hudson	B	Olentangy River n/o Woody Hayes Dr		≥5
MH Maynard & Velma	A	Olentangy River n/o Woody Hayes Dr		≥6

Relief Location	Type	Receiving Stream	Notes	2003 Discharge*
MH Republic & Ontario	A	Glen Echo Ravine w/o I-71		≥4
MH Lexington & alley n/o Hudson	B	Olentangy River n/o Woody Hayes Dr		≥4
MH Briarwood & alley w/o McGuffy	A	Glen Echo Ravine w/o I-71		
MH Hamilton & alley n/o Duxberry	B	Olentangy River n/o Woody Hayes Dr		≥8
MH n/o Pacemont @ Olentangy River	A	Olentangy River n/o Pacemont		≥1
MH e/o Olentangy St & Indianola	A	Glen Echo Ravine & Indianola		≥2
MH Midgard & alley e/o Indianola	A	Wahalla Ravine		≥3
MH Akola & alley w/o Osceola	A	Glen Echo Ravine w/o I-71	Removed	
MH Akola & alley e/o Homecroft	A	Glen Echo Ravine w/o I-71		≥2
MH Osceola & alley s/o Weber	A	Glen Echo Ravine w/o I-71		
MH Alamo & alley w/o Osceola	A	Glen Echo Ravine w/o I-71		≥1
MH Alamo & alley w/o Pontiac	A	Glen Echo Ravine w/o I-71		≥1
MH Akola & alley w/o Pontiac	A	Glen Echo Ravine w/o I-71	Removed	
MH Minnesota & Hamilton	A	Glen Echo Ravine w/o I-71		≥1
MH e/o McGuffey & Aberdeen	A	Glen Echo Ravine w/o I-71	New	≥1
MH n/o N. Broadway & e/o Olentangy River	A	Olentangy River n/o W.N. Broadway	Removed	
MH Olentangy Blvd & Montrose Way	A	Olentangy River w/o relief		≥1
MH Como & High	A	Olentangy River w/o Como	New	≥7
MH Webster Pk & Olentangy Blvd	A	Ditch s/s Webster Park w/o Olentangy Blvd		≥2
MH e/s Indianola & alley E.N. Broadway	A	Wahalla Ravine & Wahalla /Diana		≥1
MH Pauline & Atwood Terrace	A	Overbrook Ravine e/o Indianola		≥2
MH Richards & Granden	A	Olentangy River n/o W.N. Broadway		≥8
Gauging station in Park of Roses	B	Adena Brook/Indian Springs Run n/o gauging station		
MH Northridge & Atwood Terrace	A	Overbrook Ravine e/o Indianola		≥3
MH w/o Rustic Pl & Olentangy Blvd	A	Olentangy River w/o relief		≥2
MH n/s Weisheimer & Starrett	A	Olentangy River w/o relief		≥2
MH alley e/o High St & s/o Schreyer Pl	B	Creek w/o High & s/o Croswell, Whetstone Park		≥3

Relief Location	Type	Receiving Stream	Notes	2003 Discharge*
MH r/o 4895 Olentangy Blvd w/o Olentangy Blvd & n/o Royal Forest	A	Olentangy River w/o relief		≥3
MH Wetmore & alley e/o High St	B	Ditch e/o Rustic Bridge & s/o Beechwold Blvd		≥7
MH s/o Rathbone & e/o Delawanda	A	Ditch s/o Rathbone & Delawanda		≥2
MH f/o 320 Kanawha (Franklin County service area)	*D*	*Olentangy River @ Kanawha*	*New*	*≥7*
MH SR 315 NB off ramp to Henderson	A	Olentangy River e/o manhole	New	≥3
MH California & High	A	Olentangy River s/o Sunset & Tulane	New	
MH alley e/o High & s/o Lincoln	A	Rush Run r/o 126 Sharon Springs		
r/o 4075 N. High St.	S	Olentangy River	New	1
along Olentangy River n/o Dodridge	S	Olentangy River	New	1
4385 Olentangy River Rd	S	Olentangy River	New	2

MH = Manhole
A = Discharge occurs when a manhole fills with sewage to a certain elevation.
B = Discharge occurs when sewage flows over a weir.
D = Discharge occurs when a sewer pipe fills to a certain level
S = Surcharge directly from manhole into street (storm sewer) or river. No sanitary sewer relief structure in manhole
?/o = north, south, east, west, front, or rear /of
Removed = Sanitary sewer overflow structure has been removed by the City sometime after 1999.
New = Sanitary sewer overflow structure has been newly discovered sometime after 1999.
* = June - September 2003. Column includes minimum number of discharges as noted.

Table 31. List of combined sanitary/storm sewer overflows (CSOs) and sanitary sewer overflows (SSOs) located in the City of Columbus sewerage system that are listed in the NPDES permit for the City of Columbus.

Location	Outfall Number	Type	Receiving Waters
First and Perry	4PF00000032	CSO regulator	Olentangy River
Third and Perry	4PF00000027	CSO regulator	Olentangy River
King Avenue	4PF00000007	CSO regulator	Olentangy River
OSU/Indinola Ave.	4PF00000006	CSO regulator	Olentangy River
Tuttle Park at Frambes	4PF00000031	CSO regulator	Olentangy River
Frambes and Neil Ave.	4PF00000005	CSO regulator	Olentangy River
Hudson St.	4PF00000004	CSO regulator	Olentangy River
Third Ave.	4PF00000039	CSO no regulator	Eliminated by city
Main Interceptor sewer, N. of Hill Ave.	4PF00000040	SSO no regulator	Olentangy River

Table 32. Bypass events at the Upper Olentangy Water Reclamation Center (aka City of Delaware WWTP, Outfall 002) from April 2003 - August 2004. AH = No sample obtained.

Date	Flow Rate	Duration	Total Volume	$CBOD_5$		TSS	
	(mgd)	(hrs)	(liters)	(mg/l)	(kg)	(mg/l)	(kg)
5/9/03	0.32	7	353,265	24	8.5	28	9.9
5/10/03	0.11	6	104,088	31	3.3	30	3.4
5/11/03	0.02	3	9,463	32	0.30	18	0.17
8/30/03	1.43	14	3,157,318	7	22.1	27	85.2
9/2/03	1.82	24	6,888,700	AH		3	62.0
9/3/03	0.10	2	31,542	AH		24	0.76
9/27/03	0.88	12	1,665,400	44.9	74.8	24	40.0
1/4/04	1.25	8	1,577,083	12.5	19.7	22	34.7
1/5/04	2.51	24	9,500,350	11.3	107.4	7	66.5
1/6/04	0.01	1	1,578	7.0	0.01	32	0.05
6/14/04	0.62	13	1,271,129	6.5	8.3	28	35.6
6/15/04	0.23	2	72,545	AH		56	4.1
6/16/04	0.14	9	198,713	AH		32	6.4

Table 33. Comparison of background nutrient and demand parameter concentrations with those found in the Olentangy River study area, June through August 2003. Comparisons are made to Eastern Corn Belt Plains (ECBP) ecoregion background 50th percentile (plain text), 75th percentile (*italic text*), 90th percentile (underlined text), and 95th percentile (**boldface text**) values for headwaters, wadeable, and small river sites. Units are mg/l for all values. Plain text river miles indicate Warmwater Habitat, boldface river miles are designated Exceptional Warmwater Habitat, areas designated Modified Warmwater Habitat are underlined, and undesignated streams have a letter U following the river mile. Shaded areas are tributary streams to the Olentangy River

River/Stream (Trib. River Mile)	QHEI	Olentangy River Mile	Drainage Area (mi^2)	Parameter	Value
Lower Olentangy River (HUC 05060001-120)					
Mill Run (RM 0.17)		**25.71**	2.0	TSS NH_3 NO_2+NO_3 TKN T-P	(*21*, *19*, 12, 9) (0.173, *0.091*) (**8.54**, *4.44*, *3.91*, 1.35) (1.09, *0.96*, 0.55, 0.49, 0.40) (*0.160*, 0.074, 0.067, 0.055, 0.049, 0.044)
		24.51		TSS NH_3 NO_2+NO_3 TKN T-P	**114** **0.158**, 0.10, 0.097, 0.088, 0.087, 0.076 7.10, *4.57*, *4.44*, *4.40*, 2.22, 2.14 *0.96*, *0.86*, *0.82*, *0.82*, *0.81* 0.397, 0.201, 0.182, 0.151
		19.40	455	BOD_5 TSS NH_3 NO_2+NO_3 TKN T-P	3.0 **116**, 85, 28 **0.164**, 0.105, 0.075, *0.058*, *0.057* 7.25, *3.85*, *3.73*, *3.37*, 2.08, 1.86 *1.00*, *0.85*, 0.79, 0.78, 0.67 0.519, 0.179
Lewis Center Trib. (RM 0.01)		**18.19**	5.7	TSS NH_3 NO_2+NO_3 TKN T-P	(*17*) (*0.087*) (**8.62**, *3.42*, 1.53, 1.49, 1.33) (*1.03*, *0.97*, *0.68*, 0.57) (*0.166*, *0.149*, *0.113*, *0.106*, *0.095*, *0.095*)
Deep Run (RM 0.50)		**15.20**	1.1	TSS TKN T-P	(8) (*0.84*, *0.65*, *0.61*, 0.54, 0.50, 0.40) (0.045, 0.042, 0.037, 0.032, 0.026)
		15.00	483	BOD_5 TSS NH_3 NO_2+NO_3 TKN T-P	3.0, 2.3 **244**, **110**, **86**, *50*, 37, 37, 29 **0.150**, **0.146**, 0.086, 0.075, *0.070*, *0.065*, *0.050* 6.95, 6.45, *4.06*, *3.45*, *3.35*, *3.35*, 1.98 *1.01*, *0.99*, *0.90*, 0.76, 0.70, 0.69, 0.67 **0.605**, 0.237, 0.178

River/Stream (Trib. River Mile)	QHEI	Olentangy River Mile	Drainage Area (mi^2)	Parameter	Value
		11.50	497	BOD_5 TSS NH_3 NO_2+NO_3 TKN T-P	2.3, 2.3, 2.3 **206**, **109**, 32 **0.154**, 0.128, *0.068*, *0.050* 6.90, 6.75, *3.66*, *3.43*, 2.45, 2.14, 2.00 *0.86*, *0.80*, 0.79, 0.78, 0.75, 0.69 0.229, 0.216, 0.203
Turkey Run (RM 0.70)		5.82	2.4	BOD_5 TSS NH_3 NO_2+NO_3 TKN T-P	(*2.2*) (11) (0.103, *0.063*) (1.87, 1.52, 1.51) (*0.78*, *0.62*, 0.55, 0.54, 0.48, 0.42) (**0.757**, *0.198*, 0.067, 0.049, 0.047, 0.036)
Wahalla Hollow (RM 0.80)		4.60	0.4	NH_3 NO_2+NO_3 TKN T-P	(*0.060*, *0.057*, *0.053*) (2.16, 2.06, 1.78, 1.78, 1.53, 1.30) (0.57, 0.51, 0.50, 0.45) (0.354, 0.344, 0.276, *0.194*, *0.190*, *0.144*)
Glen Echo Ravine (RM 0.70)		4.10	0.5	NH_3 NO_2+NO_3 TKN T-P	(**0.527**) (1.97, 1.53, 1.36, 1.29, 1.00) (**1.72**, *0.75*, 0.55, 0.47, 0.42) (0.242, *0.182*, *0.151*, *0.143*, *0.096*, 0.074)
		3.93	535	BOD_5 TSS NH_3 NO_2+NO_3 TKN T-P	*4.3* **248**, **90**, 35, 34 **0.188**, *0.050*, *0.050*, *0.050* 6.75, 3.43, 3.09, 2.48 0.73, 0.66, 0.65, 0.63, 0.61 **0.587**, 0.502, 0.233
		2.06		BOD_5 TSS NH_3 NO_2+NO_3 TKN T-P	2.6, 2.5 **92**, 37, 34 **0.149**, 0.127, *0.061*, *0.050* 6.70, *3.47*, *3.15*, 2.90 0.82, 0.81, 0.74, 0.69 *0.329*, 0.166
		1.85	540	BOD_5 TSS NH_3 NO_2+NO_3 TKN T-P	*5.3* **520**, *51*, 41 **0.333**, 0.077, *0.071*, *0.050*, *0.050* 6.95, *3.38*, *3.23*, 2.92 *0.88*, 0.74, 0.72, 0.65, 0.60 **0.584**, **0.577**, *0.363*
		0.93	543	BOD_5 TSS NH_3 NO_2+NO_3 TKN T-P	*4.2* **188**, *45*, 41, 41 **0.186**, *0.066*, *0.066*, *0.059*, *0.055*, *0.050* 6.75, *3.41*, *3.15*, *3.15* *0.87*, 0.76, 0.72 *0.279*, 0.225, 0.208, 0.154

Table 34. Results of chemical/physical water quality sampling conducted in the Olentangy River study area during July-October, 2003. **WC1** = Whetstone Creek at McKibben Road (RM 25.5, HUC 100), **WC2** = Whetstone Creek downstream Mt. Gilead WWTP (RM 21.53, HUC 100), **WC3** = Whetstone Creek at CR 11 (RM 12.88, HUC 100), **WC4** = Whetstone Creek at Waldo-Fulton-Chesterville Road (RM 9.17, HUC 100), **OR** = Olentangy River at SR 750 (RM 15.00, HUC 120). A **Boldface** number 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.

Olentangy River and Tributaries Water Organics					
Analyte (µg/l)	**WC1**	**WC2**	**WC3**	**WC4**	**OR**
Atrazine	1.52	1.11_{j}	2.05_{j}	0.87	1.32
bis(2-Ethylhexyl) adipate	2.08	0.53_{j}	0.70_{j}	0.52_{j}	2.40_{b}
bis(2-Ethylhexyl) phthalate		0.58_{j}	0.68_{j}	0.54_{j}	2.44_{b}
Acetochlor			0.56_{j}	0.37	
Metolachlor	1.60	0.83_{j}	1.74_{j}	0.53	1.80
Simazine	1.08	0.38_{j}	0.36_{j}	0.33	1.12
a-BHC				0.0067_{uj}	
d-BHC	0.0071				0.0080
Dieldrin	0.0040_{uj}		0.0053_{uj}		0.0054_{uj}
Bromomethane	1.12				

b = Analytical result is estimated. Analyte was detected in the associated method/trip/field blank as well as in the sample.
j = The analyte was positively identified, the associated numerical value is estimated.
uj = The analyte was not detected above the sample quantification limit (QL). However, the reported QL is estimated.

