River Raisin Watershed Management Plan, Phase 1

by

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Abstract

The River Raisin Watershed drains 2,780 square kilometers of southeastern Michigan and northern Ohio, terminating in Lake Erie. Currently, agriculture dominates the watershed (73 %) but exurban development is contributing to a changing landscape. As a result, the river and associated tributaries are heavily impacted and in need of a management plan that identifies threats to the watershed's health and proposes appropriate responses. The River Raisin Watershed Council (RRWC) and The Nature Conservancy (TNC) of Michigan, both active in advocating for watershed protection, enlisted the project team's help in developing this plan. The results of this analysis will guide TNC and the RRWC to develop strategies to effectively manage the natural resources of the watershed. The team investigated three areas of importance in developing watershed protection strategies: 1) water quality in the upper watershed, 2) identification of conservation targets in the upper watershed using a GIS model and habitat assessment, and 3) analysis of local ordinances throughout the watershed that address stormwater management, preservation of natural areas, and reduction of impervious surfaces using a scoring system developed by the Center for Watershed Protection. The main stem of the River Raisin above the village of Manchester has the best water quality and also has the largest amount of priority area for habitat conservation. The subwatersheds of Hazen and Evans creek exhibited the poorest water quality in the upper watershed. The South Branch of the River Raisin and parts of Evans Creek are also the areas of lowest conservation value based on available habitat. The cities of Tecumseh and Adrian, the major population centers in these subwatersheds, are the local governments that need the most revision of local ordinances to improve water quality and stormwater management. Based on our analysis we recommend specific locations that could serve as focal areas for conservation planning and model ordinances to improve water quality.

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1 Introduction

1.1 Problem Statement

Increasing urbanization and agricultural land use have put significant stress on the River Raisin Watershed over the past 200 years. Approximately 73% of the watershed is agriculture today, with the remaining natural areas under heavy pressure from residential development (Appendix 1). With these pressures threatening to impair the already heavily impacted watershed further, assessments are needed to synthesize all available information in order to design a comprehensive management plan for the watershed.

1.2 Background

Fur trappers and farmers in search of a new life first settled the River Raisin Watershed in the early 1800's. The life that many of these pioneers found, however, was unforgiving. Much of the land was forested swamp, difficult to cultivate and rife with disease. Over time, as more settlers moved into the watershed, the city of Monroe was founded on the banks of the River Raisin and near the shores of Lake Erie.

Following the founding of Monroe, the settlement of the River Raisin Watershed increased steadily, resulting in the conversion of much of this scenic wilderness to farmland. As development continued, dams were built to harness the power of the river and ditches dug to drain the many forested wetlands. In fact, there are nearly 3,000 miles of drainage canals today flowing into the river and its tributaries. These ditches are still authorized by the Michigan Drain Code as a necessity for the "health, convenience, and welfare" of its citizens (Mitchell et al. 1988).

The watershed today is seriously impaired due to the introduction of increased flows, pesticides, nutrients and sediments into the river from the drainage ditches. Furthermore, with the growth of cities such as Monroe, Adrian, Saline, Dundee and Tecumseh, dependence upon the river as a source of drinking, industrial and agricultural water as well as for the disposal of waste-water has dramatically increased. With more municipalities beginning to depend upon the watershed, a need to coordinate the activities and uses of the river became apparent. The River Raisin Watershed Council (RRWC) was founded in 1974 to act as a coordinating agency for the management of the watershed (Mitchell et al. 1988).

The formation of the RRWC allows municipalities to voluntarily organize on a watershed basis for common purposes. Through the watershed council, members vote upon and adopt by-laws regarding use of the river. Today, some of the major goals of the RRWC include the development of a watershed management plan for the River Raisin, creation of a water-quality monitoring program, education of watershed residents, and sponsorship of erosion and sedimentation control projects.

With many issues facing the river today, the watershed council, local non-profit agencies, and researchers have taken on various efforts to study and combat the threats to the health of the watershed. Some of those problems include sedimentation and nutrient inputs from agriculture, massive bank wasting, alteration of historic flows, habitat loss, and the introduction of non-native species. Some of the work performed by the RRWC to deal with these problems includes the development of partnerships within the community, educational programs, the hosting of river clean-up days and erosion control projects for farmers.

Other non-profits such as The Nature Conservancy (TNC) have purchased land in the watershed to conserve some of the rare native ecosystems that it holds. Ives Road Fen is a 660 acre preserve located in the headwaters of the River Raisin. Fens are rare wetlands that receive groundwater from alkaline springs providing habitat for many endangered species (TNC 2005). Currently, TNC is working to restore the fen by removing drainage tiles and invasive species that threaten the habitat of the many endangered species found in this unique ecosystem.

Research conducted in the watershed is extensive and covers a wide range of topics. Dr. David Allan is one of the lead researchers of the River Raisin, investigating the relationship between the biotic integrity of streams and the surrounding land uses in the watershed (Allan 2004; Allan et al. 1997; Castillo et al. 2000; Diana et al. 2004; Kopplin et al. 2004; Roth et al. 1996). Many of his findings indicate that local habitat conditions and the subcatchment's land use are excellent indicators of biotic integrity in streams and rivers. In addition, he has worked with many students and professors collecting data regarding nutrient concentrations, fish assemblages, mussel diversity, and macroinvertebrate assemblages in the River Raisin (Allan et al. 2002; Diana et al. 2004; Kopplin et al. 2004; Roth et al. 1996). This has helped lead to a better understanding of habitat requirements of aquatic organisms, effects of land use on aquatic systems, and ability to assess ecological health of fluvial systems.

Dr. Tom Johengen, a nutrient chemist for the Cooperative Institute for Limnology and Ecosystems Research (CILER) with the National Oceanic and Atmospheric Administration (NOAA), has conducted research into the influence of agricultural non-point source pollution in tributaries of the River Raisin Watershed. His work has provided insight into the use of Best Management Practices (BMPs) to improve water quality and their effectiveness (Johengen et al. 1989).

In addition to this research, Professor Donna Erickson has conducted significant research into the land use/land cover of the River Raisin watershed (Allan et al. 1997; Erickson 1995; Roth et al. 1996). Her research has helped develop a better understanding of local planning issues associated with watersheds similar to the Raisin. Erickson's research has also provided insight into the problems that planning agencies face and the collaborative strategies that these agencies may use.

The research conducted by Drs. Allan, Johengen, and Erickson has laid a foundation for further research to synthesize the existing data into a watershed management plan.

1.3 Organization of this Report

The following chapters will provide a detailed analysis of three subject areas to be referenced in the forthcoming River Raisin Watershed Management Plan: assessment of water quality (Chapter 2), prioritization of lands eligible for habitat protection (Chapter 3), and an analysis of land use policy and laws affecting water quality (Chapter 4).

The analysis contained in Chapters 2 and 3 will be limited to the upper watershed only. That area, for the purposes of this report, is defined as the land drained by the River Raisin upstream of the confluence with the South Branch River Raisin near the city of Adrian (Appendix 2). Chapter 4 will address issues across the entire watershed. There are several reasons for the division of the watershed and the limiting of scope for Chapters 2 and 3.

The upper watershed lies within the Eastern Corn Belt Ecoregion, while the lower watershed lies within the Huron-Erie Lakeplain Ecoregion. The Eastern Corn Belt Ecoregion of the River Raisin Watershed is comprised of the Ann Arbor Moraines and Jackson Interlobate physiographic subsections. The Jackson Interlobate portion is between three glacial lobes that existed approximately 13,000 to 16,000 years B.P. (Albert et al. 1995). These glacial formations left behind steep, coarse-textured end moraines surrounded by outwash plains and ice-contact topography that support a variety of ecosystems including oak savanna, oak-hickory forest, hardwood swamps, prairie fens, and bogs (Albert et al. 1995; Appendices 3 and 4).

The Ann Arbor Moraines system lies east of the Jackson Interlobate within the Eastern Corn Belt Ecoregion. The Ann Arbor Moraines are primarily fine and medium textured end and ground moraines that support oak-hickory forest, beech-sugar maple forest, and deciduous swamp forest (Appendices 3-5; Albert et al. 1995). Soils are primarily loam and especially fertile in this region leading to extensive farming except upon the steep slopes of the moraines and the lower poorly drained ground moraine portions.

The Maumee Lake Plain occurs in the Huron-Erie Lakeplain Ecoregion and is flat on primarily clay soils. Loamy and clayey soils are common here, which drain extremely poorly and require extensive drainage for agriculture. Presettlement ecosystems supported here consist of beech-sugar maple forest, elm-ash forest, deciduous swamp, white oak-black oak savannas, wet prairies and coastal marshes. Most of the land is heavily farmed today utilizing drainage tiles, ditches and dikes to take advantage of these nutrient rich soils (Albert et al. 1995).

These geological differences and the large scale of the watershed make it extremely difficult to perform a detailed analysis of the entire watershed. Furthermore, a focus on the upper watershed's water quality and natural features is justified because what happens in the upper portions of the watershed will potentially contribute to the water quality downstream.

Lastly, the upper watershed is of significant interest to land trusts including the Nature Conservancy, the Raisin Valley Land Trust, the Washtenaw-Potawatomi Land Trust, and the Southeast Michigan Land Conservancy. The upper portion of the watershed is less disturbed and contains more public land that could be linked to other areas and consolidated into larger tracts of open space, for example through conservation easements. Thus there is a higher chance of success in terms of acres of land conserved and miles of improved riparian habitat.

Chapter 4 examines policy issues that are relevant to the entire watershed. Land use laws and policies that affect water quality and stewardship are mostly made at the local level, but county, regional, state, and federal laws guide and/or restrict those local decisions. Thus, a broader scope is necessary for this section. An important purpose of a watershed management plan is to shift planning and land use decisions away from conventional boundaries and toward a more holistic watershed approach. In particular, the topics addressed in Chapter 4, including stormwater management and impervious surface coverage, are intimately linked with drainage (Arnold and Gibbons 1996). Therefore, limiting the analysis to a small portion of the watershed would ignore natural hydrologic processes. Lastly, administrative boundaries of cities and counties do not follow watershed boundaries, making it difficult to align administrative boundaries with the upper and lower watershed units used in Chapters 2 and 3. Hopefully, a broader perspective of watershed stewardship and land use policy will provide local governments with the incentive necessary to strengthen those ordinances which directly or indirectly affect the health of the river.

1.4 The River Raisin Watershed Management Plan

The impetus for this project, as mentioned above, is the efforts by the River Raisin Watershed Council (RRWC) to develop a watershed management plan. This plan will be used as the "blueprint" for communities in the watershed to improve their stewardship efforts with an ultimate goal of improved water quality, riparian habitat, quality of life, and social and economic growth. A secondary goal of the plan is to make citizens aware of the need to approach environmental protection from a watershed perspective by looking outside existing administrative boundaries. The main objectives of the watershed management plan are to:

1. Coordinate, inform and improve planning and implementation activities
2. Establish eligibility for state and federal grant funds
3. Increase stakeholder participation
4. Foster stewardship
5. Improve river image
6. Improve water quality and habitat impairments

The watershed management plan is also an integral factor in future funding decisions made at the state level. Currently, the management plan is funded by a federal Clean Water Act Section 319 grant in the amount of $277,084. The Michigan Department of Environmental Quality (MDEQ) will no longer fund projects such as streambank restoration and the purchase of development rights without a watershed management plan in place. Thus, a watershed plan is an absolute necessity if the watershed council wishes to pursue projects that require state funding.

Furthermore, this plan will allow the RRWC to apply for other state funding, including Clean Michigan Initiative (CMI) funds. CMI funds are a $675 million bond approved by Michigan voters to protect Michigan's water resources. MDEQ and the Michigan Department of Natural Resources (MDNR) administer CMI funds for programs that work towards the improvement of water quality, management of conservation land, and brownfield remediation (MDEQ, 2005)

Until a watershed management plan is developed, however, the watershed council and stakeholders of the River Raisin may not apply for CMI funds. These funds can have far-reaching impacts as a great diversity of wildlife and societal needs are met by the river. Improvements to water quality and stabilization of river flows will not only ensure drinking water for the hundreds of thousands that depend on the river, but preserve the biological integrity that exists in the watershed. Moreover, improvements to the River Raisin will reduce impacts to Lake Erie.

1.5 Further Research

Due to the large size of the watershed and the many pieces that must go into an effective watershed management plan, this report is only one part of the final product. Other groups involved in various activities include the RRWC; the Lenawee Soil Conservation District; two consulting firms: Ayers, Lewis, Norris and May; and JF New; as well as other groups of graduate students from the University of Michigan's School of Natural Resources and Environment (SNRE). Several other groups will also contribute data, and help to review and implement the finished product.

A group of four graduate students from SNRE has already begun work to contribute to additional components of the watershed management plan, with a planned completion date of April 2007. Their work will cover three areas of assessment. First, an ecological history of the River Raisin watershed as well as a more comprehensive history of human settlement and impact will be used by the RRWC in their educational outreach programs. Second, an analysis of existing local, state, and federal regulations pertaining to agriculture will be made to assess their effectiveness at preventing discharge of pollutants to the river. Third, a geographically comprehensive field assessment will identify current stressors and areas of concern in the upper watershed, and will supplement previous, fragmented studies in guiding both the Nature Conservancy and the River Raisin Watershed Council towards conservation priorities. Surveys will focus on the progression of degradation by sampling fish, macroinvertebrate communities, water chemistry, and physical habitat parameters near the mouth of each subwatershed and along the mainstem of the River Raisin.

2 Water Quality

2.1 Introduction

Although 70 % of the earth's surface is water, freshwater makes up only 2.5 %, and of that less than 1 % remains as free freshwater (i.e. aquifers, wetlands, streams, etc.). It is this minuscule fraction that is available worldwide as drinking water. This makes freshwater a valuable and precious natural resource—valuable because all forms of life depend on water in order to survive and precious because vast amounts are either being withdrawn or polluted. Thus, the importance of conserving and protecting freshwater resources cannot be understated. As the burgeoning human population makes more and more demands on natural resources, particularly water, it is critical to develop and implement sustainable practices that will ensure water resources remain suitable for human and wildlife use. Moreover, the increasing global demand for potable water is the primary driver for studying water quality (Waite 1984, p. 2).

Water quality of aquatic environments is assessed through the "sampling and analysis of water constituents and conditions" (EPA 1997, Chapter 5). Water constituents include organic and inorganic compounds, in particulate and dissolved form, that may be natural or anthropogenic in origin. Since the enactment of the Federal Water Pollution Control Act (also known as Clean Water Act or CWA) in 1972 and its subsequent amendments, pollutants and associated contaminants have been of central interest. The effects of pollutants and contaminants vary widely, however, both are characterized by a similar trait: the ability to adversely affect a body of water (refer to next section for further discussion). Impairments to freshwater resources have been increasing over decades as a result of human activities altering the landscape. The Environmental Protection Agency (EPA) is the main regulatory body at the federal level charged with oversight of various water-related programs to help control and prevent water pollution. One example is the CWA Section 319 non-point source grants, which generally fund state projects that identify, address, and reduce non-point source pollution and threats in specific water bodies (EPA 2003a). This allows state agencies to develop and implement programs or management plans that target problems in impaired surface waters within drainage basins. In several cases, these programs or management plans are based on either regional or watershed scales. In the case of the River Raisin, a watershed management plan will be developed with the procurement of federal and state funding (refer to Chapter 1, Section 1.4 for background information).

Watershed management is the "analysis, protection, development, operation or maintenance of the land, vegetation, and water resources…for the benefit of its residents" (StreamNet 2002). Collaborative efforts between stakeholders and agencies should lead to sound decision-making and planning based on goals that will maintain, protect, and restore the natural resources in a watershed. Watershed management planning is a multi-disciplinary and multi-tiered approach that leads to the development and implementation of a document known as the "watershed management plan." A watershed management plan is composed of several integrated elements including: a description of watershed characteristics, baseline information on past and current land cover, wildlife and vegetation communities, water quality, and habitat areas. In addition, this plan "considers all uses, pollutant sources, and impacts within a drainage area" (MDEQ 2006). A management plan's main purpose is to guide stakeholders and agencies in achieving water quality goals that will help improve river conditions through mitigation, restoration, and monitoring. For further information on how to put together a management plan, refer to "Developing a Watershed Management Plan for Water Quality: An Introductory Guide" by the Michigan Department of Environmental Quality (2000).

2.1.1 Water Pollution

Problems in water quality usually arise from a source of pollution—including trash, industrial waste, stormwater discharge, and other forms of anthropogenic debris. Pollution entering surface waters (i.e. rivers, lakes, oceans) degrades water quality for human uses including drinking, fishing, swimming, boating, and other activities. Additionally, pollution can affect aquatic organisms such as invertebrates, amphibians, shellfish, plants, and fishes. Urban runoff, a form of pollution that can carry pollutants resulting from urban land use practices into surface waters, can negatively impact invertebrates and fishes by causing declines in abundance and diversity (Wang et al. 2001).

The Clean Water Act (CWA) revised the designation of water pollutants in 1977, with subsequent additions in 1979. In general, the CWA mandates the control of three main categories of water pollutants: conventional (e.g. biochemical oxygen demanding materials, suspended solids, sediments, factors affecting pH, fecal coliform, oil and grease, and nutrients); toxic or priority (e.g. DDT, PCBs); and non-conventional (e.g. chlorine, iron; Vincoli 1993, p. 96-98). Although all three are important to the field of water quality, this chapter focuses mainly on conventional pollutants such as nutrients and suspended solids, and their sources.

2.1.2 Point source & Non-point source Pollution

There are two types of sources of water pollution: point source and non-point source. The Clean Water Act defines point sources as:

> "…any discernible, confined, and discrete conveyance, including but not limited to any pipe, ditch, channel, conduit…concentrated animal feeding operation or vessel or floating craft from which pollutants are or maybe discharged."
> (33 U.S.C 1251 § 502)

These inputs are easily identifiable and visible because they directly discharge into receiving waters from a pipe or conveyance as described above. Types of discharges include municipal and industrial wastewater effluents, runoff and leachate from solid waste disposal sites, storm sewer outfalls, oil spillage, etc. The most notorious incident of point source pollution occurred in 1989 when the Exxon Valdez oil tanker spilled eleven million gallons of crude oil into Prince William Sound in Alaska (Peirce et al. 1998, p. 33).

Five essential strategies are employed through the CWA to achieve the goal of attaining water quality that "provides for the protection and propagation of fish, shellfish, and wildlife, and provides for recreation in and on the water." One of the five strategies utilizes control and prevention measures to reduce or eliminate point source pollution through the National Pollutant Discharge Elimination System (NPDES) permit program (EPA 2006a). The NPDES permitting system is the single most important program that specifies discharge standards, monitoring and reporting requirements from municipal, non-municipal and industrial facilities that directly discharge pollutants into surface waters (MDNR 1990, p. 217). In general, it is illegal to discharge wastewater into rivers and streams without a NPDES permit—facilities or operations found to do so are penalized.

NPDES permits are typically issued to point source dischargers such as concentrated animal feeding operations (CAFOs), publicly owned treatment works (POTWs, also known as wastewater treatment plants), and operators of activities which may have runoff flowing from their sites during storm events (e.g. construction sites). First, animal feeding operations (AFOs) are those in which feed is brought to the animals as opposed to grazing or seeking food in pastures. AFOs must first be designated as *concentrated* or *confined* AFOs to be regulated under the NPDES permitting program. CAFOs are classified based on the actual number of livestock on their farms that are confined for "at least 45 days in a 12-month period and there is no grass or vegetation in the confinement area during the normal growing season" (for classifications refer to Appendix 6). Although CAFOs are required to hold NPDES permits under Section 502 of the Clean Water Act, not all of them do. In Michigan, it is estimated there are approximately 52,000 farms and of those around 200 are classified as CAFOs, though the exact number is not known. This unknown number leads the Sierra Club of Michigan and other concerned citizens to believe that numerous CAFOs are unregulated and violating water quality standards (Woiwode & Henning 2005). This assumption carries serious implications for water quality in the state because animal wastes and wastewater can enter waterways following spills or breaks in waste storage structures, or following application of manure to crop land (ECCSCM 2006). As a result, this causes contamination of rivers and could potentially damage aquatic habitats and/or harm sensitive aquatic species.

Publicly owned treatment works (POTWs) are municipal sources of pollution that collect and treat wastewater from residential, commercial and industrial areas. After treatment processes, the water is then discharged into surface waters. There are four additional areas under the NPDES program that apply to POTWs: the National Pretreatment program, Municipal Sewage Sludge program, combined sewer overflows, and the Municipal Stormwater Program. POTWs can also receive wastewater from "indirect dischargers" which use either combined sewer systems (CSSs) or separate sewer systems (SSSs). Discharges from facilities with either CSSs or SSSs are regulated under the National Pretreatment program of NPDES. This program imposes effluent limits and regulations on industrial or non-municipal facilities in order protect POTWs from pollutants that may interfere with their operations (EPA 2006a). CSSs collect and convey domestic, commercial, and industrial sewage as well as stormwater through a single pipe to a POTW where it is treated and then discharged into a river. During heavy rains or snowmelt, the capacity of a CSS is exceeded and "overflows," dumping untreated wastewater and stormwater runoff directly into rivers and streams (EPA 2006a). Separate sewer systems convey only sanitary wastewater to a POTW and stormwater goes through a different pipe. As with CSSs, these systems can overflow when capacity is exceeded and any untreated sewage resulting from overflows are discharged into waterways. Both combined sewer overflows (CSOs) and separate sewer overflows (SSOs) contaminate rivers with sewage, debris, and other wastes, causing severe water quality problems. Additionally, they can cause beach closures, halt shellfish harvests, and threaten public health (EPA 2004).

Lastly, other land activities that may generate runoff during rain events are also considered point sources and need to obtain a stormwater NPDES permit. Operators of these activities fall under one of two phases of stormwater management: phase I applies to medium and large municipal separate storm sewer systems (MS4s), construction sites larger than five acres, and other industries; phase II applies to small MS4s and construction sites larger than one acre (EPA 2006a). The stormwater management program helps achieve water quality standards and emphasizes best management practices (BMPs). BMPs are preventative measures or treatment controls to land use activities in order to limit the release of pollutants into stormwater discharges (EPA 2005).

In contrast to point sources, non-point sources (NPS) of pollution are more difficult to identify and control, and are one of the main reasons that rivers fail to meet water quality standards (e.g. total maximum daily loads). In fact, NPS pollution is the nation's biggest water quality problem (EPA 2006b). NPS pollution occurs when runoff (i.e. rainfall, snowmelt, or irrigation) runs over land or other impermeable surfaces, carrying pollutants and transporting them into rivers and/or groundwater supplies. There are several factors that influence the movement of runoff into rivers: soil permeability, topography, presence of vegetation, precipitation intensity and duration, and land use practices. NPS pollution is widespread—agriculture, forestry, grazing, septic systems, recreational boating, acid mine drainage, construction sites, impervious surfaces, houses, etc., all contribute to this problem (EPA 2006b). Non-point source pollutants and their sources are summarized in Appendix 7.

Although provisions of the NPDES program address specific types of agricultural activities (i.e. CAFOs), the majority of agricultural operations remain as non-point sources and are exempt from CWA regulation. In Michigan, agriculture is a major source of pollutants, causing impairments to rivers and degrading river quality (EPA 2002). Agricultural activities can contribute chemicals from fertilizers, herbicides, and insecticides; sediments from crop lands and erosion; and bacteria and nutrients from animal wastes. Farmers who do not employ proper land management practices can also result in significant stream degradation (Silk & Ciruna 2004). For instance, erosion associated with agriculture can expose soils and supply fine sediments to runoff entering rivers. Several studies have documented that high concentrations of fine sediments in lotic waters adversely impact aquatic organisms, particularly fish by hindering growth and development, reducing suitability of spawning habitat, and clogging their gills (Wood & Armitage 1997). Elevated nutrient concentrations (e.g. nitrogen and phosphorus) originating from agriculture are another concern. The effects of nutrient enrichment extend beyond simply causing eutrophication in rivers—nuisance algal growth, oxygen depletion, fish kills, and habitat loss are all caused by excessive nutrients in aquatic environments (Carpenter et al. 1998)

Impervious surfaces are another major source of non-point pollution. Imperviousness occurs when impermeable surfaces "do not allow stormwater to percolate into the ground." Examples of impervious surfaces include roads, sidewalks, parking lots, rooftops, driveways, patios, and pools (Warbach 1998). Arnold and Gibbons (1996) identify impervious surface coverage as a key indicator of stream health. Several studies (Klein 1979; Schueler 1987; Booth & Reinfelt 1993) have shown that there is a strong correlation between the percentage of land covered by impervious surfaces and stream health. In general, streams become "impacted" when impervious coverage reaches 10% and are "degraded" at about 30% (Figure 1). Bannerman et al. (1993) tested pollutant loads from various impervious surfaces, and concluded that water running off roads has the highest pollutant loads, followed by residential lawns and roofs. However, reducing "impervious surface coverage may often be the most feasible and cost-effective vehicle for addressing water pollution" (Arnold & Gibbons 1996).

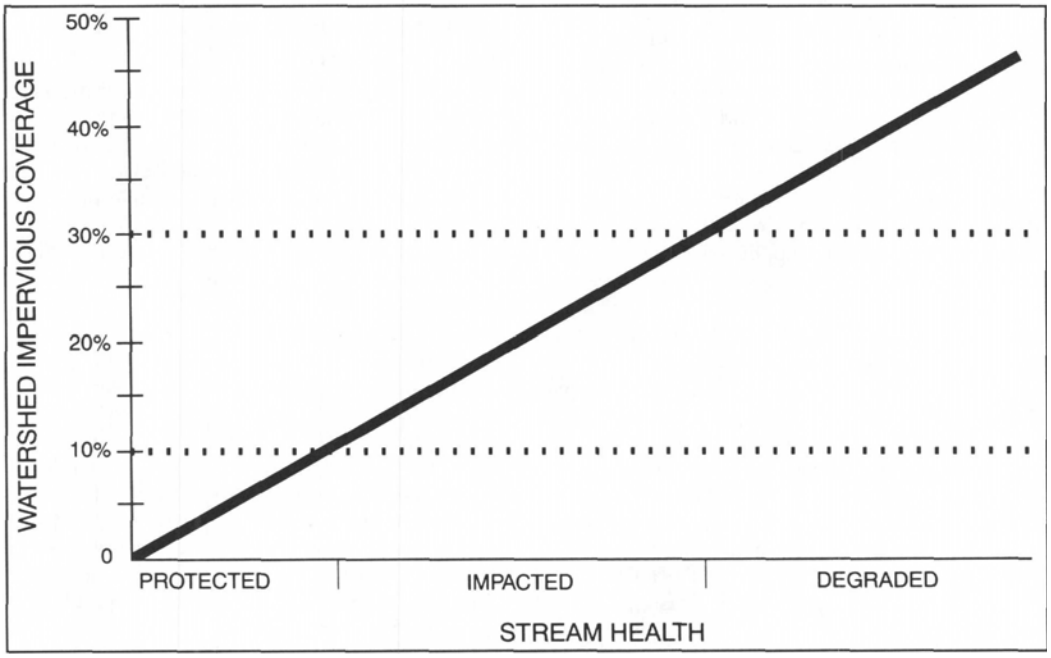


Figure 1. Percentage of impervious surface coverage is an indicator of stream health.
Source: Schueler 1992 in Arnold and Gibbons 1996, p. 246

2.1.3 Threats to Rivers

Pollutants, human activities and land use practices all affect river health, however, other factors such as climate change, invasive species, and impoundments or dams have also been identified as potential threats to freshwater environments (Allan 1995; Allan 2004). Meyer et al. (1999) and Poff et al. (2002) report that aquatic ecosystems, their processes, and their biotic communities will respond to fluctuations in climate. However, due to the complex nature of climate change, long-term impacts on rivers and their ecosystems are not clearly understood so it is important to continue researching this field. In any case, the River Raisin watershed suffers from two of these threats: invasive species and dams.

Invasive species, whether introduced intentionally or unintentionally, become a nuisance and can be impossible to eradicate once they have established themselves in a new habitat (Allan 1995).

Invasive or exotic species cause negative impacts not only to freshwaters and native species, but public health and local economies can be affected as well. The zebra mussel is one of many exotics proliferating in Michigan and throughout other states. In 1988, the zebra mussel was transported to North America via ballast water and first colonized Lake St. Clair, which connects Lake Huron and Lake Erie. Two years later, this species had spread to all five Great Lakes including other downstream drainage basins. Due to certain competitive advantages, zebra mussels have been very successful at outcompeting native mussels found in Michigan rivers, reducing availability of food and spawning habitat for native fishes, and negatively affecting local economies. For instance, the city of Monroe, which lies within the River Raisin watershed, lost its water supply for three days in 1989 due to massive colonization of zebra mussels in the city's water-intake pipes. The city and other industries have expended substantial money and effort in cleaning intake pipes clogged by zebra mussels. It is estimated that the potential economic impact for industries within the Great Lakes region is approximately $5 billion over the next decade (USGS 2000).

Throughout the history of the United States, impoundments or dams have been used in water regulation for various purposes—from harnessing hydroelectric power to supplying water for irrigation and industry (Allan 1995). Although humans are the beneficiaries of these structures, impacts from dams cause detrimental alterations to rivers and their ecosystems. Physical changes to rivers typically occur downstream from a dam—discharges and sediment loads may reduce, temperature regimes fluctuate, water quality may degrade. Dams also interrupt the course of a river, creating a barrier between habitats and migration routes, particularly for fish (Giller & Malmqvist 1998). Additionally, dams that release high discharges cause scouring in channels and streambanks, increasing suspended sediments in the water column and possibly affecting aquatic organisms. According to the River Raisin Watershed Council (2006), there are 22 dams on the main stem of the Raisin and 38 dams on its tributaries. These dams interrupt the natural flow of the Raisin and its tributaries, creating fragmented stream segments. River and stream quality are influenced by a variety of factors, though it is important to identify which of these factors are adversely impacting these waterways in order to develop and implement strategies that would best improve their quality and health.

2.1.4 Water Quality Assessment

Water quality assessment or monitoring is an effective tool for determining the characteristics and condition of an aquatic system. In particular, it provides vital information on whether the waters from rivers and streams are safe to swim in, safe to fish from, safe to drink, and/or safe to use for other industrial purposes such as irrigation. Water quality data collected from rivers can be used to inform scientists, political officials, and community members on the river's status and assist them in the decision-making process concerning policies and regulations which aim for river protection. A comprehensive assessment of water quality indicators can determine whether conditions are meeting water quality criteria and regulations. Consequently, a river found to have water quality problems is usually an impetus behind developing and implementing a strategy to help improve its condition.

"River health" (or "stream health") is a term coined by river ecologists to describe the ecological integrity and status of fluvial systems (Allan 2004). It takes into account the biological, chemical, and physical conditions of rivers. A "healthy" river is considered to have the following features: clear water or low turbidity, stable vegetated banks, occurrence of multiple habitats (snags, pools, riffles), high species richness, natural concentrations of essential nutrients, and low levels of pollutants. Rivers that depart from these conditions may indicate human interference and ecological disturbance. Karr and Chu (2000) found that the biological integrity of rivers is influenced by five factors commonly altered by human activities: channel characteristics, energy sources, chemical variables, flow conditions, and biotic interactions. Rivers and streams are under constant threat from land development activities—they experience hydrologic flow modifications due to channelization, chemical variations via inputs of runoff, etc., all of which can negatively affect rivers and their ecosystems. These impacts usually create the need to restore the ecological integrity of impaired rivers in urban areas and drives efforts for watershed protection.

Water quality indicators are typically measured to obtain a snapshot of current biological, chemical, and physical conditions. Indicators also provide clues into natural and anthropogenic processes that may be influencing the river. The following describes in detail the water chemistry parameters that were measured in this study of the River Raisin and briefly discusses their significance in water quality assessment.

2.1.5 Water Chemistry

Dissolved Oxygen & Temperature

Aquatic organisms such as fish, invertebrates, and plants require oxygen for survival. In aquatic systems, oxygen is typically measured in its dissolved available form as dissolved oxygen (DO) and has been long used as an indicator of water quality. Dissolved oxygen levels fluctuate diurnally and seasonally due to environmental factors such as ambient temperature and flow (Allan 1995). Elevated DO concentrations indicate a healthy river capable of supporting a variety of aquatic species. The main factor contributing to the decline of DO is pollution—accumulation of organic waste and nuisance algae deplete DO in river water due to their decomposition, making it difficult for sensitive aquatic organisms to live in that environment.

Additionally, DO levels is inversely related with stream temperature—cold, lotic waters tend to be well-oxygenated (or aerated) compared with warm, lentic waters. Like dissolved oxygen, water temperature varies seasonally and daily, though other factors such as river size, groundwater supply, and shade from plants influence the magnitude of these changes (Allan 1995). Temperature can also have an indirect or direct effect on physiological processes of aquatic life. If temperatures fall outside of a species' optimal range, organisms will likely become stressed and die. Moreover, human activities can alter water temperature and consequently disturb habitat for aquatic organisms. Removal of streamside riparian vegetation not only increases water temperature, it also takes away critical habitat for fish and invertebrates. Lastly, discharge of heated effluents from industrial sources into rivers may increase temperature as well as supplement deleterious chemicals.

pH

The degree of acidity or the concentration of hydrogen ions in river water is measured as pH, using a logarithmic scale from 0 (extremely acidic) to 14 (extremely basic). A pH of 7 is neutral while extreme values, either below 5 or above 9, are harmful to aquatic organisms (Allan 1995). Certain organisms are only able to tolerate narrow pH ranges, thus significant variations in pH can adversely affect the distribution of a species. Rain water is naturally acidic at about 5.6 though the more acidic the precipitation, particularly around mining areas where high concentrations of nitrous and sulphur oxides are found, the more likely is precipitation to contribute hydrogen ions to a watershed.

The geology (or soils) of a drainage basin can also affect pH in streams. Certain rock types have a specific buffering capacity which may or may not reduce the impact of acidic precipitation. Catchments that lie on granite and igneous rocks have a low buffering capacity, thus acid rain has an impact on surface waters, causing acidic stream conditions (i.e. pH 3.5 to 5.5). In contrast, catchments on carbonate-rich sedimentary rocks have a stronger buffering capacity, thus streams tend to be slightly basic (i.e. pH 7.5 to 8.5). In this case, stream pH is not easily influenced by acidic precipitation (Giller & Malmqvist 1998).

Conductivity & Total Dissolved Solids

Conductivity or specific conductance is a measure of the ability of water to carry an electrical current. This ability depends on the presence of ions and their total concentration, mobility and valence, and is an approximate predictor of total dissolved ions (AWWA 2003). Ions that carry positive charges include sodium, magnesium, iron, and calcium; anions include chloride, nitrate, sulfate, and phosphate. As with pH, geological patterns in catchments can determine how much conductivity is in the water—sedimentary rocks or clay soils increase conductivity (Allan 1995). Other possible sources are salts or dissolved solids from industrial effluent, which can be used as an indicator of water pollution.

Total dissolved solids (TDS) is the sum of dissolved solids or ions present in the water column. It can consist of bicarbonates, carbonates, chloride, sulfate, sodium, calcium, magnesium, and potassium. Calcium is the most abundant ion in rivers and derives from carbonate-rich sedimentary rocks (Allan 1995). In general, most ions are derived from the weathering of carbonate materials. According to drinking water regulations, TDS concentrations are not exceed to 500 mg/L. TDS levels exceeding this limit in drinking water can result in an undesirable taste and thus unfit for human consumption (AWWA 2003).

Turbidity

Turbidity measures the clarity of water. The transmission of light can be obstructed or scattered by suspended particles in the water column. Clear streams have low turbidity while cloudiness indicates high turbidity. The more suspended material in the river, the higher the turbidity (AWWA 2003). High turbidity reduces the amount of light penetrating the water, which reduces photosynthesis and the production of DO. Like TDS, soil and streambank erosion, wastewater discharge, and urban runoff can contribute to turbidity. Elevated turbidity levels often indicate pollution from nearby activities such as construction, agriculture, or logging.

Total Suspended Matter

Total suspended matter (TSM) or total suspended solids (TSS) is particulate matter suspended in the water column. Suspended materials include soil particles (clay, silt, and sand), algae, zooplankton, microorganisms, and other matter. Like turbidity, total suspended matter affects water clarity, and human activities such as agriculture, logging, mining, and urbanization are likely contributors. Elevated TSM levels adversely affect invertebrate and fish populations (Dodds & Whiles 2004). Similarly, suspended sediments are especially considered a detrimental pollutant in rivers because it impacts both aquatic habitat and wildlife.

Nitrate

Nitrate is a form of inorganic nitrogen and an essential nutrient for plants. It is usually present at elevated concentrations in rivers that flow through agricultural lands and urban areas. Runoff coming from these land uses is regarded as the primary non-point sources of nitrate. Fertilizers, pesticides, sewage, leakages from septic tanks, and animal wastes all contribute into waterways. Excessive nitrate concentrations in rivers and streams can cause water quality problems such eutrophication, increased algal growth, and anoxic conditions (Dodds & Welch 2000). In addition, large quantities of nitrate found in drinking water can be harmful to people. High nitrate levels reduce the oxygen carrying capacity of blood in infants, also known as “blue baby syndrome.” Consequently, nitrate must not exceed 10 mg/L in drinking water supplies (Carpenter et al. 1998).

Total Phosphorus

Total phosphorous (TP) includes both organic and inorganic phosphorus present in either dissolved or particulate forms. Phosphorus is another important nutrient for plants and it is also required for metabolic processes in animals. Like nitrate, elevated TP levels in aquatic ecosystems may contribute to toxic algal blooms and eutrophication. Excessive algal growth not only interferes with the designated uses of surface waters, it also causes taste and odor problems, depletes oxygen supply, clogs industrial water intakes, and fish kills (Dodds & Welch 2000).

Phosphorus derives from fertilizer, erosive landscapes, and sewage, with greater quantities emerging from industrial effluent such as wastewater treatment plants. In particular, runoff from agricultural operations which apply fertilizers on crops is a major non-point source of TP in streams. Homeowners who also apply fertilizers on their lawns are another source. Fertilizers are composed of a combination of nitrogen, phosphate, and potassium. During high periods of precipitation, fertilizers can be washed off from crops or lawns and transport phosphorus into nearby rivers. In addition, phosphorus has the tendency to attach itself to soils or sediments, thus runoff from mining and construction areas also carry phosphorus into surface waters (Carpenter et al. 1998).

2.2 Methods

2.2.1 Study Area & Location

The study area for this water quality assessment lies within three sub-catchments in the upper region of the River Raisin watershed located in southeastern Michigan. Sampling sites were selected along Evans Creek, Hazen Creek (South Branch), and the main stem of the River Raisin in order to determine the status of water quality in the upper watershed (Figure 2). Water sampling took place at three sites along Hazen and Evans Creeks (headwaters, midstream, and mouth) and at two sites along the main stem (upstream and downstream the village of

Manchester) on three occasions: 6 August 2005, 12 November 2005, and 11 March 2006. This sampling design was employed to account for variation across seasons and sampling sites.

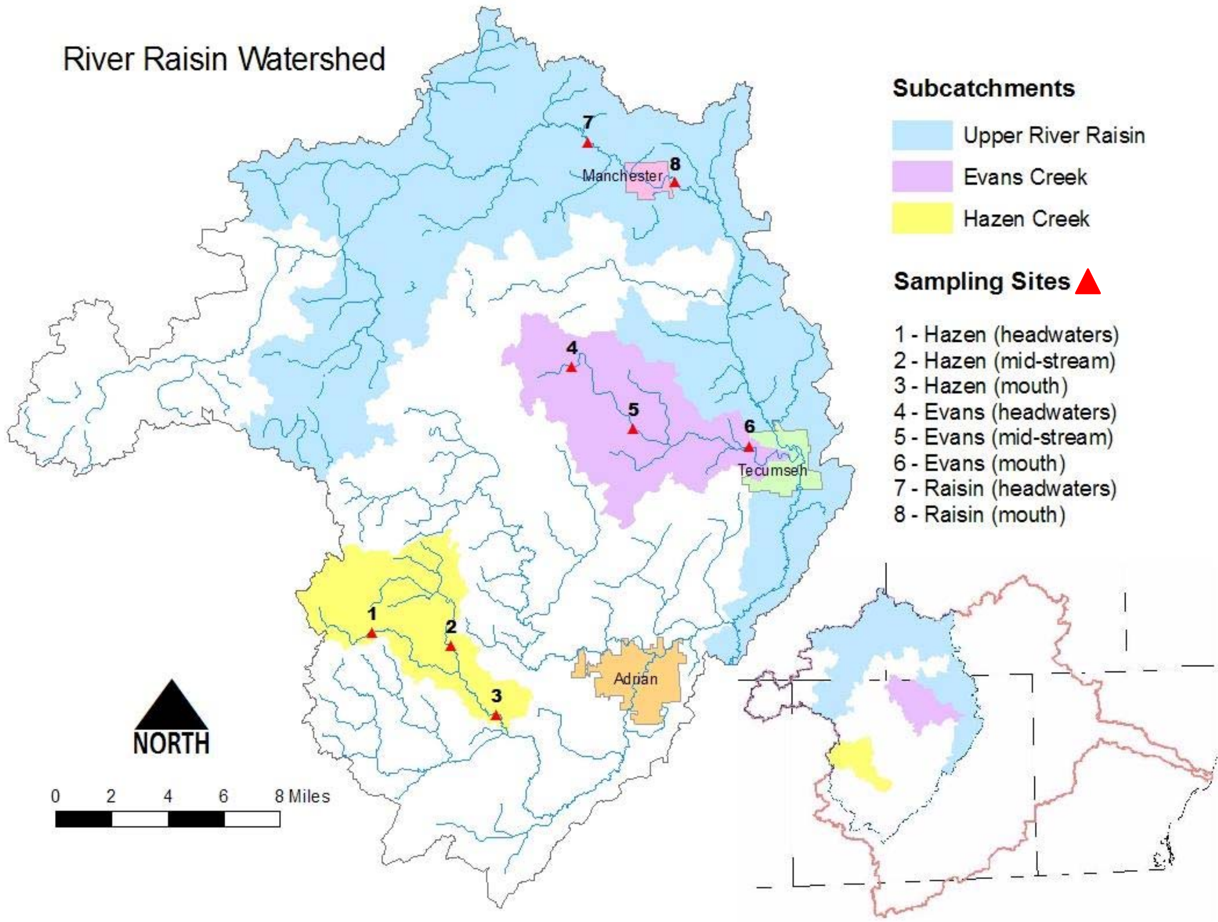


Figure 2. Location of sampling sites on Hazen Creek, Evans Creek, and the main stem of the River Raisin in the upper reaches of the watershed. Note: inset not to scale.

2.2.2 Water Chemistry

Sampling

Water samples were collected mid-channel with a chemically clean bucket and immediately processed into designated tubes for nutrient analyses and total suspended matter (TSM). Samples for dissolved nutrients (nitrate, ammonia, and phosphate) were filtered through a 0.2 micron nylon filter into polypropylene tubes and later frozen until analyzed. Samples for total phosphorus were measured out in a clean BD plastic syringe and dispensed into acid-cleaned pyrex tubes. The remaining water was returned to the lab in clean polypropylene bottles to use for determining TSM. Samples were placed on ice and in the dark during transport from the field to the laboratory. Additionally, water temperature, specific conductance, dissolved oxygen, percent dissolved oxygen, pH, turbidity, and total dissolved solids were also measured in the field directly using a Hydrolab™ DS 5 instrument. Observations of the surrounding environment were also recorded.

Analytical

Nutrient concentrations were analyzed in the laboratory using standard automated colorimetric techniques on a Technicon auto analyzer II (APHA 1990) as detailed in the laboratory manual of Davis and Simmons (1979). Nitrate plus nitrite was measured using the cadmium reduction method. Ammonia concentrations were determined using the automated colorimetric phenate method, and soluble reactive phosphorus (SRP) was determined by the ascorbic acid method. Total phosphorous was determined by an oxidative digestion with potassium persulfate, followed by analysis as SRP. Total suspended matter (TSM) was determined gravimetrically. Samples were filtered through a rinsed, dried and pre-weighed Whatman GFC 47 mm filter until nearly clogged (typically between 300–900 mL), and the volume recorded. Filters were then dried at 60°C for 48 hours and reweighed. TSM was calculated as the difference between the two weights divided by the volume filtered.

