SURVEY OF SUSPENDED SOLIDS SOURCES AND RIPARIAN CORRIDOR CONDITION FOR THE LOWER MAHONING RIVER

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ABSTRACT

The Mahoning River experiences high turbidity and total suspended solids (TSS) concentrations, particularly during and after rainfall events. The loading of suspended solids to the river, both from runoff and bank erosion, depends partly on the condition of riparian corridor adjacent to the river. Two major goals of this project were to estimate TSS fluxes in the Lower Mahoning River and to study the riparian corridor condition along the river in Trumbull County.

Eighteen sampling sites were chosen from Lowellville to Milton Dam along the river and tributaries. Nine sampling trips were accomplished from January 17 to July 6, 2005. The highest average TSS concentration and flux rates on the Mahoning River were 26.1 mg/L and 40,670 MT/yr, respectively for Lowellville. Among tributaries, Mill Creek had the highest average TSS concentration (19.5 mg/L) and Mosquito Creek had the highest TSS flux/loading (2258 MT/yr). Mass balance analyses between Leavittsburg and Lowellville showed net deposition of TSS on the river bed for five sampling dates and net resuspension for three dates. For the trip of May 14, 2005 (after heavy rainfall), the estimated flux was 547,000 kg/d, which was so high that it probably included river bank erosion as well as resuspension of earlier deposited sediment from the river bottom. Two metrics of the Qualitative Habitat Evaluation Index (QHEI) – Riparian Width and Flood Plain Quality – were determined for the Lower Mahoning River by analyzing aerial photos for 259 river segments using ArcView GIS software. Most of the segments from Braceville and Weathersfield townships were ranked "Excellent" for the combined score of these two metrics.

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CHAPTER 1

INTRODUCTION

1.1 Background Information

Water is essential to sustain human life. The human body is about 70% water, and an individual can typically survive one week or less without water (Martin, 2004). Our Earth seems to be unique among the other known celestial bodies. It has water, which covers three-fourths of its surface and constitutes 60-70% by wt of the living world. Water regenerates and is redistributed through evaporation, making it seem endlessly renewable. Actually, only 1% of the world's water is usable to us. About 97% is salty sea water, and 2% is frozen in glaciers and polar ice caps. Thus that 1% of the world's water supply is a precious commodity necessary for our survival. Dehydration will kill us faster than starvation. Since the plants and animals we eat also depend on water, lack of it could cause both dehydration and starvation. The scenario gets worse. Water that looks drinkable can contain harmful elements, which could cause illness and death if ingested (Exploring the Environment, 2005).

Most of the civilizations have flourished along the banks of great rivers, so rivers have always been an unavoidable part of human civilization. The Nile and Ganges Rivers were used as sources of water for ancient Egyptians and Aryans respectively. Likewise Mahoning River had the same importance in the development of Cities of Youngstown and Warren in Ohio.

1.1.1 Water Resources and Water Quality

Water resources are sources of water that are useful for almost every creature, especially human beings. Human uses of water include agricultural, industrial, household, recreational and environmental activities. The water resources that communities use to meet their needs are divided into two major categories – surface water and groundwater. Those water bodies that are visible at the earth's surface are surface waters, and include rivers, lakes, and wetlands. Groundwater is the water that occupies the spaces between grains of soils and the cracks in rocks below the earth's surface. These two waters are not entirely separate. Surface water can seep into the ground and become groundwater. Groundwater can flow to the earth's surface through springs or be pumped to the surface from wells; it can also become surface water by flowing through the soil into stream channels, lakes or wetlands (Martin, 2004).

The dependency on usage of water is increasing rapidly in modern times, whether it is for day to day household works or for the many industrial purposes. Fig. 1.1 shows the USA water withdrawals and its productive and distributive uses in 2000.

The water of even the healthiest rivers and lakes is not absolutely pure. All water contains many naturally occurring dissolved and suspended substances. Dissolved salts include bicarbonates, sulphates, sodium, chlorides, calcium,

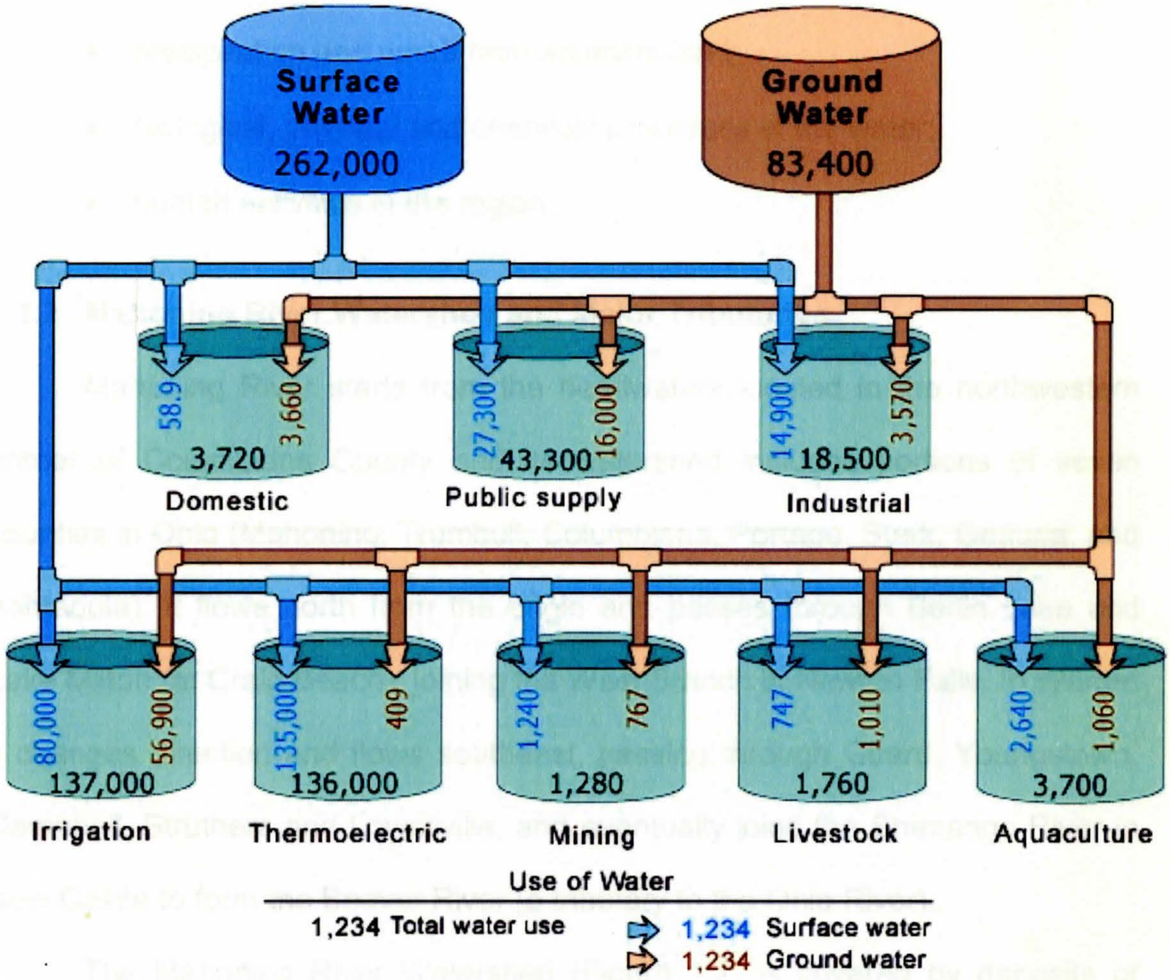


Fig 1.1. Source and Use of Freshwater (Mgal/day) in the United States in 2000.
http://ga.water.usgs.gov/edu/summary95.html

magnesium, and potassium. Suspended solids (SS) include silt, clay, algae, and products of organic matter decomposition. All of these are collectively known as Total Solids (TS). Pollution begins after the surface and groundwater comes in contacts with (Environment Canada, 2005):

- soil, geologic formations and terrain in the catchment area (river basin);

- surrounding vegetation and wildlife;
- precipitation and runoff from adjacent land;
- biological, physical and chemical processes in the water;
- human activities in the region.

1.1.2 Mahoning River Watershed and Major Tributaries

Mahoning River starts from the headwaters located in the northwestern corner of Columbiana County and its watershed includes portions of seven counties in Ohio (Mahoning, Trumbull, Columbiana, Portage, Stark, Geauga, and Ashtabula). It flows north from the origin and passes through Berlin Lake and Lake Milton (at Craig Beach), joining the West Branch in Newton Falls. In Warren it changes direction and flows southeast, passing through Girard, Youngstown, Campbell, Struthers and Lowellville, and eventually joins the Shenango River in New Castle to form the Beaver River (a tributary to the Ohio River).

The Mahoning River Watershed (Figure 1.2) is covered by deposits of unconsolidated clay, sand, and gravel, left by two continental ice sheets. The entire watershed was at one time covered by glaciers, and the glaciers scoured and eroded the soils and bedrock as they advanced and accumulated an unsorted mixture of clay, sand, and gravel. The total watershed area of Mahoning River is about 2952.6 square kilometers (1140 square miles) in northeastern Ohio and Pennsylvania (Martin, 2004). The watershed area of Mahoning River at Lowellville is about 2779 square kilometers (1073 square miles).

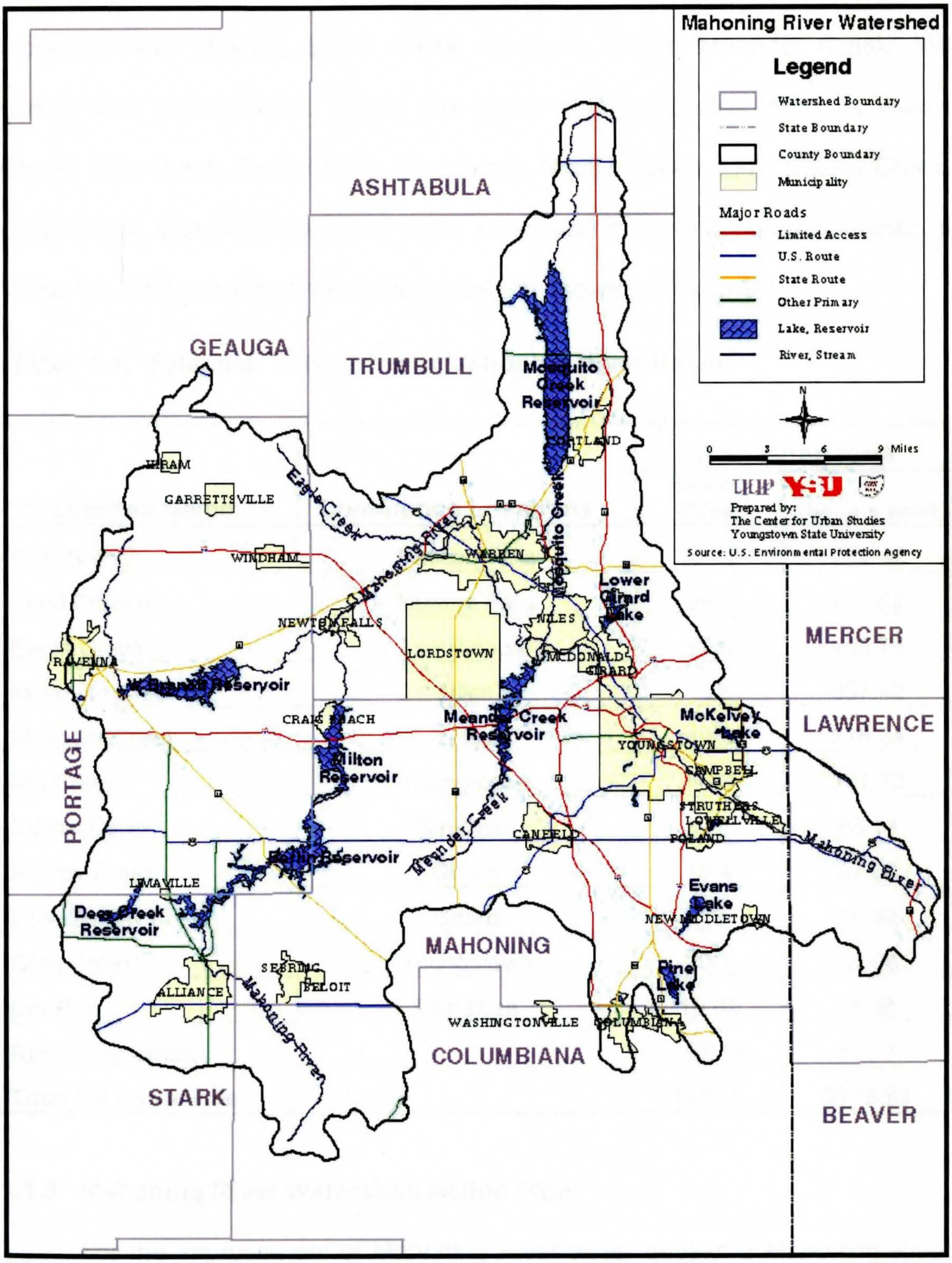


Figure 1.2. The Mahoning River Watershed.

The whole Mahoning River watershed consists of several major tributaries including West Branch, Eagle Creek, Mosquito Creek, Meander Creek, Mill Creek, and Yellow Creek. It also has some minor tributaries, such as Willow Creek, Kale Creek, Duck Creek, Mud Creek, Squaw Creek, Little Squaw Creek, Crab Creek, and Dry Run. All of these major and minor tributaries are listed in Table 1.1. Watersheds of major tributaries are shown in Figure 1.3.

Table 1.1. Selected Tributaries of Mahoning River Basin.

Tributaries Name	Confluence Locations	Watershed Area	
		(Square Miles)	(Square kms)
East Branch	Newton Falls	306.7	794.35
West Branch	Newton Falls	96.3	249.42
Eagle Creek	Leavittsburg	97.6	252.78
Mosquito Creek	Niles	138	357.42
Meander Creek	Niles	84.3	218.34
Mill Creek	Youngstown	66.3	171.72
Yellow Creek	Struthers	32.1	83.14
Squaw Creek	Girard	18.4	47.66
Little Squaw Creek	Girard	6.3	16.32
Crab Creek	Youngstown	20.1	52.06
Dry Run	Campbell	10.02	25.95
Remaining areas		197.18	510.7
Total (At Lowellville)		**1073.3**	**2779.83**

1.1.3 Mahoning River Watershed Action Plan

For the improvement of Mahoning River water quality, a Mahoning River Watershed Action Plan has been prepared by Dr. Scott C. Martin in 2004 for the Mahoning River Consortium (MRC). The planning was supported by a Clean

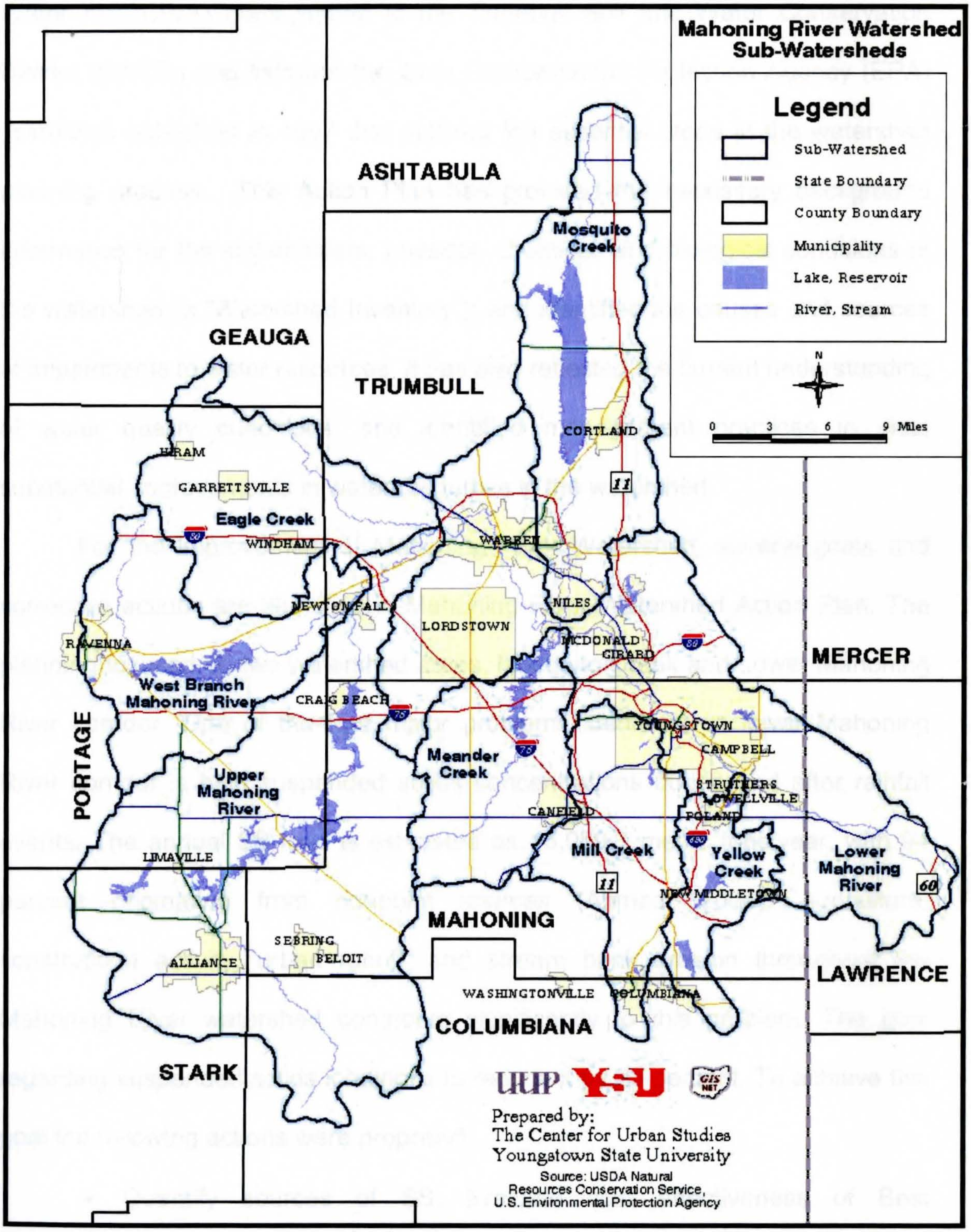


Figure 1.3. Mahoning River sub-watersheds.

Water Act (CWA) grant issued to the Trumbull Soil and Water Conservation District (SWCD) and followed the Ohio Environmental Protection Agency (EPA) guidelines published in 1997 that outlined the essential steps in the watershed planning process. This Action Plan has provided the necessary background information for the stakeholders; physical, chemical, and biological conditions of the watershed (a "Watershed Inventory"); and identified the causes and sources of impairments to water resources. It has also reflected the current understanding of water quality conditions, and identified management practices to yield substantial improvements in water resources in the watershed.

For the improvement of Mahoning River Watershed, several goals and corrective actions are identified in Mahoning River Watershed Action Plan. The planning focused on two watershed areas, Mosquito Creek and Lower Mahoning River corridor. One of the four major problems identified on lower Mahoning River corridor is high suspended solids concentrations during and after rainfall events. The annual SS load is estimated as 15,059.3 metric tons/year, with 94 percent originating from nonpoint sources (Ahmad, 2004). Agriculture, construction activity, urban runoff, and stream bank erosion throughout the Mahoning River watershed contribute significantly to this problem. The goal regarding suspended solids loading is to reduce it by 25 percent. To achieve this goal the following actions were proposed:

- Quantify sources of SS; evaluate cost effectiveness of Best Management Practices (BMPs).

- Promote Natural Resources Conservation Programs (NRCPs) and agricultural BMPs to farmers.
- Increase use of conservation tillage to 90 percent of crop land.
- Encourage reforestation and wetland development in the watershed.
- Conduct survey of river bank erosion and QHEI; and establish riparian buffer where necessary.
- Establish 50 miles of riparian buffers and filter strips.
- Stabilize erosion from lake bed.

The leading parties to achieve these goals are Mahoning River Consortium (MRC), Youngstown State University (YSU), Ohio EPA, Natural Resources Conservation Service (NRCS), and county Soil and Water Conservation Districts (SWCD).

1.1.4 Suspended Solids Loading Problem:

The lower reaches of the Mahoning River in Youngstown, Ohio, have been characterized by the Ohio EPA as historically having poor water quality (Water Resources Investigations Report, USGS, 2002). The Mahoning River experiences high turbidity and suspended solids concentration, particularly during and after heavy rainfall/runoff events. Though the suspended solids flux has been estimated, the relative importance of internal sources (i.e., bank erosion) versus external sources (i.e. runoff and soil erosion) is unknown.

The suspended solids loading to the Mahoning River from bank erosion and runoff depends partly on the condition of the riparian corridor and flood plain quality on both banks of the river. Because of this problem, detailed surveys of suspended solids loading and condition of the riparian corridor along the length of the river will be useful for refinement of the Mahoning River Watershed Action Plan. This information would be beneficial to identify and evaluate corrective measures mentioned in the Mahoning River Watershed Action Plan.

1.2 Goals of the study:

This study included the collection of water samples from several sampling stations on the Mahoning River and tributaries; analysis of these samples to determine suspended solids (SS) concentrations; and mass balance analysis of SS flux in different river reaches.

In addition to this, analysis of aerial photographs of the Lower Mahoning River corridor in Trumbull County was performed to estimate Qualitative Habitat Evaluation Index (QHEI) metrics of riparian width and flood plain quality. Then maps showing the values of these metrics along the river were developed.

CHAPTER 2

LITERATURE REVIEW

2.1 Sources of Water Pollution

It is easy to dispose of waste by dumping it into a river or lake. In large or small amounts, dumped intentionally or accidentally, it may be carried away by the current, but will never disappear. It will reappear downstream, sometimes in changed form, or just diluted. Freshwater bodies have a great ability to break down some waste materials either chemically or by the routine decomposition actions of living organisms. The decomposition produces carbon dioxide, nutrients and other substances needed by plants and animals living in the water. The purification cycle continues when these plants and animals die and the bacteria decompose them, providing new generations of organisms with nourishment (Environment Canada, 2005).

Unfortunately, the quantities discarded by today's society are by far exceeding the self-cleaning capacity of water bodies. The overload that results, called pollution, eventually puts the ecosystem out of balance and is of great environmental concern. Our waterways are being polluted by municipal, agricultural and industrial wastes, including many toxic synthetic chemicals which cannot be broken down at all by natural processes. Even in tiny amounts, some of these substances can cause serious harm. But also our every day activities like washing, eating, house-cleaning, tending the lawn and garden, and driving can cause water pollution as we are normally using hundreds of chemicals

(Tequila, 2005). Water contaminants come from two categories of sources - point sources and distributed or non-point sources. They are shown in Figure 2.1 and described below in detail.

