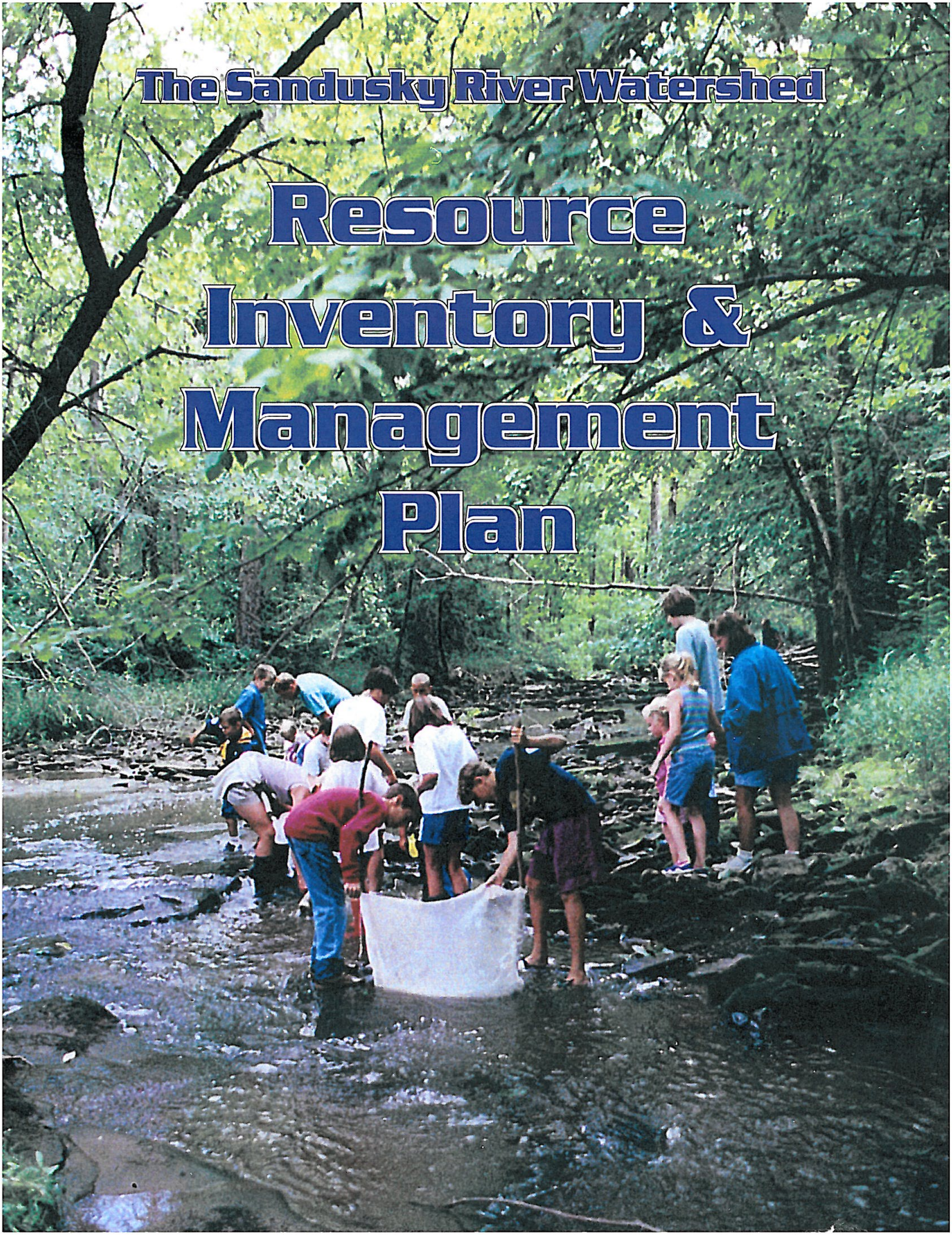
The Sandusky River Watershed

Resource Inventory & Management Plan



The Sandusky River Watershed:
Resource Inventory and Management Plan

The Sandusky River Watershed Coalition
Steering Committee

David B. Baker, Lead Author and Compiler
Monica Ostrand, Watershed Coordinator

The Sandusky River Watershed Coalition
219 South Front Street
P.O. Box 590
Fremont, Ohio 43420

Telephone 419/334-5016

February 2000 (Resource Inventory)
June 2001 (Management Plan)
November 2001 (Additions)

November 2001

Credits

This Resource Inventory was prepared in partial fulfillment of a grant from the Ohio EPA to the Sandusky River Watershed Coalition to implement the watershed planning program outlined in the Ohio EPA publication *"A Guide to Developing Local Watershed Action Plans in Ohio."* This Ohio EPA grant primarily covered purchase of educational materials, publication costs, office supplies, and secretarial help for the Coalition. The help of Katie McKibben of the Northwest Division of the Ohio EPA is appreciated.

Support for the preparation of this inventory came primarily from a grant from the USDA Cooperative State Research, Education, and Extension Service (CSREES) to Ohio State University, Heidelberg College, and Case Western Reserve University. This USDA grant included the provision of technical support to the Coalition by staff of the Water Quality Laboratory (WQL) at Heidelberg College. This support included provision of geographical information system services to the Coalition by the WQL's Jack Kramer and Nancy Miller, as well as considerable writing time to the lead author. This USDA grant, entitled the Lake Erie Agricultural Systems for Environmental Quality (LEASEQ) project, also produced several of the data summaries used in the Resource Inventory.

A major factor in helping to advance progress on the Resource Inventory, and its use in the development of the Sandusky Watershed Action Plan, has been the recent hiring of a Watershed Coordinator for the Sandusky River Watershed Coalition. This position is currently funded by a grant from the Ohio Lake Erie Protection Fund to the Sandusky River Watershed Coalition, through the offices of the WSOS Community Action Commission, Inc. in Fremont, Ohio.

By its nature, this inventory includes a compilation of data and information from many sources. These include the Ohio EPA, the Ohio Department of Natural Resources, the Toledo Metropolitan Area Council of Governments, The Ohio State University Extension Service, the Water Quality Laboratory of Heidelberg College, the Natural Resource Conservation Service, the U.S. Geological Survey, and the U. S. EPA. Much of the material is available on the internet and WWW addresses are noted throughout the text.

This inventory could not have been completed without the voluntary efforts of the members of the Coalition's Steering Committee. These include Becky Duncan, Kurt Erichsen, Russ Gibson, Clark Hutson, Ann Keefe, Ed McConoughey, Scott Miller, Monica Ostrand, and Julie Ward.

Credits for Revisions through November 2001

The development of the Management Plan for the Sandusky River Watershed was supported by Grant #99-04, "Watershed Planning and Implementation for the Sandusky River Watershed," from the Ohio Lake Erie Protection Fund. The Lake Erie Protection Fund also supported the extension of the data bases in the appendix to include 11-digit watersheds draining directly into Sandusky Bay and the printing of additional copies of the Resource Inventory and Management Plan.

Numerous partners of the Coalition have contributed time, energy and other resources to the development of the committee action plans. We would like to give special recognition to the committee chairpersons for taking lead responsibility for working with the diverse interests of their committees to produce the items in the action plans. Those individuals are Becky Duncan, Natural Resources Conservation Service; Brad Borer, Tiffin Water Pollution Control Center; David Little, Ohio American Water Co.; David Baker, Heidelberg College; Ann Keefe, Seneca County Soil and Water Conservation Service; and David Wolfe, Wyandot Dolomite.

Preface

The Steering Committee of the Sandusky River Watershed Coalition considers this Resource Inventory to be a "working document." Consequently, we have chosen a three ring binder format, so that chapter contents can be updated and new materials added, as they become available. To receive these updates and new materials, it is necessary that the Coalition office have the names and addresses of those individuals and organizations that have received copies of the document. Thus, we ask recipients to write down their names and addresses at the time they pick up copies of the inventory. If you are unsure whether your name is on the list to receive updates, please contact the Coalition office at 419/334-5016.

As a working document, we welcome comments and questions regarding the inventory, as well as new contributions. These comments, questions and contributions should be directed to the Sandusky Watershed Coordinator, 219 S. Front Street, P.O. Box 590, Fremont, OH 43420 (Fax 419/334-5124 or e-mail monica_ostrand@hotmail.com).

The purpose of this Resource Inventory is to provide basic information regarding the water resources of the Sandusky Watershed and the factors that affect those resources. The target audiences for the Inventory are the many individuals, organizations and agencies concerned with the current and future quality of the water resources in the Sandusky Watershed. Through sets of public meetings in each of the subwatersheds of the Sandusky Watershed, an action plan will be developed that will provide a map for addressing both local subwatershed issues as well as issues common to the entire watershed.

An unusually large amount of water resource information is available for the Sandusky Watershed. It is the hope of the Steering Committee and the authors of this inventory that this information can support the implementation of efficient and effective water resource protection and improvement programs throughout the Sandusky Watershed.

David Baker (Lead Author and Compiler)
Water Quality Laboratory
Heidelberg College
Tiffin, Ohio 44883

Preface to the Management Plan and Additions through November 2001

After completion of the Sandusky River Watershed Resource Inventory in February 2000, the Coalition proceeded to develop a Management Plan for the Watershed. Because of the close linkages between the Management Plan and the earlier Resource Inventory, the Steering Committee decided to merge them into a single document -- The Sandusky River Watershed: Resource Inventory and Management Plan. Our earlier decision to publish the Resource Inventory in a three-ring binder format facilitated this action. The Management Plan is Chapter 11 of the combined publication. The procedures used in the development of the Management Plan are outlined in the initial pages of Chapter 11.

The addition of the Management Plan, the change in the title of the publication, and the addition of several new portions to other parts of the Inventory and Appendices have required changes to the title pages, the Table of Contents, the List of Appendices. These additions and replacement pages are being distributed to holders of the original Resource Inventory and will be incorporated into subsequent publication of additional copies of the combined document. So that users of the publication can keep abreast of these changes, publication dates are being added to the bottom of all new pages for the document. In addition, a running list of Additions and Revisions to the publication is being distributed so that readers can quickly determine if their copy is up-to-date relative to the master copy at the Coalition offices.

The Steering Committee and Watershed Coordinator of the Sandusky River Watershed Coalition welcome comments and suggestions regarding the Resource Inventory and Management Plan. Information for contacting the Coalition, its Steering Committee, Coordinator, and Committees may be found at the Coalition's website – www.riverwatershed.org.

David Baker (Lead Author and Compiler)
Steering Committee
Sandusky River Watershed Coalition

1	*Introduction*
2	*Land Resources*
3	*Water Resources*
4	*Biological Resources*
5	*Aquatic Life Use Attainment*
6	*Water Supply Use Attainment*
7	*Recreational Use Attainment*
8	*Pollutant Loading to Lake Erie*
9	*Point Sources of Pollutants*
10	*Nonpoint Sources of Pollutants*
11	*Management Plan*
12	*Appendices*

November 2001

Chapter 1 – Introduction

Water is essential to all life and the quality of our water affects the quality of our life. None of us wants to live where drinking water is unhealthy or tastes bad. Nor do we want to live where streams, rivers and lakes are befouled with wastes, devoid of fish or unsafe for recreational use. Instead, we want attractive streams and lakes that provide safe drinking water, support diverse populations of fish and wildlife, and offer safe and enjoyable recreational opportunities.

Many essential human activities, such as manufacturing, food production, commerce, travel, and simply the "business of living" can and do adversely impact the quality of our water resources. While much progress has been made in reducing adverse water quality impacts of these essential activities, much remains to be done. We also recognize that current and future programs for water quality improvement must be both effective and efficient.

While few would argue with the generalities stated in the previous two paragraphs, such generalities do not provide useful information that supports initiation of specific steps to improve water quality in any particular location. To be effective and efficient, water quality improvement programs must offer implementable, site-specific solutions to site-specific problems. For a variety of reasons that have become apparent in recent years, these site-specific solutions to site-specific problems must also be integrated at the watershed level.

Within the Sandusky River Watershed, a group of concerned individuals, many of whom have jobs that are either affected by water quality or involve efforts to improve water quality, have formed an organization named **The Sandusky River Watershed Coalition.** One of the objectives of the coalition is to develop an integrated **Watershed Action Plan** for the Sandusky River Watershed. Ideally, the action plan will contain an outline of site-specific solutions for site-specific problems, that, when taken together, will address water quality concerns throughout the Sandusky Watershed. To be implementable, the solutions must be practical and have broad stakeholder support in the watershed. The coalition has received a grant from the Ohio Environmental Protection Agency to "test" a procedure that the agency has developed for aiding local groups in the development of watershed action plans. This procedure is detailed in the Ohio Environmental Protection Agency's 1997 publication entitled *A Guide to Developing Local Watershed Action Plans in Ohio* (Ohio EPA, 1997).

The steps for developing a watershed action plan suggested by the Ohio EPA are summarized in Figure 1.3 of their guide, which is reproduced in its entirety as Figure 1.1 in this report. This report, entitled the *Sandusky River Watershed Resource Inventory*, addresses information needs indicated in the two shaded circles of Figure 1.1. These are the circles entitled "Create an Inventory of the Watershed" and the "Define the Problems".

Conceptual Frameworks for Water Quality Problems and Programs

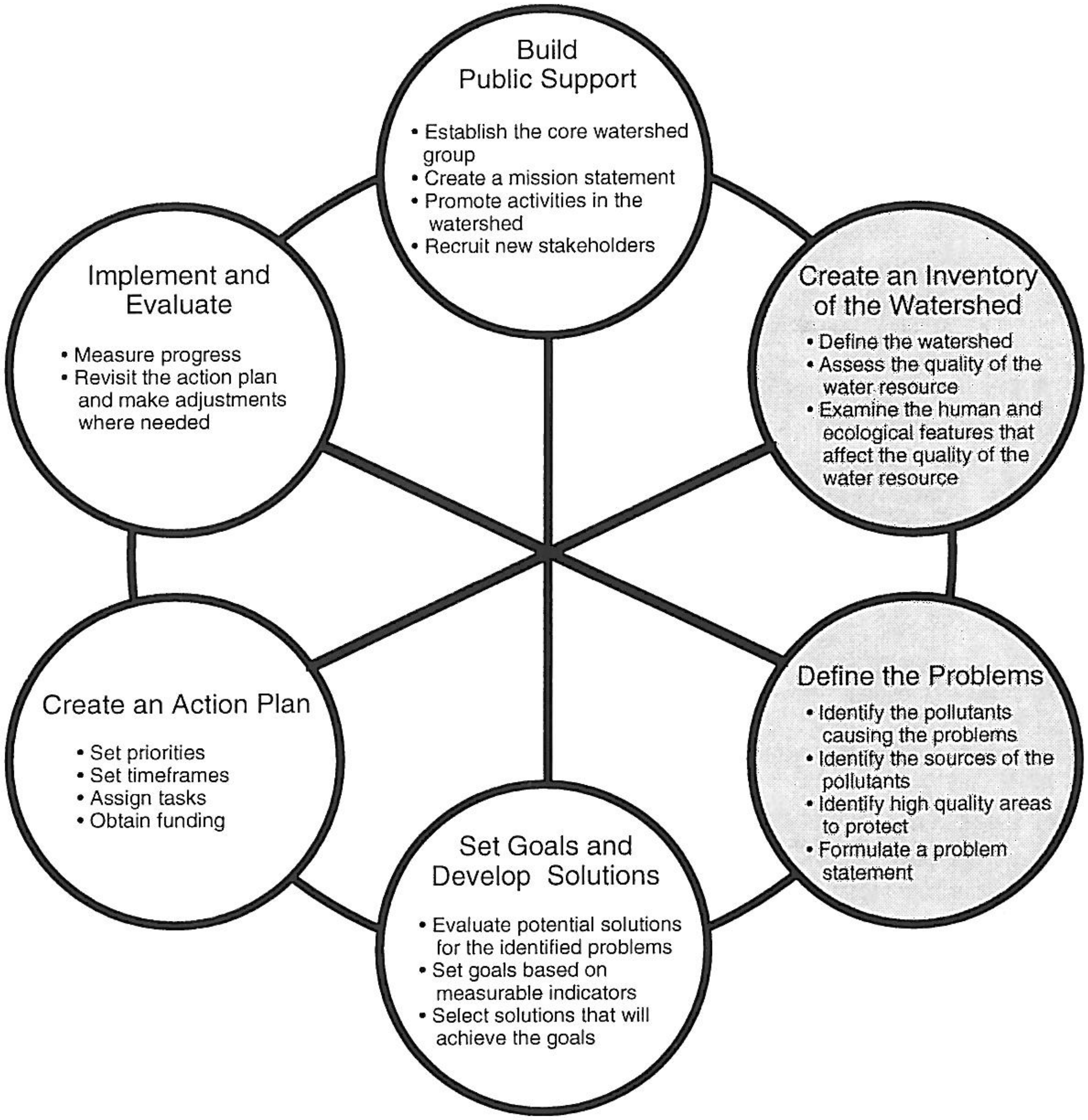
Before plunging into the many details contained in subsequent chapters of this inventory, it is useful to consider some of the major organizing principles and concepts of current water quality assessments and programs.

1. Ambient Water Quality versus Watershed Loading

Water quality improvement programs can focus on improving the water quality in the streams, rivers, and lakes contained within a watershed. The water quality in streams, rivers, and lakes is referred to as **ambient water quality (Figure 1.2)**. Ambient water quality is typically measured in terms of the concentrations (amount per volume) of various pollutants or the quality of biological communities at specific locations in streams, rivers or lakes. For example, the nitrate concentrations in milligrams of nitrate per liter of water at the location of a drinking water intake or the fecal coliform bacterial concentrations in numbers of bacteria per 100 milliliters of water at a bathing beach reflect ambient water quality. The status of the biological community in a particular segment of a stream system would also be a reflection of ambient water quality.

Water quality improvement programs can also focus on reducing the amounts of pollutants exported from a watershed into a receiving body of water, such as a lake or estuary (Figure 1.2). The amount of pollutants exported from a watershed is referred to as **watershed loading.** Loading is typically reported in terms of amounts of pollutant exported per unit of time. For example, the phosphorus or sediment loading from the Sandusky River Watershed into Sandusky Bay would be reported as tons per year. The term pollutant loading is also used to describe the amounts of pollutants entering streams or lakes from various point and nonpoint sources, such as municipal or industrial treatment plants or farmland runoff.

Pollutant loading is important because it does affect ambient water quality in receiving waters. Distinctions between ambient water quality and watershed loading are particularly important when assessing the relative contributions of point and nonpoint sources to water quality problems. For the same pollutant in a single watershed, nonpoint sources may be more important relative to watershed loading while point sources may be more important relative to ambient water quality within the watershed. For example, agricultural runoff is the major source of phosphorus relative to phosphorus loading from the Sandusky River Watershed into Lake Erie, while point sources are largely responsible



Watershed groups often start at the top of the wheel by building public support and then move clockwise. A group is likely to travel around the wheel several times, with each cycle building upon the information and experience gained previously. The "spokes" connecting each step to the center illustrate that the process does not always proceed in one direction, and that the steps are interrelated. Information gained at one step may lead the group to move to another step in the process. For example, information gained during the inventory step may lead the group back to seeking new stakeholders.

Figure 1.1 Components in the development of a watershed action plan (adapted from Figure 1.3 in OEPA's *Guide to Developing Local Watershed Action Plans in Ohio*).

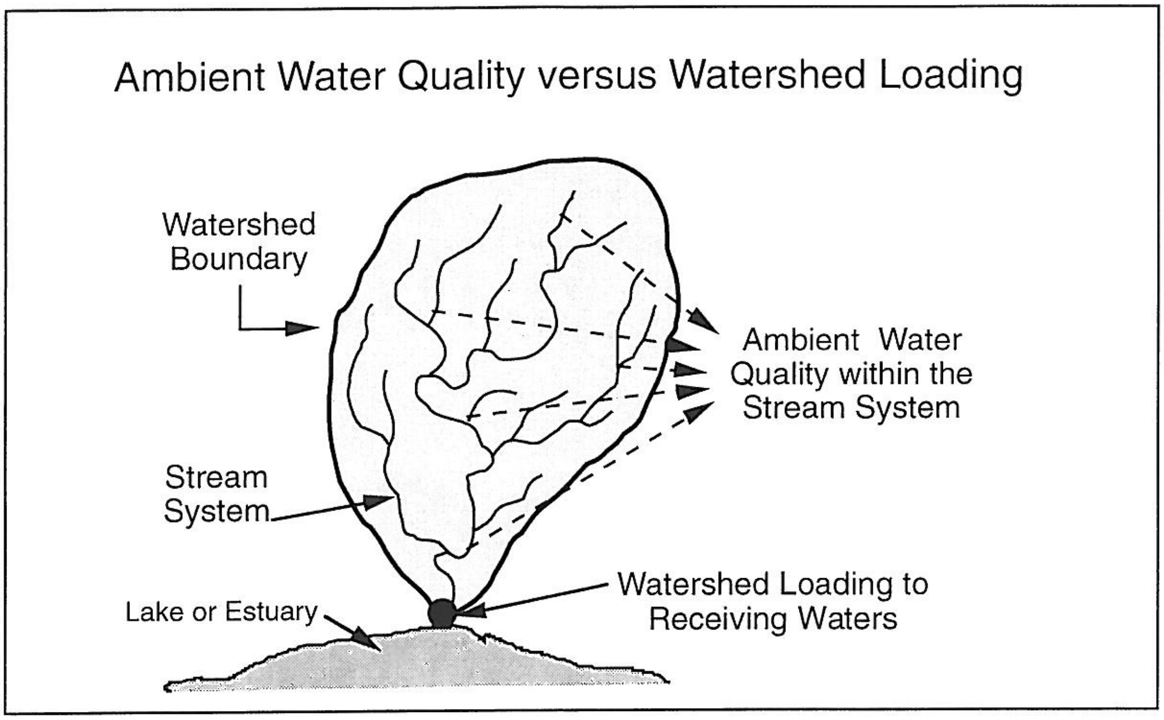


Figure 1.2 Ambient water quality versus watershed loading

for ambient water quality problems associated with elevated phosphorus concentrations in the streams of the Sandusky Watershed. This can happen because most of the phosphorus loading from the Sandusky Watershed into Lake Erie occurs during periods of high stream flow associated with surface runoff from agricultural lands. These periods of high stream flow occupy relatively short durations of time. Ambient water quality problems from phosphorus primarily occur during periods of low stream flow when point sources are the primary source of phosphorus entering the stream. These periods of low flow extend for much longer durations of time than the durations of high flow that dominate watershed loading.

2. Habitat Effects Versus Pollutant Concentration Effects

When the aquatic life present within a stream segment is impaired, it is important to recognize that the causes of the impairment can extend well beyond the simple presence of chemical pollutants in the stream. There has been so much attention focused on the identification and control of chemical pollutants that when aquatic communities are impaired, we tend to automatically assume that some chemical pollutant must be responsible. However, the Ohio EPA has concluded that limitations imposed by physical habitat in streams are now more often the causes of impaired stream communities than are chemical pollutants.

Human land use activities have often adversely affected the physical habitat within streams. Flow alterations, siltation, removal of riparian vegetation, channel modifications, and dam construction can all adversely impact stream habitat. Many natural features of the landscape through which the stream flows also affect the physical habitat. Stream bottom substrates, stream gradients and stream flow volumes are important aspects of stream habitat that affect aquatic communities. Programs aimed at improving stream habitats must take into account natural factors that may limit the quality of aquatic communities present in a stream. Programs to improve stream habitat can differ markedly from programs aimed at reducing chemical pollutant inputs into streams.

3. Point Sources Versus Nonpoint Sources of Pollutants

The sources of pollutants can be classified into two major categories – point sources and nonpoint sources (Figure 1.3). Point sources of pollution are typically associated with **water use** by municipalities or industries. Water is withdrawn from surface or groundwater sources and treated as necessary to support a particular use. For public water supplies, the treated water is then distributed to our homes and businesses where various types of human and household wastes are added to the water. Ideally, the water is then collected by sewer systems and delivered to municipal waste treatment plants where various pollutants are removed. The treated wastewater is released back into surface waters through pipes, with the point where the pipe empties into the stream referred to as an outfall or **municipal point source**. Since not all of the wastes are removed by the treatment plants, these pipes represent specific sources of pollutants that enter streams or lakes. Similar wastewater collection systems, treatment, and release through pipes occur for industrial water users, resulting in **industrial point sources**.

Much progress has been made in controlling pollution from point sources. Pollutant loading from point sources has been reduced considerably by improving sewage and waste collection systems and by improving treatment at waste treatment plants. Even so, point sources of pollutants still adversely impact water resources. Since water use by municipalities and industries is relatively constant from day to day, pollutant loading from point sources is also relatively constant. However, the impacts on streams which receive these wastes varies considerably, depending on variations in stream flow at the discharge point. As stream flow decreases, there is less water present to dilute the pollutants from the point sources. Consequently, for point sources, pollutant concentrations increase as stream flow decreases.

Another important characteristic of point sources is that point source loading can be measured rather easily. Consequently, the effectiveness of investments to reduce point source pollutant loading can be readily determined. Most governmental investments in pollution control have focused on reductions of pollutant loading from point sources.

While point sources of pollution are associated with water use, nonpoint sources of pollution are associated with **land use** (Figure 1.3). In particular, nonpoint pollution is associated with the interaction of the hydrological cycle and land uses. As part of the hydrological cycle, rain falls across landscapes. Portions of the rainfall infiltrate into soils and portions of that infiltrated water recharge groundwater aquifers. Other portions

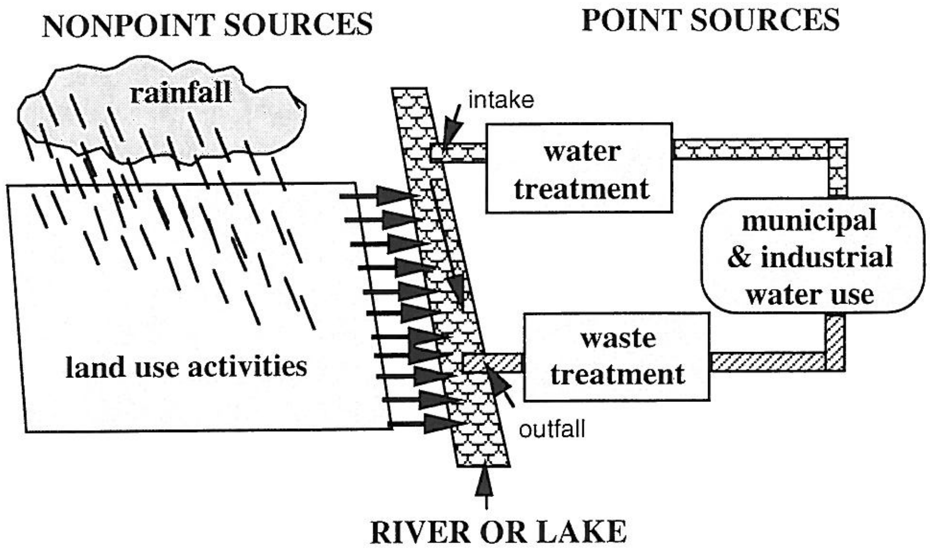


Figure 1.3 Comparison of point and nonpoint sources of pollutants

of the rainwater contribute to surface runoff, which moves water from land surfaces directly into streams, rivers and lakes. Since water is an excellent solvent, water infiltrating through the soil, as well as water flowing over land surfaces, dissolves soluble chemicals associated with each land use. These dissolved chemicals follow the pathways of water as it infiltrates into the soil or runs off the land surfaces. Because water is relatively dense, it also erodes soil particles and other particulate matter, carrying these particles into streams, rivers and lakes. Many of the chemicals that follow water through the hydrological cycle act as pollutants and degrade water quality. As rain falls through the atmosphere, it picks up chemicals that can act as pollutants when they reach surface or ground waters.

Particular land uses often present characteristic sets of chemicals that act as nonpoint source pollutants. For example, agricultural land use often includes applications of fertilizers and pesticides, many of which can move into groundwater or surface waters. Roads and parking lots often accumulate salts used for ice control or oils and breakdown materials from tires and fuels. These too can move into streams and lakes as nonpoint pollutants. Some chemicals, such as nitrates and phosphorus, enter streams from a variety of land uses, as well as from point sources.

Quantitative measurements of nonpoint sources of pollution are very difficult, because, unlike point sources, they enter surface waters all along the banks of streams and shores of lakes. Because of this, a watershed approach must be used to measure nonpoint sources of pollution (Figure 1.4), especially as it relates to watershed loading. The total export of a pollutant from a watershed is measured, and any point source contributions of that pollutant within the watershed is subtracted from the total export to determine the nonpoint source contributions.

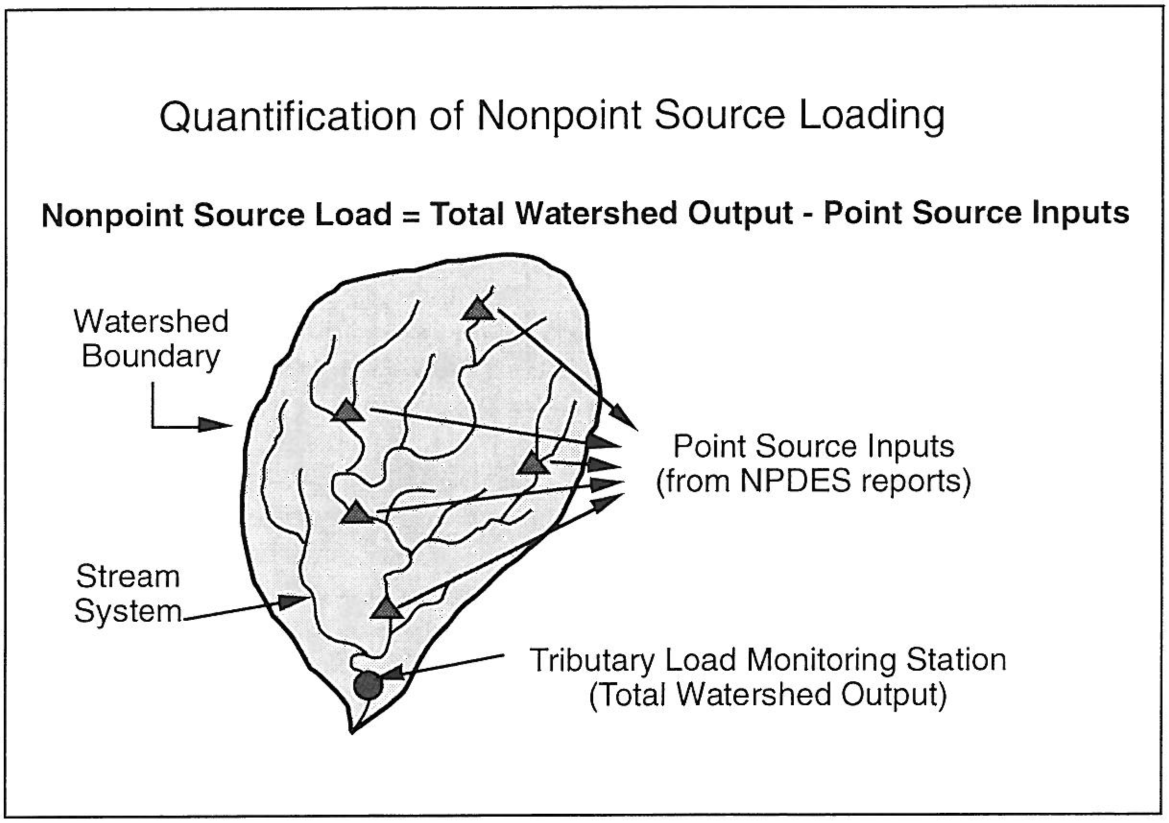


Figure 1.4 Use of watershed approach to quantify nonpoint source contributions to total watershed loading.

There are two important characteristics of nonpoint source pollution that are distinct from point sources. First, nonpoint sources are highly variable from day to day, month to month and year to year. This variability is associated with variations in the amounts, intensities and forms of precipitation. Second, the concentrations of pollutants from nonpoint sources usually increase as stream flow increases, since it is the storm runoff water that carries the nonpoint pollutants into stream systems.

The terms point and nonpoint source pollution are also applied to groundwater contamination, although for groundwater, these terms have different meanings than for surface water. Nonpoint sources of groundwater contamination would occur over large areas of the landscape, in recharge areas for the aquifer. Thus, movement into the groundwater of fertilizers or pesticides that are applied to large fields is an example of nonpoint contamination. Point sources of groundwater contamination are associated with concentrated sources, such as leaking underground storage tanks, landfills, or toxic waste disposal sites. For groundwater contamination, movement of materials from either point or nonpoint sources is associated with the movement of water through the hydrological cycle.

In terms of adverse impacts on water quality, nonpoint sources of pollution are now thought to be more important than point sources.

4. Improved Management of Existing Land Uses Versus Changes in Land Use

Nonpoint source pollution links land use activities on both private and public lands to publicly owned water resources, such as streams, rivers, lakes and groundwater. Consequently, reductions in nonpoint source pollution generally involve modifications of land use activities on both private and public lands. Most land use activities are associated with essential human activities, such as food production, forestry, transportation, housing, business, industry and recreation. For each of these activities, sets of "best management practices" (BMPs) have been developed which allow a continuation of the existing land uses while minimizing the generation of nonpoint pollutants. Thus, one approach to reducing nonpoint sources of pollution is to improve the management of existing land uses through adoption of appropriate BMPs. For example, the production of corn using reduced tillage, nutrient management, and integrated pest management results in reductions of nonpoint source pollution.

In other cases, reduction of nonpoint sources of pollution can involve changes in land use. For example, conversions of portions of cropland to riparian buffer strips or wetlands can reduce agricultural nonpoint source pollution. Since urban lands often generate more nonpoint pollution per unit area than agricultural lands, prevention of urban sprawl into farmland can prevent increases in nonpoint sources of pollutants.

Since all private and public lands can contribute to nonpoint source pollution, effective reduction of nonpoint pollution must involve cooperation and participation of many individuals and organizations. Addressing nonpoint sources of pollution represent the current "frontier" in water resource management.

Data Sources in the Sandusky River Watershed Resource Inventory

The Ohio EPA Guide for developing watershed action plans describes many sources of data from governmental agencies that can be used for developing watershed resource inventories. These governmental sources have been used for this inventory.

An unusual feature of the Sandusky River Watershed is the extent of university/college research that has also occurred in this watershed. In 1975, Heidelberg College and Bowling Green State University co-sponsored the Sandusky River Basin Symposium, which sought to summarize much of the then existing research in the Sandusky Watershed. The International Joint Commission published the Proceedings of the Sandusky River Basin Symposium as part of the studies of the International Reference Group On Great Lakes Pollution From Land Use Activities (Baker, Jackson and Prater, 1975).

Following the symposium, the Water Quality Laboratory (WQL) at Heidelberg College initiated detailed studies of nutrient and sediment export by the Sandusky River and several of its major tributaries. In the early 1980s, pesticide monitoring was added to the loading studies. These monitoring programs continue through the present, making up one of the most detailed tributary loading data bases available in the United States for the study of agricultural nonpoint pollution and its control. The WQL also received funding to expand the tributary loading studies to other Lake Erie tributaries, including the Maumee, Cuyahoga and Grand rivers. In 1996, funding became available to launch tributary loading studies to major Ohio tributaries to the Ohio River, including the Muskingum, Scioto and Great Miami rivers. These parallel studies in other Ohio watersheds allow inclusion of comparative approaches in this inventory.

Financial support for these tributary loading studies has come from many sources over the years, including the Army Corps of Engineers, the U. S. EPA, the U. S. Department of Agriculture, the State of Ohio, and various pesticide and detergent producers.

In collecting the data for calculating tributary loads of sediments, nutrients and pesticides, the WQL automatically develops detailed concentration data for storm runoff periods. Thus the data characterize not only tributary loading, but also ambient water quality during storms when the concentrations of pollutants from nonpoint sources are at the highest levels. Such data is seldom available for watershed inventories.

In 1995, Heidelberg College, The Ohio State University and Case Western Reserve University received a major grant from the U. S. Department of Agriculture to assess the effectiveness of agricultural pollution abatement programs in the Lake Erie Basin. This provided WQL staff and opportunity to conduct a thorough review of the historical data for the Sandusky Watershed, as well as to conduct detailed trend studies. As part of the research effort, a variety of geographical information system layers were also developed. Much of the information and assessments completed as part of the USDA grant has been incorporated into this resource inventory. In fact, the USDA grant included funding for WQL staff to support the Sandusky River Watershed Coalition in the preparation of the Resource Inventory.

It is the hope of the Sandusky River Watershed Coalition that, by including data from the above research programs, as well as data from the normal governmental sources, that this Resource Inventory will support the development of an unusually implementable, efficient, and effective management plan for the Sandusky Watershed.

References

Baker, D. B., W. B. Jackson, and B. L. Prater, editors. 1975. *Proceedings of the Sandusky River Basin Symposium.* International Joint C ommission, Windsor, Ontario. 474 pages.

Ohio EPA, 1997. *A Guide to Developing Local Watershed Action Plans in Ohio.* Ohio Environmental Protection Agency, Div. of Surface Water, Columbus, Ohio. 79 pages.

Chapter 2 - Land Resources

Watersheds and Hydrological Units

For purposes of assessing and managing water resources, it is becoming more and more common to organize land areas into watersheds. A watershed is composed of all of the land area that drains to a particular location on a stream or river system. The recent emphasis on watersheds stems from the recognition that land runoff is an important source of pollutants that can impair water resources. At a particular location on a stream or river system, its watershed boundaries define the land area from which these so-called "nonpoint" pollutants may originate.

Watershed boundaries can be determined for any point in a drainage network, such as for the Sandusky River drainage where the river moves from Crawford County into Wyandot County or from Wyandot County into Sandusky County. Consequently, there are an infinite number of possible watersheds and watershed areas. To facilitate watershed studies and water resource planning, the land area of the United States has been divided into specific watersheds, which are referred to as hydrological units. Each hydrological unit has a specific code number, with the number of digits in the code reflecting the level of subdivision of the land (see Table 2.1).

The Sandusky River Watershed is located within the Great Lakes Region, one of 21 specific hydrologic regions in the United States. Each region has a 2-digit code. The code for the Great Lakes region is 04. The Great Lakes Region is divided into 15 sub-regions, each of which has a 4-digit code. The Sandusky River is located in the Western Lake Erie Subregion, which has the code 0410. The Western Lake Erie Subregion contains only a single accounting unit, Western Lake Erie, which has the 6-digit code 041000.

The Western Lake Erie Accounting Unit is divided into 12 cataloging units. All of the lands that drain into Sandusky Bay make up the Sandusky Cataloging Unit. The Sandusky Cataloging Unit has the 8- digit code 04100011. A map of the Sandusky Hydrologic Unit is shown in Figure 2.1. In the watershed cataloging system, two units are added to the code for each level of subdivision from hydrologic region to cataloging unit.

The Sandusky Hydrologic Unit is subdivided into fourteen 11-digit hydrologic units. For the 11-digit hydrological units, three digits are added to the 8-digit cataloging unit codes. Eleven of these units drain into the Sandusky River and make up the Sandusky River Watershed. Three of the units drain smaller tributaries that directly enter Sandusky Bay. The Sandusky Hydrologic Unit has a drainage area of 1,850 square miles, while the Sandusky River Watershed has a drainage area of 1,421 square miles.

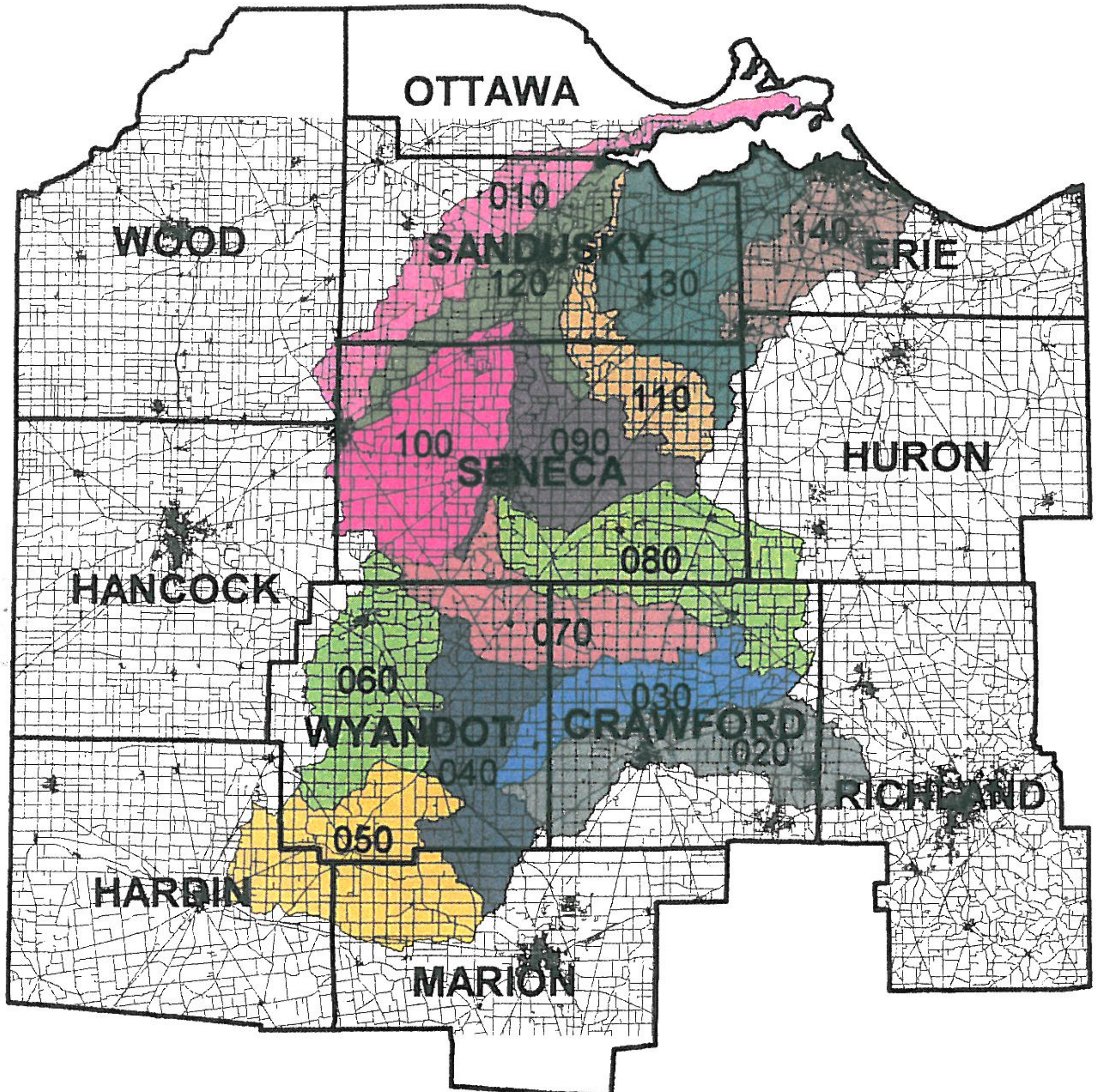
Table 2.1 Unit names, abbreviations and hydrological unit codes for lands in the Sandusky Hydrological Unit.

Hydrologic Unit Codes (HUCs)	Unit Level	Unit Name	Abbreviated Name (for this inventory)
04	Region	The Great Lakes	
0410	Subregion	Western Lake Erie	
041000	Accounting Unit	Western Lake Erie	
04100011	Cataloging Unit	Sandusky	Sandusky HU
		The Sandusky River Watershed	
04100011020	11-digit HUCs	Sandusky River (headwaters to above Broken Sword Creek)	Sandusky-Bucyrus
04100011030		Broken Sword Creek	Broken Sword
04100011040		Sandusky River (below Broken Sword Creek to above Tymochtee Creek)	Sandusky-Upper Sand
04100011050		Tymochtee Creek (headwaters to below Warpole Creek)	Tymochtee-headwaters
04100011060		Tymochtee Creek (below Warpole Creek to Sandusky River)	Tymochtee-lower
04100011070		Sandusky River (below Tymochtee Creek to above Honey Creek)	Sandusky-Mexico
04100011080		Honey Creek	Honey Creek
04100011090		Sandusky River (below Honey Creek to above Wolf Creek)	Sandusky-Tiffin
04100011100		Wolf Creek	Wolf Creek
04100011110		Green Creek	Green Creek
04100011120		Sandusky River (below Wolf Creek to Sandusky Bay)	Sandusky-Fremont
		Direct Drainage to Sandusky Bay	
04100011010		Muddy Creek and north shore of Sandusky Bay	Muddy Creek
04100011130		South Shore Sandusky Bay tribs (below Sandusky River to above Mills Creek)	South Shore-west
04100011140		South Shore Sandusky Bay tribs (above Mills Creek to below Sawmill Creek)	South Shore-east

Each of the 11-digit hydrologic units has been further subdivided into 14-digit hydrologic units. The boundaries of these units are available from the USDA's Natural Resource Conservation Service in Columbus, Ohio.

For this inventory, land resource information will be organized and identified as follows:

1. The entire Sandusky Cataloging Unit (04100011) is called the Sandusky HU.
2. The Sandusky River Watershed is called Sandusky River Watershed.
3. The individual 11-digit units are called subwatersheds and identified by the last three digits of their code and/or by the abbreviations listed in Table 2.1.
4. By county, where information cannot be reasonably allocated to specific hydrologic units.



Subwatersheds:

010 Muddy Creek
020 Sandusky-Bucyrus
030 Broken Sword
040 Sandusky-Upper Sand
050 Tymochtee-headwaters
060 Tymochtee-lower
070 Sandusky-Mexico
080 Honey Creek
090 Sandusky-Tiffin
100 Wolf Creek
110 Green Creek
120 Sandusky-Fremont
130 South Shore-west
140 South Shore-east

Figure 2.1 Sandusky Hydrologic Unit showing counties, roads, and subwatersheds.

Table 2.2 County areas in the Sandusky Hydrological Unit.

County	Area in Sandusky Hydrological Unit, acres	Percent of county area in Sandusky Hydrological Unit	Percent of Sandusky Hydrological Unit in county
Crawford	193,538	75.1	16.6
Erie	75,682	47.1	6.5
Hancock	1,005	0.3	0.1
Hardin	28,325	9.4	2.4
Huron	16,169	5.1	1.4
Marion	51,337	19.8	4.4
Ottawa	18,473	11.1	1.6
Richland	10,972	3.4	0.9
Sandusky	202,938	76.7	17.4
Seneca	332,420	93.9	28.5
Wood	4,216	1.1	0.4
Wyandot	232,608	89.1	19.9
Total	1,167,683		100.0

The Sandusky HU drains portions of 12 north central Ohio counties (Figure 2.1 and Table 2.2). The land area of the Sandusky HU in each county is listed in Table 2.2, along with the percentage of the total county area located in the hydrological unit and the percentage of the hydrological unit located in each county. Four counties - Sandusky, Seneca, Wyandot and Crawford - contain 82% of the land area in the Sandusky HU and 89% of the land area in the Sandusky River Watershed.

Geological History[1]

Early Geological History of the Watershed- Ohio's bedrock layers are sedimentary legacies of the vast, warm seas covering the state more than 400 million years ago. Within the Sandusky River Watershed, evidence of these seas is borne in the limestone, dolomite and shale bedrock layers of the Silurian and Devonian periods, and small amounts of sandstone from the Mississippian Period (Figure 2.2).

The oldest bedrock in the region is the crystalline Silurian-aged dolomites of the Niagara group, blue-gray rock ranging in thickness up to 200 feet (Figure 2.3). These rocks contain fossilized evidence of the abundant life thriving in the warm, shallow and clear seas of the period. The fossil record of this period is dominated by corals, which became most abundant during the Silurian period. However, other organisms are also found in the Niagara group, including the clam Megalomus, or "beefheart", as it is better known by quarrymen and collectors. Overlaying the Niagara dolomite is another group of Silurian-aged rocks, the Bass Island group. These are also dolomites, though they generally are not as thick and tend to be more brown or gray than the bluish Niagara dolomites.

[1] Primarily from theODNR (Scenic Rivers) Physical Inventory of the Sandusky Watershed.

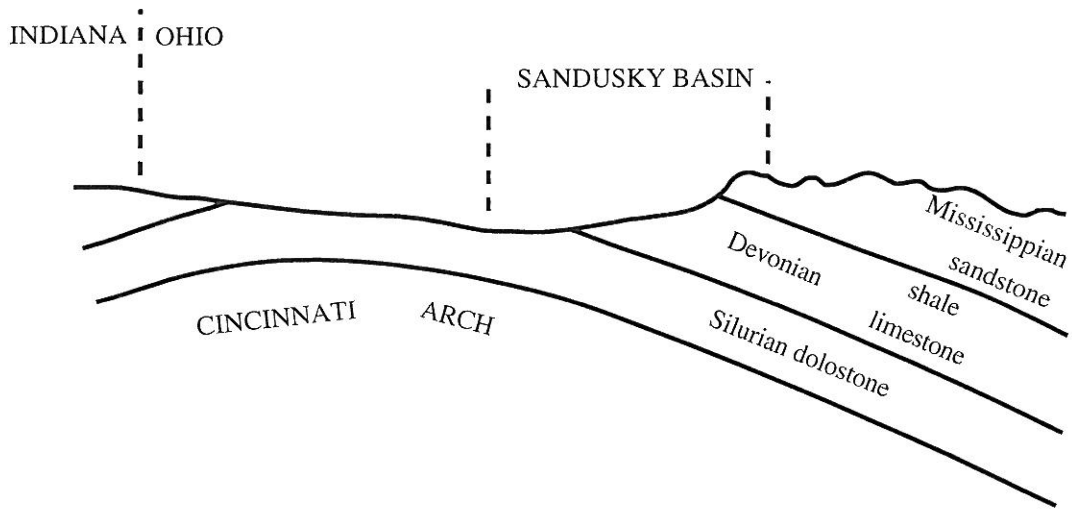


Figure 2.2 Generalized cross-section of Ohio's bedrock. Cross-section diagrammatically shows how erosion of the Cincinnati Arch has produced the arrangement of older (Silurian and Devonian) bedrock in the west and younger (Mississippi) bedrock in the east in Ohio. From Forsyth, J.L. The Geological Setting of the Sandusky River Basin. In the *Proceedings of the Sandusky River Basin Symposium*, International Joint Commission, 1975.

Southeast of a line extending from Lake Erie near Sandusky and Erie counties, through eastern Seneca, Wyandot and Crawford counties, the Silurian rocks are overlain by limestone, dolomite and some shale of the Devonian period. One of the most important of these Devonian rocks is the Columbus Limestone, a light gray nearly pure limestone about 100 feet thick. In addition to having an abundant fossil record of corals, clams, brachiopods and marine snails, the Columbus Limestone also provides the first record of the emerging fish life during the Devonian period. Some of the fish occupying Devonian seas in Ohio were up to 25 feet long.[1]

Because of its very high calcite content[2], the Columbus Limestone is a very important resource in Ohio. Columbus Limestone is mined throughout the Till Plains region of Ohio and is used for building stone, manufacturing cement, and burned as fluxstone to remove impurities in iron ore during the steel-making process.

Other bedrock formations from the Devonian period found in eastern portions of the watershed include the Olentangy and Ohio shales. Where typically exposed, the Olentangy shale ranges in thickness of 15 to 35 feet. Generally, outcroppings of these shales within the main channel of the Sandusky River are not common. In the eastern most portion of the Sandusky River Basin, the bedrock is composed of Mississippian sandstone.

[3] A reconstruction of *Dunkleosteus*, a fossil fish measuring nearly 25 feet collected from Devonian shale near Cleveland is on display at the Rocky River Trailside Interpretive Center within the Cleveland Metroparks System.

[2] Calcite is the mineral that composes shells and shell fragments from coral and other organisms that were very abundant in the Devonian seas. When they died and settled to the bottom, they were the basis for the sedimentary limestone bedrock layers that were formed.

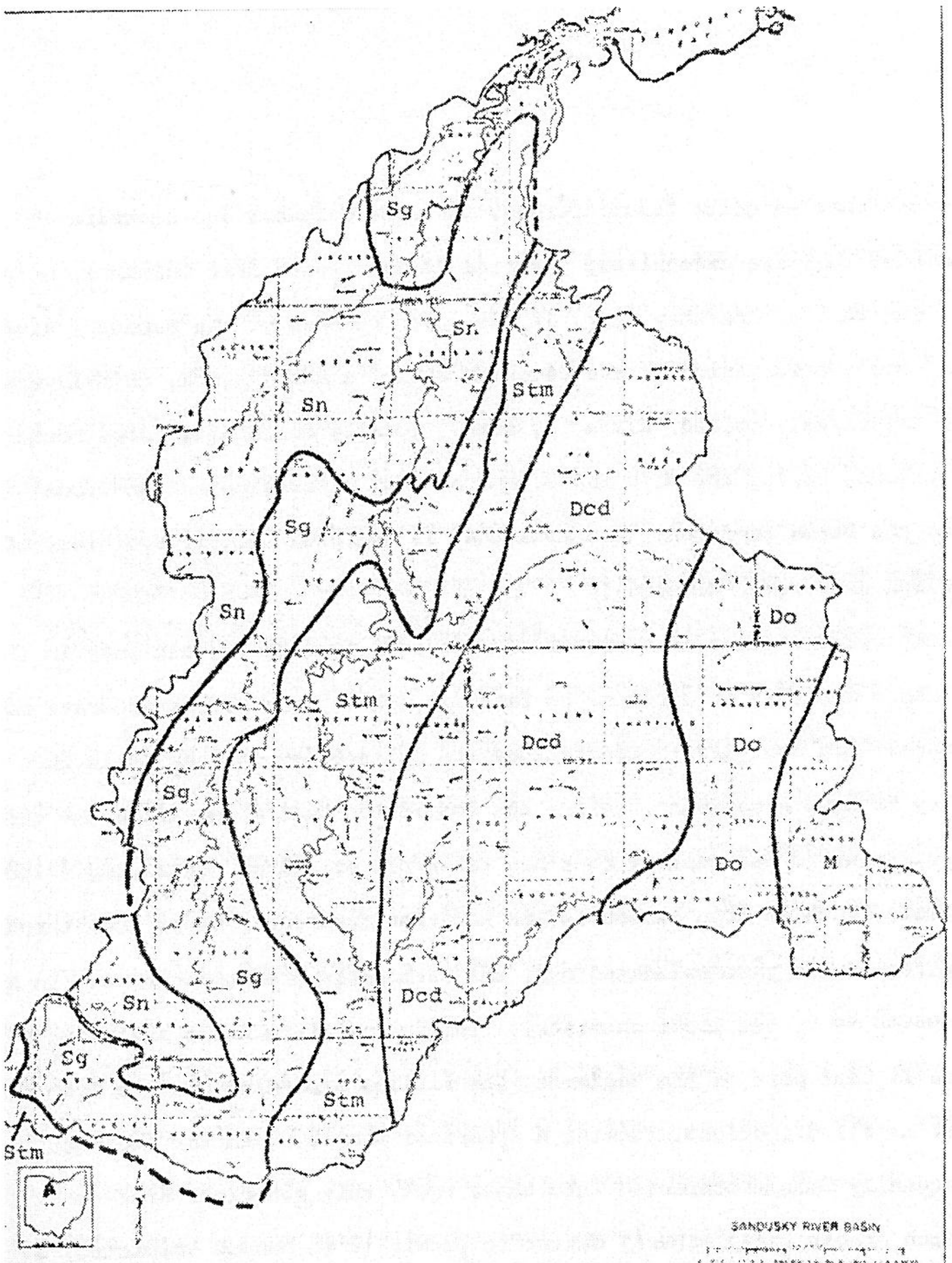


Figure 2.3 Bedrock geologic map of the Sandusky River Basin area. Bedrock units are identified by the following symbols. M-Mississippian Berea Sandstone; Do-Devonian Ohio Shale; Dcd-Devonian Columbus and Delaware Limestones; Stm-Silurian Tymochtee and "Monroe" Dolostones; Sg-Silurian Greenfield Dolostone; Sn-Silurian Niagaran-aged Lockport Dolostone. All these rock units are dipping very gently to the east, as a result of their location on the east limb of the Cincinnati Arch.

Post-Glacial Geological History - The most significant geological events influencing the watershed occurred about 22,000 years ago when the last of the Wisconsinian glaciers entered Ohio (Figure 2.4). Glaciers covered all of Canada and most of the northern United States, including 56 of Ohio's 88 counties. As recently as 13,000 years ago, the entire Sandusky River Watershed was covered by great ice sheets nearly a mile thick. Moving very slowly (about 200 feet per year), glaciers carved and scoured the landscape with each advance southward. With each recession, they deposited glacial till, boulders, gravel, sand and other debris. Such deposits are small ridges referred to by geologists as end moraines. The Sandusky watershed is influenced by three such moraines. The Defiance end moraine traverses Hancock, Seneca and Huron counties in the northern section of the watershed. The Fort Wayne and the Wabash end moraines influence southern portions of the watershed through Crawford, Wyandot and Marion counties. These moraines occur as low ridges comprised predominately of clay intermingled with small sand and gravel deposits.

The Sandusky watershed flows through two physiographic regions of Ohio, the Lake Plains and the Glaciated Till Plains. Northern sections of the watershed, from Tiffin to Lake Erie lie within the Lake Plains. Vast shallow lakes created when glaciers receded 13,000 years ago formed the Lake Plains. Glacial meltwater was impounded between the retreating wall of ice and glacial materials that had been deposited to the south. The resulting lakes included the prehistoric Lake Maumee whose shoreline crested at an elevation of 780 feet. Others included Lake Whittlesy (735 feet) and Lake Warren (700 feet).[1]

With each recession of the glacial lakes, wave action smoothed fine clay sediments on the ancient lakebeds. The resulting landscape is an extremely flat plain, interrupted only by remnants of the ancient beach ridges. One needs only travel north of Tiffin and Fremont to observe the influence of the Lake Plains on the landscape.

The Till Plains influence the watershed south and east of Tiffin. This region is characterized by extensive flat to very gently rolling plains and heavy till soils. The gently rolling landscape of northern Wyandot County is quite characteristic of the Till Plains region.

When the glaciers retreated northward for the last time, draining the glacial lakebed of what would become Lake Erie, the Sandusky River flowed across the exposed bottom and joined a larger stream that was the forerunner to the Maumee River. This drainage system flowed eastward into remnants of the glacial lake. With the rising of the Niagara outlet to the east, Lake Erie flooded the lakebed and the Sandusky was confined to its current stream channel.

Soils of the Sandusky Hydrological Unit

The parent material for soils in the southern part of the Sandusky River Watershed is primarily late Wisconsin-age glacial till. The northern part of the watershed is primarily lacustrine sediments with some beach ridge sands. Limestone bedrock is close to the surface in some areas, and in some places, is exposed in the bed of the river.

---

[1] The shorelines of these ancient glacial lakes were more than 200 feet higher than the current shore of Lake Erie and at one time inundated most of the Sandusky River watershed area north of Fremont, Ohio.

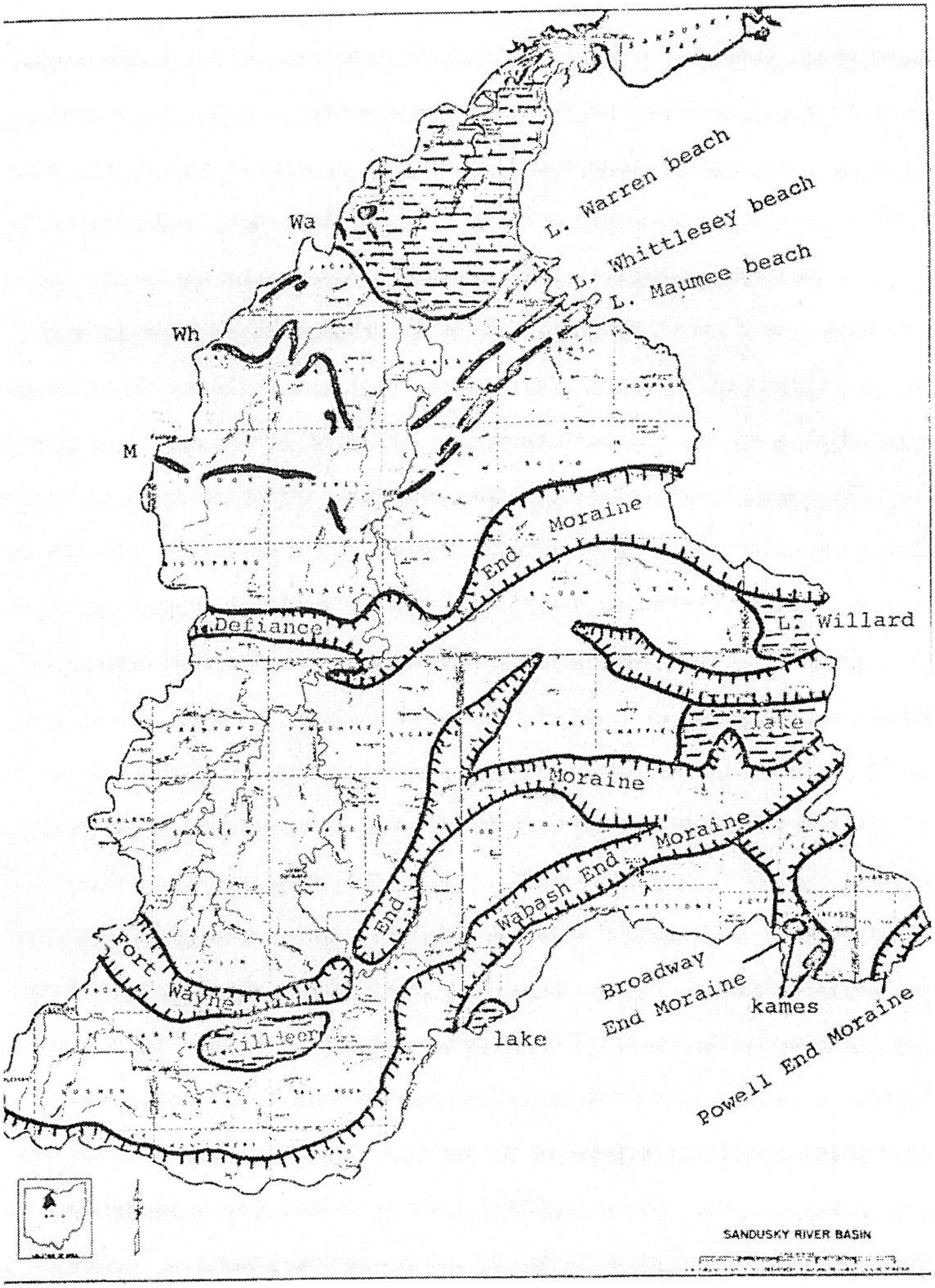


Figure 2.4 Glacial map of the Sandusky River Basin area. Glacial deposits shown are end moraines (enclosed by hashures and named), ground moraine (left white), lake beaches (marked by black bands and named), and lake-bottom silts and clays (identified by horizontal-dash pattern). Areas of alluvial deposits along the Sandusky River and its tributaries are too small to be shown on this map.

In Crawford County, most soils formed in glacial till with some small areas which formed in lacustrine (lake deposited) material. Topography is gently rolling to nearly flat with occasional moderately steep areas, especially along stream channels. For more information on soils in Crawford County, refer to the Soil Survey of Crawford County (1979).

In Wyandot County, soils formed either in glacial till or glacial lake deposited sediments. Topography is level to gently rolling with a few steeper areas along stream channels. For more information on the soils in Wyandot County, refer to the Soil Survey of Wyandot County (1982).

Soils in Seneca County formed in late Wisconsin-age glacial till and glacial lake deposited sediments, including beach ridges; limestone is at or near the surface in localized areas. Limestone, in the bedrock controlled area, is prone to dissolution, and sinkholes are abundant in parts of Thompson Township, Seneca County. Topography is nearly level to undulating, with steeper areas along streams. For more information on the soils in Seneca County, refer to the Soil Survey of Seneca County (1980).

In Sandusky County, soils formed primarily in glacial lake deposited sediments. Prominent beach ridges are evident in the county. There are also areas where soils formed in late Wisconsin-age glacial till and areas that are shallow to limestone or dolomite bedrock. Bedrock is exposed in some places in the bed of the Sandusky River and its tributaries in this County. Karst topography, with numerous sinkholes, is evident in localized areas in York Township, Sandusky County. Topography is nearly level throughout much of the County, although beach ridges and bedrock highs provide significant variation in the landscape. For more information on the soils in Sandusky County, refer to the Soil Survey of Sandusky County (1987).

The major soil mapping units for the four counties comprising the bulk of the Sandusky River Watershed are listed in Table 2.3. These soils occur in soil associations which are natural land types containing two or more major soil units in a characteristic pattern. The soil associations are named for the major soils in them, but other soils may also be present. The major soils in one general soil association may also be present in other associations. The major soil associations of the Sandusky Hydrological Unit, based on a 1973 ODNR map "Know Ohio's Soil Regions", are listed in Table 2.4. This table includes information regarding the major soil units in each association. A more recent organization of soil associations in the Sandusky HU, as grouped by the Natural Resource Conservation Service, is shown in Figure 2.5. The extent of each of these soil associations in the Sandusky HU is shown in Table 2.5.

Table 2.3 Predominant (greater than 5%) soil map units in each of four primary counties in the Sandusky River/Sandusky Bay Watershed (Note: only a portion of each county listed is in this watershed).

County	Soil Name	Acreage	Percent	Drainage class
Crawford	Bennington silt loam, 0-2%	20,332	7.9	SWP
Crawford	Bennington silt loam, 2-6%	35,649	13.8	SWP
Crawford	Condit-Bennington silt loams	25,122	9.7	PD/SWP
Crawford	Luray silty clay loam	18,693	7.2	VPD
Crawford	Pewamo silty clay loam	24,143	9.3	VPD
Crawford	Tiro silt loam, 0-2%	23,419	9.1	SWP
Wyandot	Blount silt loam, 0-2%	42,007	16.2	SWP
Wyandot	Blount silt loam, 2-6%	19,120	7.4	SWP
Wyandot	Pandora silty clay loam	14,522	5.6	PD
Wyandot	Pewamo sily clay loam	28,477	11.0	VPD
Seneca	Blount silt loam, 0-2% slopes	69,731	19.8	SWP
Seneca	Blount silt loam, 2-6% slopes	52,884	15.0	SWP
Seneca	Hoytville silty clay loam	38,662	11.0	VPD
Seneca	Pandora silt loam	25,985	7.4	PD
Seneca	Tiro silt loam, 0-2% slopes	19,717	5.6	SWP
Sandusky	Hoytville silty clay loam	55,075	21.0	VPD
Sandusky	Kibbie fine sandy loam, 0-2% slopes	19,825	7.6	SWP
Sandusky	Lenawee silty clay loam	19,845	7.6	VPD
Sandusky	Toledo silty clay	21,230	8.1	VPD

VPD Very poorly drained
PD Poorly drained
SWP Somewhat poorly drained
MWD Moderately well drained
WD Well drained

Table 2.4 Major soil associations in the Sandusky River/Sandusky Bay Watershed.

Characteristic	Soil #1	Soil #2	Soil #3	Soil #4
Soil association	Toledo	Bono		
Drainage class	VPD	VPD		
Parent material	Limy glacial lake deposited sediments	Limy glacial lake deposited sediments		
Soil association	Bennington	Cardington		
Drainage class	SWP	MWD		
Parent material	Silty clay loam or clay loam, low lime glacial till	Silty clay loam or clay loam, low lime glacial till		
Soil association	Bennington	Cardington	Pewamo	
Drainage class	SWP	MWD	VPD	
Parent material	Limy clay loam glacial till	Limy clay loam glacial till	Limy clay loam glacial till	
Soil association	Tiro	Luray		
Drainage class	SWP	VPD		
Parent material	Silt over loam till	Glacial lake-laid silt		

Table 2.4 (Continued).

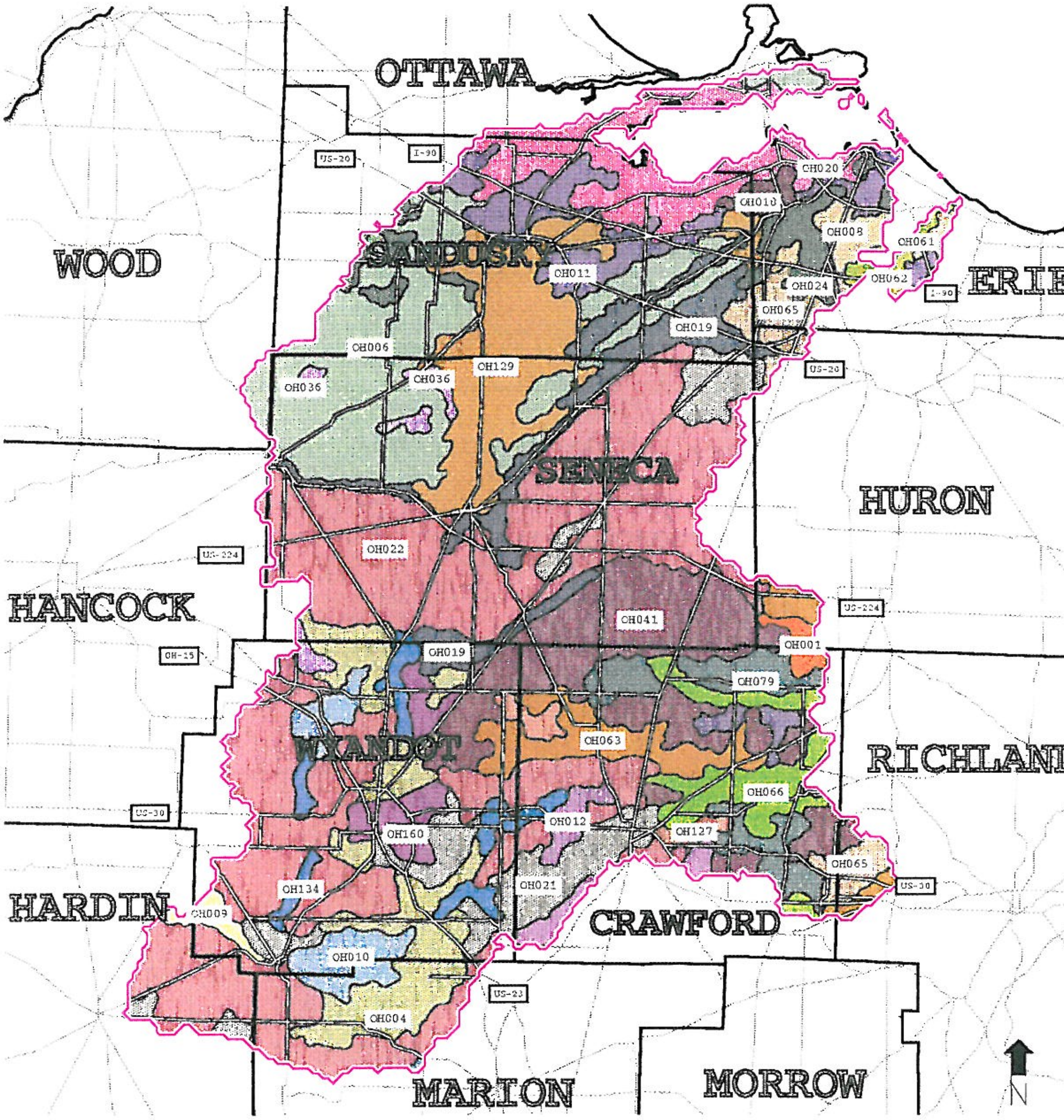
Characteristic	Soil #1	Soil #2	Soil #3	Soil #4
Soil association	Blount	Pewamo		
Drainage class	SWP	VPD		
Parent material	High lime silty clay loam glacial till	High lime silty clay loam glacial till		
Soil association	Blount	Toledo	Del Rey	
Drainage class	SWP	PD	SWP	
Parent material	High lime silty clay loam till	Clayey glacial lake deposited sediments	Silty glacial lake deposited sediments	
Soil association	Haney	Haskins	Belmore	
Drainage class	MWD	PD	WD	
Parent material	Sandy and loamy deposits	Loamy deposits underlain with limy clay till	Sandy and loamy deposits	
Soil association	Granby	Ottokee	Tedrow	
Drainage class	VPD	MWD	SWP	
Parent material	Glacial lake and wind deposited sands	Glacial lake and wind deposited sands	Glacial lake and wind deposited sands	
Soil association	Montgomery	Pewamo	Del Rey	
Drainage class	VPD	VPD	SWP	
Parent material	Clayey glacial lake sediments	Glacial till	Silty glacial lake sediments	
Soil association	Bennington	Pewamo		
Drainage class	SWP	VPD		
Parent material	Limy clay loam glacial till	Limy clay loam glacial till		
Soil association	Lewisburg	Castalia	Milton	Millsdale
Drainage Class	MWD	WD	WD	VPD
Parent Material	Limy glacial till	Limestone bedrock	Thin glacial till over limestone bedrock	Thin glacial till over limestone bedrock
Soil association	Tuscola	Sisson	Kibbie	
Drainage class	MWD	WD	SWP	
Parent material	Limy silty and fine sandy glacial lake sediments	Limy silty and fine sandy glacial lake sediments	Limy silty and fine sandy glacial lake sediments	
Soil association	Hoytville	Napanee		
Drainage class	VPD	SWP		
Parent material	Limy clayey glacial till	Limy clayey glacial till		
Soil association	Toledo	Fulton		
Drainage class	VPD	SWP		
Parent material	Limy silty clay glacial lake sediments	Limy silty clay glacial lake sediments		

VPD Very poorly drained
PD Poorly drained
SWP Somewhat poorly drained
MWD Moderately well drained
WD Well drained

U.S. DEPARTMENT OF AGRICULTURE NATURAL RESOURCES CONSERVATION SERVICE

SANDUSKY RIVER WATERSHED

Soil Associations



- STATSGO SOIL ASSOCIATION
- OH006:HOYTVILLE-NAPPANEE-BLOUNT
- OH010:PAULDING-LATTY-FULTON
- OH018:WEYERS-SANDUSKY-PITS
- OH021:BLOUNT-GLYNWOOD-MORLEY
- OH036:MILTON-MILLSDALE-RANDOLPH
- OH062:JIMTOWN-BOGART-MAHONING
- OH066:BENNINGTON-PEWAMO-CARDINGTON
- OH127:CARDINGTON-BENNINGTON-SLOAN
- OH160:TIRO-FITCHVILLE-GLENFORD
- OH001:LENAWEE-COLWOOD-LENAWEE VARIANT
- OH008:KIBBIE-TUSCOLA-GALEN
- OH011:LENAWEE-DEL REY-KIBBIE
- OH019:BELMORE-SPINKS-KIBBIE
- OH022:BLOUNT-PEWAMO-GLYNWOOD
- OH041:TIRO-PANDORA-BENNINGTON
- OH063:BENNINGTON-CARDINGTON-ORRVILLE
- OH079:BENNINGTON-CONDIT-CARDINGTON
- OH129:KIBBIE-COLWOOD-BIXLER
- WATER
- OH004:MILFORD-DEL REY-SHINROCK
- OH009:LATTY-FULTON-NAPPANEE
- OH012:MILFORD-LURAY-TIRO
- OH020:TOLEDO-FULTON-NAPPANEE
- OH024:CASTALIA-MILLSDALE-MILTON
- OH061:ALLIS-URBAN LAND-PROUT VARIANT
- OH065:PEWAMO-BENNINGTON-MEDWAY
- OH084:RITTMAN-WADSWORTH-ORRVILLE
- OH134:GLYNWOOD-BLOUNT-GENESEE

Patrick K. Wolf, USDA-NRCS State Conservationist, 614-469-6962
Source: USDA-NRCS STATSGO Digital Soils Data, Scale 1:708660

OHIO NRCS GIS

Table 2.5 Aerial extent of soil associations as shown in Figure 2.5.

	Description	Acres	%cover
1	OH001:Lenawee-Colwood-Lenawee Variant	4729	0.41
2	OH004:Milford-DelRey-Shinrock	63,213	5.47
3	OH006:Hoytville-Nappanee-Blount	119,107	10.31
4	OH008:Kibbie-Tuscola-Galen	12,372	1.07
5	OH009:Latty-Fulton-Nappanee	5125	0.44
6	OH010:Paulding-Latty-Fulton	22,975	1.99
7	OH011:Lenawee-DelRey-Kibbie	49,059	4.24
8	OH012:Milford-Luray-Tiro	13,460	1.16
9	OH018:Weyers-Sandusky-Pits	5649	0.49
10	OH019:Belmore-Spinks-Kibbie	51,953	4.49
11	OH020:Toledo-Fulton-Nappanee	54,688	4.73
12	OH021:Blount-Glynwood-Morley	59,655	5.16
13	OH022:Blount-Pewamo-Glynwood	315,448	27.29
14	OH024:Castalia-Millsdale-Milton	25,676	2.22
15	OH036:Milton-Millsdale-Randolph	9133	0.79
16	OH041:Tiro-Pandora-Bennington	97,246	8.41
17	OH061:Allis-Urban Land-Prout Variant	4801	0.42
18	OH062:Jimtown-Bogart-Mahoning	1001	0.09
19	OH063:Bennington-Cardington-Orrville	35,288	3.05
20	OH065:Pewamo-Bennington-Medway	22,605	1.96
21	OH066:Bennington-Pewamo-Cardington	30,077	2.60
22	OH079:Bennington-Condit-Cardington	31,545	2.73
23	OH084:Rittman-Wadsworth-Orrville	20	0.00
24	OH127:Cardington-Bennington-Sloan	7868	0.68
25	OH129:Kibbie-Colwood-Bixler	75,042	6.49
26	OH134:Glynwood-Blount-Genesee	20,178	1.75
27	OH160:Tiro-Fitchville-Glenford	17,873	1.55
28	Water	5	0.00
	TOTAL	1,155,790	100.00

Land Use in the Sandusky Hydrological Unit

The Ohio Department of Natural Resources has provided land use data for the Sandusky HU, based on satellite imagery from the LANDSAT Thematic Mapper, September and October, 1994. From the satellite imagery, land use for contiguous 30 meter x 30 meter areas are classified into seven categories: urban, agriculture, shrub, wooded, water, non-forested wetlands, and barren. These categories are based on interpretation of land cover conditions. Some land uses, such as golf courses or grassy parks, are categorized as farm land by these techniques. Likewise, woods containing houses are categorized as wooded rather than urban. Although the classifications do contain some errors, the picture of land use provided by this satellite data is generally accurate.

The resulting land use data are illustrated in Figure 2.6 and summarized in Table 2.6 and Figure 2.7. Land use maps for individual 11-digit hydrological units are presented in the appendix, against the background of highway systems and stream segments.

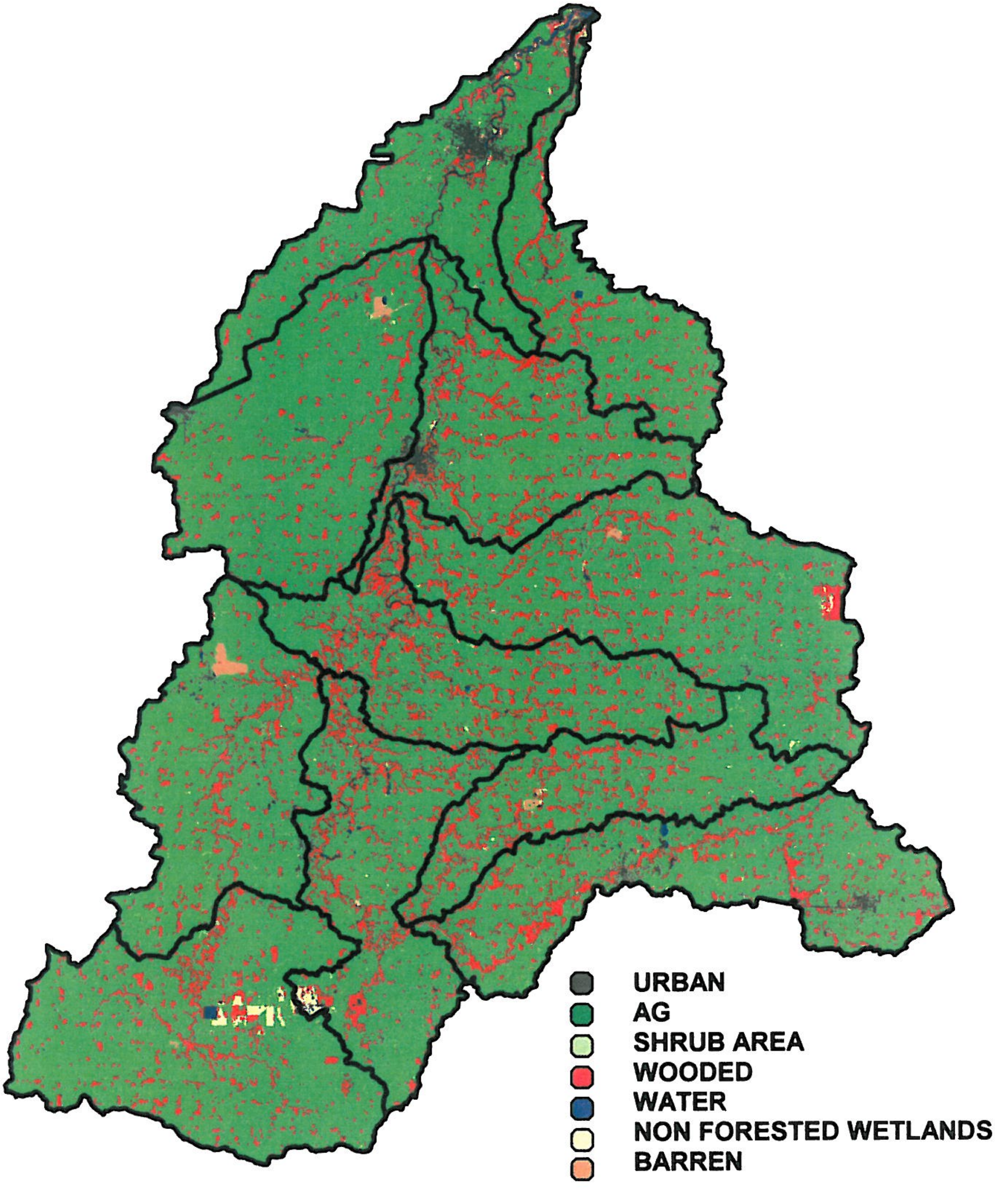


Figure 2.6 Land Use in the Sandusky River Watershed.

Table 2.6 Land use in the Sandusky Hydrological Unit, the Sandusky River Watershed, and the component 11-digit hydrological units.

Code	Hydrological Unit Name (Abbreviation)	Total Land Area	Urban		Agriculture		Shrub Area		Wooded		Water		Non-forested Wetlands		Barren	
		acres	acres	%	acres	%	acres	%	acres	%	acres	%	acres	%	acres	%
020	Sandusky, Bucyrus	87,920	1,685	1.9	72,006	81.9	402	0.5	12,534	14.3	314	0.4	960	1.1	19	0.0
030	Broken Sword	60,545	87	0.1	50,592	83.6	240	0.4	8,755	14.5	41	0.1	572	0.9	258	0.4
040	Sandusky, Upper Sand.	77,693	356	0.5	62,562	80.5	664	0.9	12,281	15.8	409	0.5	1,348	1.7	73	0.1
050	Tymochtee, headwaters	109,857	75	0.1	94,931	86.4	865	0.8	11,484	10.5	331	0.3	2,097	1.9	74	0.1
060	Tymochtee, lower	83,321	617	0.7	71,967	86.4	483	0.6	8,483	10.2	178	0.2	554	0.7	1,039	1.2
070	Sandusky, Mexico	77,978	110	0.1	62,686	80.4	413	0.5	13,743	17.6	245	0.3	764	1.0	17	0.0
080	Honey Creek	115,090	586	0.5	97,577	84.8	241	0.2	15,424	13.4	62	0.1	1,010	0.9	190	0.2
090	Sandusky, Tiffin	74,690	1,693	2.3	59,681	79.9	436	0.6	12,089	16.2	266	0.4	487	0.7	38	0.1
100	Wolf Creek	101,075	1,752	1.7	89,781	88.8	268	0.3	8,361	8.3	78	0.1	292	0.3	543	0.5
110	Green Creek	51,917	365	0.7	44,496	85.7	79	0.2	6,368	12.3	193	0.4	396	0.8	20	0.0
120	Sandusky, Fremont	69,380	3,335	4.8	57,352	82.7	203	0.3	5,469	7.9	1,157	1.7	1,667	2.4	197	0.3
	Sandusky River Watershed, total	909,466	10,661	1.2	763,631	84.0	4,294	0.5	114,991	12.6	3,274	0.4	10,147	1.1	2,468	0.3
010	Muddy Creek	86,970	2,496	2.9	72,258	83.1	339	0.4	7,924	9.1	730	0.8	2,752	3.2	475	0.5
130	South Shore, west	104,779	2,453	2.3	85,338	81.4	345	0.3	10,479	10.0	1,407	1.3	4,360	4.2	397	0.4
140	South Shore, east	66,820	7,169	10.7	50,945	76.2	229	0.3	4,767	7.1	961	1.4	1,825	2.7	924	1.4
	Total Sandusky Hydrological Unit	1,168,035	22,779	2.0	972,172	83.2	5,207	0.4	138,161	11.8	6,372	0.5	19,084	1.6	4,264	0.4

Agriculture dominates land use in the Sandusky River Watershed (84.0%) and the Sandusky HU (83.2%). Within the 11-digit units, the percentage of agricultural land use ranges from 88.8% (Wolf Creek) to 76.2% (South Shore, east). Data from agricultural statistics for the state confirms the assessments from satellite imagery. These statistics show that agriculture in the Sandusky River Watershed is dominated by row crop production (Table 2.7 and Figure 2.8). If you were to fly over the Sandusky River Watershed, about 69% of the time you would be over soybean, corn or wheat fields. Most of the cropland in this region is drained by tile systems. This area, along with other agricultural areas in Northwestern Ohio, represents the most intensively tile-drained cropland in the United States.

Wooded land occupies 12.6% of the land area in the Sandusky River Watershed and 11.8% of the land area in the Sandusky HU. Within the 11-digit units, wooded land percentages range from 17.6% (Sandusky, Mexico) to 7.1% (South Shore, east).

An important characteristic of the wooded lands in this area is their extensive fragmentation. A large proportion of the wooded land is composed of relatively small wood lots. Examination of Figure 2.6 indicates that many of these wood lots are oriented in east-west lines, particularly on the eastern side of the area. Other wooded lands are more contiguous and follow curving paths. Examination of the land use maps for subwatersheds in the appendix indicates that east-west lines of woods are located in the middle of the "blocks" formed by the county road systems. These roads run east-west or north-south and occur at one mile intervals. Often, it is the land farthest from the road, in the middle of these "blocks," that has not been cleared for cropland. The more contiguous wooded land, in the curving paths, represents the riparian woodlands along the Sandusky River and its major tributaries.

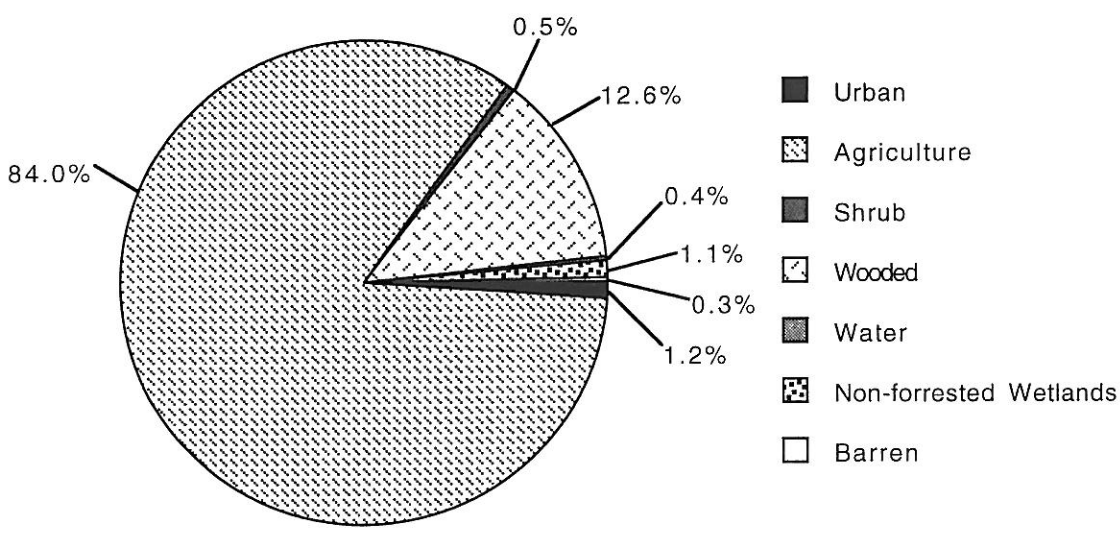


Figure 2.7 Land use in the Sandusky River Watershed, based on satellite imagery.

Table 2.7 Land in farms and crop acreages for major counties in the Sandusky River Watershed*.

County/feature	Crawford	Sandusky	Seneca	Wyandot	Total	% of total land area
Total Area, acres	257,728	267,392	353,536	260,864	1,139,520	
Number of Farms	820	880	1,340	690	3,730	
Land in Farms, acres	230,000	217,000	305,000	219,000	971,000	85.2
Soybean, acres	94,000	86,400	119,000	93,300	392,700	34.5
Corn, acres	69,400	55,900	71,300	60,000	256,600	22.5
Wheat, acres	34,100	21,200	45,400	39,100	139,800	12.3
Oats, acres	0	1,500	3,000	0	4,500	0.4
Hay, acres	5,700	5,300	7,300	4,500	22,800	2.0
CRP,acres	3,070	1,271	10,700	1,684	16,725	1.5
Other Farm, acres	23,730	45,429	48,300	20,416	137,875	12.1
Non-farmland, acres	27,728	50,392	48,536	41,864	168,520	14.8

* Data from 1995 Annual Report, Ohio Agricultural Statistics and Ohio Department of Agriculture.

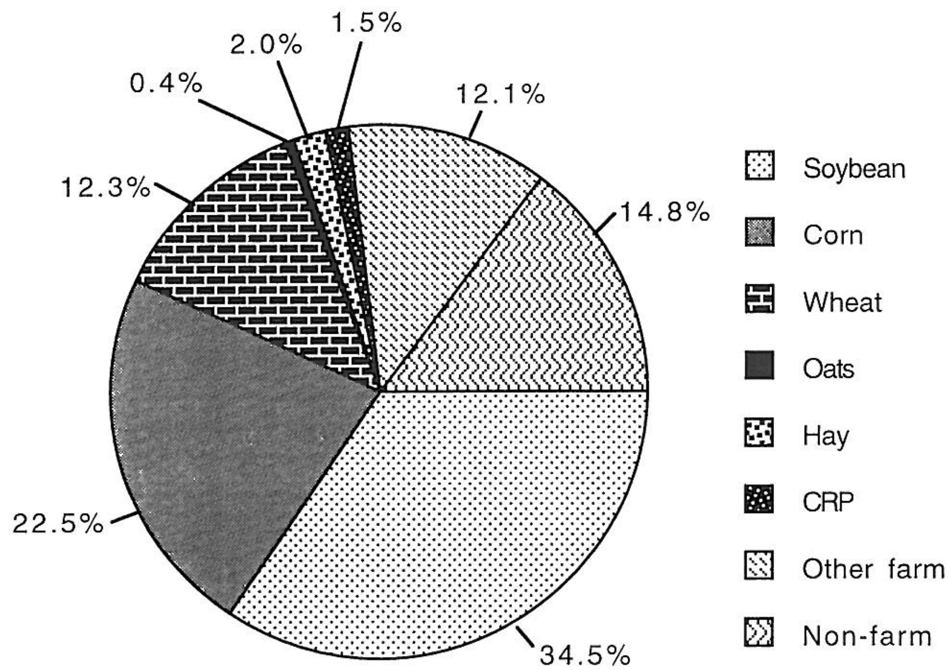


Figure 2.8 Land use in the four major Sandusky River Watershed counties, based on Ohio Agricultural Statistic, 1995.

Urban lands comprise about 1.2% of the land area in the Sandusky River Watershed and 2.0% of the land area in the Sandusky HU. For the subwatersheds, urban land ranges from 0.1% (Broken Sword, Tymochtee-headwaters, and Sandusky-Mexico) to 10.7% (South Shore, east). Information for the largest cites and villages in the watershed is shown in Table 2.8 and their locations are shown in Figure 2.9.

Non-forested wetlands make up 1.1% of the Sandusky River Watershed and 1.6% of the Sandusky Hydrological Unit. Among the subwatersheds, wetlands range from 0.3% (Wolf Creek) to 4.2% (South Shore, west). Current wetlands in the area are primarily located in state and privately owned wildlife areas, such as Killdeer Plains, the Willard Marsh, and wetlands adjacent to Sandusky Bay. These areas are remnants of the much more extensive wetlands prevalent in this area prior to their conversion to cropland.

Other land uses (shrub, water, and barren) each make up less than 1% of the land area. The barren areas are primarily quarries from which limestone and dolomite are extracted. Water areas reflect the surface areas of stream systems, upground reservoirs, and farm ponds.

Table 2.8 Major cities and villages in the Sandusky River Watershed.

Code	Subwatershed	City/Village	Population	County
020	Sandusky, Bucyrus	Bucyrus	13,198	Crawford
		Crestline	5,021	Crawford
		North Robinson	229	Crawford
030	Broken Sword	Nevada	889	Wyandot
040	Sandusky, Upper Sand.	Upper Sandusky	6,148	Wyandot
050	Tymochtee, headwaters	Marseilles	132	Wyandot
		Harpster	236	Wyandot
060	Tymochtee, lower	Carey	3,788	Wyandot
		Kirby	180	Wyandot
070	Sandusky, Mexico	Sycamore	937	Wyandot
		Chatfield	194	Crawford
		McCutchenville		Seneca/Wyandot
080	Honey Creek	Attica	1,040	Seneca
		Bloomville	1,027	Seneca
		Melmore		Seneca
		New Washington	1,028	Crawford
		Tiro	250	Crawford
090	Sandusky, Tiffin	Tiffin	18,530	Seneca
		Republic	654	Seneca
		Old Fort		Seneca
100	Wolf Creek	Bettsville	753	Seneca
		Bascom		Seneca
		Fostoria (pt.)	11,007	Seneca
		New Riegel	300	Seneca
110	Green Creek	Green Springs	723	Sandusky
120	Sandusky, Fremont	Fremont	18,133	Sandusky
		Burgoon	259	Sandusky

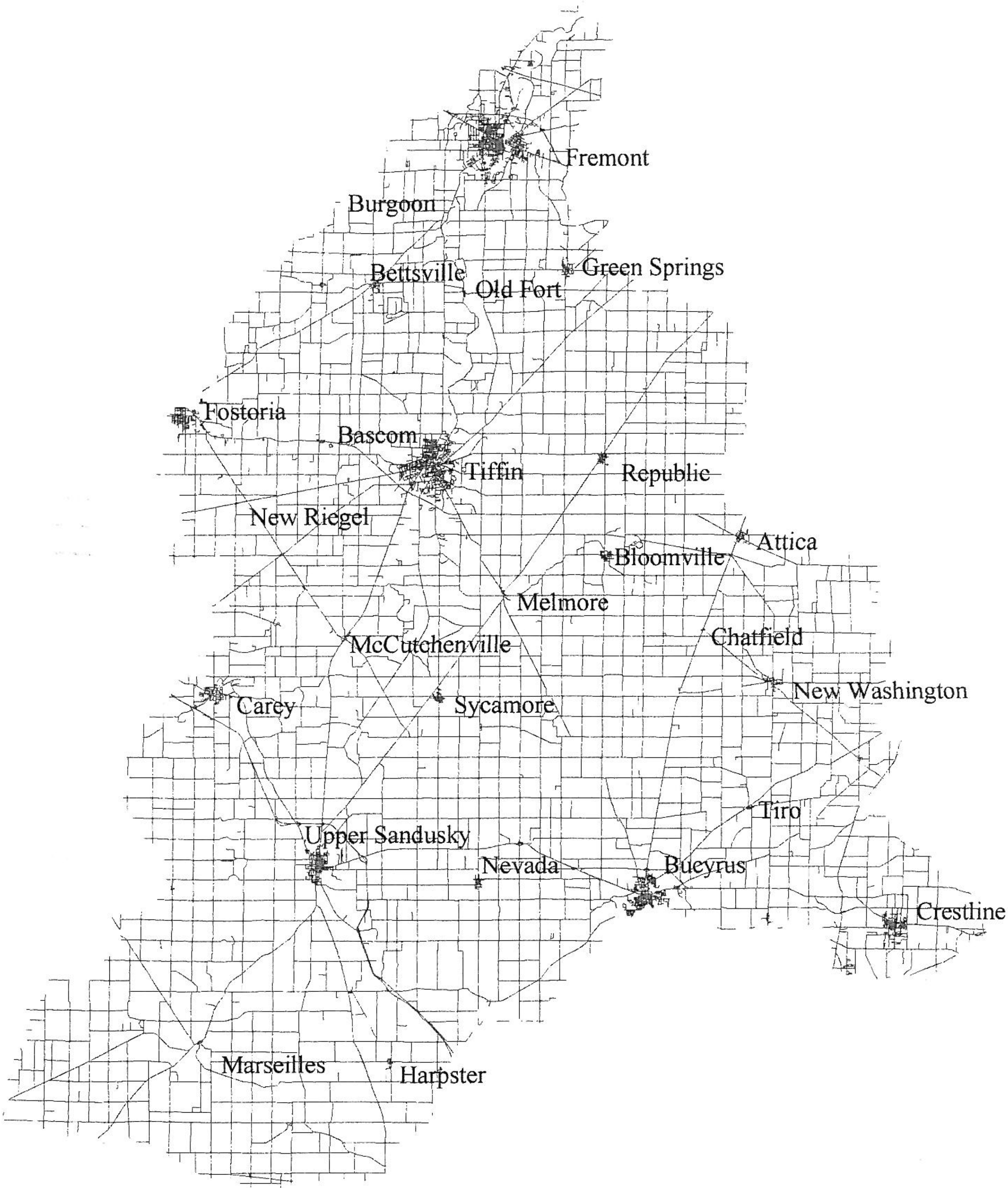


Figure 2.9 Locations of major cities and villages in the Sandusky Watershed.

Chapter 3 - Water Resources of the Sandusky River Watershed

The interaction of the lands of the Sandusky River Watershed with the hydrological cycle determines the quantity of water available within the watershed. How much rain and snow does the watershed receive? How much of that precipitation runs off the surface of the watershed into streams and rivers? How much of the precipitation percolates into the soil to recharge groundwater? How much water evaporates from surfaces or is absorbed from the soil by plant roots and transpired through leaves into the atmosphere? How much ground water supports the base flow of the streams and rivers? How much water moves through regional aquifers into and out of the watershed?

Various types of monitoring programs are in place to provide answers to some of the above questions. Precipitation is measured at weather stations, stream flow is measured at stream gauging stations and ground water level is measured at observation wells. In the Sandusky River Watershed, there are five National Weather Service Cooperative Weather Stations that are part of the National Oceanic and Atmospheric Administration's (NOAA) network and that report data to the National Climatic Data Center in Asheville, North Carolina. The watershed also contains five stream gauging stations and four ground water level recording stations operated by the U.S. Geological Survey. The locations of NOAA cooperative weather stations, USGS stream gauges, and USGS ground water level recorders are shown in Figure 3.1. The network of rivers, streams and ditches that drain the Sandusky River Watershed, as well as subwatershed boundaries, are also shown on the map.

The state agency primarily responsible for tracking the quantity of water available in Ohio is the Ohio Department of Natural Resources (ODNR) within its Division of Water. Numerous publications and maps regarding components of the hydrological cycle in Ohio are available on the Division's www site (http://www.dnr.state.oh.us/odnr/water/).

Precipitation

The names and code numbers of the cooperative weather stations, the local observers, periods of record, and long-term average annual precipitation are shown in Table 3.1. At all of these stations, daily precipitation (rain and/or melted snow and ice), daily snow fall and snow cover, daily maximum and minimum temperatures, and temperature at time of observation are recorded. At the Tiffin and Fremont stations, hourly precipitation is also recorded. Hourly precipitation data provides information on rainfall intensities. These stations are part of a set of 9 North Central Ohio Cooperative Weather Stations and 150 stations statewide in Ohio. Data from these stations are available in printed form from the National Climatic Data Center, 151 Patton Avenue, Asheville, NC 28801-5001 (704 271-1800).

Average annual precipitation at these stations ranges from 34.69 inches at Fremont to 37.97 inches at Bucyrus. This precipitation is not uniformly distributed throughout the year. The long-term monthly average precipitation, based on the combined data from the

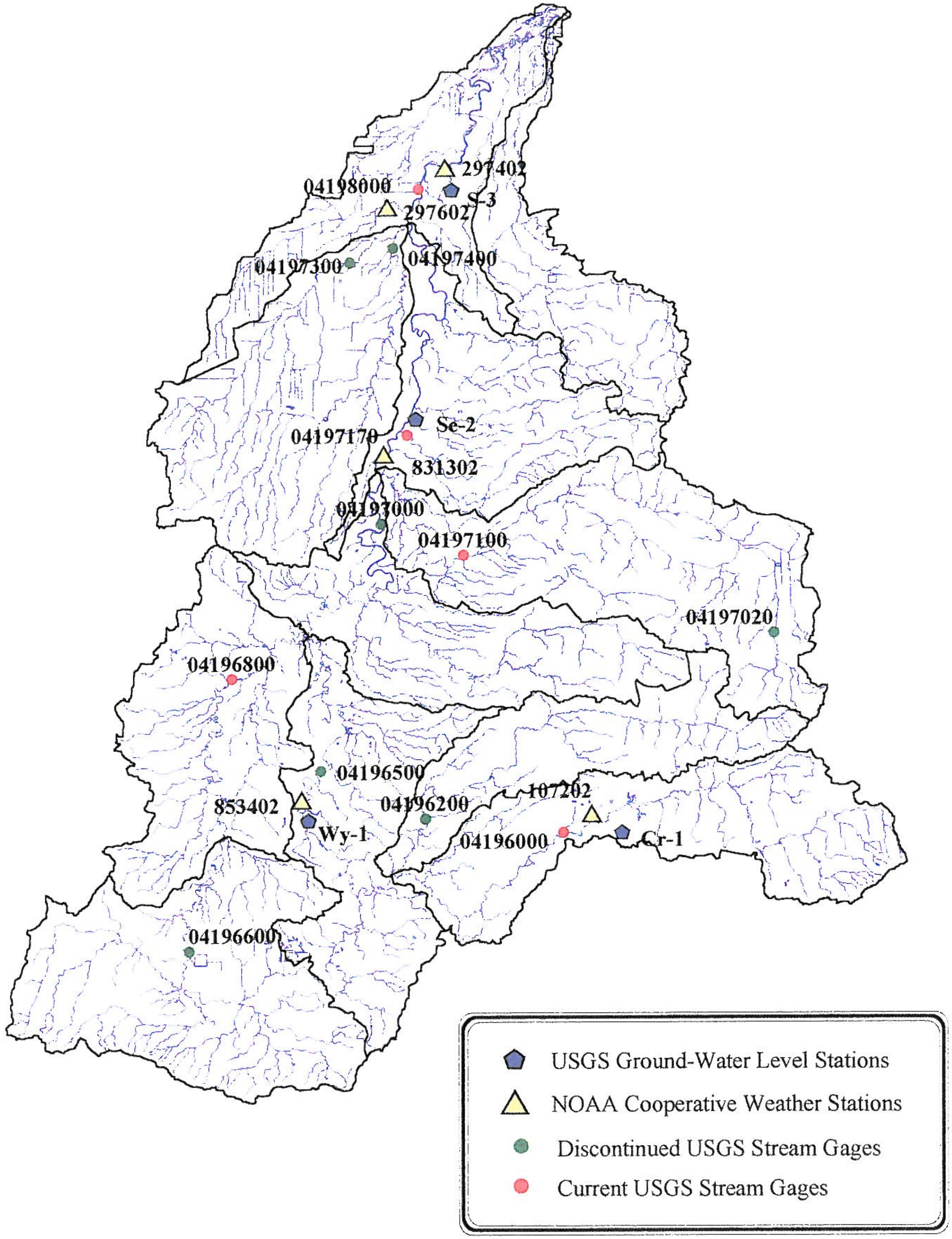


Figure 3.1 Hydrological monitoring facilities in the Sandusky River Watershed.