Table 35. Results of chemical/physical sediment quality sampling conducted in the Olentangy River study area during July-September, 2003. Parameters in *italic* have no established guideline for comparison. Underlined values indicate concentrations below the method reporting limit. NA means not analyzed. Parameters noted with a ◙ are compared with the Ontario guidelines published by Persaud and Jaagumagi, 1993 (LEL = greater than the Lowest Effect Level but less than the Severe Effect Level, SEL = greater than the severe effect level). All metals parameters are compared with ecoregional (default) or statewide (noted by a subscript s) sediment reference values determined by Ohio EPA (Ohio EPA, 2003). Metals values in **boldface** and shaded are greater than the reference value.

Olentangy River Sediments (HUC 05060001-120)								
		Olentangy River Mile						**Turkey Run River Mile**
Analyte	Units	**24.51**	**19.40**	**15.00**	**11.50**	**2.06**	**1.85**	**0.70**
Solids	*%*	*71.6*	*56.2*	*52.7*	*70.8*	*36.8*	*55.5*	*76.1*
NUTRIENTS								
TOC ◙	%	2.2_{LEL}	2.9_{LEL}	2.6_{LEL}	1.9_{LEL}	5.0_{LEL}	4.5_{LEL}	4.9_{LEL}
Ammonia	*mg/kg*	*10*	*NA*	*18*	*NA*	*NA*	*42*	*9*
Phosphorus ◙	mg/kg	554	NA	647_{LEL}	NA	NA	740_{LEL}	348
METALS								
Aluminum	mg/kg	13500	22600	25500	8720	38000	27800	9840
Arsenic	mg/kg	15.1	14.6	14.7	11.7	16.7	10.0	13.8
Barium	mg/kg	141_J	151_J	161_J	80.8_J	230_J	111_J	108_J
Cadmium	mg/kg	0.325	0.453	0.394	0.206	**0.946**	0.506	0.251
Calcium	mg/kg	19300	26000	22600	20000	41400	32200	81800
Chromium	mg/kg	18_J	27_J	27_J	15_{UJ}	**66_J**	27J	15_J
Copper	mg/kg	15.6	24	24.7	9.8	**53.4**	15.3	14.5
Iron	mg/kg	22000	23100	22200	17800	30100	18400	16300
$Lead_s$	mg/kg	35	37	28	21	**967**	28	20
Magnesium	mg/kg	5820	8500	8160	6920	15500	9410	27800
Manganese	mg/kg	359	526	426	263	334	311	299
Nickel	mg/kg	21	29	28	21	39	28	20
Mercury*	mg/kg	0.029	0.056	0.055	0.030	0.088	0.064	0.044
Potassium	mg/kg	3870_J	5640_J	6380_J	2500_J	9100_J	6830_J	3180_J
Selenium	mg/kg	1.03	1.42	1.38	1.03	1.94	1.39	0.99

Olentangy River Sediments (HUC 05060001-120)								
		Olentangy River Mile						Turkey Run River Mile
Analyte	Units	**24.51**	**19.40**	**15.00**	**11.50**	**2.06**	**1.85**	**0.70**
Sodium	*mg/kg*	*2590*	*3560*	*3450*	*2570*	*4850*	*3460*	*2480*
Strontium	mg/kg	70	87	77	35	124	290	94
Zinc	mg/kg	98.9	91.6	92.2	59.4	**445**	82.0	63.9

J - The analyte was positively identified, the associated numerical value is estimated.
UJ - The analyte was not detected above the sample quantification limit (QL). However, the reported QL is estimated.
LEL = greater than the Lowest Effect Level but less than the Severe Effect Level (marginally to significantly polluted)

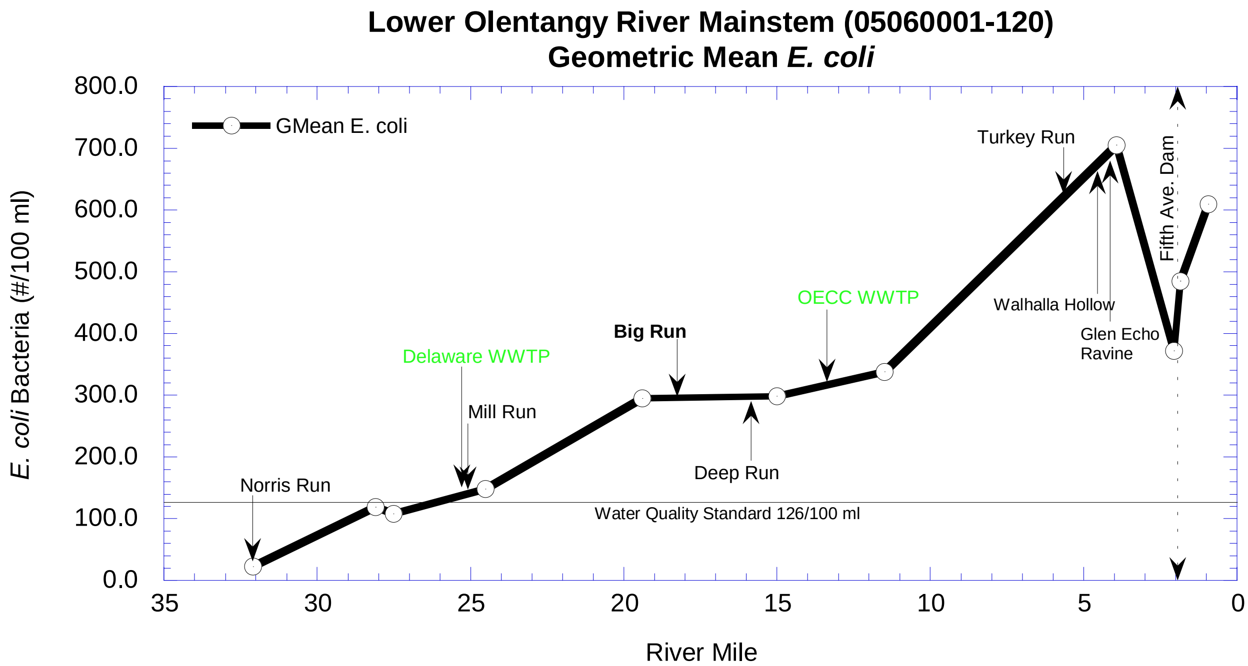


Figure 95. Geometric mean *E. coli* for the Olentangy River mainstem within the LOWAU, 2003.

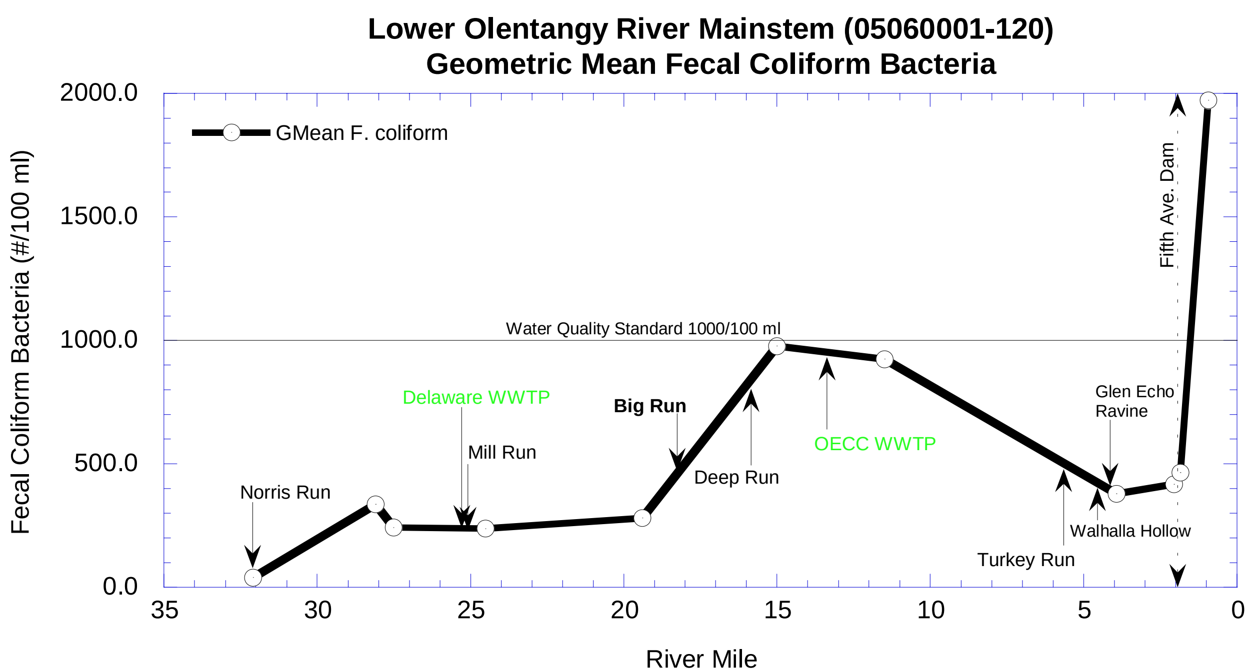


Figure 96. Fecal coliform sampling results for the Olentangy River within the LOWAU, 2003.

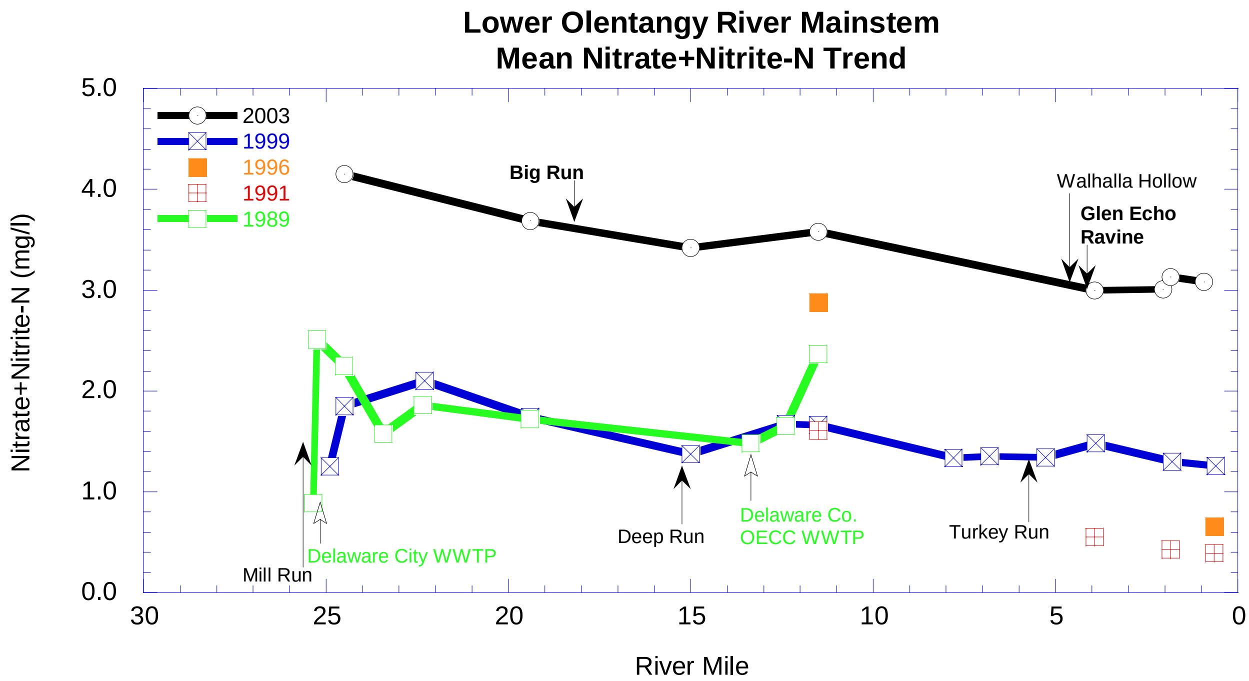


Figure 97. Mean nitrate+nitrite-N for the Olentangy mainstem within the LOWAU over time.

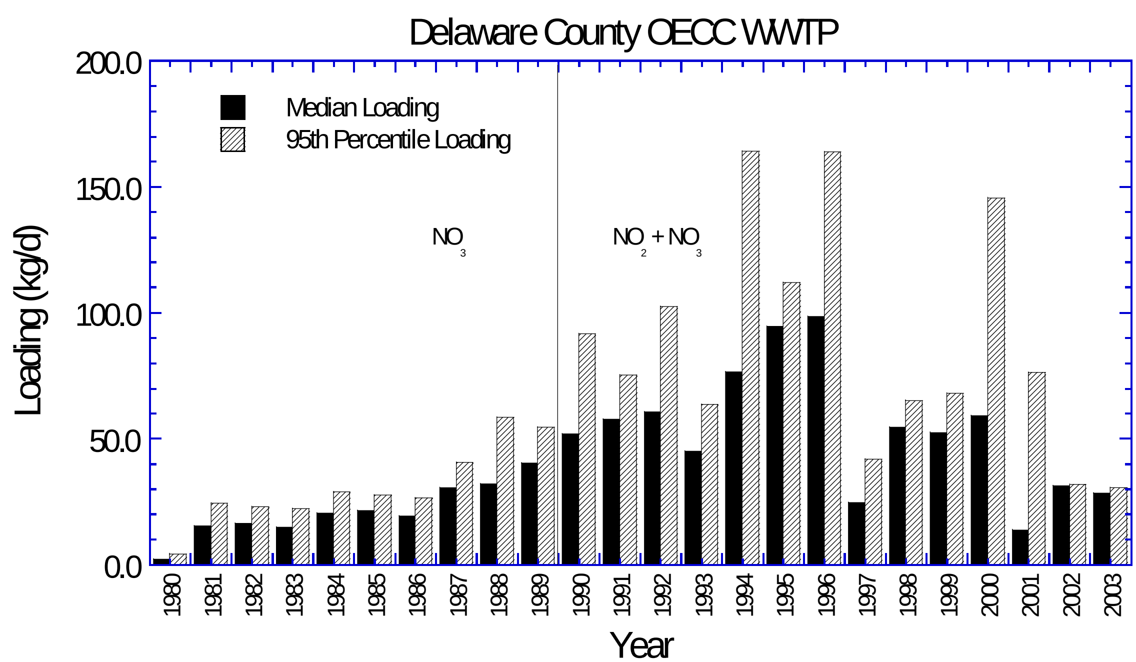


Figure 98. Nitrate loading from OECC WWTP over time.