2.1.1 Point Sources of Water Pollution

The term point source pollution refers to pollutants discharged from one discrete location or point, such as an industry or municipal wastewater treatment plant. Pollutants discharged in this way might include, for example, fecal coliform bacteria and nutrients from sewage, and toxics such as heavy metals, or synthetic organic contaminants.

Since the passage of the 1972 Clean Water Act, most water pollution control efforts have focused on point source pollution. Point source pollution generally comes from the millions of gallons of wastewater discharged from the pipes of industrial facilities and municipal sewage treatment plants into rivers, streams, lakes, and the ocean. Sources of wastewater may include domestic wastewater inflow and infiltration – where storm water and groundwater get into the wastewater collection system – commercial operations such as restaurants, food processing facilities such as canneries, agricultural operations, and industrial facilities (Texas Environmental Profiles, 2005).

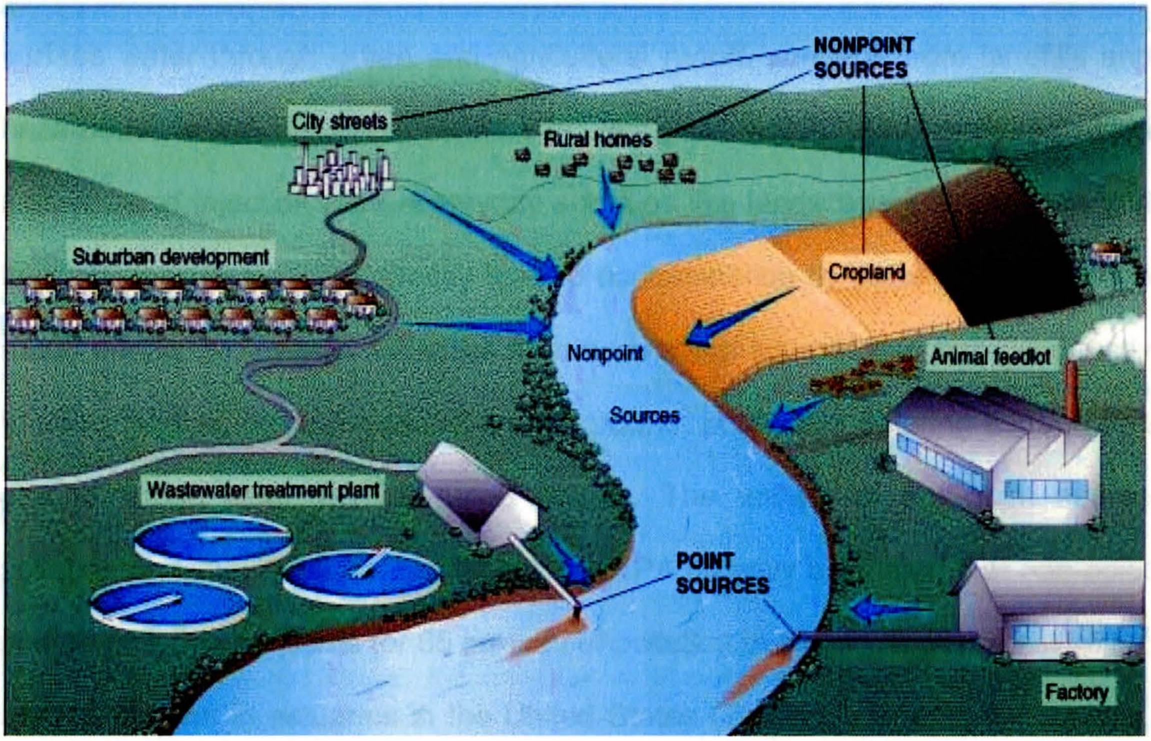


Figure 2.1. **Point and Non Point Sources of Water Pollution.** **(http://cwx.prenhall.com/bookbind/pubbooks/nebel2/chapter18/medialib/FG18_002.JPG)**

2.1.2 Non-Point Sources (NPS) of Water Pollution:

The term non-point source pollution refers to pollutants that cannot be identified as coming from one discrete location or point. Examples are oil and grease that enter the water with runoff from urban streets, nitrogen from fertilizers and pesticides, and animal wastes that wash into surface waters from agricultural lands. Natural and unknown causes of pollutants also can impact water quality and may be related to human activities. For example, highway or housing construction may increase the runoff of natural pollution sources, such as sediment.

Apart from point source discharges, toxics and other pollutants can enter surface water through urban and agricultural runoff, seepage from landfills and hazardous waste facilities, spills on land or water, and seepage from underground injection sites. Everyday activities like landscape maintenance and building construction can directly lead to contamination of water bodies through runoff during rain events. Air toxics from a variety of sources can also fall directly to water bodies, or be deposited on the ground, potentially entering surface and ground water when rainfall runoff occurs. The impact of non-point source pollution on water quality is significant: the EPA recently estimated that non-point source pollution accounts for 65 percent of pollution in rivers, 76 percent in lakes, and 45 percent in estuaries in the United States (Texas Environmental Profiles, 2005).

2.2 The Riparian Corridor

Every river has its own environmental habitat in which many creatures can enjoy their life cycle. Aquatic animals, birds and many more species of insects depend on the river and surrounding land for their food and living place.

2.2.1 Definition/ Description

A riparian corridor is a unique plant community consisting of the vegetation growing near a river, stream, lake, lagoon or other natural body of water. It serves a variety of functions important to people and the environment as a whole by preserving water quality by filtering sediment from runoff before it enters rivers and streams. The riparian corridor protects stream banks from erosion, provides a storage area for flood waters, and supplies food and habitat for fish and wildlife (County of Santa Cruz, 2005). Riparian habitats, at the interface between wet and dry systems, are defined by the plants that inhabit them. Riparian plants depend on an intact hydrological regime where groundwater is maintained and natural surface flows occur (CP-LUHNA, 2005).

Riparian ecosystems are critical components of the landscape ecosystem, incorporating both ecological and cultural values. The function of riparian ecosystems in the landscape is dictated by their role as both a transition zone between the aquatic and terrestrial environments and as a corridor through the landscape. Consideration of the integrity of riparian ecosystems in community planning can serve to address multiple community planning objectives, such as open space preservation, water resources management, and enhancement of community character (Oakland County, Michigan, 2005). Riparian corridors are important in landscape ecology because they connect variable landscapes across regions. These corridors have several critical ecological functions (Federal Interagency Team, 1998) as they:

- provide habitat
- act as wildlife conduits
- act as filters and barriers to species movement
- and act as sinks and sources of wildlife, nutrients, and energy

2.2.2 Importance in NPS Pollution Control

Wetlands and riparian areas can play a critical role in reducing non-point source pollution (NPS) by intercepting surface runoff, subsurface flow, and shallow groundwater flows. Their role in water quality improvement includes processing, removing, transforming, and storing such pollutants as sediment, nitrogen, phosphorus, and certain heavy metals (Washington State Department of Ecology, 1996). Research also shows that riparian areas function to control the release of herbicides into surface waters. Thus, wetlands and riparian areas buffer receiving waters from the effects of pollutants or they prevent the entry of pollutants into receiving waters. It is important to consider that degradation of wetlands and riparian areas can inhibit their ability to treat NPS pollution. Degraded wetlands and riparian corridor can also become sources of NPS pollution (US EPA, 2001).

The functions of wetlands and riparian areas include: water quality improvement; stream shading; flood attenuation; shoreline stabilization; groundwater exchange; and habitat for aquatic, semi-aquatic, terrestrial, migratory, and rare species. Riparian corridors and wetlands typically occur as natural buffers between uplands and adjacent water bodies. Loss of these systems allows for a more direct contribution of NPS pollutants to receiving waters. The pollutant removal functions associated with wetlands and riparian area vegetation and soils combine the physical process of filtering and the biological processes of nutrient uptake and denitrification. Riparian systems have been found not only effective to stabilize the recharge of shallow aquifers in a manner that support streamflows of longer natural duration, but also to be effective at reducing in-stream pollution during flood flows (US EPA 2001).

Ideally, all of the surface water bodies should be surrounded by a wide vegetated buffer zone. However, because of human activities, the riparian buffer has often been disturbed and trees, shrubs, grasses become sparsely distributed. In some locations along the Mahoning River, riparian vegetation is healthy (Figure 2.2). In other locations, because of dense urban populations in the Cities of Youngstown and Warren and the establishment of large steel mills along the banks of the Mahoning River, the riparian corridor has become seriously degraded.

Figure 2.2. Mahoning River and its Riparian Bank at Ohio Edison (Niles).
(Photo- Mahesh Adhikari)

2.3 Qualitative Habitat Evaluation Index (QHEI)

2.3.1 General Description

Regulatory activities under the Federal Water Pollution Control Act of 1972 and its 1977 and 1987 amendments require knowledge of the potential fish or biological community that can be supported in a stream or river. A procedure for relating stream potential to habitat quality would provide some insight into how habitat might affect biological expectations in a given water body. The QHEI is designed to do just that by providing a qualitative measure of the habitat corresponding to the physical features that affect fish and invertebrate communities (Northeast Ohio River Project, 2005).

The presence of organisms in a stream is strongly related to the physical and chemical characteristics of the stream. The habitat provides shelter for organisms, attachment sites to grow on, turbulent areas for mixing with oxygen, and areas to hunt or graze on algae. Shifts in the make-up of the community are responses to nutrient availability and habitat changes. Organisms intolerant of pollution (natural or man-made) tend to be found in habitat having a lot of cover, a variety of flows, lots of different substrates that are clear of silt and sand, and low levels of toxic material in the water. Generally, pollution intolerant organisms are very specific in their life needs and do not have the versatility to adapt to a wide range of environmental conditions. On the other hand pollution tolerant organisms tend to be associated with slow moving water, live much of their life in silt and sediment and tend to exhibit adaptability to a wide range of environmental conditions (Northeast Ohio River Project, 2005).

The QHEI data sheets are divided into several metrics, and each of the metrics is broken down into individual components. For each component, one can assess the status of any river and assign a score based on that status. The score for each component is shown in square brackets for each state of the stream (Northeast Ohio River Project, 2005). There are six types of metrics within QHEI as shown below:

i. Substrate
ii. In-stream Cover
iii. Channel Morphology
iv. Riparian Zone and Bank Erosion
v. Pool/Glide and Riffle/Run Quality
vi. Gradient

The maximum possible score is 100.The higher scores represent streams that exhibit diverse aquatic life and other biological indices. The Ohio EPA has established a minimum QHEI of 60 as desirable to support warm water species of fish (Ohio EPA, 1995). Table 2.1 shows the QHEI metrics and scoring which is applicable for any stream or river.

2.3.2 Riparian Width

Riparian width is the average width of the riparian vegetation, measured in meters. Vegetation may include forest, shrub, swamp, old field vegetation, and/or fairly mature successional fields that have stable, woody plant growth (Ohio State, 2005). Riparian width scoring is done by taking an average of left and right banks. The main categories of vegetation width are wide, moderate, narrow, very narrow, narrow, and none. Table 2.2 shows the classifications and corresponding scores for riparian width.

Table 2.1. QHEI Metrics (OEPA, 1989)

Metrics	Controlling Factors	Maximum Points
Substrate	**Type**	**20**
	Quality	
Instream Cover	**Type**	**20**
	Amount	
Channel Morphology	**Sinuosity**	**20**
	Development	
	Channelization	
	Stability	
Riparian Zone and Bank Erosion	**Width**	**10**
	Flood Plain Quality	
	Bank Erosion	
Pool/Glide and Riffle/Run Quality	**Maximum Depth**	**20**
	Current Velocity	
	Pool Morphology	
	Riffle/Run Depth	
	Riffle/Run Substrate	
	Riffle/ Run Embeddness	
Gradient		**10**
Total Score		**100**

Table 2.2. Riparian Width Scoring (OEPA 1989)

Classification	Width	Score
Wide	**>50 m**	**4**
Moderate	**10-50 m**	**3**
Narrow	**5-10 m**	**2**
Very Narrow	**1-5 m**	**1**
None	**0 m**	**0**

2.3.3 Flood Plain Quality

In QHEI scoring, the two most predominant flood Plain quality types or land uses, are to be checked. Flood Plain refers to areas immediately outside of the riparian zone or greater than 100 meters from the stream, whichever is wider on each side of the stream (Ohio State, 2005). The Flood Plain Quality scoring is also determined by taking the average of the scores for both banks. The types of flood plain quality are categorized as forest, swamp, shrub or old field, residential, park, new field, fenced pasture, conservation tillage, urban or industrial, open pasture, row crop, and mining/construction (OEPA, 2001). Table 2.3 shows the categories of flood plain quality and corresponding scores.

Table 2.3. Flood Plain Quality Scoring (OEPA, 1989)

Vegetation	Score
Forest/Swamp	**3**
Shrub or Old Field	**2**
Residential, Park, New Field	**1**
Fenced Pasture	**1**
Conservation Tillage	**1**
Urban or Industrial	**0**
One Pasture, Row Crop	**0**
Mining/Construction	**0**

2.4 Previous Studies

2.4.1 Ohio EPA Survey

As part of Ohio EPA's Five-year Basin Approach for Monitoring and National Pollutant Discharge Elimination System (NPDES) permitting, chemical, physical, and biological sampling was conducted in the Mahoning River basin study area during the summer and early fall of 1994. The principal objectives of that study (Ohio EPA, 1996) were to:

- Determine the extent to which uses designated in the Ohio Water Quality Standards (WQS) are or are not attained (i.e., determine use attainment status);
- Evaluate existing use designations and recommend any changes which may be needed;
- Identify causes and sources associated with any non-attainment or partial attainment of uses designated in the Ohio WQS;
- Provide information for the development of Water Quality Permit Support Documents (WQPSDs) in support of NPDES permit reissuance for selected point sources; and
- Assess and characterize changes (trends) in biological performances and chemical/physical water quality since previous surveys and subsequent upgrades by major municipal and industrial wastewater treatment facilities.

In general, the Ohio EPA surveys show that the quality of waters in Ohio have improved because of the initiative taken by private industries and government entities who have improved point source discharge controls and upgraded sewage treatment facilities. Now, the majority of water pollutants come from non-point sources and storm water runoff which transports contaminants from broad areas of the landscape, like construction sites, farms, orchards, nurseries, and failing septic systems.

Since the 1950's, significant loading reductions of wastewater volume, total suspended solids, oil and grease, total iron, and phenolics have occurred in the Mahoning River. These reductions became possible with pollution control improvements at several steel mills but mostly because of the partial to total shutdown (since 1978) of five major steel producing facilities. During 1974, eight major steel mills were discharging to the lower Mahoning River mainstream with a combined wastewater volume of 627 MGD (92% of the total wastewater volume discharged to the Mahoning River). It was estimated that in 1975 the major steel facilities used the entire flow of the Mahoning River 5.6 times during winter low flow and nearly 2.6 time during summer low flow (Amendola *et al.*, 1977). The total volume of wastewater discharged by industries declined to 154 MGD in 1980, and to 56 MGD in 1985.

Drainage patterns within the Mahoning River watershed were principally formed during the Wisconsin glacial period. Surface glacial deposits comprised of ground and end moraines cover most of the watershed and bedrock consists of mixture of sandstone, conglomerate, shale, and limestone formed during the Pennsylvanian and Mississippian periods. The construction of numerous dams on the mainstem of the Mahoning River has adversely affected the natural habitats and created an alternating series of free-flowing and impounded segments throughout its length. Free flowing sites have distinctly higher QHEI scores (i.e., quality physical habitat for aquatic life) than the impounded segments. The segment average for free-flowing site was 70.6 (range 78.8 – 60.5) compared to an average of 47.4 (range 55.0 – 42.5) for predominantly impounded sites. Physical habitat in the mainstem is also affected by impoundments on many of its tributaries (e.g., controlled reservoir releases) (Ohio EPA, 1996).

Table 2.4. shows data on the total suspended solids (TSS) along the Mahoning River. This table is in a simplified form, so some modifications were done from the original. Total suspended solids (TSS) increased significantly from the headwaters, and it further increased below the Berlin Lake dam and the Lake Milton dam. The increases in TSS may be related the hypolimnetic discharge of water from these two reservoirs. Mean TSS decreased to 16 mg/L between Newton Falls and the Leavittsburg dam and remained fairly low between Leavittsburg and Girard, again increased between Girard and Youngtown and remained slightly higher up to Lowellville dam. Elevated TSS levels under low flow stream conditions can have a significant effect on fish communities by decreasing potential sight feeding predatory activity (Ohio EPA, 1996).

Table 2.4. Total Suspended Solids (TSS) in Major Townships Along the Mahoning River (Ohio EPA, 1996).

Major Township Locations	Total Suspended Solids (mg/L)	River Mile
Lowellville	23	12.5
Struthers	18	14.1
Youngstown	22	20.2
Girard	17	26.1
Niles	17	28.9
Warren	20	35.2
Leavittsburg	16	45.5
Newton Falls	27	57.2
Lake Milton	23	63

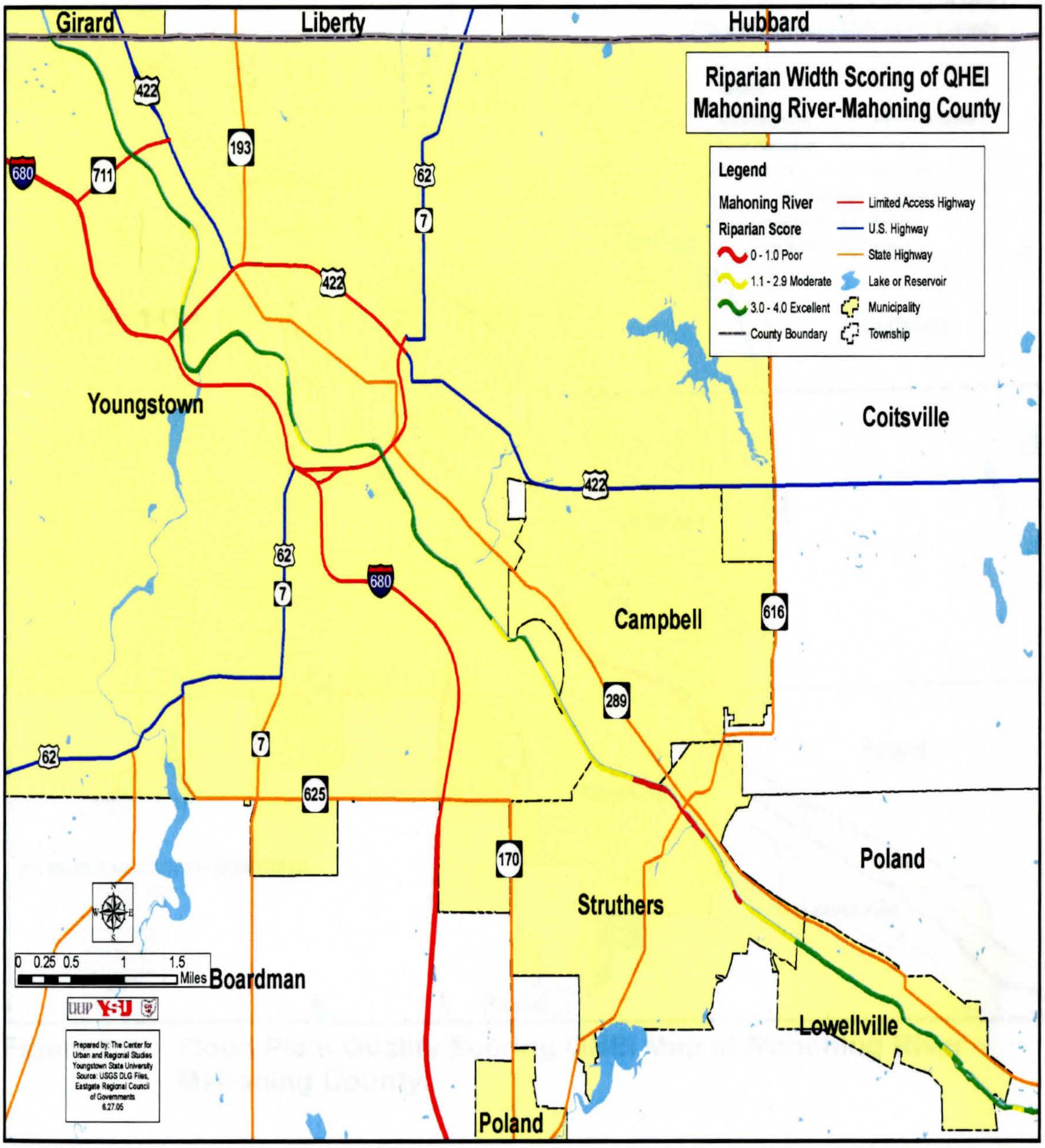
The results of Ohio EPA's biological and water quality survey in 1994 showed only slight improvement in the warm water habitat (WWH) aquatic life use attainment status of the lower half of the Mahoning River mainstem during the periods of 1980 – 1994. Since 1980, the number of miles in full attainment increased to only 0.3, the number in partial attainment increased from 1.8 to 5.8 while the number of miles in non-attainment decreased from 45.2 to 41.3. The number of miles of poor to very poor quality remained unchanged (i.e., 38.2 in 1980 and 38.2 in 1994)

2.4.2 Ahmad (2004) Study

For the purpose of contribution to the Mahoning River Watershed Inventory, Faraz Ahmad (2004) estimated the point source and non-point sources loadings of total suspended solids (TSS), ammonia nitrogen (AN), nitrite and nitrate nitrogen, and carbonaceous biological oxygen demand (CBOD) in the Mahoning River Watershed. Pollutant fluxes in the Mahoning River watershed were calculated at Leavittsburg and Lowellville using monthly monitoring data collected by Ohio EPA. These fluxes were considered to represent the sum of point and non-point source loadings above those stations. The non-point source loadings were calculated by subtracting the sum of point sources from the total flux for each parameter at each location. During his study, Ahmad found non-point sources loadings at both Leavittsburg and Lowellville were higher than the point source loadings. The point and non-point sources loadings of TSS were estimated to be 168 and 46,914 kg/day, respectively at Leavittsburg and 4,086 and 67,339 kg/day, respectively at Lowellville.

2.4.3 Eastgate QHEI Maps

For the improvement of riparian corridor of Mahoning River, substantial studies and research work have been done by several concerned organizations. Likewise, Eastgate Regional Council of Governments (RCOG) conducted a of QHEI study for the riparian width and flood plain quality along the banks of Mahoning River in Mahoning County. That study was performed by Joe Warino; riparian width and flood plain scoring sheets and the related maps of the Mahoning River corridor, are available in Center for Urban and Regional Studies (CURS) at YSU. For the detailed analysis of riparian corridor, aerial photographs of Mahoning River banks in Mahoning County were viewed and evaluated using various tools of Arcview GIS. Figures 2.3 – 2.5 show the maps from that study. Some modifications have been applied in the original maps to maintain uniformity in the score ranges and the color pattern with the study done by Kolwalkar (2003) and this research.



