FLAT CREEK, GRIFFEN DITCH, FLEMING DITCH, AND SOMERS CREEK WATERSHED DIAGNOSTIC STUDY
Wells County, Indiana

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FLAT CREEK, GRIFFEN DITCH, FLEMING DITCH, AND SOMERS CREEK WATERSHED DIAGNOSTIC STUDY
EXECUTIVE SUMMARY

Flat Creek, Griffen Ditch, Fleming Ditch, and Dowty Ditch (Somers Creek) drain 29,307 acres (11,860 ha.) or 45.8 square miles of northern Wells County into the upper Wabash River system. These subwatersheds drain the relatively flat Tipton Till Plain and part of the Wabash Moraine and have soils comprised of 90% silt and clay. Approximately 84% of the land is in row crop agriculture on prime farmland and about 10% of the watershed land surface consists of highly erodible soils. The easily erodible soils, coupled with the existing land use and waste treatment systems on severely limited soils for septic absorption fields, have contributed to impaired water quality in the sampled streams. Existing Best Management Practices (BMP's) being utilized in the watersheds included set-asides, grassed waterways, and filter strips. One percent of the watershed area is enrolled in the Conservation Reserve Program. (CRP) filter strips and grassed waterways were sparse and many were in need of maintenance. Conservation tillage is practiced on about 66% of the land in the county; however, most landowners rotate to conventional till prior to realizing the proven benefits after three years in no-till.

The watersheds were studied by aerial and driving tours, mapping of existing land uses and highly erodible land, aquatic macroinvertebrate and water sampling at nine locations, and the scoring of habitat indices at each of the sampling locations. QHEI habitat scores ranged from 15 to 44 out of 100 points possible, well below the standard of 60 set for the level conducive to the existence of warm water fish species. Macroinvertebrate index scores (mIBI) ranged from a score of 0 to 5.7 meaning the streams are severely to slightly impaired for aquatic life according to Indiana Department of Environmental Management (IDEM) standards. Nitrate levels exceeded state standards during base and storm flows in all streams and ranged from 12 to 21 mg/l. Ammonia concentrations exceeded state standards in Griffen Ditch, Fleming Ditch, and Somers Creek during storm flows. *E. coli* concentrations of 1,200 to 12,000 in all the streams exceeded the state standard for contact recreation of 235 colonies per 100 ml during storm events. Suspended sediment concentrations were low at base flow but exceeded 40 mg/l in all streams during storm flows with the highest concentration in Somers Creek (160 mg/l) and the highest loading (330 lbs/day or 150 kg/day) in the lower section of Flat Creek. Phosphorus was predominantly found as soluble reactive phosphorus and ranged from 0.02 to 0.46 mg/l. All the sites exhibited greater than 0.28 mg/l phosphorus during storm flows, the acceptable limit for modified warm water habitats. (Modified warm water habitats are those that have been changed from their natural condition in order to support human activities like agriculture or urban development.)

Recommended actions to improve water quality include the prioritized Best Management Practices for the middle of the Flat Creek, Fleming Ditch, Griffen Ditch, and Somers Creek watersheds: use of alternative technology waste treatment systems; exclusion of cattle from stream access; education and outreach; maintenance of previously installed practices; and developing a watershed management plan.

ACKNOWLEDGEMENTS

This Watershed Study was performed with funding from the Indiana Department of Natural Resources – Division of Soil Conservation and the Wells County Soil and Water Conservation District. J.F. New and Associates, Inc. and Indiana University – School of Public and Environmental Affairs documented the historical information available, completed tributary stream sampling for nutrient and sediment loading, and modeled nutrient and sediment loading to major rivers. Significant contributors to this study included Brian Wurm and Stacia Henderson of the Wells County Soil and Water Conservation District and Dennis Chenoweth of the Jay County Soil and Water Conservation District. A special thank you is due Doug Nusbaum for his initiative and assistance in getting this study completed. Jill Hoffman, Ed Braun, Brant Fisher, and numerous others assisted with their comments and contributions on historic watershed activities. Bill Horan of the Wells County Purdue Cooperative Extension Agency provided valuable comments about agricultural practices in the area. Authors of this report include William Jones, Melissa Clark, and Joel Klumpp at Indiana University and Cornelia Sawatzky, Marianne Giolitto, John Richardson, and Steve Zimmerman at J.F. New and Associates, Inc.

TABLE OF CONTENTS

Introduction....1
Review of Existing Information....5
Watershed Physical Characteristics....5
Climate....7
Soils…. 9
Land Use....16
Agricultural Best Management Practices....20
Chemistry and Macroinvertebrates....39
Fisheries Studies....40
Natural Communities and Endangered, Threatened, and Rare Species....47
Watershed Study....48
Watershed Investigation....48
Introduction....48
Aerial Tour....48
Windshield Tour....59
Watershed Investigation Conclusion....64
Stream Sampling and Assessment....64
Introduction....64
Sampling Locations....67
Water Chemistry....68
Methods....68
Results....72
Discussion....87
Summary....88
Macroinvertebrates and Habitat....89
Macroinvertebrate Sampling Methods....89
Habitat Sampling Methods....91
Results....91
Discussion....97
Summary....100
Relationships Among Chemical, Biological, and Habitat Characteristics....100
Loading Model....102
Recommendations....105
Funding Sources and Watershed Resources....109
Literature Cited....114

TABLE OF FIGURES

Figure 1. Location Map 2
Figure 2. Flat Creek, Grifen Ditch, Fleming Ditch, Somers Creek, and Eightmile Creek Watersheds.....3
Figure 3. Moraine Deposits in Northern Indiana from the Wisconsian Glacial Period.....6
Figure 4. Moraine Deposits and Topography in the Wells County Area 8
Figure 5. Highly Erodible Soil and Highly Erodible Land Tracts (HEL) 11
Figure 6. Land Use and Land Cover.....17
Figure 7a. CRP and HEL Tracts within the Flat Creek Subwatersheds 23
Figure 7b. CRP and HEL Tracts within the Griffen Ditch, Fleming Ditch, and Somers Creek Watersheds.....24
Figure 8. Rooting Depths of Native Grasses and Forbes 26
Figure 9. The Riparian Management System Model (Isenhart et al., 1997).....31
Figure 10. The Multispecies Riparian Buffer Strip Component of the Management System Model (Isenhart et al., 1997).....32
Figure 11. Indiana USLE Soil Loss in Excess of T by Tillage System.....36
Figure 12. IDNR 1994 Fisheries Survey Sampling Locations on the Little Wabash River.....42
Figure 13. Numbers of Fish Species Sampled by IDNR during the 1994 Survey of the Little Wabash River.....45
Figure 14. Little Wabash River QHEI Scores as Calculated by IDNR in 1994.....46
Figure 15. Aerial Tour Photos 49-55
Figure 16a. Aerial Tour and Windshield Survey Photo Locations for the Flat Creek Subwatersheds 56
Figure 16b. Aerial Tour and Windshield Survey Photo Locations for the Griffen Ditch, Fleming Ditch, and Somers Creek Watersheds.....57
Figure 17. Windshield Survey Photos 60-61
Figure 18a. Sampling Locations within the Flat Creek Subwatersheds 65
Figure 18b. Sampling Locations within the Griffen Ditch, Fleming Ditch, and Somers Creek Watersheds.....66
Figure 19. Discharge Measurements 74
Figure 20. Nitrate Concentration Measurements.....77
Figure 21. Ammonia Concentration Measurements 78
Figure 22. Total Kjeldahl Nitrogen Concentration Measurements.....79
Figure 23. Soluble Reactive Phosphorus Concentration Measurements 80
Figure 24. Total Phosphorus Concentration Measurements.....81
Figure 25. Total Suspended Solid Concentration Measurements.....82
Figure 26. *E. coli* Bacterial Concentration Measurements 83
Figure 27. Nitrate Loading Measurements 84
Figure 28. Ammonia Loading Measurements 85
Figure 29. Total Kjeldahl Nitrogen Loading Measurements.....85
Figure 30. Soluble Reactive Phosphorus Loading Measurements 86
Figure 31. Total Phosphorus Loading Measurements 86
Figure 32. Total Suspended Solid Loading Measurements 87
Figure 33. Reference Site Sampling Location on Eightmile Creek.....92

Figure 34. Site 1 Sampling Location on Flat Creek 93
Figure 35. Site 2 Sampling Location on Flat Creek 93
Figure 36. Site 3 Sampling Location on Flat Creek 94
Figure 37. Site 4 Sampling Location on Flat Creek 94
Figure 38. Site 5 Sampling Location on Flat Creek 95
Figure 39. Site 6 Sampling Location on Griffen Ditch.....95
Figure 40. Site 7 Sampling Location on Fleming Ditch 96
Figure 41. Site 8 Sampling Location on Somers Creek.....97
Figure 42. Site 9 Sampling Location on Somers Creek.....97
Figure 43. Relationship Between Phosphorus Loading and Area
Estimated by the Export Model 103
Figure 44. Phosphorus Loading per Unit Area as Estimated by the Export Model 104

TABLE OF TABLES

Table 1. Stream Length and Watershed Area for the Four Study Watersheds 5
Table 2. Monthly Rainfall Data for Year 2000 9
Table 3. Soil Units Considered Highly Erodible 10
Table 4. Area Mapped in Highly Erodible Map Units by Subwatershed and Watershed 12
Table 5. Dominant Soil Types in the Study Watersheds and Their Suitability for On-Site Wastewater Treatment Systems 14
Table 6. Land Use in the Study Watersheds 18
Table 7. Percent (Number) and Acreage of Wells County Fields with Indicated Present Crop for Year 2000 20
Table 8. Acreages of Land Enrolled in the CRP by Subwatershed and Watershed 22
Table 9. Recommended Native Cool Season Grass Species and Seeding Rates for Filter Strip Planting 27
Table 10. Recommended Native Legume Species and Seeding Rates for Filter Strip Planting 27
Table 11. Recommended Native Wildflower Species for Filter Strip Planting 28
Table 12. Optimal Seed Mix for Filter Strip Planting 28
Table 13. Economy Seed Mix for Filter Strip Planting 28
Table 14. Ultra Economy Seed Mix for Filter Strip Planting 29
Table 15. Wildlife Habitat Management Seed Mix for Filter Strip Planting 29
Table 16. Plant Species that are Generally not Good Candidates for Use in Filter Strips 29
Table 17. Plant Species Suitable for Filtration and Nutrient Uptake in Restored or Created Wetlands 33
Table 18. Tillage Type Descriptions 35
Table 19. Percent (Number) of Crop Fields with Indicated Tillage System Since 1990 for Wells County 36
Table 20. Griffen Ditch Stream Chemistry Data Collected by the Hoosier Riverwatch Program 39
Table 21. Griffen Ditch Macroinvertebrate Data Collected by the Hoosier Riverwatch Program 39
Table 22. Flat Creek mIBI Data Sampled by IDEM Biological Studies Section 40
Table 23. Fish Species Present in the Little Wabash River in 1994 and in Eightmile Creek in 1995 43
Table 24. List of Locations of Impairment Photographed during the Aerial Tour of the Flat Creek Watershed 58
Table 25. List of Locations of Impairment Photographed during the Aerial Tour of the Griffen Ditch Watershed 58
Table 26. List of Locations of Impairment Photographed during the Aerial Tour of the Somers Creek Watershed 59
Table 27. List of Sites and Corresponding BMPs Compiled during the Windshield Survey of the Flat Creek Watershed 62
Table 28. List of Sites and Corresponding BMPs Compiled during the Windshield Survey of the Griffen Ditch Watershed 63
Table 29. List of Sites and Corresponding BMPs Compiled during the Windshield Survey of the Fleming Ditch Watershed 63

Table 30. List of Sites and Corresponding BMPs Compiled during the Windshield Survey of the Somers Creek Watershed 64
Table 31. Minimum Criteria for Reference Sites 67
Table 32. Detailed Sampling Location Information 67
Table 33. Physical Characteristics of the Four Study Watershed Streams 72
Table 34. Chemical and Bacterial Characteristics of the Four Study Watershed Streams 75
Table 35. Sampling Sites Representing Flat Creek Subwatersheds, Griffen Ditch Watershed, Fleming Ditch Watershed, and Somers Creek Watershed 87
Table 36. Areal Loading of TSS, TP, and *E. coli* by Subwatershed and Watershed 88
Table 37. Benthic Macroinvertebrate Scoring Metrics and Classification Scores Used by IDEM 90
Table 38. Classification Scores and mIBI Scores for Sampling Sites and Reference Site 91
Table 39. QHEI Scores for Sampling Sites and Reference Site 92
Table 40. Phosphorus Export Coefficients Used to Model Phosphorus Loading 102
Table 41. Phosphorus Export for Each Subwatershed 103
Table 42. Groups That Have Participated in the Hoosier Riverwatch Volunteer Monitoring Program 113

TABLE OF APPENDICES

Appendix 1. Detailed Highly Erodible Soil and Land Maps for Each Watershed
Appendix 2. Detailed Land Use Maps for Each Watershed
Appendix 3. Detailed Land Use and Land Cover for the Four Study Watersheds
Appendix 4. Photos from the Riparian Management System Model in the Bear Creek Watershed, Iowa (Isenhart et al., 1997)
Appendix 5. Endangered, Threatened, and Rare Species List, Flat Creek, Griffen Ditch, Fleming Ditch, and Somer Creek Watersheds
Appendix 6. Endangered, Threatened, and Rare Species List, Wells and Huntington Counties
Appendix 7. Stream Sampling Laboratory Data Sheets
Appendix 8. QHEI Datasheet
Appendix 9. Detailed mIBI Results

THE FLAT CREEK, GRIFFEN DITCH, FLEMMING DITCH, AND SOMERS CREEK WATERSHED DIAGNOSTIC STUDY WELLS COUNTY, INDIANA

INTRODUCTION

The Flat Creek, Griffen Ditch, Flemming Ditch, and Somers Creek (also known as Dowty Ditch) Watersheds are located northwest of Bluffton in Wells and Huntington Counties, Indiana (Figure X). The four watersheds lie within two 14-digit watersheds, the Little River-Flat Creek Watershed (HUC 051201011200200) and the Flat Creek-Headwater Watershed (HUC 05120101120010). The watersheds are part of the 11-digit watershed HUC 05120101120 and the 8-digit watershed HUC 05120101.

The Flat Creek watershed is the largest (18,093 acres (_ ha) or _ square miles) with areas lying in both Wells County (Union Township) and Huntington County. Due to its large size, the Flat Creek Watershed was further divided for purposes of this study into five smaller subwatersheds (Figure XX). Griffen Ditch Watershed, which lies completely in Wells County, is 5,345 acres (_ ha or _ square miles) in size (Rock Creek and Union Townships). The Flemming Ditch and Somers Creek Watersheds are also located entirely within Wells County. The Flemming Ditch watershed encompasses 1,507 acres (_ ha) or _ square miles (Rock Creek and Lancaster Townships). The Somers Creek watershed is 4,362 acres (_ ha) or _ square miles in size (Lancaster Township). Water from Flat Creek discharges into the Little Wabash River. The Little Wabash River joins the Wabash River southwest of the town of Huntington. Griffen Ditch, Flemming Ditch, and Somers Creek flow into the Wabash itself just east of Markle, Indiana. The Wabash River eventually reaches the Ohio River in southwestern Indiana. It is important to note that all the study streams are legal drains.

The drainage basins of Flat Creek, Griffen Ditch, Flemming Ditch, and Somers Creek were formed during the most recent retreat of the Pleistocene or Quaternary Era. The advance and retreat of the Ontario-Erie Lobe of the last Wisconsian glaciation and the deposits left by the lobe shaped much of the landscape found in the northern two-thirds of Indiana (Wayne, 1966). In Wells County, the receding glacier left a nearly level topography overlain by morainal deposits of high clay content.

The four study watersheds are located in the east-central portion of the Central (Bluffton) Till Plain Natural Region (Homoya et al., 1985). The Central Till Plain is the largest natural region in Indiana and includes most of the central part of the state. Prior to European settlement, the region was a beech-maple-oak forested plain, accompanied by small bog, prairie, fen, marsh, and lake areas (Homoya et al., 1985). The poorly-drained flatwoods were likely forested with red maple, pin oak, bur oak, swamp white oak, Shumard's oak, American elm, swamp cottonwood, and green ash. Slightly better-drained soils probably harbored beech, sugar maple, black maple, white oak, red oak, shagbark hickory, tulip poplar, red elm, basswood, and white ash. The first plat of Indiana by the General Land Surveyors documented beech-maple forests as comprising 50% or more of the original vegetation of the state (Petty and Jackson, 1966).

Changes in land use have altered the watersheds' natural landscape. Settlers to the region drained wet areas and cleared forests in order to farm soils rich in both nutrients and humic material. However, this layer of rich soil was thin and years of crop removal and erosion depleted nutrient supplies. Around 1850, fertilization with potassium and phosphorus began. Fertilization had no effect on crop yield until 1940 when Dr. George Scarseth discovered that massive doses of nitrogen could significantly increase productivity. Technology and industry have increased and continue to increase farm production. Today, approximately _% of the watersheds is utilized for agricultural purposes.

Installation of subsurface tile drain networks, excavation of drainage channels, and straightening of streams has resulted in conversion of prairies and wetlands to agriculture resulting in off-site, downstream water flow and quality concerns. In a review of agricultural practices and their impacts on the natural structure and function of aquatic systems, Menzel (1983) concluded that effects other than water quality problems have emerged. These include alterations in water quantity, habitat structure, and energy transfer within streams.

Few studies have been conducted to document water quality and health within the Flat Creek, Griffen Ditch, Flemming Ditch, or Somers Creek Watersheds. However, Indiana Department of Environmental Management 305(b) reports from 1989 to the present have indicated non- or only partial support of beneficial uses at sampling sites on the Wabash River near the towns of Markle and Huntington. Evidently, human impacts within this area of the Wabash River watershed are having an adverse effect on water quality and beneficial uses.

Because there is little information about these watersheds and in order to gain a better understanding of them, the Wells County Soil and Water Conservation District applied for and received funding through the Indiana Department of Natural Resources Lake and River Enhancement Program for a watershed study. The purpose of the study is to describe the conditions in the watersheds of interest, identify potential problems, and make prioritized recommendations addressing these problems. The study included a review of historical data and information, correspondence with landowners, business owners, and state and local regulatory agencies, collection of stream water quality samples and benthic macroinvertebrates, and field investigations identifying land use patterns and locations for best management practice (BMP) installation. This report documents the results of the study.

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The Flat Creek watershed is the largest (18,093 acres (7,325 ha) or 28.3 square miles) with areas lying in both Wells County (Union Township) and Huntington County. Due to its large size, the Flat Creek Watershed was further divided for purposes of this study into five smaller subwatersheds (Figure 2). Griffen Ditch Watershed, which lies completely in Wells County, is 5,345 acres (2,164 ha or 8.4 square miles) in size (Rock Creek and Union Townships). The Fleming Ditch and Somers Creek Watersheds are also located entirely within Wells County. The Fleming Ditch watershed encompasses 1,507 acres (610 ha) or 2.4 square miles (Rock Creek and Lancaster Townships). The Somers Creek watershed is 4,362 acres (1,766 ha) or 6.8 square miles in size (Lancaster Township). Water from Flat Creek discharges into the Little Wabash River. The Little Wabash River joins the Wabash River southwest of the town of Huntington. Griffen Ditch, Fleming Ditch, and Somers Creek flow into the Wabash itself just east of Markle, Indiana. The Wabash River eventually reaches the Ohio River in southwestern Indiana. It is important to note that all the study streams are legal drains. Legal drains are important for necessary water conductance to sustain a variety of land uses, including agriculture. Disturbance to the system is inevitable due to periodic drainage improvement projects. Additionally, projects constructed within the drainage easement require County Drainage Board permission. Some projects may not be permitted should they impede drainage.

The drainage basins of Flat Creek, Griffen Ditch, Fleming Ditch, and Somers Creek were formed during the most recent retreat of the Pleistocene or Quaternary Era. The advance and retreat of the Ontario-Erie Lobe of the last Wisconsian glaciation and the deposits left by the lobe shaped much of the landscape found in the northern two-thirds of Indiana (Wayne, 1966). In Wells County, the receding glacier left a nearly level topography overlain by morainal deposits of high clay content.

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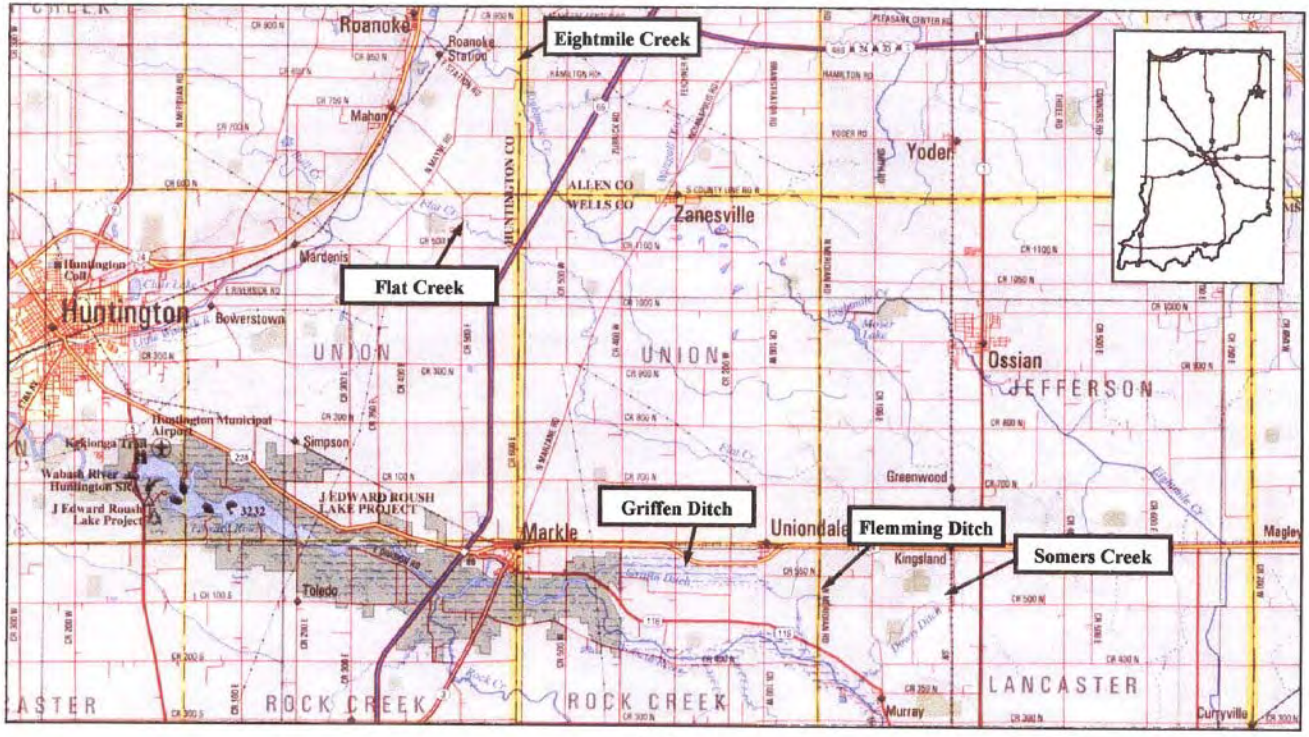

Scale: 1" = 2.5 miles

FIGURE 1. Location map of the diagnostic study watersheds and the reference watershed in Wells and Huntington Counties, Indiana.

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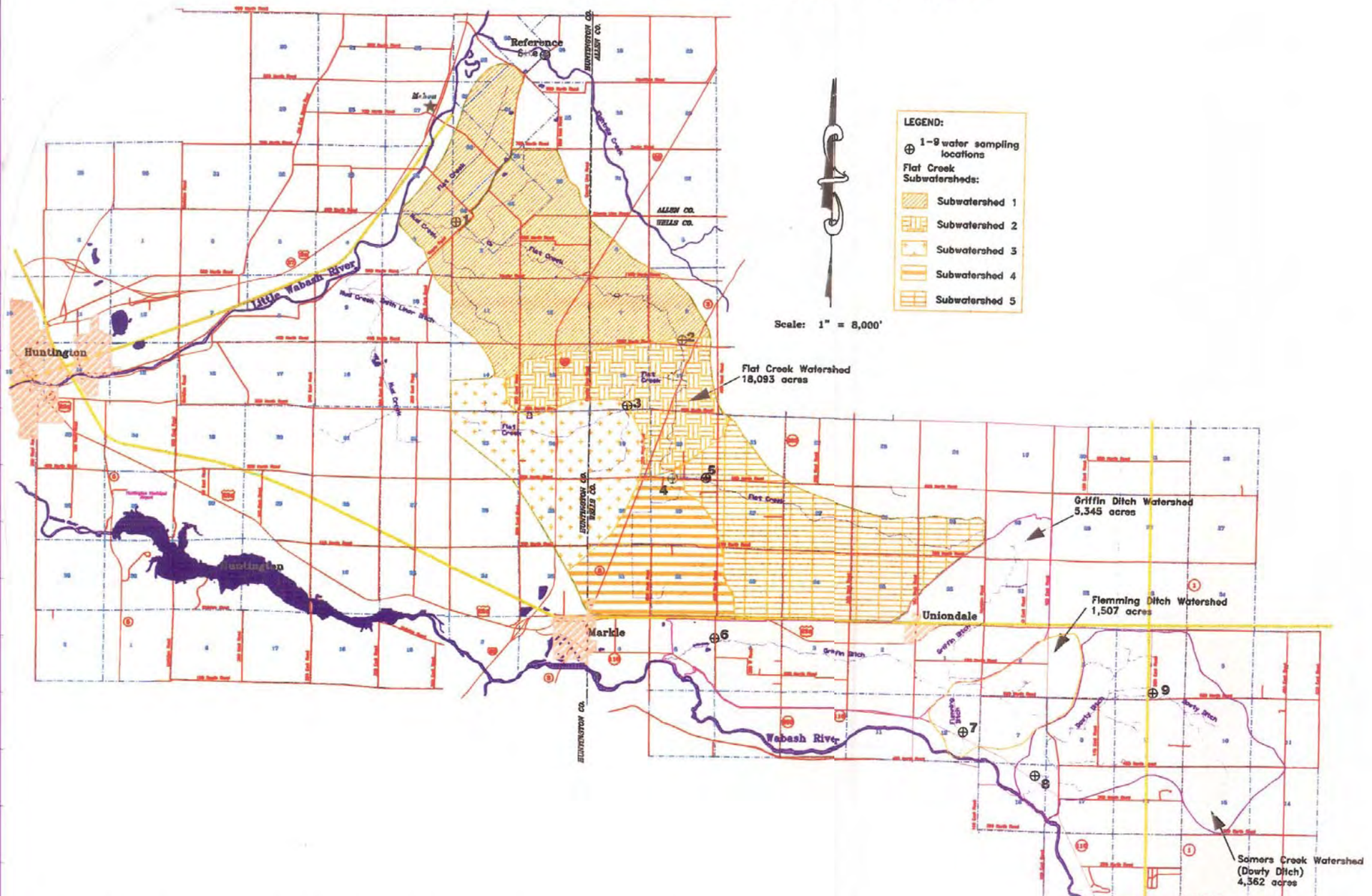
Flat Creek, Griffin Ditch, Fleming Ditch and Somers Creek Watersheds



Source of Base Map: U.S.G.S. 7.5 Minute Topographical Map

FIGURE 2. Reference Stream and the Flat Creek, Griffen Ditch, Fleming Ditch, and Somers Creek Watersheds.

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and green ash. Slightly better-drained soils probably harbored beech, sugar maple, black maple, white oak, red oak, shagbark hickory, tulip poplar, red elm, basswood, and white ash. The first plat of Indiana by the General Land Surveyors documented beech-maple forests as comprising 50% or more of the original vegetation of the state (Petty and Jackson, 1966).

Changes in land use have altered the watersheds' natural landscape. Settlers to the region drained wet areas and cleared forests in order to farm soils rich in both nutrients and humic material (decaying organic matter). However, this layer of rich soil was thin and years of crop removal and erosion depleted nutrient supplies. Around 1850, fertilization with potassium and phosphorus began. Fertilization had no effect on crop yield until 1940 when Dr. George Scarseth discovered that massive doses of nitrogen could significantly increase productivity. Technology and industry have increased and continue to increase farm production. Today, an average of 94% of the watersheds is utilized for agricultural purposes including row crop, pastureland, and wood lots.

Over time forests in the area have been cleared, and installation of subsurface tile drain networks, excavation of drainage channels, and straightening of streams has resulted in downstream water quality concerns. In a review of agricultural practices and their impacts on the natural structure and function of aquatic systems, Menzel (1983) concluded that effects other than water quality problems have emerged. These include alterations in water quantity, habitat structure, and energy transfer within streams.

Few studies have been conducted to document water quality and health within the Flat Creek, Griffen Ditch, Fleming Ditch, or Somers Creek Watersheds. However, Indiana Department of Environmental Management 305(b) reports from 1989 to the present have indicated non- or only partial support of beneficial uses at sampling sites on the Wabash River near the towns of Markle and Huntington. Evidently, human impacts within this area of the Wabash River watershed are having an adverse effect on water quality and beneficial uses as defined by state water quality standards.

Because there is little information about these watersheds and in order to gain a better understanding of them, the Wells County Soil and Water Conservation District applied for and received funding through the Indiana Department of Natural Resources Lake and River Enhancement Program for a watershed study. The purpose of the study is to describe the conditions in the watersheds of interest, identify potential problems, and make prioritized recommendations addressing these problems. The study included a review of historical data and information, correspondence with landowners, business owners, and state and local regulatory agencies, collection of stream water quality samples and benthic macroinvertebrates, and field investigations identifying land use patterns and locations for best management practice (BMP) installation. This report documents the results of the study.

REVIEW OF EXISTING INFORMATION

Watershed Physical Characteristics and Geology

The Flat Creek, Griffen Ditch, Fleming Ditch, and Somers Creek Watersheds together total 29,307 acres (11,092 ha or 42.8 square miles). Table 1 contains overview data for each of the watersheds. The landscape can be described as a relatively flat till plain, known as the Tipton Till Plain in physiographic terms. All four streams drain either directly or indirectly into the Wabash River, which eventually reaches the Ohio River in southwestern Indiana. The Wabash River drains water from about two-thirds of the state (Hale, 1966).

TABLE 1. Stream length and watershed area for the four study watersheds. Watershed areas are also given for the five Flat Creek subwatersheds.

Watershed/Subwatershed	Stream Length	Watershed Area
Flat Creek	30.5 mi (49.1 km)	18,093 acres (7,325 ha)
Subwatershed 1	-	6,269 acres (2,538 ha)
Subwatershed 2	-	2,342 acres (948 ha)
Subwatershed 3	-	2,880 acres (1,166 ha)
Subwatershed 4	-	2,244 acres (909 ha)
Subwatershed 5		4,358 acres (1,764 ha)
Griffen Ditch	8.4 mi (13.6 km)	5,345 acres (2,164 ha)
Fleming Ditch	3.5 mi (5.6 km)	1,507 acres (610 ha)
Somers Creek	12.5 mi (20.1 km)	4,362 acres (1,766 ha)
Total of Study Watersheds	**54.9 mi (88.3 km)**	**29,307 acres (11,865 ha)**

The watersheds drain part of the Wabash Moraine (Figure 3), a deposit left behind by the clay-rich, Ontario-Erie Lobe of the most recent Wisconsian glacier about 14,000 years ago. Prior to the Wisconsian Age, Indiana had been glaciated twice, though the Wisconsian glacier can be credited with building northeastern topography in Indiana. During the main advance about 21,000 years ago, the Wisconsian glacier covered two-thirds of the state. The glacier then advanced and retreated many additional times forming the topography of the state.

Figure 3 shows the terminal moraines deposited by the Erie Lobe at different times during the Wisconsian glaciation (Indiana University/Purdue University, Ft. Wayne, 1996). From the oldest to youngest they include: the Union City, Mississinewa, Salamonie, Wabash, and Fort Wayne Moraines. The Mississinewa and the Wabash Moraines are the largest, spanning up to several miles in width and standing 100 feet above adjacent plains. After the deposition of the Salamonie Moraine, the melting glacier retreated a large distance. The meltwater formed a greatly enlarged ancestral Lake Erie which produced very fine lacustrian mud and till. These are the modern day components of the Wabash Moraine. After depositing the most northern moraine (Fort Wayne Moraine), the glacier melted forming Lake Maumee. The overflow of the massive amounts of water contained in the glacier carved out a broad floodplain which is currently occupied by the Wabash River.

Distinct landforms and topography are evident in and adjacent to the Wabash Moraine and are associated with distinctive sediment types. The four morainal landforms traversed by the study watersheds include: the face, the toe, the till plain area, and the Wabash River Valley. The face

Source: Atlas of Mineral Resources of Indiana, Map No. 10

FIGURE 3. Moraine deposits in Northern Indiana from the Wisconsian Glacial Period during the Pleistocene Period.

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is the steep, south-facing slope of the moraine. Flat Creek and Somers Creek begin on the face terrain. Figure 4 shows the relatively steep topography associated with this face area. The toe lies a bit further south immediately in front of the face and is very gently sloping. It is associated with several small streams which drain water from the face (the headwaters of Flat Creek, Griffen Ditch, and Somers Creek). The till plain or washed area borders the toe to the south. This area is associated with larger streams that have their origins higher on the face or toe of the moraine. Of highly dissected topography, this feature represents former meltwater channels that carried water away from the melting glacier. Eightmile Creek, the reference site for this study, and Fleming Ditch lie within till plain areas. Flat Creek, Griffen Ditch, and Somers Creek cross this area as they flow toward the Wabash River Valley. The Wabash was the principle channel carrying meltwater from the ice front when the moraine was formed (IU/Purdue Ft. Wayne, 1996).

Climate

Indiana Climate

Indiana's climate can be described as temperate with cold winters and warm summers. "Imposed on the well known daily and seasonal temperature fluctuations are changes occurring every few days as surges of polar air move southward or tropical air moves northward. These changes are more frequent and pronounced in the winter than in the summer. A winter may be unusually cold or a summer cool if the influence of polar air is persistent. Similarly, a summer may be unusually warm or a winter mild if air of tropical origin predominates. The action between these two air masses of contrasting temperature, humidity, and density fosters the development of low-pressure centers that move generally eastward and frequently pass over or close to the state, resulting in abundant rainfall. These systems are least active in midsummer and during this season frequently pass north of Indiana" (National Climatic Data Center, 1976). Prevailing winds are generally from the southwest, but are more persistent and blow from a northerly direction during the winter months. Flooding is common in Indiana and occurs in some part of the state almost every year. The months of greatest flooding frequency are December through April. Causes of flooding vary from prolonged periods of heavy rain to precipitation falling on snow and frozen ground.

Wells County Climate

The climate of Wells County is characterized as cool and humid. Winters are cold, averaging 28ºF (-2.2 ºC), while summers are warm, averaging 72ºF (22 ºC). The highest temperature ever recorded was 102ºF (39 ºC) on August 31, 1951. Mild drought conditions occur occasionally during the summer when evaporation is highest. Yearly annual rainfall averages 37 inches (94 cm), while winter snowfall averages about 33 inches (84 cm). During summers, relative humidity varies from about 60 percent in midafternoon to near 80 percent at dawn. The growing season typically begins in early April and ends in mid-October.

In 2000, just over 33 inches (13 cm) of precipitation (Table 2) was recorded at Bluffton in Wells County (http://shadow.agry.purdue.edu/sc.index.html). This amount exceeded that received during 1999, which was widely recognized as a drought year. However, both 1999 and 2000 were dry when compared to the 30-year average, 36.17 inches. Although the difference between the annual total precipitation in 2000 compared to the annual average is not drastic, the year was characterized by significant wetter-than-normal and drier-than-normal periods. During 2000, the

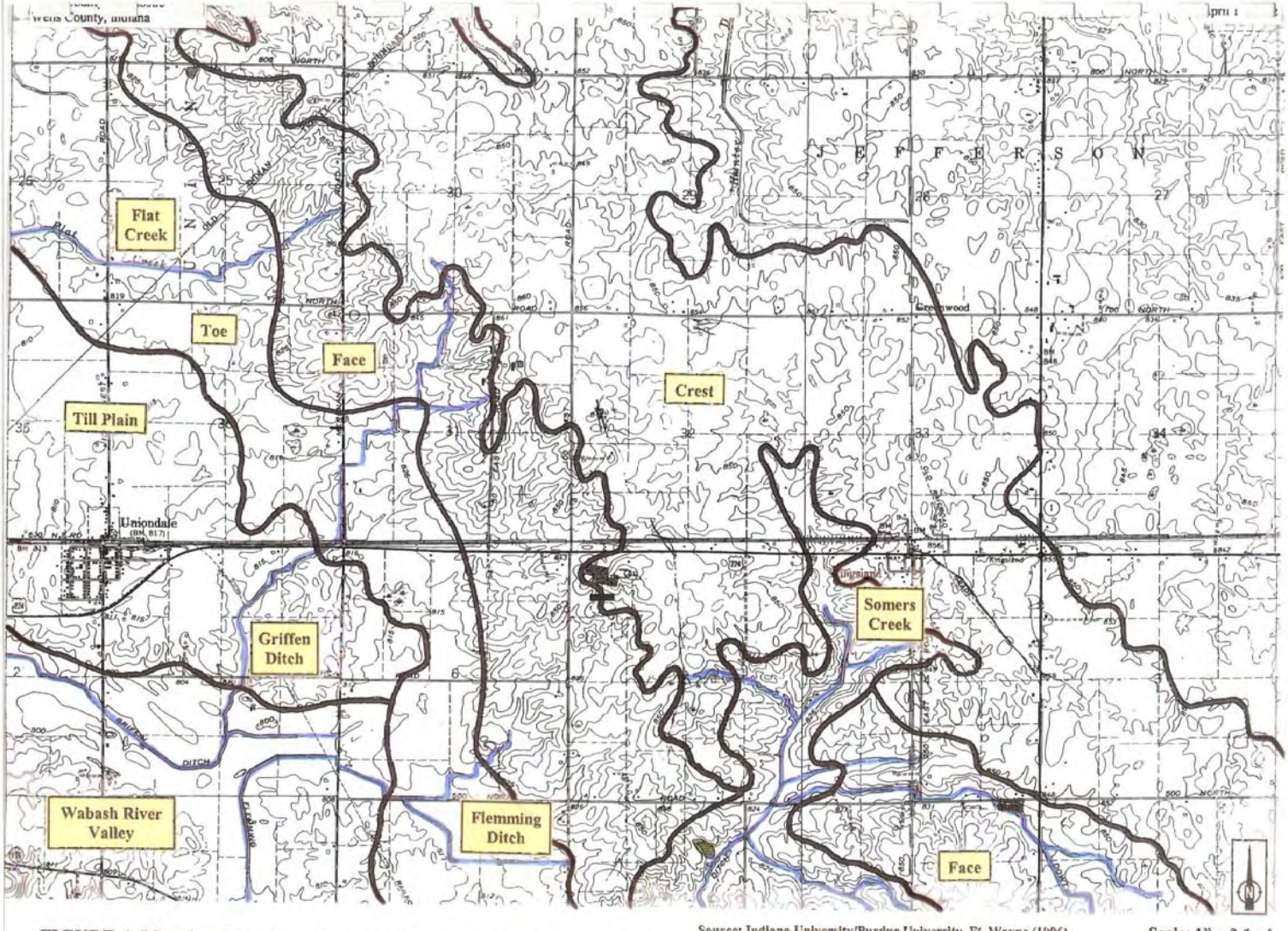


FIGURE 4. Moraine deposits and topography in the Wells County Area.

Source: Indiana University/Purdue University, Ft. Wayne (1996)

Scale: 1" = 0.5 mi

spring period (during the months of March and April) was drier than normal, while the area received three inches more than normal in June. July was drier than normal and August wetter. The fall (October and November) saw less than normal amounts of precipitation.

TABLE 2. Monthly rainfall data (in inches) for year 2000 as compared to average monthly rainfall. Averages are based on available weather observations taken during the years of 1961-1990 (http://shadow.agry.purdue.edu/sc.index.html).

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	TOTAL
2000	1.31	1.72	2.31	1.86	4.26	6.71	1.68	5.38	2.89	0.93	1.50	2.91	33.46
Average	1.80	1.81	2.86	3.46	3.66	3.84	3.62	3.47	3.22	2.53	3.01	2.89	36.17

Soils

Introduction

The soil types found in Wells and Huntington Counties are a product of the original parent materials deposited by the glaciers that covered the area 12,000 to 15,000 years ago. The main parent materials found in these two counties are glacial outwash and till, lacustrine material, alluvium, and organic materials that were left as the glaciers receded. The interaction of these parent materials with the physical, chemical, and biological variables found in the area (climate, plant and animal life), time, and the physical and mineralogical composition of the parent material formed the soils located in Wells and Huntington Counties today. Surficial Erie Lobe deposits are extremely fine-grained silty clay to silty-clay loams within and east of the Wabash moraine, the morainal structure drained by the four watersheds (Figure 3). In fact, incorporation of ancestral Lake Erie mud led to the deposition of till that is commonly about 90% silt and clay (Fleming, in prep.).

The USDA soil survey of Wells County (Neely, 1992) and Huntington County (Lockridge and Jensen, 1982) maps the watersheds in soil types derived from glacial till parent materials. The soils developed under forests are light colored with intermingled dark color former marshland soils (Ulrich, 1966). The drainages of Flat Creek and Dowty Ditch are composed primarily of Blount-Del Ray-Pewamo, and Blount-Del Ray-Glynwood Associations. The watershed of Griffen Ditch is mostly Pewamo-Blount-Del Ray Association with Milford-Del Ray-Blount and Blount-Del Ray-Glynwood Associations. The Fleming Ditch drainage is mapped in Pewamo-Blount-Del Ray and Blount-Del Ray-Glynwood Associations. Most of these soil associations are nearly level to gently sloping and are somewhat poorly to poorly drained. The bedrock underlying the surficial soil associations in the counties is composed of limestone, shale, and sandstone.

Highly Erodible Soils

Soils in the watersheds and their ability to erode or sustain certain land use practices, can impact the water quality of the river systems with which they converge. For example, highly erodible soils are, as their name implies, easily erodible. Soils that erode from the landscape are transported to waterways where they impair water quality, interfere with recreational uses, and impair aquatic habitat and health. In addition, such soils carry attached nutrients, which further impair water quality by increasing production of plant and algae growth. Soil-associated chemicals like some herbicides and pesticides can kill aquatic life and damage water quality.

Figure 5 maps the presence of highly erodible soils in the study watersheds. (See Appendix 1 for more detailed highly erodible soil maps for each watershed.) It is important to note that this map is based on the Natural Resource Conservation Service (NRCS) criteria for highly erodible soils and is not field checked. Soil unit names considered highly erodible by the NRCS are included in Table 3. Two thousand two hundred seventy-five acres (921 ha) of land (about 7.6% of the watersheds together) are mapped as highly erodible soil. The Flat Creek 1, Griffen Ditch, and Fleming Ditch Watersheds contain the largest amounts of highly erodible soil area. The Flat Creek Subwatersheds 3, 4, and 5 contain the least amount of soil types mapped as highly erodible.

TABLE 3. Soil units considered highly erodible by the NRCS offices of Wells and Huntington Counties.

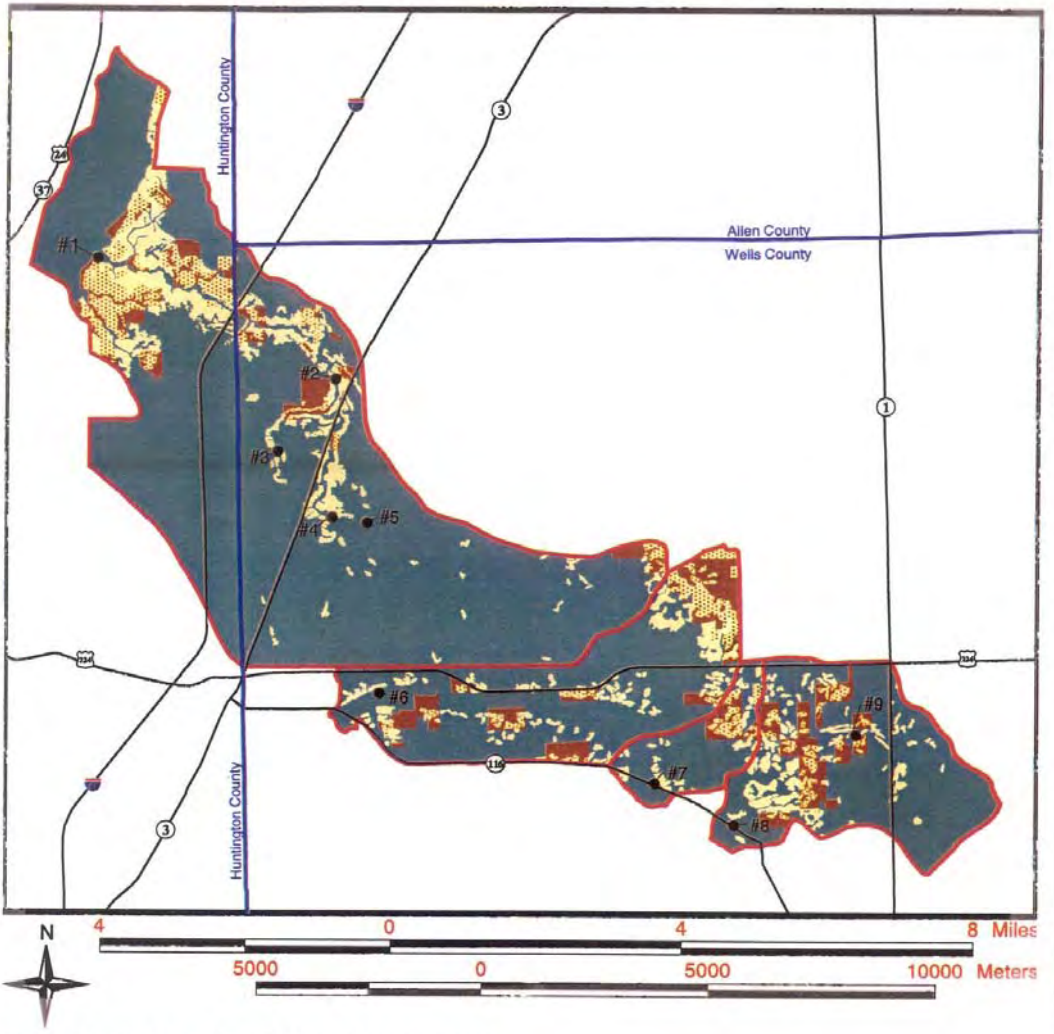
Soil Unit	Soil Name	Soil Description
BkB2	Blount silt loam	1-4% slopes, eroded, HEL when associated with Morley and GlB2
EpC3	Eldean gravelly clay loam	6-12% slopes, severely eroded
FoC2	Fox loam	6-12% slopes, eroded
GnB2	Glynwood silt loam	3-7% slopes, eroded
GpB3	Glynwood clay loam	2-6% slopes, severely eroded
HeG	Hennepin loam	3-7% slopes
MtC	Milton silt loam	6-15% slopes
MuE	Morley loam	15-30% slopes
MvC2	Morley silt loam	4-8% slopes, eroded
MxC2	Morley silt loam	6-12% slopes, eroded
MxD2	Morley silt loam	12-18% slopes, eroded
MxE2	Morley silt loam	18-30% slopes, eroded
MxC3	Morley clay loam	6-12% slopes, severely eroded
MzC3	Morley clay loam	6-12% slopes, severely eroded
MzD3	Morley clay loam	12-18% slopes, severely eroded

Source: 1987 USDA/SCS Indiana Technical Guide Section II-C.

These soils types are limited for certain classes of land use, and erosion hazard is a major management concern. Some of the above soils tend to be wet in nature making soil compaction under agricultural land uses a problem. Other highly erodible soils are poorly suited for crop production due to their high erosion potential. Most of the highly erodible soils within the study watersheds are Blount silt loams or Glynwood silt loams. These two soil types are suitable for agricultural usages as long as active erosion control and soil management practices are employed. According to Figures 5 and 6, much of the highly erodible land within each watershed is utilized for agricultural purposes. This type of land use on highly erodible, marginal soils has definite implications for the receiving waterway's ability to support its beneficial uses especially if conservation measures are not common practice.

Highly Erodible Land

Highly Erodible Land (HEL) is a designation used by the Farm Service Agency (FSA). For a field or tract of land to be labeled HEL by the FSA, at least one-third of the parcel must be situated in highly erodible soils. Unlike the soil survey, these fields must be field checked to



Highly Erodible Soil and Land Classification

- Highly Erodible Soil
- Highly Erodible Land
- Highly Erodible Soil and Land Overlap
- Non-Highly Erodible Soil

- Site Locations
- Main Roads
- Sub-watershed Boundary
- County Boundaries

FIGURE 5. Highly erodible soils and highly erodible land tracts (HEL). The map was created by Melissa Clark. Road source: US Department of Transportation. Sources of other information: Wells County SWCD and USDA Soil Conservation Service.

ensure the accuracy of the mapped soils types. Farm fields mapped as HEL are required to file a conservation plan with the FSA in order to maintain eligibility for any financial assistance from the U.S. Government. Figure 5 also shows the location of HEL fields in the study watersheds. Approximately, 2,757 acres (1,116 ha) of HEL exist within boundaries of the study watersheds. This is about 10% of the watersheds together. Table 4 breaks the information down by watershed. The Flat Creek Watershed has the most HEL acreage but the least percentage of its watershed mapped as HEL (7.3%). Most of the HEL in this watershed is located in Subwatershed 1. The Fleming Ditch Watershed contains the least amount of HEL, but the largest percentage of its watershed is considered HEL (16.6%). The Griffen Ditch Watershed also contains a fair amount of HEL (812 acres). Over 15% of its watershed is designated HEL.