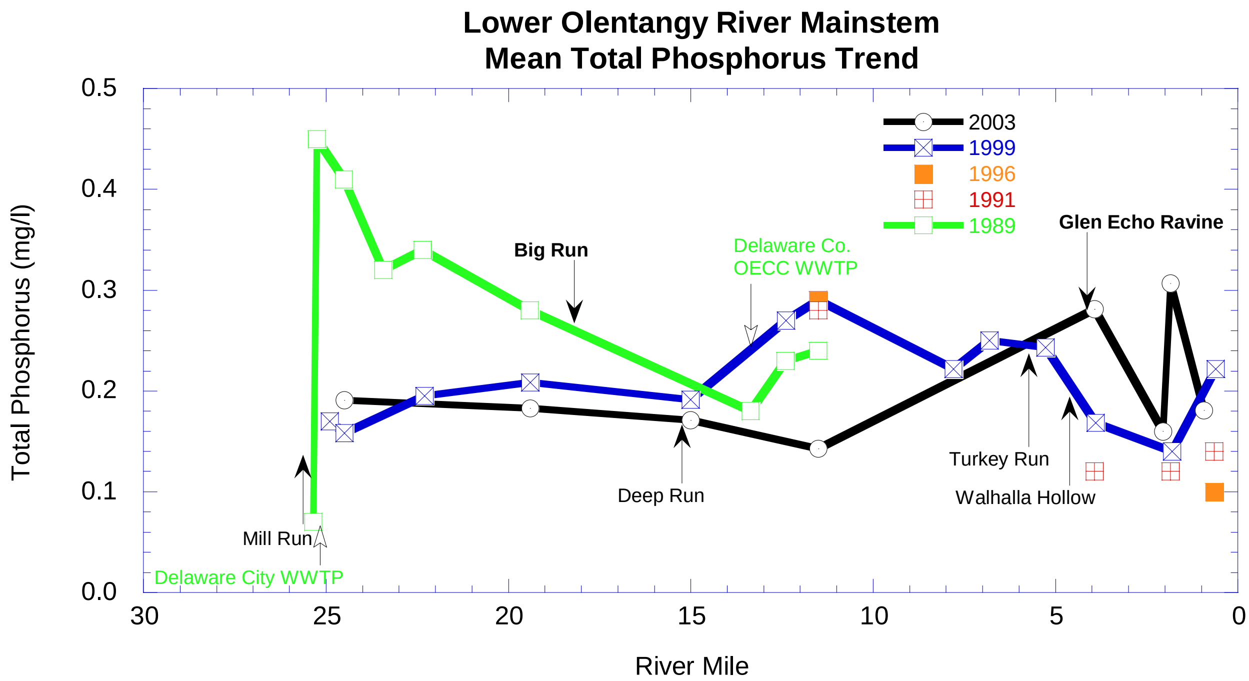


Figure 99. Mean total phosphorus for the Olentangy mainstem in the LOWAU over time.

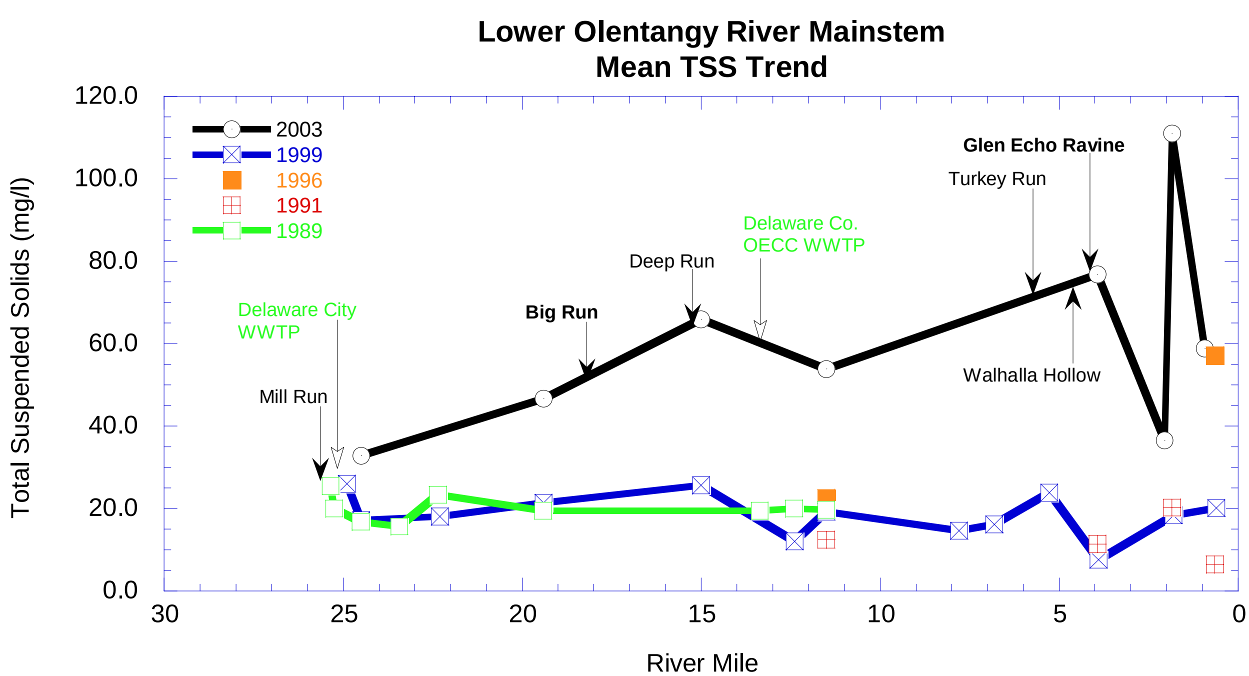


Figure 100. Mean total suspended solids for the Olentangy mainstem within the LOWAU over time.

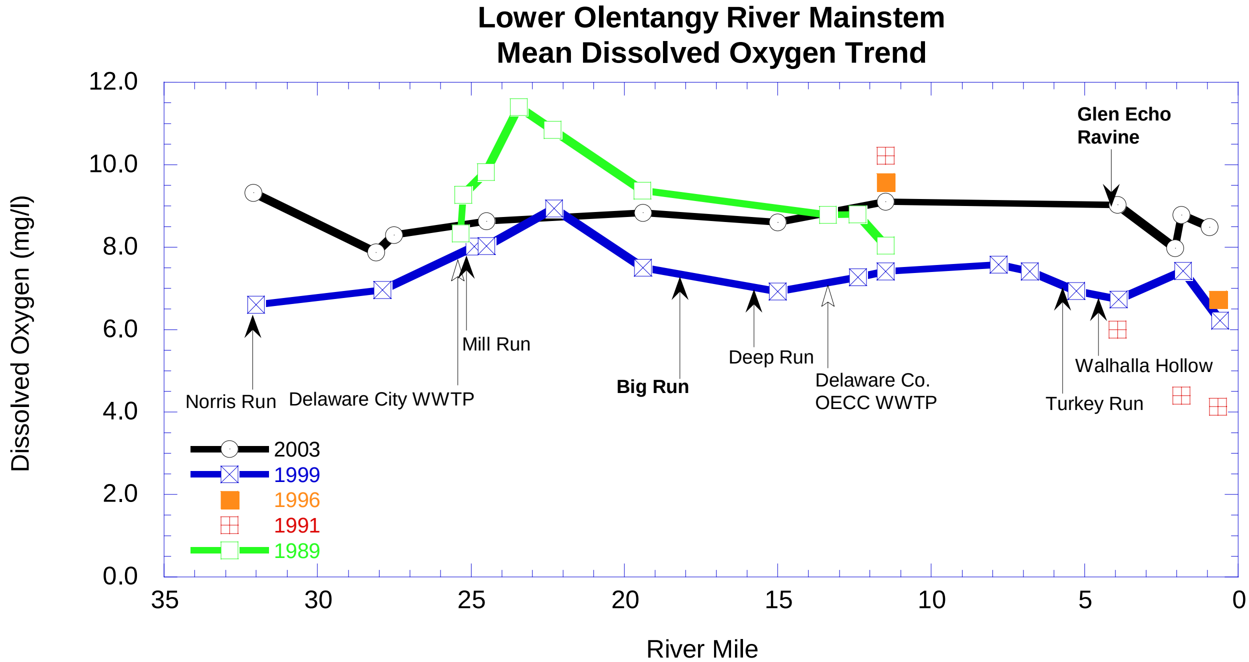


Figure 101. Dissolved oxygen concentration for the Olentangy mainstem within the LOWAU over time.

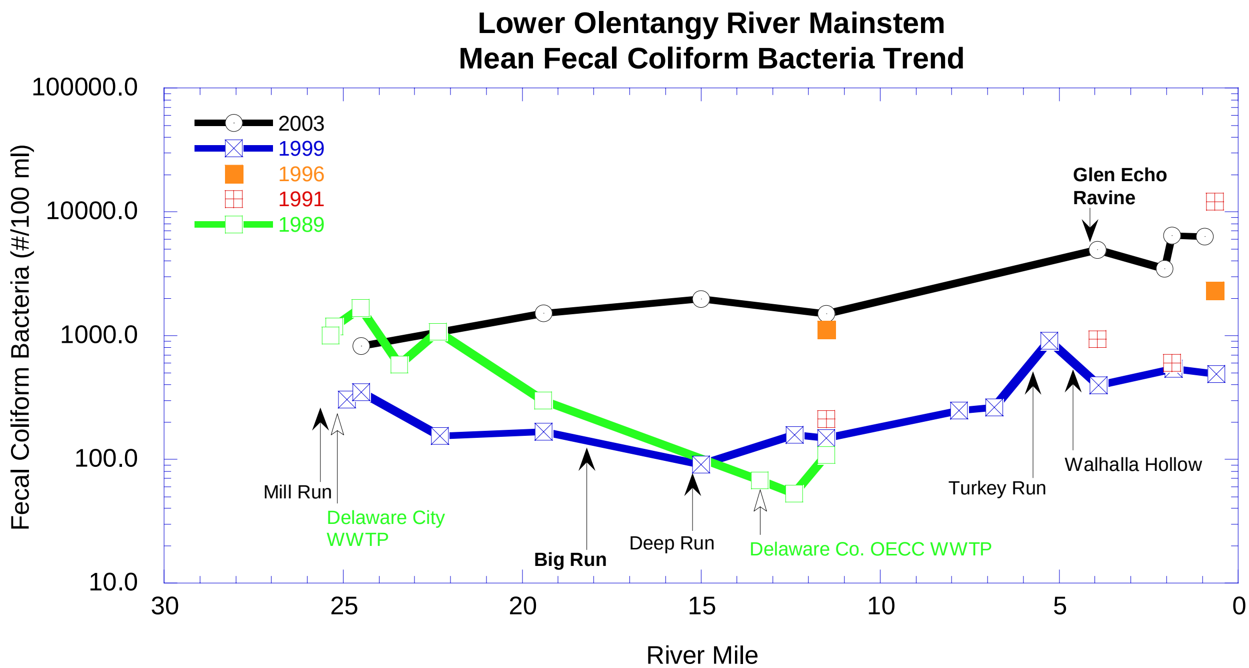


Figure 102. Fecal coliform bacterial levels over time for the Olentangy River within the LOWAU.

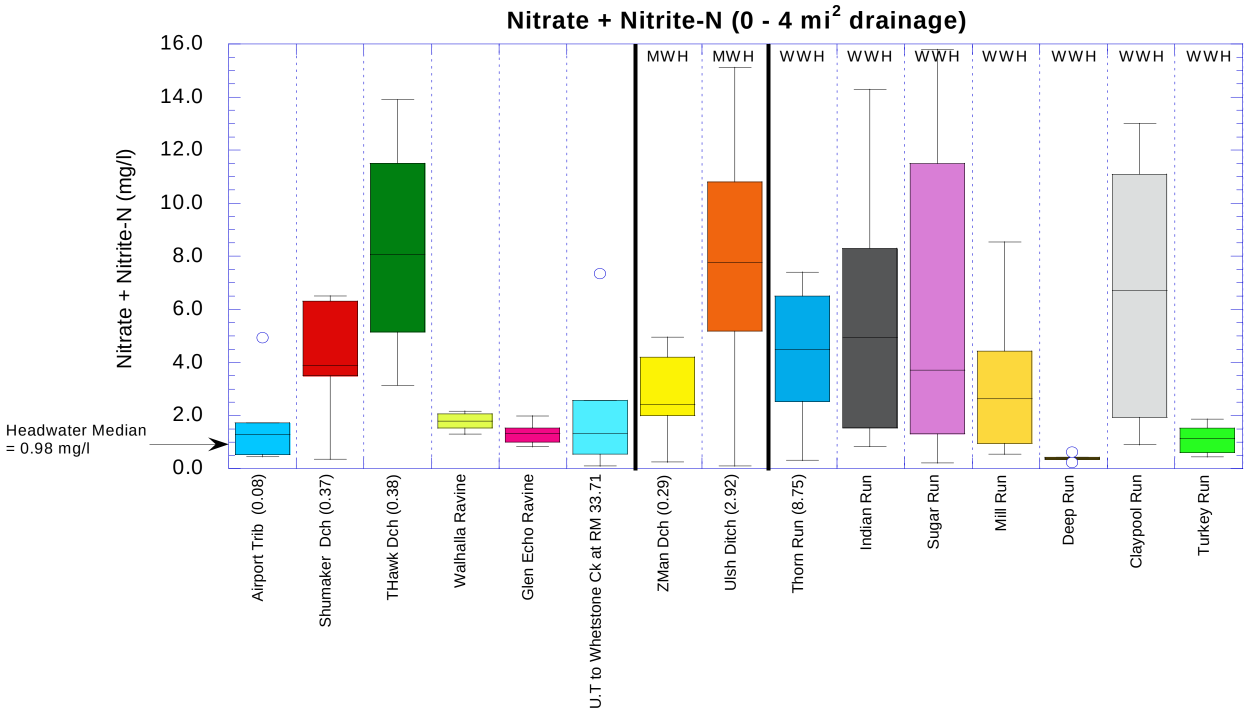


Figure 103. Nitrate-nitrite-N for 0-4mi^2 drainage area streams throughout the Olentangy basin, 2003.