Table 3.1. NOAA Cooperative Weather Stations in the Sandusky Watershed.

Station Name	Station Code Number	Current Local Observer	Years of Record (through 1997)	Average Annual Precipitation, inches
Bucyrus	1072-02	Bucyrus City Water Plant	106	37.97
Fremont	2974-02	Fremont Water Works	59	34.69
Fremont Ag Station	2976-02	OARDC Vegetable Crops Branch	3	
Tiffin	8313-02	Heidelberg College, WQL	117	36.40
Upper Sandusky	8534-02	Richard P. Landversicht	116	35.44
North Central Ohio (9 sites)	-02			35.33

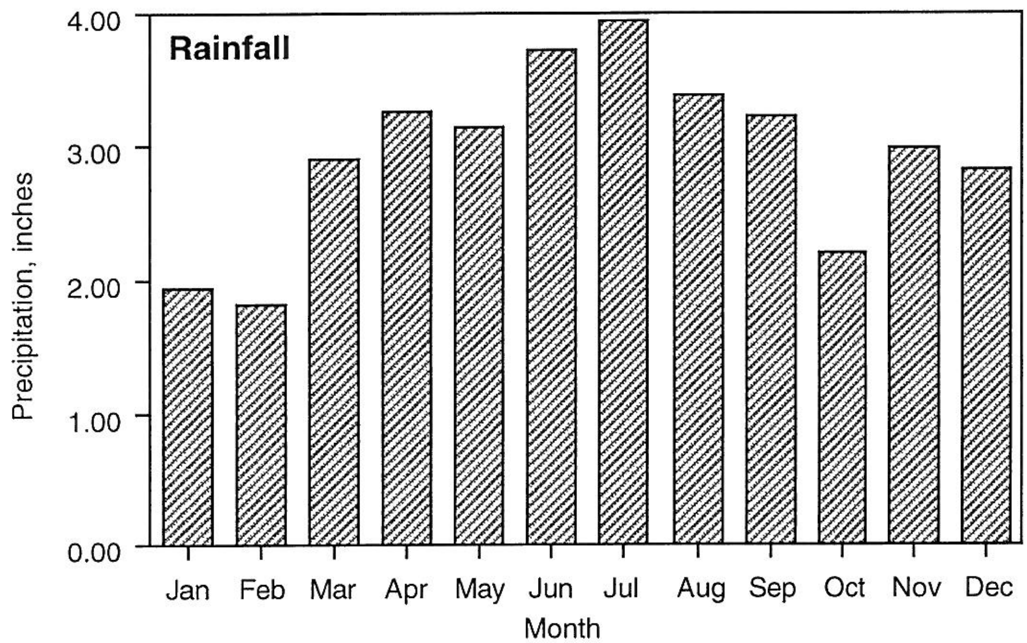


Figure 3.2 Average monthly precipitation for the four long-term cooperative weather stations in the Sandusky River Watershed.

Bucyrus, Fremont, Tiffin and Upper Sandusky stations, is shown in Figure 3.2. February is the month with the least precipitation, followed by January and October. July is the month with the highest average precipitation followed by June and August.

Across Ohio, precipitation is generally least in the northwest portion of the state, and increases to the east, south and southeast. Average annual precipitation in the Lake Erie snowbelt of northeastern Ohio totals 43 inches. Average annual precipitation in the southern tip of Ohio along the Ohio River is 43 inches.

Annual and seasonal precipitation varies considerably from year to year. In Figure 3.3, the annual and seasonal variations in rainfall are illustrated for 1975 to 1995. These data are the average values for the nine North Central Ohio weather stations. The height of the bars indicates the annual precipitation, while the colors within the bar indicate the season (October-December: yellow; January-March: blue; April-June: green; and July-September: red). During the drought year of 1988, the fall, winter and summer precipitation was near normal, but the spring precipitation was very low.

Spatial variations in rainfall are large, especially during seasons when thunder storm activity accounts for large proportions of the rainfall. Because of the importance of rainfall to agricultural in this watershed, networks of daily rainfall measurements are maintained by volunteers in Seneca and Wyandot counties. The Seneca County Program is operated by the Heidelberg College Water Quality Laboratory in cooperation with the Seneca Soil and Water Conservation District. Approximately 40 volunteers, using standardized rain gauges, report daily rainfall from April through October. The type of data generated by the network is illustrated in Table 3.2 for part of June 1998. On June 12, rainfall ranged from 0.58 to 3.35 inches among the observers. Total rainfall for the 14 day period ranged from 2.51 to 6.59 inches. Data from this network, that began in 1982, are available from the Heidelberg WQL.

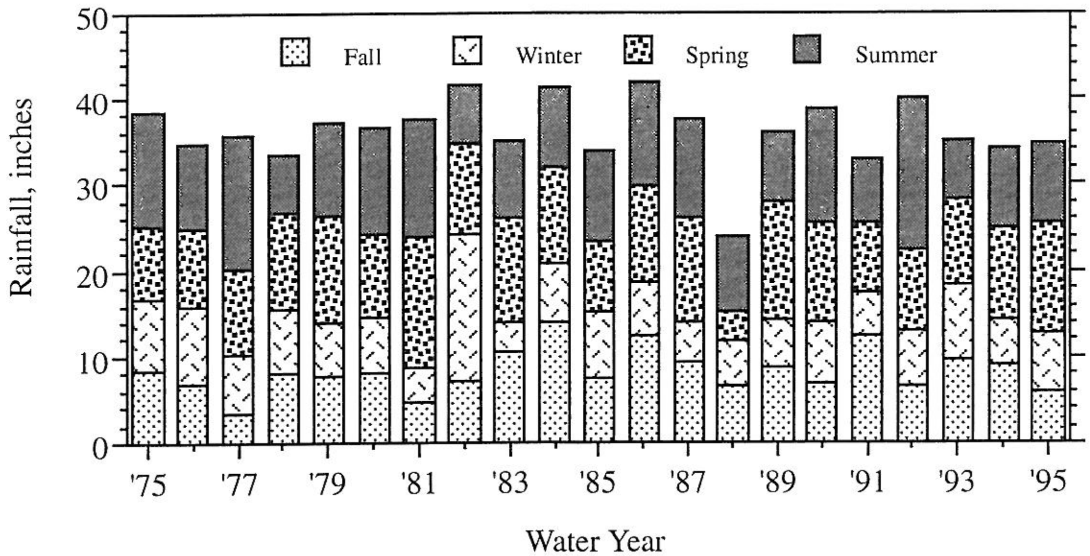


Figure 3.3. Annual and seasonal variations in precipitation, based on averages for North Central Ohio Weather Stations.

Streams and Rivers

The major surface water resources of the Sandusky River Watershed are the 2,200 miles of rivers, streams and drainage ditches that make up the drainage network of the Sandusky River Watershed (Figure 3.4). The major tributaries of the Sandusky River Watershed, along with their lengths, drainage areas and average gradients, are listed in Table 3.3. Several of the 11-digit hydrological units are named for the major tributaries. These include Broken Sword Creek, Tymochtee Creek (headwaters and lower), Honey Creek, Wolf Creek and Green Creek. The locations and names of all major tributaries listed in Table 3.3, as well as many other smaller tributaries, are shown for each subwatershed in the appendix.

Table 3.2 Daily precipitation for June 6-19, 1998, as reported in the Seneca County Rainfall Network.

Township/ Name	6	7	8	9	10	11	12	13	14	15	16	17	18	19	total
Adams															
Frankart	0	0	0	0.44	0	0.51	1.42	1.25	0	0	0	0	0	0	3.62
Hessick	0.17	0	0	0	0.40	0	0.80	1.52	0.24	0.06	0	0	0	0.05	3.24
Snavely	0.07	0	0	0	0.34	0	1.25	1.45	0.85	0.15	0.11	0	0	0.07	4.29
Weller	0	0	0	0.37	0	0	1.25	1.60	0.20	0.10	0	0	0.05	0	3.57
BigSpring															
Feck	0.18	0	0	0	1.30	0.02	2.75	0.90	0.08	0	0	0.12	0	0.49	5.84
Reinhart	0.24	0	0	0	0.66	0	1.50	1.20	0.10	0	0	0	0	0	3.70
Bloom															
Crum	0.17	0	0	0	0.40	0	1.60	1.15	0.43	0.05	0.05	0.23	0	0.27	4.35
Davis	0.26	0	0	0	0.50	0	1.30	1.34	0.40	0.10	0	0.24	0	0.50	4.64
Price	0.20	0	0	0	0.54	0.05	1.70	1.40	0.40	0.14	0.10	0.30	0	0.60	5.43
Clinton															
Baugher	0	0	0	0	0	0	3.00	1.50	0	0	0.50	0	0.20	0	5.20
Crabill	0.20	0	0	0	0.66	0	1.25	1.30	0.44	0	0	0	0	0.08	3.93
Eden															
Bumb	0.20	0	0	0	0.44	0	1.65	1.15	0.14	0.05	0	0.38	0	0.74	4.75
Morter	0.20	0	0	0	0.58	0	1.90	0.90	0.12	0	0.18	0.09	0	0.60	4.57
Siegle	0.20	0	0	0	0.56	0.03	1.77	1.10	0.2	0.03	0.08	0.09	0	0.40	4.46
Wallrabenstein	0.18	0	0	0	0.40	0	2.46	0.90	0.27	0.02	0.05	0.06	0	0.60	4.94
Hopewell															
Dewald	0.20	0	0	0	0.31	0	1.00	1.24	0	0	0	0	0	0.25	3.00
Kelbley	0.20	0.04	0	0	0.90	0	1.20	1.00	0.40	0.04	0	0	0.04	0.40	4.22
Jackson															
Brubaker	0.15	0	0	0	0.50	0	1.24	0.90	0.17	0	0.03	0.05	0	0.10	3.14
Liberty															
Hunker	0	0	0	0	0.40	0	0.85	1.00	0	0	0	0	0	0.26	2.51
Miller	0.16	0	0	0	0.46	0	0.68	1.20	0.15	0	0	0	0	0.33	2.98
Loudon															
Gillig	0.26	0	0	0	0.76	0	1.25	1.27	0.22	0	0	0	0	0.42	4.18
Lowery	0	0	0	0.50	0	1.25	0.90	0.24	0	0	0.04	0	0.50	0	3.43
Pleasant															
Knoblaugh	0.15	0	0	0	0.40	0	0.70	1.40	0.13	0	0	0	0	0.04	2.82
Stover	0.15	0	0	0	0.50	0	0.60	1.15	0	0.06	0	0.20	0	0.04	2.70
Reed															
Gore	0.15	0	0	0	0.70	0	1.95	1.50	0.82	0.08	0.06	0.10	0	0.14	5.50
Miller	0.18	0	0	0.28	0	0	1.99	1.2	0.5	0.08	0.18	0.06	0	0.10	4.57
Willman	0	0	0	0.48	0	1.30	1.25	0.84	0.08	0	0.44	0	0.05	0	4.44
Scipio															
Hall	0.02	0	0	0	0.40	0.02	1.75	0.96	0.23	0.02	0.15	0.20	0	0.16	3.91
Hopple	0.18	0	0	0	0.40	0.02	1.40	1.40	0.90	0.13	0.36	0.05	0	0	4.84
Powell	0	0	0	0	0.40	0.10	3.35	0	0	0.45	0	0	0	0.10	4.40
Seneca															
Brose	0.21	0	0	0	1.05	0	2.55	0.98	0.10	0.02	0.01	0.07	0	1.60	6.59
Thompson															
Eberhard	0.18	0	0	0	0.38	0	0.80	1.60	0.56	0.08	0	0.08	0	0.06	3.74
Miller	0	0	0	0.60	0	1.70	1.40	0.70	0	0	0	0	0.08	0	4.48
Zieber	0	0.08	0	0	0.46	0	0.58	1.55	0.40	0	0.13	0	0	0	3.20
Venice															
Biller	0.25	0	0	0	0.75	0	1.00	1.25	0.60	0.05	0	0.20	0	0.15	4.25
Featheringill	0.20	0	0	0	0.50	0	1.25	1.26	0.70	0.08	0.20	0.40	0	0.12	4.71

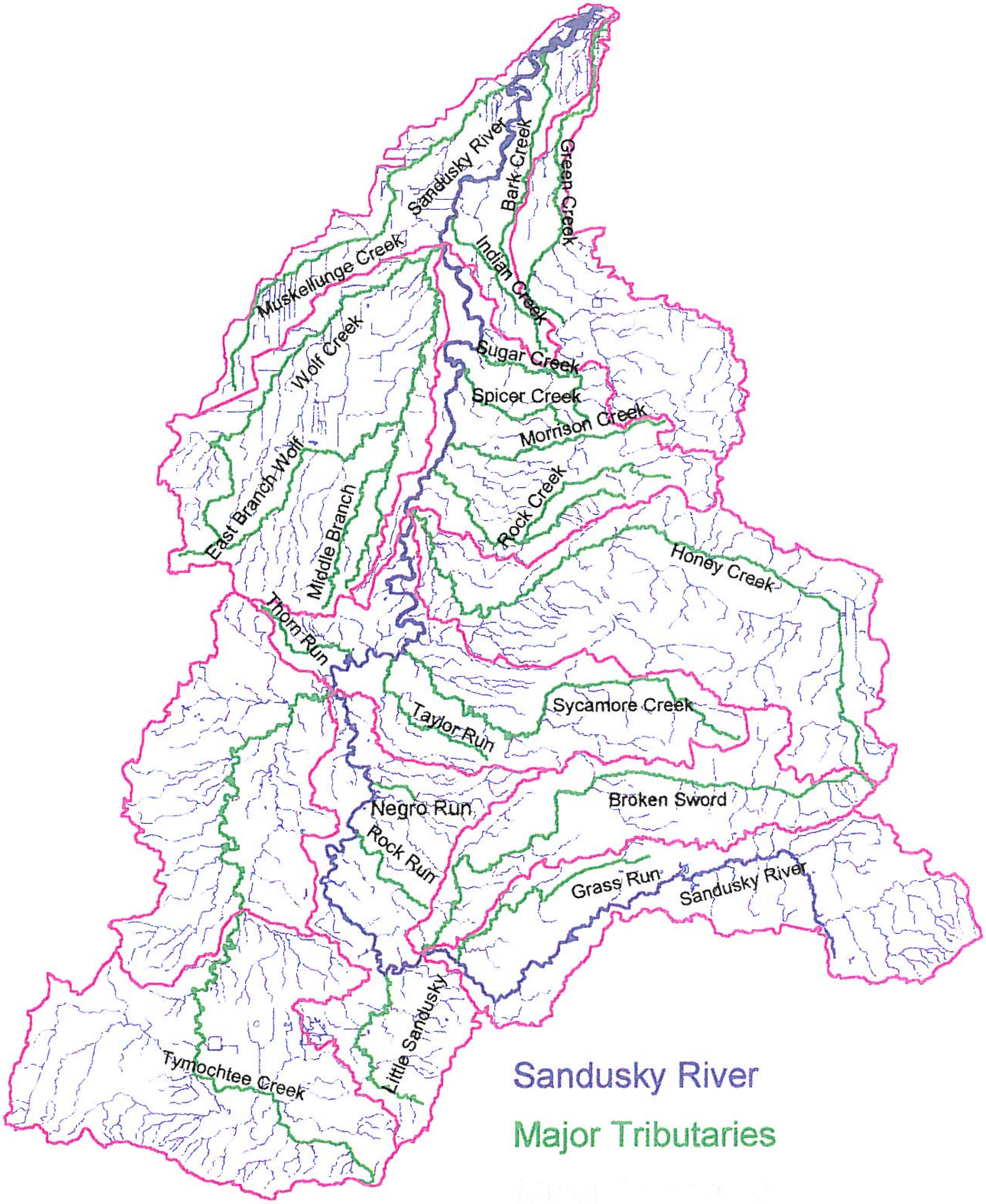


Figure 3.4 The Sandusky River and its tributaries.

Table 3.3. Gazatteer of principal streams in the Sandusky River Watershed (ODNR, Division of Water).

STREAM NAME	Length Miles	Elevation at Source	Elevation at Mouth	Avg. Fall Feet/Mile	Size of Drainage
SANDUSKY RIVER	130.2	1093	573	3.9	1420.7
Green Creek	22.9	727	573	6.7	80.8
Beaver Creek	3.6	727	682	12.5	49.8
Westerhouse Ditch	11.8	869	727	12.0	20.9
Emerson Creek	12.0	828	727	8.4	23.0
Royer Ditch	8.4	828	777	6.1	16.2
Bark Creek	10.7	656	575	7.5	12.8
Muskellunge Creek	18.3	7.5	576	7.0	46.7
Indian Creek	7.5	705	633	9.6	11.8
Wolf Creek	23.9	802	637	6.9	158.0
East Branch	18.2	775	649	6.9	84.5
East Branch	7.6	790	714	10.0	21.9
Middle Branch	3.2	768	739	9.1	11.5
Sugar Creek	10.4	805	648	15.1	13.5
Spicer Creek	6.1	777	660	19.2	12.6
Morrison Creek	11.0	836	703	12.2	20.3
Rock Creek	19.6	888	722	8.5	34.8
Armstrong & Beighly Ditch	5.2	888	855	6.4	11.4
Honey Creek	39.3	1005	728	7.1	179.0
Silver Creek	8.3	947	845	12.3	24.4
Aichholz Ditch	10.0	958	885	7.3	18.1
Brokenknife Creek	5.0	952	917	7.0	19.0
Sycamore Creek	20.0	955	745	10.5	64.2
Taylor Run	8.6	889	746	16.6	19.2
Thorn Run	4.0	795	749	11.5	9.6
Tymochtee Creek	54.8	901	757	2.6	302.0
Spring Run	6.5	828	764	9.8	30.1
Poverty Run	5.1	815	769	9.0	11.5
Little Tymochtee Creek	13.1	845	768	5.9	31.4
Lick Run	3.0	824	792	10.6	9.6
Oak Run	6.6	869	809	9.1	15.2
Warpole Creek	6.1	875	821	8.8	20.6
Little Tymochtee Creek	12.5	949	858	7.3	49.6
Reevhorn Run	8.1	970	892	9.6	14.5
Pawpaw Run	7.4	916	859	7.7	16.3
Carroll Ditch	3.6	879	869	2.8	14.7
Prairie Run	5.0	895	874	4.2	15.4
Negro Run	4.1	845	775	17.1	13.6
Rock Run	7.0	892	785	15.3	10.5
Little Sandusky River	12.5	938	837	8.1	38.5
Broken Sword Creek	32.0	1018	855	5.1	94.7
Brandywine Creek	6.1	1008	949	9.7	11.2
Grass Run	13.4	987	868	8.9	24.3
Loss Creek	5.4	1113	1012	18.7	12.2
Paramour Creek	9.6	1190	1093	10.1	27.8

The relationship between the hydrological unit boundaries and the stream network is also illustrated in Figure 3.4. Surface water flows out of each hydrological unit at a single point. All of the stream segments within a subwatershed originate in the subwatershed, except for those subwatersheds located along larger streams. For those watersheds, the main stream enters the subwatershed at a single point. There are five subwatersheds along the Sandusky River and two along Tymochtee Creek.

The U.S. Geological Survey currently operates five stream gauging stations in the Sandusky River Watershed (Figure 3.1). In addition, historical stream flow data are available for seven other stations that have been discontinued (Figure 3.1). The station names, identification numbers, drainage areas, period of records, and average annual discharges are shown in Table 3.4.

At each stream gauging station, the stage of the stream (height of water surface above a fixed reference point) is recorded at 15 or 30 minute intervals. Frequent measurements of river stage are required because, during runoff events and floods, water levels can change very rapidly. At each station, stream discharge measurements are periodically taken and the stream stage is recorded. The discharge measurements indicate the discharge rate of the river, in cubic feet per second (cfs) at a particular stage. Discharge measurements are made at a variety of stages, ranging from low flows to floods. A rating curve is developed for each station which indicates the relationship between stage (feet) and discharge (cfs). The rating curves are used to calculate daily, monthly and annual discharges for the streams. Discharge data are published annually by the USGS in their series entitled "*Water Resources Data, Ohio, Water Year 19xx.*" The data are also available on the www at http://www.oh.er.usgs.gov/.

Stream gauging stations are seldom located where water exits from a hydrological unit. These exit points are generally located where tributaries join or where tributaries enter lakes (Figure 3.4). At such locations, accurate stream gauging is difficult because the stage-discharge relationships may fluctuate through interactions of the flows from the two tributaries or with lake level. Instead stream gauging stations are located upstream from hydrological unit boundaries. Consequently, the drainage areas upstream from stream gauging stations differ from those of the hydrological units in which they are located. Discharge for hydrological units are generally estimated by extrapolation from nearby gauging stations. Approximately 88% of the drainage area of the Sandusky River Watershed is upstream from the Fremont gauging station, so that station reflects the cumulative surface runoff from most of the watershed.

The average annual volume of water discharged from the Sandusky River at the Fremont gauging station can be determined by multiplying the annual mean discharge in cubic feet per second by the number of seconds per year. This indicates that, on average, 32,400,000,000 cubic feet or 242,000,000,000 gallons of water flow past the Fremont gauging station on the Sandusky River per year. If this amount of water were spread out uniformly across the entire watershed area upstream from the Fremont station, the depth of the water would be 11.16 inches. This value represents the average annual runoff as listed for the Fremont station in Table 3.4.

Note that the annual mean discharge in cfs increases as the watershed size increases (Table 3.4). As watershed size increases, the volume of water discharged from a watershed will also increase, assuming that precipitation, ground water recharge and evaporation/transpiration are approximately the same. By calculating annual watershed runoff in inches, variations in watershed size are taken into account, and the runoff from various sized watershed can be directly compared. For the currently operating gauging stations in the Sandusky Watershed, annual runoff varies from 11.16 to 13.6 inches.

Table 3.4. Summary data for stream gauging stations in the Sandusky Watershed.

Station Name	Station Number	Drainage Area (mi^2)	Period of Record	Annual Mean Discharge (cfs)	Average Annual Runoff (inches)
Current Stations					
Sandusky River near Bucyrus	04196000	88.8	1925-35, 1938-51 1963-81, 1995-current	88.9	13.60
Tymochtee Creek at Crawford	04196800	229	1964-current	188	
Honey Creek at Melmore	04197100	149	1976-current year	133	12.15
Rock Creek at Tiffin	04197170	34.6	1983-current	31.0	12.17
Sandusky River near Fremont	04198000	1,251	1923-35 1938-current year	1027	11.16
Discontinued Stations					
Broken Sword Creek at Nevada	04196200	83.8	1976-82	102	16.50
Sandusky River near Upper Sandusky	04196500	298	1922-35, 1938-82	246	11.21
Tymochtee Creek near Marseilles	04296600	137	1970-74		
Sandusky River near Mexico	04197000	774	1923-36, 1938-83	587	10.30
Honey Creek near New Washington	04197020	17	1976-90	16.0	12.78
Wolf Creek at Bettsville	04197300	66.2	1976-82	58.5	12.0
East Branch Wolf Creek near Bettsville	04197450	82.4	1976-82	96.8	15.95

Surface water runoff is equivalent to about 30% of the average annual precipitation that falls on the Sandusky Watershed (36.6 inches, Table 3.1 average). Approximately 15% of the rain that falls on the watershed goes into ground water recharge, while the bulk of the rainfall (55%) is lost back to the atmosphere by evapo-transpiration.

Average annual stream runoff is generally lower in northwestern Ohio than in other parts of the state. Northeastern Ohio has areas with the highest annual runoff (up to 21 inches per year) while areas along the Ohio River range up to 18 inches per year.

Just as for rainfall, there are significant seasonal variations in discharge. In Figure 3.5, the average monthly discharge is shown for the Sandusky River at Fremont. The variations in monthly discharge are much greater than the variations in monthly rainfall (Figure 3.2). Months with the highest precipitation (June, July and August) do not have the highest stream discharge. A much larger proportion of precipitation leaves the watershed as runoff during the winter and early spring than during the summer because of the lower rates of evaporation/transpiration and higher soil moisture conditions in the winter. As evaporation/transpiration increases during the summer, soils dry out and a much smaller proportion of precipitation leaves the watershed as runoff.

From year to year, annual and seasonal discharge has considerable variation. In Figure 3.6, annual and seasonal discharge is shown for 1975-1995. Annual variations in discharge are much larger than annual variations in precipitation, due in large part to the annual variations in seasonal precipitation (Figure 3.3). During this time interval, the lowest annual discharge occurred during the drought of 1988, while the highest discharge occurred in 1984.

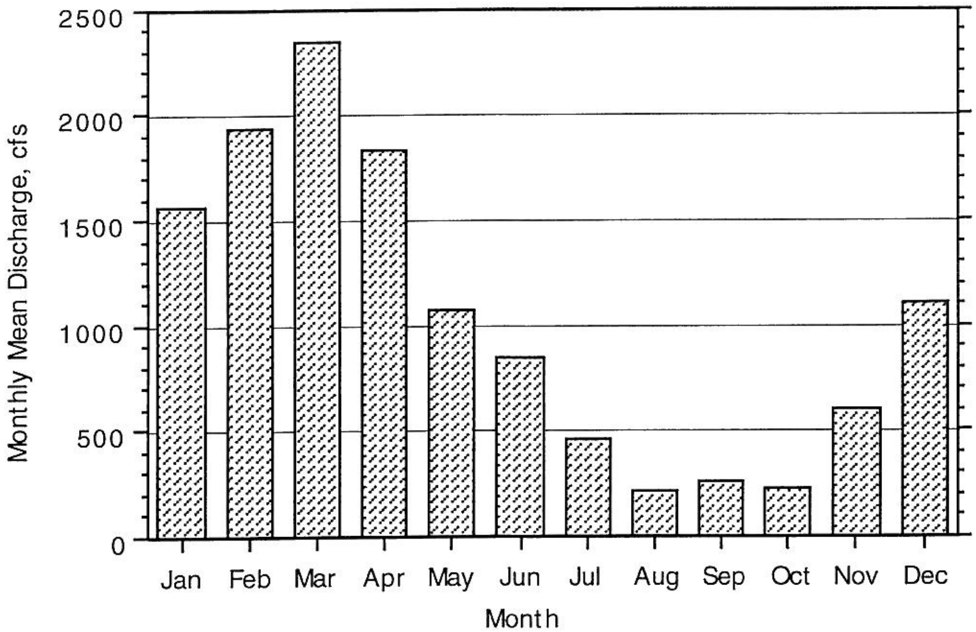


Figure 3.5 Average monthly discharge from the Sandusky River at Fremont for the period from 1924 to 1997.

Data from stream gauging stations are published annually by the U.S. Geological Survey. Table 3.5 is a reproduction of the discharge data for the Sandusky River Fremont gauging station for the 1997 Water Year as published by the USGS. Water years begin during October of the preceding year and end in September of that year. Thus, the 1997 Water Year includes data from October 1, 1996 through September 30, 1997. The discharge data provide mean daily discharges in cubic feet per second (cfs) for each day of the water year. Discharges prefixed by an "e" are estimated values. Estimations are required when the stage recording data fail or when ice jams or other factors disrupt the normal stage discharge relationships at the station.

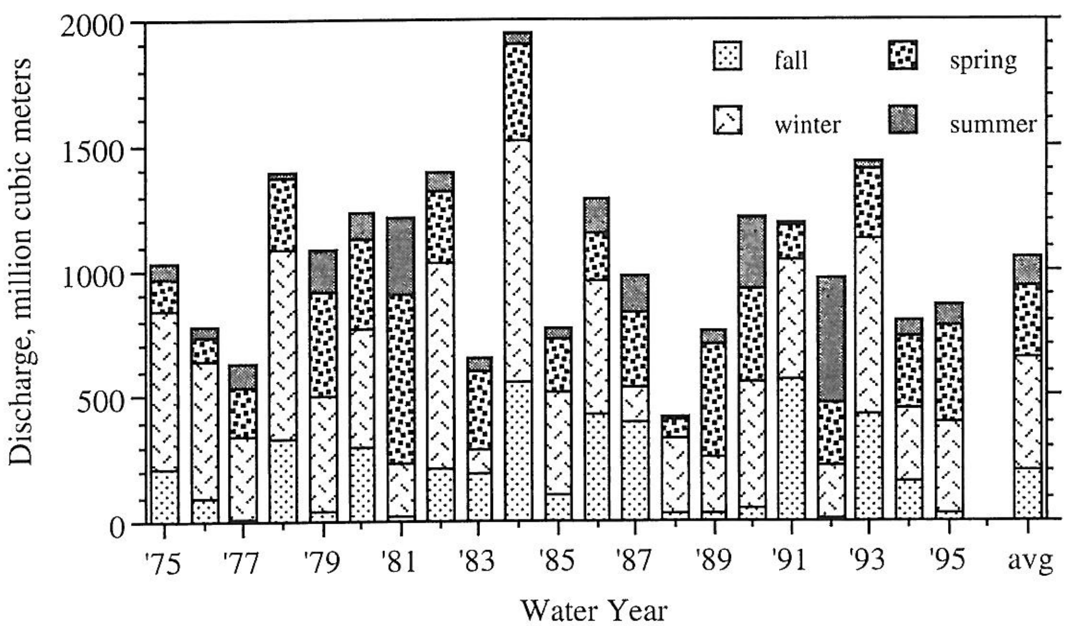


Figure 3.6 Annual and seasonal variations in discharge at the Sandusky Fremont gauging station, 1975-1995.

04198000 SANDUSKY RIVER NEAR FREMONT, OHIO

LOCATION.--Lat 41°18'28", long 83°09'32", in sec. 17, T.4 N., R.15 E., Sandusky County, Hydrologic Unit 04100011, on left bank at downstream side of county road bridge, 2.3 mi upstream from Ballville diversion dam, 2.5 mi downstream from Wolf Creek, and 3.5 mi southwest of Fremont.
DRAINAGE AREA.--1,251 mi².

WATER-DISCHARGE RECORDS

PERIOD OF RECORD.--November 1898 to March 1901 (gage height and discharge measurements only, published as "at Fremont"), October 1923 to December 1935, July 1938 to current year. Monthly discharge only for October 1923, published in WSP 1307.
REVISED RECORDS.--WSP 744: 1931-32. WSP 874: 1938. WSP 1144: 1924-30. WSP 1387: 1925, 1928-29, 1931-35. WSP 1912: Drainage area.
GAGE.--Water-stage recorder. Datum of gage is 626.3 ft above sea level. Nov. 18, 1898, to Mar. 10, 1901, nonrecording gage at site 4 mi downstream at different datum. Nov. 8, 1923, to Sept. 5, 1930, nonrecording gage at present site and datum.
REMARKS.--Records good except for periods of estimated record, which are poor, and July 8-18, which are fair. Water-quality data collected at this site.

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1996 TO SEPTEMBER 1997
DAILY MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	693	90	933	1170	e1000	9640	1550	391	14400	e967	e140	152
2	382	98	3670	925	e700	8950	1110	395	23700	e826	e209	137
3	234	176	3930	832	e620	7710	874	522	18400	571	e180	128
4	146	143	2640	814	e1500	5570	729	1500	15500	410	e160	114
5	100	115	1450	959	e10000	3450	682	2750	8820	339	e250	104
6	81	101	844	1720	e6600	3470	836	2360	3540	279	e350	97
7	76	99	656	1760	e4000	5090	783	1660	1760	255	e260	90
8	64	113	550	1130	e2300	4260	658	1340	1250	227	e209	88
9	60	109	485	720	e1200	2910	559	1080	944	4370	e160	86
10	63	135	431	e500	e880	2790	471	1020	738	8510	e125	94
11	57	138	462	e400	e700	3510	413	1080	613	4010	e103	111
12	51	174	4540	e350	e580	2860	580	894	541	1940	e85	301
13	50	225	8360	e320	e522	1720	2600	723	708	1070	149	470
14	47	234	e7400	e300	e470	3560	2260	616	767	758	640	309
15	45	207	6260	e370	e410	6140	1640	556	557	613	408	228
16	45	167	3310	e480	e360	4310	1100	490	458	551	269	178
17	46	141	5360	e400	e320	2550	1030	449	390	410	1580	140
18	55	131	10200	e370	e400	1510	1040	476	386	292	3600	114
19	79	123	e7000	e320	1760	1160	797	1720	468	236	3050	99
20	73	120	e4200	e290	2310	989	662	2770	507	216	2010	292
21	85	111	e1700	e260	3330	875	576	2960	435	228	1160	399
22	108	116	e1200	e1000	5070	795	513	1670	e1160	213	598	483
23	116	120	e930	e5000	3870	709	466	984	e679	240	447	304
24	116	114	2790	e4000	2280	610	429	710	e420	259	378	216
25	99	123	5610	e3000	1370	620	404	5720	e260	e262	391	169
26	90	300	e4500	e2500	1010	884	379	17800	e560	e245	429	138
27	81	2410	2960	e2200	11000	863	351	11300	e680	e227	345	117
28	79	3140	1450	e3000	16100	711	358	6270	e280	e204	272	104
29	81	2040	1130	e5500	---	1140	369	2740	e250	e190	242	92
30	106	1050	1590	e3500	---	1960	378	1830	e2100	e170	214	82
31	110	---	1580	e2000	---	1990	---	2670	---	e155	178	---
TOTAL	3518	12363	98121	46090	80662	93306	24597	77446	101271	29243	18591	5436
MEAN	113	412	3165	1487	2881	3010	820	2498	3376	943	600	181
MAX	693	3140	10200	5500	16100	9640	2600	17800	23700	8510	3600	483
MIN	45	90	431	260	320	610	351	391	250	155	85	82
CFSM	.09	.33	2.53	1.19	2.30	2.41	.66	2.00	2.70	.75	.48	.14
IN.	.10	.37	2.92	1.37	2.40	2.77	.73	2.30	3.01	.87	.55	.16

STATISTICS OF MONTHLY MEAN DATA FOR WATER YEARS 1924 - 1997, BY WATER YEAR (WY)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
MEAN	225	593	1101	1554	1930	2341	1826	1072	814	460	216	257
MAX	2521	4413	5495	7659	7504	8261	5524	3654	6091	3479	1660	3713
(WY)	1927	1993	1991	1930	1984	1978	1957	1969	1981	1992	1958	1981
MIN	9.94	25.4	32.6	53.5	60.3	319	144	100	43.4	30.9	22.4	13.5
(WY)	1964	1954	1964	1961	1964	1941	1946	1941	1988	1934	1952	1953

SUMMARY STATISTICS	FOR 1996 CALENDAR YEAR		FOR 1997 WATER YEAR		WATER YEARS 1924 - 1997	
ANNUAL TOTAL	550943		590644			
ANNUAL MEAN	1505		1618		1027	
HIGHEST ANNUAL MEAN					2167	1984
LOWEST ANNUAL MEAN					275	1934
HIGHEST DAILY MEAN	15700	Jan 19	23700	Jun 2	36000	Mar 15 1978
LOWEST DAILY MEAN	36	Sep 5	45	Oct 15	5.0	Oct 20 1963
ANNUAL SEVEN-DAY MINIMUM	38	Sep 3	48	Oct 12	6.3	Jul 9 1988
INSTANTANEOUS PEAK FLOW			24800	Jun 2 a	36500	Mar 16 1978
INSTANTANEOUS PEAK STAGE			10.59	Jun 2	16.14	Feb 24 1979
INSTANTANEOUS LOW FLOW			45	Oct 15	4.4	Feb 29 1964
ANNUAL RUNOFF (CFSM)	1.20		1.29		.82	
ANNUAL RUNOFF (INCHES)	16.38		17.56		11.16	
10 PERCENT EXCEEDS	4510		4090		2750	
50 PERCENT EXCEEDS	475		557		275	
90 PERCENT EXCEEDS	54		104		39	

a Peaks above base shown in table of peak discharges and stages at continuous-record surface-water-discharge stations.
e Estimated.

Table 3.5 USGS Sample page for Sandusky River gauge near Fremont.

The summary data (Table 3.5) also provide information on historical flow at the station. For the period from 1924-1997, 90% of the time the flow exceeded 39 cfs, 50% of the time flow exceeded 275 cfs, and 10% of the time flow exceeded 2,750 cfs. The highest daily mean discharge during this period was 36,500 cfs which occurred on March 15, 1978, while the lowest daily mean discharge was 5.0 cfs on October 20, 1963. Information of this type is extremely important for water resources planning. Low flow information indicates the volumes of water available to dilute pollutants entering from point sources. High flow and flood frequency data provide information useful for bridge and highway construction.

The extent of daily variability in discharge at the Fremont station is shown in Figure 3.7. Graphs of discharge versus time are referred to as hydrographs. This graph indicates the periods during which runoff events and floods occurred during the 1997 water year, as well as the periods of low flow. The highest daily mean discharge during the 1997 Water Year occurred on June 2 and was 23,700 cfs. The lowest mean daily discharge occurred on October 15 (1996) and was 45 cfs.

Specialized studies on stream flow in the Sandusky River include time-of-travel studies by the USGS. (USGS, 1976. Water Resources Investigations 76-50. Arthur O. Westfall. *Time of Travel of Solutes in Selected Reaches of the Sandusky River Basin, Ohio 1972 and 1973*) Such studies indicate the time it takes for water to move through sequential stream segments along the river. Travel times decrease dramatically as stream flows increase. Time-of -travel data are useful for predicting the arrival times at drinking water plants of chemicals that may have been spilled into the river.

There are currently five low-head dams located along the Sandusky River. These dams were constructed to provide municipal water supplies or to provide water power for grinding mills or electric power generation. The locations of these dams and their functions are listed in Table 3.6.

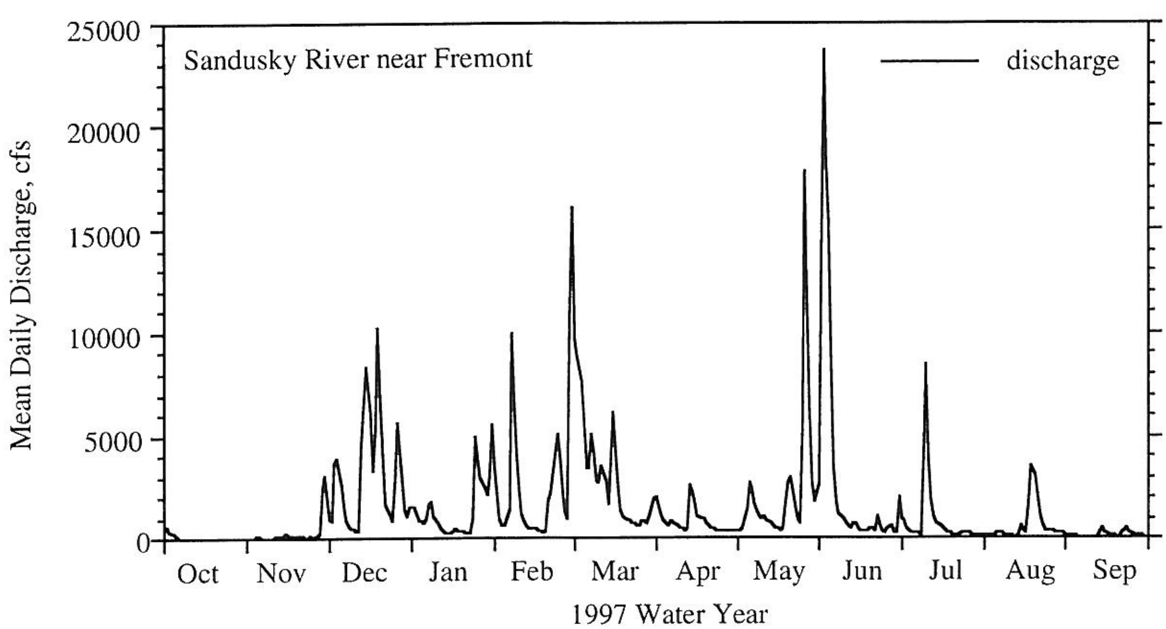


Figure 3.7 Annual hydrograph for the Sandusky River near Fremont for the 1997 water year.

Table 3.6 Dams located along the main stem of the Sandusky River.

Location	River Mile	Function
Ballville Dam		Water supply for Fremont, also historically for electrical power generation.
Bacon's Dam		Formerly water power for milling operations and for electrical power generation.
Ella Street Dam		Water supply for Tiffin.
St. John's Dam		Water supply for Tiffin.
Indian Mill Dam		Formerly water power for milling operations.

Lakes and Reservoirs

Natural lakes are uncommon within the Sandusky River Watershed. The most important lake environments are the several upground, pumped storage reservoirs that are used for public water supplies and recreation. There are also several quarries that are now filled with water, providing lake environments. Numerous farm ponds dot the landscape and there are also several large borrow-pit lakes adjacent to major highways. Standing water environments are also present in several natural areas/wetlands. Table 3.7 provides a listing of the major reservoirs and lakes in the Sandusky River Watershed, organized by subwatershed.

Table 3.7 Upground Reservoirs, Lakes and Major Wetlands in the Sandusky River Watershed.

Code	Subwatershed	Upground Reservoirs/Lakes/Major Wetlands
020	Sandusky, Bucyrus	Bucyrus Upground Reservoirs (four) Lake Galion Walton Lake
040	Sandusky, Upper Sand.	Upper Sandusky Upground Reservoir Ma-chri-ka-ba Lake
050	Tymochtee, headwaters	Killdeer Reservoir Killdeer Plains Wildlife Area, several ponds
080	Honey Creek	Attica Upground Reservoir Mohawk Lake Garlow Lake/Silver Creek Wetlands Willard Marsh New Washington Upground Reservoirs Bloomville Quarry on CR 19
090	Sandusky, Tiffin	Morrison Lake
100	Wolf Creek	Eells Park Lake (Bettsville) Quarry along Rt. 18, south of Bascom
110	Green Creek	Beaver Creek Upground Reservoir/Clyde

The major lake environments available to residents of the Sandusky River Watershed are Sandusky Bay and Lake Erie. These represent major international water resources that interact with the surface and ground water resources of the Sandusky River Watershed.

Ground Water

Ground water underlying the Sandusky River Watershed is an important part of the hydrological cycle. Ground water serves as the source for drinking water for many public water supplies as well as for private water supplies in the watershed. Ground water also sustains base flow in streams and rivers, and consequently maintains aquatic environments at times when surface runoff is not occurring.

The carbonate and dolomite bedrock which underlies glacial till and lake deposits form the most important aquifers in this area. Water readily flows through the cracks and solution channels of this bedrock. Consequently, these aquifers have high to moderate water yields, often supporting pumping rates over 100 gallons per minute. Such aquifers are found in western and north central portions of Seneca County and in most of Sandusky and Wyandot Counties. In the southeastern portion of Seneca County and the eastern two thirds of Crawford County, the bedrock is composed of shale. Shale is not a good source of water, with many wells providing less than 5 gallons per minute. Well drillers often encounter dry holes in these areas of shale bedrock.

In the northeast corner of Seneca County, as well as in adjacent parts of Sandusky, Erie and Huron Counties, the limestone is sufficiently close to the surface that sinkholes have developed. These sinkholes allow surface water to directly flow into the shallow bedrock aquifers and thereby carry surface water pollutants directly into the aquifers.

Areas of terminal moraines (see Figure 2.4) generally have greater depths to bedrock. In these locations, lenses of sand and gravel within the clay and silt deposits can provide limited sources of ground water.

The various types of bedrock underlying the watershed reflect geological activities that have occurred hundreds of millions of years in the past. Consequently the boundaries of the related aquifers do not match the boundaries of overlaying watersheds. Geologically more recent glacial activities have a much more direct impact on subwatershed boundaries.

The general direction of ground water movement within the bedrock aquifers is from south to north, with much of the ground water discharge occurring in Sandusky Bay and Lake Erie. Several of the streams in the northern portion of the Sandusky Hydrological Unit also receive considerable ground water, and consequently have higher base flow and lower summer time temperatures than streams in the southern portion of the watershed. The Blue Hole at Castalia as well as several nearby streams receive major ground water discharges, with some of the streams supporting cold water fisheries.

Detailed Ground Water Resource Maps have been published by the ODNR's Division of Water for all of the counties in Ohio and are available in print for Sandusky, Seneca, Wyandot and Crawford Counties. The Division of Water has also published Ground Water Pollution Potential Maps that are available for Sandusky and Seneca counties. Ordering information for these maps and other published information is available on ODNR's www pages (www.dnr.state.oh.us/odnr/water/pubs/maps/mapsmain.html).

Descriptions of ground water quantity and quality for counties throughout Ohio are also available as Ohio State University Extension Service Fact Sheets. These fact sheets are available at http://ohioline.ag.ohio-state.edu/lines/ennr.html#EFACT.

Chapter 4. Biological Resources

The biological resources of the Sandusky River Watershed consist of the many species of plants and animals that live within its boundaries. This Chapter contains lists of some of the major groups of animals found within the watershed, along with lists of both plant and animal species that are of special interest because of their threatened or endangered status. These lists were adapted from the Sandusky River Watershed Physical Inventory compiled by the Division of Natural Areas and Preserves of the Ohio Department of Natural Resources.

Lists of species found within the watershed include the fishes (Table 4.1), the mammals (Table 4.2), the snakes and lizards (Table 4.3), the turtles (Table 4.4), the frogs and toads (Table 4.5), the salamanders (Table 4.6) and breeding birds (Table 4.7). Several of the above species are either threatened or endangered at the state or national level. These endangered species of interest include birds (Table 4.8), aquatic wildlife (Table 4.9), terrestrial wildlife (Table 4.10), and plants (Table 4.11).

Biological resources essential to the functioning of the Sandusky Watershed as an ecosystem include the soil fauna and flora that support the fertility and productivity of the areas soils. In aquatic systems the algae, fungi and Zooplankton play essential roles in aquatic food chains. Likewise the diverse species of terrestrial and aquatic insects are essential to the functioning of the Sandusky Watershed as an ecosystem.

Eagles of the Sandusky River Watershed

Bald eagles have made a remarkable recovery in Ohio. From only four active nests in 1975 to 33 nests in 1996, the bald eagle is becoming more and more common in the skies over Ohio. The counties making up the Sandusky Hydrological Unit have been the center of bald eagle recovery in the state. In 1996 there were six nests in Ottawa County, seven in Sandusky County and three each in Erie, Seneca and Wyandot counties. Thus 22 of the 33 nesting sites were in this area.

The Sandusky River and its tributaries have become a major pathway for inland migration of eagles from Lake Erie to interior portions of Ohio. There are more eagles nests along the Sandusky River than along any other river in Ohio. Eagles nests are also located in tributary areas of the Sandusky including Honey Creek and the Killdeer Wildlife Area.

(Additional text is in Preparation)

Table 4.1 Fishes of the Sandusky River Watershed and their tolerance to pollutants.

COMMON NAME	SCIENTIFIC NAME	GENERAL TOLERANCE
Bass, Largemouth	*Micropterus salmoides*	Moderately Tolerant
Bass, Rock	*Ambloplites rupestris*	Not Rated by EPA
Bass, Smallmouth	*Microptera dolomieui*	Moderately Intolerant
Bass, White	*Morene chrysops*	Not Rated by EPA
Buffalo, Bigmouth	*Ictiobus cyprinellus*	Not Rated by EPA
Buffalo, Smallmouth	*Ictiobus bubalus*	Not Rated by EPA
Goldfish	*Carassisu auratus*	Tolerant
Carp	*Cyprinus carpio*	Tolerant
Carpsucker, Highfin	*Carpiodes velifer*	Not Rated by EPA
Carpsucker, Quillback	*Carpiodes cyprinus*	Not Rated by EPA
Carpsucker, River	*Carpiodes carpio carpio*	Not Rated by EPA
Catfish, Bullhead, Black	*Ictalurus melas*	Moderately Tolerant
Catfish, Bullhead, Brown	*Ictalurus nebulosus*	Tolerant
Catfish, Bullhead, Yellow	*Ictalurus natalis*	Tolerant
Catfish, Channel	*Ictalurus punctatus*	Not Rated by EPA
Central Stoneroller	*Campostoma anomalum*	Moderately Tolerant
Chub, Bigeye **(STATE THREATENED)**	*Notropis amblops*	Intolerant
Chub, Creek	*Semotilus atromaculatus*	Tolerant
Crappie, Black	*Poxomis nigmaculatus*	Not Rated by EPA
Crappie, White	*Pomoxis annularis*	Not Rated by EPA
Dace, Blacknose	*Rhinichthys atratulus*	Tolerant
Darter, Blackside	*Percina maculata*	Moderately Tolerant
Darter, Fantail	*Etheostoma flabellare*	Not Rated by EPA
Darter, Greenside	*Etheostoma blenniodides*	Moderately Intolerant
Darter, Johnny	*Etheostoma nigrum*	Moderately Tolerant
Darter, Rainbow	*Etheostoma caeruleum*	Moderately Intolerant
Eel, American **(STATE THREATENED)**	*Anguilla rostrata*	Not Rated by EPA
Freshwater Drum	*Aplodinotus grunniens*	Moderately Tolerant
Gar, Longnose	*Lepisosteus osseus*	Not Rated by EPA
Gizzard Shad	*Dorosoma cepdianum*	Not Rated by EPA
Grass Pickerel	*Esox americanus*	Moderately Tolerant
Logperch	*Percina caprodes*	Moderately Intolerant
Madtom, Stonecat	*Noturis flavus*	Intolerant
Minnow, Bluntnose	*Pimephales notatus*	Tolerant
Minnow, Bullhead	*Pimephales vigilaz*	Not Rated by EPA
Minnow, Fathead	*Pimephales promelas*	Tolerant
Minnow, Silverjaw	*Ericymba buccata*	Not Rated by EPA
Minnow, Suckermouth	*Phenacobius mirabilis*	Not Rated by EPA
Mottled Sculpin	*Cottus bairdi*	Not Rated by EPA
Muskellunge **(STATE SPECIAL INTEREST)**	*Esox masquinongy*	Not Rated by EPA
Northern Pike	*Esox lucius*	Not Rated by EPA
Perch, White	*Morene americana*	Not Rated by EPA
Perch, Yellow	*Perca flavenscens*	Not Rated by EPA
Shiner, Common	*Notropis cornutus*	Not Rated by EPA
Shiner, Emerald	*Notropis atherinoides*	Not Rated by EPA
Shiner, Ghost **(DNAP SPECIAL INTEREST)**	*Notropis buchanani*	Not Rated by EPA
Shiner, Golden	*Notemigonus crysoleucas*	Tolerant

Table 4.1 Fishes of the Sandusky River Watershed and their tolerance to pollutants, continued.

COMMON NAME	SCIENTIFIC NAME	GENERAL TOLERANCE
Shiner, Mimic	Notropis volucellus	Intolerant
Shiner, Redfin	*Notropis mirabilis*	Not Rated by EPA
Shiner, Sand	*Notropis stramineus*	Moderately Intolerant
Shiner, Spotfin	*Notropis spilopterus*	Not Rated by EPA
Shiner, Spot-tail	*Notropis hudsonius*	Moderately Tolerant
Shiner, Striped	*Notropis chrysocephalus*	Not Rated by EPA
Sucker, Black Redhorse	*Moxostoma duquensnei*	Intolerant
Sucker, Golden Redhorse	*Moxostoma eryuthrurum*	Intolerant
Sucker, Greater Redhorse **(STATE THREATENED)**	*Moxostoma valenciennesi*	Intolerant
Sucker, Northern Hogsucker	*Hypentelium nigricans*	Moderately Intolerant
Sucker, River Redhorse **(STATE SPECIAL INTEREST)**	*Moxostoma carinatum*	Intolerant
Sucker, Shorthead Redhorse	*Moxostoma macrolepidotum*	Intolerant
Sucker, Silver Redhorse	*Moxotoma anisurum*	Moderately Intolerant
Sucker, Spotted	*Minytrema melanops*	Not Rated by EPA
Sucker, White	*Catastomus commersoni*	Tolerant
Sunfish, Bluegill	*Lepomis macrochirus*	Moderately Tolerant
Sunfish, Green	*Lepomis cyanellus*	Tolerant
Sunfish, Longear	*Lepomis megalotis*	Moderately Intolerant
Sunfish, Orangespotted	*Lepomis humilis*	Moderately Tolerant
Sunfish, Pumpkinseed	*Lepomis gibbosus*	Moderately Tolerant
Topminnow, Eastern Blackstripe	*Fundulus notatus*	Not Rated by EPA
Walleye	*Stizostedion vitreum v.*	Not Rated by EPA

Table 4.2 Mammals of the Sandusky River Watershed.

ORDER	COMMON NAME	SCIENTIFIC NAME
Artioldactyla	White-tail Deer	*Odocoileus virginianus*
Carnivora	Badger	*Taxidea taxus*
Carnivora	Eastern Coyote	*Canis latrans*
Carnivora	Gray Fox	*Urocyon cinereoargenteus*
Carnivora	Least Weasel	*Mustela rixosa*
Carnivora	Long-tailed Weasel	*Mustela fernata*
Carnivora	Mink	*Mustela vison*
Carnivora	Raccoon	*Procyon lotor*
Carnivora	Red Fox	*Vulpes fulva*
Carnivora	Striped skunk	*Mephitis mephitis*
Chitoptera	Big Brown Bat	*Eptesicus fuscus*
Chiroptera	Eastern Pipistrelle	*Pipistrellus subflavus*
Chiroptera	Hoary Bat	*Lasiurus cinereus*
Chiroptera	Little Brown Bat	*Myotis lucifugus*
Chiroptera	Red Bat	*Laiurus borealis*
Chirptera	Silver-haired Bat	*Lasionycteris noctivagens*
Insectivora	Eastern Mole	*Scalops aquaticus*
Insectivora	Hairy-tailed Mole	*Parascalops breweri*
Insectivora	Star-nosed Mole	*Condylura cristata*
Insectivora	Least Shrew	*Cryptosis parva*
Insectivora	Short-tail Shrew	*Blarina brevicauda*
Lagomorpha	Cottontail Rabbit	*Sylvilagus floridanus*
Marsupialia	Virginia Opossum	*Didelphis marsupialis*
Rodentia	Beaver	*Castor canadensis*
Rodentia	Deer Mouse	*Peromyscus maniculatus*
Rodentia	Eastern Chipmunk	*Tamias striatus*
Rodentia	Fox Squirrel	*Sciurus niger*
Rodentia	Gray Squirrel	*Sciurus carlinensis*
Rodentia	Red Squirrel	*Tamiasciurus hudsonicus*
Rodentia	House Mouse	*Mus musculus*
Rodentia	Woodland Vole	*Microtus pinetorum*
Rodentia	Prairie Vole	*Microtus pennsylvanicus*
Rodentia	Meadow Jumping Mouse	*Zapus hudsoniaus*
Rodentia	Meadow Volc	*Microtus pennsylvanicus*
Rodentia	Muskrat	*Ondatra zibethica*
Rodentia	Norway Rat	*Rattus norvegicus*
Rodentia	Southern Flying Squirrel	*Claucomys colans*
Rodentia	Thirteen-lined Ground Squirrel	*Citellus tridecemlineatus*
Rodentia	White-footed Mouse	*Permoysucs leucopus*
Rodentia	Woodchuck	*Marmota monax*

Table 4.3 Snakes and lizards of the Sandusky River Watershed.

ORDER	COMMON NAME	SCIENTIFIC NAME
Squamata	Black Rat Snake	*Coluber constrictor*
	Blue Racer	*Coluber constrictor foxi*
	Butler's Garter Snake	*Thamnophis butleri*
State Endangered	Plains Garter Snake	*Thamnophis radix (State Endangered)*
State Special Interest	Easter Garter Snake MELANISTIC	*Thamnophis sirtalis*
	Eastern Garter Snake	*Thamnophis sirtalis*
State Endangered	Eastern Massasauga	*Sistrurus catenatus catenatus*
	Eastern Milk Snake	*Lampropeltis triangulum*
	Eastern Ribbon Snake	*Thamnophis sauritus*
DNAP Special Interest	Smooth Green Snake	*Opheodrys vernalis*
	Five-lined Skink	*Eumeces fasciatus*
State Special Interest	Eastern Fox Snake	*Elaphe vulpina*
	Northern Brown Snake	*Storeria dekayi*
	Northern Water Snake	*Nerodia sipedon*
	Queen Snake	*Natrix harteri*

Table 4.4 Turtles of the Sandusky River Watershed.

ORDER	COMMON NAME	SCIENTIFIC NAME
Testudines	Common Map Turtle	*Graptemys geographica*
State Special Interest	Blandings Turtle	*Emydoidea blandingi*
	Common Snapping Turtle	*Chelydra serpentina*
	Eastern Box Turtle	*Terrapene carolina*
	Midland Painted Turtle	*Chrysemys picta marginata*
	Stinkpot	*Sternotherus odoratus*
	Spiny Softshell Turtle	*Trionyx spiniferus*
State Special Interest	Spotted Turtle	*Clemmys gutatta*

Table 4.5 Frogs and toads of the Sandusky River Watershed.

ORDER	COMMON NAME	SCIENTIFIC NAME
Anura	American Toad	*Bufo americanus*
	Bullfrog	*Rana catesbeiana*
	Fowler's Toad	*Bufo woodhousei fowleri*
	Gray Treefrog	*Hyla versicolor*
	Green Frog	*Rana clamitans*
	Northern Cricket Frog	*Acris crepitans*
	Northern Leopard Frog	*Rana pipiens*
	Pickerel Frog	*Rana palustris*
	Spring Peeper	*Hyla crucifer*
	Western Chorus Frog	*Pseudacris triseriata*
	Wood Frog	*Rana slyvatica*

Table 4.6 Salamanders of the Sandusky River Watershed

ORDER	COMMON NAME	SCIENTIFIC NAME
Caudata	Eastern Tiger Salamander	*Ambystoma tigrinum tigrinum*
Caudata	Jefferson's Salamander	*Ambystoma jeffersonianum*
Caudata	Marbled Salamander	*Ambystoma opacum*
Caudata	Silvery Salamander	*Ambystoma platineum*
Caudata	Small-mouthed Salamander	*Ambystoma texanum*
Caudata	Spotted Salamander	*Ambystoma maculatum*
Caudata	Tremblay's Salamander	*Ambystoma tremblayi*
Caudata	Eastern Red-backed Salamader	*Plethodon cinereus*
Caudata	Slimy Salamander	*Plethodon glutinosus*
Caudata	Two-lined Salamander	*Eyrycea bisleneata*
Caudata	Red-Spotted Newt	*Notophthalmus viridescens v.*

Table 4.7 Breeding birds of the Sandusky River Watershed.

ORDER	COMMON NAME	SCIENTIFIC NAME
Anseriformes	Wood Duck	*Aix sponsa*
	Blue-Winged Teal	*Anas discors*
DNAP Special Interest	Green-winged Teal	*Anas crecca*
	Mallard	*Anas platyrhychos*
	Lesser Scaup	*Aythya affinis*
	Ring-necked Duck	*Aythya collaris*
DNAP Special Interest	Gadwall	*Anas strepera*
	Redhead	*Aythya americana*
	Canvasback	*Aythya valisineria*
	American Widgeon	*Mareca americana*
	Common Goldeneye	*Bucephala clangula*
	Bufflehead	*Bucephala albeola*
	Common Merganser	*Mergus merganser*
	Hooded Merganser	*Lophodytes cucullatus*
DNAP Special Interest	Northern Pintail	*Anas acuta*
DNAP Special Interest	Northern Shoveler	*Anas clypeata*
State Special Interest	Black Duck	*Anas rubripes*
	Canada Goose	*Branta canadensis*
Apodiformes	Chimney Swift	*Chaetura pelagica*
	Ruby-Throated Hummingbird	*Archilochus colubris*
Caprimulgiformes	Common Nighthawk	*Chordeiles minor*
	Killdeer	*Characdrius vociferus*
Ciconiiformes	Great Blue Heron	*Ardea herodias*
	Green Heron	*Butorides striatus*
Columbiformes	Mourning Dove	*Zenaida macroura*
	Rock Dove	*Columba livia*
Coraciiformes	Belted Kingfisher	*Ceryle torquata*
Falconiformes	American Kestrel	*Falco sparverius*
	Coopers Hawk	*Accipiter cooperii*
	Red-tailed Hawk	*Buteo jamaicensis*
	Red-Shouldered Hawk	*Buteo lineatus*
	Broad-Winged Hawk	*Buteo platypterus*
	Sharp-shinned Hawk	*Accipiter striatus*
	Bald Eagle	*Haliaeetus leucocephalus*
State endangered	Northern Harrier	*Circus cyaneus*
State endangered	Osprey	*Pandion haliaetus*
	Turkey Vulture	*Cathartes aura*
Gruiformes	Virginia Rail (State Special Interest)	*Rallus Limicola*
State Special Interest	Sora	*Porzana carolina*
Galliformes	Ring-Necked Pheasant	*Phasianus colchicus*
	Wild Turkey	*Meleagris gallopavo*
Passeriformes	Acadian Flycatcher	*Empidonax virescens*
	American Crow	*Corvus brachyrhynchos*
	American Goldfinch	*Carduleis tristis*
	American Redstart	*Septophaga ruticilla*
	American Robin	*Turdus migratorius*
	Black-billed Cuckoo	*Coccyzus erythropthalmus*
	Black-Capped Chickadee	*Parus atricapillus*

Table 4.7 Breeding birds of the Sandusky River Watershed, continued

ORDER	COMMON NAME	SCIENTIFIC NAME
	Blue Jay	*Cyannocitta cristata*
	Boblink	*Dolichonyx oryzivorous*
	Brown Creeper	*Certhia familiaris*
	Brown Thrasher	*Toxostoma rufum*
	Brown-Headed Cowbird	*Molothrus ater*
	Cedar Waxwing	*Bombycilla cedrorum*
	Common Crow	*Corvus brachyrhynchos*
	Common Grackle	*Quiscalus quiscula*
	Common Starling	*Sturnus vulgaris*
	Eastern Bluebird	*Sialia sialis*
	Eastern Kingbird	*Tyannus verticalis*
	Meadowlark, Eastern	*Sturnella magna*
Special Interest	Meadowlark, Western	*Sturnella neglecta*
	Eastern Phoebe	*Sayornis phoebe*
	Eastern Wood Pewee	*Contopus virens*
	Flycatcher, Willow	*Empiconax traillii*
	Gnatcatcher, Blue-Gray	*Polioptila caerulea*
	Gray Catbird	*Dumetella carolinensis*
	Horned Lark	*Eremophila alpestris*
	House Finch	*Carpodacus mexicanus*
	Indigo Bunting	*Passerina cyanea*
State Endangered	Loggerhead Shrike	*Lanius ludovicianus*
	Northern Cardinal	*Cardinalis cardinalis*
	Northern Junco	*Junco hyemalis*
	Northern Mockingbird	*Mimus polyglottos*
	Northern Oriole	*Icterus galbula*
	Orchard Oriole	*Icterus spurius*
	Northern Waterthrush	*Seivrus noveboracensis*
	Nuthatch, White-Breasted	*Sitta carolinensis*
	Ovenbird	*Seiurus aurocapillus*
	Purple Martin	*Progne subis*
	Red-Winged Blackbird	*Agelaius phoeniceus*
	Rose-breasted Grossbeak	*Pheucticus ludovicianus*
	Rufous-Sided Towhee	*Pipilo erythrophthalmus*
	Scarlet Tanager	*Piranga olivacea*
	Sparrow, Chipping	*Spizella passerina*
	Sparrow, Field	*Spizella pusila*
	Sparrow, Grasshopper	*Ammodramus savannarum*
	Sparrow, Henslow's	*Passerherbulus henslowii*
	Sparrow, House	*Passer domesticus*
	Sparrow, Savannah	*Passerculus sandwichensis*
Passeriformes	Sparrow, Song	*Melospiza meoldia*
	Sparrow, Swamp	*Melospiza georgiana*
	Sparrow, Vesper's	*Pooecetes gramineus*
	Swallow, Barn	*Hirundo rustica*
	Swallow, Northern Rough-Winged	*Stelgidopteryx serripennis*
	Swallow, Tree	*Tachycineta bicolor*
	Thrush, Wood	*Hyocichla mustelina*

Table 4.7 Breeding birds of the Sandusky River Watershed, continued

ORDER	COMMON NAME	SCIENTIFIC NAME
	Thrush, Swainson's	*Hylocichla ustulata*
	Tufted Titmouse	*Parus bicolor*
	Veery	*Catharus fuscenscens*
Piciformes	Woodpecker, Downy	*Picoides pubescens*
	Woodpecker, Hairy	*Dendrocopos villosus*
	Northern Flicker	*Colaptes aurotus*
	Woodpecker, Pileated	*Dryocopus pileatus*
	Woodpecker, Red-Bellied	*Melanerpes carolinus*
	Woodpecker, Red-Headed	*Melanerpes erythrocephalus*
Strigiformes	Barred Owl	*Strix varia*
	Great Horned Owl	*Bub virginianus*
	Screech Owl	*Otus asio*
Tringa	American Woodcock	*Philohela minor*
State Special Interest	Common Snipe	*Capella gallingo*
	Solitary Sandpiper	*Tringa solitaria*
State Threatened	Upland Sandpiper	*Bartramia Longicauda*
	Spotted Sandpiper	*Actitis hypoleucous*

Table 4.8 Endangered or threatened birds of the Sandusky River Watershed.

SPECIES	SCIENTIFIC NAME	STATUS	YEAR	COUNTY
Bald Eagle	*Haliaeetus leucocephalus*	State Endangered	1998	Seneca
			1998	Wyandot
			1998	Seneca
			1997	Sandusky
			1997	Sandusky
			1997	Sandusky
			1997	Sandusky
			1998	Wyandot
Osprey	*Pandion haliaetus*	State Endangered	1998	Seneca
			1998	Wyandot
Loggerhead Shrike	*Lanius ludovicianus*	State Endangered	1981	Seneca
			1981	Seneca
			1984	Seneca
Western Meadowlark	*Sturnella neglecta*	Special Interest	1987	Seneca
			1987	Seneca
			1984	Wyandot
Grn Wing Teal	*Anas crecca*	Special Interest	1983	Sandusky
Gadwall	*Anas strepera*	Special Interest	1983	Sandusky
Sora Rail	*Porzana Carolina*	Special Interest	1983	Wyandot
Northern Harrier	*Circus cyaneus*	State Endangered	1983	Wyandot
Shoveler	*Anas clypeata*	Special Interest	1983	Wyandot
Virginia Rail	*Rallus limicola*	Special Interest	1984	Wyandot
			1984	Wyandot
Upland Sandpiper	*Bartramia longicauda*	State Threatened	1981	Seneca
			1981	Seneca
			1984	Wyandot
			1983	Wyandot
			1986	Wyandot
Black-throated Green Warbler	*Dendroica virens*	Special Interest	1985	Wyandot
Sedge Wren	*Cistothorus platensis*	State Endangered	1976	Seneca
			1986	Wyandot
			1976	Wyandot
			1985	Wyandot

Table 4.9 Endangered or threatened aquatic wildlife of the Sandusky Watershed.

SPECIES	SCIENTIFIC NAME	STATUS	YEAR	COUNTY
Bigeye Chub Fish	*Notropis amblops*	Threatened	N/A	Seneca
Blandings Turtle Reptile	*Emydoidea blandingii*	Special Interest	1990	Sandusky
Ghost Shiner Fish	*Notropis buchanani*	Special Interest	N/A	N/A
Greater Redhorse Fish	*Moxostoma valenciennesi*	Threatened	1981	Seneca
			1981	Seneca
Northern Riffleshell Mussel	*Epioblasma rangiana*	Endangered	1970	Wyandot
Plains Clubtail Dragonfly	*Gomphus externus*	Endangered	1990	Seneca
			1990	Wyandot
			1990	Wyandot
Purple Wartyback Mussel	*Cyclonaias tuberculata*	Special Interest	1970	Seneca
			1965	Seneca
			1978	Wyandot
			1970	Wyandot
			1971	Wyandot
			1970	Wyandot
Rayed Bean Mussel	*Villosa fabalis*	Endangered	1971	Wyandot
			1970	Wyandot
			1978	Wyandot
			1979	Wyandot
			1971	Wyandot
			1979	Wyandot
			1970	Wyandot
River Redhorse Fish	*Moxostoma carinatum*	Special Interest	1981	Sandusky
			1993	Seneca

Table 4.10 Endangered or threatened terrestrial wildlife of the Sandusky River Watershed.

SPECIES	SCIENTIFIC NAME	STATUS	YEAR	COUNTY
Plains Gartern Snake Reptile	*Thamnophis radix*	Endangered	1995	Wyandot
			1985	Wyandot
			1980	Wyandot
			1980	Wyandot
			1954	Marion
Beer's Noctid Insect	*Papaipema beerina*	Endangered	1995	Wyandot
Eastern Massasauga Reptile	*Sistrurus catenatus*	Endangered	1995	Wyandot
			1995	Wyandot
			1979	Wyandot
			1986	Wyandot
Kirtland's Snake Reptile	*Clonophis kirtlandi*	Threatened	1985	Wyandot
Smooth Green Snake Reptile	*Opheodrys vernalis*	Special Interest DNAP Monitored	1985	Wyandot
Melanistic Garter Snake Reptile	*Thamnophis sirtalis*	Special Interest	1980	Sandusky
Badger Mammal	*Taxidea taxus*	Special Interest	1998	Seneca
			1998	Seneca
Spartina Moth Insect	*Spartiniphaga inops*	Endangered	1995	Wyandot

Table 4.11 Endangered or threatened plants of the Sandusky River Watershed.

SPECIES	SCIENTIFIC NAME	STATUS	YEAR	COUNTY
Ashy Sunflower	*Helianthus mollis*	Threatened	1981	Wyandot
Baltic Rush	*Juncus balticus*	State Protected	1960	Crawford
Bicknell's Sedge	*Carex bicknellii*	Threatened	1996	Crawdord
Crinkled Pulp Lichen	*Collema crispum*	Extirpated	1962	Seneca
False Hop Sedge	*Carex lupuliformis*	Threatened	N/A	N/A
Fireweed	*Epilobium angustifolium*	Endangered	1971	Huron
Glomerate Dodder	*Cuscuta Glomerata*	Threatened	1990	Wyandot
Lg. Round Leaf Orchid	*Platanthera orbiculata*	State Protected	1985	Crawford
Little Yellow Sedge	*Carex cryptolerpis*	State Protected	1969	Wyandot
Netted Chain-fern	*Woodwardia areolata*	State Protected	1986	Huron
N. Bog Violet	*Viola Nephrophylla*	Endangered	1967	Sandusky
Pale Carrion Flower	*Smilax herbacea*	Threatened	1961	Seneca
			1962	Wyandot
Prairie Fringed Orchid	*Platanthera leucophaea*	Threatened	1997	Sandusky
			1997	Sandusky
Prairie Ironweed	*Vernonia fasciculata*	State Protected	1974	Wyandot
			1990	Wyandot
			1980	Wyandot
			1990	Wyandot
Prairie False Indigo	*Baptisia lactea*	State Protected	1996	Wyandot
			1978	Wyandot
Sartwells Sedge	*Carex sartwellii*	State Protected	1993	Crawford
Schweintz's Umbrella Sedge	*Cyperus schweinitzii*	State Protected	1960	Crawford
Southern Wapato	*Lophotocarpus calycinus*	Undetermined	1968	Wyandot
Swamp Birch	*Betula pumila*	Threatened	1976	Wyandot
Swamp Cottonwood	*Populus hereophylla*	State Protected	1988	Seneca
Tall Manna-Grass	*Glyeceria grandis*	State Protected	1965	Seneca
Tall St. Johns-Wort	*Hypercium majus*	State Protected	1994	Sandusky
			1977	Wyandot
Tuberculed Rein-Orchid	*Platanthera flava*	State Protected	1985	Crawford
			1960	Wyandot
Twig-Rush	*Cladium mariscoides*	State Protected	1977	Wyandot
Wheat Sedge	*Carex atherodes*	State Protected	1993	Crawford
			1996	Wyandot
			1994	Wyandot
			1993	Wyandot
			1996	Wyandot

Chapter 5. Aquatic Life Use Attainment

General Approaches to Water Quality Assessment

This chapter, along with the next three chapters, will focus on the quality of the water resources in the Sandusky River Watershed. The term "quality of water resources" can mean many things, depending on the perspectives of the observer. From the standpoint of governmental agencies charged with protecting water resources, the quality of water resources is assessed for each of the potential major uses of the resource. Thus waters are first classified as to their existing and potential uses. As noted in Sidebar 5.1, the designated uses of Ohio's streams and rivers are divided into three major categories -- support for aquatic life, provision of water supplies for drinking water, agriculture and industry, and support for recreational activities.

State and federal agencies develop water quality standards for each of the designated uses. Many water quality standards are expressed as concentrations of specific chemicals that should not be exceeded. In the case of dissolved oxygen, standards take the form of minimum concentrations necessary to sustain specified aquatic communities. For drinking water, standards are applicable to the treated drinking water rather than to the source water. However, the source waters should be of sufficient quality that standard treatment techniques can result in meeting the drinking water standards. For aquatic life, the standards take the form of numerical indices that reflect the characteristics of the aquatic life communities that streams should support. Where these indices drop below values specified for specific streams, the streams are deemed to be in violation of state water quality standards.

State and federal agencies, as well as other organizations, operate various types of monitoring programs to determine if water quality standards are being met. Where standards are being violated, the causes and sources of the violations are determined and remedial programs are developed. In these chapters, the use designations, water quality standards, monitoring results, and causes and sources of violations of water quality standards in the Sandusky River Watershed will be presented.

Aquatic Habitat Use Designations for the Sandusky Watershed

The stream segments with specific aquatic habitat use designations in the Sandusky River Watershed are shown in Figure 5.1. A total of 845 miles (38.5%) of streams in the watershed have specific use designations. These represent 110 specific stream segments. The OEPA segment numbers and names of these 110 segments are shown in the appendix to this report. Streams lacking use designations are largely restricted to many of the small, headwater streams throughout the watershed and to constructed drainage ditches. The miles of designated and undesignated streams in each subwatershed, as well as for the Sandusky Watershed as a whole are shown in Table 5.1. The low percentage of designated streams in the Wolf Creek and Sandusky-Fremont subwatersheds reflect the large numbers of drainage ditches they contain.

Sidebar 5.1 : Designated Uses for Water Resources in Ohio

Aquatic Life Habitat Use Designations

In assessing the quality of Ohio's streams and rivers, the Ohio EPA relies heavily on whether or not a stream segment is achieving its aquatic life habitat use designation. The aquatic habitat use designations used by the Ohio EPA are:

- **Exceptional Warmwater Habitat (EWH)**
- **Warmwater Habitat (WWH)**
- **Modified Warmwater Habitat (MWH)**
- **Limited Resource Water (LRW)**
- **Seasonal Salmonid Habitats (SSH)**
- **Coldwater Habitat (CH)**

The vast majority of streams and rivers in Ohio are designated as Warmwater Habitat. Waters classified as Warmwater Habitat should be "capable of supporting and maintaining a balanced, integrated, adaptive community of aquatic organisms". This is the principal restoration target for water resources management in Ohio. Descriptions of the other aquatic life habitat use designations are available at the Ohio EPA web site (http://chagrin.epa.state.oh.us/watershed/aquatdef.htm).

Water Supply Use Designations

The Ohio EPA specifies the following three water supply use designations (ref):

- **Public Water Supplies** - these are waters that with conventional treatment will be suitable for human intake and meet federal regulations for drinking water. Criteria associated with this use designation apply within 500 yards of surface water intakes for human consumption
- **Agricultural Supplies** - these waters are suitable for irrigation and livestock watering without treatment.
- **Industrial Supplies** - these waters are suitable for commercial and industrial uses with or without treatment.

Recreation Use Designations

In Ohio, Recreational Use Designations are in effect during the recreation season - May 1- October 15. There are three subdivisions of recreational use.

- **Bathing Waters** - these waters are suitable for swimming where a lifeguard and/or bathhouse facilities are present, and include any additional similar areas where the water quality is approved by the Director of the Ohio EPA.
- **Primary Contact Recreation** - these waters are suitable for full-body contact recreation such as swimming, canoeing and scuba diving with minimal threat to public health as a result of water quality.
- **Secondary Contact Recreation** - these waters are suitable for partial body contact recreation such as, but not limited to, wading, with minimal threat to public health as a result of water quality.

State Resource Waters Use Designation

State Resource Waters are water bodies that lie within park systems, wetlands, wildlife areas, wild, scenic and recreational rivers and publicly owned lakes and waters of exceptional recreational or ecological significance.

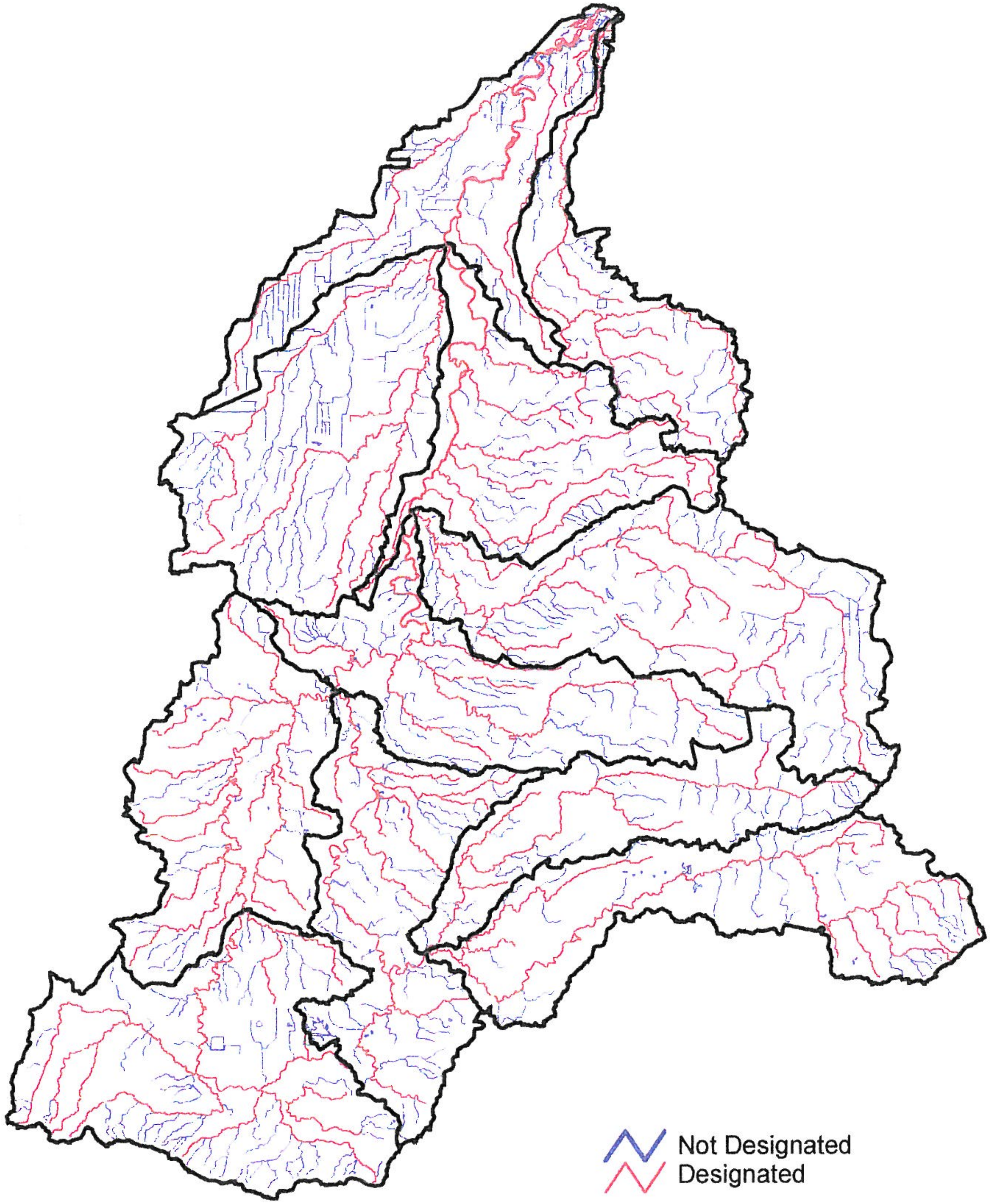


Figure 5.1. Aquatic habitat use designations in the Sandusky River Watershed.

Table 5.1 Aquatic habitat use designations for the subwatersheds of the Sandusky River Watershed.

Code number	Hydrological Unit Name (Subwatershed)	Total Stream Length miles	Designated WWH miles	Designated MWH/LRW miles	Undesig-nated miles	Percent Designated %
020	Sandusky-Bucyrus	171.8	87.9		83.9	51.2
030	Broken Sword	110.5	47.7		62.8	43.2
040	Sandusky-Upper Sand.	199.3	80.1	4.6(MWH-C)	114.6	42.5
050	Tymochtee-headwaters	255.9	89.9		166.0	35.1
060	Tymochtee-lower	179.5	93.5		86.0	52.0
070	Sandusky-Mexico	198.7	64.4		134.3	32.4
080	Honey Creek	248.6	88.7		159.9	35.7
090	Sandusky-Tiffin	199.6	91.7		107.9	45.9
100	Wolf Creek	250.4	54.9	11.6(LRW)	183.9	26.6
110	Green Creek	130.0	71.3		58.7	54.8
120	Sandusky-Fremont	248.6	59.2		189.4	23.8
	Sandusky River Watershed, total	2,192.9	829.3	16.2	1347.4	38.6

Of the total of 845 stream miles with aquatic habitat use designations in the Sandusky Watershed, 829 of them are designated Warmwater Habitat (WWH). A total of 4.6 miles are designated as Modified Warmwater Habitat (MWH-C) and a total of 11.6 miles are designated as Limited Resource Water (LRW). The definitions of these designations are:

Warmwater Habitat (WWH) - Defines the typical assemblage of aquatic organisms for Ohio rivers and streams. It is the principal restoration target for the majority of water resource management efforts in Ohio. Criteria vary by ecoregion and site type.

Modified Warmwater Habitat (MWH) - Applies to streams with extensive and irretrievable physical habitat modifications, such that WWH criteria are not attainable. The activities contributing to the modified habitat designation have been sanctioned and permitted by state or federal law. The representative aquatic assemblages are generally composed of species that are tolerant to low dissolved oxygen, silt, nutrient enrichment, and poor habitat quality. The **MWH-C** designation applies to streams that have been heavily channelized. The biocriteria are set separately for each subcategory.

Limited Resource Water (LRW) - Applies to streams that have drainage areas of less than three square miles and either may lack water on a recurring annual basis, or have been irretrievably altered to the extent that no appreciable assemblage of aquatic life can be supported; no formal biological criteria are established for this designation.

Aquatic Life Water Quality Standards and Monitoring in Ohio

The OEPA conducts detailed biological monitoring studies on streams and rivers throughout Ohio. Standardized procedures, applicable to the size of streams under investigation, are used to sample the fish and invertebrate communities. These sampling methods are detailed in publications of the OEPA's Division of Surface Water.

From the results of the biological monitoring, the following three numerical indices are calculated:

Index of Biological Integrity (IBI) - This index is based on fish species diversity and species populations. The highest score is 60.

Invertebrate Community Index (ICI) - This index is based on the macroinvertebrate communities living in a stream or river. The highest score is 60.

Modified Index of Well Being (Miwb) - This index is based on fish mass and density, with 13 pollution tolerant species of fish removed from certain calculations.

To develop numerical standards, in terms of the above indices, the OEPA conducts studies at streams and rivers termed "reference sites" for each of the five major ecoregions of Ohio (Figure 5.2). These ecoregions are areas of generally comparable habitats in terms of geology, soils and natural vegetation. The reference sites are selected such that they have minimal pollutant impacts and optimal habitat characteristics for that ecoregion. In general, the 25th percentile value of the indices for the reference sites in a given ecoregion becomes the warmwater standard index value for streams of comparable size in that ecoregion.

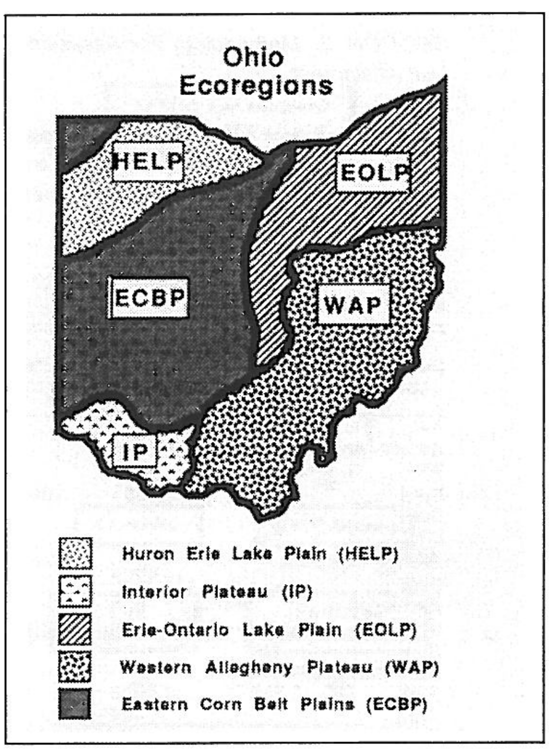


Figure 5.2 Ecoregions of Ohio.

The streams and rivers in the Sandusky River Watershed are located in either the Eastern Corn Belt Plains or the Huron/Erie Lake Plains. The aquatic life standards for warmwater habitat streams in these ecoregions are shown in Table 5.2.

Aquatic life standards for modified warmwater habitats as well as those for WWH and MWH for other ecoregions are shown in Table 7.1 of the OEPA manual entitled "Biological Criteria for the Protection of Aquatic Life: Volume II: Users Manual for Biological Field Assessment of Ohio Surface Water," October 30, 1987 (Updated January 1, 1988).

The OEPA has also developed a standard set of terms for describing the degree of use attainment of streams and rivers that they have monitored. These terms are described in Table 5.3.

Table 5.2 Aquatic Life Standards for Warmwater Habitat (WWH) use designation and applicable to the Sandusky River Watershed.

Index/Ecoregion	Eastern Corn Belt Plains	Huron/Erie Lake Plain
Index of Biological Integrity (Fish)		
Headwaters sites	40	32
Wading sites	40	32
Boat sites	42	34
Modified Index of Well-Being (Fish)		
Wading sites	8.5	7.3
Boat sites	8.7	8.6
Invertebrate Community Index		
Artificial Substrate Samplers	38	34

Table 5.3 Degrees of Use Attainment for Ohio streams and rivers.

Status Description	Qualifications
Fully attaining	All indices meet standards.
Fully attaining but threatened.	All indices meet standards, but land use activities in the watershed pose an immediate threat to maintaining water quality at this level.
Partially attaining	One of two or two of three indices does not meet criteria and are not in the poor or very poor category.
Non-attaining	None of the indices meet standards or one organism group indicates a severe toxic impact (poor or very poor category) even if the other organism groups indicate attainment.

Aquatic Life Use Attainment in the Sandusky Watershed

The degree of use attainment for monitored stream and river segments in the Sandusky River Watershed is shown in Figure 5.3. These results are extracted from the OEPA's 1996 305B Report and the OEPA's 1998 Addendum to the 1996 305B Report, which are available on the WWW at http://chagrin.epa.state.oh.us/document_index/305b.html. Some of the data were also obtained from OEPA's *Explore Your Watershed* site

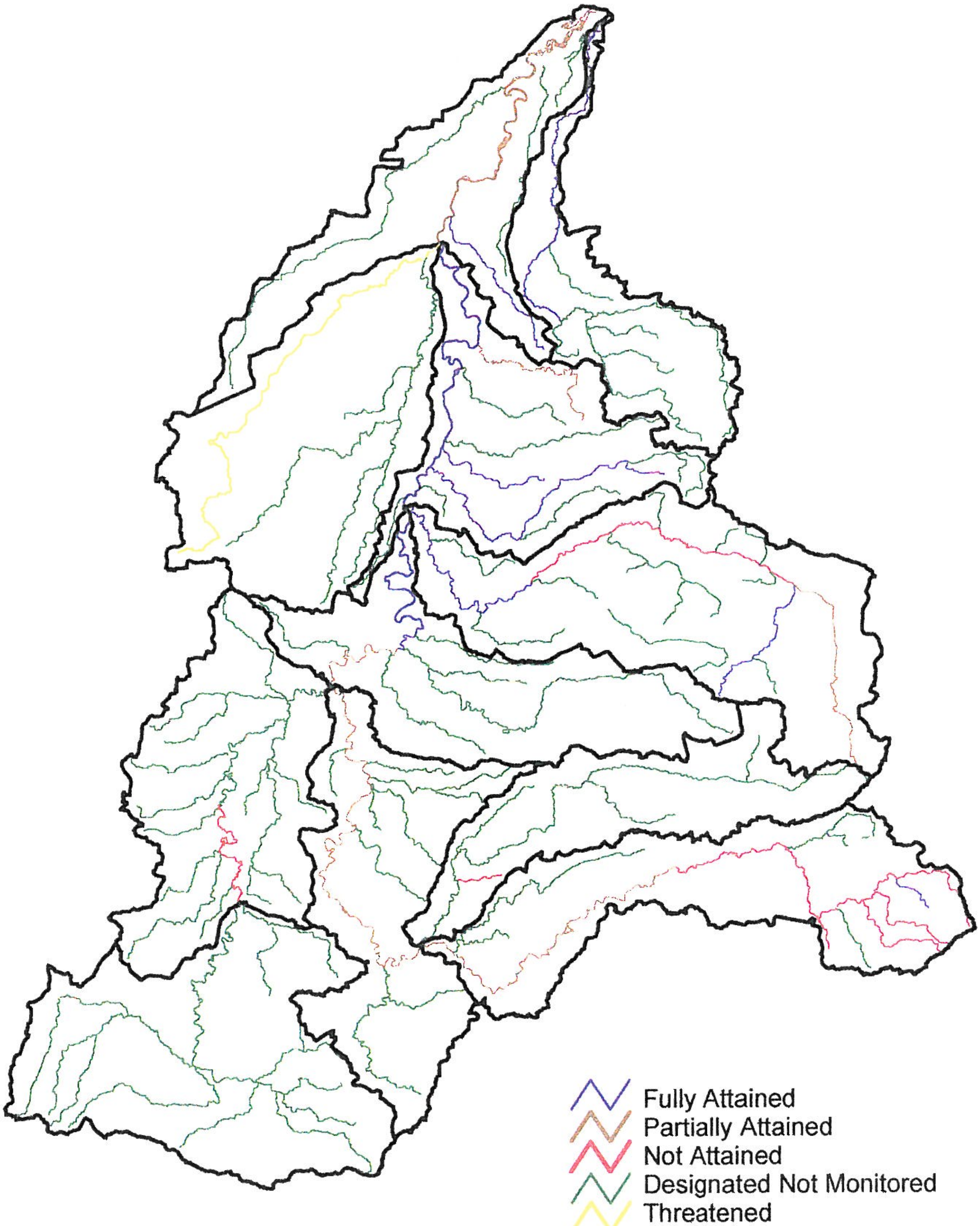


Figure 5.3 Aquatic life use attainment of the Sandusky River Watershed.

(http://chagrin.epa.state.oh.us/watershed/index.html). This figure contains only the designated stream segments in the watershed. About 59% of the designated miles have never been monitored by OEPA, and only 22% of the designated miles have been monitored within the last 10 years (1986 and beyond).

In Figure 5.3, each stream segment is categorized by the dominant attainment status in that segment. A segment that is indicated as fully attaining (blue), may also contain some miles that were "partially attaining" or even "not attaining." The largest number of assessed miles in that segment would have been "fully attaining."

Use attainment maps for each subwatershed are shown in the appendix. These maps include the names of both the monitored and unmonitored streams. Use attainment tables for each subwatershed are also provided in the appendix. These tables indicate the numbers of miles falling into each degree of attainment for each stream segment. The major causes and sources of impairment are also listed in the tables.

In Table 5.4, the assessment status (i.e. the extent of monitoring) and use attainment of the individual subwatersheds is summarized. In this table, the data reflect all sampling programs conducted by the OEPA in the Sandusky Watershed. These sampling programs spanned the time period from 1978 to 1996 and the resulting data are summarized in OEPA's Explore Your Watershed site and in the 1998 Addendum to the 1996 305 B Report - Appendix. These data indicate that, for the whole watershed, 35% of the assessed stream miles were fully attaining the applicable warmwater aquatic life standards, while 23% were partially attaining and 41% were not attaining those standards.

Results based on data collected from 1987 and beyond are shown in Table 5.5. The OEPA considers data from 1988 on as likely reflecting current conditions in streams and rivers. Only 22% of the designated stream miles in the watershed have been monitored by OEPA during this time and are considered current. For three of the subwatersheds, no assessments were completed during this time. Based on this more current data, only 24% of the assessed miles are fully attaining their use designation, while 38% are partially attaining and 38% are not attaining the use designation.

A major reason for the paucity of current biological monitoring data by the OEPA for the Sandusky River is that the Surface Water Division of the OEPA had insufficient funds to conduct the scheduled 1995 sampling program for the Sandusky River Watershed. Instead, a much more limited sampling program was conducted in the Tymochtee-headwaters and Sandusky-Upper Sandusky subwatersheds in connection with proposed expansion of poultry facilities in that portion of the watershed. The monitoring focused on headwater streams, which in agricultural areas tend to have low use attainment. Consequently, the overall degree of use attainment for the Sandusky River Watershed dropped.

The Sandusky River Watershed had been scheduled for detailed monitoring by the OEPA in the year 2000. However, the OEPA has had to reschedule future sampling to support planning under the Total Maximum Daily Load program of the Clean Water Act. Consequently the upper portions of the watershed will not be studied until 2005 and the lower portions will not be studied until 2010. The missed sampling in 1995 coupled with the changing schedules for future sampling will result in considerable uncertainty regarding the status of biological communities in the Sandusky Watershed over the next several years.

Table 5.4 Summary of assessment status and use attainment for subwatersheds based on all data from 1996 and 1998 305B reports (1978-1996 collections).

Hydro-logic Unit Code	Name of Hydrological Unit	Designated Stream Miles (miles)	Full Attain-ment (miles)	Threat-ened (miles)	Partial Attain-ment (miles)	Not Attain-ing (miles)	Assessed Stream Miles (miles)	Percent Assessed (%)
020	Sandusky Bucyrus	87.9	11.5	0.0	14.4	36.3	62.2	70.8
030	Broken Sword	50.2	2.0	0.0	0.0	2.5	4.5	9.0
040	Sandusky-Upper Sand	84.7	2.0	0.0	25.3	19.4	46.7	55.1
050	Tymochtee-headwaters	94.3	0.0	0.0	0.0	46.5	46.5	49.3
060	Tymochtee-lower	93.5	0.0	0.0	1.1	20.3	21.4	22.9
070	Sandusky-Mexico	64.4	9.3	0.0	13.5	0.0	22.8	35.4
080	Honey Creek	100.0	23.1	0.0	6.4	18.0	47.5	47.5
090	Sandusky-Tiffin	91.7	43.8	0.0	4.2	0.3	48.3	52.7
100	Wolf Creek	69.5	0.0	1.9	0.0	0.7	2.6	3.7
110	Green Creek	71.3	19.3	0.0	0.0	0.0	19.3	27.1
120	Sandusky-Fremont	59.2	12.2	0.0	17.0	1.0	30.2	51.0
Watershed Totals, miles		866.7	123.2	1.9	81.9	145.0	352.0	40.6
Watershed, percent of Assessed Stream Miles			35.0	0.5	23.3	41.2	100.0	

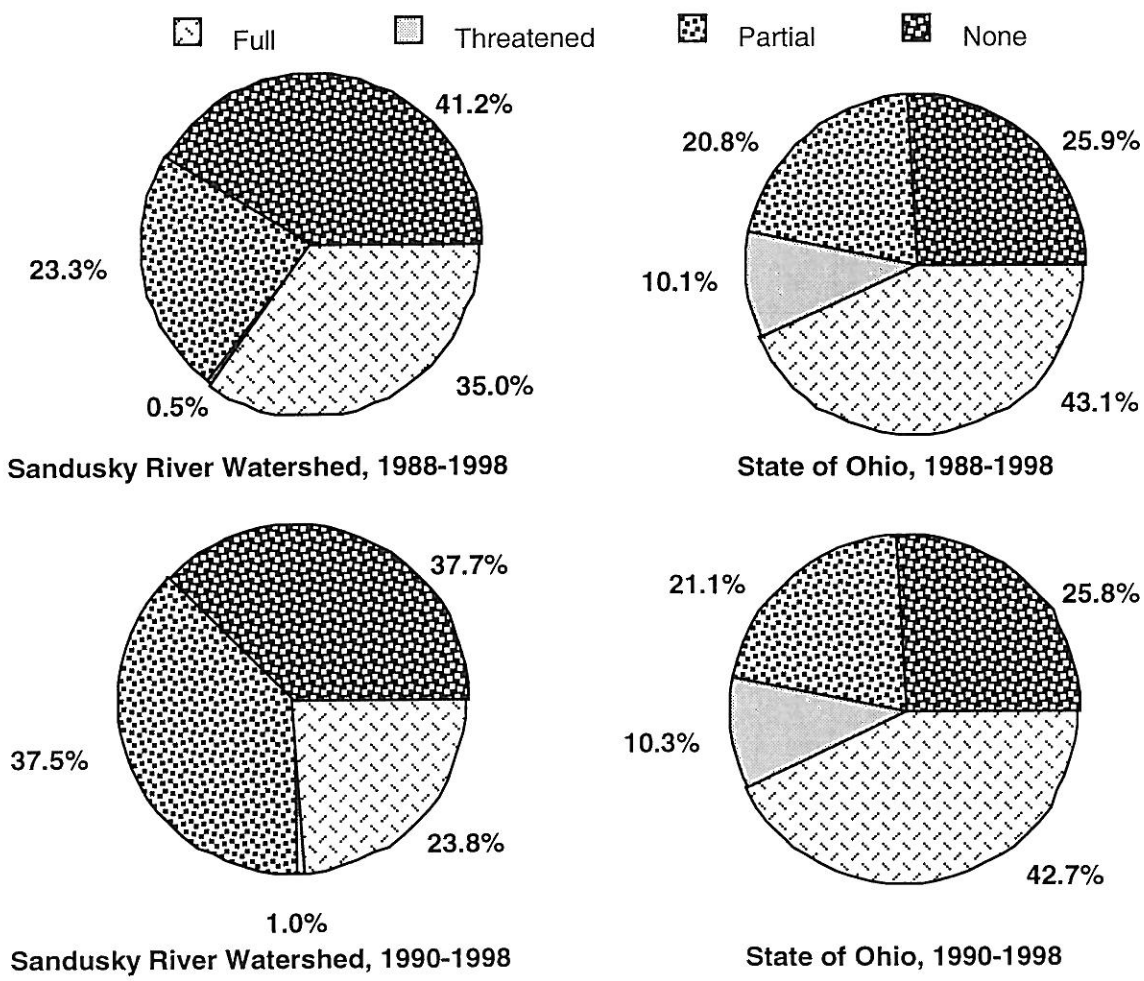
Table 5.5 Summary of assessment status and use attainment for subwatersheds based on current data (1986 – 1996 collections).

Hydro-logic Unit Code	Name of Hydrological Unit	Designated Stream Miles (miles)	Full Attain-ment (miles)	Threat-ened (miles)	Partial Attain-ment (miles)	Not Attain-ing (miles)	Assessed Stream Miles (miles)	Percent Assessed (%)
020	Sandusky-Bucyrus	87.9	7.8	0.0	10.8	3.2	21.8	24.8
030	Broken Sword	50.2	2.0	0.0	0.0	0.0	2.0	4.0
040	Sandusky-Upper Sand.	84.7	2.0	0.0	25.3	19.4	46.7	55.1
050	Tymochtee-headwaters	94.3	0.0	0.0	0.0	46.5	46.5	49.3
060	Tymochtee-lower	93.5	0.0	0.0	0.0	0.0	0.0	0.0
070	Sandusky-Mexico	64.4	9.3	0.0	13.5	0.0	22.8	35.4
080	Honey Creek	100.0	0.0	0.0	0.0	0.0	0.0	0.0
090	Sandusky-Tiffin	91.7	19.2	0.0	4.2	0.3	23.7	25.9
100	Wolf Creek	69.5	0.0	1.9	0.0	0.7	2.6	3.7
110	Green Creek	71.3	0.0	0.0	0.0	0.0	0.0	0.0
120	Sandusky-Fremont	59.2	4.7	0.0	17.0	1.0	22.7	38.3
Watershed Totals, miles		866.7	45.0	1.9	70.8	71.1	188.8	21.8
Watershed, percent of Assessed Stream Miles			23.8	1.0	37.5	37.7	100.0	

Comparison of Use Attainment in the Sandusky Watershed with Statewide Use Attainment.

The degree of use attainment in the Sandusky River Watershed is compared with that for all streams in the State of Ohio in Figure 5.4. The figure contains information for two comparable time periods, all data (1978-1996 collections) and "current" data (1986-1996 collections).

For all of the rivers in Ohio, about 53% of the streams were fully attaining their designated use for both time periods, although about 10% of these were threatened. Only about 26% of the designated miles were in non-attainment. For the Sandusky River Watershed, the 1988-1998 data indicated 35% of the stream miles were fully attaining their designated use, while 41% were in non-attainment and 23% were in partial attainment. Using data from the 1990 to 1998 assessments, only 24% of the streams and rivers in the Sandusky Watershed were fully attaining the WWH standards, while 38% were in non-attainment and 38% were in partial attainment.



5.4 Comparison of aquatic life use attainment in the Sandusky River Watershed with statewide averages for two time periods.