TABLE 4. Area mapped in highly erodible map units by watershed.

Watershed	Acres	Hectares	Percent of Watershed
Flat Creek	1,184	479	7.3%
Subwatershed 1	1,074	435	17.1%
Subwatershed 2	43	18	1.3%
Subwatershed 3	0	0	0.0%
Subwatershed 4	0	0	0.0%
Subwatershed 5	29	12	0.7%
Griffen Ditch	812	329	15.2%
Fleming Ditch	250	101	16.6%
Somers Creek	510	206	11.7%
Total	**2,757**	**1,116**	**10%**

Source: Farm Service Agency of Wells and Huntington Counties.

Considerations for On-Site Wastewater Disposal Systems

Background Information

Nearly half of Indiana's population lives in residences having private waste disposal systems. As is common in rural Indiana, septic tanks and septic tank absorption fields are utilized for wastewater treatment in the four study watersheds. This type of wastewater treatment system relies on the septic tank for primary treatment to remove solids and the soil for secondary treatment to reduce the remaining pollutants in the effluent (waste discharge) to levels that protect surface and groundwater from contamination.

A variety of factors can affect a soil's ability to function as a septic absorption field. Seven soil characteristics are currently used to determine soil suitability for on-site sewage disposal systems: position in the landscape, slope, soil texture, soil structure, soil consistency, depth to limiting layers, and depth to seasonal high water table (Thomas, 1996). The ability of soil to treat effluent depends on four factors: the amount of accessible soil particle surface area, the chemical properties of the surfaces, soil conditions like temperature, moisture, and oxygen content, and the types of pollutants present in the effluent (Cogger, 1989).

The amount of accessible soil particle surface area depends both on particle size and porosity. Because they are smaller, clay particles have a greater surface area per unit volume than silt or sand and therefore, a greater potential for chemical activity. However, soil surfaces only play a

role if wastewater can contact them. Soils of high clay content or soils that have been compacted often have few pores that can be penetrated by water and are not suitable for septic systems because they are too impermeable. Additionally, some clays swell and expand on contact with water closing the larger pores in the profile even more. On the other hand, very coarse soils may not offer satisfactory effluent treatment either because the water can travel so rapidly through the soil profile. Soils located on sloped land also may have difficulty in treating wastewater due to reduced contact time.

Chemical properties of the soil surfaces are also important for wastewater treatment. For example, clay materials all have imperfections in their crystal structure which gives them a negative charge along their surfaces. Due to their negative charge, they can bond cations of positive charge to their surfaces. However, many pollutants in wastewater are also negatively charged and are not attracted to the clays. Clays can help remove and inactivate bacteria, viruses, and some organic compounds.

Environmental soil conditions influence the microorganism community which ultimately carries out the treatment of wastewater. Factors like temperature, moisture, and oxygen availability influence microbial action. Excess water or ponding saturates soil pores and slows oxygen transfer. The soil may become anaerobic if oxygen is depleted. Decomposition process (and therefore, effluent treatment) becomes less efficient, slower, and less complete if oxygen is not available.

Many of the nutrients and pollutants of concern are removed safely if a septic system is sited correctly. Most soils have a large capacity to hold phosphate. On the other hand, nitrate (the end product of nitrogen metabolism in a properly functioning septic system) is very soluble in soil solution and is often leached to the groundwater. Care must be taken in siting the system to avoid well contamination. Nearly all organic matter in wastewater is biodegradable as long as oxygen is present. Pathogens can be both retained and inactivated within the soil as long as conditions are right. Bacteria and viruses are much smaller than other pathogenic organisms associated with wastewater and therefore, have a much greater potential for movement through the soil. Clay minerals and other soil components may adsorb them, but retention is not necessarily permanent. During stormflows, they may become resuspended in the soil solution and transported in the soil profile. Inactivation and destruction of pathogens occurs more rapidly in soils containing oxygen because sewage organisms compete poorly with the natural soil microorganisms, which are obligate aerobes requiring oxygen for life. Sewage organisms live longer under anaerobic conditions (conditions without oxygen) and at lower soil temperatures because natural soil microbial activity is reduced.

Wells County

Soil conditions such as slow permeability and high water table, coupled with poor design, faulty construction, and lack of maintenance reduce the average life span of septic systems in Indiana to 7-10 years (Jones and Yahner, 1994). Likewise, several onsite systems located on the Wabash Moraine in Wells County are known to perform poorly or to have failed completely. Localized soil-geologic conditions are responsible for most of the problems. In fact, the Indiana State Department of Health and the Wells County Health Board have instituted a moratorium on residential development within the Wabash End Moraine in an area known as “Buttermilk

Ridge", a part of Union Township (Section 14, T.28N., R.11E.). This area is located in the watershed of Eightmile Creek, just north of the Flat Creek Watershed.

The NRCS ranks each soil series in terms of its limitations for use as a septic tank absorption field. Each soil series is placed in one of three categories: slightly limited, moderately limited, or severely limited. Use of septic absorption fields on soils in the moderately or severely limited categories generally requires special designs, planning, or maintenance to overcome the limitations. Table 5 summarizes the predominant soil series located in the study watersheds in terms of their suitability for use as a septic tank absorption field.

TABLE 5. Dominant soil types in the study watersheds and their suitability for on-site wastewater treatment systems.

Symbol	Name	Depth of Water Table	Suitability for Septic Absorption Field
BkB2	Blount-Del Ray silt loam, 1-4% slopes, eroded	1-3 ft	severe: wetness, percs slowly
GnB2	Glynwood silt loam, 2-5% slopes, eroded	2-3.5 ft	severe: wetness, percs slowly
Pm	Pewamo silty clay loam	+1-1 ft	severe: ponding, percs slowly
Mn	Millgrove clay loam	+1-1 ft	severe: ponding
Rr	Rensselaer loam	+0.5-1 ft	severe: ponding
DeA	Del Ray-Blount silt loam, 0-1% slopes	1-3 ft	severe: wetness, percs slowly
MvC2	Morley silt loam, 4-8% slopes, eroded	>6 ft	severe: percs slowly

Source: Soil Survey of Wells County.

Blount-Del Ray silt loams (BkB2) are nearly level or gently sloping soils found along drainageways and on swells of till plains and moraines. The soils are not permeable making water retention capacity high. Therefore, Blount-Del Ray silt loams are well suited to agricultural land uses. Because of wetness and impermeability, soils of this type are not suited for septic effluent treatment.

Glynwood silt loams (GnB2) are typically located on ridges and knolls of till plains and moraines. They are limited for septic use for the same reasons as the Blount-Del Ray silt loams.

Pewamo silty clay loams (Pm) are very poorly drained soils found in low-lying areas of till plains and moraines. Wetness and ponding is so severe that it can even limit crop growth. Because of the wetness, these soils are unsuitable as septic absorption fields.

Millgrove clay loams (Mn) and Rensselaer loams (Rr) are also very poorly drained soils situated in stream floodplain areas and are frequently ponded by runoff from surrounding slopes. Due to ponding tendencies, these soils do not satisfactorily treat wastewater effluent.

Del Ray-Blount silt loams (DeA) can be found on slight rises of till plains and moraines. Typically, due to permeability and wetness concerns, these soils are severely limited as sites for septic tank absorption fields.

Morley silt loam (MvC2) are well drained soils of till plains and moraines. However, permeability severely limits their use for septic tank effluent treatment, although enlarging and filling or mounding the absorption field may improve the soil's capacity to treat wastewater.

The dominant soil types in the study watersheds have severe limitations for septic suitability (Table 5). Geologic conditions in many parts of the moraine especially along its face and toe are not likely to promote satisfactory septic system function resulting in surface and groundwater pollution. Water quality sampling conducted during the current study implicates improperly functioning systems as a possible cause of surface water pollution in the four watersheds particularly in the Somers Creek watershed where *E. coli* concentrations reached 12,000 col/100ml. Because there are few (if any) animal operations in the area, the likely cause of failure is related to improperly sited septic systems and soil impermeability in leach field areas. A study conducted at the request of the Wells County Health Department in 1995 documented several characteristics present in test pits that are significant contributors to on-site system problems:

1. Sediments in most pits exhibited considerable moisture content at depths of >10 inches. Many upland samples were close to saturation despite mild drought conditions.
2. All pits demonstrated poor soil development. The geologic or biologic processes that develop macroporosity which allows for water movement never occurred.
3. Many pits exhibited a near-surface, virtually impervious "hardpan" within two feet of the surface.

These characteristics indicate severely limited vertical water movement; the primary hydraulic conductivity of clayey lake-based sediments like those found in the test pits is about 10^{-8} cm/sec (less than one inch per year) (Stephenson et al., 1988). In conclusion, the landscape along the south face of the Wabash Moraine and in front of the Moraine have thin, eroded, poorly developed soils overlying unfractured lake sediment. These soils types are not conducive to the satisfactory operation of conventional on-site treatment systems.

To address these issues and concerns, development should proceed with caution along the south face of the Wabash Moraine. Competent soils scientists that are familiar with conditions should evaluate potential development sites for evidence of poor water movement and soil development. Alternative technology, like the mound system, the at-grade system, the pressure-dosed system, or wastewater wetlands may provide a solution is soils are unsuitable. Some soils may be suitable for alternating field technology which requires that a second field be available to accept effluent while the primary field "rests". Enlarged septic fields should be installed to increase the area of absorption. It is important to note, however, that some soils are too wet, too shallow, too impermeable, or too steep for any type of system.

Once the proper technology has been installed, proper maintenance is very important. Depending on the size of the system and the loading to it, systems should be cleaned out every 2-5 years. Property owners should divert surface runoff away from absorption fields, keep a cover of vegetation over the field, and keep foot and vehicular traffic over the field to a minimum.

Soil Discussion and Summary

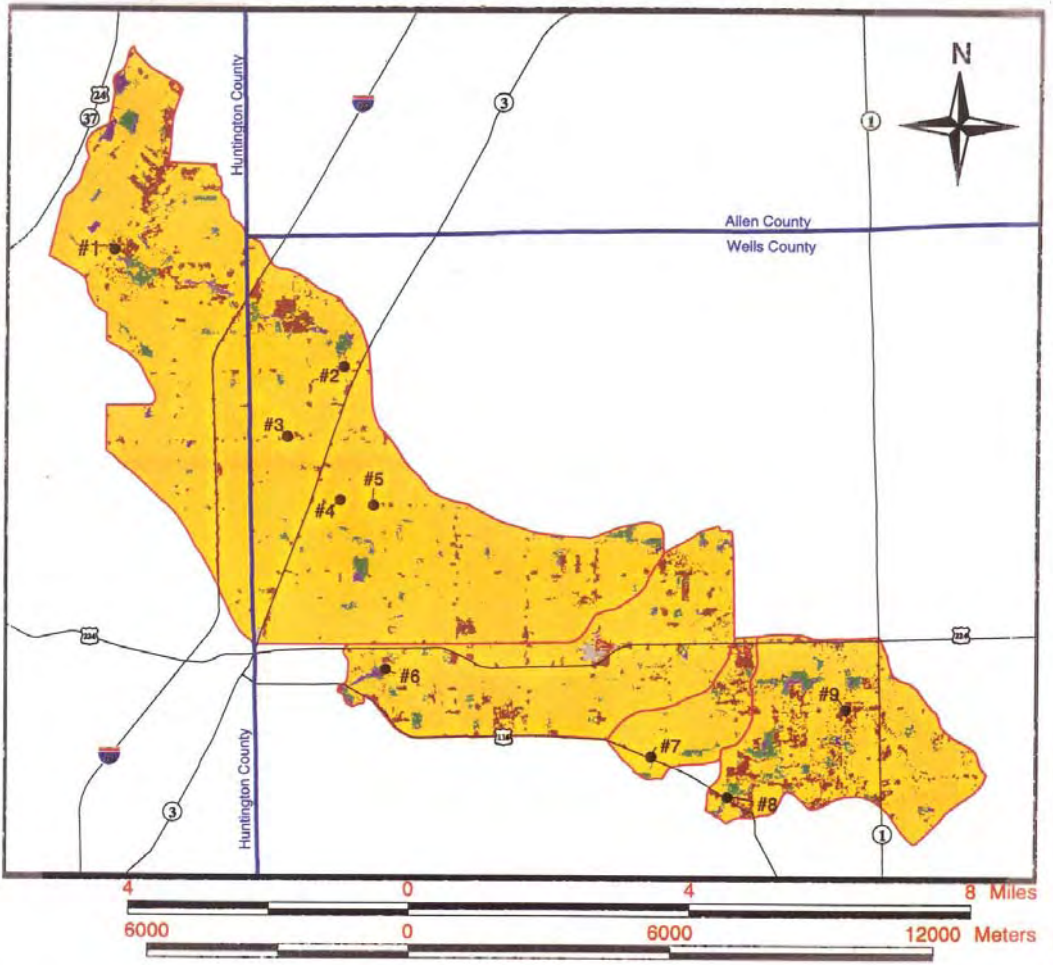
The type of soils in a watershed and the land uses practiced on those soils can impact the quality of the water leaving the watershed. Highly erodible land is concentrated primarily in the Flat Creek Watershed in terms of acreage. However, Fleming and Griffen Ditch Watersheds contain the most HEL per unit of watershed acreage. Soil erosion contributes sediment to the rivers reducing water quality downstream and interfering with aquatic habitat and recreational uses. Nutrients attached to eroded soils fertilize and increase aquatic production to unhealthy levels. Additionally, soil eroding from the landscape silts in ditches and drainageways necessitating costly dredging maintenance projects. While a certain amount of aquatic plants is healthy and beneficial to aquatic systems, excessive growth can reduce drainage and aesthetics. Nutrients and nutrient-rich sediment can promote the growth of nuisance levels of algae and plants downstream in other waterbodies. Consequently, conservation methods and best management practices (BMPs) should be utilized when soils are disturbed in these areas. This includes residential development and farming practices in highly erodible soils.

Soil type should also be considered in siting septic systems. Some soils do not provide adequate treatment for septic tank effluent. Almost all of the land in the study watersheds is mapped in soils that rate as severely limited or generally unsuitable for use as septic tank absorption fields. This is typical for much of Indiana, as research by Dr. Donald Jones suggests that 80% of the soils in Indiana are unsuitable for wastewater treatment (Grant, 1999).

Pollution from septic tank effluent can affect waterways, the life it supports, and its users in a variety of ways. It can contribute to eutrophication and water quality impairment of lakes and other waterbodies in the watersheds. In addition, septic tank effluent potentially poses a health concern for users of both surface and groundwater in the watersheds. Swimmers, anglers, or boaters that have body contact with contaminated water may be exposed to waterborne pathogens. (This issue is not as much of a concern for the small tributaries that are the focus of this study, but it is of concern for their receiving waterbodies, the Wabash and the Little Wabash Rivers. According to the State of Indiana, both of these rivers should support contact recreation as a beneficial use (IDEM, 2000).) Fecal contaminants can be harmful to humans and cause serious diseases, such as infectious hepatitis, typhoid, gastroenteritis, and other gastrointestinal illness. Additionally, nitrogen and pathogens may also leach into the groundwater compromising well water for drinking.

Land Use

Figure 6 and Table 6 present land use information for each of the four study watersheds. (See Appendix 2 for more detailed land use maps for each watershed.) Land use data was obtained from the Indiana Gap Analysis project. This data was checked with recent aerial photography and in some areas was field checked. Data was then corrected to reflect current conditions in the watersheds. The land use categories shown in Table 6 are general in nature. Appendix 3 breaks the data into subwatersheds and more detailed categories.



Landuse and Landcover

- Open Water
- Low Intensity Residential
- High Intensity Residential
- Commercial/Indutstrial/Transport.
- Deciduous Forest
- Evergreen Forest
- Pasture/Hay
- Row Crop
- Woody Wetland
- Emergent Herbaceous Wetland
- Site Locations
- Main Roads
- Sub-watershed Boundary
- County Boundaries

FIGURE 6. Land use and land cover. The map was created by Melissa Clark. Road source: US Department of Transportation. Land use information source: USGS MLRC National Land Cover Data, last updated 03/16/00.

TABLE 6. Land Use in the Flat Creek, Griffen Ditch, Fleming Ditch, and Somers Creek Watersheds.

Flat Creek			
Landuse	**Area (acres)**	**Area (ha)**	**%**
Open Water	12.01	4.86	0.06
Low intensity residential	15.35	6.21	0.08
High intensity residential	1.78	0.72	0.01
Commercial/industrial/transport	89.86	36.36	0.48
Deciduous Forest	534.47	216.27	2.86
Evergreen Forest	0.22	0.09	0.00
Pasture/Hay	1138.33	460.62	6.10
Row Crop	16702.15	6758.46	89.51
Woody Wetland	162.59	65.79	0.87
Emergent Herbaceous Wetland	3.78	1.53	0.02
TOTAL	**18660.53**	**7550.91**	**100.00**

Griffen Ditch			
Landuse	**Area (acres)**	**Area (ha)**	**%**
Open Water	2.45	0.99	0.04
Low intensity residential	39.37	15.93	0.72
High intensity residential	2.67	1.08	0.05
Commercial/industrial/transport	16.24	6.57	0.30
Deciduous Forest	174.82	70.74	3.20
Evergreen Forest	0.22	0.09	0.00
Pasture/Hay	487.09	197.10	8.93
Row Crop	4692.10	1898.64	85.98
Woody Wetland	41.15	16.65	0.75
Emergent Herbaceous Wetland	1.33	0.54	0.02
TOTAL	**5457.43**	**2208.33**	**100.00**

Fleming Ditch			
Landuse	**Area (acres)**	**Area (ha)**	**%**
Open Water	0.44	0.18	0.03
Low intensity residential	2.22	0.90	0.17
High intensity residential	2.22	0.90	0.17
Commercial/industrial/transport	18.24	7.38	1.40
Deciduous Forest	57.61	23.31	4.41
Pasture/Hay	122.77	49.68	9.41
Row Crop	1100.96	445.50	84.34
Woody Wetland	0.89	0.36	0.07
TOTAL	**1305.36**	**528.21**	**100.00**

Somers Creek			
Landuse	**Area (acres)**	**Area (ha)**	**%**
Open Water	4.67	1.89	0.10
Low intensity residential	8.23	3.33	0.18
High intensity residential	0.44	0.18	0.01
Commercial/industrial/transport	2.89	1.17	0.06
Deciduous Forest	334.96	135.54	7.23
Evergreen Forest	2.67	1.08	0.06
Pasture/Hay	662.13	267.93	14.29
Row Crop	3576.24	1447.11	77.17
Woody Wetland	40.48	16.38	0.87
Emergent Herbaceous Wetland	1.56	0.63	0.03
TOTAL	**4634.27**	**1875.24**	**100.00**

Approximately 94% of the watersheds is used for agricultural purposes, including cropland, pasture, and agricultural woodlots. Eighty-four percent is used for row crop production. This percentage is close to the percentage estimated for Wells County (83%) (U.S. Census of Agriculture, 1997). U.S. Census of Agriculture data (1997) also reveals that in 1997, there were 660 farms in Wells County and 195,900 acres (79,312 ha) were farmed. Agricultural land use is spread evenly across the watersheds, and aside from agricultural uses, deciduous and evergreen forest represents the only other notable land use. Each of the watersheds contains some pastureland. According to the landuse maps, much of the pastureland is located in close proximity to waterways. The Flat Creek Subwatershed 1 contains significant amounts of pastureland, and almost 15% of the Somers Creek Watershed is pasture for livestock. Residential land occupies less than 1% of the total area of the watersheds.

Only a meager 0.38% of the watersheds together is still classified as wetland. Some natural riparian areas still do exist like the deciduous forests and woody wetlands located in Flat Creek Subwatershed 1, near the mouth of Griffen Ditch, and in a few scattered locations throughout the Somers Creek Watershed. Not only do these wetlands and vegetated areas help moderate stream water temperature and velocity, they also offer water storage capacity and sediment and nutrient filtration. Due to the small remaining concentration of wetland land use within the watersheds, their protection is merited, and any chance for enhancement or restoration should be explored. Farmers should also be encouraged to route drainage tiles toward wetland areas. Riparian buffer area filtration is drastically reduced when drainage tiles completely bypass them, carrying drainage waters directly to the ditch.

Other land uses are very negligible within the four study watersheds. Commercial and industrial land use occupies 0.56% of the watersheds. The remaining land uses compose a meager 0.41% including residential and open water areas.

Soybeans, corn, and small grains are the major crops grown in Wells County. Although exact percentages of each crop were not recorded for each study watershed, 52% of the agricultural fields in Wells County were planted with soybeans and 39% in corn in 2000 (Purdue University Cooperative Extension Service, 2000). It is likely that the study watersheds closely mirror these percentages. Table 7 contains more detailed information regarding percentage and acreage of

Wells County fields used to produce different crops and commodities and estimated numbers of cattle in 2000.

TABLE 7. Percent (number) and acreage of Wells County fields with indicated present crop for year 2000. Percentages are taken from a field sampling of points along transects across the County. No data are available for percent or acreage of land in permanent pasture. The last three rows give the number of beef cattle, dairy cattle, and total cattle in Wells County in 2000. Of the 92 counties in Indiana, Wells County ranks 49 with respect to cattle production.

Crop/Commodity	Percent (Number)	Acreage of Land
Soybeans	52 (256)	98,200
Corn	39 (195)	82,600
Small Grains	4 (19)	**
Winter Wheat	**	7,500
Hay/Forage	2 (15)	3,100
Idle (CRP or other programs)	2 (9)	**
Beef Cattle	400	
Dairy Cattle	1,900	
All Cattle	8,000	

Source: Purdue Cooperative Extension Service, 2000 and U.S. Census of Agriculture, 2000.
** indicates that the data was not available.

Prime farmland is one of several land types classified and recognized by the USDA. Prime farmland is land that is best suited for crops. The land is used for cultivation, pasture, woodland or other production, but it is not urban land or water areas. This type of land produces the highest yields with minimal inputs of energy and economic resources. Farming it results in the least damage to the environment. Therefore, when possible, the optimal land use strategy places industrial and residential development on the marginal lands while keeping prime farmland available for production. According to the USDA soil survey of Wells County, approximately 225,798 acres, or 95% of the total acreage in the county, meets prime farmland requirements. The land is evenly distributed across the county, so much of the land in the study watersheds is classified as prime farmland.

"A recent trend in land use in some parts of the county has been the loss of some prime farmland to industrial and urban uses. The loss of prime farmland to other uses puts pressure on marginal lands, which generally are more erodible, wet or droughty, and less productive and cannot be as easily cultivated." (Neely, 1992). Cultivation of more marginal land also results in more damage to the environment. During the watershed driving tour (which will be discussed in more detail later), several areas of new, rural development exist within the study watershed. This type of change in land use will have obvious impacts on water quality, especially if it results in more farming of marginal land. Again, careful land use and development planning can minimize the need to produce crops on compromised land.

Agricultural Best Management Practices (BMPs)

Approximately 94% of the watersheds is utilized for agricultural purposes. This land use, particularly on highly erodible soils and in other environmentally sensitive areas, can have an

impact on water quality downstream. Runoff from farm fields can contain a variety of pollutants including nutrients (nitrogen and phosphorus), herbicides, pesticides, sediment, and bacteria (*E. coli*). In addition, the original creation of agricultural land involved draining low wet areas using drainage tiling. This has decreased the storage capacity of the land and increased peak flows of water in streams and channels in the watersheds. An increase in both the volume and velocity of peak flows typically leads to increases in land erosion and ultimately increases in sediment and sediment-associated particle loading to the receiving waterbody. According to the National Research Council (1993), non-point source pollution by contaminants in agricultural runoff is a major cause of poor surface water quality in the USA.

Several programs and Best Management Practices (BMPs) have been developed to address non-point source pollution associated with agriculture. Filter strips, riparian buffer strips, grassed waterways, land set-asides, conservation tillage, nutrient and pesticide management, and use of erosion control structures are all examples of BMPs. Each is aimed at conservation to help ensure a healthy and productive land through watershed and natural system protection. Programs and BMPs that are currently in use in the study watersheds or that could potentially be used more frequently or consistently are discussed below.

The Conservation Reserve Program

Introduction

The Conservation Reserve Program (CRP) is the single, largest environmental improvement program offered by the federal government. The program arose out of concerns raised by USDA studies conducted in the early 1980s showing that the nation's cropland was eroding and losing soil at a rate of 3 billion tons per year (USDA, 1997). The CRP provides volunteer participants with an annual per-acre rent and 50% of the cost of establishing permanent land cover. Matt Jarvis of the USDA added that with the current incentive payment and cost-share, the initial payment can be as high as 90% of the total project cost. In return, participants are required to retire the cropland from production for 10-15 years.

Removing land from production and planting it with vegetation has a positive impact on water quality within the given watershed. In a review of Indiana lakes sampled from 1989 to 1993 for the Indiana Clean Lakes Program, Jones (1996) showed that lakes within ecoregions reporting higher percentages of cropland in CRP had lower mean trophic state index (TSI) scores. A lower TSI is indicative of lower productivity and better water quality.

The New Conservation Reserve Program established in 1997 is targeted at enrolling the most environmentally sensitive land into the program. The program was capped by Congress at 36.4 million acres, meaning that only about 15% of eligible cropland could be enrolled. Land is evaluated and scored for environmental benefit, including: wildlife habitat enhancement, water quality benefits, reduced erosion, long-term retention benefits, air quality benefits, land's location in a Conservation Priority Area, and cost of enrollment per acre. The CRP attempts to maximize conservation and economic benefits by focusing on highly erodible land, riparian areas, cropped wetlands, and cropland associated with wetlands.

CRP in the Study Watersheds

A variety of conservation practices are currently in use in the study watersheds. Figures 7a and 7b show the locations of cropland enrolled in the CRP and the years when the tracts will be released from the program. Instead of farming the tracts, landowners have installed filter strips, grassed waterways, and wildlife set-asides. Table 8 contains acreages of land enrolled in the CRP. The largest of the study watersheds, Flat Creek, contains the largest acreage of currently enrolled CRP. However, only 0.86% of the Flat Creek Watershed is enrolled. The Griffen Ditch Watershed enrolls only 15.7 acres of land in the CRP. This is only 0.29% of the total land area in the watershed. The smallest watershed, Fleming Ditch, contains the least acreage of CRP participation at 14 acres. On the other hand, the Somers Creek Watershed currently lists 104 acres of CRP cropland. This is nearly 2.4% of its total watershed area.

TABLE 8. Acreages of land enrolled in the CRP by watershed.

Watershed	Acres	Hectares	**Percent of Watershed**	**HEL:CRP**
Flat Creek	140	57	0.86%	8.4:1
Subwatershed 1	85	35	0.01%	12.6:1
Subwatershed 2	23	9	0.01%	1.9:1
Subwatershed 3	11	5	0.00%	0
Subwatershed 4	0	0	0.00%	0
Subwatershed 5	46	19	0.01%	0.6:1
Griffen Ditch	16	6	0.29%	52:1
Fleming Ditch	14	5	0.93%	18:1
Somers Creek	104	42	2.39%	5:1
Total	**274**	**111**	**1.00%**	**10:1**

Source: Farm Service Agency of Wells and Huntington Counties.

The Flat and Somers Creek Watersheds have more CRP set-asides that overlap with HEL (Figure 7) than the Griffen or Fleming Ditch Watersheds. The ratio of HEL acreage to CRP acreage is least for the Somers Creek Watershed and then the Flat Creek Watershed (Table 8). When compared to its HEL acreage, Griffen Ditch has the lowest amount of land protection and treatment through the CRP (CRP:HEL = 50:1). For comparison, land protection in the Somers Creek Watershed is 10 times that in the Griffen Ditch Watershed. Flat Creek Subwatersheds 3 and 4 contain no CRP but also contain no HEL.

Within some areas of the study watersheds, CRP set-asides are situated on tracts that are designated highly erodible. Most of the CRP cropland in the Flat Creek Watershed is located within Subwatersheds 1 and 2, concentrated mainly to the south and north of Flat Creek (Figure 7). As noted earlier, most of the HEL in the Flat Creek Watershed is located in Subwatersheds 2 and 3. The CRP should be applied within the large area of HEL that borders Flat Creek in Subwatershed 3. Additionally, effective set-asides could be instituted within the HEL tracts that border Mud Creek in Subwatershed 2. Four hundred sixty-three acres of HEL exist at the headwaters of Griffen Ditch. These tracts, especially those that border the ditch, would be optimal sites for CRP enrollment. Treatment of HEL tracts with CRP status could also benefit areas within the Fleming Ditch Watershed. Most CRP cropland is located high in the Somers

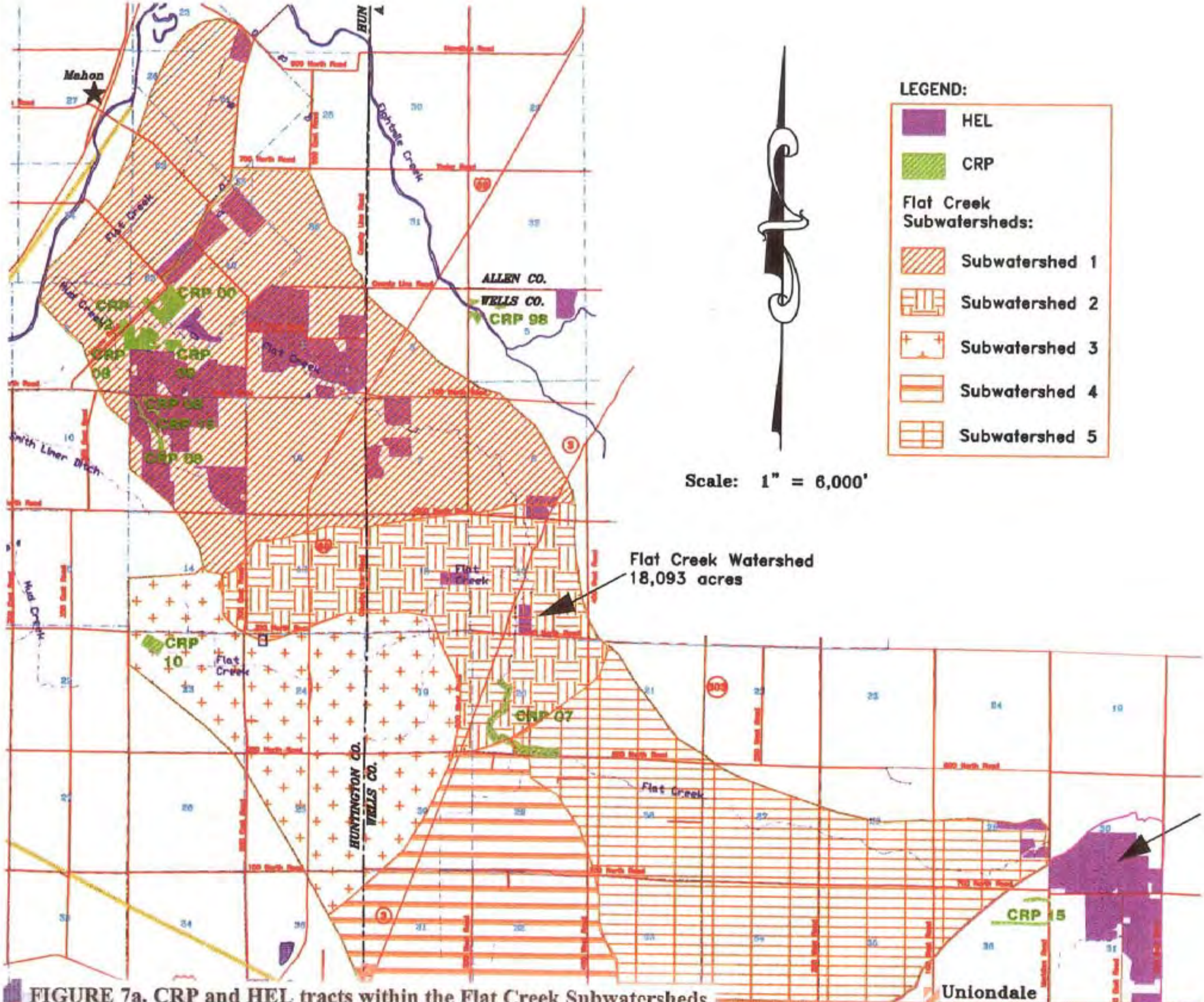


FIGURE 7a. CRP and HEL tracts within the Flat Creek Subwatersheds.

Source of Information: Wells County and Huntington County Farm Service Agencies

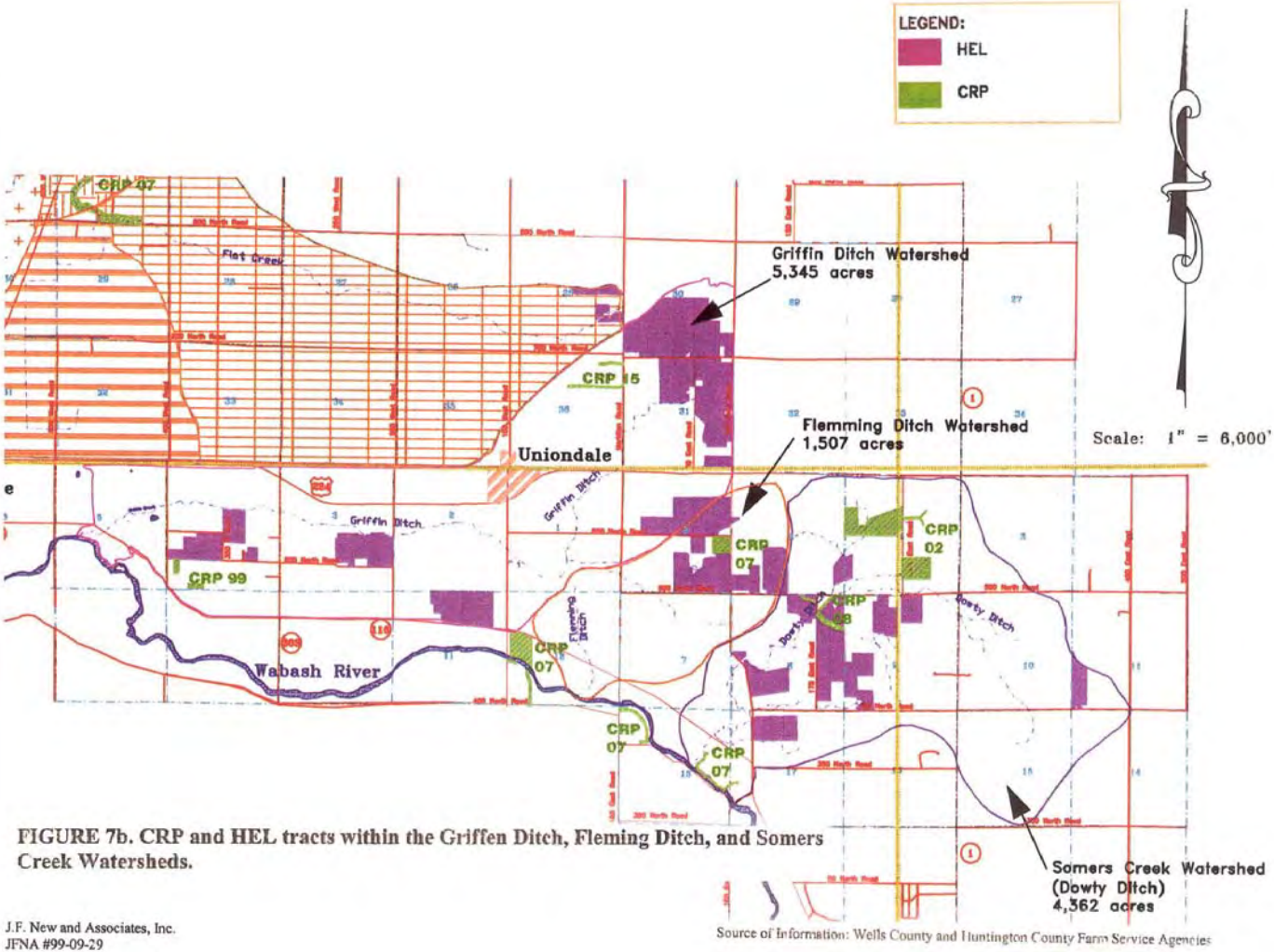


FIGURE 7b. CRP and HEL tracts within the Griffen Ditch, Fleming Ditch, and Somers Creek Watersheds.

Source of Information: Wells County and Huntington County Farm Service Agencies

Creek Watershed; however, added benefit is possible on HEL tracts further downstream closer to the Wabash River.

Conservation Practices

Continuous sign-up is permitted through the CRP for special high-priority conservation practices that lead to significant environmental benefits. These practices are specially designed to protect and enhance wildlife habitat, improve air quality, and improve waterway condition. These conservation practices and relevant research involving their use are discussed in more detail below.

Filter Strips

A filter strip is an area of grass or other permanent vegetation used to reduce sediment, organics, nutrients, pesticides, and other contaminants from runoff. Filter strips slow the velocity of water, allowing settling of suspended particles, infiltration of runoff, adsorption of pollutants on soil and plant surfaces, and uptake of soluble pollutants by plants. Slower runoff velocities and reduced flow volumes lead to decreased downstream erosion. A modeling study by Texas A&M University suggests that if filters were properly installed in all appropriate locations, sediment delivery to rivers and lakes could be reduced by two-thirds (National Conservation Buffer Council, 1999).

Typically, filter strips are planted on cropland at the lower edge of a field or adjacent to waterways. They are most effective when receiving shallow, uniform flow rather than concentrated runoff localized in channels or gullies. The Natural Resources Conservation Service (NRCS) recommends minimum filter strip widths based on intended purpose of the area (NRCS, 2000). The minimum flow length is set at 20 ft (6 m), but the minimum can be increased to 30 ft (9 m) based on sediment, particulate organic matter, and sediment-adsorbed contaminant loading in runoff. The average watershed slope above the filter strip must be greater than 0.5% but less than 10%. The NRCS standard is site-specific with plans and specifications required for each field site where a filter strip will be installed. It is important to keep in mind that effective filter strip width is also dependent on the amount of land draining into the filter. Ratios of the field drainage area to the filter area should be no greater than 50:1. Based on a survey of more than 2,700 CRP sites in the U.S., the ratio averaged approximately 3:1 (Leeds et al., 1993).

A wide variety of vegetation types have been used for planting filter strips. The ideal plant or combination of plants would be characterized as: native to Indiana, sod-forming, palatable as forage, somewhat cool season so as to grow early in spring when most runoff events occur, hardy, rapidly growing, tolerant of nutrient-poor conditions so as to not need fertilization, able to remain standing throughout the winter providing shelter for wildlife, and economical/affordable.

The use of plants native to Indiana is ecologically the most desirable alternative. (Please see the NRCS Conservation Practice Standard Code 393 for specifics and requirements regarding vegetation planting within filter strips where federal dollars were used for cost-share (NRCS, 2000).) Advantages of planting native vegetation include: 1.) native species possess extensive rooting structures that hold soil and reduce erosion (Figure 8 depicts rooting depths of several native grass species); 2.) many can be hayed for forage use; 3.) natives are hardy and able to

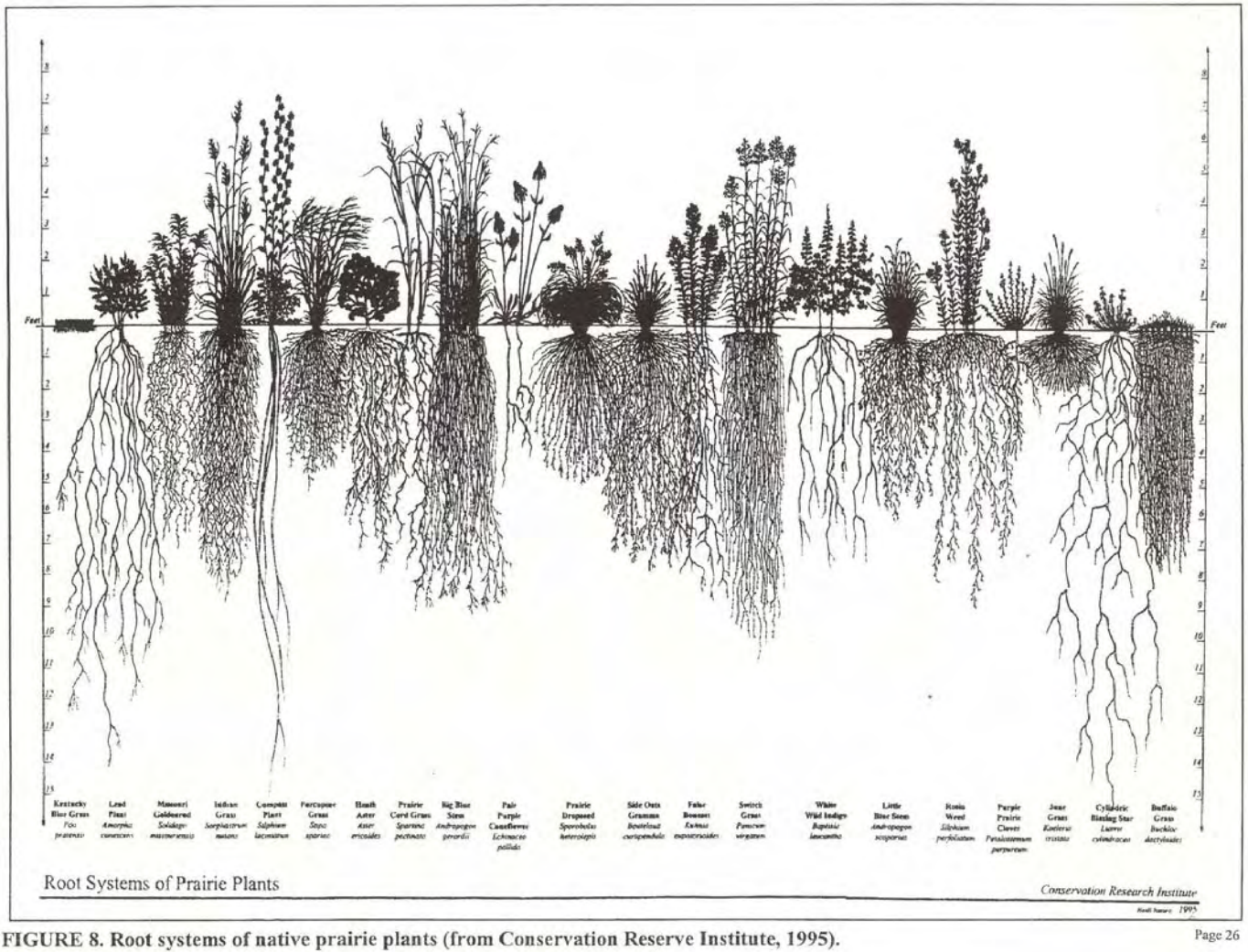


FIGURE 8. Root systems of native prairie plants (from Conservation Reserve Institute, 1995).

withstand various hydrologic regimes; 4.) low maintenance and cost over the long-run due to natural re-seeding processes and hardiness; 5.) low nutrient demand so as to not require costly fertilization which can further impair water quality; 6.) native plants provide wildlife habitat by remaining standing through the winter; 7.) native wildflowers are beautiful, and their seeds can be added to mixes for aesthetic value. Some disadvantages of establishing native herbaceous vegetation in filter strips also exist: 1.) most native grasses are warm season (except for red top and Virginia wildrye) and may not offer optimal nutrient uptake in early spring when many runoff events occur; 2.) some species have been reported to be difficult to establish and may take years for full stand development (Leeds et al., 1993); 3.) native wildflower plants and other forbs can be quite susceptible to herbicides used in crop production; 4.) many are quite expensive to produce (see tables below).

The following Tables 9-15 present lists of recommended native cool season grasses, legumes, and wildflowers. Information is also presented on species that are considered less than desirable as filter strip vegetation. Five different recommended mixes are provided along with seeding rates in lbs/acre and approximate costs according to the February of 2001 price listing of Sharp Bros. Seed Company of Missouri and the J.F. New Native Plant Nursery 2001 Wholesale Catalogue. Mixes should be chosen based on management application and available finances. Table 16 lists vegetation types that should not be used due to severe limitations. It is important to remember that a filter strip or conservation easement planted with any vegetation type is better than not having the easement at all. Even if optimal mixes are not chosen or applied, an individual's willingness to participate in a set-aside program will have positive effects for water quality.

It is also necessary here to caution landowners who receive federal and/or state monies for planting vegetation. Certain programs may require special seeding mixtures. For example, Conservation Reserve Program filter strips must be planted as per Tables 1 and 2 in the NRCS Conservation Practice Standard Code 393. The following eight tables give recommendations for landowners who may be purchasing their own seed or have received cost-share monies from programs that are more flexible with respect to seeding requirements.

TABLE 9. Recommended native cool season grass species and seeding rates (lbs/acre) for filter strip planting with price/lb per Sharp Bros. Seed Company of Missouri as of February, 2001.

Species	Seeding Rate	Price/lb
Red top	4 lbs/acre	$3.40
Virginia wildrye	4 lbs/acre	$6.90

* If seeding both together, use 2.5 lbs/acre of each.

TABLE 10. Recommended native legume species and seeding rates (lbs/acre) for filter strip planting with respective prices/lb.

Species	Seeding Rate	Price/lb
Roundhead lespedeza	0.25 lbs/acre	$98.00
Partridge pea	0.25 lbs/acre	$16.10
Illinois bundleflower	0.25 lbs/acre	$6.90
Purple prairie clover	0.25 lbs/acre	$23.00

* These forbes should be sown with native grass seed mixture.

TABLE 11. Recommended native wildflower species for filter strip planting with respective prices/lb.

Species	Price/lb
Black-eyed susan	$22.50
Lanceleaf coreopsis	$27.00
White prairie clover	$137.50
Ashy sunflower	$55.50
Pale purple coneflower	$108.90
Pitcher sage	$72.00
Compass plant	$99.00
Rosinweed	$74.25
Leadplant	$99.00
Purple coneflower	$29.70
Rattlesnake master	$99.00

* These native wildflowers can be seeded in small quantities (<0.25 lbs/acre) along with recommended seeding of native grasses.

TABLE 12. Optimal seed mix for filter strip seeding. This mix is considered optimal based on water quality and soil protection benefits, habitat management benefits, and economy/affordability. Six species are included plus a mix of wildflowers for a total seeding rate of 5.25 lbs/acre.

Species	Seeding Rate
Big bluestem	1.3 lbs/acre
Indiangrass	1.5 lbs/acre
Little bluestem	1.5 lbs/acre
Sideoats grama	0.5 lbs/acre
Switchgrass	0.2 lbs/acre
Mixed wildflowers	0.25 lbs/acre
TOTAL PRICE	**$64.25/acre**

* Virginia wildrye and red top can be seeded with the above mixture to increase cool season growth. Virginia wildrye should be seeded at 1 lb/acre and red top at 2 lbs/acre.

TABLE 13. Economy mix for filter strip seeding. This mix also offers native grass species at a more affordable cost. Only three species are included for a total seeding rate of 4.0 lbs/acre.

Species	Seeding Rate
Big bluestem	1.0 lbs/acre
Indiangrass	1.0 lbs/acre
Little bluestem	2.0 lbs/acre
TOTAL PRICE	**$49.90/acre**

* Virginia wildrye and red top can be seeded with the above mixture to increase cool season growth. Virginia wildrye should be seeded at 1 lb/acre and red top at 2 lbs/acre.

TABLE 14. Ultra economy mix for filter strip seeding. This mix offers only one native grass species at the most affordable cost. It is recommended that Virginia wildrye and red top be seeded with the switchgrass to increase species and habitat variety and to increase cool season growth in the filter strip.

Species	Seeding Rate
Switchgrass	5 lbs/acre
TOTAL PRICE	**$15-20 lbs/acre depending on variety selected**

TABLE 15. Wildlife habitat management seed mix for filter strip planting or for other areas where managing prairie-type habitat for wildlife is desirable. The total cost for 51.5 lbs for seeding of one acre is $450.00 (J.F. New Native Plant Nursery Wholesale Catalogue, 2001). The temporary grasses serve only to stabilize soils and provide habitat until the permanent, perennial grasses fully develop.

Species	Seeding Rate
Permanent Grasses	5 lbs/acre
Big bluestem	
Little bluestem	
Sideoats grama	
Virginia wildrye	
Switchgrass	
Temporary Grasses	44 lbs/acre
Seed oats	
Annual rye	
Timothy grass	
Native Forbs	2.5 lbs/acre
Butterfly milkweed	
New England aster	
Partridge pea	
Sand coreopsis	
Purple coneflower	
False sunflower	
Rough blazing star	
Wild lupine	
Yellow coneflower	
Black-eyed susan	

TABLE 16. Plant species that are generally not good candidates for use in filter strips and reasons for their unsuitability.