Prepared by: The Center for Urban and Regional Studies Youngstown State University
Source: USGS DLG Files, Eastgate Regional Council of Governments
6.27.05

Figure 2.3. Riparian Width Scoring QHEI Map of Mahoning River – Mahoning County.

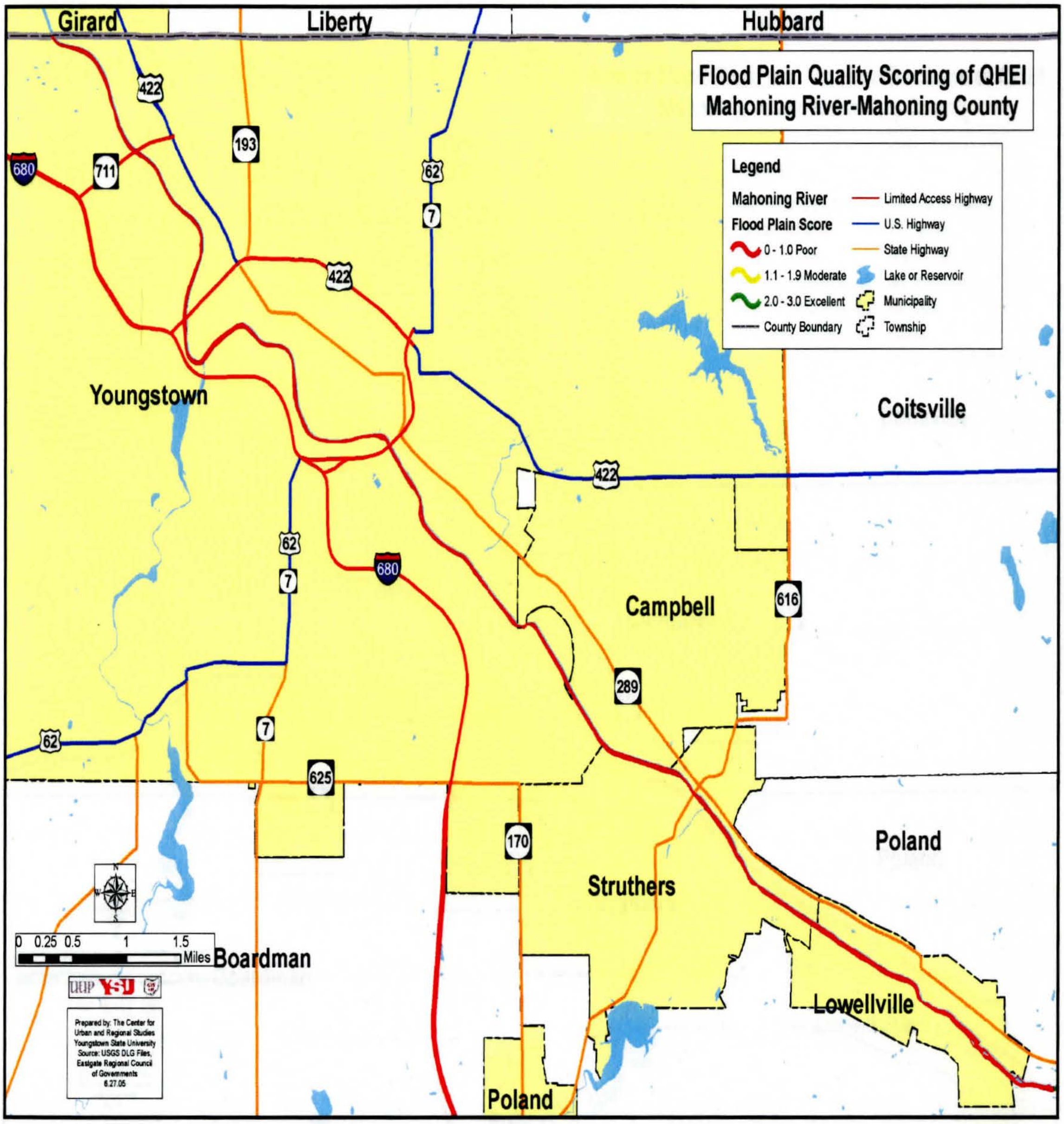
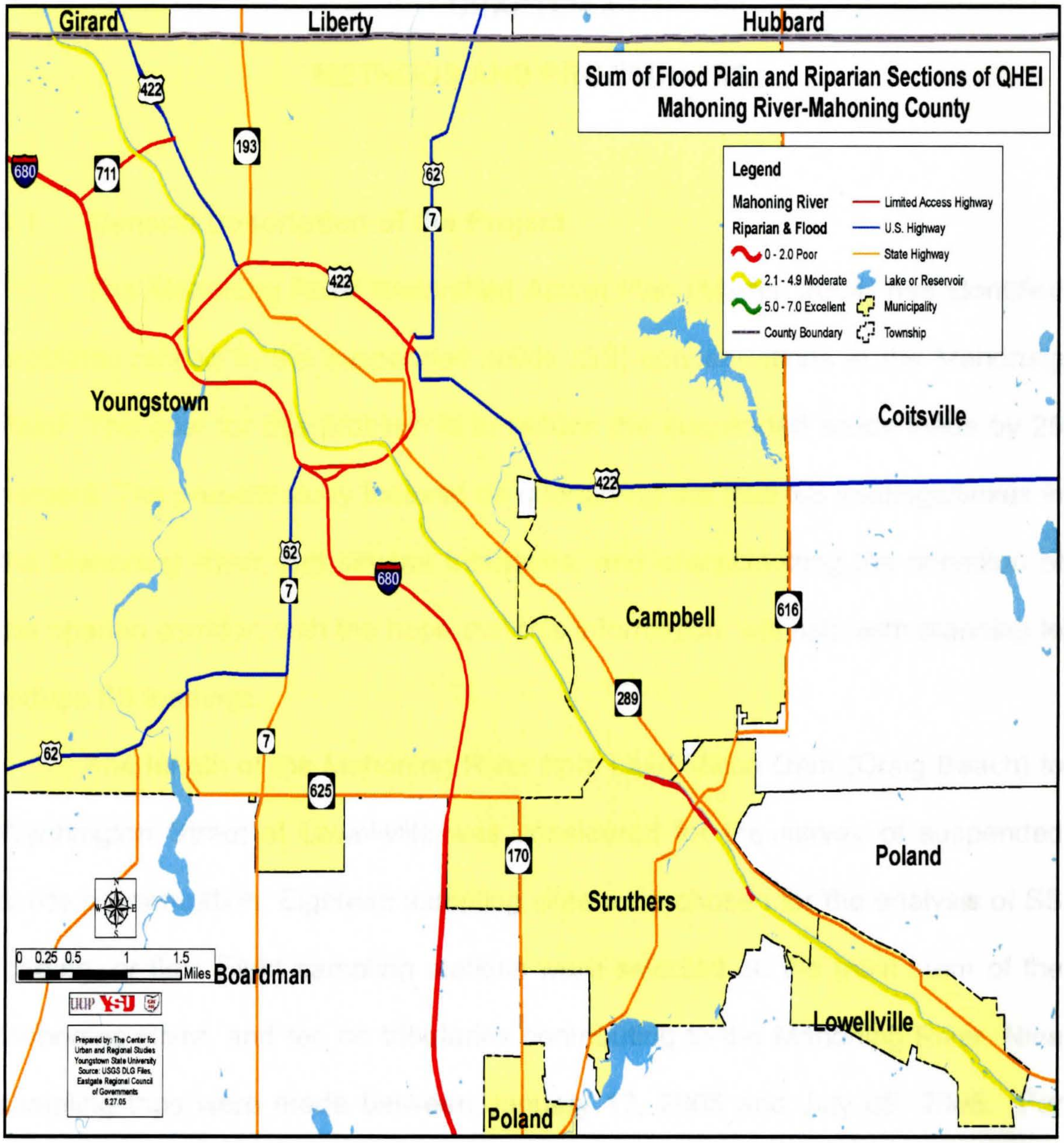


Figure 2.4. **Flood Plain Quality Scoring QHEI Map of Mahoning River – Mahoning County.**



Prepared by: The Center for Urban and Regional Studies Youngstown State University Source: USGS DLG Files, Eastgate Regional Council of Governments 6.27.05

Figure 2.5. **Sum of Riparian Width and Flood Plain Quality Scoring QHEI Map of Mahoning River – Mahoning County.**

CHAPTER 3

METHODS AND PROCEDURES

3.1 General Description of the Project

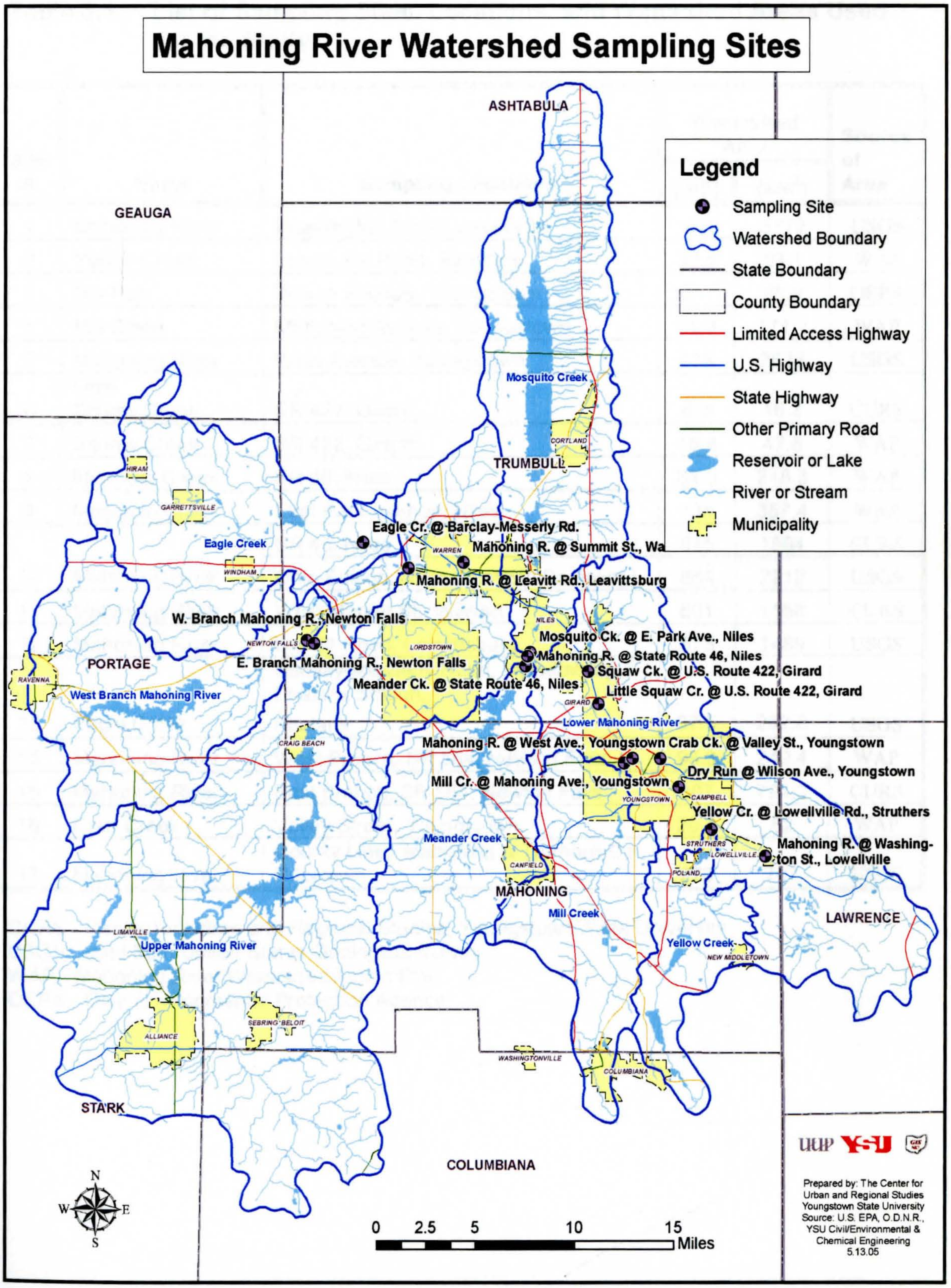
The Mahoning River Watershed Action Plan (Martin, 2004) has identified problems related to the suspended solids (SS) concentrations in the Mahoning River. The goal for this problem is to reduce the suspended solids loads by 25 percent. The present study focused on quantifying the total SS loadings/fluxes in the Mahoning River and several tributaries, and characterizing the condition of the riparian corridor, with the hope that this information will help with planning to reduce SS loadings.

The length of the Mahoning River from Lake Milton Dam (Craig Beach) to Washington Street at Lowellville was considered for the survey of suspended solids concentration. Eighteen sampling sites were chosen for the analysis of SS loading, or flux. Eight sampling stations were selected on the main stem of the Mahoning River, and ten on tributaries contributing to the Mahoning River. Nine sampling trips were made between January 17, 2005 and July 06, 2005. For each sampling site the flow was estimated either by field measurements or from United States Geological Survey (USGS) gauging station data.

Samples were collected for the suspended solids concentration and turbidity tests. SS flux calculations were performed by spreadsheet. Also, the QHEI metrics of riparian width and flood plain quality were estimated for the Trumbull County section of the Mahoning River from aerial photos. Color-coded maps were produced using ArcView geographic information system (GIS) software.

3.2 Descriptions of the Sampling Sites

Eighteen sampling sites were chosen along the length of the Mahoning River and near the confluence of ten tributaries to the river. The sampling sites and their locations are shown in Figure 3.1 and described in Table 3.1. Figure A.1 also shows the enlarged view of these sampling sites. The watershed areas for these sampling stations were obtained from a variety of sources, including the USGS official website, Mahoning River Watershed Action Plan, Ohio EPA, and Center for Urban and Regional Studies (CURS, YSU). Figure 3.2. shows a schematic diagram of the Mahoning River and its tributaries. Most of the water samples were taken from (or near) bridges on the roads that cross the Mahoning River and its tributaries. Among these sampling sites, four sites along the Mahoning River have United States Geological Survey (USGS) flow gauging stations. These are sites #1 at Washington Street, Lowellville, #5 at West Avenue, Youngstown, #10 at Ohio Edison, Niles, and #12 at Leavitt Road, Leavittsburg. Active gauging stations are also available on Eagle Creek and Mosquito Creek. At two sampling sites - #10 (Mahoning River at Niles) and #13 (Eagle Creek) – the sampling locations were changed during the study in order to utilize USGS gauging stations for flow estimates. The surface water data, including flow rate (in cfs) are available online on a daily basis.



Prepared by: The Center for Urban and Regional Studies Youngstown State University Source: U.S. EPA, O.D.N.R., YSU Civil/Environmental & Chemical Engineering 5.13.05

Figure 3.1. Sampling Locations in the Mahoning River Watershed.

Table 3.1. List of Sampling Sites, Locations, and Watershed Areas Used for the Study.

Site #	Name	Sampling Locations	Watershed Area		Source of Area
			(mi^2)	(km^2)	
1	Mahoning River	Washington Street,Lowellville	1073	2779	USGS
2	Yellow Creek	Lowellville Road, Struthers	32.1	83.1	WAP
3	Dry Run	Wilson Avenue, Youngstown	10	25.9	OEPA
4	Mill Creek	Mahoning Avenue, Youngstown	66.3	171.7	WAP
5	Mahoning River	West Avenue, Youngstown	978	2533	USGS
6	Little Squaw Creek	SR 422, Girard	6.3	16.3	CURS
7	Squaw Creek	SR 422, Girard	18.4	47.6	WAP
8	Meander Creek	SR 46, Niles	84.3	218.3	WAP
9	Mosquito Creek	East Park Avenue, Niles	138	357.4	WAP
10	Mahoning River	SR 46, Niles	615	1594	CURS
		Ohio Edison, Niles (from 5th Sampling)	854	2212	USGS
11	Mahoning River	West Market St., Warren	601	1558	CURS
12	Mahoning River	Leavitt Road, Leavittsburg	575	1489	USGS
13	Eagle Creek	Barclay-Messerly Road, Leavittsburg & Phalanx Station, Phalanx	97.6	252.8	USGS
14	Mahoning River	West Branch, SR 564, Newton Falls	96.3	249.4	WAP
15	Mahoning River	East Branch, SR 564, Newton Falls	307	794.3	CURS
16	Crab Creek	Valley Street, Youngstown	20.1	52	WAP
17	Mahoning River	County Line, Mahoning & Trumbull Co., Pricetown	273	707	USGS

CURS - Center for Urban and Regional Studies, Youngstown State University
USGS - data from United States Geological Survey
WAP - Mahoning River Watershed Action Plan
OEPA - Ohio Environmental Protection Agency

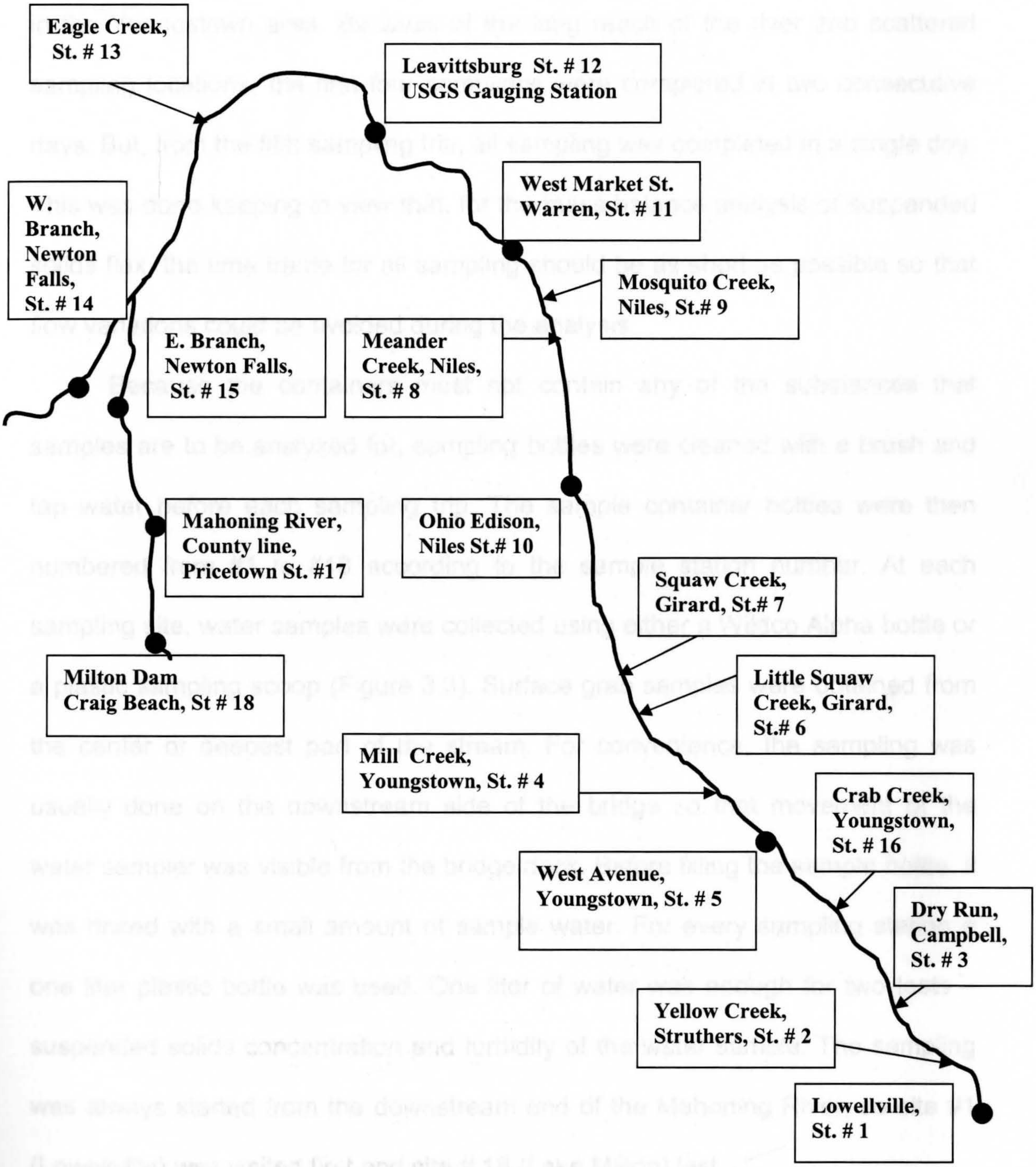


Figure 3.2. Schematic Diagram of Sampling Sites on Mahoning River and Tributaries.

3.3 Field Sampling and Measurements

The sampling was started on January 17, 2005, a time with heavy snowfall in the Youngstown area. Because of the long reach of the river and scattered sampling locations, the first four samplings were completed in two consecutive days. But, from the fifth sampling trip, all sampling was completed in a single day. This was done keeping in view that, for the mass balance analysis of suspended solids flux, the time frame for all sampling should be as short as possible so that flow variations could be avoided during the analysis.

Because the containers must not contain any of the substances that samples are to be analyzed for, sampling bottles were cleaned with a brush and tap water before each sampling trip. The sample container bottles were then numbered from #1 to #18 according to the sample station number. At each sampling site, water samples were collected using either a Wildco Alpha bottle or a plastic sampling scoop (Figure 3.3). Surface grab samples were obtained from the center or deepest part of the stream. For convenience, the sampling was usually done on the downstream side of the bridge so that movement of the water sampler was visible from the bridge deck. Before filling the sample bottle, it was rinsed with a small amount of sample water. For every sampling station a one liter plastic bottle was used. One liter of water was enough for two tests – suspended solids concentration and turbidity of the water sample. The sampling was always started from the downstream end of the Mahoning River, so site #1 (Lowellville) was visited first and site # 18 (Lake Milton) last.

Figure 3.3. Vertical Alpha Water Sampler and a Typical Water Sampling Scoop.
(Source:http://www.wildco.com/vw_prdct_mdl.asp?prdct_mdl_cd=1100V& http://www.bestlabdeals.com/product_p/bamp430.htm)

At sites # 2, 4, 6, 7, 8, and 16, flow measurements were made in the field using a Global Water Flow Probe (Figure 3.4). The water velocity probe consists of a protected turbo prop positive displacement sensor coupled with an expandable probe handle to a digital readout display. Magnetic material in the propeller tip passes a pickup point in the base of the meter handle, producing electrical impulses that are carried to the readout display by an internal cable. The readout displays instantaneous velocity and true average velocity. The water flow meter incorporates true velocity averaging for the most accurate flow measurements (Global Water, 2005).