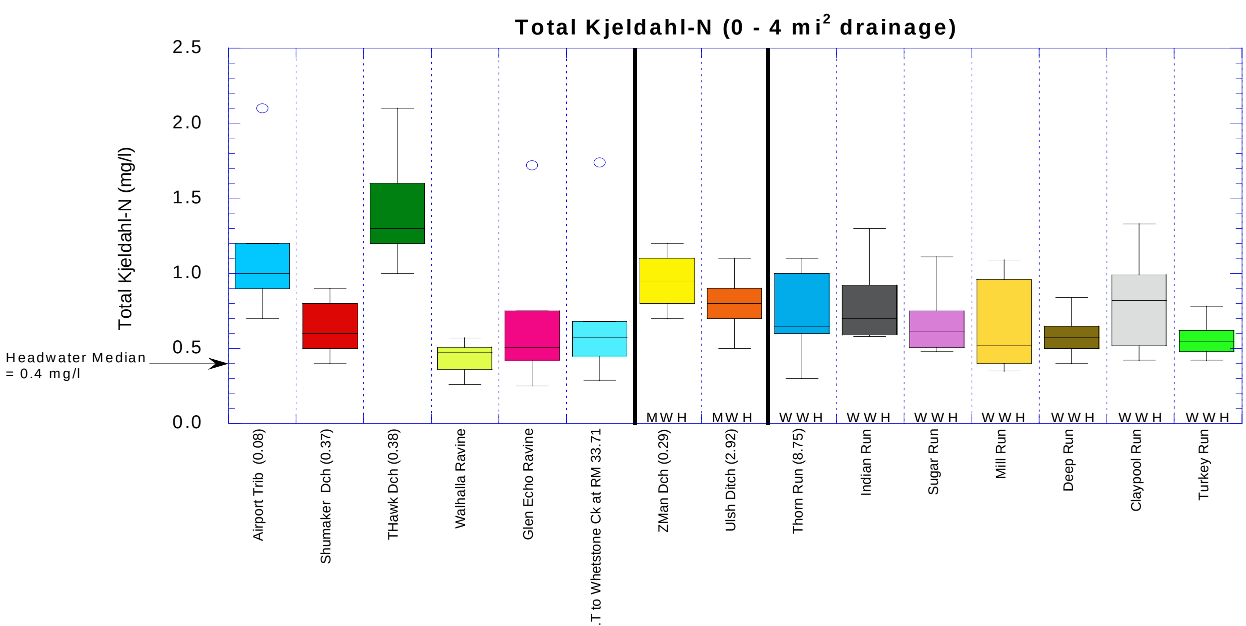


Figure 104. Total Kjeldahl-N for 0-4mi^2 drainage area streams throughout the Olentangy basin, 2003.

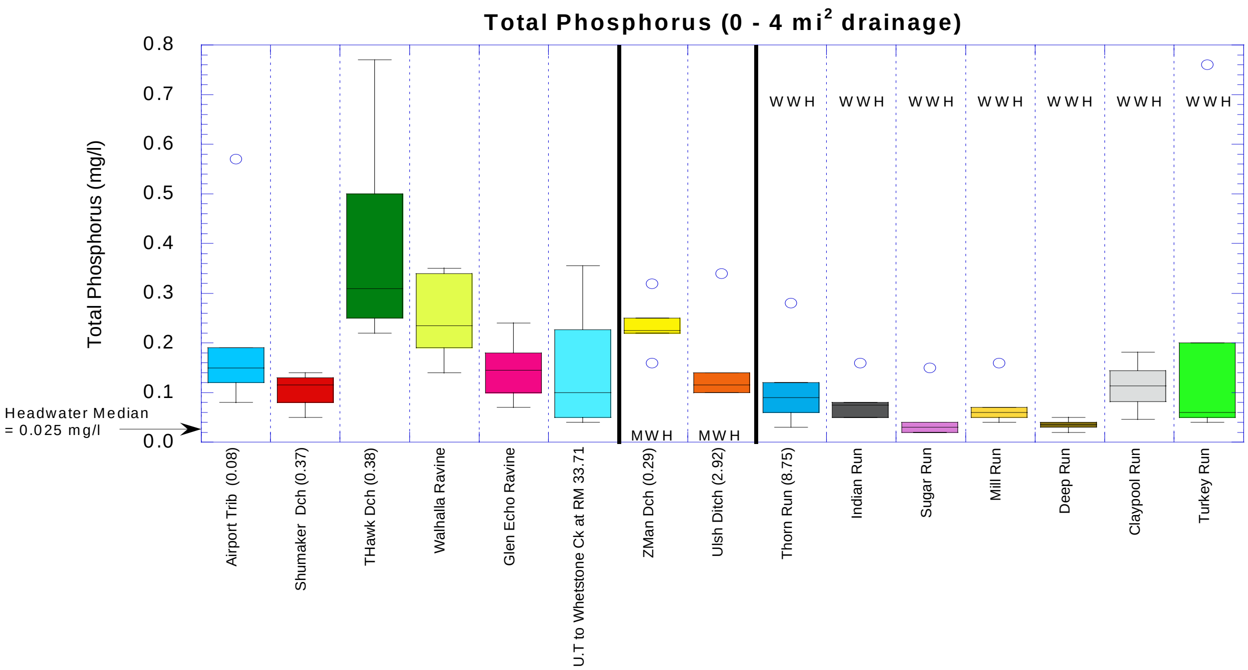


Figure 105. Total phosphorus concentrations for 0-4mi^2 drainage area streams throughout the Olentangy basin, 2003.

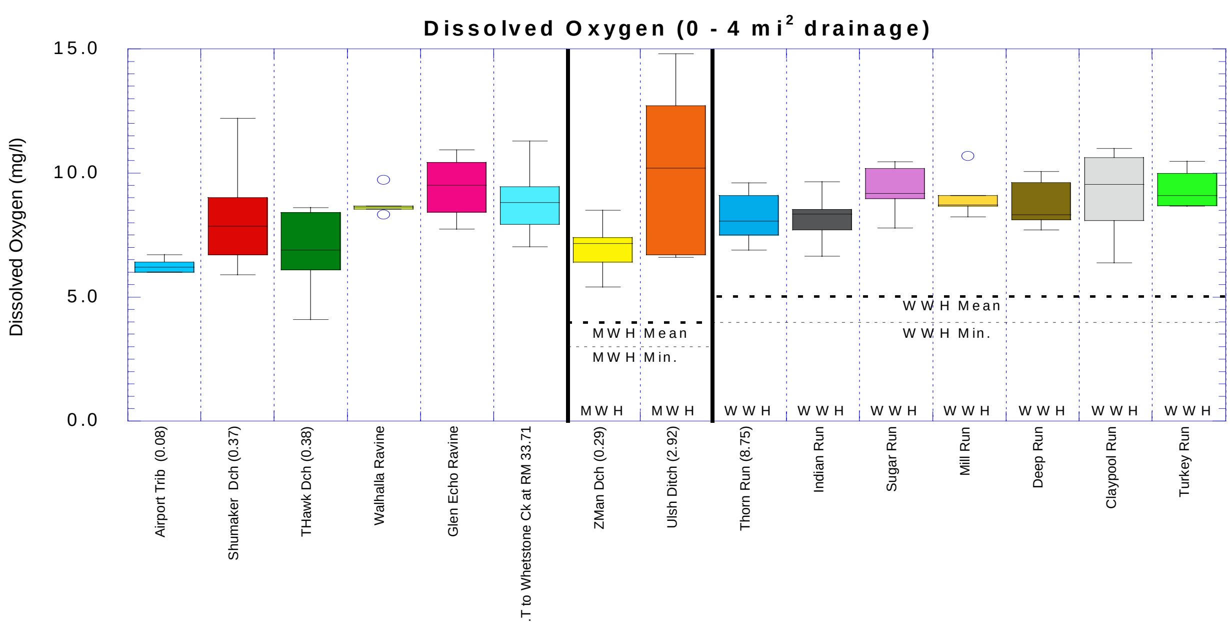


Figure 106. Dissolved oxygen concentrations for 0-4mi^2 drainage area streams throughout the Olentangy basin, 2003.

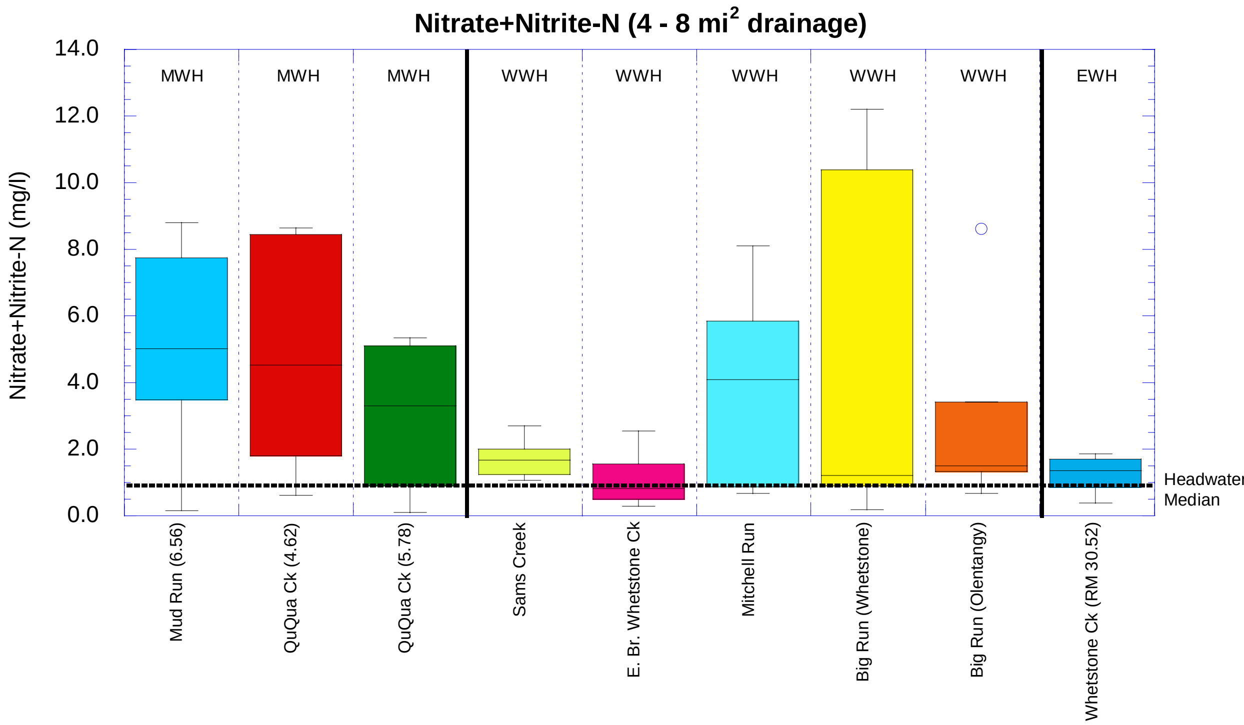


Figure 107. Nitrate-Nitrite-N concentrations for 4-8mi^2 drainage streams throughout the Olentangy basin, 2003.

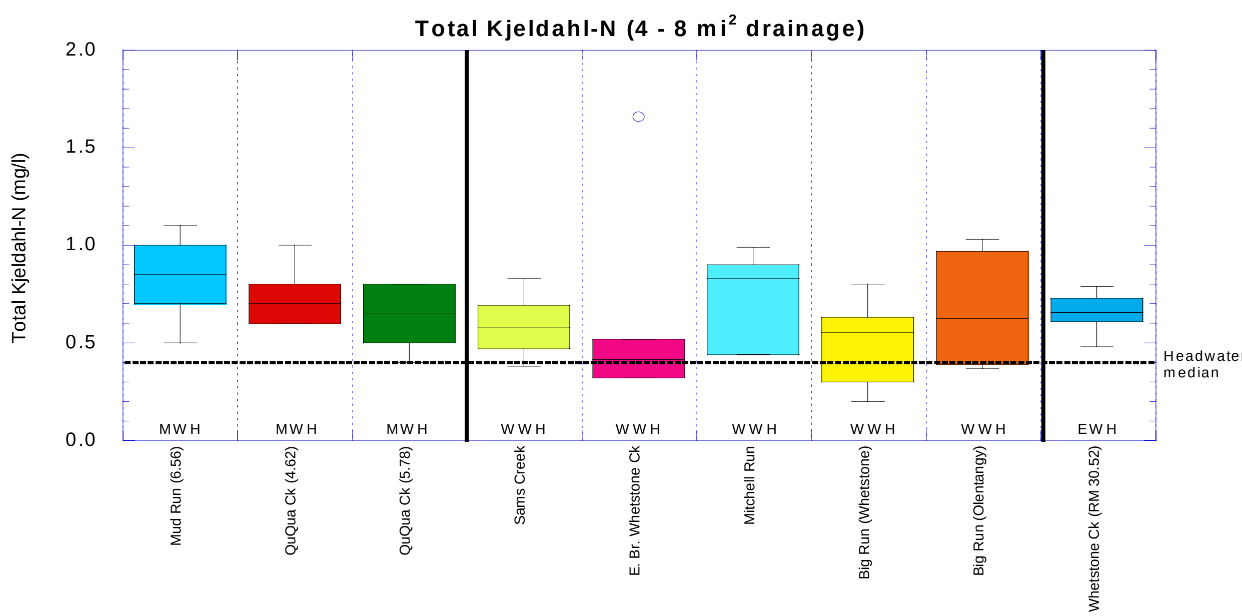


Figure 108. Total Kjeldahl-N concentrations for 4-8mi^2 drainage streams throughout the Olentangy basin, 2003.