Species	Reason for Insuitability
Birdsfoot trefoil	poor rooting structure with little ability to stabilize soil
Smooth brome	poor rooting structure with little ability to stabilize soil
Fescue	poor rooting structure with little ability to stabilize soil
Japanese millet	poor rooting structure with little ability to stabilize soil
Orchardgrass	poor rooting structure with little ability to stabilize soil
Reed canarygrass	poor rooting structure with little ability to stabilize soil; invasive;

	excludes other more beneficial vegetation; no wildlife habitat benefit
Crownvetch	poor rooting structure with little ability to stabilize soil; invasive
Kentucky bluegrass	very shallow root system; invasive; excludes other more beneficial vegetation; no wildlife habitat benefits
Perennial rye	invasive; excludes other more beneficial vegetation
Red clover	poor rooting structure with little ability to stabilize soil; somewhat weedy and invasive
White clover	poor rooting structure with little ability to stabilize soil; somewhat weedy and invasive

Filter strip effectiveness has been the subject of voluminous recent research. Most research indicates that filter strips are effective at sediment removal from runoff with reductions ranging from 56-95% (Arora et al., 1996; Mickelson and Baker, 1993; Schmitt et al., 1999). Most of the reduction occurs within the first 15 feet (4.6 m). Smaller additional amounts are retained and infiltration is increased by increasing the width of the strip (Dillaha et al., 1989). Filter strips have been found to reduce sediment-bound nutrients like total phosphorus but to a lesser extent than they reduce sediment load itself. Phosphorus predominately associates with finer particles like silt and clay that remain suspended longer and are more likely to reach the strip's outfall (Hayes et al., 1984). Filter strips are least effective at reducing dissolved nutrient concentration like those of nitrate, dissolved phosphorus, atrazine, and alachlor, although reductions of up to 50% have been documented (Conservation Technology Information Center, 2000). Additionally, up to 60% of pathogens contained in runoff may be effectively removed. Computer modeling also indicates that over the long run (30 years), filter strips significantly reduce amounts of pollutants entering waterways.

Filter strip age is an additional factor of importance for effective function. Schmitt et al. (1999) found older grass plots (25 yr-old) to be more effective filters than recently planted ones (2 yr-old). A longer amount of time was required for runoff to reach the outfall of the older plots, suggesting that a strip's ability to slow runoff and filter pollutants increases with age.

Filter strips are effective in reducing sediment and nutrient runoff from feedlot or pasture areas as well. Olem and Flock (1990) report that buffer strips remove nearly 80% of the sediment, 84% of the nitrogen, and approximately 67% of the phosphorus from feedlot runoff. In addition, they found a 67% reduction in runoff volume. However, it is important to note that filter strips should be used as a component of an overall waste management system and not as a sole method of treatment.

Filter strips, like all conservation practices, require regular maintenance in order to remain effective. Maintenance consists of: 1.) inspection of the project frequently, especially after large storm events; 2.) repairing and reseeding of any areas where erosion channels develop; 3.) reseeding of bare areas; 4) mowing and removing hay to maintain moderate vegetation height while not mowing closer than 6 inches. To avoid destruction of wildlife nesting areas, delay mowing until after mid-July; 5.) controlling trees, brush, and noxious or invasive weeds within the filter; 6.) applying fertilizer and lime at rates suggested by regular soil testing.

Riparian Buffers

In many ways similar to filter strips, riparian buffers are streamside plantings of trees, shrubs, and grasses intended to intercept pollutants before they reach a river or stream. Although comparisons reveal that riparian buffers are no better than grassed strips at retaining nutrients and sediment, they offer shade and cover to the stream, thereby providing valuable fish and wildlife habitat (Daniels and Gilliam, 1996). Due to their deeper rooting systems, riparian buffers can filter both surface and subsurface runoff before it reaches the waterway. The rooting systems of riparian buffers can also serve to stabilize banks and soils especially along ditches that pass through mucky or easily erodible soil.

Riparian Management System Model

The Agroecology Issue Team of the Leopold Center for Sustainable Agriculture and the Iowa State University Agroforestry Research Team banded together in the early 1990s to promote restoration of the Bear Creek Watershed in central Iowa via development of a riparian management system model. Results of their study provide valuable lessons relative to management decisions and practices in the Flat, Griffen, Flemming, and Somers Creek Watersheds. The purpose of the study was to design a management system composed of several parts so that each part could be modified individually to meet site conditions and landowner objectives. Specific goals of the management system include: interception of eroding soil and agricultural chemicals, slowing of flood waters, stabilization of streambanks, and provision of wildlife habitat and an alternative, marketable product (Isenhart et al., 1997). The system model consists of a multispecies riparian buffer, streambank stabilization, a constructed wetland, and a rotational grazing strategy (Figure 9).

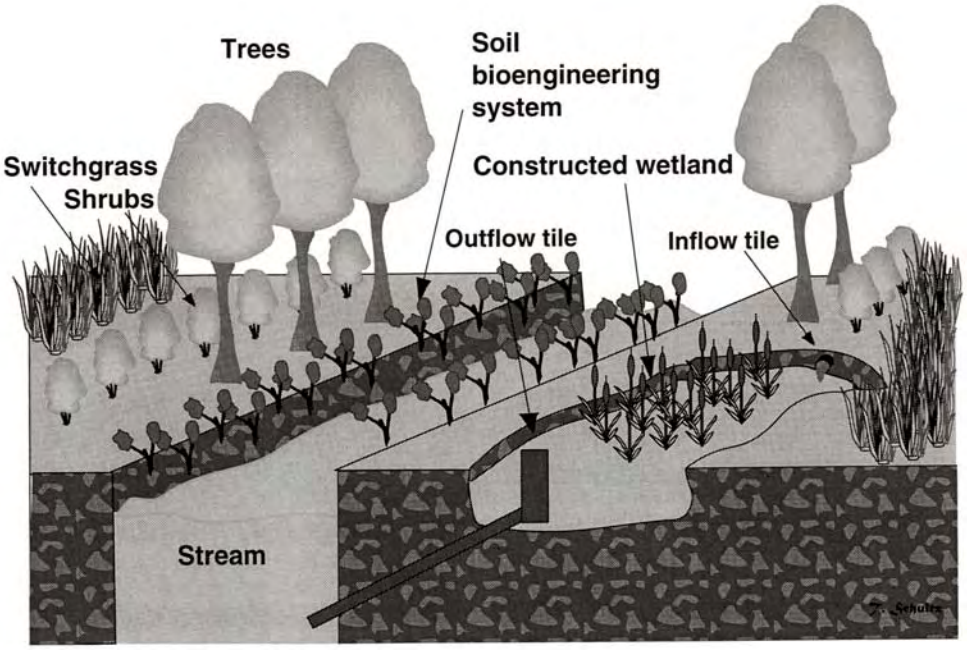


FIGURE 9. The riparian management system model (Isenhart et al., 1997). Used with permission from the American Fisheries Society.

The riparian buffer strip component consists of three zones (Figure 10): 1) A 33-foot-wide strip of trees bordering the stream. Fast-growing, native species like green ash, willow, poplar, and silver maple are recommended. Slower-growing trees like oaks and walnuts may be planted in the outer edge if desired. 2) A 12-foot-wide strip of shrubs. Shrubs, like trees, have permanent rooting structures and offer habitat diversity. Recommended species include ninebark, redosier and gray dogwood, chokeberry, witch hazel, nannyberry, and elderberry. 3) A 21-foot-wide strip of warm-season grasses. Species mixes were discussed in the filter strip section. Altogether the strip is 66 feet wide, but each component may be altered to address landscape requirements, desired buffer physical and/or biological functions, landowner objectives, and cost-share program standards. Appendix 4 includes before and after pictures of a riparian management system installation site in the Bear Creek Watershed.

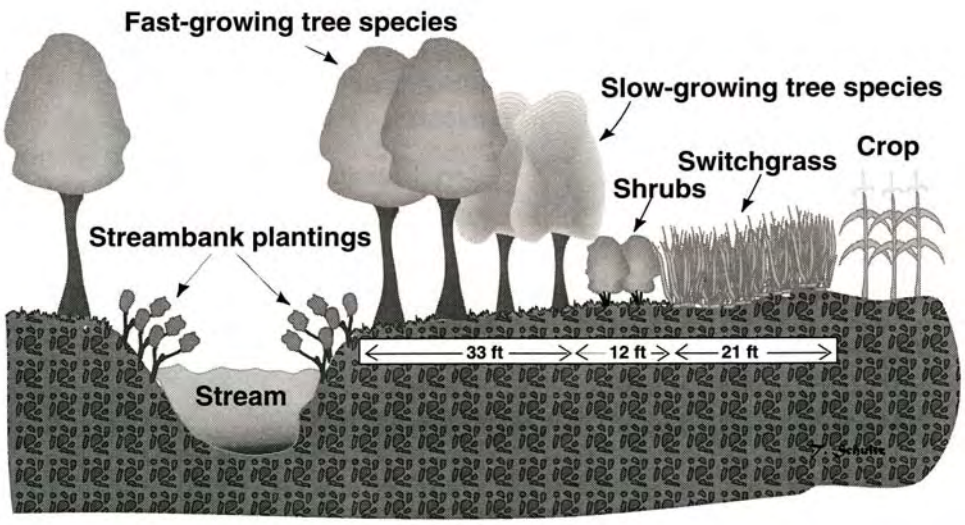


FIGURE 10. The multispecies riparian buffer strip component of the management system model. Used with permission from the American Fisheries Society.

Streambank stabilization using soil and vegetation bioengineering techniques is the second component of the comprehensive riparian management system model. Feasible techniques include installation of native, live plant material in combination with revetments of rock or wood and biodegradable erosion control fabric. According to Klingeman and Bradley (1976) bank vegetation provides a list of stabilization benefits: 1) plant roots hold soils together and in place; 2) above-ground vegetation increases surface flow resistance, decreasing flow velocities and routing energy dissipation toward plant material and away from soils; 3) vegetation buffers the channel from abrasion by materials transported from upstream; 4) vegetation induces sediment deposition, helping to keep soil on the land and to rebuild streambanks.

The final two components of the model include a constructed wetland designed to fit into the 66-foot buffer strip and a rotational grazing system to control livestock stream access. Constructed wetlands have a known track record for nitrate removal (via the process of denitrification) from surface water. In the Iowa study, water from a 12-acre field was tiled into a 2,900 ft^2 (<0.10 acre) wetland. A gated tile at the outlet of the structure provides control of water levels (Figure 9). Vegetation was planted in the wetland to jump-start nutrient uptake (See Appendix 4 for photo). Other studies suggest that a wetland area to cultivated crop area ratio of 1:100 will

provide the adequate water retention time during normal runoff events necessary to remove significant nitrate amounts. Table 17 includes recommended native plant species for created wetland planting.

TABLE 17. Plant species suitable for filtration and nutrient uptake in restored or created wetlands.

Grasses	**Forbs**
Redtop	Sweet flag
Creeping bent grass	Common water plantain
Spike rush	Cardinal flower
Common rush	Great blue lobelia
Rice cut grass	Monkey flower
Soft-stem bulrush	Arrow arum
Bur reed	Smartweed
Temporary Grasses	Pickerel weed
Seed oats	Broad-leaf arrowhead
Annual rye	

* Seed the permanent grasses at 3 lbs/acre, the temporary grasses at 42 lbs/acre, and the forbs at 2.75 lbs/acre.

An important part of any study, the Bear Creek project sites were monitored for success (Isenhart, et al., 1997). The monitoring studies indicated that the 21-foot-wide switchgrass component of the model reduced sediment load to the stream by 75%. Nitrate-nitrogen concentrations moving in groundwater below the buffer were markedly lower than those moving below the adjacent, cropped field. In contrast, groundwater nitrate concentrations in a field cultivated to the stream's edge showed no reduction nearer the stream. Wildlife use of the restored area was also markedly improved. While only four bird species per day were observed in channelized reaches, 18 species per day were recorded in 4-year-old buffer sections. Additionally, constructed wetland outflow concentrations of nitrate-nitrogen were significantly lower than inflow concentrations during most sampling periods.

The Iowa management system model provides valuable lessons for management within the Flat, Griffen, Flemming, and Somers Creek Watersheds. The approach is flexible for site-specific conditions and respectful of private landowners' desires and objectives. Within the Bear Creek Watershed, two relatively small sites were initially built and then used to garner the interest and support of other landowners. Similar management system models hold great promise for application within the study watersheds.

Field Borders

Field borders are 20-ft wide filter strips or bands of perennial vegetation planted at the edge of fields that can be used as turning areas for machinery. They also provide wildlife cover, protect water quality, and reduce sheet, rill, and gully erosion. Borders should be repaired and reseeded after storms and should be mown and harvested in the fall to encourage growth.

Shelterbelts/Windbreaks

Shelterbelts are rows of trees, shrubs, or other vegetation used to reduce wind erosion and protect crops while also providing protection for wildlife, livestock, houses, and other buildings. Similar

to shelterbelts, windbreaks or hedgerows are located along crop borders or within fields themselves. Air quality improvement and wildlife habitat provision are the greatest benefits of these vegetation belts.

Grassed Waterways

Grassed waterways are natural or constructed channels that are seeded with filter vegetation and shaped and graded to carry runoff at a non-erosive velocity to a stable outlet and vegetated filter. Vegetation in the waterway protects the topsoil from erosion and prevents gully formation, while providing cover for wildlife. The stable outlet is designed to slow and spread the flow of water and direct it towards the vegetated filter.

Grassed waterways are typically used where water tends to concentrate, like in draws, washouts, or other low-lying gully areas. They can also be used as outlets from other conservation practices (like terraces) or in any other situation where a stable outlet and vegetated filter can be built and maintained.

These vegetated filter systems may be trapezoidal or parabolic in shape, but should be broad and shallow in construction. They should be able to carry the runoff of a 10-year storm event. The stable outlet should be planted with perennial, sod-forming grasses to provide a dense filter. The vegetated filter below the outlet should be constructed as a typical filter strip would be.

Proper operation and maintenance is necessary for effective grassed waterway function. Tillage and crop row direction should be perpendicular to the waterway to allow drainage and to prevent water movement along edges. Machinery crossing areas should be stabilized to prevent damage to the waterway. Vegetation within the filter should be protected from direct herbicide applications. Certain species may be more tolerant of certain herbicide chemicals. It is also important to keep the strip and its outlet as wide as is possible. The waterway may need reconstruction from time to time to maintain proper shape.

Shallow Water Areas

Shallow water areas within or near farmland provide cover and a water source for wildlife while also acting as a filter. Embankments and berms that pond water increase the land's water storage capacity helping to reduce volumes and flow rates of runoff.

Wellhead Protection Area

Wellhead protection areas help assure the quality of public water supplies drawn from wells. Continuous CRP enrollment is available for land within a 2000-ft radius of a public well. Vegetation planted in these areas can further help prevent water supply contamination.

Conservation Tillage

Introduction

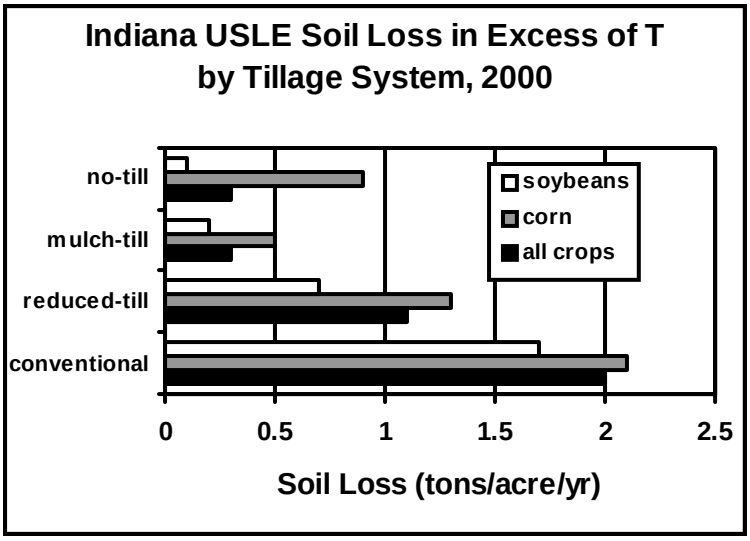
Removal of land from agricultural production may not be economically feasible in some cases. Conservation tillage offers the potential for reducing erosion without removing the land from production. Conservation tillage is a crop residue management system that leaves at least one-third of the soil covered with crop residue after planting. Table 18 offers description of the different tillage types. No-till, ridge-till, and mulch-till are all examples of conservation tillage.

A comprehensive comparison of tillage systems shows that no-till results in 70% less herbicide runoff, 93% less erosion, and 69% less water runoff volume when compared to conventional tillage (CTIC, 2000). Figure 11 illustrates calculations of soil loss with respect to the "tolerable" amount of soil that can be lost while still maintaining the productivity of the soil through natural formation processes. On average, all tillage methods exceed the T value for Indiana soils; however, soil loss is less using no-till and mulch tillage. Reductions in pesticide loading have also been reported (Olem and Flock, 1990). In his review of Indiana lakes, Jones (1996) documented lower TSI scores in ecoregions with higher percentages of conservation tillage. No-till practices are also good for wildlife. North Carolina researchers have found that crop residues provide the food that quail chicks need to survive the first few weeks of life. Additionally, conservation tillage reduces carbon dioxide emissions from the soil. Carbon dioxide, the most ubiquitous of the greenhouse gases, is being found at ever-increasing concentrations in the atmosphere and has been linked to global warming.

TABLE 18. Tillage type descriptions.

Type	**Description**	**% Remaining Residue**	**Conservation Tillage Type?**
No-till/strip-till	soil is undisturbed except for strips up to 1/3 of the row width	>30%	Yes
Ridge-till	4-6" ridges are formed on strips up to 1/3 of the row width	>30%	Yes
Mulch-till	full width of the row is tilled using only one or two tillage passes	>30%	Yes
Reduced-till	full width of the row is tilled using multiple tillage passes	15-30%	No
Conventional-till	full width of the row is tilled using multiple tillage passes	<15%	No

FIGURE 11. Indiana average USLE soil loss in tons/acre in excess of T by tillage system for 2000. USLE is the Universal Soil Loss Equation. Values shown are in excess of T, which is the "tolerable" amount of soil that can be lost while maintaining the productivity of the soil. Most Indiana soils have a T-value of 3-5 tons per acre per year.



Source: Clean Water Indiana Education Program, Purdue University.

Tillage Patterns in the Study Watersheds

While conservation tillage patterns were not estimated for the four study watersheds, they are in use throughout Wells County and on many fields within the watersheds. Table 19 shows conservation tillage usage patterns since 1990 for Wells County. In general, most cropland used to raise corn is conventionally tilled. The percentage of no-till fields used to grow soybeans is significantly higher at 66%. All (100%) of the fields planted in small grains utilized no-till practices in 2000 (Purdue Cooperative Extension Service, 2000). Wells County ranked 70th and 35th for percent of corn and soybeans, respectively, planted using a no-till system in 2000 (Evans et al., 2000).

TABLE 19. Percent (number) of crop fields with indicated tillage system since 1990 for Wells County. No 1990 data is available for small grain tillage.

Year	No-till	Ridge-till	Mulch-till	Reduced-till	Conventional-till
Corn					
1990	1 (1)	1 (1)	0 (0)	0 (0)	99 (155)
1995	18 (35)	0 (0)	2 (3)	0 (0)	80 (155)
2000	10 (20)	0 (0)	2 (4)	9 (17)	79 (154)
2001	8 (18)	0(0)	24 (51)	24 (51)	50 (107)
Soybeans					
1990	7 (15)	0 (1)	1 (2)	0 (0)	92 (205)
1995	67 (148)	0 (0)	2 (4)	0 (0)	32 (70)
2000	66 (168)	0 (0)	6 (16)	6 (15)	22 (57)
2001	68 (161)	0(0)	14 (33)	6 (13)	12 (29)

Small Grain					
1995	69 (24)*	69 (24)*	3 (1)	0 (0)	29 (10)
2000	100 (19)*	100 (19)*	0 (0)	0 (0)	0 (0)

* Data did not distinguish between no-till and ridge-till for small grains.
Source: Purdue Cooperative Extension Service, 2000.

In 2000, conservation tillage was used on 45% of Indiana's cropland. Even though Indiana is a no-till leader among cornbelt states, data suggest that few fields were no-tilled over the long term. Given that most research suggests that no-till benefits to soil begin to appear no earlier than the 3rd consecutive year of no-till, many farmers are abandoning no-till at about the time one would expect its benefits (Evans et al., 2000). Data from the Purdue Agronomy Research Center suggest that over the past 25 years, no-till used in a corn-soybean rotation economically outperformed conventional, mulch, and strip tillage systems (West et al., 1999). Producers should be encouraged to give no-till practices the continuous time necessary to reap yield, economic, and environmental benefits.

Nutrient Management

Management of nutrients applied in fertilizer can greatly benefit water quality. The first step in effective nutrient management is regular soil testing. Soils should be tested every three years, and according to Bill Horan of the Wells County Purdue Cooperative Extension agency, most cropland in Wells County is tested every 4-5 years (personal communication). Fertilizer should be applied based on realistic yield goals; however, most farmers in Wells County set maximum yield goals resulting in over-fertilization (Bill Horan, personal communication). Producers should also make allowances in nitrogen applications for N contributions of any previous legume crops in the rotation or any legume cover crops. Horan stated that most farmers in Wells County use a soy-corn or soy-wheat rotation and do account for legume N-addition in their fertilizer regimes. Fertilizer adjustment may also be necessary when transitioning from conventional to conservation tillage.

In special areas of environmental concern, such as fields which border streams and other waterbodies, fertilizer setbacks should be utilized. Setbacks are strips or borders where fertilizer is either not applied or applied in smaller quantities. Fertilizers should not be applied directly next to streams and certainly not in them. According to the Wells County Purdue Cooperative Extension Agency, some fertilizer setbacks are present, but are not as common as they should be. Producers near the Wabash River tend to be more conscientious with respect to fertilizer application (Bill Horan, personal communication).

Weed and Pest Management

Weed and pest management results in fewer herbicide and pesticide applications at reduced rates and thereby helps to protect the environment by reducing polluted runoff. Proper management entails: 1.) being familiar with the threshold at which weed and pest populations begin to cause economic damage; 2.) using local weather forecasting to time field scouting to determine if pest problems are great enough to warrant the use of a control measure; 3.) planting cover crops to suppress weed growth; 4.) planting seed that has been bred for pest resistance during optimal conditions; 5.) using insect traps near target crops to track infestations; 6.) promoting and attracting natural enemies that help control pests; 7.) applying the most effective and appropriate

pesticide or herbicide during optimal weather conditions. In general, producers in Wells County conduct insect scouting during times of the year when infestations of the European corn-borer and the bean-leaf beetle typically occur. Little insecticide is needed or used on most Wells County farms (Bill Horan, personal communication).

Resource Management Planning

Resource management planning is an individually-based natural resource problem solving and management process advocated by the NRCS (NRCS, 2001). It addresses economic, social, and ecological concerns to meet both public and private needs while emphasizing desired future conditions. NRCS personnel work directly with landowners to understand his or her objectives to ensure that all parties understand relevant resource problems and opportunities and the effects of decisions. The process has three phases and nine steps:

Phase I – Collect and Analyze

1. Identify Problems and Opportunities
2. Determine Objectives
3. Inventory Resources
4. Analyze Resource Data

Phase II – Decision Support

5. Formulate Alternatives
6. Evaluate Alternatives
7. Make Decisions

Phase III – Application and Evaluation

8. Implement the Plan
9. Evaluate the Plan

Though not widely used, Resource Management Plans have met with success in most areas. According to Doug Nusbaum, an agriculture conservation specialist with the Indiana Department of Natural Resources (IDNR) and the USDA, most if not all fields (including highly erodible ones) can be responsibly managed and used for production with the development of a Resource Management Plan.

BMP Summary

Agricultural BMPs are currently used in the Flat Creek, Griffen Ditch, Fleming Ditch, and Somers Creek Watersheds. The Somers Creek Watershed enrolls the most acreage in the CRP, while Griffen Ditch, due to relative lack of current CRP participation, should be targeted in future sign-up efforts. Although some cropland within the watersheds is treated using filter strips and grassed waterways, more participation should be sought and encouraged, particularly on highly erodible tracts that border waterways. Conservation tillage is readily used throughout the study watersheds, but farmers should be encouraged to stay with the minimum till practices longer than 2-3 years. The best way to protect against soil loss is to keep the soil covered, minimizing disturbance. As a result of conservation tillage used in combination with other BMPs, 75% of Indiana's cropland is losing soil at or below the tolerable level of T for the 2000 growing season (Evans et al., 2000). In fact, scientific evidence indicates that about 80% of environmental issues that result from cropland can be corrected by integrating BMPs into farm management (CTIC, 1999).

Chemistry and Macroinvertebrates

Local, state, and federal databases only contained records of data taken at two sites within the four study watersheds. Stacia Henderson and other volunteers working with the Wells County Soil and Water Conservation District monitored Griffen Ditch near Site 6 sampled during this study for water chemistry parameters and benthic macroinvertebrates (aquatic insects). The Indiana Department of Environmental Management (IDEM) Biological Studies Section sampled benthic macroinvertebrates in Flat Creek at its intersection with Mayne Road on July 31, 1991 and again on August 18, 1998. This site closely corresponds to Site 1 chosen for this study, and IDEM's results will be compared with results from this study in the Stream Sampling and Assessment Section.

Stream chemistry and macroinvertebrate results of the volunteer monitoring of Griffen Ditch are given in Tables 20 and 21. In general, Hoosier Riverwatch volunteers found the stream to be chemically conducive to warmwater aquatic life with dissolved oxygen levels between 7.6 and 17. Nutrient concentrations were somewhat elevated, but fecal coliform levels were near or below Indiana state standards for contact recreation. Please see the Stream Sampling and Assessment Section for a more detailed discussion of water chemistry parameters. Calculation of the Hoosier Riverwatch Pollution Tolerance Index (PTI), which is based on aquatic macroinvertebrate samples indicated that stream water quality varied from fair to excellent in Griffen Ditch. The PTI involves counting insects from four different pollution indicator groups, assigning points to each individual collected, and totaling the points to obtain a water quality index value. For example, stonefly nymphs are indicative of better water quality than blood midges and would receive a higher score.

TABLE 20. Historical Griffen Ditch stream chemistry data collected by the Hoosier Riverwatch Program near Site 6 sampled during this study.

Date	pH	Temp (^oC)	Turbidty (NTU)	D.O. (ppm)	NO_3^- (mg/l)	TP (mg/l)	Fecal Coliform (col/100ml)	Flow (cfs)
06/17/97	8.1	22.0	18.0	7.6[a]	*	0.36	*	*
10/16/97	7.8	8.0	20.0	11.7[a]	16.0	0.38	73.4	*
03/20/98	7.3	6.7	60.0	10.0	3.0	0.00	6	4.32
04/13/98	7.3	10.0	50.0	11.6	9.0	0.00	0	0.70
06/16/98	7.6	19.0	30.0	10.0	12.0	0.91	60	0.72
03/31/99	7.7	15.0	8.0	17.0	5.0	16.00	240	0.18

[a]Calculated from reported % saturation data
*Data not available

TABLE 21. Historical Griffen Ditch benthic macroinvertebrate data collected by the Hoosier Riverwatch Program near Site 6 sampled during this study. An X indicates the presence of each species during that sampling period.

Date	Stonefly Nymph	Mayfly Nymph	Dobsonfly Larvae	Riffle Beetle	Damselfly Nymph	Dragonfly Nymph	Leech	Blood Midge	Pollution Tolerance Index
6/17/97	X	X					X	X	Good
10/16/97		X	X	X	X	X	X	X	Excellent

4/13/98		X					X	X	Fair
6/16/98		X					X	X	Fair
3/31/99		X			X		X	X	Good

Macroinvertebrate assessments of Flat Creek resulted in scores of moderate impairment for Flat Creek on both sampling dates (Table 22). The mIBI score on both dates was only 3.4 of a possible 8. It is important to note that the mIBI is different in nature from the PTI employed by Hoosier Riverwatch volunteers. The mIBI requires organism identification to the family level and assignment of scores for each of the ten metrics listed in Table 22. It was developed by IDEM based on EPA's Rapid Bioassessment Protocol III and will be discussed in more detail in the Stream Sampling and Assessment Section.

TABLE 22. mIBI scores for Flat Creek at its intersection with Mayne Road as sampled by the IDEM Biological Studies Section on July 31, 1991 and August 18, 1998.

	Value	**Metric Score**
July 31, 1991		
HBI	5.38	2
No. Taxa (family)	11	4
No. Individuals	230	6
% Dominant Taxa	58.3	2
EPT Index	5	4
EPT Count	74	4
EPT Count/Total Count	0.32	4
EPT Abun./Chir. Abun.	0.55	0
Chironomid Count	134	2
No. Individuals /Square	230	6
mIBI Score		**3.4**
August 18, 1998		
HBI	4.57	4
No. Taxa (family)	11	4
No. Individuals	126	2
% Dominant Taxa	32.5	4
EPT Index	5	4
EPT Count	41	2
EPT Count/Total Count	0.33	4
EPT Abun./Chir. Abun.	1.24	2
Chironomid Count	33	4
No. Individuals /Square	126	4
mIBI Score		**3.4**

Fisheries Studies

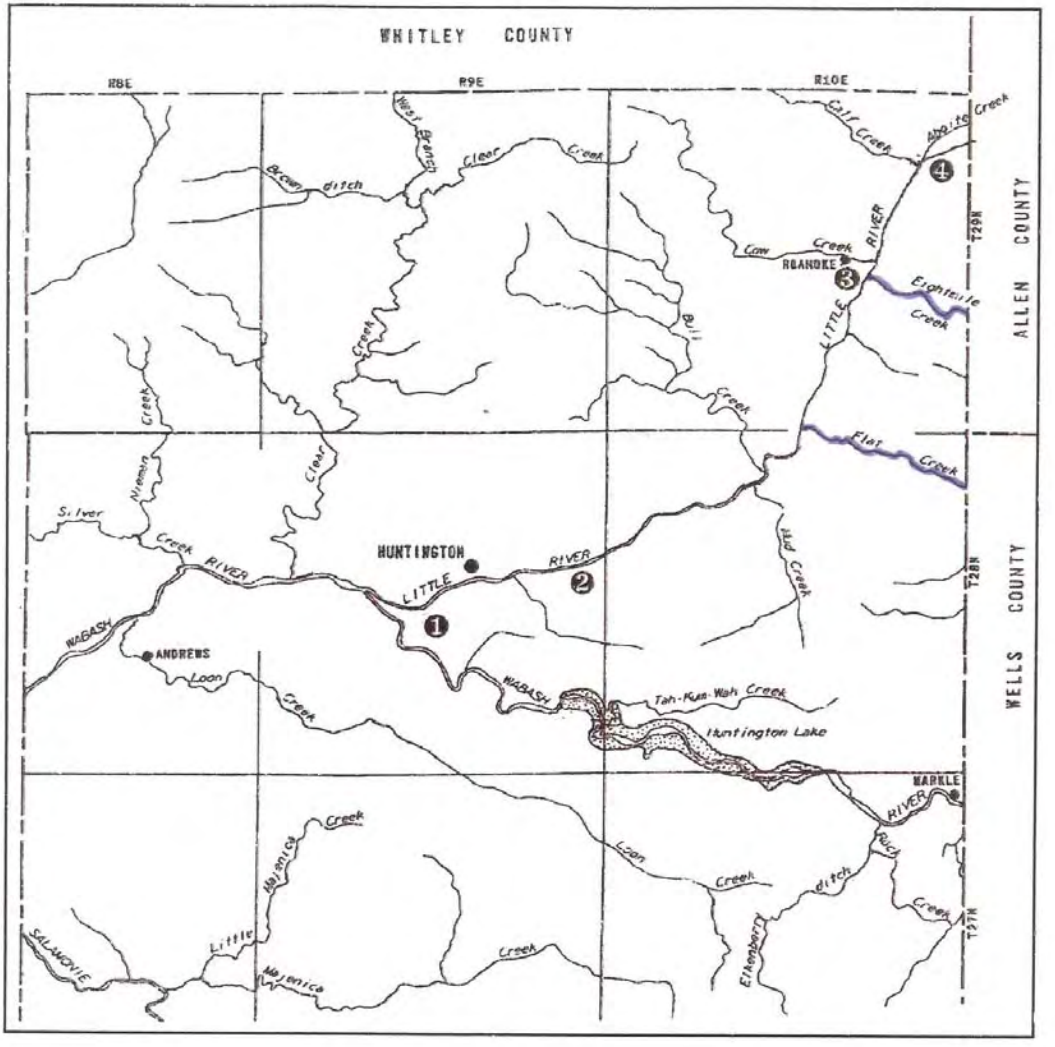
Introduction

No mussel or fisheries surveys have been conducted in the Flat Creek, Griffen Ditch, Fleming Ditch, or Somers Creek Watersheds by the Indiana Department of Natural Resources (IDNR), Indiana Department of Environmental Management (IDEM), or the U.S. Fish and Wildlife

Service (USFWS). However, the IDNR completed a fisheries survey on the Little Wabash River in Huntington County within the reach where Flat Creek joins the river (Braun, 1995). The USFWS also conducted a fish survey in September 1995 on Eightmile Creek, the reference stream used for this study (Simon, unpublished data).

IDNR Study

In June and August of 1994, fish sampling at four stations (Figure 12) was conducted using electrofishing gear on the Little Wabash River (Braun, 1995). Station locations were assigned using river mileage (RM). RM 1.55 and 3.52 were located near the town of Huntington where the Little Wabash converges with the Wabash River. RM 12.32 was at the confluence of Eightmile Creek with the Little Wabash River in Adams County about two miles upstream of where Flat Creek empties into the Little Wabash River. RM 14.7 was located further upstream. In addition, fish habitat at each station was scored using the Qualitative Habitat Evaluation Index (QHEI). Reaches that score above 60 are considered good habitat for fish. (See the Stream Sampling and Assessment Section for a more detailed explanation of the QHEI).



Scale: 1" = 2 miles

FIGURE 12. 1994 IDNR fisheries survey sampling locations on the Little Wabash River relative to the mouths of Flat Creek and Eightmile Creek (adapted from Braun, 1995).

J.F. New & Associates, Inc.
708 Roosevelt Road
P.O. Box 243
Walkerton, IN 46574
Phone: 219-586-3400
FAX: 219-586-3446
Permitting • Delineations • Mitigation Design • Biological Inventories
Wetland and Prairie Nursery • Lake and Stream Enhancement
Natural Systems for Wastewater Treatment

The June sampling resulted in the collection of 37 species of fish. Refer to Table 23 for a list of species present in the Little Wabash River in 1994. The white sucker was the most abundant species collected, accounting for a third of the total fish sampled. Thirteen species from the minnow family (*Cyprinidae*) were collected. Of these, the central stoneroller was the most abundant species sampled. Seven members of the sunfish family (*Centrarchidae*) were sampled.

TABLE 23. Fish species present at four sampling stations on the Little Wabash River during June and August of 1994 and at one sampling reach on Eightmile Creek in 1995.

Common Name	Scientific Name	Little Wabash RM 1.55	Little Wabash RM 3.52	Little Wabash RM 12.32	Little Wabash RM 14.7	Eightmile Creek
Bigeye shiner	*Notropis boops*			X		
Black crappie	*Pomoxis nigromaculatus*	X			X	
Blackside darter	*Percina maculata*		X			
Blackstripe topminnow	*Fundulus notatus*					
Black bullhead	*Ameiurus melas*				X	
Blacknose dace	*Rhinichthys atratulus*			X		
Bluegill	*Lepomis macrochirus*	X	X	X	X	X
Bluntnose minnow	*Pimephales notatus*	X	X	X	X	
Brassy minnow	*Hybognathus hankinsoni*	X				
Carp	*Cyprinus carpio*	X	X	X	X	X
Central mudminnow	*Umbra lima*		X	X	X	
Central stoneroller	*Campostoma anomalum*	X	X	X	X	X
Channel catfish	*Ictalurus punctatus*	X	X	X	X	X
Creek chub	*Semotilus atromaculatus*	X	X	X	X	X
Emerald Shiner	*Notropis atherinoides*	X				
Fantail darter	*Etheostoma flabellare*	X	X	X		
Fathead minnow	*Pimephales promelas*			X		
Flathead catfish	*Pylodictis olivaris*	X				
Freshwater drum	*Aplodinotus grunniens*	X				
Gizzard shad	*Dorosoma cepedianum*	X			X	
Golden redhorse	*Moxostoma erythrurum*	X	X	X	X	
Golden shiner	*Notemigonus crysoleucas*				X	
Green sunfish	*Lepomis cyanellus*	X	X	X	X	X
Greenside darter	*Etheostoma blennioides*	X	X	X		X
Johnny darter	*Etheostoma nigrum*	X	X	X	X	X
Largemouth bass	*Micropterus salmoides*		X	X	X	
Logperch	*Percina caprodes*	X	X	X		
Longear sunfish	*Lepomis megalotis*	X	X	X	X	X
Longnose gar	*Lepisosteus osseus*	X				
Mottled sculpin	*Cottus bairdi*	X	X	X		X
Norther hogsucker	*Hypentelium nigricans*	X	X	X	X	
Orangethroat darter	*Etheostoma spectabile*					X
Pumpkinseed	*Lepomis gibbosus*		X		X	X

Quillback	*Carpiodes cyprinus*	X				
Rainbow darter	*Etheostoma caeruleum*	X		X		
Redfin shiner	*Cyprinella lutrensis*		X			
River chub	*Nocomis microlophus*	X				
River redhorse	*Moxostoma carinatum*	X				
Rock bass	*Ambloplites rupestris*	X	X	X		
Sand Shiner	*Notropis ludibundus*	X	X	X		
Shorthead redhorse	*Moxostoma macrolepidotum*	X				
Silverjaw minnow	*Notropis baccatus*			X		
Silver redhorse	*Moxostoma anisurum*	X				
Silvery minnow	*Hybognathus nachalis*		X			
Smallmouth bass	*Micropterus dolomieu*	X				
Spotfin shiner	*Cyprinella spiloptera*	X		X		
Spotted bass	*Micropterus punctulatus*	X				
Spotted gar	*Lepisosteus oculatus*	X				
Steelcolor shiner	*Cyprinella whipplei*	X				
Spotted sucker	*Minytrema melanops*	X	X	X	X	
Stonecat	*Noturus flavus*	X				
Striped shiner	*Luxilus chrysocephalus*	X		X	X	
Suckermouth minnow	*Phenacobius mirabilis*	X	X	X		
Walleye	*Stizostedion vitreum*	X				
White bass	*Morone chrysops*	X				
White crappie	*Pomoxis annularis*			X	X	
White sucker	*Catostomus commersoni*	X	X	X	X	
Yellow bullhead	*Ameiurus natalis*	X	X	X		X
Yellow perch	*Perca flavescens*	X				X

The bluegill dominated the sunfish catch. Mottled sculpin, central mudminnows, channel catfish, gizzard shad, five species of darter, and freshwater drum were also collected.

In August, 49 species of fish were collected. Central stonerollers were the most abundant species collected, accounting for almost 34% of the total sample. Fourteen other species of cyprinids (minnows) were collected along with gizzard shad, eight centrarchids (sunfish), channel catfish, seven members of the perch family (*Percidae*), mottled sculpin, and central mudminnows.

The sample site at RM 1.55 contained 44 species when combining the June and August samples. Twelve intolerant or sensitive species of fish were sampled at RM 1.55. This is above average, indicating that water quality and habitat conditions were good. However, 12 species of fish that are considered highly tolerant to both water quality and habitat degradation were also sampled. Individuals of these 12 species accounted for over 50% of the total sample. This indicated that perhaps the conditions were only average.

The sample site at RM 3.52 contained 27 fish species when combining the June and August samples. Seven sensitive and eight tolerant species of fish were sampled at the site. This number is typical of a stream with average water and habitat quality. The overall stream condition at RM 3.52 was probably average.

The sample site at RM 12.32 contained 31 species collected in the June and August samples combined. This site contained eight sensitive and eight tolerant species indicating that this station also contained average water quality and habitat conditions.

The sample site at RM 14.7 contained 22 species of fish in the June and August samples combined. This sample site contained only three species of sensitive fish and eight tolerant species. The fish community indicated that water and habitat conditions were average to poor.

Overall, the Little Wabash River fishery sample indicated that the number of species present decreased as the stream size diminished, which is typical (Figure 13). The number of sensitive and tolerant species appeared to follow closely the trend indicated by the number of species per sample site (Figure 13). The number of sensitive and tolerant species remained closely related at each station indicating average water quality and habitat for fish.

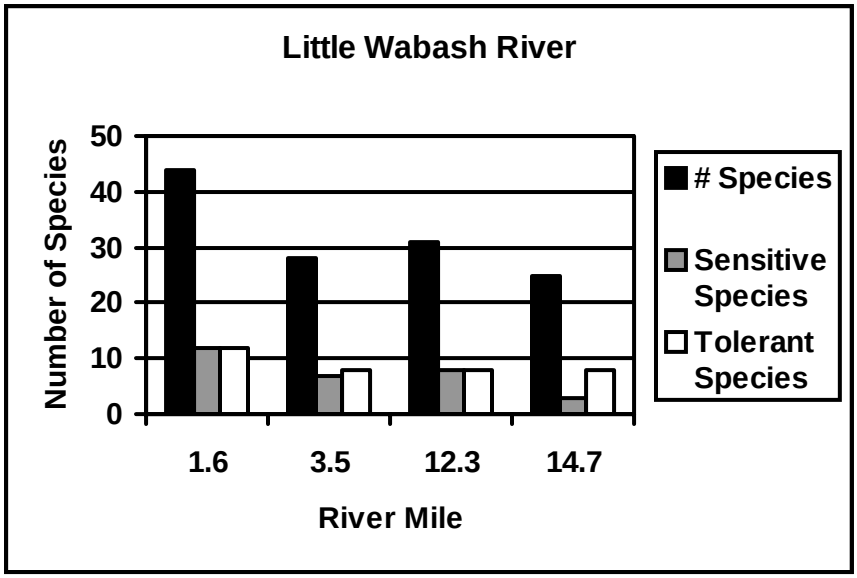


FIGURE 13. Number of species, sensitive species, and tolerant species at each river mile sampled during the 1994 fisheries sample.

QHEI scores for the Little Wabash River were variable. Figure 14 illustrates QHEI scores for each of the four sites. Since a score of 60 or above is considered good, all three lower stations were good for fish habitat. It is important to note that the report characterized the agricultural nature of the upper two stations. The Little Wabash River had been extensively altered in these areas, including dredging and straightening of the channel. The station at RM 14.7 scored low primarily due to its silt and muck substrate, which is unsuitable for most fish species. All other stations offered good fish habitat primarily due to a sand or rock substrate which is a more

suitable habitat for fish. However, the sand substrate at RM 12.3 was unstable enough that the location and depths of pools had changed between the June and August samples.

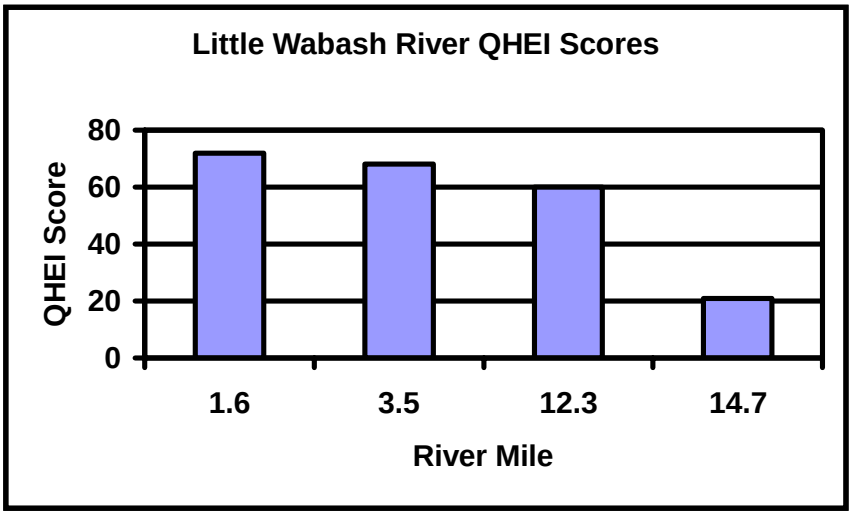


FIGURE 14. Little Wabash River QHEI scores by river mile as calculated by the IDNR in 1994.

Despite the relatively decent QHEI scores at the sampling locations, habitat alterations have impacted the river's fish community. Since Gerking (1945) collected smallmouth bass from the Little Wabash River in 1941, the species has all but disappeared from the river. Channel modifications in the river and its tributaries upstream of RM 3.5 including dredging, straightening, and debrushing have resulted in loss of habitat for smallmouth bass spawning and rearing of young. Dams near the city of Huntington prevent the migration of smallmouth upstream from the Wabash River to the Little Wabash. Smallmouth bass are likely extirpated from the river downstream of downtown Huntington.

The IDNR report recommends cooperation with the USDA to promote Best Management Practice (BMP) installation in the agricultural portions of the watershed. BMPs could help reduce erosion, siltation, and the need for further dredging and cleaning work.

USFWS Study

In 1995 the USFWS sampled Eightmile Creek, the reference stream used in this study (Table 23). The sample resulted in the collection 14 fish species representing six families. Creek chub and central stoneroller dominated the collection. An Index of Biotic Integrity (IBI) was calculated at this site. The IBI assesses biotic integrity or health by examining 12 attributes of fish communities in streams. The 12 attributes include characteristics like percent of pollution tolerant individuals present and numbers of diseased individuals present. Scores are given to each of the 12 metrics. These scores are totaled to obtain an IBI score with a highest possible score of 60. The IBI at the Eightmile Creek sample station was a 32. According to the IBI integrity classification, Eightmile Creek is a poor quality stream that is dominated by omnivores, tolerant fish, and habitat generalists. Poor quality streams support few top predators, and individuals often demonstrate depressed growth rates and disease.

Summary

Even though no fish community surveys have been conducted within the study watersheds, water quality and habitat near the confluence of Flat Creek with the Little Wabash were found to be average to poor. Eightmile Creek is most similar in size and character to Flat Creek; therefore, the poor quality fish community documented in Eightmile Creek is probably similar to that supported by Flat Creek. It is likely that the biological health of Griffen Ditch, Fleming Ditch, and Somers Creek is also similar. Due to waterway maintenance practices, erosion, and the lack of widespread BMP usage within the watersheds, habitat and water quality only support pioneer and pollution-tolerant fish species.

Natural Communities and ETR Species

The Indiana Natural Heritage Data Center database provides information on the presence of endangered, threatened, or rare species, high quality natural communities, and natural areas in Indiana. The database was developed to assist in documenting the presence of special species and significant natural areas and to serve as a tool for setting management priorities in areas where special species or habitats exist. The database relies on observations from individuals rather than systematic field surveys by the Indiana Department of Natural Resources (IDNR). Because of this, it does not document every occurrence of special species or habitat. At the same time, the listing of a species or natural area does not guarantee that the listed species is present or that the listed habitat is in pristine condition. To assist users, the database includes the date that the species or special habitat was last observed and reported in a specific location.

Results from the database search for the four study watersheds are presented in Appendix 5. (For additional reference, a listing of endangered, threatened, and rare species documented in Wells and Huntington Counties are included in Appendix 6). According to the database, neither the Flat Creek, Griffen Ditch, Fleming Ditch, nor Somers Creek Watersheds support any high quality community types. The great blue heron (*Ardea herodias*) was noted in 1987 in the reach of Flat Creek located in Section 8 of Township 28N, Range 11E. This heron is not state or federally listed, but is a species associated with more natural habitats.

WATERSHED STUDY

The watershed study is composed of two main components: the watershed investigation and the stream sampling and assessment. The watershed investigation entailed both an aerial tour and a windshield survey of the areas. The stream sampling and assessment involved: 1.) stream water quality sampling at nine sites and one reference site during baseflow and during stormwater runoff; 2.) a Qualitative Habitat Evaluation Index (QHEI) calculation for all ten sites; 3.) a macroinvertebrate Index of Biotic Integrity (mIBI) calculation for each stream sampling site.

Watershed Investigation

Introduction

Targeting areas of concern and selecting sites for future management are the goals of a visual watershed inspection. The four study watersheds were toured by airplane in April of 2000 and a windshield survey was conducted in late January of 2001. The results of and observations made during these two surveys are presented below.

Aerial Tour

The aerial tour consisted of flying over the watersheds at fairly low altitudes in order to photograph high priority and environmentally sensitive areas. Areas of concern with corresponding aerial photos (Figure 15) are presented by watershed for each of the four study watersheds in Tables 24-26. Aerial photo locations are shown on Figures 16a and b. The circles on the figures indicate areas where best management practice implementation may benefit water quality based on information collected during the aerial tour.

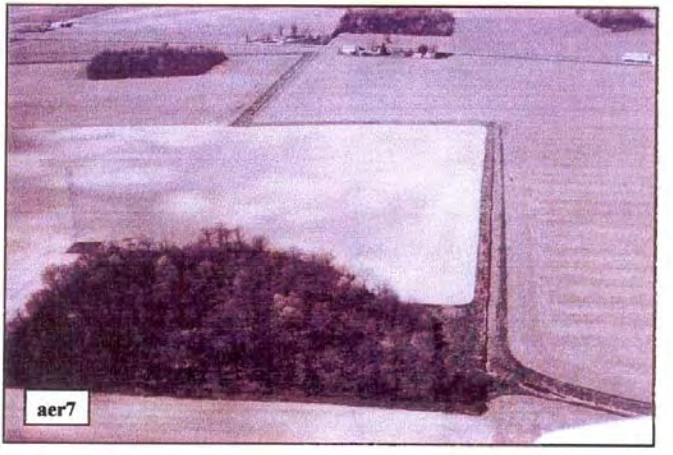
Flat Creek Watershed. Figure 15 contains aerial photographs showing impairment within the Flat Creek Watershed. Table 24 lists locations of the impaired areas in the photos and the causes of impairment. Exact photo locations are mapped on Figure 16a. An analysis of the photos points out that Flat Creek suffers from straightening or dredging projects. The lack of natural stream meandering and increased flow volumes and velocities from drained land have led to bank erosion problems. Filter strip installation would benefit water quality in most of the areas shown in photos aer1-9. An additional concern is the area demarcated in aer6. According to Farm Service Agency (FSA) tracking, this area is currently enrolled in the Conservation Reserve Program (CRP); however, little evidence of Best Management Practice (BMP) installation is evident along the northern reach of this area.