Velocity measurement was performed by zeroing the flow probe and moving the turbo propeller end back and forth across stream just above mid-depth. This process was repeated until at least of two consistent values were obtained. Width of the stream was estimated by extending the flow probe (with length scale) across the stream. Mean depth was estimated by measuring depth at several locations across the stream with the scale on the flow probe, and averaging them. Finally cross-sectional area of the stream was obtained as the product of width and mean depth.

Figure 3.4. Global Flow Probe's Digital Readout Display and Turbo-Propeller.
(Source: http://www.globalw.com/products/flowprobe.html)

3.4 Laboratory Analysis

3.4.1 Suspended Solids

Principle

A well-mixed sample is filtered through a weighed standard glass-fiber filter and the residue retained on the filter is dried to a constant weight at 103 to 105°C. The increase in weight of the filter represents the total suspended solids. If the suspended material clogs the filter and prolongs filtration, it may be necessary to decrease the filtering volume of water sample. Filter clogging may produce high results owing to increased colloidal materials captured on the clogged filter.

Apparatus

- Desiccator, provided with a desiccant containing a color indicator of moisture concentration or an instrumental indicator.
- Drying oven, for operation at 103 to 105°C.
- Analytical balance, capable of weighing to 0.1 mg.
- Aluminum weighing dishes.
- Glass-fiber filters disks without organic binder.
- Membrane filter funnel.
- Suction flask, of sufficient capacity for sample size selected.

Procedure

The samples were usually kept at room temperature prior to filtration. Sometimes, if immediate filtration was not possible, samples were kept inside a refrigerator at 4°C to prevent microbial growth. First the Fisher GF-C glass fiber filters were rinsed with de-ionized water. Water was removed using a vacuum pump and washings were discarded. Then the filter was removed from the filtration apparatus and transferred to an inert aluminum weighing dish. The dish with filter was dried in an oven at 103°C for at least one hour. It was cooled in a desiccator and weighed on a Mettler AG245 analytical balance.

Sample volume was chosen based on the appearance of the water, and generally the range of 250 ml to 750 ml was used for filtration. The filter was placed in the filtration apparatus. The water sample was well mixed. Then the selected volume of sample was measured in a graduated cylinder and the filtration was started by turning on the vacuum pump. After filtering was done, the filter was removed carefully from the filtration apparatus and returned to the same aluminum weighing dish. Then the aluminum dish and filter were again placed in a preheated oven at 103°C for at least one hour. After cooling in a desiccator, the final weight of dish, filter and residue was measured on the analytical balance.

The equation used to calculate the concentration of Total Suspended Solids (TSS), is:

$$TSS\,(mg\,/\,L) = \frac{(B - A) * 10^{6}}{V_s} \qquad (3.1)$$

where:

B = weight of aluminum dish + filter + dried residue (g)

A = weight of aluminum dish + filter (g)

V_s = Sample volume, mL

10^6 = Conversion factor

3.4.2 Turbidity

Turbidity is a cloudiness or haziness of water (or other liquid) caused by individual particles that are too small to be seen without magnification, thus being much like smoke in air. Liquids can contain suspended solid matter consisting of particles of many different sizes. While some suspended material will be large enough and heavy enough to settle rapidly to the bottom of a container if a liquid sample is left to stand (the settleable solids), very small particles will settle only very slowly or not at all if the sample is regularly agitated or the particles are colloidal. These small solid particles cause the liquid to appear turbid. Measurement of turbidity is a key test of water quality (Wikipedia, 2005). The unit of turbidity is expressed in Nephelometric Turbidity Units (NTU).

All the water samples from each sampling trip were tested for the turbidity. For the turbidity test, a Hach Ratio Turbidimeter was used. First, the turbidimeter was turned on and left to warm up for about twenty minutes. With nothing in the sample chamber, the instrument readout was set to zero. Then the standardization of the turbidimeter was performed by using 18 NTU and 180 NTU standard samples supplied from the manufacturer. The empty sample cells were cleaned with de-ionized water and wiped properly using Kimwipes. The water sample was shaken well, and a sample cell was filled and placed inside the turbidimeter. When the reading became steady, the turbidity was recorded. The most sensitive instrument range possible was used for all measurements.

3.5 Flow Estimates for Sampling Sites

To determine suspended solids flux at a particular site, the concentration and the flow rate of the river at the sampling site are needed. Stream flow, or discharge, is the volume of water that moves past a designated point over a fixed period of time. It is often expressed in cubic meters or cubic feet per second (m^3/s or ft^3/sec). The flow of a stream is directly related to the amount of water moving off the watershed into the stream channel. It is affected by weather, increasing during rainstorms and decreasing during dry periods. It also changes during different seasons of the year, decreasing during the summer months when evaporation rates are high and shoreline vegetation is actively growing and removing water from the ground. August and September are usually the months of lowest flow for most streams and rivers in the country (Ohio EPA, 2005).

Three different approaches were used to estimate the stream flow at sampling sites. Where a USGS gauging station exists at the sampling site, discharge on each sampling date was obtained from the USGS web site. For sites with no USGS gauging station, but where stream access was feasible, stream velocity and cross-sectional area were measured during sampling visits. For sites with no USGS gauging station, and where stream access was not feasible, discharge was estimated by applying a ratio of watershed area to flow measurements at an appropriate nearby gauging station. The approach taken for each sampling site is listed in Table 3.2.

3.5.1. USGS Gauging Stations

Nationally, USGS surface-water data includes more than 850,000 station years of time-series data that describe stream levels, stream flow (discharge), reservoir and lake levels, surface-water quality, and rainfall. The data are collected by automatic recorders and manual measurements at field installations across the nation. Data are collected by field personnel or relayed through telephones or satellites to offices where it is stored and processed. The data relayed through the Geostationary Operational Environmental Satellite (GOES) system are processed automatically in near real time, and in many cases, real-time data are available online within minutes.

Table 3.2. Sampling Stations along the Mahoning River and Tributaries.

Site #	Stream	Sampling Locations	Flow Measurement Method
1	Mahoning River	Washington Street,Lowellville	From USGS station
2	Yellow Creek	Lowellville Road, Struthers	Flow velocity and c/s area
3	Dry Run	Wilson Avenue, Youngstown	Flow velocity and c/s area
4	Mill Creek	Mahoning Avenue, Youngstown	Flow velocity and c/s area
5	Mahoning River	West Avenue, Youngstown	From USGS station
6	Little Squaw Cr.	SR - 422, Girard	Flow velocity and c/s area
7	Squaw Creek	SR - 422, Girard	Flow velocity and c/s area
8	Meander Creek	SR - 46, Niles	Flow velocity and c/s area
9	Mosquito Creek	East Park Avenue, Niles	Using watershed ratio
10	Mahoning River	SR 46, Niles	Using watershed ratio
		Ohio Edison, Niles	From USGS station
11	Mahoning River	West Market St., Warren	Using watershed ratio
12	Mahoning River	Leavitt Road, Leavittsburg	From USGS station
13	Eagle Creek	Barclay-Messerly Road,	Flow velocity and c/s area
		Phalanx Station, Phalanx	From USGS station
14	Mahoning River	W. Branch, SR 564, Newton Falls	Using watershed ratio
15	Mahoning River	E. Branch, SR 564, Newton Falls	Using watershed ratio
16	Crab Creek	Valley Street, Youngstown	Flow velocity and c/s area
17	Mahoning River	County Line, Mahoning & Trumbull Co., Pricetown	From USGS station
18	Lake Milton	Craig Beach, above dam	N/A

Once a complete day of readings are received from a site, daily summary data are generated and stored in the data base. Recent provisional daily data are updated on the web once a day when the computation is completed. Annually, the USGS finalizes and publishes the daily data in a series of water-data reports. Daily stream flow data and peak data are updated annually following publication of the reports (USGS, 2005).

3.5.2 Applying Watershed Ratios

For those sampling stations which do not have USGS gauging stations, and where the locations are inaccessible to measure the flow rate in the field, discharge was estimated using equation 3.2.

$$Q_s = Q_g \left(\frac{A_s}{A_g}\right) \qquad (3.2)$$

Where,

Q_s = Flow rate of sampling site in cfs or m^3/s

A_s = Watershed area of sampling site in sq. miles or km^2

Q_g = Flow rate at selected gauging station in cfs or m^3/s

A_g = Watershed area of gauging station, in sq. miles or km^2

This approach is based on the assumption that the discharge per unit of watershed area is the same for the sampling site as for the selected nearby station.

3.5.3 Using the Field Measurement Approach

Field measurements of stream flow required the use of Global Water flow probe to estimate water velocity and the cross-sectional area of the stream. Then, a simple discharge formula (Eq. 3.3) was used to estimate the flow.

$$Q = V \times A \qquad (3.3)$$

Where

Q = discharge, m^3/s

A = Cross-sectional area, the product of stream width multiplied by average water depth, m^2

V = Average velocity of the stream at the sampling station, m/s

3.6 Suspended Solids Flux Calculations

Once discharges and TSS concentrations were obtained, the loading rates, or fluxes, of TSS at each site were calculated using Equation 3.4.

$$\dot{M}\,(\frac{kg}{d}) = Q\,(\frac{m^3}{\sec}) * C\,(\frac{g}{m^3}) * (\frac{24 * 3600 \sec}{1\,d}) * (\frac{1\,kg}{1000\ g})$$

$$\dot{M}\,(\frac{kg}{d}) = Q\,(\frac{m^3}{\sec}) * C\,(\frac{g}{m^3}) * 86.5 \qquad (3.4)$$

Where

$\dot{M}$ = TSS loading, or flux, rate;

Q = Flow rate, or discharge; and

C = TSS concentration.

The ratio of suspended solids flux to the drainage area (watershed area) was also calculated (Equation 3.5). This parameter indicates the areal TSS loading from the drainage area for any particular sampling site.

$$Areal\,TSS\,Loading\ (\frac{kg}{km^2 * d}) = \frac{\dot{M}}{A} \qquad (3.5)$$

Where

$\dot{M}$ = TSS flux, kg/d

A = Drainage area, km^2

3.7 Qualitative Habitat Evaluation Index (QHEI) Maps

3.7.1 QHEI Metrics and Scoring

Only three decades ago, the riparian corridor and the water quality of Lower Mahoning River were in a highly deteriorated condition when large steel mills were in operation and the urbanization of Warren and Youngstown were at record highs. After the closure of all the steel mills (except one), the situation is now improving. As identified in Mahoning River Watershed Action Plan (WAP), Mahoning River is impounded at nine locations by low head dams, mostly built by steel manufacturers to provide a source of cooling water. These dams impede fish migration and recreation, have negative impacts on water quality (e.g., higher temperature and lower dissolved oxygen) and degrade aquatic habitat (deposition of contaminated sediment; decreased habitat diversity). The dams are an important factor contributing to the non-attainment of warm water habitat criteria (Martin, 2004).

Two goals to overcome these problems are also stated in the WAP – to increase the QHEI score to 65, and to achieve the warm water habitat criteria throughout the Lower Mahoning River. This study was undertaken with the hope that, after completion, it will suggest some guidance towards the improvement of aquatic habitat and eventually upgrade the QHEI score. There are six variables which comprise the QHEI – Substrate Quality, Instream Cover, Channel Morphology, Riparian Zone, Pool Quality, and Riffle Quality. All of them have an important role for maintaining a river as superior habitat for aquatic animals.

The study of the riparian zone along the length of the Mahoning River for the Mahoning County segment was completed by Eastgate Regional Council of Governments (RCOG). In this study, the analysis of the riparian zone condition along the length of the Lower Mahoning River in Trumbull County was performed. The appropriate way to study the riparian corridor is either conducting a rigorous field survey along the river banks or analyzing the aerial photographs taken by qualified organizations.

For this research, the latter approach was used and the aerial photographs for Trumbull County were available from Trumbull County GIS Department. The whole length of the Mahoning River in Trumbull County is 38.5 miles. This length was divided into 259 segments and each segment was 800 ft (243.8 m) in length. Riparian Width and Flood Plain Quality scores were estimated for each segment. In addition, a composite score was determined for each river segment by summing the scores for Riparian Width and Flood Plain Quality. The scoring ranges for these two metrics were given earlier in Tables 2.2 and 2.3, respectively. After all scores were determined, qualitative rankings were applied for each metric in each segment. The same ranking system used by Kolwalkar (2003) for Meander Creek watershed (Table 3.3) was applied in this study.

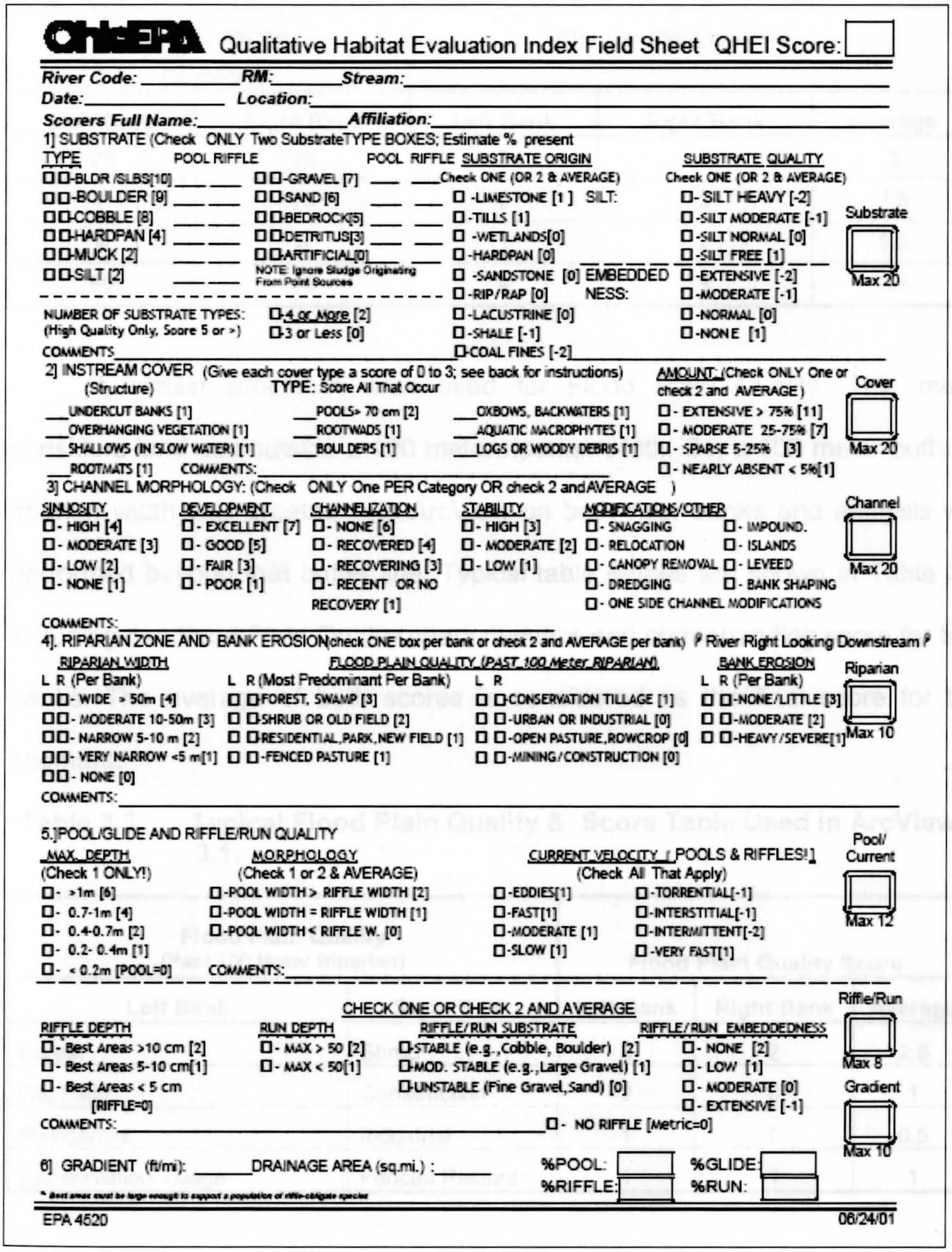
Table 3.3. Qualitative Rankings of River Segments Based on QHEI Metric Scores. (from Kolwalkar, 2003)

Ranking	Riparian Width	Flood Plain Quality	Composite
Poor	0.0-1.0	0.0-1.0	0.0-2.0
Moderate	1.01-2.99	1.01-1.99	2.01-4.99
Excellent	3.0-4.0	2.0-3.0	5.0-7.0

3.7.2 Using ArcView GIS

The application of Geographical Information Systems (GIS) is a rapidly growing technological field that incorporates graphical features with tabular data in order to assess real-world problems. The concept involves overlaying different mapped features on top of each other to determine patterns and causes of spatial phenomenon. On the most basic level, GIS is used as computer cartography, i.e. mapping. However, the real power in GIS is through using spatial and statistical methods to analyze attribute and geographic information. The end result of the analysis can be derivative information, interpolated information or prioritized information (GIS Lounge, 2005).

Figure 3.5 shows a Qualitative Habitat Evaluation Index Field Sheet for QHEI scoring which is available on the Ohio EPA website. Scores were estimated for two parameters – Riparian Width and Flood Plain Quality. The riparian corridor study was performed in the GIS laboratory, located in the Center for Urban and Regional Studies (CURS) at Youngstown State University (YSU). The aerial photographs of Trumbull County were uploaded for the analysis into the GIS software named ArcView 3.1. These aerial photographs were available from Trumbull County GIS Department. After uploading the photographs, the boundary layer of river banks was highlighted to make the analysis easier. Since the segment length of 800 ft (243.8 m) was chosen, demarcation of each segment was performed by using the dividing tool of ArcView GIS. For the riparian width determination, vegetation width on each bank was measured by using the measuring tool of ArcView GIS. All the data of riparian width (in meters) and Riparian Width score for 259 segments were tabulated by creating a table within ArcView. Typical table entries are shown in Table 3.4. As can be seen in the table, the score for a particular segment is taken as the average of the two river banks.



OhioEPA Qualitative Habitat Evaluation Index Field Sheet QHEI Score: ☐

River Code: ________ ***RM:*** ______ ***Stream:*** ________________

Date: ____________ ***Location:*** ________________

Scorers Full Name: ____________ ***Affiliation:*** ________________

1] SUBSTRATE (Check ONLY Two SubstrateTYPE BOXES; Estimate % present

TYPE — POOL RIFFLE

☐☐-BLDR /SLBS[10] ___ ___
☐☐-BOULDER [9] ___ ___
☐☐-COBBLE [8] ___ ___
☐☐-HARDPAN [4] ___ ___
☐☐-MUCK [2] ___ ___
☐☐-SILT [2] ___ ___

POOL RIFFLE

☐☐-GRAVEL [7] ___ ___
☐☐-SAND [6] ___ ___
☐☐-BEDROCK[5] ___ ___
☐☐-DETRITUS[3] ___ ___
☐☐-ARTIFICIAL[0] ___ ___

NOTE: Ignore Sludge Originating From Point Sources

SUBSTRATE ORIGIN
Check ONE (OR 2 & AVERAGE)

☐ -LIMESTONE [1]
☐ -TILLS [1]
☐ -WETLANDS[0]
☐ -HARDPAN [0]
☐ -SANDSTONE [0]
☐ -RIP/RAP [0]
☐ -LACUSTRINE [0]
☐ -SHALE [-1]
☐-COAL FINES [-2]

SUBSTRATE QUALITY
Check ONE (OR 2 & AVERAGE)

SILT:
☐- SILT HEAVY [-2]
☐-SILT MODERATE [-1]
☐-SILT NORMAL [0]
☐-SILT FREE [1]

EMBEDDEDNESS:
☐-EXTENSIVE [-2]
☐-MODERATE [-1]
☐-NORMAL [0]
☐-NONE [1]

Substrate ☐ Max 20

NUMBER OF SUBSTRATE TYPES: (High Quality Only, Score 5 or >)
☐-4 or More [2]
☐-3 or Less [0]

COMMENTS ________________

2] INSTREAM COVER (Give each cover type a score of 0 to 3; see back for instructions)
(Structure) TYPE: Score All That Occur

___UNDERCUT BANKS [1]
___OVERHANGING VEGETATION [1]
___SHALLOWS (IN SLOW WATER) [1]
___ROOTMATS [1]
___POOLS> 70 cm [2]
___ROOTWADS [1]
___BOULDERS [1]
___OXBOWS, BACKWATERS [1]
___AQUATIC MACROPHYTES [1]
___LOGS OR WOODY DEBRIS [1]

COMMENTS: ________________

AMOUNT: (Check ONLY One or check 2 and AVERAGE)

☐ - EXTENSIVE > 75% [11]
☐ - MODERATE 25-75% [7]
☐ - SPARSE 5-25% [3]
☐ - NEARLY ABSENT < 5%[1]

Cover ☐ Max 20

3] CHANNEL MORPHOLOGY: (Check ONLY One PER Category OR check 2 and AVERAGE)

SINUOSITY
☐ - HIGH [4]
☐ - MODERATE [3]
☐ - LOW [2]
☐ - NONE [1]

DEVELOPMENT
☐ - EXCELLENT [7]
☐ - GOOD [5]
☐ - FAIR [3]
☐ - POOR [1]

CHANNELIZATION
☐ - NONE [6]
☐ - RECOVERED [4]
☐ - RECOVERING [3]
☐ - RECENT OR NO RECOVERY [1]

STABILITY
☐ - HIGH [3]
☐ - MODERATE [2]
☐ - LOW [1]

MODIFICATIONS/OTHER
☐ - SNAGGING
☐ - RELOCATION
☐ - CANOPY REMOVAL
☐ - DREDGING
☐ - ONE SIDE CHANNEL MODIFICATIONS
☐ - IMPOUND.
☐ - ISLANDS
☐ - LEVEED
☐ - BANK SHAPING

Channel ☐ Max 20

COMMENTS: ________________

4]. RIPARIAN ZONE AND BANK EROSION(check ONE box per bank or check 2 and AVERAGE per bank) ⁋ River Right Looking Downstream ⁋

RIPARIAN WIDTH
L R (Per Bank)
☐☐- WIDE > 50m [4]
☐☐- MODERATE 10-50m [3]
☐☐- NARROW 5-10 m [2]
☐☐- VERY NARROW <5 m[1]
☐☐- NONE [0]

FLOOD PLAIN QUALITY *(PAST 100 Meter RIPARIAN)*
L R (Most Predominant Per Bank)
☐ ☐-FOREST, SWAMP [3]
☐ ☐-SHRUB OR OLD FIELD [2]
☐ ☐-RESIDENTIAL,PARK,NEW FIELD [1]
☐ ☐-FENCED PASTURE [1]

L R
☐ ☐-CONSERVATION TILLAGE [1]
☐ ☐-URBAN OR INDUSTRIAL [0]
☐ ☐-OPEN PASTURE,ROWCROP [0]
☐ ☐-MINING/CONSTRUCTION [0]

BANK EROSION
L R (Per Bank)
☐ ☐-NONE/LITTLE [3]
☐ ☐-MODERATE [2]
☐ ☐-HEAVY/SEVERE[1]

Riparian ☐ Max 10

COMMENTS: ________________

5.]POOL/GLIDE AND RIFFLE/RUN QUALITY

MAX. DEPTH
(Check 1 ONLY!)
☐- >1m [6]
☐- 0.7-1m [4]
☐- 0.4-0.7m [2]
☐- 0.2- 0.4m [1]
☐- < 0.2m [POOL=0]

MORPHOLOGY
(Check 1 or 2 & AVERAGE)
☐-POOL WIDTH > RIFFLE WIDTH [2]
☐-POOL WIDTH = RIFFLE WIDTH [1]
☐-POOL WIDTH < RIFFLE W. [0]

CURRENT VELOCITY [POOLS & RIFFLES!]
(Check All That Apply)
☐-EDDIES[1]
☐-FAST[1]
☐-MODERATE [1]
☐-SLOW [1]
☐-TORRENTIAL[-1]
☐-INTERSTITIAL[-1]
☐-INTERMITTENT[-2]
☐-VERY FAST[1]

Pool/ Current ☐ Max 12

COMMENTS: ________________

CHECK ONE OR CHECK 2 AND AVERAGE

RIFFLE DEPTH
☐- Best Areas >10 cm [2]
☐- Best Areas 5-10 cm[1]
☐- Best Areas < 5 cm [RIFFLE=0]

RUN DEPTH
☐- MAX > 50 [2]
☐- MAX < 50[1]

RIFFLE/RUN SUBSTRATE
☐-STABLE (e.g.,Cobble, Boulder) [2]
☐-MOD. STABLE (e.g.,Large Gravel) [1]
☐-UNSTABLE (Fine Gravel,Sand) [0]

RIFFLE/RUN EMBEDDEDNESS
☐- NONE [2]
☐- LOW [1]
☐- MODERATE [0]
☐- EXTENSIVE [-1]

Riffle/Run ☐ Max 8

COMMENTS: ________________ ☐- NO RIFFLE [Metric=0]

Gradient ☐ Max 10

6] GRADIENT (ft/mi): ______ DRAINAGE AREA (sq.mi.) : ______

%POOL: ☐ %GLIDE: ☐
%RIFFLE: ☐ %RUN: ☐

* Best areas must be large enough to support a population of riffle-obligate species

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Figure: 3.5. A QHEI Field Score Sheet from Ohio EPA.