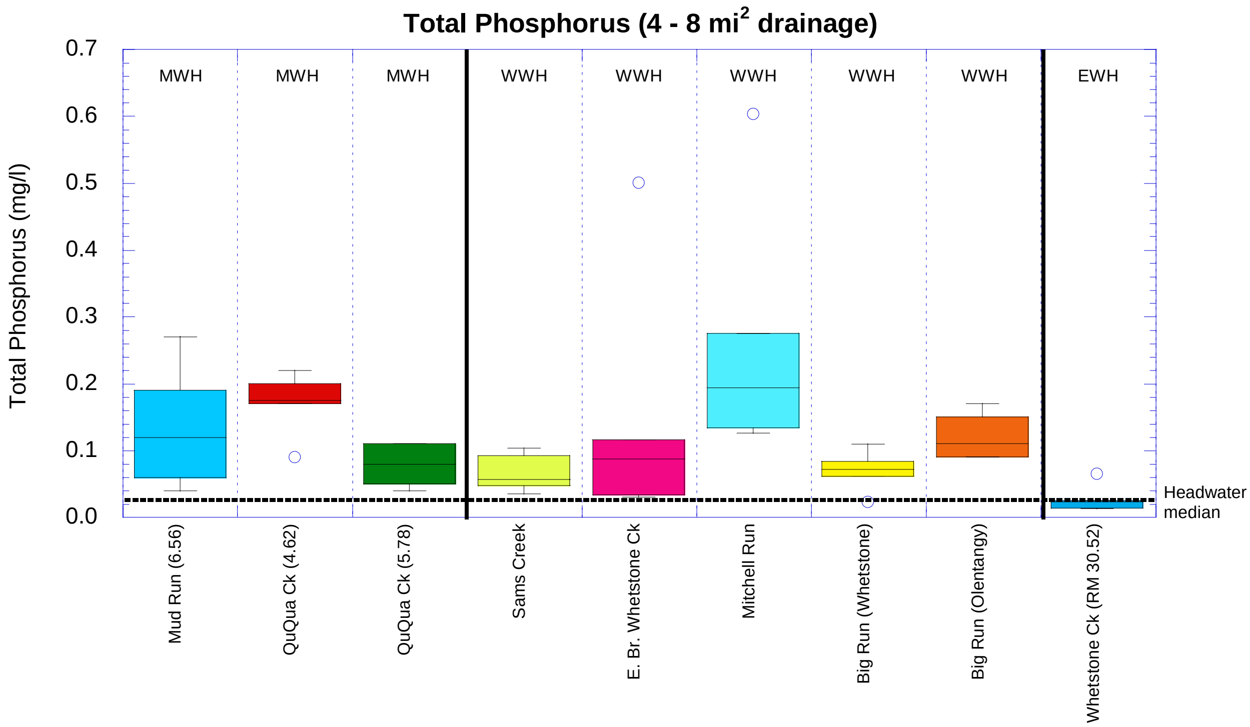


Figure 109. Total phosphorus concentrations for the 4-8mi^2 drainage area sites within the Olentangy basin, 2003.

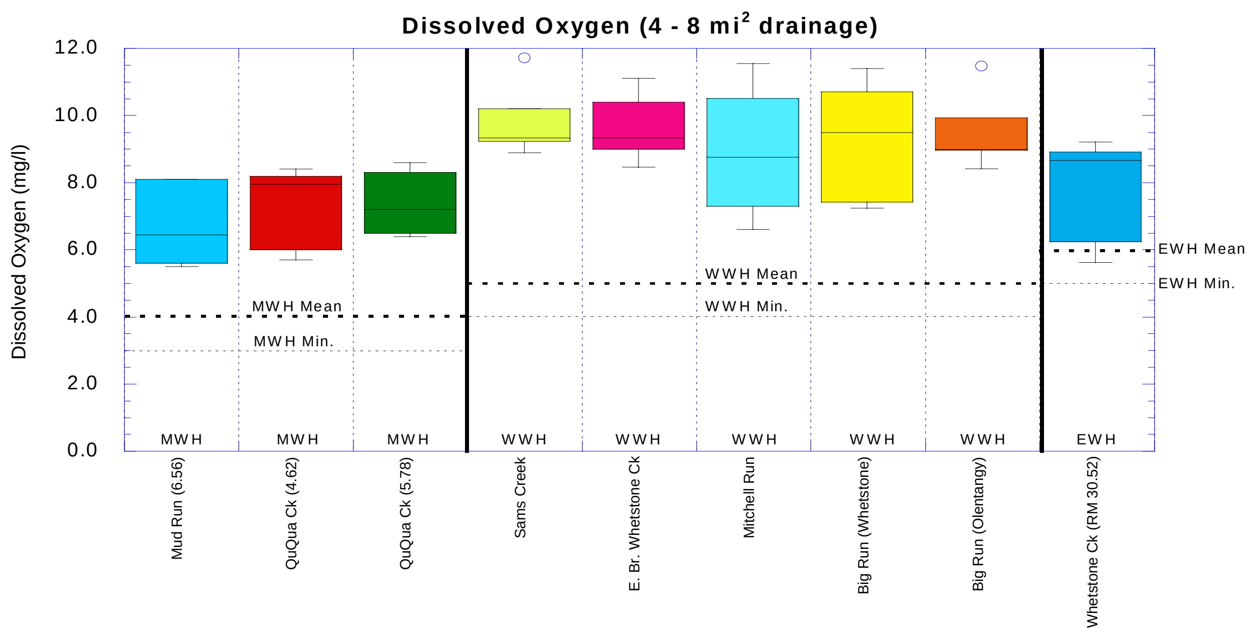


Figure 110. Dissolved oxygen concentrations for the 4-8mi^2 drainage area sites within the Olentangy basin, 2003.

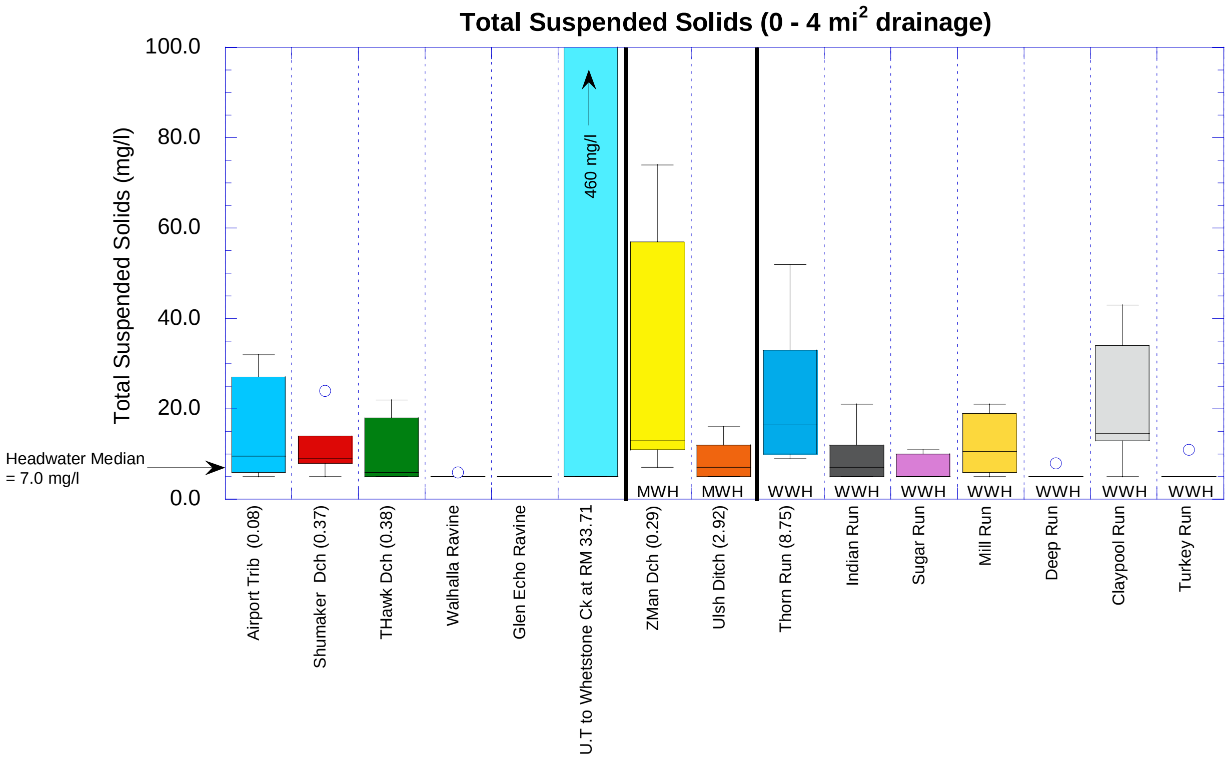


Figure 111. Total suspended solids in 0-4mi^2 drainage area sites within the Olentangy basin, 2003.

Physical Habitat

The physical habitat of twenty-two locations was sampled throughout the LOWAU. The tributary sites were all <10mi^2 in drainage area and are considered to be headwater type streams. All of the streams scored within the fair to good range, even though their hydrologic regimes have been greatly altered by changes in the landscape (Figure 112). For example, much of the flow in Glen Echo Ravine comes directly from storm sewers and sanitary sewer overflows. The highly urbanized nature of the flow regime and water quality overrides the available habitat present for aquatic organisms.

The Olentangy River mainstem sites scored primarily within the good to very good range, except for the 5th Avenue dam pool (RM 2.1) which scored within the poor range and the Panhandle Road dam pool (RM 28.1) which scored within the fair range. Dams create monotypic pools which results in habitat suitable for fewer species. Therefore, it is not surprising that the expectations of these areas are significantly lower than free flowing portions of the Olentangy River.

Olentangy River

The lower reach of the Olentangy River from Main Road (RM 32.1) to the Goodale exit of State Route 315 (RM 0.9) contains numerous dams which impede flow and create impoundments characterized by slow currents and monotypic habitats of long pools with occasional areas of woody debris and fallen logs. Substrate features in the free-flowing portions of the river were predominated by boulder, cobble, gravel, sand and bedrock, though occasional areas of boulder slabs, hardpan and silt were also observed. Silt was present in normal to moderate amounts while embedded substrates were present in moderate to extensive amounts. Moderate amounts of instream cover present in the free flowing portions of the lower Olentangy mainstem were provided by undercut banks, overhanging vegetation, shallows, rootmats, deep pools, rootwads, boulders and woody debris. The portions of the river adjacent to State Route 315 through Worthington and downstream from Dodridge Avenue were recovering from hydromodifications performed many years ago. The remaining portions of the Olentangy mainstem were unmodified except where impounded by low head dams or where it was levied adjacent to OSU campus. Low to moderate amounts of sinuosity was common, though channel development varied from fair near Dodridge (RM 3.9) in a previously modified area to good and excellent in the remaining free flowing portions. Riffle-run complexes were made up of stable substrates such as cobble and boulders and also unstable materials of fine gravel and sand. The riffles, runs, pools and glides provided multiple niches of habitat for aquatic organisms and provided various flow regimes of slow, moderate, and fast currents with occasional eddies along some banks.

Outside of the lower Olentangy mainstem, land use intensified in a downstream direction, transitioning from woods and sparse residential areas in the upper portion to heavily urbanized areas in the downstream portion. Riparian buffers were larger in the upper portion and nearly nonexistent in several areas of the lower portion. Though impounded areas had more narrow buffers than the free-flowing portions, the intensity of land use determined the extent of buffers present.

Just as the intensity of land use can affect the quality of habitat available to aquatic life, the conditions available to organisms in free-flowing areas can support more diverse assemblages than the monotypic conditions present in the impounded portions of the lower Olentangy mainstem. The average QHEI scores of the free-flowing portions of the lower Olentangy mainstem were 76.9 (ranging from 66 to 89) while the average QHEI score in the impounded reaches were 44.0 (ranging from 32.5 to 55.5).

Indian Run

The substrates of Indian Run near Horseshoe Road (RM 0.9) appeared to be derived primarily from glacial tills. Sand and cobble were the primary substrate types and were intermixed with gravel and boulders. Moderate to heavy amounts of silt were present, though substrates were only embedded in normal to moderate amounts. Moderate amounts of instream cover were available to aquatic organisms and included undercut banks, overhanging vegetation, shallows, rootmats, deep pools (>70cm), rootwads, boulders, aquatic macrophytes and logs. A small log jam was present which provided a deep pool upstream and a small riffle area along the left descending bank downstream. Only two small riffle areas were noted, with the majority of observed flow being slow to moderate throughout the stream. The stream appeared to be recovering from past channelization as low to moderate sinuosity with fair to good development and moderate to high stability were noted.

Outside of the stream channel, narrow (5-10m) to moderate (10-50m) buffers extended along row crop fields and forested areas, respectively along the left descending bank. Row crops and fenced pastures were evident beyond the very narrow (<5m) to moderate (10-50m) buffers along the right descending bank. The QHEI score of 69.0 reflects a good diversity of habitat and niches available to aquatic organisms throughout Indian Run.

Norris Run

The physical habitat of Norris Run was evaluated near Penry Road (RM 1.3) as it flowed through a low density residential neighborhood. The stream substrate originated from glacial tills. Gravel and cobble were the primary substrate types present, with smaller areas of sand and boulder also observed. Large quantities of silt were present and embedded the substrates extensively, especially within the riffles.

Upstream of Penry Road, Norris Run appeared to have been channelized with its riparian area maintained by the landowner as a mowed lawn with few trees. Instream cover upstream of Penry Road consisted primarily of boulders, and aquatic macrophytes with little overhanging vegetation. In contrast, the portion of the site downstream of Penry Road appeared free from channelization with moderate amounts of instream cover including undercut banks, overhanging vegetation, shallows, rootmats, boulders, aquatic macrophytes and woody debris. Though the entire stream segment exhibited moderate sinuosity with fair development, the maintained area in the upper portion appeared moderately stable while the lower portion exhibited higher bank erosion with low stability. The lower portion of the stream was likely influenced by stormwater run-off from the roadway and increased flows from the upper channelized portion of the stream. The open canopy in the upstream portion exposed the stream to sunlight contributing to the large mass of algae present within this portion of the stream. Very narrow (<5m) riparian buffers consisting of trees and shrubs were noted along the downstream portion of the site. The mixture of a highly maintained riparian corridor in the upper portion of the stream with a relatively natural setting in the lower portion of the stream resulted in a QHEI score of 69.0.

Sugar Run
Sugar Run appeared to contain substrates originating from shales and glacial tills. Dominant substrate types included bedrock and cobble, though areas of boulders, gravel, and sand were also present. Silt was present in moderate amounts and embedded substrates were present in normal to moderate amounts. Moderate amounts of instream cover were provided by undercut banks, overhanging vegetation, shallows, rootmats, boulders and woody debris. The stream appeared free from channelization with moderate to high sinuosity, good development and moderate to high stability. Riffles and pool areas provided diverse habitats and flows including slow, moderate and fast portions of stream.