Within Ohio, the lowest degrees of use attainment are currently found in the agricultural watersheds of northwestern Ohio (Figure 5.5). Figure 5.5 was copied from OEPA Fact Sheet #: FS-9-MAS-98. In most parts of the state, there were considerable improvements in aquatic life use attainment between 1978-1987 and 1988-1996, due to major reductions in pollutant loading from point sources. Similar reductions in point source pollutant loading have occurred in northwestern Ohio. The OEPA attributes the absence of improvements in northwestern Ohio to the poorer habitat conditions of streams in this portion of the state, relative to other areas of the state. These poor stream habitat conditions are associated with the intensive agricultural land use in northwestern Ohio.

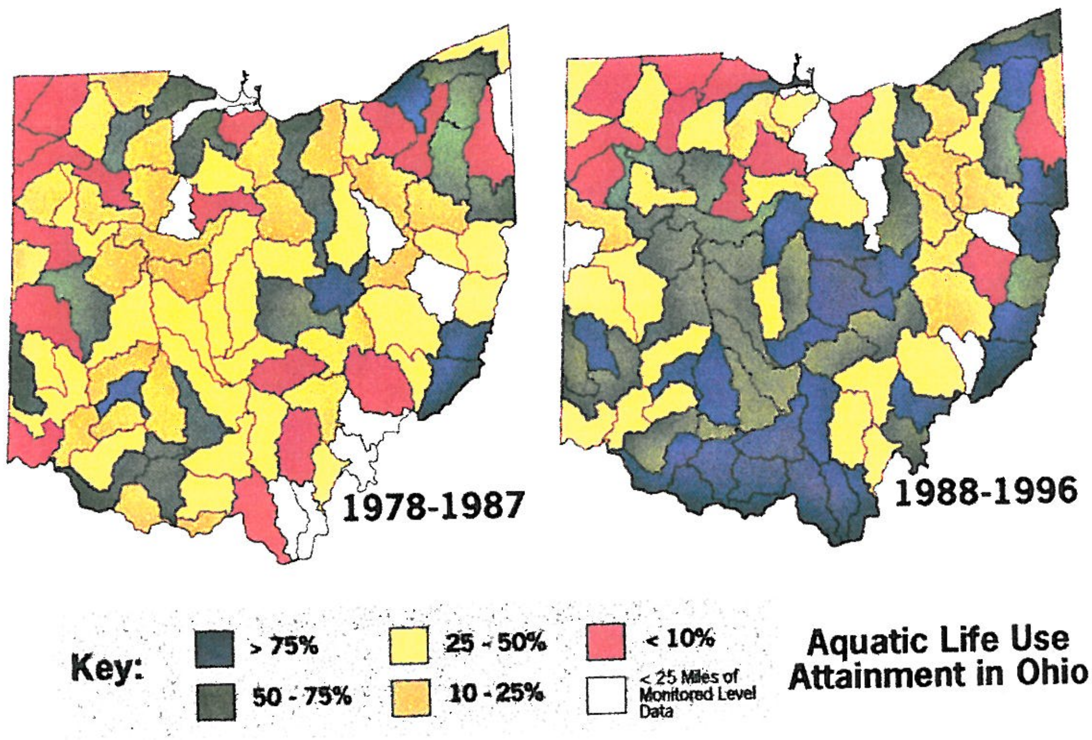


Figure 5.5 Statewide patterns of aquatic life use attainment for two time periods, 1978-1987 and 1988-1996.

Causes of Aquatic Life Impairment

Many factors affect the quality of the aquatic community that occurs in any particular stream reach (Figure 5.6). These factors include stream flow, habitat structure, energy sources, stream chemistry, and biotic. As OEPA staff conduct their biological monitoring programs, they also attempt to identify the likely causes of any impairments to aquatic communities. They survey the habitat in each stream segment using their Qualitative Habitat Evaluation Index (QHEI). This survey uses standardized procedures for habitat evaluation and generates a numerical index. They collect water and sediment samples for chemical analysis of nutrients, organic chemicals and potential toxic chemicals and also measure oxygen concentrations, temperature and pH.

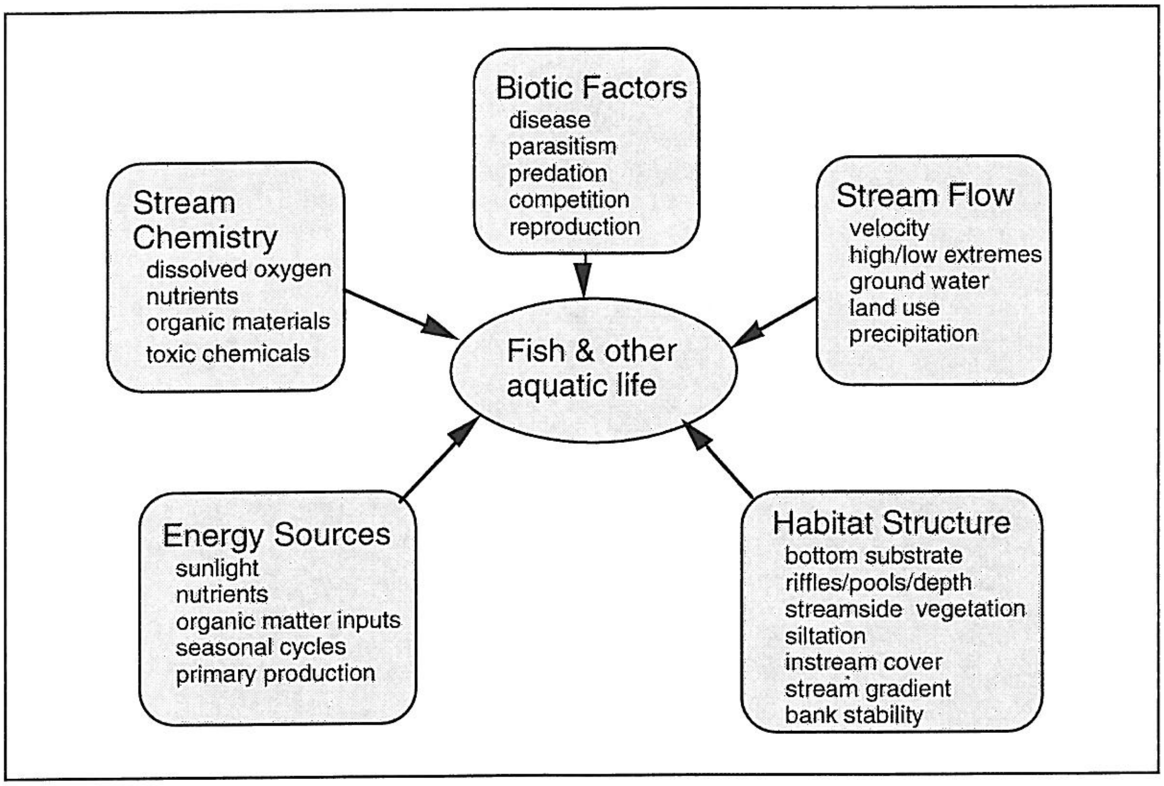


Figure 5.6 Factors affecting aquatic life in streams.

The above information allows OEPA staff to indicate the probable causes of the impairments to aquatic life in each stream segment. These causes are broken down into the following ten categories:

1. Siltation
2. Flow Alterations
3. Other Habitat Alterations
4. Nutrient Enrichment
5. Unionized Ammonia
6. Oil and Grease
7. Organic Enrichment /DO
8. Priority Organics
9. Metals
10. Cause Unknown

The OEPA also indicates whether each cause has high, moderate or slight effects. The causes of impairments for each impaired stream segment in the Sandusky Watershed are listed in the appendix.

The major causes of aquatic life impairment in the Sandusky River Watershed, as reported by the Ohio EPA, are shown in Figure 5.7. For this graph, the miles of both partial attainment and non-attainment associated with each stream segment, as presented in the appendix, were summed for the entire watershed. It is noteworthy that habitat

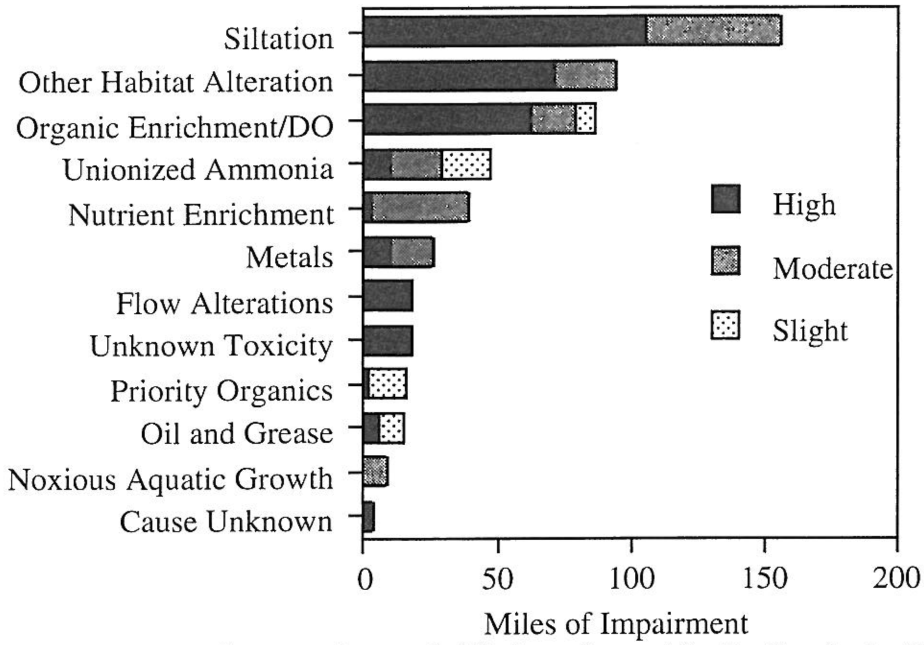


Figure 5.7. Causes of aquatic life impairment in the Sandusky River Watershed.

problems are more important than chemical pollutants as causal factors for aquatic life impairment in the Sandusky Watershed. Siltation is the major cause of impairment in the watershed, followed by other habitat modifications. Organic enrichment and related dissolved oxygen (DO) problems are the third major cause of impairment, followed by elevated concentrations of ammonia, nutrients and metals.

In Figure 5.8, the average QHEI index value for 11-digit watersheds in Ohio is indicated. It is clear that stream habitat conditions are poorest in the agricultural watersheds of northwestern Ohio. Figure 5.8 is reproduced from OEPA Fact Sheet #: FS-10-MAS-98. The statewide patterns of habitat quality shown in Figure 5.8 closely match the statewide patterns of aquatic life use attainment shown in Figure 5.5 for the 1988-1996 period.

The average habitat quality of the 14 subwatersheds in the Sandusky Hydrological Unit is shown in Figure 5.9. These data are taken from Figure 5.8 and expanded to illustrate conditions in the Sandusky Watershed. Only one subwatershed ranks in the good category, four in the fair category, four in the poor category and one in the very poor category. Three subwatersheds are unclassifiable due to insufficient data.

Additional details of the OEPA studies in the Sandusky Watershed are included in the following reports:

- Sandusky River Basin Water Quality Survey (Modified 303e Report).OEPA, Division of Surveillance, Northwest District Office. March 1995.
- Water Quality Study of the Sandusky River, Crawford and Wyandot Counties, Ohio. OEPA, Office of Wastewater Pollution Control, Columbus, OH, 1981.
- Comprehensive Water Quality Report of the Lower Sandusky River, Sandusky and Seneca Counties, Ohio. OEPA, Office of Wastewater Pollution Control, 1982.
- Biological and Water Quality Study of the Sandusky River & Selected Tributaries: Crawford, Wyandot and Seneca Counties. OEPA. June 20, 1991.

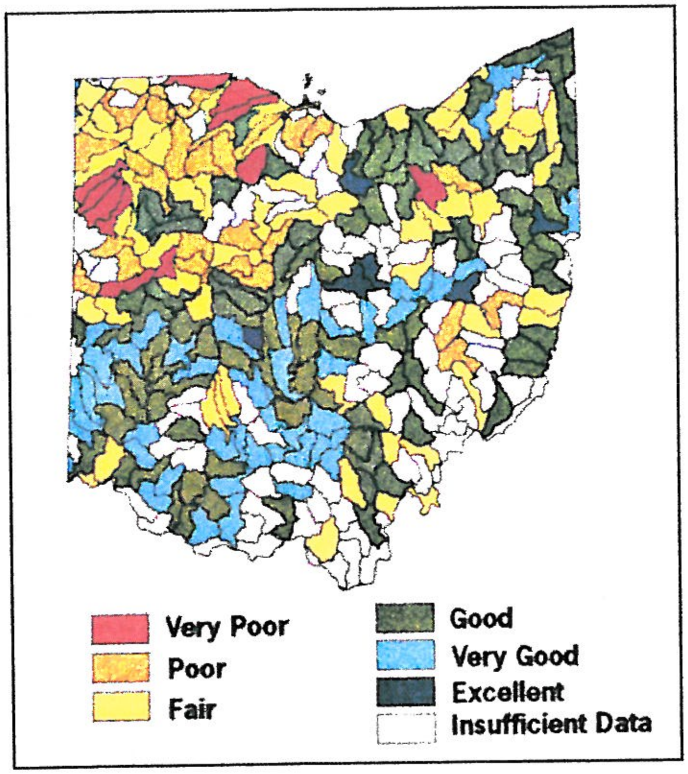


Figure 5.8 The average habitat quality by watershed for the state of Ohio.

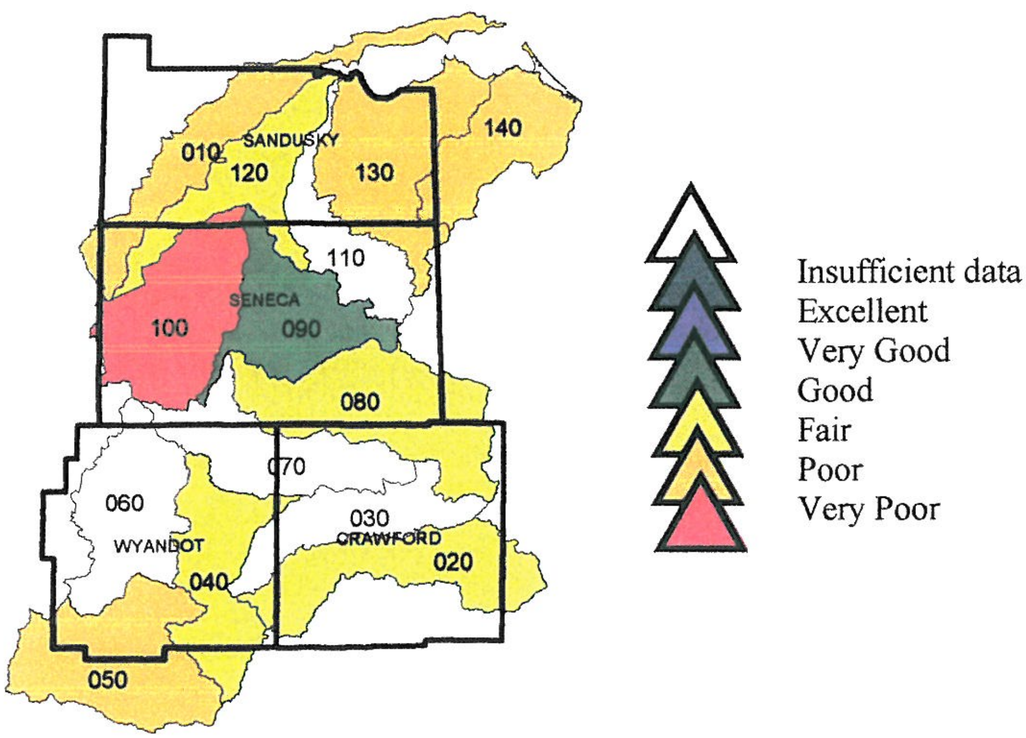


Figure 5.9 The average habitat quality for the Sandusky River Watershed

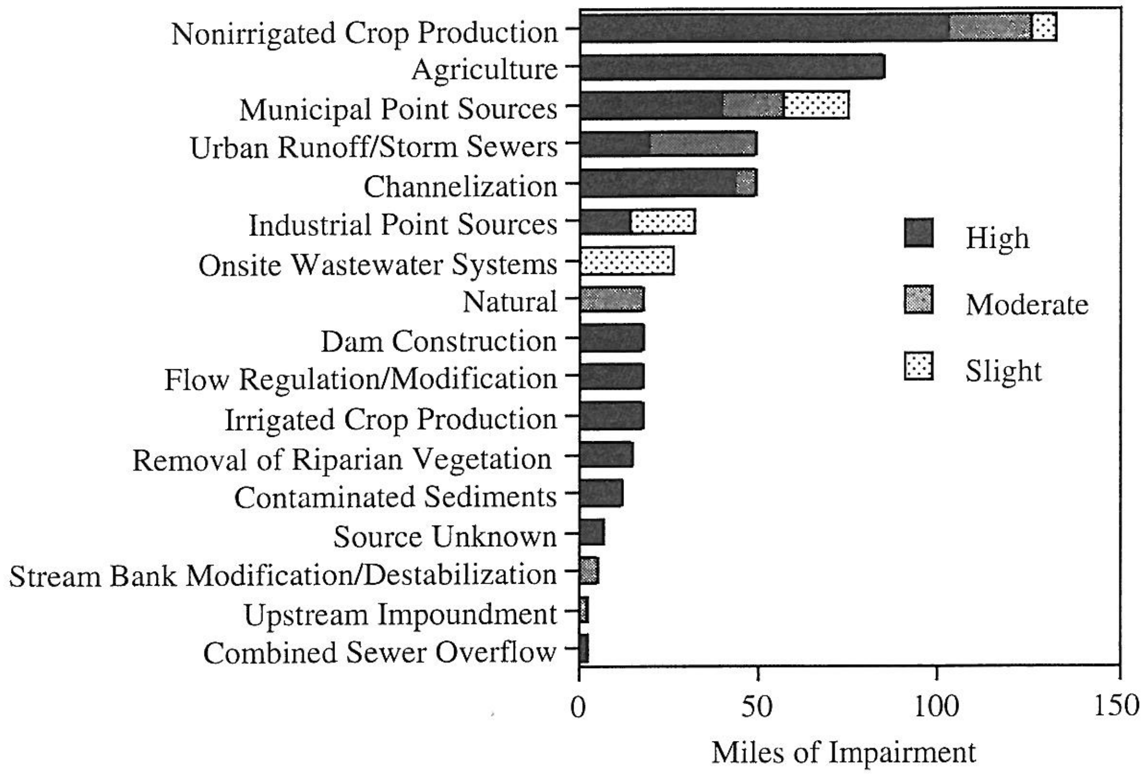


Figure 5.10 Sources of water quality impairment in the Sandusky Watershed.

Sources of Water Quality Impairment

As the OEPA identifies the causes of impaired aquatic life in streams, they also identify the probable sources of the causes. For example, where nutrients are the cause of impairment, OEPA attempts to determine the source of the nutrients. Did the nutrients arise from point sources or nonpoint sources. If the cause of impairment is poor habitat quality, is the source of the poor habitat associated with natural factors or with human land use activities, and, if land use activities, which land uses are most responsible. The OEPA has identified the following sources for aquatic life impairment in Ohio streams:

1. Nonirrigated Crop Production
2. Irrigated Crop Production
3. Agriculture
4. Channelization
5. Municipal Point Sources
6. Industrial Point Sources
7. Urban Runoff/Storm Sewers
8. Onsite Wastewater Systems
9. Flow Regulation/Modification
10. Contaminated Sediments
11. Upstream Impoundment
12. Dam Construction
13. Removal of Riparian Vegetation
14. Other
15. Source Unknown
16. Natural

The sources of aquatic life impairment in the Sandusky Basin, as identified by the OEPA, are shown in Figure 5.10. Nonirrigated crop production and agriculture are listed as the two major sources of water quality impairment in the watershed. These activities are the primary causes of the siltation and other habitat alterations that impact aquatic communities. Municipal point sources and urban runoff/storm sewers rank next in importance as sources of water quality impairment. These sources are primarily responsible for problems associated with organic enrichment/dissolved oxygen, unionized ammonia and nutrients.

Most of the channelization in the watershed is associated with drainage for crop production. Channelization alters flow patterns and causes other habitat modifications. Industrial point sources are often a source of metals. Onsite wastewater systems contribute to ammonia, nutrient, and organic enrichment/dissolved oxygen problems. Numerous other activities serve as sources of aquatic life impairment for shorter distances along the streams.

Efforts to improve aquatic communities in stream systems throughout the Sandusky Watershed need to focus on the above sources of water quality impairments.

Other Biological Monitoring Programs in the Sandusky River Watershed

A second systematic and long-term biological monitoring program is operated in the Sandusky River Watershed. This is the Ohio Volunteer Stream Quality Monitoring Project that has been set up for Ohio's Scenic Rivers. In 1970, the Sandusky River, from Upper Sandusky to Fremont, was designated an Ohio Scenic River. Beginning in 1985, volunteers, both individuals and groups, have been trained to use the Stream Quality Monitoring (SQM) procedures which have been developed by the Ohio Department of Natural Resources. These procedures focus on the invertebrate communities that are found in riffles.

Annual reports are published by the Ohio Scenic Rivers Program, Division of Natural Areas and Preserves, of the Ohio Department of Natural Resources that summarize the data for each scenic river. For the latest information regarding the Sandusky River, see the following document: Ohio Scenic Rivers Program, Stream Quality Monitoring Project, Annual Report No. 12 (1997), Sandusky State Scenic River.

For the Sandusky River, this program includes studies at seven locations along the section of the river designated as a scenic river.

Chapter 6 – Water Supplies

The water resources of the Sandusky River Watershed are designated for use in providing water for public drinking water supplies, for agricultural supplies and for industrial supplies. The general requirements for meeting each of these designated uses are listed below.

- **Public Water Supplies** – These are waters that, with conventional treatment, will be suitable for human intake and meet federal regulations for drinking water. Criteria associated with this use designation apply within 500 yards of surface water intakes for human consumption.
- **Agricultural Supplies** - These waters are suitable for irrigation and livestock watering without treatment.
- **Industrial Supplies** – These waters are suitable for commercial and industrial uses with or without treatment.

The extent of water used for each of the above types of supplies within the Sandusky Hydrological Unit is shown in Table 6.1. This table is adapted from water use data provided by the USGS for 8-digit hydrological units and is available at the U. S. Geological Survey web site (http://water.usgs.gov/watuse/spread95.html). Public water supplies withdraw 14.84 mgd (million gallons per day) from the surface and ground waters of the Sandusky Hydrological Unit, based on 1995 data. These public water supplies provide water for domestic, commercial and industrial use. Private water supplies withdraw 4.50 mgd. Other direct withdrawals of water include industries (9.65 mgd), mining (5.92 mgd), commercial (2.88 mgd), animal agriculture (0.79 mgd) and irrigation (0.48 mgd).

Public and Private Drinking Water Systems in Ohio

Public water systems in Ohio are divided into the following three major categories:

- **Community Water Supplies** provide water to cities, villages, mobile home parks and residential centers such as nursing homes. To be classified as a community water supply, the public water system must have at least 15 service connections or provide water to at least 25 year-round residents.
- **Non-transient Non-community** public water systems regularly serve at least 25 of the same people for at least six months of the year and include places such as schools, businesses and industries.
- **Transient Non-community** public water systems provide water to at least 25 different people for at least 60 days of the year and include places like campgrounds, roadside rests, gas stations, restaurants and churches.

Table 6.1 Fresh water utilization within the Sandusky River Hydrological Unit for 1995, based on data from the U.S. Geological Survey.

Category of Use	Amount of Use Population	Mgal/Day
Public Water Supply		
Population served by ground water	24,980	
Population served by surface water	136,180	
Total population served by public water supplies	161,160	
Total population of hydrological unit	222,280	
Ground water withdrawals		1.64
Surface water withdrawals		13.20
Total withdrawals		14.84
Domestic		
Self-supplied population (private water supplies)	61,120	
Self-supplied ground water withdrawals		4.49
Self-supplied surface water withdrawals		0.09
Total self-supplied withdrawals		4.58
Public supplied population	161,160	
Deliveries from public supplies		5.19
Total withdrawals plus deliveries		9.77
Commercial		
Ground water withdrawals		1.14
Surface water withdrawals		1.74
Total withdrawals		2.88
Deliveries from public supplies		3.71
Total withdrawals plus deliveries		6.59
Industrial		
Self-supplied ground water withdrawals		2.95
Self-supplied surface water withdrawals		6.70
Total self-supplied withdrawals		9.65
Deliveries from public supplies		3.71
Total withdrawals plus deliveries		13.36
Mining Use		
Ground water withdrawals		4.93
Surface water withdrawals		0.99
Total withdrawals		5.92
Agriculture-Livestock		
Ground water withdrawals		0.12
Surface water withdrawals		0.67
Total withdrawals		0.79
Agriculture-Irrigation		
Ground water withdrawals		0.17
Surface water withdrawals		0.31
Total withdrawals		0.48
Irrigated Land, acres	1,780	
Totals		
Ground water withdrawals		15.44
Surface water withdrawals		23.70
Total withdrawals		39.14
Consumptive Use		20.44
Wastewater Treatment Plant Returns (includes storm water and infiltration)		92.11

The number of each type of public water supply in Ohio is shown below, along with the sources of water associated with each type.

Type	Surface Water	Ground Water
Community	**140**	**1,046**
Non-transient Non-community	**8**	**1,111**
Transient Non-community	**12**	**3,541**

Although there are many fewer public water systems using surface water than groundwater in Ohio, these surface water systems often serve large cities and towns. Consequently, almost 60% of Ohio's population are served by community water supplies that rely on surface water sources.

In all, community water supplies provide drinking water to about 90% of Ohio's population. The remaining 10% of Ohio's population rely on **private water supplies**. Private water supplies generally utilize groundwater as a water source, and are particularly important in rural areas. In the Sandusky Hydrological Unit, 27% of the population rely on private water supplies.

The above definitions and statewide figures are based on information provided in the State of Ohio's Source Water Assessment and Protection Program, Draft Document of August, 1998, as prepared by the Ohio Environmental Protection Agency, Division of Drinking and Ground Waters and the Division of Surface Water.

Water Supplies in the Sandusky River Watershed

There are 26 community water supplies in the Sandusky River Watershed, supplying drinking water to about 91,500 residents. These community water supplies, along with the size of populations served, type of water source, and treatment plant capacity, are listed in Table 6.2. The locations of these community water supplies are shown in Figure 6.1. A listing of all of the public water supplies, including community, non-transient-non-community and transient-non-community, is shown in the appendix for each of the four major counties in the Sandusky River Watershed. In these four counties, there are approximately 254 public water supplies in the non-transient-non-community and transient-non-community categories.

Seven of the community supplies, serving a total of about 74,300 residents, utilize surface water as a source of raw water for their water treatment plants. Bucyrus and Upper Sandusky use water from the Sandusky River that is stored in reservoir systems, while Tiffin and Fremont withdraw water directly from the Sandusky River. Fostoria uses water from reservoirs that are filled from the Portage River. Attica and New Washington withdraw water from reservoirs that are filled from Honey Creek and Broken Knife Creek, respectively. The city of Clyde, while in the Sandusky HU, is not located in the Sandusky River Watershed. Its water supply is largely derived from the Beaver Creek Reservoir that is located in the Green Creek subwatershed of the Sandusky River Watershed. The Clyde drinking water supply serves a population of 7,000 residents.

Table 6.2 Community Water Supplies in the Sandusky River Watershed*.

Source/Name	Public Water System ID	Population Served	Water Usage Gallons/day	Treatment Plant Capacity Gallons/day
Surface Water Sources				
Bucyrus	1700011	13,500	1,980,000	4,115,000
New Washington	1700411	1,100	96,000	224,000
Upper Sandusky	8800511	6,600	945,000	1,730,000
Tiffin (Ohio-American Water Co.)	7400614	21,000	1,980,000	3,340,000
Fostoria (in part)	7400411	10,957	2,183,000	6,000,000
Attica	7400011	1,200	211,000	479,000
Fremont	7200311	20,500	4,917,000	7,500,000
Total Surface Water		**74,857**	**12,312,000**	
Ground Water Sources				
Crestline	1700112	4,950	841,000	1,080,000
Carey	8800012	3,700	491,000	1,202,400
Sycamore	8800412	950	113,000	230,000
Nevada	8800312	849	77,684	169,000
Bloomville	7400212	940	85,000	317,000
Bettsville	7400112	800	75,000	337,000
Green Springs	7400512	1,592	158,000	346,000
Republic	7400812	714	50,000	698,000
St. Catherines Care Center	7400912	112	4,010	
Brook Park Estates MHP	7401312	90	7,600	
Hopewell Estates MHP	7401412	200	12,800	
Pelton Mobile Home Park	7401212	225	18,600	
Fostoria Mobile Estates	7400712	195	17,200	
Lindsey	7200512	500	70,000	140,000
Appollo Mobile Home Park	7200012	52	5,600	
Bower, Richard MPH	7200112	55	3,600	
Emerald Estates MPC	7200612	135	14,500	
Shorewood Village Subdiv.	7201012	410	28,900	
Riviera Mobile Manor	7201312	180	19,500	
Total Ground Water		**16,649**	**2,092,994**	

* Data from county water resources fact sheets published by The Ohio State University Extension service web page (http://ohioline.ag.ohio-state.edu/) and from Ohio EPA data files on community water supplies.

Nineteen of the community supplies, serving a total of 16,650 people, derive their water from ground water sources. All but one of the 254 non-transient-non-community and transient-non-community public water supplies in the four-county area utilize ground water.

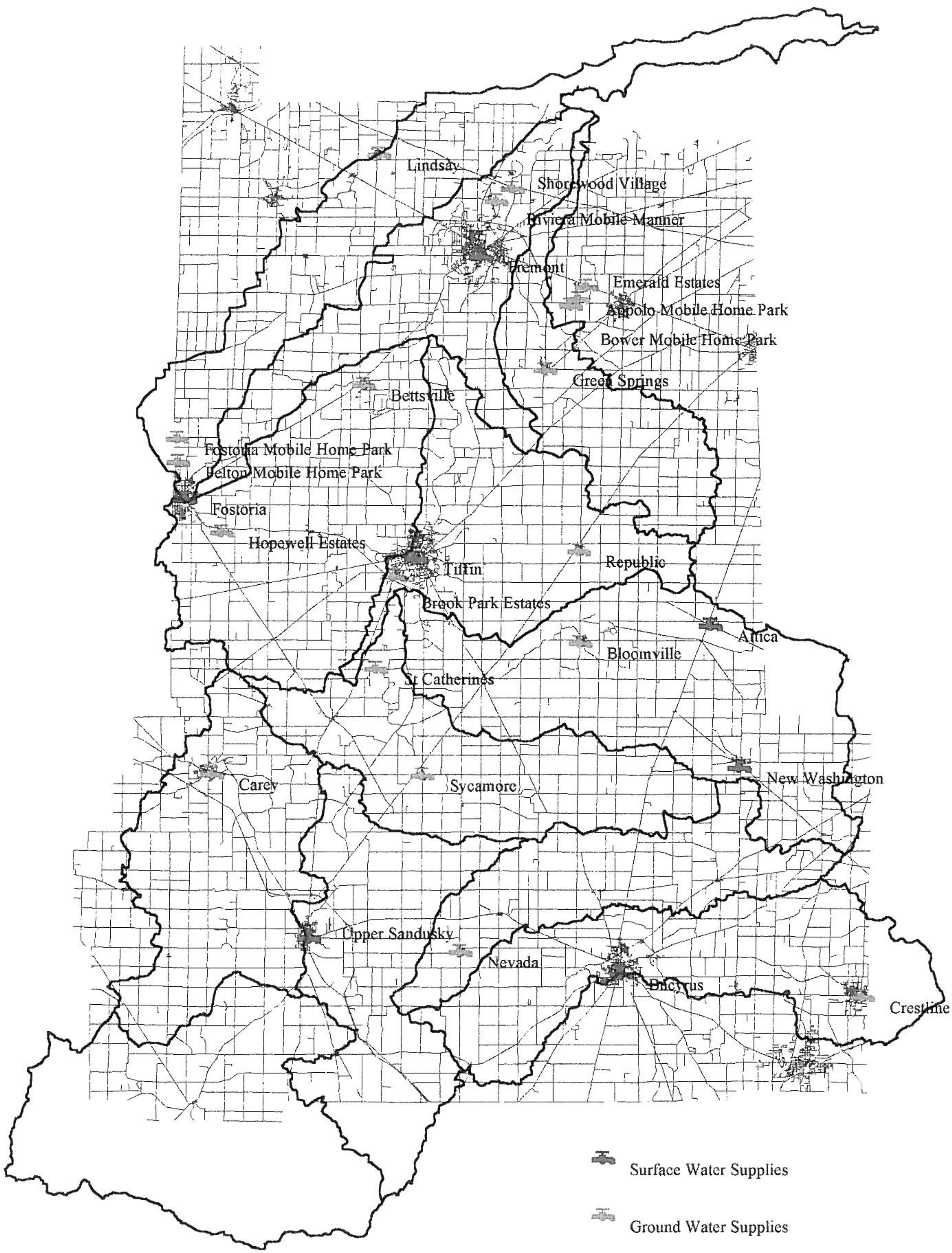


Figure 6.1 Community water supplies in the Sandusky River Watershed.

Drinking Water Standards and Health Advisories

The U. S. Environmental Protection Agency has set **National Primary Drinking Water Regulations** for specific contaminants that can adversely affect public health and are known or anticipated to occur in public water supplies. These standards are applicable to community water supplies, non-transient-non-community supplies, and transient-non-community supplies. At the present time, national primary standards have been established for 16 inorganic chemicals, 53 organic chemicals, 3 radionuclides, and six parameters associated with microorganisms. Copies of the current drinking water standards are available at a US EPA web site (www.epa.gov/OGWDW/wot/appa.html). These standards are shown in Appendix 2.

One form of primary drinking water standards is referred to as the *Maximum Contaminant Level Goal* (MCLG). The MCLG represents the maximum concentration, or maximum annual average concentration, of a contaminant in drinking water at which no known or anticipated adverse human health effect would occur, and which also allows for a margin of safety. MCLGs are non-enforceable public health goals.

Enforceable drinking water standards take two forms – *Maximum Contaminant Levels* (MCLs) and *Treatment Techniques* (TTs). An MCL is the maximum permissible concentration, or, more often, the maximum annual average concentration, of a contaminant in water that is delivered to any user of a public water system. MCLs are generally equal to the MCLGs, except for the 21 organic contaminants that are thought to be probable or known human carcinogens. For these carcinogens, the MCLG is always set at zero, while the MCL is set at a concentration whereby the added lifetime risk of cancer is very small (10^{-4} to 10^{-6}). Where MCLs are equal to MCLGs, the margins of safety are such that concentrations slightly in excess of the MCL should not pose a significant health risk.

Drinking water standards are designed to protect against both acute and chronic effects of pollutants (See Sidebar: Chronic versus Acute Effects and Drinking Water Standards). Acute effects result from exposures to relatively high concentrations of a pollutant for short periods of time. Chronic effects results from exposure to pollutants at relatively low concentrations for a long period of time. The actual concentrations that result in acute or chronic effects depend on the nature and/or toxicity of the pollutant. Acute effects typically occur at concentrations hundreds of times higher than do chronic effects. For the vast majority of pollutants, the public health concern is related to chronic rather than acute health effects. By setting standards to protect against chronic effects, the standards automatically provide protection against acute effects.

The Treatment Technique standard is an enforceable procedure or level of technical performance which public water systems must follow to ensure control of microorganisms, turbidity, or lead and copper. These TTs consist of procedures for both disinfecting and filtering surface water supplies or ground water supplies directly affected

Sidebar 6.1

Chronic Versus Acute Effects and Drinking Water Standards

To understand the health risks posed by pollutants present in drinking water, it is essential to understand the relationships between three variables – the concentration of the pollutant in the drinking water, the length of time (duration) drinking water containing that pollutant is consumed, and the resulting health effects.

If a chemical is present in a high enough concentration, consumption of a single glass of water containing that chemical at that concentration could result in immediate illness or even death. As the concentration of the chemical is lowered, it might take several glasses of water, or water consumption over several days, to result in illness or death. At still lower concentrations of that pollutant, it might take years of drinking water consumption before illness or death would result. Often the nature of the health effect changes between high-concentration, short-term effect and the low-concentration, long-term effect.

Where the concentration of the chemical is high enough that a short duration of exposure results in adverse health effects, the concentration is said to be in the acute range. Where the concentration of the chemical is sufficiently low that illness occurs only after years of exposure, the concentration is said to be in the chronic range. Drinking water standards are set to protect the public with respect to both acute and chronic effects of pollutants in drinking water. This is accomplished by setting standards that are effective in preventing chronic effects of pollutants. This automatically provides protection relative to acute effects, since acute effects occur only at much higher concentrations than chronic effects.

Studies have shown that chronic health effects are generally proportional to the long-term average concentration of pollutants, so long as the peak concentrations of the pollutants don't approach the acute range of concentrations. Consequently, drinking water standards (MCLs) for many pollutants are set in terms of average annual concentrations rather than peak daily concentrations.

The above situation often confuses consumers, since concentrations can exceed drinking water standards (maximum contaminant levels) without representing violations of those standards, so long as annual average concentrations don't exceed the standards. Herbicides provide an excellent example of this situation. The concentrations of herbicides in rivers vary seasonally. Peak concentrations generally occur in the spring and early summer, and individual herbicides may exceed their drinking water standards during these seasons. However, during other seasons, their concentrations are sufficiently low that the average annual concentrations don't exceed the standards. Thus the herbicides are considered to be meeting the drinking water standards and are not deemed to pose health threats to consumers. The safety factors incorporated into drinking water standards also provide a "cushion" such that seasonal excursions above the standard should not pose health threats.

by surface water. TTs for lead and copper relate to the lead content of pipes, valves and faucets used in the delivery of water to consumers, and to the corrosivity of the water.

In addition to the National Primary Drinking Water Regulations that are described above, the U. S. EPA has also set **National Secondary Drinking Water Regulations**. The resulting *Secondary Maximum Contaminant Levels* (SMCLs) are non-enforceable guidelines which indicate concentrations of contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. SMCLs have been set for 15 compounds. These are also listed in Appendix 2.

To further aid the public in interpreting the health significance of chemicals that may be present in drinking water, the U. S. Environmental Protection Agency has established a **Health Advisory (HA)** program. HAs differ from MCLs in several important ways. HAs are calculated separately for children (10-kg) and for adults (70-kg). For children, HAs are calculated for short-term exposures (One-day and Ten-day), and for longer-term (7-years) exposures, while for adults, HAs are calculated for longer-term (7-years) and lifetime exposures. These various forms of HAs contrast with MCLs which are calculated for lifetime exposures for adults only. Thus the Health Advisory program provides information upon which to judge the effects of acute (short-term) exposures for children as well as 7-year and chronic (long-term) exposures for adults. As with MCLs, all of the HAs include margins of safety.

Combined lists of MCLs and HAs are available for a total of 201 organic compounds and 39 inorganic chemicals (see EPA web site - http://www.epa.gov/OST/Tools/dwstds-s.html). In Table 6.3, MCLs and HAs are shown for contaminants frequently present in public water supplies relying on surface water in this area.

MCLs and lifetime HAs are based on the same toxicological data and are calculated in the same way. Thus, the lifetime HA concentrations are the same as the MCL concentrations. HAs are not calculated for those contaminants whose MCLs are based on either probable or known human carcinogenicity.

Monitoring Programs for Public Drinking Water Supplies

All public water supplies are required to measure the concentrations of chemicals or microbiological contaminants for which MCLs have been established. In addition, many supplies are required to measure concentrations of a set of unregulated contaminants, so that information on their concentrations will be available to regulatory agencies. The frequency of the monitoring depends on the type of public water supply, and, for community water supplies, on the size of the population served. The frequency of the sampling also depends on the source (surface or ground) of water used by the supply and on the environmental behavior of the specific contaminant. Some chemicals are measured at the point where treated water leaves the treatment plant and enters the distribution system, while other chemicals and/or microbiological contaminants are measured at a representative set of consumer taps.

Table 6.3 Examples of MCLs and Health Advisories for chemicals of possible concern in the Sandusky Watershed.

Chemicals	Primary Standard MCL	Health Advisories (HAs)				
		10 kg child			70 kg adult	
		One-day	Ten-day	Longer-Term	Longer-Term	Lifetime
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Herbicides						
Alachlor	0.002	0.1	0.1	-	-	-
Atrazine	0.003	0.1	0.1	0.05	0.2	0.003
Cyanazine	-	0.1	0.1	0.02	0.07	0.001
Metolachlor	-	2.0	2.0	2.0	5.0	0.07
Simazine	0.004	0.07	0.07	0.07	0.07	0.004
Disinfection Byproducts						
Cloroform (THM)	0.10	4	4	0.1	0.4	-
Bromodichloro-methane (THM)	0.10	6	6	4	13	-
Bromoform (THM)	0.10	5	2	2	6	-
Clorodibromo-methane (THM)	0.10	6	6	2	8	-
Total Trihalomethanes (THMs)	0.10					
Nitrates and Nitrites						
Nitrate (as N)	10	-	10	-	-	-
Nitrite (as N)	1	-	1	-	-	-
Nitrate + nitrite (as N)	10	-	-	-	-	-

Specific analytical techniques are required for each chemical or biological parameter. Laboratories performing analyses for public water supplies must be certified for each parameter that they analyze. The Ohio EPA conducts the certification program for laboratories conducting analyses for Ohio's public water supplies.

Each public water supply and/or the analytical laboratory must submit the results of all analyses to the Ohio EPA. If the results indicate that any MCLs have been exceeded, the water supply is required to initiate programs to come into compliance with the standard. Whenever a MCL is exceeded, the water supply must also notify its customers of the violation. If the violation is of an acute nature, such as contamination by coliform bacteria or by nitrate, notification must be by public announcements (radio, television, &

newspapers), so that even transient consumers (restaurants and gas stations) would be warned of the condition. Boiling water advisories are an example of the type of warnings issued when bacterial counts exceed safe levels.

In 1999, many public water supplies were required to initiate distribution of "consumer confidence reports." In these reports, all of the analytical results for regulated contaminants are presented, even for chemicals that have not exceeded their MCLs. This allows consumers to better judge the quality of their drinking water supplies.

Violations of Standards by Community Supplies in the Sandusky Watershed

Information on violations of drinking water regulations by all public water supplies in the United States is available on the www at http://www.epa.gov/ogwdw/dwinfo/oh.htm. This site lists all of the violations for each public water supply for the past 10 years.

Violations of drinking water standards for public water supplies can take three forms:

- Concentrations may exceed MCLs.
- The water supply may not be using proper Treatment Techniques.
- The water supply may not be implementing its required monitoring and/or reporting program.

Community water supplies in the Sandusky watershed have very few violations of MCLs. The City of Fremont was the only supply in which violations of a chemical standard were noted. In both 1997 and 1998, nitrate exceeded 10 mg/L for brief periods. No other chemical violations have been reported for community water supplies in the Sandusky Watershed.

Coliform bacteria violations have been noted for five community water supplies. These include Upper Sandusky (1993), Carey (1992), Attica (1991 and 1998), Republic (1995 and 1996), and Brook Park Estates (1989, 1995, 1998). Following each violation, steps were taken by the treatment plants to return to compliance.

Violations regarding Treatment Techniques have occurred in four plants, all of which draw on surface waters. These include Fremont (1993-1995), Tiffin (1993 and 1994), Attica (1993, 1994, 1996 and 1998) and Fostoria (1996 and 1998).

The largest number of violations occurs in the area of monitoring. Most of the monitoring violations occur in small community supplies that rely on ground water. Since the ground water in this region rarely contains chemicals in excess of MCLs, it is unlikely that the lack of monitoring masks MCL violations. Monitoring violations for the larger community water supplies in the region are infrequent.

Source Water Assessment and Protection Programs (SWAP)

The 1996 Amendments to the Safe Drinking Water Act require every state to develop and submit a Source Water Assessment Program to the U. S. EPA **for every public water supply**. The intent of the Source Water Assessment and Protection Program is to extend drinking water protection programs beyond removal of contaminants at the treatment plants to prevention of contaminants reaching excessive levels in the source waters entering the treatment plants. The Amendments require that the following three steps be taken for each public water system:

- **Delineate** the area to be protected (the SWAP area), based on the area that contributes water to the well or intake;
- **Inventory** potential significant contaminant sources within the SWAP area;
- **Determine the susceptibility** of each public water supply to contamination, based on the information developed in the first two steps.

The State of Ohio has developed a detailed plan for conducting its SWAP program (see OEPA's www site at http://www.epa.ohio.gov/ddagw/pdu/swap.html). The plan outlines specific strategies for ground water based supplies and surface water based supplies in Ohio. Data from this inventory should be useful for the implementation of SWAP programs in this region. The WSOS Community Action Commission, Inc. in Fremont, Ohio is conducting regional SWAP for public water supplies in a karst portion of the Sandusky Hydrological Unit.

Drinking Water Contaminants in Streams of the Sandusky Watershed

Nitrate Contamination – The streams of Sandusky River Watershed, along with those of its neighboring Maumee River Watershed, contain unusually high concentrations of nitrate. In Figure 6.2, the concentrations of nitrate measured at the Fremont gauging station for a one-year period beginning on April 1, 1989 are illustrated. The graph also shows the stream flow during this same time interval. It is evident from the graph that elevations in nitrate concentration occur in connection with storm runoff events and that concentrations occasionally exceed the 10 mg/L MCL for nitrate.

Compliance with the drinking water standard for nitrate is based on peak daily concentrations, rather than average annual concentrations, because nitrate poses an acute health risk to infants under six months of age. Exposures of infants to nitrate above 10 mg/L for relatively short periods can give rise to the "blue baby syndrome" (methemoglobinemia). Because of its high solubility, there is no economical way to remove nitrates at water treatment plants. When the concentration of nitrates exceeds 10 mg/L in its source water, community supplies are faced with violations of drinking water standards and must advise customers not to use the water for infants because of the associated health risks.

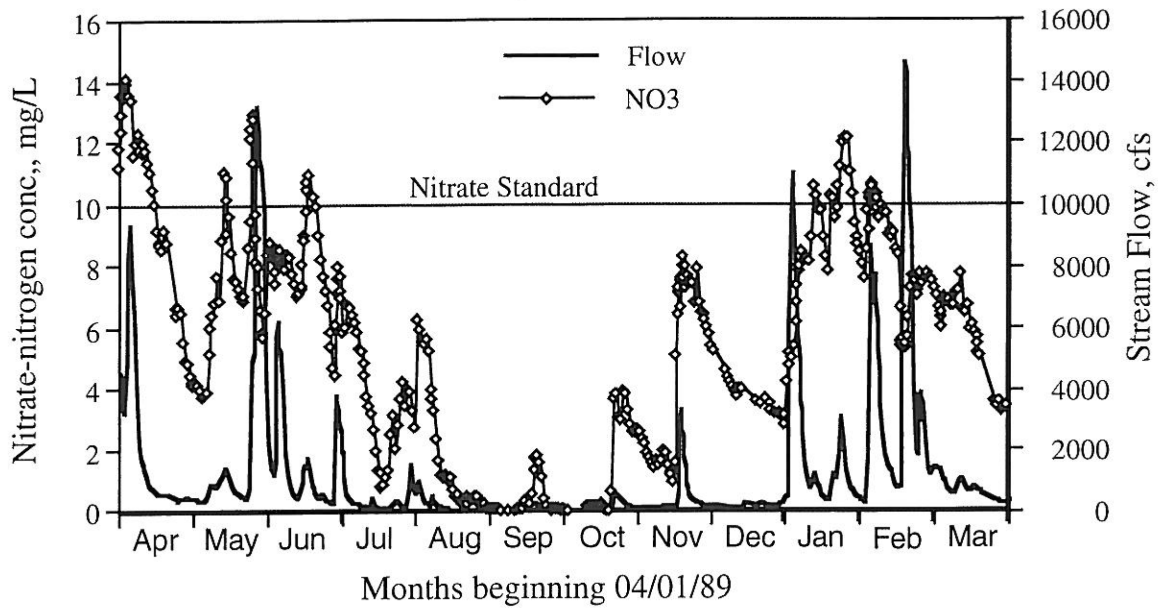


Figure 6.2 Relationships between nitrate concentrations and stream flow for a one-year period beginning April 1, 1989 for the Sandusky River near Fremont

The fact that the elevated concentrations of nitrate are associated with runoff events suggests that the nitrate contamination is derived from nonpoint sources. Studies of the nitrate concentration in tile drainage, which underlies much of the cropland in northwestern Ohio, coupled with comparative watershed studies indicates that the unusually high nitrate concentrations in area streams are associated with the tile-drained cropland.

The duration of time that nitrate exceeds the drinking water standard in the Sandusky River at Fremont varies from year to year, depending largely on rainfall patterns. Over the past 25 years, the Water Quality Laboratory at Heidelberg College has collected more than 10,000 water samples at the Fremont station. One way to summarize long term data sets is to construct concentration exceedency curves (Figure 6.3). Such curves represent the percentage of time any particular concentration is exceeded. From Figure 6.3, it is evident that a concentration of 10 mg/L has been exceeded 5% of the time in the Sandusky River for the period between 10/01/89 and 09/30/99. It is also evident that 50% of the time, the nitrate concentrations exceeded 3.5 mg/L.

Concentration exceedency curves can also be used to compare concentrations among rivers. Figure 6.4 illustrates the nitrate concentration exceedency curves for seven Ohio rivers that are monitored by the Heidelberg Water Quality Laboratory. These data compare nitrate concentrations for each river for a two year period between 96/04/22 and 98/04/21. The data illustrate that nitrate concentrations in the Maumee and Sandusky rivers are higher than for other rivers in Ohio. Nitrate concentrations in the Sandusky and Maumee Rivers are also high relative to most Midwestern rivers.

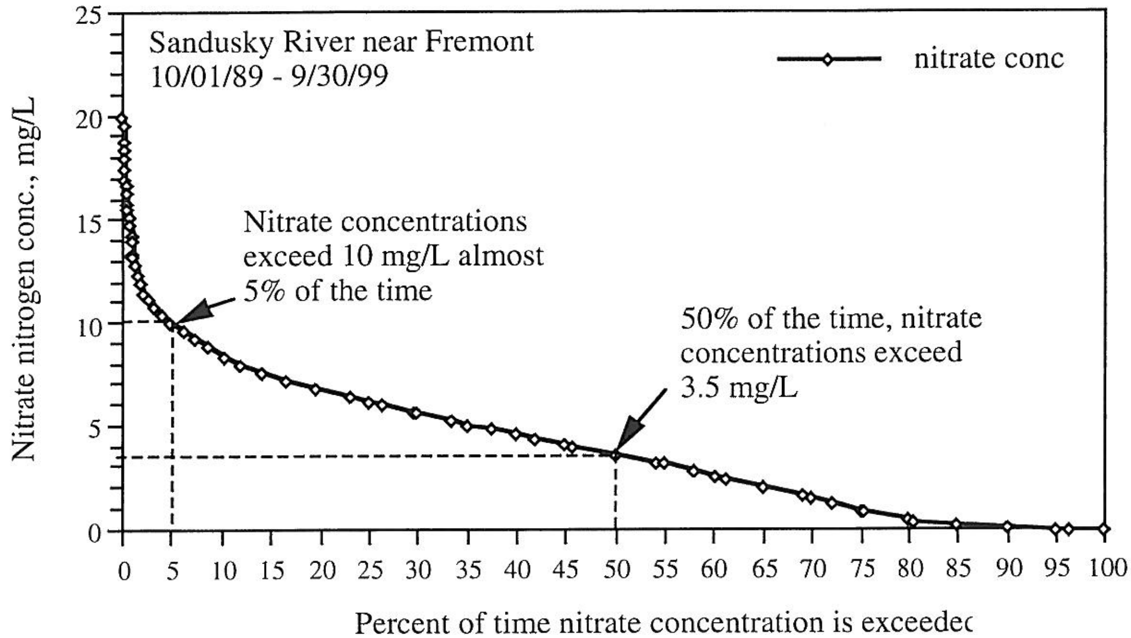


Figure 6.3 Nitrate concentration exceedency curve for the Sandusky River at Fremont for the period between 10/01/89 and 09/30/99.

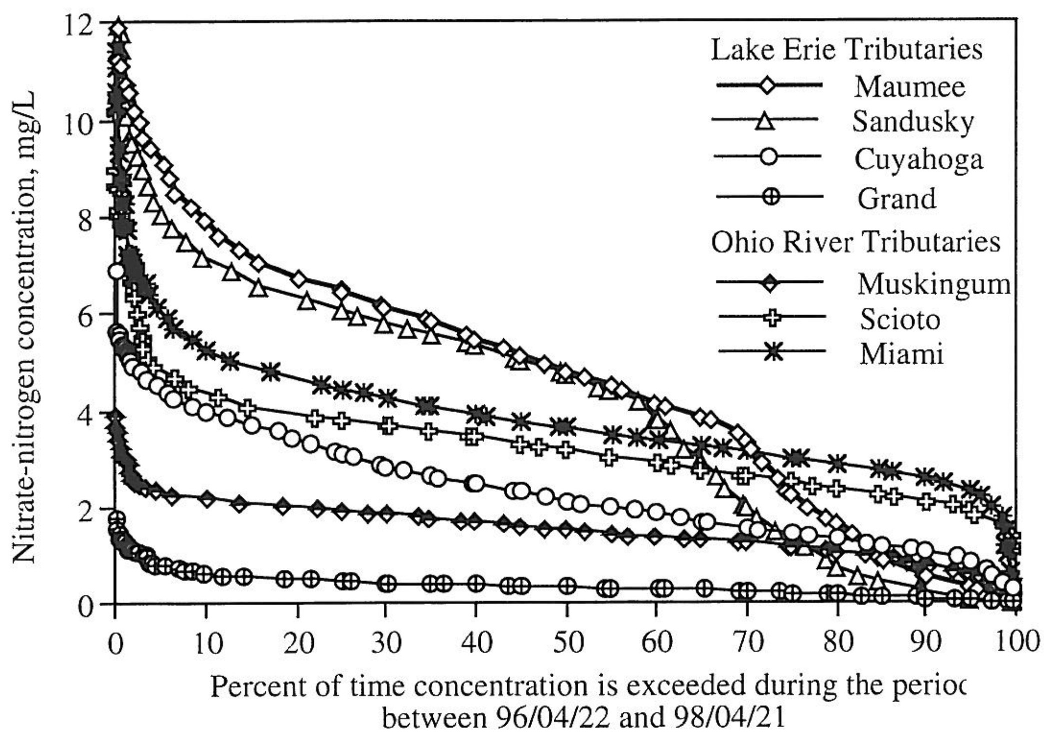
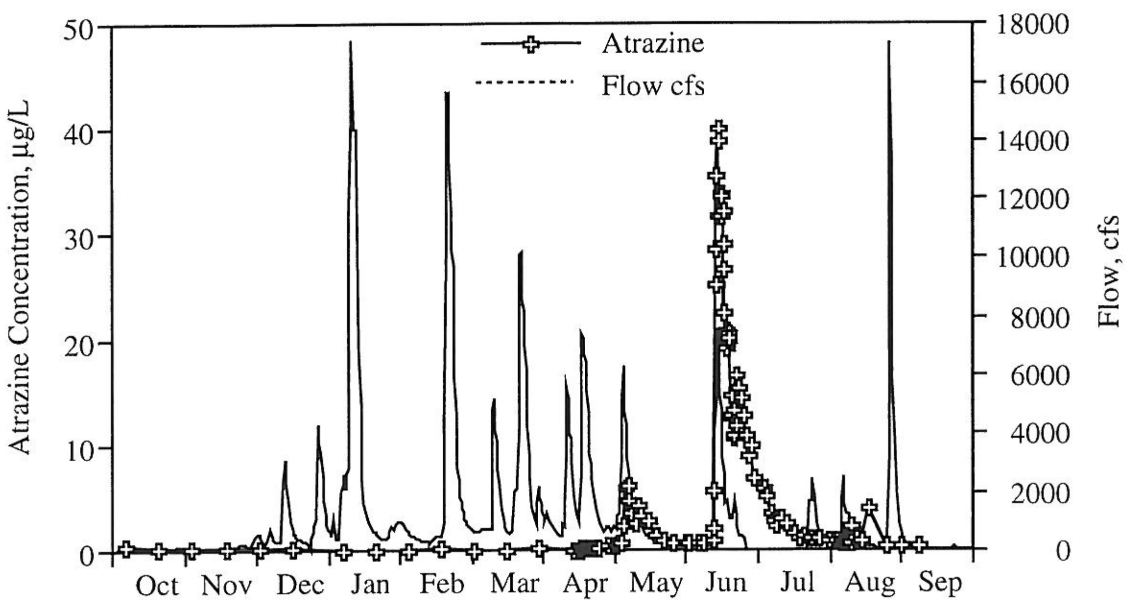


Figure 6.4 Comparison of nitrate concentrations is seven major Ohio rivers using concentration exceedency curves.

Of the community water supplies in the Sandusky River Watershed, the supply for Fremont is the most vulnerable to elevated nitrate concentrations. The Fremont supply has no alternate source of water to dilute nitrate concentrations in the Sandusky River. For the supply for Tiffin, wells supplying ground water are used to dilute water from the Sandusky River whenever nitrate exceeds 10 mg/L in the river water. Nitrate concentrations are below 1 mg/L in the ground water and consequently are very effective in lowering the concentration of finished drinking water for Tiffin residents. Other surface based supplies in the Sandusky watershed utilize water stored in reservoirs that provide lower nitrate concentrations than river water. Even when water with high nitrate is pumped into the reservoirs, it is generally diluted by water already present in the reservoir. During storage, nitrate concentrations of the reservoir water decrease as a result of nitrate uptake by algae.

Herbicide Contamination – As with other Midwestern rivers draining cropland to which herbicides are applied, herbicides are present in the Sandusky River and its tributaries following spring runoff events. Figure 6.5. illustrates the 1998 water year runoff pattern of atrazine, the herbicide applied in the greatest quantities in the Sandusky Watershed. Peak atrazine concentrations accompanied storm runoff events in May and June. Runoff events at other times of the year were not accompanied by large increases in atrazine concentrations. During the runoff events, atrazine concentrations can exceed its MCL. However, compliance with the drinking water standard for atrazine is based on annual average concentrations, not peak concentrations for shorter time periods.

Just as for other nonpoint source contaminants, large annual variations occur in herbicide concentrations. In Figure 6.6, monthly and annual concentrations of atrazine and alachlor are shown for the period from 1983 to 1988. The graphs indicate that



1998 Water Year, Sandusky River near Fremont

Figure 6.5 Annual concentration of atrazine for the Sandusky River at Fremont in relation to storm runoff events for the 1998 Water Year.

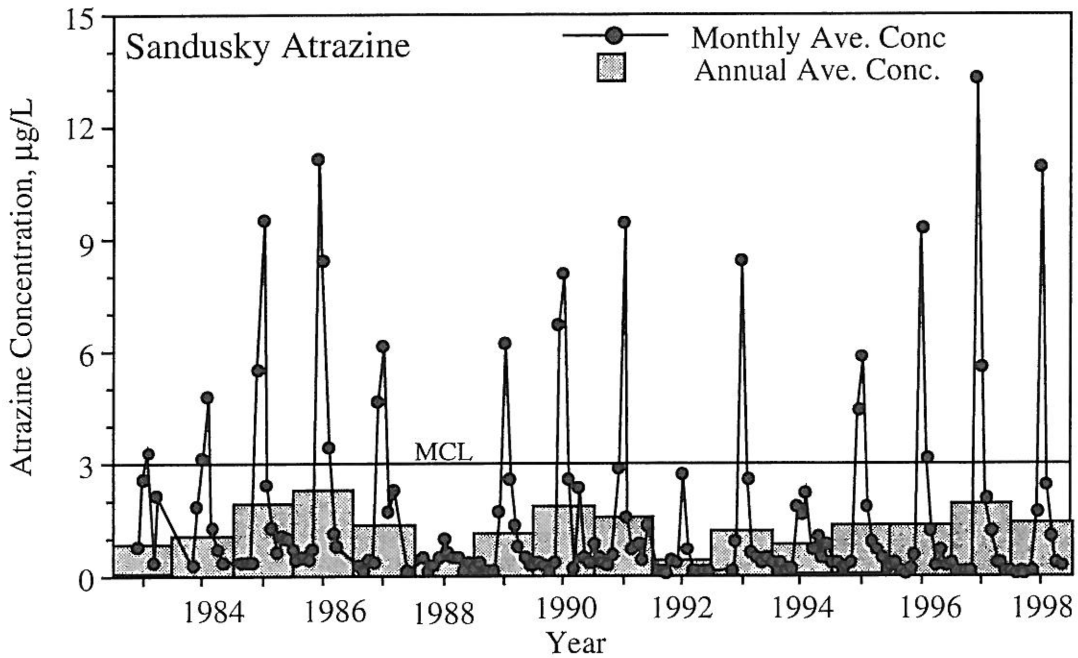


Figure 6.6 Monthly and annual average concentrations of atrazine in the Sandusky River at Fremont for a 16-year period beginning in 1983.

monthly average concentrations (circles) frequently exceed the MCL, but that annual average concentrations (rectangles) have not exceeded the MCL values. Peak concentrations of this herbicide have not exceeded the shorter-term health advisories for this compound (Table 6.3). Consequently, the peak concentrations do not pose acute health risks to consumers.

Other herbicides, such as metolachlor, alachlor and acetochlor, have similar patterns of concentration as atrazine. Figure 6.7 illustrates the 1998 spring chemographs of the four major herbicides used in the Sandusky Watershed. The concentrations of metolachlor are very similar to those of atrazine, while acetochlor and alachlor have lower concentrations. Acetochlor, which was introduced in 1994, is a herbicide that is largely replacing alachlor in terms of its use in this region. Ten-year concentration exceedency curves for three herbicides, atrazine, metolachlor and alachlor, are shown in Figure 6.8. The shape of these curves again indicates that the high concentrations are present for relatively short periods of times. The 10-year average concentrations of atrazine, metolachlor and alachlor were, respectively, 1.42 µg/L, 1.31 µg/L and 0.34 µg/L.

The illustrations of herbicide concentrations, shown above, have focused on the data from the monitoring station on the Sandusky River at Fremont. Monitoring programs for two tributaries of the Sandusky River, Honey Creek and Rock Creek, show similar patterns of herbicide runoff. In general, smaller tributaries show somewhat higher peak concentrations, but shorter durations of intermediate concentrations.

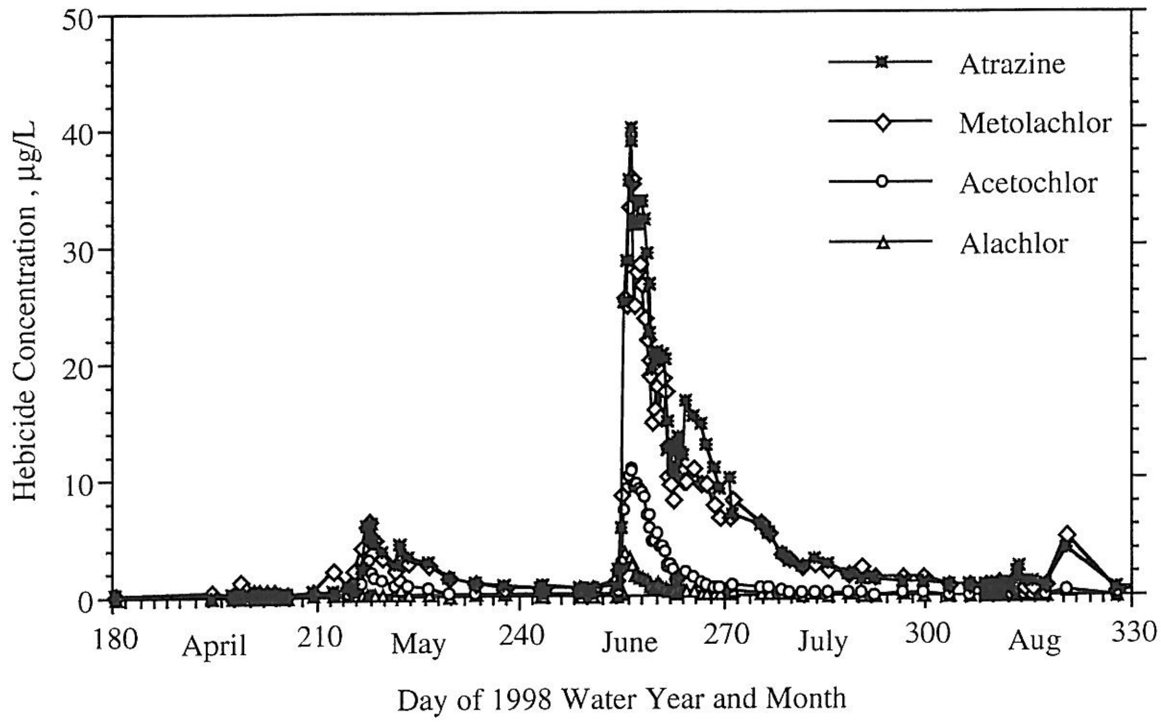


Figure 6.7 Comparison of concentration patterns for four herbicides during the 1998 spring runoff period in the Sandusky River at Fremont.

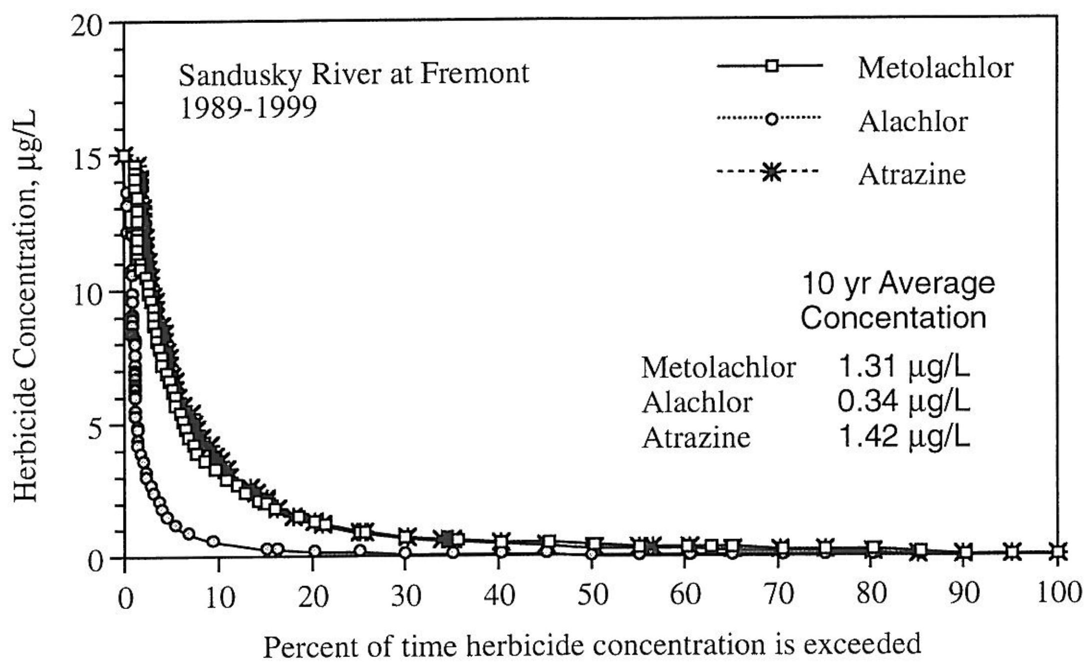


Figure 6.8 Concentration exceedency curves for atrazine, metolachlor and alachlor in the Sandusky River for the 10-year period beginning in1989.

Smaller concentrations of other herbicides and some insecticides are also present in the Sandusky River and its tributaries. For a more complete list of pesticides found in the Sandusky River monitored by the Water Quality Laboratory see the paper published by Richards and Baker, 1993[1].

Unlike for nitrates, treatment procedures are available whereby herbicide concentrations can be lowered at the water treatment plants. Treatment plants at Tiffin and Fremont include granular activated carbon filters, which lower the herbicide levels in the finished drinking water to concentrations well below those in the source water as described above. In addition, since the occurrence of herbicides is so seasonal, selective pumping to fill reservoirs used for water supplies can also be very effective in reducing herbicide concentrations in source waters. The reservoirs for the city of Bucyrus are managed using selective pumping so that, even without carbon treatment, herbicide concentrations are very low in the resulting finished drinking water. The water supplies of Upper Sandusky and New Washington have been cited by the Ohio EPA as being particularly vulnerable to excessive herbicide concentrations in their treated drinking water.

Sediment Contamination - Although there are no direct standards for suspended sediment concentrations in drinking water, there are stringent standards for turbidity. When source waters for water treatment plants have high suspended solids concentrations, it is more difficult and costly to meet the turbidity standards. The Sandusky River and its tributaries often have relatively high concentrations of suspended sediments during runoff events. Furthermore, the suspended sediments of these streams is dominated by small, clay sized particles which are more difficult to remove than larger particles such as sands. The high sediment concentrations in area streams are viewed as problems by water treatment plants, and add to consumer costs for water supplies.

Disinfection byproducts – In the process of treating water with chlorine or other disinfection agents to kill bacteria, disinfection byproducts are formed. These disinfection byproducts do pose health risks. Drinking water standards have been established for one group of these byproducts, the trihalomethanes (Table 6.3). This group includes compounds such as chloroform and bromoform. The formation of disinfection byproducts increases as the organic matter content of source water increases. There are multiple sources of dissolved organic matter in streams, and approaches for reduction of organic matter in source water are not well established. Disinfection procedures within treatment plants are adjusted to minimize formation of trihalomethanes. Since the health risks posed by bacterial and other biological pathogens are much greater than those posed by disinfection byproducts, disinfection is a necessary part of drinking water treatment.

---

[1] Richards, R. P. and D. B. Baker. Pesticide Concentration Patterns in Agricultural Drainage Networks of the Lake Erie Basin. *Environmental Toxicology and Chemistry*, Vol. 12, pp.13-26, 1993

Private Water Supplies

According to water use data of the U. S. Geological Survey, 27% of the residents in the Sandusky Hydrological Unit rely on private water supplies for their drinking water. Virtually all of these private water supplies use wells to tap ground water. Unlike public water supplies, for which periodic testing for drinking water contaminants is required, minimal testing is required for private water supplies. Often the only testing that is done consists of bacterial testing when a well is initially installed. New regulations for private water supplies are currently under development and more comprehensive testing may be required at the time of property transfers or when bank loans are requested. State agencies do maintain a network of monitoring wells in order to sample conditions in major aquifers.

More comprehensive testing of private water supplies is occasionally undertaken in response to local issues, such as concern for contamination from specific sources or where local aquifers are particularly susceptible to contamination. One such area is the karst region of northeastern Seneca County and portions of adjacent counties. Karst is the term for areas where sinkholes develop in limestone bedrock near the ground surface. Sinkholes are solution channels that form as water flowing through the bedrock gradually dissolves the rock and increases the size of the channels through which it flows. When such channels become large enough, surface water can literally flow directly into the ground water. This allows contaminants in surface water to directly enter the ground water, bypassing the filtering action of the soil and bedrock that normally removes or reduces many contaminants. Historically, sinkholes have been used to get rid of sewage from septic tanks and even from municipal sewage collection systems or treatment plants. Such practices have resulted in widespread contamination of ground water in some areas. Contamination of ground water from agricultural pollutants can also occur in karst regions.

Most of the private wells in the Sandusky Basin tap the carbonate aquifers of this region. These massive aquifers generally provide large quantities of water. The quality of the water is largely contingent on the characteristics of the local and regional bedrock through which the ground water is moving. Water from these carbonate aquifers generally has very high calcium and magnesium concentrations, making the water relatively hard. Locally, the sulfate and iron concentrations can also be high, often exceeding the secondary MCL values. These elevated sulfate and iron concentrations are not considered to pose direct threats to health.

It should be noted that private wells tap the same aquifers as public water supplies using ground water. The monitoring programs for these public water supply wells have not indicated that groundwater from these aquifers exceeds drinking water standards.

Table 6.4 Summary of nitrate contamination in private water supplies of Crawford, Sandusky, Seneca, and Wyandot Counties, based on data from the Water Quality Laboratory of Heidelberg College.

County	Nitrate-nitrogen concentration range, mg/L			
	< 0.3	0.3 - < 3.0	3.0 - <10	10 - >10
Crawford, 1988	84	12	14	4
Crawford, subsequent testing	43	7	2	0
Seneca, 1986	218	23	16	4
Seneca, subsequent testing	228	13	23	2
Sandusky, 1987	155	15	10	3
Sandusky, insignificant subsequent.				
Wyandot, 1987	207	13	11	7
Wyandot, subsequent testing	72	4	7	3
Total Number	1,007	87	83	23
Percent of total wells tested (1,200)	83.9%	7.3%	6.9%	1.9%

Bacterial Contamination of Private Water Supplies - The most common health related problem in private wells is contamination by coliform bacteria. Coliform bacteria serve as indicators of possible contamination by human or animal feces and associated pathogenic microorganisms. Contamination is most likely in very shallow wells, in dug wells, in springs, or in wells having faulty construction or maintenance. County health departments can provide advice on testing wells for coliform bacteria. Procedures to disinfect wells using chlorine are described in Ohio State Extension Manual AEX-318.

Nitrate Contamination of Private Wells - Nitrate contamination is the second most common problem in private wells. Given the intensive row crop agriculture in this area, rural residents are often concerned about the possibility of their wells being contaminated by nitrates from fertilizers or manure. Data from the Cooperative Private Well Testing Program operated by the Water Quality Laboratory at Heidelberg College indicates that contamination of private wells by agricultural chemicals is unusual in this region. Data on the extent of nitrate contamination in the wells of the four major counties of the Sandusky Watershed are shown in Table 6.4. Of the total of 1200 samples analyzed, only 1.9% of them exceeded the nitrate standard of 10 mg/L. Nitrate concentrations were less than 0.3 mg/L in 84% of the wells. In statewide testing of 16,000 private water supplies, 2.9% of the samples exceeded 10 mg/L and concentrations were below 0.3 mg/L in 68% of the samples[2]. Thus the extent of nitrate contamination in wells of this area is less than average for Ohio.

The low levels of agricultural contamination in private wells in this area can be attributed to several factors. The bedrock aquifers of this area are relatively resistant to contamination. The water contained in these aquifers often entered the ground water

[2] Baker, D. B, L.K.Wallrabenstein, R.P. Richards, and N.L. Creamer. 1989. *Nitrate and Pesticides in Private Wells of Ohio: A State Atlas.* Water Quality Laboratory, Heidelberg College, Tiffin, Ohio 44883

system several hundreds of years ago, long before the initiation of intensive row crop agriculture in the recharge areas. Much of the excess nitrate applied to crops in this region is intercepted by tile drainage systems and exported back into the surface water rather than percolating into the ground water system. Because of the relatively high organic matter content of the soils in this region, deep soil water becomes anaerobic and nitrates are reduced to ammonia. The ammonia is much less mobile in the soil than nitrate and consequently does not move rapidly into the ground water system.

It should be noted that agriculture is not the only source of nitrate that can contaminate wells. Septic tank effluent also contains nitrogen compounds that can contaminate well water. In other cases, faulty well construction can allow contamination from local surface water, such that wells can be contaminated even though the aquifer supplying water for the well is not contaminated.

Herbicide Contamination in Private Water Supplies - Among herbicides, atrazine and its breakdown products pose the greatest risk to ground water based drinking water supplies in the corn belt region. Atrazine is used in large quantities, can move into ground water, and has a relatively low drinking water standard in comparison to most other herbicides. Limited data on atrazine concentrations in private wells of the Sandusky Watershed indicate that atrazine contamination is either absent or at very low levels. Of 59 wells tested, 83% had concentrations below the detection limit of 0.05 μg/L and none had concentrations above 1.5 μg/L. In general, atrazine contamination in surface water supplies is much more likely to exceed drinking water standards than contamination of ground water.

Table 6.6 Atrazine concentrations in private water supplies in major counties of the Sandusky Watershed

County	Atrazine concentration range, μg/L			
	< 0.05	0.05-1.5	1.5 – 3.0	> 3.0
Crawford	7	2	0	0
Seneca	31	8	0	0
Wyandot	11	0	0	0
Total Count (59)	49	10	0	0
Percent in Category	83%	17%	0%	0%

Chapter 7. Recreational Water Use

Recreational Use Designations

Within Ohio's Water Quality Standards, three levels of recreational use designation are recognized. These recreational uses apply only during the recreation season, which is the period between May 1 to October 15. These three levels of recreational use are:

- **"Bathing waters"** - These are waters that, during the recreation season, are suitable for swimming where a lifeguard and/or bathhouse facilities are present, and include any additional such areas where the water quality is approved by the director (of the Ohio EPA),

- **"Primary contact"** - These are waters that, during the recreation season, are suitable for full-body contact recreation, such as, but not limited to, swimming, canoeing, and scuba diving with minimal threat to public health as a result of water quality.

- **"Secondary contact"** - These are waters that, during the recreational season, are suitable for partial body contact recreation such as, but not limited to wading with minimal threat to public health as a result of water quality.

Water Quality Standards for Recreational Uses

The suitability of waters to meet the above uses is based exclusively on the results of bacterial testing. The testing programs assess the levels of fecal bacteria in the waters, measuring either the more general category of fecal coliform bacteria, or the more specific fecal bacterium *Escherichia coli (E. coli).* Presence of these bacteria in water indicates that fecal material from either human or animal sources is entering the water. Although these forms are themselves seldom toxic, their presence is often accompanied by pathogenic bacteria or viruses. If the coliform bacterial concentrations exceed specified levels, health risks are no longer deemed minimal, and the water body is not meeting recreational criteria. The standards, as presented in the Ohio Administrative Code, Section 3745-1-07, are shown below. For each designation, at least one of the two bacteriological standards (fecal coliform or E. coli) must be met.

Bathing waters

• Fecal Coliform bacteria -- geometric mean fecal coliform content, based on not less than five samples within a thirty-day period, shall not exceed 200 per 100 ml and fecal coliform content shall not exceed 400 per 100 ml in more than ten per cent of the samples taken during any thirty day period.

• *E. coli* bacteria -- geometric mean *E. coli* content, based on not less than five samples within a thirty-day period, shall not exceed 126 per 100 ml and *E. coli* coliform content shall not exceed 235 per 100 ml in more than ten per cent of the samples taken during any thirty day period.

Primary Contact Recreation

• Fecal Coliform bacteria -- geometric mean fecal coliform content, based on not less than five samples within a thirty-day period, shall not exceed 1000 per 100 ml and fecal coliform content shall not exceed 2000 per 100 ml in more than ten per cent of the samples taken during any thirty day period.

• *E. coli* bacteria -- geometric mean *E. coli* content, based on not less than five samples within a thirty-day period, shall not exceed 126 per 100 ml and *E. coli* coliform content shall not exceed 298 per 100 ml in more than ten per cent of the samples taken during any thirty day period.

Secondary Contact Recreation

• Fecal Coliform bacteria -- shall not exceed 5,000 per 100 ml in more than ten per cent of the samples taken during any thirty-day period.

• E. coli -- shall not exceed 576 per 100 ml in more than ten per cent of the samples taken during any thirty-day period.

Sources of Fecal Bacteria Contamination

There are numerous pathways by which fecal bacteria can enter streams. Some of the most common sources are listed below:

1. Combined sewer overflows (CSOs) -- In almost all cities and towns, the sewer lines that convey household sanitary wastes and commercial and industrial wastes to sewage treatment plants also receive storm runoff water. The combined flows of wastes plus storm runoff water often exceed the capacity of the sewer lines to convey the combined waste flows and storm runoff water to the treatment plant. Rather than allowing the sewer lines to back up into basements, overflow structures are built into the sewer system that allows the combined wastes to

directly enter streams and rivers. At these overflow sites, untreated sewage, including fecal bacteria, directly enter stream systems, giving rise to very high bacterial counts.

2. Sewage treatment plant bypasses -- Even with incorporation of combined sewer overflow structures in the sewer collection systems, during storm runoff conditions flows delivered to the sewage treatment plant often exceed the capacity of the treatment plant. At such times, proportions of the incoming wastes are bypassed directly into the receiving waters. Although facilities are often present that allow disinfection of the bypassed flows, such bypasses can introduce viable fecal bacteria into the streams.

3. Cold weather treatment plant effluents. – During the recreational season, disinfection of sewage effluents is a normal part of sewage treatment. However, with the beginning of cold weather, disinfection is normally discontinued. Consequently, extremely high levels of fecal bacteria enter streams and rivers during winter months. Under cold weather conditions, fecal bacteria die off rather quickly, so the elevated counts are restricted to stream segments just below the point source discharges.

4. Septic tank and package plant effluents - Effluents from septic tanks often find their way into streams and rivers. Such effluents are seldom disinfected, and consequently these effluents often convey fecal bacteria directly into streams. Since these flows are continuous, they affect streams during dry weather conditions as well as during wet weather. Effluents from package sewage treatment plants, although more commonly disinfected, can introduce fecal bacteria into surface waters.

5. Storm sewers and agricultural tile systems -- Often storm sewers or tile systems receive effluents from septic tanks or from household sewer lines that are not connected to sanitary sewers. These dry weather flows in storm sewers can introduce fecal material into streams.

6. Livestock wastes - There are several pathways by which fecal material from livestock can enter streams and rivers. Livestock may have direct access to streams. Storm runoff water from feedlots, barnyards, pastures or fields receiving manure applications can introduce fecal wastes into streams. Failures of animal waste treatment systems, such as holding ponds and conveyance pipes, can lead to direct entry of fecal material into streams.

7. Waterfowl and other wildlife - Often elevated fecal bacteria occur as a result of concentrations of ducks, geese or gulls. In general, storm runoff water from virtually all land uses contains elevated fecal coliform bacterial counts. These elevated counts can apparently come from diverse wildlife sources and pets.

Fecal Bacteria Conditions in the Sandusky River and its Tributaries

Of the classes of recreational use listed above, routine bacteriological monitoring is required only for bathing waters. In northwestern Ohio, bathing waters are largely restricted to beaches along Lake Erie. When bacterial counts exceed those listed for bathing waters, beaches are posted as being unsafe for swimming. Although closings at Lake Erie beaches are less frequent than in the past, they still do occur. At swimming pools, chlorination is used to prevent the build up of coliform bacteria.

There are no routine monitoring programs designed to assess whether or not streams and rivers are meeting standards for primary and secondary contact recreational activities. Instead, information regarding the bacteriological safety of streams and rivers is based on information from special studies. These special studies may be (1) designed to assess the impacts of combined sewer overflows and bypasses on water quality, (2) incorporated into periodic biological stream assessments, or (3) conducted in response to nuisance complaints of sewage or livestock wastes entering stream systems.

The patterns of bacteriological contamination in the Sandusky River and its tributaries relate rather directly to the sources of contamination listed above. During dry weather conditions, standards for primary and secondary contact recreation are often met, except in local situations where septic tank effluents, package plant effluents, storm sewers, livestock wastes or waterfowl affect streams. Since the fecal coliform bacteria, as well as the associated pathogens, gradually die off, elevated counts in streams and rivers are limited to stream segments immediately downstream from the points of entry.

During conditions of storm water runoff, fecal bacterial levels often skyrocket to concentrations many times above the recreational standards. This is particularly true downstream from combined sewer overflows. It is unlikely that any stretches of the Sandusky River and its tributaries would meet primary and secondary recreational standards during periods of storm runoff.

Examples of dry and wet weather bacterial counts in the Sandusky River in the vicinity of Tiffin are shown in Tables 7.1 and 7.2. These data are taken from a combined sewer overflow study conducted by Tiffin's Water Pollution Control Center in 1998. From Table 7.1, it is evident that the dry weather concentrations of fecal coliform bacteria in the Sandusky River at Bel-Mar Landing, upstream from Tiffin CSOs, meet the standards for primary and secondary contact recreation. Dry weather concentrations of fecal coliform bacteria in Rock Creek at Hedges Boyer Park, also upstream from Tiffin CSOs, meet standards for primary and secondary contact recreation except during those periods when storms occurred in the upper portion of the Rock Creek watershed. The dry weather counts for Gibson Run at State Route 100 did not meet either of the recreational standards. Since this study, an interceptor sewer has been installed along Gibson Run. Prior to installation of the interceptor, Gibson Run received effluents from numerous septic tanks, upstream from Tiffin.

Table 7.1 Examples of fecal coliform counts in the Sandusky River, Rock Creek, and Gibson Run in Tiffin during dry weather conditions, summer 1998.

Date, 1998	Fecal Coliform Bacteria, count per 100 ml		
(dry weather flows)	Sandusky River	Rock Creek	Gibson Run
June 9	39	237	2,167
July 7	156	427	3,133
July 14	143	449	2,933
July 15	91	605	4,033
July 16	57	27,667*	1,700
July 31	202	537	4,700
August 4	37	357	4,484
August 13	270	449	4,600
August 14	156	4,530*	3,130
August 28	207	565	5,450

* Storms did occur in the upper portion of the Rock Creek Watershed on these dates.

The effects of combined sewer overflows on bacterial counts in the Sandusky River, Rock Creek, and Gibson Run are shown in Table 7.2. The upstream sampling sites were the same as those used for the dry flow studies. On most days, counts were significantly higher at downstream locations, below combined sewer overflows. Counts were often much higher than allowed for primary and secondary contact recreational uses. It is also apparent that even upstream from the combined sewer overflows, fecal coliform values increased well above those present during dry weather conditions. These elevated fecal coliform values entering the town reflect the general increases in fecal coliform counts that occur during storm runoff conditions from upstream land uses.

Other studies in the Sandusky Watershed reveal similar results. During the OEPA's 1990 study of the Sandusky River, 29 of 60 river samples exceeded Ohio's Water Quality Standards.[1] These samples were collected along the mainstream of the Sandusky River from upstream of Bucyrus to downstream of Tiffin. The elevated counts were attributed to above average rainfall and the resultant runoff from urban and rural areas and discharges from CSOs. Highest concentrations were found below CSOs in the Bucyrus area.

Fecal coliform conditions in the Sandusky River and its tributaries are similar to other streams in Ohio. Efforts to reduce the effects of CSOs on water quality are underway in most communities. Separation of storm and sanitary sewers is, however, extremely expensive. Even if CSOs were eliminated, the high levels of fecal coliform bacteria in surface runoff from both agricultural and urban landscapes would likely result in violations of the bacterial standards for recreational use. Recreational users of Ohio's streams and rivers need to be aware of the increases in health risks during periods of rainfall and storm runoff. Users should take appropriate measures to minimize accidental

[1] Ohio EPA, 1991. Biological and Water Quality Study of the Sandusky River and Selected Tributaries, Crawford, Wyandot and Seneca Counties. Doc. OEPA 05-001..

ingestion of the water or excessive contact with the skin, particularly where cuts or abrasions are present.

Table 7.2 Fecal coliform bacterial counts upstream and downstream from combined sewer overflows for three Tiffin streams during and following rainfall events.

Stream	Date, 1998	Upstream from Tiffin CSOs	Downstream from Tiffin CSOs
Sandusky River	June 10	200	5,667
	June 11	233	633
	June 12	17,000	23,000
	July 21	167	1,537
	July 22	1,120	42,333
	July 23	4,000	13,333
	August 6	5,333	7,617
	August 7	1,100	1,733
	August 8	800	1,060
Rock Creek	June 10	1,267	8,667
	June 11	333	2,167
	June 12	63,000	56,667
	July 21	1,193	80,667
	July 22	37,333	44,000
	July 23	13,333	12,667
	August 6	19,667	29,667
	August 7	6,333	10,667
	August 8	1,533	2,233
Gibson Run	June 10	3,467	8,333
	June 11	3,100	3,200
	June 12	14,333	40,000
	July 21	25,667	134,000
	July 22	29,667	44,667
	July 23	9,167	23,000
	August 6	4,017	5,250
	August 7	2,900	2,800
	August 8	2,167	4,934

Recreational Uses of the Sandusky River and its Tributaries

Although the Sandusky River and its tributaries may not always meet bacterial standards for recreational use, these streams do offer excellent recreational opportunities. These recreational opportunities include boating, canoeing, white-water kayaking, fishing, birding, and many other activities. Many of the towns and cities in the watershed have parklands located along the Sandusky River and/or its tributaries. In the rural areas, the Sandusky River offers a surprising degree of isolation. The wooded riparian zones along the rivers provide a visual screen from the cropland that dominates land use in the area. The biological resources of the watershed, as described in Chapter 4, attest to the high quality of the stream and contribute to the recreational opportunities it affords.

The Sandusky -- An Ohio Scenic River

In January 1970, the director of the Ohio Department of Natural Resources designated approximately 70 miles of the Sandusky River as Ohio's second scenic river. The area of designation begins at US Route 30 in Upper Sandusky to the Roger Young Memorial Park in Fremont. Flowing south to north for 115 miles through Crawford, Wyandot, Seneca and Sandusky counties, the Sandusky River drains 1,420 square miles before emptying into Sandusky Bay and ultimately Lake Erie.

Southern sections of the designated stretch of river flow through the rich farmlands of Wyandot and Seneca counties, carving its valley through 10-50 dolomite and limestone outcroppings. The river valley meanders through small ridges that are associated with the Defiance, Fort Wayne and Wabash End moraines. Receding glaciers formed these geological features more than 13,000 years ago. Riffle-run-pool complexes characterize physical in-stream habitat conditions and substrate materials are largely limestone and other small cobbles, gravel and boulders. Northern stretches of the river flow through extensive flats of bedrock, forming impressive long riffle areas.

The Sandusky is a serene and remarkable remote river, providing a suitable home to Ohio's largest inland population of the endangered Bald Eagle. Additionally, the Sandusky River maintains thriving and diverse communities of riparian birds, mammals and fish and other aquatic organisms. For example, the Sandusky State Scenic River is the only stream in Ohio to provide suitable habitat for all six species of the pollution intolerant redhorse suckers. Two of these suckers, the river and greater redhorse are respectively state-listed as special interest and endangered.

Aquatic life within the Sandusky is also abundant and diverse. Recent fish community surveys identify at least 68 species of fish inhabiting the river. Historically, fish life was even more abundant, with 89 species of fish having been collected at one time or another in the Sandusky. The Sandusky also provides critical spawning and nursery habitat for important populations of lake-run walleye and white bass. Each spring thousands of fishers line the banks of the Sandusky near Fremont in pursuit of spawning walleye and white bass.

Volunteer stream quality assessments also indicate a rich benthic community of aquatic macroinvertebrates. Many species of pollution intolerant species such as Dobsonfly larvae, water penny beetles and riffle beetles are routinely collected by DNAP SQM volunteers. Additionally, numerous mussel species, including several that are pollution intolerant and/or state threatened, are also found in the river.

Perhaps the Sandusky River's most important attribute is it's rich and vibrant history. An important early transportation and trading route, human occupation of the Sandusky River valley dates back thousands of years, including early native Americans such as the pre-historic Paleo-Indians to the more recent Seneca and Wyandot Indians. The Sandusky derives its name from the Wyandots: "San-uh-dus-kee", or "clear water within pools". As recently as 1840, Wyandots were housed in the last Indian reservation in Ohio, encompassing more than 15,000 acres from Upper Sandusky to just south of Fremont.

Many historic sites along the Sandusky have been restored for public visitation and interpretation. These include Indian Mill and the Old Mission Church and School near Upper Sandusky. Numerous plaques and other monuments testifying to the area's rich native history are also found throughout the river basin.

In addition to native history, the Sandusky River also played a crucial role during the war of 1812. Numerous early forts dotted the river as far south as Upper Sandusky. Several interesting and important battles also transpired along the river including Crawford's defeat on the Sandusky Plains in 1782 and an important American victory at Fort Stephenson in Fremont during the early 1800's. Other important historical figures visited the area, including the great author Charles Dickens. The McCutchenville Overland Inn, a site visited by Dickens in 1842 still stands in the small village of McCutchenville.

A listing of important locations on the river, including significant historical sites and/or resources follows.

Upper Sandusky-River Mile 83:

Upper Sandusky is a small agricultural town and the county seat of Wyandot County. Nearby historical sites in Upper Sandusky include the Old Mission Church and Boarding School. This facility is located in a cemetery within the city limits and includes gravestones pre-dating 1812. Both natives and early regional settlers are interred in this cemetery.

The Mission Church and Boarding School were constructed in 1823 by Methodist missionaries in the middle of the Wyandot Reservation, which comprised most of the region from Upper Sandusky to north of Tiffin. The Mission School operated for only a short time, from 1823 until March 17, 1842, when the last of the Wyandots were relocated to Kansas and Oklahoma.

Indian Mill-River Mile 78:

Indian Mill is a restored grist mill and small museum operated by the Ohio Historical Society immediately adjacent to the river. Across from the mill is a small picnic and scenic river access area owned and administered by the Division of Natural Areas & Preserves. Canoe and other public access at this site is good, with portable toilets available during the warm weather months.

Indian Mill was constructed in 1820 by the Federal government and given to the Wyandot Indians for their support and help during the War of 1812. Originally, two mills were constructed; a gristmill for the grinding of grain grown on the Wyandot reservation and a sawmill. Government appointed millwrights ground cornmeal and flour for the Wyandots, as well as for settlers living in the area. Wyandot grain was milled free of charge. Settlers paid for their milling services with one-half of their payments to be used for the betterment and upkeep of the Indian population. Indian Mill operated in this manner from the time of its construction in 1820 until 1843, at which time Indian title to the reservation expired and they were relocated under the Indian Removal Act.

The mills were then sold under government auction and purchased by George Myers who quickly dismantled the original mills and dam. Using materials salvaged from the original structures, the present structure was constructed in 1861. The current mill is substantially larger than the original mills and is located approximately 300 feet downstream from the original locations.

The dam at Indian Mill is one of only two wooden dams within the state of Ohio and was reconstructed several years ago by the Civilian Conservation Corps.

Indian Mill continues to be a popular site for visitors along the Sandusky State Scenic River. Fishing in the area for smallmouth bass, catfish, and numerous varieties of panfish is excellent. Canoeing and picnicking are also popular activities.

Parker Covered Bridge-River Mile 73:

The Parker Covered Bridge is the only covered bridge on the designated portion of the Sandusky River. Originally constructed in 1872, the bridge spans 180 feet across the Sandusky State Scenic River and is the longest single span covered bridge remaining in Ohio. Burned down by vandals in 1991, the bridge stands as a testament to the power of volunteerism and community activism. A group of area residents, members of the Sandusky State Scenic River Advisory council and representatives of local governments joined together to restore the bridge. Their efforts raised nearly $75,000, which when matched with a state grant, enabled the bridge to be restored and rededicated in October 1992. The Parker Covered Bridge stands today as a scenic reminder of the rich history of the Sandusky Valley.

Near Parker Covered Bridge on County Road 37 is a memorial to the Chief Tarhe the Crane, the most noted chieftain of the Wyandots. Of the chieftains present at the signing of the Treaty of Greenville in 1794, Tarhe was chosen to take custody of the ceremonial Grand Calumet, or pipe of peace. The Wyandot village of Cranetown was located near his monument, which is about one-quarter mile from the shores of the Sandusky. Tarhe lived in the valley until his death in 1818.

Parker Covered Bridge is a popular canoe take-out for those floating from Indian Mill. It is also popular as a local fishing hole. The stretch of river from Indian Mill to Parker Covered Bridge is among the most scenic along the Sandusky River.

Confluence of Tymochtee Creek-River Mile 68

One-quarter mile downstream from the bridge crossing at State Route 103 is the confluence of Tymochtee Creek and the Sandusky River. Tymochtee Creek is the largest of the Sandusky River tributaries. At one time, this site was a large Wyandot Indian Village and the starting point for the Big Spring Prairie, a large wet prairie stretching forty miles long by twenty miles wide. Remnants of this prairie may be found in Killdeer Plains State Wildlife Area in southern Wyandot County.

Canoeing in this area of the Sandusky is discouraged due to the presence of a very large logjam located upstream from the State Route 103 bridge. A long portage over private property is required to traverse this section of river. (This logjam may have been removed in 1999.)

Wyandot County Highway 35 Crossing-River Mile 62

Approximately one mile east of the river is the small town of McCutchenville. Although currently a small town with a few stores, post office and a gas station, McCutchenville was once a bustling stage coach town. The McCutchenville Overland Inn on State Route 53 stands as a reminder of an era when travel through the Ohio territory was done at a much slower pace than today.

The famed author Charles Dickens is reputed to have stopped at the McCutchenville Inn during his visit to the region in 1842.

Heck's Bridge/Howard Collier Scenic River Area-River Mile 54

A public canoe access is located on the north side of the river, with a gravel parking lot and somewhat difficult launching conditions immediately under the bridge.

On the south side of the river, the Howard Collier Scenic River Area provides easy access to approximately 300 acres of natural areas. In addition to paved parking and lightly developed picnic areas, there are well-developed trail systems and an elaborate network of boardwalks, bridges and stairs.

The Howard Collier Area provides magnificent displays of spring wildflowers and several significant vernal pools, which are heavily used in the spring by a wide variety of salamanders, toads, frogs and other amphibians. During March and April, these vernal pools are alive with the sounds of spring peepers, wood frogs and others. The Howard Collier area also provides excellent birding during the spring migration of songbirds, including numerous species of warblers and others.

This site is also an exceptional example of a mature floodplain plant community with expansive canopies of sycamores, cottonwoods, tuliptrees and others. Upland areas also provide excellent displays of mature Beech-Maple forest communities.

St. Johns Dam-River Mile 50

A small public access is available on river left, suitable for fishing and canoe launching. No public restroom or other facilities are available at this site. St. Johns Dam is the second largest dam on the Sandusky State Scenic River. Boating and fishing are the two most common activities associated with this area of the river. A private campground (Walnut Grove Campground) is located upstream from the dam and provides access for a large number of visitors to enjoy this stretch of the river.

The dam has been slightly breached and can pose a hazard to canoeists during periods of high water. The area immediately downstream from the dam provides excellent fishing for smallmouth bass, panfish and large channel catfish and also provides canoeists with a leisurely and remote paddle downstream to the State Route 224 bridge.

City of Tiffin-River Miles 42-39

Home to Heidelberg College and Tiffin University, the city of Tiffin is also steeped in early Ohio history. Fort Ball, an important fort during the War of 1812 was located here. A memorial to the fort is located along the river in downtown Tiffin.

Tiffin was severely affected by the great flood of 1913. In response, massive concrete floodwalls were constructed throughout much of the city. These walls unfortunately destroyed much of the natural character of the Sandusky through town.

Canoeists and recreational users of the Sandusky will find ample access at numerous Tiffin parks that are located immediately adjacent to the river. The city also recently completed a bike and walking path providing a variety of opportunities for numerous recreational users of the river.

Abbot's Island-River Mile 35

Abbot's Island is the largest island south of Fremont on the Sandusky State Scenic River. At 80 acres, the island provides a wide variety of local flora, including many examples of plants found in few other places in the region. The island area also includes a meander cutoff that was formed during the flood of 1913.

Abbott's Bridge Scenic River Access-River Mile 31

Located on river left, this scenic river access area is owned and administered by the Division of Natural Areas & Preserves. A gravel parking area provides ample public fishing and canoe access, while an adjacent floodplain forest provides trails and hiking.

Located on the northern-most boundary of the historic Wyandot Indian Reservation, this site is rich in local history. Indian artifacts are occasionally found in the plowed fields surrounding this site.

During 1997, Abbott's Bridge was destroyed in a vehicle accident. It was removed shortly thereafter and is not planned for replacement.

Village of Old Fort-River Mile 27

The village of Old Fort is now a small town housing a gas station, general store and several homes. However, during the War of 812 this community was the site of Fort Seneca, another of the important forts once located on the Sandusky State Scenic River.

The confluence of Wolf Creek and the Sandusky River also was the northern boundary of the Wyandot Indian Reservation.

Tindall Bridge-River Mile 19

Tindall Bridge is a large historic steel span crossing the Sandusky Scenic River along River Road south of Fremont. Prior to the construction of the Ballville Dam in Fremont, this site was the beginning of a long portage around a series of rapids that extended all the way down to Fremont.

Broken Paddle City Park-River Mile 18

Broken Paddle Park is a public park operated by the city of Fremont. Public facilities include a canoe livery, camping, water and public restrooms, Balls Battlefield, the site of a battle in the war of 1812 between American forces that were going to the relief of Fort Stephenson, is located immediately downstream of the park.

Fremont-River Miles 16-13

Fremont, located on the northern most designated portion of the Sandusky Scenic River was home to President Rutherford B. Hayes. Within the city are the Hayes

Presidential Center with a museum and library. Significant historical references and resources are available at this facility.

Additionally, Fremont is historically important due to the presence of Fort Stephenson. It was at this fort that an important victory was won during the War of 1812. The first free public library in Ohio now occupies this site.

Recreational Facilities in the Sandusky Watershed

The extent of recreational use of the water resources in the Sandusky Hydrological Unit is indicated by the numerous recreational facilities within its boundaries. Boating facilities are listed in Table 7.3. Canoeing access sites are listed in Table 7.4. Campgrounds are listed in Table 7.5. Fishing facilities are listed in Table 7.6 and birding facilities are listed in Table 7.7. The Sandusky watershed offers area residents excellent opportunities for water based recreation. These tables are not necessarily complete.

Table 7.3 Boating facilities in the Sandusky Hydrological Unit.

County	Boating Facility	Nearest To	Size	Other Features
Crawford	Bucyrus Reservoir #4/ Outhwaite Reservoir N side of SR 98, 1 1/2 mi. N of Bucyrus	Bucyrus	160 acres	6 hp limit, boat ramps, fishing, sailing, canoeing, walking trail
Crawford	New Washington Reservoir #1, #2 S edge of New Washington off SR 602	New Washington	9 acres	Fishing
Erie	Battery Park Marina E. Water St. & Meigs St., downtown Sandusky	Sandusky	Sandusky Bay	Boating, fishing; handicap accessible parking, courtesy docks, shore/pier fishing; marina, picnicking, tennis, pool
Erie	Bickley's Dock Shack 101 Shelby St., Sandusky	Sandusky	Sandusky Bay	Boating (unlimited hp); handicap accessible parking, courtesy docks, shoreline/pier fishing; boat ramp, picnicking
Erie	Cedar Point Marina	Sandusky	Sandusky Bay	Unlimited hp, large boat accommodations, marina, store, pool, picnicking, laundry, Cedar Point Amusement Park
Erie	Clemon's Marina Bayview Rd. exit off SR 2, Martins Rd. N, E on Barrett Rd.	Bayview	Sandusky Bay	Unlimited hp, boat ramps, marina, picnicking
Huron	Bellevue Reservoir #5 SE of Bellevue, E off SR 4 on SR 547	Bellevue	87 acres	Electric motors only, fishing, sailing, canoeing

Table 7.3 Boating facilities in the Sandusky Hydrological Unit, continued.