Table 3.4. Typical Riparian Width & Riparian Score Table Used in ArcView 3.1.

Riparian Width (in meter)		Riparian Width Score		
Left Bank	**Right Bank**	**Left Bank**	**Right Bank**	**Average**
25	35	3	3	3
7	15	2	3	2.5
4	8	1	2	1.5
60	15	4	3	3.5

A similar procedure was used for Flood Plain Quality. This metric considers land use outside a 100 meter riparian width. So, a 100 meter buffer of riparian width was created with ArcView on both river banks and analysis was performed beyond that buffer line. Typical table entries are shown in Table 3.5, including the Flood Plain Quality characteristics and corresponding score for both banks. The average of both scores is considered as the final score for that segment.

Table 3.5. Typical Flood Plain Quality & Score Table Used in ArcView 3.1.

Flood Plain Quality (Past 100 Meter Riparian)		Flood Plain Quality Score		
Left Bank	**Right Bank**	**Left Bank**	**Right Bank**	**Average**
Forest	Shrub	3	2	2.5
Old Field	Construction	2	0	1
Residential	Industrial	1	0	0.5
Conservation Tillage	Fenced Pasture	1	1	1

Once all scoring was completed, color-coded maps were developed to show the qualitative ranking of each metric along the Mahoning River. During this riparian zone analysis and preparation of maps for the Mahoning River in Trumbull County, support and guidance on the use of ArcView GIS was provided by Mr. John Bralich from the Center for Urban and Regional Studies, YSU.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Suspended Solids Calculations

4.1.1 Suspended Solids Flux at Major Sampling Sites

By performing laboratory analysis in the environmental laboratory at YSU, the suspended solids concentration and turbidity of all samples were determined. Discharge and TSS flux were estimated as described in Chapter 3. All the parameters obtained from the suspended solids study, including discharge, suspended solids concentrations, turbidity, TSS flux, and TSS loading per unit watershed area, are tabulated for sites # 1-16 in Tables 4.1 – 4.16, respectively. In order to evaluate the accuracy of the data and suspended solids movement in the Mahoning River, other data tables and figures were developed. In Table 4.17, all TSS concentrations measured at sites on the main stem of the Mahoning River are summarized. Tables 4.18 and 4.19 show all discharge rates and TSS flux rates, respectively, at Mahoning River sites. Averages for each site are presented at the bottom of the tables. The long term mean discharges for period of record at sampling sites with USGS gauging stations on the Mahoning River are also shown at the bottom in Table 4.18. Average TSS concentrations and flux rates for tributary sites are presented in Table 4.20.

Table 4.1. Suspended Solids Flux and Related Parameters for Sampling Site # 1 Mahoning River at Washington St., Lowellville.

Watershed Area = 2779 sq. km

Date of Sampling	Discharge Flow (m^3/sec)	Suspended Solids Conc. (g/m^3)	Turbidity (NTU)	Solids Flux (kg/d)	(Solids Loading) (Drainage Area) (kg/km^2*d)
January 17,2005	110.2	13.3	28	126961	45.7
February 4,2005	27.5	9.7	11.2	23092	8.3
February 25,2005	48.5	9.7	14.4	40751	14.7
March 11,2005	25.4	14.3	30	31376	11.3
April 1,2005	13.2	5.0	6.7	5693	2.0
April 22,2005	15.2	10.4	8	13649	4.9
May 14,2005	54.4	157	157	738064	265.6
June 01,2005	13.0	4.6	5.4	5147	1.9
July 06,2005	18.8	10.8	10.2	17532	6.31

Table 4.2. Suspended Solids Flux and Related Parameters for Sampling Site # 2 Yellow Creek at Lowellville Road, Struthers.

Watershed Area = 83.14 sq. km

Date of Sampling	Discharge Flow (m^3/sec)	Suspended Solids Conc. (g/m^3)	Turbidity (NTU)	Solids Flux (kg/d)	(Solids Loading) (Drainage Area) (kg/km^2*d)
January 17,2005	N/A	12.2	18	N/A	N/A
February 4,2005	1.0	1.47	1.5	122	1.5
February 25,2005	4.3	4.4	6	1648	19.8
March 11, 2005	1.6	8.67	14	1168	14.0
April 1,2005	3.6	2.6	3.2	808	9.7
April 22,2005	0.9	3.6	3.4	264	3.2
May 14,2005	13.4	12.2	8.8	14159	170.3
June 01,2005	0.1	0.4	1.7	5	0.1
July 06,2005	0.6	2.6	3.9	134	2

Table 4.3. Suspended Solids Flux and Related Parameters for Sampling Site # 3 Dry Run at Wilson Ave. Youngstown.

Watershed Area = 25.95 sq.km

Date of Sampling	Discharge Flow (m^3/sec)	Suspended Solids Conc. (g/m^3)	Turbidity (NTU)	Solids Flux (kg/d)	(Solids Loading) (Drainage Area) (kg/km^2*d)
January 17,2005	N/A	3	5.4	N/A	N/A
February 4,2005	0.4	1.07	3.5	39	1.5
February 25,2005	1.1	2.53	3.3	248	9.5
March 11, 2005	1.0	1.47	4.6	130	5.0
April 1,2005	0.5	0.93	2.5	41	1.6
April 22,2005	0.1	0.4	1.7	4	0.2
May 14,2005	6.4	27	15.2	14874	573.2
June 01,2005	0.1	0.2	1.6	2	0.08
July 06,2005	0.03	1.4	3	3	0.13

Table 4.4. Suspended Solids Flux and Related Parameters for Sampling Site # 4 Mill Creek at Mahoning Avenue, Youngstown.

Watershed Area = 206.7 sq.km

Date of Sampling	Discharge Flow (m^3/sec)	Suspended Solids Conc. (g/m^3)	Turbidity (NTU)	Solids Flux (kg/d)	(Solids Loading) (Drainage Area) (kg/km^2*d)
January 17,2005	N/A	14	22	N/A	N/A
February 4,2005	6.4	1.47	2.2	810	3.9
February 25,2005	8.2	5.067	8	3585	17.3
March 11, 2005	2.8	22	36	5387	26.1
April 1,2005	0.6	13.4	15.4	738	3.6
April 22,2005	0.9	26.4	19	1939	9.4
May 14,2005	6.8	52	52	30557	147.8
June 01,2005	0.5	16.4	13.6	763	4
July 06,2005	1.7	25	22	3734	18

Table 4.5. Suspended Solids Flux and Related Parameters for Sampling Site # 5 Mahoning River at West Ave., Youngstown.

Watershed Area = 2533 sq. km

Date of Sampling	Discharge Flow (m^3/sec)	Suspended Solids Conc. (g/m^3)	Turbidity (NTU)	Solids Flux (kg/d)	(Solids Loading) (Drainage Area) (kg/km^2*d)
January 17,2005	115.1	14	22	139170	54.9
February 4,2005	25.0	6.27	9.8	13559	5.4
February 25,2005	56.4	9.87	12.9	48091	19.0
March 11, 2005	23.2	13.6	22	27255	10.8
April 1,2005	12.0	6.6	8.5	6849	2.7
April 22,2005	23.6	12.4	10.5	25291	10.0
May 14,2005	62.6	42.7	39	231053	91.2
June 01,2005	15.7	7.2	8.5	9749	3.8
July 06,2005	17.9	10.2	10.2	15809	6.2

Table 4.6. Suspended Solids Flux and Related Parameters for Sampling Site # 6 Little Squaw Creek at SR - 422, Girard.

Watershed Area = 16.32 sq.km

Date of Sampling	Discharge Flow (m^3/sec)	Suspended Solids Conc. (g/m^3)	Turbidity (NTU)	Solids Flux (kg/d)	(Solids Loading) (Drainage Area) (kg/km^2*d)
January 17,2005	0.4	13.6	8.4	416	25.5
February 4,2005	0.7	20.13	8	1301	79.7
February 25,2005	0.9	20.53	20	1558	95.5
March 11, 2005	0.5	12.4	22	501	30.7
April 1,2005	0.3	10.2	7	228	14.0
April 22,2005	0.2	18.2	21	279	17.1
May 14,2005	0.9	36.7	43	2696	165.2
June 01,2005	0.3	19.2	16.1	423	25.9
July 06,2005	0.3	17.6	18	431	26.4

Table 4.7. Suspended Solids Flux and Related Parameters for Sampling Site # 7 Squaw Creek at SR - 422, Girard.

Watershed Area = 47.66 sq.km

Date of Sampling	Discharge Flow (m^3/sec)	Suspended Solids Conc. (g/m^3)	Turbidity (NTU)	Solids Flux (kg/d)	(Solids Loading) (Drainage Area) (kg/km^2*d)
January 17,2005	N/A	11	19.4	N/A	N/A
February 4,2005	2.6	6.13	9	1387	29.1
February 26,2005	1.5	4.8	7.1	615	12.9
March 11, 2005	1.1	4.27	7.6	403	8.4
April 1,2005	0.5	5.2	4.3	210	4.4
April 22,2005	0.5	7.2	8.2	291	6.1
May 14,2005	2.0	26.5	32	4672	98.0
June 01,2005	0.3	37	43	997	20.9
July 06,2005	0.2	55.3	58	948	19.9

Table 4.8. Suspended Solids Flux and Related Parameters for Sampling Site # 8 Meander Creek at SR - 46, Niles.

Watershed Area = 224 sq. km

Date of Sampling	Discharge Flow (m^3/sec)	Suspended Solids Conc. (g/m^3)	Turbidity (NTU)	Solids Flux (kg/d)	(Solids Loading) (Drainage Area) (kg/km^2*d)
January 17,2005	N/A	9.4	11.3	N/A	N/A
February 7,2005	0.6	3.59	3.2	190	0.8
February 26,2005	2.5	6.53	8.8	1407	6.3
March 12, 2005	0.8	15.07	12	1015	4.5
April 1,2005	0.5	4.6	8	198	0.9
April 22,2005	0.1	4	5	47	0.2
May 14,2005	2.5	38.8	21	8360	37.3
June 01,2005	0.2	6	4.7	88	0.4
July 06,2005	0.1	7.8	7.4	76	0.34

Table 4.9. Suspended Solids Flux and Related Parameters for Sampling Site # 9 Mosquito Creek at E. Park Ave., Niles.

Watershed Area = 360.53 sq.km

Date of Sampling	Discharge Flow (m^3/sec)	Suspended Solids Conc. (g/m^3)	Turbidity (NTU)	Solids Flux (kg/d)	(Solids Loading) (Drainage Area) (kg/km^2*d)
January 17,2005	31.0	10	13.7	26777	74.3
February 4,2005	10.6	9.33	9.5	8512	23.6
February 26,2005	11.0	7.6	8.9	7253	20.1
March 12, 2005	1.6	12.67	15.1	1727	4.8
April 1,2005	1.7	8.2	8.9	1175	3.3
April 22,2005	1.8	9.4	11.5	1446	4.0
May 14,2005	1.1	26.8	34	2529	7.0
June 01,2005	1.1	14	19.1	1371	4
July 06,2005	3.4	16.6	15.3	4877	14

$Q_s = Q_g$*1.4154 Q_g = Flow at Cortland dam, Mosquito Creek

Table 4.10. Suspended Solids Flux and Related Parameters for Sampling Site # 10 Mahoning River at SR-46, Niles.

Watershed Area = 2211 sq. km

Date of Sampling	Discharge Flow (m^3/sec)	Suspended Solids Conc. (g/m^3)	Turbidity (NTU)	Solids Flux (kg/d)	(Solids Loading) (Drainage Area) (kg/km^2*d)
January 17,2005*	89.2	19.4	22	149462	67.6
February 7,2005*	15.9	7.733	16	10639	4.8
February 26,2005*	23.4	10.53	15.2	21275	9.6
3/12/2005*	19.2	11.07	15.2	18334	8.3
April 1,2005**	12.9	8.6	11	9560	4.3
April 22,2005**	16.6	9.8	10	14037	6.3
May 14,2005**	11.4	37.2	32	36615	16.6
June 01,2005**	10.2	7.6	9.7	6698	3.0
July 06,2005**	8.4	7	10.2	5080	2

* At SR-46, Niles $Q_s = Q_g$ * 1.070261

** At Ohio Edison, Niles (Q_g = Flow rate at Leavittsberg Gauging Station)

Table 4.11. Suspended Solids Flux and Related Parameters for Sampling Site # 11 Mahoning River at West Market St., Warren.

Watershed Area = 1597.36 sq. km

Date of Sampling	Discharge Flow (m^3/sec)	Suspended Solids Conc. (g/m^3)	Turbidity (NTU)	Solids Flux (kg/d)	(Solids Loading) (Drainage Area) (kg/km^2*d)
January 17,2005	87.1	16	19.5	120443	75.4
February 7,2005	15.6	8.93	14.5	12004	7.5
February 26,2005	22.8	9.067	13.5	17899	11.2
March 12, 2005	18.7	9.2	13	14887	9.3
April1,2005	9.2	8.8	11	7007	4.4
April 22,2005	12.9	10.6	11.8	11806	7.4
May 14,2005	25.8	34.4	33	76646	48.0
June 01,2005	9.3	6.2	9.5	4994	3.1
July 06,2005	5.2	9.8	10	4367	2.73

$Q_s = Q_g * 1.045739$ (Q_g = Flow rate at Leavittsburg Gauging Station)

Table 4.12. Suspended Solids Flux and Related Parameters for Sampling Site # 12 Mahoning River at Leavitt Road, Leavittsburg.

Watershed Area = 1489.24 sq. km

Date of Sampling	Discharge Flow (m^3/sec)	Suspended Solids Conc. (g/m^3)	Turbidity (NTU)	Solids Flux (kg/d)	(Solids Loading) (Drainage Area) (kg/km^2*d)
January 17,2005	83.3	20	14	143969	96.7
February 7,2005	14.9	14	9.067	17996	12.1
February 26,2005	21.8	10.27	15.2	19387	13.0
March 12,2005	17.9	10.13	12.3	15675	10.5
April 1,2005	8.8	11.8	15.5	8985	6.0
April 22,2005	12.3	13.2	14	14059	9.4
May 14,2005	24.7	46.8	49	99691	66.9
June 01,2005	8.9	11	12.1	8457	5.7
July 06,2005	4.9	10.8	12.2	4601	3.1

Table 4.13. Suspended Solids Flux and Related Parameters for Sampling Site# 13 Eagle Creek at Barclay - Messerly Rd., Phalanx.

Watershed Area = 252.8 sq. km

Date of Sampling	Discharge Flow (m^3/sec)	Suspended Solids Conc. (g/m^3)	Turbidity (NTU)	Solids Flux (kg/d)	(Solids Loading) (Drainage Area) (kg/km^2*d)
January 17,2005	N/A	13	15.4	N/A	N/A
February 7,2005	N/A	N/A	N/A	N/A	N/A
February 26,2005	4.2	4.8	9	1751	6.9
March 12, 2005	N/A	6.8	9.6	N/A	0.0
April 1,2005	N/A	10.4	7.2	N/A	0.0
April 22,2005*	2.9	7.6	14.4	1879	7.4
May 14,2005	7.7	35.6	28	23796	94.1
June 01,2005	1.0	7.2	9.2	617	2.4
July 06,2005	0.5	4.8	7.3	188	0.7

Table 4.14. Suspended Solids Flux and Related Parameters for Sampling Site # 14 W. Branch Mahoning River at SR-534, Newton Falls.

Watershed Area = 281.3 sq.km

Date of Sampling	Discharge Flow (m^3/sec)	Suspended Solids Conc. (g/m^3)	Turbidity (NTU)	Solids Flux (kg/d)	(Solids Loading) (Drainage Area) (kg/km^2*d)
January 17,2005	15.7	N/A	N/A	N/A	N/A
February 7,2005	2.8	10.8	12.8	2622	9.3
February 26,2005	4.1	8.67	14	3091	11.0
March 12, 2005	3.4	9.73	13	2844	10.1
April 1,2005	1.7	4.27	8.5	614	2.2
April 22,2005	2.3	6.8	8.9	1368	4.9
May 14,2005	4.7	78.8	116	31703	112.7
June 01,2005	1.7	7.2	10.3	1058	3.8
July 06,2005	0.4	14.8	15.1	507	2

$Q_s = Q_g * 0.18887$ Q_g = Flow rate at Leavittsburg Gauging Station

Table 4.15. Suspended Solids Flux and Related Parameters for Sampling Site # 15 E. Branch Mahoning River at SR - 534, Newton Falls.

Watershed Area = 794.35 sq. km

Date of Sampling	Discharge Flow (m^3/sec)	Suspended Solids Conc. (g/m^3)	Turbidity (NTU)	Solids Flux (kg/d)	(Solids Loading) (Drainage Area) (kg/km^2*d)
January 17,2005	44.4	N/A	N/A	0	N/A
February 7,2005	7.9	9.6	16.9	6582	8.3
February 26,2005	11.7	11.73	16.3	11811	14.9
March 12, 2005	9.6	12.4	14.8	10235	12.9
April 1,2005	4.7	12	6	4874	6.1
April 22,2005	6.6	16.4	17.5	9317	11.7
May 14,2005	13.2	79.2	104	89987	113.3
June 01,2005	16.7	8	9.5	11537	14.5
July 06,2005	2.6	9.1	11.3	2072	2.61

$Q_s = Q_g * 0.53339$ (Q_g = Flow rate at Leavittsberg Gauging Station)

Table 4.16. Suspended Solids Flux and Related Parameters for Sampling Site # 16 Crab Creek at Valley St., Youngstown.

Watershed Area = 50.06 sq.km

Date of Sampling	Discharge Flow (m^3/sec)	Suspended Solids Conc. (g/m^3)	Turbidity (NTU)	Solids Flux (kg/d)	(Solids Loading) (Drainage Area) (kg/km^2*d)
February 4,2005	0.3	0.67	2.2	15	0.3
February 26,2005	1.6	2.4	4.4	322	6.4
March 12, 2005	0.7	4.53	8.3	280	5.6
April 1,2005	0.3	2.8	2.5	69	1.4
April 22,2005	0.2	2.8	3.3	41	0.8
May 14,2005	3.1	50.4	43	13574	271.2
June 01,2005	0.1	2.2	3.5	22	0.4
July 06,2005	0.2	2	4.2	29	0.59

Table 4.17. **Total Suspended Solids (TSS) Concentration (mg/L) at Mahoning River Sites.**

Date	Newton Falls E. Branch	Leavitts-burg	Warren	Niles	Youngs-town	Lowell-ville
17-Jan	N/A	20	16	19.4	14	13.3
4-Feb	9.6	14	8.93	7.733	6.27	9.7
25-Feb	11.73	10.27	9.067	10.53	9.87	9.7
11-Mar	12.4	10.13	9.2	11.07	13.6	14.3
1-Apr	12	11.8	8.8	8.6	6.6	5.0
22-Apr	16.4	13.2	10.6	9.8	12.4	10.4
14-May	79.2	46.8	34.4	37.2	42.7	157
1-Jun	8	11	6.2	7.6	7.2	4.6
6-Jul	9.1	10.8	9.8	7	10.2	10.8
Ave. SS	**19.8**	**16.4**	**12.6**	**13.2**	**13.6**	**26.1**
Ave. SS (Excl. 6/14/05)	**11.3**	**12.7**	**9.8**	**10.2**	**10**	**9.7**
Flow - Wt. Ave. SS	**14.44**	**19.5**	**15.13**	**15.19**	**17**	**35.57**

Table 4.18. **Discharge Rates (m^3/sec) at Different Sampling Sites Along Mahoning River.**

Date	Newton Falls E. Branch	Leavitts-burg	Warren	Niles	Youngs-town	Lowell-ville
17-Jan	44.4	83.3	87.1	89.2	115.1	110.2
4-Feb	7.9	14.9	15.6	15.9	25	27.5
25-Feb	11.7	21.8	22.8	23.4	56.4	48.5
11-Mar	9.6	17.9	18.7	19.2	23.2	25.4
1-Apr	4.7	8.8	9.2	12.9	12	13.2
22-Apr	6.6	12.3	12.9	16.6	23.6	15.2
14-May	13.2	24.7	25.8	11.4	62.6	54.4
1-Jun	16.7	8.9	9.3	10.2	15.7	13.0
6-Jul	2.6	4.9	5.2	8.4	17.9	18.8
Ave. Flow	**13.0**	**21.9**	**23.0**	**23.0**	**39.1**	**36.2**
Recorded Ave. Flow (long term means)	**N/A**	**17**	**N/A**	**26.6**	**29.7**	**32.3**

Table 4.19. TSS Flux Rates at Different Sampling Sites Along Mahoning River.