Outside the stream channel, riparian buffers ranged from nonexistent to narrow (5-10m) along the left descending bank adjacent to a new field and forested area, while the buffers along the right descending bank were narrow (5-10m) adjacent to the salt storage facility and moderate (10-50m) adjacent to the forested area. The QHEI score of 69.0 reflected the diverse habitat features that provided niches for a variety of aquatic organisms.

Mill Run
The physical habitat of Mill Run was evaluated near the Cactus Hollow campground south of State Routes 36 & 37 (RM 0.9). An attempt was made to evaluate Mill Run near North Street (RM 0.7), but due to the ravine setting of the stream at North Street with slopes descending over 60 feet, access was not possible. However, access was possible near the Cactus Hollow campground, and the stream appeared to be derived primarily from limestone and tills. Bedrock and cobble were the dominant substrate types and were intermixed with areas of sand, gravel and boulders. Silt was present in normal amounts and coarse substrates were moderately embedded. Instream cover consisting of overhanging vegetation, undercut banks, shallows, rootmats, rootwads, boulders, and logs with woody debris was present in moderate amounts. No evidence of channelization was apparent as the stream exhibited high sinuosity with good channel development and moderate to high stability.

Outside of the stream channel, narrow riparian buffers (5-10m) extended along the left descending bank adjacent to the campground while wide buffers (>50m) extended along the right descending bank adjacent to an old agricultural field and forested area. Active row cropping was noted along the drive entering the campground, upstream of the sampling site. The lower intensity land use close to the stream combined with diversity of substrates and instream cover resulted in a QHEI score of 68.0.

Tributary to Olentangy River (RM 20.71)

The tributary to the Olentangy River (RM 20.7) was evaluated near Chapman Road (RM 0.2). The stream appeared to have originated primarily from shale. Bedrock was the dominant substrate type present, though occasional areas of cobble and gravel were noted. Silt was present in normal amounts with numerous interstitial spaces available for aquatic organisms. Instream cover was sparse and provided only by shallows, rootmats, rootwads and logs. The stream appeared free from channelization with low sinuosity, fair development and high stability. However, a large waterfall (>6ft drop vertically), was present just downstream of the reach sampled, and numerous dams were present upstream of the zone sampled.

Outside of the stream channel, wide (>50m) riparian buffers extended adjacent to a wooded area along the right descending bank and moderate (10-50m) riparian buffers extended adjacent to a new field area along the left descending bank. The sparse amounts of instream cover combined with the few substrate types resulted in a QHEI score of 52.5. The isolated nature of the stream, with dams located upstream and the waterfall located downstream, decreases the likelihood that the stream could support WWH communities, as fish migration is not likely.

Figure 113. Sewage fungus along septic system outfall.

Big Run

Big Run near Lewis Center was evaluated upstream of Taggert Toad (RM 0.1). The stream appeared to originate primarily from tills and shale. Cobble and bedrock were the dominant substrate types, though areas of sand, gravel, and boulders were also observed. Silt was present in normal amounts, and coarse substrates revealed average amounts of embeddedness. Instream cover was sparse and limited to overhanging vegetation, shallows, rootmats, rootwads, boulders, and woody debris with logs. No evidence of channelization was apparent, as the stream exhibited low sinuosity with good development and high stability. Currents ranged from slow to fast with riffles present in the form of broken shale upstream and cobble downstream.

Outside the stream channel, moderately wide (10-50m) riparian buffers extended along the left descending bank adjacent to a forested area and one residential home. Narrow (5-10m) buffers extended along the right descending bank adjacent to a forested area and gravel road. A small home sewage discharge was noted along the left descending bank (Figure 113). The grey water emanating from the pipe appeared to be untreated sewage as evidenced by the odor and the sewage fungus which thrived below the outfall.

The wooded riparian corridor combined with the lower intensity land use resulted in a QHEI score of 68.0, indicating the potential of the stream to support WWH communities. However, the influence of the raw sewage discharge likely impairs the water quality, lowering the stream's ability to support WWH communities.

Deep Run

The substrates of Deep Run near Owenfield Drive (RM 1.1) have developed primarily from shale bedrock. Bedrock was the dominant substrate type present, though areas of boulders and cobble were also observed. Silt was present in normal to moderate amounts and substrates appeared embedded in normal amounts. Instream cover was provided in sparse amounts by undercut banks, shallows, rootmats, boulders and logs with woody debris. The stream appeared to be free from channelization with moderate sinuosity and good development. Several small springs were noted along the stream channel. However, loose and broken shale was present along the banks which showed evidence of moderate erosion. Therefore, the channel morphology appeared to be of low to moderate stability.

Outside of the stream channel, very narrow (<5m) buffers were present adjacent to an office park along the right descending bank. Moderate (10-50m) riparian buffers were evident adjacent to construction of office complexes along the left descending bank. The shift in land use adjacent to the stream and throughout its watershed has likely contributed to the flashy nature of the stream as noted by the low to moderate stability of the stream and unstable riffles. Deep Run received a QHEI score of 48.0 which reflects the influences of the developing landscape.

Turkey Run

The habitat quality of Turkey Run was evaluated near Shattuck Avenue (RM 0.7). The stream appeared to have been derived primarily from glacial till. Cobble and gravel dominated the substrate types, though areas of boulders and sand were also observed. Silt and embedded substrates were present in normal amounts, providing some interstitial spaces for aquatic organisms. Instream cover was sparse and consisted primarily of overhanging vegetation, shallows, boulders and some woody debris. Thick, filamentous algae were present in all sunny areas, and provided some cover. The stream channel appeared free from channelization with moderate sinuosity, fair development and moderate stability.

The stream channel meandered through a residential area, with very narrow buffers (<5m) providing little protection from urban influences including erosions and nutrient enrichment (residential lawns and the OSU golf courses). Though little bank erosion was observed, rip-rap had been placed in one area. A storm drain pipe was noted downstream of Shattuck Avenue. The highly modified landscape contributed to the flashy nature of the stream, as a wide range of flow conditions were noted over short periods of time. The combination of diverse substrates with sparse instream cover and surrounding residential land use with very narrow buffers contributed to a QHEI score of 55.0 for Turkey Run. The QHEI score reflects a lower potential of the stream to support a WWH habitat community, though the large amount of algae present indicated a nutrient enrichment problem that could further limit the stream's ability to support WWH communities.

Wahalla Hollow

The physical habitat of Wahalla Hollow was evaluated as it flowed adjacent to Wahalla Road (RM 0.9). The stream substrates appeared to have originated from glacial tills and shales, though gravel and cobble were the dominant substrates intermixed with sand and boulders. Silt was present in normal amounts while substrates appeared embedded in normal to moderate amounts. Sparse amounts of instream cover were provided by overhanging vegetation, shallows, rootwads, boulders and logs. No evidence of past channelization was apparent, and stream exhibited moderate sinuosity with fair development and high stability. The stream flowed through a low density residential neighborhood and had a very narrow (<5m) buffer along the left descending bank adjacent to Wahalla Road, while a moderately sized (10-50m) riparian buffer existed along the right descending bank. Several driveways crossed the stream with culverts reducing the stream width in these areas. The QHEI score for Wahalla Ravine was 57.5.

Glen Echo Ravine

The physical habitat of Glen Echo Ravine was evaluated at Glen Echo Park along Cliffside Drive (RM 1.0). The stream substrates appeared to originate from shale bedrock, with bedrock and boulders present as the dominant substrate types. Areas of cobble, gravel, and sand were also observed. Silt was present in normal quantities and coarse substrates showed average amounts of embeddedness. Sparse to moderate amounts of instream cover were indicated by the presence of undercut banks, overhanging vegetation, boulders, woody debris and logs. Gabions, which are rock baskets used for bank stabilization, were also noted. Past hydromodification was evident, however, the stream exhibited high sinuosity and good development.

The surrounding high intensity urban and residential land use was muffled by the park setting which provided moderate (10-50m) riparian buffers along the right descending bank, though no buffer was evident along the left descending bank. The flow regime of the stream was altered by the high amount of surrounding impervious surfaces resulting in an increased flashy and intermittent nature. The QHEI score for the stream was 60.0, but due to the highly altered flow regime, it may be difficult for the stream to support

WWH communities. Much of the flow in Glen Echo Ravine arise directly from storm runoff and sanitary sewer overflows. The highly urbanized nature of the watershed and only fair water quality overrides the available habitat present for aquatic organisms.

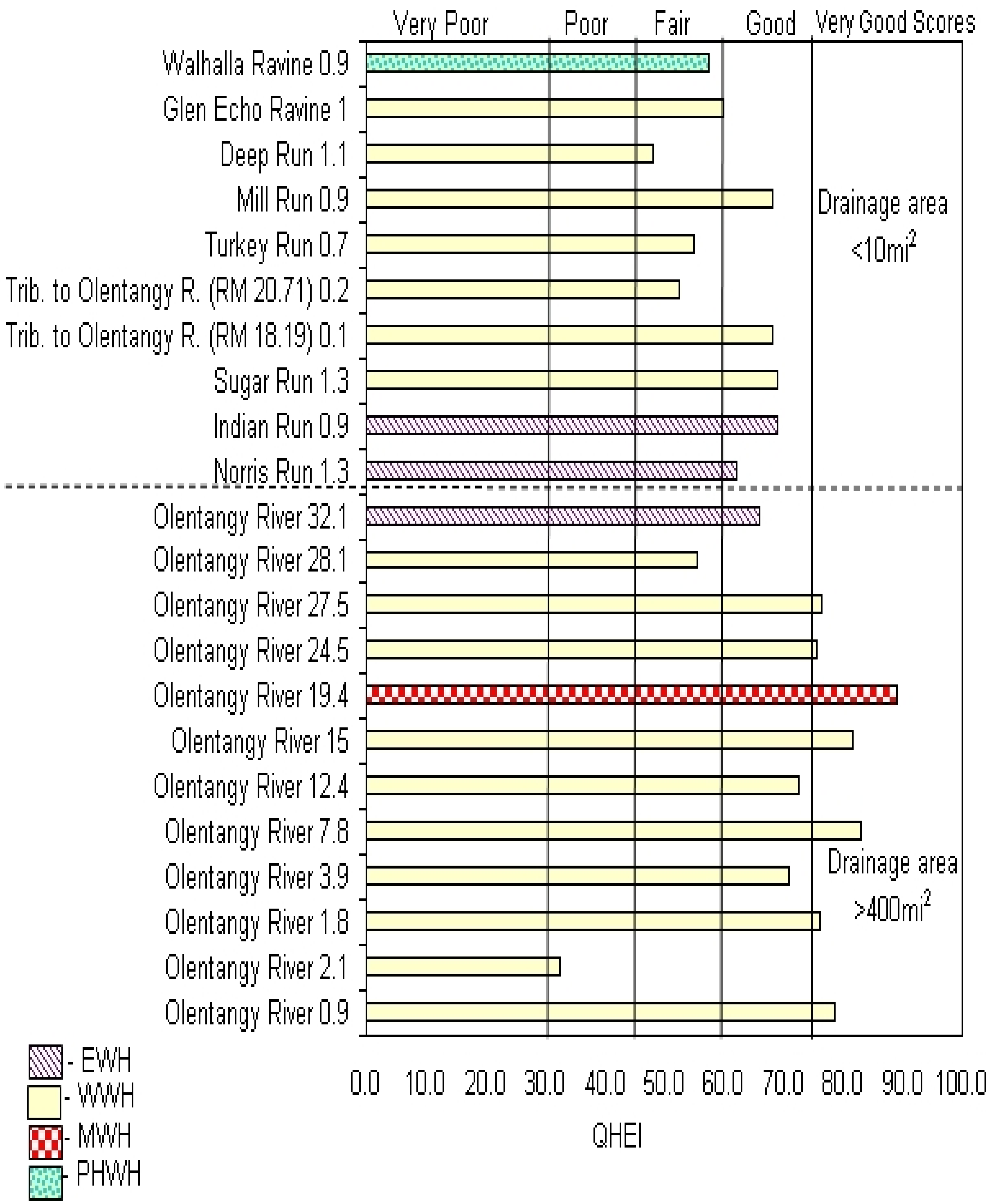


Figure 112. QHEI scores by drainage area for all biological sampling sites within the LOWAU, 2003.

Biological Communities: Fish

The fish communities of twenty-two locations were evaluated within the LOWAU for this survey. All of the tributary sites were sampled in 2003, while the mainstem sites were sampled in 2004 due to the excessive rainfall and dam releases which occurred in 2003. The landscape of the upper portion of the LOWAU is rapidly changing from primarily agriculture with fields and woodlots as residential and commercial developments expand northward from the heavily urbanized lower portion of the LOWAU.

The effects of urbanization on small streams are displayed prominently in Figure 114. Seven of the nine tributary sites performed below WWH expectations. All of the streams suffer from altered hydrologic regimes, though effects noted in the tributary to Olentangy River RM 20.71 was primarily from dams and not development. The other streams, however, exemplify the effects of both altered flow regimes and poor water quality on overall stream health, as only two of the fish communities present were able to score within WWH expectations. The two tributary streams which scored within WWH expectations were Mill Run and Indian Run, which have some of the lowest intensity land uses of all the tributary streams of the LOWAU.

The effects of urbanization were not limited to tributary streams. The Olentangy River site at Hyatts Road (RM 19.4) had the lowest score of any EWH mainstem site in the LOWAU. The surrounding area is undergoing rapid development causing increased siltation in surrounding waterways. Sight feeding fish and those which rely upon clean substrates for spawning can not compete with tolerant species under these conditions. Smart growth practices including stream set asides, conservation easements and improved storm water control should be enacted throughout the LOWAU to prevent further declines of the fish communities.

The 5th Avenue dam pool site (RM 2.1) scored within WWH expectations, even though it is considered to be MWH. While this may seem to indicate that dams may not be affecting this reach, it is important to note that the highest scoring WWH mainstem site was directly upstream of the dam pool (RM 3.9). The upstream site scored an IBI of 50, which actually meets EWH expectations. Removal of the 5th Avenue dam could result in increased biological performance and attainment of WWH criteria throughout the currently impounded area.