County	Boating Facility	Nearest To	Size	Other Features
Ottawa	Dempsey-Sandusky Bay Access 5 mi. E of SR 269 on CR 135 (Bay Shore Rd.)	Danbury or Marblehead	Sandusky Bay	Unlimited hp, boat ramps, fishing, sailing, skiing, picnicking; handicap accessible parking, shoreline/pier fishing, courtesy docks
Ottawa	Hank's Place 2350 S. Danbury Station Rd., Rt. 2 to 269 exit	Danbury	Sandusky Bay	Boat ramps, shoreline/ pier fishing, marina, camping, picnicking
Ottawa	Sonny's Beach 2304 S. Danbury Rd.	Danbury	Sandusky Bay	Boat ramps, courtesy docks, marina, camping
Sandusky	Bay Harbor Marina, White's Landing 1 mi. N of Rt. 6 off Hill Rd.	Sandusky	Sandusky Bay	Unlimited hp, boat ramps, fishing, sailing, skiing, picnicking, rental docks, fuel
Sandusky	Fremont Boat Ramp W of Sandusky Ave., N of State St. in Fremont	Fremont	Sandusky River	Unlimited hp, boat ramps, shore fishing, sailing, canoeing, skiing
Sandusky	Mad Creek Bait & Tackle N SR 53, 4 mi. S of Rt. 2	Fremont	Sandusky Bay	Boat ramp, handicap accessible, shoreline/pier fishing
Sandusky	Memory Marina 3 mi. N of Rt. 6, CR 198	Fremont	Sandusky River/Bay	Unlimited hp, boat ramps, fishing, sailing, canoeing, skiing, picnicking, rental docks, fuel, rental boats
Sandusky	Portage Trail Canoe Livery 1773 S. River Rd., Fremont	Fremont	Sandusky River/Bay	Parking lot, canoe rentals, canoe ramp, restrooms, camping, picnicking, water
Sandusky	Riverfront Marina 2 mi. N of I-80/90 on Rt. 53, at Artz Rd.	Fremont	Sandusky River	Unlimited hp, boat ramps, fishing, sailing, canoeing, skiing, picnicking, rental docks, fuel
Sandusky	White Star Park S of Gibsonburg on SR 300	Gibsonburg	572 acres	15-acre quarry, scuba diving, fishing, swimming, picnicking, play equipment, softball diamond, horseshoes, volleyball, campground, natural preserve area, nature trails, cross country skiing
Seneca	Beaver Creek Reservoir 5 mi. SW of Clyde off SR 101 on CR 34	Clyde	150 acres	Electric motors only, fishing, sailing, canoeing, picnicking
Wyandot	Killdeer Plains Wildlife Area 2 mi. S of Harpster, S on SR 294	Harpster	Various ponds	Small boats (no motors), fishing, sailing, canoeing, boat ramps, handicap accessible

Table 7.3 Boating facilities in the Sandusky Hydrological Unit, continued.

County	Boating Facility	Nearest To	Size	Other Features
Wyandot	Killdeer Upground Reservoir SR 67, N edge of Marseilles	Upper Sandusky	285 acres	10 hp limit, boat ramps, fishing, sailing, canoeing, scuba diving (by permission only), ice fishing
Wyandot	Wyandot Canoe Livery 640 E. Wyandot Avenue	Upper Sandusky	Sandusky River	Parking lot, canoe rentals, picnicking

Table 7.4 Canoe access locations for the Sandusky River Watershed.

County	Canoe Access Locations-Sandusky River	Closest to	Other Features
Sandusky	Chief Tarhe Park (abandoned) off TR 158, 2 mi. SW of Fremont Roadside Access-River Right	Fremont	Roadside parking
Sandusky	CR 35 Bridge E of SR 53 (King Rd./ Hurdic Rd. & S. River Rd.) South of Fremont Roadside Access-River Right	Fremont	Roadside parking
Sandusky	Dempsey-Sandusky Bay Public Access off Bayshore Drive 12 mi. north of the mouth of the river on Sandusky Bay Park Access-Bay at River Left	Danbury or Marblehead	Parking lot, water, trailer/cartop ramp, restrooms, picnicking
Sandusky	Elliot St. in Fremont by Brady's Island Park Access-River Right	Fremont	Parking lot, picnicking, trailer/ cartop ramp
Sandusky	Gilmore Bridge on Darr Rd. between Wolf Creek Access and Ft. Seneca Roadside Park Roadside Access-River Left	Fremont	Roadside parking
Sandusky	Portage Trail Park & Canoe Livery off South River Rd. south of Fremont Park Access-River Left	Fremont	Parking lot, canoe rentals, canoe ramp, restrooms, camping, picnicking, water
Sandusky	Roger Young Memorial Park off Front St. or Tiffin St. in Fremont Park Access-River Left	Fremont	Parking lot, restrooms, picnicking, water
Sandusky	Wolf Creek Park Scenic River Area off SR 53 south of Fremont Roadside Access-River Left	Fremont	Parking lot, canoe ramp, restrooms, picnicking, water, camping
Seneca	CR 38 Bridge and CR 33 north of Tiffin Roadside Access-River Right	Tiffin	Roadside parking
Seneca	Hecks Bridge and Howard Collier Scenic River Access off SR 53 to TR 26 to TR 131, near McCutchenville Roadside Access-River Left	McCutchenville	Parking lot, fishing access, picnicking
Seneca	Jr. Young Park in Tiffin off Huss Street Bridge Park Access-River Left	Tiffin	Parking lot, picnicking

Table 7.4 Canoe access locations for the Sandusky River Watershed, continued.

County	Canoe Access Locations-Sandusky River	Closest to	Other Features
Seneca	Abbott's Bridge Scenic River Access SR 53 to TR 152, near Fort Seneca Roadside Access-River Left	Tiffin	Parking lot, restrooms, fishing
Seneca	St. John's Bridge NE of McCutchenville off Seneca CR 6 and SR 52 Roadside Access-River Left	McCutchen ville	Parking lot
Seneca	Water Street access north of Huss Street Bridge in Tiffin Roadside Access-River Left	Tiffin	Roadside parking
Wyandot	Harrison Smith Park off SR 30 in Upper Sandusky Park Lot Access-River Left	Upper Sandusky	Parking lot, restrooms, picnicking, water
Wyandot	Indian Mill Park off US 23 north to CR 50, south of Upper Sandusky Park Access-River Right	Upper Sandusky	Parking lot, restrooms, picnicking, water, fishing
Wyandot	Parker Covered Bridge Wyandot CR 40b north of Indian Mill in Upper Sandusky Roadside Access-River Right	Upper Sandusky	Roadside parking, fishing
Wyandot	Wyandot CR 16 Bridge south of McCutchenville Roadside Access-River Right	McCutchen ville	Roadside parking
Wyandot	Wyandot CR 124a Bridge off SR 23 E of Harpster Roadside Access-River Left	Harpster	Roadside parking
Wyandot	Wyandot Canoe Livery off SR 30 N in Upper Sandusky Park Access-River Right (with permission)	Upper Sandusky	Parking lot, canoe rentals, picnicking

Table 7.5 Campgrounds in or near the Sandusky Hydrological Unit

County	Campground Facility	Nearest To	Other Features
Erie	Bayshore Est. RV Park & Campground 2311 Cleveland Rd., 3/4 mi. E of Causeway Dr. on Rt. 6	Sandusky	Swimming pool, shower, laundry, game room, store, waterfront, playground, volleyball, basketball
Erie	Camper Village Cedar Point	Sandusky	Swimming (beach), shower, laundry, store, waterfront
Erie	Crystal Rock Campground 710 Crystal Rock Rd., 4 mi. W of Sandusky	Sandusky	Swimming pool, laundry, showers, game room, store
Erie	Traveland Family Campground 3518 Tiffin Avenue	Sandusky	Fishing, swimming pool, game room, store, laundry, shower, propane
Sandusky	Broken Paddle Campground 1885 S. River Rd.	Fremont	Canoe launch, picnicking
Sandusky	Cactus Flats Campground 639 CR 26	Helena	Shelter, picnicking, fishing, swimming, volleyball, horseshoes, game room

Table 7.5 Campgrounds in or near the Sandusky Hydrological Unit, continued.

County	Campground Facility	Nearest To	Other Features
Sandusky	Memory Marina & Campground 2815 CR 198	Fremont	Boating (unlimited hp), launch ramps, fishing, sailing, canoeing, skiing, picnicking, rental docks, fuel, rental boats
Sandusky	Portage Trail Campground 1773 S. River Rd.	Fremont	Canoe launch/rental, fishing, shelter
Sandusky	Riverfront Marina & Campground 4257 N. SR 53	Fremont	Fishing, picnicking, bait store, boat launch, horseshoes
Sandusky	The Tackle Box 420 Sandusky Avenue	Fremont	Boat launch/rental, dockage, fishing, restaurant, bait store
Sandusky	Wooded Acres Campground 2232 CR 106	Fremont	Fishing, picnicking, shelter, playground, swimming, tennis, volleyball, horseshoes, dumping station, concession stand, game room
Sandusky	Young's RV Center 1450 Dickinson St.	Fremont	Picnicking
Seneca	Clinton Lake Camping 4990 E TR 122	Tiffin or Republic	Swimming pond, fishing (4 acre lake), hiking trails, shelter houses, horseshoes, volleyball, basketball, playground, store, toilets, showers, planned weekend activities
Seneca	Meadowbrook Park SR 18, Bascom	Tiffin or Fostoria	Fishing, swimming pool, hiking, basketball, tennis, softball, volleyball, horseshoes, shuffleboard, playground, shelter, showers, toilets
Seneca	Seneca Campgrounds 6955 S. SR 101	Clyde	Swimming & fishing pond, shelter, playground, basketball, store, planned weekend activities, toilets, showers
Seneca	Walnut Grove Campground 7325 S. Seneca TR 131	Carey or Tiffin	Swimming pool, fishing, store, toilets, showers, game room, canoe rentals, canoe launch, horseshoes, playground, hiking, shelter, planned weekend activities
Wyandot	Fox Fire Family Fun Park 3699 Crawford-Wyandot Rd.	Nevada	Boating, swimming, fishing, game room, shower
Wyandot	TeePee Campgrounds 6499 S. SR 199	Carey or Upper Sandusky	Swimming pool, pond, fishing, store, toilets, showers, hiking, hay rides, store

Table 7.6 Fishing facilities in the Sandusky Hydrological Unit

County	Fishing Facility	Nearest To	Acreage Land/Water	Other Features
Crawford	Bucyrus Reservoir #1 SR 98, 1 1/2 mi. NE of Bucyrus	Bucyrus	30 acres	Boating (10 hp limit)
Crawford	Bucyrus Reservoir #2 SR 96, 1 1/2 mi. E of Bucyrus	Bucyrus	33 acres	Boating (10 hp limit)
Crawford	New Washington Reservoir #1, #2 S edge of New Washington off SR 602	New Washingto n	9 acres	No boats
Crawford	Outhwaite Reservoir/Bucyrus Reservoir #4 N side of SR 98, 1 1/2 mi. NE of Bucyrus	Bucyrus	160 acres	Boating (6 hp limit), boat ramp, walking trail, sailing, canoeing, hunting/trapping (with written permission) for waterfowl and deer
Crawford	Riley Reservoir 2 mi. E of Bucyrus between SR 96 & SR 98 on Kiess Rd.	Bucyrus	30 acres	Boating (electric motors only)
Erie	Battery Park Marina E. Water St. & Meigs St. in downtown Sandusky	Sandusky	Sandusky Bay	Boating, handicap accessible parking, courtesy docks and shore & pier fishing, marina, picnicking
Erie	Bayview Sandusky Bay Bridge Bayview Rd. exit off SR 2, Martins Rd. N to Barrett W	Bayview	Sandusky Bay	Shoreline fishing
Erie	Bickley's Dock Shack 101 Shelby St., Sandusky	Sandusky	Sandusky Bay	Boating (unlimited hp), handicap accessible parking, courtesy docks, shoreline/pier fishing, boat ramp, picnicking
Erie	Castalia State Fish Hatchery 2 mi. N of Castalia, off Homegardner Rd.	Castalia		
Erie	Clemon's Marina Bayview Rd. exit off SR 2, Martins Rd. N, E on Barrett Rd.	Bayview	Sandusky Bay	Boating (unlimited hp), boat ramps, marina, picnicking
Erie	Lions Park Off W. Monroe St., W of Sandusky	Sandusky	Sandusky Bay	Picnicking, shelters, playground, tennis
Erie	Pipe Creek Wildlife Area River Rd., E of Cedar Point Causeway	Sandusky	5 acres/ 95 acres	Natural area, shore fishing, waterfowl hunting (by permit)
Erie	Resthaven Wildlife Area SR 269, Castalia	Castalia	1831 acres/ 444 acres	Small boats (electric motors only), handicap accessible, boat ramps
Erie	Sandusky Railroad Property Shoreline Dr. at end of Franklin St., Sandusky	Sandusky	Sandusky Bay	No boats, handicap accessible, shoreline/pier fishing & parking, picnicking
Erie	Sandusky City Pier, Battery Park Shoreline Dr. at end of Jackson St., Sandusky	Sandusky	Sandusky Bay	No boats

Table 7.6 Fishing facilities in the Sandusky Hydrological Unit, continued.

County	Fishing Facility	Nearest To	Acreage Land/Water	Other Features
Erie	Shoreline Park Shoreline Drive, Sandusky	Sandusky	Sandusky Bay	Picnicking, shelters, playground
Erie	Willow Point Wildlife Area 5 mi. NW of Castalia, N of US 6 on Wahl Rd.	Castalia	318 acres/ 303 acres Sandusky Bay	Boating (unlimited hp), shore fishing access
Huron	Bellevue Reservoirs #1,2,3,4,5; #5 SE of Bellevue, E off SR 4 on SR 547; #1,2,3,4 at SE edge of Bellevue	Bellevue	146 acres	Boating (electric motors only) on Reservoir #5, sailing, canoeing, waterfowl blind drawing (#5)
Ottawa	Dempsey-Sandusky Bay Access 5 mi. E of SR 269 on CR 135 (Bay Shore Rd.)	Danbury or Marblehea d	68 acres/ Sandusky Bay	Boating (unlimited hp), boat ramps, sailing, skiing, picnicking; handicap accessible parking, shoreline & pier fishing & courtesy docks
Ottawa	Hank's Place 2350 S. Danbury Station Rd, Rt. 2 to 269 exit	Danbury	Sandusky Bay	Boat ramps, shoreline/ pier fishing, marina, camping, picnicking
Ottawa	Sandusky Bay Bridge Access 6 mi. E of Port Clinton off SR 2 on SR 269 (Sandusky Bay)	Danbury	36,000 acres	No boats, shoreline/pier fishing, year-round access, restrooms, handicap access parking
Ottawa	Sonny's Beach 2304 S. Danbury Rd.	Danbury	Sandusky Bay	Boat ramps, courtesy docks, marina, camping
Sandusky	Aldrich Pond Wildlife Area 2 mi. NW of Lindsey off US 20 on Sommers Rd. (TR 149)	Lindsey	40 acres	Boating (electric motors only), natural area
Sandusky	Bay Harbor Marina, White's Landing 1 mi. N of Rt. 6 off Hill Rd.	Sandusky	Sandusky Bay	Boat ramp, rental dock, marina, picnicking, sailing, skiing, fuel
Sandusky	Fremont Boat Ramp W of Sandusky Ave., N of State Street in Fremont	Fremont	Sandusky River	Boating (unlimited hp), boat ramp, shore fishing access, sailing, canoeing, skiing
Sandusky	Memory Marina 3 mi. N of Rt. 6, CR 198	Fremont	Sandusky River/ Bay	Boat ramp, rental docks, bait/tackle shop, rental boats, sailing, canoeing, skiing, picnicking
Sandusky	Mill Pond Park Community Center 800 Monroe St., Bellevue	Bellevue		Fishing, shelter, picnic, playground, pond, amphitheater, basketball, volleyball, ball diamonds, swimming pool, miniature golf, recreation center
Sandusky	Millers Blue Hole Wildlife Area SR 6, 10 mi. NE of Fremont	Vickery	1 acre	No sport fishing, natural area

Table 7.6 Fishing facilities in the Sandusky Hydrological Unit, continued.

County	Fishing Facility	Nearest To	Acreage Land/Water	Other Features
Sandusky	Mad Creek Bait and Tackle Rt. 53, 4 mi. S of Rt. 2	Fremont		Boat ramp, handicap accessible shoreline/pier fishing, bait/tackle shop
Sandusky	Pickerel Creek Wildlife Area 10 mi. SW of Sandusky on US 6	Vickery	2582 acres/ Sandusky Bay	Shoreline fishing, limited access to boating/fishing, natural area observations blind/ tower, waterfowl hunting (by permit)
Sandusky	Raccoon Creek Reservoir/ Hendricks Park SR 101 near Clyde off US 20	Clyde	35 acres	Boating (electric motors), walking path, shelter, playground, picnic, tennis
Sandusky	Riverfront Marina 2 mi. N of I-80/90 on Rt. 53, at Artz Rd.	Fremont	Sandusky River	Marina, boat ramp, rental docks, picnicking, skiing, sailing, camping, fuel
Sandusky	Robert Walsh Memorial Park Morrison Rd., Fremont	Fremont	Sandusky River	Nature trail, shelter, picnic, playground, paved walking path, sledding hill, pond, ice skating
Sandusky	Roger Young Park Off Tiffin St., S end of Fremont	Fremont	Sandusky River	No boats, shore fishing access, shelter, picnic, ball diamonds, volleyball, playground, tennis
Sandusky	White Star Park S of Gibsonburg on SR 300	Gibsonburg	572 acres	15-acre quarry, non-power boats, shelters, picnicking, swimming, scuba diving, volleyball, horseshoes, playground, camping, nature trails, natural area, cross-country skiing, hunting with permission
Sandusky	Williams Park E Stone St., Gibsonburg	Gibsonburg	22 acres	Quarry fishing, shelter, picnic, playground, ball diamonds, volleyball, horseshoes
Sandusky	Wolf Creek Park Scenic River Area SR 53, 6 mi. S of Fremont	Fremont	93 acres/ Sandusky River	Unlimited hp, fishing access, canoe launch (no ramps), shelter, picnicking, playground, camping, nature trails, natural area
Seneca	Attica Reservoir SR 4, 1 mi. S of Attica	Attica	5 acres	No boats, bank fishing only
Seneca	Beaver Creek Reservoir 5 mi. SW of Clyde off SR 101 on CR 34	Clyde	150 acres	Boating (electric motors only), boat ramp, sailing, canoeing, picnicking, hunting with permission

Table 7.6 Fishing facilities in the Sandusky Hydrological Unit, continued.

County	Fishing Facility	Nearest To	Acreage Land/Water	Other Features
Seneca	Collier Scenic River Area TR 28, 7 mi. S of Tiffin, W off CR 19 to river	Tiffin	284 acres/ Sandusky River	No boats
Seneca	Honey Creek Access 3/4 mi. S of Attica on SR 4	Attica	4 acres	No boats
Seneca	Izaak Walton Scenic River Area 1 mi. N of Tiffin, E off SR 53, W side of river	Tiffin	11 acres/ Sandusky River	No boats
Wyandot	Killdeer Plains Wildlife Area 2 mi. SW of Harpster, S on SR 294	Upper Sandusky	7317 acres/ 1255 acres	Reservoir (10 hp limit), ponds (electric motors only), sailing, canoeing, handicap accessible, boat ramps
Wyandot	Killdeer Upground Reservoir SR 67, N edge of Marseilles	Upper Sandusky	285 acres	Reservoir (10 hp limit), boat ramps, sailing, canoeing, scuba diving (by permission only), ice fishing
Wyandot	Upper Sandusky Reservoir SE edge of Upper Sandusky, 1/2 mile S of US 30 off SR 182	Upper Sandusky	38 acres	Boating (electric motors only)
Wyandot	Wyandot Wildlife Area 1 mi. S of Carey off US 23 on CR 97	Carey	338 acres/ 7 acres	Boating (no motors)

Table 7.7 Birding/Wildlife Facilities in the Sandusky Hydrological Unit.

County	Birding/Wildlife Viewing Facility	Closest To	Size	Other Features
Crawford	Lowe-Volk Park SR 598, Crestline	Crestline	38 acres	Natural area, hiking trail, historic landmark, youth fishing pond, Sandusky River
Crawford	Sears Woods/Carmean Woods State Nature Preserves 1 mi. SW of Bucyrus on SR 4, 2 mi. W on Mt. Zion Rd.	Bucyrus	138 acres	Parking lot, natural area, hiking trail
Crawford	Unger Park Off Nevada Rd., Bucyrus	Bucyrus	43 acres	Natural area, historic farm, hiking trails
Erie	Castalia Pond/Quarry Reserve Rt. 101, 1 mi. W of SR 269, Castalia	Castalia	12 acres	Hiking trails, mountain bike trails
Erie	Pipe Creek Wildlife Area River Rd., E of Cedar Point Causeway	Sandusky	100 acres	Shore fishing, natural area, waterfowl hunting (by permit)

Table 7.7 Birding/Wildlife Facilities in the Sandusky Hydrological Unit, continued.

County	Birding/Wildlife Viewing Facility	Closest To	Size	Other Features
Erie	Resthaven Wildlife Area SR 269, Castalia	Castalia	2272 acres	Parking, handicap accessible, boat ramp, small boats (electric motors only), fishing, natural area
Erie	Sandusky Harbor US 6, Sandusky	Sandusky	Sandusky Bay	
Erie	Sheldon Marsh State Nature Preserve 1 mi. W of Huron on US Rt. 6	Huron	435 acres	Parking, natural area, hiking trail, observation blind/tower, handicap accessible
Erie	Willow Point Wildlife Area 5 mi. NW of Castalia, N of SR 6 on Wahl Rd.	Castalia or Bayview	621 acres/ Sandusky Bay	Fishing, natural area
Sandusky	Aldrich Pond Wildlife Area 2 mi. NW of Lindsey off US 20 on Sommers Rd. (TR 149)	Lindsey	40 acres	Fishing, boating (electric motors only), natural area
Sandusky	Blue Heron Reserve CR 260 at US Rt. 6	Clyde	160 acres	Natural area, boardwalk, nature trail
Sandusky	Brady's Island Sandusky River, Downtown Fremont	Fremont	Sandusky River	Natural area, limited access
Sandusky	Clyde Community Park South St., Clyde	Clyde		Nature trail, shelter, picnic, playground, pond, fishing, ice skating, ball diamonds, pool
Sandusky	Miller's Blue Hole Wildlife Area SR 6, 10 mi. NE of Fremont	Vickery		Natural area, no sport fishing
Sandusky	Pickerel Creek Wildlife Area 10 mi. SW of Sandusky on US 6	Vickery	2582 acres	Shoreline fishing, limited access to boating/fishing, parking, observation blind/tower, natural area, waterfowl hunting (by permit)
Sandusky	Robert Walsh Memorial Park Morrison Rd., Fremont	Fremont		Nature trail, shelter, picnicking, playground, paved walking path, sledding hill, pond, ice skating
Sandusky	Sandusky County Park District Office/Countryside Park 1970 Countryside Place, Fremont	Fremont	15 acres	Natural area, paved walking path, picnicking, shelter
Sandusky	Terra State Community College 2830 Napoleon Rd., Fremont	Fremont		Nature trail, natural area, tennis

Table 7.7 Birding/Wildlife Facilities in the Sandusky Hydrological Unit, continued.

County	Birding/Wildlife Viewing Facility	Closest To	Size	Other Features
Sandusky	White Star Park S of Gibsonburg on SR 300	Gibsonburg	572 acres	15-acre quarry, scuba diving, fishing, boating, swimming, picnicking, play equipment, softball diamond, horseshoes, volleyball, campground, natural preserve area, nature trails for walking, cross country skiing, hunting with permission
Sandusky	Wolf Creek Park Scenic River Area SR 53, 6 mi. S of Fremont	Fremont	93 acres/ Sandusky River	Camping, fishing, cross country skiing, picnic shelter, fishing access, canoe launch ramp, nature trails
Seneca	Collier Scenic River Access TR 28, 7 mi. S of Tiffin, W off CR 19	Tiffin	200 acres	Natural area, hiking trails, observation tower/platform, restrooms, parking
Seneca	Springville Marsh State Nature Preserve 1 mi. W of US 23 on TR 24, 3.5 mi. N of Carey	Carey	201 acres	Natural area, boardwalk, observation tower/blind, parking, handicap accessible
Wyandot	Killdeer Plains Wildlife Area 2 mi. SW of Harpster, S on SR 294	Upper Sandusky	8627 acres	Handicap accessible, boat ramps, small boats (no motors), fishing, sailing, canoeing, parking, wildlife refuge
Wyandot	Wyandot Wildlife Area 1 mi. S of Carey off US 23 on CR 7	Carey	345 acres	Small boats (no motors)

Chapter 8 Watershed Loading

The Sandusky River delivers pollutants derived from both point and nonpoint sources into Sandusky Bay and Lake Erie. The amounts of these pollutants are referred to as the pollutant loads. As noted in Chapter 1, these pollutant loads affect ambient water quality in the receiving waters. Many past and current pollution control efforts in the Sandusky Watershed have been geared to reducing pollutant loading into Sandusky Bay and Lake Erie, especially phosphorus loading.

Because of the value of Lake Erie as a water resource, and because of its vulnerability to pollutant loading, the Water Quality Laboratory (WQL) at Heidelberg College has been able to mount some of the most detailed pollutant loading studies in the United States. Among the Lake Erie tributaries included in these studies, the most detailed studies have been done in the Sandusky River and its tributaries. These studies serve as the basis for this chapter.

Load Monitoring Programs in the Sandusky Watershed

Measurements of pollutant loading require information on both the concentrations of pollutants in the water, and the flow of the water in the stream. Consequently, most stream and river loading studies are located at stream gauging stations operated by the U.S. Geological Survey (USGS). Of the twelve Sandusky Watershed gauging stations listed in Table 3.4, the WQL has collected loading data for all of them, except for the station on Tymochtee Creek at Marseilles. Six of the gauging stations were established specifically to support loading studies. The extent of loading studies in the Sandusky Watershed is shown in Table 8.1.

Because most of the pollutant transport in rivers occurs during periods of high flow or flooding, it is necessary to measure pollutant concentrations during these times. Furthermore pollutant concentrations change very rapidly during runoff events and floods. Consequently it is necessary to have frequent sampling during these periods of high flow. At all of the Sandusky Watershed stations, the WQL has utilized automatic sampling equipment to collect water samples from the streams. Prior to May 1988, four samples were collected per day, and since that time, when the WQL switched to refrigerated samplers, three samples per day have been collected. The automatic samplers are housed in heated structures at the gauging stations, allowing year round operation of the sample collection programs. The samples are transferred to the WQL analytical labs at weekly intervals. During periods of high stream flow, the WQL analyzes three or four samples per day, while during periods of lower flows, one sample per day is analyzed.

Additional descriptions of the sampling methods, as well as the WQL's analytical methods may be found in the publications by Baker (1988), Richards and Baker (1993), and Richards (2000a).

Table 8.1 Summary of pollutant loading studies for the Sandusky Watershed.

Loading Stations	Station Number	Drainage Area (mi^2)	Period of Record for Loading Studies	Number of Nutrient Samples
Current Stations				
Sandusky River near Fremont	04198000	1,251	1975-current year	11,215
Honey Creek at Melmore	04197100	149	1976-current year	12,122
Rock Creek at Tiffin	04197170	34.6	1983-current year	9,663
Discontinued Stations				
Sandusky River near Bucyrus	04196000	88.8	1974-1981	2,998
Tymochtee Creek at Crawford	04196800	229	1974-1981	2,471
Broken Sword Creek at Nevada	04196200	83.8	1976-1981	2,512
Sandusky River near Upper Sandusky	04196500	298	1974-1981	2,973
Sandusky River near Mexico	04197000	774	1974-1981	2,178
Honey Creek near New Washington	04197020	17	1979-81,1983-84	2,271
Wolf Creek at Bettsville	04197300	66.2	1976-1981	2,419
East Branch Wolf Creek near Bettsville	04197450	82.4	1976-1981	2,425

Total Loading of Sediments and Nutrients

Loads of sediments and nutrients are calculated by water year (October 1 – September 30). The type of data used to calculate pollutant loads is illustrated in Figures 8.1 and 8.2. The USGS provides the WQL with hourly stage data at their stream gauging stations. The stream stage is the water level of the stream, measured to the nearest hundredth of a foot, relative to some arbitrary elevation above sea level. The USGS also provides the WQL with a "rating table" that shows the relationship between stage and stream discharge, measured in cubic feet per second (CFS). The WQL's automatic samplers are set to collect on the hour, so that each WQL sample is associated with a specific stage and discharge value. In Figure 8.1A, the annual pattern of discharge is shown for the Sandusky River near Fremont for the 1992 water year. Each mark on the graph corresponds to the discharge at the time a sample has been collected and analyzed. The peaks in the graph of Figure 8.1A represent runoff events or floods.

The concentrations of suspended solids and total phosphorus for each sample collected and analyzed during the 1992 water year are shown in Figures 8.1B and 8.1C, respectively. In general, the peaks in the concentrations of both suspended sediments and

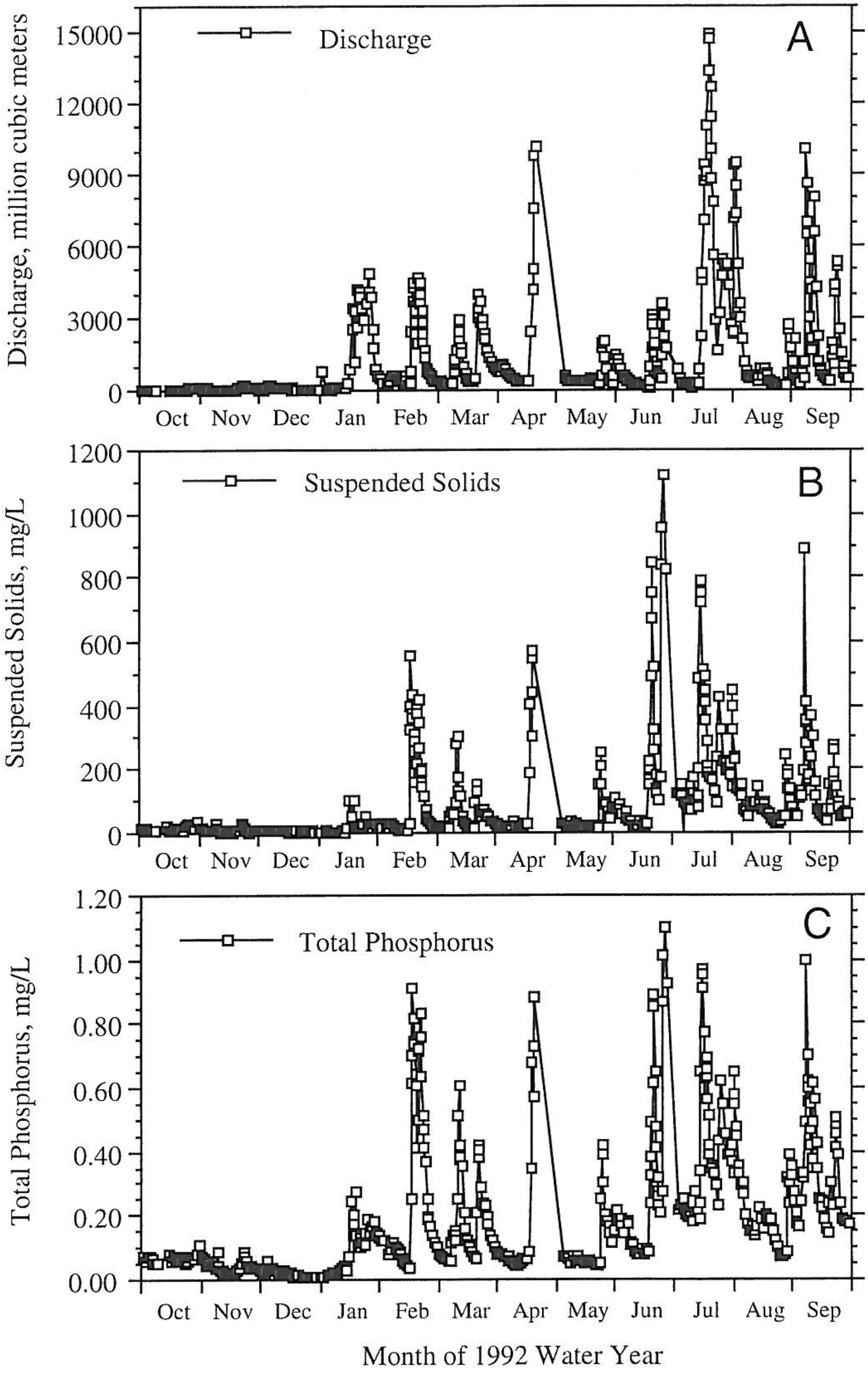


Figure 8.1 Discharge and concentrations of suspended solids and total phosphorus in the Sandusky River near Fremont for the 1992 water year.

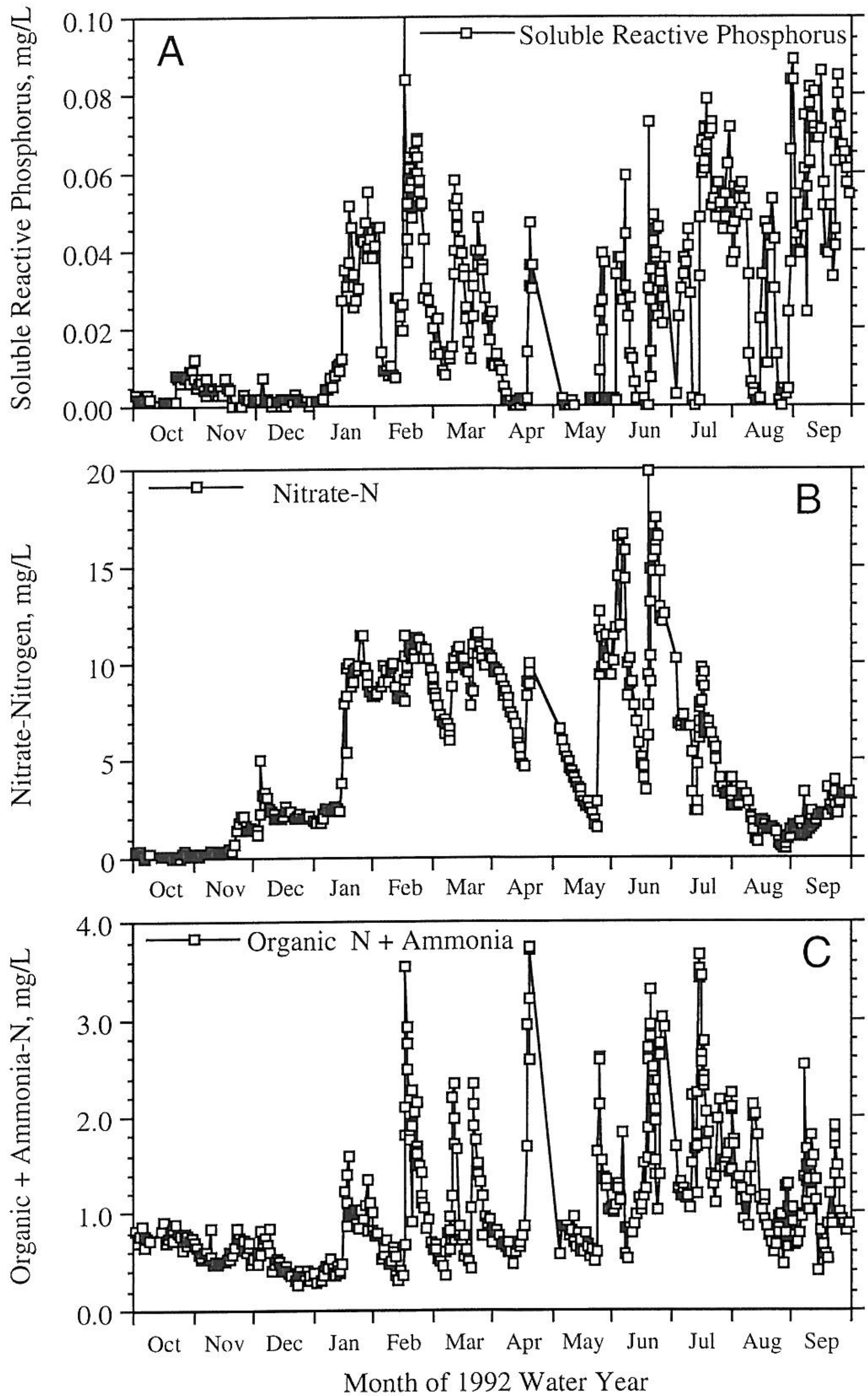


Figure 8.2 Concentrations of soluble reactive phosphorus, nitrate nitrogen and organic nitrogen plus ammonia in the Sandusky River near Fremont for the 1992 water year.

total phosphorus coincide with the peaks in flow. The data illustrate how quickly the concentrations change during runoff events. The data also show a close relationship between suspended solids concentrations and total phosphorus concentrations. Typically, 80-90% of the total phosphorus is attached to suspended solids during storm runoff conditions. The concentrations of soluble reactive phosphorus, nitrate-nitrogen and organic+ammonia nitrogen are shown in Figure 8.2. These also tend to increase with increasing flows and change rapidly during runoff events.

The data shown in Figures 8.1 and 8.2 are used to calculate the loading for a single year. The WQL uses a variety of computer programs to calculate annual loads. For each sample, the program multiplies the concentration by its associated flow, by the duration of time that sample characterizes the stream (6-24 hours), and by a conversion factor so that the product has the units of metric tons. The data for individual samples are then added to obtain the total amounts of material transported by the stream for the water year. These calculations are done for each chemical for each year of study.

A twenty five-year record of annual rainfall, discharge, and loads of sediments and nutrients are shown in Figures 8.3 and 8.4. These graphs illustrate the large annual variability that characterizes river loading data. Annual rainfall and annual discharge are included with the loading data since they account for some of the annual variability in sediment and nutrient loads. The average, standard deviation, relative standard deviation and the range for each parameter is shown in Table 8.2. The relative standard deviation is the standard deviation expressed as a percentage of the mean. It provides a way to compare the amount of variability of the different parameters.

The rainfall data (Figure 8.3A) is the average annual rainfall for the nine weather stations located in northcentral Ohio (see Figure 3.3). Annual rainfall is the least variable of the parameters, with a relative standard deviation of 11%. The ratio of the highest year (1982) to the lowest year of rainfall (1988) is 1.73 to 1.

Annual stream discharge (Figure 8.3B) is much more variable than annual rainfall. The relative standard deviation of the annual discharge is 32%. The ratio of the highest annual discharge (1984) to the lowest annual discharge (1988) is 4.65 to 1. The seasonal pattern of rainfall, as well as the rainfall intensity and timing relative to existing soil moisture, all affect the amount of rainfall that leaves the watershed as stream runoff. Consequently, annual discharge is much more variable than annual rainfall.

Annual variations in suspended solids (sediment) loads are shown in Figure 8.3C. Annual sediment loading is even more variable than annual discharge. The relative standard deviation for annual sediment loads is 50%. The ratio of the highest annual sediment load (1981) to the lowest annual sediment load (1999) is 11.5 to 1.

Total phosphorus loadings are shown in Figure 8.4A. Annual export of total phosphorus, with a relative standard deviation of 40%, is not quite as variable as suspended solids export. For total phosphorus, the ratio of the high annual export (1981) to the low (1988) is 6.29 to 1.

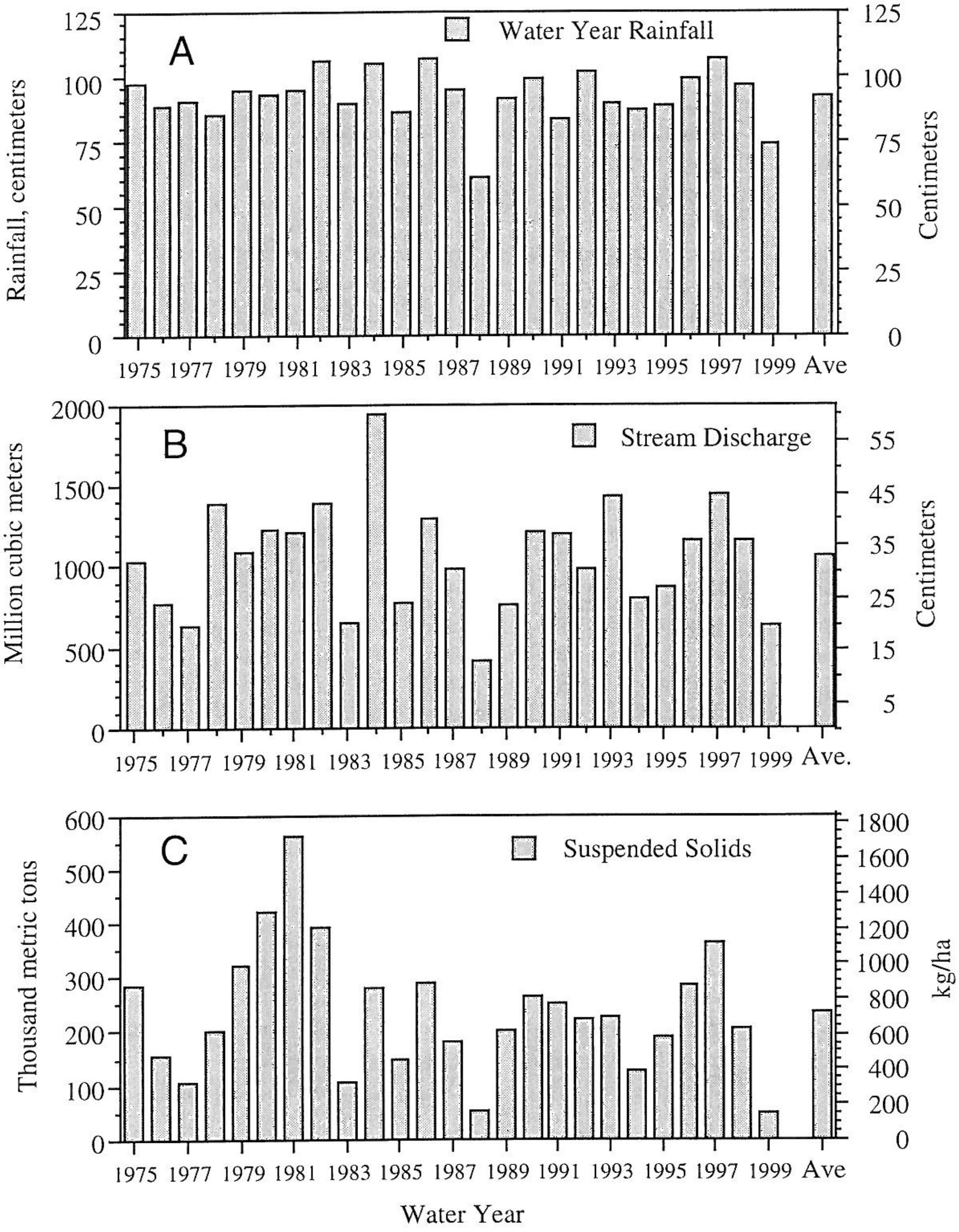


Figure 8.3 Variations in annual rainfall, discharge and suspended solids loads for the Sandusky River for the period from 1975 to 1999.

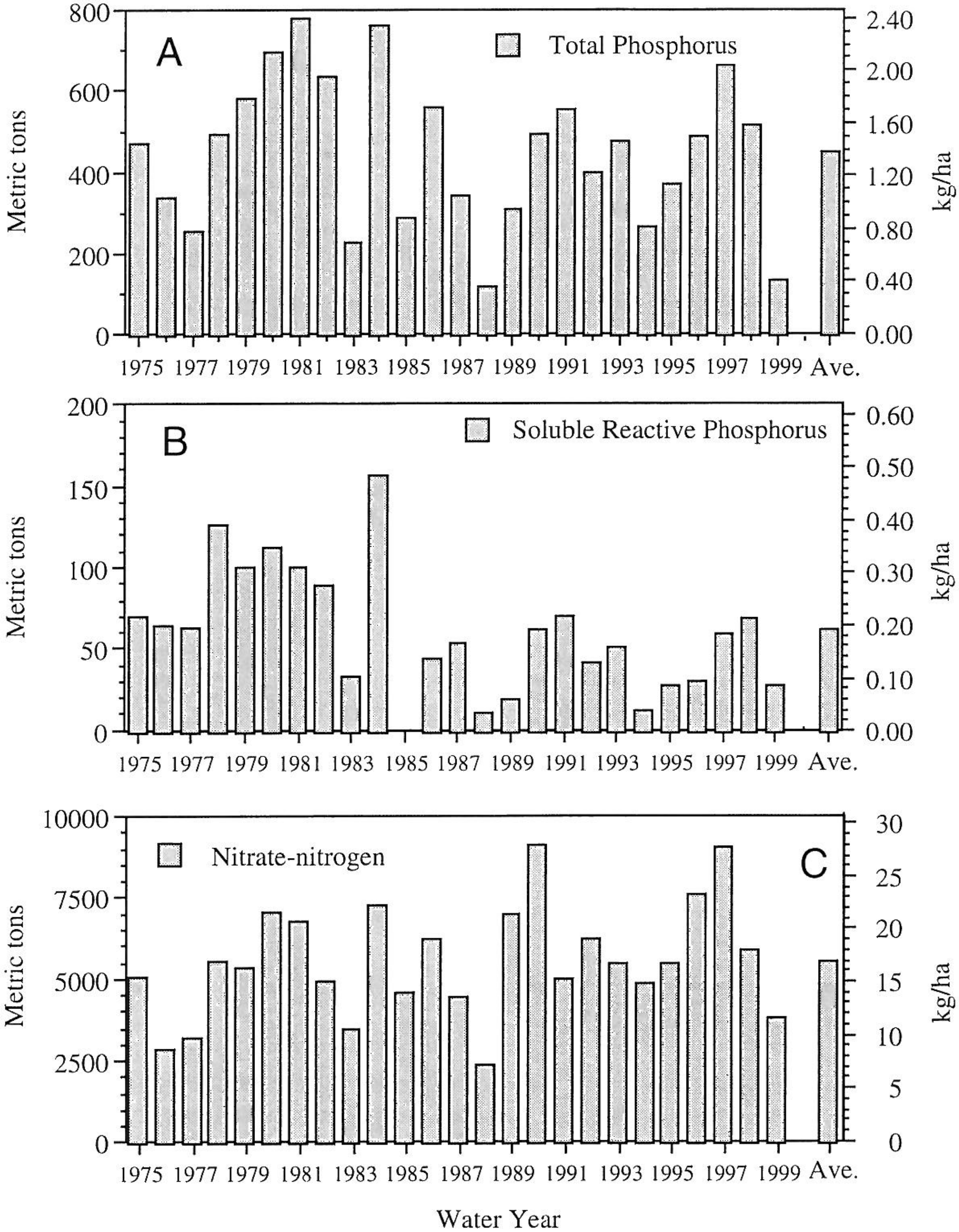


Figure 8.4 Variations in annual loads for total phosphorus, soluble reactive phosphorus, and nitrate for the Sandusky River near Fremont for the period from 1975 to 1999.

Table 8.2 Annual average values and related statistics for rainfall, discharge, sediment loads and nutrient loads for the Sandusky River near Fremont for the period from 1975 to 1999.

Sandusky River near Fremont, 1975-1999	Rainfall, cm	Discharge, million cubic meters	Suspended Sediments, metric tons	Total Phosphorus, metric tons	Soluble Reactive Phosphorus, metric tons	Nitrate-nitrogen, metric tons
Average Annual	92.3	1,055.88	235,700	453.5	63.26	5,608
Standard Deviation	10.27	339.81	118,200	182.6	37.17	1,744
Relative Standard Deviation	11.12%	32.18%	50.1%	40.3%	58.8%	31.1%
High (Year)	105.66 (1982)	1,940 (1984)	563,000 (1981)	786 (1981)	157.9 (1984)	9,178 (1990)
Low (Year)	61.04 (1988)	417 (1988	49.1 (1999)	125 (1988)	12.1 (1988)	2,442 (1988)
Ratio (high/low)	1.73	4.65	11.5	6.29	13.0	3.78

Soluble phosphorus export (Figure 8.4B) has the greatest variability over the past 25 years, with a relative standard deviation of 59%. The ratio of the high year (1984) to the low year (1988) is 13 to 1. Part of the annual variability in soluble phosphorus export is associated with a downward trend in soluble phosphorus loading during the past 25 years.

Nitrate loading is shown in Figure 8.4C. Annual variability in nitrate loading, with a relative standard deviation of 31%, is less than the variability of other nutrients and is similar to the variability in discharge. The ratio of the high to low annual nitrate loads is 3.78 to 1.

Nonpoint source contributions to phosphorus loading in the Sandusky Watershed

The total phosphorus export data from the Sandusky Watershed allows direct calculation of the nonpoint source component of phosphorus export, using the procedures described in Chapter 1. This procedure involves subtraction of point source phosphorus discharges from sewage treatment plants in the Sandusky Watershed from the total phosphorus loading. Examples of phosphorus loading from sewage treatment plants in the Sandusky Watershed are shown in Table 8.3 for 1975 and 1994.

In Figure 8.5, the total phosphorus loading is broken down into the point source and the nonpoint source component of the annual loads. Due to time lags in the reporting of point source loading to the International Joint Commission, phosphorus loading data for 1996 to 1999 were not yet available. Loads for these years were assumed to be the same as for 1995. On average, the contributions of point sources of phosphorus represent

Table 8.3 Point source phosphorus loading into the Sandusky River and its tributaries for 1975 and 1994, as reported to the Ohio EPA and the International Joint Commission.

Municipal Sewage Treatment Plant	1975 phosphorus inputs kg/day	1994 phosphorus inputs kg/day
Crestline	5.0*	9.0
Bucyrus	24	7.4
Upper Sandusky	9.5	1.9
Tiffin	58.1	9.5
Attica	2.6*	2.9
Carey	15.9*	8.0
Total	**115.1**	**38.7**

*Estimated values

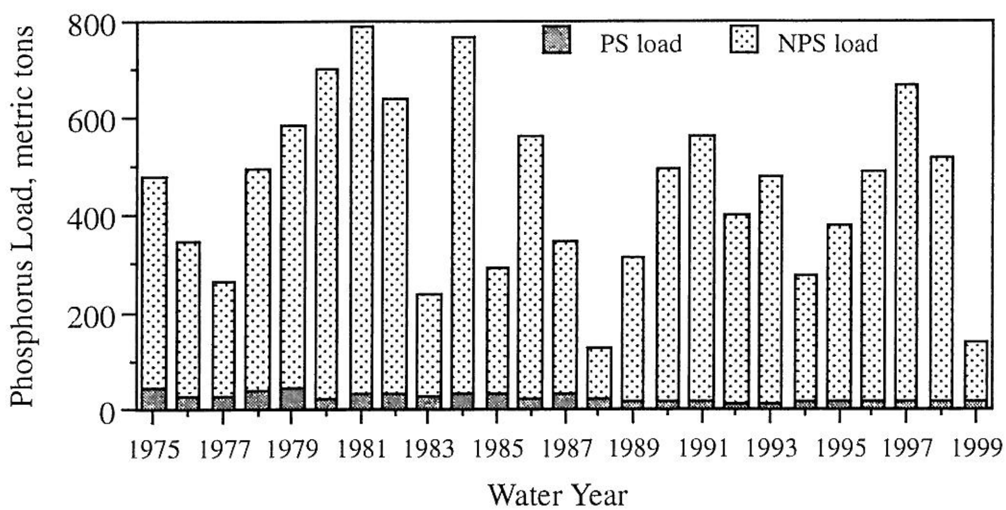


Figure 8.5 Point and nonpoint source contributions to total phosphorus loading from the Sandusky River Watershed at the gauging station near Fremont for the period from 1975 to 1999.

about 5.2% of the total phosphorus exported from the Sandusky River during the 25 year time period. The data in Table 8.3 and Figure 8.5 do indicate and there has been a decline in point source phosphorus loading into the Sandusky River during the past 25 years. For most agricultural watersheds, the percent of the nitrogen export derived from point sources is even smaller than the percent of the phosphorus from point sources.

The above procedure may overestimate contributions of point sources and, consequently, underestimate contributions of nonpoint sources of phosphorus to total loading. Much of the phosphorus that enters streams from point sources moves out of the flowing water system and onto particulate materials or biota on the stream bottom. This is especially so during medium and low flow conditions. This material is subject to resuspension and downstream transport during periods of high flow and floods. However, it is uncertain how much of the material is actually exported from the watershed and how much of it is deposited into longer term storage within the watershed, such as through deposition on flood plains.

It is evident from Figure 8.5 that most of the annual variability in phosphorus loading is associated with the nonpoint source component of the load. This is also true for other nutrients and for suspended solids. The annual variability in nonpoint source loads is primarily caused by annual variability in weather conditions. Over long periods of time, such as represented by the Sandusky River data sets, trends in loading associated with changing agricultural management practices, also can contribute to the variability. The weather-induced variability in annual loads of sediments and nutrients makes quantitative studies of nonpoint source pollution very difficult. Multi-year studies are required to characterize nonpoint loads and establish baseline conditions. The weather induced annual variability also complicates the detection of trends in response to nonpoint source control programs. The long-term studies in the Sandusky Watershed have supported trend analyses for these rivers, and progress in reducing nonpoint source loads has been documented (Richards, 1997).

Subwatershed contributions to loading from the Sandusky River Watershed

In developing plans to reduce nutrient and sediment loads from the Sandusky Watershed into Sandusky Bay, it is useful to know the relative contributions of various subwatersheds of the Sandusky to the total loads. In order to compare nutrient export among different watersheds, the exports must be converted to unit area values, such as pounds per acre per year (lbs/acre/yr) or kilograms per hectare per year (kg/ha/yr). To do this conversion, the total annual load or the average annual load, expressed as pounds or kilograms, is divided by the total area upstream from the sampling station, expressed as acres or hectares. This conversion compensates for the variations in the size of the watersheds.

As noted in Table 8.1, loading studies were conducted on many of the major tributaries of the Sandusky River, as well as at multiple locations on the Sandusky River, during the late 1970s and early 1980s. The precise durations of the sampling programs at each station, as well as the numbers of samples analyzed at each station, is also shown in Table 8.1. In Table 8.4, the average unit area loads of nutrients and sediments are shown for each of the monitoring stations in the Sandusky Watershed. The loads are the averages for the period of record for each station, except for Honey Creek and Rock Creek, where the averages are for the periods through the 1995 water year only. Note that the durations of the records for many of the tributaries are relatively short (5 years) and that the resulting averages may be influenced by unusual weather conditions. Also note that the studies for most of the tributaries were done before the onset of major agricultural pollution abatement studies.

Table 8.4 Comparison of unit area sediment and nutrient yields among subwatersheds of the Sandusky River Watershed for station periods of record*

River Loading Station	Annual Runoff, Period of Record inches	Susp. Solids lbs/acre /yr	Total Phos. lbs/acre /yr	Soluble Reactive Phos. lbs/acre /yr	Nitrate-Nitrogen lbs/acre /yr	Organic Nitrogen + NH_3 lbs/acre /yr
Stations with continuing loading studies						
Sandusky River, Fremont	11.16	649	1.25	0.18	15.4	4.9
Honey Creek, Melmore	12.15	484	1.10	0.15	14.4	4.2
Rock Creek, Tiffin	12.17	626	1.09	0.08	9.4	4.3
Discontinued Stations						
Sandusky River, Bucyrus	13.60	823	1.91	0.60	11.2	
Sandusky River, Upper Sandusky	11.21	848	1.59	0.34	12.5	
Sandusky River, Mexico	10.30	537	0.96	0.14	10.1	
Tymochtee Creek, Crawford		544	1.00	0.15	13.2	
Broken Sword Creek, Nevada	16.50	991	1.53	0.21	16.2	
Honey Creek, New Washington	12.78	724	1.30	0.25	14.4	5.2
Wolf Creek, East Branch	12.00	592	1.15	0.26	12.8	
Wolf Creek, West	15.95	553	1.02	0.20	15.3	

* Data for discontinued stations from Baker et al, 1985

The data in Table 8.4 do suggest that there are some significant variations in unit area yields among the tributary watersheds. Suspended sediment yields were highest for Broken Sword Creek and lowest for Honey Creek at Melmore. Stations along the upper portion of the Sandusky River (Bucyrus and Upper Sandusky) also had relatively high export rates of suspended solids. Relatively low sediment export rates occurred for Tymochtee Creek, both branches of Wolf Creek, and for the Sandusky River at Mexico.

Total phosphorus export rates were highest for the Sandusky River stations at Bucyrus and Upper Sandusky. These high export rates reflect the effects of point source loading from Bucyrus and Upper Sandusky at the time of these studies, as well as the relatively high sediment export rates at these stations. The high export rate at Broken Sword is associated with the high sediment export at that station. Lowest total phosphorus export rates occurred at the Sandusky River station at Mexico, Tymochtee Creek and the West Branch of Wolf Creek. Total phosphorus export rates ranged from 1.09 to 1.30 pounds per acre per year at the remainder of the stations.

Soluble phosphorus export rates were highest at the Bucyrus and Upper Sandusky Stations on the Sandusky River. High soluble phosphorus export at these stations reflects the point source contributions by Bucyrus and Upper Sandusky sewage treatment plants just upstream from these sampling stations. Rock Creek had the lowest export rate for soluble reactive phosphorus. The relatively low rates of soluble phosphorus export at the three long-term record stations (Sandusky at Fremont, Honey Creek, and Rock Creek) reflect the major reductions in soluble phosphorus export that occurred in the mid-1980s.

Nitrate export rates were lowest for the Rock Creek Watershed and next lowest for the Sandusky River station at Mexico. At other stations, the nitrate export rates ranged from 11.2 to 16.2 pounds/acre/year. Measurements for organic nitrogen plus ammonia were initiated in 1982. Consequently, export data for organic nitrogen plus ammonia is not available for the stations where the monitoring programs were terminated in 1981. Organic nitrogen export generally increases with increasing export of suspended solids.

Part of the variations in export rates among the subwatersheds is associated with variations in average annual runoff. The Broken Sword Watershed had the highest runoff and also had the highest suspended solids, total phosphorus and nitrate export rates. The Sandusky River station at Mexico had the lowest runoff rate and also had rather low export rates. Since many of the subwatersheds upstream from Mexico have higher runoff rates, as well as higher export rates of both particulate and soluble nutrients, it is unclear why the runoff and export rates at Mexico are so low. Possibly there are biases in the flow measurements at that station.

The data shown in Table 8.4 indicate that all of the subwatersheds do make substantial contributions to the total watershed export of sediments and nutrients. While there are some variations in export rates, all of these rates are relatively high in comparison with export rates from other watersheds (see next section). From the standpoint of targeting control programs to make the most efficient use of investments in nonpoint source controls, targeting to critical source areas within subwatersheds is more important than targeting to subwatersheds.

Comparison of Sandusky River export rates with export from other Ohio Rivers

The WQL expanded its river transport studies in 1997 to include seven major rivers in Ohio. In Table 8.5, the average of the unit area export rates for the 1997 and 1998 water years are shown for all seven rivers (Richards, 2000b). For this two-year period, the Sandusky River has the highest unit area exports of suspended solids, total phosphorus and nitrate-nitrogen. The Sandusky River ranks fourth in terms of export of soluble reactive phosphorus, and has the lowest export rate of chloride.

The Great Miami and Scioto rivers have the highest rates of soluble phosphorus export. The stations on both of these rivers are located downstream from major metropolitan areas and receive considerable flow from sewage treatment plants. These sewage flows contribute to the high export rates of soluble phosphorus. Chloride export is much higher in the Cuyahoga River than for the other streams. Chloride export is increased in urban areas, often as a result of the use of road salt for ice and snow control.

Table 8.5 Comparison of unit area loads for sediments, nutrients and chloride among seven major Ohio watersheds for the 1997 and 1998 water years

Watershed	Suspended Solids lbs/acre/yr	Total Phosphorus lbs/acre/yr	Soluble Reactive Phosphorus lbs/acre/yr	Nitrate-nitrogen lbs/acre/yr	Chloride lbs/acre/yr
Maumee	679	1.58	0.25	19.7	83.0
Sandusky	788	1.63	0.17	20.8	75.0
Cuyahoga	754	0.98	0.12	7.5	482.2
Grand	495	0.57	0.04	2.0	121.4
Muskingum	279	0.55	0.06	5.8	100.0
Scioto	448	1.13	0.32	13.8	109.8
Great Miami	368	1.29	0.49	16.4	140.2

Relative to the other six Ohio rivers included in this study, the Sandusky River has higher pollutant export rates for agricultural pollutants than the other rivers. However, urban influences, as reflected in chloride export rates, are low for the Sandusky Watershed.

Comparison of Sandusky River export rates with export from other streams and rivers in the United States

The U. S. Geological Survey has recently measured nutrient export at 75 sites on streams draining agricultural watersheds across the United States (USGS, 1999). In Figure 8.6, the unit area yields of total phosphorus and total nitrogen for these 75 streams are shown in relation to watershed phosphorus and nitrogen inputs. The total nitrogen export rate for the Sandusky River is the sum of the nitrate export and the organic nitrogen plus ammonia export (Table 8.4). This rate of 20.3 lbs/acre/year is clearly well above yields for most of the 75 watersheds. Only 10-12 sites had higher unit area export rates of total nitrogen.

For total phosphorus, the long term average export rate of 1.25 pounds per acre per year is also very high relative to the set of 75 USGS watersheds. Only nine of the 75 agricultural watersheds have higher export rates than the Sandusky River. It should be noted that the USGS yield data is based on much shorter-term studies (2-3 years) with many fewer samples per year than the Sandusky studies. Consequently, the uncertainty associated with the USGS data, particularly as it relates to long-term average yields, is much larger than that associated with the Sandusky data.

In an informational paper on the Ohio Tributary Loading Program, Richards (2000b) has compared the unit area yields of Ohio streams with unit area yields from other watersheds. He also noted that the unit area yields from the Ohio streams were high relative to other streams reported in the literature.

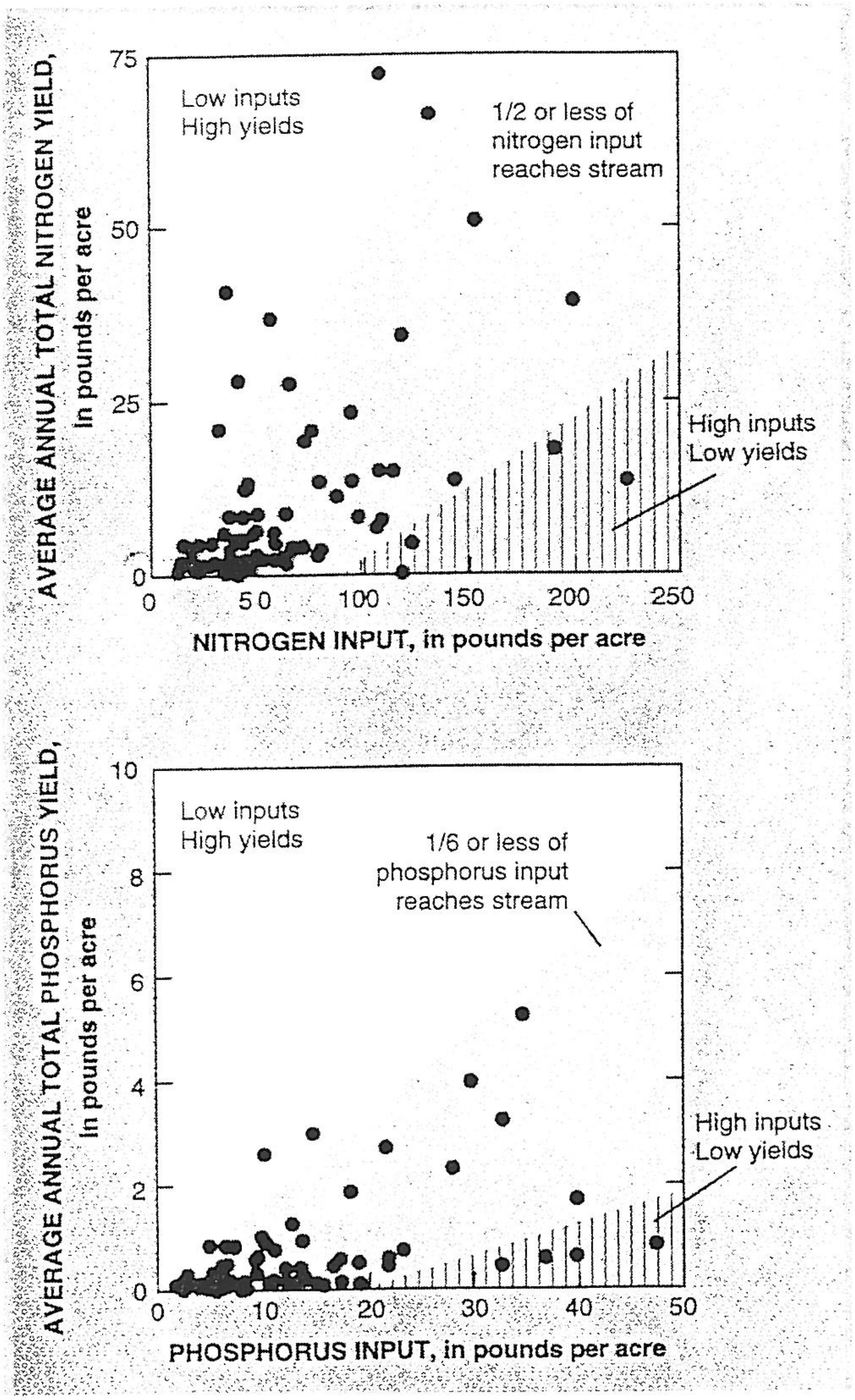


Figure 8.6 Examples of yields of total nitrogen and total phosphorus from agricultural Watersheds in the United States. Copied from USGS, 1999.

References

Baker , D. B. 1988. Sediment, Nutrient and Pesticide Transport In Selected Lower Great Lakes Tributaries. U. S. Environmental Protection Agency, Great Lakes National Program Office. EPA-905/4-88-001. 225 pages.

Baker, D. B., Krieger, K. A., Richards, R.P and Kramer, R. P. 1985. Gross Erosion Rates, Sediment Yields, and Nutrient Yields for Lake Erie Tributaries: Implications for Targeting. In Perspectives on Nonpoint Source Pollution. U. S. Environmental Protection Agency, Office of Water, Washington. DC 20460. EPA 440/5-85-001. Pages 251 –255.

Richards, R. P. and Baker, D. B. 1993. Pesticide concentration patterns in agricultural drainage networks in the Lake Erie basin. *Environmental Toxicology and Chemistry* 12:13-26.

Richards, R, P. 1997. Twenty Years of Change: The Lake Erie Agricultural Systems for Environmental Quality (LEASEQ) Project. In *Proceedings: National Watershed Water Quality Project Symposium.* U. s. EPA, Office of Water, Washington, DC 20460 EPA/625/R-97/008.

Richards, R. P. 2000a. Reports from the Ohio Tributary Monitoring Program: Program Description. Water Quality Laboratory, Heidelberg College, Tiffin, Ohio 44993. 6 pages.

Richards, R. P. 2000b. *Reports from the Ohio Tributary Monitoring Program: Annual Unit Area Yields of Sediment, Nutrients, and Chloride.* Water Quality Laboratory, Heidelberg College, Tiffin, Ohio 44993. 6 pages.

USGS. 1999. *The Quality of Our Nation's Waters: Nutrients and Pesticides.* U.S. Geological Survey, U. S. Department of Interior, Reston, VA 20192. Circular 1225. 82 Pages.

Chapter 10. Nonpoint Sources of Pollutants

It often rains sufficiently hard that water can be seen running over land surfaces, such as pavements, agricultural fields, lawns, and even forest floors. Snowmelt can also result in water flowing over these same land surfaces. Much of this water finds its way to streams, rivers and lakes through surface water drainage pathways or, in urban areas, through storm sewers or combined storm and sanitary sewers. Because water is an excellent solvent, this runoff water dissolves many chemicals that it encounters as it flows across land surfaces. These chemicals are delivered to streams, rivers and lakes, where they often degrade water quality and, consequently, are considered pollutants. Runoff water can also pick up particulate matter, such as soil particles, and deliver these particles, as well as chemicals attached to them, to surface waters, further degrading our water resources. The land surfaces from which these dissolved and particulate pollutants are derived are referred to as nonpoint sources of pollutants.

Rather than flowing over land surfaces, portions of rainwater and snowmelt percolate through soil. As water flows through the soil, it again dissolves soluble chemicals. In the agricultural areas of this region, much of the percolating water is intercepted by underdrainage (tile or perforated plastic tubing) and delivered directly to streams, rivers and lakes. This underdrainage flow provides another important pathway for the delivery of pollutants from land surfaces to streams and rivers. Other portions of the water move into the groundwater system. Springs, through which groundwater resurfaces and contributes to stream flow, provide yet another pathway by which pollutants derived from nonpoint sources can enter streams. During periods of low stream flow, groundwater is the primary source of water present in streams and rivers. Groundwater also serves as an important source of drinking water in this region.

From the above, it is clear that nonpoint source pollution is related to land use. All land uses contribute to nonpoint pollution. Urban areas, lawns, golf courses, paved surfaces, cropland, pastures, and forest can all contribute chemicals that can impair our water resources. Since agriculture occupies about 83% of the land area in the Sandusky Watershed, agricultural land uses are responsible for much of the nonpoint pollution in area streams, especially for nutrients, sediments and herbicides. Over the past twenty-five years, many farmers within the watershed have voluntarily adopted various management practices aimed at reducing nonpoint pollution from agricultural land uses. As will be discussed later in this chapter, the water quality monitoring programs at Heidelberg College have documented that these improved management practices have substantially reduced phosphorus and sediment loading to Lake Erie from the Sandusky River, as well as from the nearby Maumee River.

Land uses also impact water resources through their effects on stream flow and stream habitat. In terms of factors degrading the biological communities present in our streams and rivers, the Ohio Environmental Protection Agency considers habitat impacts to be more important than pollutant concentrations. The Ohio EPA considers habitat degradation to be a form of nonpoint source pollution. Chapter 1 contains an introduction to the topic of nonpoint source pollution and related issues.

An Overview of Nonpoint Pollution and Land Use Impacts on Water Resources in the Sandusky Watershed

Many of the impacts of nonpoint source pollution in the Sandusky Watershed have been detailed in earlier chapters of this inventory. Consequently, these impacts will simply be reviewed in this chapter. Most of the chapter will describe the current agricultural practices that account for the majority of the nonpoint pollution and degraded aquatic habitat in the watershed. Progress area farmers have made in adopting best management practices and in reducing agricultural nonpoint pollution will be described. Programs to reduce nonpoint pollution from urban areas and construction sites will also be outlined.

A. Impacts on drinking water (See Chapter 6):

- **Nitrate concentrations often exceed drinking water standards** –The nitrate concentrations in the Sandusky River and its tributaries are particularly high, due to the high proportion of cropland in the watershed and the extensive use of underdrainage. Underdrainage is a known cause of elevated nitrate concentrations in streams (Ohio State University Extension Service, 1998). The Safe Drinking Water Standard of 10 mg/L nitrate-nitrogen was exceeded 5.9% of the time at the Fremont gauging station during the period from April 1996 to June 2001(Water Quality Laboratory, Heidelberg College, unpublished data). On average, about 20 days per year, usually during the early spring, nitrate exceeds the standard. During this same period, the standard was exceeded 5.4% of the time in the Maumee at Bowling Green, 0.28% of the time on the Scioto River at Chillicothe and 1.3% of the time in the Great Miami at Miamisburg.

  Most surface water supplies in the Sandusky Watershed can avoid the elevated nitrates in streams through either selective pumping of water into upground reservoirs (Bucyrus and Upper Sandusky) or through dilution of river water with ground water (Tiffin). Fremont is the only major city in the watershed that has to issue nitrate alerts when nitrate concentrations in the Sandusky River exceed the drinking water standard.

- **Seasonally elevated herbicide concentrations** -- Herbicide concentrations in the Sandusky River and its tributaries are also high relative to many other streams draining agricultural watersheds. Average annual herbicide concentrations, particularly for atrazine, may approach but rarely if ever exceed, current drinking water standards (Richards, et al., 1995). While seasonal concentration spikes often exceed standards, the standards are related to chronic health problems and hence are applicable to annual average concentrations rather than to seasonal peak concentrations.

- **High Concentrations of Suspended Solids** – During runoff events, the Sandusky River and its tributaries have high concentrations of suspended solids. Most of these suspended solids fall into the clay size fraction. Removal of these solids, in order to meet turbidity standards, causes increased water treatment costs.

B. Impacts on Aquatic Life (See Chapter 5):

- **Aquatic Life Use Attainment** -- In many streams within the Sandusky Watershed, the quality and quantity of aquatic life do not meet the standards set by the Ohio Environmental Protection Agency (OEPA). The OEPA has identified siltation and other habitat modifications as the major causes of aquatic life impairment in this watershed. They also identify flow alterations as a major source of aquatic life degradation. Furthermore, the OEPA has identified crop production and agriculture as the major sources of the silt and flow alterations that degrade aquatic life. Nutrient enrichment and pesticides are, according to the OEPA, responsible for much smaller portions of aquatic life degradation. Point sources of nutrients are more likely responsible for the elevated nutrient levels that impair aquatic life than are nonpoint sources (See Chapter 9).

  During 2001, the OEPA initiated the most detailed biological assessment of water quality ever undertaken for portions of the Sandusky River Watershed upstream from mile point 36.50 (CR 38, north of Tiffin) as part of a Total Maximum Daily Load (TMDL) study for the Watershed. As of this writing, the OEPA has provided the Coalition with preliminary data on the fish community results and the water chemistry results. These data indicate that fish communities in most of the mainstream of the Sandusky River fall into the exceptionally good category, while most of the smaller streams in the watershed fail to meet fish community standards for Warm Water Habitat. They also indicate that phosphorus concentrations are relatively low during low flow conditions. A preliminary interpretation of the fish and chemistry data provided to the Coalition is available from the Coalition in the form of a draft document entitled "The Broken Sword Watershed: An Opportunity to Address Ecoregional TMDL Issues," March 12, 2002 (prepared by David Baker, Water Quality Laboratory, Heidelberg College).

  Of particular importance to pollution control programs in this watershed will be the extent to which small streams and drainage ditches are reclassified as Modified Warmwater Habitat rather than Warmwater Habitat (see Chapter 5). This decision will be made after the OEPA evaluates the stream habitat data and the invertebrate community data that they collected during the TMDL study. These data have not yet been provided to the Coalition. Final OEPA results and reports from the TMDL study will be available in 2003. These results will provide an up-to-date evaluation of biological communities as well as new projections of causes and sources of impairment. Upon publication of the TMDL reports, the Coalition will revise Chapter 5 of this volume and initiate any changes to its Management Plan (Chapter 11) deemed appropriate.

- **Fish and Wildlife Kills** – Accidental spills associated with the storage and transport of fertilizers and manure are major causes of fish and wildlife kills within the watershed. Over application of liquid manure and subsequent delivery of concentrated wastes to streams via plastic tubing also causes fish kills in area streams. A summary of annual wildlife kill reports from the ODNR's Division of Wildlife found that, on a state-wide basis for the 10 year period from 1980 to 1989, agricultural was responsible for 50% of the organisms killed, while industrial, municipal, and transportation sources were responsible for 15%, 24% and 4% respectively (unpublished data from the Heidelberg College Water Quality Laboratory, D. B. Baker). In the Sandusky Watershed, pipeline breaks and a tire fire have also been responsible for major wildlife kills in recent years. (Note: I have contacted Kevin Odell of ODNR, Div. of Wildlife, 614 265-7027, to obtain annual reports for fish kills for more recent years. When those become available, I will update this section. Dave Baker, 07/02/02).

C. Impacts on Recreational Water Use (See Chapter 7):

- **Primary and Secondary Contact Recreation** – Bacterial standards for recreation are generally exceeded during times of runoff events in the Sandusky River and its tributaries. Coliform bacterial counts are particularly high at locations impacted by combined sewer overflows, although high counts are also observed in cropland and urban runoff. At such times, stream water would be deemed unsafe not only for swimming, but also boating, fishing and wading.

- **Fishing** – In stream reaches where aquatic life is degraded, sport fish are also generally impacted, making those streams less satisfactory for fishing. As noted above, land use impacts on stream habitat are a form of nonpoint pollution and are responsible for most of the degradation of aquatic life.

- **Aesthetic Impairment** – The muddy appearance of stream and river water, particularly during and following runoff events, detracts from the visual appeal of the river.

D. Impacts on Lake Erie through Pollutant Loading (Chapter 8):

1. **Phosphorus Loading to Sandusky Bay and Lake Erie** – The Sandusky Watershed is a significant source of phosphorus loading to Lake Erie. Excess phosphorus loading was a major cause of the severe degradation of Lake Erie evident in the 1960s and 1970s. In the 1970s, agricultural nonpoint sources were identified as a major source of phosphorus entering the Lake. Programs to reduce agricultural nonpoint sources were initiated in the late 1980s and were effective in achieving reductions in agricultural phosphorus loading into the Lake from the Sandusky and Maumee watersheds (Richards and Baker, 2002). These programs focused on reducing phosphorus export through use of conservation tillage to reduce cropland erosion. Although decreases in phosphorus export from the Sandusky and Maumee Rivers have been documented, the export rates for these rivers, in terms of pounds of phosphorus exported per acre per year, remain very high relative to most rivers in Ohio (see Tables 8.5, 10.5) and the Midwest (Baker and Richards, 2002).

2. **Suspended Sediment Loading to Sandusky Bay and Lake Erie** -- Over the past 25 years, the Sandusky Watershed has exported, on average, about 253,000 short tons of suspended sediment per year at the Tindall Bridge gauging station near Fremont, Ohio (unpublished data, Heidelberg College Water Quality Laboratory). As this sediment settles out of the

water column, it degrades aquatic habitats in the lower portion of the Sandusky River, in Sandusky Bay and in Lake Erie. This deposited sediment also blocks navigation channels for both recreational boating and commercial shipping, necessitating expensive dredging operations to maintain navigation channels. This suspended sediment is also the vehicle that carries about 80% of the phosphorus loading into Lake Erie from agricultural watersheds. While adoption of conservation tillage in the Sandusky Watershed has reduced suspended sediment export from the watershed, further reductions in sediment loading into Sandusky Bay and Lake Erie are deemed necessary for recovery of these water bodies (Ohio Lake Erie Commission, 2000). The Conservation Reserve Program (CRP), the Continuous CRP, and the Conservation Reserve Enhancement Program (CREP) are aimed at achieving further reductions in suspended sediment export from Lake Erie agricultural watersheds. They provide support for installation of grass and tree buffers along watercourses and for construction of wetlands to trap sediments before they enter streams.

3. **Nitrate Loading to Lake Erie** – Twenty five years of nitrate export studies at the Tindall Bridge gauging station near Fremont indicate that, on average, about 6,150 short tons of nitrate-nitrogen per year are exported from the Sandusky Watershed (Table 8.2 with unit conversion). This nitrate loading contributes to eutrophication in Sandusky Bay and Lake Erie, although its impacts are less than the loading of phosphorus. (Excessive nitrate loading is particularly a problem when it enters marine environments, such as the Gulf of Mexico or Chesapeake Bay.) Programs to reduce nitrate loading are being investigated throughout agricultural regions of the United States in order to determine approaches to reducing adverse impacts on water bodies, especially coastal waters. The nitrate-nitrogen export rate of the Sandusky River watershed is about 15.4 pounds per acre per year. This export rate is relatively high in comparison with most other agricultural watersheds.

Agricultural Land Use in the Sandusky Watershed

Satellite imagery analyzed by the Ohio Department of Natural Resources indicates that approximately 84% of the land area in the Sandusky Watershed is in agricultural land use (Chapter 2, Table 2.6). Woodland occupies 12.6% of the land area, while urban land use occupies only 1.2% of the land area. Clearly most of the rain and snow that fall on the watershed fall on cropland. It is not surprising that pollutants associated with crop production (phosphorus, nitrogen, herbicides, and sediments) dominate nonpoint pollution within this watershed. It is also true that converting agricultural land to urban land would likely increase the amounts of nonpoint (and point source) pollution, since urban land has higher rates of runoff of phosphorus and insecticides per unit area than does cropland (U. S. Geological Survey, 1999). However, since urban land occupies only 1.2% of the land area, compared to 84% for agriculture, it is agriculture that is responsible for the bulk of the nonpoint source pollution in our watershed. It is noteworthy that the population density in the Sandusky River is the lowest among ten major watersheds in Ohio (Sanders, 2001). It should also be noted that farmers within the Sandusky Watershed, along with their supporting agencies, businesses and organizations, have implemented a variety of measures to reduce agricultural nonpoint pollution. Their successes in these efforts are described in a subsequent section of this Chapter.

The land use activities in a watershed largely reflect how the combination of natural resources of that watershed and its social and economic development interact with regional, national, and even international economies. Thus there are both historical and natural resource reasons why crop production is the dominant land use in this watershed. The primary focus of nonpoint source reduction programs is **not to initiate changes in land use**, but rather to reduce the adverse impacts of existing land uses **through improving the management practices** associated with those existing land uses. Thus adoption of agricultural best management practices (BMPs) is a central component of nonpoint source pollution reduction programs in this watershed.

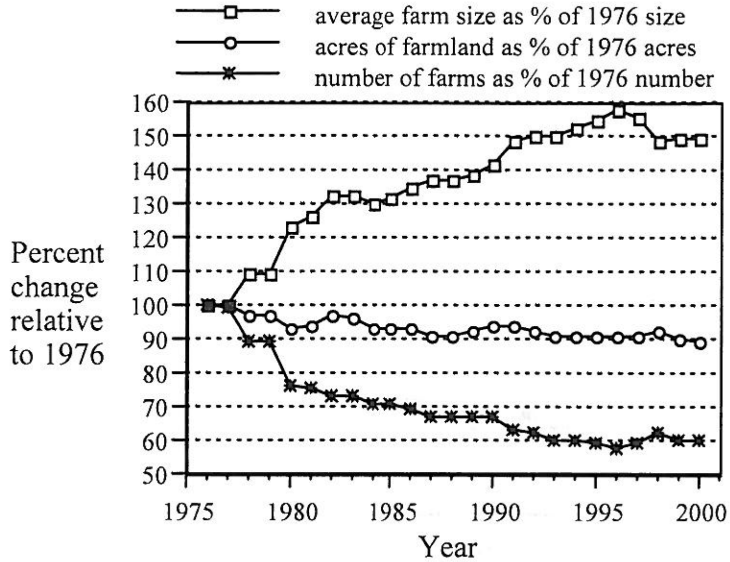
Within a comprehensive nonpoint source pollution abatement program, some changes in land use may also be appropriate. Conversions of small percentages of cropland to buffer strips, wooded stream corridors, wetlands, and greenbelts along major rivers may all be important. Changes in the type of agricultural land use, such as introduction of large animal production facilities or row crop conversion to rotational grazing, also warrants careful evaluation.

Agriculture in the Sandusky Watershed – A 25 Year Perspective

The Ohio Department of Agriculture and the USDA's Ohio Agricultural Statistics Service prepare annual reports that contain basic agricultural data for Ohio counties. To characterize agriculture in the Sandusky Watershed, the statistics for Crawford, Sandusky, Seneca and Wyandot counties have been combined. Together, these four counties make up 81.8% of the land area in the Sandusky Hydrological Unit (See Table 2.2). Trends in agriculture are shown for the 25-year period from 1976 to 2000, with various characteristics shown as a percentage of 1976 values (Figures 10.1-10.6). The actual values for 1976 and 2000 are shown in Table 10.1.

- **Land in farms, number of farms and average farm size.** – In Figure 10.1, the percentage change from 1976 in the four county totals for land in farms, number of farms and average farm size are shown. The total acres of farmland have decreased by about 10%. The number of farms has decreased by about 40%. Consequently, the average farm size has increased by about 50%.

Figure 10-1. Changes in average farm size, acres of farmland, and numbers of farms as a percentage of 1976 values for Crawford, Sandusky, Seneca and Wyandot counties through 2000.



- **Row crop acreage and percent of farmland in row crops** – Although farmland acreage has decreased since 1976, the acres of row crops (sum of corn, soybeans and wheat) have increased (Figure 10.2). Row crop acres were 16% higher in 2000 than in 1976. The percentage of farmland acres devoted to row crop production increased from 65% of the farmland in 1976 to about 86% of the farmland in 2000. The sharp drops in cropland acres in 1983 were due to a government program aimed at depleting corn reserves. The program was termed the "Payment-in-Kind" or "PiK" program. Farmers cut back corn acreage but were credited with the grain they would have produced had they planted those acres.

Figure 10.2 Changes in rowcrop acres as a percentage of 1976 values and changes in percentage of farmland in rowcrops for Crawford, Sandusky, Seneca and Wyandot counties through 2000.

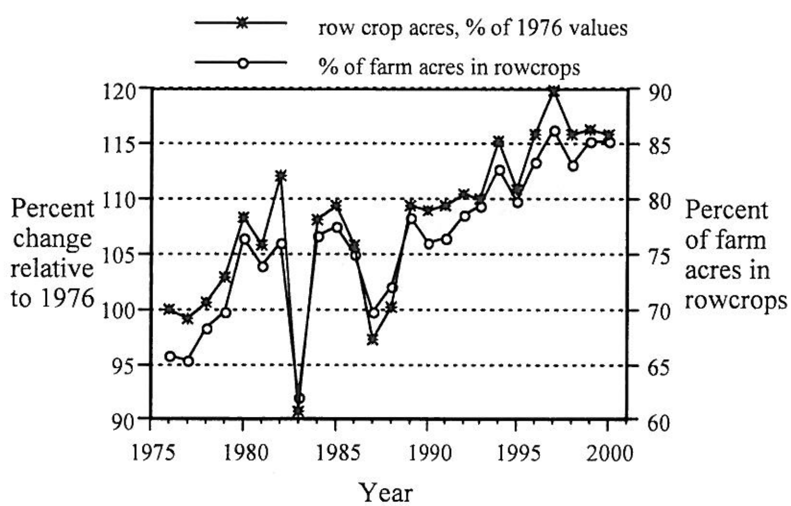
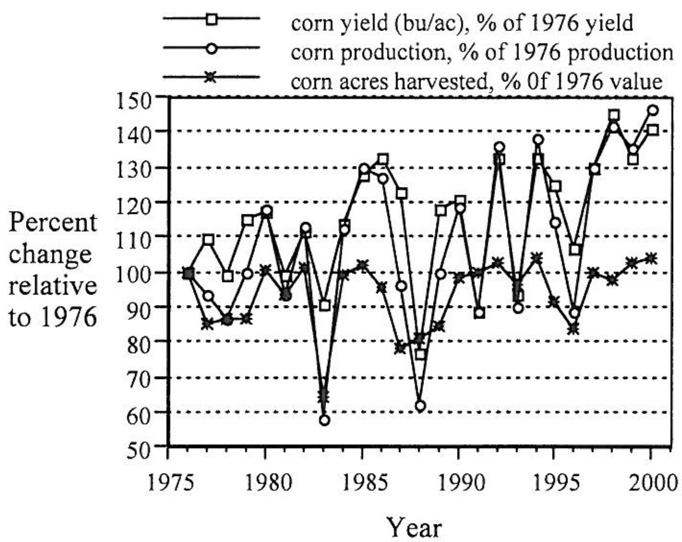


Table 10.1 Summary of changes in agricultural characteristic between 1976 and 2000 for Crawford, Sandusky, Seneca, and Wyandot Counties.

Characteristic	1976 value	2000 value
Number of farms	6,270	3,760
Farm acreage, acres	1,063,000	949,000
Average farm size, acres	170	252
Combined corn, soybeans and wheat acres harvested	698,200	808,500
Corn acres	267,600	277,900
Corn average yield, bushels/acre	105.1	148.2
Corn production, bushels	28,119,300	41,188,860
Soybean acres	274,900	399,900
Soybean average yield, bushels/acre	32.4	40.3
Soybean production, bushels	8,912,800	16,110,430
Wheat acres	155,700	130,700
Wheat average yield, bushels/acre	40.4	72.3
Wheat production, bushels	6,289,100	9,453,980
Hay acres	45,100	24,000
Hay yield, tons/acre	2.8	4.0
Hay production, tons	127,000	95,490
Hogs and pigs, number	112,400	141,400
Cattle and calves, number	77,100	34,800
Milk cows, number	12,800	4,900
Sheep, number	42,000	4,300
Phosphorus fertilizer sales, short tons P_2O_5	21,680	19,723
Nitrogen fertilizer sales, short tons nitrogen	25,292	51,796
No-till corn, acres		47,620
Mulch till corn, acres		12,392
No-till soybeans, acres		165,553
Mulch till soybeans, acres		60,891
Conservation Reserve Program, acres		23,591
Highly Erodible Land treated, acres		96,817

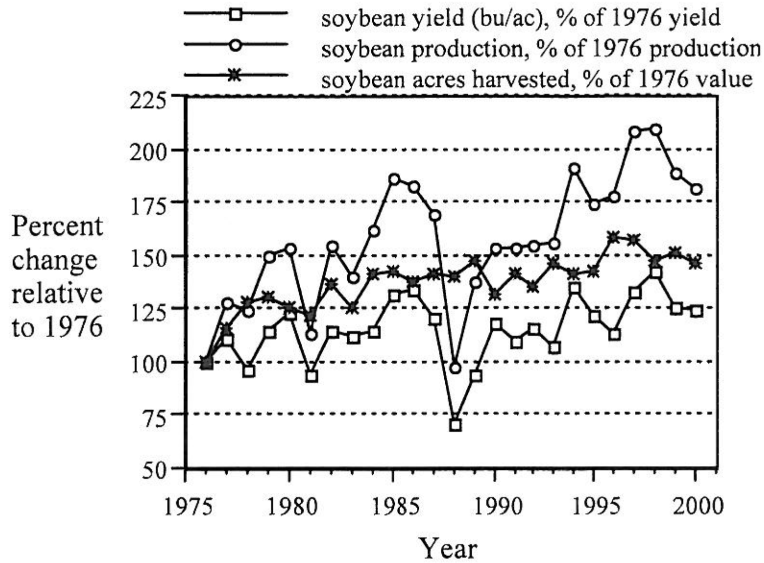
- **Changes in corn yield, corn acres harvested, and corn production –** Corn acreage has fluctuated from year to year in the four counties (Figure 10.3). The lowest corn acreage occurred in 1983, which was the year of the "Payment-in-Kind" Program. By the year 2000, the corn acreage was about 4% higher than in 1976. Although corn yields (bu/acre) also vary from year to year, depending largely on weather conditions, corn yields have steadily increased. By 2000, corn yields were 41% higher than in 1976. Corn production (bushels) reached is highest level in the year 2000, with production approximately 46% higher than in 1976. Lowest corn yields occurred in 1988, which was a year of severe drought.

Figure 10.3. Changes in corn yields, corn production, and corn acres harvested as a percentage of 1976 values for Crawford, Sandusky, Seneca, and Wyandot counties through 2000.



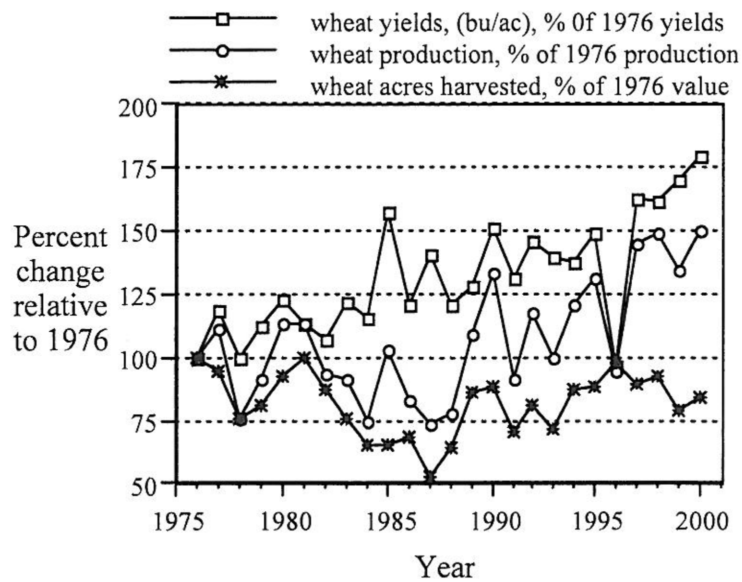
- **Changes in soybean yield, soybean acres harvested, and soybean production –** Soybean acreage has increased rather steadily since 1976. By 2000, soybean acreage was about 50% higher than in 1976. Soybean yields (bu/acre) have increased rather steadily, although annual variations associated with weather conditions are also evident. Lowest yields occurred during the drought year of 1988. In the year 2000, yields were 25% higher than in 1976. Highest yields occurred in 1998, when they were about 40% higher than in 1976. The combination of increasing acreage and increasing yields has resulted in substantial increases in soybean production in the 4-county area, with 2000 production about 80% higher than 1976 production. In 1997 and 1998, production was more than double that of 1976.

Figure 10.4. Changes in soybean yields, soybean production, and soybean acres harvested as a percentage of 1976 values for Crawford, Sandusky, Seneca, and Wyandot counties through 2000.



- **Changes in wheat yield, wheat acres harvested, and wheat production**—Wheat acreage has generally decreased since 1976. Lowest amounts of wheat acreage occurred in the mid-1980s, when they dropped to 50% of the1976 value. By 2000, wheat acreage was 82% of the 1976 value. Wheat yields have increased substantially since 1976. In 2000, wheat yields were 75% higher than in 1976. Because of the increased yields, total wheat production has increased, even though acreage decreased. In 2000, wheat production was 50% higher than in 1976.

Figure 10.5. Changes in wheat yields, wheat production, and wheat acres harvested as a percentage of 1976 values for Crawford, Sandusky, Seneca, and Wyandot counties through 2000.



- **Changes in hay acreage, hay yields, and hay production** – The acres devoted to hay production decreased rapidly from 1976 through 1991, when it amounted to about 50% of the 1976 value. Since 1991 hay acreage has remained relatively constant. Although hay yields (tons/acre) have increased by about 25%, overall production of hay has decreased due to the large decreases in hay acreage.

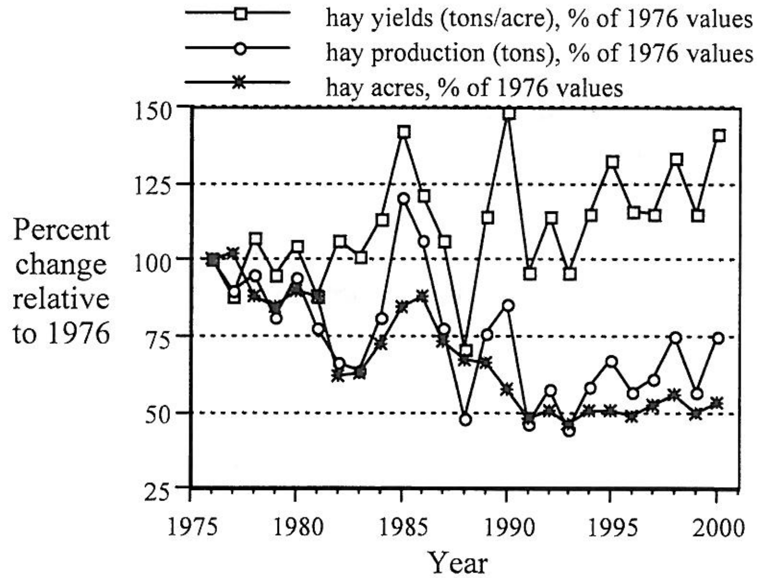
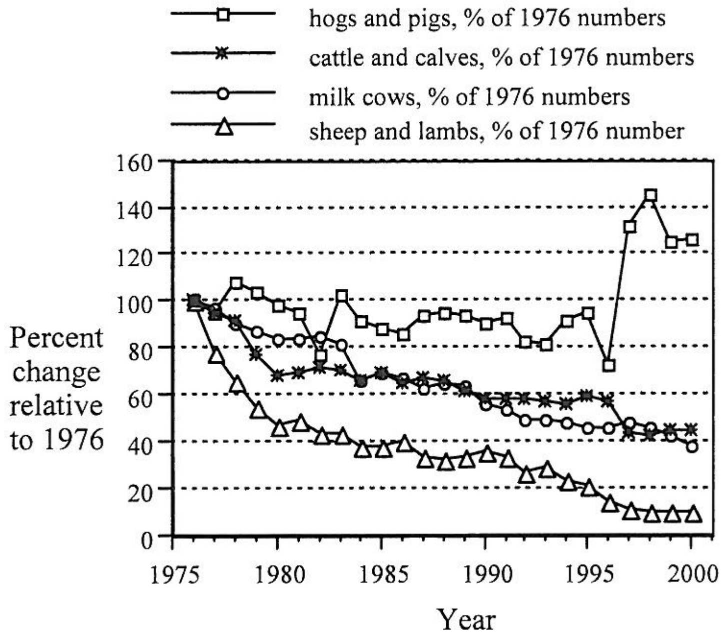


Figure 10.6. Changes in hay yields, production and acreage as a percent of 1976 values for Crawford, Sandusky. Seneca and Wyandot counties through 2000.

- **Changes in livestock numbers** – With the exception of hogs and pigs, livestock numbers in the four-county area have dropped. Sheep have declined by the largest percentage, dropping to approximately 10% of their 1976 number. Cattle and calves, as well as milk cows have dropped to about 40% of their 1976 numbers. Hogs and pigs declined as much as 20% until 1997 when their numbers increased substantially. In 2000, the numbers of hogs and pigs were about 25% higher than in 1976.

  Because of the relatively small number of egg production facilities, the Annual Reports on Agricultural Statistics don't include county level numbers for chickens for any of the four counties. However, permits have been granted by the Ohio EPA for production facilities for at least 2,500,000 chickens. This number of chickens substantially increases the number of animal units present in the Sandusky Watershed.

Figure 10.7. Changes in total numbers of hogs and pigs, cattle and calves, milk cows, and sheep and lambs as a percent of 1976 values for Crawford, Sandusky, Seneca and Wyandot counties through 2000.



- **Changes in nitrogen and phosphorus fertilizer sales --** Fertilizer sales data for counties provide important information on nutrient management practices in large watersheds. Changes in nitrogen and phosphorus fertilizer sales in the four counties are shown in Figure 10.8. Phosphorus fertilizer sales were highest in 1979-1981 and then dropped to below 1976 levels in 1982-83. Sales remained relatively constant through the rest of the 1980s, with a slight upward trend in the 1990s. By 2000, phosphorus fertilizer sales were about 90% of those in 1976. This decrease in sales occurred even though total row crop acreage increased by 15%. Most of this increase was for soybeans, and soybeans generally require much less fertilizer application than corn.

  Nitrogen fertilizer sales in the four counties have generally increased since 1976. Annual nitrogen fertilizer sales show large variations. Peaks of sales occurred in 1992 and again in 2000. The causes of these reported peaks in nitrogen sales are unknown and may represent reporting problems rather than actual differences in amounts of nitrogen fertilizer applied.

Figure 10.8. Changes in nitrogen and phosphorus fertilizer sales, as a percent of 1976 values for Crawford, Sandusky, Seneca and Wyandot counties through 2000.

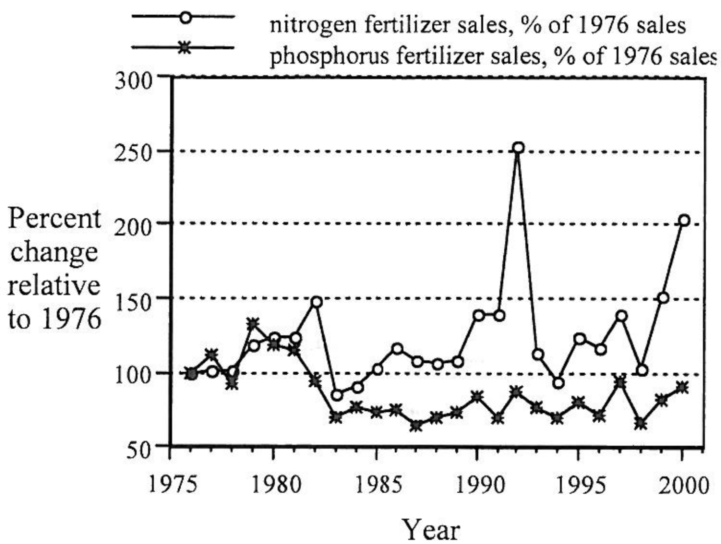
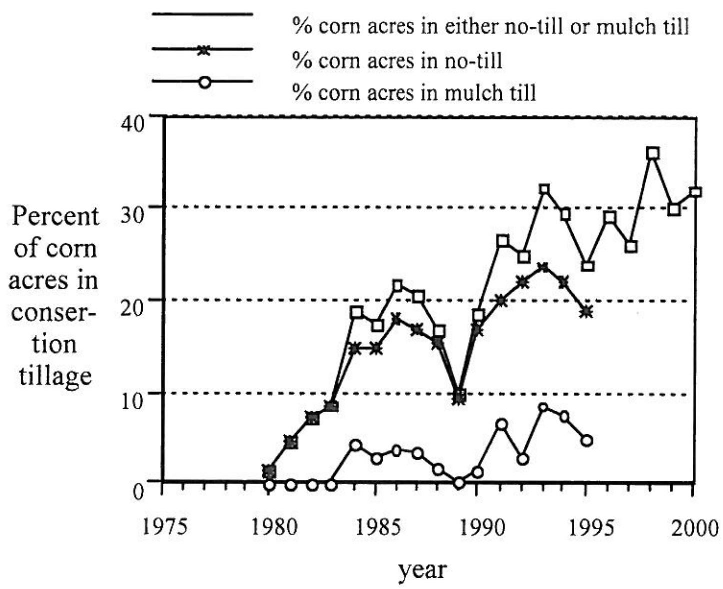


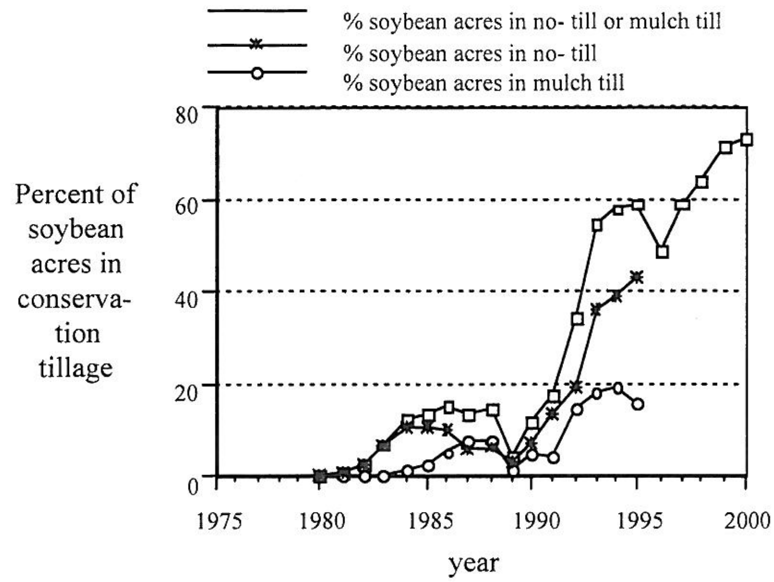
Figure 10.9. Percent of total corn acres in no-till or mulch till production for Crawford, Sandusky, Seneca, and Wyandot counties through 1995.