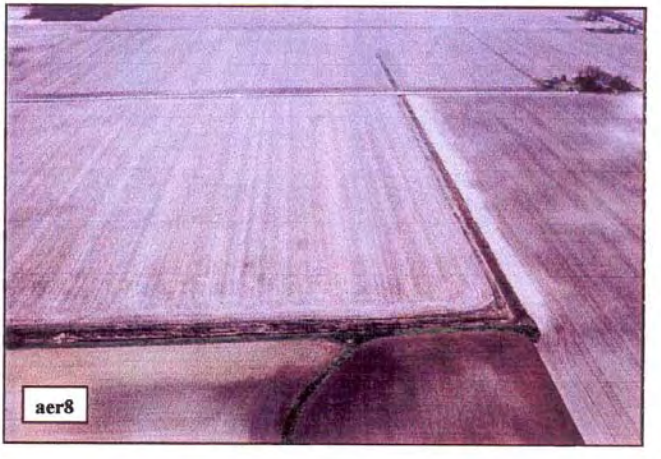
FIGURE 15. Aerial tour photos. Photos are labeled aer1-20.

aer4

aer5

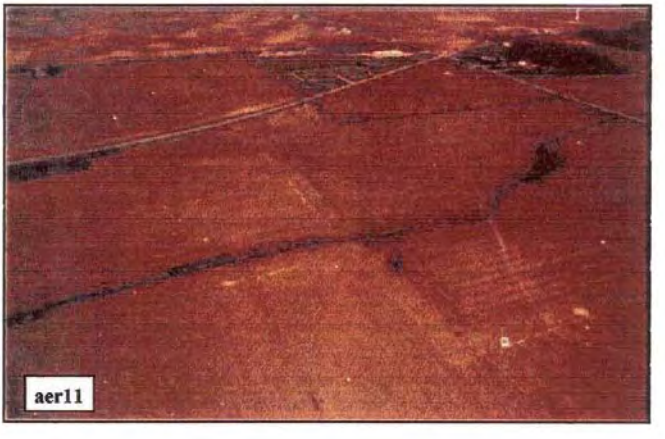
aer6


aer7


aer8

aer9

aer10


aer11

aer12

aer13

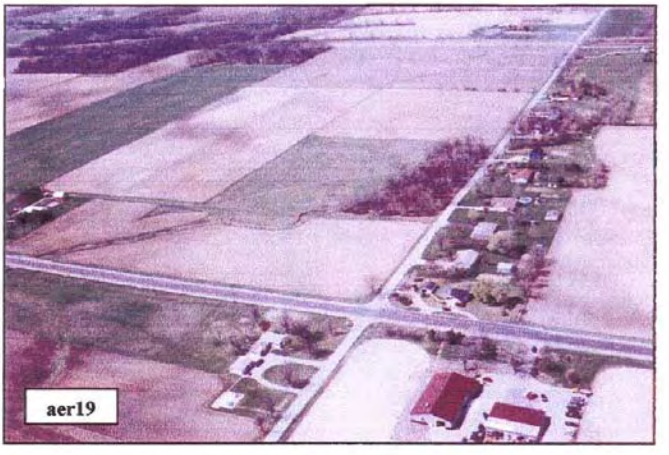
aer14

aer15

aer16

aer17

aer18


aer19

aer20

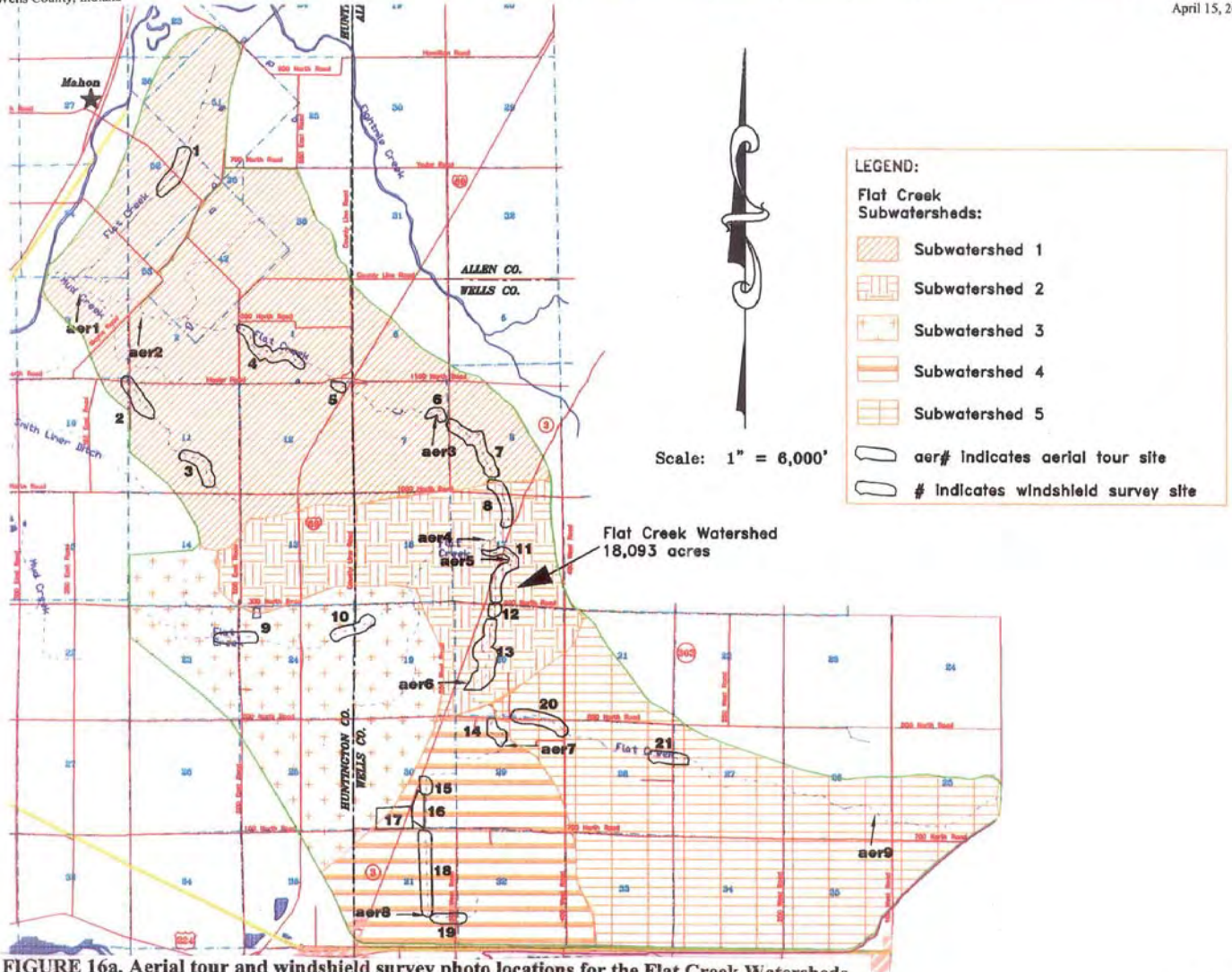


FIGURE 16a. Aerial tour and windshield survey photo locations for the Flat Creek Watersheds.

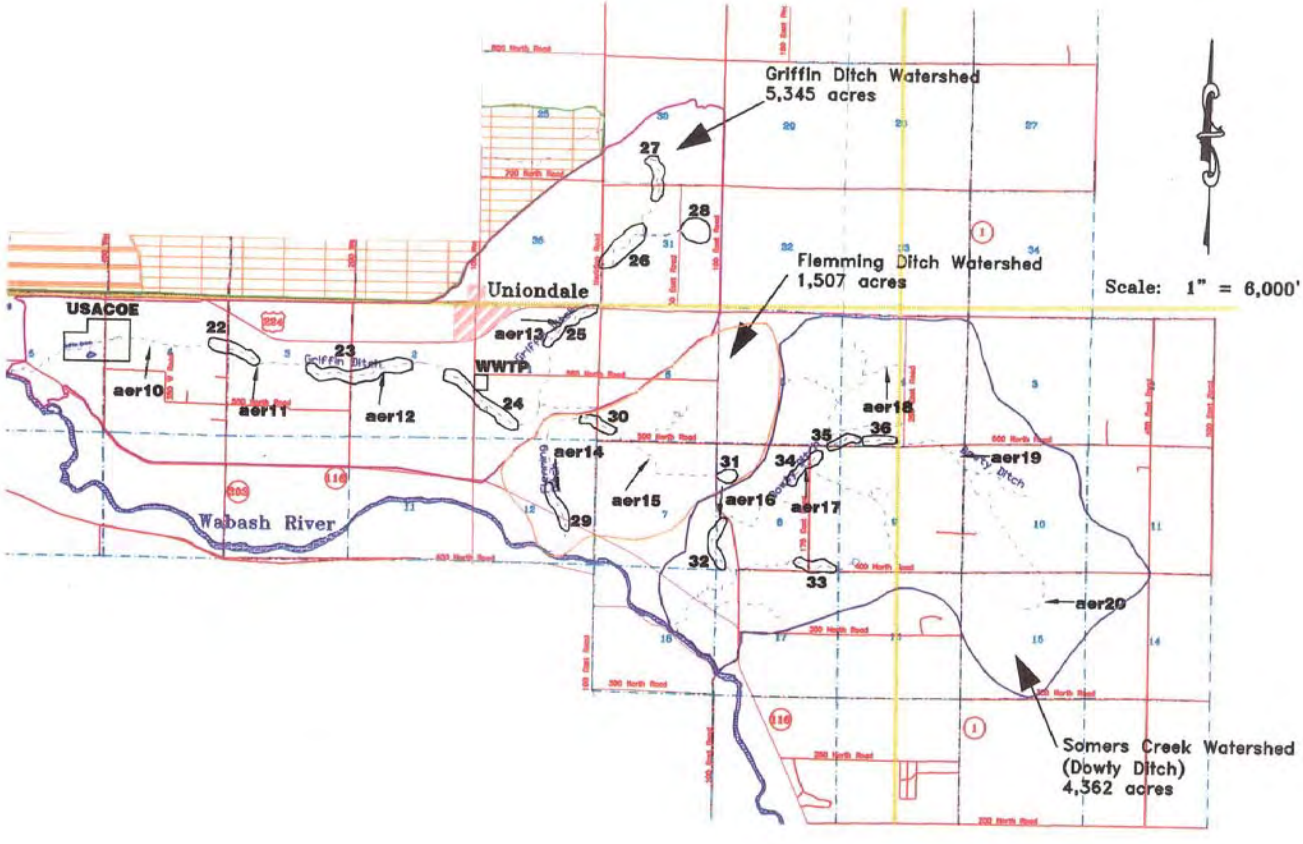


FIGURE 16b. Aerial tour and windshield survey photo locations for the Griffen Ditch, Fleming Ditch, and Somers Creek Watersheds.

TABLE 24. List of locations of areas of concern photographed during the aerial tour and their corresponding cause of impairment for the Flat Creek Watershed. Possible practices that could be used to address the impairment are listed as well.

Subwatershed(s)	Photo	Location	Cause	Practice
1	aer1	facing north; west of intersection of Mayne Rd. and 400 E	eroding banks; farming near edge of stream	bank stabilization;filter strip
1	aer2	facing north; at intersection of Flat Creek with Mayne Rd.	eroding banks	bank stabilization
1	aer3	facing north-northeast; southwest of 1100 N intersection with 500 W	farming near edge of stream; possible animal wastes entering stream	filter strip; water control structure
2	aer4	facing east from subwatershed 4 looking at branches of 3 (on left) and 5 (on right); SR 3 is in back of picture; southeast of 1000 N intersection with 500 W	farming near edge of stream	filter strip
2	aer5	facing east; SR 3 is in middle of picture; southeast of 1000 N intersection with 500 W	farming near edge of stream	filter strip
2	aer6	facing east; SR 3 is in bottom of picture; southeast of 900 N intersection with SR 3	eroding banks; farming near edge of stream	bank stabilization;filter strip
5	aer7	facing west; SR 3 is in top of picture; southwest of 800 N intersection with 400 W	farming near edge of stream	filter strip
4	aer8	facing east; north of 500 W intersection with 100 W	eroding banks; farming near edge of stream	bank stabilization;filter strip
5*	aer9	facing north; headwaters; northwest of 700 N intersection with 100 W	farming near edge of stream	filter strip

* representative photo of all the area adjacent to Flat Creek west through Section 28.

Griffen Ditch Watershed. The aerial tour also located some areas of concern within the Griffen Ditch Watershed (Table 25 and Figure 15). Causes of impairment and possible BMPS that could be implemented to address the concerns are similar to those identified for the Flat Creek Watershed.

TABLE 25. List of locations of photos, their corresponding cause of impairment, and acceptable BMPs for areas of concern in the Griffen Ditch Watershed.

Photo	Location	Cause	Practice
aer10	facing north; north of 500 N intersection with 400 W	farming near edge of stream	filter strip
aer11	facing north; SR 224 in top of picture; south of SR 224 intersection with 300 W	farming near edge of stream	filter strip
aer12*	facing north; east of SR 224 intersection with 200 W	farming near edge of stream	filter strip
aer13	facing east; southeast of SR 224 intersection with Meridian	eroding banks; farming near edge of stream	bank stabilization;filter strip

* representative photo of the area adjacent to Griffen Ditch east through Section 1.

Fleming Ditch Watershed. Several areas in the Fleming Ditch Watershed could be targeted for BMP implementation based on photos from the aerial tour. Aer14 (Figure 15) is a representative photo of several reaches along Fleming Ditch. (Aer14 was taken facing south showing SR 116 crossing Fleming Ditch as it flows south to the Wabash River.) Again, bank erosion due to artificial channelization and lack of filter strips or riparian set-aside zones contribute to water quality degradation and soil loss. Aer15 (taken facing northeast of 500 N east of Meridian Road) shows similar bank erosion and a need for filter strips on highly erodible land.

Somers Creek Watershed. The Somers Creek Watershed is noticeably different in terms of rural development within the watershed (Figure 15; aer16-20). Due to its location on the clay-rich toe of the Wabash Moraine and the relatively higher concentration of septic systems, this development has definite implications for nutrient and bacteria loading to the waterways. Like the other three study watersheds, erosion and crop planting near the stream's edge are factors for the Somers Creek Watersheds as well (Table 26). Some critical areas identified by the aerial tour are classified as HEL. Aer17 is mapped as HEL and is currently not enrolled in the CRP. Aer18 is also HEL and according to the FSA, does participate in the CRP; however, little evidence of BMP implementation exists on these tracts.

TABLE 26. List of locations of photos, their corresponding cause of impairment, and acceptable BMPs for areas of concern in the Somers Creek Watershed.

Photo	Location	Cause	Practice
aer16*†	facing south; on 100 E about ½ mile south of 500 N	farming near edge of stream	filter strip
aer17*†	facing north; southwest of 500 N and 175 E	farming near edge of stream	filter strip
aer18*#	facing north; at headwaters; southwest of SR 224 intersection with 250 E	farming near edge of stream	filter strip
aer19*	facing west; intersection of SR 1 with 500 N	eroding banks	bank stabilization
aer20	facing west; southeast of intersection of 400 N with SR 1	eroding banks; farming near edge of stream	bank stabilization;filter strip

* note that the amount of rural development is greater in this area than in any of the other watersheds.
† denotes land that is highly erodible and not enrolled in the CRP.
# denotes land that is highly erodible and also enrolled in the CRP.

Windshield Tour

The windshield survey entailed driving the watersheds and assessing the streams where they crossed or were located adjacent to roads. Particular areas of concern were examined more closely by stopping and walking areas within public right-of-way. Results are reviewed by watershed and listed by site number in Tables 27-30. Site locations are displayed in Figures 16a and b. The circles on Figures 16a and b indicate areas where best management practice implementation may benefit water quality based on information collected during the windshield survey. The tables also list any corresponding photos that were taken of the site while on the tour. Photos appear in Figure 17.

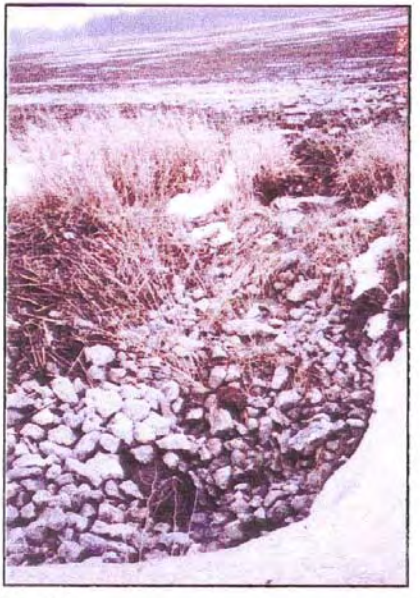
Site 9

Site 17

FIGURE 17. Windshield survey photos.

Site 23

Site 30



Site 31

Flat Creek Watershed. The windshield survey in the Flat Creek Watershed revealed many of the same problems documented in the aerial photographs. Additional areas for treatment were identified (Table 27; Figure 16a). BMPs that slow erosion processes like filter strips, grassed waterways, and wascobs would benefit water quality in many of the marked areas. Even though Site 2 is in the CRP, field observation points out that existing filter strips need to be widened. Sites 2, 3, 4, 5, 8, and 11 should be targeted for BMPs due to their proximity both to the creek and to HEL. Both the aerial and windshield tours documented a feeding operation (aer3; Site 6) within Subwatershed 3. Although the animals do not appear to have direct access to the stream, they are kept in a low-lying wet area that is connected to Flat Creek. A water control structure could be installed to prevent animal waste from entering the stream. The photo of Site 9 (Figure 17) documents the typical lack of filter strips throughout the watershed. Site 13 (also documented in aer6) is enrolled in the CRP until 2007, but no BMPs appear to be implemented in certain sections of the property.

TABLE 27. List of sites and corresponding BMPs compiled during the windshield survey portion of the watershed investigation of Flat Creek.

Subwatershed	Site	Recommended BMP
1	1	widen existing filter strips
1	2	widen existing filter strips
1	3	filter strips
1	4	structure - wascob
1	5	filter strips
1	6	water control structure to prevent animal waste from entering wetland which drains to Flat Creek
1	7	filter strips
2	8	erosion control; bank stabilization
3	9	filter strips (see Figure 17, Site 9 for photo)
3	10	filter strips; bank stabilization
2	11	filter strips; bank stabilization
2	12	filter strips
2	13	filter strips
4	14	widen existing filter strips
4	15	filter strips
4	16	grassed waterway
4	17	grassed waterway to filter water that currently drains across an eroded gully directly into a box culvert (see Figure 17, Site 17 for photo)
4	18	filter strips
4	19	filter strips
5	20	filter strips
5	21	filter strips

Griffen Ditch Watershed. Combinations of filter strips and structure installation could help to reduce soil loss within the Griffen Ditch Watershed (Table 28). In-stream structures like rock shoots and drop structures are effective for slowing bed and bank erosion. Sites 23, 27, and 28 should be prioritized because they encompass areas where highly erodible land borders the ditch.

The Uniondale Wastewater Treatment Plant (WWTP) is located at the corner of 550 N and 100 W. It is important to note however, that because of the WWTP proximity to the stream, heavy rainfalls may result in passage of untreated sewage through the plant if it is unable to handle the load. This untreated sewage may have negative impacts on Griffen Ditch. A tract near the Wabash River (see Figure 16b) is owned by the U.S. Army Corps of Engineers (USACOE). Sediment traps and/or constructed wetlands built in this area could help to remove sediment, nutrients, and other pollutants before they enter the Wabash River.

TABLE 28. List of sites and corresponding BMPs compiled during the windshield survey portion of the watershed investigation of Griffen Ditch.

Site	Recommended BMP
22	structure – grade control; filter strip
23	filter strips (see Figure 17, Site 23 for photo)
24	filter strips
25	structure; filter strips
26	structure; filter strips
27	filter strips
28	grassed waterway or other type of filtration at headwaters
USACOE	possibility for sediment traps and/or constructed wetlands

Fleming Ditch Watershed. BMP implementation could also benefit the Fleming Ditch Watershed (Table 29). Typical filter strips are needed at two sites, while a grassed waterway treatment at the headwaters of the ditch could benefit both soil and water quality. As the photo of Site 31 shows, water entering the ditch from the field east of 100 E is cutting a gully into the field. A grassed waterway would stabilize this soil and increase infiltration potential, preventing further erosion and downcutting.

TABLE 29. Lists of sites and corresponding BMPs compiled during the windshield survey portion of the watershed investigation of Fleming Ditch.

Site	Recommended BMP
29	filter strips
30	filter strips (see Figure 17, Site 30 for photo)
31	grassed waterway at headwaters (see Figure 17, Site 31 for photo); filter strip

Somers Creek Watershed. Somers Creek suffers mainly from bank erosion and impacts of new rural development. Water drained from agricultural land forces the relatively small creek to carry greater volumes of water at higher velocities than during times when the landscape held more water in swamp and bog areas. These large flows continue to sheer banks, destabilize soil, and down-cut the stream in its channel. Grade control structures and bank stabilization could help to reduce these forces (Table 30). As already mentioned, Somers Creek Watershed is more developed than the other three study watersheds. In the area around Site 35, several pipes emptying directly into the creek were noted. Water should be routed from houses to the proper treatment facility: 1.) stormwater drainage from houses and other impervious surfaces should be routed in an even sheet flow to a grassy area, grass swale, or infiltration trench; 2.) sump water should be allowed contact with soil and vegetation to allow infiltration before it reaches the

creek; 3.) household wastewater should be routed to the proper treatment system and should never be deposited directly into the stream.

TABLE 30. List of sites and corresponding BMPs compiled during the windshield survey portion of the watershed investigation of Somers Creek.

Site	Recommended BMP
32	filter strips; bank stabilization
33	bank stabilization; grade control structures
34	bank stabilization
35	route stormwater/sump pump water over grassed area; route gray water to proper treatment system

Watershed Investigation Conclusion

The goal of the watershed investigation was to target areas of concern and select sites for future management. The aerial tour pointed out that all four streams have been heavily impacted by channelization and dredging projects. The already unstable banks coupled with crop production all the way up to the ditch edge has led to and will continue to cause excessive erosion of soil off of the land and into the waterways. This siltation then requires costly drainage projects. Both the erosion and the dredging projects also wreak havoc on the biota in, around, and downstream of the location. According to the aerial tour photos, many sites within the four watersheds can be treated with combinations of filter strips and bank stabilization projects. The aerial tour also revealed several areas where land enrolled in CRP shows little or no evidence of actual BMP installation or program participation. This is of concern and should warrant further investigation. The relatively high density of new rural development within the Somers Creek Watershed was also evident from the air. Increased building in soils that are not suited for on-site waterwater treatment will continue to have definite implications for water quality and public health. The windshield survey pin-pointed the locations of some smaller, more localized problems like a feeding operation, some grassed waterway, wascob, and in-stream structure needs, and potential WWTP impacts.

By overlaying the results of mapping exercises and locations targeted by the watershed investigation, several areas within each watershed deserve prioritization and special consideration. Within the Flat Creek Watershed, Sites 2, 4, 8, and 11 should be prioritized due to their location on highly erodible soils. Problems were also noted for Sites 23 and 27 within the Griffen Ditch Watershed, aer15 within the Fleming Ditch Watershed, and Sites 34 and 35 within the Somers Creek watershed. These projects should take priority over projects on land of lower erosion potential.

Stream Sampling and Assessment

Introduction

The stream assessment portion of the watershed study consisted of water chemistry sampling during base flow and during a storm runoff event, a macroinvertebrate community assessment, and a habitat assessment. Sampling was conducted at nine sites in the four watersheds and at one reference site in the Eightmile Creek Watershed (Figures 18a and b). The stream assessment study provides information that can be analyzed to determine water quality and aquatic habitat

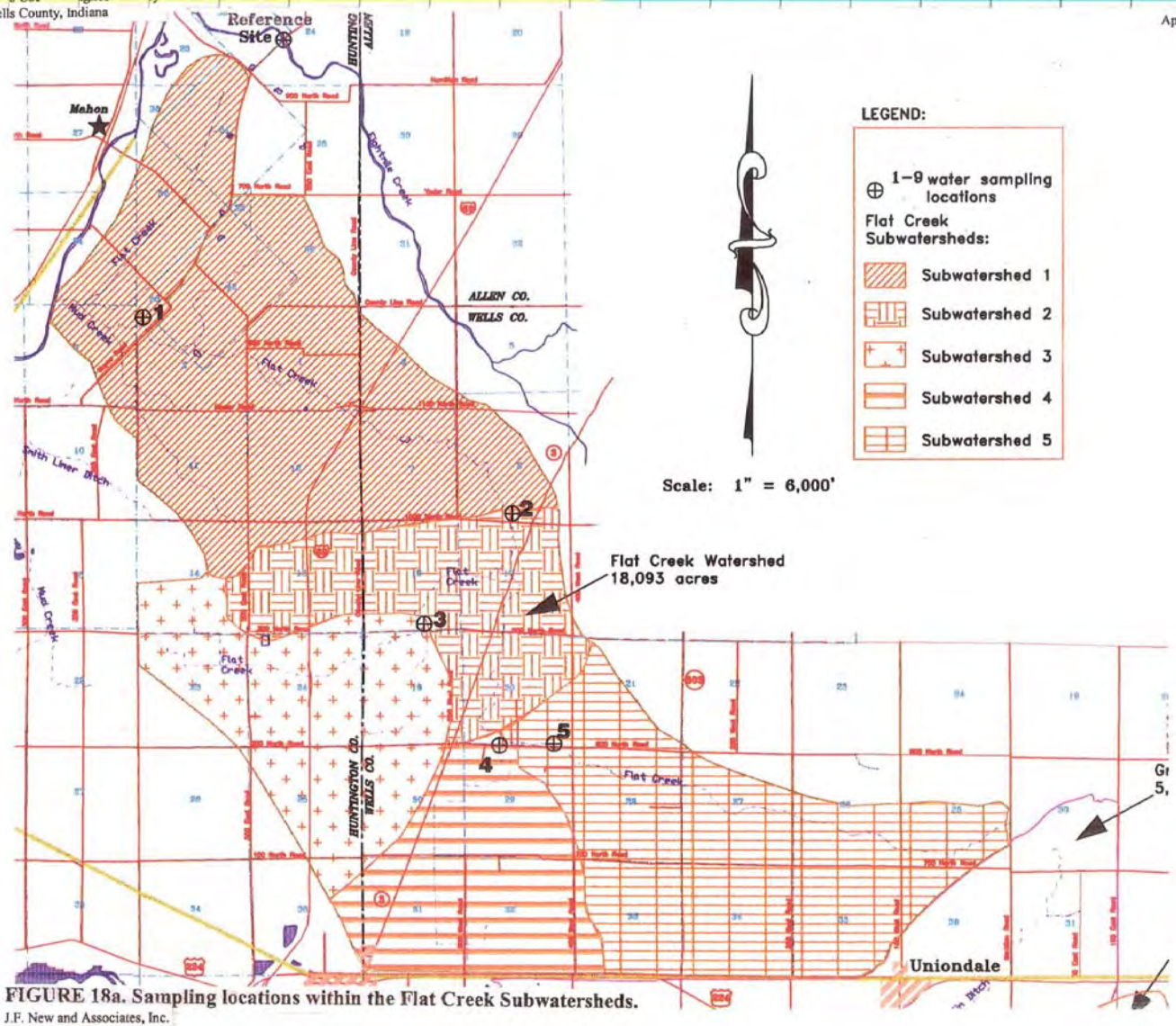


FIGURE 18a. Sampling locations within the Flat Creek Subwatersheds.

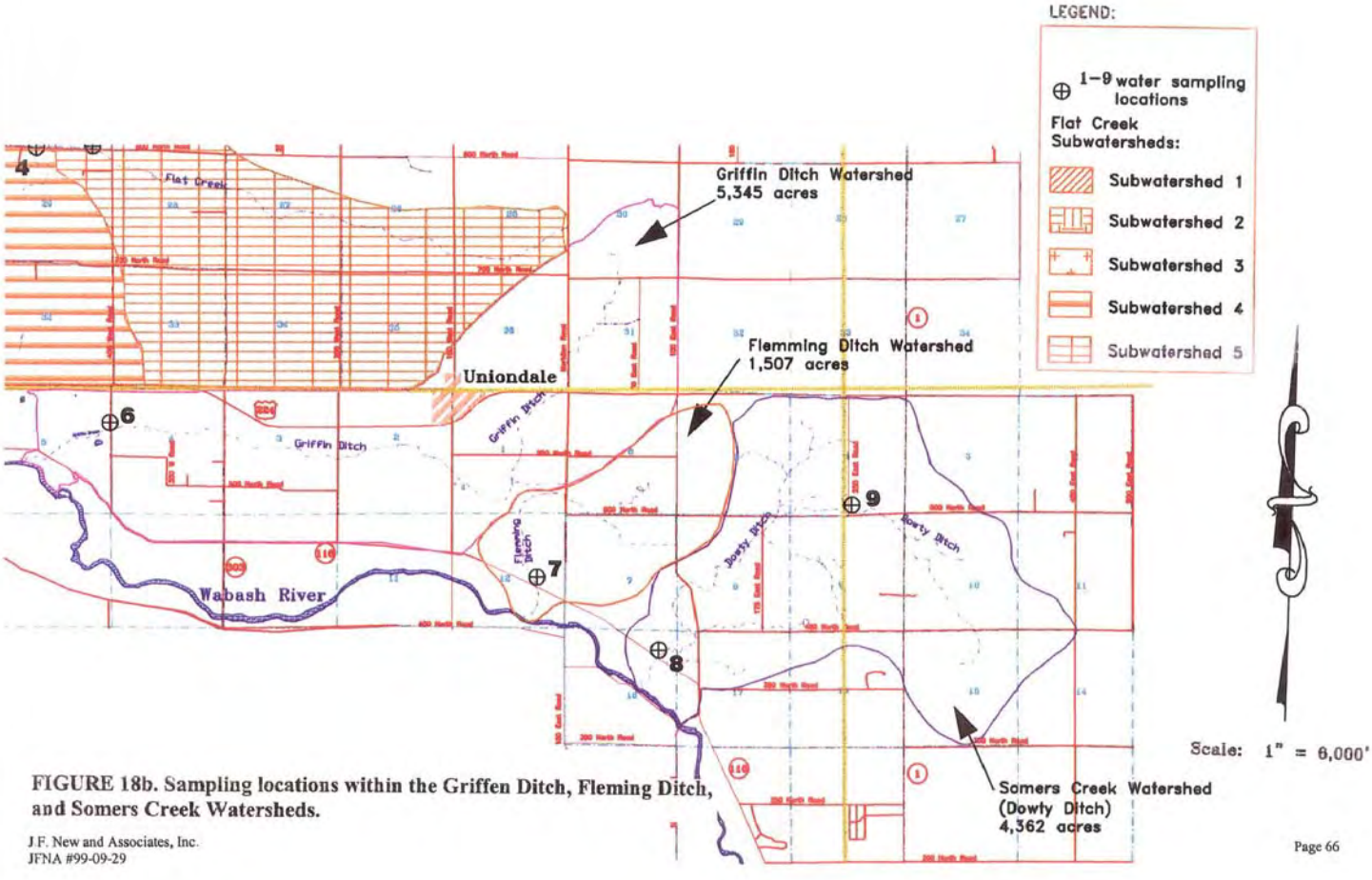


FIGURE 18b. Sampling locations within the Griffen Ditch, Fleming Ditch, and Somers Creek Watersheds.

impairment. The data can be used to guide a prioritization of management actions and direct those actions toward the most critical areas.

Sampling Locations

Nine sampling sites were strategically chosen throughout the four watersheds. The sites were selected based on accessibility and relative amount of information that could be obtained for each subwatershed. The reference site on Eightmile Creek was chosen because area SWCDs had recently targeted the creek and its watershed with several work projects. The Jay and Wells County SWCDs felt that Eightmile Creek would be a good "measuring stick" by which to compare streams within each study watershed. Streams within each drainage could then be evaluated for impairment relative to Eightmile Creek.

An ideal reference site would have a relatively undisturbed watershed with little channel alteration and would meet all criteria listed in Table 31. Because of extensive human activities throughout the watersheds in the study area, a reference site meeting all of the criteria in Table 31 could not be located, and as will be discussed later, Eightmile Creek served poorly as a reference site. Because of this, the usefulness of comparisons between the reference and study sites was somewhat limited. Doug Nusbaum of the Indiana Department of Natural Resources (IDNR) suggested that Stoney Creek, which had been the control site for a study in the Wolf Creek Watershed, may make a better reference point for future studies in the area. The Muncie Sanitary District has regularly monitored the fish and macroinvertebrate communities of Stoney Creek. The creek is known to support healthy biological communities and high quality habitat. Table 32 provides more detailed sampling location information for each of the nine sites and the reference site.

TABLE 31. Minimum criteria for stream reference sites. Source: Plafkin et al., 1999.

Example Criteria for Reference Sites (Must meet all criteria)
• **pH >=6; if blackwater stream, then pH <=6 and DOC >8 mg/l** • **Dissolved Oxygen >= 4 ppm** • **Nitrate <=16.5 mg/l** • **Urban land use <=20% of catchment area** • **Forest land use >=25% of catchment area** • **Instream habitat rating optimal or suboptimal** • **Riparian buffer width >=15m** • **No channelization** • **No point source discharges**

TABLE 32. Detailed sampling location information for the study watersheds.

Site #	Stream Name	Related Subwatershed	Road Location	Place Sampled	USGS Quad	UTM Coordinates
Ref	Eightmile Creek	Eightmile Creek	intersection with North Mayne Road	downstream of bridge	Zanesville, Section 24, T29N, R10E	639164.04 x 4534477.70
1	Flat		intersection	downstream of	Zanesville,	637072.75 x

	Creek		with North Mayne Road	bridge	Section 24, T29N, R10E	4530376.28
2	Flat Creek		intersection with CR 1000 N	downstream of bridge	Zanesville, Section 8, T28N, R11E	642397.99 x 4527609.02
3	Flat Creek		intersection with CR 300 N	downstream of bridge	Markle, Section 19, T28N, R11E	641072.50 x 4526004.47
4	Flat Creek		intersection with CR 800 N	downstream of bridge	Markle, Section 20, T28N, R11E	642304.97 x 4524516.20
5	Flat Creek		intersection with CR 800 N	upstream of bridge	Markle, Section 20, T28N, R11E	643049.11 x 4524376.67
6	Griffen Ditch	Griffen Ditch	intersection with CR 400 W	upstream of bridge	Markle, Section 4, T27N, R11E	643351.42 x 4520562.96
7	Fleming Ditch	Fleming Ditch	intersection with SR 116	upstream of bridge	Uniondale, Section 12, T27N, R11E	649777.05 x 4518493.33
8	Somers Creek	Somers Creek	intersection with SR 116	upstream of bridge	Uniondale, Section 18, T27N, R12E	651243.63 x 4517586.41
9	Somers Creek	Somers Creek	intersection with CR 250 E	upstream of bridge	Uniondale, Section 4, T27N, R12E	653862.37 x 4519656.04

Water Chemistry

Methods

Base flow and stormwater runoff sampling included measurements of physical, chemical, and bacterial parameters. Conductivity, temperature, and dissolved oxygen were measured *in situ* using a YSI Model 85 meter. (Alkalinity, temperature, and dissolved oxygen were measured during base flow only.) Water velocity was measured using a Marsh-McBirney Flo-Mate current meter. Cross-sectional area of the stream channel was measured, and discharge was calculated by multiplying water velocity by cross-sectional area. The water stage at the reference site was too deep to wade all the way across the channel; therefore, no discharge measurement was made during base flow. The storm flow discharge was estimated by measuring accessible stream depths from both sides of the stream and estimating cross-sectional area based on available measurements. In addition, water samples were collected from just below the water surface using a cup sampler and tested for:

- pH
- alkalinity (during base flow only)
- turbidity
- total Kjeldahl nitrogen (TKN)
- ammonia-nitrogen (NH_3)
- nitrate-nitrogen (NO_3^-)
- total phosphorus (TP)
- soluble reactive phosphorus (SRP)
- total suspended solids (TSS)

Following collection, samples were stored in an ice chest until analysis either in the Indiana University School of Public and Environmental Affairs (IUSPEA) laboratory (for the base flow samples) or the A&L Great Lakes Laboratory (for the storm flow samples). All sampling

techniques and laboratory analytical methods were performed in accordance with procedures in Standard Methods for the Examination of Water and Wastewater, 19th Edition (APHA, 1995). Appendix 7 provides copies of the laboratory reports for the samples.

The comprehensive evaluation of stream chemistry requires collecting data on the different water quality parameters listed above. A brief description of the various parameters follows:

Temperature The Indiana Administrative Code (327 IAC 2-1-6) sets maximum temperature limits for Indiana streams. Temperatures during the month of May should not exceed 80°F (23.7°C) by more than 3°F (1.7°C). June temperatures should not exceed 90°F (32.2°C). The Code also states that "the maximum temperature rise at any time or place…shall not exceed 5°F (2.8°C) in streams…". Temperature can determine the form, solubility, and toxicity of a broad range of aqueous compounds.

Dissolved Oxygen (D.O.) D.O. is the dissolved gaseous form of oxygen. It is essential for respiration of fish and other aquatic organisms. Fish need at least 3-5 parts per million (ppm) of D.O. Cold-water fish such as trout generally require higher concentrations of D.O. than warm water fish such as bass or bluegill. The IAC sets minimum D.O. concentrations at 6 mg/l for cold water fish. D.O. enters water by diffusion from the atmosphere and as a byproduct of photosynthesis by algae and plants. Excessive algae growth can over-saturate (greater than 100% saturation) the water with D.O. Dissolved oxygen is consumed by respiration of aquatic organisms, such as fish, and during bacterial decomposition of plant and animal matter.

Conductivity Conductivity is a measure of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions: on their total concentration, mobility, and valence (APHA, 1995). During low discharge, conductivity is higher than during storm water runoff because the water moves more slowly across or through ion-containing soils and substrates during base flow. Carbonates and other charges particles dissolve into the slow-moving water, thereby increasing conductivity measurements.

pH The pH of stream water describes the concentration of acidic ions (specifically H^+) present in the water. The pH also determines the form, solubility, and toxicity of a wide range of other aqueous compounds. The IAC establishes a range of 6-9 pH units for the protection of aquatic life.

Alkalinity Alkalinity is a measure of the acid-neutralizing (or buffering) capacity of water. Certain substances, if present in water, like carbonates, bicarbonates, and sulfates can cause the water to resist changes in pH. A lower alkalinity indicates a lower buffering capacity or a decreased ability to resist changes in pH. During base flow conditions, alkalinity is usually high because the water picks up carbonates from the bedrock. Alkalinity measurements are usually lower during storm flow conditions because buffering compounds are diluted by rainwater and the runoff water moves across carbonate-containing bedrock materials so quickly that little carbonate is dissolved to add additional buffering capacity.

Turbidity Turbidity (measured in Nephelometric Turbidity Units) is a measure of water coloration and particles suspended in the water itself. It is generally related to suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter, plankton, and other microscopic organisms. According to the Hoosier Riverwatch, the average turbidity of an Indiana stream is 11 NTU with a typical range of 4.5-17.5 NTU (White, unpublished data). Turbidity measurements >20 NTU have been found to cause undesirable changes in aquatic life (Walker, 1978).

Nitrogen Nitrogen is an essential plant nutrient found in fertilizers, human and animal wastes, yard waste, and the air. About 80% of air is nitrogen gas. This nitrogen can diffuse into water where it can be "fixed", or converted, by blue-green algae for their use. Nitrogen can also enter lakes and streams as inorganic nitrogen and ammonia. Because of this, there is an abundant supply of available nitrogen to aquatic systems. The three common forms of nitrogen are:

Nitrate (NO_3^-) – Nitrate is dissolved nitrogen that is converted to ammonia by algae. It is found in streams and runoff when dissolved oxygen is present, usually in the surface waters. Nitrogen applied to farmland is rapidly oxidized or converted to nitrate and usually enters surface and groundwater as nitrate. The Ohio EPA (1999) found that the median nitrate-nitrogen concentration in wadeable streams that support modified warmwater habitat (MWH) was 1.6 mg/l. Modified warmwater habitat was defined as: aquatic life use assigned to streams that have irretrievable, extensive, man-induced modifications that preclude attainment of the warmwater habitat use (WWH) designation; such streams are characterized by species that are tolerant of poor chemical quality (fluctuating dissolved oxygen) and habitat conditions (siltation, habitat amplification) that often occur in modified streams (Ohio EPA, 1999). Nitrate concentrations exceeding 10 mg/l in drinking water are considered hazardous to human health (Indiana Administrative Code IAC 2-1-6).

Ammonia (NH_3) – Ammonia is dissolved nitrogen that is the preferred form for algae use. Bacteria produce ammonia as they decompose dead plant and animal matter. Ammonia is the reduced form of nitrogen and is found where dissolved oxygen is lacking. Both temperature and pH govern the toxicity of ammonia for aquatic life. According to the IAC, maximum unionized ammonia concentrations within the temperature and pH ranges measured for the study streams should range between approximately 0.13 and 0.22 mg/l.

Organic Nitrogen (Org N) – Organic nitrogen includes nitrogen found in plant and animal materials. It may be in dissolved or particulate form. In the analytical procedures, total Kjeldahl nitrogen (TKN) was analyzed. Organic nitrogen is TKN minus ammonia.

Phosphorus Phosphorus is an essential plant nutrient, and the one that most often controls aquatic plant (algae and macrophyte) growth. It is found in fertilizers, human and animal wastes, and yard waste. There are few natural sources of phosphorus to streams other than that which is attached to soil particles, and there is no atmospheric (vapor) form of phosphorus. For this reason, phosphorus is often a ***limiting nutrient*** in aquatic systems. This means that the relative scarcity of phosphorus may limit the ultimate growth and production of algae and rooted aquatic plants. Therefore, management efforts often focus

on reducing phosphorus inputs to receiving waterways because: (a) it can be managed and (b) reducing phosphorus can reduce algae production. Two common forms of phosphorus are:

Soluble reactive phosphorus (SRP) – SRP is dissolved phosphorus readily usable by algae. SRP is often found in very low concentrations in phosphorus-limited systems where the phosphorus is tied up in the algae themselves. Because phosphorus is cycled so rapidly through biota, SRP concentrations as low as 0.005 mg/l are enough to maintain eutrophic or highly productive conditions in lake systems (Correll, 1998). Sources of SRP include fertilizers, animal wastes, and septic systems.

Total phosphorus (TP) – TP includes dissolved and particulate phosphorus. TP concentrations greater than 0.03 mg/l (or 30 μg/l) can cause algal blooms. The Ohio EPA (1999) found that the median TP in wadeable streams that support MWH for fish was 0.28 mg/l.

Total Suspended Solids (TSS) A TSS measurement quantifies all particles suspended and dissolved in stream water. Closely related to turbidity, this parameter quantifies sediment particles and other solid compounds typically found in stream water. In general, the concentration of suspended solids is greater during high flow events due to increased overland flow. The increased overland flow erodes and carries more soil and other particulates to the stream. Although the State of Indiana sets no standard for TSS, total dissolved solids should not exceed 750 mg/l. In general, TSS >80 mg/l have been found to be deleterious to aquatic life (Waters, 1995).

***E. coli* Bacteria**

E. coli is one member of a group of bacteria that comprise the Fecal Coliform Bacteria and is used as an indicator organism to identify the potential for the presence of pathogenic organisms in a water sample. Pathogenic organisms can present a threat to human health by causing a variety of serious diseases, including infectious hepatitis, typhoid, gastroenteritis, and other gastrointestinal illnesses. *E. coli* can come from the feces of any warm-blooded animal. Wildlife, livestock, and/or domestic animal defecation, manure fertilizers, previously contaminated sediments and failing or improperly sited septic systems are common sources of the bacteria. The IAC sets the maximum standard at 235 col/100 ml in any one sample within a 30-day period. A study conducted by students at IUSPEA in the spring of 2000 found average fecal coliform levels of <200 colonies/100 ml in unglaciated, gravel-bottom creeks in the Stephen's Creek Watershed in Monroe County, Indiana (Klumpp et al., 2000). In general, fecal coliform bacteria have a life expectancy inside 24 hours.

Samples were collected on two dates: one following a storm event and the other during normal or "base flow" conditions. A base flow sampling provides an understanding of typical conditions in the streams. Following storm events, the increased water flow overland results in increased erosion of soil and nutrients from the land. Thus, stream concentrations of nutrients and sediment are higher following storm events. In essence, storm sampling presents a "worst case" picture of the watershed pollutant loading. The storm event samples were taken on May 10, 2000 following a storm that dumped almost three inches of rain on the watershed during a period of 48 hours, constituting a one-year storm event. Due to the magnitude of the storm event, the

soils were likely saturated at the time of sampling. Eightmile Creek was sampled on June 6, 2000. The base flow samples were collected on May 30 and 31, 2000 following a period of little precipitation. It is important to note that even though these results provide insight into the characteristics of the streams at the time of sampling, it is difficult to extrapolate these results to other times of the year and different conditions.

There are two useful ways to report water quality data in flowing water. *Concentrations* describe the mass of a particular material contained in a unit of water, for example, milligrams of phosphorus per liter (mg/l). *Mass loading* (in units of kg/day) on the other hand describes the mass of a particular material being carried per unit of time. For example, a high concentration of phosphorus in a stream with very little flow will deliver a smaller total amount of phosphorus to the receiving waterway than will a stream with a low concentration of phosphorus but a high flow of water. It is the total amount (mass) of phosphorus, solids, and bacteria actually delivered from the watershed that is the most important when considering the effects of these materials downstream.

Results

Physical Concentrations and Characteristics

Physical parameter results measured during base and storm flow sampling are presented in Table 33. Stream discharges measured during base and storm flow conditions are shown in Figure 19. The base flow conditions were likely higher than summer time low flows based on examination of the channels and water elevations at the time of the base flow sampling. Based on weather data, the stream levels were still receding from an earlier storm event. Storm flow at the reference site was 20 times greater than that of any other stream.

TABLE 33. Physical characteristics of Flat Creek, Griffen Ditch, Fleming Ditch, and Somers Creek sampled on May 30, 2000 (base) and June 6, 2000 (storm). An * indicates that the data was not available: temperature, dissolved oxygen, and alkalinity were not measured during the storm event due to faulty equipment.

Site	Timing	Flow (cfs)	Temp. (^oC)	D.O. (mg/l)	Cond. (umhos)	pH	Alk. (mg/l)	Turbidity (NTU)
Reference Site	Base	**	18.0	8.5	543	8.2	140	32.0
Reference Site	Storm	590.0	*	*	440	7.7	*	133.0
SITE 1-Flat Creek	Base	59.6	15.9	11.0	520	8.2	154	8.4
SITE 1-Flat Creek	Storm	170.0	*	*	570	7.7	*	61.0
SITE 2-Flat Creek	Base	22.9	16.3	11.8	518	8.4	158	4.9
SITE 2-Flat Creek	Storm	104.5	*	*	480	7.5	*	36.0
SITE 3-Flat Creek	Base	4.1	18.0	11.4	555	8.5	173	5.0
SITE 3-Flat Creek	Storm	32.0	*	*	490	7.4	*	18.0

SITE 4-Flat Creek	Base	11.7	16.0	11.5	512	8.1	162	2.8
SITE 4-Flat Creek	Storm	28.9	*	*	460	7.5	*	22.0
SITE 5-Flat Creek	Base	6.8	15.4	10.5	510	8.1	156	4.4
SITE 5-Flat Creek	Storm	40.0	*	*	460	7.4	*	40.0
SITE 6-Griffin Ditch	Base	7.5	17.8	10.4	634	8.1	188	3.6
SITE 6-Griffin Ditch	Storm	45.1	*	*	530	7.4	*	43.0
SITE 7-Fleming Ditch	Base	0.9	20.1	13.9	660	8.4	190	4.0
SITE 7-Fleming Ditch	Storm	18.0	*	*	440	7.6	*	121.0
SITE 8-Somers Creek	Base	3.8	18.1	8.6	626	8.1	164	25.0
SITE 8-Somers Creek	Storm	17.1	*	*	450	7.6	*	200.0
SITE 9-Somers Creek	Base	1.5	18.0	9.4	613	8.0	164	22.5
SITE 9-Somers Creek	Storm	6.9	*	*	460	7.6	*	235.0

* Data not available.

** Discharge too high to measure. Due to stream depth and flow velocity, the stream channel could not safely be waded during either storm or base flow; therefore, flow measured during the storm event is a best estimate of the actual flow.