Sampling Date	Suspended Solids Flux (kg/d)					
	Newton Falls	Leavittsburg	Warren	Niles	Youngstown	Lowellville
17-Jan	-	144109	120546	115287	76812	126780
4-Feb	6560	18044	12050	11509	9567	23074
25-Feb	11871	19366	17882	17098	10394	40694
11-Mar	10297	15685	14881	14245	8412	31419
1-Apr	4879	8982	7003	6699	4797	5709
22-Apr	9363	14044	11828	11278	7536	13674
14-May	90431	99991	76770	73497	53436	738779
1-Jun	11556	8468	4988	4773	15890	5173
6-Jul	2047	4578	4408	4154	2429	17563
Ave.SS Flux (kg/d)	18375	37030	30040	28727	21030	111429
Ave.SS Flux (MT/yr)	6707	13516	10964	10485	7676	40672

Table 4.20. Average Suspended Solids Concentration and Fluxes for Tributaries of Mahoning River.

Tributaries	Ave. SS Conc (mg/L)	Ave. SS Conc. (Excl. 5/14) (mg/L)	Flow -Wt. Ave. SS Conc (mg/L)	Mean Discharge (m^3/sec)	Ave. Suspended Solids Flux	
					kg/day	MT/year
Yellow Creek	5.3	4.5	8.3	3.2	2289	835
Dry Run	4.2	1.4	18.9	1.2	1918	700
Crab Creek	8.5	2.5	26	0.8	1794	655
Mill Creek	19.5	15.5	19.7	3.5	5939	2168
Little Squaw Creek	18.7	16.5	21.2	0.5	870	318
Squaw Creek	17.5	16.4	12.7	1.1	1190	434
Meander Creek	10.6	7.1	18.1	0.9	1423	519
Mosquito Creek	12.7	11	10.2	7	6185	2258
Eagle Creek	11.3	7.8	27.1	3.2	5646	2061
West Branch	17.6	8.9	13.8	4.1	4867	1776

4.1.2 Discussion of Suspended Solids and Turbidity Data

Total suspended solids (TSS) concentrations at the Mahoning River sites generally fell in the range of 5 – 20 mg/L, except for May 14. The average TSS concentrations for Leavittsburg and Lowellville (19.8 mg/L and 26.1 mg/L) were close to averages of 18.5 mg/L and 21.6 mg/L, respectively obtained from the STORET database for these two sites. Due to a heavy thunderstorm and rainfall on May 13, the concentrations on May 14 were much higher for most of the sampling sites. On average (excluding May 14), TSS was slightly higher at the Newton Falls and Leavittsburg sites than at the four downstream sites (Warren, Niles, Youngstown, and Lowellville). This could be due to deposition of suspended solids (SS) on the river bed as the river gradient and velocity decrease. Flow – weighted average TSS concentrations in the Mahoning River were greater than the arithmetic averages, indicating the importance of storm events such as May 14 in suspended solids transport.

Most of the time, TSS and turbidity were relatively constant along the length of the river between Newton Falls and Lowellville. However, levels were consistently lower at sites #17 (County Line Rd., Pricetown) and #18 (Lake Milton), as shown in Tables A.1 and A.2, respectively.

Average TSS in the tributaries was variable. Tributaries which meet the Mahoning River on the lower reach, including Yellow Creek, Dry Run, and Crab Creek, carry generally low concentrations (<5 mg/L), while Mill Creek, Squaw Creek, and Little Squaw Creek transport higher solids concentrations (>15 mg/L). The suspended solids concentrations and the turbidity in the water samples from

Little Squaw Creek and Squaw Creek were higher for most of the samplings. Those samples (especially from Little Squaw Creek) appeared to contain some sewage (gray solids), and because of this the samples were more turbid. Considerable amounts of suspended solids and turbidity were found from the samples of Mill Creek even in case of low discharge in the stream (Sampling #4 on April 01, 2005).

Sources of error may have occurred for TSS concentration because grab samples were not representative of the entire stream cross-section, although grab samples were obtained from the section with highest flow. Also, only one TSS analysis was performed per sample, so another source of error may have occurred due to variability in laboratory tests for TSS.

4.1.3 Discussion of Discharge Data

Though the sampling started in the mid-winter of 2005 and continued up to the mid summer of 2005, the rainfall intensity was not that high (few samplings were exceptions) which resulted in lower discharge in the river most of the time. The summer of 2005 (June and July) was considered dry because of below average rainfall. The average and recorded monthly precipitation for the Youngstown area are tabulated in Table 4.21. Precipitation was above normal in January, February and April, and below normal in March, May, June, and July.

Although the recorded precipitation for January – July, 2005, was 7.47 cm above average, discharge in the river and tributaries was lower than normal during most sampling trips. The recorded discharges at three gauging stations on the sampling dates are compared with the average for that date over the period of record in Table 4.22. The 2005 discharge is greater than the long-term average at all three stations of only two dates – January 17 and May 14.

Table 4.21. Rainfall Data (cm) Recorded for Months of 2005 and Monthly Averages for Youngstown (NOAA*, 2005).

Average and Recorded Precipitation Data of Youngstown (in.)							
Month	**January**	**February**	**March**	**April**	**May**	**June**	**July**
Average	**5.3**	**5.1**	**7.9**	**7.9**	**8.9**	**9.9**	**10.4**
Recorded for 2005	**14.9**	**7.1**	**4.2**	**13.7**	**8.0**	**7.0**	**8.0**
Differences	**9.6**	**2.0**	**-3.7**	**5.8**	**-0.9**	**-2.9**	**-2.5**

NOAA* - National Oceanic and Atmospheric Administration (Recorded at Regional Airport, Youngstown)

The highest flow rate in the Mahoning River occurred on January 17, 2005 and can be seen in Table 4.18. High groundwater inflow (due to a wet fall and winter) and snow melt contributed to this. However, TSS was not very high on that date because the ground was frozen. In general, the flow rates declined during the course of the study due to declining precipitation. The flow rate on May 14 was an exception among these data.

There appear to be some discrepancies in the discharge data from USGS gauging stations. For example, on five sampling dates, the discharge reported at site #5 (West Avenue, Youngstown) exceeded the flow reported at site #1 (Washington Street, Lowellville). This is unlikely since Crab Creek, Dry Run, and Yellow Creek all flow into the Mahoning River between these two stations. There could be some error in the rating curves used to estimate flow at these sites.

Some sources of error may have occurred in field estimation of stream flow using flow probe because of, inaccuracies in estimating width & mean depth and variability in average velocity readings.

Table 4.22. Recorded and Mean Daily Discharge (m^3/sec) at Major Sampling Sites Along Mahoning River (USGS, 2005).

Discharge at Site→	**Leavittsburg (# 12)**		**Youngstown (Site # 5)**		**Lowellville (Site # 1)**	
Date	**Recorded**	**Mean Daily^1**	**Recorded**	**Mean Daily^2**	**Recorded**	**Mean Daily^3**
17-Jan	83.3	19.3	115.2	41.3	110.2	33.1
4-Feb	14.9	22.0	25	44.2	27.5	41.8
25-Feb	21.8	29.4	56.4	38.4	48.5	59.7
11-Mar	17.9	28.3	23.2	44.5	25.4	52.9
1-Apr	8.8	24.4	12	31.6	13.2	52.9
22-Apr	12.3	21.4	23.6	40.4	15.2	35.6
14-May	24.7	21.3	62.6	39.6	54.4	41.6
1-Jun	8.9	20.6	15.7	40.6	13	32.8
6-Jul	4.9	10.4	17.9	18.6	18.8	19.8

All the discharge are expressed in m^3/sec; Mean Daily^1 - Based on 64 years of record
Mean Daily^2 - Based on 17 years of record; Mean Daily^3 - Based on 50 years of record

4.1.4 Mass Balance Analysis of Suspended Solids Flux

The mass balance analyses of suspended solids flux were performed for all sampling dates and schematic flow diagrams were prepared. Three examples are shown in Figures 4.1. – 4.3. The major sampling stations along with the Mahoning River are located as dark spots and the tributaries are shown with

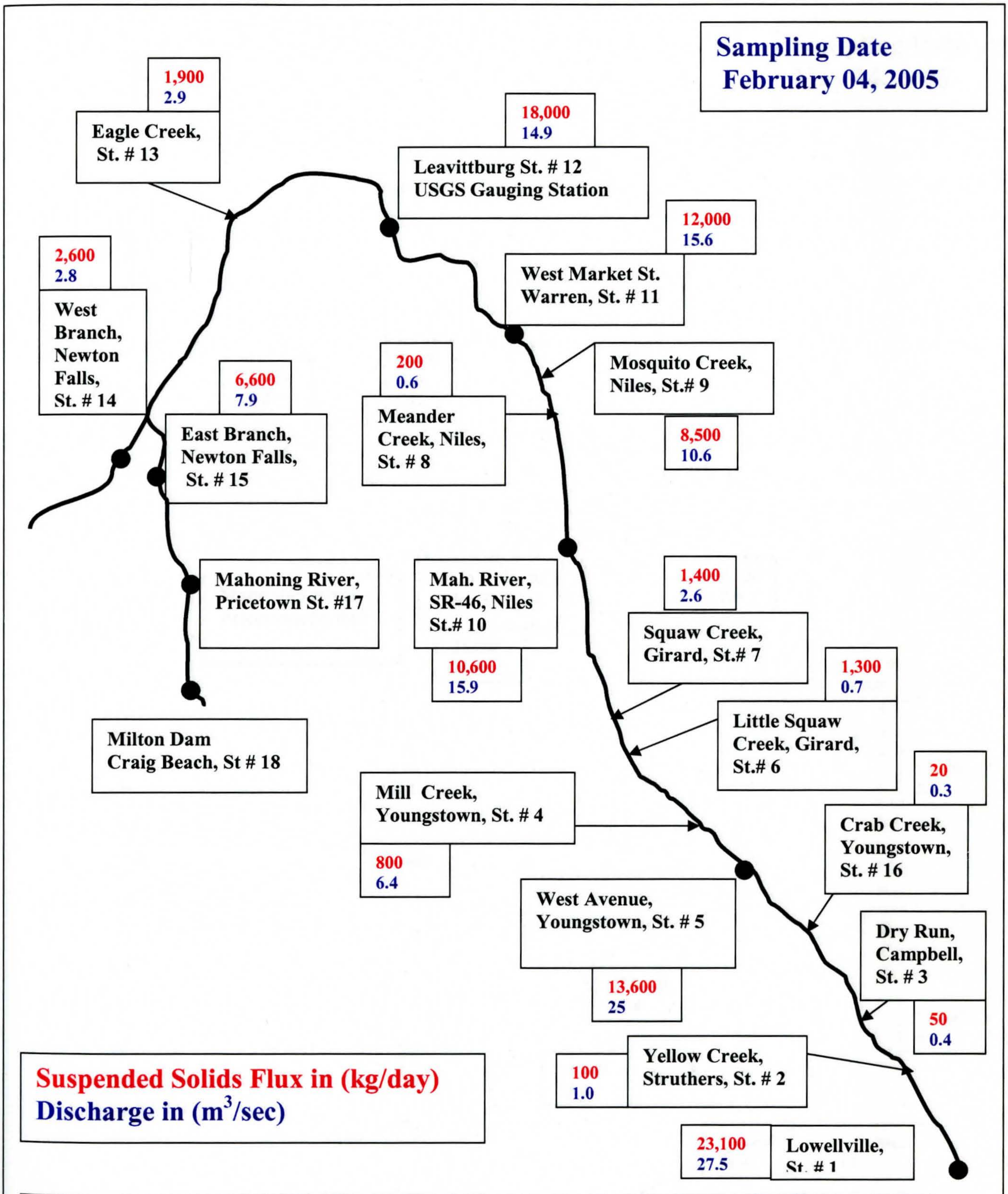


Figure 4.1. Schematic Diagram of Solids Flux and Discharge at Mahoning River and Tributaries (February 04, 2005).

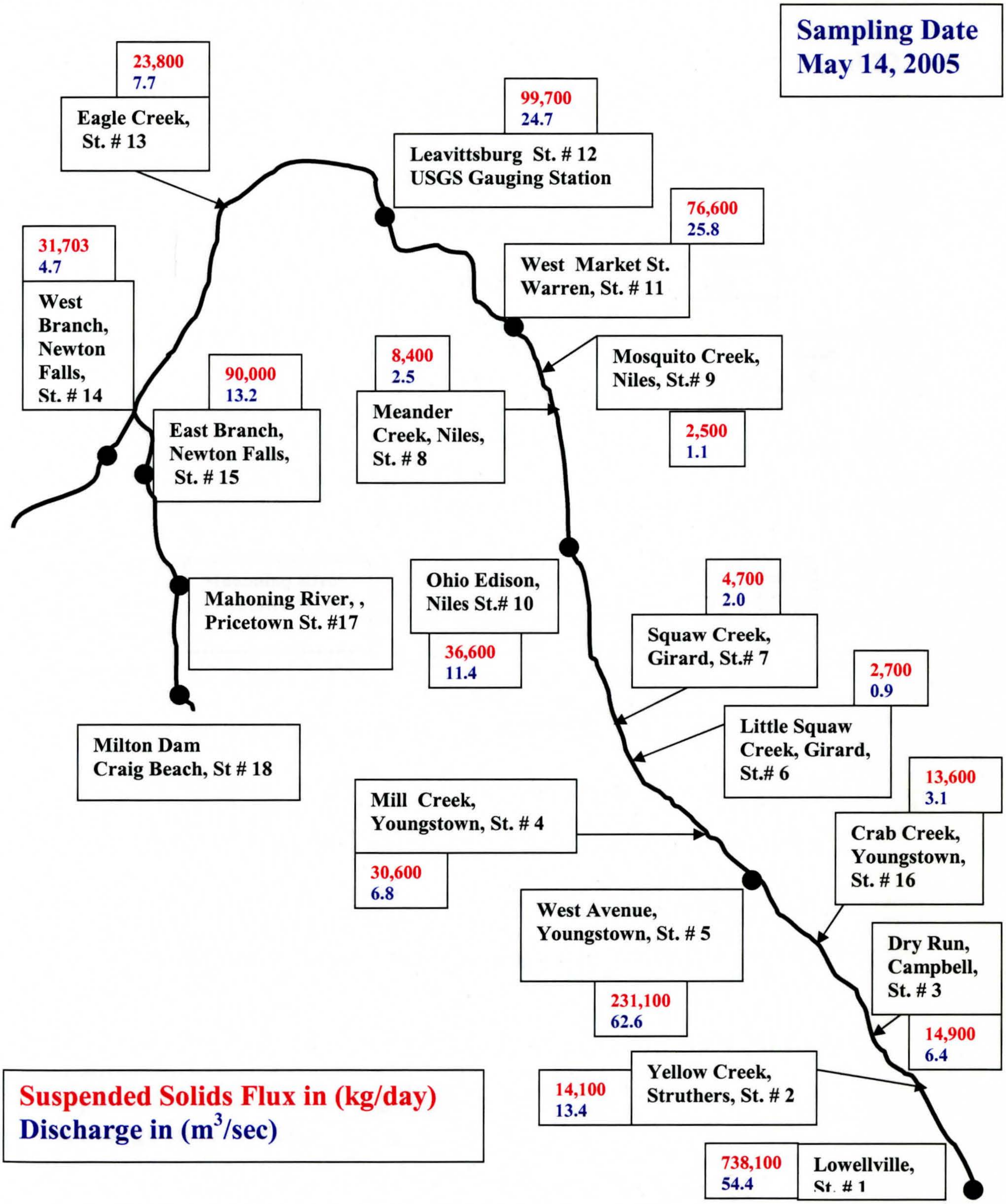


Figure 4.2. Schematic Diagram of Solids Flux and Discharge Flow at Mahoning River and Tributaries (May 14, 2005).

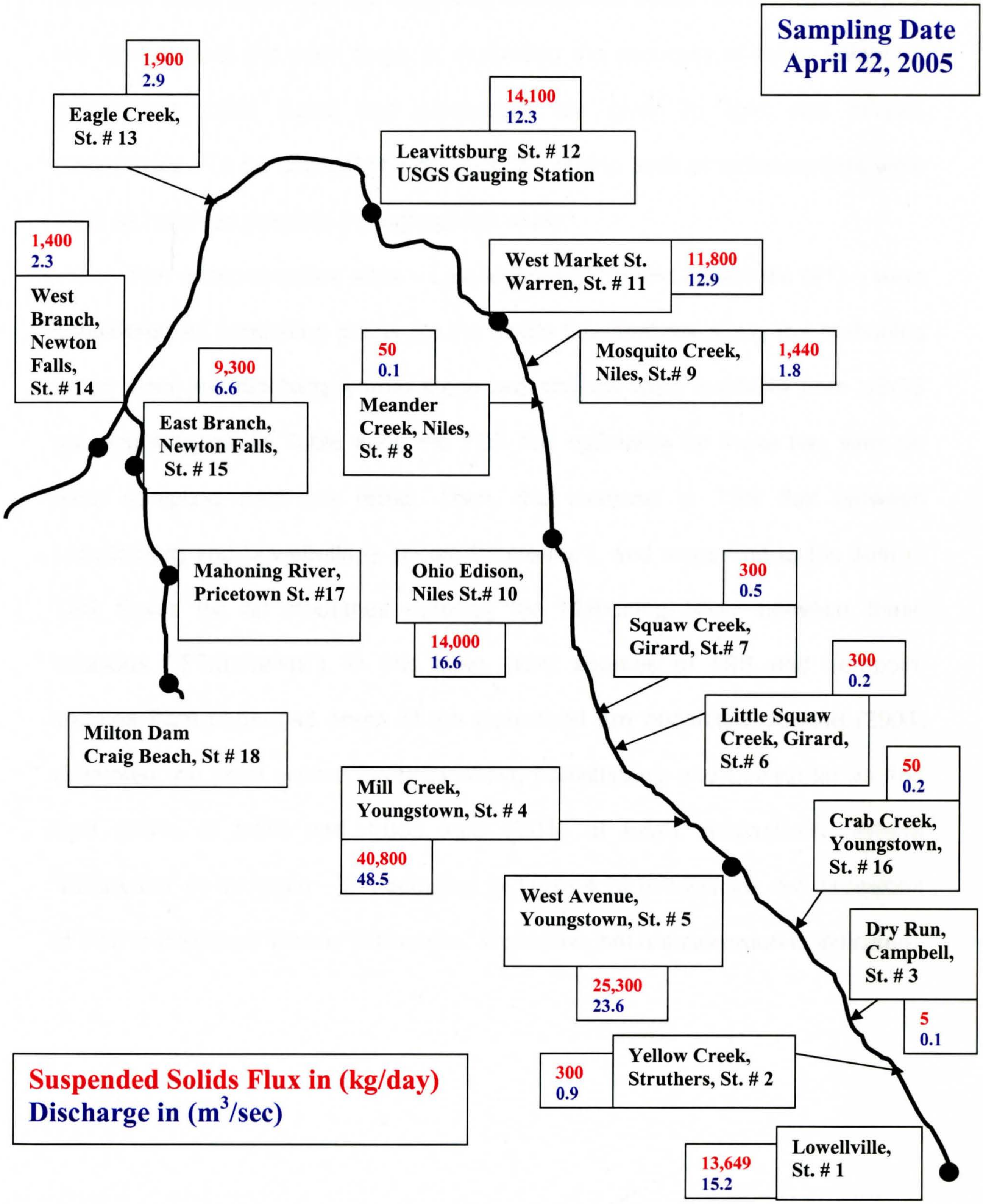


Figure 4.3. Schematic Diagram of Solids Flux and Discharge Flow at Mahoning River and Tributaries (April 22, 2005).

arrows in these schematic flow diagrams. Suspended solids flux and discharge of the stream were the main focus in evaluating the accuracy of mass balances. Suspended solids fluxes and discharges are given in kg/d and m^3/sec, respectively. To be consistent with units, the metric units of measurement were used as much as possible throughout this study.

Two water sampling sites – Leavittsburg (#12) and Lowellville (#1) – were considered as controlling points for the solids flux analysis along the Mahoning River, since the discharges from these two stations were available from USGS gauging stations. In Table 4.23, the TSS flux estimates for these two sites on each sampling date are listed. Then, the increase in TSS flux between Leavittsburg and Lowellville is shown ("Increase"), and compared to the sum of TSS fluxes for all tributaries entering the Mahoning River between these locations ("ΣTributaries"). In this table, point sources of TSS and non-point sources from ungauged areas of the watershed are neglected. Ahmad (2004) estimated the point source loadings above Leavittsburg and Lowellville as 168 kg/d (0.4% of total) and 4,086 kg/d (5.7% of total), respectively. Where "Difference" (= Increase – ΣTributaries) in Table 4.23 is negative, net deposition of TSS is indicated. Where "Difference" is positive, net resuspension is indicated.

Table 4.23. Suspended Solids Mass Balance Analysis Between Two Sampling Stations – Leavittsburg and Lowellville.

Suspended Solids Flux (kg/day)									
Date	**17-Jan**	**4-Feb**	**26-Feb**	**11-Mar**	**1-Apr**	**22-Apr**	**14-May**	**1-Jun**	**6-Jul**
Leavittsburg	143969	17996	19387	15675	8985	14059	99691	8457	4601
Lowellville	126961	23092	40751	31376	5693	13649	738064	5147	17532
Increase	-17008	5096	21364	15701	-3292	-410	638373	-3310	12931
ΣTributaries	27193	12376	16636	10610	3467	4311	91421	3671	10231
Difference	-44201	-7280	4728	5091	-6759	-4721	546952	-6981	2700

4.1.5 Discussion of Suspended Solids Flux Rates

The river channel of the Mahoning River becomes wider and deeper as it flows from Leavittsburg towards Youngstown. Because of this widening, the flow velocity decreases. Under normal flow conditions, this decreasing velocity may cause the settling of the suspended solid particles, which ultimately results in the formation of a deposition layer of these settled particles on the bottom of river bed. This deposition process continues up to Youngstown for normal flow. Figure 4.4 shows the average fluxes and evidence of TSS deposition along the Mahoning River between Leavittsburg and Youngstown. Heavy rainfall in the watershed area causes high flow discharge and obviously high suspended solids concentration also. When the flow increased after the considerable rainfall on May 14, scouring of sediment was found in the solids flux analysis. During low flow periods, the Mahoning River may experience a small net deposition or resuspension of suspended solids, but it is not clear which process is dominant.