- **Changes in Tillage Practices** – In the early 1980's major efforts were undertaken to foster adoption of conservation tillage in corn production in order to reduce erosion and particulate phosphorus transport into Lake Erie. These efforts were often led by county Soil and Water Conservation Districts (SWCDs), extension agents, farm implement dealers and innovative farmers. Rather steady increases in no-till and mulch till corn production occurred, from 1980 through 1993 (Figure 10.9). A noticeable drop did occur following the drought year of 1988. Decreases also occurred in 1994 and 1995.

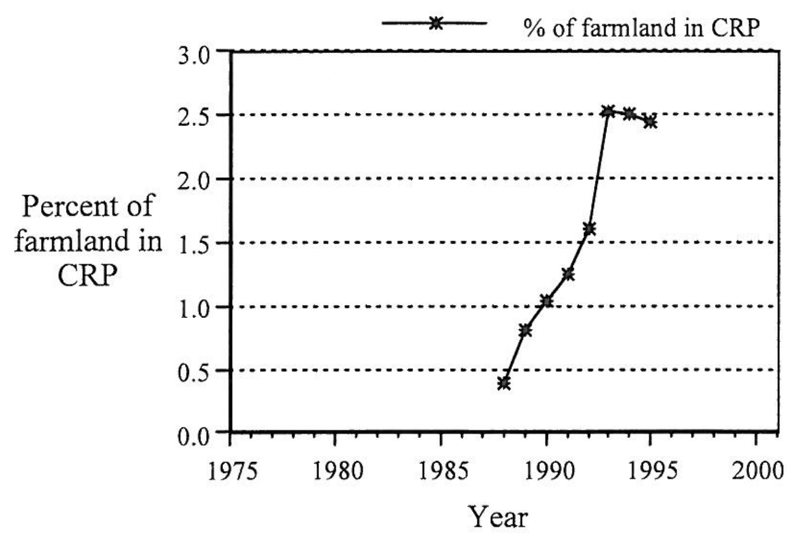
  Use of conservation tillage in soybean production also increased greatly, especially in the early 1990s (Figure 10.10). Adoption of no-till in soybean production was not anticipated at the time the Lake Erie phosphorus control program was established. Herbicide development was apparently an important factor leading to conservation tillage production in soybeans. By 1995, no-till methods were used for 44% of the soybean production and mulch till by another 16%.

Figure 10.10. Percent of total soybean acres in no-till or mulch till production for Crawford, Sandusky, Seneca, and Wyandot counties through 1995.



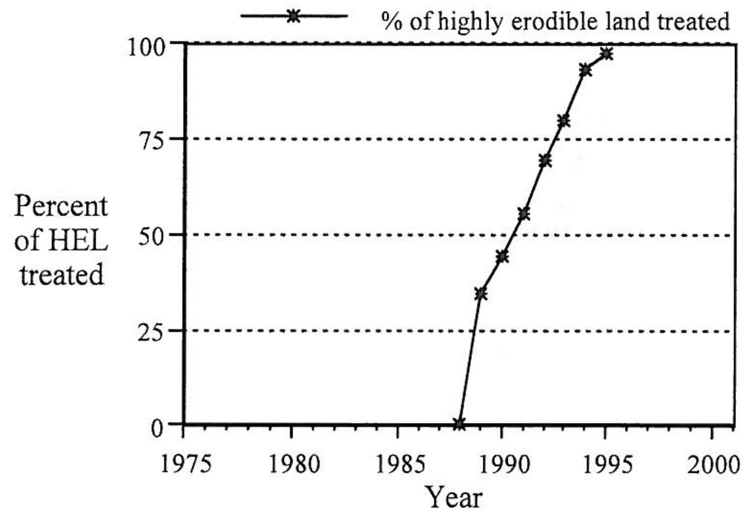
- **Farmland placed in the Conservation Reserve Program (CRP)** -- The Conservation Reserve Program originally provided funds so that highly erodible cropland could be removed from production and converted to permanent cover. As the program evolved, land eligibility was expanded to other than "highly erodible land." Even so, much of the cropland in the four counties does not meet the "highly erodible" requirement. Consequently, only about 2.5% of the farmland in the watershed has been placed in the program (Figure 10.11). However, from the standpoint of erosion reduction in the watershed, this program has been important.

Figure 10.11. Percent of total farmland in the Conservation Reserve Program (CRP) for Crawford, Sandusky, Seneca, and Wyandot counties through 1995.



- **Treatment of Highly Erodible Land** – As noted above, a relatively small percentage of the farmland within the four county area is classified as highly erodible (about 10% in Seneca County). Analysis of that land shows that by 1995 about 98% of the highly erodible land was receiving some kind of treatment (Figure 10.12). This treatment included either conservation tillage or enrollment in the Conservation Reserve Program (CRP). As the CRP program evolved, land eligibility was expanded to other than "highly erodible land." As a result, CRP programs have resulted in significant additional adoption of conservation measures in the watershed.

Figure 10.12. Percent of highly erodible land (HEL) treated with conservation measures for Crawford, Sandusky, Seneca, and Wyandot counties through 1995.



- **Changes in Agricultural Drainage** – In much of Northwestern Ohio, including the Sandusky Watershed, successful crop production is dependent on subsurface tile drainage. Tile drainage itself is dependent on adequate outlets. In this area, constructed ditches provide most of those outlets. These ditches carry both surface runoff and tile drainage to natural stream channels. The conversion of forests, swamps and prairies to tile drained cropland has resulted in large changes to the flow regimes in the streams and rivers of this area. Peak flows are much higher and base flows much lower than would have been the case in pre-settlement times. Many of the habitat problems in area streams, including siltation, stem from these altered flow regimes.

Numerous improvements in tile drainage have occurred during the past 25 years. Many of the original clay tile systems have been replaced by perforated plastic tubing. These more recent systems are frequently installed using narrower spacing to provide more effective drainage. Plastic tubing has also been installed in many fields that previously were undrained. Data on the full extent of subsurface drainage in the watershed are not available. In Ohio, a higher percentage of cropland is drained than in any other state in the North Central United States (Zucker and Brown, 1998).

Maintenance of drainage ditches for tile outlets has been an important activity of SWCDs and/or county engineers in the watershed. To protect this investment from siltation, SWCDs have also worked with landowners to construct grassed waterways for control of gully erosion and to plant grassed filter strips and field windbreaks.

Trends in Nonpoint Source Pollution in the Sandusky Watershed

Some of the changes in agriculture noted in the preceding section would have tended to increase pollutant export from the Sandusky Watershed while others would have tended to decrease pollutant export. Increased row crop acreage would be expected to increase sediment and particulate phosphorus export. Also, since soybeans provide little residue to protect the soil from erosion, the big increases in soybean acreage could be expected to increase erosion. Decreases in winter cover associated with decreases in wheat acreage could also increase erosion. Increased nitrogen fertilizer applications could be expected to increase nitrate export, as could improvements in tile drainage. The large increase in soybean acreage, with its accompanying increase in nitrogen fixation, could also be expected to increase nitrate export.

Decreases in sediment and particulate phosphorus export could be expected as a result of the increases in conservation tillage, in Conservation Reserve Program acres, and other conservation measures. The decreases in phosphorus fertilizer applications could also have resulted in decreased phosphorus export.

Determination of the net effects of the above changes in agriculture on pollutant export from the Sandusky and Maumee rivers has been the object of a major study funded by a grant from the U. S. Department of Agriculture's Cooperative State Research, Extension and Education Service. This grant supported researchers from Ohio State University, Heidelberg College, and Case-Western Reserve University, who analyzed the changes in both agriculture management practices and pollutant export for the period from 1976 to 1995. The results of this research have been published in 12 papers that appeared in the January-February 2002 issue of the *Journal of Environmental Quality* (Volume 31, pages 1-108).

This research indicates that there have been substantial reductions in sediment, total phosphorus and soluble phosphorus export from the Sandusky and Maumee watersheds. The research also indicates that changes in agriculture are the most likely causes of these decreases in sediment and phosphorus export. However, nitrate export has increased from these watersheds. The sizes of these changes in pollutant export are summarized in Table 10.2.

Table 10.2. Percent change in stream discharge and pollutant export based on trends from 1975 to 1995. (After Richards and Baker, 2002)

River	Flow	Total Suspended Sediments	Total Phosphorus	Soluble Reactive Phosphorus	Nitrate-nitrogen	Organic nitrogen + NH_3- N
Maumee	+9.2	-18.1	-41.6	-84.5	+21.3	-28.4
Sandusky	+6.7	-27.2	-46.3	-87.9	+12.0	-21.0

While, except for nitrate, the above reductions in pollutant export have been impressive, it should still be noted that pollutant export rates in lbs. per acre for the Sandusky River remain among the highest of Ohio rivers, and also rank high relative to agricultural watersheds in the Midwest. Data for various area rivers, for the four–year period from 1997-2000, are shown in Table 10.3. This Table is an update of Table 8.5 from Chapter 8, with data for the River Raisin in Michigan substituted for the Muskingum River of southeastern Ohio. It should be noted that the Cuyahoga, Scioto, and Great Miami rivers all receive sewage effluents from major metropolitan areas. These point source inputs account for the high soluble phosphorus export rates for these watersheds.

Table 10.3. Comparison of unit area pollutant export rates for various area rivers for the 1997-2000 water years, as measured by the Heidelberg College Water Quality Laboratory.

Watershed	Suspended Solids lbs/acre/yr	Total Phosphorus lbs/acre/yr	Soluble Reactive Phosphorus lbs/acre/yr	Nitrate-nitrogen lbs/acre/yr	Chloride lbs/acre/yr
Maumee	494	1.13	0.184	16.9	74.0
Sandusky	494	1.07	0.138	17.2	69.3
Cuyahoga	670	0.89	0.142	6.9	508.0
Grand	457	0.48	0.035	2.1	118.0
Scioto	333	0.92	0.298	11.9	110.8
Great Miami	253	0.99	0.404	13.4	131.1
River Raisin (MI)	256	0.50	0.068	11.4	84.4

Phosphorus Budget for Cropland of the Sandusky River Watershed

One approach to evaluating the long-term effects of agricultural production practices on water quality is to construct watershed nutrient budgets. Such budgets are similar to nutrient budgets for individual farms as they might be worked out in manure management or nutrient management plans. Components of the phosphorus budget for a watershed are shown in Figure 10.13.

One difference between a watershed budget and an individual farm budget is that the watershed budget includes river export. Baker and Richards (2002) developed watershed budgets for the Maumee and Sandusky watersheds for 1975-1995. Here we have updated the budget for the Sandusky River through the year 2000. Data used for calculating phosphorus inputs and outputs are the same as presented above where four county fertilizer sales, animal numbers and grain production were presented. However, for the watershed budgets, data are used from all nine counties that drain into the Sandusky River upstream from the Tindall Bridge gauging station near Fremont. Each county's data is adjusted by the proportion of the county that drains into the Sandusky River (at Tindall Bridge).

Conversion factors from the Ohio Livestock Manure and Wastewater Management Guide (The Ohio State University, 1992) are used to convert livestock numbers into phosphorus content of manure. In similar fashion phosphorus content per bushel harvested of each kind of grain and for tons of hay harvested are used to calculate crop removal of phosphorus. Sewage phosphorus is divided into two components -- (1) sludge that is applied to cropland and (2) point source phosphorus inputs to the stream. The latter is subtracted from total phosphorus export by the stream to obtain the nonpoint source phosphorus export, the majority of which is derived from cropland. Additional information on the procedures for developing watershed budgets for phosphorus are presented by Baker and Richards, 2002.

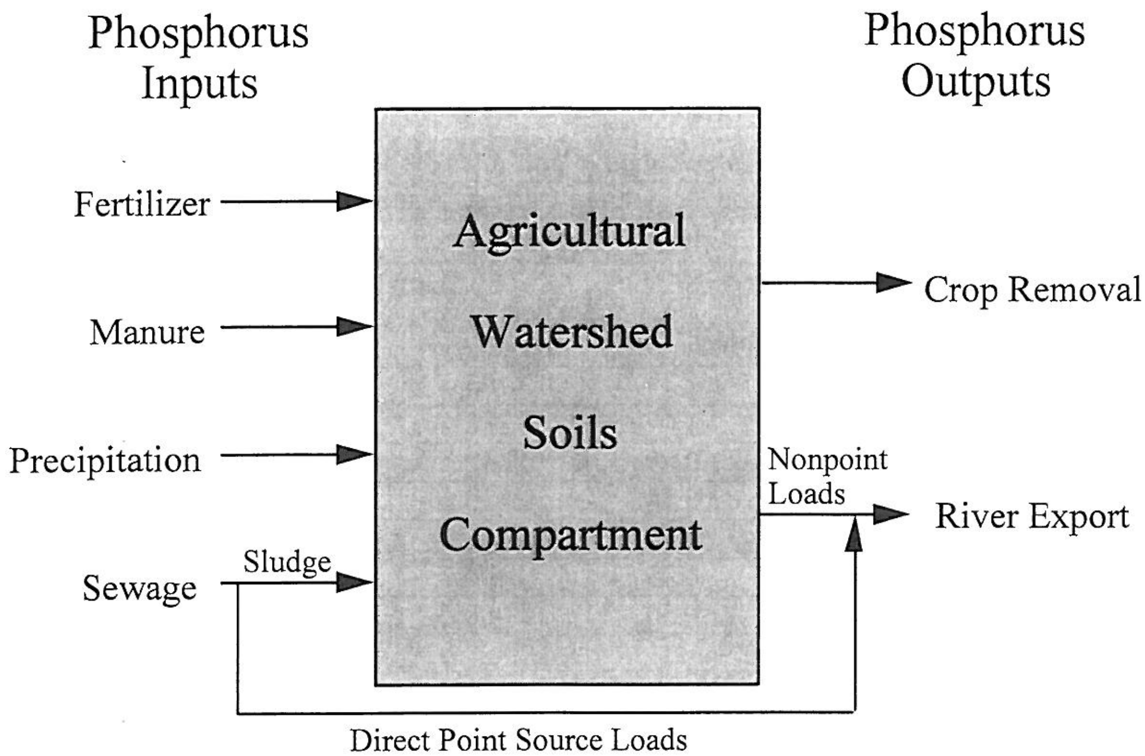


Figure 10.13. Components of a phosphorus budget for the soils of an agricultural watershed as described by Baker and Richards, 2002.

- **Phosphorus inputs into the Sandusky Watershed** – In Figure 10.14, the changes in annual phosphorus inputs from fertilizer and livestock manure, as well as the total input of phosphorus to the watershed, are shown for 1976- 2000. The total phosphorus inputs include not only fertilizer and manure phosphorus, but also phosphorus deposition in the watershed from rainfall and phosphorus inputs from sewage sludge. These latter two inputs make up only 2.3 % of the total phosphorus inputs, so they have not been graphed. The graphs have two Y-axes, so that they can be read either in metric tons per year (left axis) or in pounds of phosphorus per acre per year (right axis) for the entire watershed.

- **Phosphorus Export from the Watershed** -- The major pathways of phosphorus removal from cropland in the Sandusky Watershed is through the harvest of grain (Figure 10.15). Corn and soybean harvests remove approximately equal amounts of phosphorus. Since grain production has increased due primarily to increased yields per acre, phosphorus export has gradually increased. Wheat accounts for the next most significant removal of phosphorus, followed by removal through erosion and subsequent runoff as particulate and dissolved phosphorus. These latter exports are estimated by the nonpoint source component of river export (see Figure 8.5). Phosphorus removal by hay is smaller than removal as nonpoint pollution. Removal through hay harvest is not shown in Figure 10.15. It is, however, included in the total phosphorus removal that is shown.

Total phosphorus removal has increased significantly over time. The two dips in removal correspond to the Payment-in-Kind program of 1983, which greatly reduced corn acreage, and the drought year of 1988.

Fig. 10.14. Major phosphorus inputs to cropland in the Sandusky River Watershed.

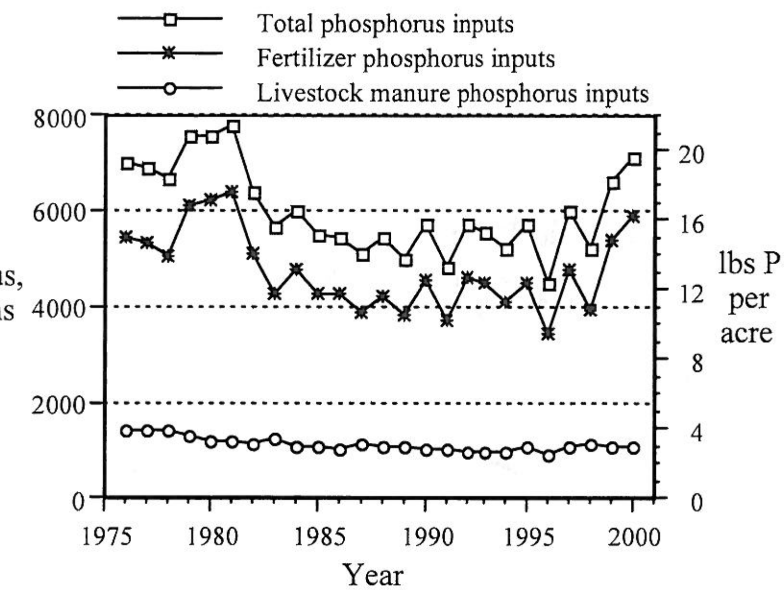
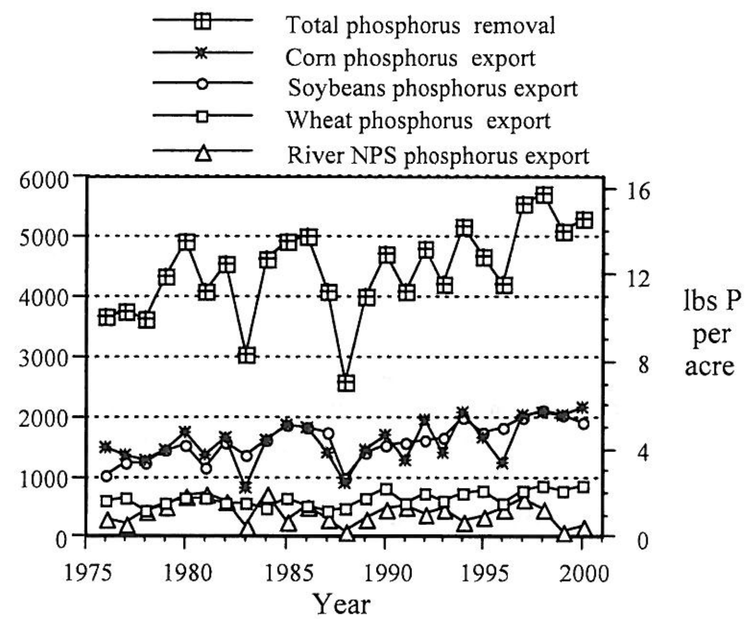
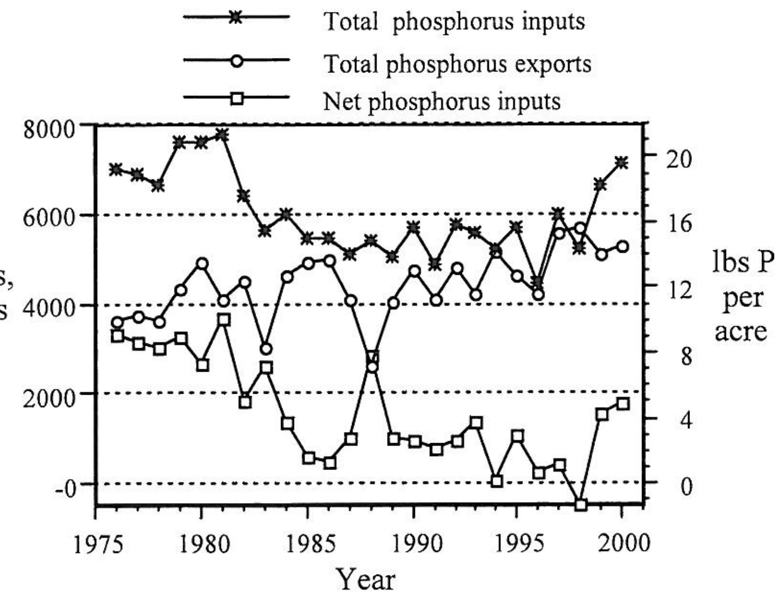


Figure 10.15. Major phosphorus exports from cropland in the Sandusky River Watershed.



- **Total phosphorus inputs, exports and net input--** Figure 10.16 illustrates the total phosphorus input (from Figure 10.14), the total export (from Figure 10.15), and the net input, as calculated by subtracting export from import. In 1976, inputs greatly exceeded outputs. The net input was almost identical to the total export. Thus only half of the phosphorus applied to cropland was actually removed by crop harvest. Under those conditions, phosphorus buildup occurs in the cropland soils. Net inputs have generally decreased with time. In 1998, for the first time, exports actually exceeded inputs, so that net input dropped to a negative value. In that year, more phosphorus was removed from the watershed than was added to the watershed as fertilizers and manure. In 1999 and 2000, net inputs increased substantially, due primarily to increased total inputs and secondarily to slightly reduced exports.

Figure 10.16. Total inputs, exports, and net inputs of phosphorus to cropland in the Sandusky River Watershed.



Studies of phosphorus soil test data in Northwestern Ohio do show continuous increases during the period from 1975-1995, increasing from a mean of 25 mg/kg in 1975 to a mean of 50 mg/kg in 1995 (Calhoun et al., 2002). Phosphorus budgets, such as those shown in Figure 10.16, are used in water pollution control studies to predict long-term trends in phosphorus export from cropland. So long as phosphorus inputs exceed phosphorus export, phosphorus soil tests should increase. Considerable research supports that prediction (see Calhoun et al, 2002 and Baker and Richards, 2002). Increasing phosphorus concentrations and export in streams and rivers draining cropland generally accompany increasing phosphorus soil tests. The soil test values often exceed those necessary for optimal (or maximal) crop production.

The data in Figure 10.16 indicate that phosphorus soil tests levels should be increasing throughout the past 25 years. The rate of increase should have been slower in more recent years than in the 1970s through the mid-1980s. By itself, these data predict constantly increasing phosphorus export and concentrations in the Sandusky River. As noted earlier, monitoring data indicate substantial reductions in both total and soluble phosphorus exports. These decreasing trends in phosphorus export suggest that other conservation practices adopted by farmers have more than compensated for the increasing phosphorus soil test values on watershed soils. Baker and Richards (2002) attribute the reductions in phosphorus export to the combined effects of increasing conservation tillage, installation of buffer strips, and enrollment of "highly erodible" and other land into the Conservation Reserve Program. The data also suggest that improved fertilizer management techniques, such as more incorporation and less broadcasting of fertilizer may also have been very important.

In the long-term, constantly increasing phosphorus content of watershed soils will likely adversely impact water resources. Consequently, more effort should be placed on nutrient management programs that lead to a balance of inputs and exports for the watershed. In this regard, careful attention should be placed on the effects of large livestock operations on watershed nutrient budgets. In many instances, applications of manure nutrients aren't compensated for by corresponding drops in application of fertilizer nutrients. This situation can give rise to excessive build-up of phosphorus soil test levels.

Nitrogen Budget for the Sandusky River Watershed

Nitrogen budgets for watersheds are far more complex than phosphorus budgets. This is due to the complexity of the nitrogen cycle within soils. In addition to the inputs of nitrogen to the watershed via fertilizers, manures and point sources, legumes, such as soybeans fix gaseous nitrogen. Both wet (rainfall) and dry deposition of nitrogen as nitrate and ammonia are also significant inputs to watershed nitrogen budgets. In addition to removal of nitrogen via grain harvests and river export, denitrification, wherein fixed nitrogen is converted back to nitrogen gas, occurs in soils. These added complexities make development of a nitrogen budget for the Sandusky Watershed beyond the scope of this Chapter. Development of a nitrogen budget constitutes a research project, which may be on the agenda of watershed researchers at Heidelberg College and The Ohio State University.

Urban Nonpoint Source Issues in the Sandusky Watershed

Nonpoint pollution from urban areas differs in significant ways from nonpoint pollution from agricultural or forested lands. Some of these differences are listed below.

1. Because urban areas have greater proportions of impervious surfaces (roof tops and paved areas) a given amount of rainfall (e.g., 0.3 inches) will generate much greater flow volumes in urban areas than it would in non-urban areas.

2. To handle these storm flows, urban areas generally install collection systems (sewer systems) to convey runoff waters to streams, rivers, lakes, or wetlands. These collection systems generally fall into two categories –

    - **Combined Sewers** - These sewers combine sewer lines carrying sanitary wastes with sewer lines carrying storm runoff. During many storm flows, the combined sanitary and storm flows exceed the capacity of collector sewers to transport the combined wastes to treatment plants. Overflow structures are built into the collection systems so that mixed wastes discharge directly into surface waters. The locations of these overflow structures are referred to as CSOs (Combined Sewer Overflows). These overflows prevent the combined wastes from backing up into basements or low lying streets, but the mixed wastes often have adverse impacts on the receiving surface waters.

- **Storm Sewers** - These sewers convey urban surface runoff directly to receiving waters without intermingling the storm runoff water with sanitary wastes. Generally the storm runoff water does not receive any treatment prior to discharge.

3. A second problem related to combined sewers occurs when the storm flows reach the sewage treatment plant. The combined flows may exceed the capacity of the treatment plant to remove wastes. The high flows actually disrupt the treatment processes to make them less efficient. Consequently during storm flows, treatment plants often bypass certain amounts of combined sanitary and storm runoff waters directly into the stream.

4. Storm runoff from urban areas contains a different set of chemical pollutants than runoff from agricultural lands. Urban runoff often contains oil and grease, various metals, materials derived from automotive parts (tire materials and break lining), particulates from air pollution sources, and insecticides used in urban settings. Urban runoff often has higher phosphorus concentrations than agricultural runoff. Runoff from construction sites is also classified as urban runoff, and often contains high sediment concentrations.

5. Programs to control urban storm runoff treat such flows as point sources, since these flows are generally conveyed to surface waters via pipes that enter surface waters at specific locations. Discharge of urban storm runoff is regulated through the use of NPDES permits (National Pollutant Discharge Elimination System permits). These same permits are used in the control of municipal and industrial point sources of pollution.

   - Discharges from **combined sewers** are regulated through the State of Ohio's Combined Sewer Overflow Strategy of March 1995.
   - Discharges of storm runoff water through **storm sewers** are regulated through the federal Phase I and Phase II Storm Water Program, as implemented by the Ohio Environmental Protection Agency.

Although urban lands make up only 1.2% of the land surface in the Sandusky River Watershed and only 2.0% of the land area in the Sandusky Hydrological Unit, runoff from these urban areas does impact water resources in this watershed. Those impacts and associated control strategies are briefly outlined below.

Combined Sewer Overflow Problems and Programs --

Most of the documented problems from combined sewer overflows (CSOs) are associated with the sanitary waste component of the combined wastes. In particular, combined sewer overflows are a major source of elevated fecal bacterial counts in surface waters. As noted in Chapter 7 (Recreational Water Use), coliform bacterial counts downstream from CSOs frequently exceed standards for both primary and secondary water contact recreation.

Adverse impacts on aquatic life by organic wastes from CSOs have been noted in the Bucyrus area (OEPA, 1991). Additional information regarding the effects of CSOs on the water resources of the Sandusky Region should be available upon the conclusion of the TMDL monitoring programs currently underway in the watershed.

In January 2002, the OEPA completed a statewide CSO inventory. The number of CSOs and associated permit numbers are shown in Table 10.4.

Table 10.4. Communities in the Sandusky Hydrological Unit with CSO permits and the number of CSOs in each community.

Community	Permit Number	Number of CSOs
Attica	2PB00001	12
Bloomville	2PB00053	0
Bucyrus	2PD00021	22
Clyde	2PD 00004	4
Crestline	2PC00006	1
Fostoria	2PD00031	5
Fremont	2PD00007	13
Green Springs	2PB00026	1
Sandusky	2PF00001	17
Tiffin	2PD00025	39
Upper Sandusky	2PD00039	7

The goals of Ohio's Combined Sewer Overflow Strategy, as stated in that strategy, are threefold (OEPA, 1995).

1. Discharges from combined sewer overflows shall not cause or significantly contribute to violations of water quality standards or impairment of designated uses.

2. During wet weather, the total loading of pollutants discharged from the entire wastewater treatment system shall be minimized; and the discharge of pollutants from CSOs should not increase above current levels.

3. Combined sewer overflows shall be eliminated when this is a cost effective, economically achievable control option, and when it does not cause new or significantly increased overflows elsewhere in the system.

All communities with CSOs must develop and submit a Combined Sewer System Operational Plan. The plan must document how the community will implement the following nine minimum control measures identified by the U. S. EPA. These are:

1. Proper operation and maintenance programs for the sewer system and CSO points;
2. Maximum use of collection system for storage;

3. Review and modification of pretreatment programs or other local programs to minimize the impact of non-domestic discharges from CSOs.
4. Maximization of flow to the Publicly Owned Treatment Works (POTW) for treatment;
5. Prohibition of dry weather overflows;
6. Control of solid and floatable materials in CSO discharges;
7. Required inspection, monitoring and reporting of CSOs;
8. Pollution prevention to reduce CSO impacts; and
9. Public notification for any areas affected by CSOs, especially beach areas and areas where contact recreation occurs.

Communities must also develop and implement a long-term control plan that ultimately meets the objectives of the Clean Water Act. Since the Sandusky River is a State Resource Water, the ultimate goal will be elimination of CSOs.

The above descriptions of the Ohio's CSO program are taken from the State of Ohio Combined Sewer Overflow Strategy (OEPA 1995). This document is available at the Ohio EPA's web site.

Programs to Regulate Urban Storm Runoff via Separate Storm Sewer Systems --

Phase I requirements for storm water discharge permits were published in the Federal Register on November 16, 1990 (40 CFR 122.26). Phase I requirements were applicable to municipalities with populations greater than 100,000 having separate storm sewer systems, to industries that were covered by effluent limitation guidelines, and to construction sites more than 5 acres in size. More information on this program is available in the Storm Water Program Phase I Fact Sheet available from the OEPA's web site (http://www.epa.state.oh.us/dsw/storm/).

Under Phase II of the Storm Water Program, small municipalities that operate municipal separate storm sewer systems (MS4s) will have to develop a storm water control program that implements the following six minimum control measures.

1. Public Education and Outreach Program on the impacts of storm water on surface water and possible steps to reduce storm water pollution. The program must be targeted at both the general community and commercial, industrial and institutional dischargers.

2. Public Involvement and Participation in developing and implementing the Storm Water Management Plan.

3. Elimination of Illicit discharges to the MS4.

4. Construction Site Storm Water Runoff Ordinance that requires the use of appropriate BMPs, pre-construction review of Storm Water Pollution Prevention Plans (SWP3s), site inspections during construction for compliance with the SWP3, and penalties for non-compliance.

5. Post-Construction Storm Water Management Ordinance that requires the implementation of structural and non-structural BMPs within new development and redevelopment areas, including assurances of the long-term operation of these BMPs.

6. Pollution Prevention and Good Housekeeping for municipal operations such as efforts to reduce storm water pollution from the maintenance of open space, parks and vehicle fleets.

In the Sandusky Hydrological Unit, Phase II municipalities include Bucyrus, Fostoria, Fremont, Sandusky and Tiffin. Construction site programs are applicable to all sites involving one acre or more. More information is available on the Phase II Storm Water Program at the Ohio EPA web site (http://www.epa.state.oh.us/dsw/storm/phase2_fs.html).

References

Baker, David B. and R. Peter Richards. 2002. Phosphorus Budgets and Riverine Phosphorus Export in Northwestern Ohio Watersheds. *Journal of Environmental Quality*, 31:96-108.

Calhoun, Frank G., Jerry M. Bigham, and Brian K. Slater. 2002. Relationships among Plant Available Phosphorus, Fertilizer Sales, and Water Quality in Northwestern Ohio. *Journal of Environmental Quality*. 31:38-46.

OEPA. 1991. *Biological and Water Quality Study of the Sandusky River and Selected Tributaries: Crawford, Wyandot and Seneca Counties (Ohio)*. Ohio Environmental Protection Agency. Doc. OEPA 05-001 1990 BWQS. June 1991.

OEPA. 1995. State of Ohio Combined Sewer Overflow Strategy. Ohio Environmental Protection Agency, Division of Surface Water. March 1965.

Ohio Lake Erie Commission. 2000. *Lake Erie Protection and Restoration Plan*. State of Ohio. Columbus, Ohio. 48 pp.

Richards, R. Peter, and David B. Baker. 2002. Trends in Water Quality in LEASEQ Rivers and Streams (Northwestern Ohio). *Journal of Environmental Quality*, 31:90-96.

Richards, R. Peter, David B. Baker, Brian R. Christensen, and Dennis P. Tierney. 1995. Atrazine Exposures through Drinking Water: Exposure Assessments for Ohio, Illinois, and Iowa. *Environmental Science and Technology*, 29:406-412.

Sanders, Randall E. 2001. *A Guide to Ohio Streams*. Ohio Chapter of the American Fisheries Society. Columbus, Ohio.

United States Geological Survey. 1999. The Quality of Our Nations Waters: Nutrients and Pesticides. U. S. Geological Survey Circular 1225. Reston, Virginia. 82 pp.

Zucker, L.A, and L.C. Brown, 1998. *Agricultural Drainage: Water Quality Impacts and Subsurface Drainage Studies in the Midwest*. The Ohio State University Extension Service, Bulletin 871. The Ohio State University, Columbus, Ohio. 40 pp.

Chapter 11. Management Plan

Introduction and Background

In order to promote the protection and enhancement of water resources within the Sandusky River Watershed, the Sandusky River Watershed Coalition (SRWC) has prepared this *Management Plan.* This plan includes descriptions of the many programs and projects that are already underway within the watershed to improve and protect our water resources. The plan describes activities planned by the SRWC to support, promote, and accelerate those programs and projects. New initiatives for the protection and enhancement of water resources are also described.

The SRWC was formed in 1997 with the general mission of providing information and opportunities for public participation in the stewardship of the Sandusky River Watershed. The SRWC received a grant from the Ohio Environmental Protection Agency (OEPA) to develop a local watershed action plan using the OEPA's *Guide to Developing Local Watershed Action Plans in Ohio.* With the support of that grant, the Coalition produced *The Sandusky River Watershed Resource Inventory.* The *Resource Inventory*, which was published in February 2000, is available in printed form from the SRWC. Most of the *Inventory* is also available on the SRWC web site at www.riverwatershed.org.

The *Resource Inventory* includes chapters that describe the land, water, and biological resources of the watershed. These are followed by Chapters describing the causes and sources of use impairments relative to biological communities, drinking water, and recreational uses, as well as watershed export of pollutants to Lake Erie. An appendix to the inventory contains detailed GIS generated maps of land use, roads and highways, aquatic life use attainment by stream segment, and location of point sources for each of the eleven major subwatersheds that make up the Sandusky River Watershed.

Following publication of the *Resource Inventory,* the coalition hosted public meetings in each of the eleven sub-watersheds during March 2000. These meetings provided an opportunity for concerned citizens in each sub-watershed to review the contents of the *Resource Inventory,* to comment on local water resource concerns, and to suggest methods to address those concerns. Invitations were sent to 3,500 identified "stakeholders." The news media also helped to spread the word about the meetings to the rest of the community. One hundred and twenty people attended the public meetings and contributed 500 comments about their water issues of concern. About 32% of those attending were from the general public, 25% from local government, 20% represented business, 5% from agencies, and 8% from education and environmental groups.

These data were summarized by the watershed coordinator and grouped into various topics. At the SRWC general meeting of April 27, 2000, five subcommittees were formed -- (1) agriculture, (2) wastewater, (3) drinking water, (4) stream flow and habitat, and (5) education and special events. A sixth subcommittee, addressing issues of development, was subsequently formed. The water quality concerns summarized in the Resource Inventory and/or raised in the public meetings were divided among the subcommittees for the development of specific action plans. A general format was developed for the action plans and consensus procedures were to be used in the development of the plan.

Draft action plans for each subcommittee were reviewed at a Strategic Planning Meeting on September 11, 2000. At that meeting presentations were also made regarding other planning efforts underway in the Lake Erie Basin and Ohio. These included the Lake Erie Buffer Team, The Lake Erie Coastal Management Plan, the Lake Erie Protection and Restoration Plan, the Lakewide Management Plan (LAMP) & Statewide Streams and Rivers Plan, and the Karst Source Water Assessment and Protection Plan. Gaps in the action plans and opportunities for plan integration were also discussed.

The action plans for the original five subcommittees were revised as needed and the subcommittee action plans were approved at the SRWC annual meeting on October 26, 2000. The action plan for the Development Subcommittee was approved at the annual meeting of October 18, 2001. In addition to the action plans developed by each subcommittee, this *Management Plan* contains the following information/topics:

1. A review of the OEPA's terminology for water quality management plans.

2. A summary of the causes of water resource problems in the Sandusky Watershed (including a description of the adverse effects and the "sources" of the causes).

3. A summary of the various tools available for improving water resources.

4. A summary of the action plan, including a matrix showing the effectiveness of various tools for reducing the various causes of water resource problems.

5. The detailed action plans of each subcommittee.

6. The evaluation approaches scheduled for use by the SRWC.

7. A brief description of current and potential water research programs in the Sandusky Watershed.

Since the *Resource Inventory* and the *Management Plan* are integrally related, we are packaging them together. The *Management Plan* is added as Chapter 11 of the *Sandusky River Watershed Resource Inventory*. The combined publication is entitled *The Sandusky River Watershed Resource Inventory and Management Plan*. To facilitate addition of sections and updates, the original *Sandusky River Watershed Resource Inventory* was published in a three-ring binder. Copies of the Chapter 11 and associated changes to the title page, table of contents, preface and credits will be distributed to those who have previously received copies of the *Resource Inventory*. The SRWC's web page will also be updated to include the management plan.

Development of this management plan was supported by a grant to the SRWC by the Lake Erie Protection Fund. A January 2001 draft of the Management Plan was reviewed extensively by the SRWC steering committee as well as by various OEPA and ODNR staff. The suggestions of the reviewers have been very helpful in the development of the final draft of this document. David Baker, chairman of the Stream Flow and Habitat subcommittee, served as the main compiler and author of this Chapter. W.S.O.S. Community Action Commission, Inc. of Fremont, Ohio serves as the fiscal agent for the SRWC.

A Review of Terminology Used in the Management Plan

The terminology used in both the *Resource Inventory* and the *Management Plan* follows that used by the Ohio EPA in their many reports and publications and is shown in Figure 11.1. The waters of the state are given a set of designated uses, such as support of aquatic life, suitability for drinking water supplies and suitability for recreational use. Where pollutants, habitat degradation or other factors interfere with those designated uses, the uses are said to be impaired. Thus water resource problems are referred to as **impairments**. Wherever possible, the Ohio EPA attempts to identify the "**causes**" of the impairments. These "causes" may be specific pollutants, habitat alterations, hydrologic alterations, or other factors. While often there can be a chain of cause-effect events that lead to water quality impairments, the term "cause" is generally restricted to the factor that directly results in the impairment. Thus "causes" generally operate within the aquatic environment.

The Ohio EPA then attempts to identify the "**sources**" of the various causes of water resource impairments. Where pollutants are the causes of impairments, sources are further subdivided into nonpoint sources (associated with land uses) and point sources (associated with municipal and industrial water uses). Sources of habitat and hydrological alterations in stream systems often originate from alterations of land surfaces. Efforts to reduce water resource impairments generally focus on adoption of **treatment practices** or **best management practices (BMPs)** to reduce the sources.

Treatments/ BMPs →	Sources →	Causes →	Impairments
Examples			
Phosphorus removal at treatment plants	Municipal sewage	Phosphorus loading	Excessive algal growth
No-till crop production	Sheet erosion on cropland	Particulate phosphorus loading	Excessive algal growth

Figure 11.1. Terminology used in water resource assessment and protection by the Ohio EPA and in this Management Plan.

Causes of Water Resource Problems in the Sandusky Watershed

In the *Resource Inventory*, water resource problems in the Sandusky River Watershed were presented in terms of impairments to biological communities (Chapter 5), water supply (Chapter 6), recreational use (Chapter 7), and Lake Erie, through pollutant loading (Chapter 8). In general, these problems reflect unintended consequences of human land and water uses within the watershed. Conversion of land from pre-development conditions to agricultural, urban, industrial, and suburban land uses resulted in major changes to the pathways of water movement to streams and to the chemical quality of the water moving in surface runoff pathways. These land use changes accelerated surface runoff to streams and decreased infiltration into ground water, resulting in higher flood peaks and lower base flows. Additionally, the surface runoff water picked up chemicals characteristic of those land uses. For example, surface runoff from cropland picks up soil particles, phosphorus and pesticides and carries these substances into streams. The extensive use of tile drainage to support timely field operations by farmers in this region further alters the pathways and timing of water movement into streams, and increases delivery of soluble agricultural chemicals, such as nitrates, to streams. Pollutants carried into streams via surface water (and to a lesser extent, groundwater) pathways are said to be derived from nonpoint sources (see Chapter 1).

A major use of water is to remove wastes from our homes, businesses and industries and discharge them into streams that carry the wastes away. As populations increased in the watershed, these waste disposal practices soon resulted in intolerable conditions in streams. Consequently, sewer lines, often referred to as interceptor sewers, were installed to convey the wastes to sewage treatment plants where treatment reduces the concentrations of pollutants in waters discharged into streams. Industrial water users also added water treatment to reduce pollutant concentrations in their discharges. Over the years, the degree of treatment provided by municipal and industrial waste treatment plants has increased, greatly diminishing pollutant discharges into streams. The Ohio Environmental Protection Agency now regulates the discharge of pollutants from both municipal and industrial sources through the National Pollutant Discharge Elimination System (NPDES). However, untreated sewage still reaches streams through combined sewer overflows and treatment plant bypasses. Some smaller towns have yet to install sewer lines and treatment plants. Even where treatment plants are meeting current treatment requirements, pollutants may still be entering streams at levels which, together with other sources of that pollutant, may result in impairments to water resources. The above are referred to as point sources of pollutants (see Resource Inventory, Chapter 1).

The major causes of water resource impairments resulting from land and water use activities in the Sandusky Watershed are listed in Table 11.1. For each cause, the water resource problem or effect it causes is summarized. Also, the sources or conditions that lead to the cause are summarized. These sources or conditions are the specific land or water uses that contribute to the cause. Note that many of the "causes" have both multiple "effects" and multiple "sources."

Table 11.1. Summary of causes of water resource impairments, their effects on water resources, and the sources or conditions that lead to the causes.

Cause of problem	Water Resource Problem	Sources and conditions leading to causes
Sediment	Excessive sediment deposition in stream systems adversely affects aquatic habitats and increases flooding; suspended sediment in streams increases water treatment costs, adversely affects aquatic life, and decreases recreational values; excessive sediment loading into Lake Erie causes similar problems in the lake, and contributes to high dredging costs.	Sheet erosion of cropland; gully erosion on farmland; stream bank erosion; sheet and gully erosion at construction sites; movement of deposited sediments through drainage networks; down-cutting of streams; higher peak flow increases erosion and lower base flow allows increased deposition in stream channels.
Phosphorus	Can stimulate excessive growth of aquatic plants, giving rise to oxygen problems, taste and odor problems, nuisance conditions, and possible release of toxins from blue-green algae. Historically responsible for many of the above problems in Lake Erie.	Attached to eroding sediments, especially from cropland; fertilizer; manure; human wastes, through sewage, combined sewer overflows, and failed septic tanks; urban storm runoff.
Nitrate	Drinking water contaminant in surface and in some ground water; Can stimulate excessive growth of aquatic plants, but this effect is more likely in marine than in fresh water environments.	Fertilizer; nitrogen fixation, especially by legumes; manure; human wastes; rainfall; delivery of nitrate from cropland to streams is enhanced by tile drainage systems.
Ammonia	Direct toxicity to aquatic life; contributes to oxygen deficiencies in streams.	Manure; human wastes via failed septic tanks and inadequate sewage treatment; spills of concentrated animal wastes, fertilizers, and industrial chemicals.
Pesticides	Some drinking water risk in surface water supplies and, to a lesser extent, ground water supplies in the Sandusky Watershed. Some risk to aquatic life.	Herbicides, primarily from agricultural uses; some herbicides from urban land uses; insecticides, primarily from urban uses
Organic wastes	Can deplete oxygen concentrations in streams and lakes; can result in sludge beds on stream bottom.	Untreated sewage from bypasses and combined sewer overflows; septic tank effluents; manure runoff; food processing wastes; industrial wastes; spills; biomass decomposition.
Fecal bacteria, as indicated by presence of fecal coliform bacteria.	Health risks to recreational users; drinking water contaminants, especially private water supplies.	Failed septic tanks; combined sewer overflows; cross connections between water and sewer lines; loss of pressure in water lines, often due to broken water mains, allows infiltration of contaminated water; animal wastes/manure; wildlife.
Other toxic chemicals (metals and organic chemicals)	Wildlife kills; drinking water contamination; fish consumption advisories.	Sewage effluents; industrial effluents; spills; fires; pipeline breaks; leaking hazardous waste sites; atmospheric deposition.

Table 11.1. Causes of water resource impairments … continued.

Cause of problem	Water Resource Problem	Sources and conditions leading to causes
Higher peak flows than for natural stream flows	Flood damages to crops, housing, businesses, bridges and roads; increased stream bank erosion; habitat and channel modifications.	Agricultural land use increases surface runoff; agricultural drainage projects and ditch maintenance speed delivery of water to downstream sites resulting in higher peak flows; impervious surfaces associated with urban and industrial land uses increase surface runoff; urban storm runoff.
Lower base flows than for natural stream flows	Inadequate public water supplies during dry weather flows; limits aquatic habitats; less dilution of point sources; slow water movement facilitates growth of algae in streams; higher water temperatures.	Agricultural land use; agricultural drainage projects, including tile drainage and surface drainage; wetland conversions to cropland or urban uses; impervious surfaces associated with urban and industrial land uses. All of above reduce ground water recharge, lowering water tables and diminishing spring water discharges that provide dry weather (base) flows in streams.
Lack of forested riparian corridors	Increases water temperatures; reduces source of large woody debris, root masses, and log jams, all of which enhance stream habitat; breaks continuum of forest habitat that benefits wildlife; adverse aesthetic effects for stream users; increases erosion and downstream flooding.	Agricultural, suburban, urban and industrial land uses which encroach on stream banks.
Channel modifications	Simplify stream habitats; alter stream substrates; decrease local flooding/increases downstream flooding. Reduces flood plain function.	Constructed to support local agricultural or urban land uses; reduce local flooding; provide stream bank protection.
Natural habitat limitations	Stream gradients affect distribution of pools and riffles; local soils and bedrock affect stream substrates (bedrock, fine sediments, sand, gravel, etc.); affects ecoregional aquatic life standards.	Natural geographical features that predated human impacts.
Logjams (+/-)	(+) Provide habitat diversity in streams, reduce downstream flooding; (-) can aggravate local flooding and bank erosion.	Logjams are natural features of streams having forested riparian corridors. Logjam removal is common to reduce local flood-ing that can adversely affect land uses.
Trash and debris	Reduce aesthetic values of streams; can pose hazards to recreational users of water resources.	Careless human behavior.
Exotic species	Reduce diversity of native flora and fauna; direct economic damages.	Globalization of commerce and travel; deliberate human introductions (carp, multiflora rose)
Dams (+/-)	(-) Alter stream habitat; often prevent longitudinal migration of fish; (+) Provides sources of drinking water and/or industrial supplies; power generation (historical); flood prevention/reduction; recreational uses.	Often dams no longer serve the purposes for which they were originally constructed. In the mean time, developments upstream from dams benefit from the ponded conditions created by the dam.

Tools for Improving Water Resources

Point Source Controls

A wide variety of tools have been developed to reduce the adverse effects of land and water uses on water resources. Because the adverse impacts of point sources of pollutants were so obvious, initial efforts to improve water quality focused on the collection and treatment of domestic and industrial wastes. It is beyond the scope of this plan to describe in any detail the various techniques of municipal and industrial waste treatment. However, these treatment programs are so important to maintaining water quality in our streams and rivers that they require noting. Furthermore, the continuing regulation of treated effluents from these point sources, through NPDES permits, may offer opportunities for additional improvements in water quality. Chapter 9 (unfinished) of the Resource Inventory describes point sources of pollutants in the Sandusky Watershed.

At present, opportunities for improvements in water quality in the Sandusky Watershed, relative to point sources, occur within the category of improved collection of wastewater. Many of the sewer lines in our communities receive both sanitary (household) and storm runoff water. During rainfall events, the combined flows from these sources often exceed the flow capacity of the interceptor sewers. Rather than have the mixed wastes back up into basements, overflow structures are built into the interceptor sewers, so that portions of the combined wastes overflow directly into streams. Combined flows reaching the treatment plants may also exceed the capacity of the treatment plants for waste treatment, and must be bypassed with minimal treatment into the receiving streams or rivers. Various tools are available to reduce the adverse effects of combined sewers on water quality.

In areas not served by sewer lines, septic tanks and infiltration beds provide treatment of domestic sewage. Often these systems fail, resulting in untreated or poorly treated sewage directly entering streams. Replacement of failed septic tanks, extension of sewer lines into unsewered areas, and installation of sewage collection and treatment systems in communities previously lacking such systems are all important tools in water quality management in the Sandusky Watershed.

A listing and brief description of the major tools in the reduction of pollutants derived from point sources is shown in Table 11.2.

Table 11.2. Tools for the control of point sources of pollutants.

Tools	Description
Municipal waste treatment plants	Includes primary and secondary treatment of domestic sewage and some industrial wastes. These greatly reduce organic waste content of the sewage. Various chemicals can be added to improve treatment and remove additional phosphorus. Ammonia may be oxidized to nitrate. Effluents are chlorinated, or otherwise disinfected, to kill fecal bacteria, and de-chlorinated to reduce toxicity of effluent. Tertiary treatment is also possible to further clean up effluents. A variety of other treatment systems are used in smaller communities. (See Resource Inventory – Chapter 9). Effluents must meet standards set in NPDES permits that are specific for each waste treatment plant and receiving stream.
Industrial waste treatment plants	Treatment systems are specific to each industry. Effluents must meet standards set in NPDES permits that are specific for each discharger and receiving stream.
Combined sewer separation, remediation.	This involves construction of storm sewers in areas previously served by combined sewers. This reduces storm water movement into the sewer lines and thereby reduces combined sewer overflows. This is very expensive, but nevertheless is being required in most communities.
Reduction of combined sewer overflows.	This involves sets of practices that reduce the volume of storm runoff water reaching combined sewer lines. Discharging run gutters onto lawns rather than driveways would be an example. Stenciling storm drains so that people don't discard wastes directly into the drains can also reduce pollutant entrance into streams.
Sewer line extension/rural sewer district formation	Often developments at the edges of cities may lack sewer lines, resulting in treatment via septic tanks or package plants. These treatment systems are less effective that municipal sewage treatment plants. Extension of sewers into these developing areas provides a permanent solution.
Septic tank replacement/repair	Septic tanks and leach fields, if not properly maintained, can fail to effectively treat household wastes, resulting in off-lot movement of wastes. Replacing these systems and requiring maintenance can reduce these problems.
Pollution Prevention	Substitution of hazardous raw materials in manufacturing processes; reuse of wastes or discarded goods (sludge, used tires, etc.); proper use, storage, and disposal of household chemicals (not down the drain), substitution with non-toxic household cleaners.

Nonpoint Source Controls

In the 1970s, as it became apparent that controls of point sources of pollutants were insufficient to achieve water quality goals, attention broadened to include efforts to control nonpoint sources of pollution. Since the land use activities within a watershed reflect essential human activities (food production, industrial production, living space, commerce, transportation, forestry, recreation, etc.), improving water quality by changing land uses has only limited applicability. Instead, attention has focussed on improving the management practices associated with existing land uses. These improvements support continuation of existing land uses while reducing adverse impacts on water resources. In general these practices are referred to as best management practices (BMPs).

Because of the complexity of the interaction between rainfall, runoff, and conditions on the land surface, BMPs are often site specific. What works in one place, may not work in another.

Because agricultural land use is a major source of nonpoint source pollutants, extensive research has been conducted to develop site specific agricultural BMPs. Numerous technical handbooks and computerized decision aids are available to help farmers and their advisors select appropriate BMPs. County soil and water districts and the cooperative extension service of The Ohio State University can provide detailed information on locally appropriate BMPs.

Some of the common agricultural BMPs are listed and briefly described in Table 11.3. The list also indicates that BMPs are available for construction sites and urban storm runoff, although these are not described in any detail.

Table 11.3. Summary of some of the tools used to reduce nonpoint sources of pollution and water resource impairment in the Sandusky Watershed.

Tool/BMP	Description
Filter strips	Strips of grass or other vegetation used to intercept or trap sediment, nutrients, pesticides or other pollutants before they reach a water body.[1]
Riparian corridors	Streamside vegetation consisting of trees, shrubs, and grasses that can intercept pollutants from both surface and ground waters before they reach a stream.[1]
Flow through wetlands	Tracts of land either temporarily or permanently covered by shallow water. Wetlands serve as sinks to trap water, sediment and other pollutants.[1]
Conservation tillage	Crop production procedures that retain at least 30% soil cover so as to reduce erosion.
Grassed waterway	Strips of grass on areas where water concentrates as it runs off of a field; primarily used to prevent gully erosion; can be combined with filter strips to filter contaminants.
Wildlife habitat establishment	Conversion of cropland to grass, shrub and /or tree habitats. Usually applied to portions of fields difficult to access with large equipment or to very small parcels.
Windbreak establishment	Rows of trees planted along the edges of fields to reduce wind erosion; can also function as filter strips.
Land set-a-sides; Conservation Reserve Program (CRP)	Conversion of highly erodable cropland to fallow land with adequate cover; can include rental payments through CRP
Tile outlet maintenance	Methods of reducing erosion and back cutting at tile outlet sites.
Agricultural water management	Improvements in traditional surface and tile drainage systems to reduce adverse water quality impacts and improve production; can include wetland reservoir subirrigation systems and water table management systems.
Nutrient management plans	Programs to increase the efficiency of crop production and reduce water quality impairments through careful nutrient management; includes soil and/or plant tissue testing.
Integrated pest management	Programs to increase the efficiency of pest (insects and weeds) control through scouting, economic threshold analysis, and careful selection of pesticides.
Agrochemical storage and handling	Programs to reduce accidental spills during the storage and handling of pesticides and fertilizers.
Manure nutrient management	Plans to assure appropriate utilization of manure nutrients so as to avoid nutrient buildup in local areas and avoid manure runoff into surface waters.
Manure storage facilities	Provide safe storage for sufficient quantities of manure to facilitate appropriate manure nutrient management.
Livestock exclusions	Provide fencing to exclude livestock from direct access to streams.
Stream bank protection	Various techniques to protect stream banks from erosion; primarily used where such erosion threatens adjacent land uses.
Ditch maintenance	Sets of practices which maintain channel capacity and provide for tile outlets; can include dredging, control of woody vegetation through use of herbicides, and maintenance and shaping of grass banks.

Table 11.3. Summary of some of the tools used to reduce nonpoint sources ... continued.

Tool/BMP	Description
Construction site BMPs	Sets of practices used to reduce erosion and off-site sediment transport from construction sites of various types.
Urban storm water management	Sets of practices to reduce the quantity and improve the quality of surface runoff from urban, industrial and suburban areas. Can include treatment of urban storm runoff.
Cover crop establishment	Planting a fall/winter cover crop, especially on fields where "specialty crops" are grown (sugar beets, tomatoes, cabbage pickles, etc.) to reduce erosion and retain nutrients.
Sinkhole management	Planting grass or vegetated buffers around sinkholes. Sinkholes in towns/public areas should be "stenciled" similar to storm sewer drains.

[1] Definition for the Ohio Lake Erie Buffer Program, Strategic Plan 2000-2004

Other Tools for Water Resource Management

There are important additional approaches to water resource management applicable to this area. These include Source Water Assessment and Protection Programs, regional planning, zoning, farmland protection, park system expansion, flow augmentation, waste site remediation, enforcement of existing regulations and future legislation/regulations. The relevance of these issues to water quality management is briefly described in Table 11.4.

Table 11.4. Some additional approaches to water resource protection and management.

Approach	Relevance to water resource management
Source Water Assessment and Protection Programs (SWAP)	This is a specific program required of all public water supplies. It involves detailed identification of the risks posed to both surface water and ground water based supplies. Source waters are to be protected such that conventional treatment can bring the finished water into compliance with drinking water standards. These risks may come from point sources, nonpoint sources, or from accidental spills associated with the storage and transport of various chemicals. Following identification of these risk factors plans for addressing the risks must be developed. These plans will intersect with more comprehensive watershed management plans. The SRWC Drinking Water Committee is working on the SWAP programs for the Sandusky Watershed.
Regional Planning	Regional planning is aimed at guiding and fostering development in a particular area. There is increasing recognition that the course of development, and the resulting pattern of land use, has important implications for the environmental quality in an area, including its water resources. Terms such as "smart" development and "sustainable" development reflect the incorporation of long-term environmental considerations into regional planning.
Zoning	Zoning, particularly as it applies to flood plains, is very important for water resource management. Flood plains are natural parts of streams and rivers. Construction of homes, businesses and industries on flood plains increases the potential damages from floods. Such construction also results in calls for flood protection efforts that are costly, can increase downstream flood magnitudes, and have other undesirable effects on stream systems.

Table 11.4. Some additional approaches ... continued.

Approach	Relevance to water resource management
Farm Land Protection	Much of the growth of communities in this region occurs at the expense of farmland. Loss of farmland, especially of prime farmland, reduces the capacity for future food production. This can lead to farming of increased acreage of less suitable land, which is often accompanied by increased erosion problems. Since the "unit area" adverse impacts of farmland on water resources are generally less than the "unit area" adverse impacts of developed land, development generally is accompanied by increased pressure on water resources.
Parklands, Natural Areas, and easements	Transfer of existing forest lands and flood plain areas into parklands, natural areas or natural easements achieves long-term protection of these areas, and their generally beneficial functions relative to water resources.
Flow Augmentation	Because of the exceptionally low base flows of the Sandusky River and some of its major tributaries, release of water from up-ground storage reservoirs can significantly increase base flows in the streams. This capacity could be incorporated into low-flow water quality management. Many of the existing up-ground reservoirs in the watershed were constructed with capacity of flow augmentation included in their design and funding.
Waste Site Remediation	There are numerous closed land fills and waste disposal sites in the watershed (See Resource Inventory, Chapter 9). Some of these may be leaking into the streams or rivers. Where such leakage represents a significant threat to aquatic life or humans through fish consumption or drinking water, remediation of the sites may be warranted.
Enforcement of Existing Regulations	There are numerous regulations pertaining to large livestock producers, littering, point sources and some nonpoint sources, that, if more strongly enforced, would improve water resources.
New legislation/regulations	In Ohio, new regulations regarding large livestock operations are being developed. These have the potential to protect and improve water resources.

Total Maximum Daily Load (TMDL) programs

An important component of the *Federal Clean Water Act* is the Total Maximum Daily Load program (Section 303(d)). This program applies to stream segments that will not achieve use attainment goals through application of normal point source controls. For these stream segments, the causes of impairments must be identified and plans developed to bring the stream segment into compliance. These plans often involve a combination of point source and nonpoint source controls. Where the effectiveness of the plans is uncertain, the plans must include a margin of safety. The plans also allow for trading of pollutant load reductions between point and nonpoint sources so as to achieve water quality goals in the most economic manner. Generally modeling techniques are used to estimate the nonpoint source components of the loads and to calculate the assimilative capacity of the streams (i.e. the maximum loading of a pollutant that a stream can receive and still maintain water quality goals). In Ohio, the TMDL program is primarily aimed at reducing impairments to biological communities of Ohio's streams and rivers.

The timetables for Ohio EPA's biological monitoring efforts are now tied to the state's schedule for developing TMDLs for Ohio's streams and rivers (see http://www.epa.state.oh.us/dsw/tmdl/303dnotc.html). At the onset of the preparation of the *Resource Inventory* and this *Management Plan*, the upper portions of the Sandusky River were scheduled for TMDL completion in 2006, with monitoring starting in 2004, and the lower portions of the Sandusky River in 2011, with monitoring starting in 2009. However, early in 2001, the OEPA decided to advance the TMDL program by three years for both the entire upper portion of the Sandusky River Watershed and by six years for a portion of the lower Sandusky River Watershed. Intensive biological sampling of these areas will occur during 2001. The resulting data will help set priorities for remedial programs and provide baseline biological data upon which to evaluate the effectiveness of future programs. The SRWC will play an important role in the development of the nonpoint source control portions of the TMDL plan.

Role of Education

Because the reduction of nonpoint source pollution involves such a large number of watershed residents, education will be particularly important in its control. This education must address two major topics. First of all, residents must understand the importance of water resources within the watershed, the extent of the water resource impairment, and the causes of those impairments. Secondly, residents must know the steps they can take to reduce the causes of water resource impairments, as well as the programs and people that can help them take those steps. A primary role of the SRWC is to mount educational efforts within the watershed to help accomplish the above. This will involve the Education Subcommittee, working in cooperation with the other SRWC subcommittees.

Summary of the Action Plans

Improvements in water resources in the Sandusky Watershed will come from applying the relevant tools to the causes of the water quality problems in this watershed. The general applicability of these tools to the causes of the problems is summarized in Table11. 5. The major intent of Table 11.5 is to illustrate the following two points:

1. Many of the individual tools are effective in addressing multiple causes of water resource degradation.
2. Many of the individual causes of water resource problems can be addressed by a variety of tools.

Table 11.5 does attempt to indicate the general effectiveness (large, medium or small) of various tools in addressing individual causes of degradation. There were differences of opinion both within and among subcommittees regarding the effectiveness of some of the practices. In part, these differences are due to the site-specific nature of BMPs. A particular BMP may be very effective in one landscape but much less effective in another. For example, buffer strips may be very effective in reducing sediment transport into streams where large portions of runoff water move by sheet flow from fields, over buffers and into streams. Where large portions of

Table 11.5. Matrix summarizing the applicability of various tools for improving water resources to the important causes of water resource degradation in the Sandusky River Watershed.

Treatments/ BMPs ⟶ **Sources** ⟶ **Causes** ⟶ **Impairments**

Tools--BMPs & Treatments / Causes of problems	sediment	phosphorus	nitrate	ammonia	pesticides	organic wastes	fecal bacteria	other toxic chemicals	high peak flows/flooding	low base fows	lack of riparian corridors	channel modification	natural habitat limitations	insufficient in-stream cover	log jams (+/-)	trash and debris	exotic species	dams (+/-)	future problems
buffer strips (grass)	L	L	M		M		S?		M	S									
woody riparian corridor establishment	L	L	M		M		M		M	M	L			L	M				
flow-through wetland establishment	M	M	M		M		M		L	L				L					
conservation tillage	L	L	N?		S	N?			S	S									
grassed water ways	L	M			S														
wildlife habitat improvement	M	M	M		S				M	M	M				S				
windbreak establishment	M	M							M	M									
land retirement (CRP)	L	L	S		S		S?		M	M									
tile outlet maintenance	S	S																	
agricultural water management	S	S	N?						L	L		M			M				
fertilizer nutrient management plans		L	L	M															
integrated pest management					L														
pesticide storage and handling					L														
manure nutrient management		L	L	L		L	M												
manure storage facilities		L	L	L		L	L												
livestock exclusions	L	M	M	M		M	L												
stream bank protection	L																		
construction site BMPs	L	S																	
urban storm water management	S	M			S	S		L	L	L		M?			M				
improved waste treatment (NPDES)		L	L	L	M	L	L	L											
storm/sanitary sewer separation		L	L	L	N	L	L	L											
sewer extension/rural sewer district		L	L	L		L	L												
septic tank replacement/repair		M	M	M		L	L												
source water assessment & protection	S		S		S			L											
park system expansion	S								L	L	L			L					
regional planning								L	L	L	L							L	
zoning									L	L	L								
farmland protection									L	L	L				S				
flow augmentation/upground reservoirs										L								M	
constructed ditch maintenance	M								+/-	N	N	N		+/-	+/-				
enforcement of existing regulations	L	L	L					L								L			
stream clean-ups																L			
education	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	
research	L		L		L				L	L							M	M	
waste site remediation								L											

L = tool has a **large** effect in reducing that cause of impairment from the applicable source
M = tool has a **medium** effect in reducing that cause of impairment from the applicable source
S = tool has a **small** effect in reducing that cause of impairment from the applicable source
N = tool has a **negative** effect in reducing that cause of impairment from the applicable source
? = effect of tool is **uncertain** relative to that cause from the applicable source
+/- = effect of tool may be positive or negative depending on site specific conditions

water move by concentrated flow, such as by grassed waterways, from fields to streams, buffer strips are much less effective in reducing sediment loading.

Furthermore, the tools are source specific. The effectiveness of the tools was judged relative to the source it was addressing, irrespective of the importance of that source in the watershed. For example, sewage treatment is very effective in reducing phosphorus loading from sewage treatment plants and thus has a large effect of phosphorus from that source. Municipal sewage treatment plants are responsible for only about 3.5% phosphorus export from the Sandusky River to Lake Erie. Nonpoint sources are the major source of phosphorus loading to Lake Erie (Chapter 8). Thus, although sewage treatment is very effective in reducing phosphorus loading from sewage treatment plants, its potential for reducing phosphorus loading to Lake Erie is very limited. This aspect of water management planning is not included in the matrix of Table 11.5.

The matrix of Table 11.5 also indicates that that some tools have positive effects relative to some causes and negative effects relative to others. Use of these tools involves trade-offs that must again be evaluated on a site-specific basis. Tile drainage, an essential agricultural water management practice, tends to reduce surface runoff and associated sediment and phosphorus export, but it increases nitrate export into streams and decreases groundwater recharge. Blank spaces in the matrix of Figure 5 indicate no relationship between the tool and a particular cause of water resource degradation. Some tools and causes are marked +/-. These indicate that the environmental effects of a particular tool relative to a particular cause of problems varies from positive to negative on a site specific basis. For example, logjams may increase erosion adjacent to the logjam but decrease downstream erosion by reducing peak flows.

Often, application of an individual tool for a particular problem in a particular location may seem to be a fruitless endeavor relative to the scope of the problem at the watershed level. Yet the nature of the water resource problems we are facing is such that it is unlikely that we will identify many single actions at single sites that will result in measurable improvements in water quality. Instead, we must recognize that significant improvements will generally occur only through the collective effects of many small steps and actions at local sites.

This Management Plan represents an effort to accelerate and integrate implementation of water resource protection activities in this watershed. We recognize that such efforts have a long history in the watershed, and that many individuals, agencies, and organizations are currently using the various tools listed in Table 11.5 to improve water resources in this watershed. We believe that by calling attention to the breadth of activities currently underway, and supporting both existing and new programs through a watershed approach, we can help usher in a new level of effort toward improving and protecting the water resources in the Sandusky Watershed. We further believe that all watershed residents will benefit from such improvements.

This Action Plan for the Sandusky River Watershed, as well as similar plans for adjacent watersheds, complement action plans that have been developed for Lake Erie (Lake Erie Protection and Restoration Plan, Ohio Lake Erie Commission, 2000) and the Ohio Coastal Management Program (http://www.dnr.state.oh.us/odnr/relm/coastal/cmp.htm).

Various subcommittees of the SRWC have developed detailed action plans related to the responsibilities of each committee. These subcommittee action plans, taken together, represent the current Action Plan for the SRWC. Some of the tools listed in Table 11.5 do not fall within the areas of responsibility of the existing subcommittees. The relevance of these tools, such as zoning and regional planning, have been briefly discussed by the SRWC steering committee. A new subcommittee will be formed to develop an action plan related to these tools for water resource management.

The Action Plans

<u>Agricultural Committee Action Plan</u> **(approved October 26, 2000)**

Problem Statement: Sediment, nutrients and pesticide loading in the Sandusky River Watershed reduces overall water quality.

Overall Goal: To improve water quality in the Sandusky River Watershed.

Resources Needed: Funding for water testing, promotions and/or incentive payments. NRCS Best Management Practices Standards and Specifications. OSUE guidelines, bulletins and fact sheets. Assistance from NRCS, SWCD, FSA, OSUE, ODNR, and others.

Funding Sources: Utilize existing sources and programs (CRP, CREP, and EQIP). Watershed Grants (319's or others). Explore funding from EPA from fines, etc.?

Success Indicators: Water testing/monitoring as documented by the Water Quality Laboratory at Heidelberg College through their Tributary Monitoring Program and by public water suppliers.

Time Frame: Variable

Goal 1: Reduce sediment, nutrient, and pesticide loading from agricultural lands into streams of the Sandusky Watershed.

Goal 1a: General actions to reduce agricultural pollutant loading into streams.

Action	Who	Funding	Success
Promote establishment of buffers (trees or grass)	Landowners, NRCS/SWCD, FSA	CRP, CREP, EQIP, Other grants	1,200 acres over 3 years
Promote establishment of wetlands	Landowners, ODNR NRCS/SWCD, FSA	CRP. CREP, WRP, ODNR	50 acres over 3 years
Encourage use of conservation tillage	Landowners, OSU, NRCS/SWCD	EQIP, 319 grants	Increase over current levels
Encourage enforcement of current laws and regulations (animal agriculture)	EPA, ODA, SRWC	OEPA, ODA	

Goal 1b: Specific **actions to reduce sediment loading in the watershed.**

Action	Who	Funding	Success
Promote installation of grassed waterways	Landowners, NRCS/SWCD	CRP, CREP, EQIP	90 acres over 3 years
Encourage maintenance of tile outlets	Landowners, SWCD, county engineers	Land owners, ditch maintenance	
Promote establishment of windbreaks	Landowners, NRCS/SWCD, ODNR	CRP, CREP, ODNR	30,000 row feet over 3 years
Encourage construction site BMPs	(See Stream Flow and Habitat Committee Action Plan)		

Goal 1c: Specific actions to reduce nutrient loading in the watershed.

Action	Who	Funding	Success
Encourage adoption of manure nutrient management plans	SWCD/NRCS, ODNR, OSUE, consultants	EQIP, SWCD, 319 grants	45 nutrient management plans signed over 3 years
Encourage manure storage facilities to contain minimum of 6 months storage capacity	Landowners, NRCS/SWCD, ODNR, OSUE	EQIP, ODNR, 319 grants	12 improved or installed over 3 years.
Encourage use of BMPs with commercial fertilizer application	Landowners, NRCS/SWCD, OSUE, consultants	EQIP, 319 grants	
Failing septic system and wastewater treatment improvements	(See Wastewater Subcommittee Action Plan)		

Goal 1d: Specific actions to reduce pesticide loading in the watershed.

Action	Who	Funding	Success
Encourage use of proper storage and containment systems	Landowners, OSUE, ODA, NRCS/SWCD	319 grants, EQIP	
Encourage use of Integrated Pest Management	Landowners, OSUE, consultants, NRCS/SWCD	OSUE, 319 grants	Reduced pesticide concentrations in streams.

Goal 2: Provide opportunities for education in the watershed.

Action	Who	Funding	Success
Promote BMPs	SRWC, agencies, individuals	Grants, agencies	(see Education Subcommittee Action Plan)
Interpret and distribute results of new research	SRWC, agencies	Grants, agencies	
Encourage soil and plant tissue tests	SRWC, OSUE, NRCS/SWCD	Grants, agencies	
Promote Agricultural Education in schools and student groups			

List of Abbreviations:

BMP – Best Management Practice
CREP – Conservation Reserve Enhancement Program
CRP – Conservation Reserve Program
EQIP – Environmental Quality Incentives Program
FSA – United States Department of Agriculture, Farm Service Agency
NRCS – United States Department of Agriculture, Natural Resources Conservation Service
ODA – Ohio Department of Agriculture
ODNR – Ohio Department of Natural Resources
OEPA – Ohio Environmental Protection Agency
OSUE – The Ohio State University Extension
SRWC – Sandusky River Watershed Coalition
SWCD – Soil and Water Conservation District(s)

Wastewater Subcommittee Action Plan (approved October 26, 2000)

Problem Statement #1: Pathogenic contamination and nutrients escaping from improperly operating septic systems resulting in ground and surface water contamination.

Goal: Upgrade and/or repair failed septic systems.

Action Plan: Pursue alternative system while repairing 100+ conventional systems. Using rural hardship grant funds provided by the county commissioners and Ohio EPA 319 Grant funds.

Action Item	Time Frame	Responsible	Resources Needed/Cost	Success Indicator
Failed septic systems	Annually (3 years for rural hardship grant funding)	county health departments	319 Grant (a non-point source grant through Ohio EPA). Estimated $6500 - $9000 per site. Rural Hardship Grant estimated 5000 – 10000 per site.	Minimum of 100+ systems to be replaced using rural hardship funds and obtaining 319 grant funding for alternative systems installations.

Problem Statement #2: In the public perception of wastewater and its effects, wastewater awareness needs to be elevated.

Goal: Increase awareness and appreciation of the affects of wastewater on ground and surface water quality.

Acton Plan: Three-fold plan, beginning with assisting teachers with proficiency in the wastewater subject of offering presentations and working with the education subcommittee. This will be geared towards 4-6 grades. Second, a manual would be developed to assist package plant operators and on-site system owners with understanding their system. Third, homeowners would be targeted, by township, for educating them on their systems through community visits and information dissemination.

Action Item	Time Frame	Responsible	Resources Needed/Cost	Success Indicator
Education of the public	Phase in over a three-year period.	Sandusky River Watershed Coalition	$5000 annually (funded by Ohio Environmental Education Fund through Ohio EPA)	Teachers give before and after quizzes to monitor retention and feedback. Attendance at presentations

Problem Statement #3: Pathogenic and fecal contamination to receiving streams, especially recreational waters, poses a health hazard to communities and degrades water quality.

Goals: Raise public awareness of contributing factors to combined sewer overflows, as well as encouraging the reduction and/or elimination of abuse water (downspouts, sump pumps, etc.).

Action Plan: Work through children's groups and organizations (i.e. church projects, Boy and Girl Scouts, 4-H, high school clubs) to promote awareness through stenciling of storm water drains and other pollution prevention activities. Groups will have to be solicited and affected cities contacted for final approval. "Soaker hoses" would be displayed with other information material at booths during county fairs and Earth Day events.

Action Item	Time Frame	Responsible	Resources Needed/Cost	Success Indicator
Combined Sewer Overflows and bypasses from wastewater treatment plant	Earth Day in April and county fairs.	Sandusky River Watershed Coalition	Approx. $3000 (funded by Solid Waste District?; Cities?; OWEA?; Safety Council?) for stencils and paint. Distributors of "soaker hoses" will be contacted and request free demonstrator models for use at events.	Participation of groups wishing to become involved, as well as amount of educational material distributed.

Water Supply Subcommittee Action Plan (approved October 26, 2000)

The Water Supply Subcommittee is concerned with both public and private drinking water supplies within the Sandusky River Watershed.

Problem Statement #1: Agricultural runoff has a negative impact on operating costs, increased risk to public health, and results in a negative image of the utility by the consumer.

Goal: Work to reduce agricultural runoff in the Sandusky River and its tributaries.

Action Plan: Water purveyors are not regulatory agencies. Therefore, they cannot directly control the introduction of contaminants into the water supply. They can increase public awareness and encourage Best Management Practices. The actions of this committee will work to increase awareness of this issue.

Goal 1: Become actively involved in the reduction of agricultural runoff in the Sandusky River and its tributaries

Action item	Time frame	Person/agency responsible	Resources needed/cost	Funding sources	Success indicator
Letters to our legislators encouraging them to address water quality issues	Complete letter campaign by December 31, 2002	Entire committee	Stationery & postage (approx. $50)	unknown	Response from 10% of legislators contacted

Goal 2: Provide feedback on changes in raw water quality to the Agriculture Committee

Action item	Time frame	Person/agency responsible	Resources needed/cost	Funding sources	Success indicator
Compile information and note trends on pesticides, herbicides, nitrates, and turbidity; provide to the Ag Committee	Annually	Entire committee	Stationery & postage (approx. $10/annum)	Ohio-American Water Co.	Annual Report

Problem Statement 2: There are numerous sources of pollution/contamination existing within the watershed, many of which have not been readily identified and/or controlled. Industrial sites, agricultural bulk tanks, poorly maintained and installed septic systems, and many other sources of pollution adversely affect water treatment.

Goal: Perform a Source Water Assessment and Protection (SWAP) analysis of the Sandusky River and its tributaries

Action Plan: This analysis will be performed in conjunction with OEPA

Goal 1: Inform Water Committee of requirements for SWAP.

Action item	Time frame	Person or agency responsible	Resources needed/cost	Funding sources	Success indicator
Conduct seminar to explain the extent of SWAP	October 5, 2000	Dave Little	Facility for meeting; OEPA representative - $0.00	N/A	Meeting is scheduled and completed

Goal 2: Perform SWAP of the Sandusky River & its tributaries.

Action item	Time frame	Person or agency responsible	Resources needed/cost	Funding sources	Success indicator
Exchange information with OEPA as they conduct SWAP	December 31, 2003	Entire Committee	Unknown at this time		Affirmation by OEPA of completion

Problem Statement #3: There has been limited communication between water utilities within the watershed. The sharing of information can only enhance the operation of each water district.

Goal: Develop a formal communications process for water purveyors, regulatory agencies, and emergency response representatives within the Watershed area

Action Plan: A compilation of all water purveyors, regulatory agencies, law enforcement agencies, and regional emergency planning committees in the watershed will be developed and distributed.

Goal 1: Create & distribute a formal line of communication among water utilities and emergency planning committees.

Action item	Time frame	Person or agency responsible	Resources needed/cost	Funding sources	Success indicator
Compile complete list of all water purveyors, regulatory agencies, emergency response personnel, and health departments within the watershed	December 31, 2000	Dave Little	Stationery & postage - $100.00	Ohio-American Water Co.	Distribution of list to all stakeholders

Acronyms used and program descriptions

OEPA – Ohio Environmental Protection Agency (www.epa.state.oh.us)

The Ohio Environmental Protection Agency (Ohio EPA) was created on October 23, 1972. It combined under a single agency the functions that previously had been scattered throughout a number of State departments.

Ohio EPA has authority to implement laws and regulations regarding air and water quality standards; solid, hazardous and infectious waste disposal standards; water quality planning; supervision of sewage treatment and public drinking water supplies; and cleanup of unregulated hazardous waste sites.

Ohio EPA cooperates with government and private agencies, manages some federally funded pollution control projects, obtains technical and laboratory services, establishes advisory boards, investigates environmental problems, and disseminates information on environmental programs. The director also authorizes enforcement actions against violators of pollution laws and regulations.

Ohio EPA's central office is located in Columbus. To manage the Agency's programs at the local level, the state is served by five Ohio EPA district offices.

SWAP – Source Water Assessment and Protection Program

To help ensure adequate supplies of safe drinking water, the 1996 amendments to the Safe Drinking Water Act require all states to adopt a Source Water Assessment and Protection (SWAP) program. This program will apply to Ohio's approximately 6,200 public water systems that provide drinking water to homes, businesses, schools and industry using both surface water and ground water sources. Source Water Assessment involves determining an area that contributes drinking water to the public water supply well or intake and evaluating the potential threats to the safety of that water supply. Source Water Protection safeguards the public health by preventing contamination of the drinking water supply. Source water protection for public water supply systems using ground water has in the past been referred to as wellhead protection.

Ohio's SWAP Program document was originally submitted to the United States Environmental Protection Agency on February 8, 1999, with a Revised Version submitted in May 1999. On May 27, 1999, U.S. EPA approved Ohio's Source Water Assessment and Protection Program. U.S. EPA commented that Ohio's program strongly ties an ambitious assessment program to protection activities that further protect Ohio's drinking water resources, making it one of the best source water programs in the country.

Stream Flow and Habitat Subcommittee Action Plan (approved October 26, 2000)

Problem Statement #1: Stream Sedimentation

Accumulation of silts and clays on stream bottoms represents the major cause of aquatic life impairment in the Sandusky Watershed. This conclusion is based on habitat surveys conducted by the Ohio Environmental Protection Agency in connection with their biological assessments of streams in the watershed (Figure 5.7). These sediments destroy spawning habitat for fish and reduce habitat volume and diversity for macroinvertebrates. In addition stream sedimentation reduces channel capacity causing local flooding, interferes with tile drainage outlets, and necessitates costly ditch dredging. Major sources of the sediment include sheet erosion from cropland, stream bank erosion, and construction activities.

Related Problems: High suspended sediment concentrations during storm runoff events and associated high turbidity affect aquatic life and increase drinking water treatment costs. Loading of suspended sediments from the watershed to Lake Erie causes a variety of damages within the Lake.

Goal: To reduce the number of stream miles in the Sandusky Watershed where deposition of fine-grained sediments adversely impacts aquatic life.

Action Item	Time Frame	Person/Agency Responsible	Resources Needed/Cost	Funding Sources	Success Indicator
Construction BMPs	3 years	Construction Companies, Zoning Boards, Building inspectors		Cost of construction	
Install buffer strips along channel banks	(See Goals 1a and 1b of agricultural management plan.)				
Establish riparian corridors	(See Goals 1a and 1b of agricultural management plan.)				
Establish wetlands	(See Goals 1a and 1b of agricultural management plan.)				
Conservation Tillage	(See Goals 1a and 1b of agricultural management plan.)				
Grassed Waterways	(See Goals 1a and 1b of agricultural management plan.)				
Windbreaks	(See Goals 1a and 1b of agricultural management plan.)				
Stream flow	(See action items for stream flow)				

Problem Statement #2: Need for Natural Stream Flow Restoration.

Historical land use changes, including land clearing for agriculture, surface and subsurface agricultural drainage, increased urbanization, dam construction, stream channelization, and flood protection structures have greatly altered the natural stream flow regimes in the Sandusky River and its tributaries. In particular, peak flood flows are higher and base flows are lower as a result of the above land use changes. Dams alter longitudinal connectivity and flood protection structures separate portions of the streams from their floodplains. These altered flow regimes have major adverse impacts on stream habitat and aquatic communities.

Related Problems: The high peak discharges increase erosion of stream banks and channels. The low base flows contribute to sedimentation within stream channels

Goal: To restore more natural stream flow regimes in the Sandusky Watershed

Action Item	Time Frame	Person/Agency Responsible	Resources Needed/Cost	Funding Sources	Success Indicator
Model and characterize the natural flow regime in the Sandusky Watershed	2 years	Ohio Geological Survey (Scudder Mackey)	Currently funded research	Great Lakes Protection Fund	Annual Progress Reports
Identify areas in watershed w/ natural infiltration & storage capacity	2 years	Heidelberg College (Sabine Grunwald)	Currently funded research	Lake Erie Protection Fund	GIS Base maps
Promote Controlled Drainage/ WRSIS (demonstration projects)	?	OSU E, USDA ODNR - Div. of Water		OSUE USDA-NRCS CRP	# acres in controlled drainage (# of demo. projects)
Increase acreage in county park systems, nature preserves and/or other public areas	3 years	County park districts, Sandusky River Watershed Coalition		County park districts, state and federal grants for corridor development	# acres in parkland, local preserves, and corridors
Promote work w/ natural channel processes to allow the stream to efficiently manage flow and sediment		OSU Ag-Extension			
Information & Education to explain water quantity issues		SRW Coalition (Education committee)			
Implement biological monitoring strategy to assess long-term benefits of improved flow regimes	10 years	OEPA		State	Biological monitoring reports for the Sandusky Watershed
Establish recommended minimum base flow requirement (based on model)		ODNR - Division of Water			
Continue to monitor the flow regime to track possible changes		Heidelberg College; USGS		Continue existing state/federal funding sources	Maintenance of current monitoring and hydrological stations

Problem Statement #3: Logjams

Logjams on streams can result in localized erosion and flooding problems. Bank erosion undercuts trees, which subsequently fall into the streams, often spanning the entire stream. The trees subsequently trap other debris moving downstream during floods, resulting in logjams. While logjams may be a natural part of the landscape, high rates of bank erosion increase their frequency and associated damage (e.g. crops). During public meetings for subwatersheds, logjams were the second most frequently cited problem in the watershed.

Related Problems: High peak flows aggravate stream bank erosion problems, resulting in more undercutting of banks and the formation of more logjams.

Goal: To reduce flooding and other damages connected to logjams.

Action Item	Time Frame	Person or Agency Responsible	Resources Needed/Cost	Funding Sources	Success Indicator
Map via GIS locations of logjams; Frequency; Area of damage or flooding	One year for county, subwatershed, and whole watershed GIS maps	SWCDs, SRWC, Heidelberg, Volunteers, ODNR	SRWC People-volunteers	SRWC, SWCDs?	GIS products showing locations of problems
Research to explain distribution of logjams in the watershed	1.5 years	Same as above			Determine the problem areas and educate the public of the causes
Reduce peak flows via filter strips, riparian areas, wetlands, and tile removal in marginal lands	(see Agricultural Action Plan)	SWCDs, Wildlife official, ODNR, Ag groups		CREP USDA	# acres in programs
Logjam Removal Demonstration Project	Years 2 and 3	SWCD Coalition contractor	?	Demonstra-tion Grants	Number of logjams removed
Produce educational materials on how to deal with problem logjams	Year 3	SRW Coalition	?	Demonstra-tion Grant	Educational materials distributed
Evaluate and consider alternatives to Senate Bill 160 Projects	Three Years	Sandusky Watershed coalition	?	?	

Problem Statement 4: Selective **Dam Removal**

Historically, dams have been constructed on rivers for a variety of purposes including flood control, water supply, power generation and recreation. Shorelines along the waters backed up by the dams have often been the sites of substantial commercial and private development. With increasing awareness of the detrimental impacts of dams on aquatic biota and ecosystems, coupled with changing sources of power and water supplies, movements to remove dams are gaining momentum. Continuing dam maintenance costs also tend to support dam removal, especially where original functions are no longer operative. The commercial and private developments historically associated with the water backed up by the dams are generally opposed to dam removal. There are five dams across the Sandusky River between Upper Sandusky and Fremont. Discussions are underway regarding possible removal of two of these, the Ballville Dam above Fremont and nearest to Lake Erie and the St. Johns Dam near the Seneca County/Wyandot County line.

Goal: To study the impacts of dam removal on aquatic ecosystems and people at selected sites in the Sandusky Watershed.

Action Item (Ballville Dam)	**Time Frame**	**Person or Agency Responsible**	**Resources Needed/Cost**	**Funding Sources**	**Success Indicator**
Provide a forum for discussions among stakeholders concerned with issues of dam removal.	Tied to water supply planning and ecological impact assessment of dam removal by EPA and ODNR	Sandusky River Watershed Coalition, Corps of Engineers ODNR OEPA Fremont		OEPA ODNR Fremont	
Summarize current research assessing environmental and social impacts of dam removal.	2 years	Sandusky River Watershed Coalition, ODNR			
Action Item (St. John's Dam)	**Time Frame**	**Person or Agency Responsible**	**Resources Needed/Cost**	**Funding Sources**	**Success Indicator**
Provide forum for discussions	As needed	SRWC			

Acronyms used in the Stream Flow and Habitat Subcommittee Action Plan

BMPs – Best Management Practices
CREP – Conservation Reserve Enhancement Program
NRCS – Natural Resource Conservation Service
ODNR – Ohio Department of Natural Resources
OEPA – Ohio Environmental Protection Agency
OSUE – Ohio State University Extension Service
SRWC- Sandusky River Watershed Coalition
SWCD – Soil and Water Conservation District
USDA – United States Department of Agriculture
WRSIS – Wetland Reservoir Subirrigation System

Education Subcommittee Action Plan (approved October 26, 2000)

The subcommittee has decided upon four problems, each defined in the charts below, that we would like to address. Along with each problem statement, a goal is listed with action items (steps) to define our solutions to each problem. All of our action items will be started within three years. The committee will meet regularly to review progress of this plan and make adjustments to the time frames by either adding more goals or reducing them accordingly. A limiting factor for many of the time frames is that, at the present time, funds are only available through grants. Funding will ultimately drive the education committee's priorities for each of these action items, although they are currently listed in order of importance.

Problem Statement #1: General public lacks understanding of the importance of the river and the opportunities it holds.

Goal 1: Have **annual events to promote the importance of river, its problems, and its opportunities.**

Action Item	Time Frame	Person or Agency Responsible	Resources Needed cost	Funding Sources	Success Indicators
Have a river tour for community Leaders.	October 1, 2001	Scenic Rivers, Coalition, and Community leaders.	$1,000	Continue with current fund raising source.	Good Press & Attendance
Have a Sandusky River wide Clean-Sweep for the 4 major counties.	August 30, 2001	Recycling and Litter Prevention, in the 4 counties	$3,000-5,000 per county	Grants, Fund Raisers,	Participation and reduced amounts of trash collected each year.
Have Sandusky River Watershed Festival Weekend.	August 4, 2001	County Park Districts & Education Committee	$6,000-$8,000	Unknown	Attendance
Include Scenic Rivers Program in all events and public awareness campaigns	Ongoing	Scenic Rivers staff	None	None	Participation in Scenic Rivers Events, At least one Scenic River item in each newsletter

Problem Statement #2: Lack of communication between coalition sub-committees.

Goal 2: Develop **information distribution processes among committees and develop education request process.**

Action Item	Time Frame	Person or Agency Responsible	Resources Needed cost	Funding Sources	Success Indicators
Set up email/fax list serve of all committee officers, and in time all full coalition members	January 2002	Clark Hutson OSU Ext. & Ann Keefe, Seneca SWCD	$0	NA	All members receiving memos effectively.
Develop education request form, and vote on priorities requested.	January 2002	Education Vice Chair, (Scott Grenerth	$0	NA	Prioritize 2 request to work on during 2001 year
Training all committee officers on how to update websites	January 2002	WSOS Intern, & Clark Hutson OSU Ext.	Computer Lab Instructor, costs unknown	?	By August 31, 2001 website being updated monthly by all committees.

Problem Statement #3: Work/Goals of Sandusky River Watershed Coalition are not known by majority of general public.

Goal 3: Public Awareness campaign development.

Action Item	Time Frame	Person or Agency Responsible	Resources Needed cost	Funding Sources	Success Indicators
Fair Display in all 4 major county fairs	Have in all county fairs By October 1, 2001 Have updated display by June 30, 2002.	Education committee secretary	Display, new pictures of yearly events, volunteers to set up booth and cost of booth	LEPF/OEEF	Successful booth at each county fair during 2001
Develop a media strategy	January 2002	Education Committee w/coordinator	20 hours	Current Grants	Implementable plan developed
Action Item	**Time Frame**	**Person or Agency Responsible**	**Resources Needed cost**	**Funding Sources**	**Success Indicators**
Present Sandusky River Watershed Management Plan to at least 20 organizations or communities throughout the watershed	September –December 2001	SRWC coordinator and volunteer spokes-persons	120 hours plus cost of printing the management plan	Current SRWC grants	Evaluation forms following the meetings. Increased participation with SRWC.

Problem Statement #4: No "generic/canned" programs available at this time that can be used by local educators.

Goal 1: Develop several programs for various ages that can be used by coalition members to locally promote our goals.

Action Item	Time Frame	Person/agency Responsible	Resources Needed cost	Funding Sources	Success Indicators
Develop one adult slide show "canned" program focusing on the Watershed Coalition in General	December 31, 2000	Ann Keefe (Chair Educ. Committee), Scott Grenerth, (Vice chair)	$200 for slides, slide trays etc.	LEPF Grant	Two copies available for use, and an increase in number of programs requested
Develop one school "canned" program per year.	March 31, 2001	Scott Grenerth Earth Literacy Center	Cost for displays, kits, models etc.	Grants, (ODNR, OEPA)	Written evaluations, Increase in number of programs requested.
Develop on adult education "canned" program using other committees topics	December 31, 2001	Clark Hutson, OSU Ext. & Scott Grenerth, Earth Literacy Center	$0	NA	Written evaluations, and increase in the number of programs requested.
Develop a general River Coalition video explaining our goals, etc.	Within 3 Years	Monica Ostrand, Coalition, All committees	$5000-20,000	Grants, Donations	Getting it aired on Local Public Broadcasting Stations.

ABBREVIATIONS LIST FOR EDUCATION ACTION PLAN:

SWCD = Soil & Water Conservation District
ODNR = Ohio Department of Natural Resources
OSU Ext.= Ohio State University Extension
WSOS RCAP = Wyandot Sandusky Ottawa Seneca Rural Community Assistance Program
LEPF = Lake Erie Protection Fund
OEEF = Ohio Environmental Education Fund
OEPA = Ohio Environmental Protection Agency

Development Subcommittee Action Plan (approved October 18, 2001)

Problem Statement #1: There is a need to identify and promote the numerous resources that are found along the Sandusky River and its tributaries, by incorporating resource inventory information into a map and separate publication.

Goal: Produce public information guides of watershed.

Action Plan: Create an easy to use map and a detailed publication that would be used by the public to identify resources along the watershed.

Action Item	Time Frame	Person/Agency Responsible	Resources Needed/Cost	Funding Sources	Success Indicator
1. Map	Spring 2002	Entire development subcommittee	Unknown at this time	Grant, fund raiser	An increased use of river
2. Publication	Winter 2003, in time for Ohio's bicentennial				A need for additional republication of materials.

Problem Statement #2: There is a need to identify and inform the public of the boundaries of the Sandusky River Watershed.

Goal: "You are entering the Sandusky River Watershed" signs.

Action Plan: To place watershed signs along major state highways delineating the boundaries of the Sandusky River Watershed.

Action Item	Time Frame	Person/Agency Responsible	Resources Needed/Cost	Funding Sources	Success Indicator
Place signs along major state highways	Spring 2002	ODOT, Bob Vargo, Development Committee	0 dollars (funds already available)	ODOT	Signs placed along highways

Problem Statement #3: There is a need to further develop and protect the Sandusky River.

Goal: Establish a 130-mile long greenbelt corridor.

Action Plan: To establish a greenbelt corridor encompassing the entire length of the Sandusky River. This corridor could encompass a bike or walking path enabling travel form the headwater to the mouth of the river.

Action Item	Time Frame	Person/Agency Responsible	Resources Needed/Cost	Funding Sources	Success Indicator
Establish a greenbelt (Ave 50') along the Sandusky River	10 miles per year.	Sandusky River Watershed Coalition	unknown	CREP, other grants	An uninterrupted 130 mile greenbelt corridor along the Sandusky River

Evaluation Procedures for the Management Plan

The Action Plan described in the previous section will do nothing, by itself, to improve water resources in the Sandusky Watershed. Those improvements will come only to the extent that the plans are implemented and that the implementation has the anticipated benefits on water resources. Thus, our overall Management Plan includes an evaluation plan that addresses both of the above needs – **tracking** the implementation of the action plans and **monitoring** the status of water resources in the watershed.

Tracking Implementation of the Action Plan

As noted in the Summary of the Action Plan, many agencies, organizations and individuals are already involved in applying the tools currently used to maintain and improve water resources in this watershed. The individual action plans list those who are involved in applying the action items. The funding sources for these many programs generally require reporting of the extent of implementation. Thus under CREP and CRP programs, acres of buffer strips, wetlands, and windbreaks installed must be reported annually. Likewise, the numbers of manure nutrient management plans developed must be recorded annually, as well as other management programs supported by government programs. Annual reports of the county SWCDs provide another source of information for tracking water-related projects. NRCS/SWCD staff conduct annual tillage surveys to track the status of conservation tillage. These conservation tillage surveys include information regarding the subwatershed location (11.digit level).

Information for tracking changes in agriculture is also available in the Ohio Department of Agriculture Annual Report and Statistics. These reports include data on acres of crops, average crop yields, fertilizer sales and animal numbers for each county. Such data can support the calculation of watershed nutrient budgets.

Efforts to control point sources of pollution can also be tracked by project. Numbers of septic tanks replaced or improved are available from county health departments. Major sewer extension projects, combined sewer separations, and treatment plant improvements will be tracked by the wastewater committee.

Many of the action plan items of the SRWC involve supporting and encouraging implementation programs of other agencies and groups through educational efforts. The specific educational programs mounted by the SRWC through its subcommittees will be noted on an annual basis. Annual reports required by grants supporting the efforts of the SRWC will also provide a way a tracking implementation of those portions of the action plans undertaken by SRWC subcommittees.

Monitoring Water Resource Responses to Implementation

The fundamental goals of the action plans are to protect and enhance the water resources of the Sandusky Watershed. Thus continued and enhanced monitoring of those resources is essential to know whether the current action plan is effective.

Of central importance is the question of whether or not biological use impairments within the Sandusky Watershed are being reduced. Answers to this question will be based on the biological monitoring programs of the OEPA. As noted in Chapter 5 of the Resource Inventory, OEPA monitoring within the Sandusky Watershed has not been fully implemented during the past 10 years. For most the main stem of the Sandusky River, the most recent OEPA monitoring was done in 1990. Consequently, current information regarding the status of biological communities in this watershed is largely unavailable. Data developed by the Ohio Chapter of the American Fisheries Society and published under the title "A Guide to Ohio Streams" confirm that the Sandusky Watershed has had the least amount of "current" monitoring of any of the other ten major watersheds in Ohio.

Monitoring of the upper portions of the Sandusky Watershed by the Ohio EPA were not scheduled to begin until 2004 and, for the lower portions of the watershed, until 2009. This would have represented gaps in monitoring of 14 to 19 years for the main stem and even longer for most tributaries. As noted earlier, the OEPA advanced the TMDL assessments for the Sandusky Watershed and major biological monitoring efforts will be initiated in the summer of 2001. This monitoring will provide current data to support detailed planning for water resource protection programs in the watershed and baseline data upon which to judge the effectiveness of the programs.

To evaluate the effectiveness of implementation directed toward reducing sediment loading, the SRWC will rely on the ongoing tributary monitoring programs operated by the Water Quality Laboratory of Heidelberg College. This program is described in detail in Chapter 8 of the Resource Inventory. At present, the laboratory is monitoring watershed export for the Sandusky Watershed at the USGS gauging station near Fremont, for the Honey Creek Watershed at the gauging station at Melmore, and for Rock Creek at the gauging station in Tiffin. Because of the long-term sediment export data now available for these stations, ongoing data collection at these stations supports trend analysis.

The above tributary loading data also provides information on the concentrations and export of phosphorus, nitrates and pesticides. As noted in Chapter 6 of the Resource Inventory, nitrates and pesticides represent a source water concern for drinking water supplies in the Sandusky Watershed. The ongoing programs of the laboratory will also support trend analysis for nitrate and pesticide concentrations at the above stations. In addition, data collected by the water treatment plants will also be used to monitor trends in water quality.

The Water Quality Laboratory of Heidelberg College plans to conduct a repeat testing of nitrate contamination in private water supplies of Ohio. Between 1987 and 1989 the laboratory analyzed more than 17,000 private wells across Ohio. Plans to retest as many of those same wells as possible are now being developed. Such a study would evaluate whether there have been changes in water quality during the intervening 12-14 years, as well as possibly identify new problems.

A variety of volunteer and student monitoring projects are also underway within the Sandusky Watershed. These include ODNR's Stream Quality Monitoring program for Scenic Rivers. In this program, volunteers use techniques developed by ODNR's Division of Natural Areas and Preserves to collect and analyze aquatic invertebrate communities at seven stations along the Sandusky between Upper Sandusky and Fremont. This program started in 1988 and has been conducted annually since that time.

Students within the Water Resources Program at Heidelberg College conduct a variety of studies as part of their class work and as independent research projects. These include a synoptic survey at six stations during low flow conditions with the Water Chemistry class, studies of stream invertebrates within the Limnology class, and studies of fish communities in the Ichthyology course.

Tiffin Columbian and Calvert high schools in Tiffin received a grant in 2000 to conduct studies of urban storm runoff within their science curriculum. In addition to their educational value, these studies may serve to identify problem areas. Other schools within the Sandusky Watershed may have similar programs. The SRWC stands ready to work with school groups so that data produced in these efforts can be integrated into the information base supporting water resource management in the watershed.

Adaptive Management

As noted in the Summary of the Action Plan, many of the improvements in water resources in this watershed will result from the cumulative effects of multiple local applications of BMPs. The diffuse nature of BMP application makes it difficult to both predict and measure the water resource benefits of these programs. By developing a monitoring strategy designed to look for early signs of improvements in water resources, it should be possible to determine whether or not current implementation programs are on the right track. By providing feedback from monitoring and research programs to those planning and implementing actions aimed at improving water resources, it may be possible to incorporate some "mid-course corrections" into the management plans. Such feedback between monitoring, research, planning and implementation is referred to as **adaptive management**. The SRWC looks to incorporate adaptive management into its long-term stewardship of the water resources of the Sandusky Watershed.

Role of Research

There is both a need for – and opportunities for – water resource research programs within the Sandusky Watershed. Several research opportunities are described below.

1. Within the Sandusky Watershed, not all farmland contributes equally to the sediment, nutrient and pesticide loading into stream systems. If best management practices could be targeted to those portions of the landscape that represent critical pollutant source areas, investments in agricultural nonpoint source pollution control could be more efficient. Some computer models offer the potential to identify critical source areas. Such research is currently underway through a grant from the Lake Erie Protection Fund to Dr. Sabine Grunwald of the Heidelberg College Water Quality Laboratory. This research should continue and the results should be linked into agricultural nonpoint pollution management programs.

2. There is considerable uncertainty regarding the effectiveness of filter strips in reducing nitrate and pesticide runoff from fields into streams. Nitrates largely enter streams through tile drainage, which normally is conveyed directly into stream systems. Pesticides, especially major herbicides, are transported as dissolved substances in water. While it can be expected that filter strips will trap suspended sediments and sediment associated pollutants such as phosphorus, their effectiveness for these substances may also be limited where concentrated flows, such as those conducted by grassed waterways, discharge directly into streams. The extensive background data on watershed export of suspended sediments, phosphorus, nitrate and herbicides available within the Sandusky Watershed can allow evaluation of the combination of practices adopted by farmers to reduce the export of these materials.

3. The extent to which selective log jam removal could more economically minimize local flooding problems, in comparison with complete log jam removal, such as accomplished through Senate Bill 160 projects, needs evaluation. A hydrological study of the Sandusky River and its tributaries is needed to identify stream reaches where log jams do significantly aggravate local flooding and reaches where flooding induced by log jams is inconsequential, relative to the habitat and hydrological benefits of log jams. In some areas, logjams are constructed in streams because of their benefits. Logjam removal projects are currently under consideration on two major tributaries of the Sandusky Watershed – Broken Sword Creek and Green Creek.