2.3 Results

Total Phosphorus

Total phosphorus (TP) concentrations varied seasonally and across eight sampling sites (Fig. 3 a-c). Hazen Creek showed variable TP concentrations over the course of eight months, with lower levels observed in November and higher levels in the previous August and following March (Fig. 3a). Additionally, TP increased downstream in Hazen Creek in early March. This pattern is largely attributed to rainfall events that occurred before sampling took place. Evans Creek showed a similar trend in TP levels in March as well, though a significantly high peak of 195 μg/L was observed in the middle reaches in August (Fig. 3b). As with Hazen Creek, TP increased downstream in Evans Creek in March as a result of spring runoff. Total phosphorus concentrations generally were lower in the main stem of the River Raisin than in the tributaries, however, concentrations were slightly higher in the headwaters than downstream during November and March samplings (Fig. 3c).

Soluble Reactive Phosphorus

Soluble reactive phosphorus (SRP) concentrations generally increased downstream, particularly in both Evans Creek and the main stem (Fig. 4b and 4c). SRP levels in the middle reaches of Hazen Creek showed otherwise in August, though levels tended to increase downstream in November and in the following March (Fig. 4a). In Evans Creek, concentrations in August and in March displayed the same pattern in which SRP increased downstream (Fig 4b). In November, levels remained nearly the same along the tributary. As with total phosphorus, SRP concentrations were found to be the lowest at sampling sites along the River Raisin. SRP remained less than 2 μg/L in the headwaters of the main stem and increased significantly near the mouth across the three sampling dates, (Fig. 4c). The highest value at the mouth of the Raisin reached 8 μg/L in August, which is still considerably low compared to levels seen at the mouths of Hazen and Evans Creek.

Ammonia

Ammonia (NH_3) concentrations fluctuated across all sampling sites with no discernible pattern during August or November sampling dates. Ammonia levels were high in the headwaters during August 2005, reaching up to 100 μg/L and 150 μg/L in Hazen Creek and the main stem, respectively (Fig. 5a and 5c). In contrast, Evans Creek experienced a high peak in its middle reaches on the same day in August (Fig. 5b). In November 2005, ammonia concentrations were less than 10 μg/L in Hazen and approximately 20 μg/L in both Evans and the main stem. The only trend in ammonia occurred in early March during spring runoff, in which concentrations increased downstream along each stream. The highest peak recorded at this time was 153 μg/L and it occurred at the mouth of Evans Creek.

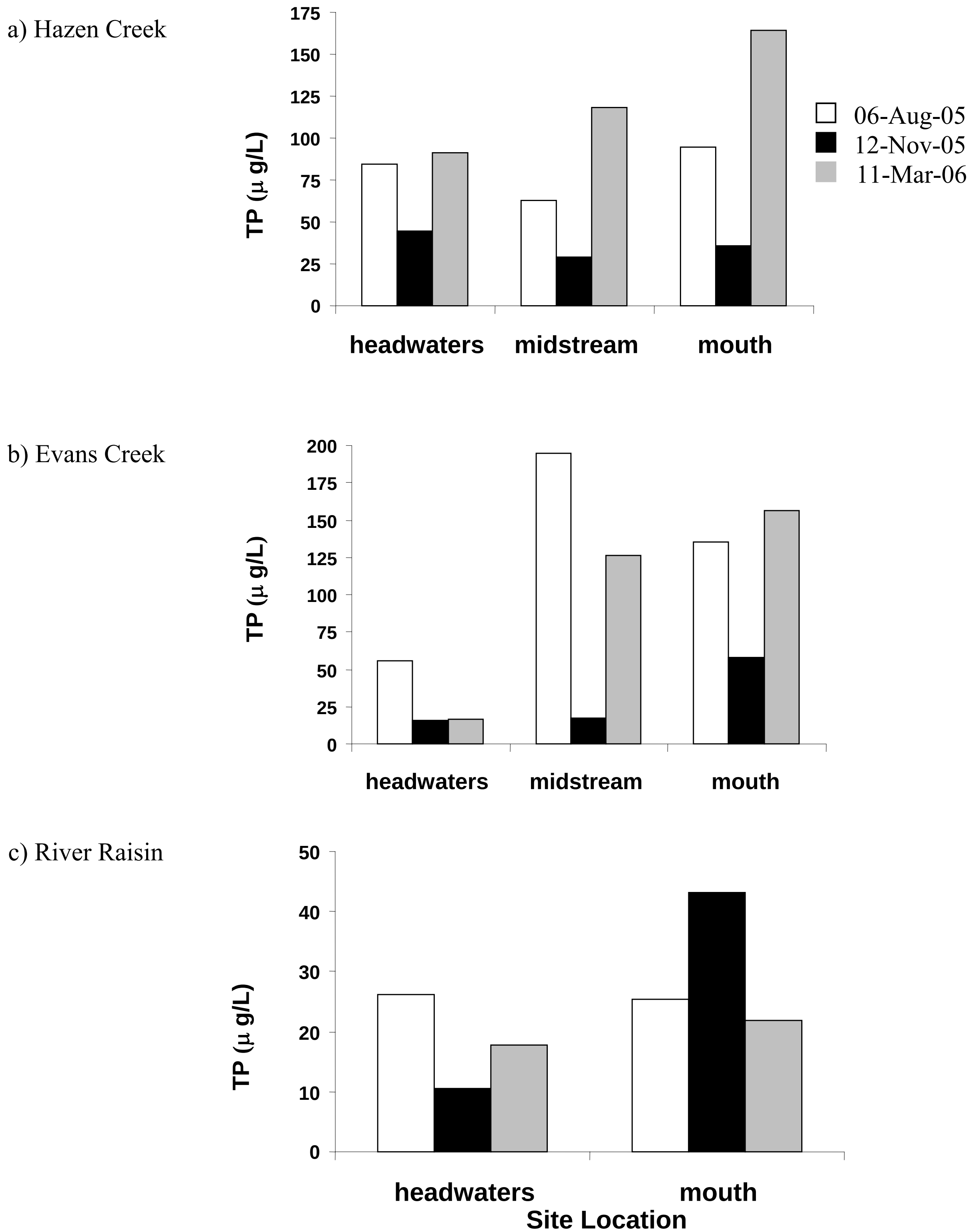


Figure 3 a-c. Total phosphorus (TP) concentrations in a) Hazen Creek, b) Evans Creek, and c) main stem on three sampling dates. Note: figures contain different vertical scales.

a) Hazen Creek

b) Evans Creek

c) River Raisin

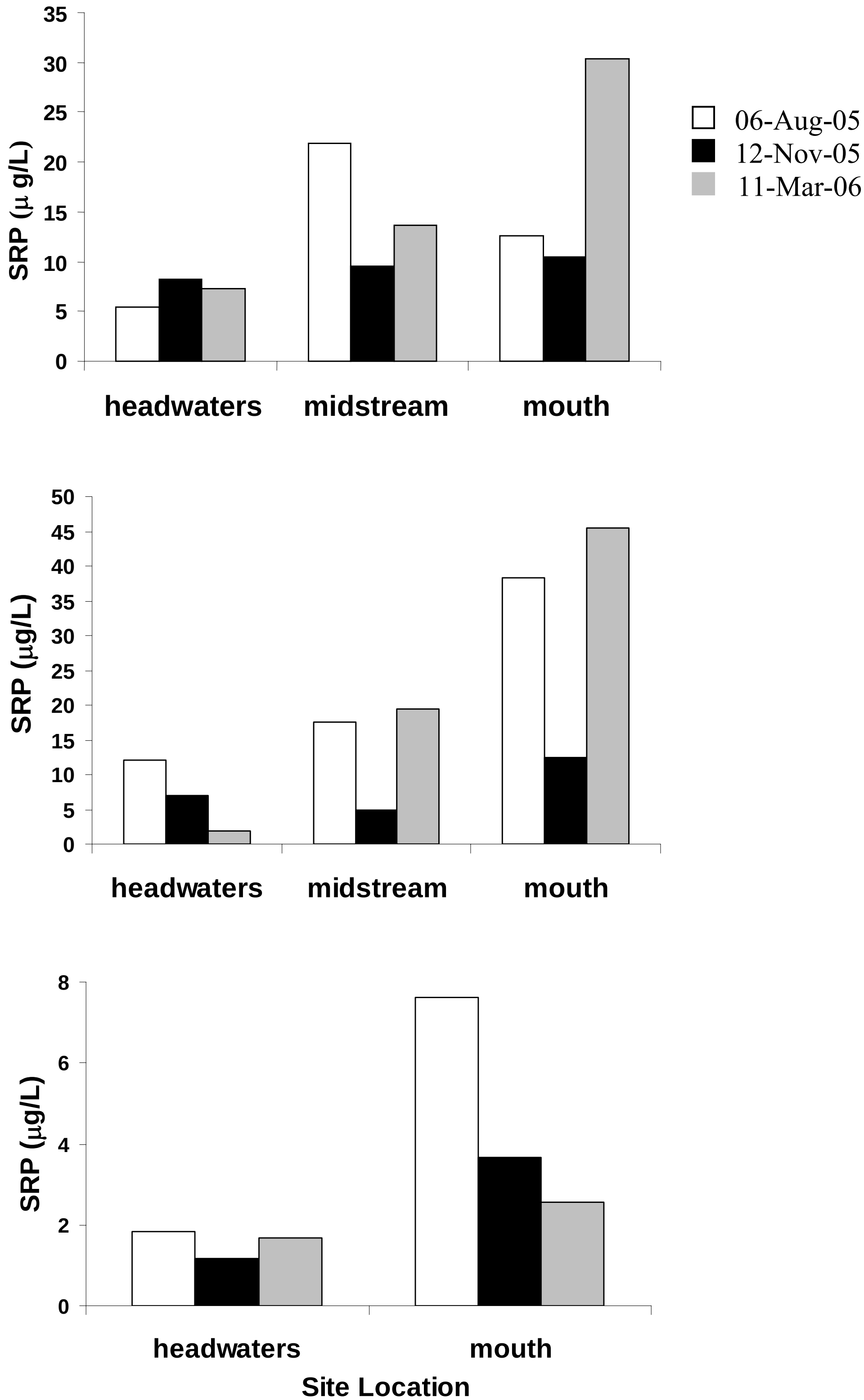
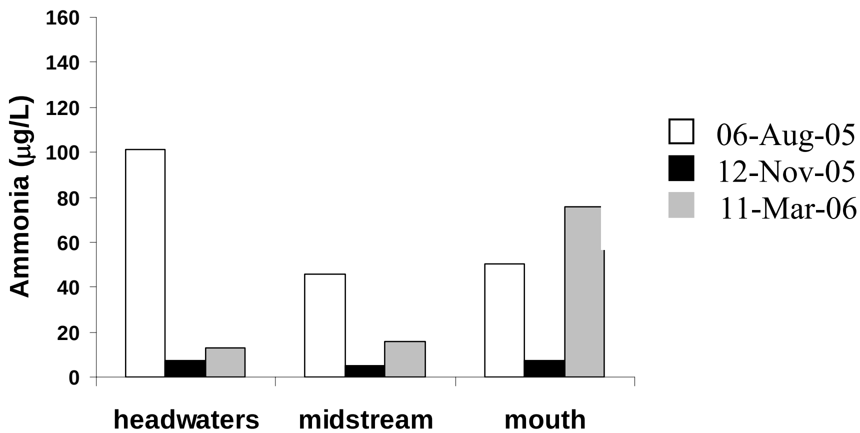
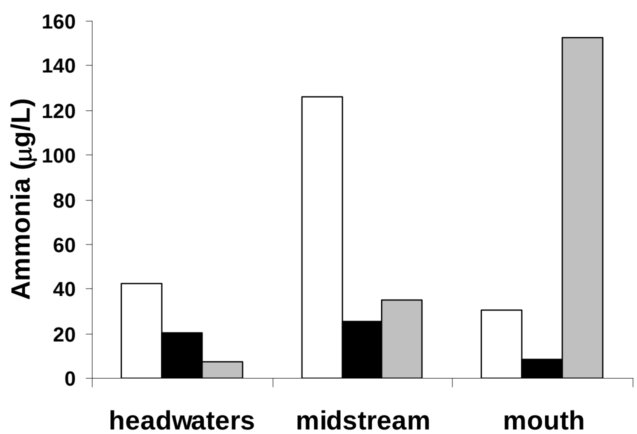


Figure 4 a-c. Soluble reactive phosphorus (SRP) levels in two tributaries, Hazen and Evans Creek, and in the main stem. Note: figures contain different vertical scales.

a) Hazen Creek



b) Evans Creek



c) River Raisin

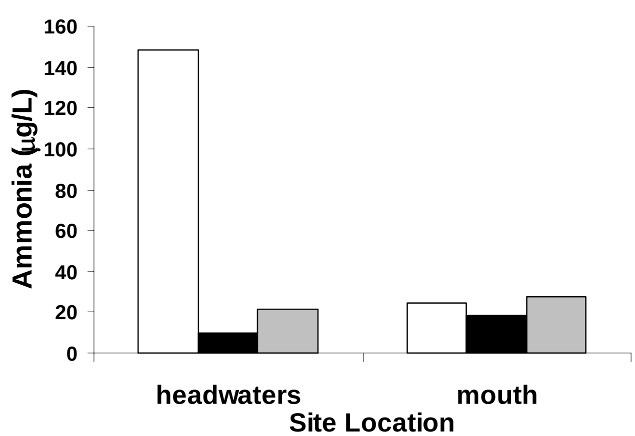


Figure 5 a-c. Variation in ammonia concentrations across sampling sites in a) Hazen Creek, b) Evans Creek, and c) main stem of the River Raisin.

Nitrate

Nitrate (NO_3) concentrations averaged less than 0.40 μg/L along the course of Hazen Creek in August and then further declined to near detection limits for the November samples (Fig. 6a). Concentrations were significantly higher in both tributaries in early March 2006, with Evans Creek experiencing greater nitrate concentrations than Hazen (Fig. 6b) and concentrations increased as one proceeded downstream. This pattern is attributed to agricultural land dominating the landscape in the Evans Creek subcatchment and is also due to spring runoff. It also suggested that there is a significant amount of biological processing of nitrate within the tributary streams. In general, concentrations were less than 1 mg/L along two sites in the River Raisin regardless of season.

Total Suspended Matter

Hazen Creek, Evans Creek, and the River Raisin main stem all exhibited increased levels of total suspended matter (TSM) downstream in early spring. Runoff during this time could be a major contributor of suspended materials, especially because the watershed is dominated by agricultural land. In particular, values along Hazen Creek in March ranged from 50 μg/L in the headwaters and up to 56 μg/L downstream (Fig. 7a). In addition, sites along Hazen Creek showed higher TSM levels than in Evans or the Raisin. In contrast, TSM levels decreased downstream in Hazen Creek during the low flow period in August. The pattern for Evans Creek differed, with a high peak of TSM in the middle reaches (Fig.7b). TSM concentrations at the two sites along the main stem of the Raisin were significantly lower than for the tributaries but also tended to increase downstream in August and in March (Fig. 7c). Furthermore, it is important to note that trends in TSM mirror trends found in total phosphorus for all streams. This is due to the affinity of phosphorus to suspended sediments in the water column.

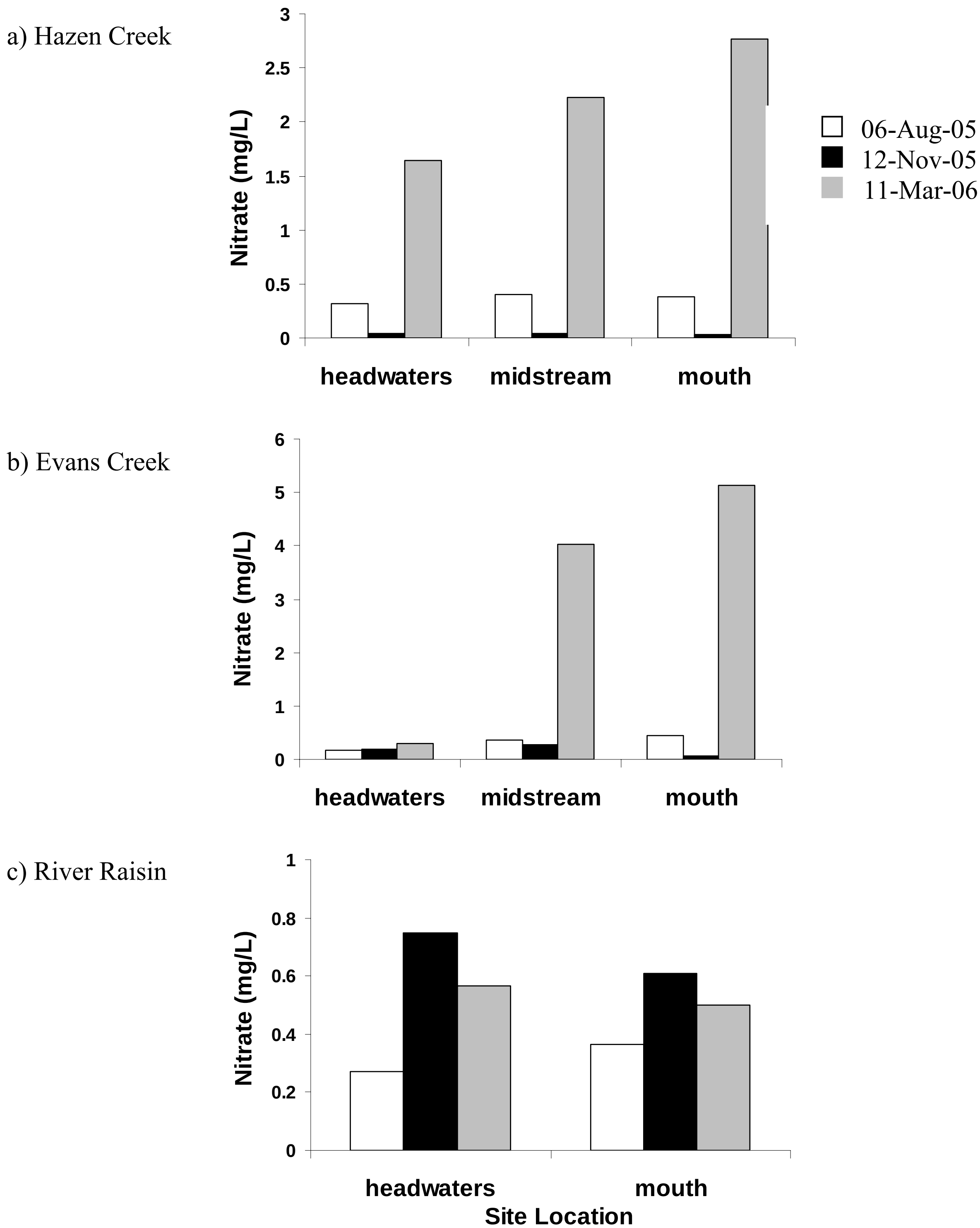


Figure 6 a-c. Nitrate concentrations at eight sampling sites in the upper region of the River Raisin watershed. Note: figures contain different vertical scales.

a) Hazen Creek

b) Evans Creek

c) River Raisin

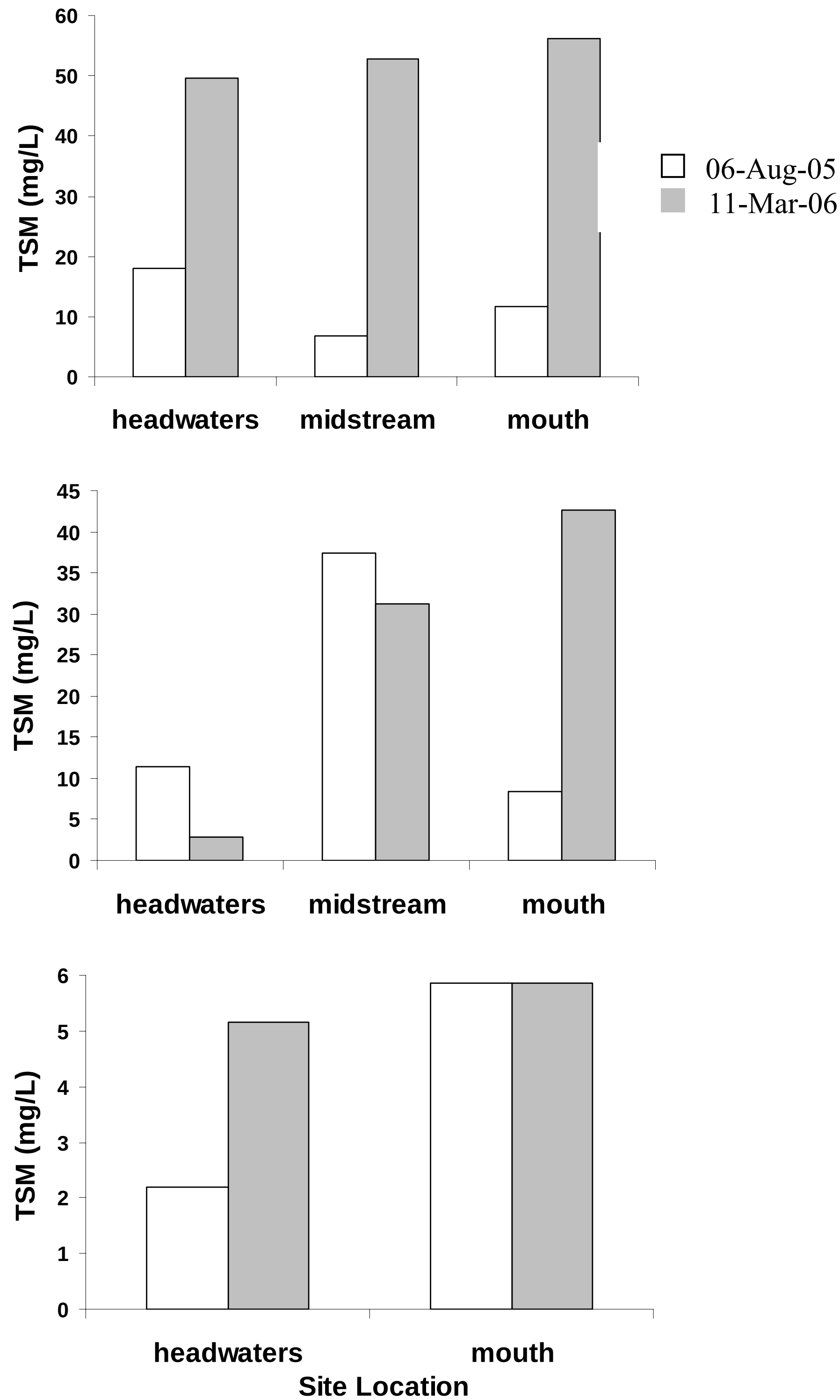


Figure 7 a-c. Total suspended matter (TSM) concentrations in Hazen Creek, Evans Creek, and the River Raisin. Note: figures contain different vertical scales.

Water Chemistry

Other water chemistry parameters measured with a Hydrolab instrument including water temperature, specific conductance, dissolved oxygen and percent dissolved oxygen, pH, turbidity, and total dissolved solids are summarized in Appendix 8-9. Unfortunately, readings for March 2006 could not be obtained due to equipment malfunction.

2.4 Discussion & Recommendations

2.4.1 Limitations

Due to the limitations of this study, thorough and accurate statistical analyses could not be conducted to infer correlations between different variables (e.g. relating nutrient concentrations with discharge or land cover or species diversity). For instance, sampling was only conducted once per season, with the exception of winter, for a total of 3 data values per nutrient per sampling site. In addition, data for total suspended matter were missing in the November 2005 sampling, and water chemistry data were missing for March 2006. However, data that was obtained during sampling sessions provide a snapshot view of water quality conditions for a particular site at a specific time. Consequently, recommendations are based on what others have documented as possible actions to control and/or prevent pollution from entering rivers and streams. Thus, the recommendations provided in this section are meant to help guide the River Raisin Watershed Council, stakeholders, and agencies in establishing what measures should be considered to reduce pollution in the basin. In order to accomplish this, the Council should continue stream monitoring such that heavily impaired waters are identified and prioritized for protection.

Streamflow gage data was also obtained from the U.S. Geological Survey (2006). The gage on the River Raisin main stem near Manchester serves as a reference for flow data because there are currently no gages on any tributaries. Although this streamflow data is not meant as a substitute, it will be used as a reference point for tributary streamflow. Mean discharge is shown in blue (Figure 8).

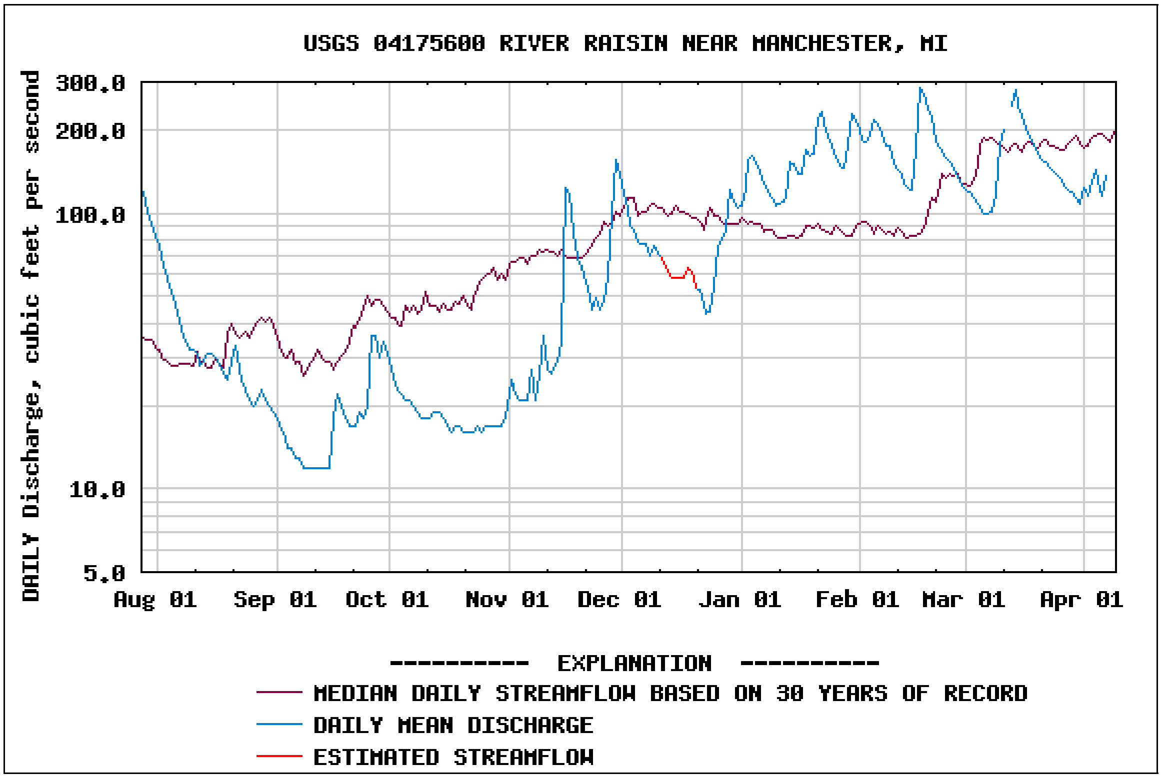


Figure 8. Streamflow gage data at the River Raisin near Manchester. Source: USGS 2006.

2.4.2 Water Quality

Nitrate & Ammonia

Nitrate concentrations reached a high of 3 mg/L and 5 mg/L in March 2006 near the mouths of Hazen and Evans Creek, respectively. On the two other sampling occasions, levels remained below 0.5 mg/L along midstream and headwater sites at these two streams. This indicates influence of spring runoff on Hazen and Evans Creek, especially because both subcatchments are dominated by agricultural lands. This supports a previous study that found that nitrate concentrations peaked in the springtime, particularly in tributaries where agriculture is the primary land use (Castillo et al. 2000). Numerous studies conclude that non-point source pollution from agricultural land activities strongly influences stream water nitrogen, as well as phosphorus (Arheimer & Liden 2000; Johnson et al. 1997; Ahearn et al. 2005; Novotny & Olem 1994). Thus, it is inferred that agriculture-generated non-point sources of nitrate are polluting Hazen and Evans, especially during periods of rainfall (refer to Figure 8 for streamflow data). In contrast, nitrate concentrations in the Raisin main stem remained below 0.8 mg/L on all three occasions, though slight decreases were noted downstream (below Manchester). It is possible that biological processes (e.g. denitrification) influenced these lower concentrations. Nonetheless, nitrate remains an important nutrient to monitor in streams because of potential public health risks in nutrient-rich potable water.

Ammonia concentrations also mirrored patterns observed during March 2006 in both Hazen and Evans Creek, though ammonia reached a high of 160 μg/L (0.16 mg/L) at the mouth of Evans Creek. This peak is regarded as potentially causing acute and/or chronic effects in aquatic life (Dodds & Welch 2000). Furthermore, a study in Ohio streams reported that ammonia levels greater than 1 mg/L have adverse impacts on fishes (Miltner & Rankin 1998 in Dodds & Welch 2000). Although ammonia levels found in Evans Creek did not exceed this threshold, ammonia has not been well documented as an indicator of water quality within subcatchments of the River Raisin drainage basin. Nonetheless, decay of nitrogenous wastes and breakdown of animal and plant waste are possible sources of ammonia in rivers, implying that agricultural practices may contribute ammonia to the environment.

A report to Congress compiled by the EPA (1998) claimed that "40 % of streams or rivers surveyed were impaired because of the nutrients [nitrogen and phosphorus]." Since then, water quality criteria have been established to institute total maximum daily loads (TMDLs) for nutrients as a way for states and tribal lands to limit the amount of nutrients entering surface waters (Dodds & Welch 2000). For instance, a maximum contaminant level of 10 mg/L was established for nitrate in U.S. surface waters. Concentrations exceeding this level cause nuisance algal growth and interfere with designated uses of rivers. Moreover, it is considered toxic to humans and is fatal to infants. In this study, nitrates in Hazen, Evans, and the Raisin did not rise above this level, though it is not safe to assume that these streams are in excellent form. Agriculture dominates the landscape within these subcatchments and runoff generated from fields and crops is likely to increase nitrates in nearby streams. In addition, because farmers usually apply animal manure to croplands, nitrogen losses from manure can reach up to 20 % especially if rain immediately follows application (Carpenter et al. 1998). Based on this information, recommendations will primarily focus on reducing nitrogen through different management practices.

The use of riparian buffers or constructed (also "created") wetlands as nutrient sinks has been attracting attention nation-wide and instances of restoring riparian vegetation along streams has grown over the past decades (Fink & Mitsch 2004; Lowrance et al. 1984). If designed and managed correctly, riparian buffers and constructed wetlands serve as a sink and uptake nitrogen from runoff that is flowing into the system. Nitrogen is an essential nutrient for plants because they readily uptake nitrogen for growth.
Because nitrogen comes from various sources (i.e. atmosphere, fertilizers, crop fixation, organic wastes) nutrient budgets vary depending on inputs and outputs. Consequently, adequate design and construction of riparian filters and wetlands is crucial to intercepting nutrients from agricultural runoff (Fink & Mitsch 2004). First, the ability of wetland vegetation to remove pollutant loads is more effective if wetlands are located in headwaters of rivers or as fringe wetlands adjacent to rivers (Mitsch & Gosselink 2000). Due to the nature of rivers, pollutants are carried and accumulate downstream, adversely affecting habitats and aquatic organisms found near river outlets. If vegetation is planted or restored in headwater stream segments, this would maximize their nutrient removal capability and improve water quality. It is also important to consider how wetlands or riparian vegetation will function during high snowmelt and rain events. High periods of discharge affect the rate at which vegetation can uptake and filter nutrients. Raisen et al. (1997) report that during high runoff, wetlands draining agricultural watersheds are only able to retain 10 and 20 % of nitrogen and phosphorus loads. Regardless, riparian zones along rivers can provide short-term and long-term effects on water quality (Lowrance et al. 1984). Furthermore, experts suggest that if between 3 % and 5 % of a watershed were returned to wetlands, this would make a substantial impact on river flooding and water quality (Mitsch & Gosselink 2000).

Riparian buffer zones and constructed wetlands are only two of several techniques farmers and land developers can use to improve river water quality. The EPA has developed a technical guide for states and managers of agricultural operations to apply the "best available, economically achievable" management practices to reduce non-point source pollution (EPA

2003b). Abatement and control measures emphasize using the "best approach to minimizing nutrient transport." When fertilizers, crop residues, manure, and sludge are applied to soils, nitrogen is transported by movement of soils and water. Thus, soil and water must be managed effectively. The simplest way to reduce nitrogen is to apply less commercial fertilizer onto fields. EPA also requires large, concentrated animal feeding operations (CAFOs) to develop and implement nutrient management plans. Nutrient management aims for crop production and water quality protection while reducing nutrient losses to surface waters. In general, nutrient plans are meant to assist farmers with management decisions while helping to protect the environment. The Watershed Council should provide supplementary information to educate farmers who are interested developing nutrient management plans for their lands.

Total Suspended Matter

Hazen Creek, Evans Creek, and the River Raisin experienced increases in total suspended matter (TSM or total suspended solids, TSS) concentrations in March after a rain event. The limitations of this study as discussed earlier allow us only to speculate on the relation between TSM concentrations and spring runoff. Because TSM levels were higher in the two tributaries after it had rained, it is critical to continue monitoring in these subcatchments (refer to Figure 8 for flow data). Although concentrations in sites along the River Raisin fell below 6 mg/L, a relatively low concentration, this does not imply that monitoring should not occur on the main stem.

Dodds and Whiles (2004) and Waters (1995) report three tiers of TSS concentrations: 10 mg/L is considered too high in some states; above 80 mg/L may harm fisheries; and above 400 mg/L degrades fish habitat. Fortunately, levels in both Hazen and Evans Creek fall well below the 400 mg/L and 80 mg/L mark. This does not suggest that all is well in these subcatchments. Agriculture accounts for two-thirds of land use in Hazen Creek and around half in Evans (Figure 9 a, b). Several studies have documented that improper land management practices on farms can have detrimental impacts on local streams by causing erosion and increasing sediments, which is a constituent of TSS (Dodds & Whiles 2004; Wood & Armitage 1997). Additionally, there can be "substantial localized sediment input after heavy rains in areas where there is disturbed cropland…" (Dodds & Whiles 2004). Agriculture is clearly a primary source of sediments and storm runoff is likely to contribute this pollutant to surface waters. Several measures exist to reduce sedimentation from entering rivers—control measures are not well documented for TSS per se, thus, measures for controlling sediments are prescribed.

To reduce sediment loads in catchments, it is essential to first educate farmers and operators of animal feeding operations on the benefits of implementing soil engineering techniques on their properties. The primary aim of most techniques is to prevent soil detachment in the first place. Detachment likely occurs when water (i.e. rain, irrigation) is splashed onto soil surfaces or strong winds dislodge soil particles from the surface. Therefore, keeping sufficient cover on soils by adding crop residues or planting grasses is key to preventing erosion. Other practices include conservation tillage, chiseling and subsoiling, windbreaks or shelterbelts, surface roughening, vegetation and tree planting, contour buffer strips, etc. These management practices and other technical guidance can be found in "National Management Measures to Control Nonpoint Source Pollution from Agriculture" by the Environmental Protection Agency (2003b). Some techniques require a lot of effort and may not be economically feasible to farmers, however, non-engineering cost-efficient measures are as simple as putting a fence in place to prevent animals from trampling on exposed soils near stream channels. These measures mostly focus on reducing sediments and controlling soil erosion but there is an added bonus: reducing associated pollutants such as phosphorus and organic compounds from pesticides. Not only will farmers benefit, but stream quality and wildlife will also benefit from these measures.

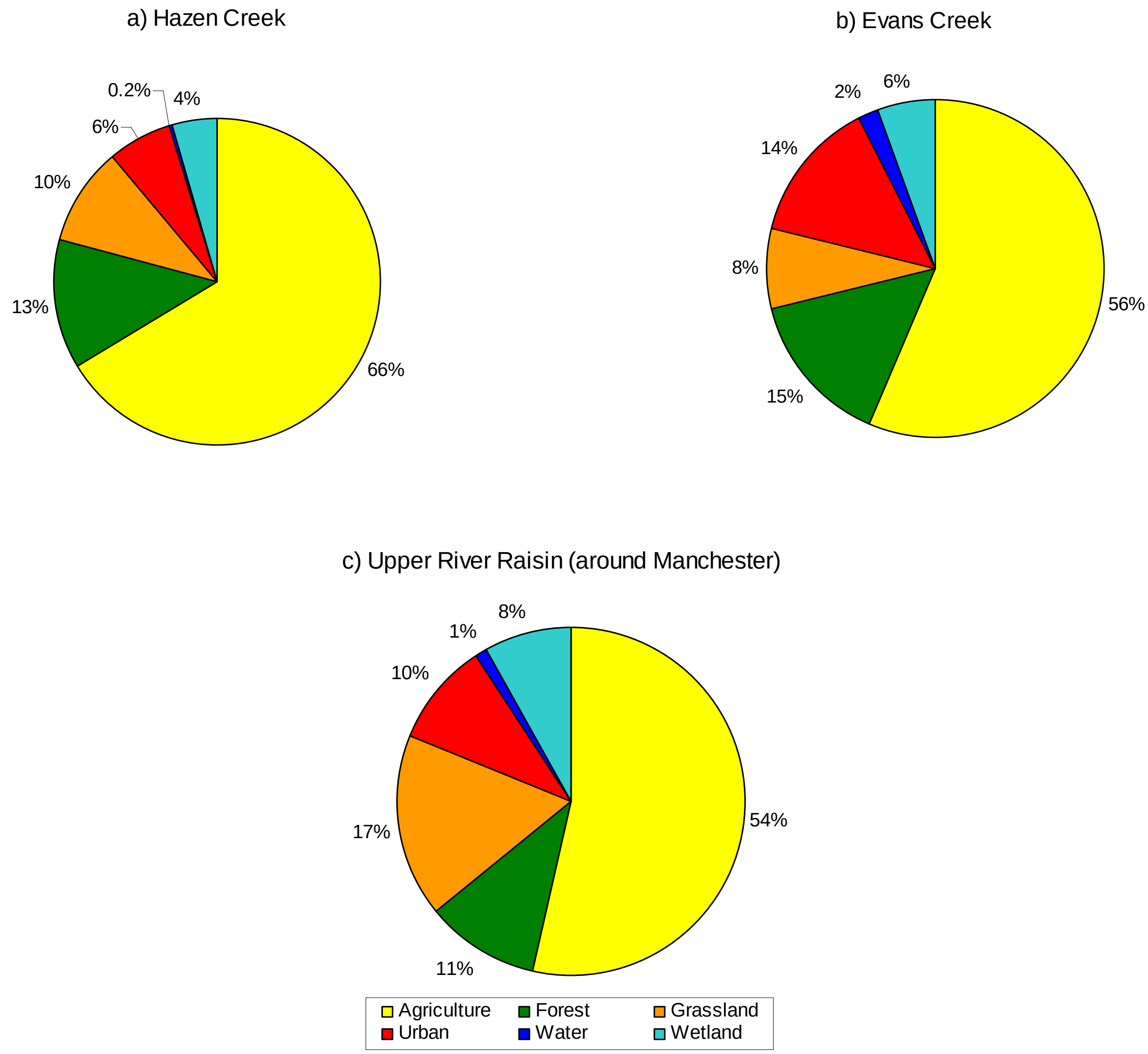


Figure 9 a-c. Percent land cover of subcatchments based on available data.

Total Phosphorus & Soluble Reactive Phosphorus

As with nitrate and ammonia, total phosphorus (TP) and soluble reactive phosphorus (SRP) concentrations were greater in Hazen and Evans Creek than in the Raisin. In particular, high peaks of TP and SRP were observed in Evans. TP levels were almost two times higher in both tributaries than in the main stem. TP concentrations also reflected similar trends with total suspended matter (refer to previous section). This mainly corresponds with the fact that phosphorus adsorbs to sediments in stream substrates. SRP concentrations increased downstream in all streams. These results correlate with findings from Castillo et al. 2000.

Nutrient criteria for TP were set at 0.17 mg/L (170 μg/L) and surpassing this standard carries a "significant effect on biotic integrity index" of fishes and invertebrates (Dodds & Welch 2000). In this study, peak TP concentrations at the mouth of Hazen Creek in March 2006, and at midstream of Evans Creek in August 2005 exceeded 170 μg/L and clearly indicates poor stream quality.

Elevated phosphorus concentrations usually lead to extensive algal blooms in rivers, which in turn has negative impacts on fish and invertebrate communities. The primary point source of phosphorus in surface waters is publicly owned treatment works (POTWs) or sewage treatment plants. Other possible sources include fertilizers, detergents, and industrial products. POTWs are required to obtain NPDES permits (refer to Chapter 2, Section 2.1.2) and effluent limits have been established for phosphorus loadings. Rule 60 of the Michigan Water Quality Standards (Part 4 of Act 451) sets a TMDL of 1 mg/L of total phosphorus as a monthly average for direct dischargers. Non-point sources include chemical weathering or erosion of phosphate-rich rocks and of course runoff. Phosphorus readily adsorbs onto soil and/or sediments—eroded sediments from mining areas or agricultural lands will carry phosphorus into surface waters during storm events. This input can potentially degrade water quality of streams. Unlike nitrogen, phosphorus does not have any public health effects.

Measures to control and prevent increased phosphorus loadings in rivers are very similar to those mentioned for nitrogen and suspended matter. Additionally, because fertilizers are made out of nitrogen, phosphorus, and potassium fractions, they are a major source of TP. Runoff from homeowner's lawns and agricultural operations carries phosphorus into rivers and increases loadings of the nutrient in rivers. Practical Soy LLC, a company based in Washtenaw County, Michigan, has developed an alternative "environmentally-friendly" fertilizer unlike more toxic chemical types. Clean Green™ is a fertilizer made from processed soybeans, is free of excess phosphorus, and is non-toxic to children and animals. If used and applied properly, this fertilizer stimulates plant growth without doing a lot of damage to the environment. This alternative fertilizer is a step in the right direction in terms of protecting the environment from harmful chemicals and pollutants.

The River Raisin Watershed Council does not have the authority or the man-power to enforce such measures on agricultural operations. In turn, some farmers are not expected to cooperate with the council's efforts in watershed protection. It is desirable, though, for RRWC to continue adequate monitoring of impaired streams and continue educating the public about how they can employ best management practices to help protect streams from pollution. There is not one definitive solution due to a number of factors, but with collaborative efforts between invested parties, the River Raisin can be restored to a state that benefits all, humans and wildlife included.

The area or land bounded by a watershed is a mosaic of distinct natural and unnatural features and is inhabited by both humans and wildlife. Natural resources are influenced by their surrounding landscape and people play a major role in altering this landscape. Human impacts need to be charted and governed through effective watershed management and planning. Water quality is just one component of a watershed management plan. The following chapter addresses conservation of natural areas within the watershed. The subsequent chapter (Ch. 4) focuses on policies and ordinances that affect water quality.

3 Conservation of Natural Areas

3.1 Introduction

3.1.1 Conservation of Biodiversity

Dramatic and unprecedented changes to the natural landscape are occurring worldwide, resulting in increasing habitat loss and the occurrence of isolated habitat patches throughout the landscape (Bennett 1999). Habitat loss is one of the greatest threats to wildlife and native plants today (Ewing et al. 2005). It is estimated that human alteration of the landscape is occurring at a rate 1,000 times faster than that of natural processes (Tabarelli and Gascon 2005).

Southeast Michigan is no exception. Over a 15 year period between 1980 and 1995 the amount of built area in Michigan increased by 471 square miles (a 25% increase), while the population increased only by 3% (Public Sector Consultants 2001). Analysis of land use changes from 1965-1995 in the River Raisin Watershed (Cifaldi et al. 2004) confirms these trends of rapid exurban development identified by Public Sector Consultants. Southeastern Michigan Council of Governments (SEMCOG) forecasts that, by the year 2030, an additional 390,000 acres of open space and farm land will be developed in Southeastern Michigan (SEMCOG 2003).

The potential effects of these landscape changes for wildlife and ecosystems are severe. Many of the natural ecosystem processes occurring in our forests, wetlands, and grasslands provide critical support to agriculture, industry, and communities in the watershed. When these natural ecosystem processes are damaged and/or lost, human beings also are negatively impacted. Benefits of preserving contiguous natural areas include flood abatement, cleaner water, groundwater recharge, and climate control.

In recognition of this, some cities such as New York City have invested in the conservation of headwater natural areas to protect drinking water. It is estimated that over $5 billion was saved by avoiding expenditures on treatment plants that would otherwise need to be built to remove sediments (Ewing 2005).