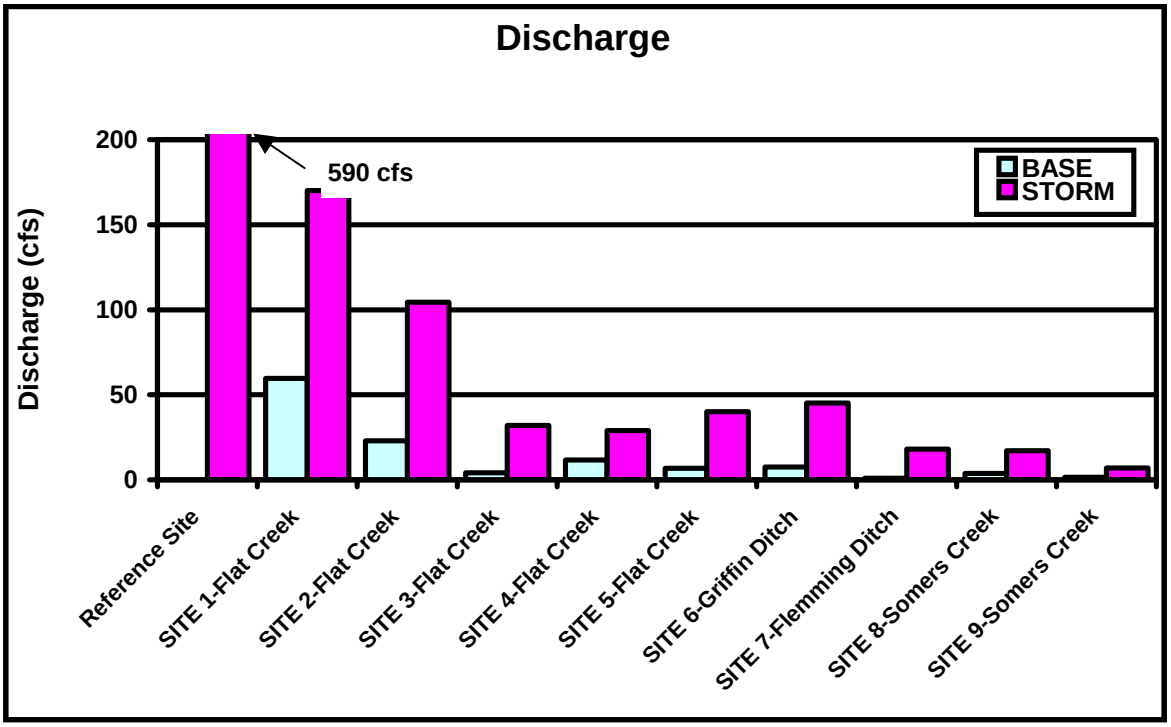


FIGURE 19. Discharge or flow measurements during base flow and storm flow sampling of the Flat Creek, Griffen Ditch, Fleming Ditch, and Somers Creek Watershed streams.

During base flow conditions, temperatures in the creeks varied from 15.4°C at Site 5 in the Flat Creek Watershed to 20.1°C at Site 7 in the Fleming Ditch Watershed. Those creeks with cooler temperatures likely were receiving greater groundwater inputs. Streamside vegetation that provides shading to the water can also prevent heat gain. The high temperature at Site 7 likely reflects the lack of riparian vegetation along the creek noted during the site visit. (See the QHEI results in the Macroinvertebrates and Habitat Section.)

Dissolved oxygen (DO) concentrations varied from 8.5 to 13.9 ppm. Because DO varies with temperature (cold water can contain more oxygen than warm water), it is relevant to consider DO saturation values. This refers to the amount of oxygen dissolved in water compared to the maximum possible when water is saturated with oxygen. The saturation value of water at 18°C is 9.5 ppm or mg/l. Stream dissolved oxygen concentrations that are less than this value suggest that: a) decomposition processes within the streams consume oxygen more quickly than it can be replaced by diffusion from the atmosphere, and b) flow in the streams is not turbulent enough to entrain sufficient oxygen. Results from these sites indicate that oxygen was sufficient. DO in all streams exceeded the Indiana state minimum standard of 6 mg/l for aquatic life.

Conductivity in study watershed streams ranged from 510-660 umhos during base flow and from 440-570 umhos during storm water runoff. In general during low discharge, conductivity was higher than during the storm sampling. High flows tend to dilute charge-bearing ions and allow little time for ion dissolution into the water from the soils.

Values of pH were well within the range of 6-9 units established by the Indiana Administrative Code. pH levels during base flow were generally greater (8.0-8.6) than levels measured during storm flow conditions (7.4-7.7). During low water periods, stream water has a longer amount of time to accrue buffering compounds from alkaline soils.

Alkalinity measurements taken during base flow conditions indicate that the study watershed streams are well-buffered. The reference site actually had the lowest alkalinity at 140 mg/l and would be the least capable of buffering or resisting changes in pH.

Turbidity was greatest during storm flow conditions for all sites. At base flow conditions, Site 4 had the lowest turbidity of 2.8 NTU while Site 8 had the greatest turbidity of 25.0 NTU. During periods of high flow, turbidity is greater due to increased overland flow carrying suspended sediments with it into the creeks. Fleming Ditch (Site 7) and Somers Creek (Sites 8 and 9) became notably more turbid during runoff.

Chemical and Bacterial Concentrations

Chemical and bacterial concentration data for the Flat Creek, Griffen Ditch, Fleming Ditch, and Somers Creek Watershed streams are listed by site in Table 34. Figures 20-26 present concentration information graphically.

TABLE 34. Chemical and bacterial characteristics of Flat Creek, Griffen Ditch, Fleming Ditch, and Somers Creek Watershed streams sampled on May 30, 2000 (base) and June 6, 2000 (storm).

Site	Timing	NO_3^- (mg/l)	NH_3 (mg/l)	TKN (mg/l)	SRP (mg/l)	TP (mg/l)	TSS (mg/l)	E. coli col/100ml)
Reference Site	Base	0.02	0.081	0.605	0.104	0.171	42.0	*
Reference Site	Storm	18.70	0.10[a]	3.000	0.10[a]	0.10[a]	208.0	4800
SITE 1-Flat Creek	Base	17.22	0.037	0.230[a]	0.079	0.079	13.3	*
SITE 1-Flat Creek	Storm	20.70	0.180	1.000	0.120	0.360	72.0	3200
SITE 2-Flat Creek	Base	19.52	0.023	0.230[a]	0.033	0.074	11.8	*
SITE 2-Flat Creek	Storm	20.70	0.10[a]	1.0[a]	0.110	0.380	33.0	1200
SITE 3-Flat Creek	Base	17.15	0.050	0.230[a]	0.025	0.047	11.8	*
SITE 3-Flat Creek	Storm	21.60	0.10[a]	1.0[a]	0.10[a]	0.410	4.0	1600
SITE 4-Flat Creek	Base	17.17	0.018[a]	0.230[a]	0.036	0.054	6.0	*
SITE 4-Flat Creek	Storm	19.60	0.10[a]	1.0[a]	0.110	0.380	18.0	800
SITE 5-Flat Creek	Base	19.34	0.049	0.230[a]	0.047	0.071	7.4	*
SITE 5-Flat	Storm	17.90	0.130	1.0[a]	0.140	0.360	23.0	2600

Creek								
SITE 6-Griffin Ditch	Base	16.52	0.025	0.230[a]	0.046	0.094	10.6	*
SITE 6-Griffin Ditch	Storm	21.00	0.470	1.000	0.180	0.320	41.0	4000
SITE 7-Fleming Ditch	Base	15.15	0.018[a]	0.230[a]	0.027	0.040	30.8	*
SITE 7-Fleming Ditch	Storm	14.50	0.170	1.0[a]	0.160	0.420	55.0	4800
SITE 8-Somers Creek	Base	11.45	0.077	0.421	0.095	0.161	23.6	*
SITE 8-Somers Creek	Storm	20.00	0.800	6.000	0.460	0.320	104.0	12000
SITE 9-Somers Creek	Base	14.31	0.104	0.578	0.117	0.181	2.8	*
SITE 9-Somers Creek	Storm	11.30	0.390	1.000	0.250	0.790	172.0	11800

* Data not available
[a] Below the listed detection limit value

Nitrate concentrations in study watershed streams are illustrated in Figure 20. Nitrate concentrations at every site during storm water runoff exceeded 1.6 mg/l, the median nitrate concentration of wadeable streams found by the Ohio EPA to support modified warmwater habitat (MWH). During base flow conditions every site except the reference site exceeded 1.6 mg/l. Because nitrate is very mobile in soils, an additional concern is groundwater and well water contamination. All sites exceeded the IAC water consumption standard of 10 mg/l during both base and storm flow events.

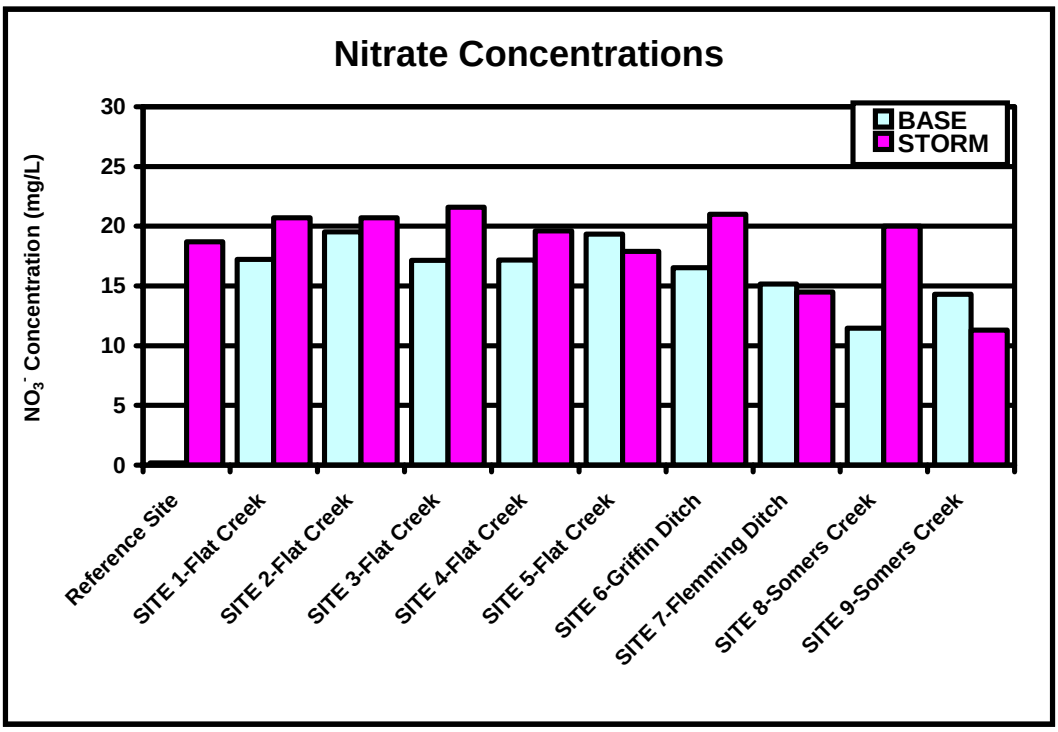


FIGURE 20. Nitrate concentration measurements during base flow and storm flow sampling of Flat Creek, Griffen Ditch, Fleming Ditch, and Somers Creek Watershed streams.

Ammonia concentrations (Figure 21) generally fell within the range (0.13-0.22 mg/l) set by the IAC as determined by *in situ* temperatures and pH values. During storm flows, Somers Creek (Sites 8 and 9) and Griffen Ditch (Site 6) exceeded the top end of the range, while both Flat Creek (Site 1) and Fleming Ditch (Site 7) exceeded the low end of the range. At the very least, these concentrations are near the minimum water quality standard for aquatic life. High rates of runoff during storms can wash ammonia from farm fields and livestock areas into the streams.

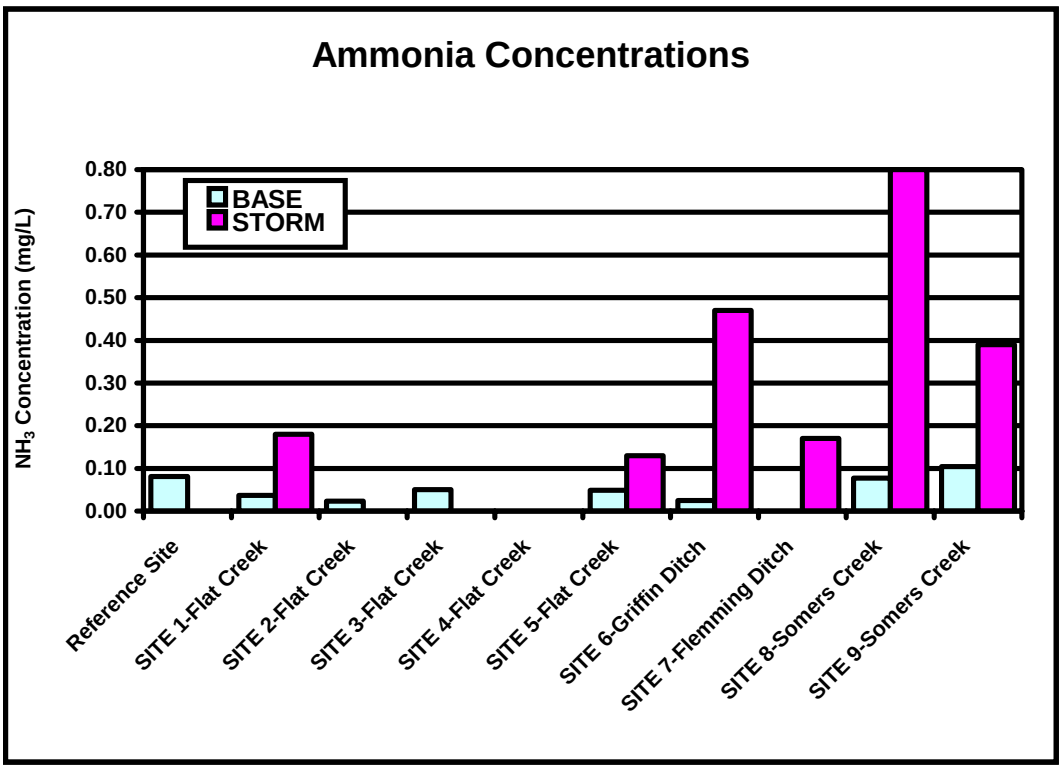


FIGURE 21. Ammonia concentration measurements during base flow and storm flow sampling of Flat Creek, Griffen Ditch, Fleming Ditch, and Somers Creek Watershed streams.

Total Kjeldahl nitrogen (TKN) concentrations detected in streams were also elevated during storm flows (Figure 22). Concentrations of organic nitrogen measured in the Flat Creek Watershed were low with samples from Sites 1, 2, 3, 4, and 5 at or below detection limits. TKN readings were elevated at Site 8 on Somers Creek during the storm event.

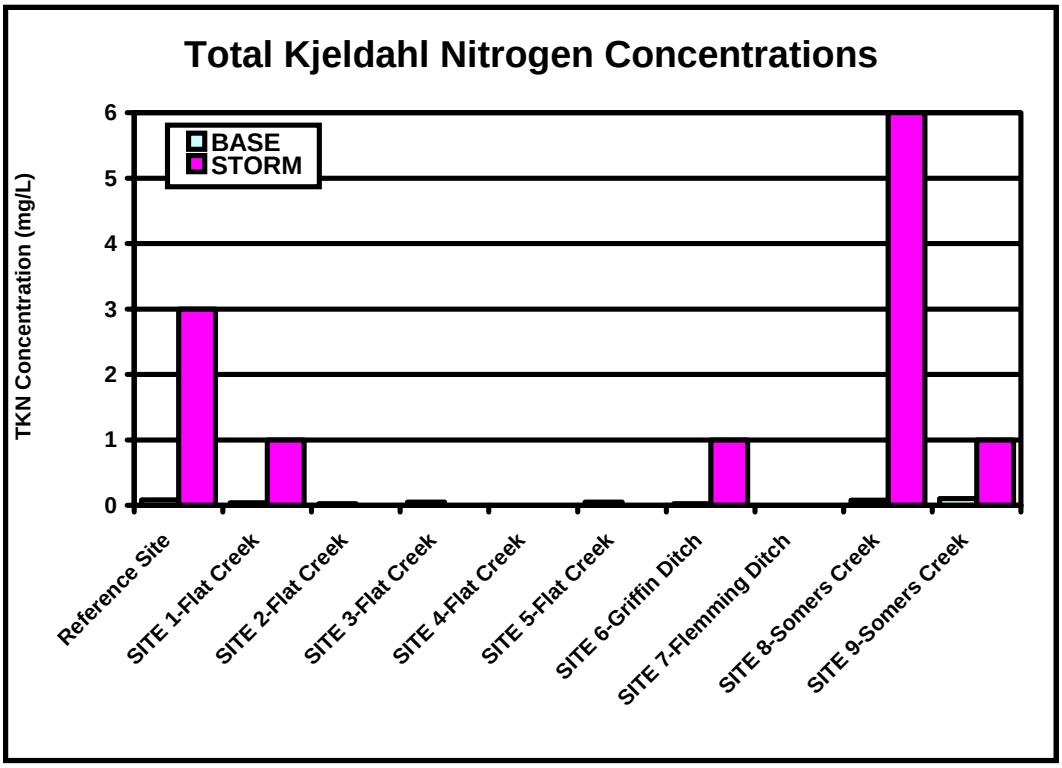


FIGURE 22. Total Kjeldahl nitrogen concentration measurements during base flow and storm flow sampling of Flat Creek, Griffen Ditch, Fleming Ditch, and Somers Creek Watershed streams.

All detected concentrations of soluble reactive phosphorus (SRP) exceeded minimum levels that prevent overproductivity in aquatic systems (Figure 23). Soluble phosphorous comprised 29-100% of the total phosphorus measured at the sampling sites. At Flat Creek (Sites 1, 3, 4, and 5), Griffen Ditch (Site 6), Fleming Ditch (Site 7), and Somers Creek (Sites 8 and 9), SRP was >50% of the measured TP, suggesting that a large fraction of the phosphorus coming off the land and into surface drainageways was soluble rather than particulate. It is also important to note that measurements of SRP taken at Site 8 during the storm event are actually greater than measurements of TP. Laboratory error is suspected in this case.

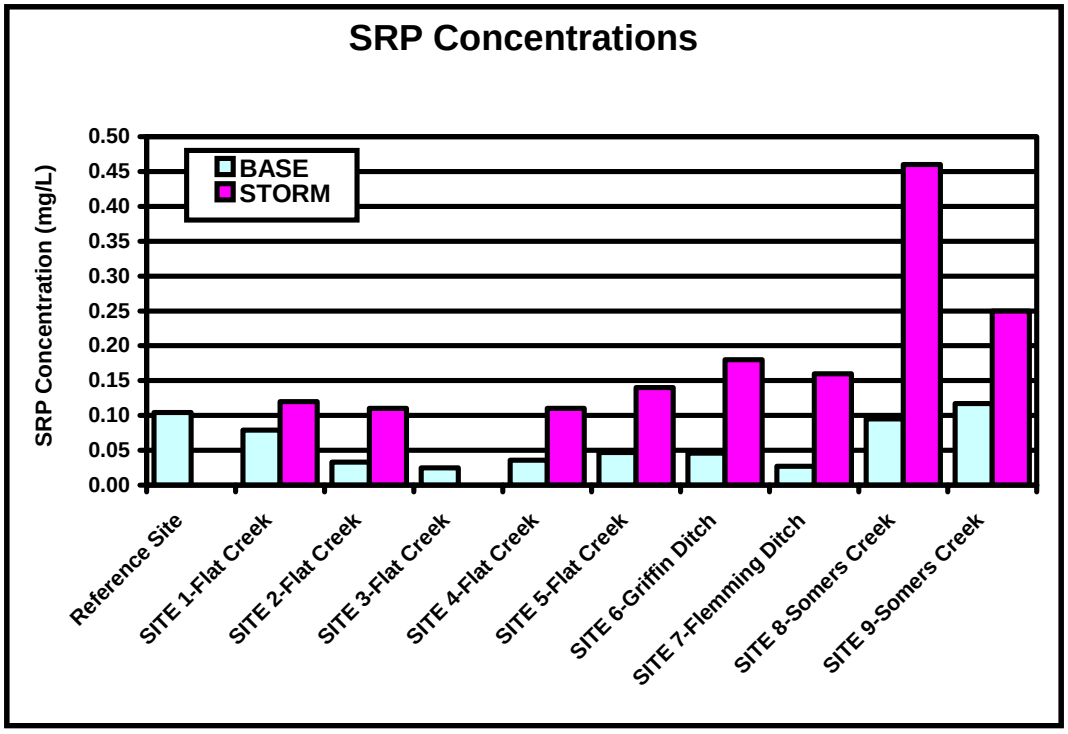


FIGURE 23. Soluble reactive phosphorus (SRP) concentration measurements during base flow and storm flow sampling of Flat Creek, Griffen Ditch, Fleming Ditch, and Somers Creek Watershed streams.

Total phosphorus concentrations (Figure 24) were also greater than minimum levels known to stimulate algal production. During base flow, none of the sites exceeded the 0.28 mg/l level acceptable for modified warmwater habitat (MWH, Ohio EPA, 1999). However, storm flow concentrations were considerable higher, and all of the sites exceeded the 0.28 mg/l level. Phosphorus concentrations (both particulate and dissolved) measured in Somers Creek were elevated and merit concern.

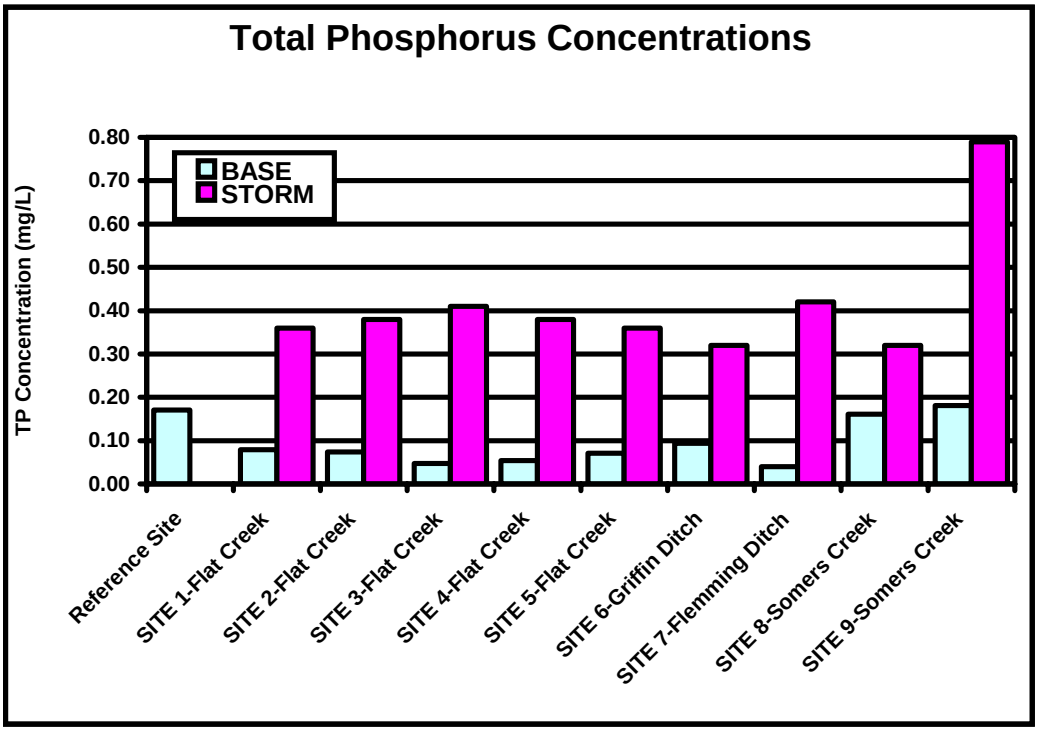


FIGURE 24. Total phosphorus concentration measurements during base flow and storm flow sampling of Flat Creek, Griffen Ditch, Fleming Ditch, and Somers Creek Watershed streams.

Concentrations of total suspended solids (TSS) were greater during storm flow conditions than during base flow conditions for every site except for Site 3 in the Flat Creek Watershed (Figure 25). Large differences in base and storm flow measurements point out the importance of erosion for all four watersheds and the reference watershed. Storm flow concentrations of TSS in Somers Creek (Sites 8 and 9) were greater than the 80-mg/l level known to be deleterious to aquatic life (Waters, 1995).

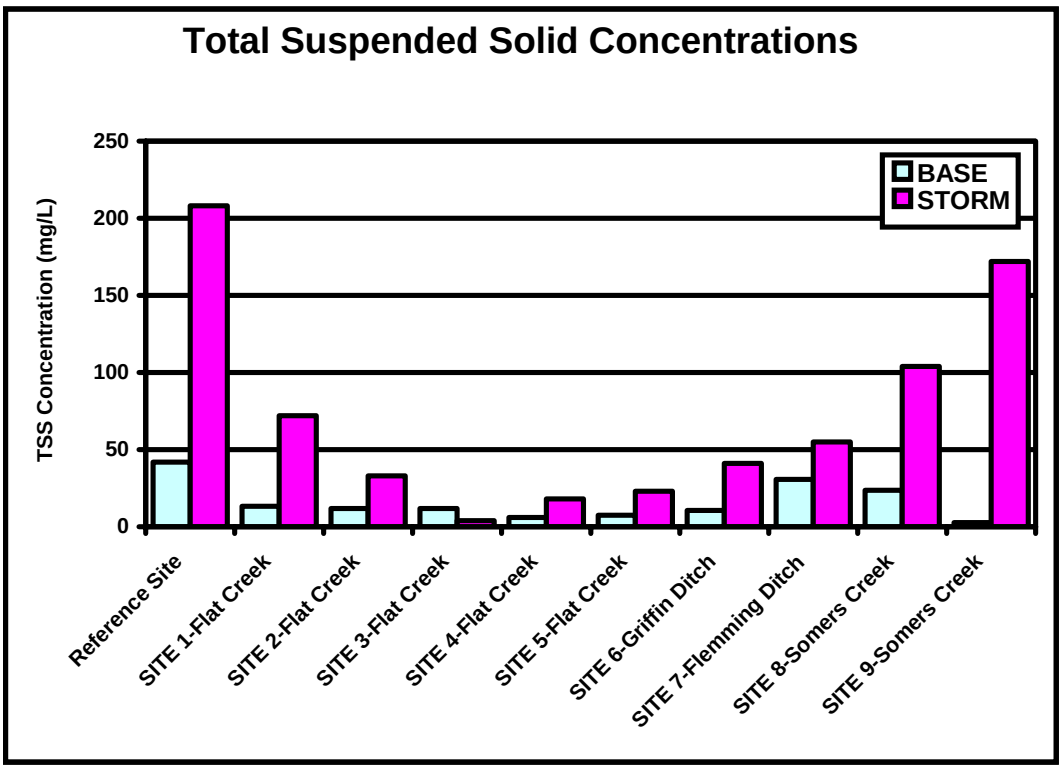


FIGURE 25. Total suspended solid concentration measurements during base flow and storm flow sampling of Flat Creek, Griffen Ditch, Fleming Ditch, and Somers Creek Watershed streams.

All storm water samples for *E. coli* violated the Indiana state standard for recreational waterbodies of 235 col/100ml (Figure 26). *E. coli* concentrations ranged from 1,200 col/100ml at Site 2 in the Flat Creek Watershed to 12,000 col/100ml at Site 8 in the Somers Creek Watershed. Based on this analysis, humans and pets may contract disease from water in the creeks following storm events and should not come into contact with it without appropriate protection.

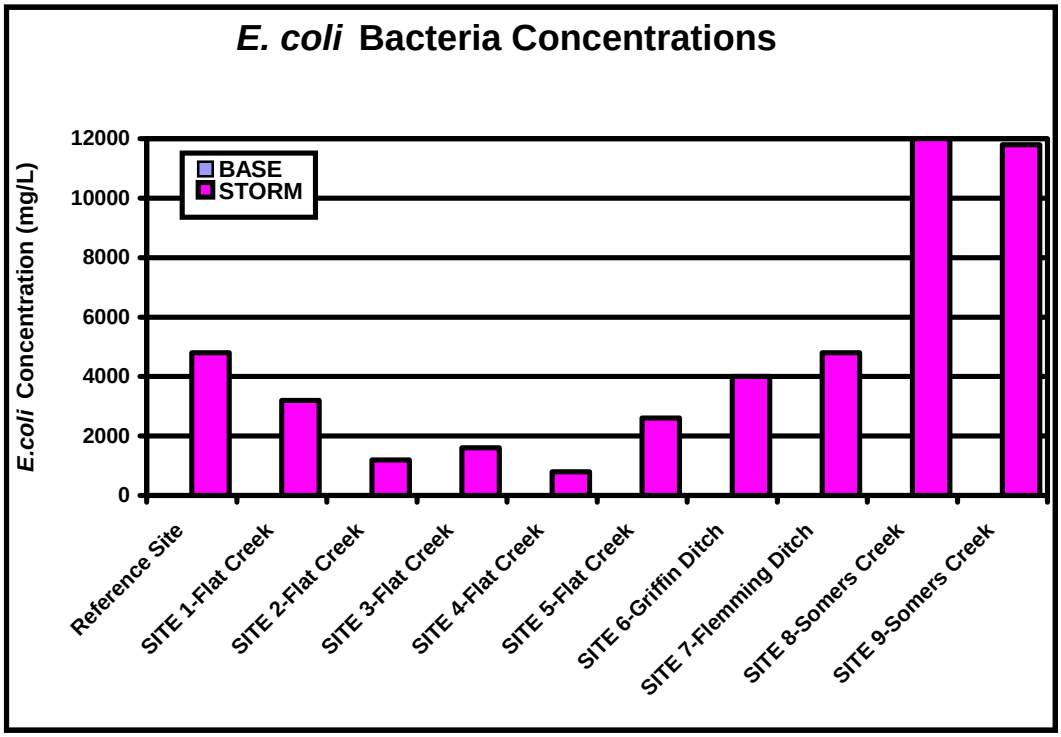


FIGURE 26. *E. coli* bacteria concentration measurements during base flow and storm flow sampling of Flat Creek, Griffen Ditch, Fleming Ditch, and Somers Creek Watershed streams.

Sediment and Chemical Loading

Except for a few patterns exhibited by samples taken at certain locations, nutrient and sediment loading from streams in the watersheds was mostly governed by flow rate (i.e., streams with higher rates of flow also contributed higher nutrient and sediment loads). Nitrate loading was governed by flow rate except that Somers Creek (Site 8) exhibited greater loading relative to flow during the storm event (Figure 27). While water samples from a few sites were below method detection limits, Griffen Ditch (Site 6) and Somers Creek (Site 8) contributed significantly to ammonia loading despite having relatively smaller rates of flow (Figure 28). Total Kjeldahl nitrogen was low (below detection limits) at most sites in the Flat Creek Watershed; however, organic nitrogen loading increased greatly in the reach between Sites 2 and 1. During the storm flow, Griffen Ditch (Site 6) and Somers Creek (Site 8) also contributed to the organic nitrogen load (Figure 29). Flat Creek Subwatershed 3 (represented by sampling Site 3) contributed little dissolved phosphorus (SRP) relative to flow, but Somers Creek (Site 8) loaded disproportionately higher amounts of SRP (Figure 30). Aside from slightly elevated total phosphorus loading measured on Somers Creek at Site 9, TP loading was driven by flow rate

(Figure 31). The storm water runoff event resulted in significantly increased sediment loading rates from the four watersheds (ranging from 313 to 29,949 kg/day or 690 to 66,038 lbs/day; Figure 32). The reach between Sites 2 and 1 on Flat Creek and Sites 8 and 9 on Somers Creek contributed disproportionately to sediment loading relative to flow rates. The higher soil loading rate suggests that Flat Creek Subwatershed 1 and the Somers Creek Watershed have soil erosion problems not detected in the other two watersheds.

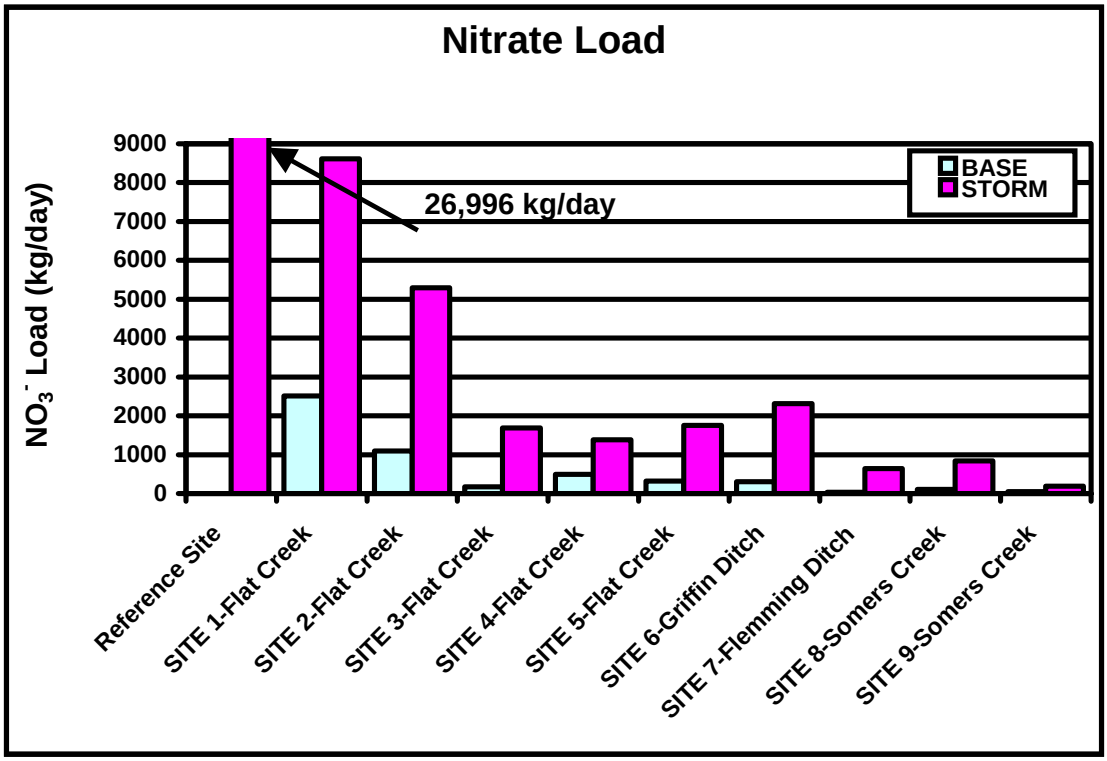


FIGURE 27. Nitrate loading measurements during base flow and storm flow sampling of Flat Creek, Griffen Ditch, Fleming Ditch, and Somers Creek Watershed streams.

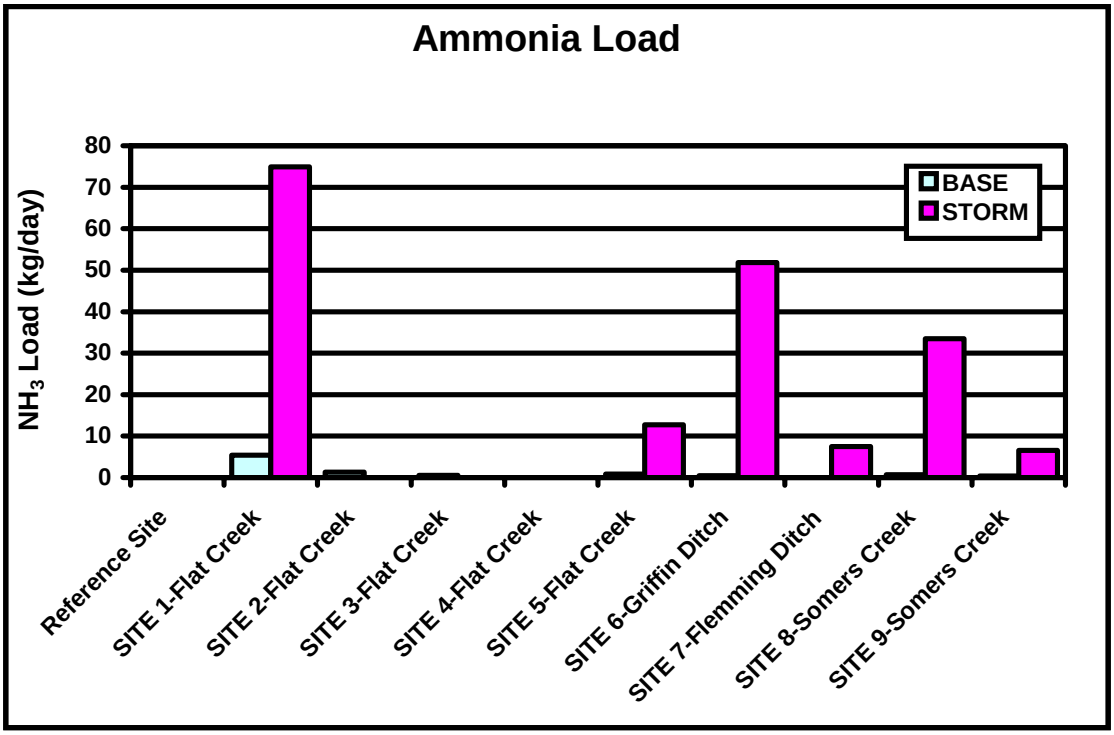


FIGURE 28. Ammonia loading measurements during base flow and storm flow sampling of Flat Creek, Griffen Ditch, Fleming Ditch, and Somers Creek Watershed streams.

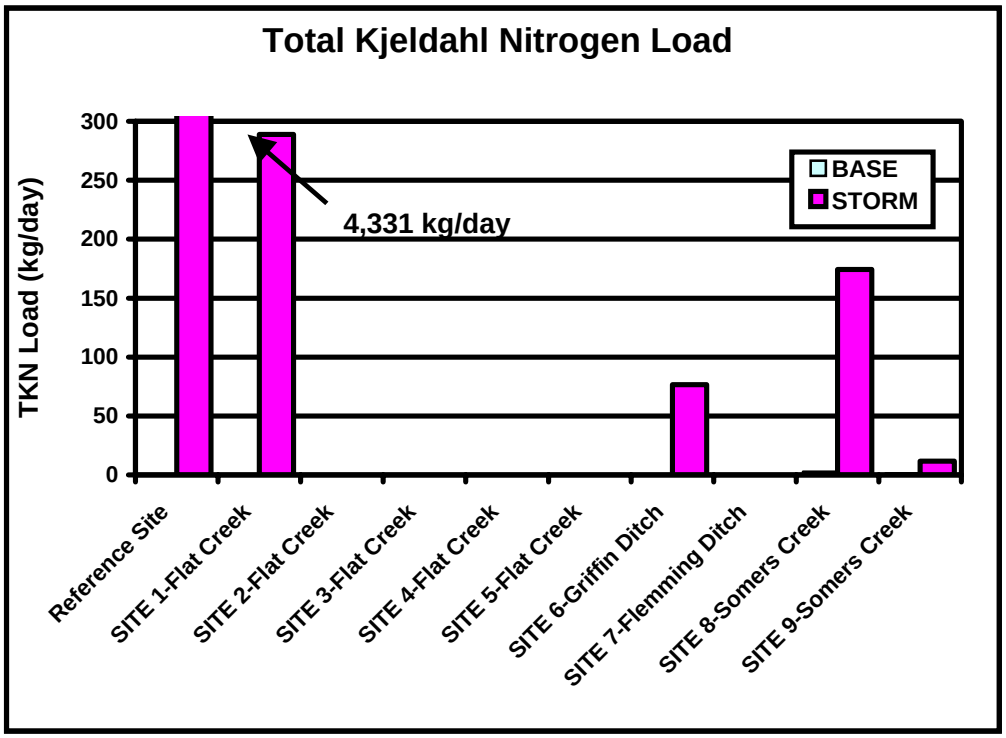


FIGURE 29. Total Kjeldahl nitrogen (TKN) loading measurements during base flow and storm flow sampling of Flat Creek, Griffen Ditch, Fleming Ditch, and Somers Creek Watershed streams.

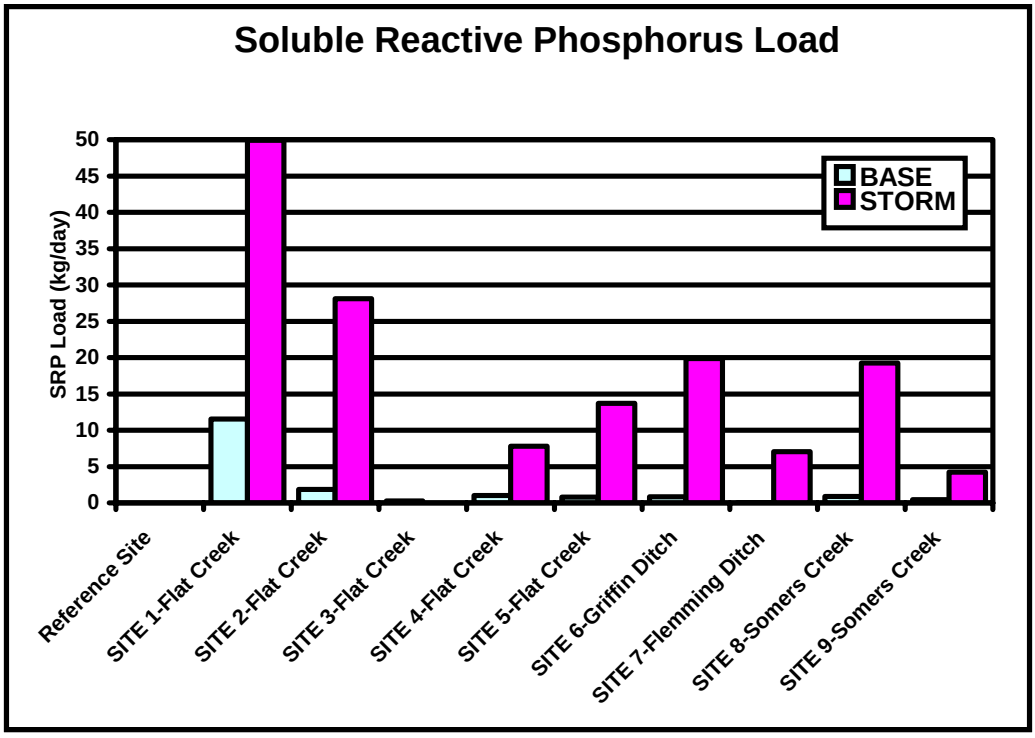


FIGURE 30. Soluble reactive phosphorus (SRP) loading measurements during base flow and storm flow sampling of Flat Creek, Griffen Ditch, Fleming Ditch, and Somers Creek Watershed streams.

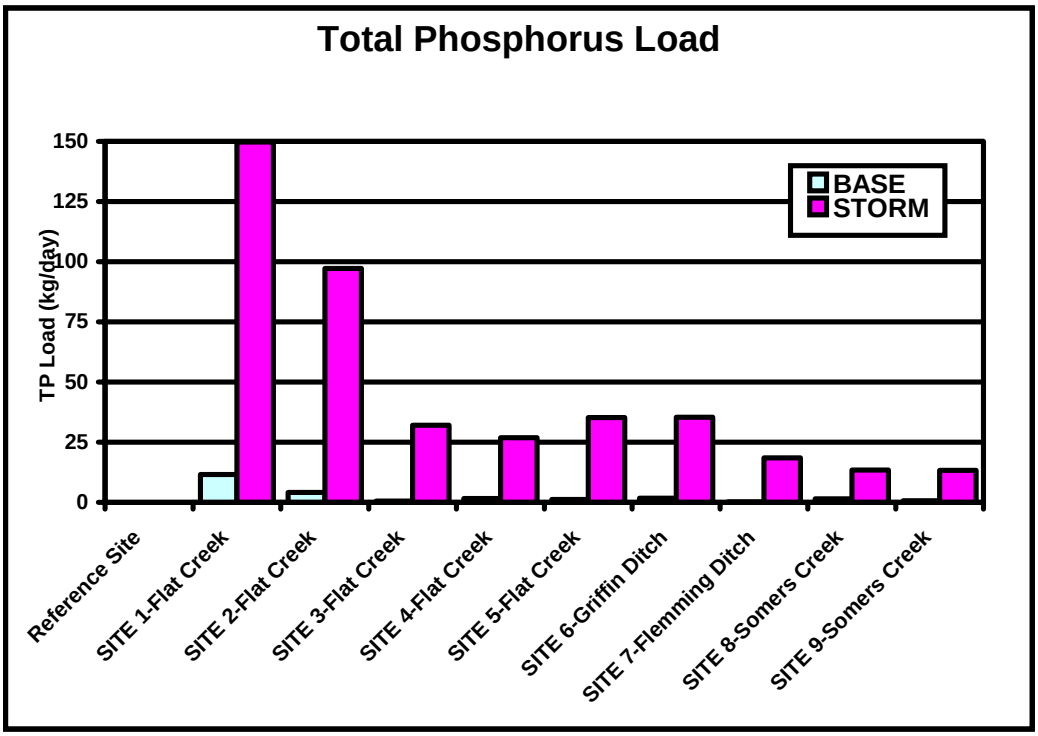


FIGURE 31. Total phosphorus (TP) loading measurements during base flow and storm flow sampling of Flat Creek, Griffen Ditch, Fleming Ditch, and Somers Creek Watershed streams.

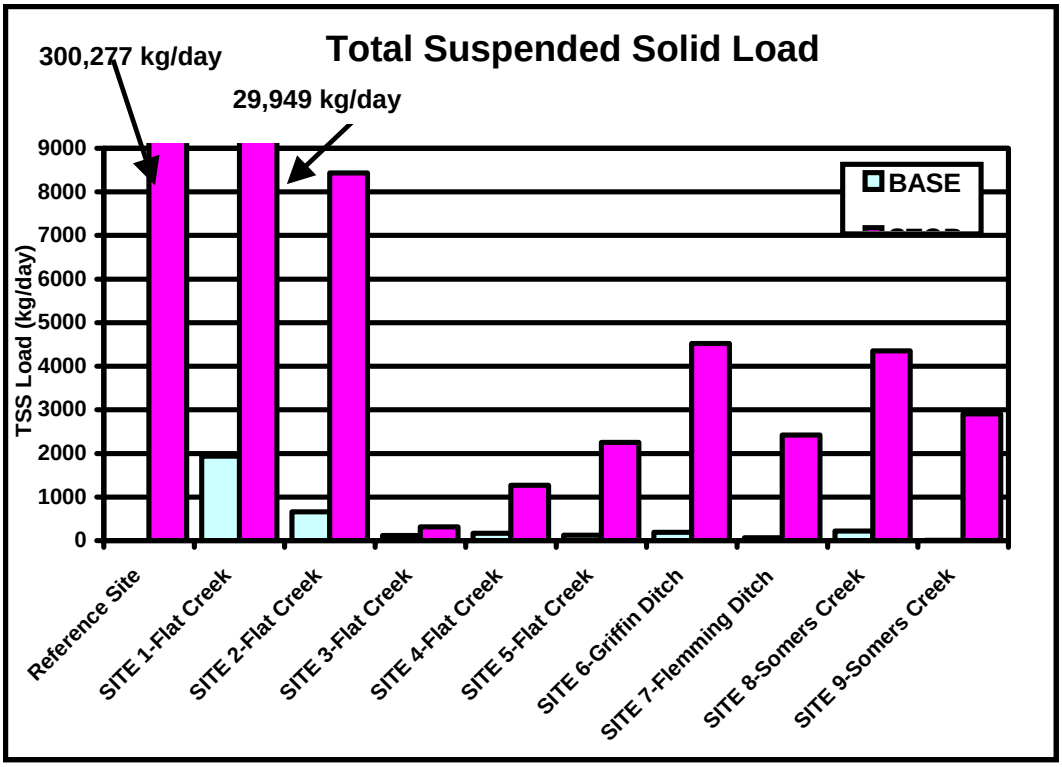


FIGURE 32. Total suspended solid (TSS) loading measurements during base flow and storm flow sampling of Flat Creek, Griffen Ditch, Fleming Ditch, and Somers Creek Watershed streams.

Discussion

In an effort to normalize the sediment, nutrient, and bacteria loading rates, the rates were divided by subwatershed size above each sampling site. Sampling Sites 1 and 2 in the Flat Creek Watershed received loading from adjacent subwatersheds. In these cases, loads from adjacent subwatersheds were subtracted from the subwatershed of consideration. Table 35 shows sample sites representing the respective watersheds and subwatersheds. The results of the analysis are included in Table 36.

TABLE 35. Sampling sites representing The Flat Creek Subwatersheds and the Griffen Ditch, Fleming Ditch, and Somers Creek Watersheds.

Watershed/Subwatershed	Sampling Site(s)
Flat Creek Subwatershed 1	=1-2
Flat Creek Subwatershed 2	=2-(3-4-5)
Flat Creek Subwatershed 3	3
Flat Creek Subwatershed 4	4
Flat Creek Subwatershed 5	5
Griffen Ditch Watershed	6
Fleming Ditch Watershed	7
Somers Creek Watershed	8

TABLE 36. Areal loading of TSS, TP, and *E. coli* watershed or subwatershed based on the base flow and storm flow samplings.