4. While it is recognized that historical land use changes have greatly altered the hydrological characteristic of the Sandusky River and its tributaries, strategies for restoring more natural stream flow regimes need to be developed. Use of models to more accurately characterize historical hydrological conditions in area streams and rivers would be useful. The Ohio Geological Survey is involved in some research addressing these issues.

5. While sedimentation within streams represents the habitat modification most often cited as limiting to aquatic life in the Sandusky watershed, the effectiveness of programs aimed at

reducing sheet erosion and sediment delivery into stream systems (e.g. filter strips) in actually improving stream habitat, relative to sedimentation, is uncertain. Possibly, hydrological modification is more important in causing sedimentation than the amounts of sediment reaching the stream. Research to address these issues could also be launched within the Sandusky Watershed.

List of Appendices

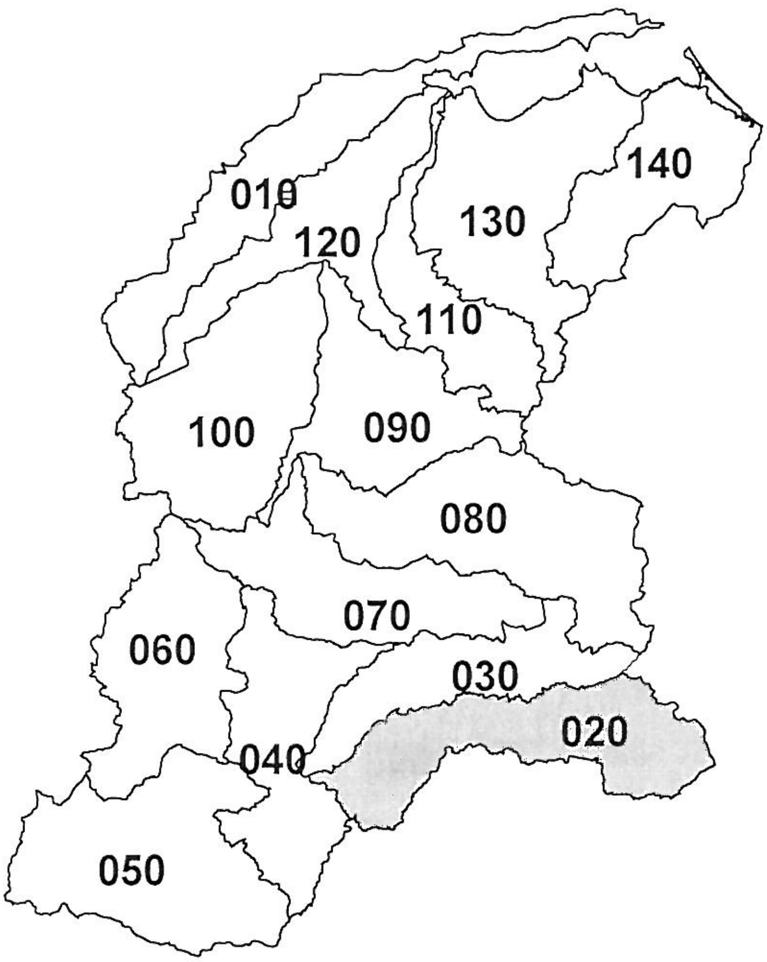
1. Sub-basin Data and Maps for the Sandusky Watershed

Hydrological Unit Code	Name of Subwatershed	Page	Tab
020	Sandusky-Bucyrus	A1-1	2
030	Broken Sword	A1-7	3
040	Sandusky-Upper Sand	A1-13	4
050	Tymochtee-headwaters	A1-19	5
060	Tymochtee-lower	A1-25	6
070	Sandusky-Mexico	A1-31	7
080	Honey Creek	A1-37	8
090	Sandusky-Tiffin	A1-43	9
100	Wolf Creek	A1-49	10
110	Green Creek	A1-55	11
120	Sandusky- Fremont	A1-61	12

2. Sub-basin Data and Maps for Areas Draining Directly into Sandusky Bay

Hydrological Unit Code	Name of Subwatershed	Page	Tab
010	Muddy Creek	A2-1	second 1
130	South Shore - West	A2-7	second 2
140	South Shore - East	A2-13	second 3

Subwatershed: Sandusky – Bucyrus
Hydrological Unit Code 04100011-020
Sandusky River (headwaters to above Broken Sword Creek)

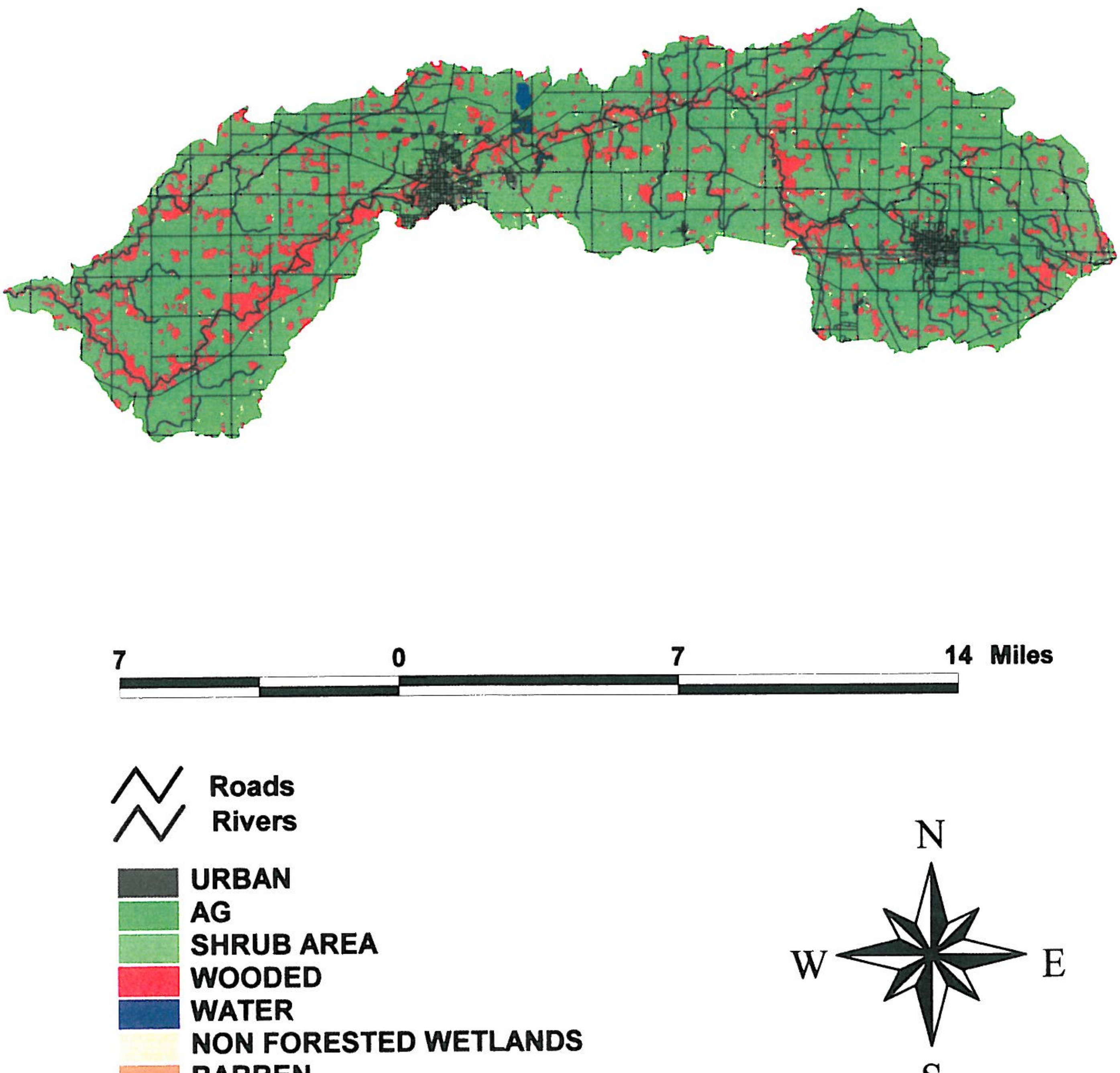


Subwatershed Characteristics
Area (square miles): 137.4
Area (acres): 87,920
Upstream Area (square miles): 0
Total Stream Miles: 171.8
Designated Warm Water Habitat (WWH) Miles: 87.9
Undesignated Stream Miles: 51.2
Counties: Crawford, Richland, Wyandot
Monitored WWH Stream Miles: 62.2
Percent Monitored: 70.8%
Community Water Supplies: 2
Cities and Towns (population) Bucyrus (13,198) Crestline (5,021) North Robinson (229)

Land Use by Percent		
	Sandusky-Bucyrus	Sandusky Watershed
Agriculture	81.9%	84.0%
Wooded	14.3%	12.6%
Urban	1.9%	1.2%
Wetlands	1.1%	1.1%
Barren	0.0%	0.3%
Shrub	0.5%	0.5%%
Water	0.4%	0.4%

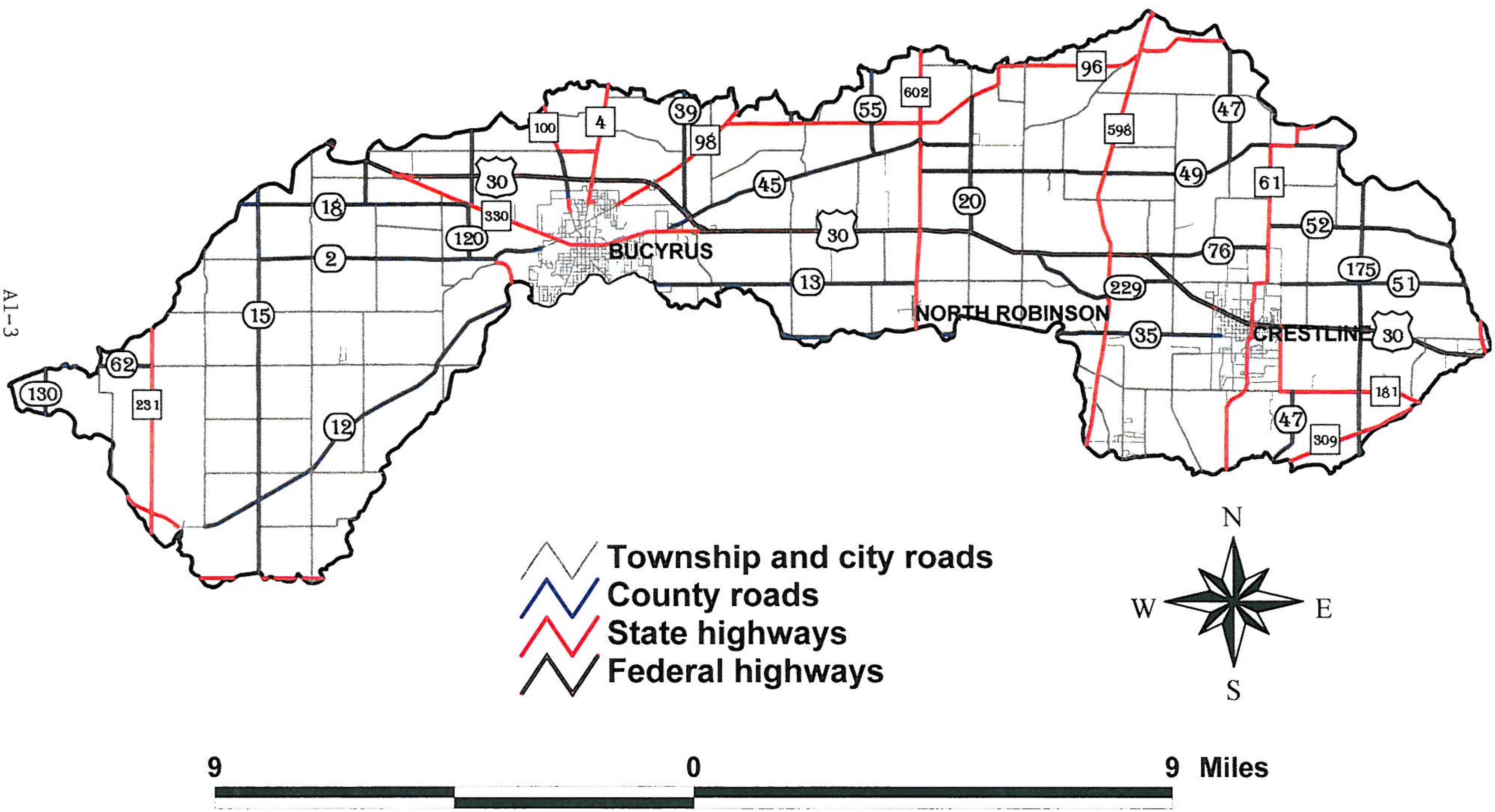
Aquatic Life Use Attainment		
Attainment Status	Sandusky-Bucyrus	Sandusky Watershed
Fully Attaining	18.5%	35.0%
Threatened	0.0%	0.5%
Partial Attainment	23.2%	23.3%
Not Attaining	58.4%	41.2%

Sandusky-Bucyrus
Hydrological Unit 04100011-020
Land Use in Relationship to Streams and Roads



Water Quality Laboratory Heidelberg College

Roads in the Sandusky-Bucyrus Subwatershed 020



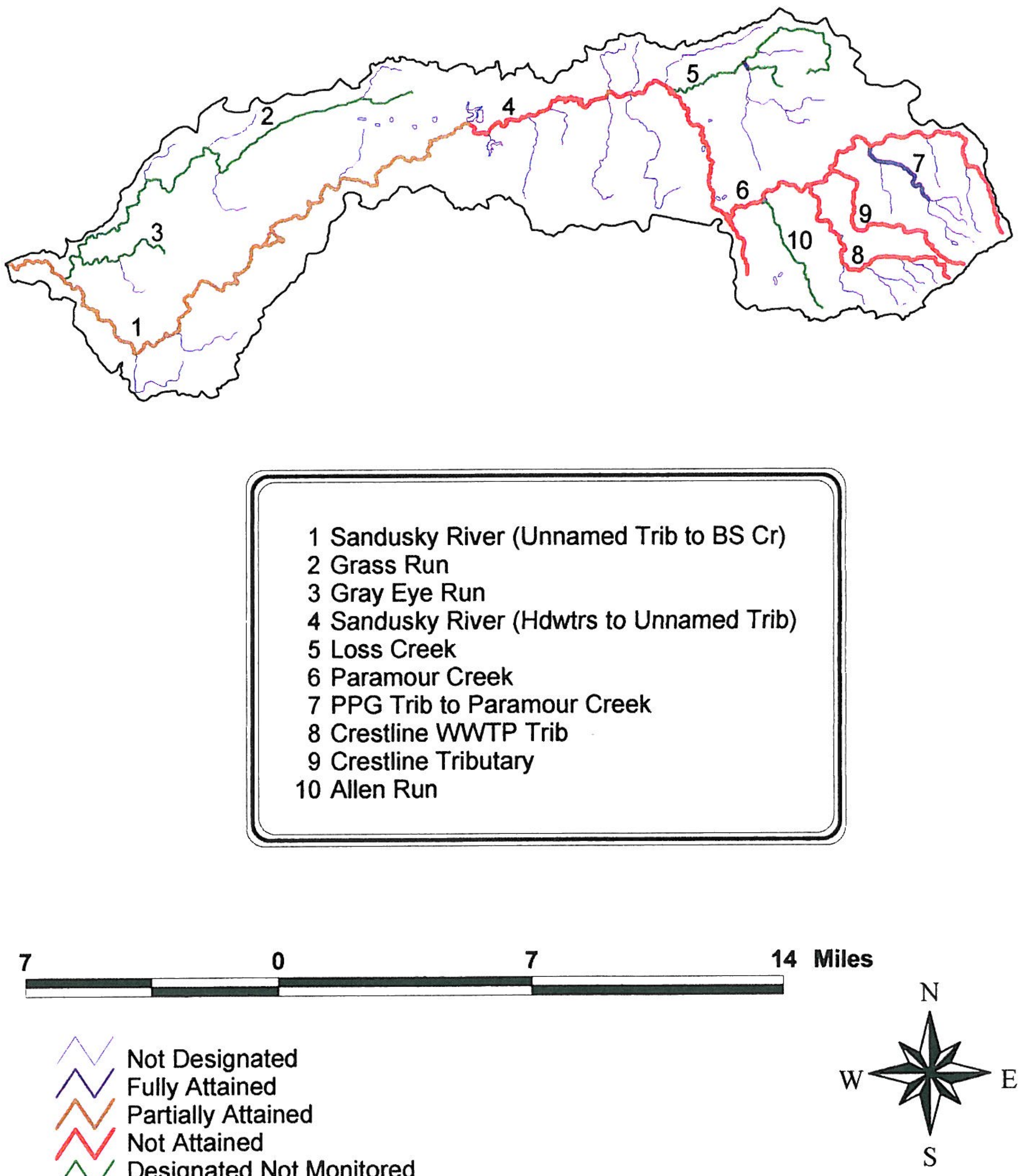
Summary of OEPA biological monitoring data for the Sandusky-Bucyrus subwatershed (-020).

Map Number	OEPA Segment Number	Segment Name	Segment Length	Drainage Area	Fully Attain.	Threat-ened	Partial Attain.	Not Attain-ing	Use Desig-nation	Year Moni-tored	Causes of Impair-ment	Sources of Impairment
	Number		miles	sq. miles	miles	miles	miles	miles	nation		ment	ment
1	OH80-17	Sandusky River (Unnamed Trib to Broken Sword Cr)	21.8	137.0	7.8	0	10.8	3.2	WWH	1990	1-H; 7-H; 8-S	3-H; 5-H; 7-M
2	OH80-18	Grass Run	13.4	23.1	0	0	0	0	WWH	none	NA	NA
3	OH80-19	Gray Eye Run	3.5	4.4	0	0	0	0	WWH	none	NA	NA
4	OH80-20	Sandusky River (Hdwtrs to Unnamed Tr)	13.6	78.0	0	0	3.4	10.2	WWH	1979	7-H; 1-M; 5-M	5-H; 7-H; 1-M; 8-S
5	OH80-21	Loss Creek	5.4	14.1	0	0	0	0	WWH	none	NA	NA
6	OH80-22	Paramour Creek	9.6	27.4	0	0	0.2	9.4	WWH	1985	3-H; 5-H; 7-H; 9-M; 1-M; 6-S	4-H; 5-H; 7-M; 1-M
7	OH80-22.1	PPG Trib. to Paramour Creek	5.3	4.0	3.7	0	0	1.6	WWH	1985	3-H; 1-M	1-H
8	OH80-23	Crestline WWTP Tributary	6.2	7.0	0	0	0	6.2	WWH	1985	7-H; 5-M; 9-M	6-H; 7-M; 10-H
9	OH80-24	Crestline Tributary	5.7	3.5	0	0	0	5.7	WWH	1985	6-H; 1-M; 3-M; 9-M	6-H; 7-H; 10-H; 4-M; 17-M
10	OH80-25	Allen Run	3.4	4.7	0	0	0	0	WWH	none	NA	NA
		Subwatershed Total	87.9		11.5	0	14.4	36.3				
		Percent of Assessed Miles			18.5%	0.0%	23.2%	58.4%				

Key to causes and sources of impairment

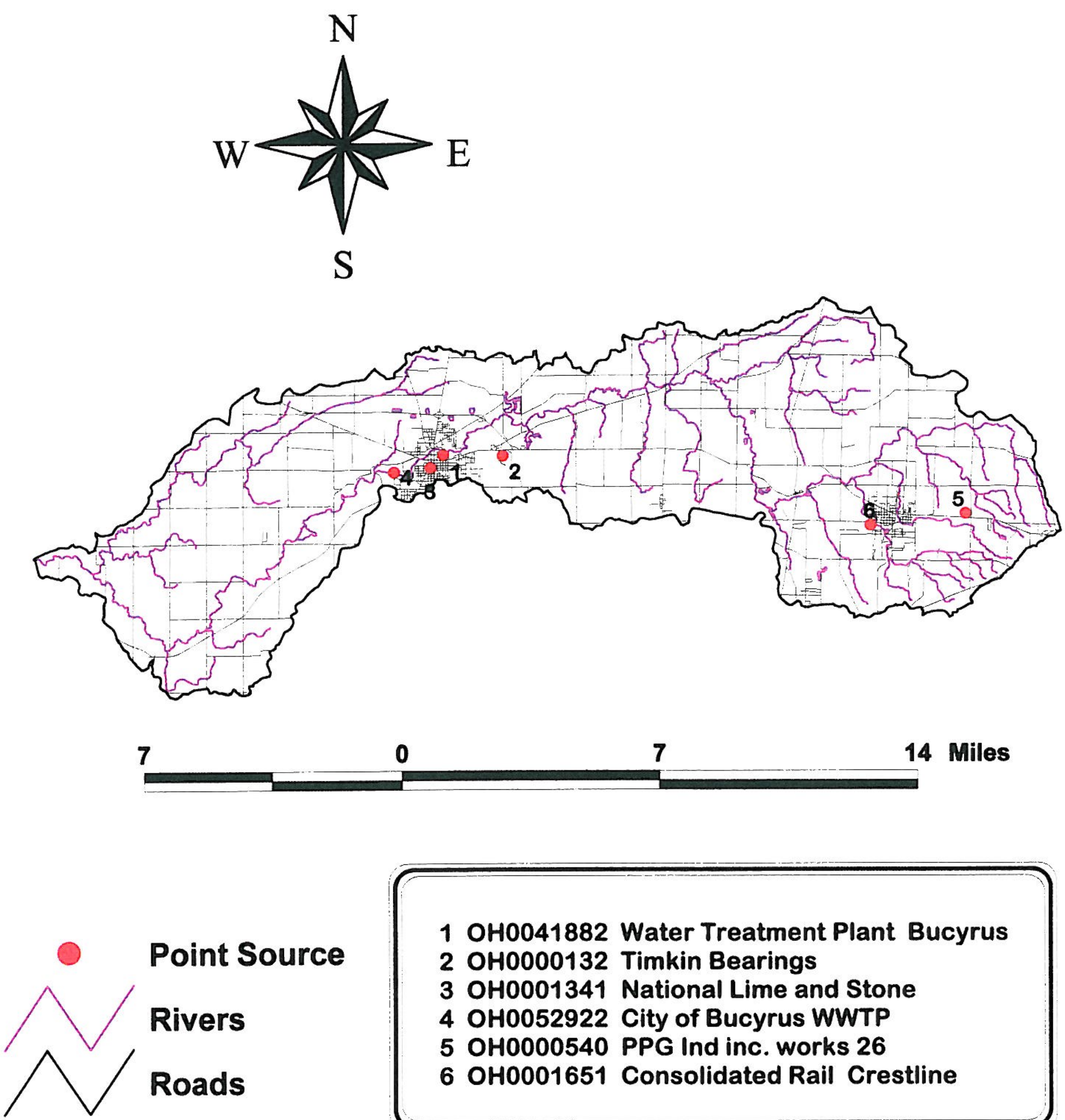
Causes of Impairment	Sources of Impairment	
1. Siltation	1. Nonirrigated Crop Production	10. Contaminated Sediments
2. Flow Alterations	2. Irrigated Crop Production	11. Upstream Impoundment
3. Other Habitat Alterations	3. Agriculture	12. Dam Construction
4. Nutrient Enrichment	4. Channelization	13. Removal of Riparian Vegetation
5. Unionized Ammonia	5. Municipal Point Sources	14. Other
6. Oil and Grease	6. Industrial Point Sources	15. Source Unknown
7. Organic Enrichment /DO	7. Urban Runoff/Storm Sewers	16. Natural
8. Priority Organics	8. Onsite Wastewater Systems	17. Stream Bank Modification/Destabilization
9. Metals	9. Flow Regulation/Modification	18. Combined Sewer Overflows
10. Cause Unknown		
11. Noxious Aquatic Weeds		
12. Unknown Toxicity		
H - High Impact; M - Moderate Impact; S - Slight Impact		

Sandusky, Bucyrus
Hydrological Unit 04100011-020
Use Attainment



Water Quality Laboratory Heidelberg College

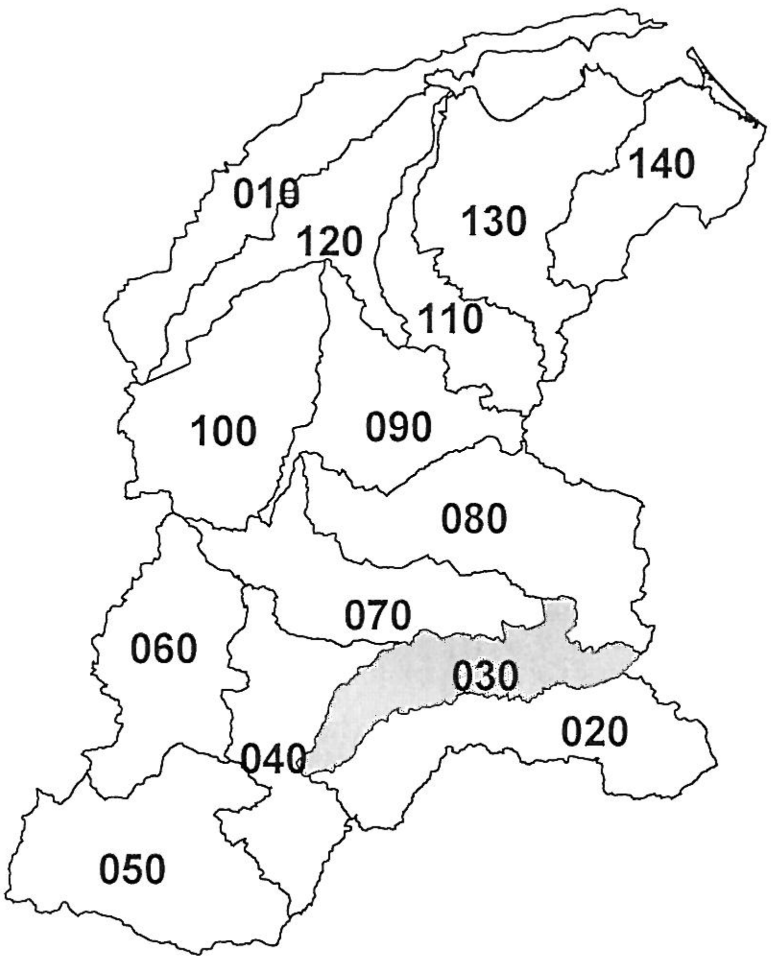
Sandusky-Bucyrus
Hydrological Unit 04100011-020
Point Sources



1 OH0041882 Water Treatment Plant Bucyrus
2 OH0000132 Timkin Bearings
3 OH0001341 National Lime and Stone
4 OH0052922 City of Bucyrus WWTP
5 OH0000540 PPG Ind inc. works 26
6 OH0001651 Consolidated Rail Crestline

Water Quality Laboratory Heidelberg College

Subwatershed: Broken Sword
Hydrological Unit Code 04100011-030
Broken Sword Creek

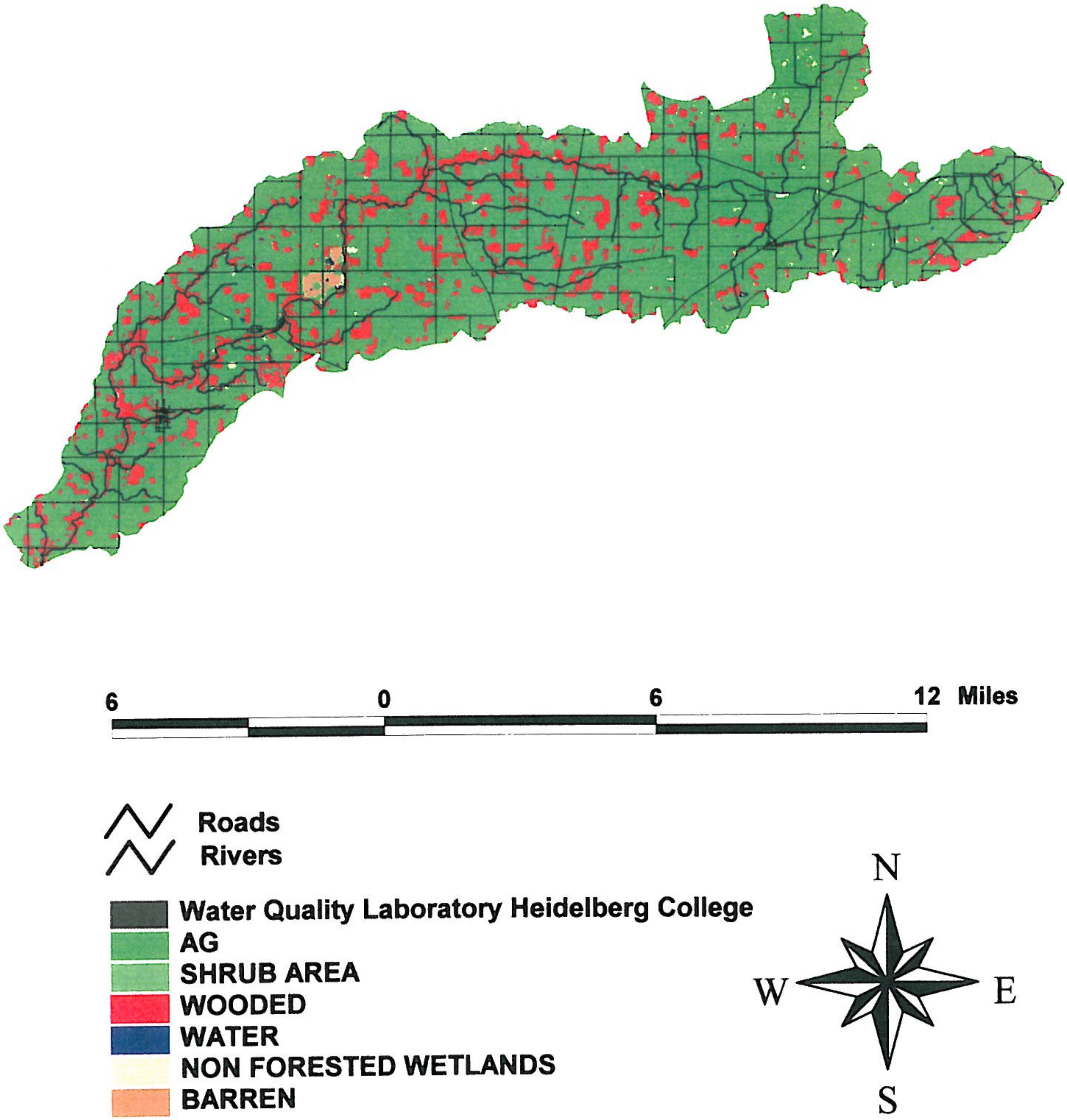


Subwatershed Characteristics
Area (square miles): 94.6
Area (acres): 60,545
Upstream Area (square miles): 0
Total Stream Miles: 110.5
Designated Warm Water Habitat (WWH) Miles: 47.7
Undesignated Stream Miles: 62.8
Counties: Crawford, Wyandot
Monitored WWH Stream Miles: 4.5
Percent Monitored: 9.0%
Community Water Supplies: 1
Cities and Towns (population) Nevada (889)

Land Use by Percent		
	Broken Sword	Sandusky Watershed
Agriculture	83.6%	84.0%
Wooded	14.5%	12.6%
Urban	0.1%	1.2%
Wetlands	0.9%	1.1%
Barren	0.4%	0.3%
Shrub	0.4%	0.5%%
Water	0.1%	0.4%

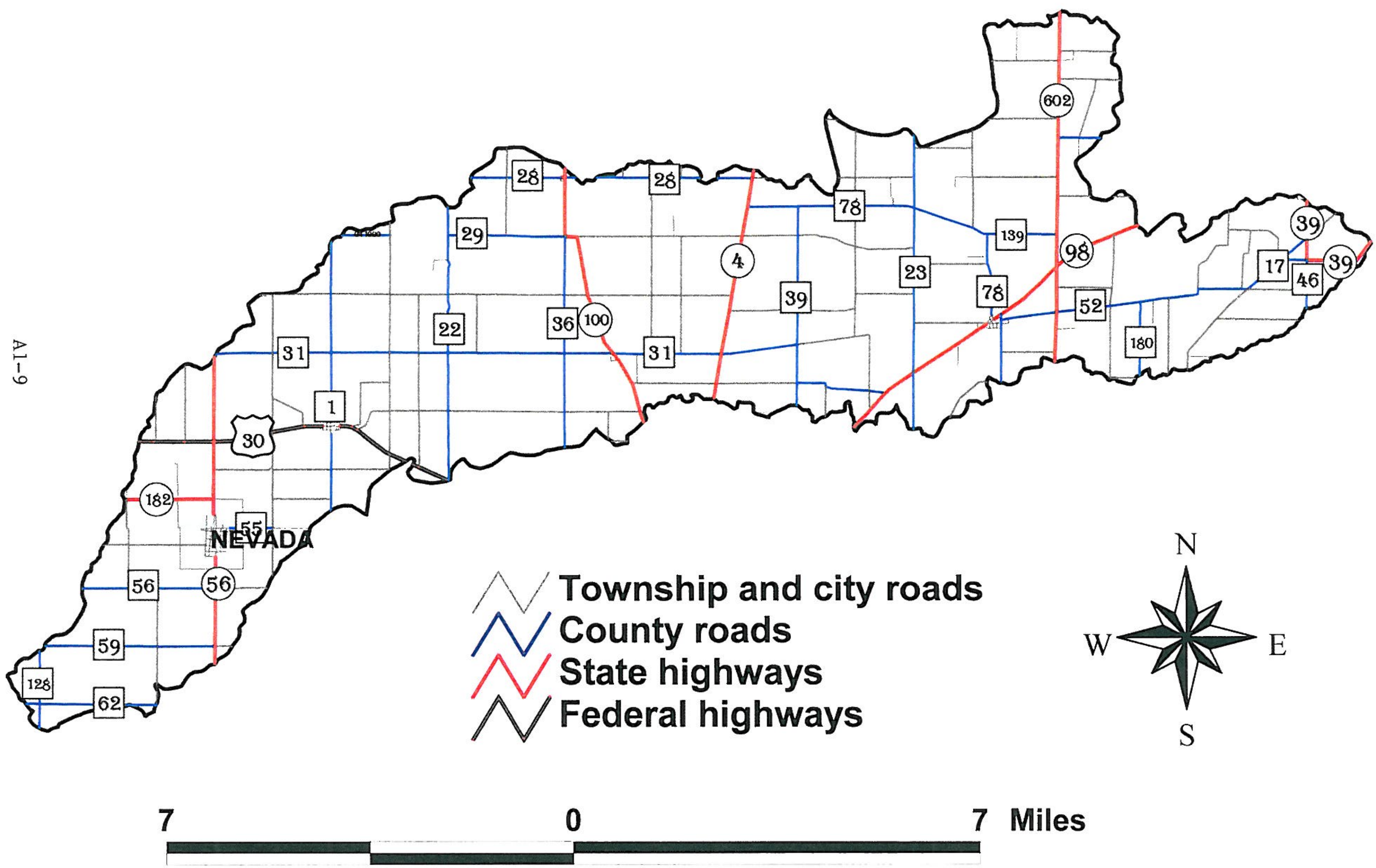
Aquatic Life Use Attainment		
Attainment Status	Broken sword	Sandusky Watershed
Fully Attaining	44.4%	35.0%
Threatened	0.0%	0.5%
Partial Attainment	0.0%	23.3%
Not Attaining	55.6%	41.2%

Broken Sword
Hydrological Unit 04100011-030
Land Use in Relationship to Streams and Roads



Water Quality Laboratory Heidelberg College

Roads in the Broken Sword Subwatershed 030



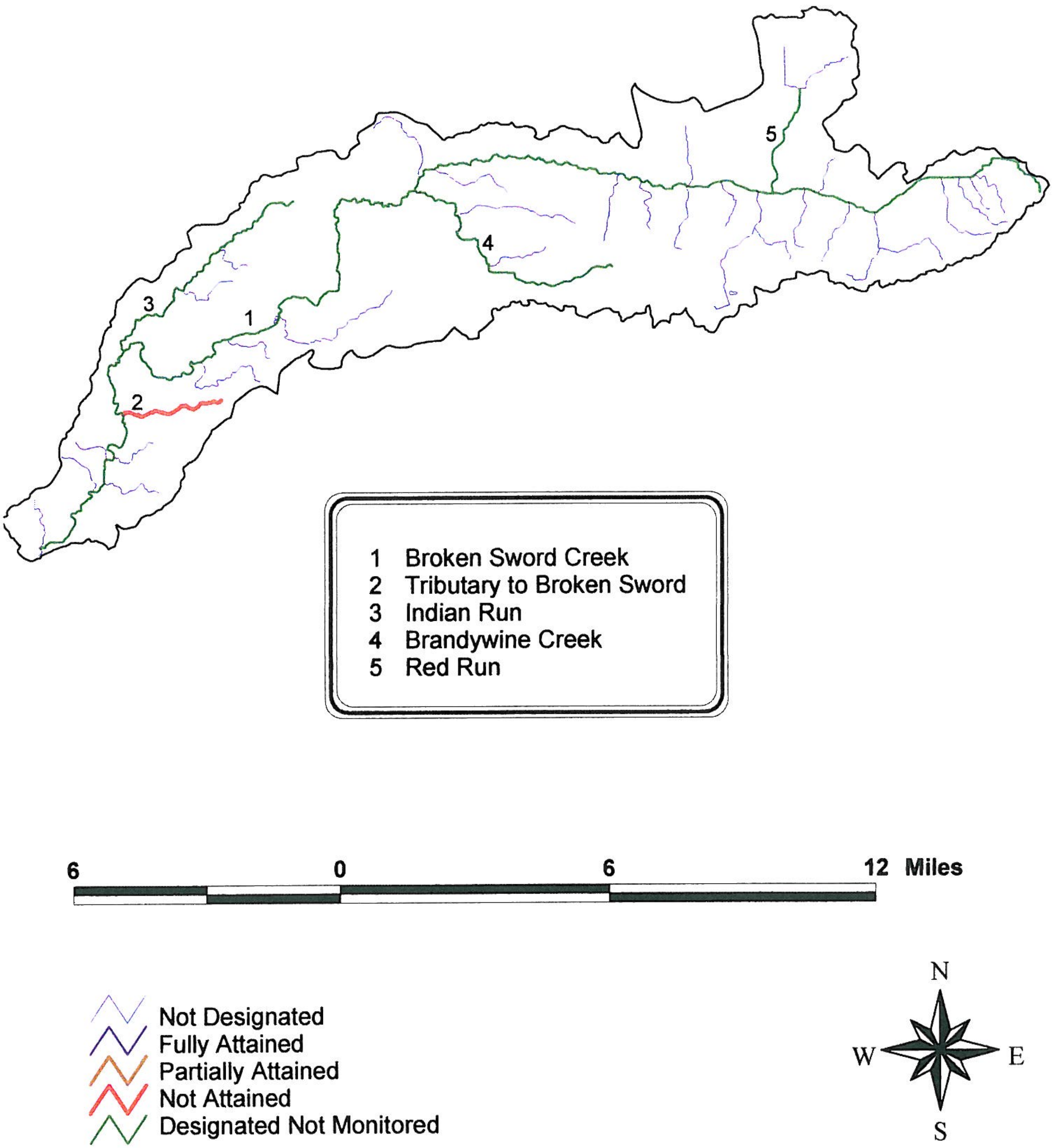
Summary of OEPA biological monitoring data for the Broken Sword subwatershed (-030).

Map Number	OEPA Segment Number	Segment Name	Segment Length	Drainage Area	Fully Attain.	Threat-ened	Partial Attain.	Not Attain-ing	Use Desig-nation	Year Moni-tored	Causes of Impair-ment	Sources of Impair-ment
			miles	sq. miles	miles	miles	miles	miles				
1	OH80-13	Broken Sword Creek	32.0	90.6	2	0	0	0	WWH	1990	None Identified	None Identified
2	OH80-13.1	Trib to Broken Sword Cr (Nevada)	2.5	1.0	0	0	0	2.5	none	1986	7-H	15-H
3	OH80-14	Indian Run	4.7	8.1	0	0	0	0	WWH	none	NA	NA
4	OH80-15	Brandywine Creek	6.1	11.3	0	0	0	0	WWH	none	NA	NA
5	OH80-16	Red Run	4.9	4.8	0	0	0	0	WWH	none	NA	NA
		Subwatershed Total	50.2		2	0	0	2.5				
		Percent of Assessed Miles			44.4%	0.0%	0.0%	55.6%				

Key to causes and sources of impairment

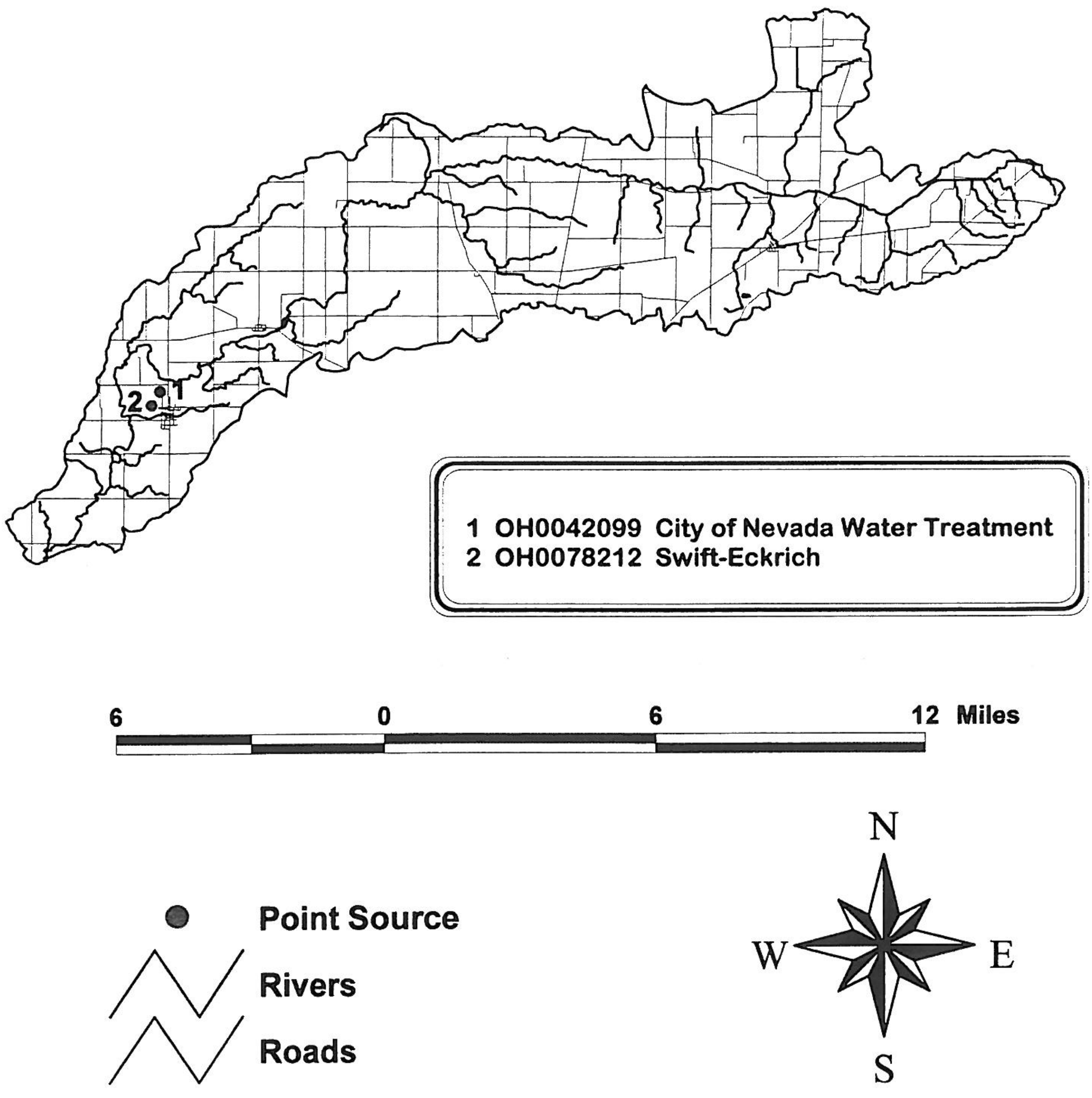
Causes of Impairment	Sources of Impairment	
1. Siltation	1. Nonirrigated Crop Production	10. Contaminated Sediments
2. Flow Alterations	2. Irrigated Crop Production	11. Upstream Impoundment
3. Other Habitat Alterations	3. Agriculture	12. Dam Construction
4. Nutrient Enrichment	4. Channelization	13. Removal of Riparian Vegetation
5. Unionized Ammonia	5. Municipal Point Sources	14. Other
6. Oil and Grease	6. Industrial Point Sources	15. Source Unknown
7. Organic Enrichment /DO	7. Urban Runoff/Storm Sewers	16. Natural
8. Priority Organics	8. Onsite Wastewater Systems	17. Stream Bank Modification/Destabilization
9. Metals	9. Flow Regulation/Modification	18. Combined Sewer Overflows
10. Cause Unknown		
11. Noxious Aquatic Weeds		
12. Unknown Toxicity		
H - High Impact; M - Moderate Impact; S - Slight Impact		

Broken Sword Creek
Hydrological Unit 04100011-030
Use Attainment



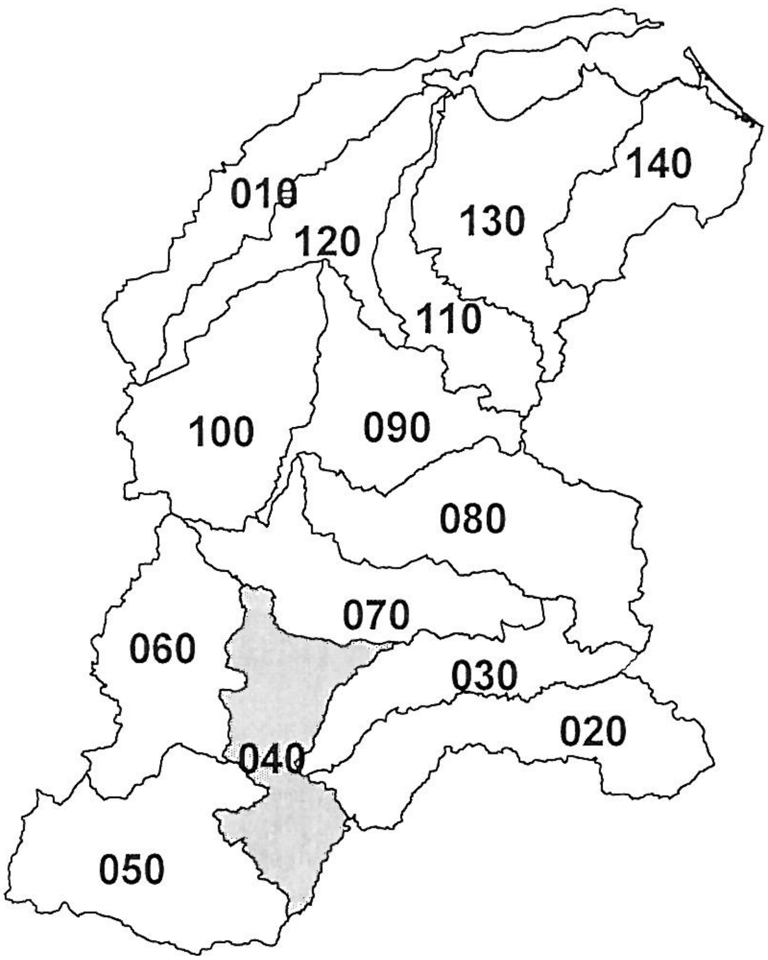
Water Quality Laboratory Heidelberg College

Broken Sword
Hydrological Unit 04100011-030
Point Sources



Water Quality Laboratory Heidelberg College

Subwatershed: Sandusky – Upper Sand
Hydrological Unit Code 04100011-040
Sandusky River (below Broken Sword Creek to above Tymochtee Creek)



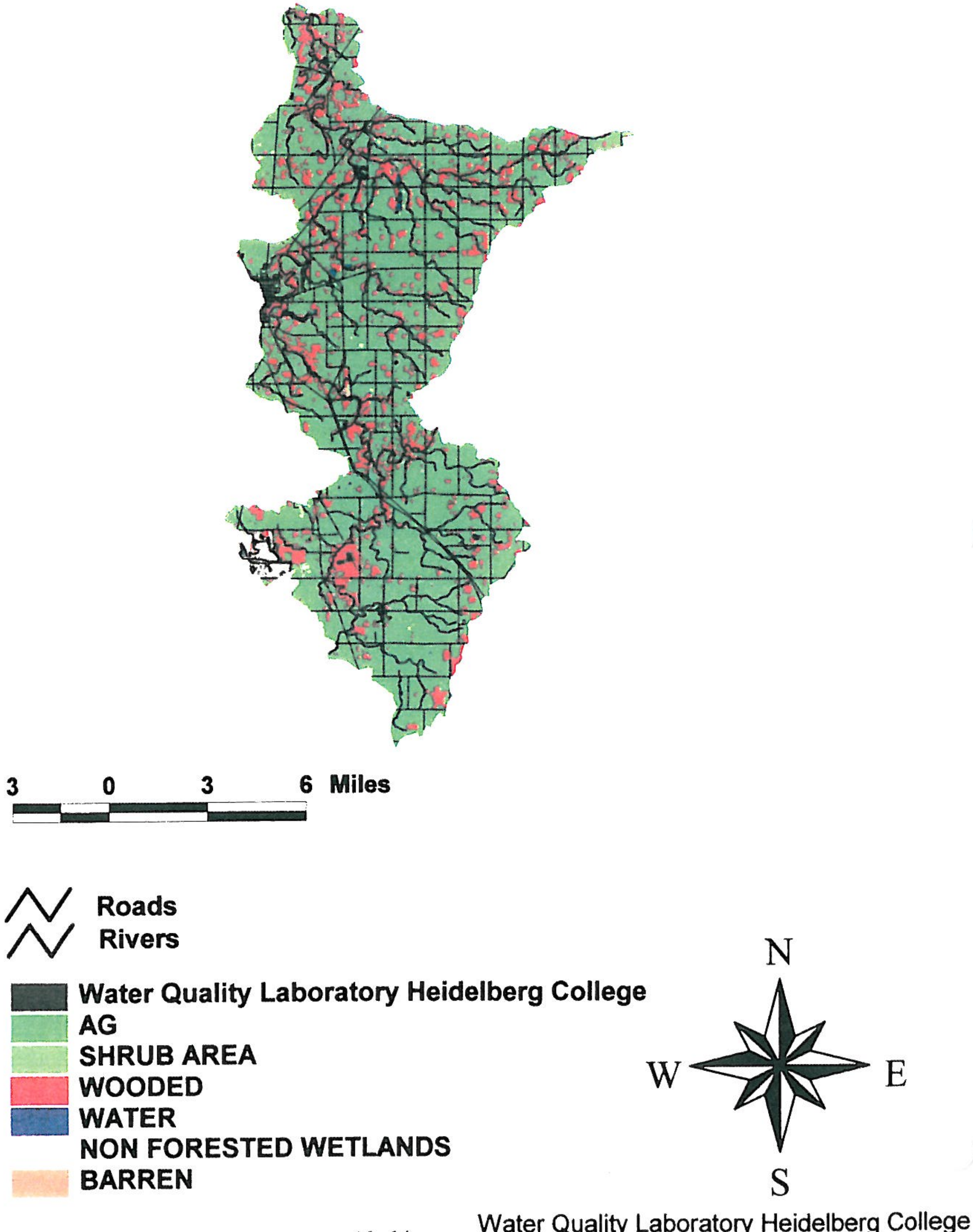
Subwatershed Characteristics
Area (square miles): 121.4
Area (acres): 77,693
Upstream Area (square miles): 232.0
Total Stream Miles: 199.3
Designated Warm Water Habitat (WWH) Miles: 80.1 (MWH) Miles: 4.6
Undesignated Stream Miles: 114.6
Counties: Marion, Wyandot, Crawford
Monitored WWH Stream Miles: 46.7
Percent Monitored: 55.1%
Community Water Supplies: 1
Cities and Towns (population) Upper Sandusky (6,148)

Scenic River from Harrison - Smith Park in Wyandot Co.

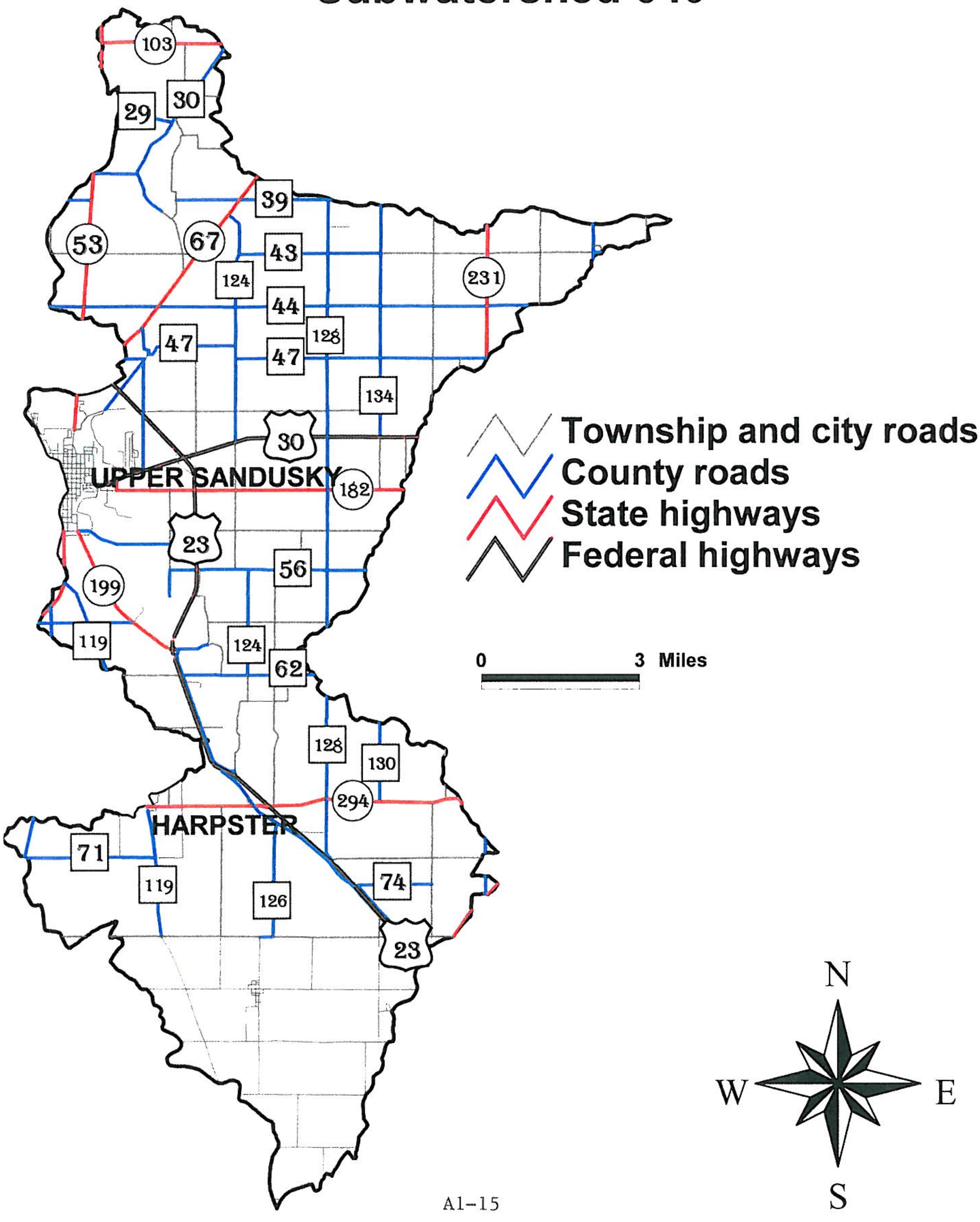
Land Use by Percent		
	Sandusky-Upper Sand	Sandusky Watershed
Agriculture	80.5%	84.0%
Wooded	15.8%	12.6%
Urban	0.5%	1.2%
Wetlands	1.7%	1.1%
Barren	0.1%	0.3%
Shrub	0.9%	0.5%%
Water	0.5%	0.4%

Aquatic Life Use Attainment		
Attainment Status	Sandusky-Upper Sand	Sandusky Watershed
Fully Attaining	4.3%	35.0%
Threatened	0.0%	0.5%
Partial Attainment	54.2%	23.3%
Not Attaining	41.5%	41.2%

Sandusky-Upper Sand
Hydrological Unit 04100011-040
Land Use in Relationship to Streams and Roads



Roads in the Sandusky-Upper Sandusky Subwatershed 040



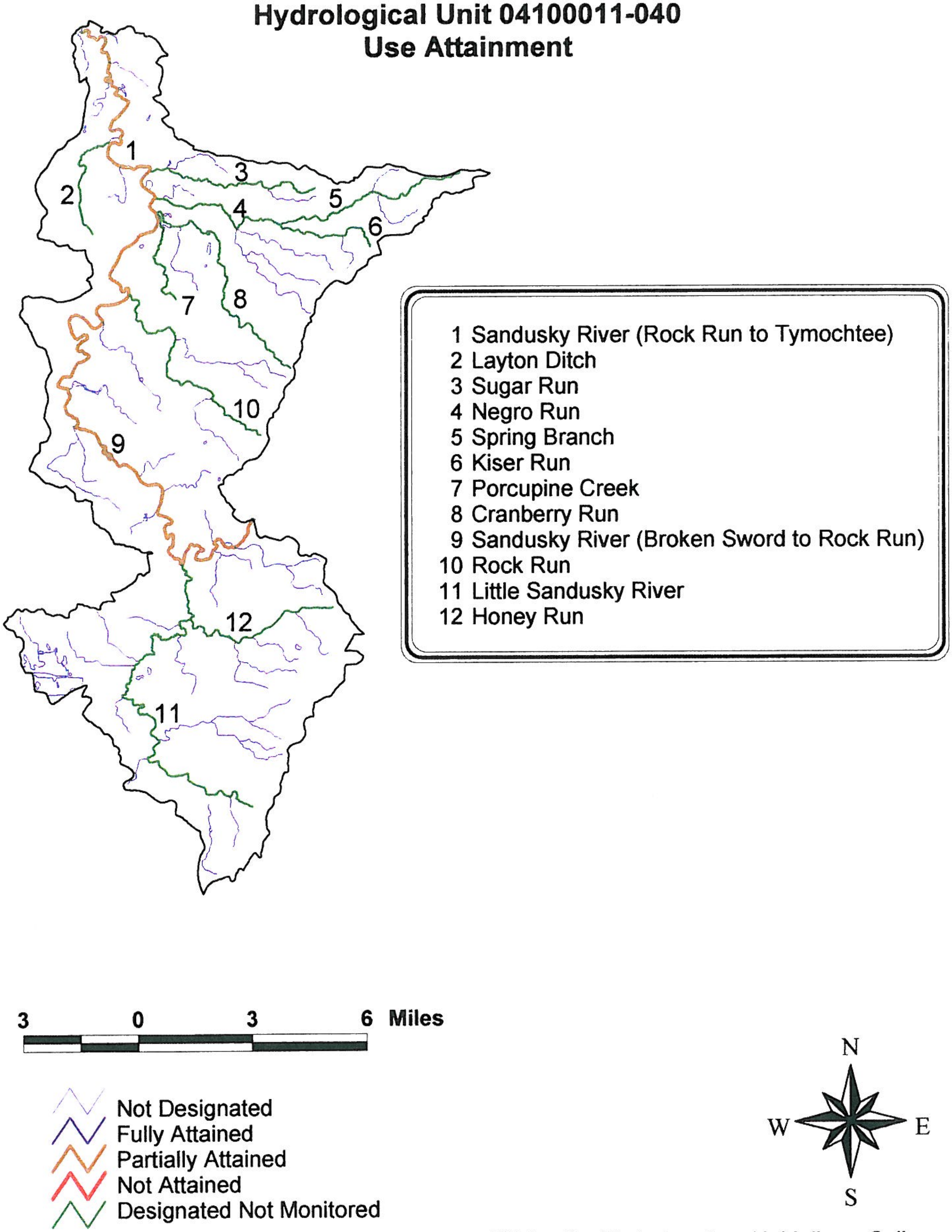
Summary of OEPA biological monitoring data for the Sandusky- Upper Sand Subwatershed (-040).

Map Number	OEPA Segment Number	Segment Name	Segment Length	Drainage Area	Fully Attain.	Threat-ened	Partial Attain.	Not Attain-ing	Use Desig-nation	Year Moni-tored	Causes of Impair-ment	Sources of Impair-ment
	Number		miles	sq. miles	miles	miles	miles	miles				
1	OH80-1	Sandusky River (Rock Run to Tym Cr)	11.7	353.0	0	0	11.7	0	WWH	1990	1-H	3-H
2	OH80-2	Layton Ditch	3.6	3.8	0	0	0	0	WWH	none	NA	NA
3	OH80-3	Sugar Run	5.5	5.4	0	0	0	0	WWH	none	NA	NA
4	OH80-4	Negro Run	4.1	13.8	2	0	0	0	WWH	1990		
5	OH80-5	Spring Branch	4.8	4.9	0	0	0	0	WWH	none	NA	
6	OH80-6	Kiser Run	2.0	1.5	0	0	0	0	WWH	none	NA	
7	OH80-7	Porcupine Creek	3.0	8.4	0	0	0	0	WWH	none	NA	
8	OH80-8	Cranberry Run	4.8	6.6	0	0	0	0	WWH	none	NA	
9	OH80-9	Sandusky River (Broken Sw to Rock R)	17.1	299.0	0	0	11.6	5.5	WWH	1990	1-H; 7-M; 5-S	3-H; 5-M
10	OH80-10	Rock Run	7.0	10.7	0	0	2	0	WWH	1990	1-H	3-H
11	OH80-11	Little Sandusky River	12.5	40.0	0	0	0	9.3	WWH	1995	7-H; 1-H; 11-M	4-H; 1-H
	OH80-11.1	Trib to Little Sandusky R (RM 8.93)	4.6	7.4	0	0	0	4.63	MWH-C	1995	1-H; 7-H; 3-H	1-H; 4-H; 13-H
12	OH80-12	Honey Run	4.0	8.5	0	0	0	0	WWH	none	NA	
		Subwatershed Total	84.7		2	0	25.3	19.4				
		Percent of Assessed Miles			4.3%	0.0%	54.2%	41.5%				

Key to causes and sources of impairment

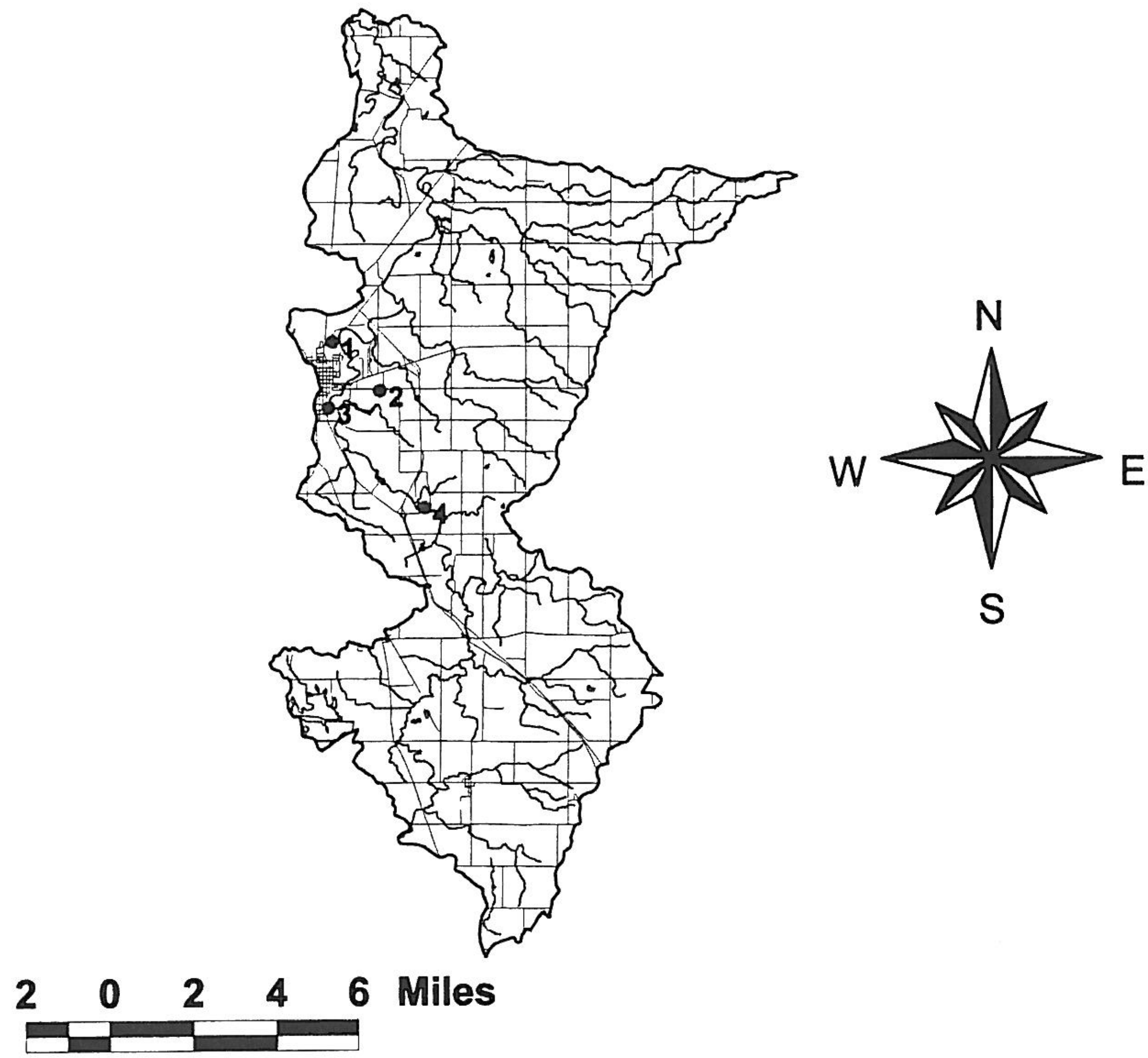
Causes of Impairment	Sources of Impairment	
1. Siltation	1. Nonirrigated Crop Production	10. Contaminated Sediments
2. Flow Alterations	2. Irrigated Crop Production	11. Upstream Impoundment
3. Other Habitat Alterations	3. Agriculture	12. Dam Construction
4. Nutrient Enrichment	4. Channelization	13. Removal of Riparian Vegetation
5. Unionized Ammonia	5. Municipal Point Sources	14. Other
6. Oil and Grease	6. Industrial Point Sources	15. Source Unknown
7. Organic Enrichment /DO	7. Urban Runoff/Storm Sewers	16. Natural
8. Priority Organics	8. Onsite Wastewater Systems	17. Stream Bank Modification/Destabilization
9. Metals	9. Flow Regulation/Modification	18. Combined Sewer Overflows
10. Cause Unknown		
11. Noxious Aquatic Weeds		
12. Unknown Toxicity		
H - High Impact; M - Moderate Impact; S - Slight Impact		

Sandusky, Upper Sandusky
Hydrological Unit 04100011-040
Use Attainment



Water Quality Laboratory Heidelberg College

Sandusky -Upper Sand
Hydrological Unit 04100011-040
Point Sources



Point Source

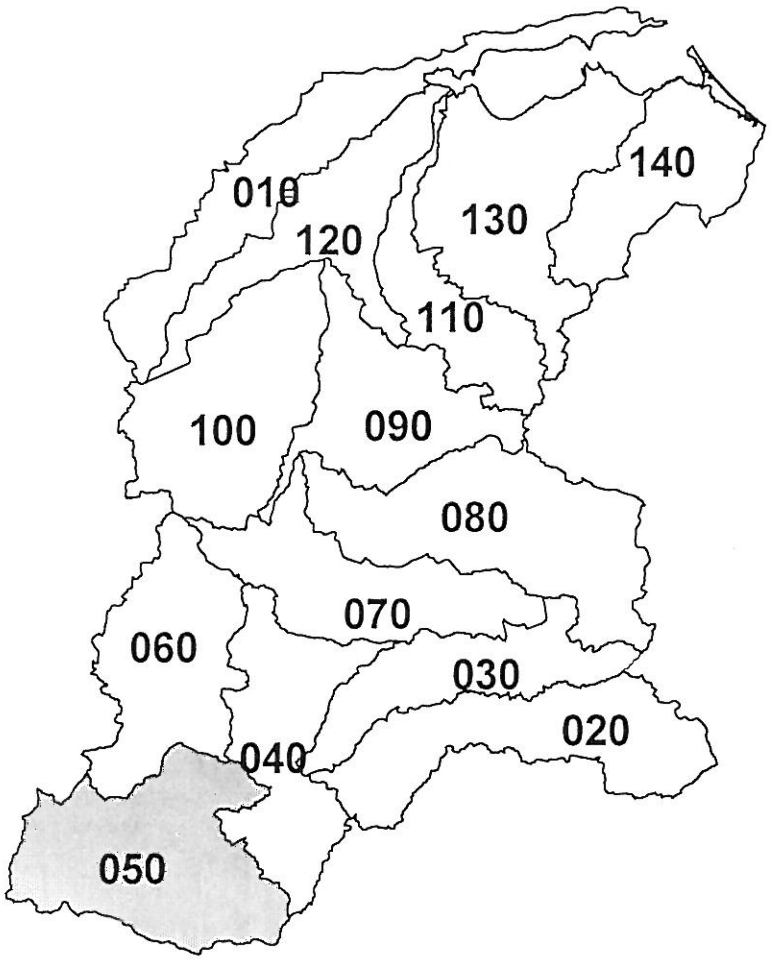
Rivers

Roads

1 OH0020001 Upper Sandusky WWTP
2 OH0054143 Liqui-Box Corp
3 OH0031534 City of Upper Sandusky
4 OH0058360 Charles H McCarthy Quarry

Water Quality Laboratory Heidelberg College

Subwatershed: Tymochtee -headwaters
Hydrological Unit Code 04100011-050
Tymochtee Creek (headwaters to below Warpole Creek)

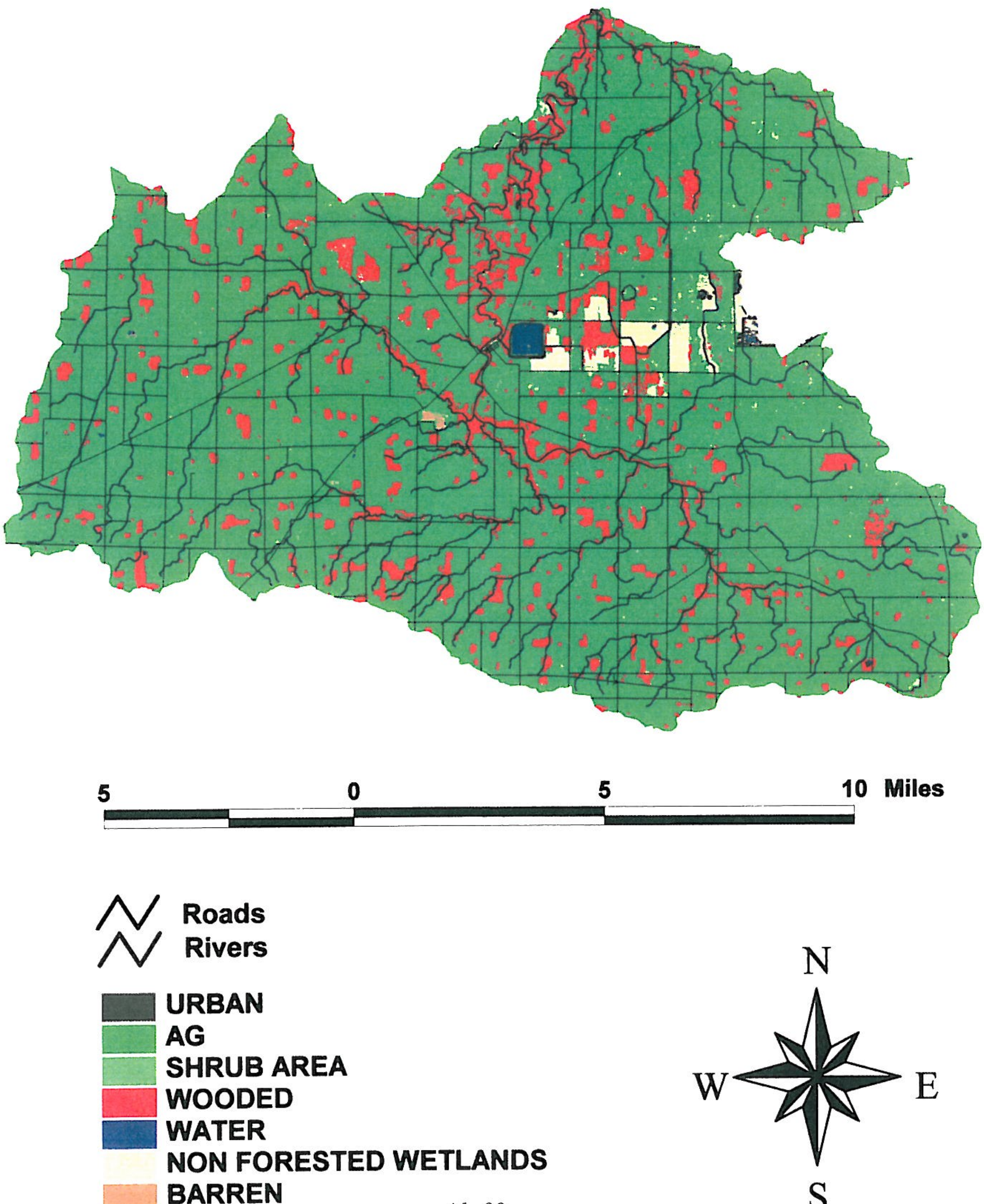


Subwatershed Characteristics
Area (square miles): 171.7
Area (acres): 109,857
Upstream Area (square miles): 0
Total Stream Miles: 255.9
Designated Warm Water Habitat (WWH) Miles: 94.3
Undesignated Stream Miles: 166.0
Counties: Hardin, Marion, Wyandot
Monitored WWH Stream Miles: 46.5
Percent Monitored: 49.3%
Community Water Supplies: 0
Cities and Towns (population) Marseilles (132) Harpster (236)

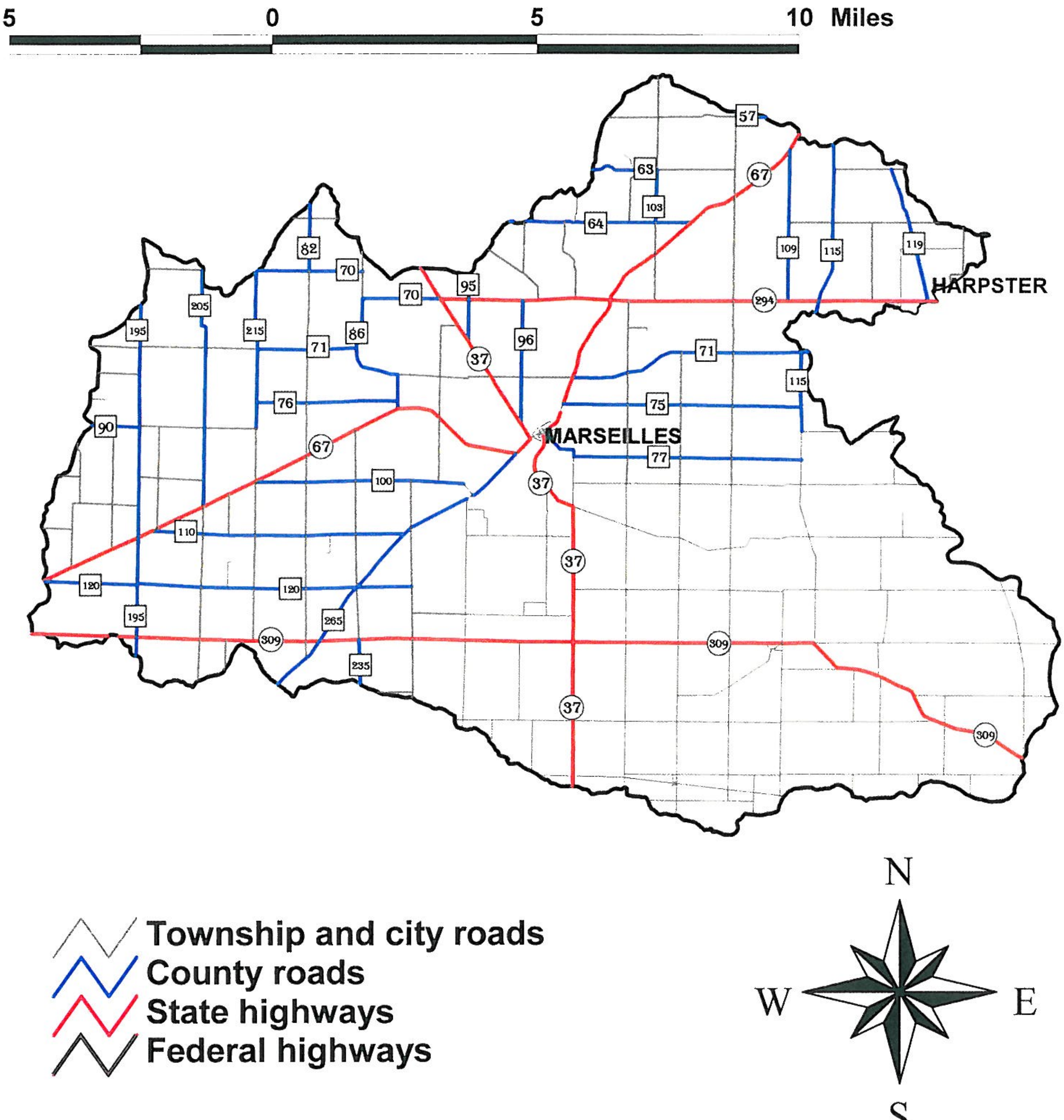
Land Use by Percent		
	Tymochtee headwaters	Sandusky Watershed
Agriculture	86.4%	84.0%
Wooded	10.5%	12.6%
Urban	0.1%	1.2%
Wetlands	1.9%	1.1%
Barren	0.1%	0.3%
Shrub	0.8%	0.5%%
Water	0.3%	0.4%

Aquatic Life Use Attainment		
Attainment Status	Tymoch-tee -head-waters	Sandusky Watershed
Fully Attaining	0%	35.0%
Threatened	0.0%	0.5%
Partial Attainment	0%	23.3%
Not Attaining	100%	41.2%

Tymochtee Creek-headwaters
Hydrological Unit 04100011-050
Land Use in Relationship to Streams and Roads



Roads in the Tymochtee-headwaters Subwatershed 050



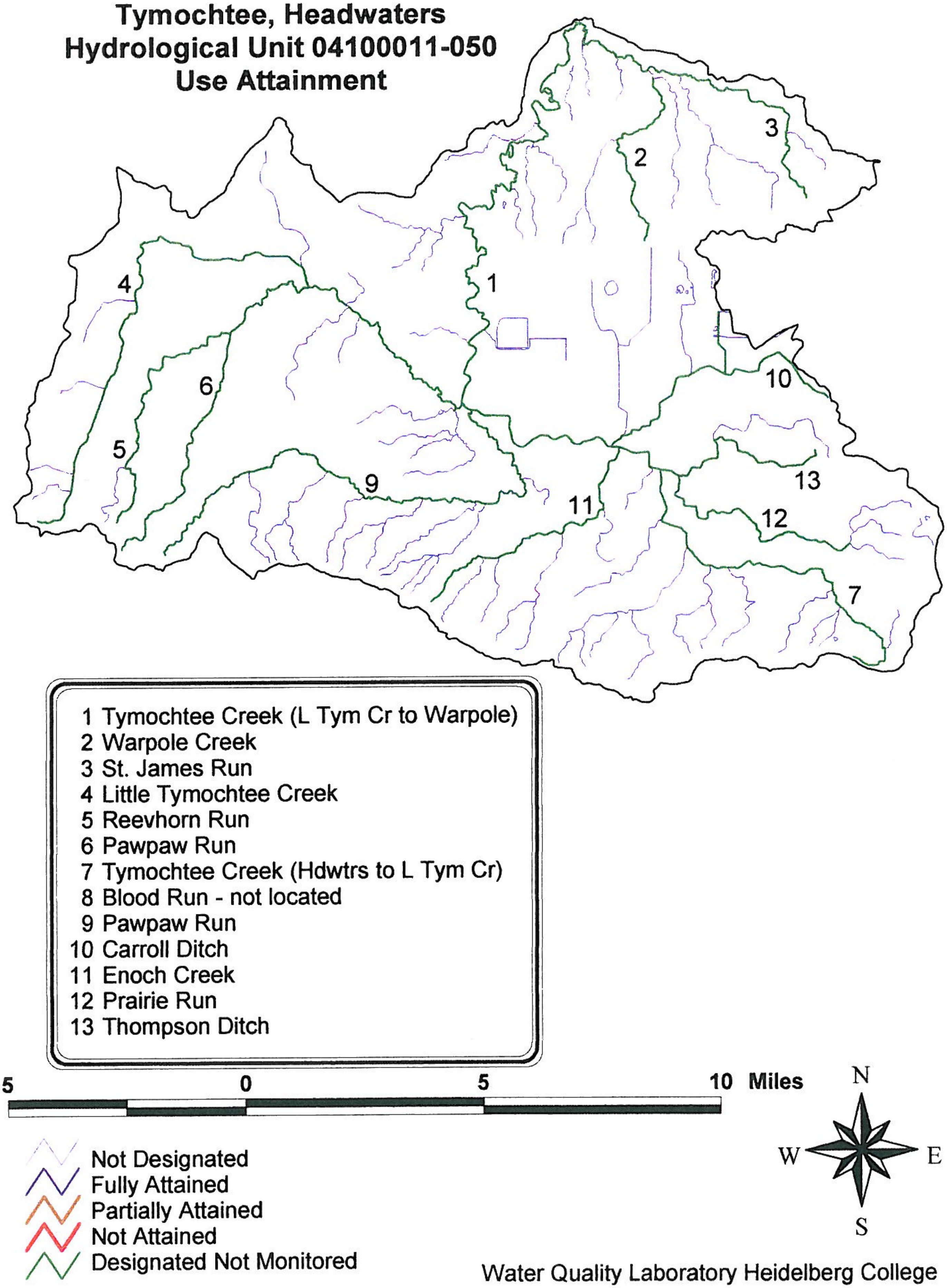
Summary of OEPA biological monitoring data for the Tymochtee-Headwaters subwatershed (-050).

Map Number	OEPA Segment Number	Segment Name	Segment Length	Drainage Area	Fully Attain.	Threat-ened	Partial Attain.	Not Attain-ing	Use Desig-nation	Year Moni-tored	Causes of Impair-ment	Sources of Impair-ment
			miles	sq. miles	miles	miles	miles	miles				
1	OH79-16	Tymochtee Creek (L Tym Cr to Warpole)	15.56	151	0	0	0	4.4	WWH	1995	4-M; 9-H	3-H
2	OH79-17	Warpole Creek	6.1	21.2	0	0	0	0	WWH	none	NA	NA
3	OH79-18	St. James Run	4.4	5.9	0	0	0	0	WWH	none	NA	NA
4	OH79-19	Little Tymochtee Creek (RM 42.30)	12.5	48.2	0	0	0	0	WWH	none	NA	NA
5	OH79-20	Reevhorn Run	8.1	14.3	0	0	0	0	WWH	none	NA	NA
6	OH79-21	Pawpaw Run	5.5	7	0	0	0	0	WWH	none	NA	NA
7	OH79-22	Tymochtee Creek (Hdwtrs to L Tym Cr)	12.5	80.4	0	0	0	12.5	WWH	1995	3-H; 4-M	1-H;4-H; 8-S
8	OH79-22.1	Blood Run	4.44	5	0	0	0	4.44	none	1995	10-H	15-H
9	OH79-23	Pawpaw Run	7.4	17.4	0	0	0	7.4	WWH	1995	1-H; 4-M	1-H; 4-H; 16-M
10	OH79-24	Carroll Ditch	3.6	13.6	0	0	0	3.6	WWH	1995	3-H	4-H; 13-H; 16-M
11	OH79-25	Enoch Creek	2.9	8.8	0	0	0	2.9	WWH	1995	4-H	1-H;16-M
12	OH79-26	Prairie Run	7.1	14.2	0	0	0	7.1	WWH	1995	1-H; 4-M; 3-H	1-H; 4-H; 13-H
13	OH79-27	Thompson Ditch	4.2	7	0	0	0	4.2	WWH	1995	3-H; 4-M	4-H; 16-M
		Subwatershed Total	94.3		0	0	0	46.5				
		Percentof Assessed Miles			0%	0%	0%	100%				

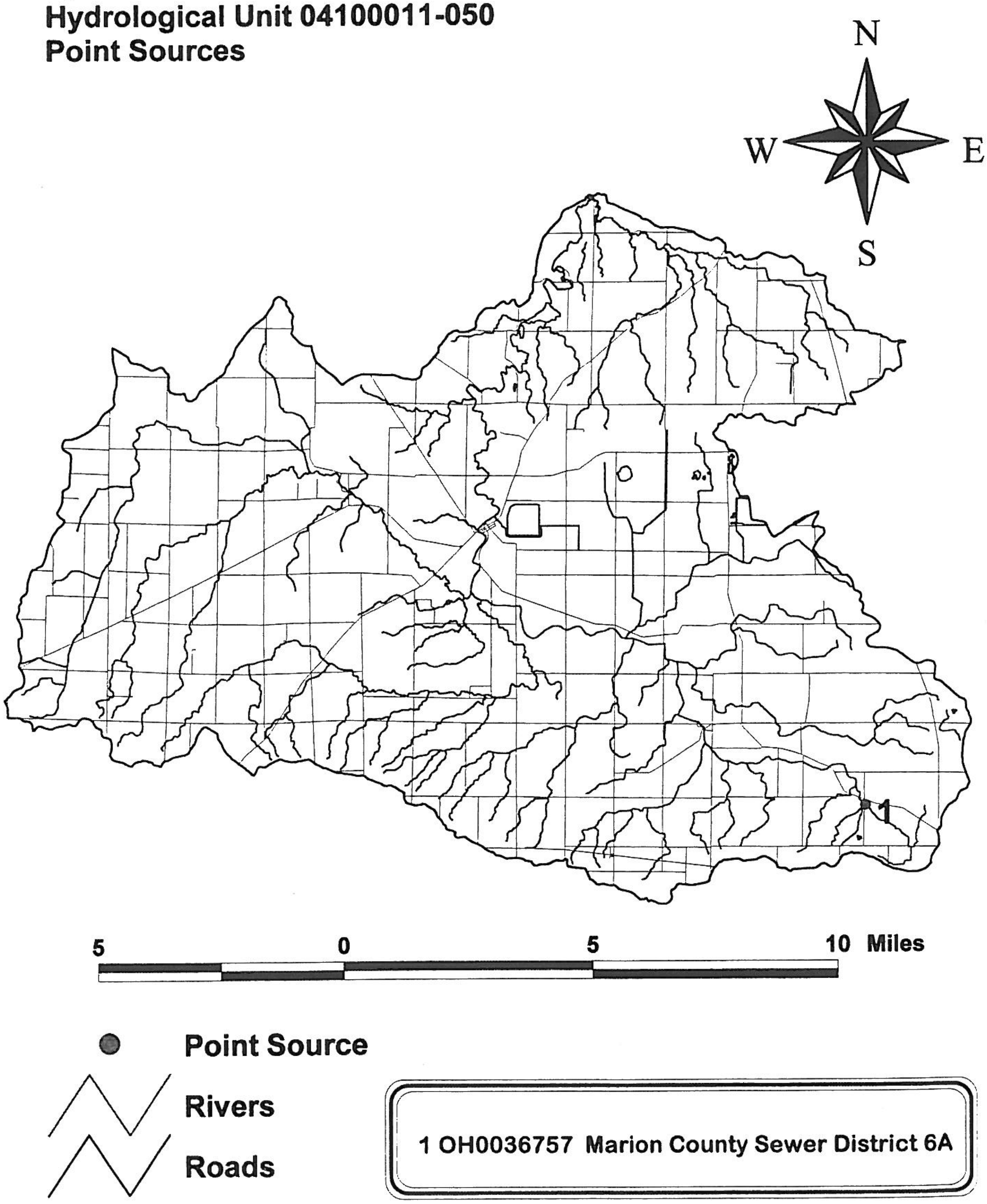
Key to causes and sources of impairment

Causes of Impairment	Sources of Impairment	
1. Siltation	1. Nonirrigated Crop Production	10. Contaminated Sediments
2. Flow Alterations	2. Irrigated Crop Production	11. Upstream Impoundment
3. Other Habitat Alterations	3. Agriculture	12. Dam Construction
4. Nutrient Enrichment	4. Channelization	13. Removal of Riparian Vegetation
5. Unionized Ammonia	5. Municipal Point Sources	14. Other
6. Oil and Grease	6. Industrial Point Sources	15. Source Unknown
7. Organic Enrichment /DO	7. Urban Runoff/Storm Sewers	16. Natural
8. Priority Organics	8. Onsite Wastewater Systems	17. Stream Bank Modification/Destabilization
9. Metals	9. Flow Regulation/Modification	18. Combined Sewer Overflows
10. Cause Unknown		
11. Noxious Aquatic Weeds		
12. Unknown Toxicity		
H - High Impact; M - Moderate Impact; S - Slight Impact		

Tymochtee, Headwaters
Hydrological Unit 04100011-050
Use Attainment

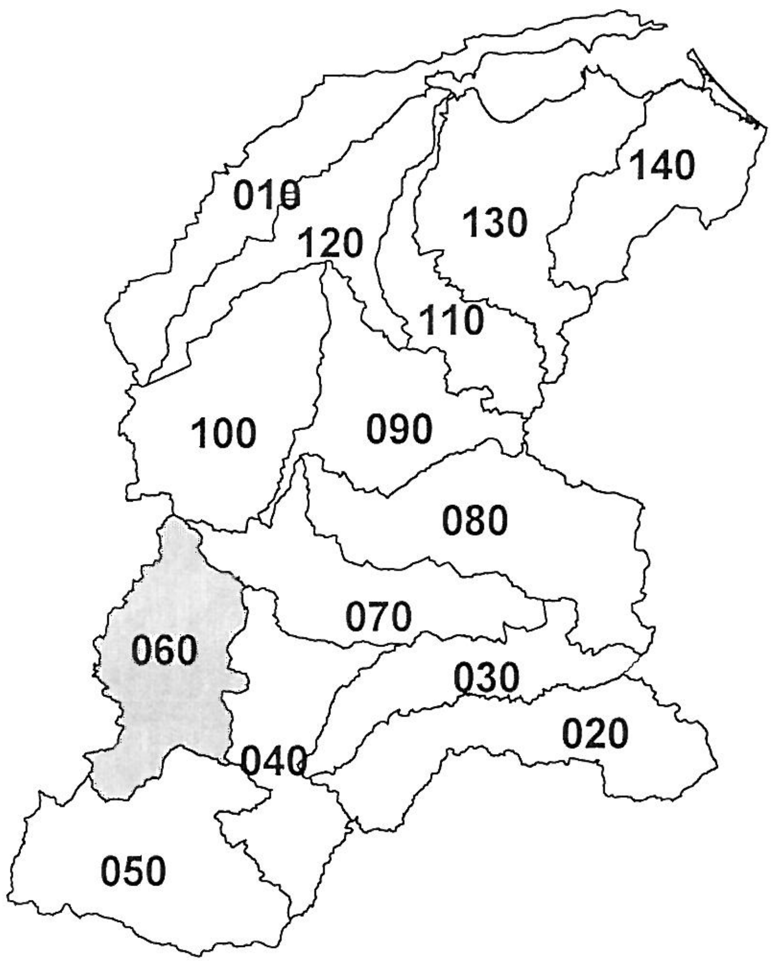


Tymochtee Creek-headwaters
Hydrological Unit 04100011-050
Point Sources



Water Quality Laboratory Heidelberg College

Subwatershed: Tymochtee-lower
Hydrological Unit Code 04100011-060
Tymochtee Creek (below Warpole Creek to Sandusky River)

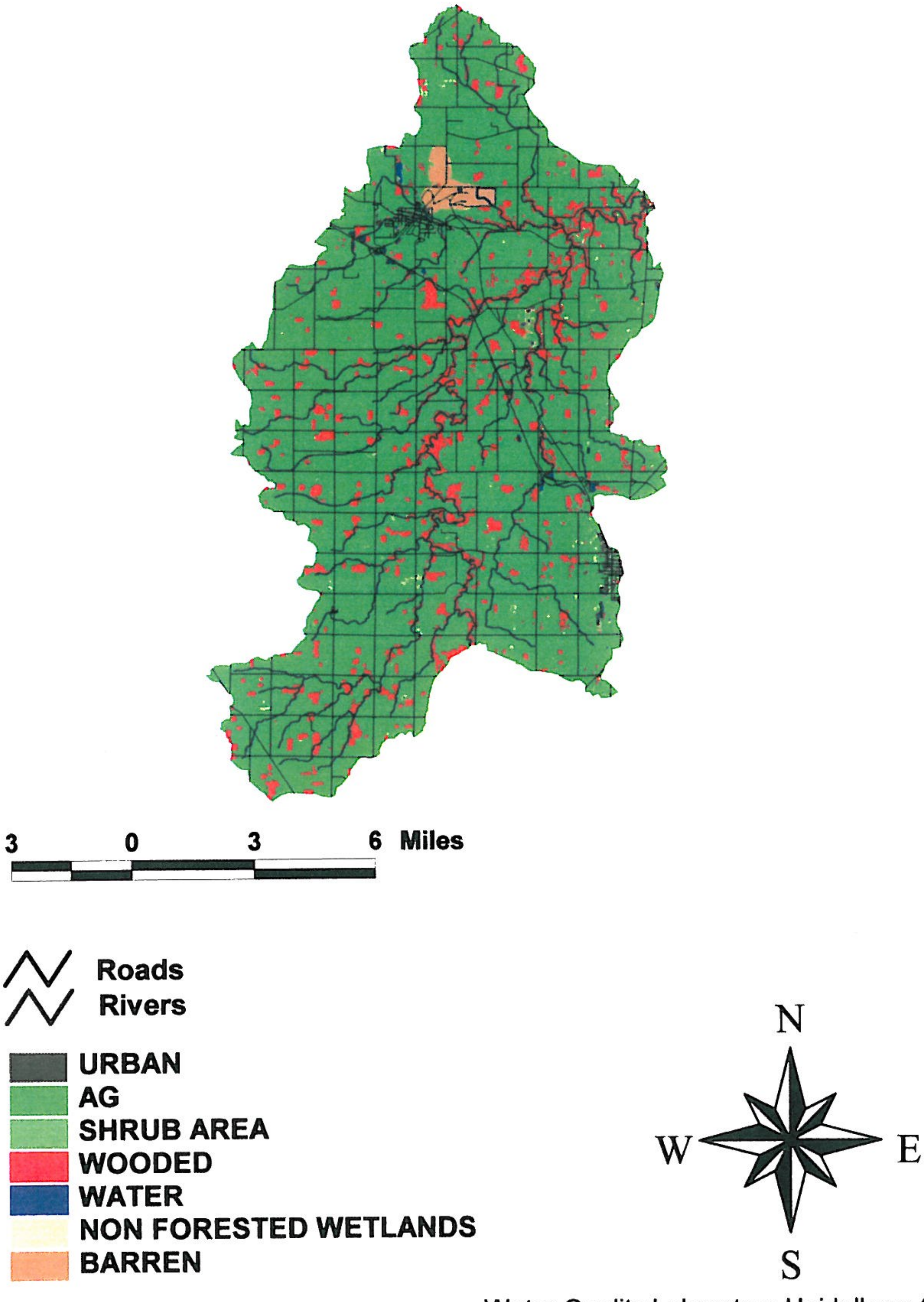


Subwatershed Characteristics
Area (square miles): 130.2
Area (acres): 83,321
Upstream Area (square miles): 171.7
Total Stream Miles: 179.5
Designated Warm Water Habitat (WWH) Miles: 93.5
Undesignated Stream Miles: 86.0
Counties: Wyandot, Seneca
Monitored WWH Stream Miles: 21.4
Percent Monitored: 22.9%
Community Water Supplies: 1
Cities and Towns (population) Carey (3,788) Kirby (180)

Land Use by Percent		
	Tymochtee -lower	Sandusky Watershed
Agriculture	86.4%	84.0%
Wooded	10.2%	12.6%
Urban	0.7%	1.2%
Wetlands	0.7%	1.1%
Barren	1.2%	0.3%
Shrub	0.6%	0.5%%
Water	0.2%	0.4%

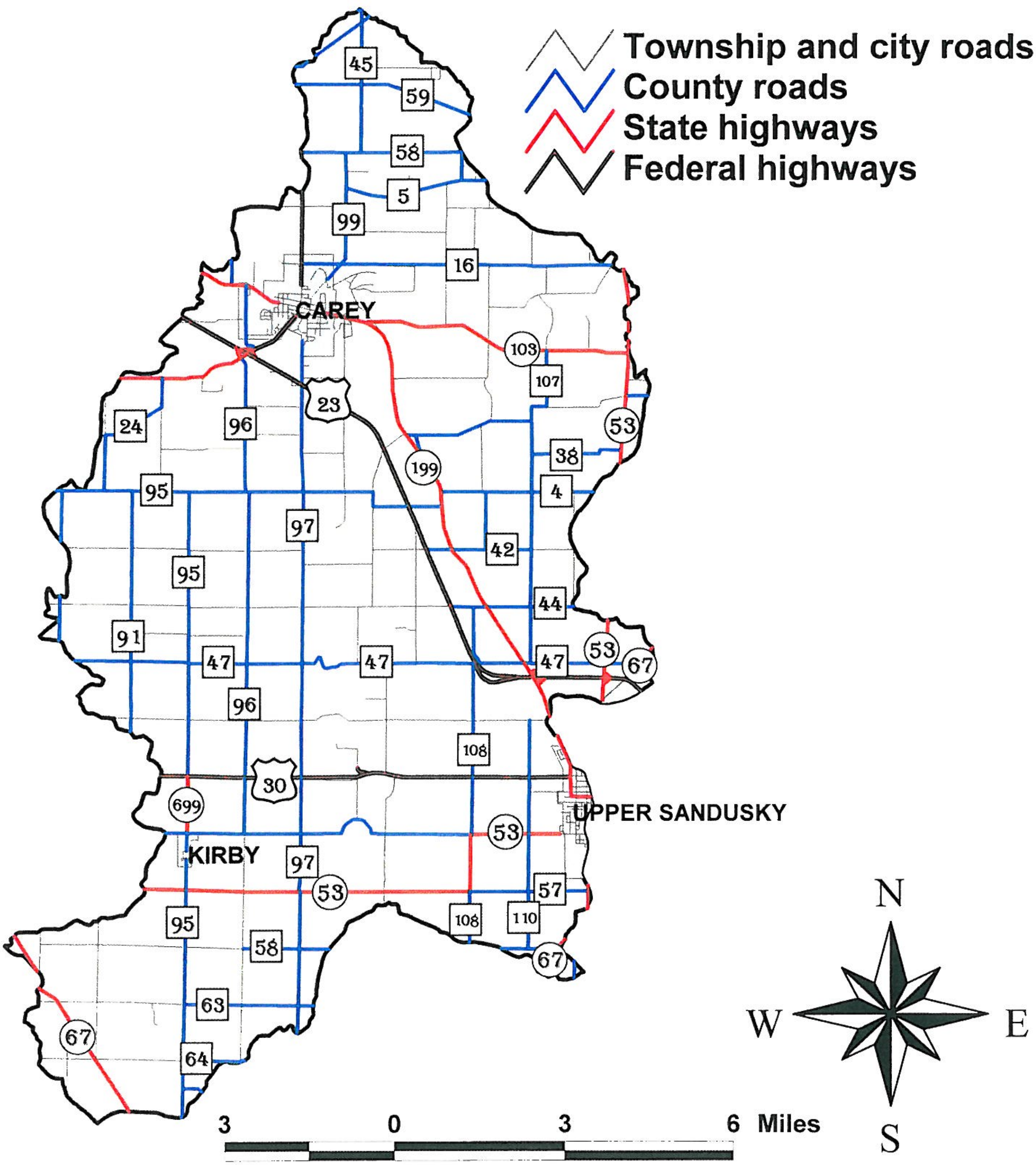
Aquatic Life Use Attainment		
Attainment Status	Tymoch-tee-lower	Sandusky Watershed
Fully Attaining	0%	35.0%
Threatened	0.0%	0.5%
Partial Attainment	5.1%	23.3%
Not Attaining	94.9%	41.2%

Tymochtee Creek-lower
Hydrological Unit 04100011-060
Land Use in Relationship to Streams and Roads



Water Quality Laboratory Heidelberg College

Roads in the Tymochtee-lower Subwatershed 060



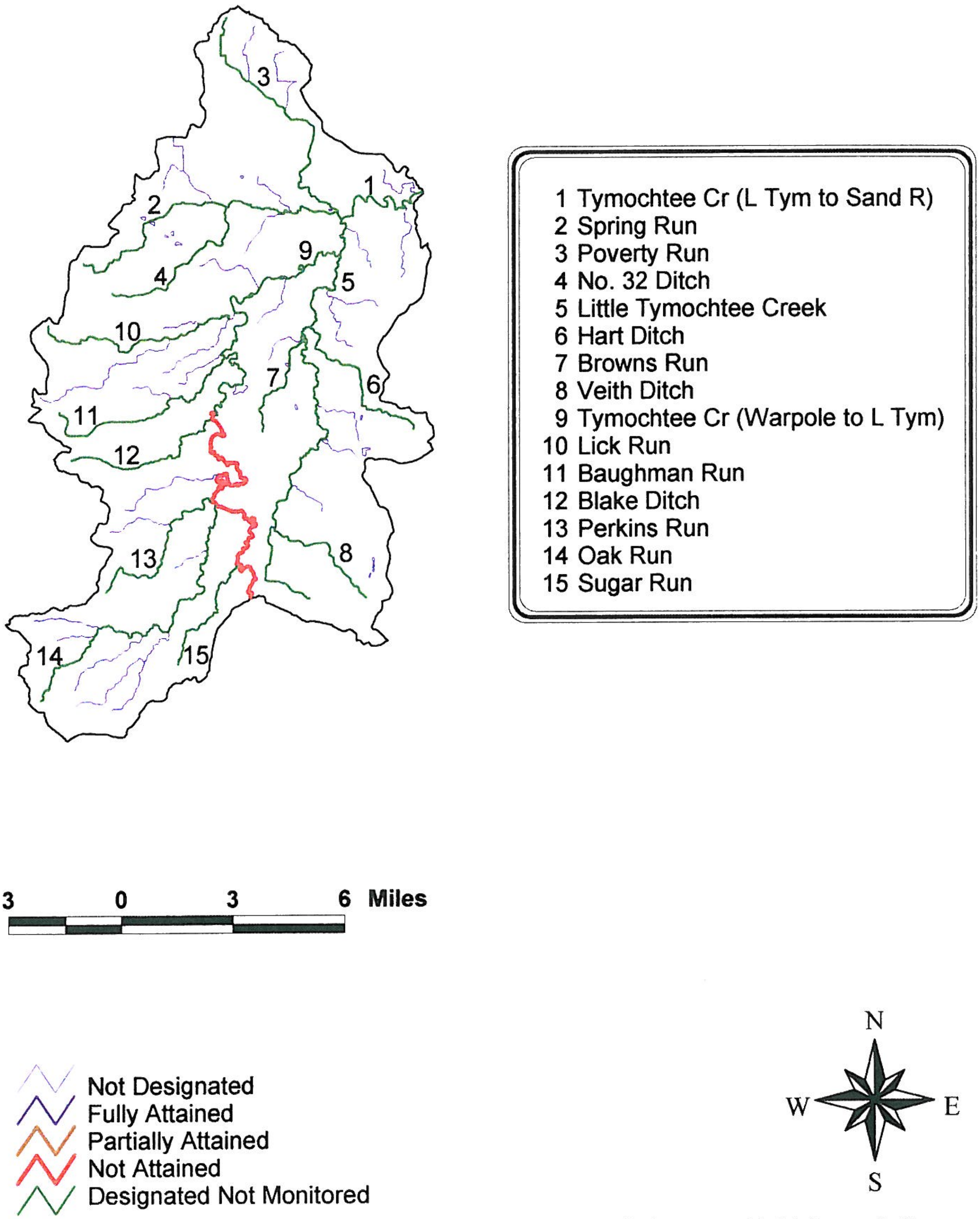
Summary of OEPA biological monitoring data for the Tymochtee-Lower subwatershed (-060).