Moreover, preservation of forest, wetlands, and grasslands offers habitat for wildlife, maintains migration patterns, and protects ecosystem functioning on a landscape scale. Currently, the Lake Erie to Lake Huron corridor is an important flyway for over 90 species of migratory birds that travel from as far as South America. Access to natural areas in the River Raisin watershed for resting and feeding is essential to the survival of many of these birds. It is estimated that half of these migratory birds will die during migration due to habitat loss, predation, colliding with buildings, and automobiles (Appel et al. 2002).

Not only is the wildlife of Southeastern Michigan facing extirpation, but entire ecosystems are in danger of being lost. Today only 1% of the original oak savanna and prairie ecosystems of Southeast Michigan exist, which puts them at risk of global extinction due to human development (Appel et al. 2002).

Principles of Landscape Ecology

Landscape ecology is the study of ecological processes and interactions affected by spatial configuration across a heterogeneous landscape (Turner et al. 2001). Commonly the landscape is a mosaic of patches comprised of multiple habitats and land uses, which often experience a dynamic exchange of energy, species, and nutrients (Turner 2001; Wiens 2002). The study of landscape ecology has dramatic implications for land use planning and conservation biology. The following sections discuss the core concepts of landscape ecology, which will guide the decision support model developed for the River Raisin Watershed.

Patches

In landscape ecology terms, a patch is defined as "a relatively homogeneous area that differs from its surroundings" (Freemark et al. 2002, p. 60). A patch can be composed of various types of habitat, including a stand of forest, a wetland, farmland, or even a woodlot in a residential neighborhood. The formation of these patches is the result of multiple factors such as a disturbance to vegetation structure, the introduction of a new habitat type, or the isolation of an old habitat type (Dramstad et al. 1996). For example, a natural disturbance such as a forest fire that clears a portion of a forest may create a new patch within the original forest. In this context, the increased heterogeneity as a result of the disturbance to the forest patch structure will improve species richness and maintain important ecological processes. Clearing of forest land for a residential development, however, may actually decrease species richness due to creation of a new patch that cannot support as much wildlife.

The edge of a patch is defined as the "portion of a patch near the perimeter where the environment differs significantly from the core or interior" in structure, species composition, or environmental conditions (Freemark et al. 2002, p. 59). Patches with convoluted boundaries and that are not compact contain a higher ratio of edge to core interior habitat (Dramstad et al 1996). The effects of edge habitat on individual species and overall ecosystem functioning vary depending upon the type of ecosystem and the adjacent environment. For example, a shopping mall adjacent to a forest may result in a much more drastic edge effect than would an adjacent pasture.

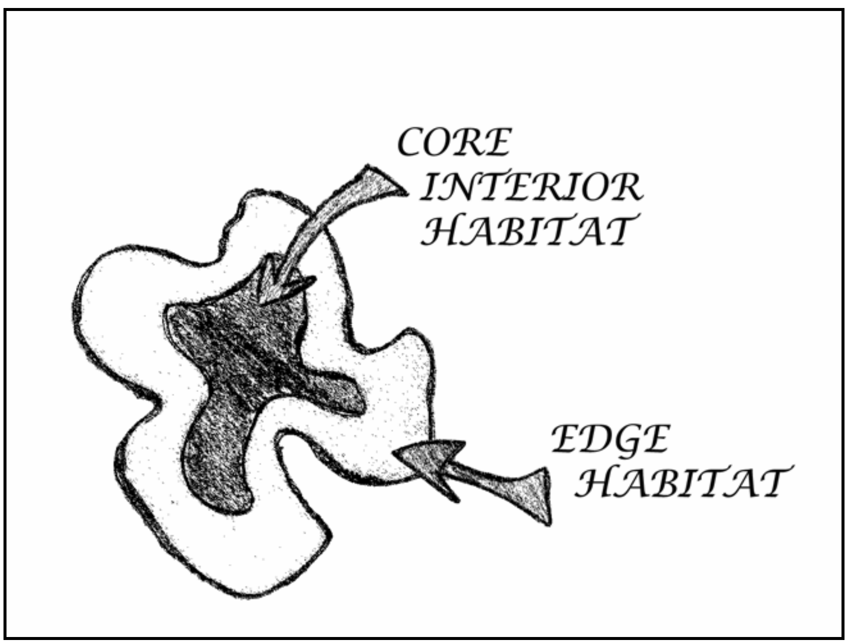


Figure 10. Diagram of edge and core interior habitat.

Edges are evident for a significant distance into a patch. Edge effects cause changes in light penetration, wind speed, and microclimate altering vegetation as far as 92 meters within a forest patch (de Blois et al. 2002; Dramstad et al. 1996; Freemark et al. 2002). Edge habitats experience frequent disturbances and thus favor generalist or disturbance-adapted plant species. These disturbance regime species are often invasive and may out-compete native interior vegetation, eventually changing the composition of the entire patch (Foreman and Alexander 1998; de Blois et al. 2002; Environment Canada 2004; Dramstad et al. 1996).

Roadsides are a perfect example of edge effects on vegetation composition. Frequently, exotic invasive plant species occur along roadsides because they are the only species that can tolerate the high disturbance level caused by increased exposure to road salt, atmospheric pollution, mowing, and stormwater (Zedler 2004; Forman and Alexander 1998). These conditions enable large invasive plant populations to develop in edge habitat and then move into the interior of natural areas (Forman and Alexander 1998; A. Bennett 1999). Exotic plant species can have disastrous effects on habitat quality by altering food webs and increasing the vulnerability of animals to predators (Zedler 2004). Studies in South-Central Ontario revealed that instances of predation on forest birds' nests were significantly higher in the first 100 meters of forest edge (Burke and Nol 2000).

For these reasons, when prioritizing natural areas for conservation it is important to minimize edge effects by considering patch shape and the amount of core interior habitat existing in a patch. Core habitat is the interior portion of a patch that is not influenced by edge effects. Often these interior portions resemble the remnant conditions of natural ecosystems and provide refuge for sensitive species from pollutants, predation by exotic species, and alterations to the microclimate caused by human disturbance (de Blois et al. 2002; Burke and Nol 2000; Dramstad et al. 1996; Swihart et al. 2003). Protection of these core habitats is essential as the survival of many sensitive species depends upon these areas.

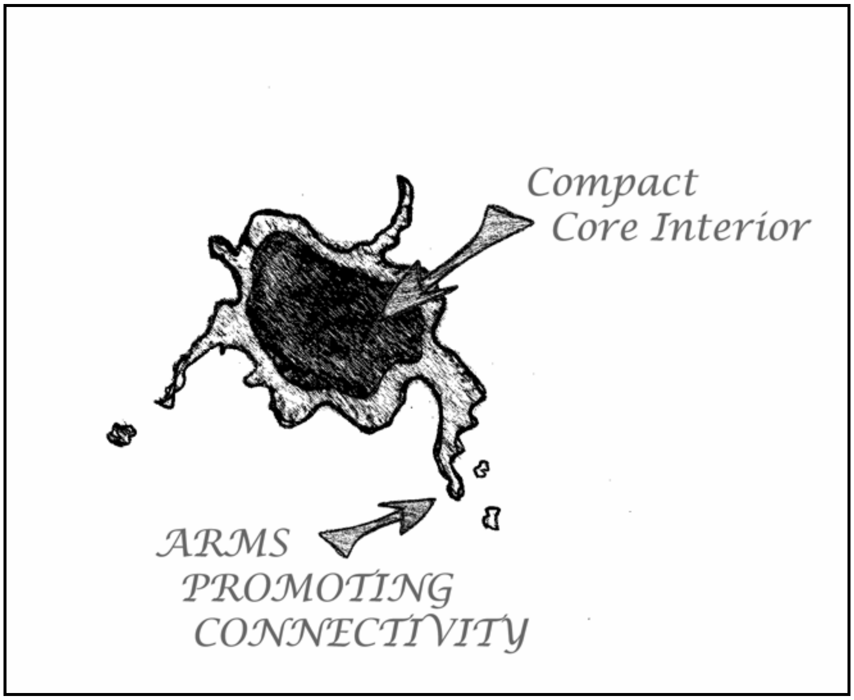


Figure 11. An ideal patch shape has a compact core with linkages that extend outward to promote the movement of species between habitat patches (Dramstad et al. 1996).

Landscape Connectivity

Landscape connectivity is described as the spatial arrangement of heterogeneous elements across the landscape (A. Bennett 1999; Turner 2001). The level of connectivity that exists across the landscape strongly influences the ability of species to move through the environment, repopulate patches, reproduce, and complete their life cycles (A. Bennett 1999; Freemark et al 2002). As habitat fragmentation continues to threaten biodiversity, landscape ecologists emphasize the importance of maintaining connectivity between habitat patches (Dramstad et al. 1996).

Species of wildlife discern connectivity in differing ways depending upon their habitat preferences (A. Bennett 1999; Freemark et al. 2002). Depending upon the scale at which a species moves (e.g., birds cover much larger distances than salamanders), and a species perception of structural contrasts in habitats, a species may or may not perceive a habitat gap as a barrier (Dramstad et al. 1999). In a study conducted of 18 different forest birds in Southern Ontario, less than 5% traveled greater than 22-25 m from the forest edge (Bélisle and Desrochers 2002). Given that many patches of natural areas are separated by much more than 22 – 25 m, connectivity can easily be lost, resulting in isolation of habitat and species.

A major consequence of patch isolation is increased inbreeding among local floral and fauna populations (Britten and Baker 2002). Inbreeding leads to reduced genetic exchange that subsequently leads to reductions in genetic diversity and species stability. Genetic diversity is crucial to the long-term maintenance of floral and faunal populations (Britten and Baker 2002). In addition to the loss of genetic diversity due to isolation, the inability of species to repopulate other disturbed patches increases the potential for local extirpation (A. Bennett 1999; Dramstad et al. 1996; Hobbs 2002).

The characteristics of gaps between patches are also important to consider when prioritizing conservation efforts in a watershed. A gap may be small in distance, but if it is a highly hostile environment (such as a road), it may be a greater impediment to movement than a larger gap that is more benign. Studies have shown roads just 10 m in width can dramatically inhibit small mammal movement (A. Bennett 1999). It is estimated that 1 million vertebrates are killed daily in the United States due to vehicular traffic (Forman and Alexander 1998). The implications of these differing wildlife viewpoints distinctly complicate conservation and land management efforts in a developed landscape.

Wildlife Corridors

To compensate for habitat fragmentation natural resource managers often try to devise wildlife corridors through developed areas in order to maintain migratory pathways and support wildlife requiring large habitats. Corridors are ". . . linear habitats, embedded in a dissimilar matrix that connects two or more blocks of large habitat . . ." (Beier and Noss 1998, p. 1242). The effectiveness of corridors in facilitating wildlife movement is constrained by corridor width and degree of connectivity (Dramstad et al. 1996). Examples of corridors include riparian zones, hedgerows, greenways, rights-of-way, and patches configured to act as stepping stones.

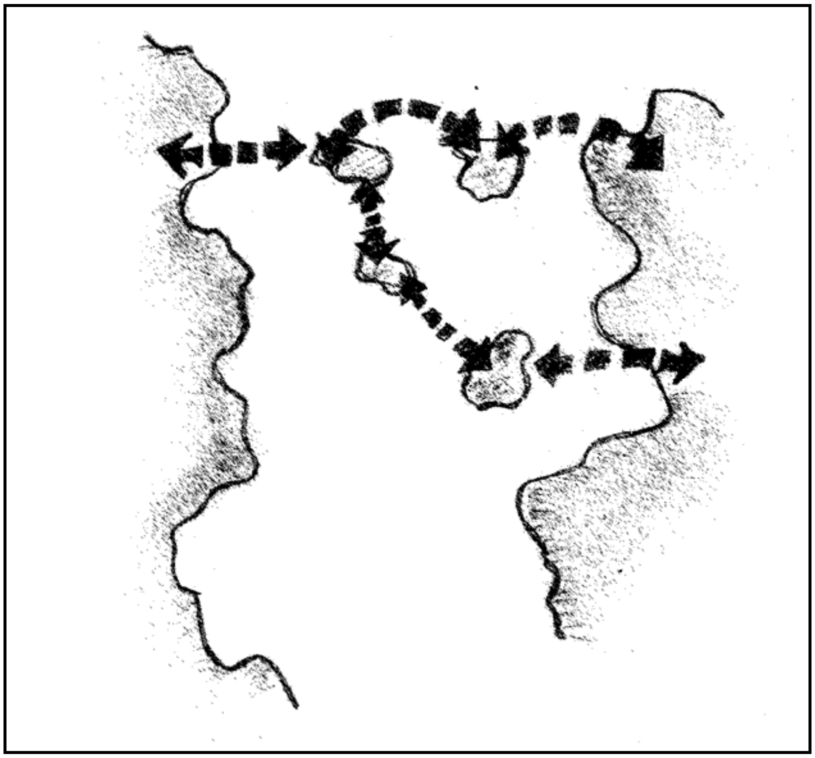


Figure 12. Patches may act as stepping stones linking larger habitats.

The appropriate width for a corridor depends entirely on the species of interest. A 10 m wide corridor of wildflowers will easily disperse traveling butterflies, but may act as a barrier to chipmunks. While narrow corridors of this sort can facilitate movement of some wildlife, quite often they do more harm than good. In studies of greenways, the presence of mammalian predators was significantly higher in narrow corridors, putting many smaller mammals, birds, and amphibians at high risk of predation (Sinclair et al. 2005). Under such conditions a corridor can act as sink habitat in which mortality exceeds a population's reproduction rate (A. Bennett 1999).

Taking these factors into consideration, the widest possible corridor is preferred. Greater corridor width provides opportunities for resting and feeding during travel (A. Bennett 1999; Dramstad et al. 1996; Turner et al. 2001). Increased width is especially important for corridors in which there are great distances between habitat patches. Extremely long corridors with high predation rates and external threats pose the greatest risk to species traveling through them, due to the long residence time spent in the corridor (A. Bennett 1999).

3.1.2 Prioritization of Conservation Areas

The movement towards regional conservation planning to protect biological diversity has gained wide recognition in recent years (Hoctor et al. 2000). To prioritize conservation efforts in the headwaters of the River Raisin Watershed, a decision support model was developed to help identify important areas for habitat protection. The model, developed in ArcGIS 9.1, analyzes the land cover and land use of the River Raisin headwaters in order to identify 1) areas of habitat within the headwaters that may serve as refuges for species of concern, 2) corridors that will promote wildlife migration and 3) habitat patches that protect water quality in the River Raisin.

The decision support model is fashioned after a similar regional conservation analysis conducted in Florida to create the Florida Ecological Network (Hoctor et al. 2000). The present model is based upon an extensive literature review, in conjunction with pre-existing natural features data for the State of Michigan. Literature pertinent to landscape ecology, bird, amphibian, and mammal habitat requirements, as well as to wetland, forest and riverine ecosystem functioning was thoroughly reviewed to develop criteria for habitat conditions that would promote biodiversity.

In the following sections I discuss the framework for this decision support model first by identifying habitat patches that may support sensitive species. I then evaluate the ability of each habitat patch to promote connectivity in the watershed, and extent of remnant habitat is evaluated to develop a composite habitat suitability score. Then, potential patches and riparian buffers that protect water quality are identified that preserve the ecological integrity of the River Raisin. Finally, wildlife corridors currently existing within the watershed are modeled to determine potential routes of wildlife migration.

3.2 Methods

3.2.1 Overview

In order to identify natural areas of high conservation importance within the headwaters of the

River Raisin, ArcGIS 9.1 was used to assess habitat conditions previously mapped by a variety of organizations and agencies in Michigan. Particular emphasis was placed upon identifying: (1) potential natural areas that may serve as biodiversity hotspots, (2) existing wildlife corridors and linkages, and (3) natural areas that may serve to protect water quality.

Our approach focused on identifying habitat patches that met the needs of an *umbrella species,* rather than an individual species (Lambeck 1997). In the *umbrella species* approach, the habitat requirements of a group of highly sensitive wildlife species are used as the basis for prioritizing habitat conservation efforts. In this way, the needs of a larger range of species and ecosystems are met. Conservation efforts that focus on a single species fail to capture the needs of other important species and ecosystems (Freemark et al. 2002; Lambeck 1997; Turner et al. 2001).

3.2.2 Land Cover Data Set

Land cover and land use data in the form of Geographical Information System data layers were compiled from a variety of public sources. Data layers covering Washtenaw and Jackson County were created by the Michigan Resource Inventory System (MIRIS) in 1978 and updated with new urban development through 1995 by the Southeast Michigan Council of Governments (SEMCOG). Land cover and land use layers for Lenawee County were created in 1998 with aerial photography. A resolution of ~25 m was achieved in creation of these data layers (Cifaldi et al. 2004).

All data layers were then updated with urban and residential land cover data from the 2004 Landsat Thematic Mapper ™ imagery produced by Michigan Department of Natural Resources. By updating the land cover layer with urban and residential land cover identified with the 2004 Landsat Thematic Mapper, new developments within the landscape could be added to the analysis. The 2004 Landsat Thematic Mapper ™ imagery is coarser in resolution than the 1998 data layers and does not as accurately represent current vegetation conditions at a fine scale. Consequently, older data layers were utilized in order to maintain the highest accuracy possible for assessing and analyzing natural habitat conditions. Aerial photography covering the entire headwaters was compared against all data layers to insure this high level of accuracy was maintained throughout the analysis. A list of all data layers is included in Table 1.

Natural habitat patches were also overlaid with data from the National Wetlands Inventory (NWI). The NWI has mapped all existing wetlands previously mapped on the ground or identifiable from aerial photography in the State of Michigan. Because of the expertise of NWI Scientists in wetland identification, this information was used in comparison with the 1995/1998 land cover data layer to further classify habitat patches. Natural habitat patches identified by the NWI as forested wetlands, but as terrestrial upland forests by SEMCOG, were converted to wetlands habitat patches to further refine the data being evaluated.

All data layers were converted into the projection and coordinate system, Michigan State Plane South and North American Datum Harn 1983. Michigan State Plane South was selected due to its high level of measurement precision and its minimal distortion of map feature shapes. Because this decision support model places a strong emphasis on patch size and the distance between patches, the Michigan State Plane was by far the best system to utilize.

Preliminary ground-truthing of all habitat patches in the River Raisin headwaters was conducted in order to assess the accuracy of the data layers. Utilizing a Global Positioning System, all ground-truthed areas were mapped and also photographed in order to confirm habitat conditions at the time that the decision support model was being developed. Ground-truthing was only conducted in areas easily accessible by public roads due to the time constraints involved with getting approval from private land owners to survey individual parcels. Any differences between observable ground conditions and the identified habitat patches were noted and factored into the model design. Further ground-truthing will be necessary in order to verify the accuracy of the data layers more thoroughly.

Table 1. Spatial data layers and sources.

Dataset Layer	Year Published	Data Format	Resolution	Data Source
GAP Land Stewardship	2001	Grid	30 m	MDNR
Land Use pre-settlement	1978	Polygon coverage	45 m	R. A. Comer et al 1995b (MNFI)
Land Use 1978	1985	Polygon coverage	25 m	MIRIS
Land Use 1995/98	1998	Polygon coverage	25 m	SEMCOG
Landsat Thematic Mapper ™ imagery	2004	Grid	30 m	MDNR
National Wetlands Inventory	1979-1994	Polygon coverage	30 m	U.S.F.W.S.; National Wetlands Inventory
Stream	1987	Line coverage	Varies	USGS
T & E Survey Data	2005	Polygon coverage	Varies	MNFI
Watersheds & Subwatersheds	1998	Polygon coverage	25 m	Dr. Dave Allan

3.2.3 Description of Habitat Suitability Criteria

To arrive at a composite score of habitat patches the hierarchical combination approach was employed in the final rating of all properties measured (Hopkins 1977). Hierarchical combination was used because it is capable of representing the interdependence of factors and providing an explicit determination of ratings (Hopkins 1977). Using the hierarchical combination method, the decision support model rates individual characteristics (such as core habitat size, connectivity, and amount of remnant habitat) of each habitat patch in the Upper River Raisin Watershed. Ratings were based upon a literature review of studies that assessed the requirements for properly functioning ecosystems and wildlife requirements.

Once the characteristics were rated individually, the model then developed a composite score by following a decision making tree that weighted each characteristic against one another. An example decision making tree used to score each habitat patch is shown in Figure 13 (See Appendix 10 for the complete tree). These weighted values were based upon the degree of interdependence between characteristics. This method allows all criteria/characteristics to be overlaid and evaluated as an integrated, interdependent unit (Hopkins 1977).

A complete description of how each individual habitat patch characteristic was evaluated and scored is included with each method used. When the interdependence of characteristics was assessed, certain characteristics were ranked as follows in order of importance: (1) amount of core interior habitat 2) level of connectivity 3) total amount of remnant habitat 4) percentage of remnant habitat of the total patch area. All patches that could not support sensitive species or moderately sensitive species (see methods below) were removed from the final composite analysis.

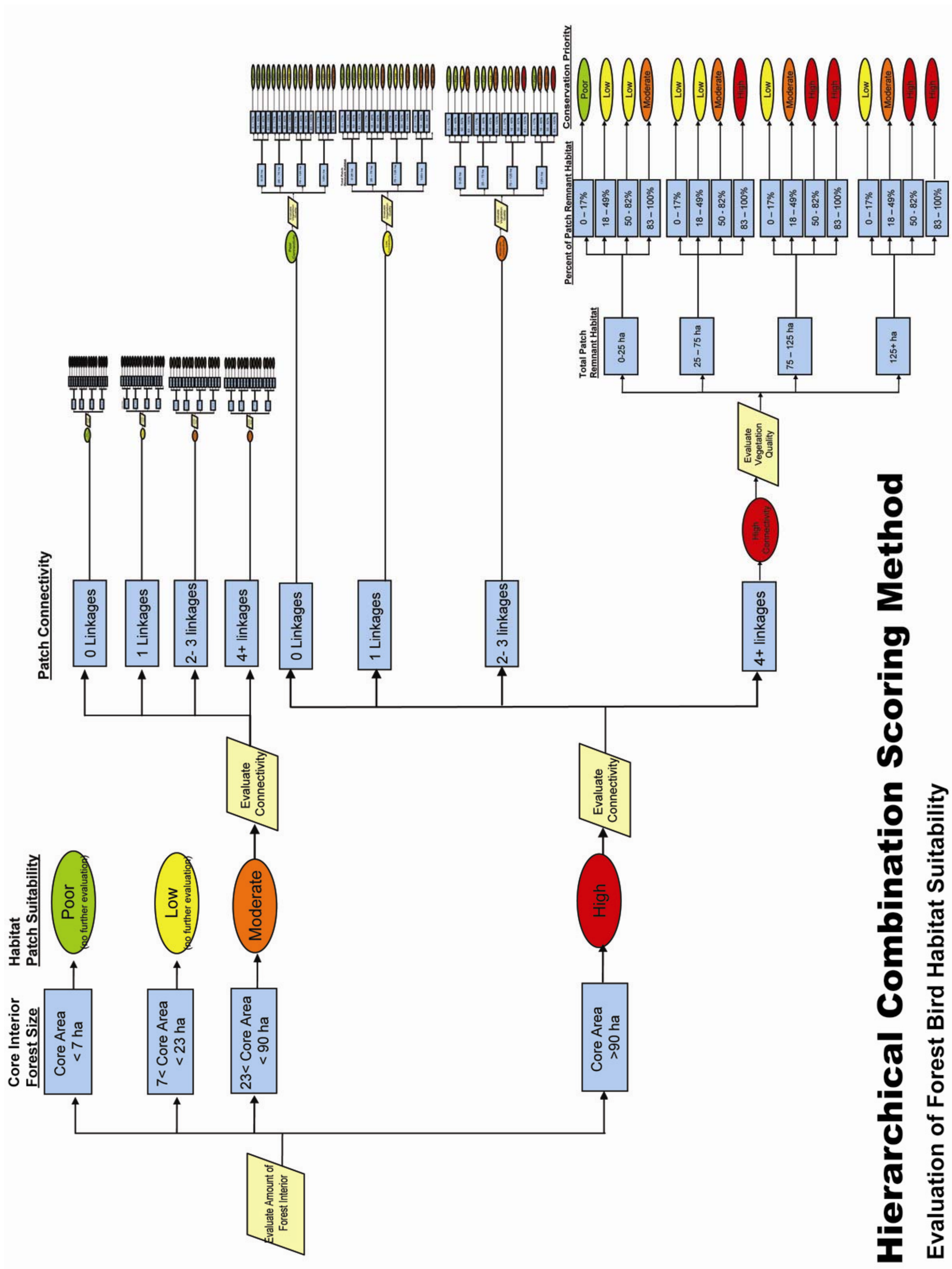


Figure 13. Hierarchical combination decision tree utilized in evaluation of habitat patches.

3.2.4 Spatial Analysis

Delineation of Edge Habitat

Edge effects were evaluated based upon land cover type and land use adjacent to natural areas (e.g. forests, wetlands etc). Effects on species and vegetation were evaluated based upon the *umbrella species* model (Lambeck 1997) and relevant literature. Descriptions of the edge effects caused by each type of land use, including literature sources, are presented in Table 2. Because edge habitat is not included as a land cover type on the data layers, the model delineated edge habitat area in ArcGIS 9.1 by buffering selected land cover categories with widths described in Table 2.

Table 2. Edge effects of different land uses. All habitats that fell within the defined edge effect distance for each associated land cover/land use type were defined as edge habitat in the model.

Land Cover/Land Use Type	Edge Effect	Reasoning/Justification	Source
Single Family/ Residential/Commercial/Urban	190 m	▪House cats predation on wildlife 190 m from natural edge ▪High predation upon birds up to 200 m from edge in natural areas ▪Cowbird parasitism of bird nest up to100 m from edge	Freemark 2002; Herkert et al. 1993; Burke and Nol 2000
Federal & State Highways & all other streets over 7,000 vehicles a day	300 m	Reduction in sensitive birds found up to 305 m in edges of roadways over 10,000 vehicles	Foreman and Alexander 1998
Roads & Streets under 7,000 vehicles a day	100 m	▪Reduction in sensitive bird populations within 100 m of the edges of roadways under 10,000 vehicles ▪Reduction in populations of mammals for roads under 5,000 vehicles a day up within first 100 m	Foreman and Alexander 1998
Agriculture	100 m	▪Herbicide drift up to 9 m ▪Significantly higher rates of predation within the first 100 m of edge	Environment Canada 2004; Burke and Nol 2000

Core Habitat Area

Core interior habitat for each habitat patch was identified by subtracting the edge effect area for each patch from the total area of each patch. This subtraction was performed in ArcGIS 9.1 by overlaying all edge effect buffers on habitat patches and conducting a 'symmetrical difference to extract' to compute the remaining core areas.

After the core interior habitat was identified, each patch's core habitat was evaluated on its ability to support birds, amphibians and reptiles. Again the *umbrella species* concept developed by Lambeck was employed for each class (birds, amphibians and reptiles) evaluated (Lambeck 1997). This method is thought to provide the greatest protection for overall ecosystems and species of importance. The habitat requirements for each *umbrella species* class are described in Tables 3-5. Core habitat areas were considered separately for forest birds, grassland birds, and amphibians and reptiles. Core habitat areas that were large enough to act as source populations of highly sensitive species were given a rating of high conservation priority, while those that could support species of low sensitivity were given a rating of low conservation priority.

Table 3. Forested habitat patch suitability based on the total amount of core interior habitat that may support forest birds

Criterion	Species Sensitivity	Habitat Suitability Rating	Core Area Habitat Requirements	Source
Forest Bird	High	High	90+ ha for patch to maintain a source population	Burke and Nol 2000; Environment Canada 2004; Herkert et al. 1993
	Medium	Moderate	23 to 90 ha to maintain source populations of moderately sensitive species	Burke and Nol 2000; Environment Canada 2004; Herkert et al. 1993
	Low	Low	7 to 23 ha may act as sink to sensitive species and maintain generalist species	Burke and Nol 2000; Environment Canada; Herkert et al. 1993
	Insensitive	Poor	Less than 7 ha acts as a population sink	Burke and Nol 2000; Environment Canada; Herkert et al. 1993

Table 4. Grassland habitat suitability based upon the total amount of core habitat available in a patch.

Criterion	Species Sensitivity	Habitat Suitability Rating	Core Area Habitat Requirements	Source
Grassland Birds	Highly	High	250+ ha for patch to act as a source populations	Herkert et al. 1993
	Moderate	Moderate	100 to 250 ha to maintain populations of sensitive species	Herkert et al. 1993
	Low	Low	25 to 100 ha may act as sink to sensitive species and maintain generalist	Herkert et al. 1993
	Insensitive Species	Poor	Less than 25 ha will serve as a population sink	Herkert et al. 1993

Table 5. Forested wetland habitat suitability based upon amount of core interior habitat that can support amphibians and reptiles.

Criterion	Species Sensitivity	Habitat Suitability Rating	Size of Upland Buffer to Aquatic Sites and Core Habitat	Source
Amphibian & Reptiles	High	High	Core habitat of 75 ha in a forested wetland	Environment Canada 2004; Herrman et al. 2004; Ficetola and Bernardi 2003; Porej et al. 2004
	Moderate	Moderate	Core Interior habitat of 12 to 75 ha in a forested wetland	Environment Canada 2004; Herrman et al. 2004; Ficetola and Bernardi 2003; Porej et al. 2004
	Low	Low	Core interior habitat 3 to 12 ha in a forested wetland	Environment Canada 2004; Herrman et al. 2004; Ficetola and Bernardi 2003; Porej et al. 2004
	Insensitive	Poor	Core interior habitat <3 ha in a forested wetland will serve as a population sink	Environment Canada 2004; Herrman et al. 2004; Ficetola and Bernardi 2003; Porej et al. 2004

Identification of Size of Terrestrial Buffer Around Aquatic Wetlands

Non-wooded, aquatic, and emergent wetlands were evaluated based upon the amount of terrestrial upland that buffered the site. Access to upland terrestrial vegetation surrounding wetland habitats is necessary for many amphibians and reptiles to complete their life cycles (Semlitsch and Bodie 2003). In fact, wetlands with less than 40% forest cover within the 1,000 m buffer zone have significantly lower species richness (Hermann et al. 2004). Another study conducted in Western Ohio confirms these results, indicating that wetlands with more than 200 m of forest buffer had higher salamander populations and species richness (Porej et al. 2004).

All aquatic wetlands in the headwaters were buffered with multiple rings of 100, 200, 500 and 1,000 m in ArcGIS 9.1. Then, each wetland patch was evaluated based upon the amount of intact terrestrial upland that buffered the aquatic site. Sites were then rated regarding their suitability as amphibian and reptile habitat based upon the width and percent of terrestrial buffer surrounding the site. Rating criteria are shown in Table 6.

Table 6. Aquatic and emergent wetland habitat suitability for amphibians and reptiles based upon the amount of terrestrial buffer surrounding site.

Criterion	Species Sensitivity	Habitat Suitability Rating	Size of Upland Buffer to Aquatic Sites	Source
Amphibian & Reptiles	High	High	500 m forested buffer around 50% of aquatic sites	Semlitsch and Bodie 2003; Herrman et al. 2004; Ficetola and Bernardi 2003; Porej et al. 2004
	Moderate	Moderate	200 to 500 m forested buffer around 50% of aquatic sites	Semlitsch and Bodie 2003; Herrman et al. 2004; Ficetola and Bernardi 2003; Porej et al. 2004
	Low	Low	100 to 200 m forested buffer around 50% of aquatic sites	Semlitsch and Bodie 2003; Herrman e. al. 2004; Ficetola and Bernardi 2003; Porej et al. 2004
	Insensitive	Poor	Less than 100 forested buffer around 50% of aquatic sites	Semlitsch and Bodie 2003; Herrman et al. 2004; Ficetola and Bernardi 2003; Porej et al. 2004

Delineation of Important Habitat Patches

Habitat patches were created by drawing polygons around contiguous natural areas that contained the identified interior habitat. To be considered by the model, habitat patches had to have some form of contiguous interior habitat. Anthropogenic land uses that altered natural areas were viewed as obstacles that might constrain movement between patches. The intersection of a habitat patch by any land use that may act as an obstacle to wildlife would result in that habitat patch being delineated as two separate patches.

Patch Connectivity

Patch connectivity was evaluated based upon the assumption that by meeting the needs of the most movement-limited species, all species needs would be met. Studies conducted on gap crossing behavior of birds in Ontario indicate that birds would not cross forest cover gaps in excess of 50 meters, in either winter or summer (Belisle and Desrochers 2002). Furthermore, studies of amphibians indicate that roads greater than 4 lanes act as barriers to movement (Foreman and Alexander 1998). Based upon this information, a tolerance of 50 m was selected as the maximum distance species would cross through unnatural habitat. If two habitat patches were separated by a gap that was less than 50m, then this gap was considered a viable 'linkage' between patches. The model identified the number of patches tolerance each patch by creating a 50 m buffer around the patch and visually checking the number of patches falling into that buffer. The more linkages a habitat patch maintained with other patches, the greater the overall connectivity of that patch. Habitat patches were rated based upon the number of linkages they formed. Table 7 displays scoring methodology.

Table 7. Criteria to Assess Patch Connectivity. Patches were given a connectivity rating based upon the number of patches within 50 m.

No. of Linkages	Connectivity Rating
0	Poor
1	Low
2-3	Moderate
4+	High

Habitat Patch Resemblance to Pre-settlement Conditions

Habitat patches were also evaluated based upon the degree to which their current vegetation structure resembled pre-settlement vegetation (See Appendix 5). Pre-settlement vegetation was identified on land surveys conducted between 1816 and 1856 (Comer et al. 1995a). Pre-settlement habitat maps were developed by the State of Michigan based upon the maps developed by and extensive field notes kept by 19th century surveyors regarding vegetation, ecosystem conditions and land types. Ecologists from the Michigan Natural Features Inventory then converted these paper maps into GIS data layers. By overlaying the habitat patches identified by our decision support model with the pre-settlement habitat maps, the degree of change (caused by human development) within each patch can be determined. Because the names used to identify habitats have changed since the early 1800's, Table 8 provides the list of habitat names used by 19th century surveyors and the corresponding names used to describe these habitats by ecologists today.

The amount of vegetation in each patch that remained unchanged from pre-settlement times (considered remnant habitat) was weighted as a percentage of the patch area plus the area of any connected patches (Paskus and Endander 2004). In this way, patches that were small in area, but high in quality and connectivity, were not ignored by the model. The total area of remnant habitat quality within each patch was also calculated (Paskus and Endander 2004). This allowed for patches with greater quantities of remnant habitat to be rated higher than those with little intact habitat. Total remnant habitat patch and percent of habitat patch were each broken down into four categories of habitat suitability. These ratings were then integrated into the decision making tree to reach a final composite score of each habitat patch. The rating system is shown in Table 9.

Table 8. Pre-settlement Land Cover and Associated Present Land Cover. Below are the pre-settlement land cover types and the associated land cover types used to describe these habitat types today.

Pre-settlement Land Cover	Current Associated Land Cover
Beech-Sugar Maple	Central Hardwood Forest/Northern Hardwood Forest/Forest
Black Ash Swamp	Hardwood Forested Wetland/Forested Wetland
Black Oak Barren	Central Hardwood Forest/Forest
Bog/Muskeg	Forested Wetland
Grassland	Herbaceous Rangeland/Open Field
Mixed Conifer Swamp	Mixed Forested Wetland/Forested Wetland
Mixed Hardwood Swamp	Mixed Forested Wetland/Forested Wetland
Mixed Oak Forest	Central Hardwood Forest/Forest
Mixed Oak Savanna	Central Hardwood Forest/Forest
Oak-Hickory Forest	Central Hardwood Forest/Forest
Shrub Swamp/Emergent Marsh	Shrub Wetland/Emergent Wetland/ Non-Wooded Wetland
Wet Prairie	Herbaceous Rangeland/Non-Wooded Wetland/Open Field

Table 9. Habitat patch conservation suitability based upon total remnant habitat and percent of patch remnant habitat

Habitat Patch Conservation Suitability	Total Remnant Habitat in Patch	Percent of Patch Remnant Habitat
Poor	0 – 25 ha	0 - 17%
Low	25 – 75 ha	18 - 49%
Moderate	75 – 125 ha	50 - 82%
High	125+ ha	83 - 100%

Patches as Water Quality Buffers

Habitat patches with core interior habitat were further evaluated based upon their ability to protect aquatic habitats and water quality. Patches were determined to be water quality buffers in ArcGIS 9.1 utilizing the “select by location” function. All patches that intersected or were within 30 m of streams and lakes were identified as protecting water quality.

Existing Riparian Buffers

Because the above analysis was restricted only to patches already identified by the model as high quality terrestrial and wetland habitat, much of the riparian zone in the watershed was excluded. However, even if not associated with large tracts of high quality habitat, riparian buffers have been shown to be extremely important to watershed health. Studies conducted on riparian vegetation indicate that a 16 m wide native grass and woody vegetation buffer removes 97% of sediments and over 80% of the nutrients in stormwater runoff (Lee et al. 2003; Shultz et al. 2004). Therefore, the model was instructed to identify stream reaches protected by riparian buffer over 16 m wide.

The model identified stream reaches that had a 16 m riparian buffer on both sides. In order to do this, the model overlaid the data layer for streams onto the existing land cover/land use data layer. The model then assigned all streams a 16 m buffer (using ArcToolbox 9.1). These newly created buffers were overlaid with the land cover layer. All buffers occurring on forest and wetland land cover were then "clipped" in ArcToolbox 9.1. Then the remaining riparian buffer layer was used to determine reaches of stream that had a 16 m buffer or greater on both sides. Reaches that did not meet this criterion were eliminated leaving only reaches of stream with 16 m riparian buffers.

Public Lands

Habitat patches, with core habitat, were identified that occurred within 100 meters of existing protected areas (e.g. conservation easements, state game areas etc.). Patches were identified by utilizing the buffering tool in ArcToolbox 9.1. A tolerance of 100 meters was selected because patches separated from protected areas by small roads and tracts of private property may easily be linked together.

Corridors

The model was instructed to identify existing wildlife corridors in the Upper River Raisin Watershed owing to their importance to species reproductive success and to migratory birds. For the purposes of this model, wildlife corridors were assessed separately from general patch connectivity because wildlife corridors operate on a grand scale. While wildlife corridors represent a type of patch connectivity, because of the scale upon which they occur, it was more straightforward to assess wildlife corridors as distinct entities.

Corridors were identified in ArcGIS 9.1 utilizing a "least-cost modeling" function in Spatial Analyst. In other words, ArcGIS 9.1 found the paths/corridors between habitat patches that would be the most efficient or "least cost" for animals to travel. First, a 30 x 30 m cost surface grid was created in ArcGIS to cover the study area. The land cover type that fell within each 30 x 30 m cell was scored based upon the level of impedance it posed to wildlife (Table 10; Adriaensen et al. 2002; Hoctor et al. 2000). Cell impedance scores represent the amount of reluctance wildlife may have to traveling through that land cover type (Adriaensen et al. 2002).

The cost surface layer was then filtered to a cell size of 120 x 120 m to prevent paths from crossing barriers that may be unsuitable (Figure 14; Adriaensen et al 2002). This also insures that a corridor width over 100 m exists facilitating its use by wildlife. Then the least-cost function in ArcToolbox 9.1 was used to identify paths between existing protected lands that offered the least impedance to wildlife (Adriaensen et al. 2002; Hoctor et al. 2000).

Table 10. Cost surface values modeling impedance to wildlife travel

Land Cover Type	Impedance Value
Aquatic beds/upland forests/wetland forests/emergent wetlands/herbaceous grasslands	1
Barrens/flats/river	15
Christmas tree farms/trails	25
Outdoor recreational areas/pastures/open fields/cemeteries	30
Streets/county roads	40
Croplands/other agricultural land	45
Farmhouse/single family housing/ornamental/orchards/nurseries	50
State roads	55
Lakes/open waters	60
Highways	65
Mobile home parks/residential neighborhoods	70
Confined feeding lots/transportation/utility/communication facilities	75
Extractive/shopping centers/utilities	85
Commercial business district/multi-family residential/secondary business district	90
Commercial/urban	95
Airport/industrial	100

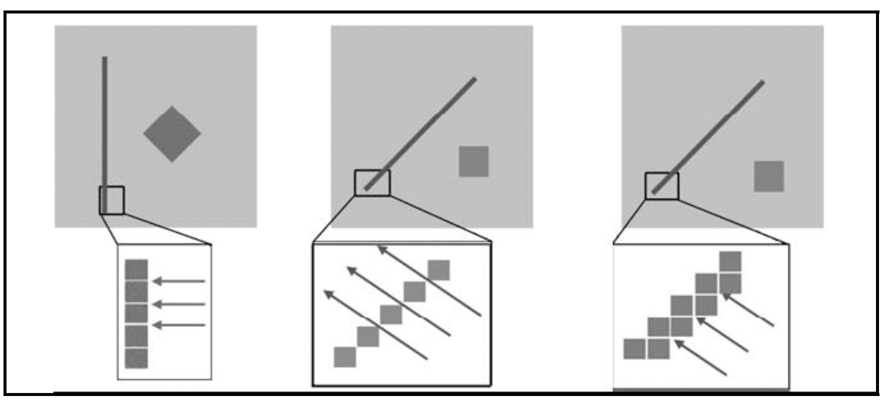


Figure 14. Least-cost path function and barriers. Column one represents a barrier to the least-cost path process. Column two represents a cost surface unfiltered and how the least-cost path process will interpret gaps in the barriers. Column three represents filtering of the cost-surface to expand the barrier appropriately to prevent the function from jumping any barriers (Adriaensen et al. 2002).

Inclusion of MNFI Threatened & Endangered Survey Data

Data on the presence/absence of threatened and endangered species in the watershed was collected by MNFI during on-the-ground surveys conducted by qualified botanists, zoologists and geologists. The data were converted into a GIS data layer that shows and describes sightings of threatened and endangered flora and fauna. Also included in the data layer are locations of unique geological formations, plant communities and ecosystems at risk locally, at the state and the global level. MNFI data was "intersected" with habitat patches in ArcGIS 9.1 to identify potential threatened and endangered species locations.

3.3 Results

3.3.1 Delineation of Important Habitat Patches

The decision support model identified 600 patches of undeveloped habitat in the headwaters of the River Raisin Watershed. Only 202 of the original six hundred contained interior habitat. These two-hundred and two patches were then further assessed as described above. As a result, each of the 202 patches was given a rating that describes qualitatively its value as a conservation priority for watershed managers.

Patch Connectivity

The connectivity of habitat patches was evaluated to determine the ease of wildlife movement between patches. Ninety-eight patches were found to be isolated from other patches based upon the 50 m tolerance used. Fourteen patches were linked to four or more patches based upon the criteria used. Forty-seven patches were found to be connected to two or three other delineated patches and forty-eight patches were identified as being connected to at least one patch. A map illustrating the proximity score of each patch is displayed as Figure 15.

The model thus demonstrates that the majority of the watershed is highly fragmented and does not promote interpatch movement of flora and fauna. Furthermore, as shown in Figure 15, many of the patches linked with other patches are clustered in the northern portion of the watershed. Connectivity of the southern portion of the River Raisin headwaters is very poor.