Watershed/Subwatershed	Watershed Size	Timing	TSS Load (kg/ha/yr)	TP Load (kg/ha/yr)	*E. coli* Load (billions of col/ha/yr)
Flat Creek Subwatershed 1	6269 ac (2538 ha)	base	184	1.1	X
Flat Creek Subwatershed 1	6269 ac (2538 ha)	storm	3094	7.6	147
Flat Creek Subwatershed 2	2342 ac (948 ha)	base	322	2.5	X
Flat Creek Subwatershed 2	2342 ac (948 ha)	storm	4484	49.0	190
Flat Creek Subwatershed 3	2880 ac (1166 ha)	base	37	0.1	X
Flat Creek Subwatershed 3	2880 ac (1166 ha)	storm	98	10.0	39
Flat Creek Subwatershed 4	2244 ac (909 ha)	base	69	0.6	X
Flat Creek Subwatershed 4	2244 ac (909 ha)	storm	511	10.8	23
Flat Creek Subwatershed 5	4358 ac (1764 ha)	base	26	0.2	X
Flat Creek Subwatershed 5	4358 ac (1764 ha)	storm	466	7.3	53
Griffen Ditch Watershed	5345 ac (2164 ha)	base	33	0.3	X
Griffen Ditch Watershed	5345 ac (2164 ha)	storm	763	6.0	74
Fleming Ditch Watershed	1507 ac (610 ha)	base	40	0.1	X
Fleming Ditch Watershed	1507 ac (610 ha)	storm	1449	11.1	126
Somers Creek Watershed	4362 ac (1766 ha)	base	45	0.3	X
Somers Creek Watershed	4362 ac (1766 ha)	storm	899	2.8	104

* X = Sample not collected

The Flat Creek Subwatershed 2 contributed more sediment per unit area than any other watershed when comparing base flow loadings and storm flow loadings. The Flat Creek 1, Fleming Ditch, and Somers Creek Watersheds each loaded over 800 kg/ha/yr (714 lbs/ac/yr) during storm flows. Sediment loading was significantly lower during low flow conditions. Per acre of watershed area, the Flat Creek Subwatershed 2 contributed the greatest load of total phosphorus. *E. coli* loading was also worst from the Flat Creek Subwatershed 2 which loaded as much as 190 billion/col/ha/yr during storm water runoff. Areal bacterial loading was also elevated in the Flat Creek 1, Fleming Ditch, and Somers Creek Watersheds.

Summary

In general, the physical and chemical characteristics of these streams indicate a high degree of degradation. The nutrient concentrations were much higher than median nutrient concentration

observed in modified Ohio streams. Additionally, multiple parameters violated Indiana state standards for both human and aquatic biota health as established by the Indiana Administrative Code. The Somers Creek Watershed is of special concern due to its high loading rate of dissolved nutrients (NO_3^-, NH_3, and SRP) relative to its flow rate. Griffen Ditch Watershed and the Flat Creek Subwatershed 1 also loaded elevated amounts of ammonia and organic nitrogen. Sediment loading rates during runoff events were found to be quite high (690-66,038 lbs/day), and the Flat Creek 1 and Somers Creek Watersheds contributed disproportionately greater loads relative to flow rate. Per unit area, all subwatersheds and watersheds were net contributors of sediments, nutrients, and bacteria. The Flat Creek Subwatershed 2 reach loaded the most total suspended solids, total phosphorus, and *E. coli* of any study area. Fleming Ditch and Somers Creek Watersheds also merit concern for sediment and bacteria loading per unit area.

Macroinvertebrates and Habitat

Macroinvertebrate Sampling Methods

Macroinvertebrate samples from each of the 10 sites and the reference site were used to calculate an index of biotic integrity. Aquatic macroinvertebrates are important indicators of environmental change. The insect community composition reflects water quality, and research shows that different macroinvertebrate orders and families react differently to pollution sources. Indices of biotic integrity are valuable because aquatic biota integrate cumulative effects of sediment and nutrient pollution (Ohio EPA, 1995).

Macroinvertebrates were collected during base flow conditions on May 30 and 31, 2000 using the multihabitat approach detailed in the USEPA Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers, 2nd ed. (Barbour et al. 1999). This method was supplemented by qualitative picks from substrate and by surface netting. Two researchers collected macroinvertebrates for 20 minutes, and a third researcher aided in the collection for 10 minutes for a total of 50 minutes of collection effort. The macroinvertebrate samples were processed using the laboratory processing protocols detailed in the same manual. Organisms were identified to the family level. The family-level approach was used: 1) to collect data comparable to that collected by IDEM in the state; 2) because it allows for increased organism identification accuracy; 3) because several studies support the adequacy of family-level analysis (Furse et al. 1984, Ferraro and Cole 1995, Marchant 1995, Bowman and Bailey 1997, Waite et al. 2000).

Macroinvertebrate data were used to calculate the family-level Hilsenhoff Biotic Index (HBI). Calculation of the HBI involves applying assigned macroinvertebrate family tolerance values to all taxa present that have an assigned HBI tolerance value, multiplying the number of organisms present by their family tolerance value, summing the products, and dividing by the total number of organisms present (Hilsenhoff, 1988). A higher value on the HBI scale indicates greater impairment.

In addition to the HBI, macroinvertebrate results were analyzed by applying the IDEM mIBI (IDEM, 1996). mIBI scores allow comparison with data compiled by IDEM for wadeable riffle-pool streams in Indiana. Table 37 lists the ten scoring metrics with classification scores of 0-8. The mean of the ten metrics is the mIBI score. mIBI scores of 0-2 indicate the sampling site is severely impaired; scores of 2-4 indicate the site is moderately impaired, scores of 4-6 indicate the site is slightly impaired, and scores of 6-8 indicate that the site is non-impaired. IDEM

developed the classification criteria based on five years of wadeable riffle-pool data collected in Indiana. The data was lognormally distributed for each of the ten metrics. Each of the ten metric's lognormal distribution was then pentasected with scoring based on five categories using 1.5 times the interquartile range around the geometric mean. Because a different sampling methodology was used in this study, only six of the ten metrics were used for the mIBI calculation: family-level HBI, number of taxa, percent dominant taxa, EPT Index, EPT count to total number of individuals, and EPT count to chironomid count.

TABLE 37. Benthic macroinvertebrate scoring metrics and classification scores used by IDEM in evaluation of riffle-pool streams in Indiana.

	SCORING CRITERIA FOR THE FAMILY LEVEL MACROINVERTEBRATE INDEX OF BIOTIC INTEGRITY (mIBI) USING PENTASECTION AND CENTRAL TENDENCY ON THE LOGARITHMIC TRANSFORMED DATA DISTRIBUTIONS OF THE 1990-1995 RIFFLE KICK SAMPLES				
		CLASSIFICATION SCORE			
	0	**2**	**4**	**6**	**8**
Family Level HBI	□5.63	5.62- 5.06	5.05-4.55	4.54-4.09	□4.08
Number of Taxa	□7	8-10	11-14	15-17	□18
Number of Individuals	□79	129-80	212-130	349-213	□350
Percent Dominant Taxa	□61.6	61.5-43.9	43.8-31.2	31.1-22.2	□ 22.1
EPT Index	□2	3	4-5	6-7	□8
EPT Count	□19	20-42	43-91	92-194	□195
EPT Count To Total Number of Individuals	□0.13	0.14-0.29	0.30-0.46	0.47-0.68	□0.69
EPT Count To Chironomid Count	□0.88	0.89-2.55	2.56-5.70	5.71-11.65	□11.66
Chironomid Count	□147	146-55	54-20	19-7	□6
Total Number of Individuals To	□29	30-71	72-171	172-409	□410

Number of Squares Sorted					

Where 0-2 = Severely Impaired; 2-4 = Moderately Impaired; 4-6 = Slightly Impaired; 6-8 = Nonimpaired

Habitat Sampling Methods

Physical habitat was evaluated using the Qualitative Habitat Evaluation Index (QHEI) developed by the Ohio EPA for streams and rivers in Ohio (Rankin 1989, 1995). Various attributes of the habitat are scored based on the overall importance of each to the maintenance of viable, diverse, and functional aquatic faunas. The type(s) and quality of substrates, amount and quality of instream cover, channel morphology, extent and quality of riparian vegetation, pool, run, and riffle development and quality, and gradient are some of the metrics used to determine the QHEI score which generally ranges from 20 to 100. An example of the QHEI data sheet is given in Appendix 8.

The QHEI is used to evaluate the characteristics of a stream segment, as opposed to the characteristics of a single sampling site. As such, individual sites may have poorer physical habitat due to a localized disturbance yet still support aquatic communities closely resembling those sampled at adjacent sites with better habitat, provided water quality conditions are similar. QHEI scores from hundreds of stream segments in Ohio have indicated that values greater than 60 are *generally* conducive to the existence of warmwater faunas. Scores greater than 75 typify habitat conditions that have the ability to support exceptional warmwater faunas (Ohio EPA, 1995).

Results

mIBI and QHEI scores for each sampling site and the reference site are given in Tables 38 and 39. Detailed mIBI results are included in Appendix 9. The mIBI scores ranged from 0.0 to 5.7. All QHEI scores within the four watersheds fell below 60, the level conducive to existence of warmwater faunas (Ohio EPA, 1999). QHEI scores were not statistically correlated with mIBI scores, meaning that degraded habitat as measured by the QHEI did not necessarily correlate with a depauperate benthic community as measured by the mIBI. Brief descriptions and representative photos of habitat quality for the reference site and each of the 10 sampling follows.

TABLE 38. Classification scores and mIBI score for sampling sites within the Flat Creek, Griffen Ditch, Fleming Ditch, and Somers Creek Watersheds and the reference site as sampled May 30-31, 2000.

	Reference Site	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 6**	**Site 7**	**Site 8**	**Site 9**
HBI	0	8	2	4	0	4	0	0	0	0
No. Taxa (family)	4	4	4	2	0	4	6	8	0	4
% Dominant Taxa	4	4	4	0	0	4	4	6	2	0
EPT Index	2	4	2	0	0	2	4	0	0	0
EPT Count/Total Count	2	6	4	0	0	4	2	0	0	0
EPT Abun./Chir. Abun.	0	8	4	4	0	6	8	2	0	0
mIBI Score	**2.0**	**5.7**	**3.3**	**1.7**	**0.0**	**4.0**	**4.0**	**2.7**	**0.3**	**0.7**

TABLE 39. QHEI Scores for the Flat Creek, Griffen Ditch, Fleming Ditch, and Somers Creek Watershed sampling sites and reference site as sampled May 30-31, 2000.

Site	Substrate Score	Cover Score	Channel Score	Riparian Score	Pool Score	Riffle Score	Gradient Score	Total Score
Maximum Possible Score	20	20	20	10	12	8	10	100
Reference Site	14	19	12	5.5	4	4	4	62.5
SITE 1-Flat Creek	16	4	6	5	3	5	4	43
SITE 2-Flat Creek	9	5	8	5.5	0	0	4	31.5
SITE 3-Flat Creek	1	3	3	4	0	0	4	15
SITE 4-Flat Creek	12	4	5	5	4	2	4	36
SITE 5-Flat Creek	5	3	5	4	0	0	4	21
SITE 6-Griffin Ditch	14	4	4	5	0	0	4	31
SITE 7-Fleming Ditch	10	3	6	5	5	1	4	34
SITE 8-Somers Creek	12	13	8	7	0	0	4	44
SITE 9-Somers Creek	5	3	4	4.5	0	0	4	20.5

Reference Site – Eightmile Creek. The substrate type at this site was 90% sand. Moderate bank erosion was present. The immediate streamside was unvegetated, but higher along the banks the primary vegetation was trees (Figure 33). The banks were steeply sloping with an average height of 16.5 ft (5 m). The Reference Site scored 62.5 of 100 total possible points on the Qualitative Habitat Evaluation Index (QHEI). The QHEI pool score was 4 of 12 and the riffle score was 4 of 8, indicating that pool-riffle development was poor.

FIGURE 33. Reference site sampling location on Eightmile Creek.

Site 1 - Flat Creek. The substrate type at this site was 65% cobble and 25% sand. Embeddedness was moderate. The average height of the banks was 2.5 m. There was little or no bank erosion. Banks were vegetated predominately by shrubs (Figure 34). Pools, riffles, overhanging vegetation, shallows and aquatic macrophytes provide in-stream cover. (Aquatic macrophytes are submerged, rooted aquatic plants.) Site 1 scored 43 of 100 total possible QHEI

points. The QHEI cover score was only 4 of 20, indicating that in-stream cover was nearly absent.

FIGURE 34. Site 1 sampling location on Flat Creek.

Site 2 - Flat Creek. The substrate type at this site was 95% sand, and the remaining 5% was rip-rap for bank stabilization. The average height of the banks was 1.5 m. There was moderate bank erosion. Banks were vegetated predominately by grasses and some shrubs (Figure 35). Site 2 scored 31.5 of 100 total possible QHEI points. The QHEI cover score was only 5 of 20, which indicates that in-stream cover was nearly absent. Little pool-riffle development was evident.

FIGURE 35. Site 2 sampling location on Flat Creek.

Site 3 - Flat Creek. The substrate type at this site was 50% silt and 50% clay. The average height of the banks was 2.5 m. Little or no bank erosion was evident. Banks were vegetated predominately by grasses (Figure 36). Aquatic macrophytes, logs, and woody debris provided in-stream cover. Site 3 scored only 15 of 100 total possible points on the Qualitative Habitat

Evaluation Index (QHEI). The QHEI cover score was only 3 of 20, which indicates that in-stream cover was nearly absent. With a score of 1 out of 20 possible points, the substrate was of very poor quality. The QHEI pool score was 0 of 12 and the QHEI riffle score was 0 of 8, which indicates that there was no pool-riffle development. No pool-riffle development was evident in the reach (pool score = 0; riffle score = 0).

FIGURE 36. Site 3 sampling location on Flat Creek.

Site 4 - Flat Creek. The substrate type at this site was 90% gravel. Embeddedness was extensive. The average height of the banks was 2.5 m. Little or no bank erosion was occurring. Banks were vegetated predominately by grasses (Figure 37). Moderately developed pools and riffles, overhanging vegetation, aquatic macrophytes, and shallows were available for in-stream habitat. Site 4 scored 36 of 100 total possible QHEI points.

FIGURE 37. Site 4 sampling location on Flat Creek.

Site 5 - Flat Creek. The substrate type at this site was 70% silt. The average height of the banks was 2 m. Banks were stabilized by rip-rap, vegetated predominately by grasses, and did not

appear to be eroding (Figure 38). Site 5 scored 21 of 100 total possible QHEI points. The QHEI cover score was only 3 of 20, which indicates that in-stream cover was nearly absent. The QHEI substrate score was only 5 of 20, which indicates that the substrate was of poor quality. With no pool-riffle development, the stream could be characterized as a glide.

FIGURE 38. Site 5 sampling location on Flat Creek.

Site 6 - Griffin Ditch. The substrate type at this site was 60% gravel and 20% cobble. The remaining 20% was composed of other fine soil particles like silt and clay. Embeddedness was moderate. The average height of the banks was 2 m. The banks were fairly unstable, moderately eroded and vegetated predominately by grasses (Figure 39). Undercut banks, shallows, and aquatic macrophytes provided a modicum of in-stream habitat. Site 6 scored 31 of 100 total possible points on the Qualitative Habitat Evaluation Index (QHEI). The QHEI pool score was 0 of 12 and the QHEI riffle score was 0 of 8, indicating that there was no pool-riffle development.

FIGURE 39. Site 6 sampling location on Griffen Ditch.

Site 7 - Fleming Ditch. The substrate type at this site was 70% gravel and 25% sand. Embeddedness was extensive. The average height of the banks was 1.5 m. Little or no bank erosion was evident. Banks were vegetated predominately by grasses and shrubs (Figure 40). Unstable, moderately developed pools and riffles, overhanging vegetation and aquatic

macrophytes provided some in-stream cover. Site 7 scored 34 of 100 total possible QHEI points. Riffle development was poor, scoring only 1 of the 8 possible points.

FIGURE 40. Site 7 sampling location on Fleming Ditch.

Site 8 – Somers Creek. The substrate type at this site was 40% cobble and 40% sand. The average height of the banks was 1 m. Evidence of bank erosion was present. Banks were vegetated predominately by grasses and shrubs (Figure 41). Overhanging vegetation, deep pools, root wads, shallows, logs, and woody debris provided in-stream habitat. Site 8 scored 44 of 100 total possible QHEI points. Neither pools (0/12) nor riffles (0/8) were well developed.

FIGURE 41. Site 8 sampling location on Somers Creek.

Site 9 – Somers Creek. The substrate type at this site was 95% silt. The average height of the banks was 1 m. Banks were stable, not eroding, and vegetated predominately by grasses (Figure 42). Undercut banks and a proliferation of macrophytes provided in-stream habitat. Site 9 scored 20.5 of 100 total possible QHEI points. The QHEI substrate score was only 5 of 20, indicating that the substrate was of poor quality. Again, pool-riffle development was absent.

FIGURE 42. Site 9 sampling location on Somers Creek.

Discussion

Because most of the stream reaches surveyed had been channelized in the past, there was little evidence of pool and riffle development, as indicated by the low QHEI scores in these areas. Pool/riffle habitats provide a diversity of habitat conditions that attract a diversity of biotic organisms. The predominant substrate in the streambeds was silt, which provides only limited habitat value. Gravel and cobble substrates provide a diversity of attachment sites that attract many different macroinvertebrates and fish. Work by the drainage board to keep the channel and its banks free of obstructions discourages overhead vegetative cover and lowers the QHEI score.

The overall habitat degradation components which impair conditions for aquatic life within the study watersheds are:

- Siltation/Substrate embeddedness: excessive loading of fine sediments and silt clogs or embeds the substrate spaces destroying habitat for aquatic invertebrates and fish.
- Channel alterations: ditching, dredging, straightening, and other changes to channel structure can affect the ability of organisms to live in the stream.
- Poor pool/riffle development: deep places (pools) and shallow places (riffles) within a stream reach offer habitat variety for aquatic organisms and can impact certain chemical characteristics of flowing water like temperature, dissolved oxygen concentrations, and suspended sediment load.
- Poor in-stream cover: in-stream cover like undercut banks, overhanging vegetation, woody debris, and aquatic vegetation offer protection and habitat for aquatic organisms. Like pools and riffles, in-stream cover also is related to certain chemical characteristics like temperature and dissolved oxygen.

The following site-by-site discussion focuses on each site individually offering analysis of the mIBI and QHEI.

Site 1 – Flat Creek. The over all habitat quality at Site 1 was marginal to submarginal, yet receiving one of the highest QHEI scores (43) and the highest mIBI score in the Flat Creek Watershed. The QHEI was negatively influenced by poor in-stream cover, recent channelization, and lack of pool development. However, habitat type diversity and periphyton abundance (an important food source for macroinvertebrates) helped to create conditions conducive to aquatic life. The sampled macroinvertebrate community was indicative of only slightly impaired conditions. Even though sediment loads were elevated at this site, *Hydropsychidae* and *Phylopotamidae*, two moderately tolerant members of the Tricopteran family, dominated the macroinvertebrate community indicating that habitat conditions were still suitable for adaptable fauna (Appendix 9, Table A-9.3). Site 1 demonstrated signs of habitat recovery and improvement based on the 1991 and 1998 historical data (Table 22). Flat Creek at Site 1 scored only 3.4 of the 8 possible mIBI points in 1991 and 1998 indicative of a moderately impaired stream. For comparison, Site 1 was scored as a slightly impaired stream during this study. The macroinvertebrate assemblage present at Site 1 was less tolerant than that sampled historically, signifying enhanced water and habitat quality for benthic insects. Even though only three samples from 1991, 1998, and 2000 are available and even though the QHEI score was still below 60, signs of habitat and biological progression are evident.

Site 2 – Flat Creek. Heavy siltation and excessive embeddedness characterized Site 2. The QHEI score of only 31.5 reflected the extremely poor in-stream cover, riparian zone quality, and pool/riffle development which characterized Site 2. The mIBI score of 3.3 also indicated impairment. Large numbers of pollution tolerant fly larvae belonging to the family Chironomidae were collected at the site. The macroinvertebrate community was possible impacted by the relative lack of available food resources. Researchers noted the absence of periphyton and other organic matter which are an important part of the food chain within streams.

Site 3 – Flat Creek. Few natural stream qualities were observed at Site 3 on Flat Creek. The mIBI score was only 1.7 of 8, and the QHEI score of 15 was the lowest score assigned to any reach during the study. Every parameter received a poor score during QHEI assessment. The substrate within the reach was 100% silt and clay resulting in a substrate score of only one of a possible 20 points. The complete absence of any in-stream cover, riparian vegetation, pools, or riffles was noted. Some habitat and food availability was available for the macroinvertebrate community in the form of periphyton, filamentous algae, and course particulate organic matter (CPOM).

Site 4 – Flat Creek. Anthropogenic disturbances including recent stream channelization, canopy removal, bank shaping, and relocation of the natural stream channel morphology characterized the Site 4 reach on Flat Creek. Extensive substrate embeddedness and lack of in-stream cover or other habitat reduced the mIBI score to 0. This agricultural drainage ditch was found to be severely impaired for aquatic life support. The macroinvertebrate assemblage was of low diversity and of high tolerance to pollution and disturbance.

Site 5 – Flat Creek. Site 5 on Flat Creek scored only 21 of the possible 100 QHEI points. The site is similar in nature to many of the other sites within the Flat Creek Watershed, characterized by extensive embeddedness and siltation, poor in-stream cover, channelization, lack of riparian buffer areas, dominance of agricultural row crop in the immediate watershed, and poor riffle/pool development. The macroinvertebrate community present at the site indicated only moderate to slight impairment due to dense macrophytic growth within the channel. Macrophyte growth influences stream habitat by reducing current velocities and promoting siltation. Increased siltation fosters increased macrophytic growth. Although siltation destroys habitat for many macroinvertebrates, it essentially creates habitat within the macrophyte beds for other macroinvertebrate types (Gregg and Rose, 1982).

Site 6 – Griffen Ditch. Typical of stream reaches within the study watersheds and similar to Site 5, Griffen Ditch (Site 6) was also dominated by degraded stream habitat:

- Very poor in-stream cover
- Recent of non-recovering channelization
- Channel modification
- Agricultural row crop as the riparian buffer area
- Poor pool/riffle development

As at Site 5, an abundance of periphyton and rooted emergent macrophytes was documented. Although the macrophyte beds provide habitat and food resources, it is interesting to note that 77% of the organisms collected and assigned tolerance values (Hilsenhoff, 1988) were highly pollution tolerant.

Site 7 – Fleming Ditch. With a QHEI score of only 34, Fleming Ditch also suffers from the typical causes of degradation that have already been discussed. Researchers noted extensive embeddedness and siltation of the substrate. Because little or no erosion was present within the stream reach, it was assumed that allochthonous sources (sources outside the stream within the watershed) are the primary sediment contributors. As in Griffen Ditch, pollution-tolerant macroinvertebrate families belonging to the Odonata (dragonfly), Isopoda (pill bug), Amphipoda (scud), and Diptera (fly) orders dominated the insect assemblage in the reach.

Site 8 – Somers Creek. Site 8 on Somers Creek received the highest QHEI score of any study reach within the watersheds. Diverse substrate types and only moderate siltation were noted. Additionally, in-stream cover such as overhanging vegetation, deep pools, root wads, and large woody debris were present within the reach. A wide forested strip comprised the right riparian buffer area bordering the stream. Despite the in-stream cover structure, the mIBI score was near 0. Based on stream chemistry samples, the degraded quality of the water itself may be in part responsible for the low diversity and high tolerance of organisms found there. Additionally, researchers noted the relative lack of plant or other organic matter in the reach. This can cause food limitation of the macroinvertebrate community.

Site 9 – Somers Creek.
In contrast to all other sites sampled during the study, the immediate watershed at Site 9 was in residential development. The QHEI scored poorly in the substrate, cover, channel, and riparian categories. The substrate was mostly silt and was heavily embedded. Aside from macrophytic growth that was choking the stream channel, little other in-stream cover was available. The

stream channel lacked pools or riffles and was not recovering from past channelization. Like the QHEI score, the mIBI score was also poor. Organisms of the pollution-tolerant family Chironomidae composed 63.25% of the sample. Only three organisms of medium tolerance were collected. Although primary producers at the base of the food chain were available, the Site 9 macroinvertebrate community was of poor diversity and quality. Other degraded habitat conditions including siltation and water quality have impacted the biota in this reach.

Summary

All sampling sites within the Flat Creek, Griffen Ditch, Fleming Ditch, and Somers Creek Watersheds demonstrate some degree of impairment as measured by the QHEI and the mIBI. The QHEI and mIBI were not statistically correlated, indicating that some other factor(s) besides the evaluated habitat parameters was playing a role in macroinvertebrate community structure. Habitat impairment was mostly due to siltation/substrate embeddedness, channel alterations, poor pool and riffle development, and poor in-stream cover. Habitat quality was most degraded on Flat Creek at Site 3, Somers Creek at Site 9, and Flat Creek at Site 5 as measured by the QHEI. mIBI scores for Flat Creek at Sites 3 and 4 and Somers Creek at Sites 8 and 9 were alarmingly low. In general the macroinvertebrate communities sampled at these sites were of low richness and composed predominantly of highly tolerant taxa. These depauperate assemblages are probably the result of poor water and habitat quality.

In summary, the impaired conditions documented within the study watershed streams are a result of both in-stream and watershed-level practices. Drainage, water quality, and biological health could be dramatically improved by incorporation of land management practices and conservation advocacy within the watershed and riparian zones.

Relationships Among Chemical, Biological, and Habitat Characteristics

Chemical parameters and biological and habitat indices were analyzed for relationships that could provide additional insight into mechanisms governing impairment within the subwatersheds. The following list includes parameters for which no statistically significant linear relationship was found:

- QHEI Score vs mIBI Score
- QHEI Substrate vs. mIBI Score
- QHEI Channel vs. mIBI Score
- QHEI Riparian vs. mIBI Score
- QHEI Cover vs. mIBI Score
- QHEI Score vs. TSS (mg/L)
- QHEI Riparian vs. HBI
- QHEI vs. HBI
- QHEI Cover vs. HBI
- mIBI vs. NO_3^- (mg/L)
- mIBI vs. Total Nitrogen (mg/L)
- mIBI vs. TSS (mg/L)
- HBI vs. NO_3^- (mg/L)
- HBI vs. TSS (mg/L)

One possible explanation for this lack of correlation is that these creeks are, in general, highly modified, somewhat artificial drainage ditches, and consequently might not reflect natural relationships among parameters of water quality, habitat quality, and biological health.

LOADING MODEL

Since phosphorus is the limiting nutrient in most lakes and reservoirs, watershed management programs often target phosphorus as a nutrient to control. The study employed a phosphorus model to estimate the dynamics of this important nutrient in these watersheds. Phosphorus export from each of the study subwatersheds was roughly estimated using phosphorus export coefficients (Table 40) after Reckhow et al. (1980). The export coefficients are based on land use and the fact that certain land uses result in more nutrient loading to streams than others. For instance, general agricultural land use with a coefficient of 0.5 results in more phosphorus loading than pasture/grassland land use with a coefficient of 0.15. Export coefficients were multiplied by the acreage in each subwatershed to give a phosphorus mass exported per year (kg/yr) by each subwatershed (Table 41). These numbers were normalized for subwatershed area to give an export estimation of mass per hectare per year (kg/ha/yr).

TABLE 40. Phosphorus export coefficients used to model phosphorus loading in the Flat Creek, Griffen Ditch, Fleming Ditch, and Somers Creek Watersheds.

Land Cover	P-Export (kg/ha/yr)
Water	0.00
Low Intensity Residential	0.50
High Intensity Residential	0.90
Commercial	0.50
Deciduous Forest	0.10
Evergreen Forest	0.15
Mixed Deciduous/Evergreen Forest	0.10
Pasture/Grassland	0.15
Row Crop	0.50
Woody Wetland	0.10
Herb. Wetland	0.05

It is important to note that this model is very general in nature. For example, not all agricultural row crop land use is best described by a 0.5 export coefficient. Different crop types and different Best Management Practice implementations certainly affect phosphorus transport from the land. Additionally, other factors like soil type and topography are not considered by a model this general in nature.

Land use is fairly homogeneous across the four study watersheds (Table 6 and Appendix 3). Agricultural row crop accounted for 77-96% of land use in all watersheds and subwatersheds. The next two most common land uses were pasture/grassland and deciduous forest. Because land uses were so similar among subwatersheds, subwatershed area tended to drive phosphorus export (i.e., larger subwatersheds like the Flat Creek 1 Subwatershed and the Griffen Ditch Watershed exported more phosphorus than smaller watersheds). Figure 43 and 44 show this result. When normalized for area, the Flat Creek 2 and 3 Subwatersheds dominated phosphorus export (Figure 44). The Griffen Ditch Watershed and the Flat Creek 5 Subwatershed also contributed significant phosphorus loads per hectare. These four areas also contain some of the highest percentages of agricultural row crop (87-96%).

TABLE 41. Phosphorus export for each watershed given in kg/yr and kg/ha/yr.

Watershed	P Export (kg/yr)	P Export (kg/ha/yr)
Flat Creek 1	4879.03	1.76
Flat Creek 2	1795.97	1.93
Flat Creek 3	2249.76	1.93
Flat Creek 4	1652.37	1.88
Flat Creek 5	3413.00	1.90
Griffen Ditch	4002.85	1.81
Fleming Ditch	945.45	1.79
Somers Creek	3166.73	1.69

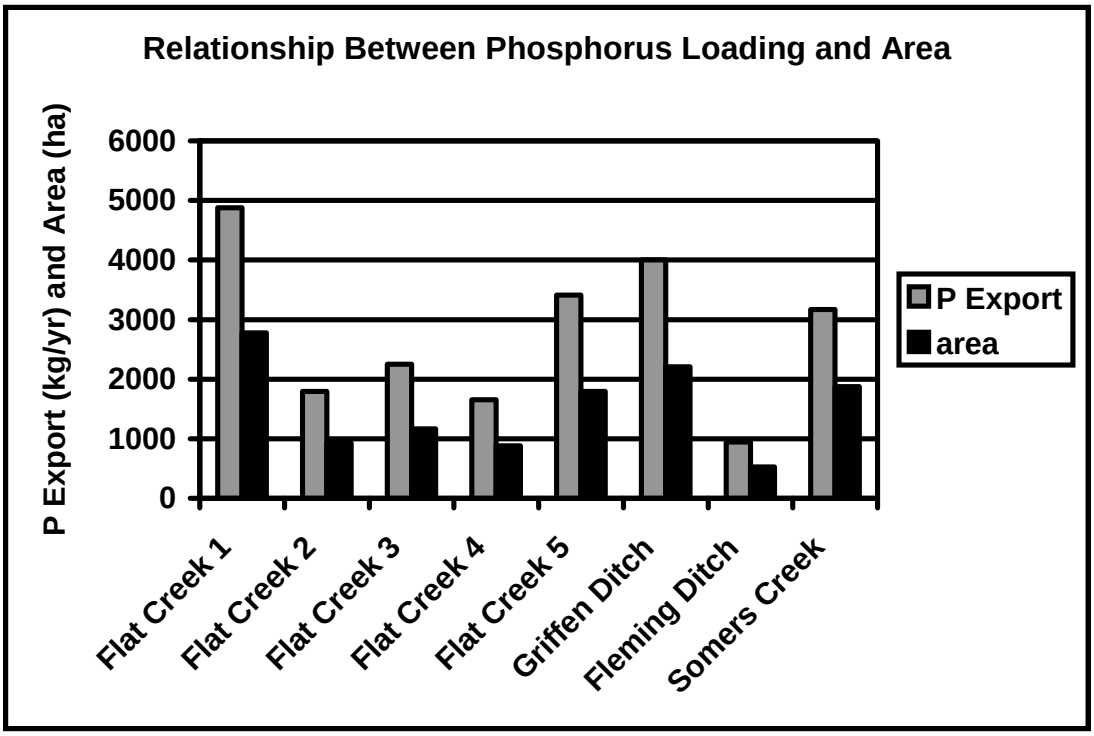


FIGURE 43. Relationship between phosphorus loading and area estimated by the export model.

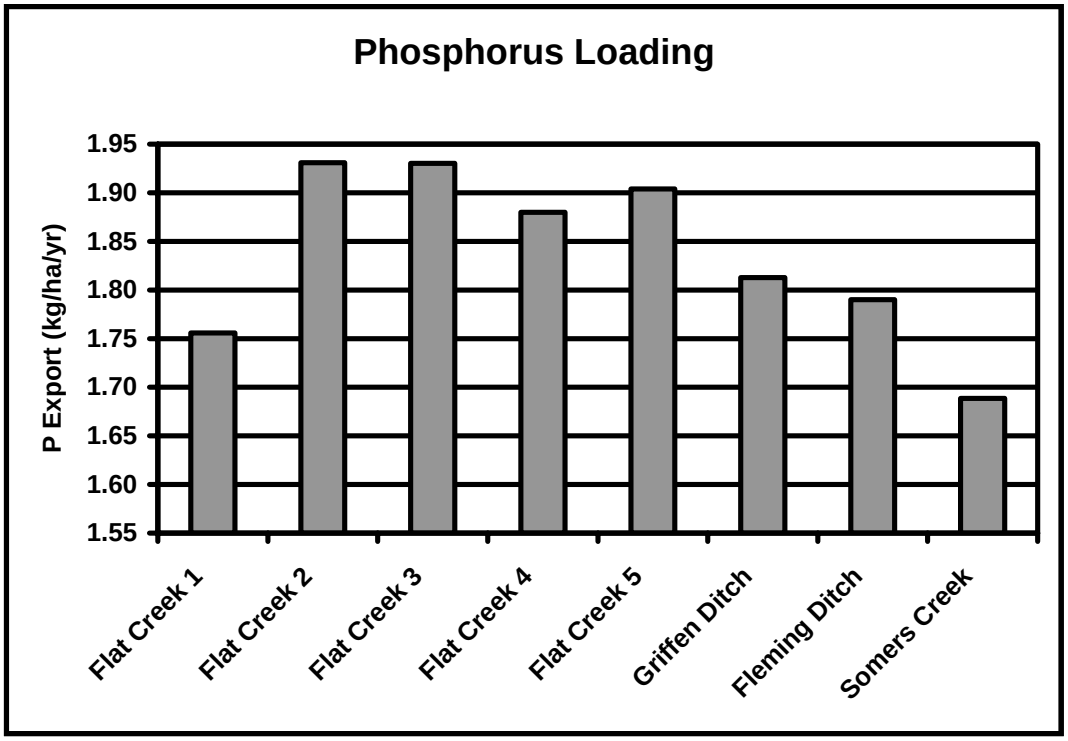


FIGURE 44. Phosphorus loading per unit area as estimated by the export model.

RECOMMENDATIONS

All of the smaller watersheds within the each of the four study watersheds could benefit from land treatment and best management strategies as already described in detail in the Watershed Investigation Section. Finances, time, manpower, and other restraints make it impossible to implement all of these management techniques at once. Thus, it is necessary to prioritize the recommendations.

These prioritizations and recommendations are simply guidelines based on conditions documented during this study. These conditions may change as land use within the watershed changes. Management efforts may need to be prioritized differently based on project feasibility and individual landowner willingness to participate. To ensure maximum participation in any management effort, all watershed stakeholders should be allowed to participate in prioritizing the management efforts in the watershed.

It is also important to note that even if all stakeholders agree that this is the best prioritization to meet their needs, action need not be taken in this order. Some of the smaller, less expensive recommendations may be implemented while funds are raised to implement some of the larger projects. Many of the larger projects will require feasibility work to ensure landowner willingness to participate in the project. In some cases, it may be necessary to attain regulatory approval as well. Landowner endorsement and regulatory approval along with stakeholder input may ultimately determine the prioritization of management efforts.

Results from the mapping exercises, the aerial tour, the windshield survey, water quality sampling, biological sampling, habitat sampling, and the modeling exercise were used to prioritize subwatersheds for future work. The subwatersheds are discussed in order of priority. It is also important to note that in order to make prioritizations, it is necessary to make some generalizations. Additional general recommendations, like innovative riparian management system use and recommended practices for homeowners, follow the prioritization section. Many of these recommendations may already be in practice; however, for the sake of thoroughness, they are reiterated here.

Prioritization

Based on the findings of this study, the order of prioritization for work, projects, and program enrollment within the Flat Creek, Griffen Ditch, Fleming Ditch, and Somers Creek Watersheds should be:

1. Flat Creek Subwatershed 2
2. Fleming Ditch
3. Griffen Ditch
4. Somers Creek
5. Flat Creek Subwatershed 1
6. Flat Creek Subwatershed 4
7. Flat Creek Subwatershed 3
8. Flat Creek Subwatershed 5

The Flat Creek Subwatershed 2 is of top priority because it was the largest contributor of sediment, phosphorus, and bacteria to its receiving waterbody especially during storm flow. The phosphorus model also pinpointed Subwatershed 2 as the dominant phosphorus contributor. Even though not much of its watershed is mapped as highly erodible, several potential projects were identified and one of these is located within a highly erodible tract.

The Fleming Ditch Watershed is also of primary concern due to large amounts of highly erodible land and large HEL:CRP ratio. Fleming Ditch also loaded significant amounts of solids, phosphorus, and *E. coli* per unit area during the storm event.

The Griffen Ditch Watershed also contains significant highly erodible acreage that is currently untreated by conservation programs. The aerial and windshield tours isolated areas where 12 potential projects could be installed, four of which were located on HEL.

Although management in the Somers Creek Watershed may differ somewhat due to small differences in land use practices, Somers Creek was placed fourth on the priority list. The QHEI and mIBI scores were depressed at both sampling sites on the creek, and 10 possible future project sites were noted during watershed tours.

The remainder of the Flat Creek Watershed occupies the last four positions on the list of priorities. Flat Creek Subwatershed 1 was prioritized due to the large amounts of HEL and the relative lack of CRP treatment near the mouth of the creek. Additionally, sediment, nutrient, and bacterial load contributions per unit of watershed area were significant. Ten projects, four of which were located on HEL, are possibilities within the subwatershed.

Even though Flat Creek Subwatersheds 4, 3, and 5 fall below 1 on the priority list, work in these areas should not be neglected. Water quality concerns in Flat Creek cannot be sustainably addressed without focusing on “headwater” area problems as well. Flat Creek Subwatershed 4 was the third largest contributor of total phosphorus during both base and storm flow. Although its watershed contains little highly erodible soil, eight potential projects were identified within the area, and biotic health as indicated by the mIBI was most depressed at Site 4. Flat Creek Subwatersheds 3 and 5 also contain little HEL. Measured sediment and nutrient loading rates were lower for the two subwatersheds, although the land use-based phosphorus model estimated that Subwatershed 3 theoretically contributed the second largest phosphorus amount of any watershed included in the study. Additionally, QHEI and mIBI scores at Site 3 were low indicating poor habitat and biotic quality.

In general, Flat Creek Subwatersheds 4, 3, and 5 are of lower priority because they were generally responsible for lower amounts of pollutant loading and generally contain less HEL than other watersheds of higher priority. In very general terms, watersheds and subwatersheds with less HEL or more HEL protected in CRP do tend to have better water and habitat quality.

General Recommendations

1. Develop a watershed or land use management plan. A watershed management plan documents current conditions within a watershed, sets forth goals for the watershed based on stakeholders’ desires, forwards a plan of how to reach the goal, and provides for

monitoring of success toward reaching the goal. To be effective, all stakeholders must be included in the plan's development. The watershed management plan can help to keep a group focused through the implementation phase and can serve as a tool to get people involved and to seek additional funding. A plan will also help to hold a group together through time as steering committee membership turns over.

2. Before initiating watershed treatment projects, consider conducting a survey of landowners in the watershed to determine landowners' concern for water quality problems, to evaluate landowers' opinions of management systems, and to quantify the value to surface and groundwater quality improvement.
3. Implement recommended BMPs and projects discussed for each subwatershed (Tables 24-30) based on subwatershed priority. These projects include: bank stabilization, encouragement of riparian vegetation growth, filter strip and grassed waterway installation, livestock fencing, grade control and other structure installation, stormwater treatment, and creating additional water storage capacity where possible. This work should focus on interested landowners in identified critical areas first.
4. Consider working with the County Drainage Board to develop improved, more sustainable drainage management plans. A sustainable drainage management plan might include maintenance or dredging in only very specific necessary locations instead of cleaning entire reaches, allowing necessity to dictate maintenance instead of budget availability, and education and outreach to help landowners understand the value of intact riparian zones. Specialists like the county surveyor and drainage administrator may have other ideas for a complete and sustainable plan.
5. Consider using innovative riparian management systems similar to the one discussed earlier in the Best Management Practice Section. Modified systems of this type would be especially beneficial for use in critical or vulnerable stream reaches where they could significantly impact non-point source pollution. Several critical stream reaches were identified by this study.
6. Consider a project to preserve the small remaining amount of wetlands near the mouth of Flat Creek. By working with landowners and area schools, the Wells County SWCD could "adopt" the area for educational activities. Alternatively, the area could be designated or recognized as a conservatory, and landowners could be formally recognized for their conservation efforts. At least one landowner (met during the windshield survey) in that area would be interested in the above ideas.
7. Consider wetland restoration and shallow water pond construction options for reducing flow volumes and velocities. Although in many situations construction of wetland areas is not feasible due to surrounding land uses and drainage needs, water filtration and storage will affect water quality downstream. It will also reduce bank and channel damage downstream.
8. Advocate CRP enrollment and participation in other programs especially on land of high erosion potential and in high priority subwatersheds. Reach out to landowners who have participated in the past and encourage re-enrollment.
9. Maintain and survey projects after completion. All projects including filter strips and grassed waterways require maintenance to ensure proper function.
10. Invite producers and other landowners out to successful project sites. There is no better advertisement than a success story. Focus on information dissemination and transfer by scheduling on-site field days during non-busy seasons.

11. Work with landowners to fence cattle and other grazing animals away from streams.
12. Encourage all landowners in the watershed to allow natural riparian vegetation growth. Their rooting systems impart many natural benefits to the stream.
13. Work on education and outreach in the watershed. Landowners who are educated about critical environmental areas on their land will be more responsive to projects and programs and will become more involved in protection and conservation of resources.
14. Promote conservation tillage practices especially on HEL tracts and in environmentally sensitive areas. Inform farmers of the benefits of no-till, especially after the 3rd consecutive year of use.
15. Work with the Wells County Purdue Cooperative Extension Agency to promote education on proper nutrient, herbicide, and pesticide management. Promote realistic yield goals instead of optimum yield goals especially on HEL tracts and in environmentally sensitive areas. Promote environmental set-backs in critical areas.
16. Work with a bulk seed distributor to make native plant seed available in large quantities at low prices.
17. Reach out to a school or other volunteer group to set up volunteer monitoring within the watershed through the Hoosier Riverwatch Program.
18. Work with the highway department and the County Drainage Board to implement best management practices for treatment of storm water runoff from roadways and other impervious surfaces. Storm water from roadways should be routed to detention basins and/or vegetated areas to allow for filtration and settlement of suspended particles. An initial detention basin project could be built for use as a demonstration and education tool.
19. Work with the County Health Department to ensure proper siting and engineering of septic systems. The use of alternative technology should be encouraged when conditions may compromise proper waste treatment. IDNR and USDA soil scientists in the area are a valuable resource for expertise in characterizing soils for septic use. Their knowledge could be tapped for future building and siting of systems. If building was necessary on a site where conditions were not suitable for a traditional system, alternative technology could be constructed and the site used as a demonstration and education/outreach tool. The SWCD may also consider an educational campaign to make homeowners and potential developers aware of septic system and septic maintenance issues in the Wabash Moraine.
20. Homeowners in the watershed should:
    a. Avoid lawn fertilizing near the stream's edge.
    b. Examine all drains that lead from roads, driveways, or rooftops to the stream, and consider alternate routes for these drains that would filter pollutants before they reach the water.
    c. Keep organic debris like lawn clippings, leaves, and animal waste out of the water.
    d. Avoid mowing up to the stream's edge; allow natural riparian vegetation growth.
    e. Properly maintain on-site wastewater treatment systems. Systems should be pumped regularly and leach fields should be properly cared for. Undue pressure on systems may be alleviated by water conservation practices as well.

ADDITIONAL FUNDING SOURCES AND WATERSHED RESOURCES

Funding and other resources are important for the actual implementation of recommended management practices in a watershed. Several cost share and grant programs are available to help offset costs of watershed projects. Additionally, both human and material resources may be available in the watershed. It is important to note that funding sources are often tailored to certain groups or individuals, and not all funding sources may be available to all landowners.

Funding Sources

There are several cost-share grants available from both state and federal government agencies specific to watershed management. Lake associations and/or Soil and Water Conservation Districts (SWCDs) can apply for the majority of these grants. The main goal of these grants and other funding sources is to improve water quality though specific BMPs. As public awareness shifts towards watershed management, these grants will become more and more competitive. Therefore, any association interested in improving water quality through the use of grants must become active soon. Once an association is recognized as a "watershed management activist" it will become easier to obtain these funds repeatedly. The following are some of the possible major funding sources available to lake and watershed associations for watershed management.

Lake and River Enhancement Program (LARE)

This is the program that funded this diagnostic study. LARE is administered by the Indiana Department of Natural Resources, Division of Soil Conservation. The program's main goals are to control sediment and nutrient inputs to lakes and streams and prevent or reverse degradation from these inputs through the implementation of corrective measures. Under present policy, the LARE program may fund lake and watershed specific construction actions up to $100,000 for a specific project or $300,000 for all projects on a specific lake or stream. Cost-share approved projects require a 0-25% cash or in-kind match, depending on the project. LARE also has a "watershed land treatment" component that can provide grants to SWCDs for multi-year projects. The funds are available on a cost-sharing basis with farmers who implement various BMPs. The watershed land treatment program is highly recommended as a project funding source for the Flat Creek, Griffen Ditch, Fleming Ditch, and Somers Creek Watersheds.

Clean Water Act Section 319 Nonpoint Source Pollution Management Grant

The 319 Grant Program is administered by the Indiana Department of Environmental Management (IDEM), Office of Water Management, Watershed Management Section. 319 is a federal grant made available by the Environmental Protection Agency (EPA). 319 grants fund projects that target nonpoint source water pollution. Nonpoint source pollution (NPS) refers to pollution originating from general sources rather than specific discharge points (Olem and Flock, 1990). Sediment, animal and human waste, nutrients, pesticides, and other chemicals resulting from land use activities such as mining, farming, logging, construction, and septic fields are considered NPS pollution. According to the EPA, NPS pollution is the number one contributor to water pollution in the United States. To qualify for funding, the water body must be listed in the state's 305(b) report as a high priority water body or be identified by a diagnostic study as being impacted by NPS pollution. Funds can be requested for up to $300,000 for individual projects. There is a 25% cash or in-kind match requirement.

Section 104(b)(3) NPDES Related State Program Grants

Section 104(b)(3) of the Clean Water Act gives authority to a grant program called the National Pollutant Discharge Elimination System (NPDES) Related State Program Grants. These grants provide money for developing, implementing, and demonstrating new concepts or requirements that will improve the effectiveness of the NPDES permit program that regulates point source discharges of water pollution. Projects that qualify for Section 104(b)(3) grants involve water pollution sources and activities regulated by the NPDES program. The awarded amount can vary by project and there is a required 5% match.

Section 205(j) Water Quality Management Planning Grants

Funds allocated by Section 205(j) of the Clean Water Act are granted for water quality management planning and design. Grants are given to municipal governments, county governments, regional planning commissions, and other public organizations for researching point and non-point source pollution problems and developing plans to deal with the problems. According to the IDEM Office of Water Quality website: "The Section 205(j) program provides for projects that gather and map information on non-point and point source water pollution, develop recommendations for increasing the involvement of environmental and civic organizations in watershed planning and implementation activities, and implement watershed management plans. No match is required. For more information on the 310, 104(b)(3), and 205(j) grants, please see the IDEM website http://www.in.gov/idem/water/planbr/wsm/Section205j_main.html.

Other Federal Grant Programs

The USDA and EPA award research and project initiation grants through the US National Research Initiative Competitive Grants Program and the Agriculture in Concert with the Environment Program.

Watershed Protection and Flood Prevention Program

The Watershed Protection and Flood Prevention Program is funded by the U.S. Department of Agriculture (USDA) and is administered by the Natural Resources Conservation Service (NRCS). Funding targets a variety of watershed activities including watershed protection, flood prevention, erosion and sediment control, water supply, water quality, fish and wildlife habitat enhancement, wetlands creation and restoration, and public recreation in small watersheds (250,000 or fewer acres). The program covers 100% of flood prevention construction costs or 50% of construction costs for agricultural water management, recreational, or fish and wildlife projects.

Conservation Reserve Program

As already discussed, the Conservation Reserve Program (CRP) is funded by the USDA and administered by the Farm Service Agency (FSA). CRP is a voluntary, competitive program designed to encourage farmers to establish vegetation on their property in an effort to decrease erosion, improve water quality, or enhance wildlife habitat. The program targets farmed areas that have a high potential for degrading water quality under traditional agricultural practices or areas that might make good wildlife habitat if they were not farmed. Such areas include highly erodible land, riparian zones, and farmed wetlands. Participants in the program receive cost share assistance for any plantings or construction as well as annual payments for any land set aside.

Wetlands Reserve Program
The Wetlands Reserve Program (WRP) is funded by the USDA and is administered by the NRCS. WRP is a subsection of the Conservation Reserve Program. This voluntary program provides funding for the restoration of wetlands on agricultural land. To qualify for the program, land must be restorable and suitable for wildlife benefits. This includes farmed wetlands, prior converted cropland, farmed wet pasture, farmland that has become a wetland as a result of flooding, riparian areas which link protected wetlands, and the land adjacent to protected wetlands that contribute to wetland functions and values. Landowners may place permanent or 30-year easements on land in the program. Landowners receive payment for these easement agreements. Restoration cost-share funds are also available. No match is required.