Olentangy River

The fish communities of the Olentangy River were sampled at twelve locations throughout the Lower Olentangy WAU. Discussed earlier, for the purposes of this report, the lower WAU is considered to begin just below Delaware dam (RM 32.1) and extend to the mouth of the Olentangy River. Community indices and narrative evaluations ranged from fair (IBI=36, MIwb=6.2) to exceptional (IBI=50, MIwb=10.3). The range of community scores reflects the influence of dams on water quality within the Lower Olentangy WAU.

The ten free flowing sites sampled within the Olentangy River had an average IBI=45 (range of 40 to 50) and an average MIwb=9.1 (range of 7.1 to 10.3). Free flowing portions of the mainstem yielded an average of 23 total species with a range of 18-30. An average of 3 common pollution intolerant species was collected at each site, though the total number of common, rare or special pollution intolerant species ranged from 1 to 5 per site (Table 37). The free-flowing sections averaged eight moderately intolerant species (range of 5 – 11). The percentage of pollution tolerant species was also low for these areas, averaging 15% per site. In addition, the state threatened bluebreast darter, a rare intolerant species, was collected near Highbanks Metro Park (RM 15.0) and near Kenny Park (RM 7.8) and the river redhorse, a state special interest species, was collected downstream of Dodridge Road (RM 3.93).

In contrast, the sampling efforts at the two sites impounded by dams, Panhandle Road dam pool at RM 28.1 and Fifth Avenue dam pool at RM 2.1, resulted in only 12 and 13 total species, respectively. No common pollution intolerant species were collected at these sites (Table 37). The Panhandle Road dam pool had two moderately intolerant species; longear sunfish and smallmouth bass, while the 5th Avenue dam pool had three moderately intolerant species; brook silverside, golden redhorse and longear sunfish. Tolerant species comprised 55% of the fish collected near Panhandle Road, while 22% of the fish collected near Fifth Avenue were tolerant. The presence of dams within the lower reach dramatically affects the biological integrity of the system by impeding flow and reducing habitat quality and availability to aquatic organisms.

Indian Run

The fish community of Indian Run was sampled near Horseshoe Road (RM 0.9). Community indices and narrative evaluations described the community as marginally good (IBI=36). A total of 17 species were collected in Indian Run, though 83% of the individuals collected were of a tolerant species and green sunfish comprised 64% of the total individuals collected. Nutrient enrichment has likely degraded water quality resulting in the high number of tolerant fish noted during sampling.

Norris Run

The fish community of Norris Run was sampled near Penry Road (RM 1.3). Community indices and narrative evaluations characterized the fish community as poor (IBI=23). The tolerant bluntnose minnow comprised nearly 70% of the catch, and tolerant species represented 88% of the individuals collected. Landowners adjacent to the stream have removed riparian cover, modified portions of the stream channel and mow up to the edges of the stream bank. Failing on-lot sewage treatment systems and rapid development in this watershed may also be contributing to the poor biological performance.

Sugar Run

The fish community of Sugar Run was sampled near a salt storage facility south of State Route 42 (RM 1.3). Community indices and narrative evaluations characterized the stream as fair (IBI=29). Five of the eight species collected were white sucker, creek chub, yellow bullhead, brown bullhead, and green sunfish which are all considered tolerant.

Mill Run

The fish community of Mill Run was sampled near Cactus Valley RV park (RM 0.9). Community indices and narrative evaluations characterized the stream as marginally good (IBI=37). Salamanders were observed within the stream while electrofishing. Though nine species were collected, 86% of the population was comprised of white sucker, blacknose dace, creek chub, fathead minnow, bluntnose minnow and green sunfish, which are all considered tolerant.

Tributary to Olentangy River at RM 20.71

The fish community of this small Olentangy River tributary was sampled near Camp Lazarus (RM 0.2). Community indices and narrative evaluations described the fish community as very poor (IBI=16). Fish movement throughout the stream is impeded by several dams upstream and a waterfall downstream of the sampling location. This isolation results in low expectations of recruitment from other areas. Creek chub and bluegill were the only species of fish collected at the site.

Big Run (Tributary to Olentangy River at RM 18.19)

The fish community of Big Run was evaluated upstream of Taggert Road (RM 0.1). Community indices and narrative evaluations described the fish community as poor (IBI=27). Twelve species were collected, though the tolerant white sucker, blacknose dace, creek chub, bluntnose minnow, yellow bullhead and green sunfish comprised 72% of population. A failing on-site sewage treatment discharge was observed and contributed to the poor fish community found at the sampling location. Permitted package WWTPs operated by Olentangy Schools and located some distance upstream may also negatively influence the fish community at this point. Also, a moderately sized cascade was present just at the confluence with the Olentangy River thereby hindering recruitment.

Deep Run

The fish community of Deep Run was sampled near Owenfield Drive (RM 1.1). Community indices and narrative evaluations described the fish community as poor (IBI=22). Urbanization continues to alter the hydrologic regime of the stream’s watershed with increased polluted stormwater run-off and flashy flows. Only pollution tolerant fish species, blacknose dace, creek chub, and green sunfish, were collected.

Turkey Run

Electrofishing sampling was conducted along Turkey Run near Shattuck Avenue (RM 0.7). Nutrient enrichment from the surrounding residential lawns and upstream golf courses contributed to poor (IBI=20) fish community performance. Goldfish, blacknose dace, creek chub, and green sunfish, all highly tolerant, were the only species collected from the site.

Wahalla Hollow

The fish community of Wahalla Hollow was sampled adjacent to Walhalla Hollow Road (RM 0.9). Creek chubs were collected during one pass, but no fish were found during the second pass. The stream did not have sufficient habitat characteristics to support a fish community and was $<1mi^2$ in drainage, and is therefore considered a Primary Headwater Habitat stream. Similar to Glen Echo Ravine, the highly urbanized surrounding land use has altered the hydrology and resulted in poor water quality.

Glen Echo Ravine

The fish community of Glen Echo Ravine was sampled near Glen Echo Park (RM 1.0). Community indices and narrative evaluations characterized the stream as very poor (IBI=14). Only three fish species including, creek chub, green sunfish and bluegill sunfish were collected. The highly urbanized watershed surrounding Glen Echo has greatly diminished the water quality available to aquatic organisms and altered the hydrologic regime of the stream resulting in an impaired community.

Table 37. Common and moderately intolerant species collected in Lower Olentangy WAU. Sites in **bold** indicate an impounded site. Species in *italics* indicate the rare intolerant bluebreast darter or the special intolerant river redhorse. Values in ( ) indicate the total number of fish caught per both passes.

Site	Common Intolerant	Moderately Intolerant
Olentangy 32.1	Black redhorse (4)	Brook silverside (1) Golden redhorse (11) Longear sunfish (1) Silver redhorse (4) Smallmouth bass (10)
Olentangy 28.1	None	Longear sunfish (53) Smallmouth bass (6)
Olentangy 27.5	Banded darter (4) Brindled madtom (1) Stonecat madtom (2)	Golden redhorse (1) Logperch darter (6) Longear sunfish (29) Northern hog sucker (3) Smallmouth bass (42)
Olentangy 24.5*	Banded darter (25) Brindled madtom (1) Stonecat madtom (4)	Golden redhorse (8) Greenside darter (10) Logperch darter (19) Longear sunfish (14) Northern hog sucker (34) Rainbow darter (1) Sand shiner (6) Silver redhorse (3) Smallmouth bass (46)
Olentangy 19.4	Banded darter (11) Black redhorse (13) Stonecat madtom (24)	Golden redhorse (7) Greenside darter (1) Logperch darter (14) Longear sunfish (26) Northern hog sucker (15) Rainbow darter (1) Sand shiner (13) Silver redhorse (3) Smallmouth bass (61)
Olentangy 15.0	Banded darter (71) *Bluebreast darter* (17) Brindled madtom (8) Stonecat madtom (9)	Golden redhorse (1) Greenside darter (11) Logperch darter (5) Longear sunfish (51) Northern hog sucker (8) Rainbow darter (2) Sand shiner (43) Silver shiner (2) Smallmouth bass (40)

Olentangy 12.4	Banded darter (10) Black redhorse (37)	Golden redhorse (46) Greenside darter (2) Logperch darter (6) Longear sunfish (10) Northern hog sucker (29) Rainbow darter (3) Sand shiner (2) Silver redhorse (3) Silver shiner (25) Smallmouth bass (35)
Olentangy 7.8	Banded darter (33) Black redhorse (2) *Bluebreast darter* (1) Brindled madtom (4) Stonecat madtom (5)	Golden redhorse (16) Greenside darter (8) Logperch darter (3) Longear sunfish (15) Northern hog sucker (10) Rainbow darter (42) Rosefin shiner (2) Sand shiner (190) Silver redhorse (1) Smallmouth bass (118)
Olentangy 3.9	Banded darter (3) Black redhorse (39) *River redhorse* (3)	Brook silverside (2) Golden redhorse (45) Greenside darter (1) Logperch darter (31) Longear sunfish (70) Northern hog sucker (6) Rainbow darter (6) Sand shiner (13) Silver redhorse (5) Silver shiner (1) Smallmouth bass (9)
Olentangy 2.1	None	Brook silverside (2) Golden redhorse (9) Longear sunfish (146)
Olentangy 1.8	Banded darter (41) Black redhorse (4) Brindled madtom (1) River chub (179)	Golden redhorse (6) Greenside darter (3) Logperch darter (20) Northern hog sucker (21) Longear sunfish (4) Sand shiner (11) Silver redhorse (1) Smallmouth bass (36) Stonecat madtom (2)
Olentangy 0.9	Banded darter (1) Black redhorse (33) Brindled madtom (1) River chub (64)	Smallmouth bass (74) Golden redhorse (29) Longear sunfish (33) Brook silverside (2) Logperch darter (3) Northern hog sucker (15) Sand shiner (5)

* - Olentangy River 24.5 total is for three passes.

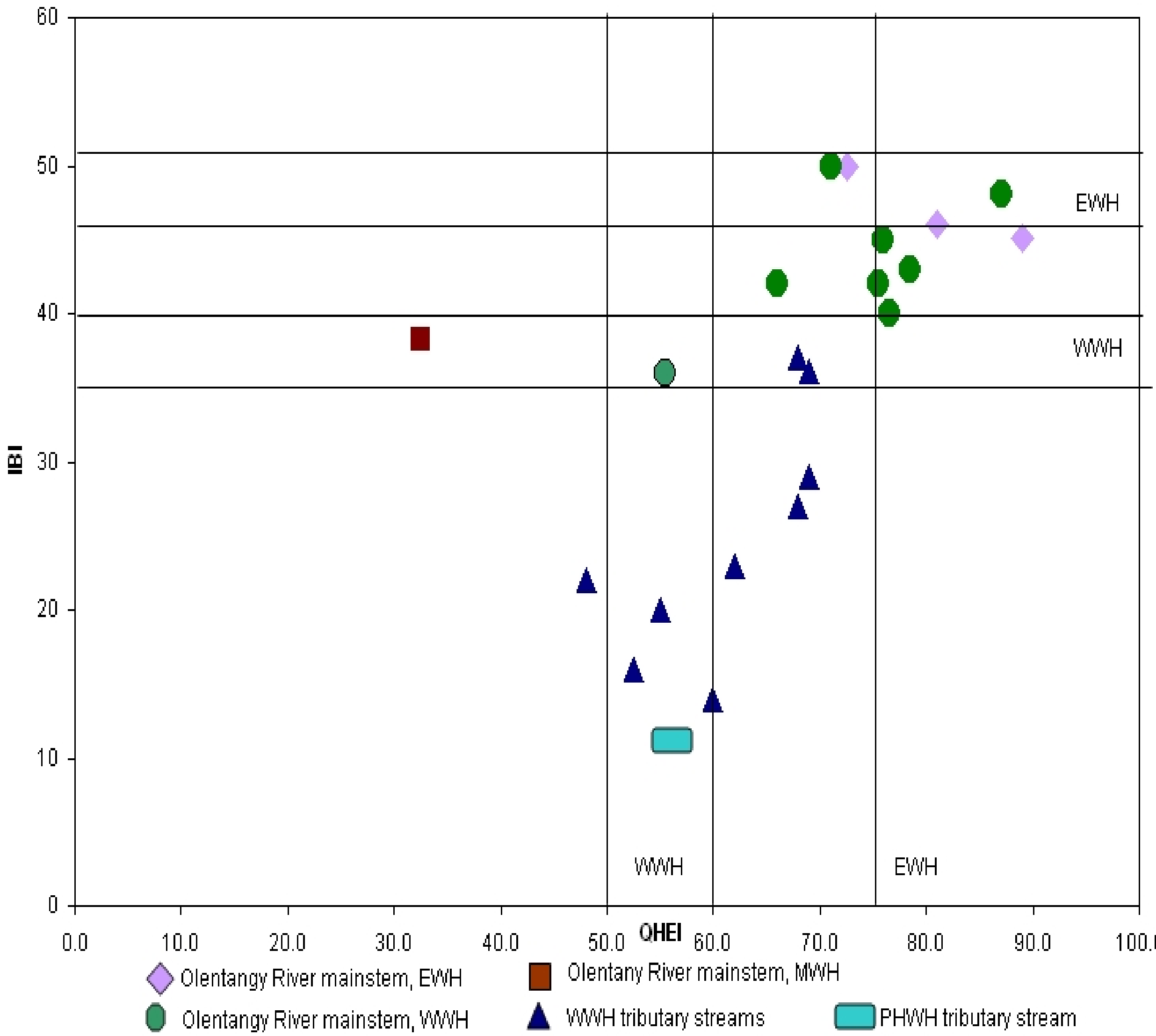


Figure 114. IBI versus QHEI for fish sampling locations throughout the LOWAU. Tributary site data is from 2003, mainstem site data is from 2004.