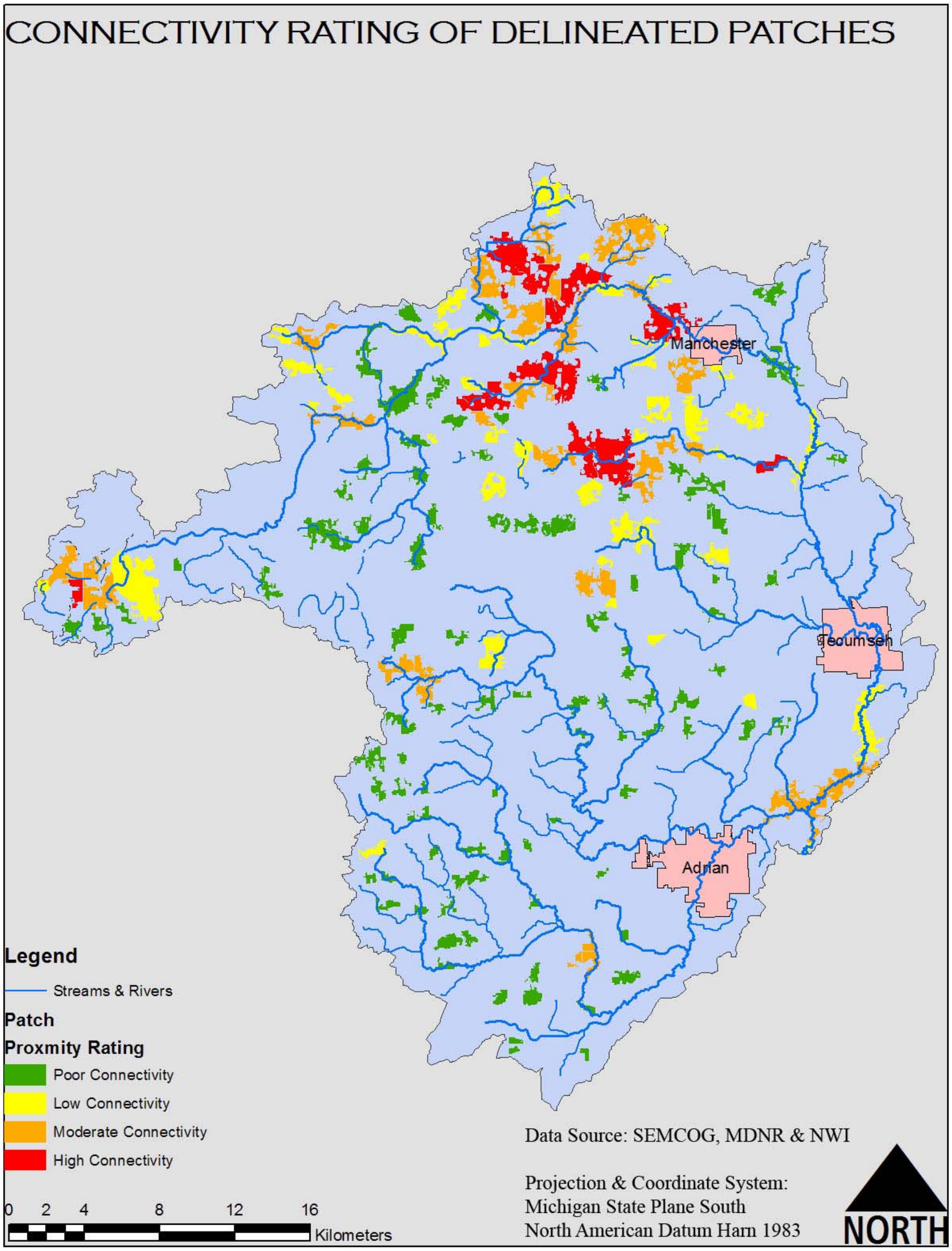


Figure 15. Habitat patch connectivity. As shown, almost all patches with high connectivity are in the northern portion of the watershed.

Habitat Quality

One-hundred and ninety-four patches had some potential remnant vegetation. Vegetation patterns can reveal anthropogenic alterations to natural disturbance regimes, soil conditions, hydrologic processes, and geomorphology (Paskus and Endander 2004). Due to fragmentation and land conversion in the watershed, the model identified very little remnant habitat within the headwaters. Many cover types such as Beech-Sugar Maple, typically found on mesic soils, are hardly found within the upper watershed today because they occurred on what became prime agricultural land. Additionally, grassland ecosystems have experienced declines to the point of near extirpation in the headwaters.

Ten of the 202 delineated patches contained over 125 ha of habitat that was unchanged from pre-settlement conditions (See Figure 17 and Appendix 11a for patch coordinates). Seven patches contained 75 – 125 and sixty-one patches contained between 25 – 75 ha of remnant habitat. One-hundred and thirty-three had no vegetation or ecosystem structure that resembled pre-settlement conditions at all. Pre-settlement land cover percentages for the headwaters are shown in figure 16.

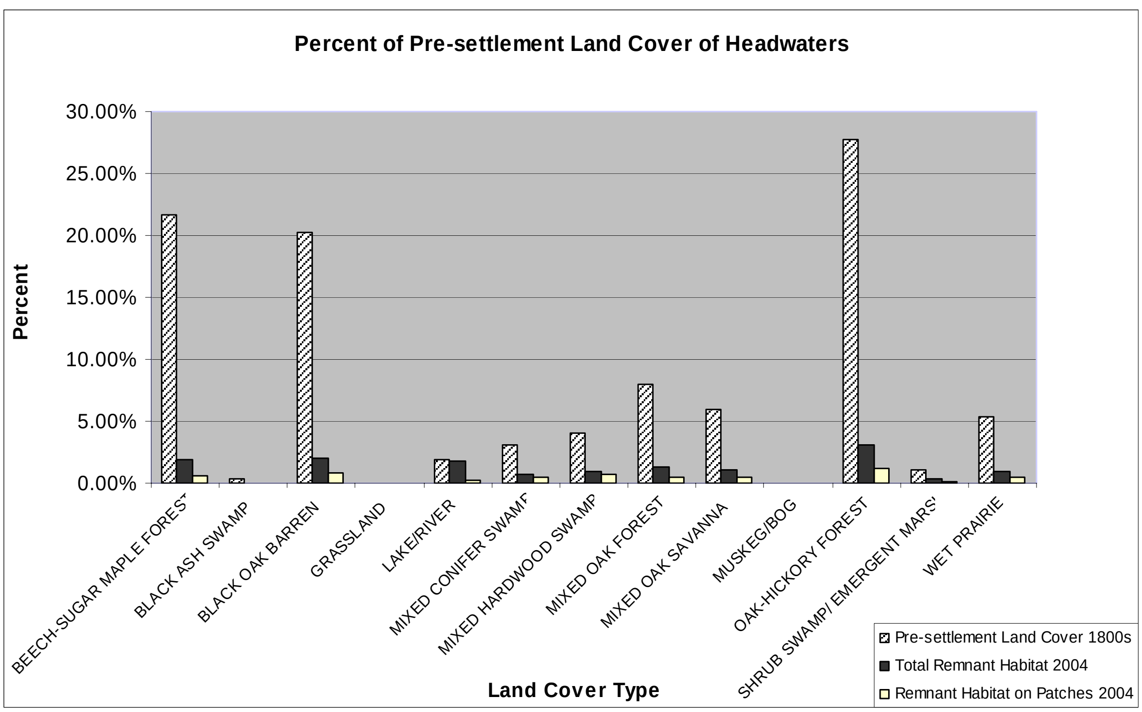


Figure 16. The original amount of pre-settlement land cover is presented in comparison with the present day amount.

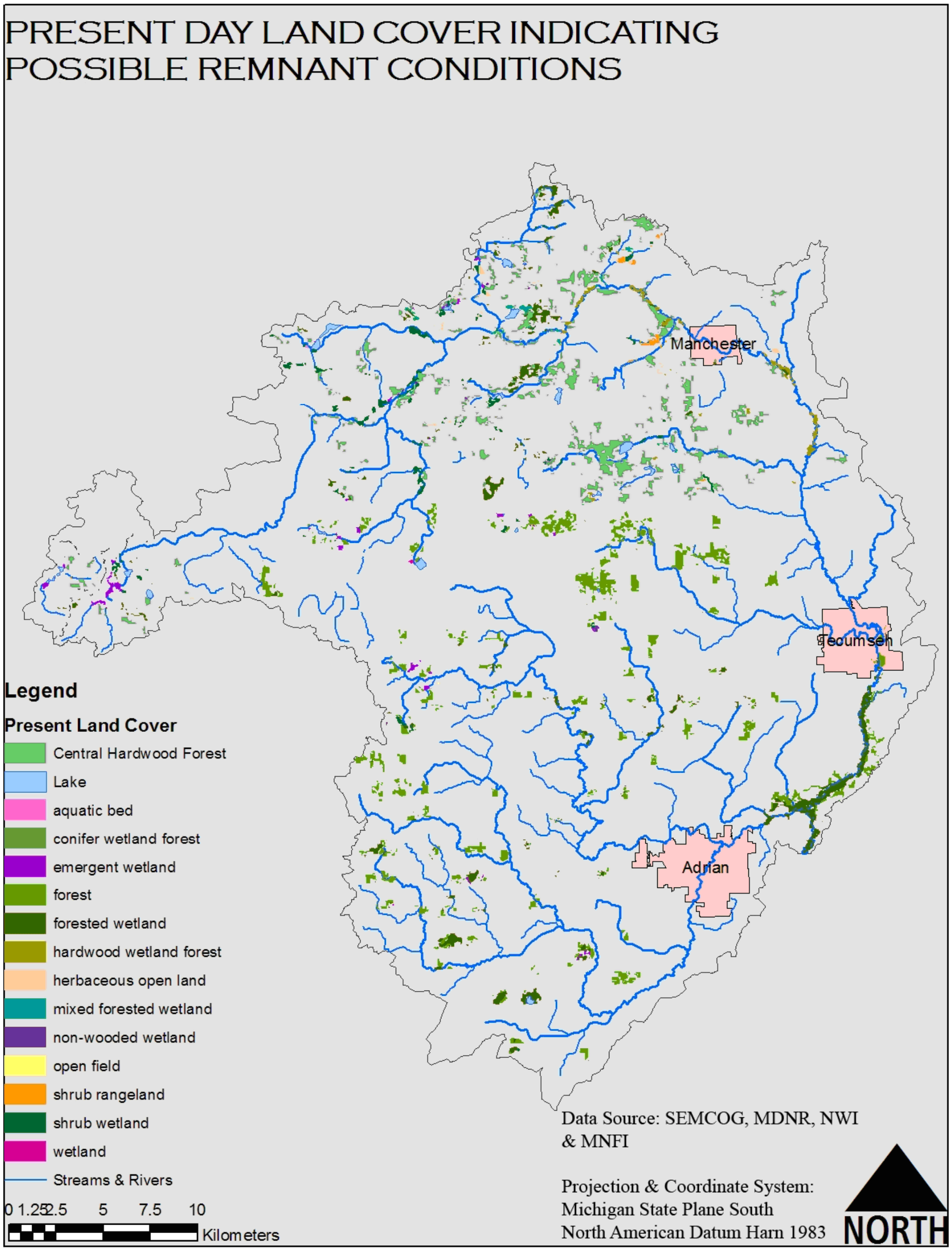


Figure 17. Remnant land cover on delineated habitat patches. Most remnant land cover that occurred on habitat patches consisted of oak-hickory forest and mixed hardwood swamp.

3.3.2 High Conservation Priority Patches

Of the 600 original habitat patches, 202 were identified as having sufficient interior habitat to potentially support sensitive species. These patches were considered to be of high overall conservation importance. However, because the habitat patches provide different types of conservation benefits, each of the 202 patches was further classified under four management objectives, which are as follows: (1) prime forest bird habitat, (2) prime grassland bird habitat, (3) prime amphibian and reptile habitat, (4) protection of water quality. Each patch was evaluated for its ability to meet these management objectives based upon relevant metrics analyzed, including the amount of interior habitat, level of connectivity, remnant habitat and/or ability to protect water quality. The following sections individually address each of these management objectives and their suitability for conservation in the River Raisin Headwaters.

Prime Forest Bird Habitat

One-hundred and ninety-four of the 202 identified patches contained core interior habitat in forested environments. The average interior habitat in a forested habitat patch was 17.0 ha, and seven patches had more than 90 ha of core area. The largest forest patch had an interior core habitat of 189.6 ha and a total patch size of 580 ha.

Twenty-nine patches were identified in the watershed that could support some sensitive forest bird species and moderately sensitive species (See Appendix 11b for patch locations). This category of forested habitat had a mean interior patch size of 41.9 ha with a range of 23.6 ha to 85.4 ha.

The model indicates that many of the forest patches have become highly disconnected by roads that link single family homes in the interior of forested areas. This has caused serious loss of interior habitat as many roads bisect what were once large contiguous forest tracts. The effects of this are extremely apparent around Sharonville State Game Area. Sharonville State Game Area has a long convoluted boundary, increasing its edge and lessening the amount of interior habitat. A map illustrating various patch scores based upon interior habitat is shown in Figure 18.

Habitat patches with core interior habitat identified as being able to support moderately sensitive and highly sensitive forest bird species were further evaluated for their connectivity with other patches and amount of remnant land cover. Only fourteen patches that contained enough core interior habitat for highly and moderately sensitive birds were linked to more than one other patch. Only one patch received a rating of 'highly suitable' based upon all three characteristics (core area, connectivity, and remnant land cover) and six patches received a rating of moderately suitable habitat based upon all three criteria.

Thus, the model indicates that there is little habitat that may serve as a source for sensitive bird populations. A map displaying the ratings of patches is shown in Figure 19 (See Appendix 12 for detail maps of highly suitable patches). Many patches in the headwaters are altered from pre-settlement conditions and are isolated by new development. The model identified habitats in the northern portion of the headwaters as of higher quality due to the increased amount of connectivity that exists there. Many patches in the southern portion of the headwaters have become isolated from one another, reducing their ability to maintain successful populations.

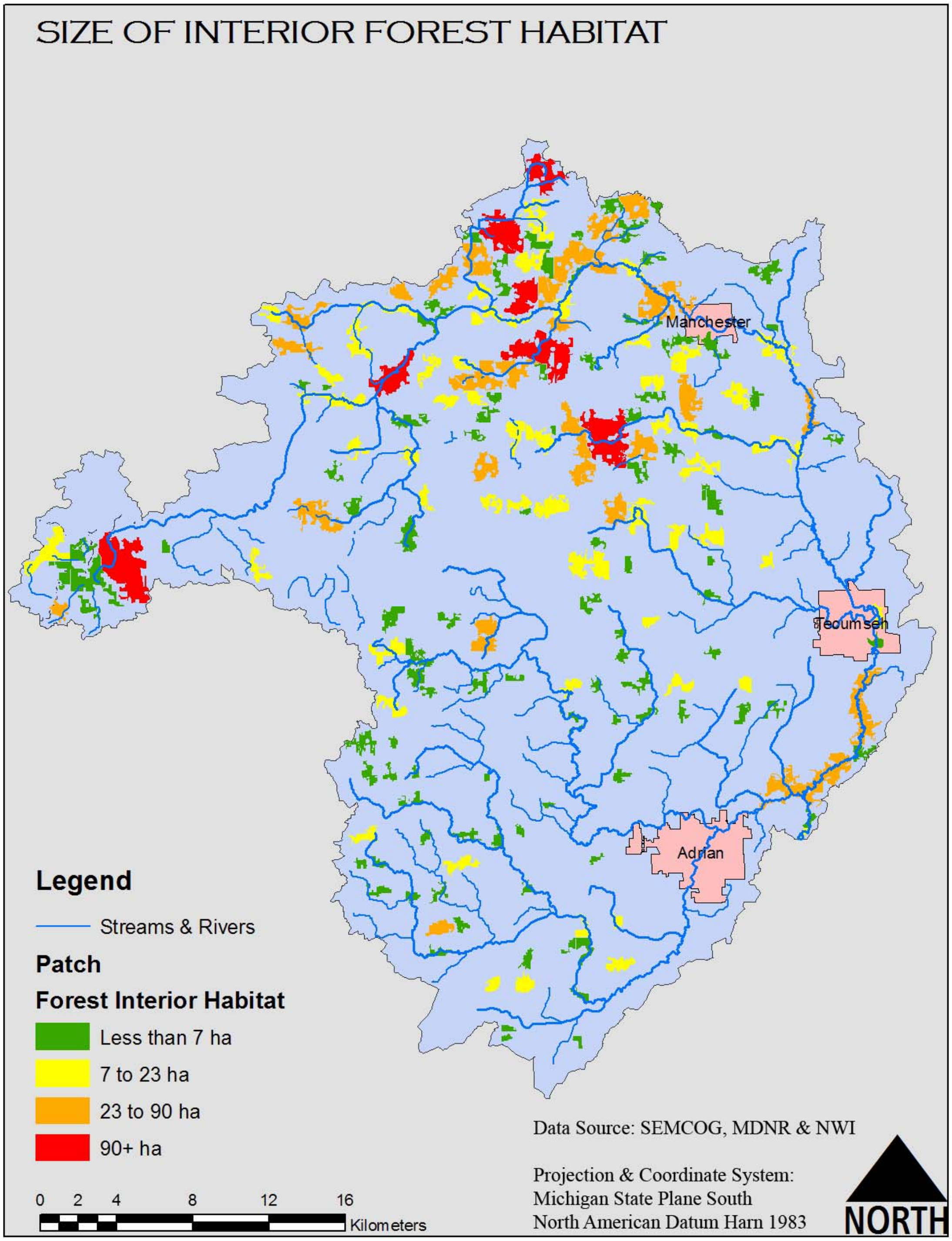


Figure 18. Forested patch core interior sizes, illustrating the amount of core interior habitat available to support bird populations. To maintain sensitive bird populations, an interior habitat greater than 90 ha is needed (Burke and Nol 2000).

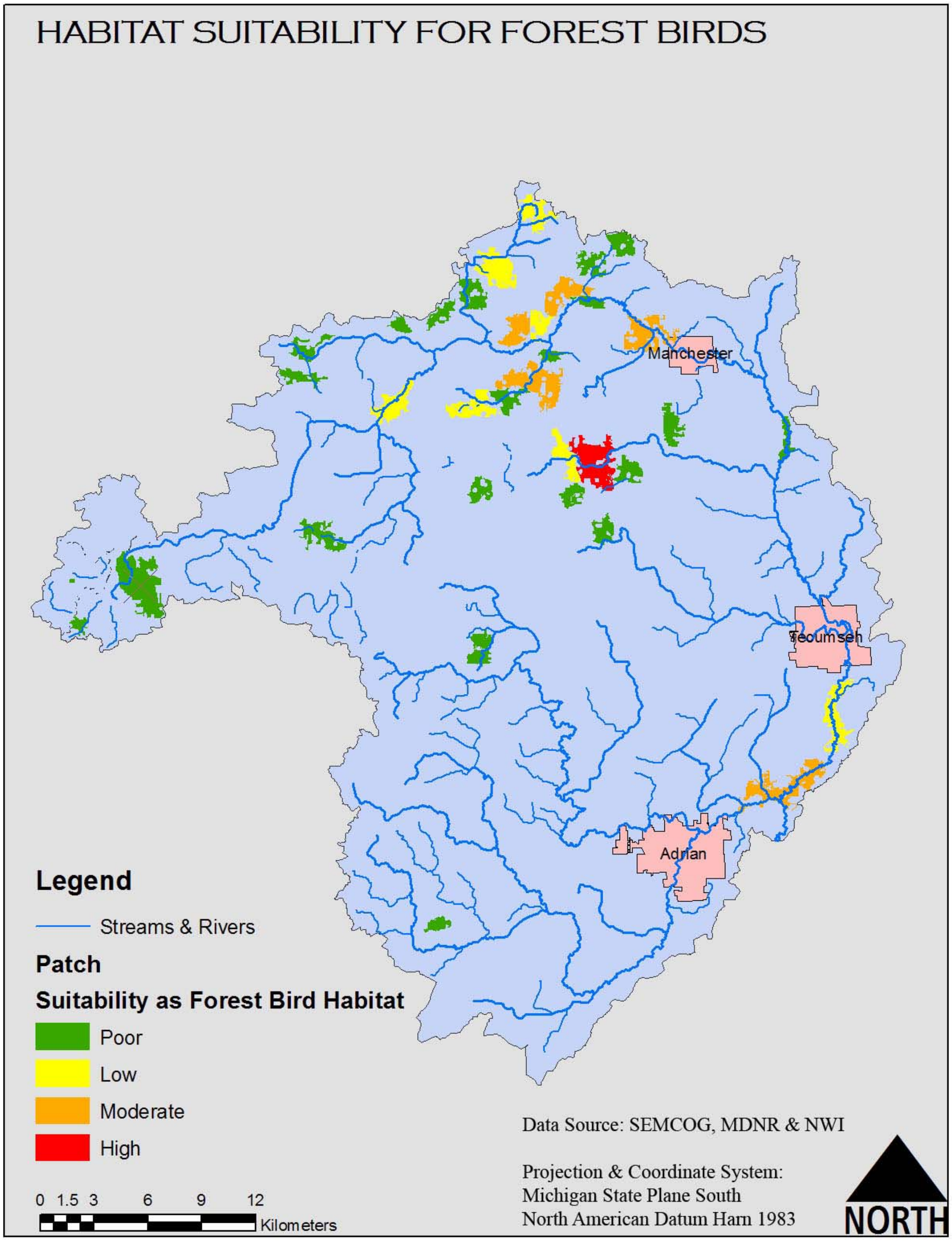


Figure 19. Forested patch suitability as bird habitat. Habitat patches that could support sensitive and moderately sensitive forest birds were further evaluated based upon connectivity and remnant habitat. Only one patch received a high rating for forest bird habitat.

Prime Grassland Bird Habitat

Seventy-nine of the 202 patches contained some core interior habitat in grassland ecosystems. The mean core habitat area of these patches was 8.4 ha with the largest core area being 34.2 ha. No patches were identified over 100 ha that could serve as habitat for moderately sensitive and highly sensitive grassland birds.

The majority of grassland habitats in the headwaters have been converted for human land use, leaving little of this ecosystem intact. The wide diminishment of grassland ecosystems throughout Southeastern Michigan threatens the existence of many grassland-dependent species throughout Southeast Michigan, making this habitat an important conservation priority not just in the watershed, but throughout the entire region. A map illustrating various patch scores based upon core habitat is shown in Figure 20. No further analysis was conducted of this habitat type due to the inability of all patches to meet the minimum criteria set by the model.

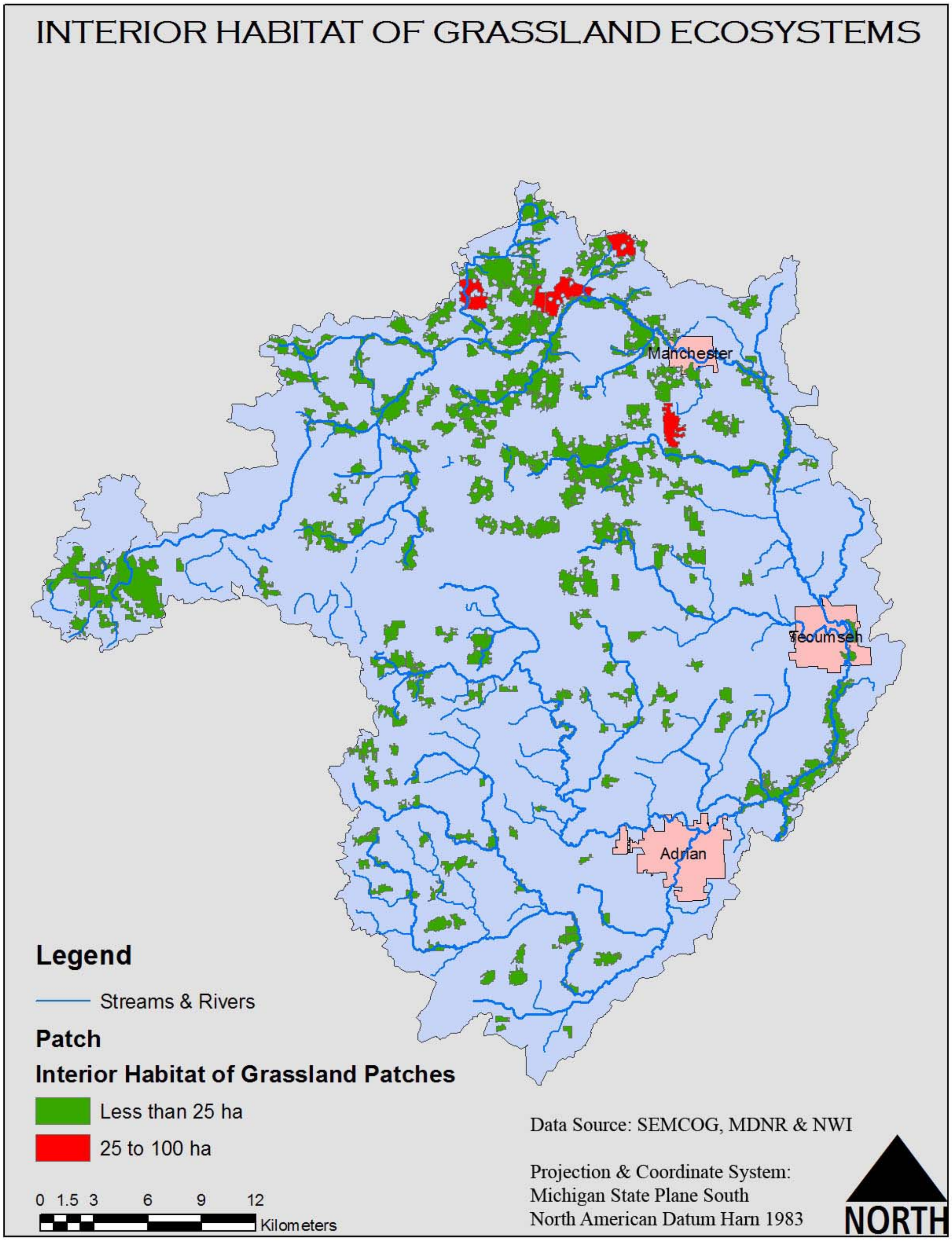


Figure 20. Interior Habitat of Grassland. No grassland patches were large enough to support moderately sensitive or sensitive bird species.

Prime Amphibian and Reptile Habitat

Within the 202 habitat patches assessed, 154 patches had forested wetland habitat and 42 patches contained aquatic or emergent wetland habitat. The average core interior habitat of a forested wetland was 11.1 ha, and the largest patch had an interior habitat of 177.3 ha. Five forested wetland patches were identified with a core interior habitat large enough to act as a source for sensitive amphibian and reptile populations. A map illustrating various patch scores is shown in Figure 21.

The average core interior habitat of an emergent wetland patch was 4.2 ha and the largest single patch had an interior habitat of 58.2 ha. Four aquatic wetland patches had terrestrial buffers over 500 m in width that surrounded more than 50% of the patch. A map displaying patch scores is shown in Figure 22. Many aquatic habitat patches within the watershed have been completely surrounded by development or are bordered by roads that cut off the wetland habitat from its terrestrial upland. This loss of access to upland habitat greatly impairs the ability of reptiles and amphibians to complete important life cycle stages.

Patches identified as being able to support moderately sensitive and highly sensitive amphibian and reptile species were further evaluated for level of connectivity and degree of land cover resemblance to pre-settlement conditions. When all four characteristics were evaluated together, only one patch received a highly suitable rating, and six patches received a rating of moderately suitable, based upon these criteria. A map displaying the ratings of patches is shown in Figure 23 (See Appendix 11c for patch locations and Appendix 12 for detail maps of highly suitable patches).

A major factor limiting patch suitability for reptiles and amphibians was the lack of current land cover's resemblance to pre-settlement conditions. For example, the largest patch at Somerset State Game Area, while largely contiguous, has developed from a wet prairie to a forested wetland. Despite the large amount of interior habitat available, it is possible that this patch is not high quality habitat given that such drastic alterations have occurred. Explanations of this alteration include the loss of natural fire regimes maintaining herbaceous vegetation and/or invasion by woody exotic species.

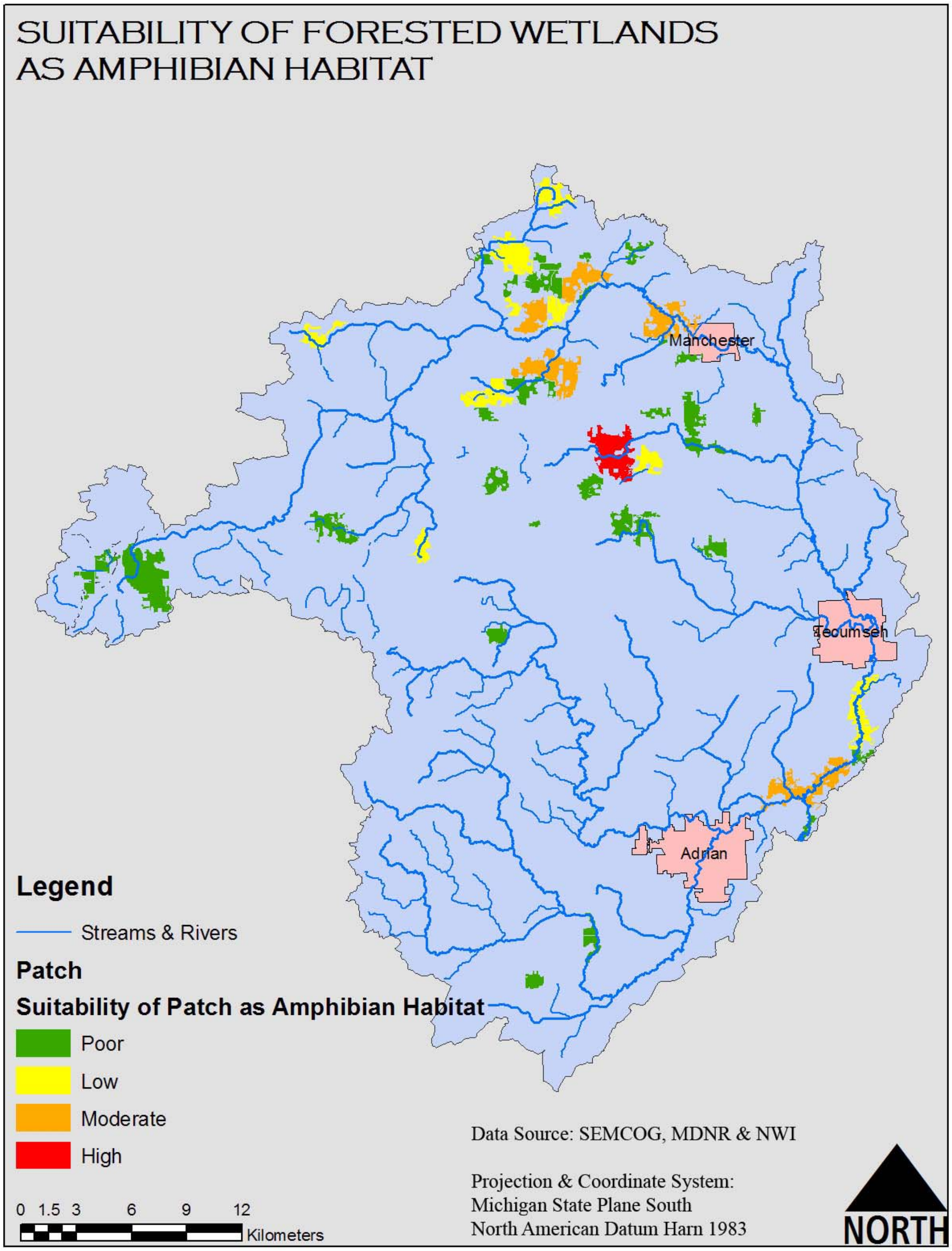


Figure 21. Core habitat of forested wetland patches, showing the amount of core interior habitat that could support amphibian and reptile species by patch.

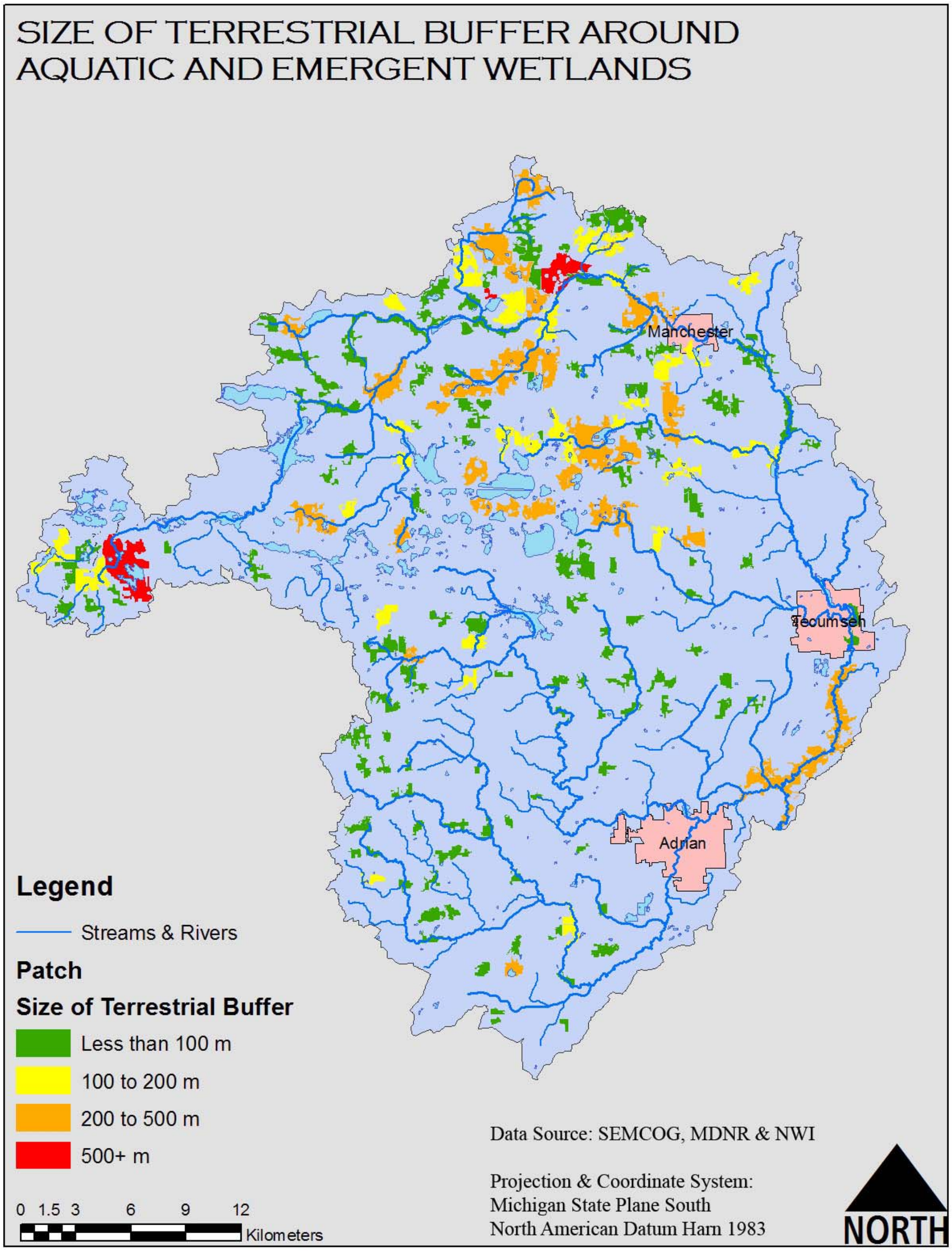


Figure 22. Terrestrial buffer width around emergent and aquatic wetlands. Lakes, streams and aquatic and emergent wetlands were evaluated based upon the amount of surrounding terrestrial upland.

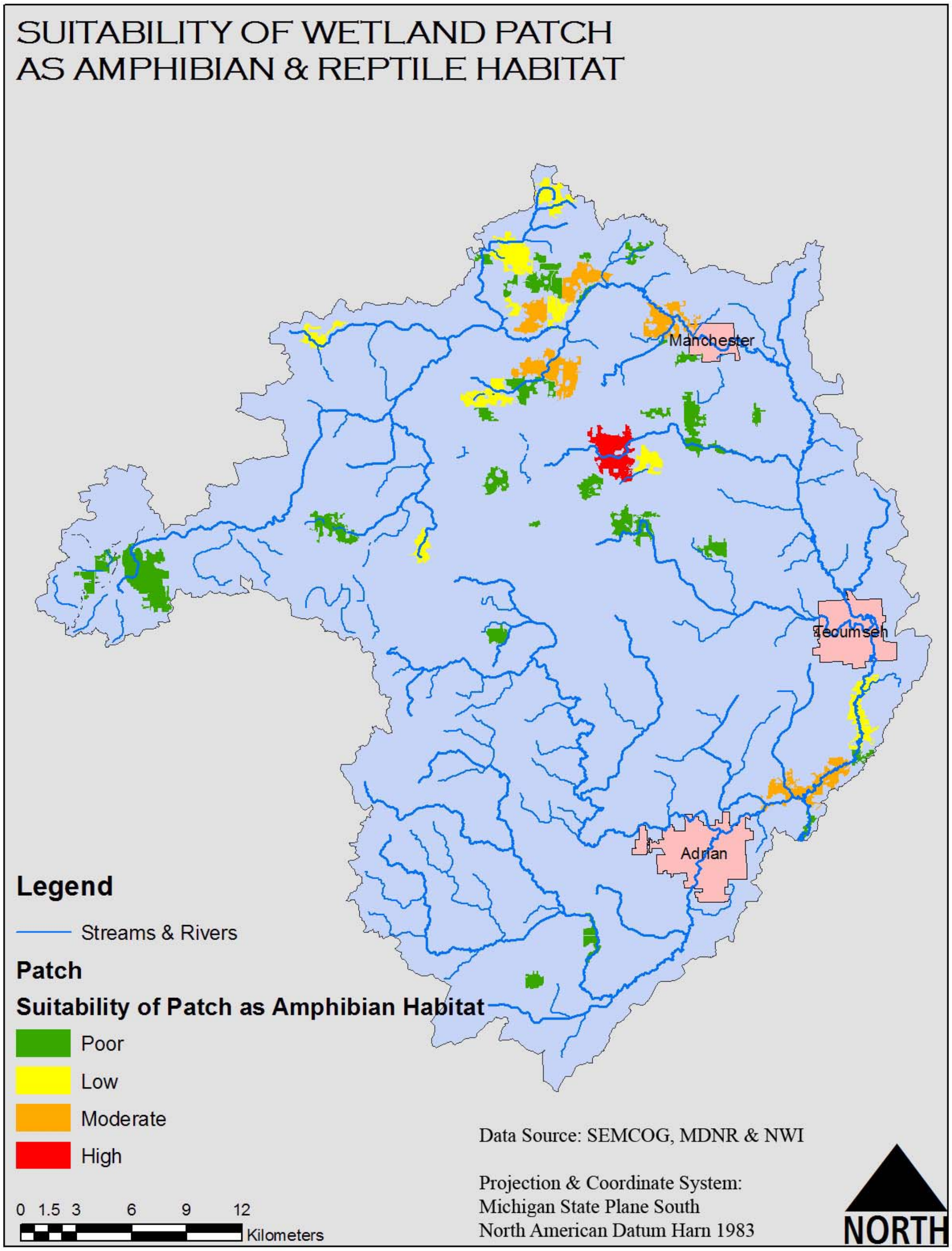


Figure 23. Overall suitability of patches as amphibian and reptile habitat. Wetland patches that could support moderately sensitive and sensitive species were further evaluated based upon connectivity, amount of interior habitat, terrestrial buffer and amount of intact remnant habitat.

Patches as Water Quality Buffers

Out of 202 patches, 119 were identified as potential water quality buffers for major streams and wetlands. Riparian wetlands capture phosphorus and sediment from surface waters traveling through them. These wetlands should be of high priority for protection due to their potential to protect aquatic habitats and purify surface waters (Mitsch and Gosselink 2000; Zedler 2003). A map illustrating locations is displayed in Figure 24.

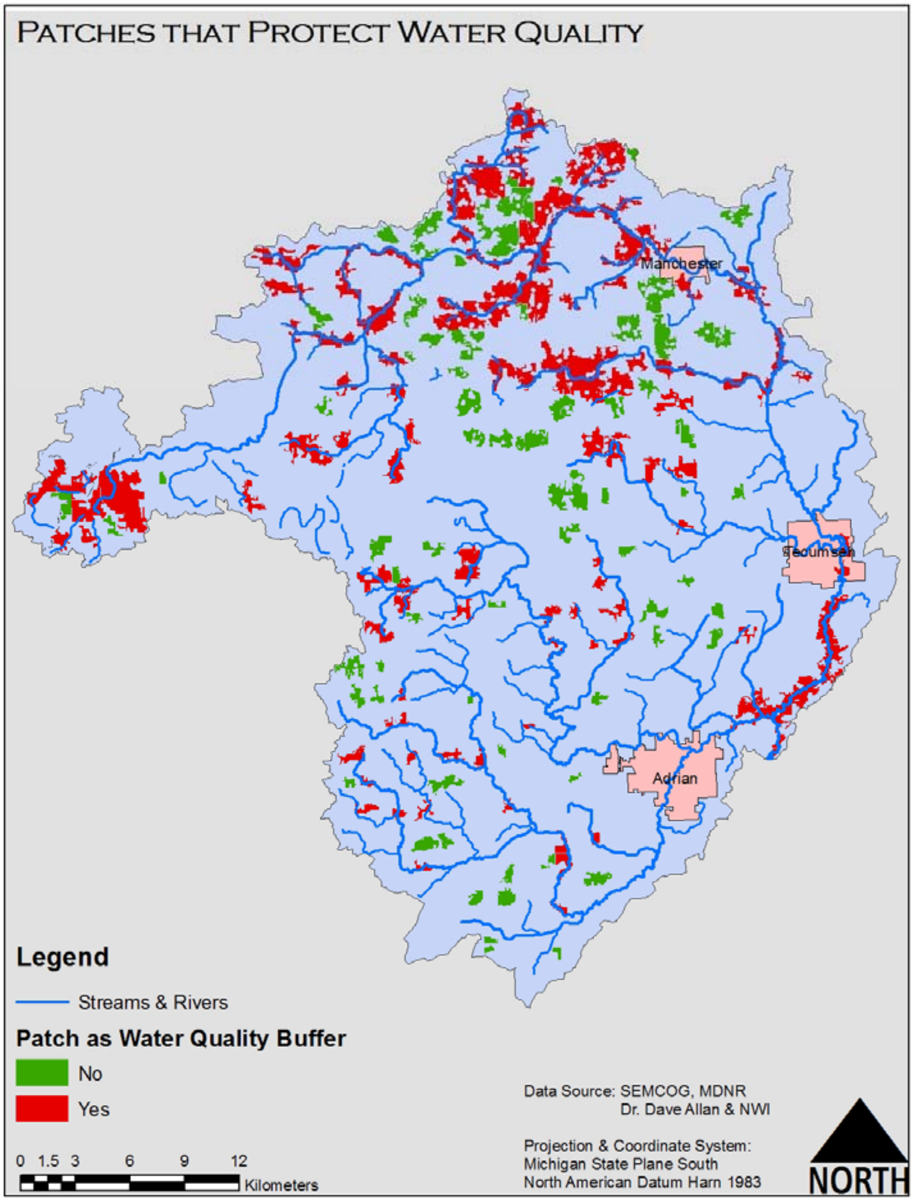


Figure 24. Patches of natural habitat that could protect aquatic habitats and water quality.

Riparian Buffer Zones

Streams were assessed on a subwatershed scale for forested and wetland riparian buffers. Forested and wetland riparian buffers play a critical role in trapping nutrients and sediments in surface runoff, stabilizing stream temperatures, and in supplying organic matter to maintain aquatic food webs (Allan 2004; Lowrance et al. 1997; Naiman and Décamps 1997; Roth et al. 1997). On average, 43.9% of the length of stream reaches within the upper watershed had 16 m riparian buffer.

Percentages of riparian buffer for each subwatershed are displayed in Figure 25. More than 50% of the streams in the Goose Creek, Iron Creek and the River Raisin subwatersheds are surrounded by a buffer of at least 16 m. Every other subwatershed in the River Raisin headwaters falls below 40%, indicating potentially impacted aquatic conditions in those subwatersheds.