North American Wetland Conservation Act Grant Program
The North American Wetland Conservation Act Grant Program (NAWCA) is funded and administered by the U.S. Department of Interior. This program provides support for projects that involve long-term conservation of wetland ecosystems and their inhabitants including waterfowl, migratory birds, fish and other wildlife. The match for this program is on a 1:1 basis.

Wildlife Habitat Incentive Program
The Wildlife Incentive Program (WHIP) is funded by the USDA and administered by the NRCS. This program provides support to landowners to develop and improve wildlife habitat on private lands. Support includes technical assistance as well cost sharing payments. Those lands already enrolled in WRP are not eligible for WHIP. The match is 25%.

Environmental Quality Incentives Program
The Environmental Quality Incentives Program (EQIP) is a voluntary program designed to provide assistance to producers to establish conservation practices in target areas where significant natural resource concerns exist. Eligible land includes cropland, rangeland, pasture, and forestland, and preference is given to applications which propose BMP installation that benefits wildlife. EQIP offers cost share and technical assistance on tracts that are not eligible for continuous CRP enrollment. Certain BMPs receive up to 75% cost share. In return, the producer agrees to withhold the land from production for five years. Practices that typically benefit wildlife include: grassed waterways, grass filter strips, conservation cover, tree planting, pasture and hay planting, and field borders. Best fertilizer and pesticide management practices are also eligible for EQIP cost-share.

Farmland Protection Program
The Farmland Protection Program (EPP) provides funds to help purchase development rights in order to keep productive farmland in use. The goals EPP are: to protect valuable, prime farmland from unruly urbanization and development; to preserve farmland for future generations; to support a way of life for rural communities; and to protect farmland for long-term food security.

Debt for Nature
Debt for Nature is a voluntary program that allows certain FSA borrowers to enter into 10-year, 30-year, or 50-year contracts to cancel a portion of their FSA debts in exchange for devoting

eligible acreage to conservation, recreation, or wildlife practices. Eligible acreage includes: wetlands, highly erodible lands, streams and their riparian areas, endangered species, or significant wildlife habitat, land in 100-year floodplains, areas of high water quality or scenic value, aquifer recharge zones, areas containing soil not suited for cultivation, and areas adjacent or within administered conservation areas.

Non-Profit Conservation Advocacy Group Grants

Various non-profit conservation advocacy groups provide funding for projects and land purchases that involve resource conservation. Ducks Unlimited and Pheasants Forever are two such organizations that dedicate millions of dollars per year to projects that promote and/or create wildlife habitat.

Watershed Resources

An important but often overlooked factor in accomplishing goals and completing projects in any watershed is resources within the watershed itself. These resources may be people giving of their time, local schools participating in projects, companies giving materials for project construction, or other donations. This study documents some of these available resources for the four watersheds. It is important to note that this list is not all-inclusive, and some groups and donors may have been missed.

Watershed Coordinator

The Indiana Department of Environmental Management (IDEM) and the USDA cosponsor three regional watershed conservationist positions. The watershed conservationist is an advocate for watershed-level work in the region. Watershed conservationists can help direct actions of groups and stakeholders who are interested in working together to address problems in their watershed. They can help with everything from structuring public meetings to assisting with the compilation of a Watershed Management Plan. Their wealth of knowledge includes ideas about how to work with and respect all stakeholders in order to find the best plan for natural resource conservation within your watershed. Matt Jarvis is the regional watershed conservationist for the northern third of Indiana and has an office in the NRCS office in Delphi, Indiana. His contact information is found below.

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Coordinated Resource Management

The Coordinated Resource Management (CRM) process is an organized approach to identification of local concerns, evaluation of natural resources, development of alternative actions, assistance from technical specialists, implementation of a selected alternative, evaluation of implementation activities, and involvement of all interested parties who wish to participate in watershed action. The goal is an effective Watershed Management Plan through the

establishment of common goals and actions to achieve those goals. Further CRM information and its complementary Watershed Action Guide can be downloaded from the USDA/NRCS website at http://www.in.nrcs.gov. The CRM gives guidance on how to plan with people to maximize benefits to the greatest number of people while enhancing or maintaining the natural resource.

Hoosier Riverwatch

The Hoosier Riverwatch Program was started in 1994 by the State of Indiana to increase public awareness of water quality issues and concerns. Riverwatch is a volunteer stream monitoring program sponsored by the IDNR Division of Soil Conservation in cooperation with Purdue University Agronomy Department. Any citizen interested in water quality may volunteer to take a short training session held from May through October. Water monitoring equipment may be supplied to nonprofit organizations, schools, or government agencies by an equipment grant. Additionally, many SWCD offices (including both the Wells and Huntington County SWCDs) have loaner equipment that can be borrowed. Groups in Wells and Huntington Counties actively participate in the Riverwatch Program. Table 42 contains information about groups that have conducted volunteer monitoring in the two counties. Because Griffen Ditch is the only study stream to have been monitored through the Hoosier Riverwatch Program, even more participation should be advocated within the study watersheds especially since loaner equipment is readily available. More detailed information is available via the Hoosier Riverwatch web site at http://www.state.in.us/dnr/soilcons/riverwatch/.

TABLE 42. Groups that have participated in the Hoosier Riverwatch volunteer monitoring program in Wells and Huntington Counties.

County	Organization	City
Huntington	Huntington Reservoir SRA	Huntington
Huntington	Riverview Middle School	Huntington
Wells	Wells County SWCD	Bluffton
Wells	Southern Wells Elementary School	Keystone

Volunteer Groups

Volunteer groups can be instrumental in planning projects, implementing projects, and monitoring projects once they are installed. This study contains data taken by Hoosier Riverwatch participants. Norwell High School Students have participated in the monitoring program led by Stacia Henderson of the Wells County SWCD. Involving the people living in the watershed, especially school-age children, is a good way to promote natural resource awareness and a good way to get data collected and projects completed. Oftentimes, data collected by volunteer groups may be the only available data for a watershed. This data is very valuable in helping to establish baseline trends with which to compare future samples.

Other Local Groups

Other local groups also may offer resources and/or assistance for accomplishing watershed goals. Many local utilities, like electric and gas companies, offer grants for educational and environmental purposes. Additionally, large corporations give challenge grants for watershed projects. For more information on private grant foundations visit the web site http://www.fdncenter.org.

LITERATURE CITED

Allen, J. David. 1995. Stream Ecology: structure and function of running waters. Chapman and Hall, London.

APHA et al. 1995. Standard Methods for the Examination of Water and Wastewater, 19th edition. American Public Health Association, Washington, D.C.

Arora, K., S.K. Mickelson, J.L. Baker, D.P. Tierney, and C.J. Peters. 1993. Herbicide retention by vegetative buffer strips from runoff under natural rainfall. Trans. ASAE 39: 2155-2162.

Barbour et al. 1999. Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers: Periphyton, Benthic Macroinvertebrates, and Fish. 2nd Edition. USEPA, Office of Water. Washington, D.C. EPA 841-B99-002.

Bowman, M.F. and R.C. Bailey. 1997. Does taxonomic resolution affect the multivariate description of the structure of freshwater benthic macroinvertebrate communities? Canadian Journal of Fisheries and Aquatic Sciences. 54:1802-1807.

Braun, E. 1995. A Survey of the Fishes of the Little Wabash River in Huntington County, 1994. Indiana Department of Natural Resources, Indianapolis, Indiana.

Cogger, C.G. 1989. Septic System Waste Treatment in Soils. Washington State University Cooperative Extension Department. EB1475.

Conservation Technology Information Center. No date. Conservation Buffer Facts. [web page] http://www.ctic.purdue.edu/core4/buffer/bufferfact.html [Accessed March 3, 2000].

Conservation Technology Information Center. No date. Benefits of High-Residue Farming. [web page] http://www.ctic.purdue.edu/Core4/CT/Checklist/Page3.html [Accessed February 9, 2001].

Correll, David L. 1998. The role of phosphorus in the eutrophication of receiving waters: a review. Journal of Environmental Quality. 27(2):261-266.

Daniels, R.B. and J.W. Gilliam. 1987. Sediment and chemical load reduction by grass and riparian buffers. Soil Sci. Soc. Am. J. 60: 246-251.

Department of Transportation. 1988. Geographic Information Systems (GIS) Coverage data for Indiana Main Roads.

Dillaha, T.A., R.B. Reneau, S. Mostaghimi, and D. Lee. 1989. Vegetative filter strips for agricultural nonpoint source pollution control. Trans. ASAE 32: 513-519.

EPA. 1976. Quality Criteria for Water. U.S. Environmental Protection Agency, Washington, D.C.

EPA. 1998. 1998 Update of Ambient Water Quality Criteria for Ammonia. EPA-822-F-98-005. U.S. Environmental Protection Agency, Washington, D.C.

Evans, M.G., K.J. Eck, B. Gauck, J.M. Krejci, J.E. Lake, and E.A. Matzat. 2000. Conservation Tillage Update: Keeping Soil Covered and Water Clean in the New Millennium. Purdue University Agronomy Department, West Layfayette, Indiana. AGRY-00-02.

Ferraro, S.P. and F.A. Cole. 1995. Taxonomic level sufficient for assessing pollution impacts in Southern California Bight macrobenthos- revisited. Environmental Toxicology and Chemistry. 14:1021-1040.

Fleming, A.H. In prep. Water Resource Availability in the Maumee River Basin. Indiana Department of Natural Resources, Division of Water, Indianapolis, Indiana.

Furse et al. 1984. The influence of seasonal and taxonomic factors on the ordination and classification of running water sites in Great Britain and on the prediction of their macroinvertebrate communities. Freshwater Biology. 14:257-280.

Gerking, S.D. 1945. Distribution of the Fishes of Indiana. In: Investigation of Indiana Lakes and Streams, Vol. 3(1), Indiana Department of Conservation, Indianapolis and Indiana University, Bloomington, 137 pp.

Grant, W. 1999. A Survey for Septic System Effects on Barbee Lake Chain, Indiana.

Gregg, W.W. and F.L. Rose. 1982. The effects of aquatic macrophytes on the stream microenvironment. Aquatic Botany. 14:309-324.

Hale, M.D. 1966. Lakes and streams. In: Lindsey, A.A. (ed.) Natural Features of Indiana. Indiana Academy of Science, Indiana State Library, Indianapolis, Indiana, p. 21-39.

Hayes, J.C., B.J. Barfield, and R.I. Barnhisel. 1984. Performance of grass filters under laboratory and field conditions. Trans. ASAE 27: 1321-1331.

Hilsenhoff, William L. 1988. Rapid field assessment of organic pollution with a family-level biotic index. Journal of the North American Benthological Society. 7(1):65-68.

Homoya, M.A., B.D. Abrell, J.R. Aldrich, and T.W. Post. 1985. The natural regions of Indiana. Indiana Academy of Science. Vol. 94. Indiana Natural Heritage Program. Indiana Department of Natural Resources, Indianapolis, Indiana.

IDEM. 2000. Indiana Water Quality Report. Department of Environmental Management, Indianapolis, Indiana.

Indiana Department of Environmental Management. 1996. Scoring criteria for the family level macroinvertebrate Index of Biotic Integrity (mIBI). Biological Studies Section, Indianapolis.

Indiana University/Purdue University, Ft. Wayne. 1996. Characteristics of Fine Grained Soils and Glacial Deposits in Northeastern Indiana for On-Site Wastewater Disposal Systems. Department of Continuing Education, Ft. Wayne, Indiana.

Isenhart, T.M., R.C. Schultz, and J.P. Colletti. 1997. Watershed Restoration and Agricultural practices in the Midwest: Bear Creek of Iowa. In: Williams, J.E., C.A. Wood, and M.P. Dombeck (eds.) Watershed Restoration: Principles and Practices. American Fisheries Society, Bethesda, Maryland, p. 318-334.

Jones, D.D. and J.E. Yahner. 1994. Operating and Maintaining the Home Septic System. Purdue University Cooperative Extension Service. ID-142.

Jones, W. 1996. Indiana Lake Water Quality Update for 1989-1993. Indiana Department of Environmental Management. Clean Lakes Program. Indianapolis, Indiana.

Kluess, S.K. 1986. Soil Survey of Blackford and Jay Counties, Indiana. U.S. Department of Agriculture-Soil Conservation Service, Washington D.C.

Klumpp, J., M. McIntosh, and E. Wilkerson. 2000. An overview of Upper Stephen's Creek, Monroe County, Indiana. School of Public and Environmental Affairs Stream Ecology Report, Indiana University, Bloomington.

Leeds, R., L.C. Brown, M.R. Sulc, and L. VanLieshout. 1993. Vegetative Filter Strips: Application, Installation and Maintenance. Extension Fact Sheet, The Ohio State University Extension, AEX-467.

Lockridge, E.D. and E.L. Jensen. 1982. Soil Survey of Huntington County, Indiana. U.S. Department of Agriculture-Soil Conservation Service, Washington D.C.

Marchant, R.L. et al. 1995. Influence of sample quantification and taxonomic resolution on the ordination of macroinvertebrate communities from running waters in Victoria, Australia. Marine and Freshwater Research. 46:501-506.

Mickelson, S.K. and J.L. Baker. 1993. Buffer strips for controlling herbicide runoff losses. Paper no. 932084. Am. Soc. Agric. Eng., St. Joseph, Michigan.

Minshall, G.W. 1984. Aquatic insect-substratum relationships. In: Resh, V.H. and D.M. Rosenburg (eds.) The Ecology of Aquatic Insects. Praeger Scientific, New York, p. 358-400.

National Climatic Data Center. 1976. Climatography of the United States. No.60.

National Conservation Buffer Council. 1999. Environmental Benefits of Buffers. [web page] http://www.buffercouncil.org/benefits.html [Accessed February 9, 2001].

National Research Council. 1993. Soil and Water Quality: Agenda for Agriculture. National Academy Press, Washington, D.C.

Natural Resources Conservation Service. 2000. Conservation Practice Standard for Filter Strips. Code 393.

Neely, T. 1992. Soil Survey of Wells County, Indiana. U.S. Department of Agriculture-Soil Conservation Service, Washington D.C.

Ohio EPA. 1999. Association between nutrients, habitat, and the aquatic biota in Ohio rivers and streams. Ohio EPA Technical Bulletin MAS/1999-1-1, Columbus.

Olem, H. and G. Flock, eds. 1990. Lake and reservoir restoration guidance manual. 2nd edition. EPA 440/4-90-006. Prepared by North American Lake Management Society for U.S. Environmental Protection Agency, Washington, DC.

Petty, R.O. and M.T. Jackson. 1966. Plant communities. In: Lindsey, A.A. (ed.) Natural Features of Indiana. Indiana Academy of Science, Indiana State Library, Indianapolis, Indiana, p. 264-296.

Plafkin, J.L., M.T. Barbour, K.D. Porter, S.K. Gross, and R.M. Hughes. 1989. Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic Macroinvertebrates and Fish. US Environmental Protection Agency, Washington, DC, EPA/440/4-89/001.

Purdue Cooperative Extension Service. 2000. Indiana T by 2000 Watershed Soil Loss Transects Data Set. Ft. Wayne, Indiana.

Rankin, E.T. 1989. The qualitative habitat evaluation index (QHEI): rationale, methods, and application. Division of Water Quality Planning and Assessment, Columbus.

Rankin, E.T. 1995. Habitat indices in water resource quality assessment, in W.S. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Risk-based Planning and Decision Making. CRC Press/Lewis Publishers, Ann Arbor.

Reckhow, K.H., M.N. Beaulac, and J.T. Simpson. 1980. Modeling phosphorus loading and lake response under uncertainty: a manual and compilation of export coefficients. EPA 440/5-80-11. US Environmental Protection Agency, Washington, D.C.

Roth, N.E. 1994. Land use, riparian vegetation, and stream ecosystem integrity in an agricultural watershed. MS Thesis, The University of Michigan, 148 pp.

Schmitt, T.J., M.G. Dosskay, and K.D. Hoagland. 1999. Filter strip performance and processes for different vegetation, widths, and contaminants. Journal of Environmental Quality, 28(5):1479-1489.

Standard Methods for the Examination of Water and Wastewater, 19th ed. 1995. Andrew D. Eaton, Lenore S. Clesceri, and Arnold E. Greenberg (eds.). American Public Health Association, Washington, D.C.

Steedman, R.J. 1988. Modification and assessment of an index of biotic integrity to quantify stream quality in Southern Ontario. Can. J. Fish. Aquat. Sci., 45:492-501.

Stephenson, D.A., A.H. Fleming, and D.M. Mickelson. 1988. Glacial Deposits. In: Back, W. (ed.) Hydrogeology: Boulder, Colorado, Geological Society of America, The Geology of North America, v. O-2.

Thomas, J.A. 1996. Soil Characteristics of "Buttermilk Ridge" Wabash Moraine, Wells County Indiana. Notes for the IU/PU (Ft. Wayne) Soils Course: Characteristics of Fine-Grained Soils and Glacial Deposits in Northeastern Indiana for On-Site Wastewater Disposal Systems.

Ulrich, H.P. 1966. Soils. In: Lindsey, A.A. (ed.) Natural Features of Indiana. Indiana Academy of Science, Indiana State Library, Indianapolis, Indiana, p. 57-90.

US Census of Agriculture. 1997. Indiana Farm Land Use History, Wells County, Indiana. http://www.nass.usda.gov/in/historic Assessed on March 22, 2001.

US Census of Agriculture. 2000. County Data for Indiana. http://www.info.aes.purdue.edu\agstat\nass.html Assessed on January 31, 2001.

USDA. 1997. The Conservation Reserve Program. Washington, D.C. PA-1603.

USFWS. 1971-1992. National Wetlands Inventory (NWI). Dates range from Feb. 1971 to Dec. 1992, Geographic Information Systems (GIS) coverage data for streams.

USGS. 2000. Multi-resolution Land Characterization (MRLC), National Land Cover Data (NLCD). Last updated 03-16-2000, Geographic Information Systems (GIS) coverages for land use land cover.

USGS. 1972. Zanesville 7.5-Minute Quadrangle Map, U.S. Geologic Survey, Washington, D.C.

USGS. 1960a. Pennville 7.5 Minute Quadrangle Map, U.S. Geologic Survey, Washington, D.C.

USGS. 1960b. Blaine 7.5 Minute Quadrangle Map, U.S. Geologic Survey, Washington, D.C.

USGS. 1960c. Ridgeville 7.5 Minute Quadrangle Map, U.S. Geologic Survey, Washington, D.C.

Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Sedell, and C.E. Cushing. 1980. The river continuum concept. Canadian Journal of Fisheries and Aquatic Science. 37:130-137.

Waite, I.R. et al. 2000. Comparing strengths of geographic and nongeographic classifications of stream benthic macroinvertebrates in the Mid-Atlantic Highlands, USA. J. N. Am. Benthol. Soc. 19(3):429-441.

Walker, R.D. 1978. Task Force on Agricultural Nonpoint Sources of Pollution Subcommittee on Soil Erosion and Sedimentation. Illinois Institute for Environmental Quality, 72 pp.

Waters, T.F. 1995. Sediment in Streams: Sources, Biological Effects, and Control. American Fisheries Society Monograph 7. Bethesda, Maryland, 251 pp.

Wayne, W.J. 1966. Ice and land: a review of the tertiary and Pleistocene history of Indiana. In: Lindsey, A.A. (ed.) Natural Features of Indiana. Indiana Academy of Science, Indiana State Library, Indianapolis, Indiana, p. 21-39.

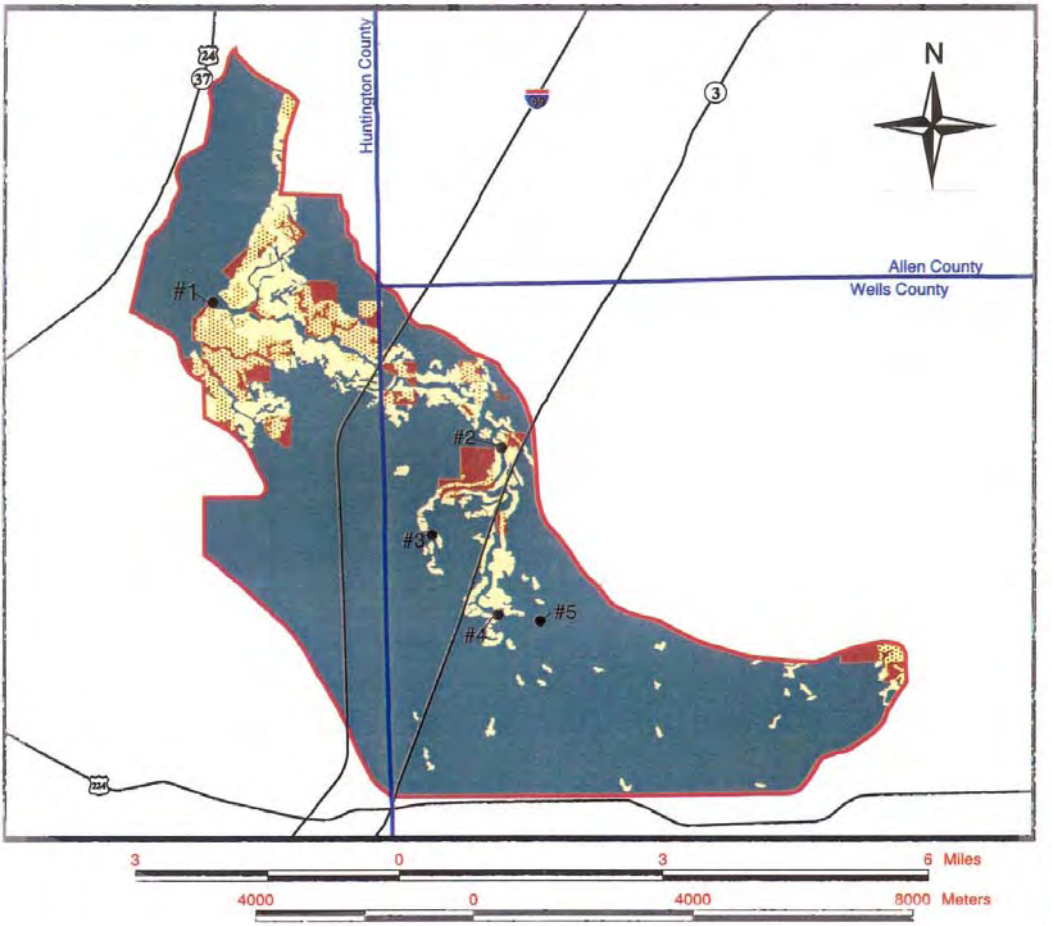
West, T.D., G.C. Steinhardt, and T.J. Vyn. 1999. Tillage Research Annual Report 1999. Purdue University Agronomy Department, West Layfayette, Indiana.

White, G. Unpublished data. Safety and Chemical Testing Instructions. Indiana Department of Natural Resources. Indianapolis, Indiana.

APPENDICES

APPENDIX 1:

Detailed Highly Erodible Soil and Land Maps for Each Watershed

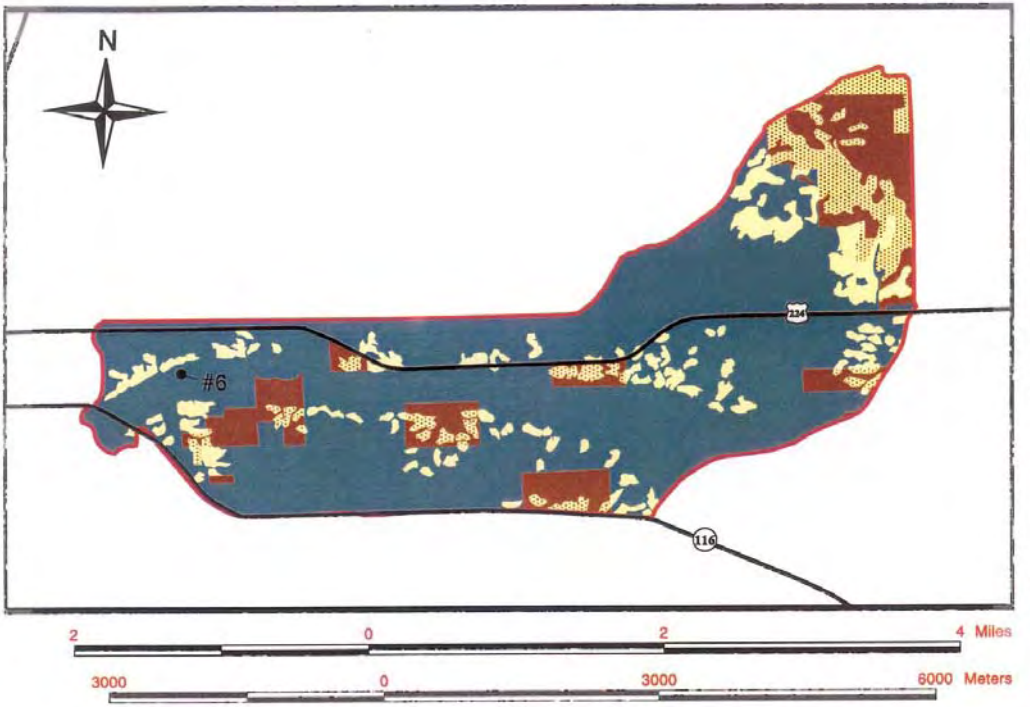


Highly Erodible Soil and Land Classification

- Highly Erodible Soil
- Highly Erodible Land
- Highly Erodible Soil and Land Overlap
- Non-Highly Erodible Soil

- Site Locations
- Main Roads
- Flat Creek Watershed
- County Boundaries

APPENDIX 1.A. Detailed highly erodible soil and land maps for the Flat Creek Watershed. The map was created by Melissa Clark. Road source: US Department of Tranportation. Sources of other information: Wells County SWCD and USDA Soil Conservation Service.

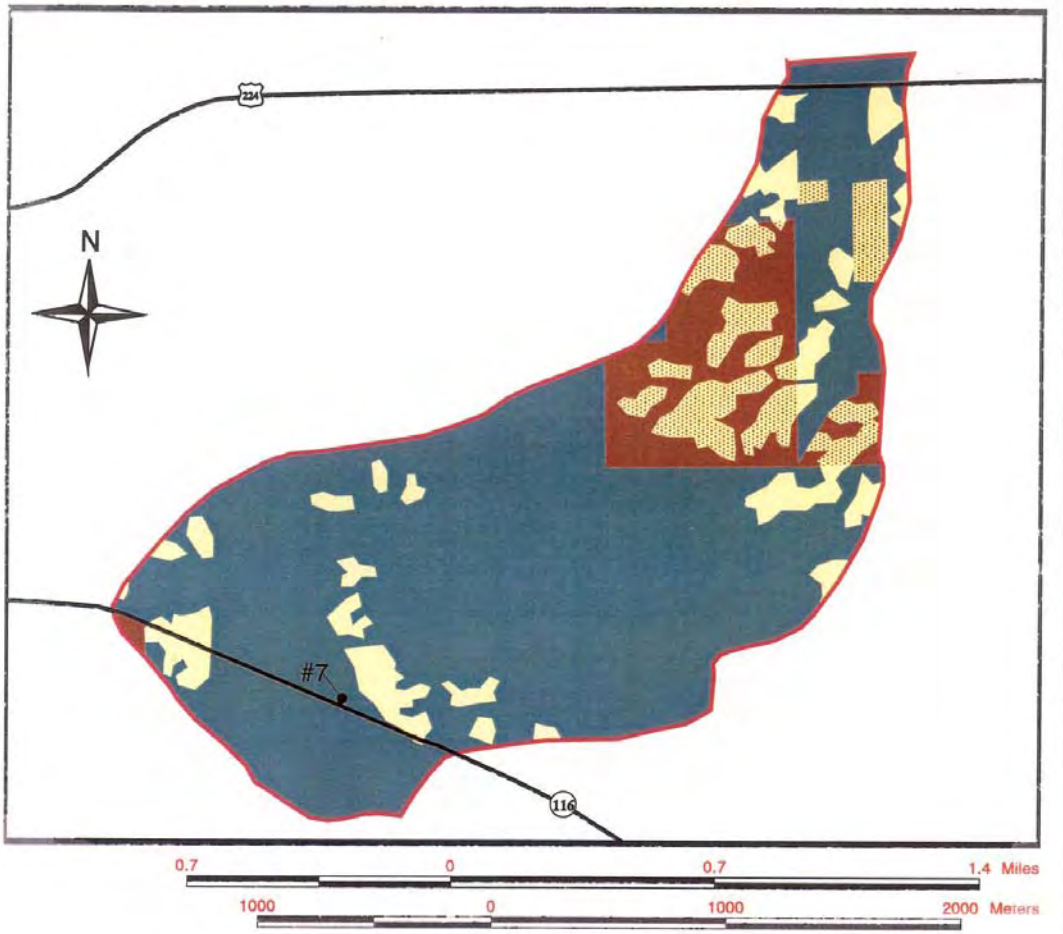


Highly Erodible Soil and Land Classification

- Highly Erodible Soil
- Highly Erodible Land
- Highly Erodible Soil and Land Overlap
- Non-Highly Erodible Soil

- Site Location
- Main Roads
- Griffin Ditch Watershed

APPENDIX 1.B. Detailed highly erodible soil and land maps for the Griffen Ditch Watershed. The map was created by Melissa Clark. Road source: US Department of Tranportation. Sources of other information: Wells County SWCD and USDA Soil Conservation Service.

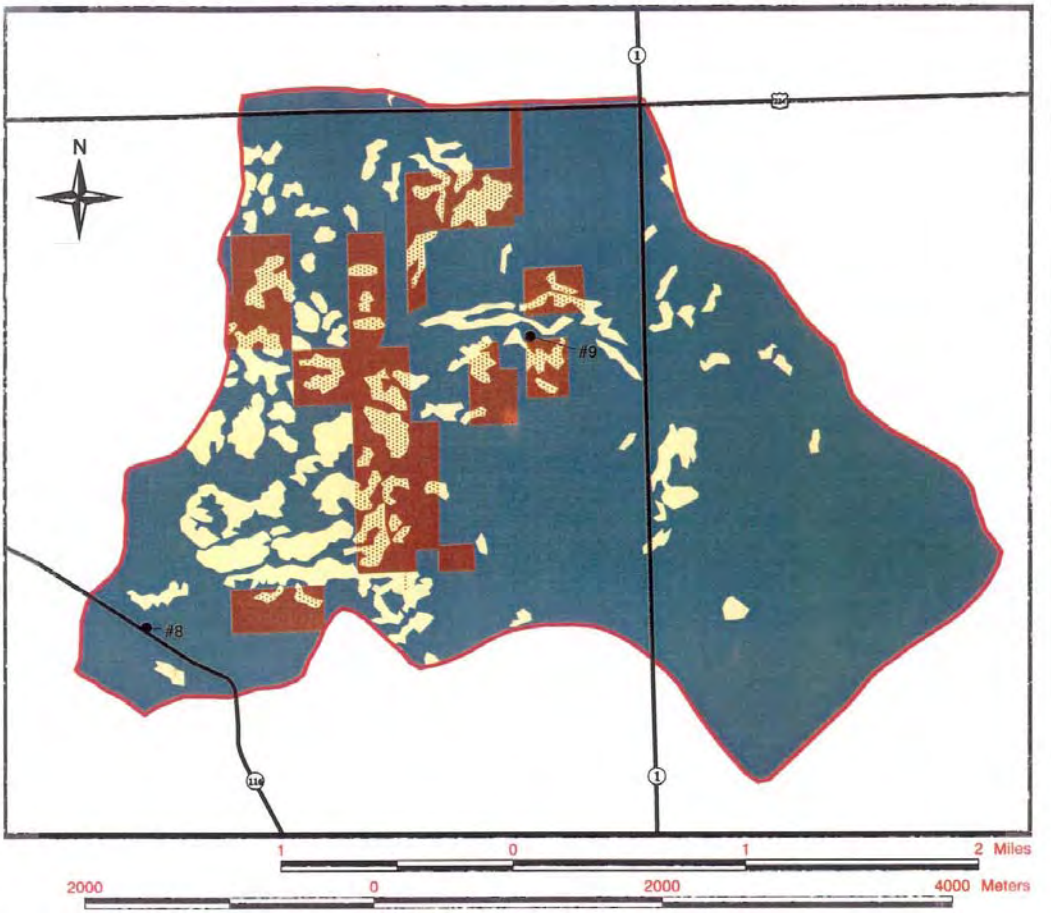


Highly Erodible Soil and Land Classification

- Highly Erodible Soil
- Highly Erodible Land
- Highly Erodible Soil and Land Overlap
- Non-Highly Erodible Soil

- Site Location
- Main Roads
- Flemming Ditch Watershed

APPENDIX 1.C. Detailed highly erodible soil and land maps for the Fleming Ditch Watershed. The map was created by Melissa Clark. Road source: US Department of Tranportation. Sources of other information: Wells County SWCD and USDA Soil Conservation Service.



Highly Erodible Soil and Land Classification

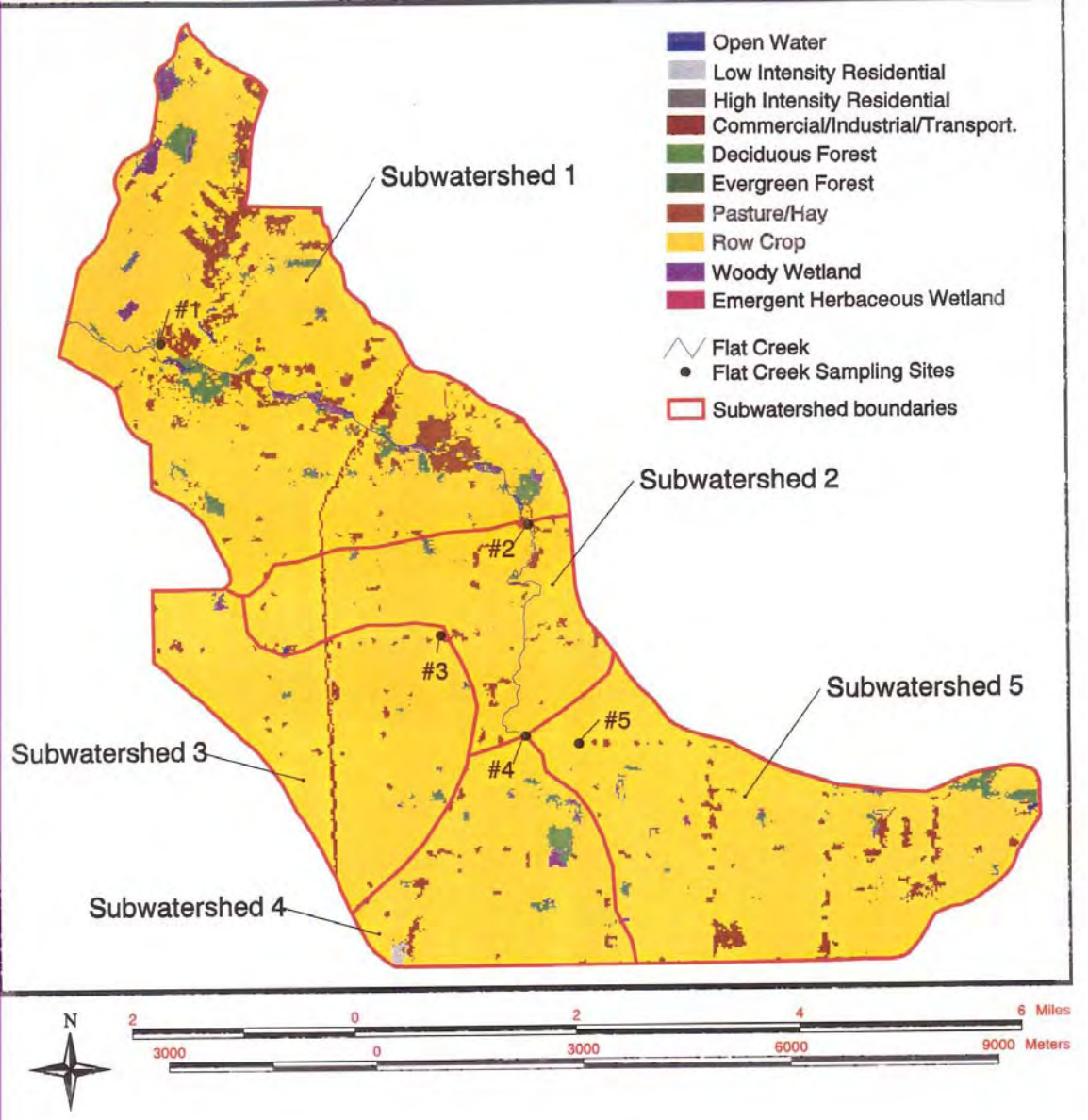
- Highly Erodible Soil
- Highly Erodible Land
- Highly Erodible Soil and Land Overlap
- Non-Highly Erodible Soil

- Site Locations
- Main Roads
- Somers Creek Watershed

APPENDIX 1.D. Detailed highly erodible soil and land maps for the Somers Creek Watershed. The map was created by Melissa Clark. Road source: US Department of Tranportation. Sources of other information: Wells County SWCD and USDA Soil Conservation Service.

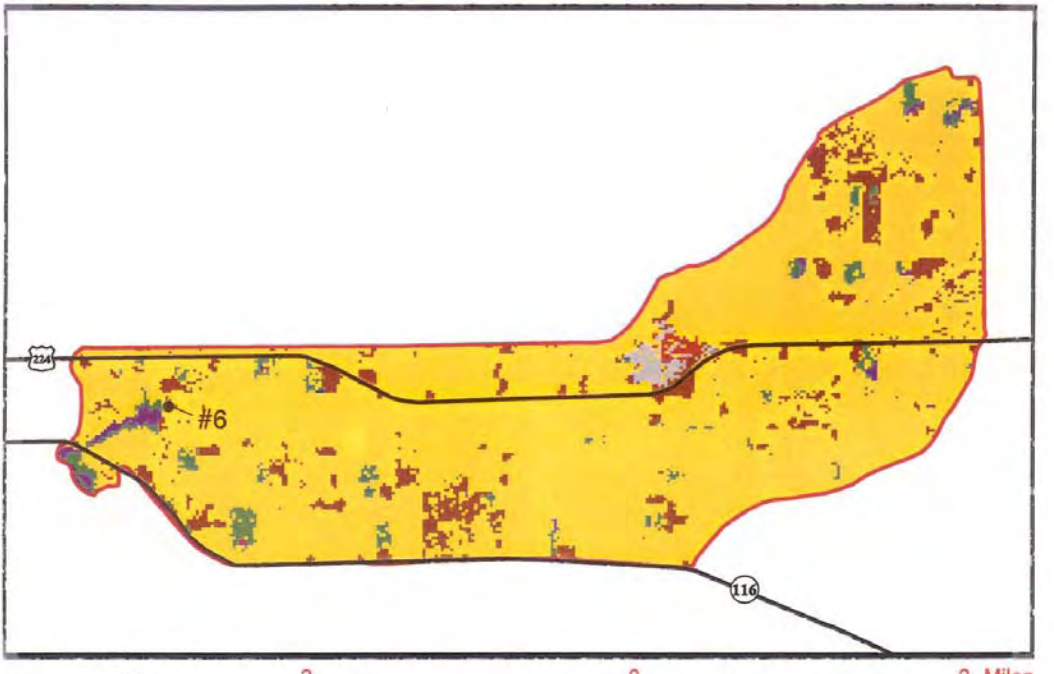
APPENDIX 2:

Detailed Land Use Maps
for Each Watershed



APPENDIX 2.A. Detailed land use map for the Flat Creek Watershed. The map was created by Melissa Clark. Streams source: US Fish and Wildlife Service, National Wetlands Inventory (NWI), 1971-1992. Land use information source: USGS MLRC National Land Cover Data, last updated 03/16/00.

S.J.F. New & Associates, Inc.



N

2 0 2 Miles

2000 0 2000 4000 Meters

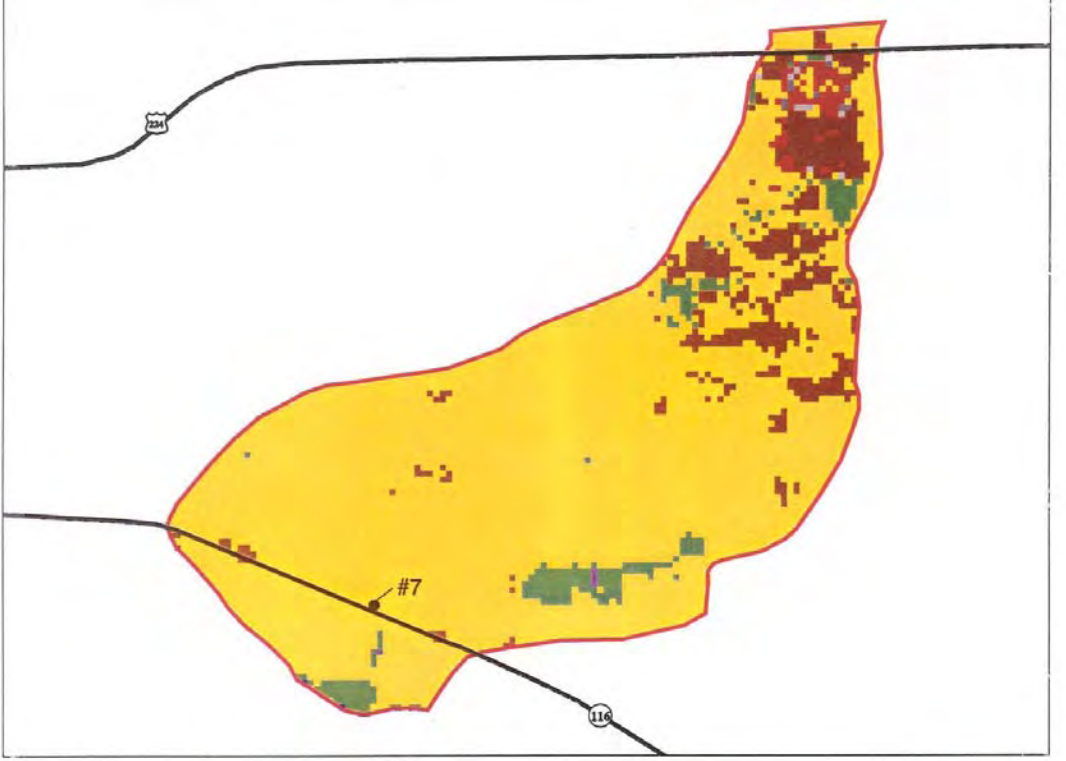
Open Water
Low Intensity Residential
High Intensity Residential
Commercial/Industrial/Transport.
Deciduous Forest
Evergreen Forest
Pasture/Hay
Row Crop
Woody Wetland
Emergent Herbaceous Wetland

Site Location
Main Roads

Griffin Ditch Watershed

APPENDIX 2.B. Detailed land use map for the Griffen Ditch Watershed. The map was created by Melissa Clark. Road source: US Department of Transportation. Streams source: US Fish and Wildlife Service, National Wetlands Inventory (NWI), 1971-1992. Land use information source: USGS MLRC National Land Cover Data, last updated 03/16/00.

D.F. New & Associates, Inc.
Permitting • Delineations • Mitigation Design • Biological Inventories
Wetland and Prairie Nursery • Lake and Stream Enhancement
Natural Systems for Wastewater Treatment



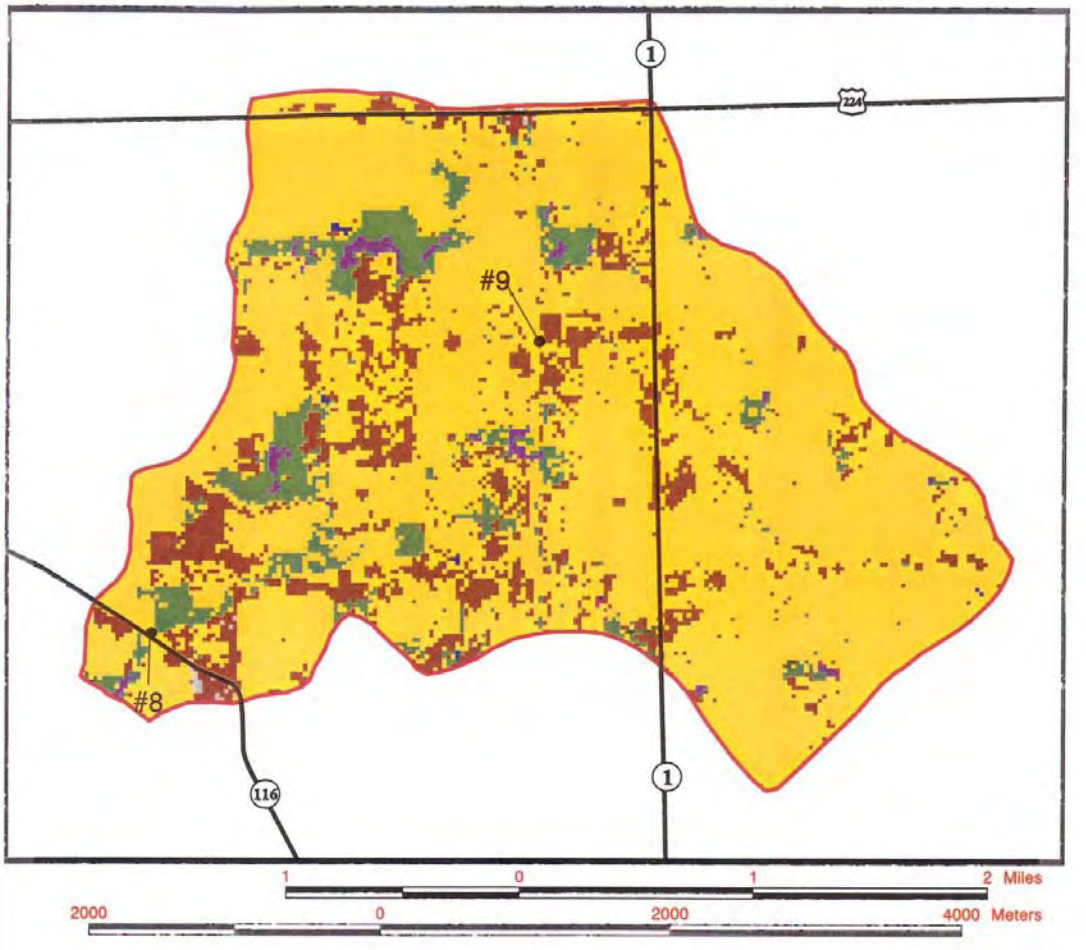
0.7 0 0.7 1.4 Miles

1000 0 1000 2000 Meters

- Open Water
- Low Intensity Residential
- High Intensity Residential
- Commercial/Industrial/Transport.
- Deciduous Forest
- Woody Wetland
- Pasture/Hay
- Row Crop
- Site Location
- Main Roads
- Flemming Ditch Watershed

APPENDIX 2.C. Detailed land use map for the Fleming Ditch Watershed. The map was created by Melissa Clark. Road source: US Department of Transportation. Land use information source: USGS MLRC National Land Cover Data, last updated 03/16/00.

J.F. New & Associates, Inc.



- Open Water
- Low Intensity Residential
- High Intensity Residential
- Commercial/Industrial/Transport.
- Deciduous Forest
- Evergreen Forest
- Pasture/Hay
- Row Crop
- Woody Wetland
- Emergent Herbaceous Wetland
- Site Locations
- Main Roads
- Somers Creek Watershed

APPENDIX 2.D. Detailed land use map for the Somers Creek Watershed. The map was created by Melissa Clark. Road source: US Department of Transportation. Land use information source: USGS MLRC National Land Cover Data, last updated 03/16/00.

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Permitting • Delineations • Mitigation Design • Biological Inventories
Wetland and Prairie Nursery • Lake and Stream Enhancement
Natural Systems for Wastewater Treatment

APPENDIX 3:

Detailed Land Use and Land Cover for the Five Flat Creek Subwatersheds

APPENDIX 3. Detailed Land Use and Land Cover for the Five Flat Creek Subwatersheds.

TABLE A-3.1 Subwatershed 1.

Landuse	Area (acres)	Area (ha)	%
Open Water	6.45	2.61	0.09
High intensity residential	0.22	0.09	0.00
Commercial/industrial/transport	34.47	13.95	0.50
Deciduous Forest	329.18	133.20	4.79
Evergreen Forest	0.22	0.09	0.00
Pasture/Hay	706.62	285.93	10.29
Row Crop	5662.73	2291.40	82.45
Woody Wetland	127.44	51.57	1.86
Emergent Herbaceous Wetland	0.67	0.27	0.01
TOTAL	**6868.00**	**2779.11**	**100.00**

TABLE A-3.2 Subwatershed 2.

Landuse	Area (acres)	Area (ha)	%
Open Water	2.45	0.99	0.11
Low intensity residential	0.22	0.09	0.01
Commercial/industrial/transport	11.79	4.77	0.51
Deciduous Forest	15.57	6.3	0.68
Pasture/Hay	94.75	38.34	4.12
Row Crop	2171.90	878.85	94.49
Woody Wetland	1.78	0.72	0.08
TOTAL	**2298.45**	**930.06**	**100.00**

TABLE A-3.3 Subwatershed 3.

Landuse	Area (acres)	Area (ha)	%
Open Water	0.22	0.09	0.01
Low intensity residential	0.89	0.36	0.03
Commercial/industrial/transport	43.59	17.64	1.51
Deciduous Forest	19.80	8.01	0.69
Pasture/Hay	46.26	18.72	1.61
Row Crop	2761.82	1117.56	95.89
Woody Wetland	6.89	2.79	0.24
Emergent Herbaceous Wetland	0.67	0.27	0.02
TOTAL	**2880.15**	**1165.44**	**100.00**

TABLE A-3.4 Subwatershed 4.