Biological Communities: Macroinvertebrates

Macroinvertebrate communities were evaluated at 16 stations in the LOWAU (Table 38). The community performance was assessed as exceptional at five stations, very good at one, good at two, fair at three, low fair at one, poor at three, and one station was considered a Primary Headwater Habitat stream (PHWH) with a poor invertebrate community. The station with the highest total EPT taxa richness was on the Olentangy River upstream from Hyatts Road (RM 19.5) with 28 taxa. The stations with the highest number of total sensitive taxa were on the Olentangy River downstream from Powell Road (RM 14.9) and downstream from the Olentangy Environmental Control Center (RM 13.2) with 41 taxa. Sensitive taxa found in this assessment unit which are not commonly collected include the mayfly *Serratella deficiens* in the Olentangy River (RMs 19.5, 14.9, 13.2), the stonefly *Agnetina capitata* complex in the Olentangy River (RMs 24.5, 19.5, 14.9, 13.2, 7.3, 4.0), the caddisflies *Hydropsyche venularis* in the Olentangy River (RMs 24.5, 19.5, 14.9, 13.2), *Macrostemum zebratum* in the Olentangy River (RMs 19.5, 14.9), and *Leucotrichia pictipes* in the Olentangy River (RMs 24.5, 19.5, 14.9), the midges *Nanocladius (Plecopteracoluthus) downesi* in the Olentangy River (RM 19.5), and *Polypedilum (Cerobregma) ontario* in the Olentangy River (RM 7.3), and the freshwater mussel *Ptychobranchus fasciolaris* (Kidney Shell) in the Olentangy River (RM 14.9).

The freshwater mussel (Unionidae) populations in the Olentangy River are on the decline. Hoggarth's 1989 study (1990) of the mussels upstream from Columbus found 21 species surviving in the river compared to 25 found in studies conducted in the 1950s and 1960s. Five species have become extirpated since the 1960s and one species (*Lasmigona complanata*) has extended its range into the river. An additional five species have been extirpated since pre-settlement times. One third of the mussel species in the Olentangy River have disappeared due to human activities in the basin and Hoggarth (1990) states that an additional three are on the verge of extirpation. This decline was attributed to increasing silt loads, impoundments, and channel modifications. In particular, many of the declining species generally live completely buried in the substrate and are therefore extremely sensitive to the suffocation and reduced feeding efficiencies caused by heavy silt deposition. The state endangered species Snuffbox (*Epioblasma triquetra*) and Rayed Bean (*Villosa fabalis*) were present in low numbers in the lower Olentangy River in 1989. The current study of the Olentangy River by the OHIO EPA was not designed or well suited to evaluate the condition of the mussel populations. Only seven species of mussels were found in the Olentangy River during this study.

The Olentangy River macroinvertebrate communities sampled in this assessment unit from Olentangy Avenue (RM 24.5) to Kenny Park (RM 7.3) were performing at an exceptional level (Table 38, Figure 115). The stations located in the WWH section were generally performing at a slightly higher level in terms of EPT and sensitive taxa diversity than the other stations. The two upstream stations in this section, Hyatt Road (RM 19.5) and Powell Road (RM 14.9), had the highest number of uncommonly collected sensitive taxa (6). The Delaware WWTP (RM 25.26) was not having a discernable impact on the community 0.76 mile downstream at Olentangy Avenue. The Olentangy Environmental

Control Center (RM 13.39) was not having a discernable impact on the community 0.19 mile downstream at RM 13.2, with the exception that the number of uncommonly collected sensitive taxa declined to three. The exceptional evaluation of the community at Kenny Park (RM 7.3) supports the extension of the State Scenic River designation downstream to at least this point. The invertebrate communities progressively decline downstream from Kenny Park into the good range, due to sanitary sewer overflows, urban runoff, and impoundments. The community located in the Fifth Avenue Dam pool was performing at a poor level due to impounded habitat conditions and poor water quality from sanitary sewer overflows and urban runoff.

The macroinvertebrate community in Mill Run (RM 0.7) was evaluated as poor. Low EPT and sensitive taxa diversity along with reduced presence of sensitive taxa and dominance of facultative and tolerant taxa were indications of community impairment. The collection station was located adjacent to a RV park in a rural area and may be impacted by poorly treated sanitary wastes.

The macroinvertebrate communities evaluated in the Tributary to Olentangy River (RM 20.71) ("Camp Lazarus Trib."), Tributary to Olentangy River (RM 18.19) ("Big Run"), and Deep Run were all demonstrating some level of impairment. All these streams flow through wooded ravines for much of their lengths. However, the areas around them are rapidly developing. A land owner adjacent to Deep Run said that the stream has become a lot more flashy since the nearby housing developments have gone in. Thick silt deposits were observed built up behind a small impoundment on Big Run. The invertebrate communities in these streams are likely impacted by increased flow variation, siltation, and stormwater runoff. A Class III (the highest category) Primary Headwater Habitat stream was sampled within the Camp Lazarus Trib. basin (reported elsewhere). This stream had sufficient groundwater recharge to support reproducing populations of indicator species of salamanders or at least three taxa of cool/coldwater macroinvertebrates.

Five Primary Headwater Habitat (PHWH) streams which are tributaries to the Tributary to Olentangy River (RM 18.19) ("Big Run") and located adjacent to and downstream from the proposed Olentangy Crossing housing development were evaluated using standard Ohio EPA methods on June 10 and 18, 2003. The results are presented in Table 39, community measures which classify a stream as Class III are in bold. The stations were numbered from 1 to 5 going north to south. All five streams qualify as Class III PHWH streams, the highest quality classification. Station 1 had the largest drainage area which is reflected in the higher Headwater Habitat Evaluation Index (HHEI) score and the more abundant two-lined salamander population. The remaining streams had small enough drainage areas to be considered rheocrenes (springs). In order to protect these high quality aquatic resources every effort should be made to protect the woody riparian of these streams, prevent construction related runoff from entering the streams, take steps to not interrupt the groundwater connection to the streams, and design storm water runoff areas to mitigate for both increased flow and impaired quality (including increased temperature).

The macroinvertebrate communities sampled from Turkey Run (RM 0.7), Wahalla Hollow Ravine (RM 1.0), and Glen Echo Ravine (RM 0.9) were all highly impacted by the surrounding urban areas. Restoration of these streams would probably require a complete rethinking of how storm water is handled in urban areas. Wahalla Hollow Ravine did not have sufficient habitat characteristics to support a fish community and has a drainage area less than one square mile so therefore is considered as a Primary Headwater Habitat stream (Table 25).

Table 38. Summary of macroinvertebrate data collected from artificial substrates (quantitative sampling) and natural substrates (qualitative sampling) in the lower Olentangy River study area, July to September, 2003.

Stream RM	Dr. Ar. (sq. mi.)	Data Codes	Qual. Taxa	EPT Ql. / Total	Sensitive Taxa Ql. / Total	Density Ql. / Qt.	Predominant Organisms on the Natural Substrates With Tolerance Category(ies) in Parentheses	ICI	Narrative Evaluation
Olentangy River (02-400)									
24.5	433	-	51	21 / 22	28 / 35	M / 752	Hydropsychid caddisflies (F,MI), midges (F,MI), *Petrophila* moth larvae (I)	50	Exceptional
19.5	455	-	64	26 / 28	35 / 39	M / 1409	Hydropsychid caddisflies (F,MI), *Petrophila* moth larvae (I), midges (F,MI)	50	Exceptional
14.9	483	-	65	24 / 26	37 / 41	M / 1238	Hydropsychid caddisflies (F,MI), *Petrophila* moth larvae (I), *Stenelmis* riffle beetles (F)	46	Exceptional
13.2	490	-	59	24 / 26	32 / 41	M / 1131	Hydropsychid caddisflies (F,MI), *Petrophila* moth larvae (I), *Stenelmis* riffle beetles (F)	50	Exceptional
7.3*	520	-	62	21 / 23	32 / 39	M / 750	Hydropsychid caddisflies (F,MI), midges (MI,F), *Petrophila* moth larvae (I), Baetid mayflies (F)	48	Exceptional
4.0*	535	-	53	20 / 22	22 / 32	M / 2594	Hydropsychid caddisflies (F,MI), midges (F,MI), Baetid mayflies (F,I), blackflies (F)	44	Very Good
2.1	540	2,8	28	1 / 5	5 / 7	L-M / 522	Midges (MT), damselflies (F), scuds (F)	10	Poor
1.8	540	-	53	15 / 18	23 / 28	M / 1189	Hydropsychid caddisflies (F,MI), midges (F,MI), *Petrophila* moth larvae (I)	40	Good
0.6	543	-	46	16 / 17	19 / 23	M-H / 2145	Hydropsychid caddisflies (F,MI), *Stenelmis* riffle beetles (F), *Petrophila* moth larvae (I)	40	Good
Mill Run (02-408)									
0.7	1.8	-	36	2	7	Moderate	Aquatic sow bugs (F), midges (F,T,MI), flatworms (F)	-	Poor

Stream RM	Dr. Ar. (sq. mi.)	Data Codes	Qual. Taxa	EPT Ql. / Total	Sensitive Taxa Ql. / Total	Density Ql. / Qt.	Predominant Organisms on the Natural Substrates With Tolerance Category(ies) in Parentheses	ICI	Narrative Evaluation
Trib. to Olentangy R. (RM 20.71) ("Camp Lazarus Trib.") (02-468)									
0.1	2.4	-	34	11	11	L-M	Hydropsychid caddisflies (F), water penny beetles (MI)	-	Marg. Good
Trib. to Olentangy R. (RM 18.19) ("Big Run") (02-437)									
0.1	5.7	-	43	8	13	Moderate	Blackflies (F), flatworms (F), midges (F,MI)	-	Fair
Deep Run (02-405)									
0.5	0.6	-	25	7	7	L-M	Blackflies (F), midges (F,MT), baetid mayflies (F), hydropsychid caddisflies (F)	-	Fair
Turkey Run (02-402)									
0.7	2.3	-	30	4	5	Moderate	Midges (F,MT,T)	-	Low Fair
Wahalla Hollow Ravine Trib. (02-439)									
1.0	0.4	29	8	0	0	L-M	Midges (F)	-	Poor
Glen Echo Ravine Trib. (02-465)									
0.9	0.5	-	21	2	0	M	Midges (T,MT,F), flatworms (F)	-	Poor

RM: River Mile.
Dr. Ar.: Drainage Area
Data Codes: 2=Dam Pool, 8=Non-Detectable Current, 29=Primary Headwater Habitat Stream.
Ql.: Qualitative sample collected from the natural substrates.
Sensitive Taxa: Taxa listed on the Ohio EPA Macroinvertebrate Taxa List as MI (moderately intolerant) or I (intolerant).
Qt.: Quantitative sample collected on Hester-Dendy artificial substrates, density is expressed in organisms per square foot.
Qualitative sample relative density: L=Low, M=Moderate, H=High.
Tolerance Categories: VT=Very Tolerant, T=Tolerant, MT=Moderately Tolerant, F=Facultative, MI=Moderately Intolerant, I=Intolerant
* 2004 sample

Table 39. Summary of biological and habitat information for Primary Headwater Habitat streams in the “Big Run” basin, 2003.

Community Measure	**Station Number**				
	1	**2**	**3**	**4**	**5**
No. macroinvertebrate taxa	22	16	7	17	20
No. EPT taxa	6	7	2	8	8
No. cool/cold water taxa	2	**7**	**4**	**9**	**8**
HMFEI	**30**	**30**	9	**29**	**28**
No. two-lined salamander larvae	**13+**	**2**	**1** (observed)	0	0
No. two-lined salamander adults	1	1	1 (observed)	0	0
HHEI	79	67	67	56	57
Drainage area at collection site (sq. mi)	0.3	≤0.1	≤0.1	≤0.1	≤0.1

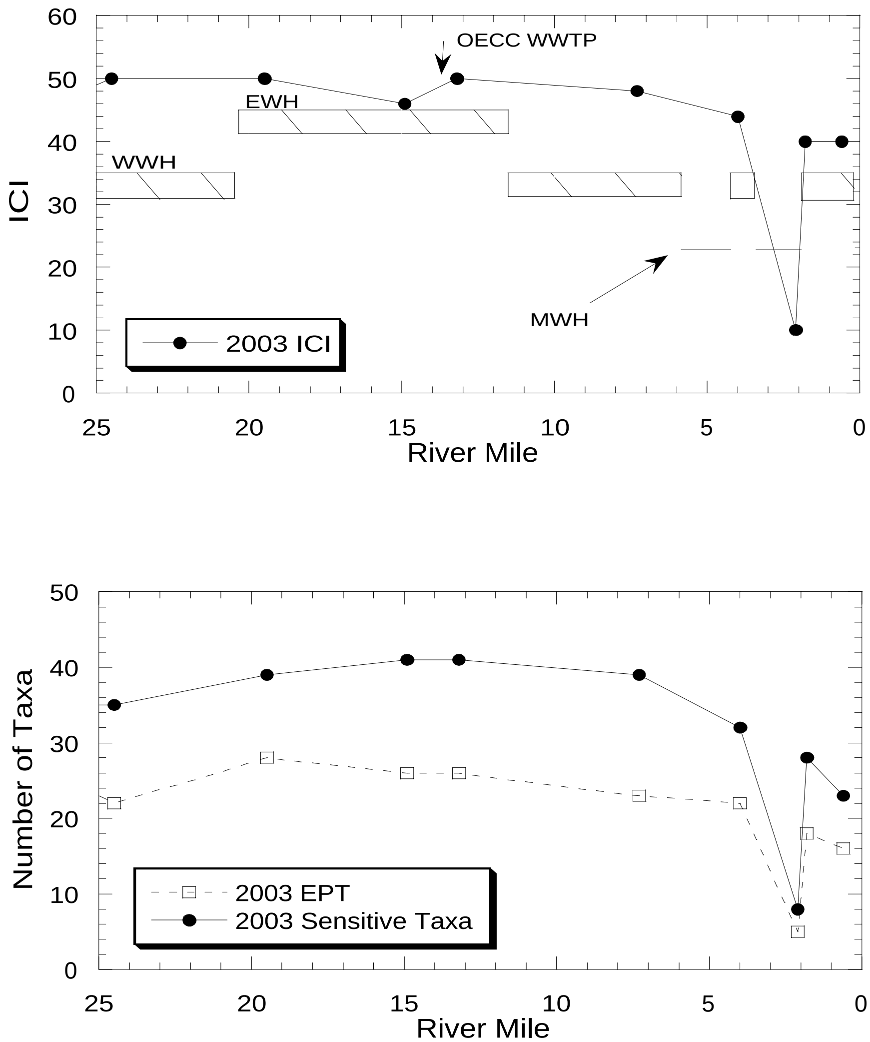


Figure 115. Longitudinal trend of the Invertebrate Community Index (ICI), total EPT, and total sensitive taxa in the lower Olentangy River, 2003. Stations RM 7.3 and 4.0 were collected in 2004.

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