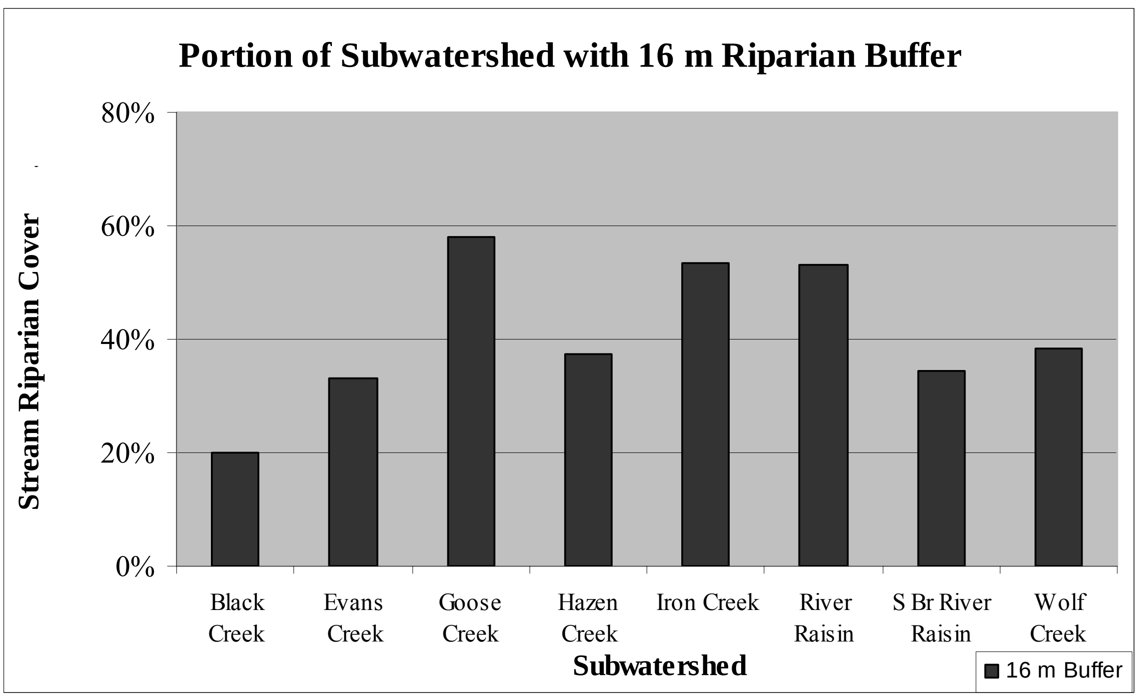


Figure 25. Percent of total stream reach within subwatershed that had 16 m riparian buffers or greater

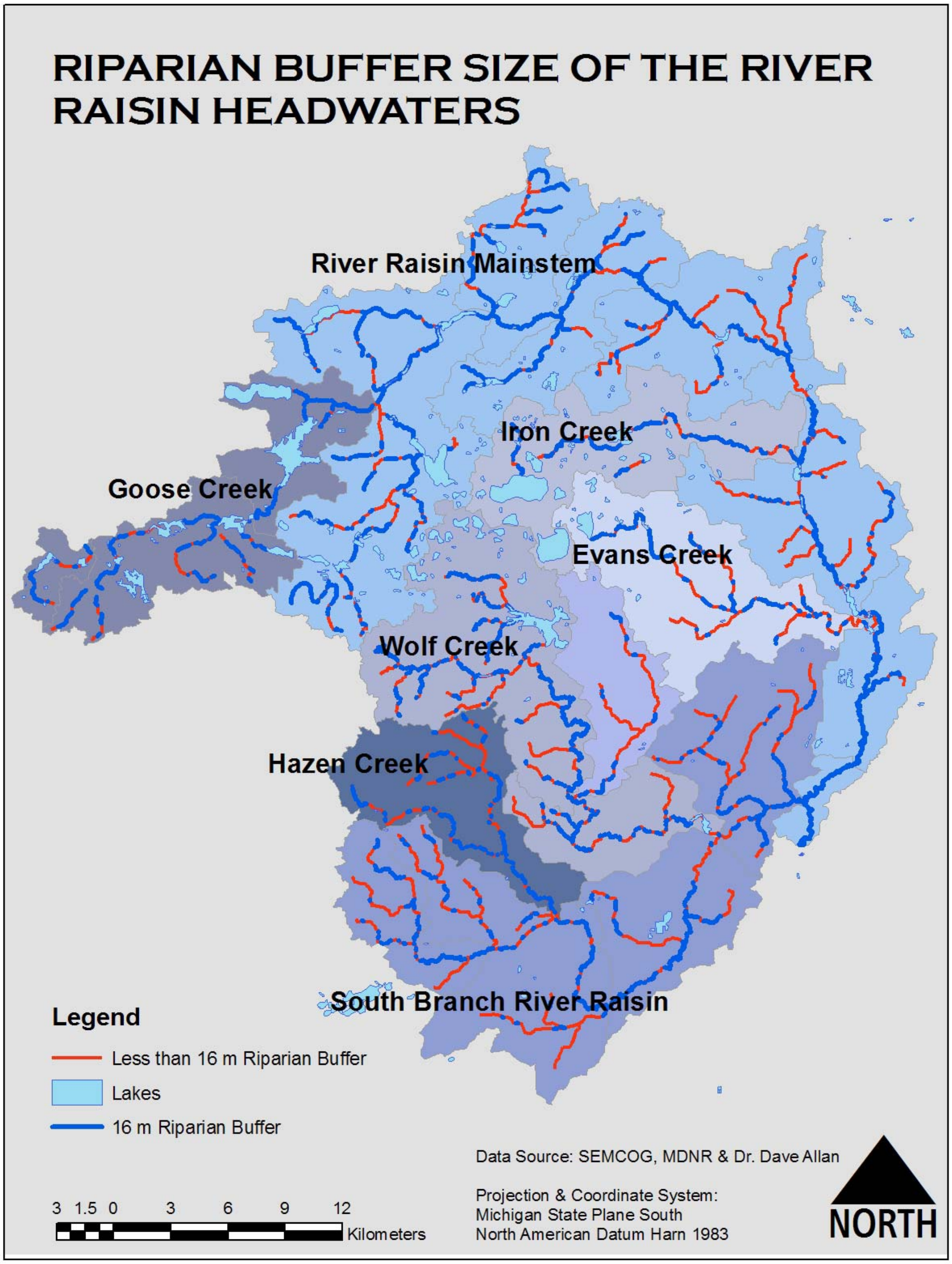


Figure 26. Riparian buffer widths of the River Raisin headwaters
Streams and rivers were analyzed to identify existing forest and wetland buffers along headwater streams.

Identification of Patches on Existing Public Lands

Thirty-one of the 202 identified patches occur on or adjacent to public lands. Expanding land already under conservation or owned by the government is one of the most economical ways to increase habitat. Preservation of these habitat patches not only will improve habitat and connectivity, but also will increase the overall size of the protected area and improve its ecological integrity as well.

Wildlife Corridors

Five primary wildlife corridors were identified in the Upper River Raisin Watershed; and it is expected that these corridors, if protected and maintained, will promote species movement between already existing protected areas. Few gaps were found within these five corridors that might pose potential barriers to migratory birds and large mammals. No gaps in natural cover of over 2 km were found in these corridors. Gaps greater than 2 km are expected to act as barriers to migratory birds travel (Environment Canada 2004), thus it is expected that these corridors will be sufficient as migratory birds pathways.

The wildlife corridor leading to and from Ives Road Fen Preserve does, however, run through the middle of Tecumseh, which might deter large mammal travel. Due to potentially large gaps in the corridor, the route was further evaluated, but was still found to represent the largest amount of contiguous natural area available between Ives Road Fen and other preserves. Figure 27 displays the identified corridors.

Patches were also identified that were within 1 km of the wildlife corridors. These patches provide resting and feeding places for migratory birds. Sixty-two patches were identified between Sharonville State Game Area, Walter J. Hayes State Park, and Onstead State Game area that may offer refuge for migrating wildlife (Figure 28). Few patches met these criteria on corridors from Ives Road Fen Preserve and Somerset State Game Area

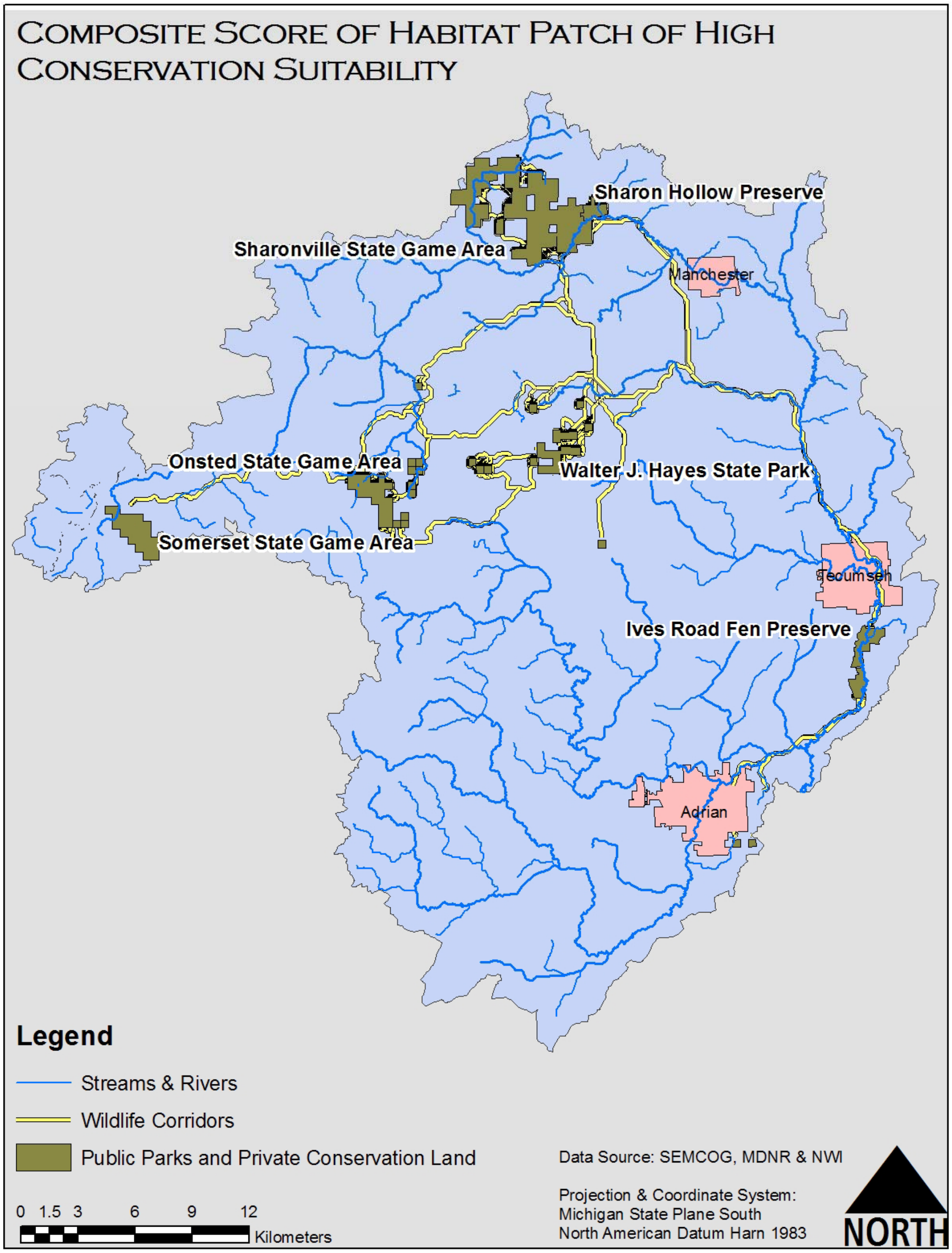


Figure 27. Corridors identified in the headwaters of the River Raisin using the least-cost method in ArcGIS 9.1.

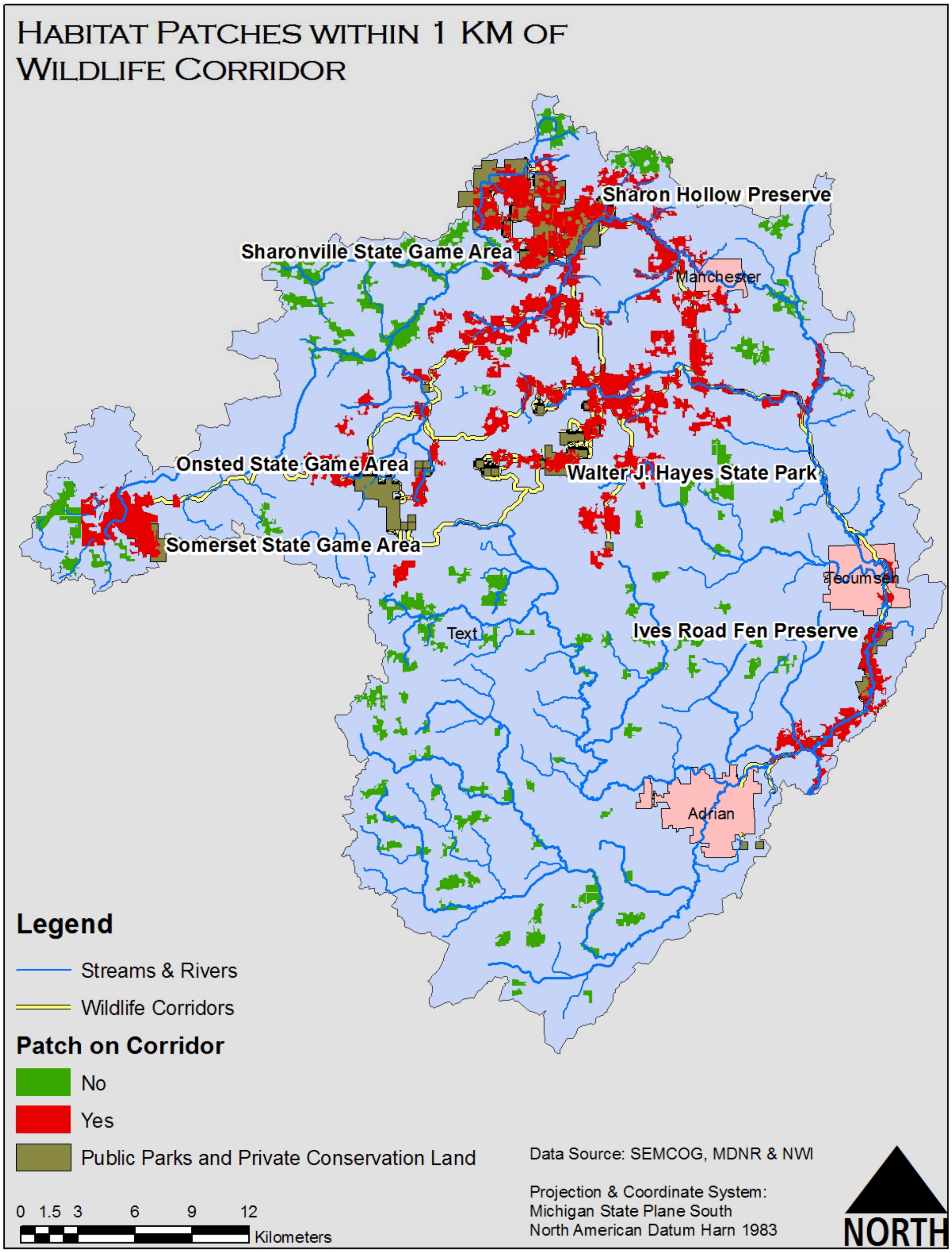


Figure 28. Patches along wildlife corridors: Patches within 1 km of the wildlife corridors potentially provide resting and feeding locations for migratory birds that may be traveling long distances.

Inclusion of MNFI Threatened & Endangered Survey Data

One-hundred and thirty-five patches overlapped with MNFI survey data. A map displaying the results of this information is shown in Figure 29. The presence/absence of a species in the MNFI data layer does not necessarily imply that the species occurs there today. The MNFI data was overlain with the model's results, however, to give model users access to potential threatened and endangered species locations when making land management decisions.

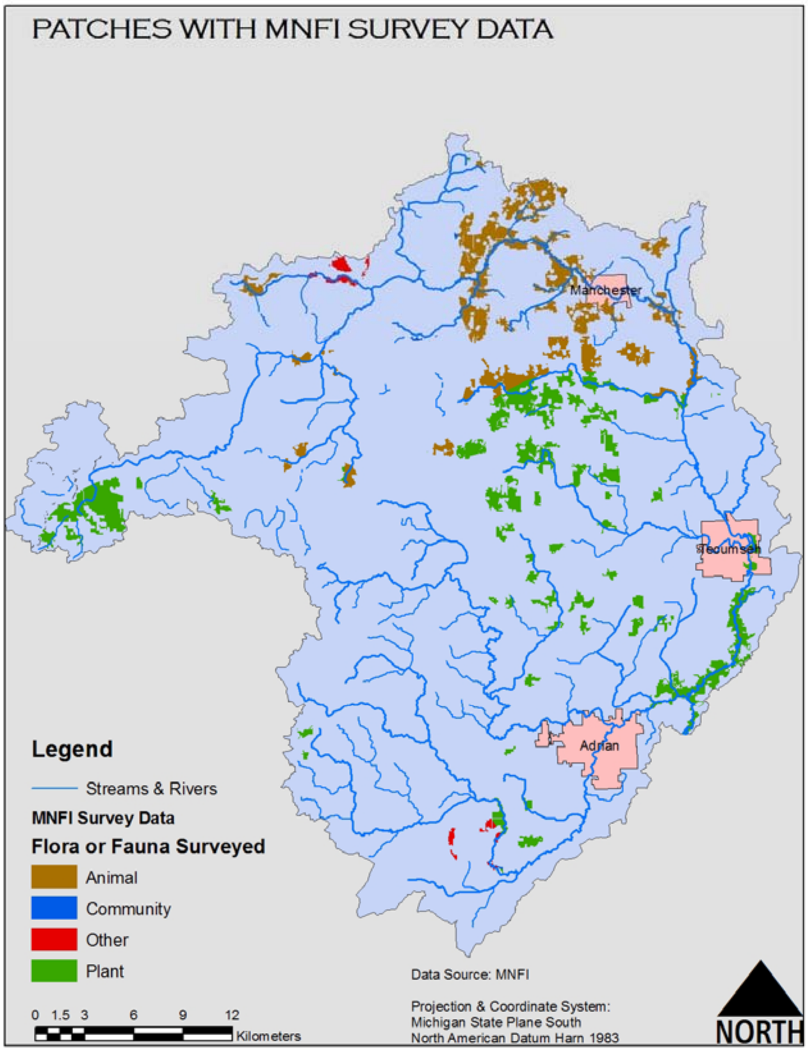


Figure 29. Locations where the MNFI identified rare flora, fauna, communities, and geologic formations was overlain with delineated patch data to aid users in the model make more informed decisions.

Patches Protecting Biodiversity and Water Quality

All patches were overlaid to develop a composite map showing their ability to support biodiversity and protect water quality. Habitat patches with the potential to support a diversity of wildlife successfully were identified based on size of core habitat, size of terrestrial buffers around aquatic habitats, proximity to other identified patches, whether current land cover resembled pre-settlement land cover, and whether the patch acted as a water quality buffer to streams or rivers.

Seven patches were identified as being highly suitable to support a diversity of wildlife, promote connectivity, and protect water quality (See Appendix 11d for locations and Appendix 12 for detail maps of patches). Only one patch met all criteria, making it highly suitable habitat for forest birds, amphibians, reptiles and protected water quality. Five patches are moderately suitable habitat for sensitive forest birds, amphibians and reptiles. These patches were also near lakes or streams and potentially act as water quality buffers. One patch was moderately suitable for sensitive forest birds, amphibians, and reptiles, but did not protect water quality. A map illustrating the ratings of patches is shown in Figure 30.

Currently, only two of the patches that could support a source population of moderately sensitive birds and amphibians are on protected land. These patches are located on TNC's Sharon Hollow Preserve and Sharonville State Game Area. The patch receiving the highest conservation suitability rating, located in the Iron Creek Watershed, is not on any protected land, but is near Walter J. Hayes State Park. Opportunities to protect this patch and link it to the Walter J. Hayes State Park should be further investigated.

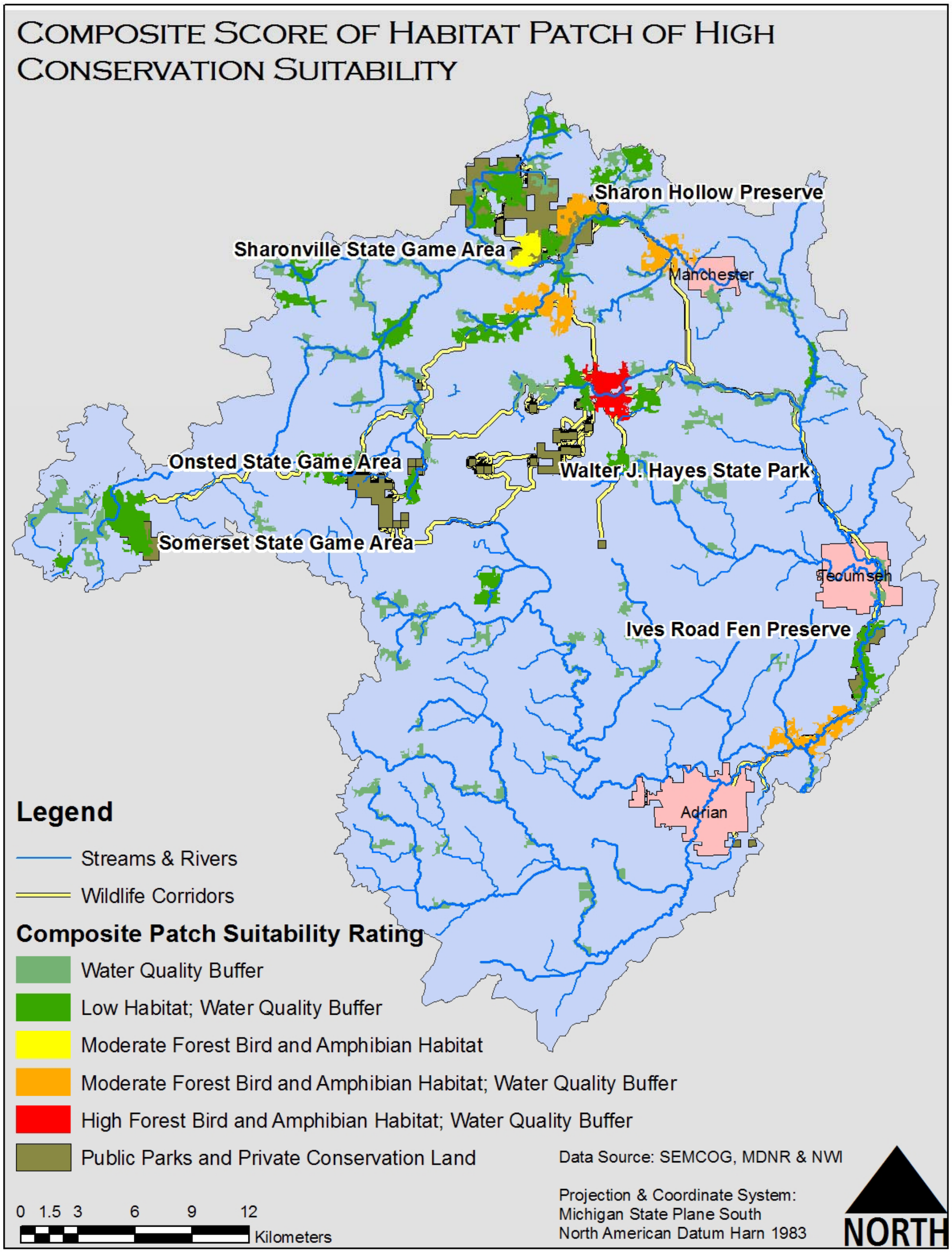


Figure 30. Composite score of all patches highly suitable for conservation

3.4 Discussion

The results of this decision support model indicate that opportunities to conserve habitat and wildlife corridors still exist in the River Raisin Watershed headwaters. Two hundred and two patches were identified that presently contain core interior habitat potentially sufficient to support a diversity of species. Of those patches, seven were determined to be habitats of high conservation priority based upon the management objectives of preserving biodiversity and water quality.

The GIS model presented here is designed to be a decision support system that aids wildlife managers, land use planners, and conservation organizations in their efforts to target land management efforts in the River Raisin Watershed. It should be recognized that this model is only as accurate as the data it evaluates. Criteria used to evaluate all of these factors are very conservative and potentially could eliminate patches of good habitat quality that did meet the criteria set for evaluation. All results should be further investigated to confirm that conditions on the ground resemble those mapped before land use decisions are made based upon the model.

3.4.1 Protection of Biodiversity and Habitat

Forest Bird Populations

Currently, the Upper River Raisin Watershed has seven patches of contiguous forest with over 90 ha of core interior habitat. Two of these patches received a moderate suitability rating and one a high suitability rating as forest birds habitat based upon all criteria evaluated. Field surveys should be conducted in these three patches to evaluate their ability to act as a population source for bird species within the watershed. The reproductive success of nesting bird populations within a landscape correlates positively with the amount of interior forest habitat available and the average patch size (Fahrig 2003; Freemark et al. 2002).

Studies conducted of forest birds in Ontario indicated that forest patches of 500 ha in size with 90 ha of core interior habitat were required to maintain successful source populations of sensitive bird species (Burke and Nol 2000). Patches with core habitat greater than 121 ha demonstrated high reproductive rates at levels required to replace individuals who leave or die (termed replacement levels), while patches with 7.8 ha core areas did not allow for adequate reproduction and thus acted as sinks, leading to reductions in bird populations (Burke and Nol 2000). After completing a similar study, the Illinois Department of Conservation issued recommendations that forest patches of 400 ha or more be conserved if 75-80% of bird species were to be sustained (Herkert et al. 1993).

Amphibian and Reptile Populations

Seventeen forested wetland patches were identified that are over 150 ha and have enough core area to support moderately sensitive to highly sensitive amphibians. Two of these were rated as highly suitable for amphibian conservation. Wetlands provide crucial breeding, over-wintering, and feeding habitat to a diversity of wildlife. Forested wetlands have the potential to support a large diversity of wildlife due to their heterogeneous composition of both upland and lowland habitat.

Two patches with aquatic wetlands in the Raisin headwaters were identified with terrestrial buffers in excess of 500 m and 16 had buffers greater than 200 m. Aquatic wetlands less than a half-hectare in size have been shown to act as vital breeding locations for salamanders (Environment Canada 2004). With this factor in mind it can take little land protection to preserve vital amphibian habitat.

In protecting wetlands, efforts should be focused not just on the wetlands themselves, but also on terrestrial uplands that surround wetlands. Terrestrial vegetation filters pollutants that may impact aquatic species and degrade wetland water quality; terrestrial vegetation provides habitat for amphibious fauna that require such habitat to complete their life cycles (Semlitsch and Bodie 2003). Many amphibians and reptiles breed and lay eggs in wetlands, but spend the majority of their life cycle in terrestrial habitats (Semlitsch and Bodie 2003). The 18 wetlands that have at least a 200 m terrestrial buffer should be targeted for protection in order to bolster efforts to conserve at risk amphibian and reptile species such as the eastern box turtle, blanchards cricket frog and marbled salamander.

Mitigation of Road Impacts on Wetlands

Currently there exist over 1,454 miles of roads within the Raisin Headwaters, which has sliced many large forested and wetland areas into isolated patches. Roads severely impact wetland ecosystem functioning and native wildlife. Stormwater runoff from roads sends heavy metals, road salt, sediment, and an excessive velocity and volume of water into wetlands (Forman and Alexander 1998). Roads are also one of the primary vectors for the transport of non-native invasive plant species. Native wetland plants, already stressed by road contaminants, are unable to compete with invasive non-native plants, such as cattails and reed canary grass. Thus, these invasive species are able to take over entire wetland ecosystems (Zedler 2003). Because native birds are not adapted to invasive exotic plant ecosystems, the introduction of invasive non-native species leads to decreases in bird and macroinvertebrate diversity (Zedler 2004). These wetlands should receive special consideration in regards to road layout by planners and developers.

Wetlands with good amphibian and reptile habitat, but which are bisected or bordered by roads, should have wildlife underpasses installed to improve connectivity and species mobility. Roads cause high mortality rates in amphibians and other small animals, particularly in and around wetland ecosystems (Forman and Alexander 1998). Additionally, road salt poses a serious threat to amphibians attempting to migrate between habitats, as increased salt levels can disrupt amphibians' ability to maintain water levels in their skin (Forman and Alexander 1998). Well-designed wildlife road crossings will allow amphibians and reptiles to pass under roads near wetlands, thereby reducing the increased mortality and stress caused by roads. Roads adjacent to or bisecting wetland patches of significance in the Upper River Raisin Watershed are illustrated in Figure 31.

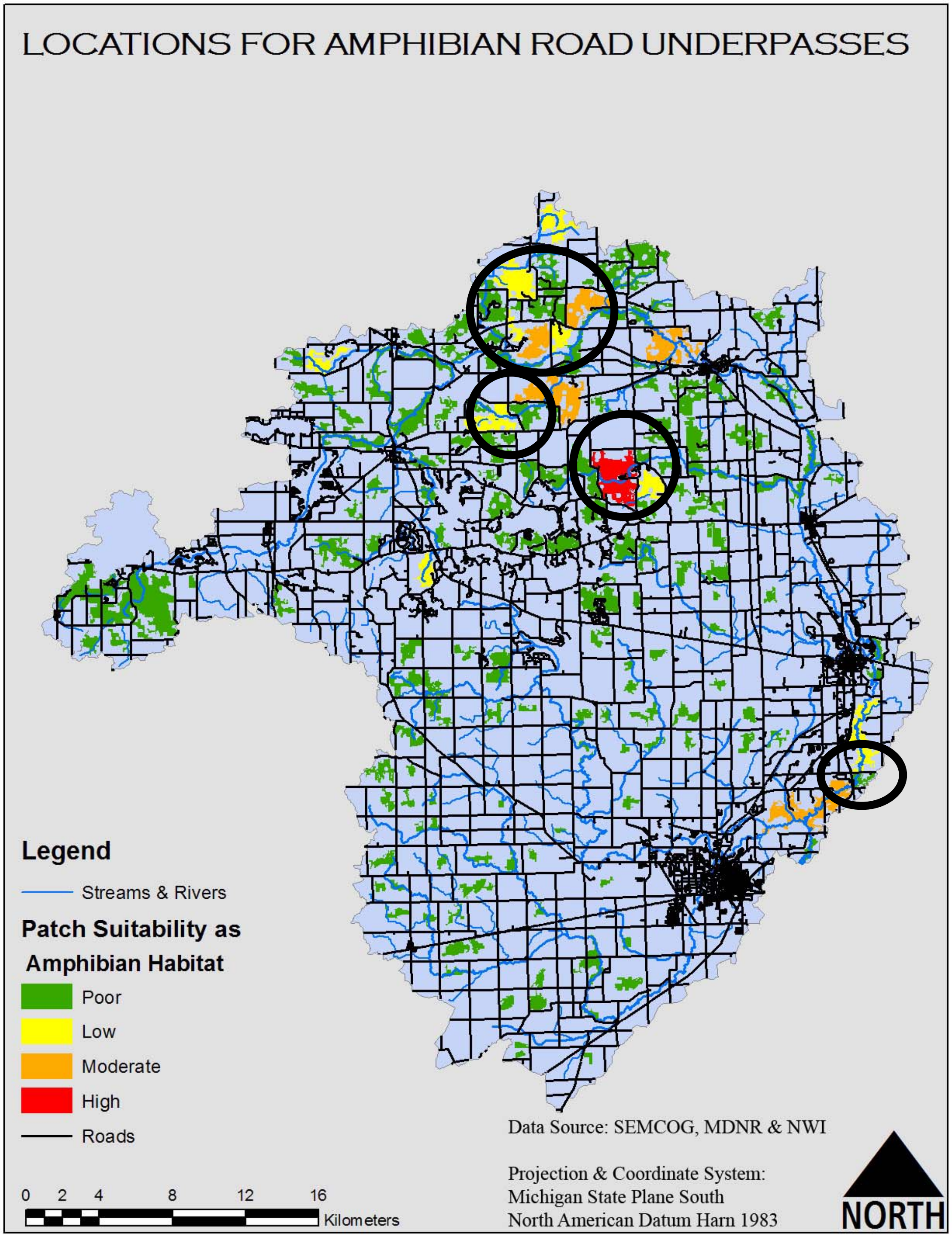


Figure 31. Ideal locations for wildlife crossings targeted toward amphibians and reptiles are circled above. These wetlands have substantial core habitat and/or large terrestrial buffers, but have lost connectivity due to roads.

Expansion of Existing Conservation Land

High quality habitat patches adjacent to existing protected areas should be targeted as high conservation priorities by local land management agencies and organizations. Protecting these patches (either through purchase of land or development rights) will preserve existing connectivity and current core area, thus helping to maintain ecological functioning. In addition, protecting habitat patches adjacent to already protected areas is economically efficient, as less land needs to be placed under protection in order to ensure that a large core habitat area is maintained. Habitat patches in Table 11 are adjacent to existing conservation land and thus are high conservation priorities.

Table 11. Priority habitat patches adjacent to existing protected areas

Overlay ID	Already Existing Conservation Area	Percentage of Patch not on Conservation Land	Overall Habitat Suitability Rating		
			Forest Birds	Amphibians & Reptiles	Water Quality
122	Sharon Hollow Preserve	16.8%	Moderate	Moderate	Yes
128	Sharonville State Game Area	39.2%	Low	Low	Yes
511	Ives Road Fen Preserve	44.2%	Low	Low	Yes
30	Walter J. Hayes State Park	95.4%	Low	Poor	Yes
107	Sharonville State Game Area	33.5%	Low	Low	Yes
106	Sharonville State Game Area	34.3%	Moderate	Moderate	No

Protection of Remnant Ecosystems

Prior to European settlement of the River Raisin headwaters, the dominant forest types were Oak-Hickory and Beech-Sugar Maple. Today, only a few of these forest ecosystems remain in the headwaters. The remnant forests that do remain are on agriculturally inferior sites that could not be converted for productive purposes (Scull and Harman 2004).

Remnant ecosystems were not rated regarding their global and state threatened status. Underrepresented remnant ecosystems of high conservation priority in the Raisin headwaters include beech-sugar maple forests, oak openings, prairie grasslands, and wet prairies. Efforts should be made to identify and target these remnant ecosystems for protection. Conservation of remnant habitats is exceedingly important to the preservation of regional ecological history. Furthermore, remnant ecosystems may provide some of the only sources of seed native to the River Raisin Watershed. These native seedbanks can be used as a seed source when restoring impacted habitats in watershed.

3.4.2 Protection of Water Quality and Aquatic Ecosystems

Forest and Wetland Coverage

Conversion of land for agricultural and suburban development purposes has resulted in the loss of forest and wetland habitats that protect the River Raisin's ecological integrity. Based upon current land cover data available, only 36% of the Raisin's headwaters is natural area. In addition to negatively impacting wildlife and ecosystem integrity, this loss of natural area has dramatically impacted the ecosystem processes that protect humans from floods, recharge the aquifers we use for drinking water, and clean the water in the river that is used for recreation and drinking (Cappiella et al. 2005; Zedler 2003).

One-hundred and eighteen of the patches identified by the decision support model potentially protect surface waters from pollution and aid in the preservation of aquatic ecosystem functioning in the River Raisin. These patches should be targeted for restoration and conservation in subwatersheds identified with poor water quality (see Chapter 2 for more information).

Research conducted by Wang and Mitsch (1998) in the Saginaw Bay area estimated that watersheds composed of 15 percent wetland habitat or more had lower phosphorus loadings by 66 percent. Mitsch and Gosselink (2000) suggest that wetland coverage, for the Midwestern U.S., should average around 5% in order to maintain the ecological benefits that wetlands contribute to overall watershed health and integrity.

Studies of catchments in the River Raisin indicate land use to be one of the most significant indicators of biological and habitat condition in surface waters (Allan et al. 1997). Forest cover protects water quality by intercepting precipitation, filtering runoff and shading streams. It is therefore suggested that 40-50% of the watershed's forested land cover be representative of pre-settlement conditions (Cappiella et al. 2005).

Preservation and Restoration of Riparian Zones

Vegetated riparian buffers provide shade that stabilizes stream temperatures; they supply organic matter that maintains aquatic food webs; and their root structure stabilizes streambanks, preventing mass wasting (Allan 2004; Lowrance et al. 1997; Naiman and Décamps 1997; Roth et al. 1997). In headwater streams, the potential benefits offered by riparian vegetation may be especially important (Lowrance et al. 1997; Naiman and Décamps 1997; Roth et al. 1997).

Subwatersheds in the Raisin Headwaters identified with little intact riparian vegetation should be prioritized for restoration efforts (Figure 31). The reversal of agricultural and urban land use is highly unlikely and the restoration of the buffers can help to mitigate many of the effects of these land use types (Allan 2004). This data should be utilized in comparison with water quality data (Chapter 2) and local ordinances (Chapter 4) to evaluate streams with the greatest need.

3.4.3 Managing a Socially and Ecologically Functioning Landscape

Our decision support model indicates that the River Raisin's headwaters are greatly fragmented as a result of the conversion of arable land to agriculture along with the rising demand for residential housing in the watershed headwaters. Consequently, the headwaters have experienced drastic reductions in species richness and disruptions to ecological processes, as well as the isolation of many ecological communities into small patch population sinks.

High quality habitats do still exist within the Raisin headwater, however, providing an excellent opportunity to create a healthy landscape that supports both wildlife and human development. By guiding residential and road development appropriately, and by prioritizing conservation efforts, it is possible to maintain a configuration of habitat patches and corridors in the headwaters that promotes movement by wildlife without adversely affecting human quality of life. For example, by zoning land use for wooded golf courses along one of the wildlife corridors identified by our model, connectivity throughout the corridor would be better maintained than if the land were zoned for small business (A. Bennett 1999).

The integration of conservation planning into community master plans and regional land use planning is both a necessity and an opportunity to protect many of the natural resources of Southeastern Michigan. However, without proper planning and analysis of the ecological landscape, flora and fauna populations will continue to suffer. Because ecosystems and watersheds are integrated and interdependent entities, what occurs in the River Raisin Watershed will affect wildlife, vegetation, ecological communities and even human beings living far outside the boundaries of watershed itself. Ecological processes do not acknowledge political boundaries.

Development of Greenways

Greenway planning is an excellent method for local and state governments to integrate conservation and social needs into land use planning efforts (A. Bennett 1999). Greenways can connect urban centers offering alternate transportation routes; they can protect private property from flood events, preserve wildlife migration routes, and increase human recreational opportunities.

The wildlife corridors identified by this decision support model would be ideal locations to establish greenways. In particular, those corridors that link Sharonville State Game Preserve, Walter J. Hayes, and Onstead State Game Area should be investigated for greenway establishment. There already exists a great deal of protected natural area between these patches, making it feasible to implement a greenway at less cost than in other parts of the headwaters. Additionally, these parks are within close proximity to one another, which also would ease financial expenditures. Other potential greenways could be established connecting the cities of Adrian, Tecumseh, and Clinton along the River Raisin. This would not only protect the Raisin, but would also provide excellent recreational and educational opportunities for residents of the watershed.

There is also the possibility of creating wildlife corridors/greenways that would link conservation areas in the Upper River Raisin Watershed to parks in other watersheds. For example, possible routes exist between the River Raisin Watershed and Waterloo State Park, which is the largest state park in the state of Michigan at 8,498.4 ha. While such routes were not identified in this decision support model, the same techniques used here to identify wildlife corridors could easily be extended to areas outside the watershed. The establishment of regional greenways presents excellent opportunities to maintain ecological connectivity throughout Southeastern Michigan.

Integrating Natural Areas into Residential Development

Many of the areas identified for conservation by this decision support model are located on private lands within the River Raisin headwaters. Purchase of all of these lands by local and state governments is economically infeasible. However, the preservation of those areas with high biological integrity and diversity is extremely important. In addition to their ecological significance, the protection and preservation of these patches will also provide societal and economic benefits.

Private home-buying decisions are highly influenced by the aesthetics of the surrounding environment, and the strategic protection of high diversity natural areas in and around residential development will not only protect ecosystem functioning, but will also increase home values (Erickson 2002). Appealing to the interests of residential home buyers perhaps can create unique opportunities to promote natural area preservation. For example, cluster developments in and around high diversity natural areas can be advertised as environmentally friendly housing. Additionally, neighborhood associations may be willing to contribute financially to the purchase of development rights on natural areas if they were allowed to use the land recreationally.

High priority conservation patches currently designated for residential land use were identified to determine potential opportunities for conservation easements, planned-unit developments, and conservation developments (Refer to Chapter 4 for additional information).

4 Laws and Ordinances

4.1 Introduction

As the population of southeast Michigan grows, there is increasing pressure to provide housing, develop land, and clear natural areas. The population increase of southeast Michigan from 1990 to 2005 was over 300,000 people (SEMCOG 2005). A growing population puts more demands on natural resources such as water supply and wastewater services that impact local waterways. Undeveloped land in some areas of the watershed has decreased by over 36% in the decade between 1990 and 2000 (Table 12). Humans are an integral part of the modern landscape, however, and so it is imperative to "change the traditional environmental planning approach toward a true synthesis of people and nature" (Hersperger 1994, as quoted by Grant et al. 1996).

Table 12. Three indicators of land use change from natural areas to residential development in Saline, Manchester, and Monroe.

	Percent Change, 1990-2000		
Indicator of Land Use Change	**Saline**	**Manchester**	**Monroe**
Single Family Residential	47.2	8.8	3.4
Active Agriculture	-67.6	-38.8	-29.1
Woodlands and Wetlands	-28.0	-12.8	31.6
Undeveloped Land	-36.3	-7.6	-5.2

Source: SEMCOG 2004a, 2004b

Though the River Raisin watershed is primarily agricultural, several small cities and villages concentrate the effects of human development on the river and other connected natural resources. This increased density already poses challenges to the long-term protection of the watershed. Therefore, local laws and policies must provide the framework for governments to prevent further degradation of water resources and increase the sustainability of the cultural, economic, and environmental assets of the watershed. Though interest in initiatives to prevent water pollution is growing, local governments are still not doing enough to reduce impervious cover, preserve open space, and effectively treat and manage stormwater.

This chapter seeks to analyze how the growing population's impact on resources are being recognized and implemented through local ordinances and regional policies. Through the scoring of local ordinances in six watershed communities, the current state of watershed stewardship in local laws can be evaluated, leading to recommendations for watershed-wide improvements. In addition, this analysis will highlight current laws that can be used as models to better meet the goals of protecting the river and ensuring long-term sustainability of the watershed.

4.1.1 Powers of Local Government

American municipalities in general are not sovereign entities, but subject to state law for many decisions, including land use. However, those operating under "home rule" have the power to perform any function that is not forbidden under state law (Platt 2004). Michigan has adopted the home rule policy, and so major land use decisions are made at the local level (Erickson 1994). Thus, whatever regulations the state does not promulgate can be addressed by local governments in their own ordinances and tailored to suit the particular social, economic, and natural resources of the area. Michigan's cities, villages and townships were granted the authority to plan by the passage of the Municipal Planning Act (PA 285 (1931)) and the Township Planning Act (PA 168 (1959)). Local governments are also responsible for division of land and creating zoning ordinances (See PA 591 (1996), PA 87 (1997), PA 207 (1921), PA 184 (1983)).

4.1.2 Ordinances for Water Quality

While the above laws provide for a wide range of interpretations of local land management and policy, there are three important areas where municipalities have significant authority that can affect the management of natural resources, and watershed protection in particular.

First, zoning laws and land use planning have a large influence on the percentage of impervious surface coverage. Impervious surfaces do not allow for the natural percolation and absorption of water into the ground. The types of man-made surfaces that contribute most to impervious cover are parking lots and roads (Madsen and Shriberg 2005). Growth of the built environment, even in small villages, can greatly alter the natural hydrograph, reduce natural drainage of stormwater, reduce groundwater recharge, and increase the amount of pollutants that enter waterways. When precipitation can no longer naturally percolate into the ground, it becomes runoff that can easily pick up pathogens, chemicals, metals and trash, and wash off into water as non-point source pollution. Non-point source pollution has been identified as the major cause of degradation to the nation's water, and this is certainly the case for the River Raisin (Environmental Protection Agency 2004). Please refer back to Chapter 2 for a more complete discussion of impervious cover and its relationship to water quality.

Municipalities in Michigan (including townships, villages, and cities) have the authority to issue bonds, borrow money, or levy taxes to construct sidewalks, roads, and other paved surfaces (Mich. Comp. Laws §§41.181 (1) (1945); 67.8(8) (1895); 117.4(d) (1909)). Therefore, improving local ordinances to reduce impervious cover and foster a more natural landscape is the most direct way to protect the Raisin and its tributaries.

Municipalities in the Raisin watershed tend to be low density, and so the guidelines for reducing impervious surface cover must be adapted to their particular land use patterns. The Nonpoint Education for Municipal Officials (NEMO) project made recommendations to educate local land use officials on how to formulate their decisions based on local or regional growth and its effect on water quality. Residential areas with one-quarter acre lots have on average 30% impervious surface, the threshold at which stream health becomes degraded (Center for Watershed Protection 2005a). Standard residential lots (in zone R1-A) throughout the watershed tend to be larger (from about 1/3 acre in Blissfield and Tecumseh to a full acre in Manchester), and thus have a lower percentage of impervious cover. In this case, NEMO identified retention and expansion of existing natural spaces as the best way to prevent further degradation of water quality (Arnold and Gibbons1996).