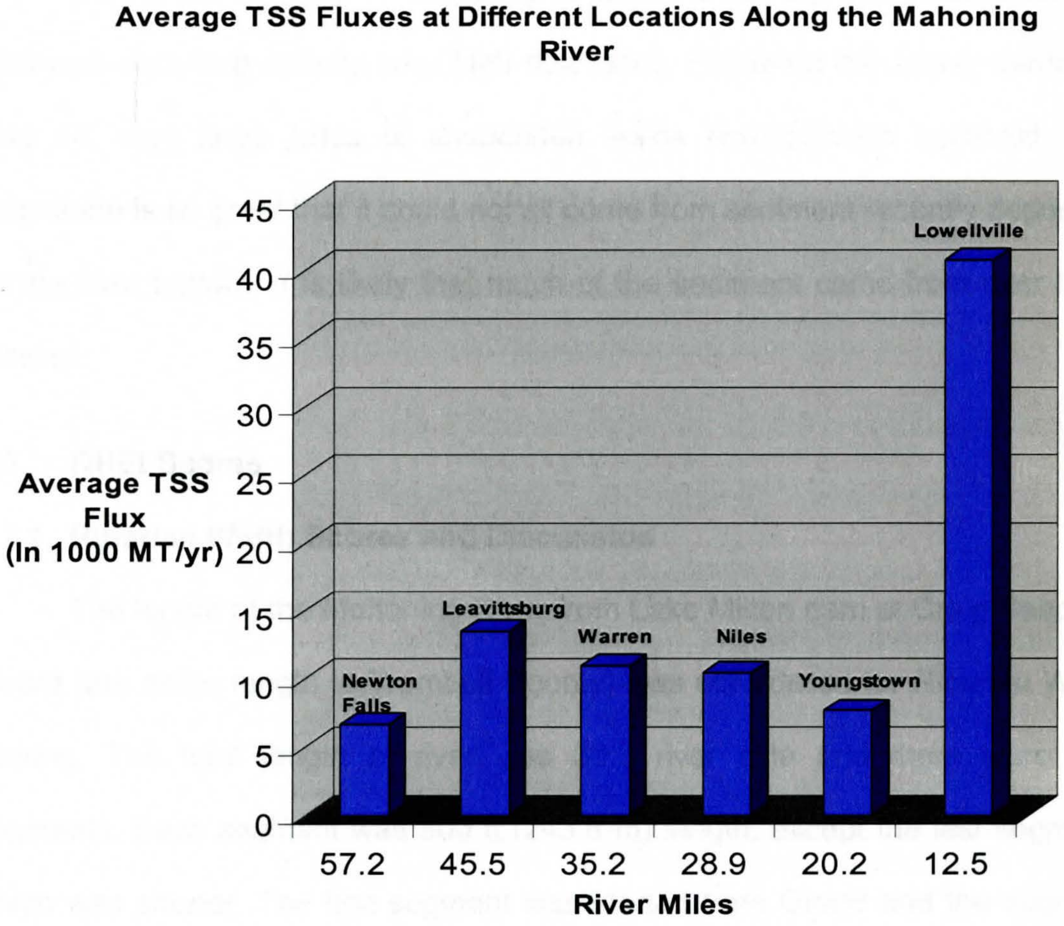


Figure 4.4. Average TSS Fluxes Along the Mahoning River

During the mass balance analysis, the highest suspended solids flux was found on two sampling days. The solids flux estimate for Lowellville on January 17, 2005 was 127,000 kg/day and for May 14, 2005 was 738,000 kg/day. Likewise for Leavittsburg, the solids flux was estimated as 144,000 kg/day and 99,700 kg/day for January 17 and May 14, respectively. According to Ahmad

(2004) study, averages TSS fluxes for Leavittsburg and Lowellville are 47,100 kg/d and 71,400 kg/d, respectively. From this study, TSS fluxes were found as 37,000 kg/d and 111,400 kg/d for Leavittsburg and Lowellville, respectively.

During the January 17 sampling, it appears that significant deposition of TSS was occurring despite very high flow rates. Following the heavy rainfall of May 14, very large rates of suspended solids resuspension occurred. The magnitude is so great that it could not all come from sediment recently deposited on the river bottom. It is likely that much of the sediment came from river bank erosion.

4.2 QHEI Scores

4.2.1 Riparian Width Scores and Discussion

The length of the Mahoning River from Lake Milton dam at Craig Beach to Girard (the entire length in Trumbull County) was considered for Riparian Width scoring. The total length of river was 38.5 river mile and there were 259 segments. Each segment was 800 ft (243.8 m) length, except the last segment, which was shorter. The first segment was started from Girard and the segment number increased upstream along the river. The range of Riparian Width scoring was 0 – 4 for poor to excellent. A map showing ranges of Riparian Width scores is shown in Figure 4.4.

During the scoring the lowest riparian score (Poor) was found for eight segments in the range of 0 – 1. The lowest score was 0.5 and it was found for two segments, segment # 98 and # 257. More than one hundred segments fell in the "Moderate" category i.e., in the range of 1.1 – 2.9. The "Excellent" range was

3.0 – 4.0 and over one hundred forty segments ranked in this category. The highest score was 4.0 and twenty-seven segments were scored in this category. Since the average riparian score was computed from summing of two individual bank scores, the excess vegetation from one bank compensated for and upgraded the lower score of the other bank. Large differences in scores on opposite banks were found for many sections during the study. The presence of railroad tracks along the river has acted as a barrier to development adjacent to the river banks. Thus, the riparian corridor is in fairly good condition for an urban river.

One excellent and two poor sections of riparian corridor along the Mahoning River in Trumbull County shown in Figure 4.5 – 4.7, respectively. Few more photos of excellent and poor riparian segments are shown in A.5 – A.7. Some photos in A.2 – A.4 reflect the river banks and riparian conditions of sampling sites. Some of the sites with lower Riparian Width scores, found after the study of aerial photos and analysis of prepared maps, are named below.

a. Girard – At intersection of I – 80; and the score was low because of road intersection and dense urban settlement.
b. McDonald – A large steel mill (probably) and mining/construction site found in this area.
c. Howland – This area was densely industrialized and more construction activities were found on the river banks.

d. Warren – Four spots were found in Warren which were rated as poor. No vegetation, dense urbanization, and residential development right next to the river on both sides was the cause for lower scores.

e. Newton Falls – Two poorly rated riparian score sections were found in Newton Falls township. Lack of vegetation, and industry and settlement right next to the river banks were the main cause.

f. Near Milton Dam – This spot was located in between the Milton dam and county line (Mahoning and Trumbull). Agricultural lands on both side of the river banks were found during the analysis.

For improvement of the riparian corridor of Mahoning River at the above mentioned locations, vegetation to increase the riparian width is desired. Most of these sites contain industrial areas, construction fields, and residential & commercial areas, so the increase of vegetation width on both sides of river banks should be implemented wherever possible. For the areas which are already built-up, increase in riparian vegetation is not possible but further decreasing of riparian width can be controlled by proper awareness programs and activities.

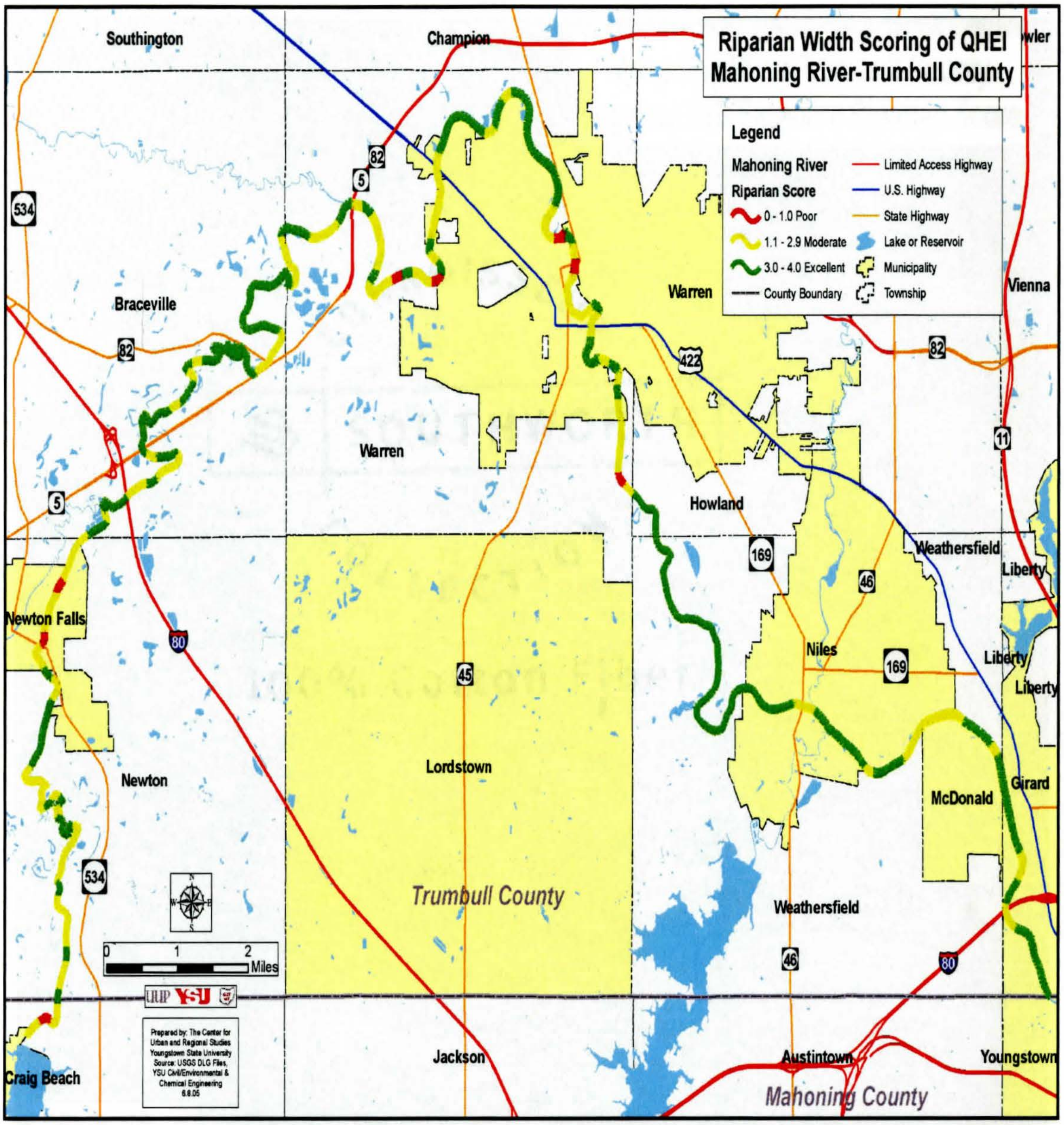


Figure 4.5. Riparian Width Scoring of QHEI for Mahoning River, Trumbull County.

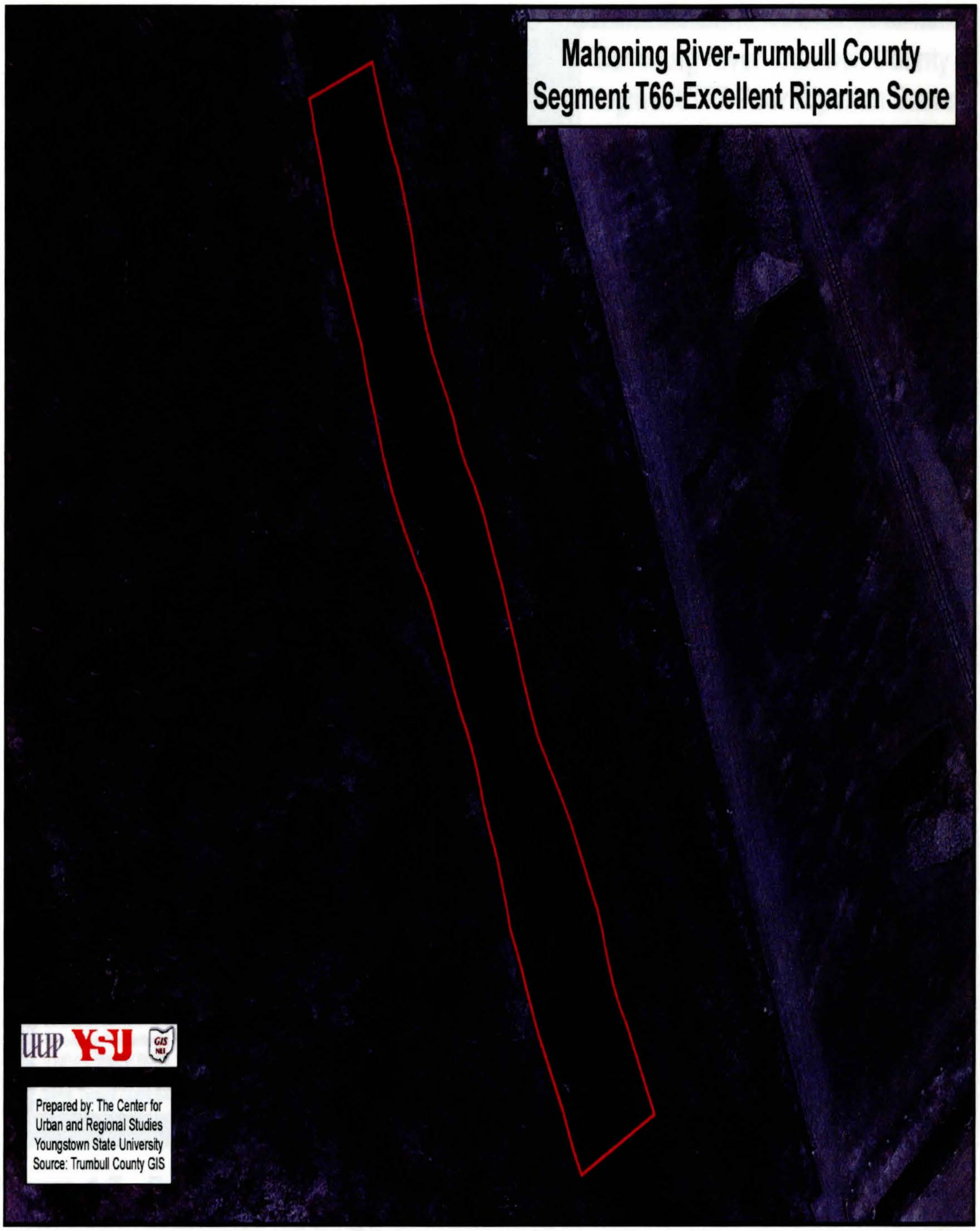
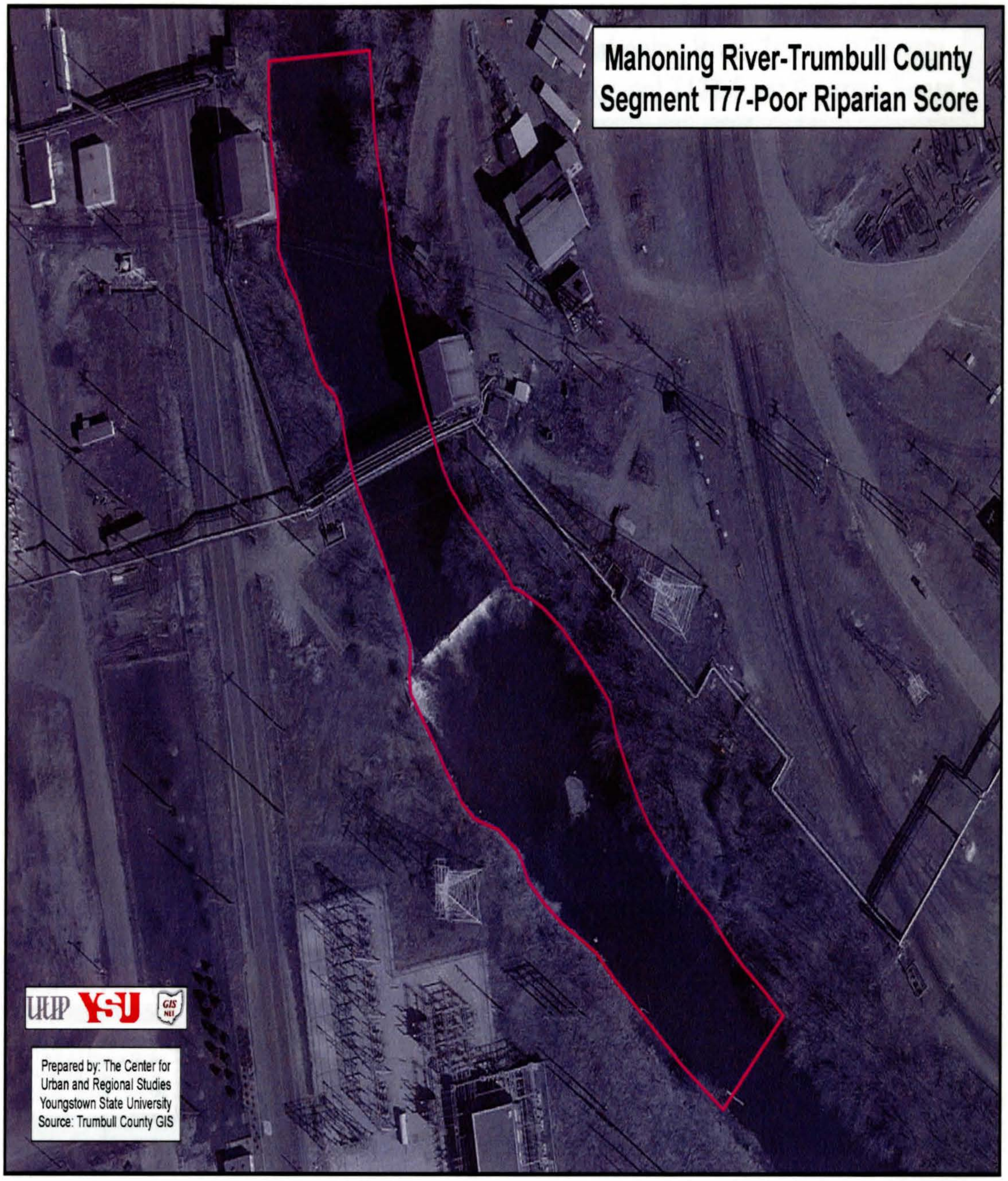


Figure 4.6. Segment T – 66 Excellent Riparian Width Score Mahoning River, Trumbull County.
Segment Length – 800 ft (243.8 m)



Mahoning River-Trumbull County
Segment T77-Poor Riparian Score

Prepared by: The Center for Urban and Regional Studies
Youngstown State University
Source: Trumbull County GIS

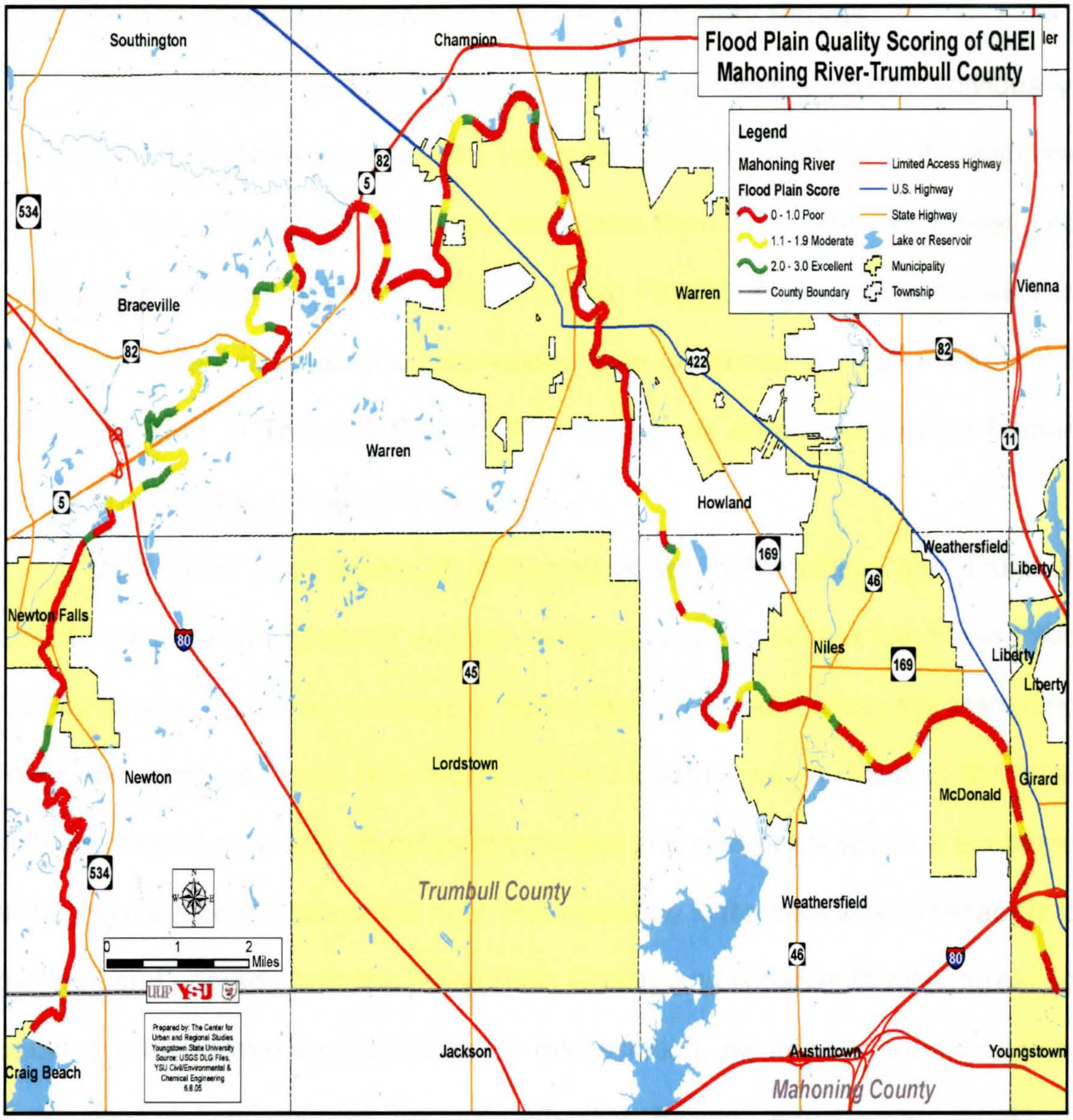
Figure 4.7. Segment T – 77 Poor Riparian Width Score Mahoning River, Trumbull County.
Segment Length – 800 ft (243.8 m)

**Figure 4.8. Segment T – 138 Poor Riparian Width Score Mahoning River, Trumbull County.
Segment Length – 800 ft (243.8 m)**

4.2.2 Flood Plain Quality Scores and Discussion

By QHEI procedures, the flood plain of the river starts after 100 meters of riparian width on both side of the banks. The Flood Plain Quality analysis of Mahoning River in Trumbull County was also a part of this study and it was performed by analyzing the aerial photographs obtained from Trumbull County GIS Department. The buffer of 100 meters of riparian width, was created with ArcView and the land use pattern beyond that buffer line was analyzed thoroughly. The scores were tabulated and the final outcomes were plotted on the watershed map. The scores from all 259 segments were categorized and ranged into three types – Poor, Moderate, and Excellent. Figure 4.8 shows the final outcome of Flood Plain Quality analysis. To maintain the uniformity between all analyses, the color coding used by Kolwalkar (2003) was applied for all maps.