Map Number	OEPA Segment Number	Segment Name	Segment Length	Drainage Area	Fully Attain.	Threat-ened	Partial Attain.	Not Attain-ing	Use Desig-nation	Year Moni-tored	Causes of Impair-ment	Sources of Impair-ment
			miles	sq. miles	miles	miles	miles	miles				
1	OH79-1	Tymochtee Cr. (L Tym to Sand R)	5.36	299.5	0	0	0	0	WWH	none	NA	NA
2	OH79-2	Spring Run	6.5	32.3	0	0	0	0	WWH	none	NA	NA
3	OH79-3	Poverty Run	5.1	11.1	0	0	0	0	WWH	none	NA	NA
4	OH79-4	No. 32 Ditch	4.2	5.3	0	0	0	0	WWH	none	NA	NA
5	OH79-5	Little Tymochtee Creek (RM 5.36)	13.1	31.4	0	0	0	0	WWH	none	NA	NA
6	OH79-6	Hart Ditch	2.8	3.9	0	0	0	0	WWH	none	NA	NA
7	OH79-7	Browns Run	4	3.8	0	0	0	0	WWH	none	NA	NA
8	OH79-8	Veith Ditch	4.6	3.4	0	0	0	0	WWH	none	NA	NA
9	OH79-9	Tymochtee Cr. (Warpole to L Tym Cr)	21.38	232.0	0	0	1.1	20.3	WWH	1979	3-H, 1-M	1-H
10	OH79-10	Lick Run	3	10.1	0	0	0	0	WWH	none	NA	NA
11	OH79-11	Baughman Run	3.7	5.5	0	0	0	0	WWH	none	NA	NA
12	OH79-12	Blake Ditch	5	3.9	0	0	0	0	WWH	none	NA	NA
13	OH79-13	Perkins Run	5.7	5.5	0	0	0	0	WWH	none	NA	NA
14	OH79-14	Oak Run	6.6	15.1	0	0	0	0	WWH	none	NA	NA
15	OH79-15	Sugar Run	2.5	2.7	0	0	0	0	WWH	none	NA	NA
		Subwatershed Total	93.54		0	0	1.1	20.3				
		Percent of Assessed Miles			0.0%	0.0%	5.1%	94.9%				

Key to causes and sources of impairment

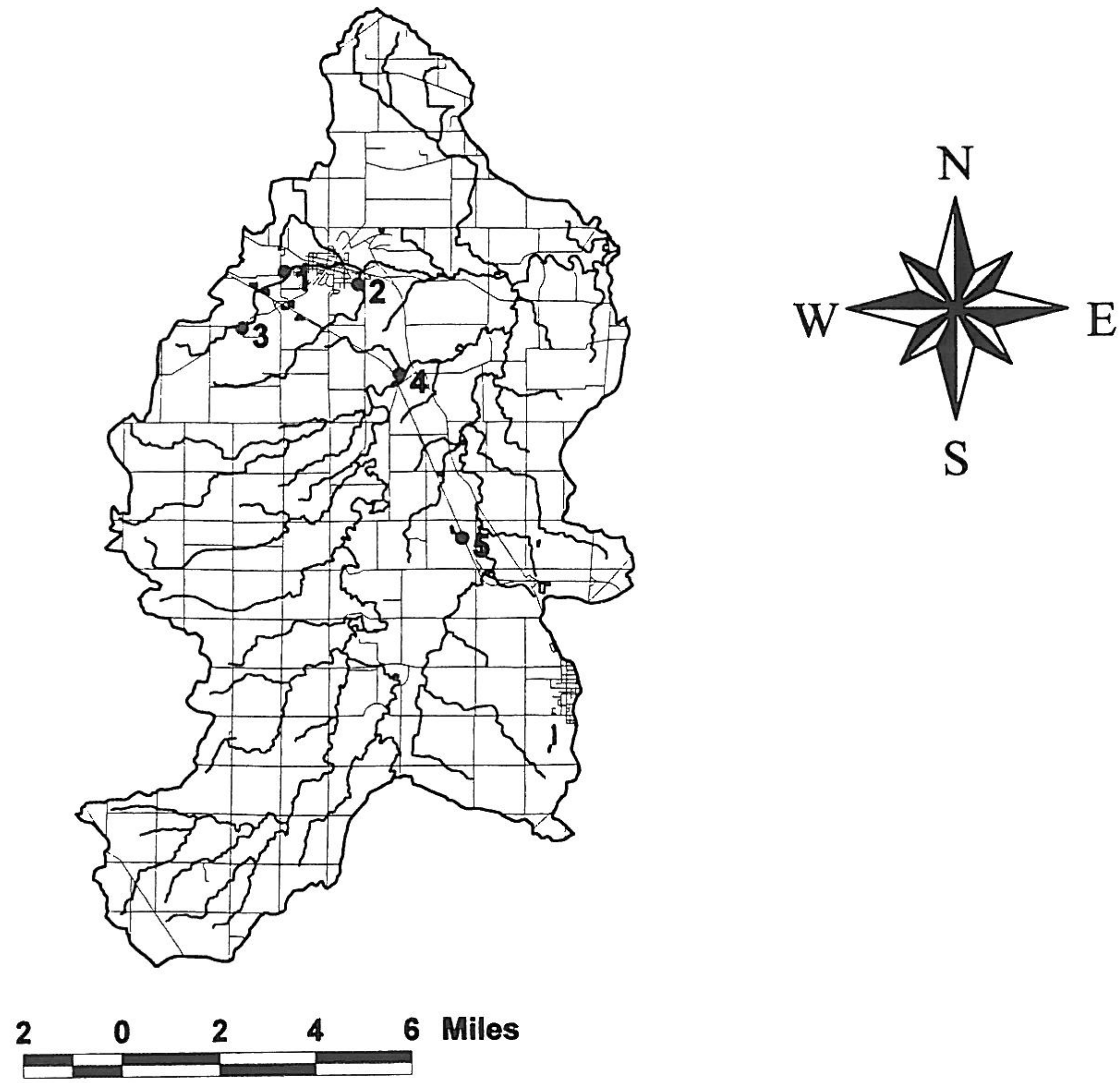
Causes of Impairment	Sources of Impairment	
1. Siltation	1. Nonirrigated Crop Production	10. Contaminated Sediments
2. Flow Alterations	2. Irrigated Crop Production	11. Upstream Impoundment
3. Other Habitat Alterations	3. Agriculture	12. Dam Construction
4. Nutrient Enrichment	4. Channelization	13. Removal of Riparian Vegetation
5. Unionized Ammonia	5. Municipal Point Sources	14. Other
6. Oil and Grease	6. Industrial Point Sources	15. Source Unknown
7. Organic Enrichment /DO	7. Urban Runoff/Storm Sewers	16. Natural
8. Priority Organics	8. Onsite Wastewater Systems	17. Stream Bank Modification/Destabilization
9. Metals	9. Flow Regulation/Modification	18. Combined Sewer Overflows
10. Cause Unknown		
11. Noxious Aquatic Weeds		
12. Unknown Toxicity		
H - High Impact; M - Moderate Impact; S - Slight Impact		

Tymochtee, Lower
Hydrological Unit 04100011-060
Use Attainment



 Water Quality Laboratory Heidelberg College

Tymochtee Creek-lower
Hydrological Unit 04100011-060
Point Sources

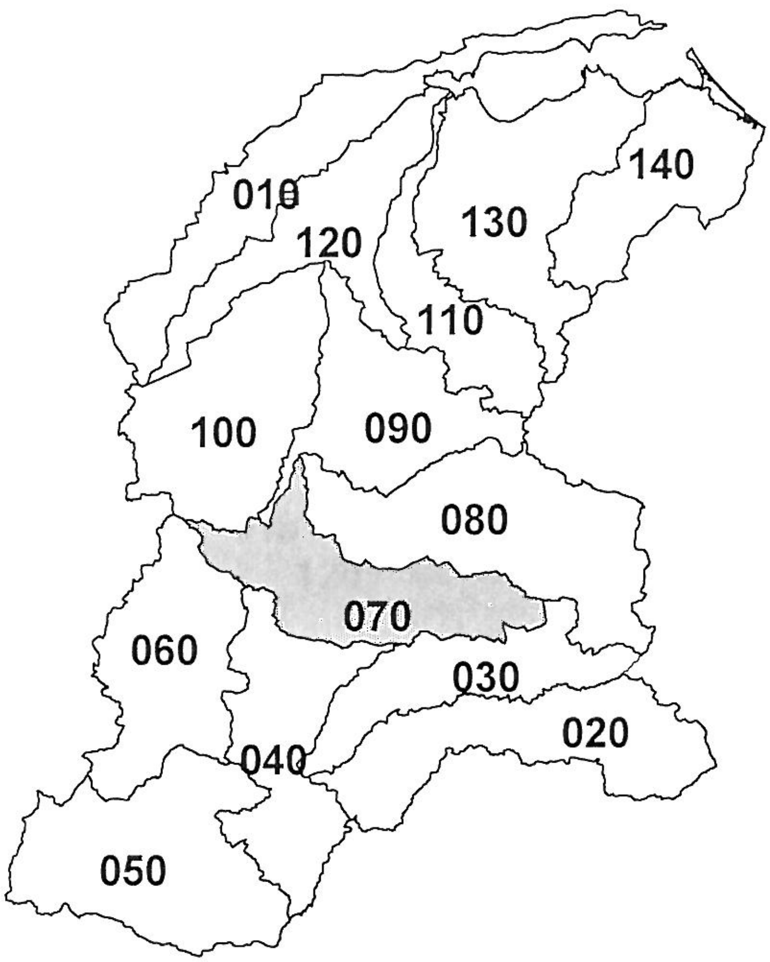


Point Source
Rivers
Roads

1 OH0058106 The Budd Company
2 OH0020206 Carey WWTP
3 OH0058441 Toledo Molding and Die
4 OH0078611 ODOT FPL-PARK 1-30
5 OH0078603 ODOT FPL-PARK 1-29

Water Quality Laboratory Heidelberg College

Subwatershed: Sandusky – Mexico
Hydrological Unit Code 04100011-070
Sandusky River (below Tymochtee Creek to above Honey Creek)

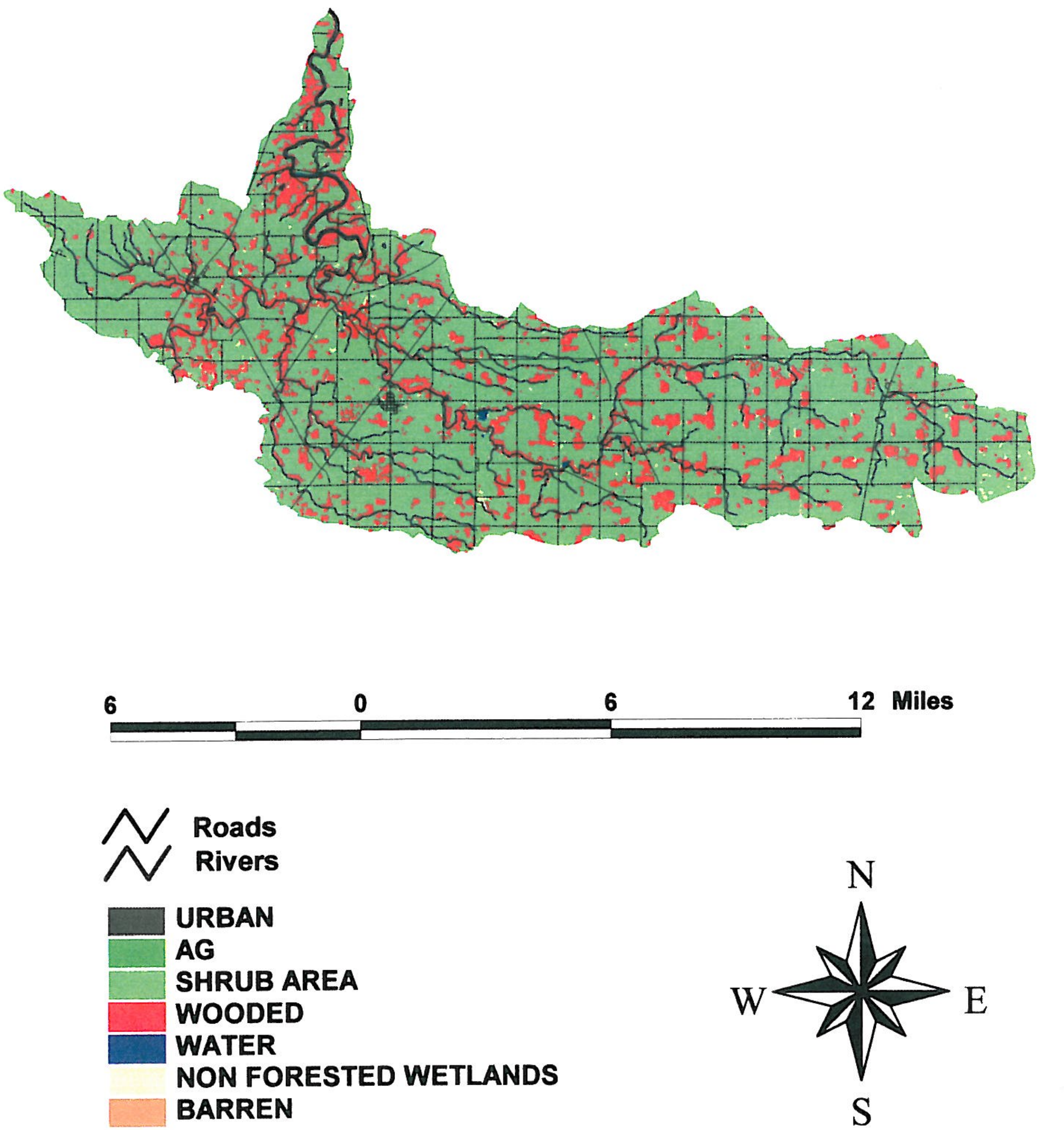


Subwatershed Characteristics
Area (square miles): 121.8
Area (acres): 77,978
Upstream Area (square miles): 655.2
Total Stream Miles: 198.7
Designated Warm Water Habitat (WWH) Miles: 64.4
Undesignated Stream Miles: 134.3
Counties: Crawford, Wyandot, Seneca
Monitored WWH Stream Miles: 22.2
Percent Monitored: 35.4%
Community Water Supplies: 2
Cities and Towns (population) Sycamore (937) Chatfield (194) McCutchenville

Land Use by Percent		
	Sandusky-Mexico	Sandusky Watershed
Agriculture	80.4%	84.0%
Wooded	17.6%	12.6%
Urban	0.1%	1.2%
Wetlands	1.0%	1.1%
Barren	0.0%	0.3%
Shrub	0.5%	0.5%%
Water	0.3%	0.4%

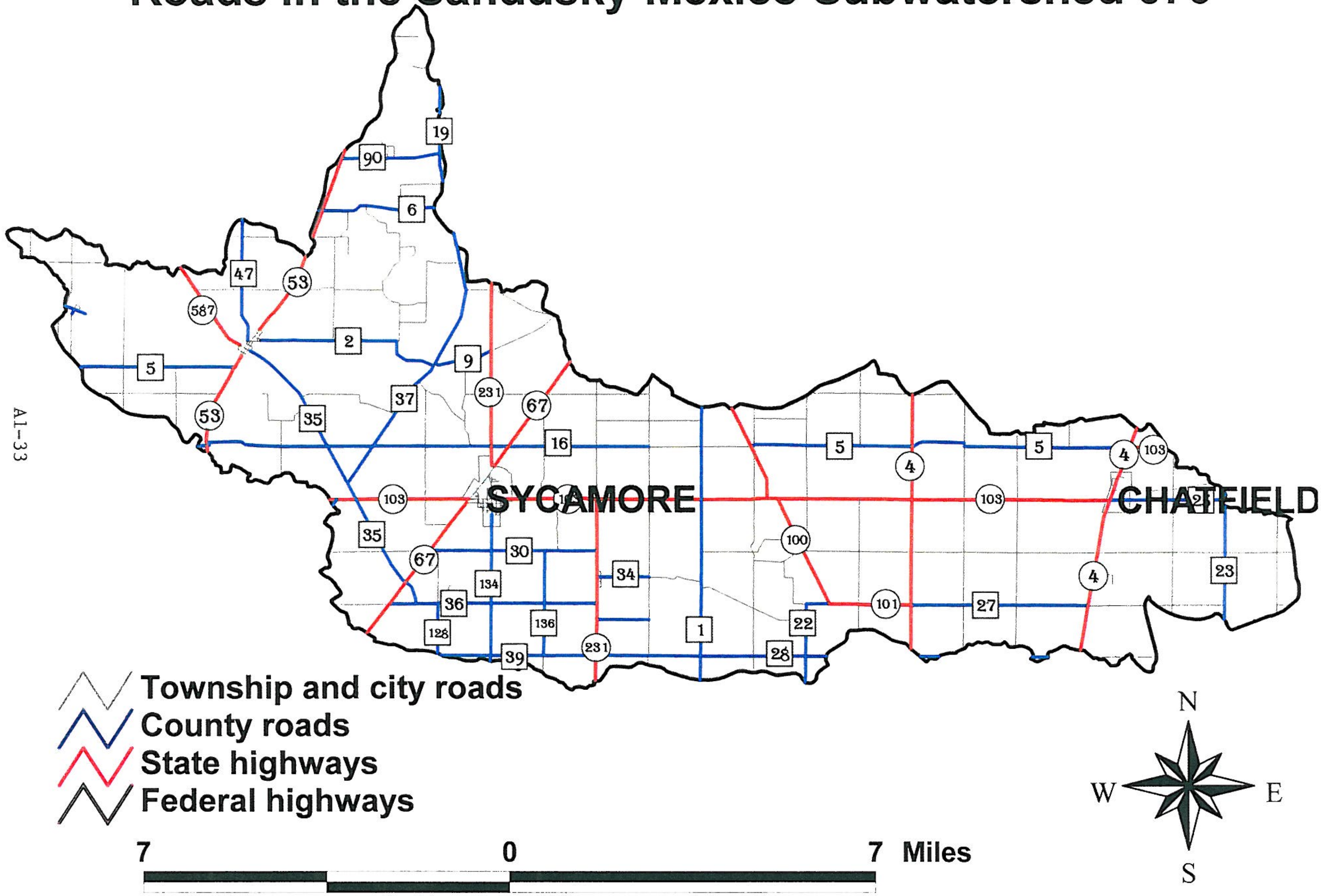
Aquatic Life Use Attainment		
Attainment Status	Sandusky-Mexico	Sandusky Watershed
Fully Attaining	40.8%	35.0%
Threatened	0.0%	0.5%
Partial Attainment	59.2%	23.3%
Not Attaining	0%	41.2%

Sandusky-Mexico
Hydrological Unit 04100011-070
Land Use in Relationship to Streams and Rivers



Water Quality Laboratory Heidelberg College

Roads in the Sandusky-Mexico Subwatershed 070



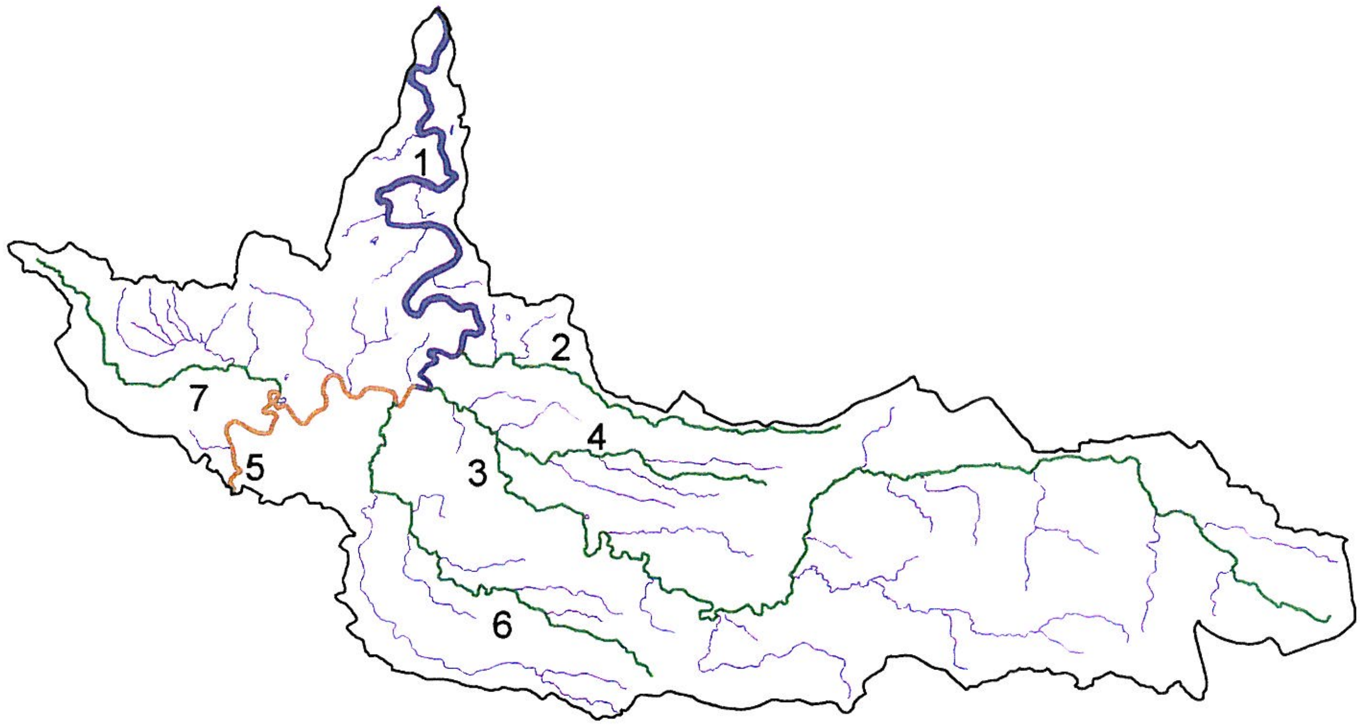
Summary of OEPA biological monitoring data for the Sandusky-Mexico subwatershed (-070).

Map Number	OEPA Segment Number	Segment Name	Segment Length	Drainage Area	Fully Attain.	Threat-ened	Partial Attain.	Not Attain-ing	Use Desig-nation	Year Moni-tored	Causes of Impair-ment	Sources of Impair-ment
	Number		miles	sq. miles	miles	miles	miles	miles				
1	OH81-23	Sandusky River (Sycamore Cr-Bells Run)	14.81	957	9.3	0	5.5	0	WWH	1990	1-H	3-H
2	OH81-25	Mile Run	5.1	7.1	0	0	0	0	WWH	none	NA	NA
3	OH81-26	Sycamore Creek	20	67.6	0	0	0	0	WWH	none	NA	NA
4	OH81-27	Greasy Run	3.9	6.1	0	0	0	0	WWH	none	NA	NA
5	OH81-28	Sandusky River (Tymochtee Cr-Sycamore Cr)	8.02	696	0	0	8	0	WWH	1990	1-H	3-H
6	OH81-29	Taylor Run	8.6	19.3	0	0	0	0	WWH	none	NA	NA
7	OH81-30	Thorn Run	4	10.8	0	0	0	0	WWH	none	NA	NA
		Subwatershed Total	64.43		9.3	0	13.5	0				
		Percent of Monitored Miles			40.79	0.00	59.21	0.00				

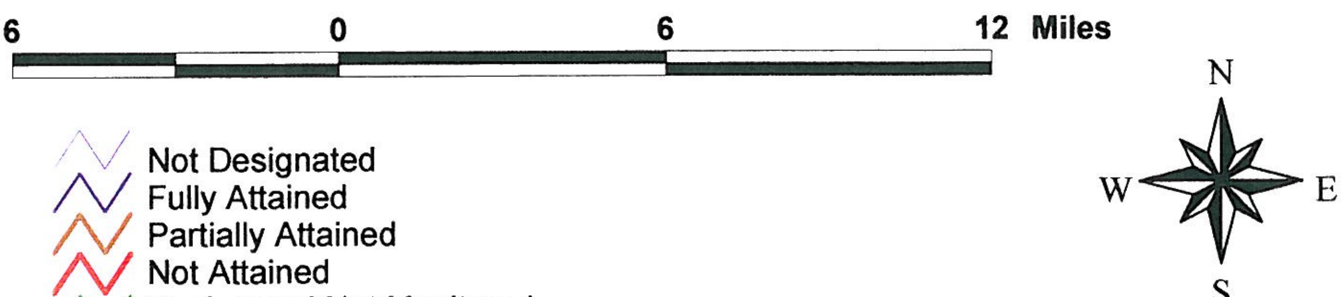
Key to causes and sources of impairment

Causes of Impairment	Sources of Impairment	
1. Siltation	1. Nonirrigated Crop Production	10. Contaminated Sediments
2. Flow Alterations	2. Irrigated Crop Production	11. Upstream Impoundment
3. Other Habitat Alterations	3. Agriculture	12. Dam Construction
4. Nutrient Enrichment	4. Channelization	13. Removal of Riparian Vegetation
5. Unionized Ammonia	5. Municipal Point Sources	14. Other
6. Oil and Grease	6. Industrial Point Sources	15. Source Unknown
7. Organic Enrichment /DO	7. Urban Runoff/Storm Sewers	16. Natural
8. Priority Organics	8. Onsite Wastewater Systems	17. Stream Bank Modification/Destabilization
9. Metals	9. Flow Regulation/Modification	18. Combined Sewer Overflows
10. Cause Unknown		
11. Noxious Aquatic Weeds		
12. Unknown Toxicity		
H - High Impact; M - Moderate Impact; S - Slight Impact		

Sandusky, Mexico
Hydrological Unit 04100011-070
Use Attainment



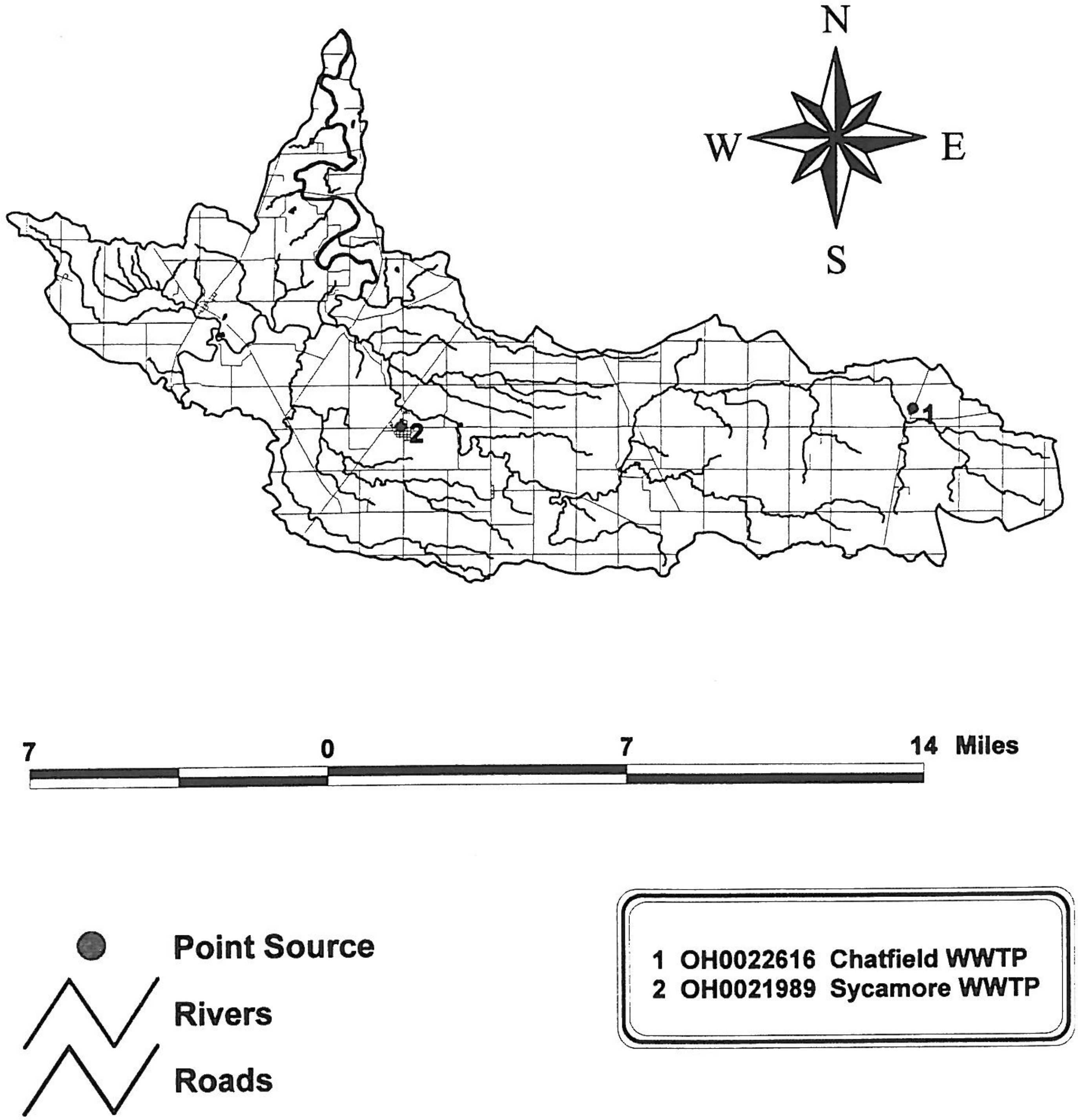
1 Sandusky River (Sycamore to Bells Run)
2 Mile Run
3 Sycamore Creek
4 Greasy Run
5 Sandusky River (Tymochtee to Sycamore)
6 Taylor Run
7 Thorn Run



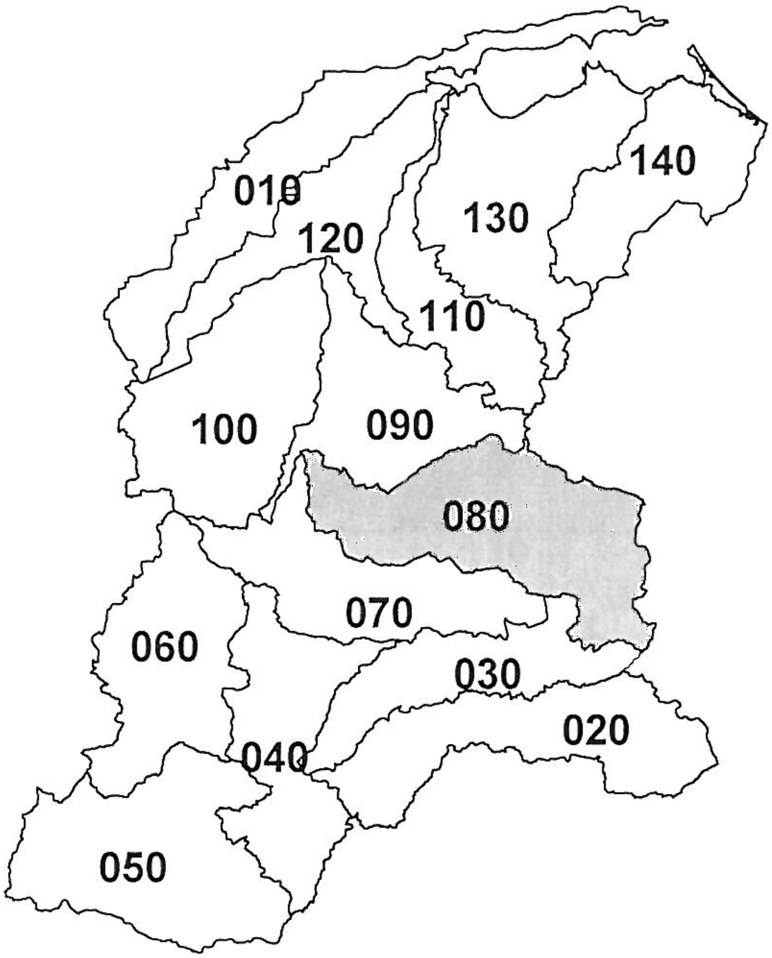
Not Designated
Fully Attained
Partially Attained
Not Attained
Designated Not Monitored

Water Quality Laboratory Heidelberg College

Sandusky River-Mexico
Hydrological Unit 04100011-070
Point Sources



Subwatershed: Honey Creek
Hydrological Unit Code 04100011-080
Honey Creek

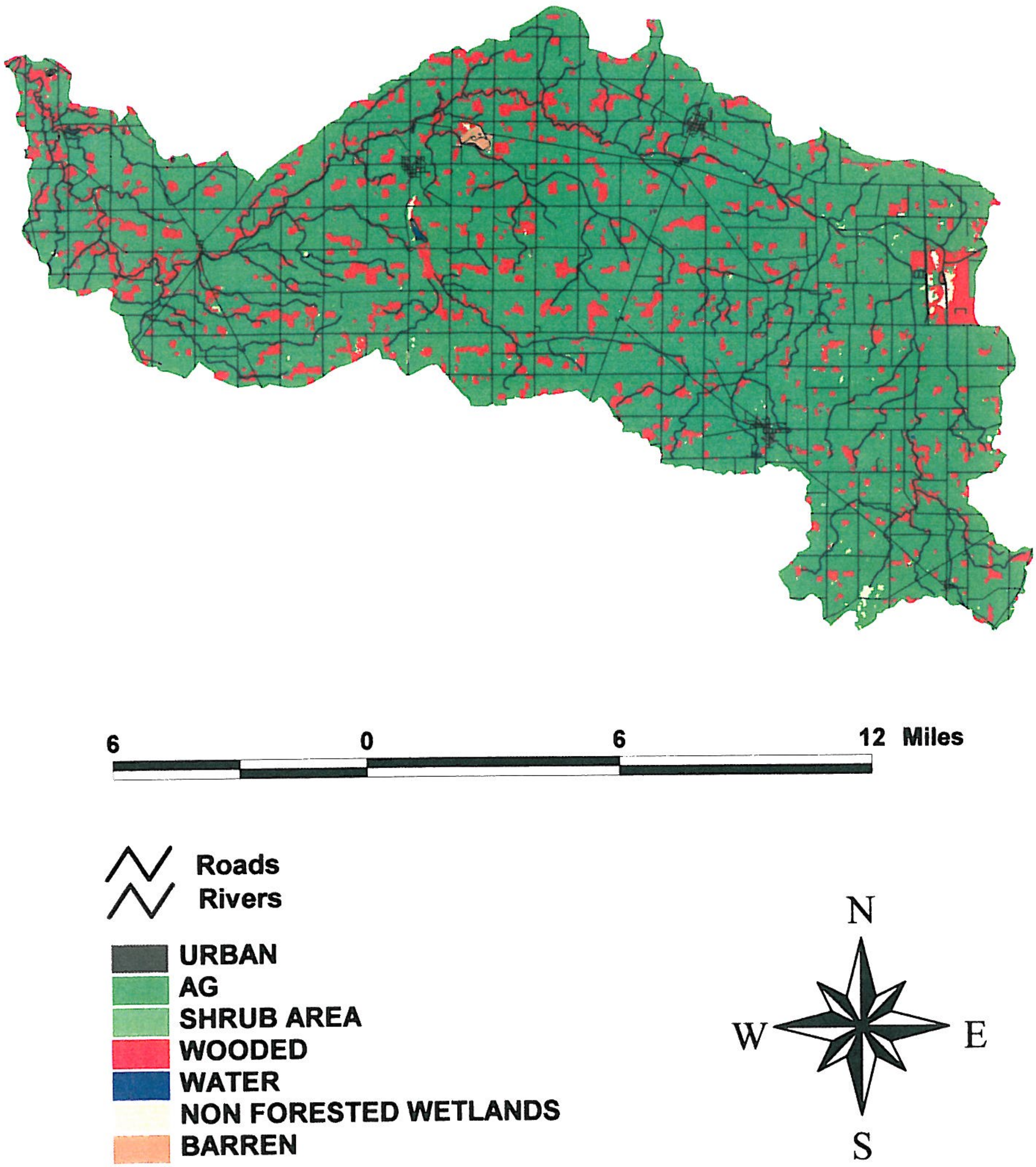


Subwatershed Characteristics
Area (square miles): 179.8
Area (acres): 115,090
Upstream Area (square miles): 0
Total Stream Miles: 248.6
Designated Warm Water Habitat (WWH) Miles: 100.0
Undesignated Stream Miles: 159.9
Counties: Crawford, Seneca, Huron, Wyandot
Monitored WWH Stream Miles: 62.2
Percent Monitored: 47.5%
Community Water Supplies: 3
Cities and Towns (population) Attica (1,040) Bloomville (1,027) Melmore New Washington (1,028) Tiro (250)

Land Use by Percent		
	Honey Creek	Sandusky Watershed
Agriculture	84.8%	84.0%
Wooded	13.4%	12.6%
Urban	0.5%	1.2%
Wetlands	1.1%	1.1%
Barren	0.2%	0.3%
Shrub	0.2%	0.5%%
Water	0.9%	0.4%

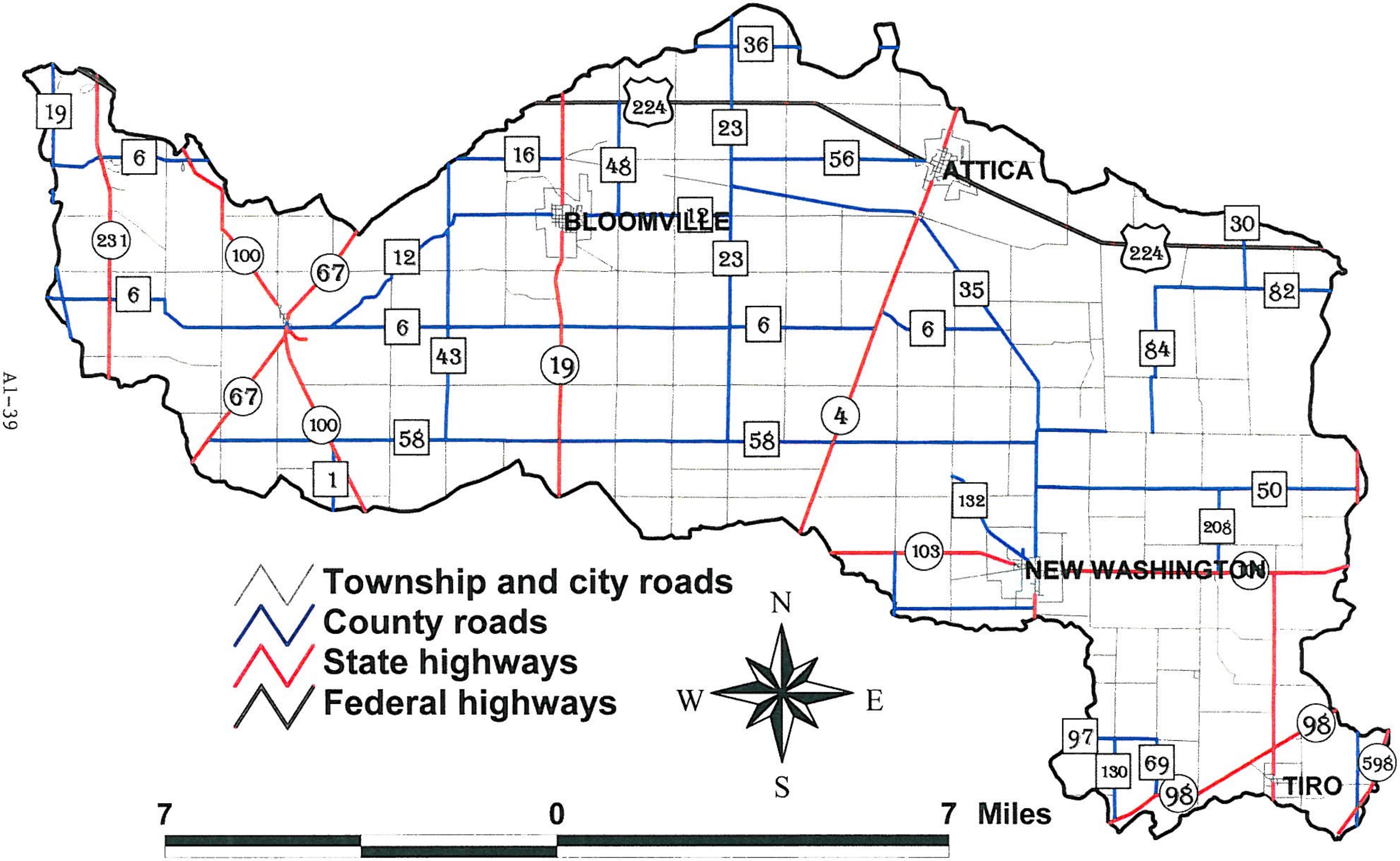
Aquatic Life Use Attainment		
Attainment Status	Honey Creek	Sandusky Watershed
Fully Attaining	48.6%	35.0%
Threatened	0.0%	0.5%
Partial Attainment	13.5%	23.3%
Not Attaining	37.9%	41.2%

Honey Creek
Hydrological Unit 04100011-080
Land Use in Relationship to Streams and Roads



Water Quality Laboratory Heidelberg College

Roads in the Honey Creek Subwatershed 080



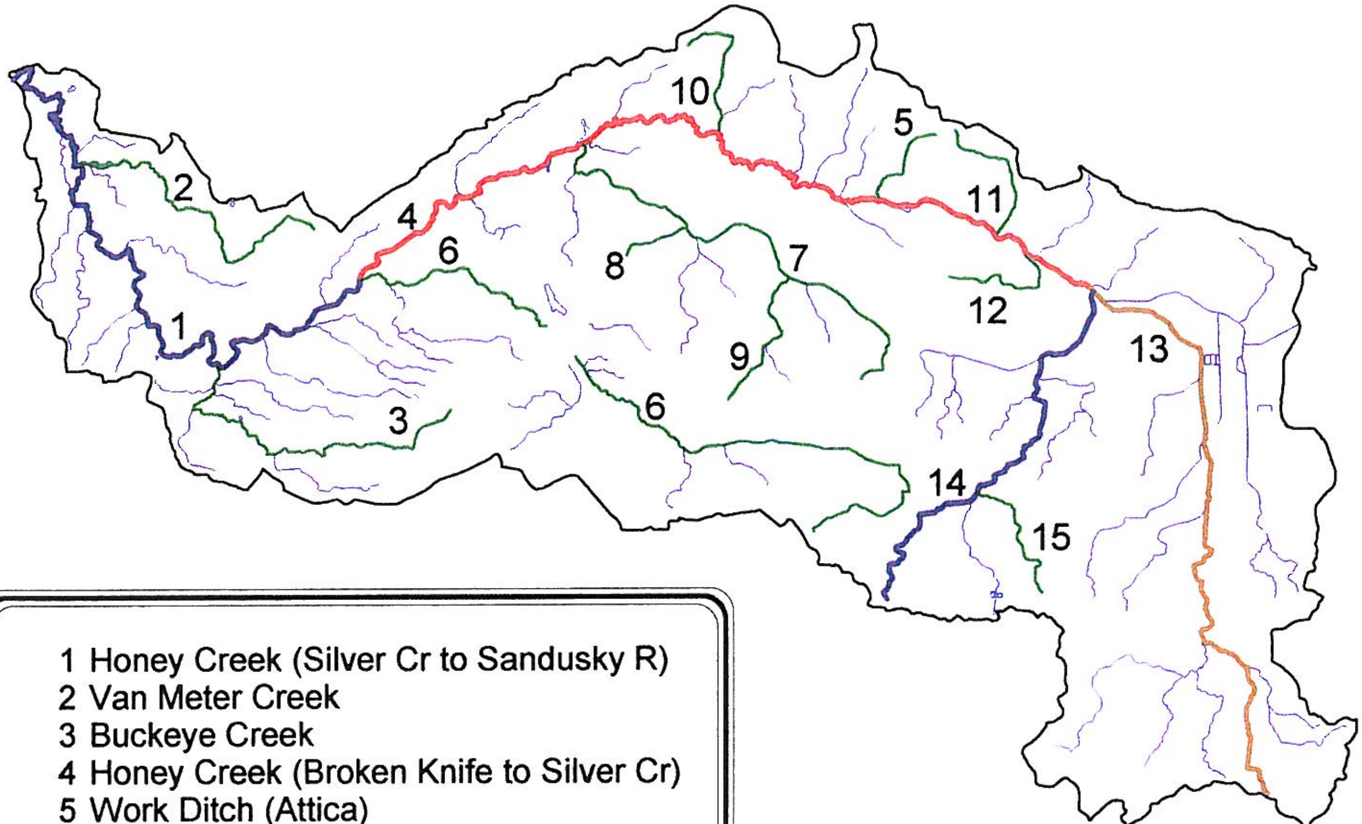
Summary of OEPA biological monitoring data for the Honey Creek subwatershed (-080).

Map Number	OEPA Segment Number	Segment Name	Segment Length	Drainage Area	Fully Attain.	Threat- ened	Partial Attain.	Not Attain- ing	Use Desig- nation	Year Moni- tored	Causes of Impair- ment	Sources of Impair- ment
			miles	sq. miles	miles	miles	miles	miles				
1	OH81-11	Honey Creek (Silver Cr to Sandusky R)	14.52	176.7	14.5	0	0	0	WWH	1984	none identified	none identified
2	OH81-11.1	Van Meter Creek	6.64	4.8	0	0	0	0	none	none	NA	NA
3	OH81-12	Buckeye Creek	6	9.1	0	0	0	0	WWH	none	NA	NA
4	OH81-13	Honey Creek (Broken Knife Cr to Silver C)	18.03	119	0	0	0	18	WWH	1984	12-H	1-H
5	OH81-13.1	Work Ditch (Attica)	1.93	1.3	0	0	0	0	none	none	NA	NA
6	OH81-14	Silver Creek	8.3	24.1	0	0	0	0	WWH	none	NA	NA
7	OH81-15	Eicholtz Ditch	10	19.6	0	0	0	0	WWH	none	NA	NA
8	OH81-16	Kagy Ditch	2	1.1	0	0	0	0	WWH	none	NA	NA
9	OH81-17	Bolinger Ditch	2.8	4.3	0	0	0	0	WWH	none	NA	NA
10	OH81-18	Hedden Ditch	2.7	3.5	0	0	0	0	WWH	none	NA	NA
11	OH81-19	Hooper Ditch	2.5	1.5	0	0	0	0	WWH	none	NA	NA
12	OH81-20	Schaaf Ditch	3.5	4	0	0	0	0	WWH	none	NA	NA
13	OH81-21	Honey Creek (Headwaters to- Broken Knife Cr)	9.37	41	1.1	0	6.4	0	WWH	1983	3-H	4-H; 1-S
14	OH81-22	Broken Knife Creek	9	16.6	7.5	0	0	0	WWH	1986	none identified	none identified
15	OH81-22.1	Kibler Ditch (New Washington)	2.66	1.8	0	0	0	0	none	none	NA	NA
		Subwatershed Total	99.95		23.1	0	6.4	18				
		Percent of Assessed Miles			48.6%	0.0%	13.5%	37.9%				

Key to causes and sources of impairment

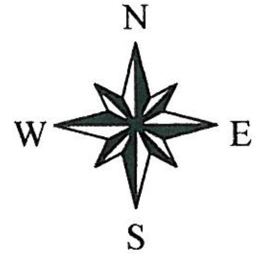
Causes of Impairment	Sources of Impairment	
1. Siltation	1. Nonirrigated Crop Production	10. Contaminated Sediments
2. Flow Alterations	2. Irrigated Crop Production	11. Upstream Impoundment
3. Other Habitat Alterations	3. Agriculture	12. Dam Construction
4. Nutrient Enrichment	4. Channelization	13. Removal of Riparian Vegetation
5. Unionized Ammonia	5. Municipal Point Sources	14. Other
6. Oil and Grease	6. Industrial Point Sources	15. Source Unknown
7. Organic Enrichment /DO	7. Urban Runoff/Storm Sewers	16. Natural
8. Priority Organics	8. Onsite Wastewater Systems	17. Stream Bank Modification/Destabilization
9. Metals	9. Flow Regulation/Modification	18. Combined Sewer Overflows
10. Cause Unknown		
11. Noxious Aquatic Weeds		
12. Unknown Toxicity		
H - High Impact; M - Moderate Impact; S - Slight Impact		

Honey Creek
Hydrological Unit 04100011-080
Use Attainment



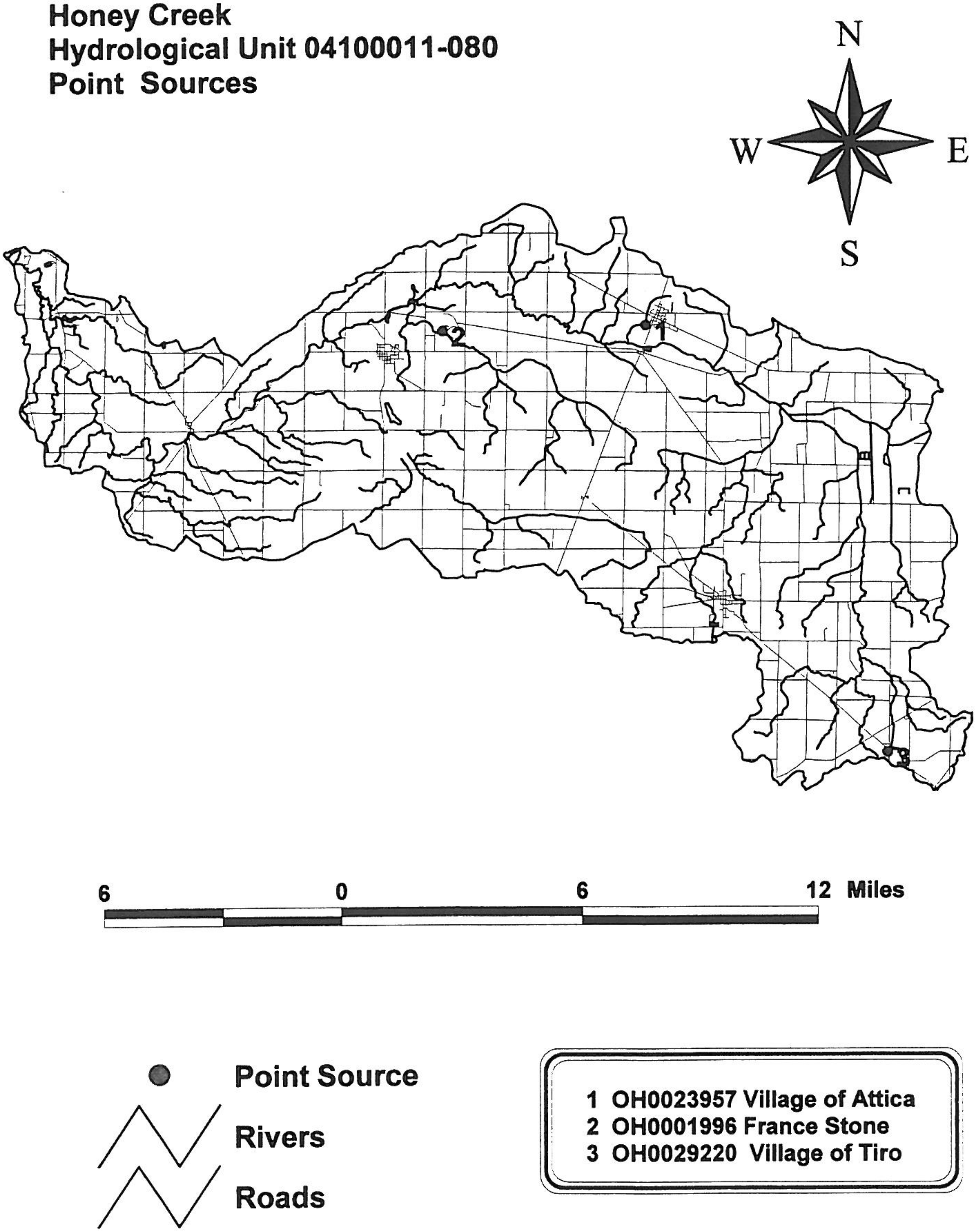
1 Honey Creek (Silver Cr to Sandusky R)
2 Van Meter Creek
3 Buckeye Creek
4 Honey Creek (Broken Knife to Silver Cr)
5 Work Ditch (Attica)
6 Silver Creek
7 Eicholtz Ditch
8 Kagy Ditch
9 Bolinger Ditch
10 Hedden Ditch
11 Hooper Ditch
12 Schaaf Ditch
13 Honey Creek (Hdwtrs to Broken Knife)
14 Broken Knife Creek
15 Kibler Ditch

Not Designated
Fully Attained
Partially Attained
Not Attained
Designated Not Monitored



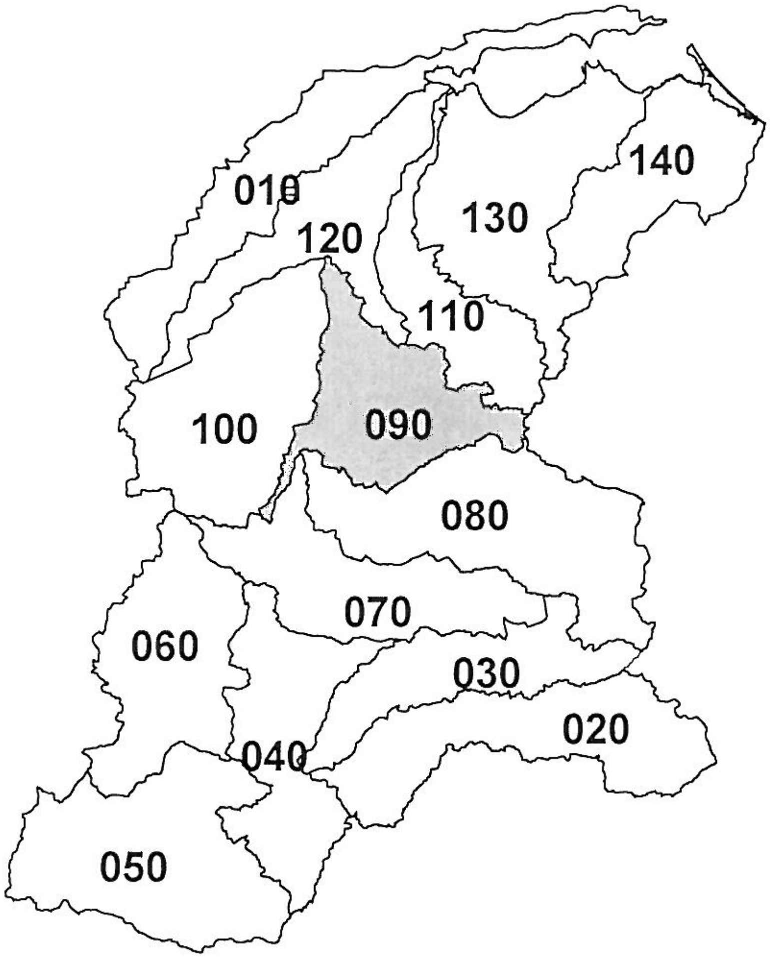
Water Quality Laboratory Heidelberg College

Honey Creek
Hydrological Unit 04100011-080
Point Sources



Water Quality Laboratory Heidelberg College

Subwatershed: Sandusky-Tiffin
Hydrological Unit Code 04100011-090
Sandusky River (below Honey Creek to above Wolf Creek)

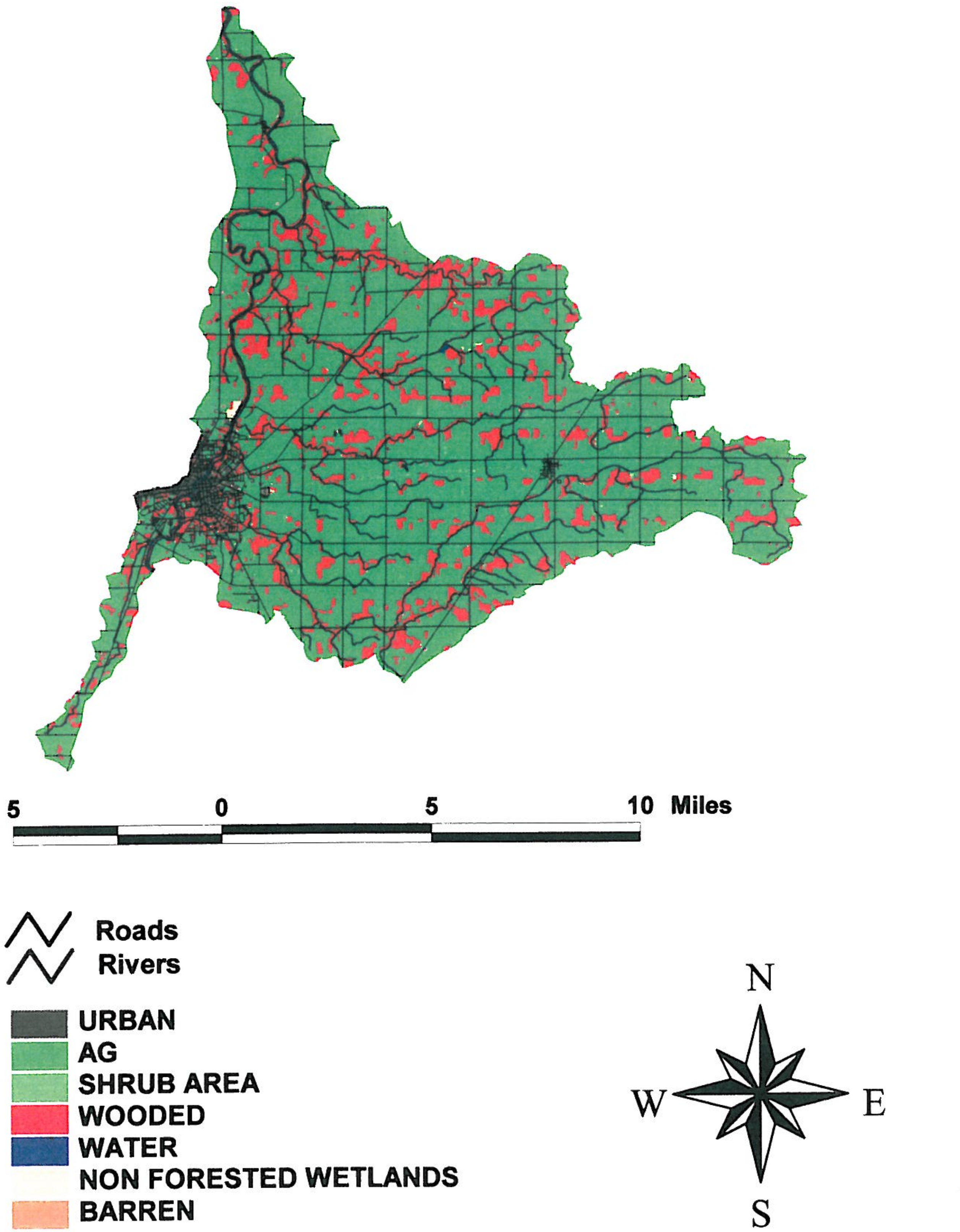


Subwatershed Characteristics
Area (square miles): 116.7
Area (acres): 74,690
Upstream Area (square miles): 956.8
Total Stream Miles: 199.6
Designated Warm Water Habitat (WWH) Miles: 91.7
Undesignated Stream Miles: 107.9
Counties: Seneca, Sandusky
Monitored WWH Stream Miles: 48.3
Percent Monitored: 52.7%
Community Water Supplies: 3
Cities and Towns (population) Tiffin (18,530) Republic (654) Old Fort

Land Use by Percent		
	Sandusky-Tiffin	Sandusky Watershed
Agriculture	79.9%	84.0%
Wooded	16.2%	12.6%
Urban	2.3%	1.2%
Wetlands	0.7%	1.1%
Barren	0.1%	0.3%
Shrub	0.6%	0.5%%
Water	0.4%	0.4%

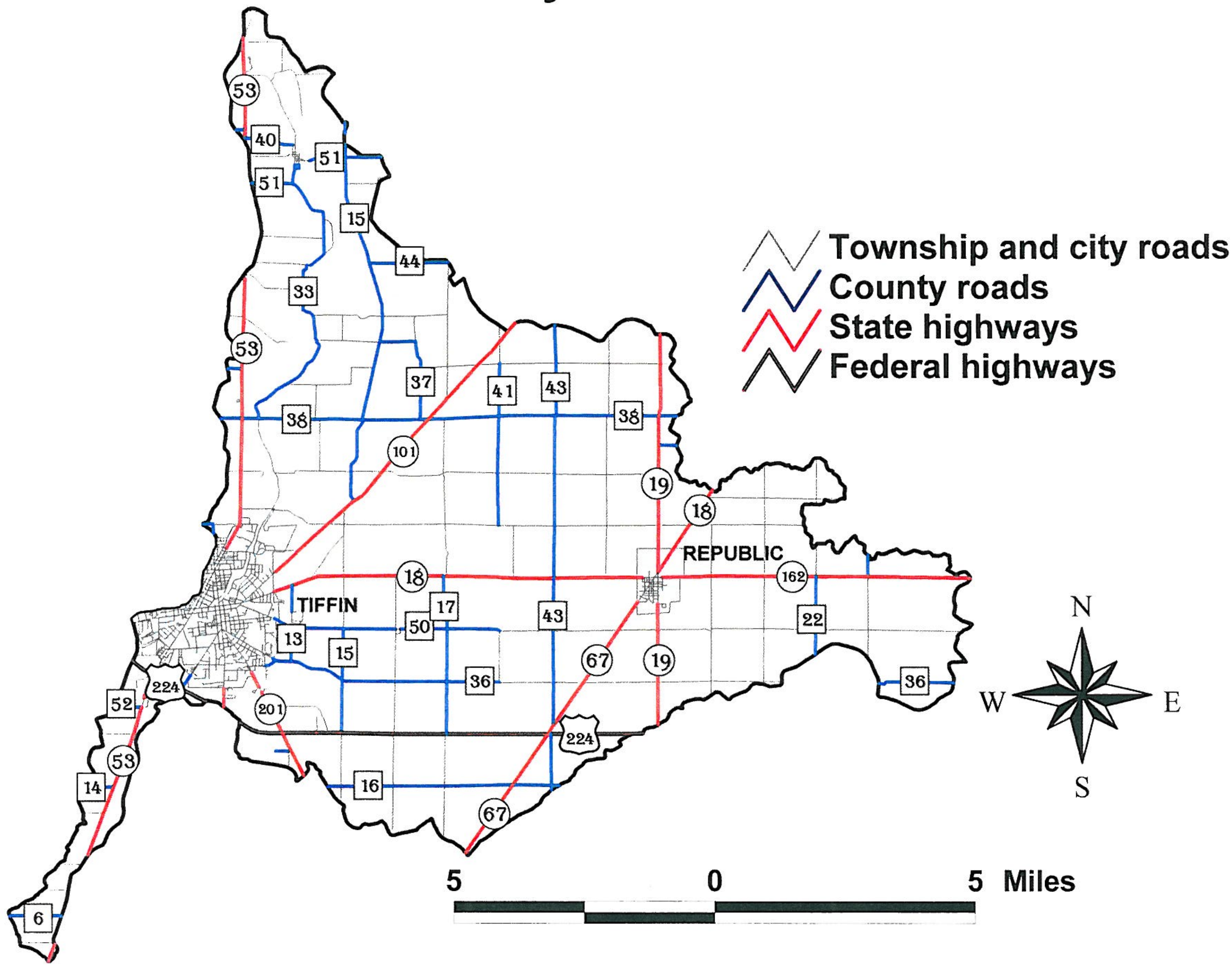
Aquatic Life Use Attainment		
Attainment Status	Sandusky-Tiffin	Sandusky Watershed
Fully Attaining	90.7%	35.0%
Threatened	0.0%	0.5%
Partial Attainment	8.7%	23.3%
Not Attaining	0.6%	41.2%

Sandusky-Tiffin
Hydrological Unit 04100011-090
Land Use in Relationship to Streams and Roads



Water Quality Laboratory Heidelberg College

Roads in the Sandusky-Tiffin Subwatershed 090



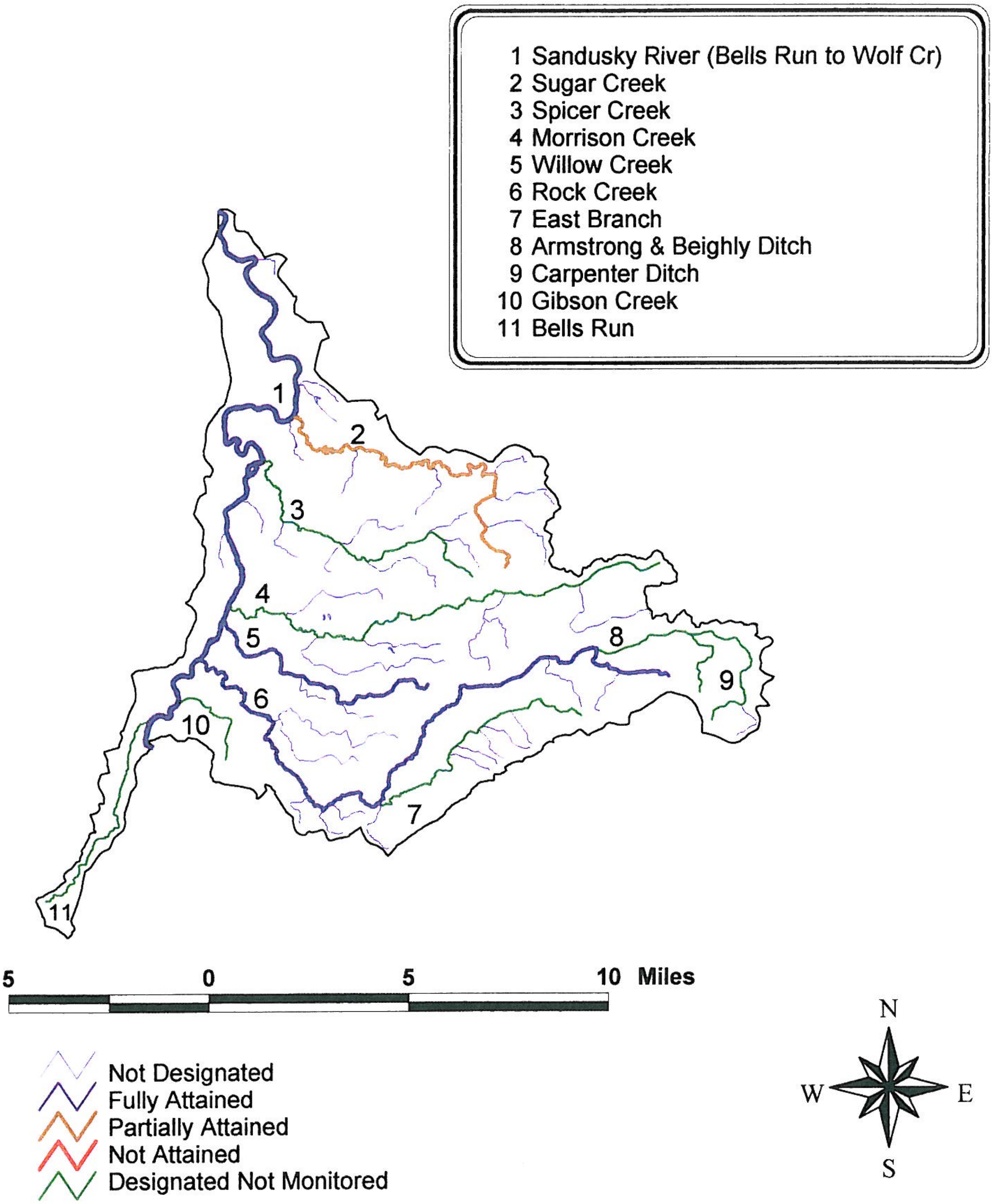
Summary of OEPA biological monitoring data for the Sandusky-Tiffin subwatershed (-090).

Map Number	OEPA Segment Number	Segment Name	Segment Length	Drainage Area	Fully Attain.	Threat-ened	Partial Attain.	Not Attain-ing	Use Desig-nation	Year Moni-tored	Causes of Impair-ment	Sources of Impair-ment
	Number		miles	sq. miles	miles	miles	miles	miles				
1	OH81-1	Sandusky River(Bells Run to Wolf Cr)	20.25	1073	18.1	0	2	0.2	WWH	1990	7-H	5-H; 18-H; 11-M
2	OH81-2	Sugar Creek	10.4	14.3	1.1	0	2.2	0.1	WWH	1989	8-H	6-H
3	OH81-3	Spicer Creek	6.1	10.9	0	0	0	0	WWH	none	NA	NA
4	OH81-4	Morrison Creek	11	21	0	0	0	0	WWH	none	NA	NA
5	OH81-5	Willow Creek	5	5.6	5	0	0	0	WWH	1982	none identified	none identified
6	OH81-6	Rock Creek	19.6	37	19.6	0	0	0	WWH	1982	none identified	none identified
7	OH81-7	East Branch	6.1	8.2	0	0	0	0	WWH	none	NA	NA
8	OH81-8	Armstrong & Beighly Ditch	5.2	11.3	0	0	0	0	WWH	none	NA	NA
9	OH81-9	Carpenter Ditch	3	3	0	0	0	0	WWH	none	NA	NA
10	OH81-10	Gibson Creek	1.9	3.3	0	0	0	0	WWH	none	NA	NA
11	OH81-24	Bells Run	3.1	3.8	0	0	0	0	wwh	none	NA	
		Subwatershed Total	91.65		43.8	0	4.2	0.3				
		Percent of Assessed Miles			90.7%	0.0%	8.7%	0.6%				

Key to causes and sources of impairment

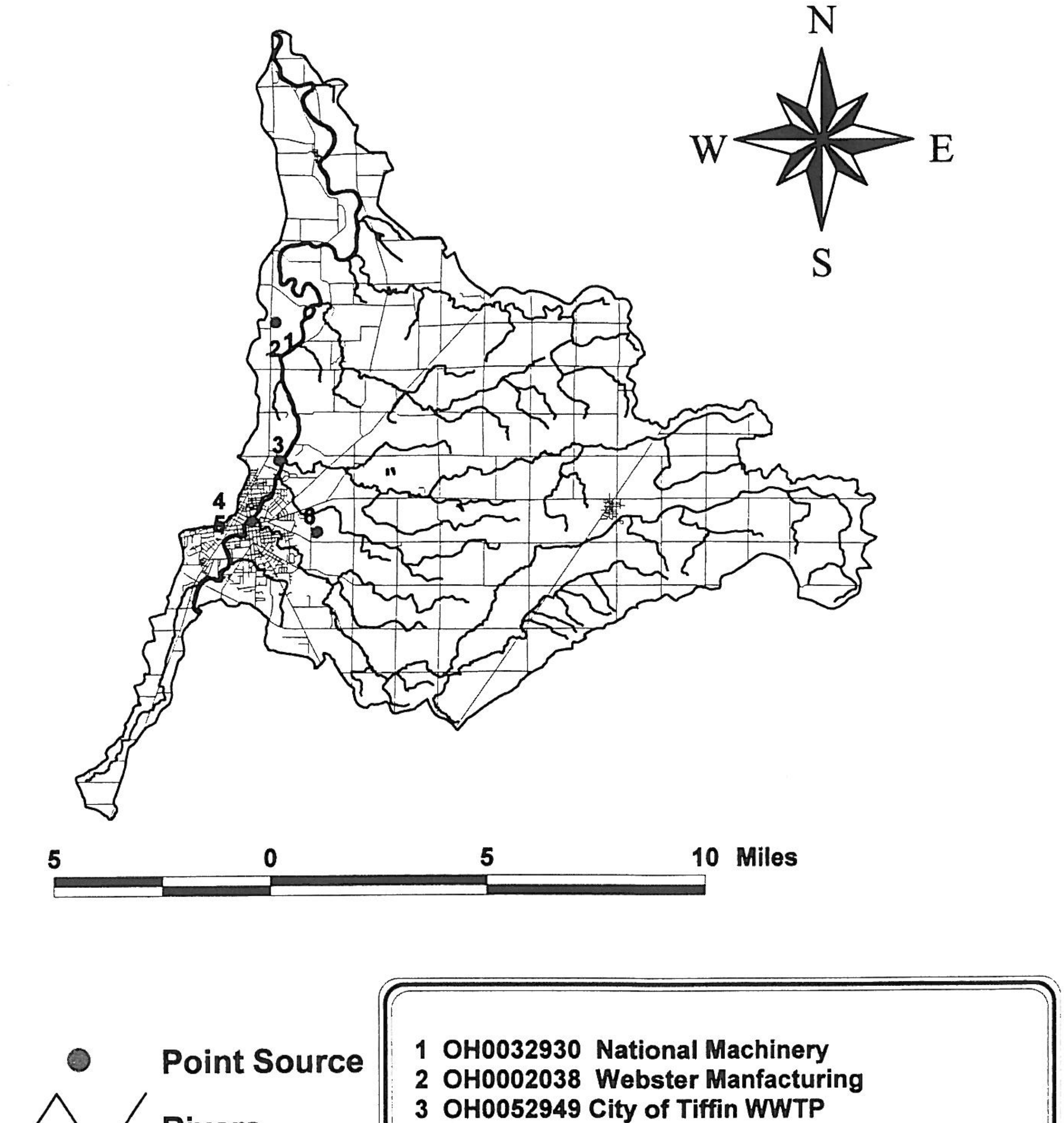
Causes of Impairment	Sources of Impairment	
1. Siltation	1. Nonirrigated Crop Production	10. Contaminated Sediments
2. Flow Alterations	2. Irrigated Crop Production	11. Upstream Impoundment
3. Other Habitat Alterations	3. Agriculture	12. Dam Construction
4. Nutrient Enrichment	4. Channelization	13. Removal of Riparian Vegetation
5. Unionized Ammonia	5. Municipal Point Sources	14. Other
6. Oil and Grease	6. Industrial Point Sources	15. Source Unknown
7. Organic Enrichment /DO	7. Urban Runoff/Storm Sewers	16. Natural
8. Priority Organics	8. Onsite Wastewater Systems	17. Stream Bank Modification/Destabilization
9. Metals	9. Flow Regulation/Modification	18. Combined Sewer Overflows
10. Cause Unknown		
11. Noxious Aquatic Weeds		
12. Unknown Toxicity		
H - High Impact; M - Moderate Impact; S - Slight Impact		

Sandusky, Tiffin
Hydrological Unit 04100011-090
Use Attainment



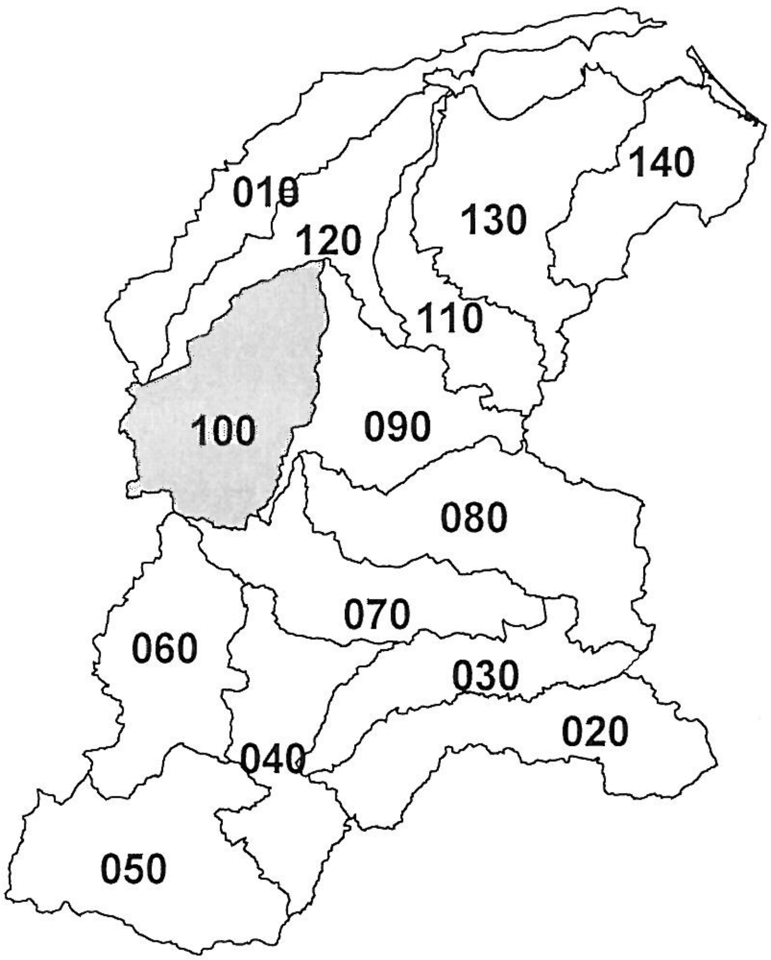
 Water Quality Laboratory Heidelberg College

Sandusky -Tiffin
Hydrological Unit 04100011-090
Point Sources



Water Quality Laboratory Heidelberg College

Subwatershed: Wolf Creek
Hydrological Unit Code 04100011-100
Wolf Creek

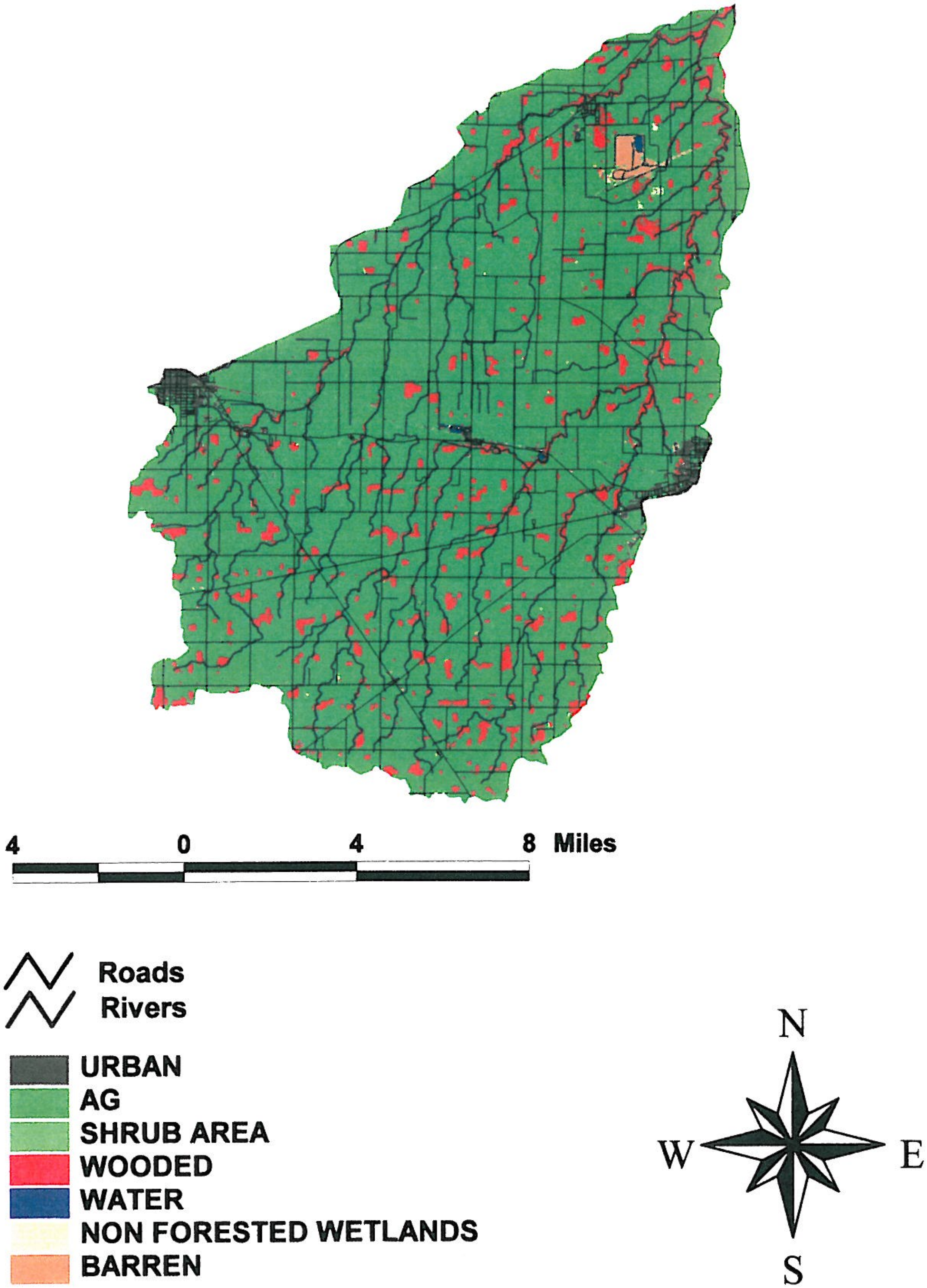


Subwatershed Characteristics
Area (square miles): 157.9
Area (acres): 101,075
Upstream Area (square miles): 0
Total Stream Miles: 250.4
Designated Warm Water Habitat (WWH) Miles: 54.9
Undesignated Stream Miles: 183.9
Counties: Seneca, Sandusky, Hancock
Monitored WWH Stream Miles: 2.6
Percent Monitored: 3.7%
Community Water Supplies: 3
Cities and Towns (population) Bettsville (753) Bascom Fostoria (part) New Riegel (300)

Land Use by Percent		
	Wolf Creek	Sandusky Watershed
Agriculture	88.8%	84.0%
Wooded	8.3%	12.6%
Urban	1.7%	1.2%
Wetlands	0.3%	1.1%
Barren	0.5%	0.3%
Shrub	0.3%	0.5%%
Water	0.1%	0.4%

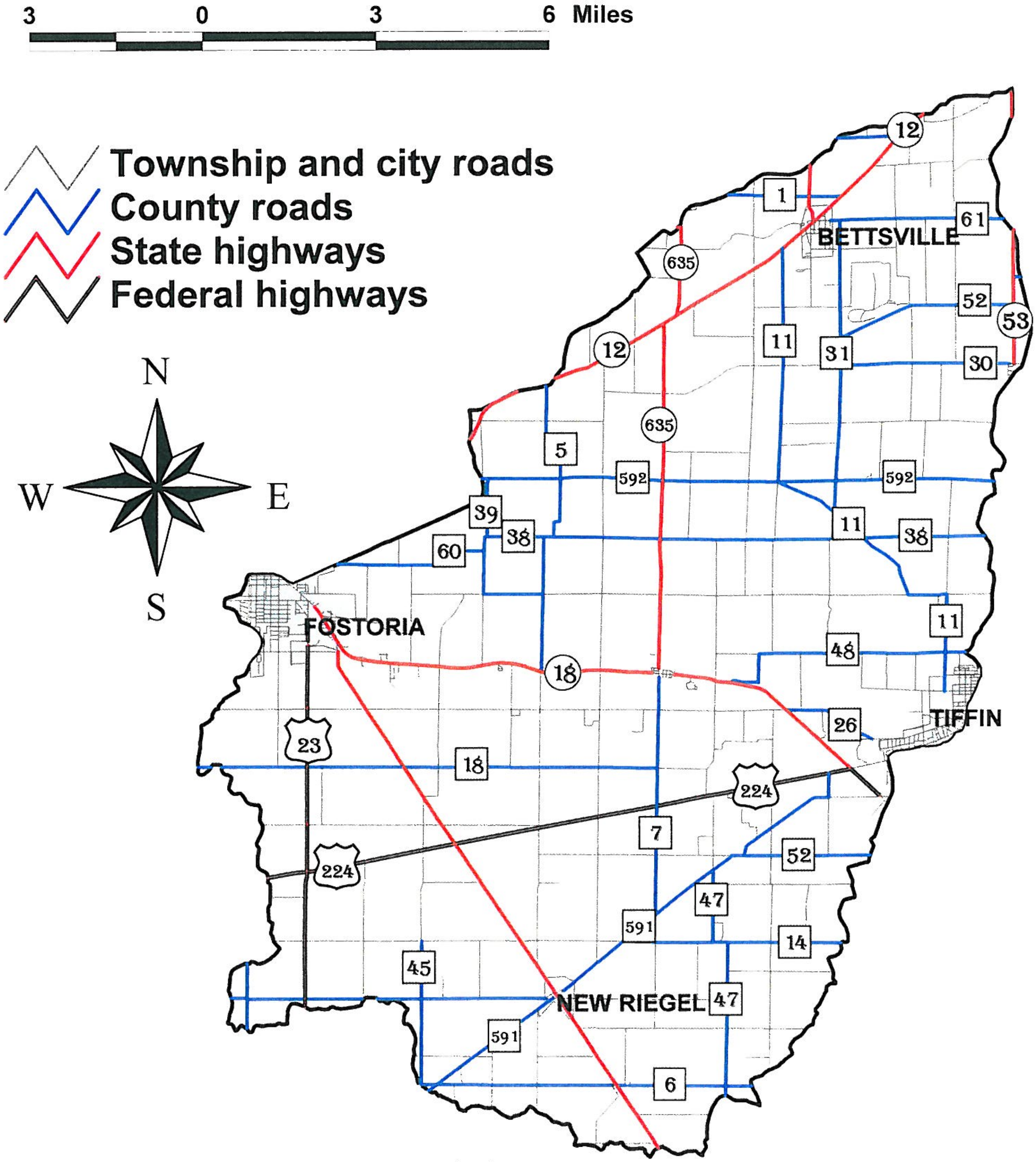
Aquatic Life Use Attainment		
Attainment Status	Wolf Creek	Sandusky Watershed
Fully Attaining	0%	35.0%
Threatened	73.1%	0.5%
Partial Attainment	0%	23.3%
Not Attaining	26.9%	41.2%

Wolf Creek
Hydrological Unit 04100011-100
Land Use in Relationship to Streams and Roads



Water Quality Laboratory Heidelberg College

Roads in the Wolf Creek Subwatershed 100



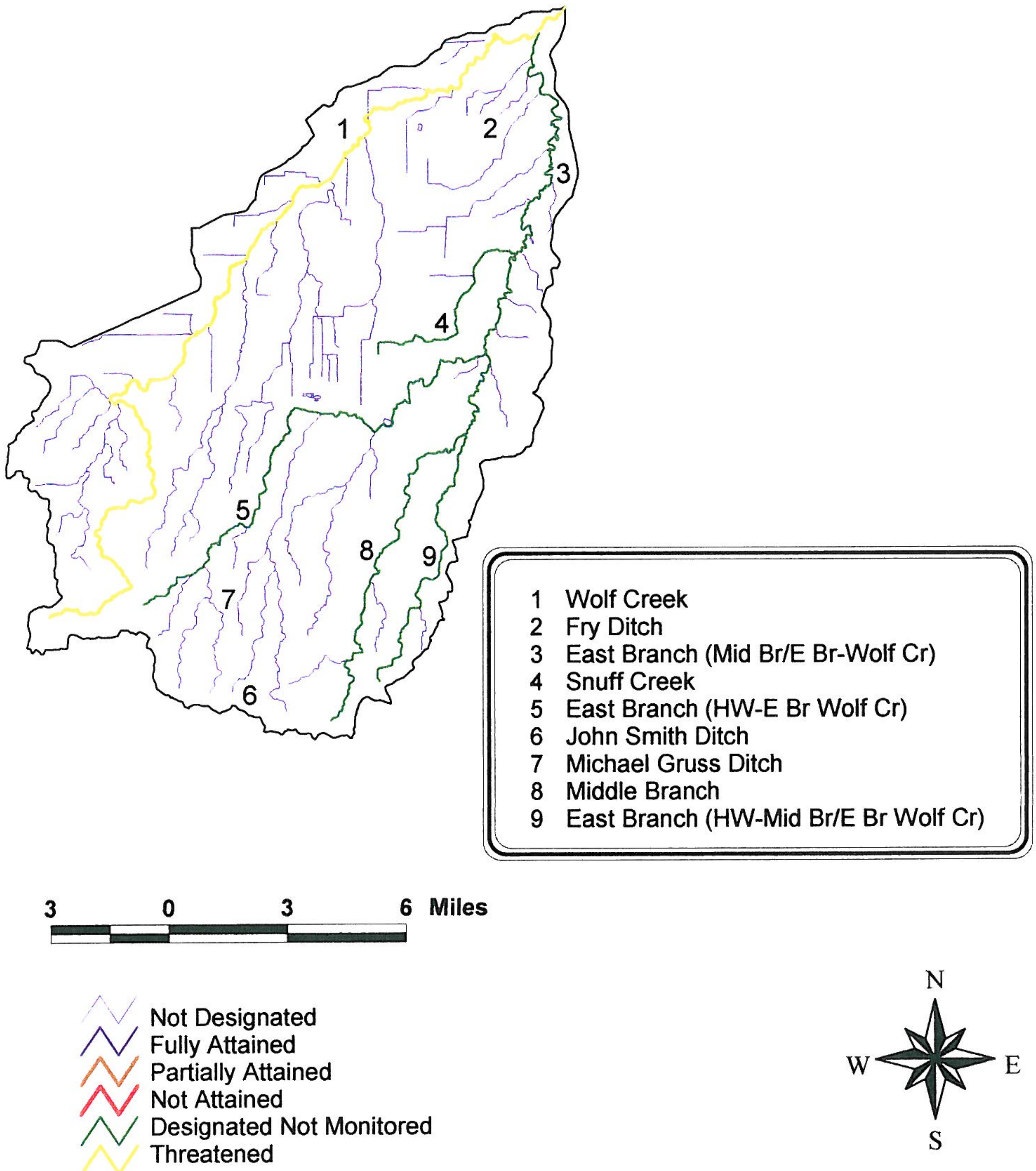
Summary of OEPA biological monitoring data for the Wolf Creek subwatershed (-100).

Map Number	OEPA Segment Number	Segment Name	Segment Length	Drainage Area	Fully Attain.	Threat-ened	Partial Attain.	Not Attain-ing	Use Desig-nation	Year Moni-tored	Causes of Impair-ment	Sources of Impair-ment
			miles	sq. miles	miles	miles	miles	miles				
1	OH82-15	Wolf Creek	23.9	153.5	0	1.9	0	0.7	WWH	1992	3-H	4-H
2	OH82-15.1	Fry Ditch	3.06	2.2	0	0	0	0	none	none	NA	NA
3	OH82-16	East Branch (Mid Br/E Br-Wolf Cr)	13.6	82.8	0	0	0	0	WWH	none	NA	NA
4	OH82-17	Snuff Creek	2	4.8	0	0	0	0	WWH	none	NA	NA
5	OH82-18	East Branch (HW-E Br Wolf Cr)	7.6	22.6	0	0	0	0	WWH	none	NA	NA
6	OH82-18.1	John Smith Ditch	8.65	9	0	0	0	0	LRW	none	NA	NA
7	OH82-18.11	Michael Gruss Ditch	2.93	1.6	0	0	0	0	LRW	none	NA	NA
8	OH82-19	Middle Branch	3.2	11.3	0	0	0	0	WWH	none	NA	NA
9	OH82-20	East Branch (HW-Mid Br/E Br Wolf Cr)	4.6	11.2	0	0	0	0	WWH	none	NA	NA
		Subwatershed Totals	69.54		0	1.9	0	0.7				
		Percent of Monitored Miles			0.0%	73.1%	0.0%	26.9%				

Key to causes and sources of impairment

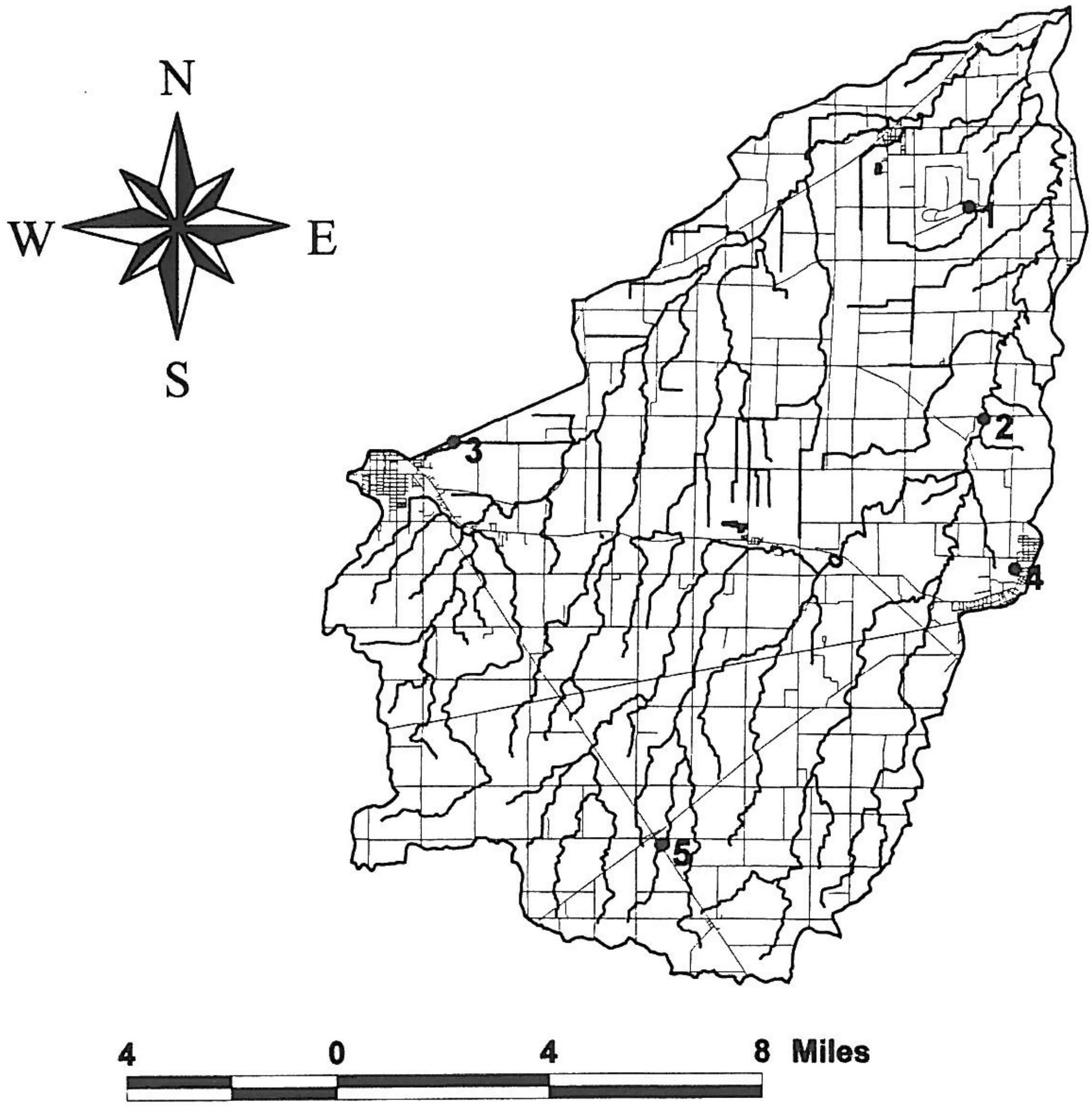
Causes of Impairment	Sources of Impairment	
1. Siltation	1. Nonirrigated Crop Production	10. Contaminated Sediments
2. Flow Alterations	2. Irrigated Crop Production	11. Upstream Impoundment
3. Other Habitat Alterations	3. Agriculture	12. Dam Construction
4. Nutrient Enrichment	4. Channelization	13. Removal of Riparian Vegetation
5. Unionized Ammonia	5. Municipal Point Sources	14. Other
6. Oil and Grease	6. Industrial Point Sources	15. Source Unknown
7. Organic Enrichment /DO	7. Urban Runoff/Storm Sewers	16. Natural
8. Priority Organics	8. Onsite Wastewater Systems	17. Stream Bank Modification/Destabilization
9. Metals	9. Flow Regulation/Modification	18. Combined Sewer Overflows
10. Cause Unknown		
11. Noxious Aquatic Weeds		
12. Unknown Toxicity		
H - High Impact; M - Moderate Impact; S - Slight Impact		

Wolf Creek
Hydrological Unit 04100011-100
Use Attainment



Water Quality Laboratory Heidelberg College

Wolf Creek
Hydrological Unit 04100011-100
Point Sources

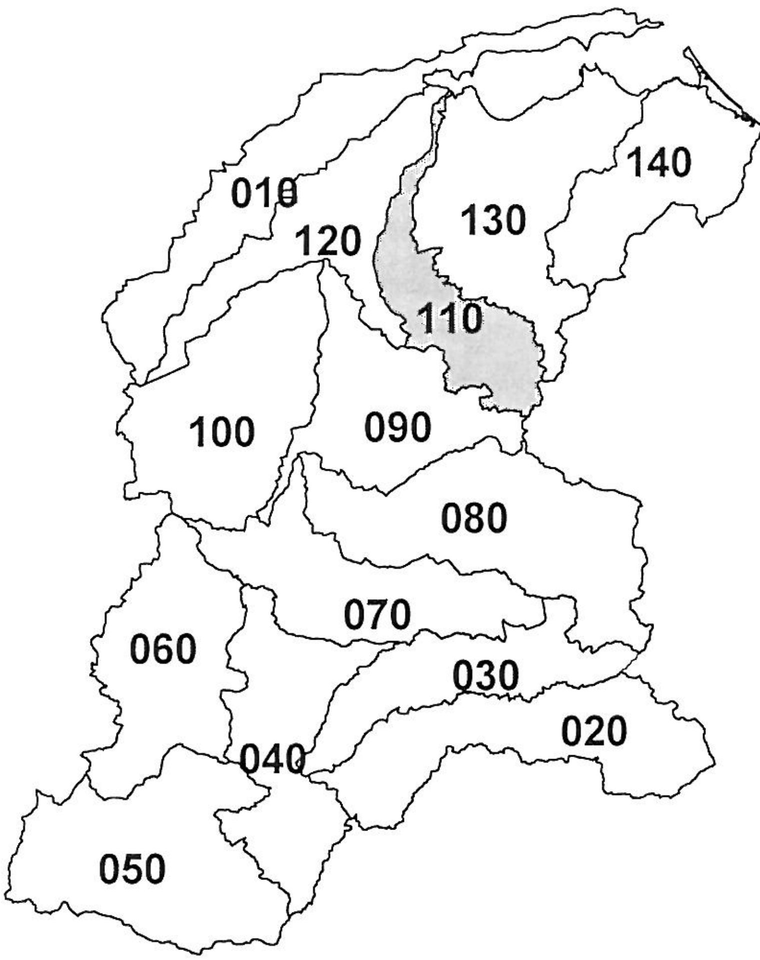


Point Source
Rivers
Roads

1 OH0000477 Basic Refractories Maple Grove
2 OH0052442 Atlas Industries
3 OH0001589 N+W RR Blair yards
4 OH0095150 unknown
5 OH0002194 Riegel Foods

Water Quality Laboratory Heidelberg College

Subwatershed: Green Creek
Hydrological Unit Code 04100011-110
Green Creek



Subwatershed Characteristics
Area (square miles): 81.1
Area (acres): 51,917
Upstream Area (square miles): 0
Total Stream Miles: 130.0
Designated Warm Water Habitat (WWH) Miles: 71.3
Undesignated Stream Miles: 58.7
Counties: Seneca, Sandusky
Monitored WWH Stream Miles: 30.2
Percent Monitored: 51.0%
Community Water Supplies: 1
Cities and Towns (population) Green Springs (723)

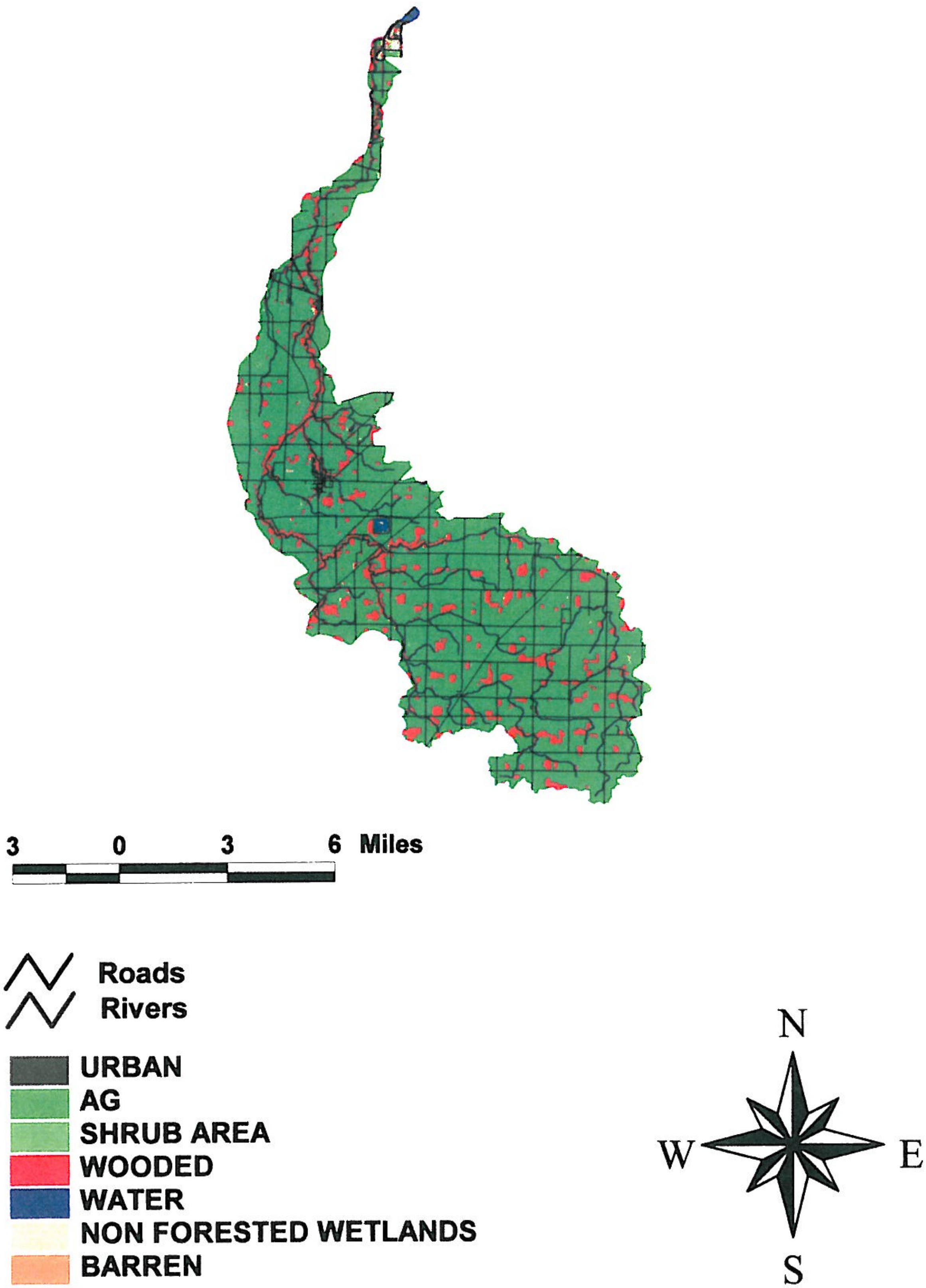
Land Use by Percent

	Green Creek	Sandusky Watershed
Agriculture	85.7%	84.0%
Wooded	12.3%	12.6%
Urban	0.7%	1.2%
Wetlands	0.8%	1.1%
Barren	0.0%	0.3%
Shrub	0.2%	0.5%%
Water	0.4%	0.4%

Aquatic Life Use Attainment

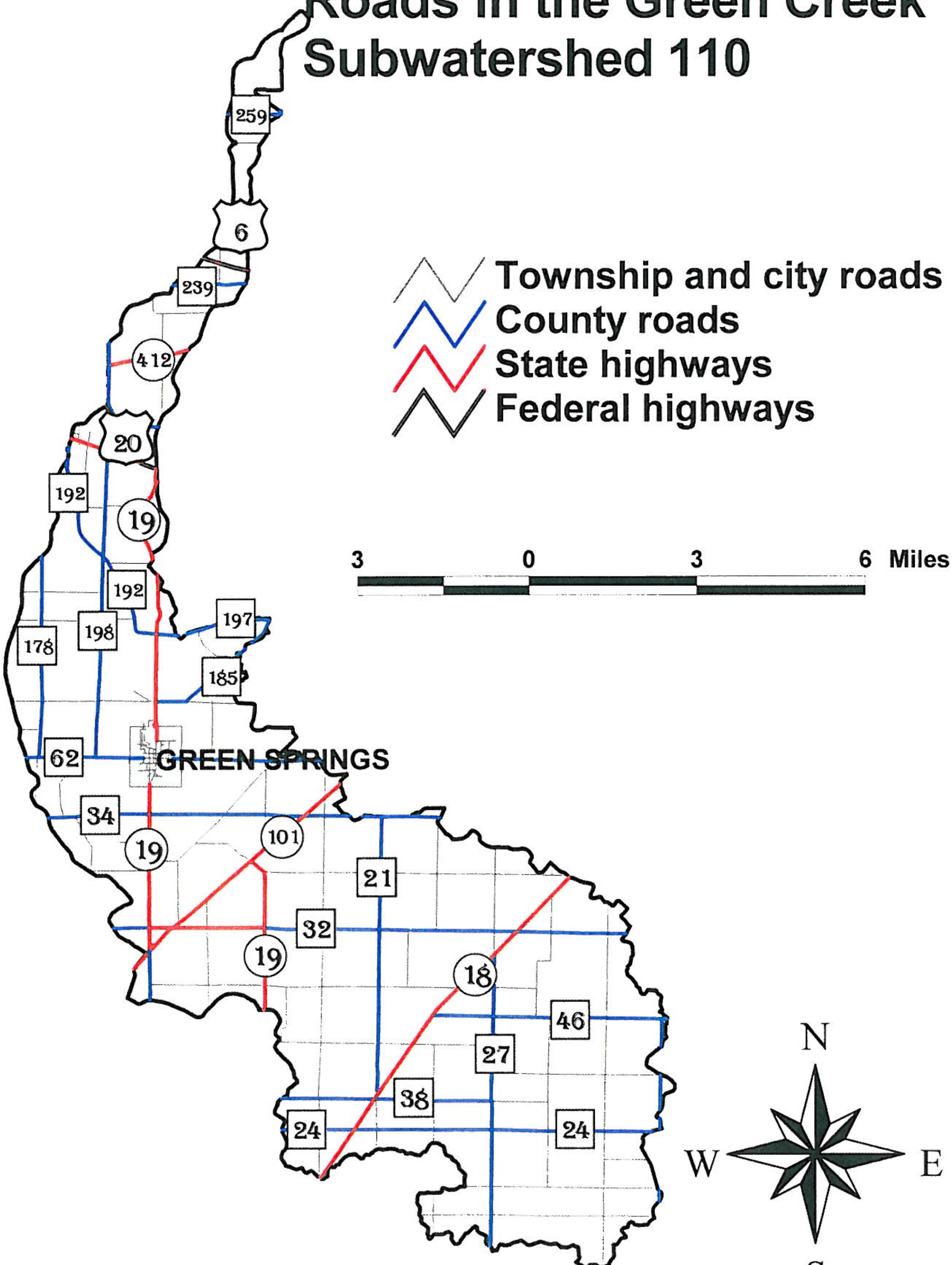
Attainment Status	Green Creek	Sandusky Watershed
Fully Attaining	100%	35.0%
Threatened	0.0%	0.5%
Partial Attainment	0%	23.3%
Not Attaining	0%	41.2%

Green Creek
Hydrological Unit 04100011-110
Land Use in Relationship to Streams and Roads



Water Quality Laboratory Heidelberg College

Roads in the Green Creek Subwatershed 110



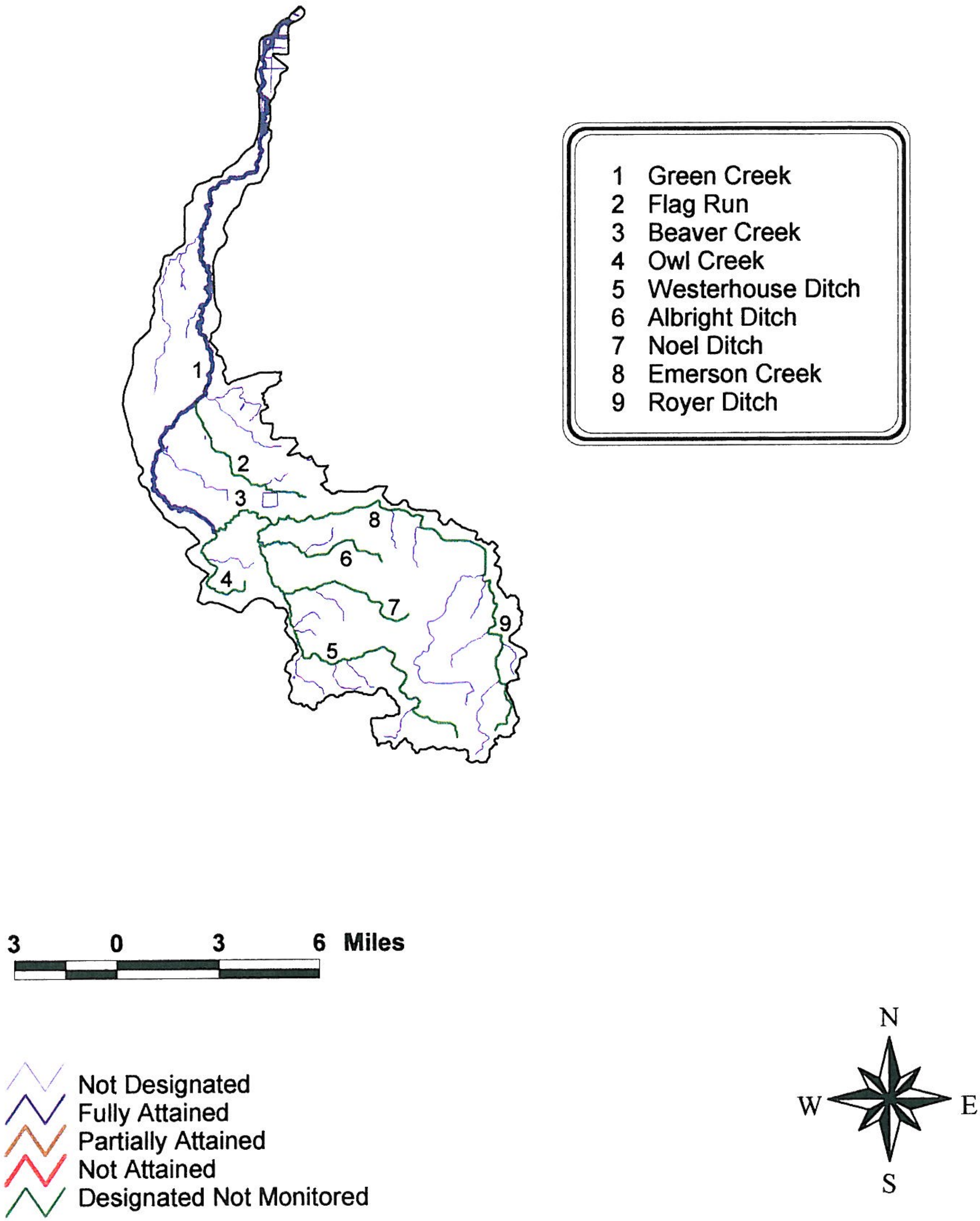
Summary of OEPA biological monitoring data for the Green Creek subwatershed (-110).