The second significant power of municipalities with regard to watershed protection is the management and preservation of open space. Preservation of natural areas is especially important in the land use decisions of small communities because this is one of the few areas where people can really make a large contribution to improving stream health. Brabec et al. (2002) explains,

> "At a basic level, stream hydrology and function are dependent on five variables: climate, geology, soils, land use, and vegetation. These 'first-order' variables directly affect the 'second-order' factors of discharge and sediment load, which in turn have an impact on the hydrology and morphology of the stream. Of these variables, land use and vegetation are the only variables over which man has direct control, underscoring their primary significance in the land use planning process" (p. 2)

There are many benefits of open space, and they are discussed in detail in Chapter 3.

Cities and villages can manage, buy, and regulate open space (Mich. Comp. Laws §125.581(1) et seq. (2003)). One way that communities can incorporate open space into their city is through the master planning process. State Law mandates the classification and allocation of natural features and waterways in any community's future growth plans (Mich. Comp. Laws §§125.36(6) et seq. (2003); 125.327(7) et seq (2003)).

Recently, the City and Village Zoning Act was amended to give developers the option of building cluster-style residential developments (Mich. Comp. Laws §125.584(b) (2003)). Planned Urban Developments (PUDs), as they usually are called, require a certain percentage of the land to be dedicated to open space. Unlike conventional developments, PUDs concentrate the homes and paved areas into smaller clusters, thus providing larger open areas for natural habitat and recreation (Figure 32).

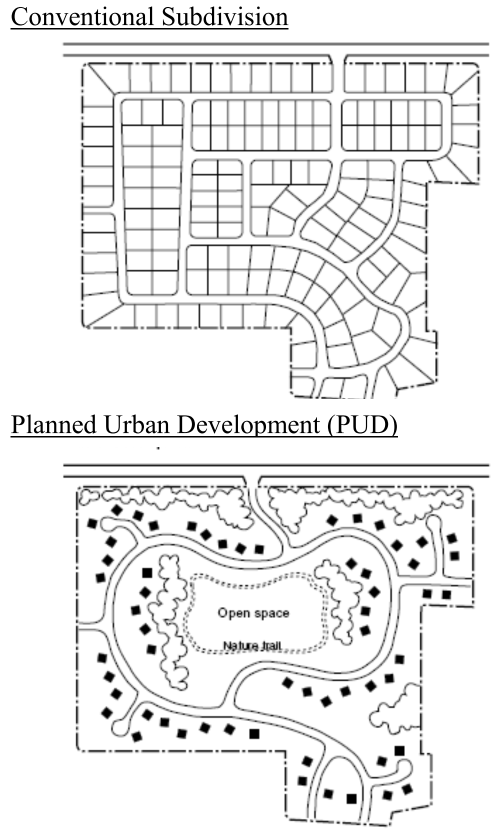


Figure 32. Comparison of conventional and cluster-type development**.**
Source: Listokin and Walker in SEMCOG 2003, p. 24

There are numerous advantages of this type of housing: for the developer, the city, and the homeowners of the development. The most important of these from the standpoint of protecting the resources of the Raisin watershed is preservation of open space and reduction of impervious surface. As explained above, reducing impervious surfaces and increasing the amount of open space can greatly improve stream health and water quality. From a developer's perspective, one important advantage of PUDs is that requirements for setbacks, height, lot size and shape, and facilities are more flexible than for other residential districts. In addition, they allow for creative design and layouts that otherwise may be more restrictive for other land uses (Mich. Comp. Laws §125.584b (2) et seq. (2003)). More and more cluster-type developments are being constructed in the Raisin watershed, as demand from homeowners has grown in recent years. Some developments can offer access to nature trails and open space areas for recreation to community members in addition to those who own a home in the development (Nancy Smith, Resident of Tecumseh and RRWC delegate for the city, personal communication 17 January

2005).

The third significant power of municipalities with regard to watershed protection, and intimately connected with impervious cover and open space preservation, is oversight of stormwater management. The Raisin watershed receives about 32-36 inches of precipitation each year (Oregon State University Spatial Climate Analysis Service 2000). Though this is not an extraordinary amount of precipitation, a greater extent of impervious surface will increase the contribution of runoff to the river. To estimate the quantity of runoff from a storm event, the following equation is commonly used:

$$Q=XCiA$$

Where Q=peak rate of runoff (cubic feet or meters per second), C=runoff coefficient, A=area of drainage basin (acres), i=rainfall intensity (inches/hour), and X≈1.01

The runoff coefficient, represented by "C" in the equation above is a constant between 0 and 1 that can be estimated based on the percentage of impervious cover. For example, the coefficient for the downtown business district of a city is 0.70-0.95, while it is only about 0.10-0.25 for parks (Burton 1996). So for a large storm event, stormwater flow from a developed area can be quite high and has the potential to be very damaging to aquatic ecosystems. Therefore, the need to manage stormwater and update sewer systems as infrastructure ages, are growing concerns for local governments.

As discussed in relation to impervious surface coverage, excess runoff from storm events and melting snow that is not absorbed into the ground can often pick up pollutants from fields, streets, lawns and buildings, and deliver them to waterways. Two of the biggest negative consequences of improper stormwater management in the Raisin watershed are erosion from the stream channel and adjacent areas, and water pollution. Both erosion and decreased water quality significantly affect fish habitat by exposing streambeds, widening channels to make them shallower and possibly contributing to higher water temperatures and decreased oxygen in the summer months (Center for Watershed Protection 2005a). Five of the six communities surveyed in the watershed have separate sewers, and so their stormwater is directly discharged into the River Raisin, or a stream or ditch that eventually discharges into the river. Thus during and after storm events a sudden surge of flow is discharged into receiving waters and can significantly impact habitat, water quality and channel hydraulics. Monroe is the exception because it treats its waste- and stormwater and then discharges into Lake Erie rather than the River Raisin (City of Monroe 2006).

Cities and villages are required to provide stormwater systems, and can levy taxes and use public funding to improve and construct such facilities (Mich. Comp. Laws §§117.4b (2002); 67.33 (1998)). Construction of stormwater systems is usually integrated with roads since most municipalities use a curb and gutter system to convey stormwater into the sewer and out to the receiving body of water.

4.1.3 Governmental Units in the Watershed

Government entities in the River Raisin watershed exist at many different layers, on different scales, and have different governing power and styles. In total, there are portions of two states, six counties, twelve cities and villages, and forty-one townships that make up the watershed. The population is generally spread out at a low density, with the major exceptions of the cities of Monroe and Adrian, where about two-thirds of the population live (Erickson 1994). Because only a small portion of the watershed is located in Ohio and that area contains no incorporated municipalities, this chapter will focus only on Michigan.

Given this complex network of government entities, the variety of laws, ordinances, policies and programs through which natural resource management is conducted is equally, if not more complex. The ability and potential for governments to make wise decisions with regard to preserving their natural resources and protecting water quality is most directly assessed through the analysis of the laws and regulations that guide their work. This chapter will focus on six municipalities and how well their ordinances promote stewardship and protection of water quality. The chapter ends by synthesizing the information provided and producing several model ordinances and recommendations for improvement at the local and watershed scale.

4.2 Methods

4.2.1 Review of Relevant Laws

Though municipalities in Michigan tend to have considerable autonomy to set regulations, they are still bound by state and federal laws. Preemption gives any federal law the power to trump state law on matters of disagreement. The 10th amendment also states that all powers not held by the federal government are delegated to the state. Thus, state and federal laws strongly influence environmental and natural resource protection. The following Michigan state laws were analyzed for their contribution to watershed protection and stormwater treatment: Natural Resources and Environmental Protection Act (NREPA; PA 454 (1994)), the Drain Code (PA 40 (1956)), City and Village Zoning Act (PA 207 (1921)), Home Rule City Act (PA 279 (1909)), Municipal Planning Act (PA 285 (1931)), and the Township Planning Act (PA 168 (1959)). Most federal oversight of water quality is summarized in the Clean Water Act (CWA; 33 U.S.C. s/s 121 et seq. (1977)).

4.2.2 Codes and Ordinances Worksheet

The Codes and Ordinances Worksheet ("the Worksheet") was developed by the Center for Watershed Protection (CWP) in order to provide communities with criteria for evaluating local ordinances' efficacy at encouraging watershed stewardship. The Worksheet is based on CWP's Better Site Design principles, which "employ a variety of methods to reduce total paved area, distribute and diffuse stormwater, and conserve natural habitats…Few watershed management practices simultaneously reduce pollutant loads, conserve natural areas, save money, and increase property values" (CWP 2005b). The goal of Better Site Design (BSD) is to accomplish these four goals at the local level.

The Worksheet is a scoring system with a total possible score of 100 (Appendix 13). It includes 66 opportunities to accumulate points. The points for each question range from one to four, though a vast majority of the questions are worth one or two points. The questions also vary by their goal: reduction of total paved area, conservation of natural habitats, or distribution and diffusion of stormwater. The points for each BSD goal are divided fairly evenly, though there are fewer opportunities to score points for distribution and diffusion of stormwater (Table 13).

The scoring process is simple because the Worksheet provides specific figures for measurements and sometimes gives partial credit for a less acceptable BSD principle. For example, "What is the minimum radius allowed for cul-de-sacs? *If the answer is less than 35 feet, award 3 points; If the answer is 36 feet to 45 feet, award 1 point"* (p. 1). The Worksheet also provides a scoring rubric to gage the progress of a given community. Those cities which score below 60 (out of 100) are encouraged to make substantial revisions to their ordinances to better implement the principles of BSD (Table 14).

Table 13. Point distribution among the three goals for ordinances in the Codes and Ordinances Worksheet

Goal of Ordinance	Number of Scoring Opportunities	Total Possible Points
Reduce Total Paved Area	24	39
Distribute And Diffuse Stormwater	14	21
Conserve Natural Habitats	28	40
Total	**66**	**100**

Table 14. Scoring Rubric from the Codes and Ordinances Worksheet

90 - 100	Community has above-average provisions that promote the protection of streams, lakes and estuaries.
80 - 89	Local development rules are good, but could use minor adjustments or revisions in some areas.
70 - 79	Opportunities exist to improve development rules. Consider creating a site planning roundtable.
60 - 69	Development rules are likely inadequate to protect local aquatic resources. A site planning roundtable would be very useful.
less than 60	Development rules are definitely not environmentally friendly. Serious reform is needed.

Selection of Municipalities

I selected six communities (Figure 33) for scoring and analysis based on four criteria. First, to ensure that the selected communities represented the entire area, three each were chosen from the upper and lower watershed using the description addressed in Chapter 1. Second, the communities had to be entirely enclosed in the watershed. This eliminated the city of Milan. The third criterion was that the communities needed to have sufficient population to have a noticeable effect if BSD principles were implemented. The main goal of evaluating local ordinances was to recommend suggestions so that their contribution to stormwater and non-point source pollutions could be reduced in the future. This last condition led to the selection of the four largest population centers in the watershed, Adrian, Monroe, Saline and Tecumseh, since they contribute the most impervious surface, industrial effluent, and stormwater to the river. With two remaining communities necessary to complete the analysis, a combination of population and proximity to the river resulted in selection of the villages of Manchester and Blissfield. Including two villages provides the opportunity to explore whether differences in population, and therefore tax base to provide resources for municipal administration in the communities affected their ability to implement BSD.

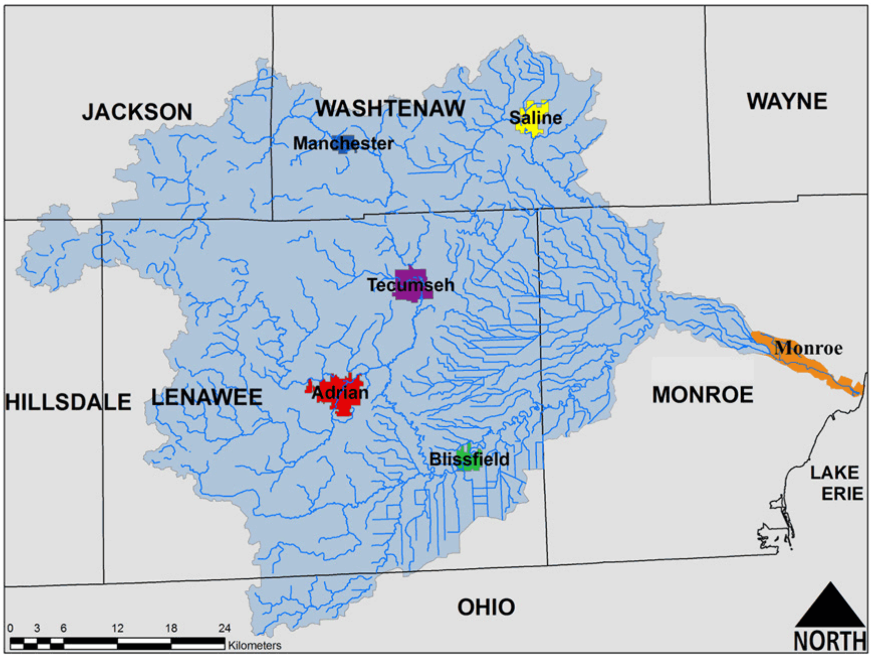


Figure 33. Map of the six municipalities analyzed using the Codes and Ordinances Worksheet

The six communities selected for scoring vary in a few characteristics, but population and median income are most relevant to this analysis. Population often correlates with the area of the community, the amount and density of houses and businesses, and the available pool of tax payers to support municipal services. Populations vary significantly: Manchester is the smallest (2,160) and Monroe is the largest (22,076), though Adrian is almost as large (21,574). However a large population does not necessarily mean a city will be more prosperous or have more services than a smaller community. For example, Adrian is the second largest community, but also has the lowest income. Median household incomes for 2000 range from $34,203 in Adrian to $59,382 in Saline. (Table 15). This variation among the communities in the watershed may lead to an equally wide variety of methods for managing stormwater, open space, and economic development.

Table 15. Population and median household income of six communities within the River Raisin watershed sampled for their performance in meeting water quality standards.

Community	Population (2000)	Median Household Income (2000)	Location in Watershed
City of Adrian	21,574	$34,203	Upper
Village of Blissfield	3,223	$39,437	Lower
Village of Manchester	2,160	$46,974	Upper
City of Monroe	22,076	$41,810	Lower
City of Saline	8,034	$59,382	Lower
City of Tecumseh	8,574	$46,106	Upper
Mean	**10,940**	**$44,652**	

Source: U.S. Census 2000

Townships were excluded from the ordinance assessment for several reasons. First, with 41 townships at least partly within the watershed, the required effort was not feasible. Second, the Codes and Ordinances Worksheet was developed for urban areas. Third, townships are unincorporated and though they have their own ordinances, they do not necessarily have a stormwater sewer system. Lastly, townships tend to have more agricultural land and less impervious surface than the other communities. Thus, their impact is likely to be less than that of villages or cities.

4.2.3 Existing Ordinances and Suggestions for Improvement

Electronic copies of municipal ordinances for five of the six communities were accessible online, while Manchester's ordinances were accessed in hard copy at the village office. (Table 16).

Table 16. Resources used for accessing municipal ordinances

Resource	Website	Municipal Ordinances Available
General Code	http://www.generalcode.com/webcode2.html#mich	• City of Monroe
Municipal Code Corporation	http://www.municode.com/Resources/code_list.asp?stateID=22	• Saline • Blissfield • Adrian • Tecumseh

The scores for each community according to the questions and associated points in the Codes and Ordinances Worksheet were entered into a spreadsheet. If there was no mention of the subject in the ordinances, that question received a score of zero. Following this initial scoring, I contacted a representative of each community regarding two matters. First, I confirmed that the ordinances online were the most up-to-date including recent revisions. Second, I asked for clarification on any areas where the municipality received a score of 0 or if the language was unclear. The total score was then summed, and expressed as a percentage of 100.

To assess the strengths and weaknesses of the ordinances across the watershed, I divided the questions into three categories: (1) all municipalities consistently met the goals of Better Site Design (BSD) principles and received full points from the Codes and Ordinances Worksheet; (2) no municipality received full points; and (3) there was a mix of scoring. Based on these categories, I suggested improvements based on the Worksheet and literature on the subject. Several model ordinances are provided as a guide for communities to use when revising ordinances in the future.

In order to get a more in-depth assessment of the strengths and weaknesses for individual community ordinances, I also analyzed each municipality's score. I divided the questions of the Codes and Ordinances Worksheet into the goals of BSD: (1) diffuse and distribute stormwater; (2) reduce paved areas; and (3) conserve natural habitat; and summed up the score under each goal. Thus, it was possible to assess the relative strengths and weaknesses of individual communities when compared to others in the watershed.

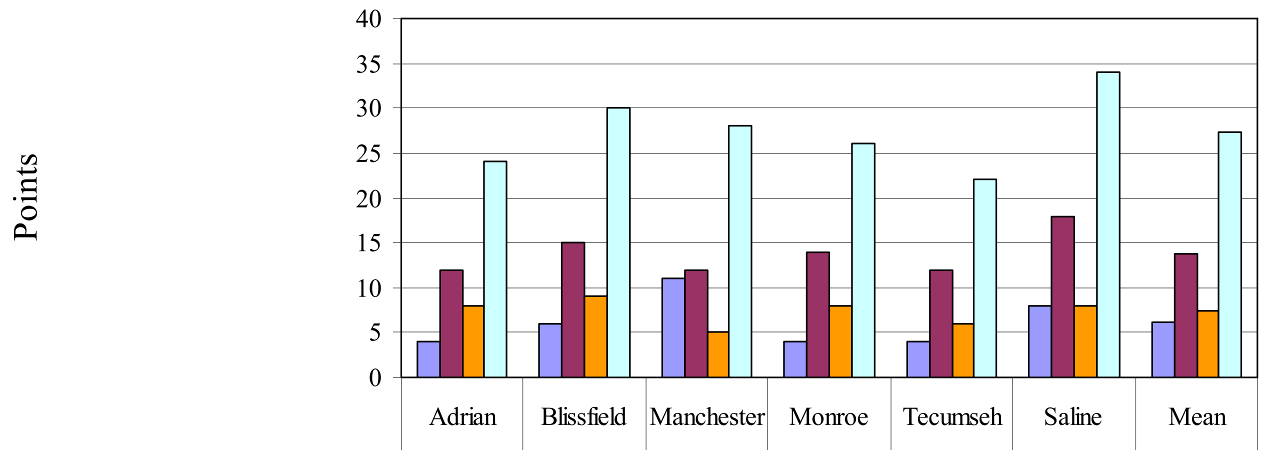
4.3 Results

4.3.1 Performance of the Watershed's Communities

As hypothesized, scores from the Codes and Ordinances Worksheet were fairly low and did not vary significantly among communities. Tecumseh received the lowest score and Saline received the highest. The scores have a range of 12 and the mean is 27.3 (Table 17). Scores for the three ordinance goals did not differ greatly among municipalities (Figure 34).

Table 17. Scores for six communities in the River Raisin Watershed from the Codes and Ordinances Worksheet

Community	Score (out of 100)
City of Adrian	24
Village of Blissfield	30
Village of Manchester	28
City of Monroe	26
City of Saline	34
City of Tecumseh	22
Mean	**27.3**
Range	**12**



	Adrian	Blissfield	Manchester	Monroe	Tecumseh	Saline	Mean
Distribute and Diffuse Stormwater	4	6	11	4	4	8	6.2
Conserve Natural Habitat	12	15	12	14	12	18	13.8
Reduce Paved Area	8	9	5	8	6	8	7.3
Total Points	24	30	28	26	22	34	27.3

Figure 34. Codes and Ordinances Worksheet scores by goal

Though no two communities' scores were identical, some broad similarities in the distribution of scores were apparent. Each of the municipalities received full points on 19 of the 66 questions (28 points) and zero points on 26 questions (43 lost points). There was a mix of scoring on the remaining 21 questions (29 points; Table 18).

Table 18. Summary of common scores by municipalities on the Codes and Ordinances Worksheet

Result	# Questions	Total Points
Received full points	19	28
Received zero points	26	43
Mixed scores	21	29
Total	66	100

The six municipalities received highest scores in the category of conservation of natural areas (mean score was 13.8 points), which also happens to be the area with the most opportunities for scoring points (40 points). A reduction of total paved areas was identified as the category of ordinances that needed the most improvement (mean score was 7.3 points). The mean score for distribution and diffusion of stormwater was 6.2. However, because there were only 21 possible points in the worksheet that address this goal, 6.2 points represents 29.4% of the total possible points. Thus, even though the mean score for reduction of paved areas is higher at 7.3 points, that score only represents 18.8% of the total possible points for this goal (Table 19). A discussion of scores for individual communities is in section 4.3.2 and resources for all of the recommendations that follow are provided in section 4.4.2 later in this chapter.

Table 19. Summary by goal of mean scores for all six communities from the Codes and Ordinances Worksheet

Ordinance Goal	Mean Score (# points)	Total Possible Points	% Mean Score/Total Possible Points
Reduce Paved Areas	7.3	39	18.8%
Conserve Natural Areas	13.8	40	34.6%
Distribute and Diffuse Stormwater	6.2	21	29.4%
Total	27.3	100	

Of the 28 points received by all six municipalities, 7 points were from ordinances which seek to reduce total paved (impervious) area (Table 19). These points came from the following ordinances. Utilities can be placed under the public right-of-way, according to the Metropolitan Extension Telecommunications Rights-of-Way Oversight Act (Act No. 48 of the Public Acts of

2002). Parking ratios for single family homes are 2 per dwelling. The minimum sidewalk width is 4 feet. "Two-track" driveway designs that have a grass strip in the middle are permitted in residential areas. Lastly, shared driveways are allowed in residential developments.

For the goal of efficiently distributing and diffusing stormwater, the communities of the watershed received full points on 3 of the 14 questions, for a subtotal score of 5 points. These points come from the following ordinances. The placement of landscaped islands in the middle of cul-de-sacs is permitted. In parking lots, a minimum percentage of the total area must be landscaped, and the incorporation of bio-retention islands (for example, between parking spaces or rows) to treat stormwater is allowed.

Lastly, the communities received 16 points, from 10 of the 27 possible questions for conservation of natural habitats (Table 19). Most of the ordinances pertain to open space or cluster-type developments, which are an option for developers in every community. Land conservation or reduction in impervious cover is stated as a major goal of these developments and flexible design criteria are permitted. Other strategies implemented by cluster developments are the minimization of side setbacks and frontages, restriction of allowable uses in open space, and designation of areas to be maintained in a natural condition. For all other residential housing, irregular-shaped lots are allowed (for example, corner or "flag lots"). For new developments (not just cluster-type), the preservation of natural vegetation is encouraged. Most importantly in this category is the prohibition of new development within the 100-year floodplain, as mandated by the National Flood Insurance Act of 1968, the National Flood Insurance Program and the Federal Emergency Management Agency.

The municipalities in the watershed received a score of zero for 26 questions; a loss of 43 points on the Codes and Ordinances Worksheet. Of these, the goal that needs the most improvement is reduction of total paved area, where municipalities lost 22 points (22% of the total points in the worksheet and 56.4% of the total points possible in this category). Reducing paved areas is possible in the following ways. First, there are several ways to improve streets. By reducing the width of residential streets, public right-of-ways, and driveways and the radii of cul-de-sacs and by incorporating strips of native vegetation among the pavement (such as landscaped islands or swales), vegetated area can be increased. Narrower streets are possible by avoiding the use of separate parking and traffic lanes on streets and designating parking lanes as traffic lanes for certain times of the day, such as morning and evening commute hours. Parking lots offer additional opportunities to reduce the area of impervious surfaces by defining the number of spaces by a median or maximum and reducing the size of individual spaces. Other methods to reduce paved area include multi-story parking structures and the use of pervious pavement.

Though scores were best for conservation of natural areas, every community still lost 15 points from 11 questions, or 15% of the total possible points in the Worksheet. Some improvements are possible through the rewriting of ordinances. First, open-space developments (like PUDs) should be a by right form of development. This means that

> "an open space plan that meets the requirements of the ordinance will go through the same permit and approval process as a conventional development. The by right form of development prohibits denial of an open space plan in favor of a conventional plan assuming the plan meets the provisions of the ordinance" (Stormwater Manager's Resource Center).

This will encourage the incorporation of open space into new developments and allow natural habitats to remain undisturbed. Along river and stream corridors, habitats can be protected and flood damage prevented through a stream buffer ordinance. In addition, designating permitted uses and mandating maintenance of the buffer with native vegetation is very important for protection of riparian areas. Not one municipality in the watershed protects the riparian corridor with a stream buffer. There are several benefits of buffers, and they are discussed in Chapter 3.

The final six points lost by all six municipalities in the worksheet came from those ordinances that specify the need to diffuse and distribute stormwater effectively. There are several ways that communities can more effectively treat stormwater. First, mandating the treatment of stormwater before it is discharged into receiving waters will prevent trash and chemicals from polluting the River Raisin. Second, preventing the discharge of stormwater into wetlands will protect these fragile ecosystems. Third, establishing effective criteria for best management practices will provide the necessary guidelines to assure proper stormwater treatment without having to build expensive structures. In Manchester, Monroe and Saline, best management practices were "encouraged" or even used by the city, but their ordinances had no specific guidelines or performance standards.

Table 20. Summary of common scores by six municipalities on the Codes and Ordinances Worksheet by goal

	Ordinance Goal			
	Reduce Paved Areas	**Conserve Natural Areas**	**Distribute and Diffuse Stormwater**	**Total**
# Points Scored	7	16	5	28
# Points Missed	22	15	6	43
# Points with Mixed Scores	10	9	10	29
Total	**39**	**40**	**21**	**100**

4.3.2 Scores by Individual Municipalities

City of Adrian

Adrian received half of its total 24 points from ordinances to meet the goal of conserving natural resources, one-third from reduction of paved area, and the remaining 17% from distribution and diffusion of stormwater (Figure 34). Compared to the other communities, Adrian had the second lowest overall score and performed below the mean in diffusion and distribution of stormwater, and conservation of natural habitat, but slightly above the mean for reduction of paved areas.

Village of Blissfield

Blissfield received the second highest score of the six communities in the watershed, just four points behind the City of Saline (30). The distribution of points for Blissfield's score was very similar to that of Adrian (Figure 34). When compared to the other municipalities, Blissfield scored just under the mean for diffusion and distribution of stormwater, but above the mean for the other two categories of ordinances. Blissfield had the best score for reduction of paved areas. One ordinance that is particularly effective at addressing this goal is encouraging the use of "t-type" intersections instead of cul-de-sacs. These are also used to discourage the extension of too many through roads and reduce traffic (Sec. 210.042(4)).

Village of Manchester

Manchester's Codes and Ordinances Worksheet score (28) was just slightly above the mean (27.3) and ranked third of all of the communities in the watershed. The village received 43% of its points from ordinances that seek to conserve natural habitats, 18% from those that try to distribute and diffuse stormwater, and the remaining 39% from those that reduce paved area (Figure 34). While Manchester scored well above the mean for its attempts to treat stormwater, the other two areas suffered and the village scored below the means. There are three examples of superior ordinances for stormwater treamtment in Manchester. First, while most other municipalities don't even mention best management practices (BMPs), Manchester's zoning ordinances encourage them and direct parties to the Washtenaw County Drain Commission for further information on design criteria. Treatment of stormwater on lawns is also encouraged to allow for infiltration (section 6.11.2). Third, pervious materials are permitted for some parking areas (section 9.5.1).

City of Monroe

Monroe is the largest city in the watershed, and is located at the point where the River Raisin drains into Lake Erie. Its score (26) ranked it fourth of the six communities, and below the mean (27.3). Over half of its total score came from attempts to conserve natural habitat (54%), about one third came from reducing paved areas (31%), and the remaining 15% was from distribution and diffusion of stormwater (Figure 34). In comparison to the other cities and villages in the watershed, Monroe scored below the mean for stormwater treatment, but just slightly above the mean for the other two ordinance goals.

City of Tecumseh

Tecumseh was the lowest-scoring community in the watershed, at 22 points out of a possible total score of 100. The city's point distribution was very similar to that of Monroe (Figure 34). Due to its low overall score, Tecumseh scored below the overall mean score for the watershed for all three ordinance goal categories.

City of Saline

Saline received the highest score out of the six communities in the watershed (34). 52% of the city's score came from conservation of natural habitats, and the rest was evenly divided between stormwater treatment and reduction of paved areas (24% each; Figure 34). In accordance with its top score, Saline performed above the mean in all three categories, though it had the highest score for conservation of natural habitats. Some ordinances that are particularly effective at meeting this goal include a city task force with the mission of identifying and preserving special "areas of concern" for open space (Sec. 2.257) and considering cluster-type housing projects a by-right form of development, with no special approval process (Zoning Ordinance Appendix A, Sec. 6.02 (2)).

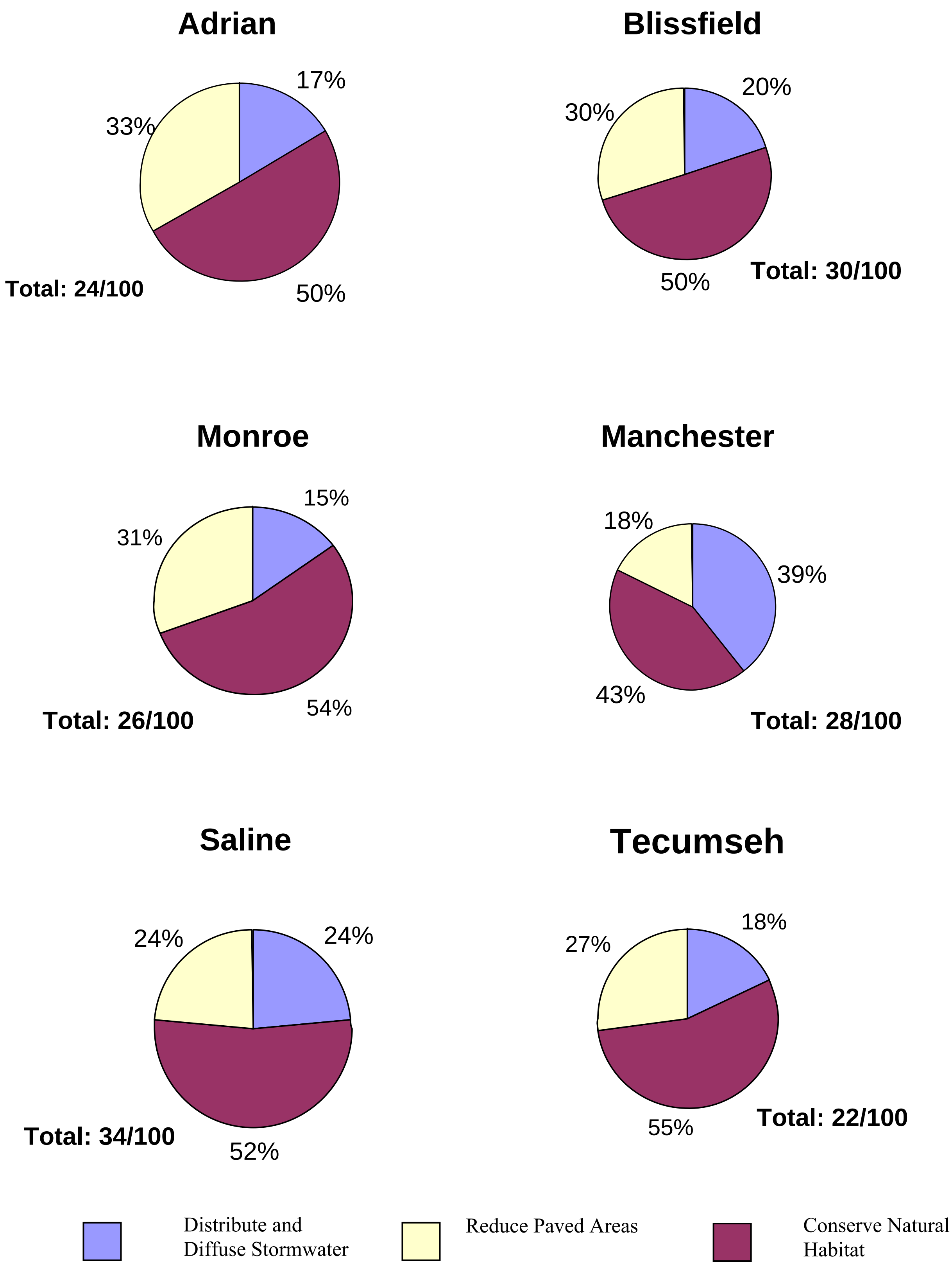


Figure 35. Distribution of scores by goal for the six watershed communities

4.4 Discussion and Recommendations

4.4.1 Evaluation of Existing Ordinances

Based on the Codes and Ordinances Worksheet's scoring rubric, the six River Raisin watershed municipalities all fall under the category, "Development rules are definitely not environmentally friendly. Serious reform is needed." However, low scores are not unusual. As a staff member at the Center for Watershed Protection reports, "Most places are scoring in the 30-50s…I haven't seen many score higher" (Anne Kitchell, personal communication 11 January 2006). Furthermore, the purpose of this scoring system is to provide an opportunity for communities to discuss the three goals of Better Site Design, and how they can improve their score by revising ordinances. The significance of these results is not to criticize existing policies, but to suggest revisions that benefit the entire watershed.

Several factors likely contribute to the reported results and should be taken into account in watershed planning. First, population dictates the potential number of customers that must be served by municipal utilities and other services like stormwater sewers. Thus, smaller communities may have less developed and less technologically advanced stormwater systems and simpler planning processes with a smaller board responsible for reviewing zoning and planning applications. Next, income and the community's tax base influences their ability to update infrastructure, hire engineers, and contribute to overall stewardship activities and responsible planning. Third, physical location within the watershed may be important. Most of this report has focused on the upper portion of the watershed because it is the least developed and populated, and has the greatest potential for restoration. The lower watershed, then, may have been unsuccessful at designing ordinances to improve water quality through Better Site Design. Furthermore, pollutants tend to accumulate downstream, and so the lower watershed is responsible for treating a more impacted river than those communities in the upper watershed.

Comparing worksheet scores between the upper and lower watershed, there is an interesting difference in scores, but income and population are fairly similar. The upper watershed received a lower mean score (24.7) from the Worksheet, whereas the mean score for the upper watershed communities (30) is almost 6 points higher. Given that the range of all six scores is only 12, the difference of six points between the two halves of the watershed is significant.

There is also an interesting correlation between Worksheet scores and median household income (Figure 36). Higher scores were obtained by those municipalities with higher median incomes (R^2=0.40). Therefore, income is a reasonable indicator of score.

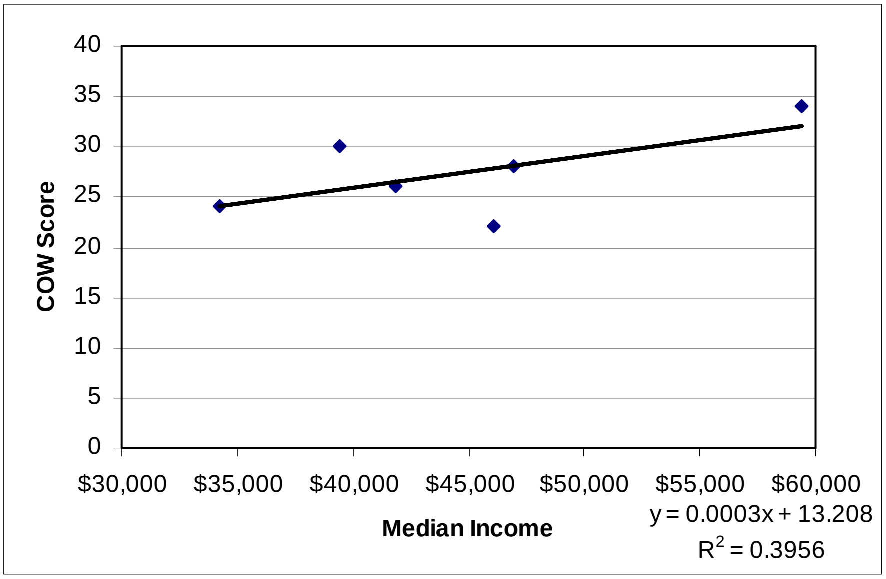


Figure 36. Relationship between Worksheet score and median household income.

4.4.2 Model Ordinances

It is not feasible to instantly reduce the amount of impervious cover, protect significant habitat, and reconfigure the stormwater distribution systems that currently exist in the watershed in order to meet the goals of improving water quality in the River Raisin. We recognize that stormwater and other public works infrastructure for many communities were designed 20-50 years ago before current environmental laws brought attention to the potential degradation of local water resources. Furthermore, changes to current laws and policies even at the local level, take time to approve, fund, and implement. Some improvements are simply too costly or on a scale that spans many municipalities and counties; either way, they are too large to undertake at this time.

Based on these considerations, this section seeks to encourage the use of Better Site Design

(BSD) instead. BSD is the basis for the questions in the Codes and Ordinances Worksheet and offers a set of guidelines that promote more sustainable land use planning in order to improve watershed health.   In order to increase the effectiveness of local ordinances, this section suggests areas in the municipal code to edit, and provides model ordinances which communities can use to re-write current ordinances that are not meeting the three goals of BSD: reduce paved areas, conserve natural habitats, and distribute and diffuse stormwater.

Goal 1: Reduce Paved Areas

Impervious cover is one of the largest contributors to non-point source (NPS) pollution in urban areas. NPS pollution is the leading source of water quality degradation in the watershed, and provides the impetus for the development of the watershed management plan. There are two major components to the impervious surface of any community: rooftops and the transportation system (including parking lots, sidewalks, streets, and driveways), with the latter being the largest contributor due to the automobile-based society of the U.S (Arnold and Gibbons 1996). The transportation network is especially important in more rural areas like the Raisin watershed, where industrial facilities with large warehouses are uncommon, residential lots are large, and farmland makes up a majority of the land use.

Reducing paved area is particularly important to the watershed because it is the area in which the six sample municipalities of the Raisin watershed scored the lowest (mean score was 18.8%). While larger residential lots can decrease the imperviousness contributed by roofs, "large lot zoning often increases the total amount of impervious created for each dwelling unit. This is caused by the longer road network needed to connect…lots" (Schueler 1995, p. 38). In addition, larger lots consume 16 times more water (mostly for outdoor landscaping) than do smaller, urban residential lots (Otto et al. 2002). Reducing paved areas in the River Raisin watershed can improve water quality and quantity.

Additional roads to connect low density residential developments contribute to exurban sprawl. Exurban and suburban sprawl are no longer separate phenomena (Nelson and Sanchez 1999). Thus, the threats to the environment from suburban growth (including air and water pollution, destruction of forests and other natural habitats, etc.) are equally as great as from the exurban growth happening in the watershed. Otto et al. (2002) conducted an analysis of sprawl in 312 U.S. metropolitan areas. The Detroit metro area was ranked 16th in total area of land developed from 1987-1992. In addition, the amount of developed land grew by 25%, while the population only increased by 1% . Thus, the rate of development far exceeds the rate of population growth. This high amount of impervious surface translates into a loss of 7.8 to 18.2 billion gallons of water from natural infiltration of precipitation to local aquifers. To control sprawl and reduce impervious surfaces, there are two components of the transportation network that can be reformed through local ordinances: parking lots and streets.

Parking lots are one of the main contributors to impervious surface within a town center. While free parking is a popular method to encourage patrons to local businesses, most spaces are underused. All six municipalities studied in the watershed report that the parking provided by city lots alone is sufficient, if not in excess. A study conducted in several suburbs of southern California (where population density is much higher than in the Raisin watershed) found that peak parking utilization was only 56% (Wilson 1995, p. 32). Thus, even at the busiest times of days, nearly half of the spaces were empty. Since population density is low in the watershed, there is a lower demand for parking and no need for large lots. Lot design and parking ratios can be made more flexible in order to reduce the impervious surface that parking lots create.

It would be infeasible and impractical to consider tearing up existing parking areas, but it could be quite simple to edit ordinances to reduce the number of parking spaces required for future development. Adrian is the only city of the six sampled in the watershed that meets the BSD guidelines for the minimum ratio of parking spaces for both professional office buildings (3 per 1000 square feet) and shopping centers (4.5 per 1000 square feet). The remaining communities suggest anywhere from 5-10 spots per 1000 square feet. In a low population area such as the Raisin watershed, this amount of parking may be unnecessary.

The City of Ann Arbor recently reduced their minimum parking requirements for office buildings and retail centers and for the first time added a maximum requirement. Previously, offices were required to have a minimum of four spaces per 1,000 square feet. Now that minimum is reduced to three and there is a new maximum of four spaces for the same floor area. For retail spaces, parking spaces were reduced from a minimum of five spaces per 1,000 square feet to a range of 3.25 to 4.25, depending on the total size of the shopping center. During the revision, the city found that no one was using five spaces per 1,000 square feet even during the holiday shopping season. Now, Ann Arbor is able to provide parking for shoppers and support the local economy while mitigating the negative impacts to the environment caused by large paved areas (SEMCOG 2003, p. 68). For examples of other model ordinances and tools for revising parking regulations, see Table 21.

Table 21. Resources for model ordinances to reduce impervious surfaces of parking lots

Issue to be Addressed	Resource	Model City
Reduce parking ratios	Land Use Tools and Techniques Handbook (accessible at http://www.semcog.org/Products/Publications/index.htm)	Ann Arbor, MI
Design Criteria for Porous Pavement	http://www.epa.gov/owm/mtb/porouspa.pdf	Rockville, MD and Prince William, VA

Residential streets are one of the major sources for common water pollutants, and are the surface from which the highest *E.coli* concentrations were found when compared to lawns and industrial streets (Warbach 1998). Since residential streets make up 50-65% of the overall road network, they are a particular area of concern for contribution to water pollution. Reducing the length and width of residential streets, then, is an important improvement that municipalities can make to reduce the total surface area where pollutants can accumulate.

Residential street minimum widths in the sampled municipalities range from 25 feet (Blissfield) to 60 feet (Adrian). BSD principles suggest that minimum street widths should vary depending on the number of homes since that will also determine the average traffic on the street. For example, for streets with less than 10 homes, 16 feet is sufficient; while streets with higher densities (more than 6 homes per acre) may need 32 feet for proper movement (Scheuler 1995).

Goal 2: Conserve Natural Habitat

The six sampled municipalities performed best in meeting the goals of conserving natural habitat, though the mean score (34.6%) still leaves plenty of room for improvement. This particular goal of local ordinances deserves even more attention to improvement than the others, because preserving natural areas is the most effective way to reduce impervious cover in rural communities (Arnold and Gibbons 1996). Furthermore, forested or open space areas provide a much more natural method for treating stormwater and filtering out pollutants that would otherwise be flushed into the river. Thus, improving ordinances to meet the goal of conserving natural habitat will also help to meet the other goals for pollution prevention.

In the Raisin watershed, several natural features including the river, forests, streams and wetlands are remarkable natural assets that should be integrated into community activities. These resources must also be included in any open space management or master plan to highlight and protect the natural assets of the watershed.

It is particularly important for local governments to plan for open space preservation since they are the entities that often “provide the genesis for most open space preservation efforts”, which can then be aided by state and federal government agencies (SEMCOG 2003, p. 14). A community can create and protect open space in several ways. First, they can acquire parkland through outright purchase. Parcels for parks should abut natural features and contribute to an overall aesthetic enhancement of the community. Second, communities can make use of conservation and open space easements.

> “A conservation easement is a voluntary, legally binding agreement that limits certain types of uses or prevents development from taking place on a piece of property now and in the future, while protecting the property’s ecological or open-space values” (The Nature Conservancy 2006).

This would be particularly applicable to farmland that has decreased or ceased production since fields are already large open spaces. Easements are flexible to meet the needs of the landowner and can grant tax breaks for the property owner, while they still maintain ownership of the land and continue to live, work, and farm the property, if desired. The Raisin Valley Land Trust has been working to preserve land in the watershed since 1992, and has successfully protected 500 acres of land in Jackson, Lenawee, and Washtenaw Counties.

A third method for establishing and protecting open space is through greenway corridors. As suggested through identification of habitat corridors in Chapter 3, two stretches of riparian land in the upper watershed are appropriate for greenways: between the cities of Tecumseh and Adrian, and between the Sharonville State Game Reserve and the Village of Manchester. A corridor of natural areas and walking trails would be an effective opportunity to draw attention to the natural beauty of the river and to culturally connect two areas that are otherwise geographically and politically separate. Intergovernmental cooperation is an integral component. County governments or land trusts experienced at identifying and acquiring land are valuable resources to the individual cities of the watershed.