As can be seen from the map, most of all segments fall into either the Poor or Moderate range. Only twenty-six segments were rated with excellent score (10% of total 259 segments). Most of these sites were observed in Braceville Township and three sites were found in Warren, Weathersfield, and Niles individually. This pattern is easily understood by viewing the prepared map. Braceville and Weathersfield townships have mostly moderate scores, but all urban areas, including Newton Falls, Warren, Niles, McDonald, and Girard, are mostly in the Poor range. Scores can only be improved by converting unused urban land to green space.



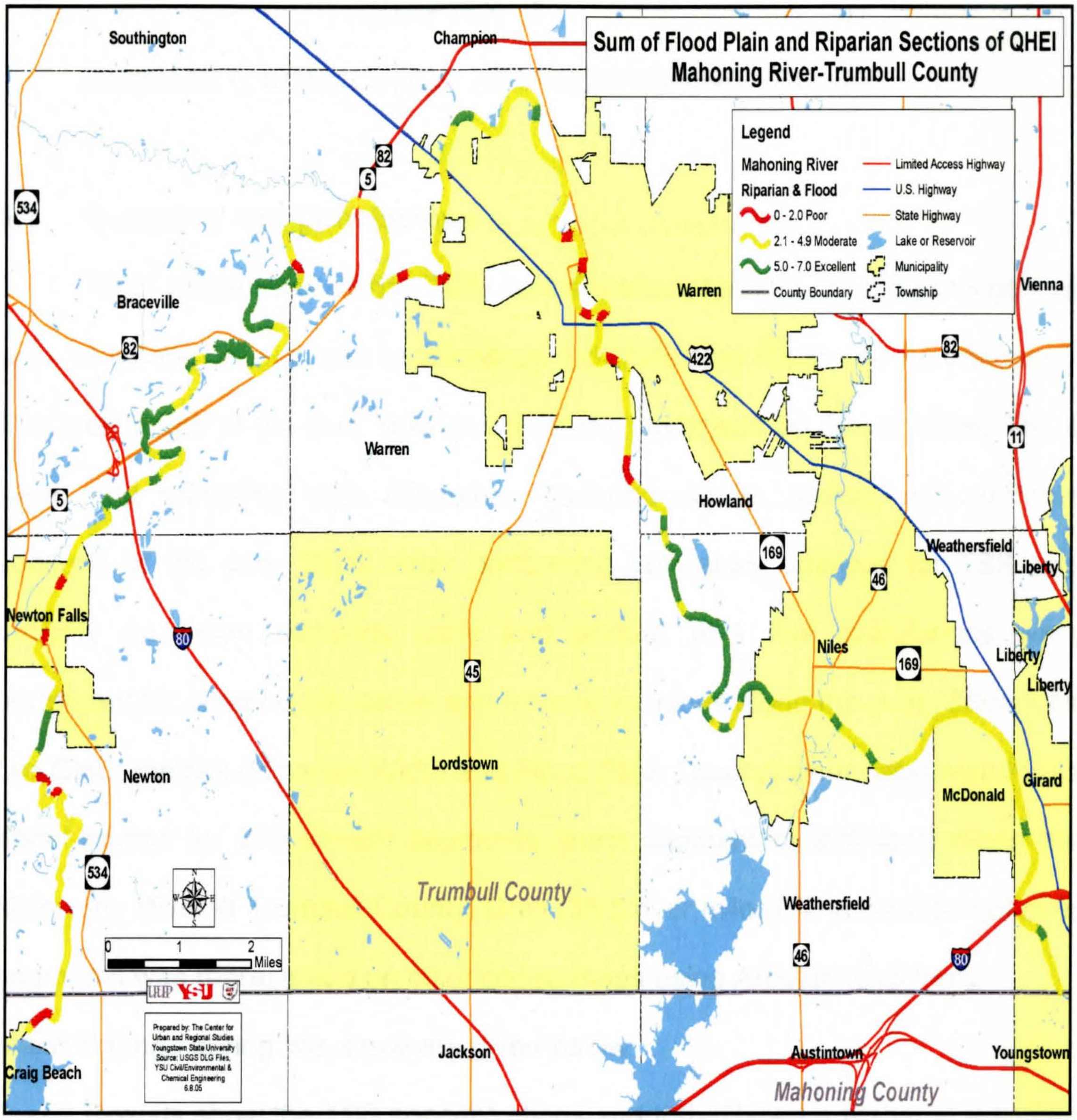
Prepared by: The Center for Urban and Regional Studies Youngstown State University
Source: USGS DLG Files, YSU Civil/Environmental & Chemical Engineering
6.8.05

Figure 4.9. Flood Plain Quality Scoring of QHEI for Mahoning River, Trumbull County.

4.2.3 Sum of Riparian Width and Flood Plain Quality Scores

After analyzing Riparian Width and Flood Plain Quality scores individually, the sums of both these scores were computed and tabulated using the ArcView software. The range of this combined score was from 0 – 7 and categorized into three types – Poor, Moderate, and Excellent. Finally, these scores for all 259 segments were presented in a color-coded map (as shown in Figure 4.9) of the Mahoning River in Trumbull County. This map gives an overall view of human impacts on the land surrounding the river.

Most flood plain areas of Mahoning River in Mahoning and Trumbull County are densely populated and industrialized and this causes low Flood Plain Quality scores. However, because of better riparian corridor along the Mahoning River, the combined map falls mostly in the Moderate range. Most of the steel mills are closed now, and abandoned industrial and residential space is scattered throughout the flood plain of the river. Reforestation is the best way to rehabilitate the land and upgrade both the Flood Plain Quality and Riparian Width scores. To obtain the landowner's cooperation for reforestation, awareness programs from concerning stakeholders will be more effective. Existing forest areas should be preserved and trees and shrubs should be planted wherever possible to upgrade the riparian and floodplain vegetation.



Sum of Flood Plain and Riparian Sections of QHEI
Mahoning River-Trumbull County

Prepared by: The Center for Urban and Regional Studies Youngstown State University
Source: USGS DLG Files, YSU Civil/Environmental & Chemical Engineering
6.8.05

Figure 4.10. Sum of Riparian Width and Flood Plain Quality Scores of QHEI Mahoning River, Trumbull County.

CHAPTER 5

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary and Conclusions

Total suspended solids (TSS) concentration, turbidity, and discharge rate were monitored at eighteen locations on the Mahoning River and its tributaries. The total length of the river considered for the study was 50.5 river miles. There were nine sampling trips altogether, included winter, spring, and summer seasons of the year 2005. After performing laboratory analysis for TSS and turbidity on those samples, daily and annual TSS flux calculations were performed for entering tributaries and several locations along the river. Scores for two QHEI metrics (Riparian Width and Flood Plain Quality) were determined from aerial photos for 259 stream segments (each segment of 800 feet) along the Mahoning River in Trumbull County, Ohio (38.5 river miles). The condition of river segments was represented on color coded maps using ArcView GIS tools.

Major findings during this study are given below:

1. Results show the TSS concentrations and turbidity were higher in the Little Squaw, Squaw, and Mill Creeks for most of the samplings and lower in Dry Run and Crab Creek. The other tributaries (Meander Creek, Mosquito Creek, Eagle Creek, and Yellow Creek) showed intermediate TSS levels.
2. Along the main stem of the Mahoning River, the highest average TSS concentration was found at Lowellville – 26.1 mg/L. But, excluding the data from the seventh sampling trip on May 14, 2005, the average TSS

concentration from Leavittsburg (12.7 mg/L) became highest. When flow-weighted average TSS was calculated for all sites, again Lowellville was highest with the value of 35.6 mg/L.

3. Based on the flow data from the USGS gauging stations for the dates of this study, the highest average flow was found at West Avenue, Youngstown, with a discharge of 39.1 m^3/sec. The average flow at Lowellville was 36.2 m^3/sec. There appear to be some discrepancies in the USGS data, since there are three tributaries (Crab Creek, Dry Run, and Yellow Creek) entering to the Mahoning River between Youngstown and Lowellville.

4. Based on monitoring results, the average TSS flux at Lowellville was the highest among all sites – 111,400 kg/d and 40,700 MT/yr. Despite the higher flow, the TSS flux at West Avenue, Youngstown, was lower – 21,000 kg/d and 7,670 MT/yr.

5. Among the tributaries, the average TSS flux was highest in Mosquito Creek, with 6,200 kg/d or 2,260 MT/yr. Average TSS flux for Mill Creek was 5,900 kg/d or 2,170 MT/yr. Since the discharge rates in Little Squaw Creek, Squaw Creek, Dry Run, and Crab Creek were not very high, the TSS fluxes were lower.

6. Mass balance analysis was used to determine whether TSS deposition or resuspension was occurring on each sampling date. For the samplings of January 17, February 4, April 1, April 22, and June 1, TSS deposition was indicated, whereas TSS resuspension was indicated for February 26,

March 11, May 14, and July 6 sampling dates (Table 4.21 and Figures 4.1 – 4.3). On May 14, there was a high difference of TSS flux between Leavittsburg and Lowellville (638,400 kg/d), which indicated the SS resuspension as well as bank erosion can occur during heavy rainfall and high flows.

7. The lowest riparian width score (0.5 – "Poor") was found for two segments, segment #98 (Warren) and #257 (Craig Beach). More than one hundred segments fell in the "Moderate" range (i.e., 1.1 – 2.9). The "Excellent" range was 3.0-4.0 and over one hundred forty segments were scored in this category.
8. As shown on the map of Flood Plain Quality (Figure 4.8), most segments fell into either the "Poor" or "Moderate" range. Only twenty-six segments were rated with "Excellent" score and most of these sites were observed in Braceville Township.
9. After summing up both Riparian Width and Flood Plain Quality scores for each segment, the combined score was obtained for these two QHEI metrics. The combined score range was 0 – 7. The "Excellent" score range of 5.0 – 7.0 was found mostly in the segments of Braceville and Weathersfield Townships.

5.2 Recommendations

The following recommendations are suggested to improve the water quality and riparian corridor of the Mahoning River with the expectation that it will eventually contribute to the goals of the Mahoning River Watershed Action Plan.

1. The sampling during the study period covered only six months; it did not cover all four seasons, especially late summer, fall, and earlier winter. One whole year of sampling is desirable for the estimation of TSS fluxes.
2. Since the flow data at the Mahoning River sites were exclusively taken from USGS gauging stations, all the discharge and flux computations were based on those data. During the study some discrepancies were seen on some of these flow data (e.g., discharge at Youngstown and Lowellville). To get the actual flow in the river and tributaries, the use of additional effective and improved flow measurement methods are recommended for those stations.
3. A few small creeks (e.g., Kale Creek, Duck Creek, Mud Creek) were not included in the study. For the estimation of solids flux, covering of all the tributaries is recommended for future research. Consideration of point sources of SS entering from several waste water treatment plants (WWTP) to the river reach is also recommended.
4. Planting vegetation is recommended in the abandoned residential, urban, and industrial areas along the Mahoning River for the improvement of two metrics of QHEI (Riparian Width and Flood Plain Quality). Also, existing vegetation in the riparian corridor, and green space in the Mahoning River watershed, should be protected.
5. The source of high TSS levels in Little Squaw Creek should be determined, and eliminated if possible.

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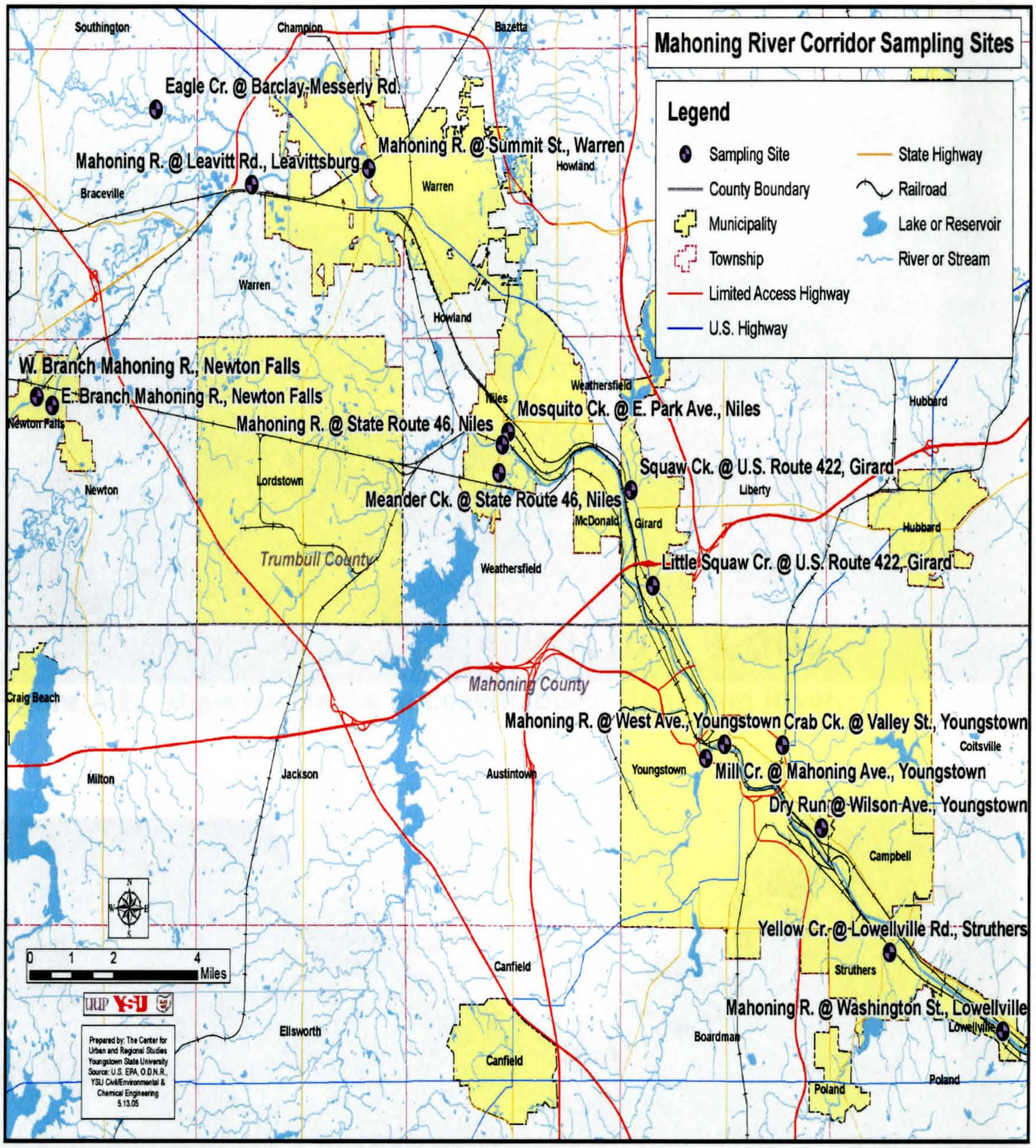
APPENDIX

Table A.1. Suspended Solids Concentrations (TSS) and Turbidity for Sampling Site #17 Mahoning River at County Line Rd., Pricetown.

Date of Sampling	Suspended solids (g/m^3)	Turbidity (NTU)
March 11, 2005	8.8	12.8
April 1,2005	10	9.3
May 14,2005	5.2	7.5
June 01,2005	5.6	7.2

Table A.2. Suspended Solids Concentrations (TSS) and Turbidity for Sampling Site #18 Mahoning River at Lake Milton, Craig Beach.

Date of Sampling	Suspended solids (g/m^3)	Turbidity (NTU)
April 22,2005	8.6	7.2
May 14,2005	12.8	11.6
June 01,2005	7.6	6.5
July 06,2005	6.4	7.5



Prepared by: The Center for Urban and Regional Studies Youngstown State University Source: U.S. EPA, O.D.N.R., YSU Civil/Environmental & Chemical Engineering 5.13.05

Figure A.1. Sampling Sites of Mahoning River Watershed.

Figure A.2. Riparian Banks at Leavittsburg, Mahoning River.

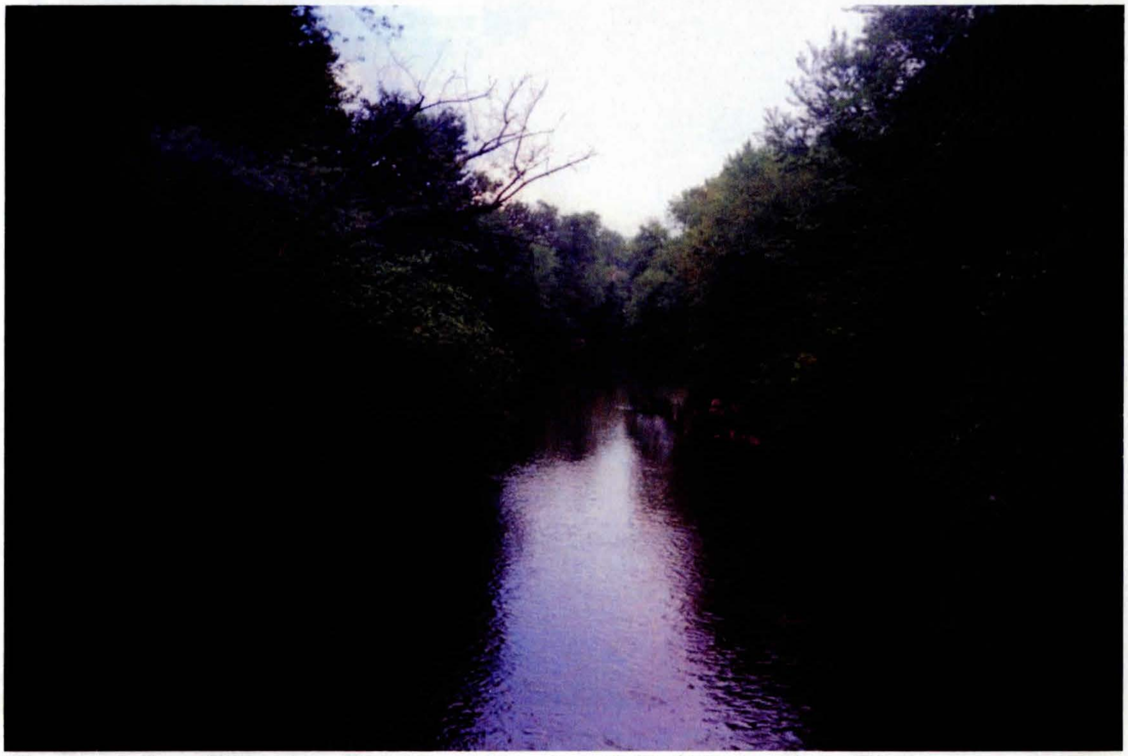


Figure A.3. Riparian Banks at Newton falls, Mahoning River.

Figure A.4. Mahoning River at West Avenue, Youngstown.

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Youngstown State University
Source: Trumbull County GIS

Figure A.5. Segment T-98 of QHEI Riparian Scoring, Mahoning River, Trumbull County. Segment Length – 800 ft (243.8 m)

Figure A.6. Segment T-101 of QHEI Riparian Scoring, Mahoning River, Trumbull County. Segment Length – 800 ft (243.8 m)

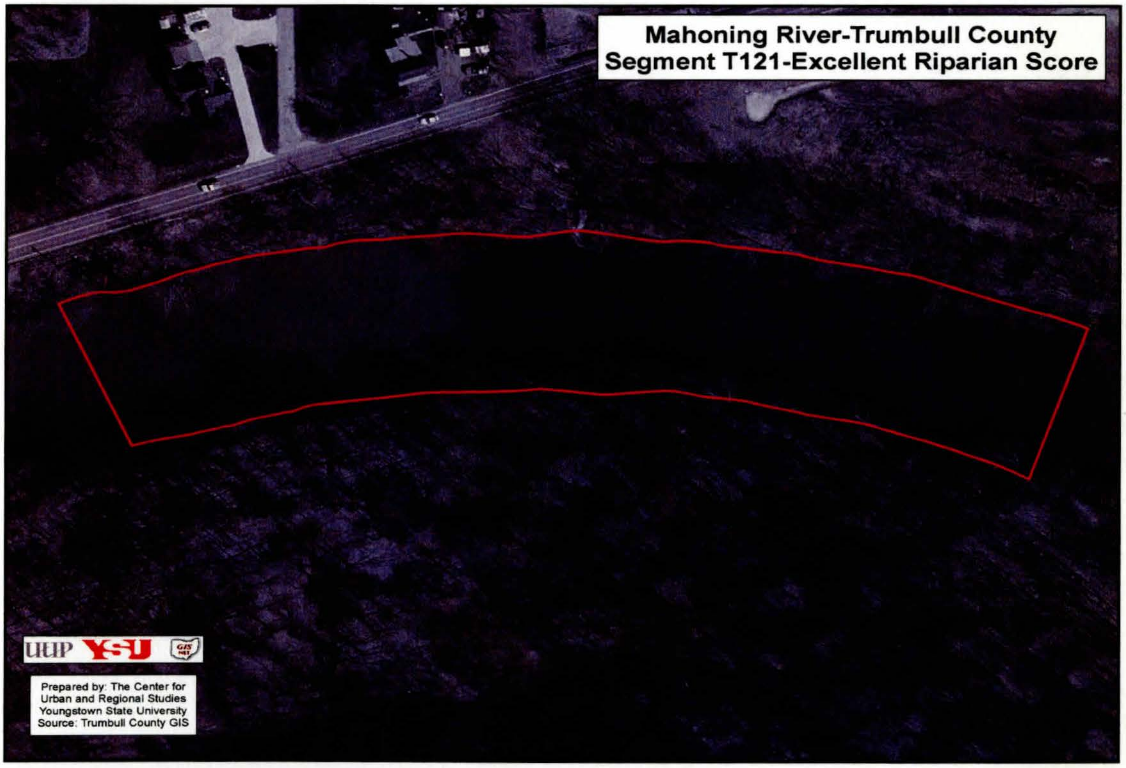

Figure A.7. Segment T-121 of QHEI Riparian Scoring, Mahoning River, Trumbull County. Segment Length – 800 ft (243.8 m)