Map Number	OEPA Segment Number	Segment Name	Segment Length	Drainage Area	Fully Attain.	Threat-ened	Partial Attain.	Not Attain-ing	Use Desig-nation	Year Moni-tored	Causes of Impair-ment	Sources of Impair-ment
	Number		miles	sq. miles	miles	miles	miles	miles				
1	OH82-2	Green Creek	19.3	83	19.3	0	0	0	WWH	1983	none identified	none identified
2	OH82-3	Flag Run	5.2	6.2	0	0	0	0	WWH	none	NA	NA
3	OH82-4	Beaver Creek	3.6	49.8	0	0	0	0	WWH	none	NA	NA
4	OH82-5	Owl Creek	2.9	3.5	0	0	0	0	WWH	none	NA	NA
5	OH82-6	Westerhouse Ditch	11.8	20.5	0	0	0	0	WWH	none	NA	NA
6	OH82-7	Albright Ditch	3.5	4.1	0	0	0	0	WWH	none	NA	NA
7	OH82-8	Noel Ditch	4.6	4.4	0	0	0	0	WWH	none	NA	NA
8	OH82-9	Emerson Creek	12	23.3	0	0	0	0	WWH	none	NA	NA
9	OH82-10	Royer Ditch	8.4	19.6	0	0	0	0	WWH	none	NA	NA
		Unit Total	71.3		19.3	0	0	0				
		Percent of Monitored Miles			100%	0.0%	0.0%	0.0%				

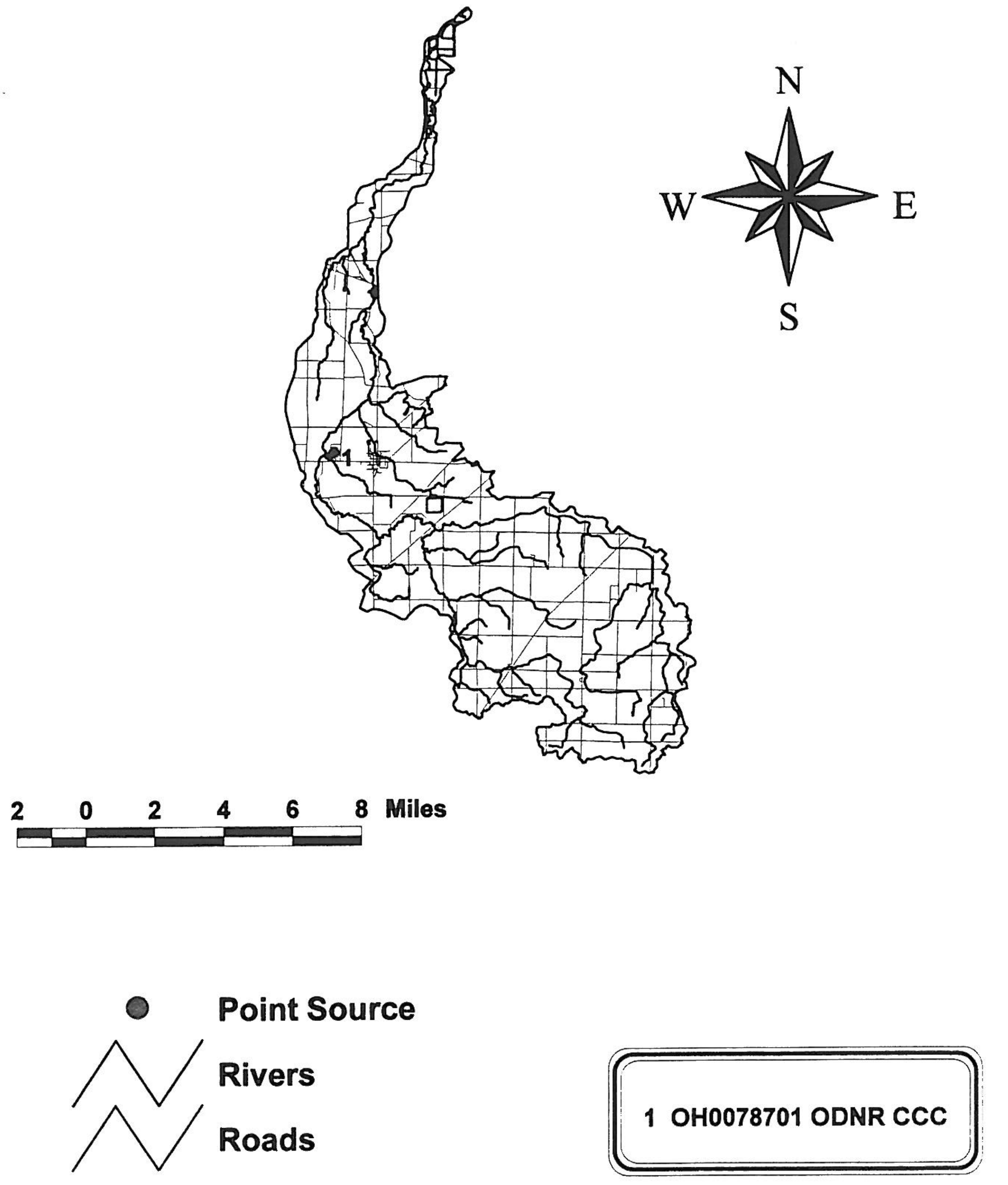
Key to causes and sources of impairment

Causes of Impairment	Sources of Impairment	
1. Siltation	1. Nonirrigated Crop Production	10. Contaminated Sediments
2. Flow Alterations	2. Irrigated Crop Production	11. Upstream Impoundment
3. Other Habitat Alterations	3. Agriculture	12. Dam Construction
4. Nutrient Enrichment	4. Channelization	13. Removal of Riparian Vegetation
5. Unionized Ammonia	5. Municipal Point Sources	14. Other
6. Oil and Grease	6. Industrial Point Sources	15. Source Unknown
7. Organic Enrichment /DO	7. Urban Runoff/Storm Sewers	16. Natural
8. Priority Organics	8. Onsite Wastewater Systems	17. Stream Bank Modification/Destabilization
9. Metals	9. Flow Regulation/Modification	18. Combined Sewer Overflows
10. Cause Unknown		
11. Noxious Aquatic Weeds		
12. Unknown Toxicity		
H - High Impact; M - Moderate Impact; S - Slight Impact		

Green Creek
Hydrological Unit 04100011-110
Use Attainment

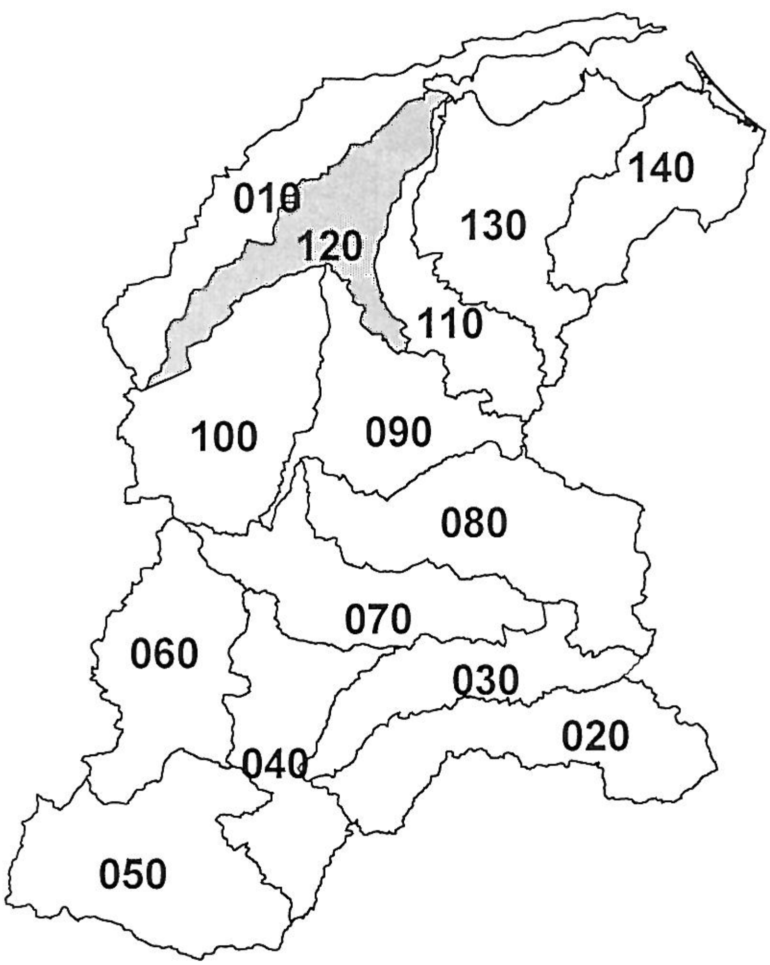


Green Creek
Hydrological Unit 04100011-110
Point Sources



Water Quality Laboratory Heidelberg College

Subwatershed: Sandusky-Fremont
Hydrological Unit Code 04100011-120
Sandusky River (below Wolf Creek to Sandusky Bay)



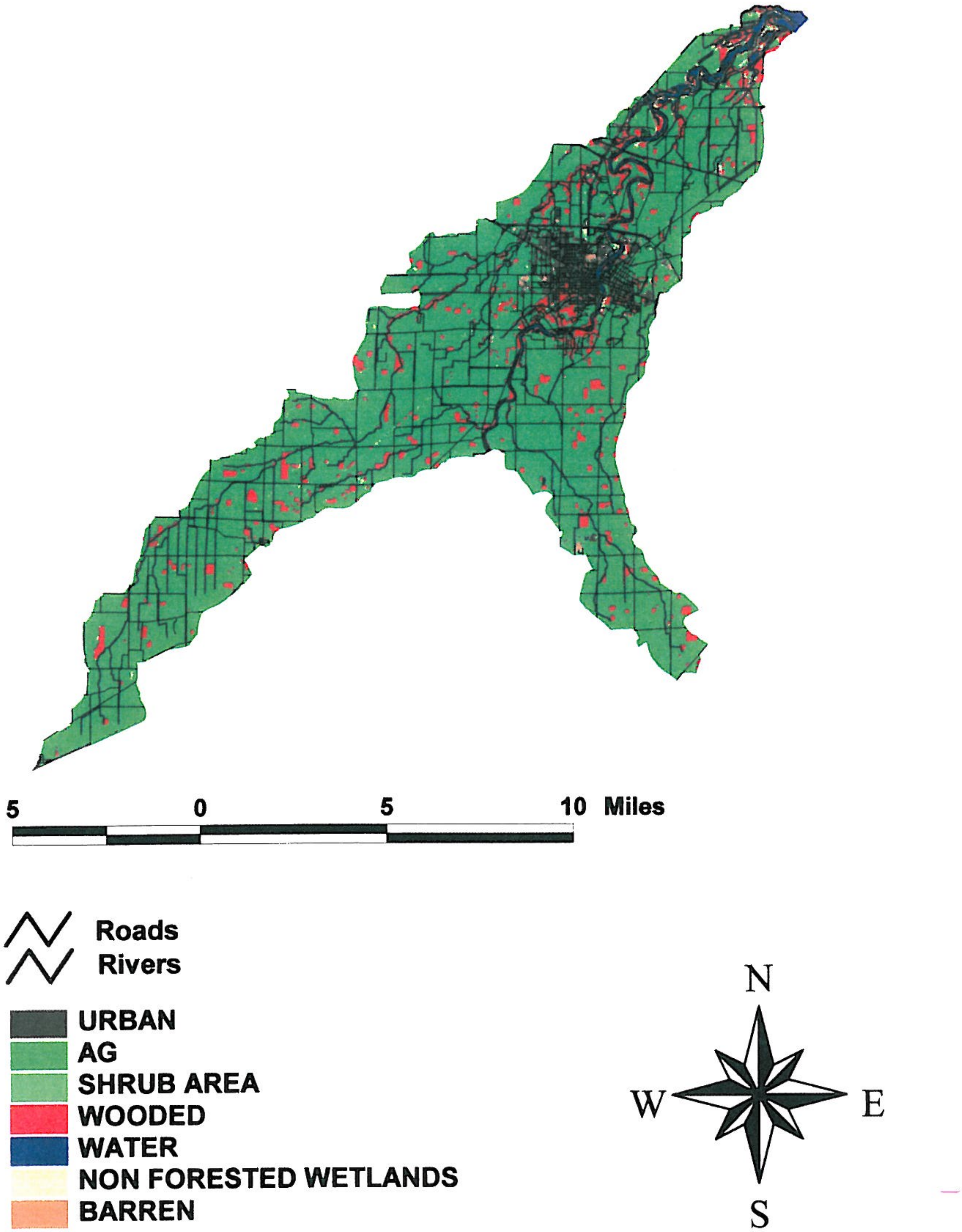
Subwatershed Characteristics
Area (square miles): 108.4
Area (acres): 69,380
Upstream Area (square miles): 1,312.5
Total Stream Miles: 248.6
Designated Warm Water Habitat (WWH) Miles: 59.2
Undesignated Stream Miles: 189.4
Counties: Sandusky, Seneca
Monitored WWH Stream Miles: 30.2
Percent Monitored: 51.0%
Community Water Supplies: 2
Cities and Towns (population) Fremont (18,133) Burgoon (259)

Scenic Rivers designation to Roger Young Park in Fremont

Land Use by Percent		
	Sandusky-Fremont	Sandusky Watershed
Agriculture	82.7%	84.0%
Wooded	7.9%	12.6%
Urban	4.8%	1.2%
Wetlands	2.4%	1.1%
Barren	0.3%	0.3%
Shrub	0.3%	0.5%%
Water	1.7%	0.4%

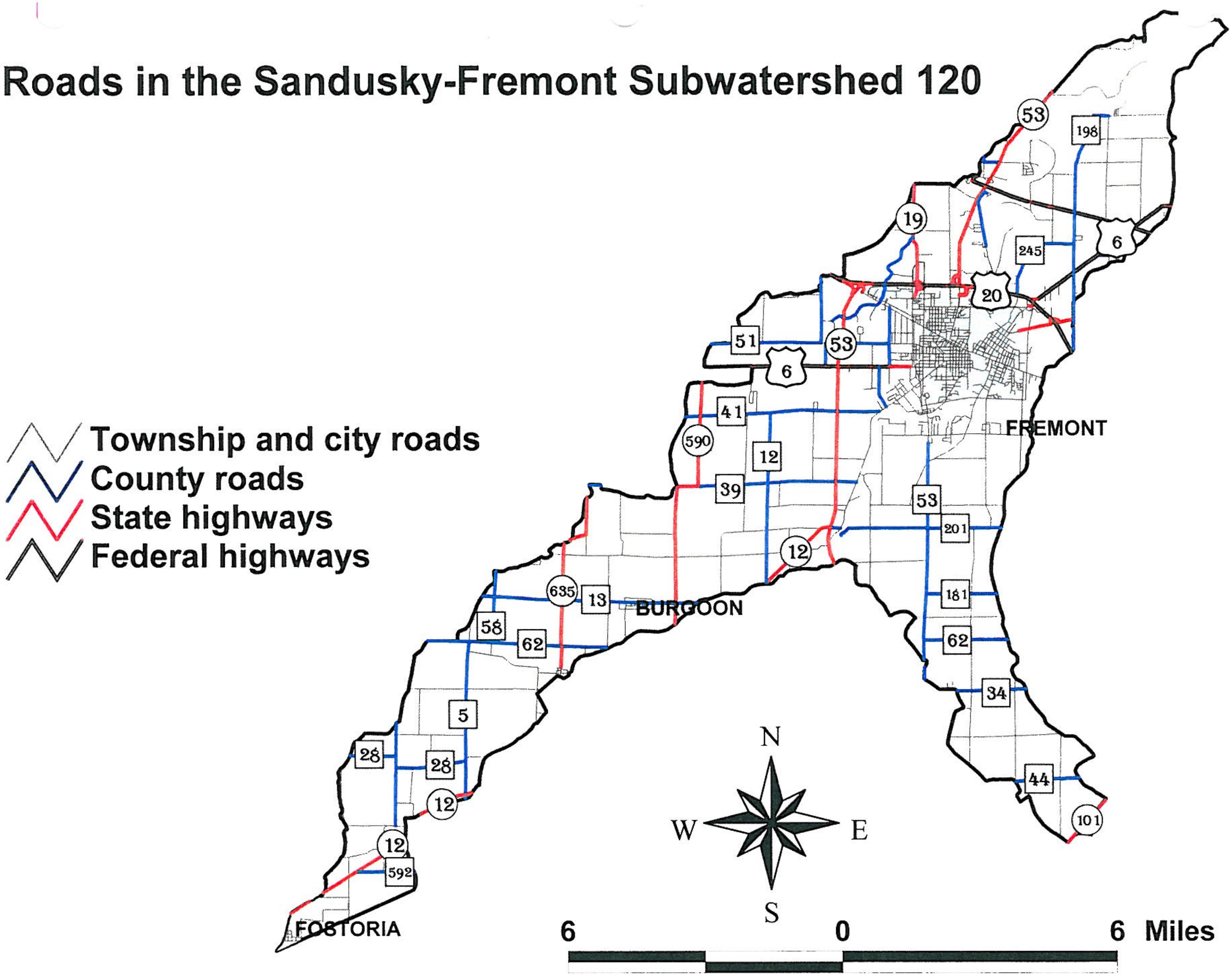
Aquatic Life Use Attainment		
Attainment Status	Sandusky-Fremont	Sandusky Watershed
Fully Attaining	40.4%	35.0%
Threatened	0.0%	0.5%
Partial Attainment	56.3%	23.3%
Not Attaining	3.3%	41.2%

Sandusky-Fremont
Hydrological Unit 04100011-120
Land Use in Relationship to Streams and Roads



Water Quality Laboratory Heidelberg College

Roads in the Sandusky-Fremont Subwatershed 120



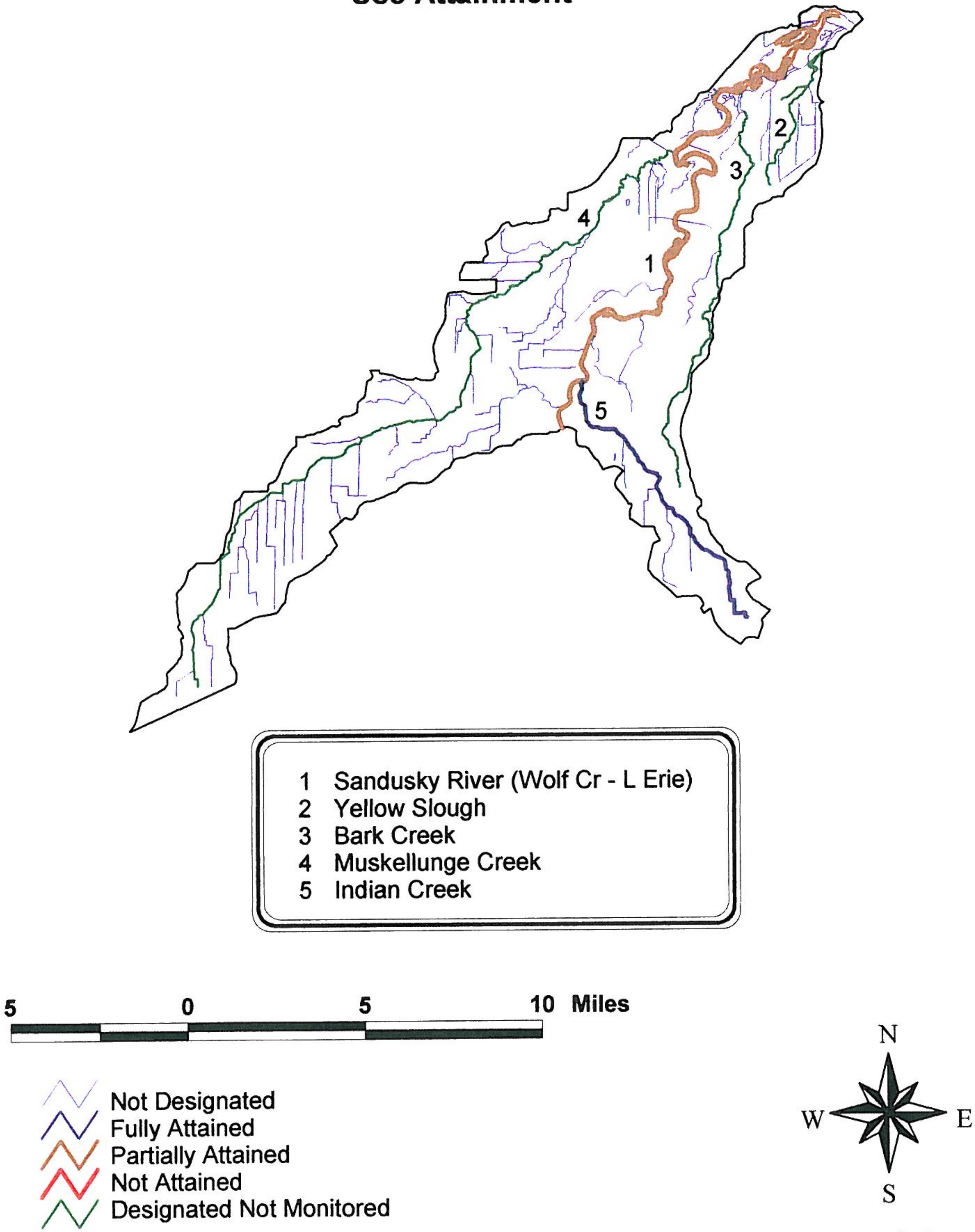
Summary of OEPA biological monitoring data for the Sandusky Fremont subwatershed (-120).

Map Number	OEPA Segment Number	Segment Name	Segment Length	Drainage Area	Fully Attain.	Threat-ened	Partial Attain.	Not Attain-ing	Use Desig-nation	Year Moni-tored	Causes of Impair-ment	Sources of Impair-ment
	Number		miles	sq. miles	miles	miles	miles	miles				
1	OH82-1	Sandusky River (Wolf Cr - Lake Erie)	22.73	1420	4.7	0	17	1	WWH	1988	2-H; 1-H; 3-M; 7-S	9-H; 1-H; 2-H; 12-M; 5-S; 6-S
2	OH82-11	Yellow Slough	2.6	3.6	0	0	0	0	WWH	None	NA	NA
3	OH82-12	Bark Creek	10.7	13.1	0	0	0	0	WWH	none	NA	NA
4	OH82-13	Muskellunge Creek	18.3	47.3	0	0	0	0	WWH	none	NA	NA
5	OH82-14	Indian Creek	7.5	10	7.5	0	0	0	WWH	1981	none identified	none identified
		Subwatershed Totals	61.83		12.2	0	17	1				
		Percent of Monitored Miles			40.4%	0.0%	56.3%	3.3%				

Key to causes and sources of impairment

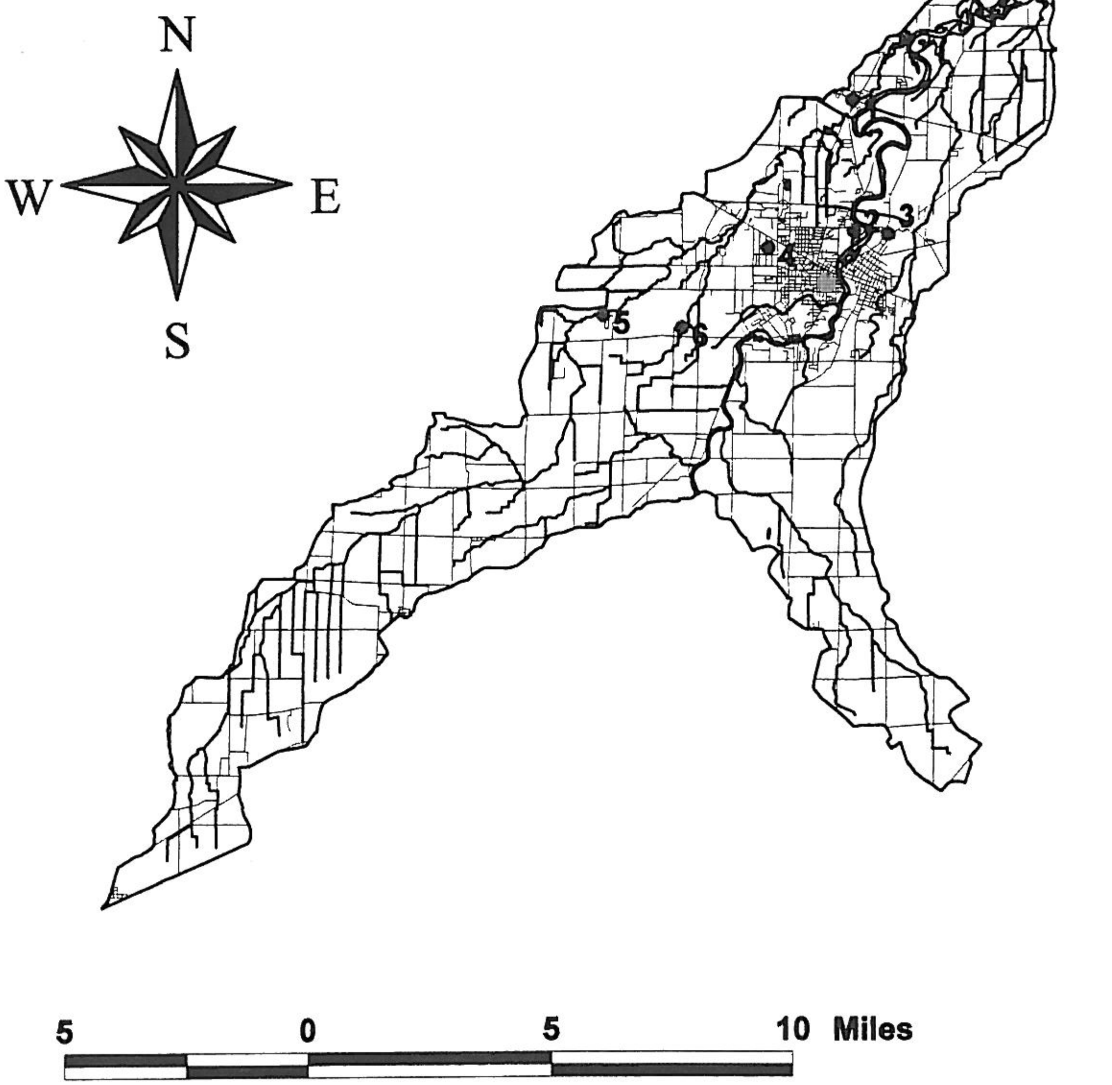
Causes of Impairment	Sources of Impairment	
1. Siltation	1. Nonirrigated Crop Production	10. Contaminated Sediments
2. Flow Alterations	2. Irrigated Crop Production	11. Upstream Impoundment
3. Other Habitat Alterations	3. Agriculture	12. Dam Construction
4. Nutrient Enrichment	4. Channelization	13. Removal of Riparian Vegetation
5. Unionized Ammonia	5. Municipal Point Sources	14. Other
6. Oil and Grease	6. Industrial Point Sources	15. Source Unknown
7. Organic Enrichment /DO	7. Urban Runoff/Storm Sewers	16. Natural
8. Priority Organics	8. Onsite Wastewater Systems	17. Stream Bank Modification/Destabilization
9. Metals	9. Flow Regulation/Modification	18. Combined Sewer Overflows
10. Cause Unknown		
11. Noxious Aquatic Weeds		
12. Unknown Toxicity		
H - High Impact; M - Moderate Impact; S - Slight Impact		

Sandusky, Fremont
Hydrological Unit 04100011-120
Use Attainment



Water Quality Laboratory Heidelberg College

Sandusky-Fremont
Hydrological Unit 04100041-120
Point Sources



● Point Source

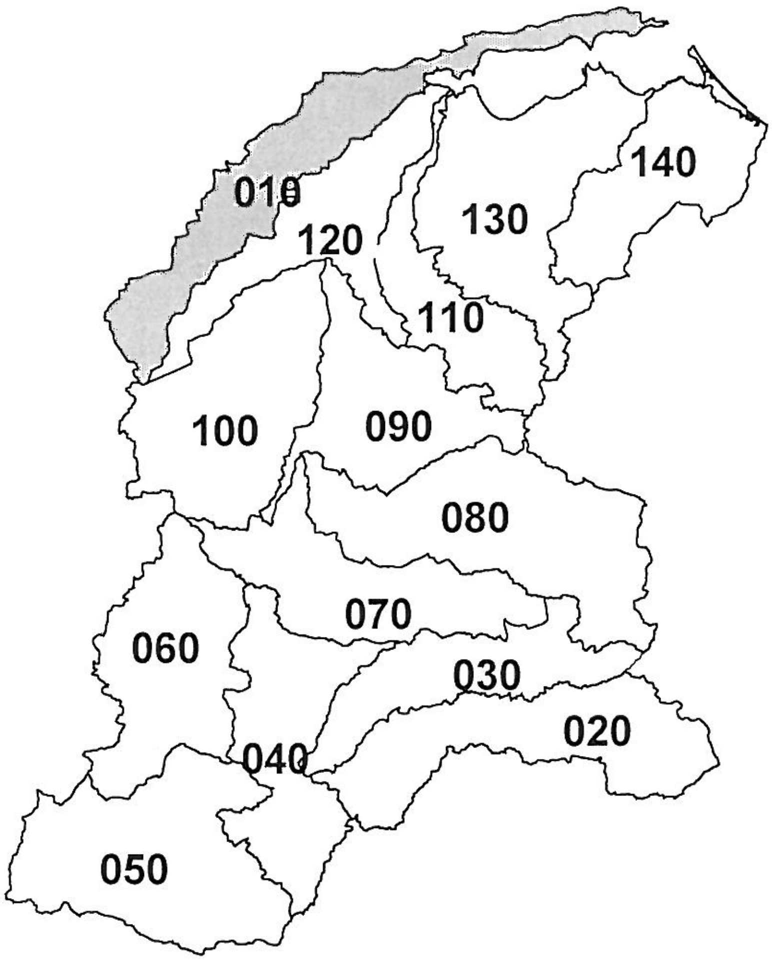
Rivers

Roads

1 OH0057916 Brighton Hotel Corp
2 OH0025291 Fremont WWTP
3 OH0000574 Heinz USA Fremont
4 OH0001899 Tony's Bakery
5 OH0079049 Sandusky Co. sewer district 6
6 OH0036501 Sandusky Co. Westwood Acres

Water Quality Laboratory Heidelberg College

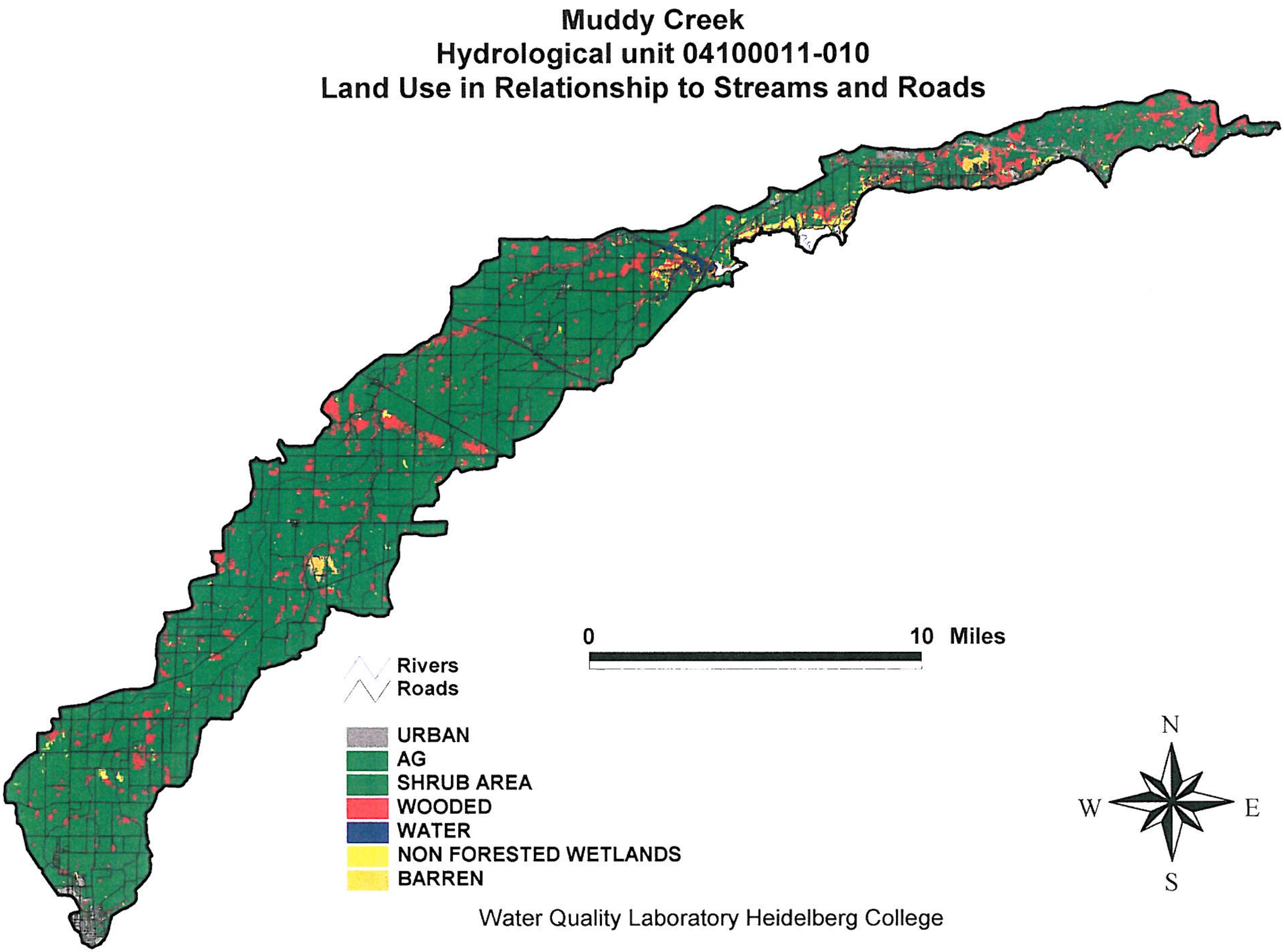
Subwatershed: Muddy Creek and north shore of Sandusky Bay
Hydrological Unit Code 04100011-010
Muddy Creek



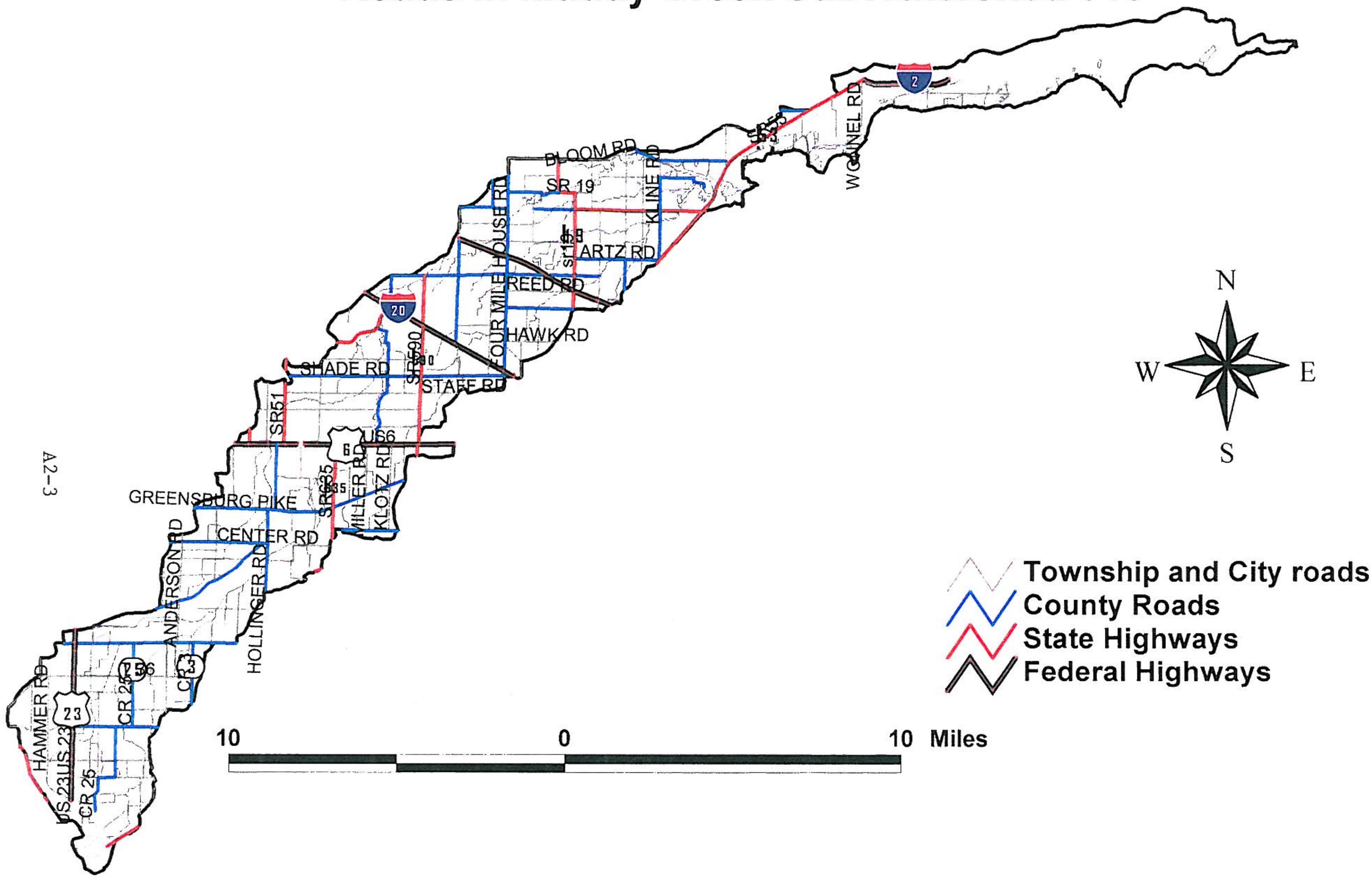
Subwatershed Characteristics
Area (square miles): 136
Area (acres): 86,970
Upstream Area (square miles): 0
Total Stream Miles:
Designated Warm Water Habitat (WWH) Miles: 67
Undesignated Stream Miles:
Counties: Ottawa, Sandusky, Seneca, Wood
Monitored WWH Stream Miles: 41.16
Percent Monitored: 61%
Community Water Supplies: 0
Cities and Towns (population) Lindsey (571), Helena (307), Hessville

Land Use by Percent		
	Muddy Creek	Sandusky Watershed
Agriculture	83.1%	84.0%
Wooded	9.1%	12.6%
Urban	2.9%	1.2%
Wetlands	3.2%	1.1%
Barren	0.5%	0.3%
Shrub	0.4%	0.5%%
Water	0.9%	0.4%

Aquatic Life Use Attainment		
Attainment Status	Muddy Creek	Sandusky Watershed
Fully Attaining	28%	35.0%
Threatened	0%	0.5%
Partial Attainment	15%	23.3%
Not Attaining	57%	41.2%


Muddy Creek
Hydrological unit 04100011-010
Land Use in Relationship to Streams and Roads
0
10 Miles
Rivers
Roads
URBAN
AG
SHRUB AREA
WOODED
WATER
NON FORESTED WETLANDS
BARREN
N
W
E
S
Water Quality Laboratory Heidelberg College

Roads in Muddy Creek SubWatershed 010



Water Quality Laboratory Heidelberg College

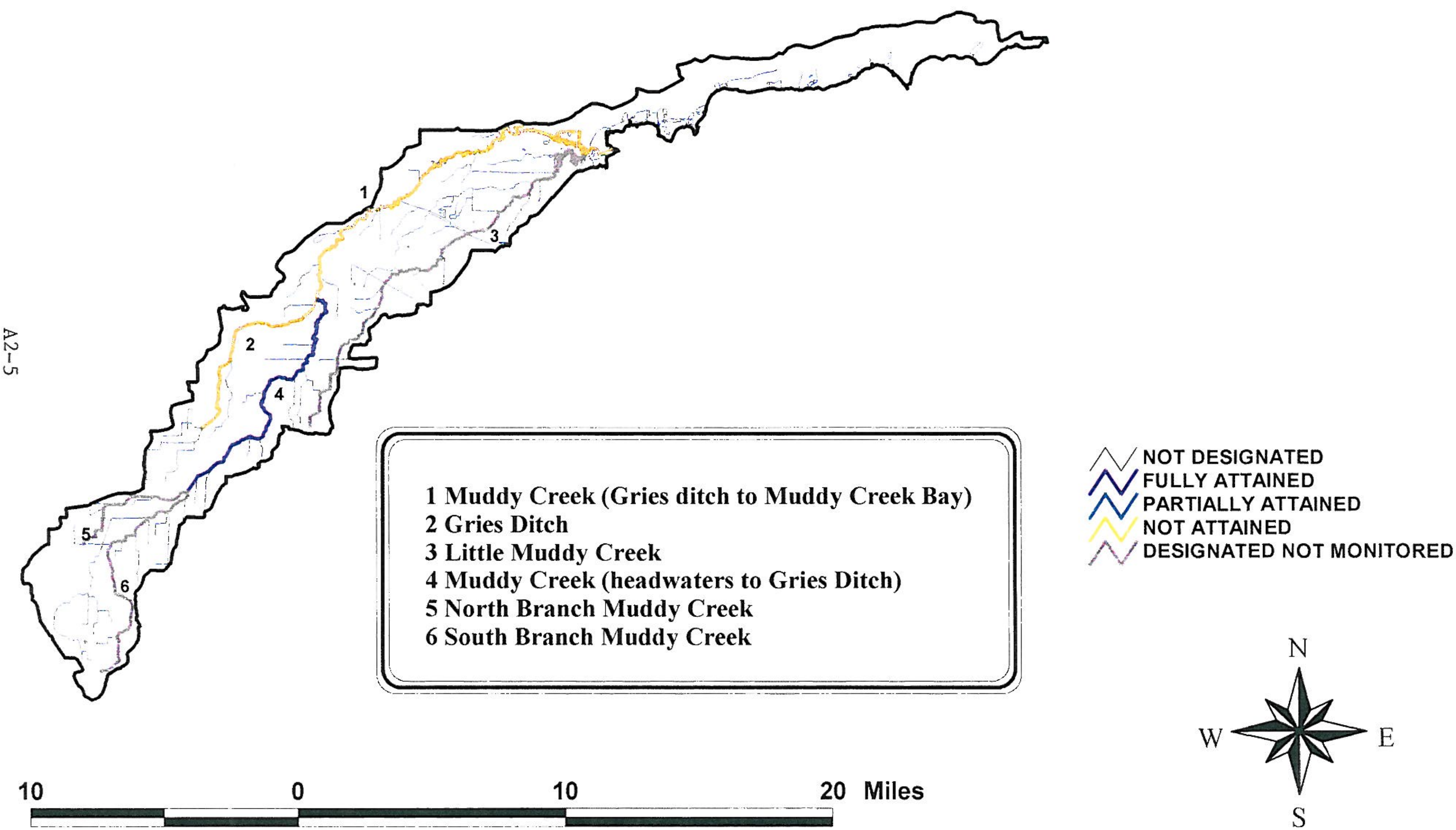
Summary of OEPA biological monitoring data for the Muddy Creek subwatershed (-010).

Map Number	OEPA Segment Number	Segment Name	Segment Length	Drainage Area	Fully Attain.	Threat-ened	Partial Attain.	Not Attain-ing	Use Desig-nation	Year Moni-tored	Causes of Impair-ment	Sources of Impair-ment
	Number		miles	sq. miles	miles	miles	miles	miles				
1	82-21	Muddy Creek (Gries ditch to Muddy Creek Bay	20	105	2.8		11.1	6.2	WWH	1982		
2	82-21.1	Gries Ditch	12	15.8				12.14	WWH	1995	4-H,7-H, 3-H	19-H, 4-H, 1-H, 8-H
3	82-22	Little Muddy Creek	12	28					WWH			
4	82-22	Muddy Creek (headwaters to Gries Creek	17.9	95	6.02		3.2		WWH	1984/ 1988	3-H, 7-S	4-H,13-M, 1-S, 7-S
5	82 -24	North Branch Muddy Creek	4						WWH			
6	82-25	South Branch Muddy Creek	10						WWH			
		Subwatershed Totals	67									
		Percent of Monitored Miles	61%									

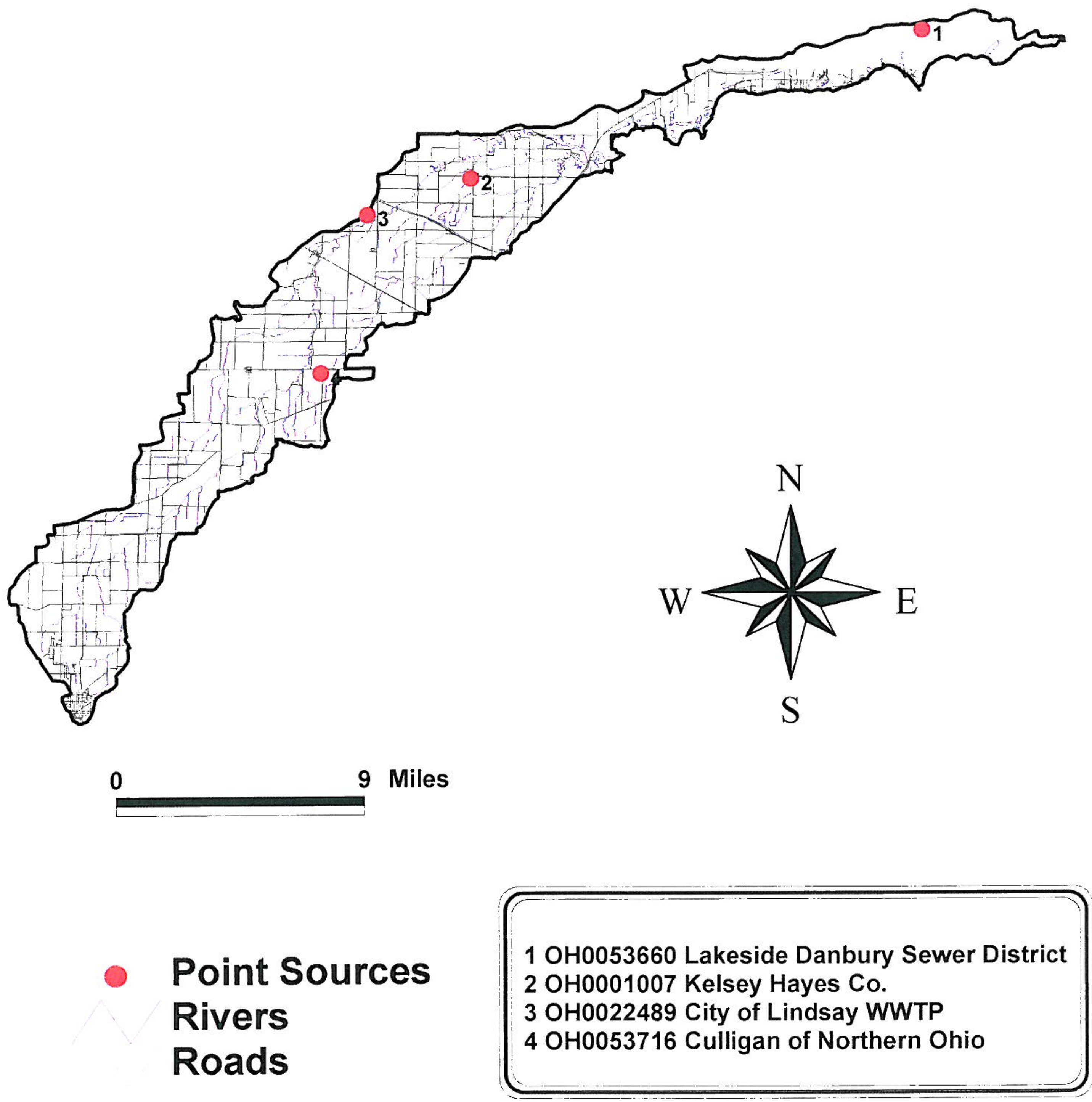
Key to causes and sources of impairment

Causes of Impairment	Sources of Impairment	
1. Siltation	1. Nonirrigated Crop Production	10. Contaminated Sediments
2. Flow Alterations	2. Irrigated Crop Production	11. Upstream Impoundment
3. Other Habitat Alterations	3. Agriculture	12. Dam Construction
4. Nutrient Enrichment	4. Channelization	13. Removal of Riparian Vegetation
5. Unionized Ammonia	5. Municipal Point Sources	14. Other
6. Oil and Grease	6. Industrial Point Sources	15. Source Unknown
7. Organic Enrichment /DO	7. Urban Runoff/Storm Sewers	16. Natural
8. Priority Organics	8. Onsite Wastewater Systems	17. Stream Bank Modification/Destabilization
9. Metals	9. Flow Regulation/Modification	18. Combined Sewer Overflows
10. Cause Unknown		19. Pasture Land
11. Noxious Aquatic Weeds		
12. Unknown Toxicity		
H - High Impact; M - Moderate Impact; S - Slight Impact		

Muddy Creek
Hydrological Unit 04100011-010
Use Attainment

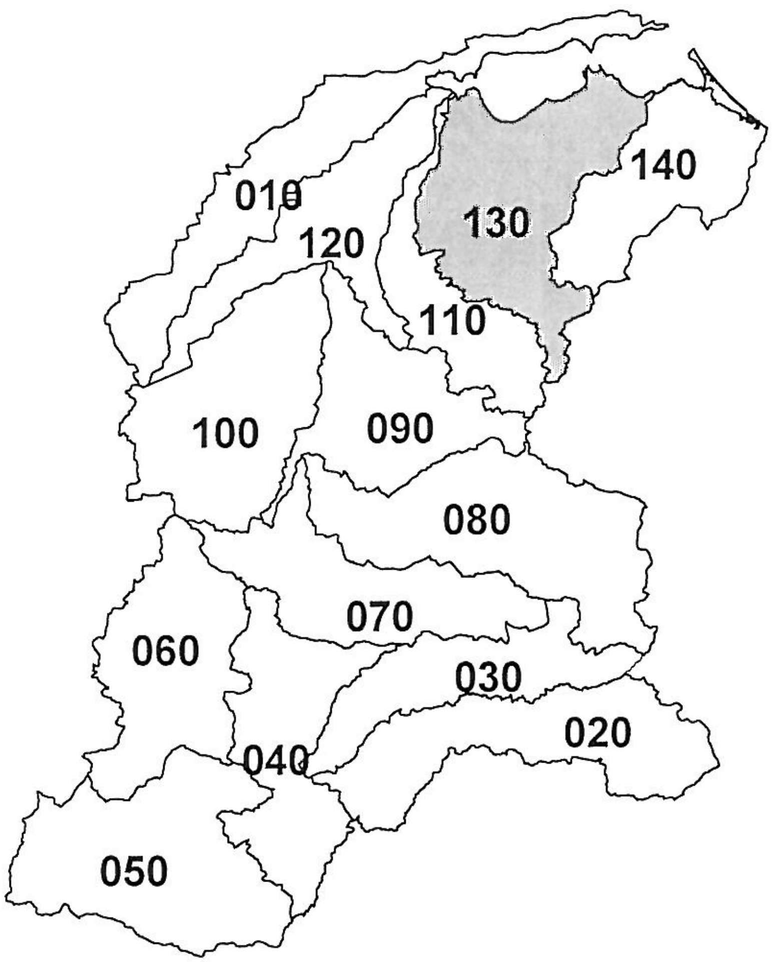


Muddy Creek
Hydrological Unit 04100011-010
Point Sources



Water Quality Laboratory Heidelberg College

Subwatershed: South Shore Sandusky Bay Tribs (below Sandusky River to above Mills Creek)
Hydrological Unit Code 04100011-130
South Shore -west

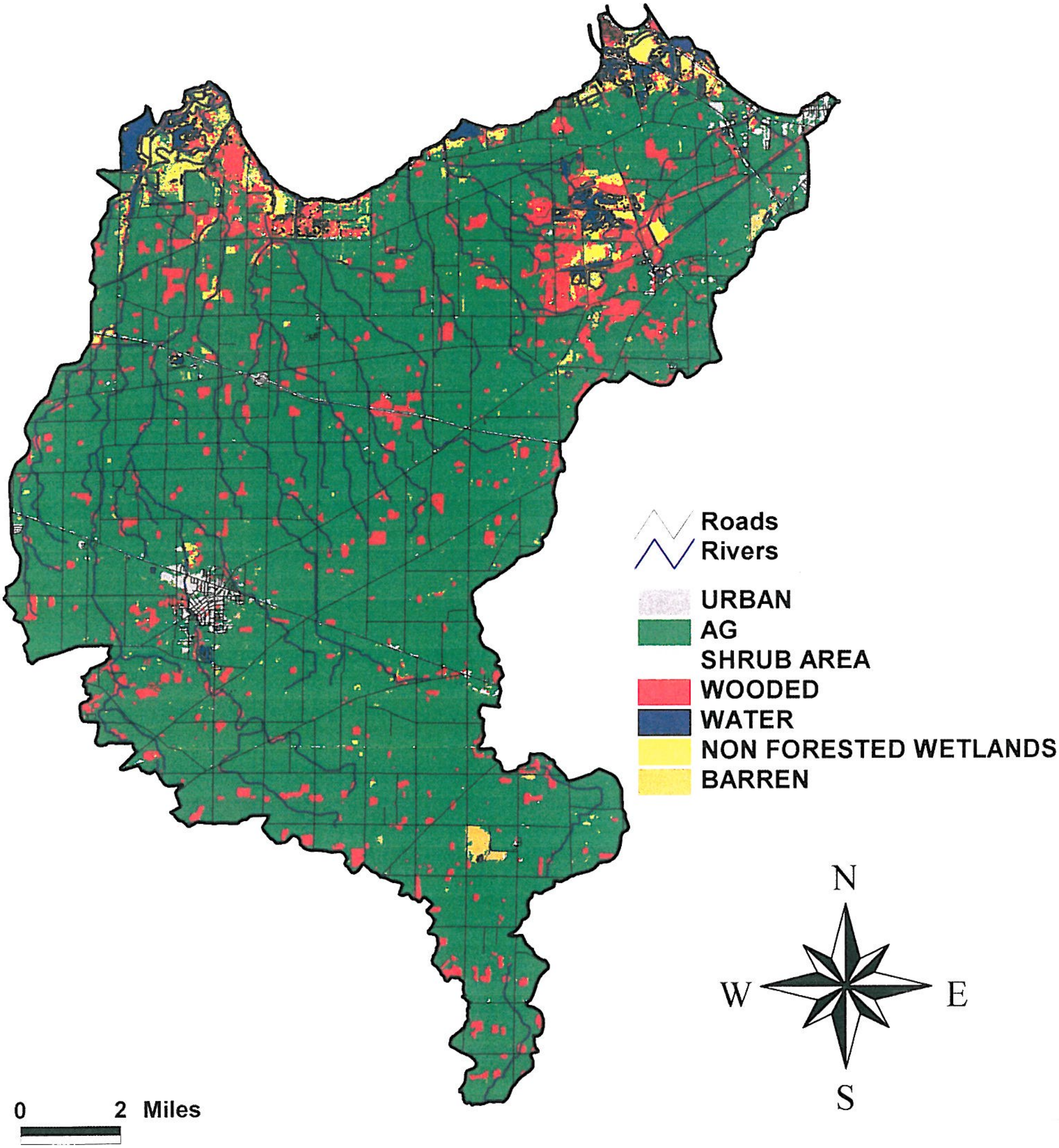


Subwatershed Characteristics
Area (square miles): 164
Area (acres): 104,779
Upstream Area (square miles): 0
Total Stream Miles:
Designated Warm Water Habitat (WWH) Miles: 89.2
Undesignated Stream Miles:
Counties: Erie, Sandusky, Seneca, Huron
Monitored WWH Stream Miles: 29.4
Percent Monitored: 33%
Community Water Supplies: 1
Cities and Towns (population) Clyde (5,930)

Land Use by Percent		
	South Shore-west	Sandusky Watershed
Agriculture	81.4%	84.0%
Wooded	10.0%	12.6%
Urban	2.3%	1.2%
Wetlands	4.2%	1.1%
Barren	0.4%	0.3%
Shrub	0.3%	0.5%%
Water	1.3%	0.4%

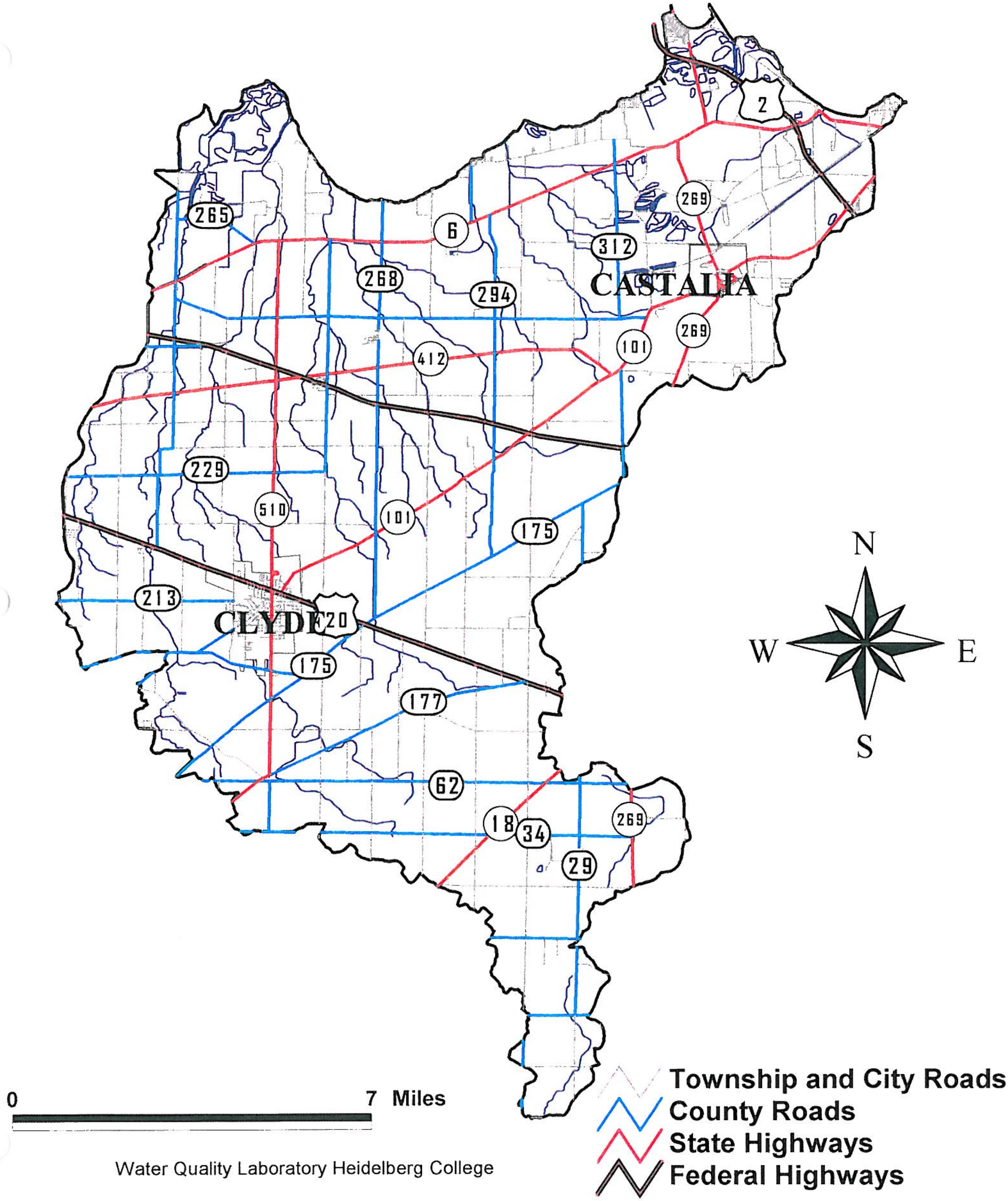
Aquatic Life Use Attainment		
Attainment Status	South Shore-west	Sandusky Watershed
Fully Attaining	8.5%	35.0%
Threatened	0%	0.5%
Partial Attainment	24.5%	23.3%
Not Attaining	67%	41.2%

South Shore-west
Hydrological Unit 04100011-130
Land Use in Relation to Streams and Roads



Water Quality Laboratory Heidelberg College

Roads in South Shore-west Subwatershed 130



Water Quality Laboratory Heidelberg College

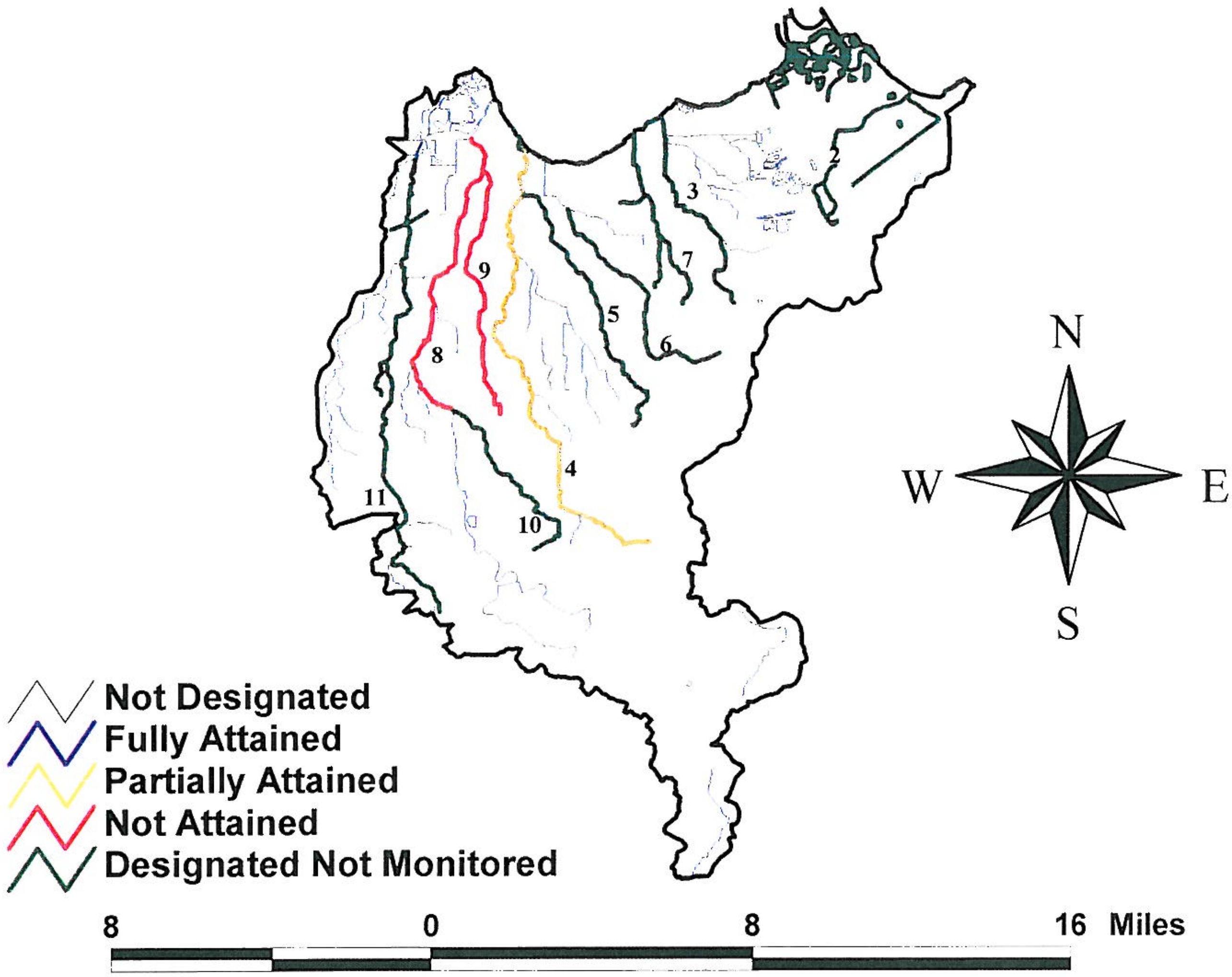
Summary of OEPA biological monitoring data for the South Shore-West Subwatershed (-130).

Map Number	OEPA Segment Number	Segment Name	Segment Length	Drainage Area	Fully Attain.	Threat-ened	Partial Attain.	Not Attain-ing	Use Desig-nation	Year Moni-tored	Causes of Impairment	Sources of Impair-ment
	Number		miles	sq. miles	miles	miles	miles	miles				
1	83-4	Lake Erie Direct Tribs, Pickeral Cr. to Mills Cr.	15						Lake Erie			
2	83-5	Cold Creek	5						WWH			
3	83-6	Little Pickeral Cr.	6						Cold Water			
4	83-7	Pickeral Creek	7				6.20	1.0	WWH	1988	3-H, 1-M	19-H 1-S
5	83-8	Strong Creek	4						WWH			
6	83-9	Fuller Creek	4						WWH			
7	83-10	Lake Erie Direct Tribs, Sandusky River to Pickeral Cr.	4						Lake Erie			
8	83-11	Raccoon Creek	14.9		2.50		1.00	11.4	WWH	1995	7-H, 3-H, 7-M 1-M, 9-M, 4-S	5-H,4-H, 5-M, 8-M, 10-M
9	83-11.1	Little Raccoon Creek	7.29					7.29	WWH	1995	3-H,7-S, 1-S	4-H, 8-S
10	83-11.2	Buck Run	7						WWH			
11	83-12	South Creek	15						WWH			
		Subwatershed Totals	89.2									
		Percent of Monitored Miles	33%									

Key to causes and sources of impairment

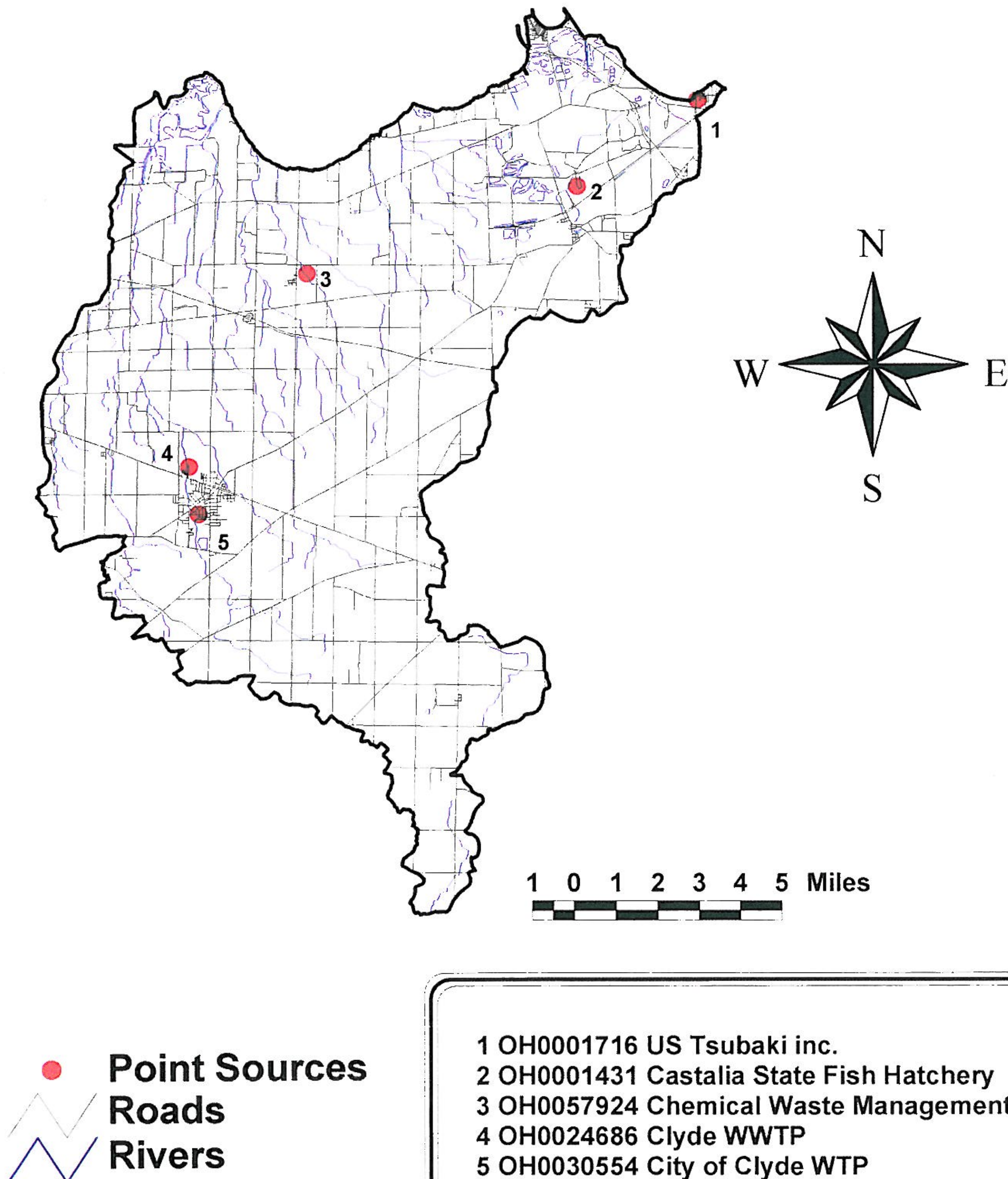
Causes of Impairment	Sources of Impairment	
1. Siltation	1. Nonirrigated Crop Production	10. Contaminated Sediments
2. Flow Alterations	2. Irrigated Crop Production	11. Upstream Impoundment
3. Other Habitat Alterations	3. Agriculture	12. Dam Construction
4. Nutrient Enrichment	4. Channelization	13. Removal of Riparian Vegetation
5. Unionized Ammonia	5. Municipal Point Sources	14. Other
6. Oil and Grease	6. Industrial Point Sources	15. Source Unknown
7. Organic Enrichment /DO	7. Urban Runoff/Storm Sewers	16. Natural
8. Priority Organics	8. Onsite Wastewater Systems	17. Stream Bank Modification/Destabilization
9. Metals	9. Flow Regulation/Modification	Combined Sewer Overflows
10. Cause Unknown		Pasture Land
11. Noxious Aquatic Weeds		
12. Unknown Toxicity		
H - High Impact; M - Moderate Impact; S - Slight Impact		

South Shore-West
Hydrological Unit 04100011-130
Use Attainment



1 Lake Erie Direct Tribs. (Pickeral Cr. to Mills Cr.)
2 Cold Creek
3 Little Pickeral Creek
4 Pickeral Creek
5 Strong Creek
6 Fuller Creek
7 Lake Erie Direct Trib (Sandusky River to Pickeral Cr.)
8 Raccoon Creek
9 Little Raccoon Creek
10 Buck Run
11 South Creek

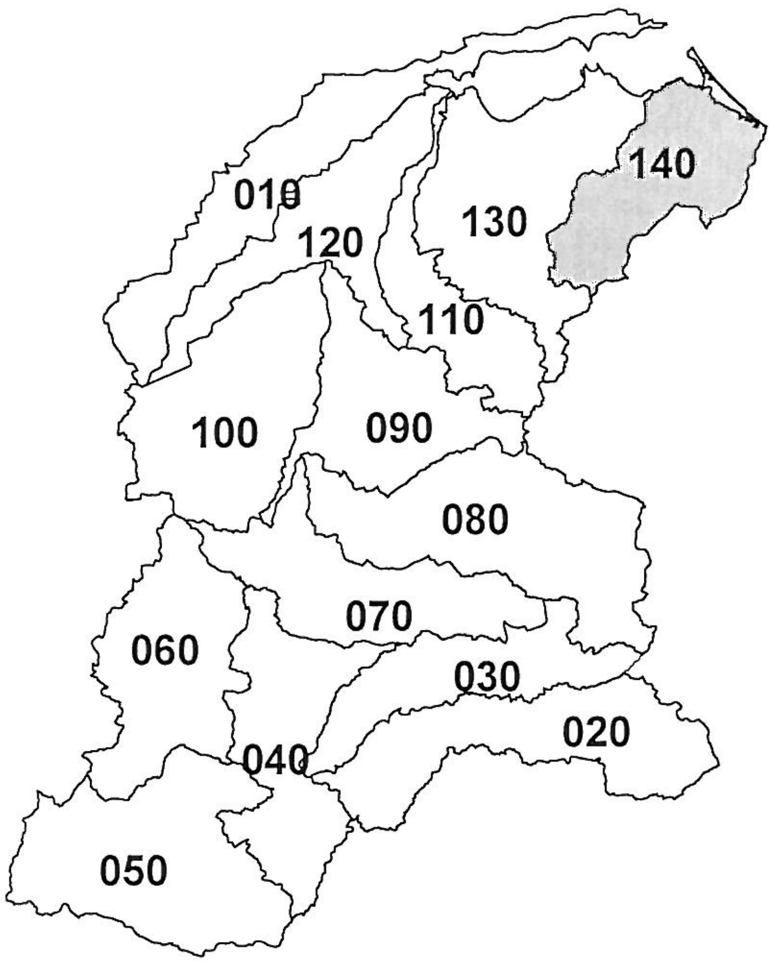
South Shore-west
Hydrological Unit 04100011-130
Point Sources



1 OH0001716 US Tsubaki inc.
2 OH0001431 Castalia State Fish Hatchery
3 OH0057924 Chemical Waste Management
4 OH0024686 Clyde WWTP
5 OH0030554 City of Clyde WTP

Water Quality Laboratory Heidelberg College

Subwatershed: South Shore Sandusky Bay tribs (above Mills Creek to below Sawmill Creek)
Hydrological Unit Code 04100011-140
South Shore -east

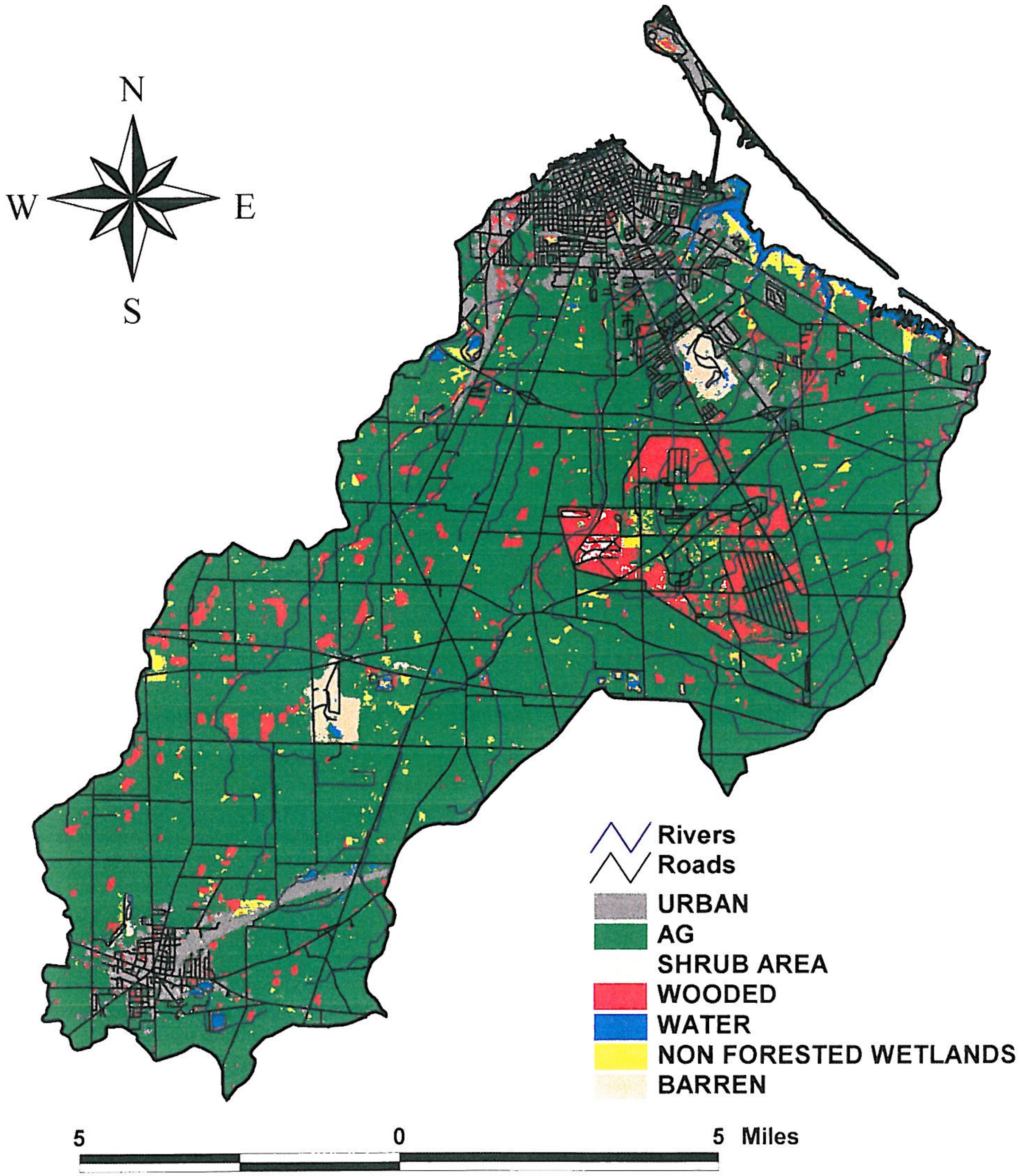


Subwatershed Characteristics
Area (square miles): 104.4
Area (acres): 66,820
Upstream Area (square miles): 0
Total Stream Miles:
Designated Warm Water Habitat (WWH) Miles: 92.1
Undesignated Stream Miles:
Counties: Erie, Huron, Sandusky
Monitored WWH Stream Miles: 12.14
Percent Monitored: 13%
Community Water Supplies: 5
Cities and Towns (population) Sandusky (28,000), Bellevue (8,157)

Land Use by Percent		
	South Shore-east	Sandusky Watershed
Agriculture	76.2%	84.0%
Wooded	7.1%	12.6%
Urban	10.7%	1.2%
Wetlands	2.7%	1.1%
Barren	1.4%	0.3%
Shrub	0.3%	0.5%%
Water	1.4%	0.4%

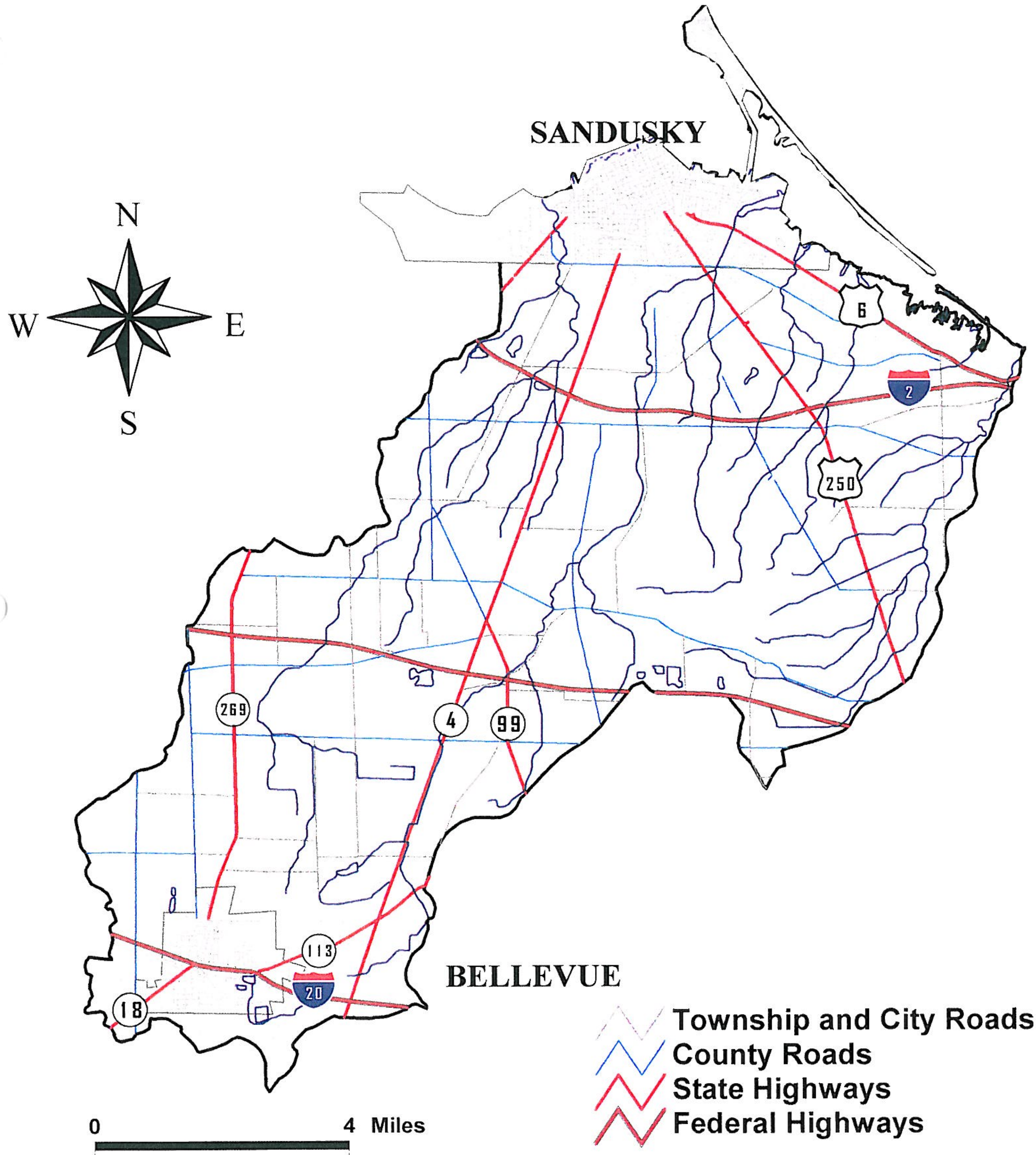
Aquatic Life Use Attainment		
Attainment Status	South Shore-east	Sandusky Watershed
Fully Attaining	0%	35.0%
Threatened	0%	0.5%
Partial Attainment	0%	23.3%
Not Attaining	100%	41.2%

South Shore-east
Hydrological unit 04100011-140
Land Use in Relationship to Streams and Roads



Water Quality Laboratory Heidelberg College

Roads in South Shore-east Subwatershed 140



Water Quality Laboratory Heidelberg College

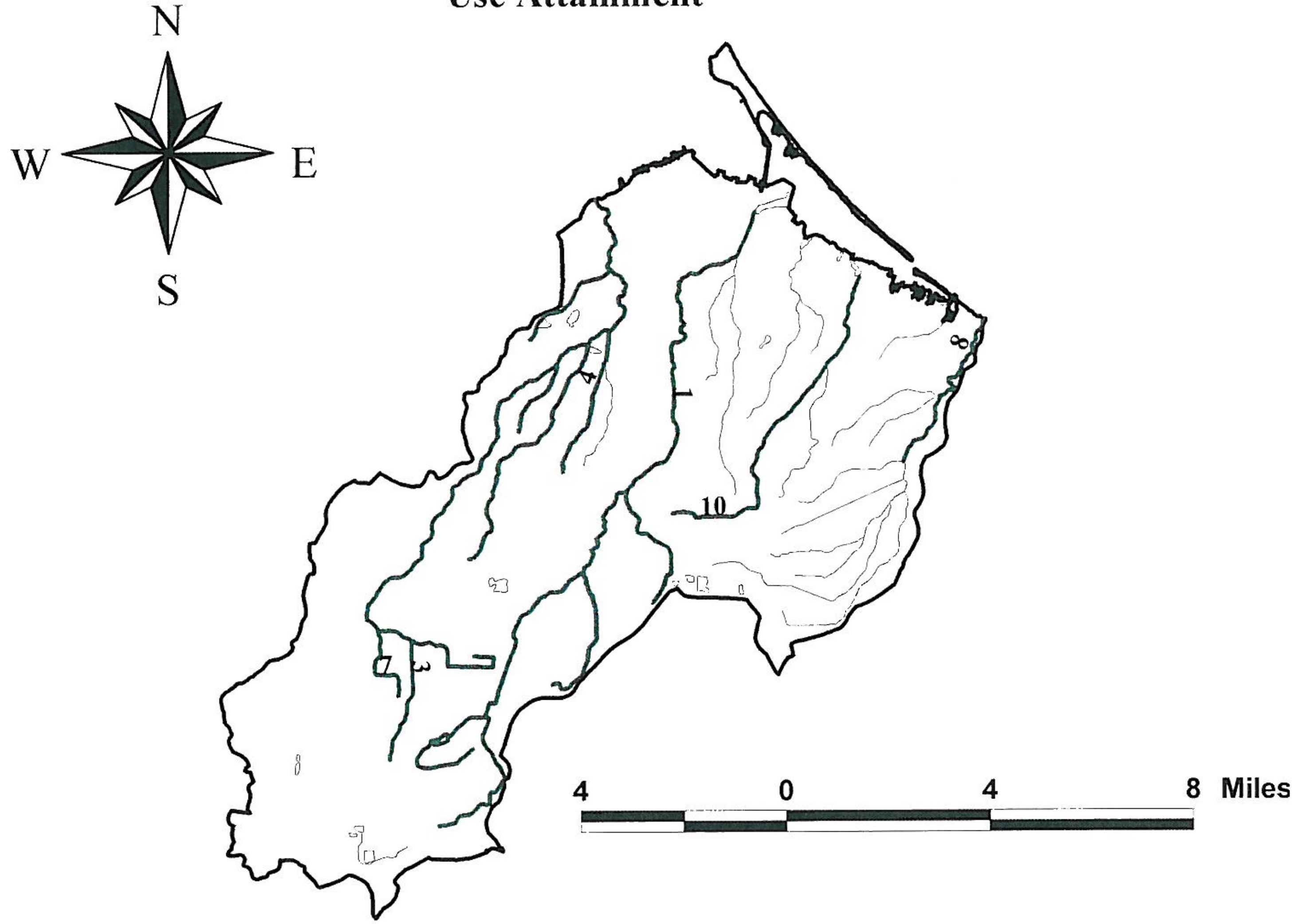
Summary of OEPA biological monitoring data for the South Shore-East Subwatershed (-140).

Map Number	OEPA Segment Number	Segment Name	Segment Length	Drainage Area	Fully Attain.	Threat-ened	Partial Attain.	Not Attain-ing	Use Desig-nation	Year Moni-tored	Causes of Impair-ment	Sources of Impair-ment
	Number		miles	sq. miles	miles	miles	miles	miles				
1	83-1	Pipe Creek	15						WWH			
2	83-2	Lake Erie Direct Tribs., (Mills Creek to Pipe Creek)	7						Lake Erie			
3	83-3	Mills Creek	12						WWH			
4	83-3.1	Liles Ditch	2						none			
5	83-3.2	Showe Ditch	2									
6	83-3	Caswell Ditch	12.14					12.14	WWH	1995	4-H, 7-H, 3-H	19-H, 4H, 1-H, 8-H
7	83-3.4	Snyders Ditch	6						MWH			
8	84-23	Sawmill Creek	17						WWH			
9	84-24	Lake Erie Direct Tribs., (Pipe Creek to Sawmill Creek)	12						Lake Erie			
10	84-25	Plum Brook	7						WWH			
		Subwatershed Totals	92.1									
		Percent of Monitored Miles	13%									

Key to causes and sources of impairment

Causes of Impairment	Sources of Impairment	
1. Siltation	1. Nonirrigated Crop Production	10. Contaminated Sediments
2. Flow Alterations	2. Irrigated Crop Production	11. Upstream Impoundment
3. Other Habitat Alterations	3. Agriculture	12. Dam Construction
4. Nutrient Enrichment	4. Channelization	13. Removal of Riparian Vegetation
5. Unionized Ammonia	5. Municipal Point Sources	14. Other
6. Oil and Grease	6. Industrial Point Sources	15. Source Unknown
7. Organic Enrichment /DO	7. Urban Runoff/Storm Sewers	16. Natural
8. Priority Organics	8. Onsite Wastewater Systems	17. Stream Bank Modification/Destabilization
9. Metals	9. Flow Regulation/Modification	18. Combined Sewer Overflows
10. Cause Unknown		19. Pasture Land
11. Noxious Aquatic Weeds		
12. Unknown Toxicity		
H - High Impact; M - Moderate Impact; S - Slight Impact		

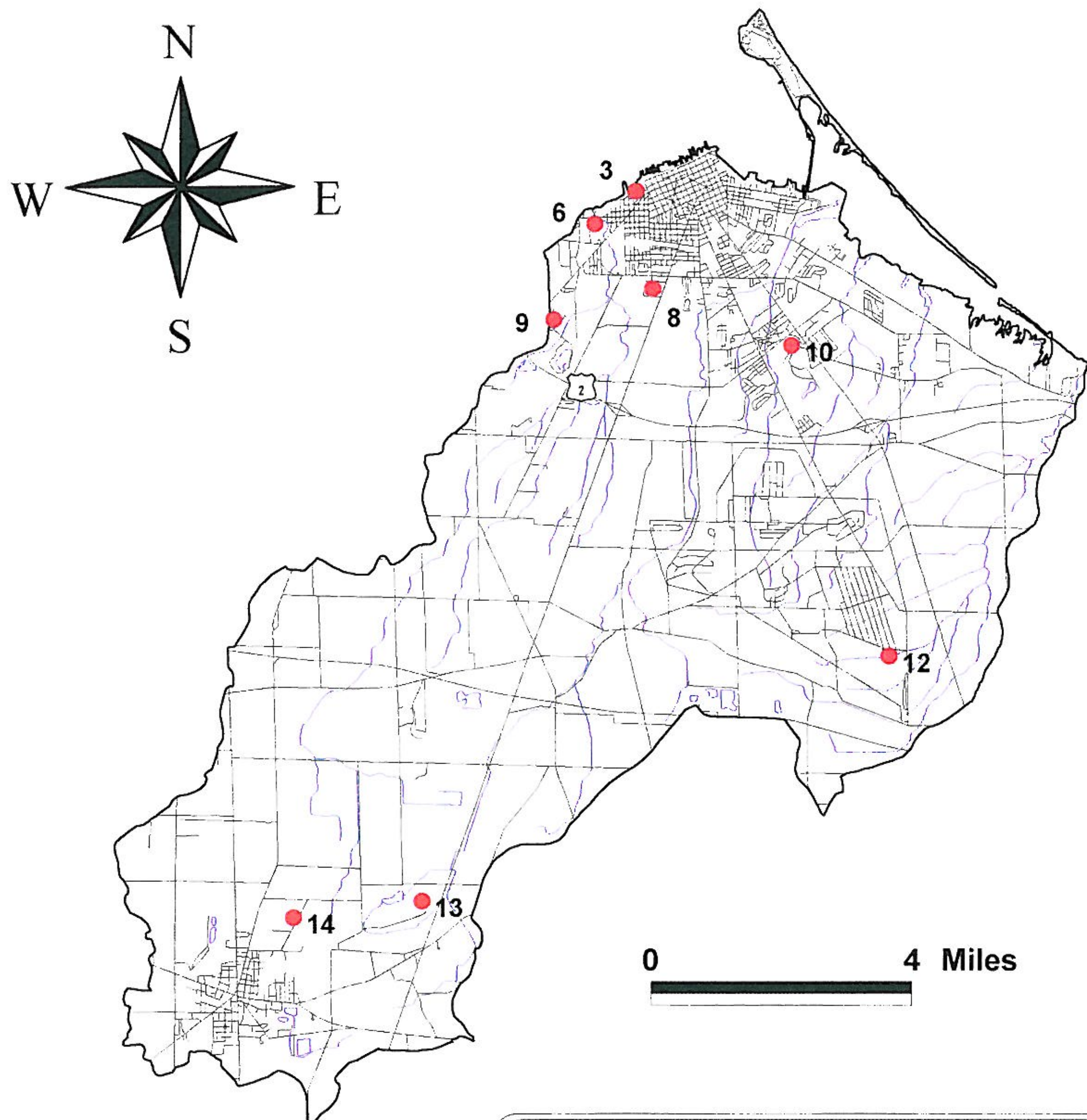
South Shore-East
Hydrological Unit 04100011-140
Use Attainment



1 Pipe Creek
2 Lakr Erie Direct Trib. (Mills Creek to Pipe Creek)
3 Mills Creek
4 Liles Ditch
5 Showe Ditch
6 Caswell Ditch
7 Snyders Ditch
8 Sawmill Creek
9 Lake Erie Direct Trib. (Pipe Creek to Sawmill Creek)
10 Plum Brook

Not Designated
Fully Attained
Partially Attained
Not Attained
Designated Not Monitored

South Shore-east
Hydrological Unit 04100011-140
Point Sources



Point Sources
Rivers
Roads

3 OH0027332 Sandusky WWTP
6 OH0001365 Thaker Aluminum Corp.
8 OH0000264 Delphi Automotive Systems
9 OH0001201 Vesteon Corp.
10 OH0022250 Wagner Quarries Co.
12 OH0001392 NASA Plum Brook
13 OH0001503 Norfolk and Western Railway
14 OH0020672 City of Bellevue WWTP

Water Quality Laboratory Heidelberg College