Barriers to open space preservation include high cost and the scarcity of appropriate land. Land is expensive, especially when it contains important natural features. It is also common for communities to grow quickly, and find themselves left with a small selection of desirable land that could be eligible for preservation. However, several local, state and federal sources of funding for parks and open space are available. Because of the numerous benefits that open space provides, several land trusts and other non-profit organizations in southeast Michigan specialize in helping local governments acquire and finance natural areas. For governmental grants, a community must provide a recreation plan to the Michigan Department of Natural Resources (MDNR) to prioritize needs, plan for specific uses, and propose financing (SEMCOG 2003). The four cities in the watershed (Monroe, Saline, Tecumseh and Adrian) already have established and successful parks or recreation departments.

Protecting open space can be a daunting task that involves several stakeholders and long-term planning. It is useful to look to model ordinances in other cities for effective language and implementation strategies (Table 22).

Table 22. Resources for model ordinances which address open space

Issue to be Addressed	Website	Model City
Establishment of Open Space Goals and Requirements	http://www.stormwatercenter.net/Model%20Ordinances/open_space_model_ordinance.htm	
Establishment of an Open Space District	http://www.stormwatercenter.net/Model%20Ordinances/open_space_land_preservation_ord.htm	Montgomery County, PA

Residential areas contribute significantly to the clearing of forests and natural areas, even when large lot zoning is implemented. Large lots often are maintained with fertilizers and other chemicals that can contribute large amounts of phosphorous and nitrogen to water resources. Therefore, by concentrating developed areas into a smaller space and setting aside the remaining area as a natural area or park one can meet all three goals of BSD and improve water quality in one way by reducing the number of chemicals applied to lawns. Thanks to recent amendments to the City and Village Zoning Act, developers have the option to plan cluster, or planned urban developments (PUDs; in Tecumseh, they are referred to as Environmental Residential Communities and in Saline, Community Unit Plans). While providing benefits to the environment and significant aesthetic benefits to residents, developers are also given more flexibility regarding setbacks, frontages, and density.

A major consideration in zoning PUDs, however, is that higher density developments will result in increased impervious cover even though open space is preserved. Concentrating paved areas in one section of the watershed or community will prevent other areas from exceeding the threshold from which impervious cover tends to negatively impact waterways. Although there is some uncertainty concerning the exact threshold for when stream quality becomes impacted (10%, Scheueler 1995; 10-30%, Allan 2004), high levels of impervious surface are to be avoided. Housing can be clustered in one area, thereby reducing the need for clearing forests and building roads and homes in other areas. This delicate balancing act forces city planners to address "the dilemma that by trying to protect one stream, it may be necessary to degrade another" (Scheuler 1995, p. 38).

Despite the small area of increased paved and rooftop area contributed by PUDs, they convey significant measurable benefits. During construction, higher density sites produce 5 percent of the runoff that is produced in lower density sites (Madsen and Shriberg 2005). Costs for public services are also lower for higher density developments. A study conducted by the American Farmland Trust (1986) "found that net public costs were approximately three times higher ($2,200 per dwelling) where the density was one unit per five acres, than where the density was 4.5 units per acre ($700 per dwelling)" (Brabec, 1994, p. 280).

It is important to give developers the option to build PUDs but it even more important to make sure that the ordinances are strong enough to ensure that the goals of increasing open space are met through the use of effective language. For an example of an effectively written PUD ordinance , please see article 14.00 of Hamburg Township's zoning ordinances, accessible at http://www.epa.gov/nps/ordinance/openspace.htm.

Stream buffers have many benefits for communities fortunate enough to border the River Raisin or its tributaries. Most incorporated cities and villages in the watershed are located on the main stem of the River Raisin or major tributaries (the city of Saline is on the Saline River). Buffers provide an excellent means to reduce water pollution and preserve forest cover along the riparian corridor (Madsen and Shriberg 2005). Buffers also have aesthetic qualities that can be used as an educational tool to teach school groups about riparian habitat and vegetation through interpretive signs. They can also provide a nice setting for a running or hiking trail. It is also important to note that buffers can be used to protect any water body, and need not be limited to the main stem of the River Raisin. Other water resources that could benefit from a buffer include creeks, wetlands, and lakes. Unfortunately, none of the communities in the watershed has implemented a stream buffer ordinance. Implementing such a law is a great opportunity for every community to contribute to protection of the River Raisin.

The Raisin Valley Land Trust (RVLT) is currently working with other land trusts and governmental agencies in the area to link up streamside lands in Washtenaw County through conservation easements to provide a buffer through Sharon, Manchester, and Bridgewater townships. They are also interested in working with landowners in other communities (RVLT

2005).

Michigan's Floodplain Regulatory Authority requires a permit for new buildings in the 100-year floodplain (Mich. Comp. Laws §324.3104). However, a stream buffer can provide much more than this restriction. With stricter regulations to ban all development in the floodplain (at present, some permits can bypass the current restrictions on development) and mandatory maintenance of the riparian corridor in a natural state (especially with native plants), the potential benefits of a stream buffer ordinance can be maximized. For more information on the benefits of a stream buffer, please see Chapters 2 and 3.

There are three parts to a buffer (in order of increasing distance from the water): the streamside, middle, and outer zone. While they are interconnected, there are different recommendations for each zone according to its function:

> "The streamside zone should be maintained as mature forest, with strict limitations on all other uses. It also produces the shade and woody debris that is so important to stream quality and biota. The middle zone is typically 50 to 100 feet usually targeted toward a managed forest with some allowable clearing. The outer zone, usually about 25 feet, encourages forest, but also can include turf. The three-zone buffer is variable in width and should be increased to allow for protection of special areas such as wetlands and the floodplain"
> (Center for Watershed Protection 2005c)

According to the Codes and Ordinances Worksheet, the minimum recommended buffer width is 75 feet, although the width depends on the area, slope, and other natural features of the floodplain (including groundwater seeps, wetlands, and plant and wildlife communities). For example, communities in New Jersey successfully protected their drinking water sources with buffers of 150 to 300 feet (Madsen and Shriberger 2005). Four of the six reviewed communities get their drinking water from local wells: Manchester, Saline, Tecumseh, and Adrian. Thus, protection of wellheads is another factor to include in delineating stream buffers. Although there is no clear consensus on optimal buffer width, there are several other elements that are important parts of a good stream buffer ordinance. Green Oak Township in Livingston County has an excellent stream buffer ordinance to protect Davis Creek because there are specific guidelines for the various constituents and uses within the buffer (Table 23).

Table 23. Elements of a model stream buffer ordinance (Green Oak Township, Livingston County, MI)

Issue to be Addressed	Requirements
Setbacks	Minimum setback is 125 feet from the high water mark for new buildings
Development on the floodplain	Cutting and/or filling of the floodplain is prohibited within 500 feet of the river's edge
Vegetation	A natural vegetative strip is designated along the river
Septic Systems	Prohibited within 150 feet of the river
Use of chemicals and fertilizers	Prohibited along the floodplain

Source: SEMCOG 2003, p. 117

No two buffers are alike, and so municipalities must tailor their ordinance depending on what exactly a city is trying to protect along the river corridor. Some resources including model ordinances are provided below in Table 24.

Table 24. Model stream buffer ordinances

Issue Addressed	Website	Model City or County
Expansion of buffers for erodable soils and steep slopes	http://www.stormwatercenter.net/Model%20Ordinances/baltimore_buffer_ordinance.htm	Baltimore County, MD
Riparian areas with little forest cover (could be appropriate for areas where agricultural land lines the River Raisin)	http://www.stormwatercenter.net/Model%20Ordinances/napa_buffer_ordinance.htm	Napa, CA
Reduce flood risk and protect natural function of floodplain	http://www.stormwatercenter.net/Model%20Ordinances/portland_buffer_ordinance.htm	Portland, OR
Comprehensive list of resources for stream buffers	http://www.gwf.org/gawater/GA%20Buffer%20Bibliography.pdf	various

Goal 3: Effectively Diffuse and Distribute Stormwater

While communities are responsible for managing their own stormwater, there are different approaches and various levels of mimicking the natural dispersal of runoff. The Natural Resources and Environmental Protection Act of Michigan (NREPA) mandates that zoning ordinances include regulations on "stormwater drainage that provides for disposal of drainage water without serious erosion" (Mich. Comp. Laws §324.35314 (1995). This section essentially prohibits municipalities from letting runoff flow in large sheets across the land, which can contribute to erosion of dirt and other materials from land surfaces and eventually cause sedimentation of streams and erosion of river banks. However, it still does mean that all runoff must be immediately shunted off the land, into sewer systems, and eventually into the River Raisin without some sort of treatment.

There is no state law that regulates stormwater treatment, and the vagueness of the Drain Code leaves much discretion up to the County Drain Commissioners. The task of stormwater quality management has fallen to some drain commissions in the state, although it is not mandated. This is due in part to the strong land development lobby in the State that finds it inconvenient and expensive to pay for stormwater systems in new developments. In addition, the Land Divison Act (1967) allows for the split of a parcel of land into 22 smaller parcels before a stormwater management plan is required. However, new subdivisions must obtain drain commission approval before they can begin construction (Michelle Bononi, Washtenaw County Drain Commission, personal communication 3 February 2006).

The counties of the watershed all have their own way of approaching stormwater management. Washtenaw County has adopted a "philosophy that considers stream channel protection and stormwater quality management in addition to flood control", the latter traditionally being the main function of the drain commission (Washtenaw Drain Commission 2000). Lenawee County has embraced the duty of providing effective design criteria for BMPs and encourages its communities to adopt the county's stormwater management plan. Included in the plan are specific design criteria for a wide range of BMPs as well as detailed instructions on how to submit a plan to the drain commission to use one of these methods of stormwater management.

Two of the three Lenawee County communities (Tecumseh and Blissfield) discussed in this report have adopted the plan, while Adrian had not as of March 16, 2005 (Lenawee County Drain Commission 2005). The city engineer of Adrian explains that he will recommend adoption of the plan in the near future, and has only resisted up to this point to maintain local control over city operations (Keith Dersham, City of Adrian, personal communication 27 February 2006). Monroe County is in the process of receiving public comment on their stormwater management plan, which has a planned implementation date of October 15, 2006 (Monroe County Drain Commission).

The Environmental Protection Agency (EPA) currently requires major metropolitan areas to obtain a permit for discharge of their stormwater to assure that effluents meet the water quality standards of the Clean Water Act. In addition, there is a second phase of such permits that is mandated in smaller cities and suburban areas. These permits (known as MS4s) are discussed in Chapter 2. Of the cities in the watershed, only Monroe and Saline fall under this category. These two cities must meet several requirements (EPA 2004). Since two-thirds of the cities analyzed in this chapter do not fall under this category, the focus of recommendations to improve stormwater treatment will be on a much smaller scale that requires smaller scale improvements: utilizing best management practices and developing a stormwater utility and fee system.

Examining the effectiveness and design of all the available best management practices is beyond the scope of this report. However, the growing interest in effectively treating stormwater before it is discharged into water bodies has encouraged the development of several helpful resources (Table 25).

Table 25. Resources for Best Management Practices (BMPs)

Issue Addressed	Website	Model City or County
BMP Efficiency	Silk, N. and K. Ciruna. 2004. A practitioner's guide to freshwater biodiversity conservation. Island Press, Washington DC, Chapter 4	
Erosion/sediment control and stormwater treatment	http://www.stormwatercenter.net/Model%20Ordinances/operat__maint_grand_traverse.htm	Grand Traverse County, MI
Maintenance of BMPs by property owners	http://www.stormwatercenter.net/Model%20Ordinances/operat__maint_albemarle.htm	Albermarle County, VA

At the local level, governments in the watershed can implement the following ordinance revisions to improve their stormwater treatment:

(1) Replace curb and gutters with vegetated swales or filter strips
(2) Allow the discharge of rooftop runoff to pond on lawns for infiltration before being let out into the stormwater sewer
(3) Design affective design criteria for best management practices

To effectively update infrastructure and dedicate staff resources to managing stormwater, the development of a special management authority to handle stormwater is an attractive option for some municipalities. As with other local utilities like public water, the stormwater utility would collect a small fee from residents for the use of the sewer system. That money would then go into a fund to improve infrastructure and hire staff to work on flooding and other related issues.

Stormwater utility fees can be calculated in several ways. A flat fee for all property owners is easiest, but this differs from normal property taxes because it is not based on the property's value. Another option based on the proportional contribution to stormwater is a graduated fee scale based on the amount of impervious cover of a given property. However, this requires significant effort in the examination of parcel plans for square footage of buildings, lawns, and other features of a property. For the communities in the Raisin watershed, the flat fee would be the easiest way to begin.

The City of Adrian is the only municipality of the six analyzed in the watershed with an established stormwater utility fee. When infrastructure repairs were urgently needed about 10 years ago, road construction funds were used for stormwater sewers. However, streets were left in disrepair and the stormwater system was not being repaired in a timely manner. Creation of the utility has helped relieve both systems of debt and is able to generate $350,000 per year to contribute to updating infrastructure (Keith Dersham, city engineer for Adrian, personal communication 27 February 2006). The city charges property owners (including the city itself) for use of the stormwater system based on the amount of impervious surface on the property. Residential property owners are charged a flat fee of $1.60 per month, while commercial and industrial owners pay anywhere from $0.08 for undeveloped land to $0.32 for heavily developed land for each 1,000 square feet. A minimum monthly fee of $1.00 is charged to all owners, even if they have a small amount of space (Sec. 74-164). The ordinances also encourage property owners to treat their stormwater on-site, and as a reward, the city will lower the stormwater fee accordingly (Sec. 74-165). This system should serve as a model for the rest of the city as an excellent means to raise funds to deal with stormwater issues in an equitable manner for all contributors to the stormwater sewer. For further examples of a stormwater utility and management plans, see Table 26.

Table 26. Model ordinances for stormwater utilities

Issue Addressed	Website	Model City
Establishing a stormwater authority	http://www.epa.gov/owow/nps/ordinance/documents/takoma_park_misc.pdf	Takoma Park, MD
Stormwater Management Plans and Design Criteria	http://www.stormwatercenter.net/Manual_Builder/stormwater_ordinance.htm	

5 Recommendations

Conversion of arable land for agricultural purposes and recent increases in exurban development in the headwaters of the River Raisin Watershed have seriously compromised the ecological integrity of the watershed. Despite these stresses and development pressures placed upon the watershed, however, many natural areas within the upper portion of the Raisin headwaters are still of high quality.

Water quality measurements conducted in Hazen and Evans subwatersheds found elevated levels of nutrients and total suspended matter, compared to the upper River Raisin subwatershed. Coinciding with the water quality data collected, Evans, Hazen and the South Branch have riparian buffers widths under 16 m on more than 60% of their streams. Efforts in these subwatersheds should be concentrated to restore riparian buffers and wetlands utilizing the Conservation Reserve Program (CRP), Landowner Incentive Program, and conservation easements.

Riparian conservation efforts should not only target degraded riparian habitats, but also must protect areas of high quality to prevent future degradation. Such opportunities to protect high quality habitats exist along wildlife corridors of the River Raisin mainstem. Greenways are one method of riparian conservation that provides excellent recreational and educational opportunities for residents of the watershed, in addition to protecting important ecosystems. There are two areas of the upper watershed that would be ideal for a greenway to protect water quality and maintain wildlife corridors: (1) along the mainstem between Adrian, Tecumseh, and Clinton Township and (2) along the mainstem between Sharonville Game Reserve and the village of Manchester.

The first of the proposed greenways is a unique case because it has a healthy wildlife corridor along the river despite two growing cities, Tecumseh and Adrian. These cities are in need of the most revision to ordinances concerning water quality and stormwater management. Thus, an opportunity exists to design ordinances to proactively address the existing weaknesses in ordinances and work to prevent further degradation. For example, these could be the first municipalities in the watershed to adopt a riparian buffer ordinance to permanently protect the wildlife corridor along the river.

Another way to protect the quality of the watershed is through better design of future developments. Promotion of compact business centers will increase density and create a pedestrian-friendly community. New developments and subdivisions in the watershed that are not infill should be targeted towards unproductive agricultural sites in order to preserve forest and wetland areas in their undeveloped state. Developments of this sort are highly desirable due to the reduced amount of impervious surface, infrastructure, and consumption of natural resources.

Recommendations developed by the team identify potential threats to the watershed and suggest management priorities requiring further investigation. This analysis creates a foundation for the River Raisin Watershed Council and Nature Conservancy to further protect the ecological health of the River Raisin. Lands of high conservation value still exist within the watershed and the integration of political, economic, and social factors that shape the management of the river must be further addressed. The integration of our analysis and recommendations into the watershed management plan will help communities dependent upon the River Raisin to preserve the rich resources of the watershed for future generations.

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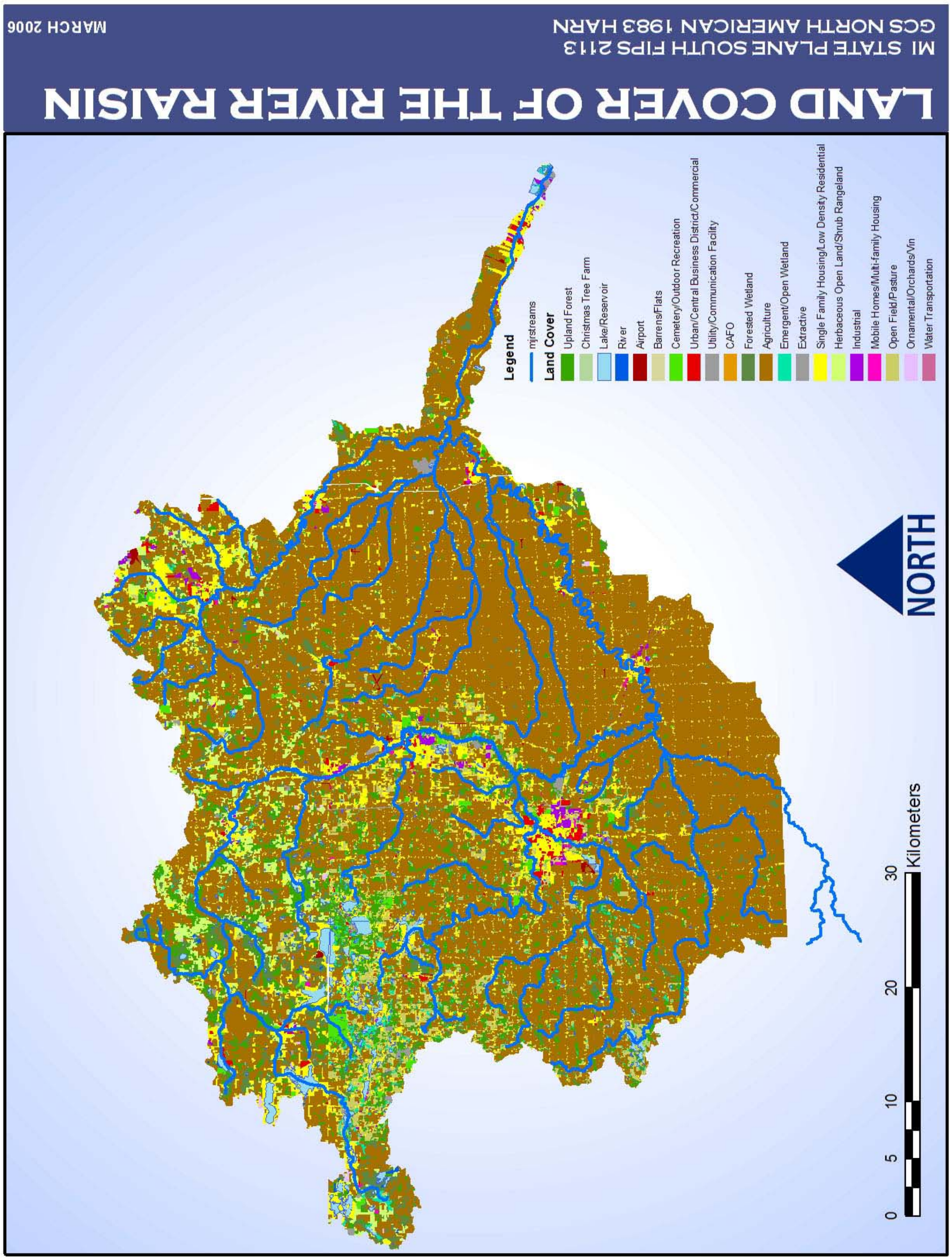
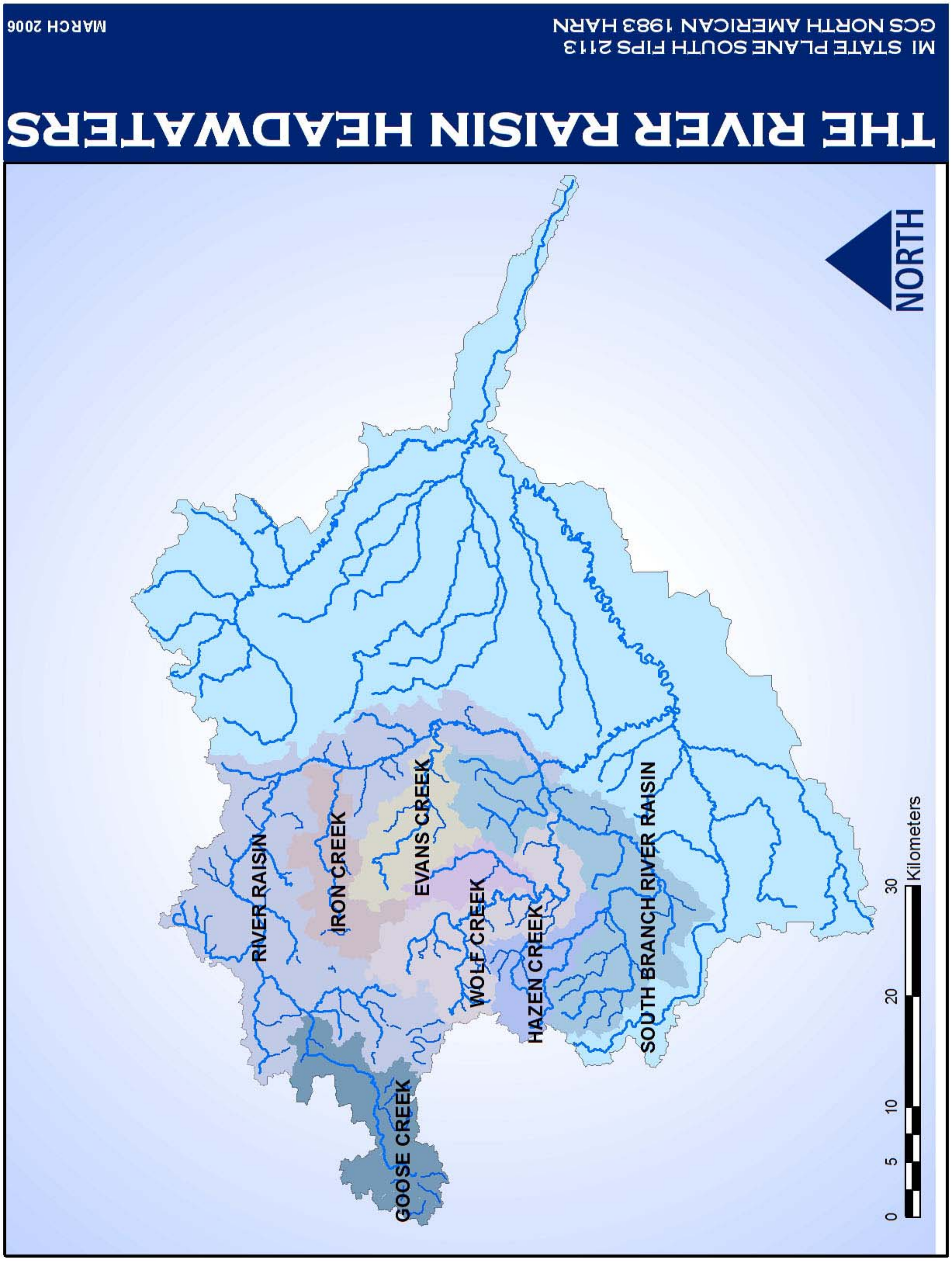
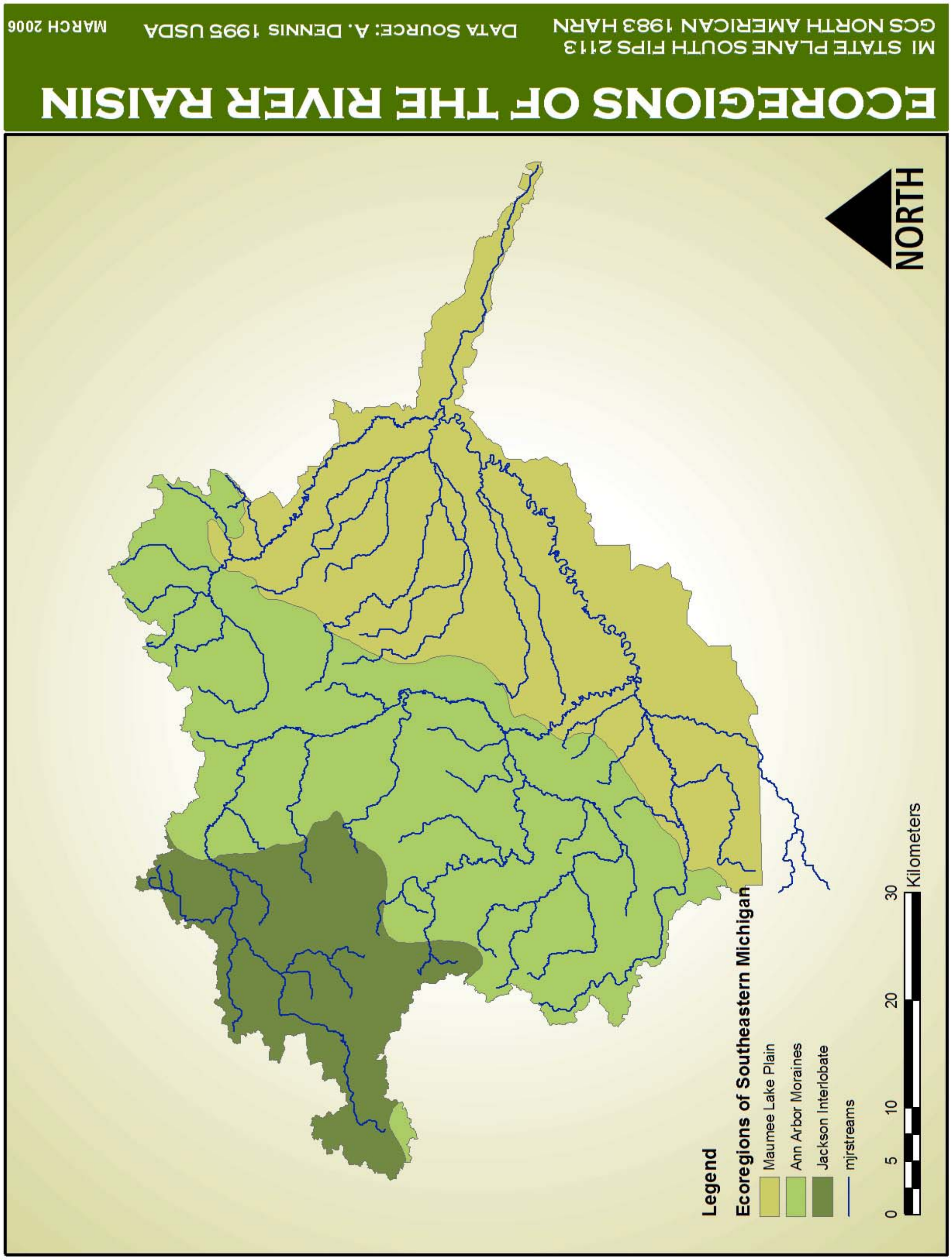
Appendix 1. Land Cover of the River Raisin Watershed



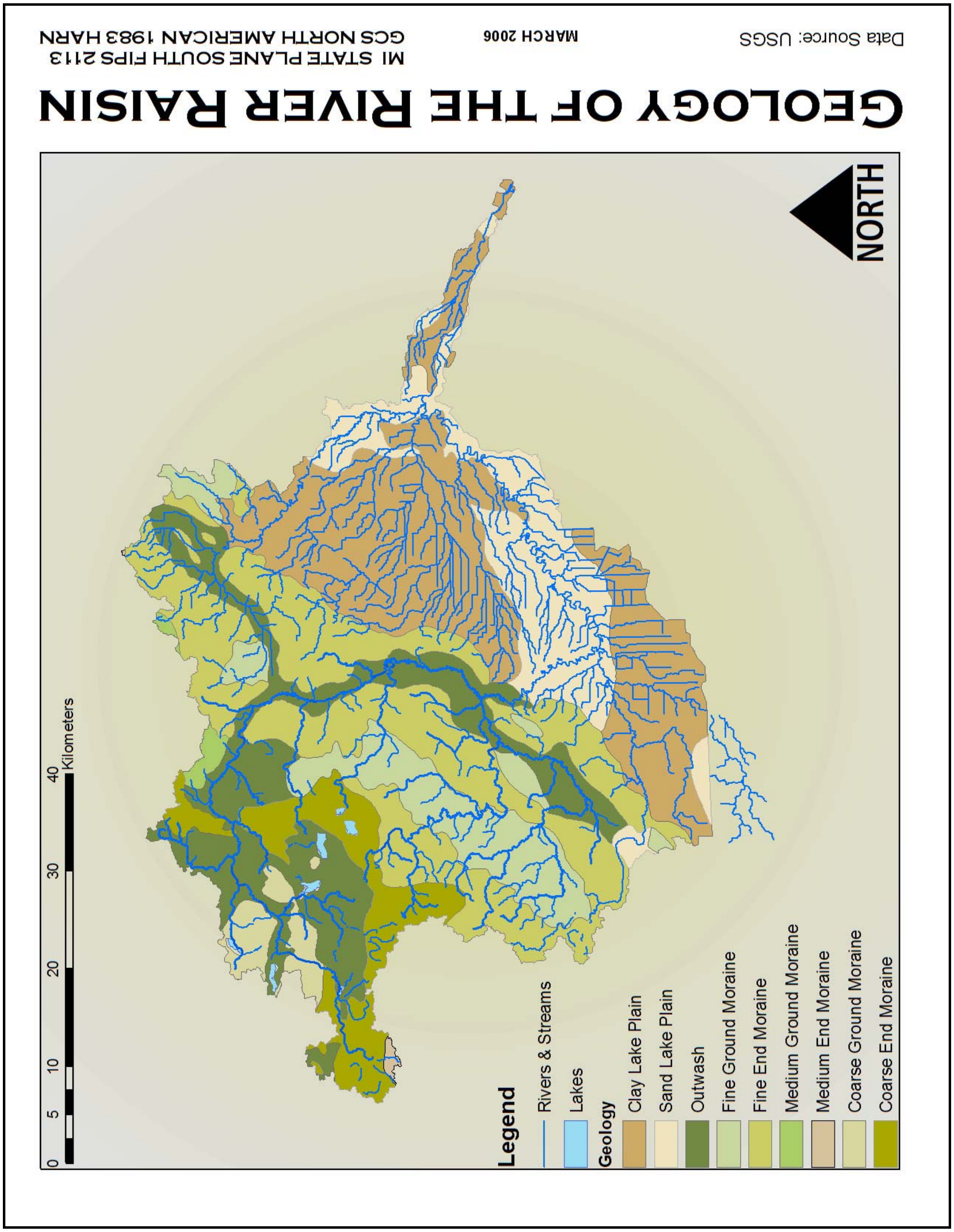
Appendix 2. Delineation of study area for Chapters 2 and 3



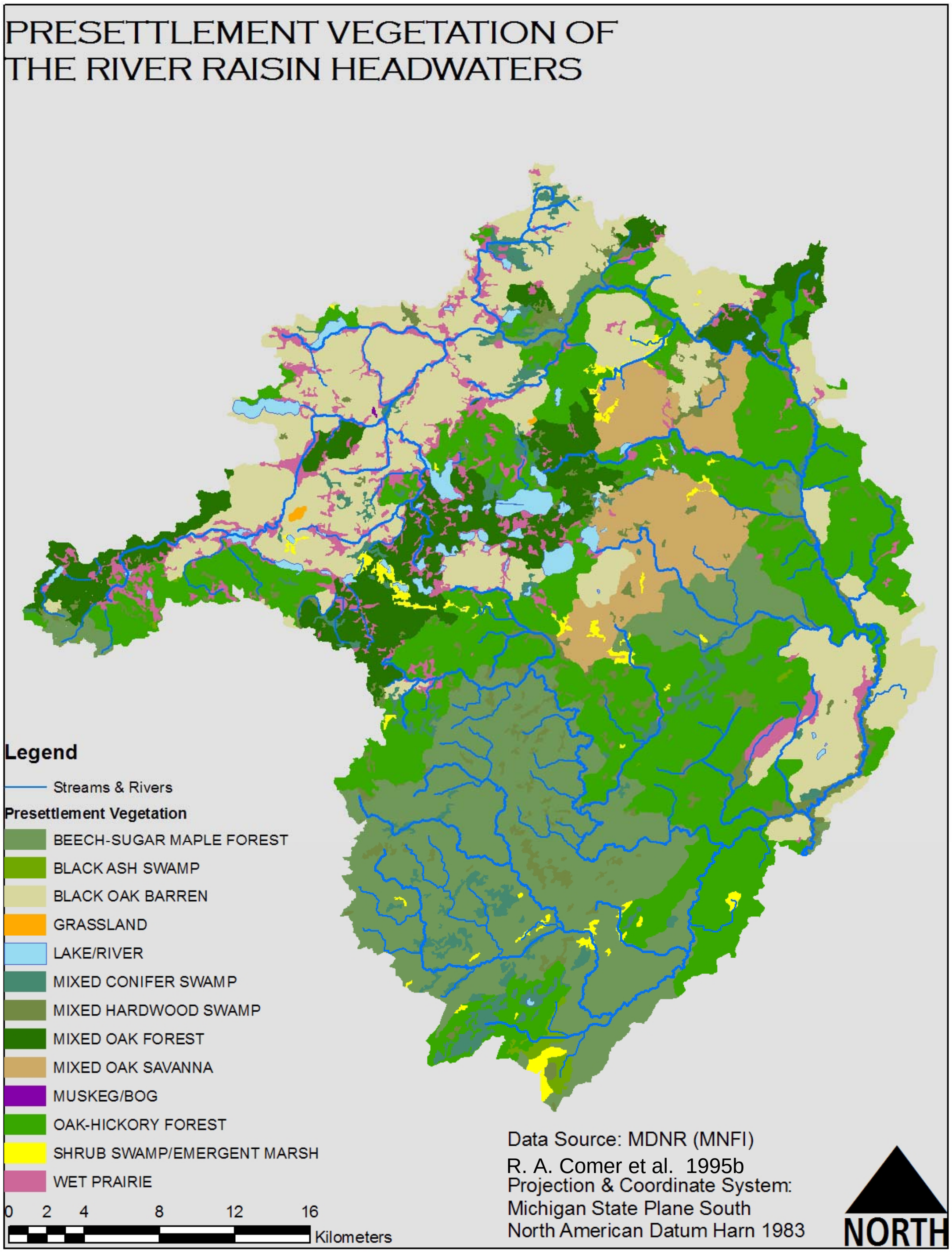
Appendix 3. Ecoregions of the Upper River Raisin Watershed



Appendix 4. Geology of the Upper River Raisin Watershed



Appendix 5. Presettlement Vegetation of the upper River Raisin Watershed



Appendix 6. Classifications of concentrated animal feeding operations (CAFOs). Source: EPA 2006a

Animal Sector	Size Thresholds (number of animals)		
	Large CAFOs	Medium CAFOs[1]	Small CAFOs[2]
cattle or cow/calf pairs	1,000 or more	300 - 999	less than 300
mature dairy cattle	700 or more	200 - 699	less than 200
veal calves	1,000 or more	300 - 999	less than 300
swine (weighing over 55 pounds)	2,500 or more	750 - 2,499	less than 750
swine (weighing less than 55 pounds)	10,000 or more	3,000 - 9,999	less than 3,000
horses	500 or more	150 - 499	less than 150
sheep or lambs	10,000 or more	3,000 - 9,999	less than 3,000
turkeys	55,000 or more	16,500 - 54,999	less than 16,500
laying hens or broilers (liquid manure handling systems)	30,000 or more	9,000 - 29,999	less than 9,000
chickens other than laying hens (other than a liquid manure handling systems)	125,000 or more	37,500 - 124,999	less than 37,500
laying hens (other than a liquid manure handling systems)	82,000 or more	25,000 - 81,999	less than 25,000
ducks (other than a liquid manure handling systems)	30,000 or more	10,000 - 29,999	less than 10,000
ducks (liquid manure handling systems)	5,000 or more	1,500 - 4,999	less than 1,500

[1]Must also meet one of two "method of discharge" criteria to be defined as a CAFO or may be designated.
[2] Never a CAFO by regulatory definition, but may be designated as a CAFO on a case-by-case basis.

Appendix 7. Non-point source pollutants and their sources (adapted from Leeds et al. 1992)

Pollutants	Sources
Sediment	Construction sites, mining areas, agricultural lands, logged areas, bank/shore erosion, grazed areas
Nutrients	Agricultural lands
Fertilizers, Grease	Nurseries, orchards
Organic Matter	Livestock areas, lawns, forests, petroleum storage areas, landfills
Acids and Salts	Irrigated lands, mining areas, urban runoff (roads, parking lots), landfills
Heavy Metals	Mining areas
Lead, Mercury	Vehicle emissions
Zinc	Urban runoff (roads, parking lots), landfills
Toxic Chemicals	Agricultural lands
Pesticides, Organics	Nurseries, orchards
Inorganic compounds	Building sites, gardens, lawns, landfills
Pathogens	Domestic sewage
Bacteria, Viruses	Livestock waste, landfills

Appendix 8. Summary of water chemistry parameters collected in situ using a Hydrolab DS 5 instrument on (a) 6 August 2005 and (b) 12 November 2005.

a. 6 August 2005

Site No.	Stream Name	Road Crossing	Temp. (° C)	Sp. Conductance (µS/cm)	DO (mg/L)	% DO	pH	Turbidity (ntu)	TDS (mg/L)
1	Hazen	Hawkins Hwy	22.5	567.2	7.5	86.0	7.7	1.4	0.4
2	Hazen	Forrister Rd	20.5	466.2	6.6	73.1	7.9	34.1	0.3
3	Hazen	Sword Hwy	19.8	703.6	7.3	79.9	7.8	0.6	0.5
4	Evans	Monagan Hwy	23.3	420.5	6.7	78.1	7.9	0.0	0.3
5	Evans	Wisner Hwy	21.0	556.8	7.0	78.4	7.8	8.4	0.4
6	Evans	Occidental Hwy	19.9	653.9	7.9	86.2	8.0	28.4	0.4
7	Raisin	Austin Rd	26.2	516.5	8.6	105.9	8.0	0.0	0.3
8	Raisin	Sharon Valley Rd	24.5	518.6	7.3	87.8	7.8	0.0	0.3

b. 12 November 2005

Site No.	Stream Name	Road Crossing	Temp. (° C)	Sp. Conductance (µS/cm)	DO (mg/L)	% DO	pH	Turbidity (ntu)	TDS (mg/L)
1	Hazen	Hawkins Hwy	4.7	542.9	10.4	81.5	7.6	3.3	0.3
2	Hazen	Forrister Rd	5.5	520.2	9.5	74.2	7.6	0.0	0.3
3	Hazen	Sword Hwy	6.4	665.5	8.8	70.6	7.4	0.0	0.4
4	Evans	Monagan Hwy	10.8	486.0	9.3	82.7	7.6	0.0	0.3
5	Evans	Wisner Hwy	7.9	753.7	12.2	103.1	7.8	0.0	0.5
6	Evans	Occidental Hwy	7.3	736.6	9.3	77.1	7.4	0.0	0.5
7	Raisin	Austin Rd	9.6	580.6	12.4	107.0	7.2	0.0	0.4
8	Raisin	Sharon Valley Rd	8.1	573.0	10.8	92.7	7.8	0.0	0.4

Appendix 9. Results of water quality analyses for total suspended matter (TSM), total phosphorus (TP), soluble reactive phosphorus (SRP), ammonia, and nitrate on (a) 6 August 2005 and (b) 12 November 2005 and (c) 11 March 2006.

a. 6 August 2005

Site No.	Stream Name	Road Crossing	TSM (mg/L)	TP (µg/L)	SRP (µg/L)	Ammonia (µg/L)	Nitrate (mg/L)
1	Hazen	Hawkins Hwy	18.1	84.2	5.4	101.3	0.32
2	Hazen	Forrister Rd	6.8	62.6	21.9	45.6	0.40
3	Hazen	Sword Hwy	11.6	94.4	12.6	50.0	0.38
4	Evans	Monagan Hwy	11.4	55.8	12.0	42.5	0.16
5	Evans	Wisner Hwy	37.4	195.0	17.5	125.8	0.37
6	Evans	Occidental Hwy	8.4	135.6	38.3	30.4	0.45
7	Raisin	Austin Rd	2.2	25.4	7.6	24.6	0.27
8	Raisin	Sharon Valley Rd	5.9	26.1	1.8	148.1	0.37

b. 12 November 2005

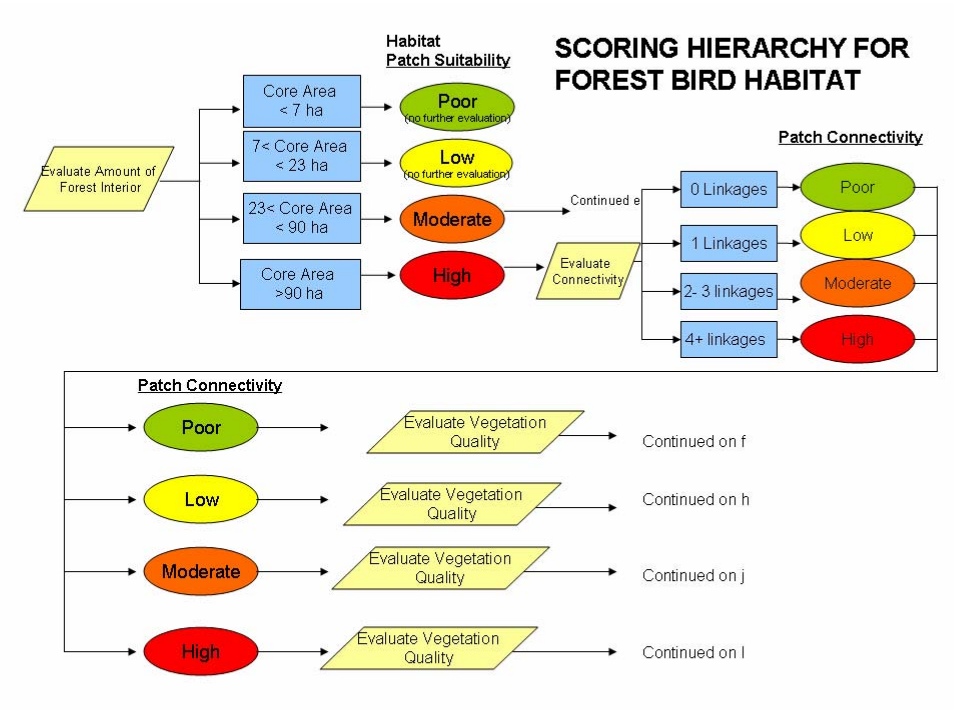
Site No.	Stream Name	Road Crossing	TSM (mg/L)	TP (µg/L)	SRP (µg/L)	Ammonia (µg/L)	Nitrate (mg/L)
1	Hazen	Hawkins Hwy	--	44.4	8.2	7.4	0.04
2	Hazen	Forrister Rd	--	28.8	9.6	5.2	0.04
3	Hazen	Sword Hwy	--	35.6	10.5	7.2	0.04
4	Evans	Monagan Hwy	--	16.0	7.0	20.5	0.18
5	Evans	Wisner Hwy	--	17.3	4.9	25.2	0.27
6	Evans	Occidental Hwy	--	57.9	12.5	8.4	0.05
7	Raisin	Austin Rd	--	43.2	3.7	18.3	0.75
8	Raisin	Sharon Valley Rd	--	10.6	1.2	9.9	0.61

c. 11 March 2006

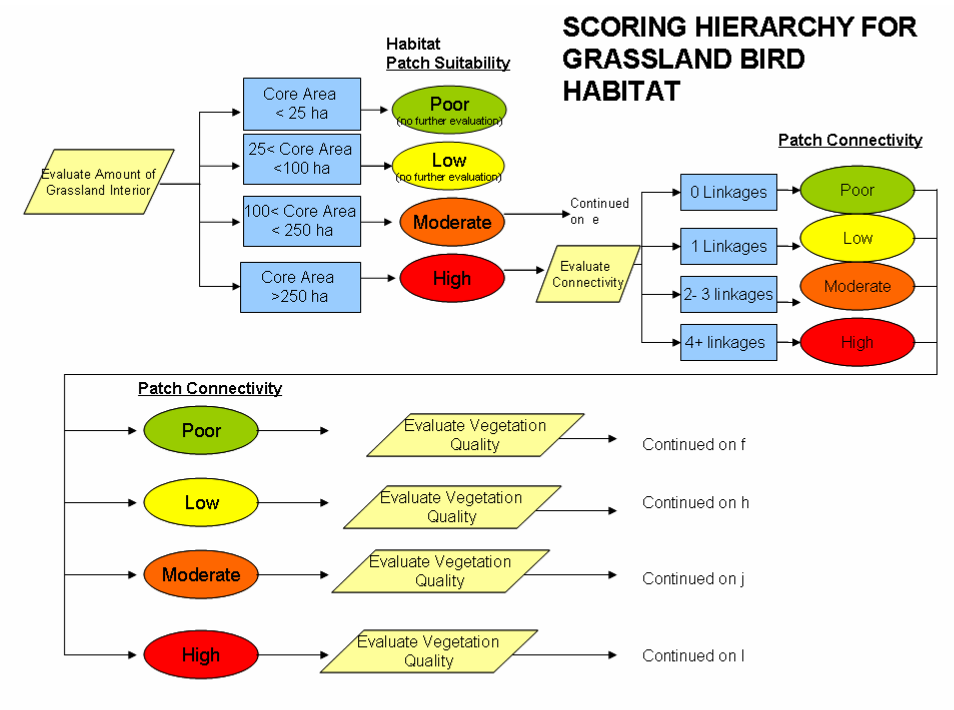
Site No.	Stream Name	Road Crossing	TSM (mg/L)	TP (μg/L)	SRP (μg/L)	Ammonia (μg/L)	Nitrate (mg/L)
1	Hazen	Hawkins Hwy	49.6	91.5	7.3	12.9	1.64
2	Hazen	Forrister Rd	52.8	118.5	13.7	15.6	2.23
3	Hazen	Sword Hwy	56.1	164.2	30.4	75.5	2.77
4	Evans	Monagan Hwy	2.9	16.8	1.9	7.6	0.29
5	Evans	Wisner Hwy	31.2	126.1	19.4	34.9	4.03
6	Evans	Occidental Hwy	42.6	156.6	45.4	152.8	5.12
7	Raisin	Austin Rd	5.2	21.9	2.6	27.6	0.57
8	Raisin	Sharon Valley Rd	5.9	17.8	1.7	21.6	0.50