Landuse	Area (acres)	Area (ha)	%
Low intensity residential	14.23	5.76	0.66
High intensity residential	1.56	0.63	0.07
Deciduous Forest	72.06	29.16	3.32
Pasture/Hay	68.73	27.81	3.16
Row Crop	1998.41	808.65	91.99
Woody Wetland	17.13	6.93	0.79
Emergent Herbaceous Wetland	0.22	0.09	0.01
TOTAL	**2172.34**	**879.03**	**100.00**

TABLE A-3.5 Subwatershed 5.

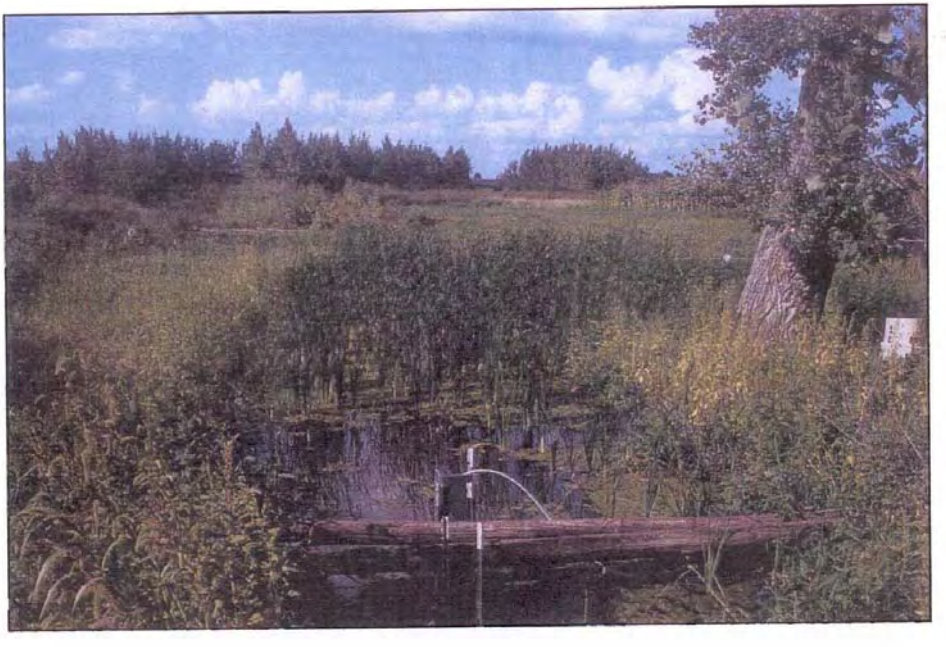
Landuse	Area (acres)	Area (ha)	%
Open Water	2.89	1.17	0.07
Deciduous Forest	97.86	39.60	2.20
Pasture/Hay	221.97	89.82	5.00
Row Crop	4107.59	1662.12	92.47
Woody Wetland	9.34	3.78	0.21
Emergent Herbaceous Wetland	2.22	0.90	0.05
TOTAL	**4441.88**	**1797.39**	**100.00**

APPENDIX 4:

Photos from the Riparian Management System Model in the Bear Creek Watershed, Iowa (Isenhart et al., 1997)

JFNA #99-09-29

Bear Creek riparian management site from the Isenhart et al., 1997 study. Top photo shows site in March 1990, prior to buffer strip establishment. The bottom photo shows the same site in June 1994 after five growing seasons. Used with permission from the American Fisheries Society.



JrNA #99-09-29

Wetland component of the Bear Creek riparian management system model from the Isenhart et al., 1997 study. Photo was taken in August 1994, a few months after construction. The water control structure can be seen in the foreground. Used with permission from the American Fisheries Society.

APPENDIX 5:

Endangered, Threatened, and Rare Species List,
Flat Creek, Griffen Ditch, Fleming Ditch, and Somers Creek Watersheds

March 15, 2000

ENDANGERED, THREATENED, AND RARE SPECIES
AND HIGH QUALITY NATURAL COMMUNITIES AND NATURAL AREAS DOCUMENTED FROM
THE FLAT CREEK, GRIFFIN DITCH, FLEMING DITCH AND SOMMERS CREEK WATERSHEDS, INDIANA

Type.....	Element Name.....	Common Name.....	State	Fed..	Townrang	Sec.....	Date	Comments
ZANESVILLE QUADRANGLE								
Bird	ARDEA HERODIAS	GREAT BLUE HERON	**	**	028N011E	08 NWQ SEQ	1987	

STATE: SX=extirpated, SE=endangered, ST=threatened, SR=rare, SSC=special concern, WL=watch list, SG=significant, SRE=state reintroduced

FEDERAL: LE=endangered, LT=threatened, LELT=different listings for specific ranges of species, PE=proposed endangered, PT=proposed threatened, E/SA=appearance similar to LE species, **=not listed

APPENDIX 6:

Endangered, Threatened, and Rare Species List,
Wells and Huntington Counties

ENDANGERED, THREATENED AND RARE SPECIES DOCUMENTED FROM WELLS COUNTY, INDIANA

SPECIES NAME	COMMON NAME	STATE	FED	SRANK	GRANK
VASCULAR PLANT					
ANDROMEDA GLAUCOPHYLLA	BOG ROSEMARY	SR	**	S2	G5
ARETHUSA BULBOSA	SWAMP-PINK	SX	**	SX	G4
ARMORACIA AQUATICA	LAKE CRESS	SE	**	S1	G4?
CAREX ARCTATA	BLACK SEDGE	SE	**	S1	G5?
CAREX ECHINATA	LITTLE PRICKLY SEDGE	SE	**	S1	G5
CAREX LIMOSA	MUD SEDGE	SE	**	S1	G5
CRATAEGUS KELLOGGII	KELLOGG HAWTHORN	SE	**	S1	G3?
ERIOPHORUM GRACILE	SLENDER COTTON-GRASS	ST	**	S2	G5
EUPHORBIA OBTUSATA	BLUNTLEAF SPURGE	SX	**	SX	G5
FRAGARIA VESCA VAR AMERICANA	WOODLAND STRAWBERRY	SE	**	S1	G5T?
PLANTAGO CORDATA	HEART-LEAVED PLANTAIN	SE	**	S1	G4
PLATANTHERA ORBICULATA	LARGE ROUNDLEAF ORCHID	SX	**	SX	G5?
VIBURNUM OPULUS VAR AMERICANUM	HIGHBUSH-CRANBERRY	SE	**	S1	G5T5
XYRIS DIFFORMIS	CAROLINA YELLOW-EYED GRASS	ST	**	S2	G5
ARTHROPODA: INSECTA: ODONATA (DRAGONFLIES; DAMSELFLIES)					
MACROMIA WABASHENSIS	WABASH BELTED SKIMMER DRAGONFLY	**	**	S1	G1G3Q
AMPHIBIANS					
RANA PIPIENS	NORTHERN LEOPARD FROG	SSC	**	S2	G5
REPTILES					
CLONOPHIS KIRTLANDII	KIRTLAND'S SNAKE	SE	**	S2	G2
NERODIA ERYTHROGASTER NEGLECTA	COPPERBELLY WATER SNAKE	SE	**	S2	G5T2T3
SISTRURUS CATENATUS CATENATUS	EASTERN MASSASAUGA	SE	**	S2	G3G4T3T4
BIRDS					
ARDEA HERODIAS	GREAT BLUE HERON	**	**	S4B,SZN	G5
BARTRAMIA LONGICAUDA	UPLAND SANDPIPER	SE	**	S3B	G5
MAMMALS					
MYOTIS SODALIS	INDIANA BAT OR SOCIAL MYOTIS	SE	LE	S1	G2
HIGH QUALITY NATURAL COMMUNITY					
FOREST - FLATWOODS CENTRAL TILL PLAIN	CENTRAL TILL PLAIN FLATWOODS	SG	**	S2	G3
FOREST - FLOODPLAIN WET-MESIC	WET-MESIC FLOODPLAIN FOREST	SG	**	S3	G3?
FOREST - UPLAND MESIC	MESIC UPLAND FOREST	SG	**	S3	G3?

STATE: SX=extirpated, SE=endangered, ST=threatened, SR=rare, SSC=special concern, WL=watch list, SG=significant,** no status but rarity warrants concern

FEDERAL: LE=endangered, LT=threatened, LELT=different listings for specific ranges of species, PE=proposed endangered, PT=proposed threatened, E/SA=appearance similar to LE species, **=not listed

ENDANGERED, THREATENED AND RARE SPECIES DOCUMENTED FROM HUNTINGTON COUNTY, INDIANA

SPECIES NAME	COMMON NAME	STATE	FED	SRANK	GRANK
VASCULAR PLANT					
COELOGLOSSUM VIRIDE VAR VIRESCENS	LONG-BRACT GREEN ORCHIS	ST	**	S2	G5T5
FRAGARIA VESCA VAR AMERICANA	WOODLAND STRAWBERRY	SE	**	S1	G5T?
JUGLANS CINEREA	BUTTERNUT	WL	**	S3	G3G4
PINUS STROBUS	EASTERN WHITE PINE	SR	**	S2	G5
VIBURNUM MOLLE	SOFTLEAF ARROW-WOOD	SR	**	S2	G5
MOLLUSCA: BIVALVIA (MUSSELS)					
EPIOBLASMA TRIQUETRA	SNUFFBOX	SE	**	S1	G3
LAMPSILIS FASCIOLA	WAVY-RAYED LAMPMUSSEL	SSC	**	S2	G4
LIGUMIA RECTA	BLACK SANDSHELL	**	**	S2	G5
PLEUROBEMA CLAVA	CLUBSHELL	SE	LE	S1	G2
PTYCHOBRANCHUS FASCIOLARIS	KIDNEYSHELL	SSC	**	S2	G4G5
TOXOLASMA LIVIDUS	PURPLE LILLIPUT	SSC	**	S2	G2
VILLOSA FABALIS	RAYED BEAN	SSC	**	S1	G1G2
FISH					
MOXOSTOMA VALENCIENNESI	GREATER REDHORSE	SE	**	S2	G3
BIRDS					
ACCIPITER COOPERII	COOPER'S HAWK	**	**	S3B,SZN	G5
ARDEA HERODIAS	GREAT BLUE HERON	**	**	S4B,SZN	G5
CISTOTHORUS PALUSTRIS	MARSH WREN	SE	**	S3B,SZN	G5
PHALACROCORAX AURITUS	DOUBLE-CRESTED CORMORANT	SX	**	SHB,SZN	G5
STURNELLA NEGLECTA	WESTERN MEADOWLARK	SSC	**	S2B	G5
MAMMALS					
LUTRA CANADENSIS	NORTHERN RIVER OTTER	SE	**	S?	G5
LYNX RUFUS	BOBCAT	SE	**	S1	G5
MUSTELA NIVALIS	LEAST WEASEL	SSC	**	S2?	G5
MYOTIS SODALIS	INDIANA BAT OR SOCIAL MYOTIS	SE	LE	S1	G2
TAXIDEA TAXUS	AMERICAN BADGER	SE	**	S2	G5
HIGH QUALITY NATURAL COMMUNITY					
FOREST - FLATWOODS CENTRAL TILL PLAIN	CENTRAL TILL PLAIN FLATWOODS	SG	**	S2	G3
FOREST - UPLAND MESIC	MESIC UPLAND FOREST	SG	**	S3	G3?

STATE: SX=extirpated, SE=endangered, ST=threatened, SR=rare, SSC=special concern, WL=watch list, SG=significant,** no status but rarity warrants concern

FEDERAL: LE=endangered, LT=threatened, LELT=different listings for specific ranges of species, PE=proposed endangered, PT=proposed threatened, E/SA=appearance similar to LE species, **=not listed

APPENDIX 7:

Stream Sampling Laboratory Datasheets

REPORT NO.
F00132-801
ACCOUNT NUMBER
98430

A & L GREAT LAKES LABORATORIES, INC.

3505 Conestoga Drive • Fort Wayne, Indiana 46808-4413 • Phone (219)483-4759 • FAX (219)483-5274

TO: J F NEW & ASSOCIATES
708 ROOSEVELT RD BOX 243
WALKERTON, IN 46574

FOR: WELLS COUNTY

ATTN: JOHN RICHARDSON

REPORT OF ANALYSIS

LAB NUMBER: 39477
SAMPLE ID: 1

DATE SAMPLED: 5/10/00 2:15 PM
DATE RECEIVED: 5/11/00
DATE REPORTED: 5/23/00 PAGE: 1

PARAMETER	RESULT	UNIT	DETECTION LIMIT	ANALYST	ANALYSIS DATE	METHOD REFERENCE
Conductivity	0.57	mmho/cm	0.01	KLH	5/11/00	EPA-120.1
pH	7.7		0.1	KLH	5/11/00	EPA-150.1
Solids, Total Suspended	72	mg/L	1	JAS	5/15/00	EPA-160.2
Nitrogen, Ammonia (as N)	0.18	mg/L	0.10	JAS	5/11/00	EPA-350.2
Nitrogen, Nitrate+Nitrite (as N)	20.70	mg/L	0.20	JAS	5/11/00	EPA-353.1
Nitrogen, Total Kjeldahl	1.0	mg/L	1.0	MJG	5/19/00	EPA-351
Phosphorus, Total	0.36	mg/L	0.10	JAS	5/17/00	EPA-365.2
Phosphorus, Ortho (as P)	0.12	mg/L	0.10	JAS	5/16/00	EPA-365.2
Turbidity	61	FTU	1	JAS	5/16/00	Hach DR Flash 3000
E. Coli	3200	col/100ml		JAS	5/11/00	SM(18th)-9222D

The Total Coliform Count = 43,400 col/100 mL.

A&L

REPORT NO.
F00132-801
ACCOUNT NUMBER
98430

A & L GREAT LAKES LABORATORIES, INC.

3505 Conestoga Drive • Fort Wayne, Indiana 46808-4413 • Phone (219)483-4759 • FAX (219)483-5274

TO: J F NEW & ASSOCIATES
708 ROOSEVELT RD BOX 243
WALKERTON, IN 46574

FOR: WELLS COUNTY

ATTN: JOHN RICHARDSON

REPORT OF ANALYSIS

LAB NUMBER: 39478
SAMPLE ID: 2

DATE SAMPLED: 5/10/00 1:40 PM
DATE RECEIVED: 5/11/00
DATE REPORTED: 5/23/00 PAGE: 2

PARAMETER	RESULT	UNIT	DETECTION LIMIT	ANALYST	ANALYSIS DATE	METHOD REFERENCE
Conductivity	0.48	mmho/cm	0.01	KLH	5/11/00	EPA-120.1
pH	7.5		0.1	KLH	5/11/00	EPA-150.1
Solids, Total Suspended	33	mg/L	1	KLH	5/11/00	EPA-160.2
Nitrogen, Ammonia (as N)	BDL*	mg/L	0.10	JAS	5/11/00	EPA-350.2
Nitrogen, Nitrate+Nitrite (as N)	20.70	mg/L	0.20	JAS	5/11/00	EPA-353.1
Nitrogen, Total Kjeldahl	BDL*	mg/L	1.0	MJG	5/19/00	EPA-351
Phosphorus, Total	0.38	mg/L	0.10	JAS	5/17/00	EPA-365.2
Phosphorus, Ortho (as P)	0.11	mg/L	0.10	JAS	5/16/00	EPA-365.2
Turbidity	36	FTU	1	JAS	5/16/00	Hach DR Flash 3000
E. Coli	1200	col/100ml		JAS	5/11/00	SM(18th)-9222D

* BDL - Below detection level of method utilized.
The Total Coliform Count = 59,800 col/100 mL.

A&L

REPORT NO.
F00132-801
ACCOUNT NUMBER
98430

A & L GREAT LAKES LABORATORIES, INC.

3505 Conestoga Drive • Fort Wayne, Indiana 46808-4413 • Phone (219)483-4759 • FAX (219)483-5274

TO: J F NEW & ASSOCIATES
708 ROOSEVELT RD BOX 243
WALKERTON, IN 46574

FOR: WELLS COUNTY

ATTN: JOHN RICHARDSON

REPORT OF ANALYSIS

LAB NUMBER: 39479
SAMPLE ID: 3

DATE SAMPLED: 5/10/00 1:15 PM
DATE RECEIVED: 5/11/00
DATE REPORTED: 5/23/00 PAGE: 3

PARAMETER	RESULT	UNIT	DETECTION LIMIT	ANALYST	ANALYSIS DATE	METHOD REFERENCE
Conductivity	0.49	mmho/cm	0.01	KLH	5/11/00	EPA-120.1
pH	7.4		0.1	KLH	5/11/00	EPA-150.1
Solids, Total Suspended	4	mg/L	1	JAS	5/15/00	EPA-160.2
Nitrogen, Ammonia (as N)	BDL*	mg/L	0.10	JAS	5/11/00	EPA-350.2
Nitrogen, Nitrate+Nitrite (as N)	21.60	mg/L	0.20	JAS	5/11/00	EPA-353.1
Nitrogen, Total Kjeldahl	BDL*	mg/L	1.0	MJG	5/19/00	EPA-351
Phosphorus, Total	0.41	mg/L	0.10	JAS	5/17/00	EPA-365.2
Phosphorus, Ortho (as P)	BDL*	mg/L	0.10	JAS	5/16/00	EPA-365.2
Turbidity	18	FTU	1	JAS	5/16/00	Hach DR Flash 3000
E. Coli	1600	col/100ml		JAS	5/11/00	SM(18th)-9222D

* BDL - Below detection level of method utilized.
The Total Coliform Count = 25,400 col/100 mL.

A&L

REPORT NO.
F00132-801
ACCOUNT NUMBER
98430

A & L GREAT LAKES LABORATORIES, INC.

3505 Conestoga Drive • Fort Wayne, Indiana 46808-4413 • Phone (219)483-4759 • FAX (219)483-5274

TO: J F NEW & ASSOCIATES
708 ROOSEVELT RD BOX 243
WALKERTON, IN 46574

FOR: WELLS COUNTY

ATTN: JOHN RICHARDSON

REPORT OF ANALYSIS

LAB NUMBER: 39480
SAMPLE ID: 4

DATE SAMPLED: 5/10/00 12:45 PM
DATE RECEIVED: 5/11/00
DATE REPORTED: 5/23/00 PAGE: 4

PARAMETER	RESULT	UNIT	DETECTION LIMIT	ANALYST	ANALYSIS DATE	METHOD REFERENCE
Conductivity	0.46	mmho/cm	0.01	KLH	5/11/00	EPA-120.1
pH	7.5		0.1	KLH	5/11/00	EPA-150.1
Solids, Total Suspended	18	mg/L	1	JAS	5/15/00	EPA-160.2
Nitrogen, Ammonia (as N)	BDL*	mg/L	0.10	JAS	5/11/00	EPA-350.2
Nitrogen, Nitrate+Nitrite (as N)	19.60	mg/L	0.20	JAS	5/11/00	EPA-353.1
Nitrogen, Total Kjeldahl	BDL*	mg/L	1.0	MJG	5/19/00	EPA-351
Phosphorus, Total	0.38	mg/L	0.10	JAS	5/17/00	EPA-365.2
Phosphorus, Ortho (as P)	0.11	mg/L	0.10	JAS	5/16/00	EPA-365.2
Turbidity	22	FTU	1	JAS	5/16/00	Hach DR Flash 3000
E. Coli	800	col/100ml		JAS	5/11/00	SM(18th)-9222D

* BDL - Below detection level of method utilized.
The Total Coliform Count = 29,800 col/100 mL.

A&L

REPORT NO.
F00132-801
ACCOUNT NUMBER
98430

A & L GREAT LAKES LABORATORIES, INC.

3505 Conestoga Drive • Fort Wayne, Indiana 46808-4413 • Phone (219)483-4759 • FAX (219)483-5274

TO: J F NEW & ASSOCIATES
708 ROOSEVELT RD BOX 243
WALKERTON, IN 46574

FOR: WELLS COUNTY

ATTN: JOHN RICHARDSON

REPORT OF ANALYSIS

LAB NUMBER: 39481
SAMPLE ID: 5

DATE SAMPLED: 5/10/00 12:25 PM
DATE RECEIVED: 5/11/00
DATE REPORTED: 5/23/00 PAGE: 5

PARAMETER	RESULT	UNIT	DETECTION LIMIT	ANALYST	ANALYSIS DATE	METHOD REFERENCE
Conductivity	0.46	mmho/cm	0.01	KLH	*/*/**	EPA-120.1
pH	7.4		0.1	KLH	*/*/**	EPA-150.1
Solids, Total Suspended	23	mg/L	1	JAS	5/15/00	EPA-160.2
Nitrogen, Ammonia (as N)	0.13	mg/L	0.10	JAS	5/11/00	EPA-350.2
Nitrogen, Nitrate+Nitrite (as N)	17.90	mg/L	0.20	JAS	5/11/00	EPA-353.1
Nitrogen, Total Kjeldahl	BDL*	mg/L	1.0	MJG	5/22/00	EPA-351
Phosphorus, Total	0.36	mg/L	0.10	JAS	5/17/00	EPA-365.2
Phosphorus, Ortho (as P)	0.14	mg/L	0.10	JAS	5/16/00	EPA-365.2
Turbidity	40	FTU	1	JAS	5/16/00	Hach DR Flash 3000
E. Coli	2600	col/100ml		JAS	5/11/00	SM(18th)-9222D

A&L

* BDL - Below detection level of method utilized.
The Total Coliform Count = 99,800 col/100 mL.

REPORT NO.
F00132-801
ACCOUNT NUMBER
98430

A & L GREAT LAKES LABORATORIES, INC.

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TO: J F NEW & ASSOCIATES
708 ROOSEVELT RD BOX 243
WALKERTON, IN 46574

FOR: WELLS COUNTY

ATTN: JOHN RICHARDSON

REPORT OF ANALYSIS

LAB NUMBER: 39482
SAMPLE ID: 6

DATE SAMPLED: 5/10/00 12:00 PM
DATE RECEIVED: 5/11/00
DATE REPORTED: 5/23/00 PAGE: 6

PARAMETER	RESULT	UNIT	DETECTION LIMIT	ANALYST	ANALYSIS DATE	METHOD REFERENCE
Conductivity	0.53	mmho/cm	0.01	KLH	5/11/00	EPA-120.1
pH	7.4		0.1	KLH	5/11/00	EPA-150.1
Solids, Total Suspended	41	mg/L	1	JAS	5/15/00	EPA-160.2
Nitrogen, Ammonia (as N)	0.47	mg/L	0.10	JAS	5/11/00	EPA-350.2
Nitrogen, Nitrate+Nitrite (as N)	21.00	mg/L	0.20	JAS	5/11/00	EPA-353.1
Nitrogen, Total Kjeldahl	1.0	mg/L	1.0	MJG	5/19/00	EPA-351
Phosphorus, Total	0.32	mg/L	0.10	JAS	5/17/00	EPA-365.2
Phosphorus, Ortho (as P)	0.18	mg/L	0.10	JAS	5/16/00	EPA-365.2
Turbidity	43	FTU	1	JAS	5/16/00	Hach DR Flash 3000
E. Coli	4000	col/100ml		JAS	5/11/00	SM(18th)-9222D

The Total Coliform Count = 95,800 col/100 mL.

A&L

REPORT NO.
F00132-801
ACCOUNT NUMBER
98430

A & L GREAT LAKES LABORATORIES, INC.

3505 Conestoga Drive • Fort Wayne, Indiana 46808-4413 • Phone (219)483-4759 • FAX (219)483-5274

TO: J F NEW & ASSOCIATES
708 ROOSEVELT RD BOX 243
WALKERTON, IN 46574

FOR: WELLS COUNTY

ATTN: JOHN RICHARDSON

REPORT OF ANALYSIS

LAB NUMBER: 39483
SAMPLE ID: 7

DATE SAMPLED: 5/10/00 11:30 AM
DATE RECEIVED: 5/11/00
DATE REPORTED: 5/23/00 PAGE: 7

PARAMETER	RESULT	UNIT	DETECTION LIMIT	ANALYST	ANALYSIS DATE	METHOD REFERENCE
Conductivity	0.44	mmho/cm	0.01	KLH	5/11/00	EPA-120.1
pH	7.6		0.1	KLH	5/11/00	EPA-150.1
Solids, Total Suspended	55	mg/L	1	JAS	5/15/00	EPA-160.2
Nitrogen, Ammonia (as N)	0.17	mg/L	0.10	JAS	5/11/00	EPA-350.2
Nitrogen, Nitrate+Nitrite (as N)	14.50	mg/L	0.20	JAS	5/11/00	EPA-353.1
Nitrogen, Total Kjeidahl	BDL*	mg/L	1.0	MJG	5/19/00	EPA-351
Phosphorus, Total	0.42	mg/L	0.10	JAS	5/17/00	EPA-365.2
Phosphorus, Ortho (as P)	0.16	mg/L	0.10	JAS	5/16/00	EPA-365.2
Turbidity	121	FTU	1	JAS	5/16/00	Hach DR Flash 3000
E. Coli	4800	col/100ml		JAS	5/11/00	SM(18th)-9222D

A&L

* BDL - Below detection level of method utilized.
The Total Coliform Count = 230,000 col/100 mL.

REPORT NO.
F00132-801
ACCOUNT NUMBER
98430

A & L GREAT LAKES LABORATORIES, INC.

3505 Conestoga Drive • Fort Wayne, Indiana 46808-4413 • Phone (219)483-4759 • FAX (219)483-5274

TO: J F NEW & ASSOCIATES
708 ROOSEVELT RD BOX 243
WALKERTON, IN 46574

FOR: WELLS COUNTY

ATTN: JOHN RICHARDSON

REPORT OF ANALYSIS

LAB NUMBER: 39484
SAMPLE ID: 8

DATE SAMPLED: 5/10/00 10:55 AM
DATE RECEIVED: 5/11/00
DATE REPORTED: 5/23/00 PAGE: 8

PARAMETER	RESULT	UNIT	DETECTION LIMIT	ANALYST	ANALYSIS DATE	METHOD REFERENCE
Conductivity	0.45	mmho/cm	0.01	KLH	5/11/00	EPA-120.1
pH	7.6		0.1	KLH	5/11/00	EPA-150.1
Solids, Total Suspended	104	mg/L	1	JAS	5/15/00	EPA-160.2
Nitrogen, Ammonia (as N)	0.80	mg/L	0.10	JAS	5/11/00	EPA-350.2
Nitrogen, Nitrate+Nitrite (as N)	20.00	mg/L	0.20	JAS	5/11/00	EPA-353.1
Nitrogen, Total Kjeldahl	6.0	mg/L	1.0	MJG	5/19/00	EPA-351
Phosphorus, Total	0.32	mg/L	0.10	JAS	5/18/00	EPA-365.2
Phosphorus, Ortho (as P)	0.46	mg/L	0.10	JAS	5/16/00	EPA-365.2
Turbidity	200	FTU	1	JAS	5/16/00	Hach DR Flash 3000
E. Coli	12000	col/100ml		JAS	5/11/00	SM(18th)-9222D

The Total Coliform Count = 177,600 col/100 mL.

A&L

REPORT NO.
F00132-801
ACCOUNT NUMBER
98430

A & L GREAT LAKES LABORATORIES, INC.

3505 Conestoga Drive • Fort Wayne, Indiana 46808-4413 • Phone (219)483-4759 • FAX (219)483-5274

TO: J F NEW & ASSOCIATES
708 ROOSEVELT RD BOX 243
WALKERTON, IN 46574

FOR: WELLS COUNTY

ATTN: JOHN RICHARDSON

REPORT OF ANALYSIS

LAB NUMBER: 39485
SAMPLE ID: 9

DATE SAMPLED: 5/10/00 2:45 PM
DATE RECEIVED: 5/11/00
DATE REPORTED: 5/23/00 PAGE: 9

PARAMETER	RESULT	UNIT	DETECTION LIMIT	ANALYST	ANALYSIS DATE	METHOD REFERENCE
Conductivity	0.46	mmho/cm	0.01	JAS	5/11/00	EPA-120.1
pH	7.6		0.1	JAS	5/11/00	EPA-150.1
Solids, Total Suspended	172	mg/L	1	JAS	5/15/00	EPA-160.2
Nitrogen, Ammonia (as N)	0.39	mg/L	0.10	JAS	5/11/00	EPA-350.2
Nitrogen, Nitrate+Nitrite (as N)	11.30	mg/L	0.20	JAS	5/11/00	EPA-353.1
Nitrogen, Total Kjeldahl	1.0	mg/L	1.0	MJG	5/19/00	EPA-351
Phosphorus, Total	0.79	mg/L	0.10	JAS	5/17/00	EPA-365.2
Phosphorus, Ortho (as P)	0.25	mg/L	0.10	JAS	5/16/00	EPA-365.2
Turbidity	235	FTU	1	JAS	5/16/00	Hach DR Flash 3000
E. Coli	11800	col/100ml		JAS	5/11/00	SM(18th)-9222D

The Total Coliform Count = 204,000 col/100 mL.

A&L

REPORT NO.
F00159-802
ACCOUNT NUMBER
98430

A & L GREAT LAKES LABORATORIES, INC.

3505 Conestoga Drive • Fort Wayne, Indiana 46808-4413 • Phone (219)483-4759 • FAX (219)483-5274

TO: J F NEW & ASSOCIATES
708 ROOSEVELT RD BOX 243
WALKERTON, IN 46574

ATTN: MARIANNE GIOLITTO

REPORT OF ANALYSIS

LAB NUMBER: 40176
SAMPLE ID: REF. 1

DATE SAMPLED: 6/6/00 2:45 PM
DATE RECEIVED: 6/6/00
DATE REPORTED: 6/12/00 PAGE: 11

PARAMETER	RESULT	UNIT	DETECTION LIMIT	ANALYST	ANALYSIS DATE	METHOD REFERENCE
Conductivity	0.44	mmho/cm	0.01	JAS	6/7/00	EPA-120.1
pH	7.7		0.1	JAS	6/7/00	EPA-150.1
Solids, Total Suspended	208	mg/L	1	JAS	6/9/00	EPA-160.2
Nitrogen, Ammonia (as N)	BDL*	mg/L	0.10	JAS	6/8/00	EPA-350.2
Nitrogen, Nitrate+Nitrite (as N)	18.70	mg/L	0.20	JAS	6/8/00	EPA-353.1
Nitrogen, Total Kjeldahl	3.0	mg/L	1.0	JAS	6/8/00	EPA-351
Phosphorus, Total	BDL*	mg/L	0.10	JAS	6/9/00	EPA-365.2
Phosphorus, Ortho (as P)	BDL*	mg/L	0.10	JAS	6/9/00	EPA-365.2
Turbidity	133	FTU	1	JAS	6/8/00	Hach DR Flash 3000
E. Coli	4800	col/100ml		JAS	6/7/00	SM(18th)-9222D

* BDL - Below detection level of method utilized.
The Total Coliform Count = 74400 col/100 mL.

ASL

APPENDIX 8:

QHEI Datasheet

STREAM: _____ RIVER MILE _____ DATE: _____ QHEI SCORE [ ]

1) SUBSTRATE: (Check ONLY Two Substrate Type Boxes: Check all types present) SUBSTRATE SCORE [ ]

TYPE		POOL	RIFFLE			POOL	RIFFLE
[ ]	[ ] BLDER/SLAB(10)	___	___	[ ]	[ ] GRAVEL(7)	___	___
[ ]	[ ] BOULDER(9)	___	___	[ ]	[ ] SAND(6)	___	___
[ ]	[ ] COBBLE(8)	___	___	[ ]	[ ] BEDROCK(5)	___	___
[ ]	[ ] HARDPAN(4)	___	___	[ ]	[ ] DETRITUS(3)	___	___
[ ]	[ ] MUCK/SILT(2)	___	___	[ ]	[ ] ARTIFIC(0)	___	___

TOTAL NUMBER OF SUBSTRATE TYPES: [ ] >4(2) [ ] <4(0)

NOTE: (Ignore sludge that originates from point sources: score is based on natural substrates)

SUBSTRATE ORIGIN (all)

[ ] LIMESTONE(1) [ ] RIP/RAP(0)
[ ] TILLS(1) [ ] HARDPAN(0)
[ ] SANDSTONE(0)
[ ] SHALE(-1)
[ ] COAL FINES(-2)

SILT COVER (one)

[ ] SILT-HEAVY(-2) [ ] SILT-MOD(-1)
[ ] SILT-NORM(0) [ ] SILT-FREE(1)

Extent of Embeddedness (check one)

[ ] EXTENSIVE(-2) [ ] MODERATE(-1)
[ ] LOW(0) [ ] NONE(1)

COMMENTS: _____

2) INSTREAM COVER: COVER SCORE [ ]

TYPE (Check all that apply)

[ ] UNDERCUT BANKS(1)
[ ] OVERHANGING VEGETATION(1)
[ ] SHALLOWS (IN SLOW WATER)(1)
[ ] DEEP POOLS(2)
[ ] ROOTWADS(1)
[ ] BOULDERS(1)
[ ] OXBOWS(1)
[ ] AQUATIC MACROPHYTES(1)
[ ] LOGS OR WOODY DEBRIS(1)

AMOUNT (Check only one or Check 2 and AVERAGE)

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

COMMENTS: _____

3) CHANNEL MORPHOLOGY: (Check ONLY ONE per Category or Check 2 and AVERAGE) CHANNEL SCORE [ ]

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)

MODIFICATION/OTHER

[ ] SNAGGING [ ] IMPOUND
[ ] RELOCATION [ ] ISLAND
[ ] CANOPY REMOVAL [ ] LEVEED
[ ] DREDGING [ ] BANK SHAPING
[ ] ONE SIDE CHANNEL MODIFICATION

COMMENTS: _____

4) RIPARIAN ZONE AND BANK EROSION: (Check ONE box or Check 2 and AVERAGE per bank) RIPARIAN SCORE [ ]

River Right Looking Downstream

RIPARIAN WIDTH (per bank)

L	R	(per bank)
[ ]	[ ]	WIDE >150 ft.(4)
[ ]	[ ]	MODERATE 30-150 ft.(3)
[ ]	[ ]	NARROW 15-30 ft.(2)
[ ]	[ ]	VERY NARROW 3-15 ft.(1)
[ ]	[ ]	NONE(0)

EROSION/RUNOFF-FLOODPLAIN QUALITY

L	R	(most predominant per bank)	L	R	(per bank)
[ ]	[ ]	FOREST, SWAMP(3)	[ ]	[ ]	URBAN OR INDUSTRIAL(0)
[ ]	[ ]	OPEN PASTURE/ROW CROP(0)	[ ]	[ ]	SHRUB OR OLD FIELD(2)
[ ]	[ ]	RESID.,PARK,NEW FIELD(1)	[ ]	[ ]	CONSERV. TILLAGE(1)
[ ]	[ ]	FENCED PASTURE(1)	[ ]	[ ]	MINING/CONSTRUCTION(0)

BANK EROSION

L	R	(per bank)
[ ]	[ ]	NONE OR LITTLE(3)
[ ]	[ ]	MODERATE(2)
[ ]	[ ]	HEAVY OR SEVERE(1)

COMMENTS: _____

5) POOL/GLIDE AND RIFFLE/RUN QUALITY **NO POOL = 0** POOL SCORE [ ]

MAX.DEPTH (Check 1)

[ ] >4 ft.(6)
[ ] 2.4-4 ft.(4)
[ ] 1.2-2.4 ft.(2)
[ ] <1.2 ft.(1)
[ ] <0.6 ft.(Pool=0)(0)

MORPHOLOGY (Check 1)

[ ] POOL WIDTH>RIFFLE WIDTH(2)
[ ] POOL WIDTH=RIFFLE WIDTH(1)
[ ] POOL WIDTH<RIFFLE WIDTH(0)

POOL/RUN/RIFFLE CURRENT VELOCITY (Check all that Apply)

[ ] TORRENTIAL(-1) [ ] EDDIES(1)
[ ] FAST(1) [ ] INTERSTITIAL(-1)
[ ] MODERATE(1) [ ] INTERMITTENT(-2)
[ ] SLOW(1)

COMMENTS: _____

RIFFLE SCORE [ ]

RIFFLE/RUN DEPTH

[ ] GENERALLY >4 in. MAX.>20 in.(4)
[ ] GENERALLY >4 in. MAX.<20 in.(3)
[ ] GENERALLY 2-4 in.(1)
[ ] GENERALLY <2 in.(Riffle=0)(0)

RIFFLE/RUN SUBSTRATE

[ ] STABLE (e.g., Cobble,Boulder)(2)
[ ] MOD.STABLE (e.g., Pea Gravel)(1)
[ ] UNSTABLE (Gravel, Sand)(0)
[ ] NO RIFFLE(0)

RIFFLE/RUN EMBEDDEDNESS

[ ] EXTENSIVE(-1) [ ] NONE(2)
[ ] MODERATE(0) [ ] NO RIFFLE(0)
[ ] LOW(1)

COMMENTS: _____

6) GRADIENT (FEET/MILE): _____ % POOL _____ % RIFFLE _____ % RUN _____ GRADIENT SCORE [ ]

APPENDIX 9:

Detailed mIBI Results

APPENDIX 9. Detailed mIBI results.

Reference Site:

TABLE A-9.1 Reference Site multi-habitat macroinvertebrate results, 05/30-31/00.

Order	Family	#	EPT	Tolerance (t)	# x t	%
Coleoptera	Dytiscidae	3			0	4.84
Coleoptera	Noteridae	3			0	4.84
Diptera	Chironomidae	22		8	176	**35.48**
Diptera	Ephydridae	3		6	18	4.84
Diptera	Stratiomyidae	1			0	1.61
Ephemeroptera	Ephemerellidae	1	1	1	1	1.61
Ephemeroptera	Heptageniidae	15	15	4	60	24.19
Hemiptera	Gerridae	1			0	1.61
Hemiptera	Hebridae	10			0	16.13
Trichoptera	Polycentropodidae	1	1	6	6	1.61
Trichoptera	Psychomyiidae	2		2	4	3.23
		62	**17**		**6.023**	
					HBI	

TABLE A-9.2 Reference Site mIBI Metrics, 05/30-31/00.

		Metric Score
HBI	6.02	0
No. Taxa (family)	11	4
% Dominant Taxa	35.5%	4
EPT Index	3	2
EPT Count/Total Count	0.27	2
EPT Abun./Chir. Abun.	0.77	0
mIBI Score		**2.0**

Site 1. Flat Creek:

TABLE A-9.3 Site 1 multi-habitat macroinvertebrate results, 05/30-31/00.

Order	Family	#	EPT	Tolerance (t)	# x t	%
Bivalvia	Sphaeriidae	1			0	0.98
Coleoptera	Dytiscidae	4			0	3.92
Coleoptera	Elmidae	17		4	68	16.67
Coleoptera	Haliplidae	1			0	0.98
Diptera	Simulidae	2		6	12	1.96
Ephemeroptera	Baetidae	22	22	4	88	21.57
Ephemeroptera	Oligoneuriidae	1	1	2	2	0.98
Hemiptera	Gerridae	10			0	9.80
Isopoda	Gammaridae	2		4	8	1.96
Odonata	Calopterygidae	1		5	5	0.98
Trichoptera	Hydropyschidae	35	35	4	140	**34.31**
Trichoptera	Philopotamidae	6	6	3	18	5.88
		102	**64**		**3.965**	
					HBI	

TABLE A-9.4 Site 1 mIBI Metrics, 05/30-31/00.

		Metric Score
HBI	3.97	8
No. Taxa (family)	12	4
% Dominant Taxa	34.3%	4
EPT Index	4	4
EPT Count/Total Count	0.63	6
EPT Abun./Chir. Abun.		8
mIBI Score		**5.7**

Site 2. Flat Creek:

TABLE A-9.5 Site 2 multi-habitat macroinvertebrate results, 05/30-31/00.

Order	Family	#	EPT	Tolerance (t)	# x t	%
Amphipoda	Talitridae	1		8	8	0.92
Coleoptera	Dytiscidae	6			0	5.50
Coleoptera	Noteridae	1			0	0.92
Diptera	Chironomidae	14		8	112	12.84
Diptera	Simulidae	1		6	6	0.92
Ephemeroptera	Baetidae	11	11	4	44	10.09
Ephemeroptera	Neoephemeridae	1	1		0	0.92
Gastropoda	Physidae	46			0	**42.20**
Gastropoda	Valvatidae	1			0	0.92
Hemiptera	Gerridae	1			0	0.92
Trichoptera	Hydropsychidae	26	26	4	104	23.85
		109	**38**		**5.170**	
					HBI	

TABLE A-9.6 Site 2 mIBI Metrics, 05/30-31/00.

		Metric Score
HBI	5.17	2
No. Taxa (family)	11	4
% Dominant Taxa	42.2%	4
EPT Index	3	2
EPT Count/Total Count	0.35	4
EPT Abun./Chir. Abun.	2.71	4
mIBI Score		**3.3**

Site 3. Flat Creek:

TABLE A-9.7 Site 3 multi-habitat macroinvertebrate results, 05/30-31/00.

Order	Family	#	EPT	Tolerance (t)	# x t	%
Coleoptera	Gyrinidae	4			0	3.96
Coleoptera	Haliplidae	9			0	8.91
Coleoptera	Hydrophilidae	11			0	10.89
Diptera	Chironomidae	2		8	16	1.98
Diptera	Stratiomyidae	1			0	0.99
Ephemeroptera	Baetidae	6	6	4	24	5.94
Gastropoda	Physidae	64			0	**63.37**
Hemiptera	Corixidae	2			0	1.98
Hemiptera	Gerridae	1			0	0.99
Hemiptera	Veliidae	1			0	0.99
		101	**6**		**5.000**	
					HBI	

TABLE A-9.8 Site 3 mIBI Metrics, 05/30-31/00.

		Metric Score
HBI	5.00	4
No. Taxa (family)	10	2
% Dominant Taxa	63.4%	0
EPT Index	1	0
EPT Count/Total Count	0.06	0
EPT Abun./Chir. Abun.	3.00	4
mIBI Score		**1.7**

Site 4. Flat Creek:

TABLE A-9.9 Site 4 multi-habitat macroinvertebrate results, 05/30-31/00.

Order	Family	#	EPT	Tolerance (t)	# x t	%
Coleoptera	Dytiscidae	1			0	0.76
Coleoptera	Haliplidae	1			0	0.76
Diptera	Simuliidae	32		6	192	24.24
Ephemeroptera	Baetidae	3	3	4	12	2.27
Gastropoda	Physidae	85			0	**64.39**
Gastropoda	Valvatidae	7			0	5.30
Trichoptera	Hydropsychidae	3	3	4	12	2.27
		132	**6**		**5.684**	
					HBI	

TABLE A-9.10 Site 4 mIBI Metrics, 05/30-31/00.

		Metric Score
HBI	5.68	0
No. Taxa (family)	7	0
% Dominant Taxa	64.4%	0
EPT Index	2	0
EPT Count/Total Count	0.05	0
EPT Abun./Chir. Abun.		
mIBI Score		**0.0**

Site 5. Flat Creek:

TABLE A-9.11 Site 5 multi-habitat macroinvertebrate results, 05/30-31/00.

Order	Family	#	EPT	Tolerance (t)	# x t	%
Coleoptera	Dytiscidae	1			0	0.97
Coleoptera	Elmidae	5		4	20	4.85
Diptera	Chironomidae	6		8	48	5.83
Diptera	Simulidae	7		6	42	6.80
Ephemeroptera	Baetidae	34	34	4	136	**33.01**
Ephemeroptera	Heptageniidae	1	1	4	4	0.97
Gastropoda	Lymnaeidae	6			0	5.83
Gastropoda	Physidae	28			0	27.18
Gastropoda	Planorbidae	5			0	4.85
Hemiptera	Gerridae	1			0	0.97
Odonata	Aeshnidae	1		3	3	0.97
Trichoptera	Hydropsychidae	8	8	4	32	7.77
		103	**43**		**4.597**	
					HBI	

TABLE A-9.12 Site 5 mIBI Metrics, 05/30-31/00.

		Metric Score
HBI	4.59	4
No. Taxa (family)	12	4
% Dominant Taxa	33.0%	4
EPT Index	3	2
EPT Count/Total Count	0.42	4
EPT Abun./Chir. Abun.	7.17	6
mIBI Score		**4.0**

Site 6. Griffen Ditch:

TABLE A-9.13 Site 6 multi-habitat macroinvertebrate results, 05/30-31/00.

Order	Family	#	EPT	Tolerance (t)	# x t	%
Amphipoda	Talitridae	15		8	120	13.76
Bivalvia	Sphaeriidae	3			0	2.75
Coleoptera	Elmidae	1		4	4	0.92
Coleoptera	Haliplidae	2			0	1.83
Diptera	Chironomidae	1		8	8	0.92
Ephemeroptera	Baetiscidae	1	1	3	3	0.92
Ephemeroptera	Caenidae	3	3	7	21	2.75
Ephemeroptera	Heptageniidae	17	17	4	68	15.60
Gastropoda	Lymnaeidae	1			0	0.92
Gastropoda	Physidae	44			0	**40.37**
Hemiptera	Gerridae	1			0	0.92
Isopoda	Asellidae	14		8	112	12.84
Odonata	Aeshnidae	1		3	3	0.92
Odonata	Coenagrionidae	3		9	27	2.75
Trichoptera	Hydropsychidae	2	2	4	8	1.83
		109	**23**		**6.448**	
					HBI	

TABLE A-9.14 Site 6 mIBI Metrics, 05/30-31/00.

		Metric Score
HBI	6.45	0
No. Taxa (family)	15	6
% Dominant Taxa	40.4%	4
EPT Index	4	4
EPT Count/Total Count	0.21	2
EPT Abun./Chir. Abun.	23.00	8
mIBI Score		**4.0**

Site 7. Fleming Ditch:

TABLE A-9.15 Site 7 multi-habitat macroinvertebrate results, 05/30-31/00.

Order	Family	#	EPT	Tolerance (t)	# x t	%
Amphipoda	Talitridae	9		8	72	8.41
Bivalvia	Sphaeriidae	1			0	0.93
Coleoptera	Dytiscidae	1			0	0.93
Coleoptera	Elmidae	1		4	4	0.93
Coleoptera	Haliplidae	1			0	0.93
Coleoptera	Hydrophilidae	4			0	3.74
Diptera	Chironomidae	8		8	64	7.48
Diptera	Sciomyzidae	1			0	0.93
Diptera	Simuliidae	6		6	36	5.61
Ephemeroptera	Baetidae	6	6	4	24	5.61
Gastropoda	Physidae	27			0	25.23
Hemiptera	Corixidae	1			0	0.93
Hemiptera	Gerridae	2			0	1.87
Hemiptera	Hebridae	1			0	0.93
Hirudinea		1			0	0.93
Isopoda	Asellidae	28		8	224	**26.17**
Odonata	Coenagrionidae	2		9	18	1.87
Trichoptera	Hydropsychidae	7	7	4	28	6.54
		107	**13**		**7.015**	
					HBI	

TABLE A-9.16 Site 7 mIBI Metrics, 05/30-31/00.

		Metric Score
HBI	7.01	0
No. Taxa (family)	18	8
% Dominant Taxa	26.2%	6
EPT Index	2	0
EPT Count/Total Count	0.12	0
EPT Abun./Chir. Abun.	1.63	2
mIBI Score		**2.7**

Site 8. Somers Creek:

TABLE A-9.17 Site 8 multi-habitat macroinvertebrate results, 05/30-31/00.

Order	Family	#	EPT	Tolerance (t)	# x t	%
Diptera	Chironomidae	55		8	440	**53.40**
Ephemeroptera	Heptageniidae	8	8	4	32	7.77
Hemiptera	Gerridae	1			0	0.97
Isopoda	Asellidae	39		8	312	37.86
		103	**8**		**7.686**	
					HBI	

TABLE A-9.18 Site 8 mIBI Metrics, 05/30-31/00.

		Metric Score
HBI	7.69	0
No. Taxa (family)	4	0
% Dominant Taxa	53.4%	2
EPT Index	1	0
EPT Count/Total Count	0.08	0
EPT Abun./Chir. Abun.	0.15	0
mIBI Score		**0.3**

Site 9. Somers Creek:

TABLE A-9.19 Site 9 multi-habitat macroinvertebrate results, 05/30-31/00.

Order	Family	#	EPT	Tolerance (t)	# x t	%
Bivalvia	Sphaeriidae	2			0	1.71
Coleoptera	Dytiscidae	1			0	0.85
Coleoptera	Elmidae	2		4	8	1.71
Diptera	Chironomidae	74		8	592	**63.25**
Diptera	Culicidae	10			0	8.55
Diptera	Simulidae	11		6	66	9.40
Diptera	Tipulidae	1		3	3	0.85
Ephemeroptera	Ephemeridae	1	1	4	4	0.85
Gastropoda	Physidae	10			0	8.55
Hemiptera	Mesoveliidae	2			0	1.71
Odonata	Aeshnidae	2		3	6	1.71
Odonata	Coenagrionidae	1		9	9	0.85
		117	**1**		**7.478**	
					HBI	

TABLE A-9.20 Site 9 mIBI Metrics, 05/30-31/00.

		Metric Score
HBI	7.48	0
No. Taxa (family)	12	4
% Dominant Taxa	63.2%	0
EPT Index	1	0
EPT Count/Total Count	0.01	0
EPT Abun./Chir. Abun.	0.01	0
mIBI Score		**0.7**