Appendix 10 Hierarchical decision making tree for conservation prioritization model

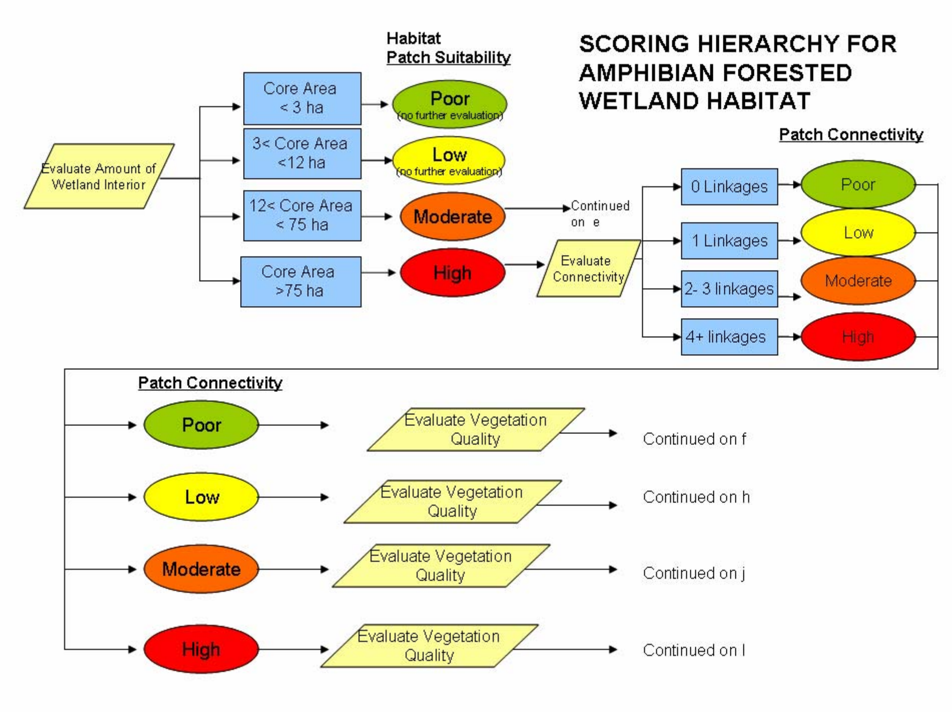
a. Hierarchy for evaluating forest bird habitat



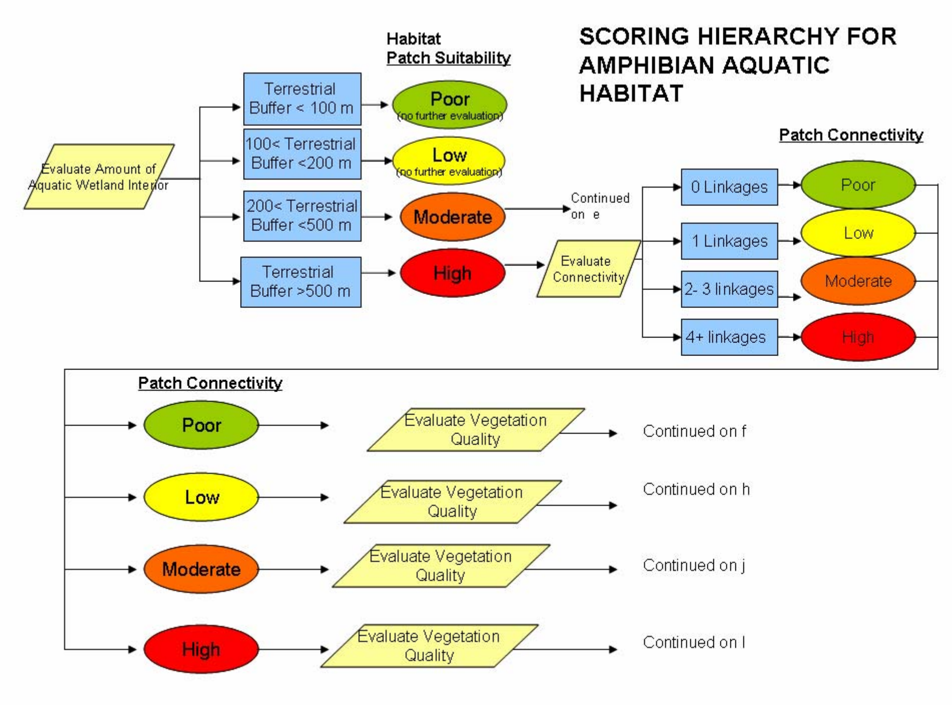
b. Hierarchy for evaluating grassland bird habitat



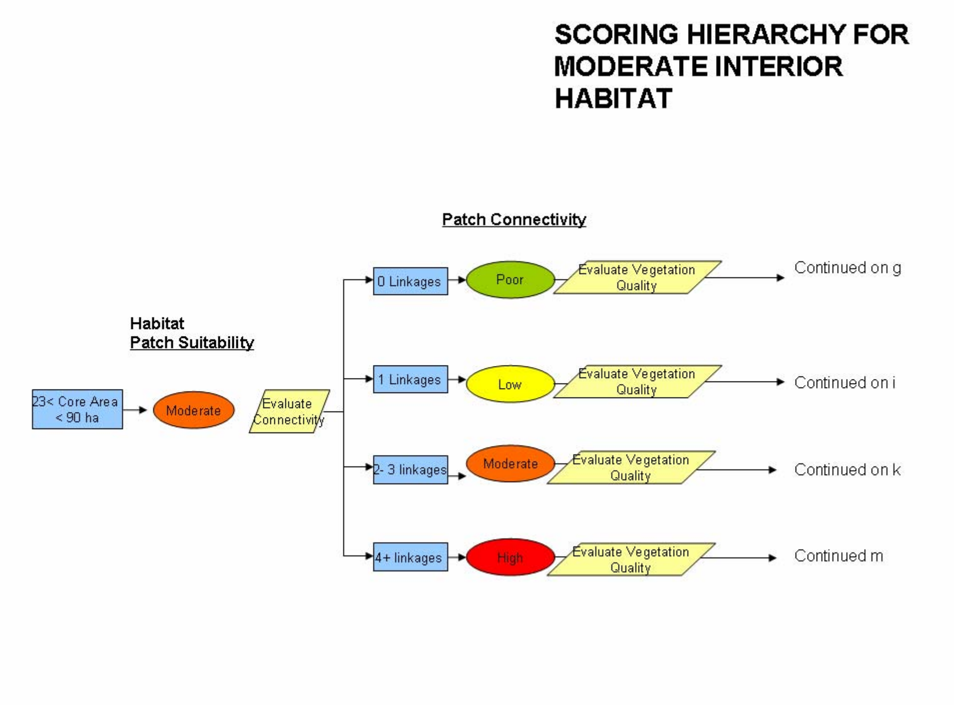
c. Hierarchy for evaluating amphibian and reptile forest wetland habitat



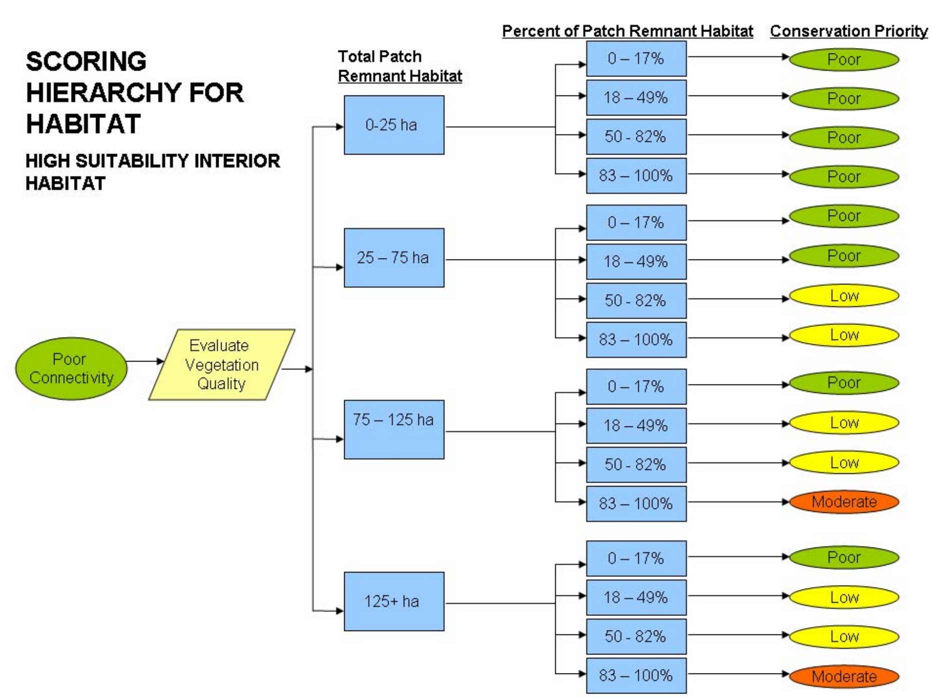
d. Hierarchy for evaluating amphibian and reptile open water habitat



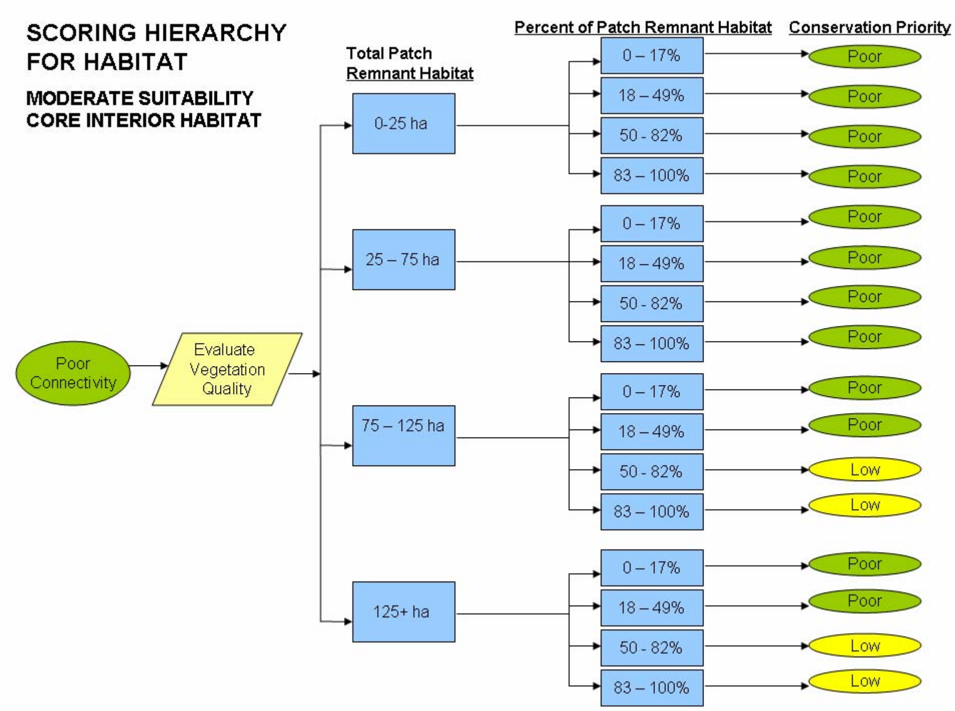
e. Hierarchy for moderate interior habitat suitability



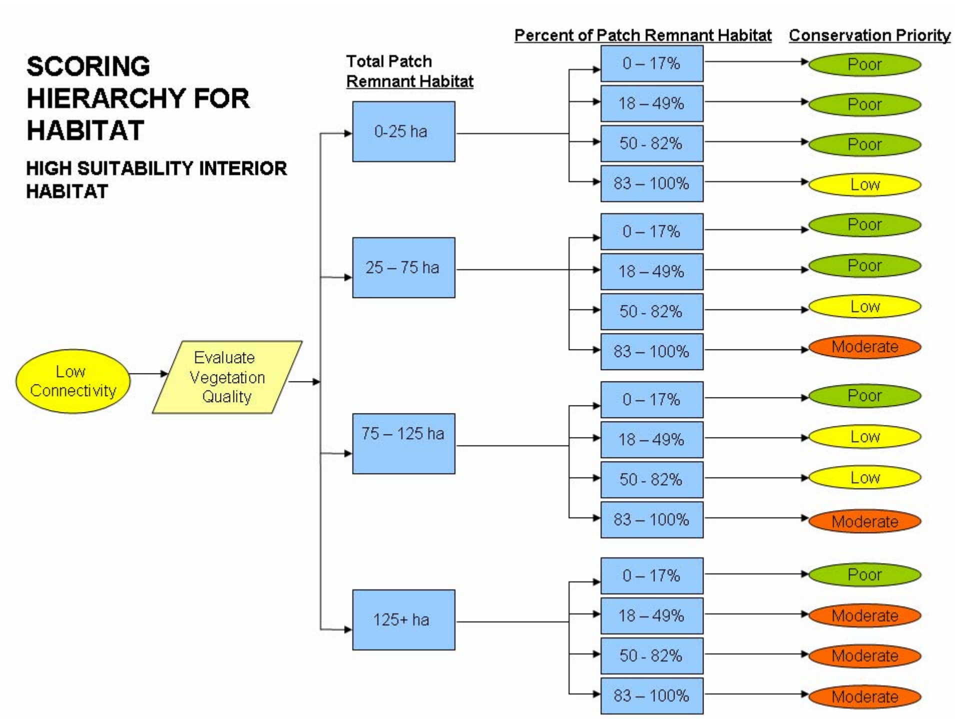
f. Hierarchy for evaluating habitat suitability for poor patch connectivity and high interior habitat suitability



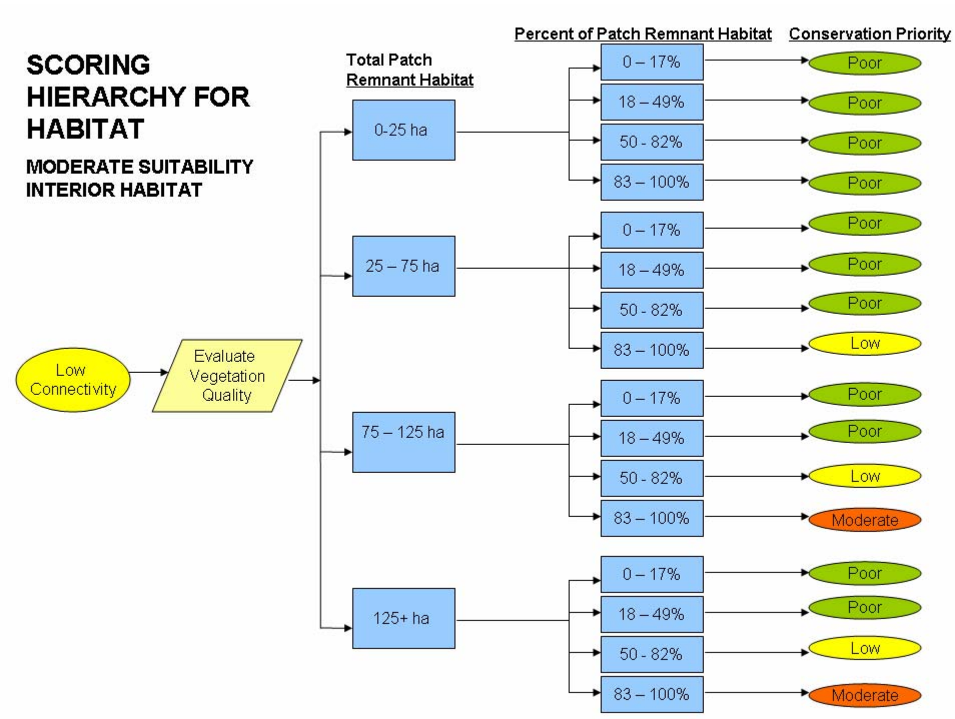
g. Hierarchy for evaluating habitat suitability for poor patch connectivity and moderate interior habitat suitability



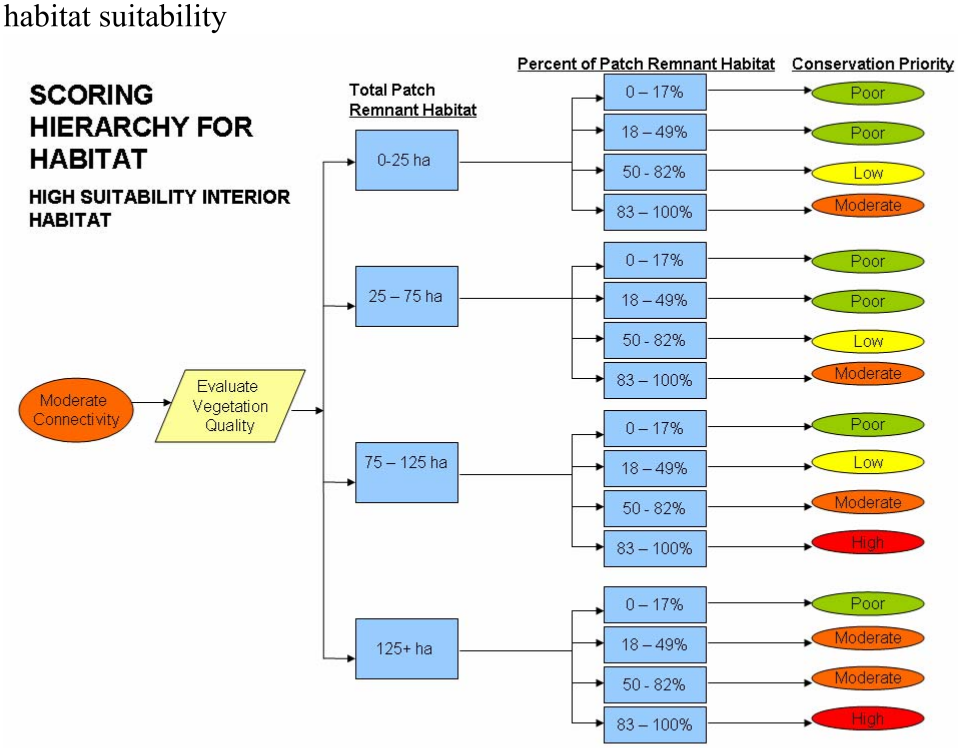
h. Hierarchy for evaluating habitat suitability for low patch connectivity and high interior habitat suitability



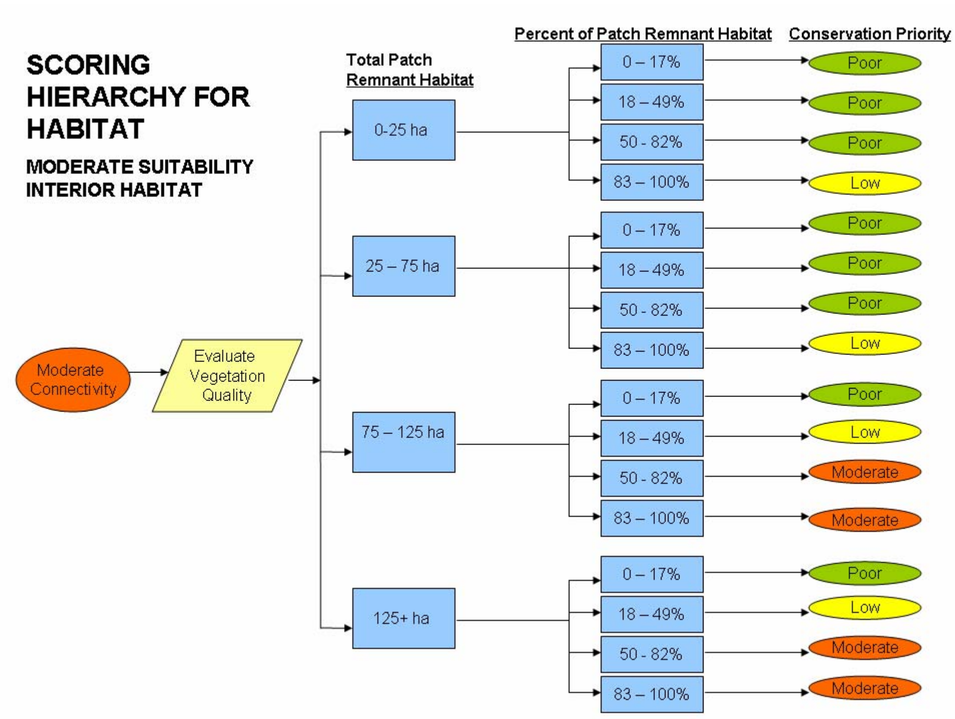
i. Hierarchy for evaluating habitat suitability for poor patch connectivity and moderate interior habitat suitability



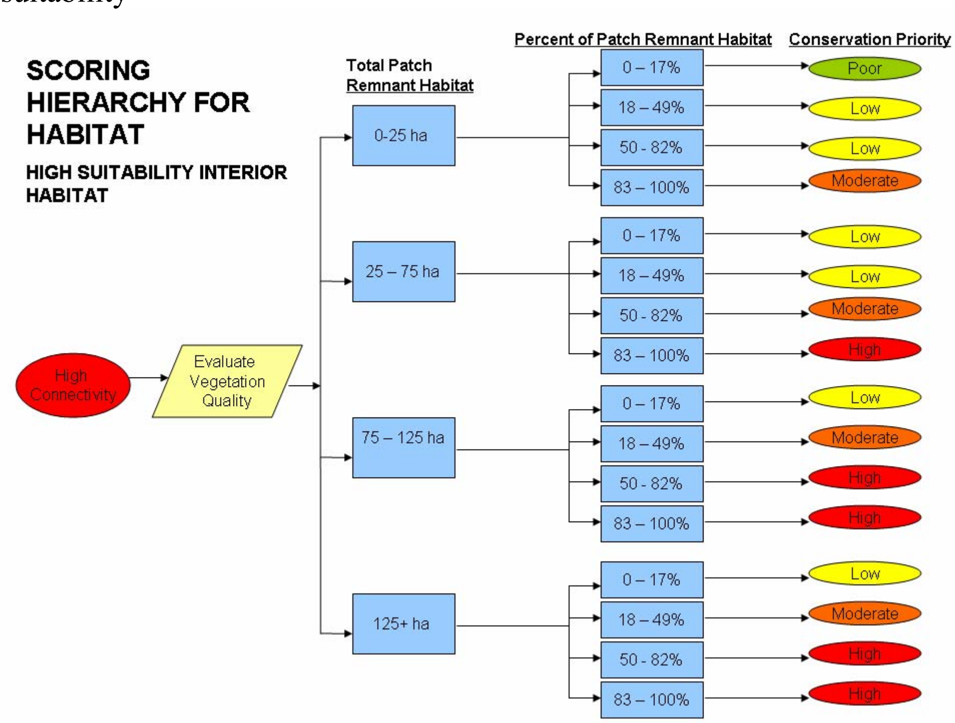
j. Hierarchy for evaluating habitat suitability for moderate patch connectivity and high interior habitat suitability



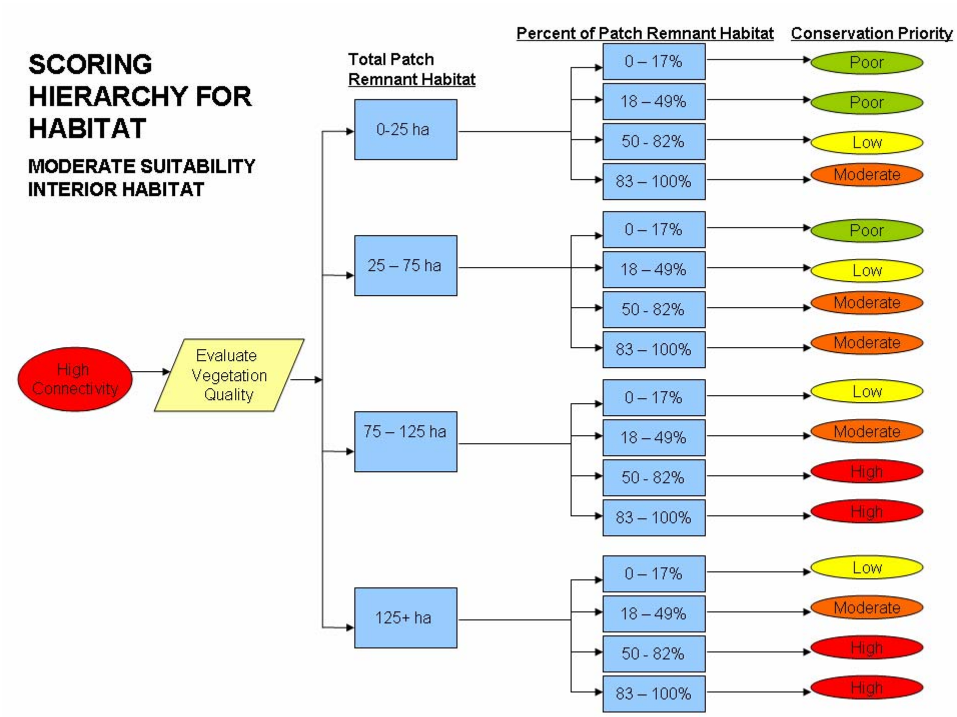
k. Hierarchy for evaluating habitat suitability for moderate patch connectivity and moderate interior habitat suitability



l. Hierarchy for evaluating habitat suitability for high patch connectivity and high interior habitat suitability



m. Hierarchy for evaluating habitat suitability for high patch connectivity and moderate interior habitat suitability



Appendix 11. Tables showing the coordinates of high quality habitat patches in the River Raisin headwates

a. Patches containing more than 125 ha of remnant habitat

				Habitat Suitability of					
Overlay ID	Connectivity Rating	Percent of Patch Remnant Habitat	Water Quality Buffer	Forest Birds	Amphibian & Reptiles	Grass-land Birds	Total Patch Size (ha)	WGS 1984 Longitude	WGS 1984 Latitude
22	Moderate	50 - 82%	Yes	Poor	Poor	Poor	10.9	-84.13449449538	42.09862436581
26	High	50 - 82%	Yes	High	High	Poor	443.8	-84.10143600138	42.09334568283
57	Moderate	50 - 82%	No	Poor	Poor	Poor	200.0	-84.11190151882	42.02812624895
98	High	18 - 49%	Yes	Moderate	Moderate	Poor	413.6	-84.14444485244	42.13434728551
124	Low	18 - 49%	No	Poor	Poor	Poor	17.9	-84.11843860420	42.19115257980
125	High	18 - 49%	No	Poor	Poor	Poor	25.9	-84.14836240288	42.18951650686
166	High	18 - 49%	Yes	Moderate	Moderate	Poor	329.8	-84.06163446604	42.15205191932
432	Moderate	18 - 49%	No	Poor	Poor	Poor	6.7	-84.45217043618	42.03568964943
502	Moderate	50 - 82%	Yes	Moderate	Moderate	Poor	322.1	-83.98450272928	41.92781517245
511	Low	18 - 49%	Yes	Low	Low	Poor	305.7	-83.93767387239	41.95206511143

b. Coordinates and ratings of patches with enough interior habitat to potentially act as a source for moderately to highly sensitive bird populations

Overlay ID	**Connectivity Rating**	**Total Patch Remnant Habitat (ha)**	**Percent of Patch Remnant Habitat**	**Forest Bird Core Habitat Size (ha)**	**Forest Bird Habitat Suitability**	**Total Patch Size (ha)**	**WGS 1984 Longitude**	**WGS 1984 Latitude**
98	High	125+	50 - 82%	90+	High	443.811	-84.10143600138	42.09334568283
106	High	125+	18 - 49%	90+	Moderate	413.697	-84.14444485244	42.13434728551
122	Moderate	75 - 125	50 - 82%	90+	Moderate	189.568	-84.15494882792	42.16050502092
166	High	75 - 125	18 - 49%	23 - 90	Moderate	245.117	-84.11677337036	42.18022536938
502	High	125+	18 - 49%	23 - 90	Moderate	329.831	-84.06163446604	42.15205191932
505	Moderate	125+	50 - 82%	23 - 90	Moderate	322.174	-83.98450272928	41.92781517245
98	Moderate	75 - 125	50 - 82%	23 - 90	Moderate	153.065	-83.95510689819	41.93863618902
128	High	25 - 75	18 - 49%	90+	Low	301.956	-84.16725103777	42.18400905397
133	Low	75 - 125	18 - 49%	90+	Low	202.916	-84.13771279836	42.20968484569
284	Poor	75 - 125	18 - 49%	90+	Low	244.726	-84.23684172102	42.12194686012
511	Low	125+	18 - 49%	23 - 90	Low	305.765	-83.93767387239	41.95206511143
16	Low	25 - 75	50 - 82%	23 - 90	Poor	108.533	-84.11577328099	42.07351458202
43	Low	25 - 75	50 - 82%	23 - 90	Poor	126.628	-84.09530436796	42.05933396379
83	Low	25 - 75	50 - 82%	23 - 90	Poor	117.353	-84.17767023228	42.07995127561
297	Low	25 - 75	50 - 82%	23 - 90	Poor	108.692	-84.20428703029	42.16520521975
443	Low	75 - 125	0 - 17%	90+	Poor	580.194	-84.40616421806	42.01934454519
489	Poor	25 - 75	50 - 82%	23 - 90	Poor	78.117	-84.20675718590	41.86369093251

c. Coordinates and ratings of wetland patches with enough interior habitat or terrestrial buffer to potentially act as a source for moderately to highly sensitive amphibian and reptile populations

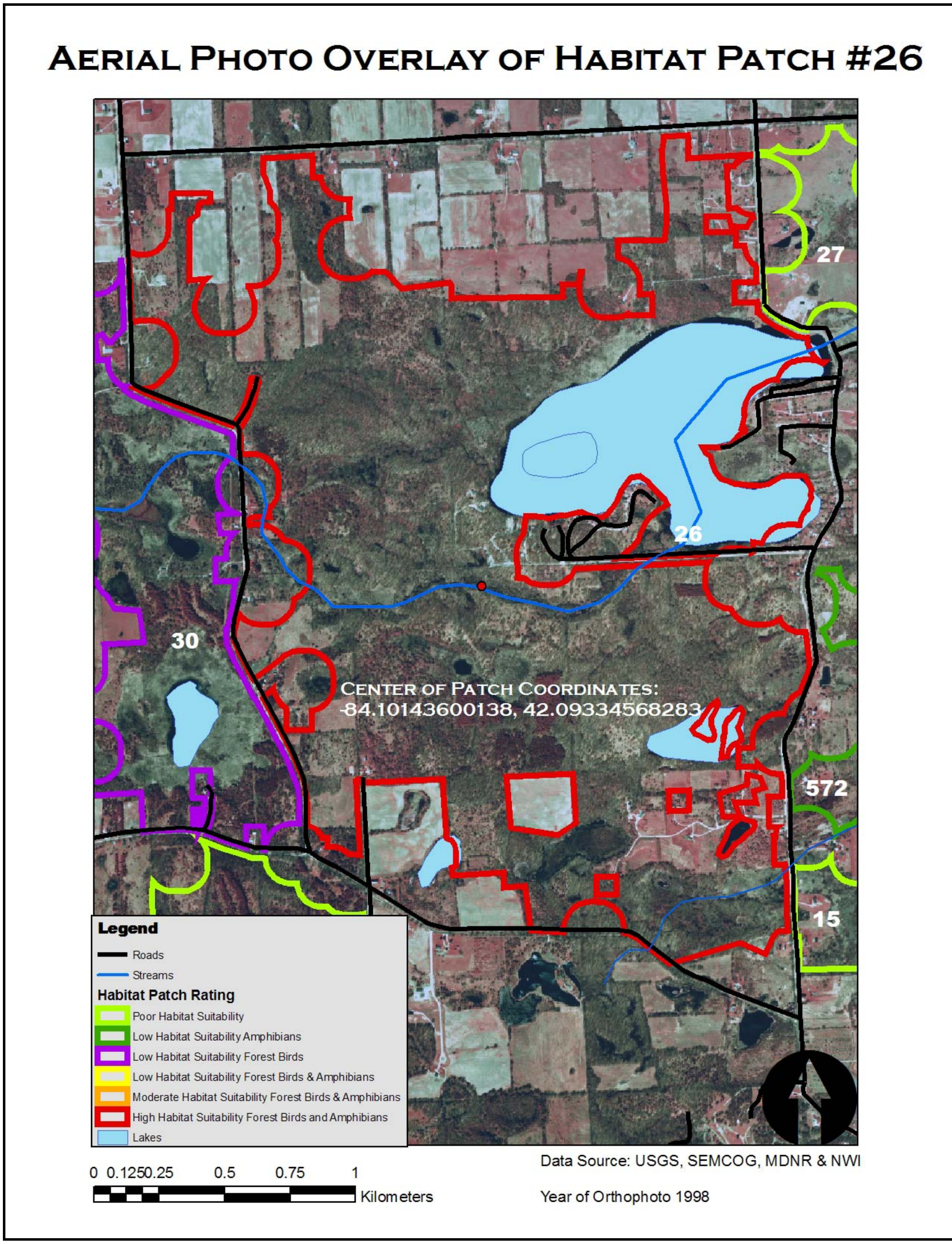
Overlay ID	Connectivity Rating	Total Patch Remnant Habitat (ha)	Percent of Patch Remnant Habitat	Amphibian & Reptile Wetland Core Habitat Size (ha)	Open Wetland Terrestrial Buffer Size (m)	Amphibian & Reptile Habitat Suitability	Total Patch Size (ha)	WGS 1984 Longitude	WGS 1984 Latitude
26	High	125+	50 - 82%	0- 3	200 - 500	High	443.8	-84.101436	42.09334568
122	High	75 - 125	18 - 49%	3 - 12	500+	Moderate	245.1	-84.11677337	42.18022537
98	High	125+	18 - 49%	75+	200 - 500	Moderate	413.6	-84.14444485	42.13434729
502	Moderate	125+	50 - 82%	75+	200 - 500	Moderate	322.1	-83.98450273	41.92781517
166	High	125+	18 - 49%	12 - 75	200 - 500	Moderate	329.8	-84.06163447	42.15205192
505	Moderate	75 - 125	50 - 82%	12 - 75	200 - 500	Moderate	153.0	-83.9551069	41.93863619
106	Moderate	75 - 125	50 - 82%	12 - 75	100 - 200	Moderate	189.5	-84.15494883	42.16050502
553	Moderate	25 - 75	50 - 82%	3 - 12	500+	Low	42.0	-84.16593848	42.16311822
128	High	25 - 75	18 - 49%	75+	200 - 500	Low	301.9	-84.16725104	42.18400905
133	Low	75 - 125	18 - 49%	75+	200 - 500	Low	202.9	-84.1377128	42.20968485
511	Low	125+	18 - 49%	12 - 75	200 - 500	Low	305.7	-83.93767387	41.95206511
443	Low	75 - 125	0 - 17%	75+	500+	Poor	580.1	-84.40616422	42.01934455
552	Moderate	0 - 25	50 - 82%	3 - 12	500+	Poor	31.79	-84.11824118	42.17306776
16	Low	25 - 75	50 - 82%	3 - 12	200 - 500	Poor	108.5	-84.11577328	42.07351458
43	Low	25 - 75	50 - 82%	3 - 12	200 - 500	Poor	126.6	-84.09530437	42.05933396
492	Low	0 - 25	50 - 82%	3 - 12	200 - 500	Poor	21.3	-83.9770721	41.90753868
493	Moderate	0 - 25	50 - 82%	3 - 12	200 - 500	Poor	28.4	-83.97270247	41.9134172
508	Moderate	25 - 75	50 - 82%	3 - 12	200 - 500	Poor	52.4	-83.93821419	41.94271209
284	Poor	75 - 125	18 - 49%	12 - 75	200 - 500	Poor	244.7	-84.23684172	42.12194686
83	Low	25 - 75	50 - 82%	12 - 75	200 - 500	Poor	117.3	-84.17767023	42.07995128
523	Poor	25 - 75	50 - 82%	12 - 75	200 - 500	Poor	70.2	-84.15294343	41.83664522
75	Poor	75 - 125	50 - 82%	0- 3	200 - 500	Poor	131.6	-84.13555248	42.06320363
269	Low	25 - 75	50 - 82%	0- 3	200 - 500	Poor	97.6	-84.03598863	42.04371772
582	Poor	25 - 75	50 - 82%	0- 3	200 - 500	Poor	56.9	-84.15578049	42.06067433
304	Poor	25 - 75	50 - 82%	12 - 75	100 - 200	Poor	61.2	-84.22497006	42.08596914
453	Poor	25 - 75	50 - 82%	12 - 75	0 - 100	Poor	79.8	-84.19270076	41.89388771
489	Poor	25 - 75	50 - 82%	12 - 75	0 - 100	Poor	78.1	-84.20675719	41.86369093

d. Coordinates of all patches of high or moderate habitat suitability for forest birds, amphibians and reptiles

Overlay ID	Connectivity Rating	Total Patch Remnant Habitat (ha)	Percent of Patch Remnant Habitat	Water Quality Buffer	Forest Bird Habitat Suitability	Amphibian & Reptile Habitat Suitability	WGS 1984 Longitude	WGS 1984 Latitude
26	High	125+	50 - 82%	Yes	High	High	-84.10143600138	42.09334568283
98	High	125+	18 - 49%	Yes	Moderate	Moderate	-84.14444485244	42.13434728551
502	Moderate	125+	50 - 82%	Yes	Moderate	Moderate	-83.98450272928	41.92781517245
106	Moderate	75 - 125	50 - 82%	No	Moderate	Moderate	-84.15494882792	42.16050502092
122	High	75 - 125	18 - 49%	Yes	Moderate	Moderate	-84.11677337036	42.18022536938
166	High	125+	18 - 49%	Yes	Moderate	Moderate	-84.06163446604	42.15205191932
505	Moderate	75 - 125	50 - 82%	Yes	Moderate	Moderate	-83.95510689819	41.93863618902

Appendix 12. Detail maps of patches receiving a habitat suitability rating moderate or high for forest birds, amphibians and reptiles.

a. Patch #26: High suitability habitat for forest birds, amphibians and reptiles.



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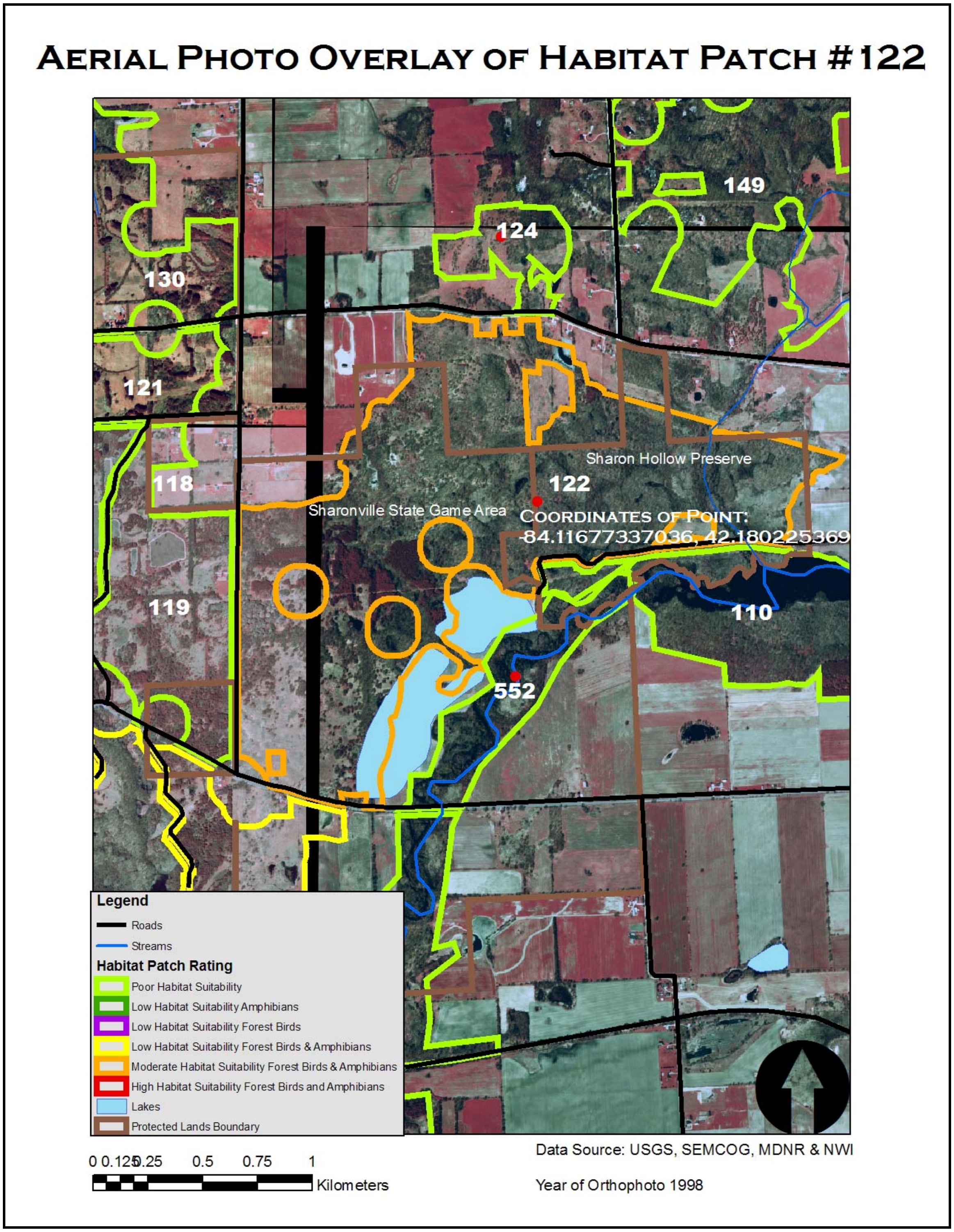
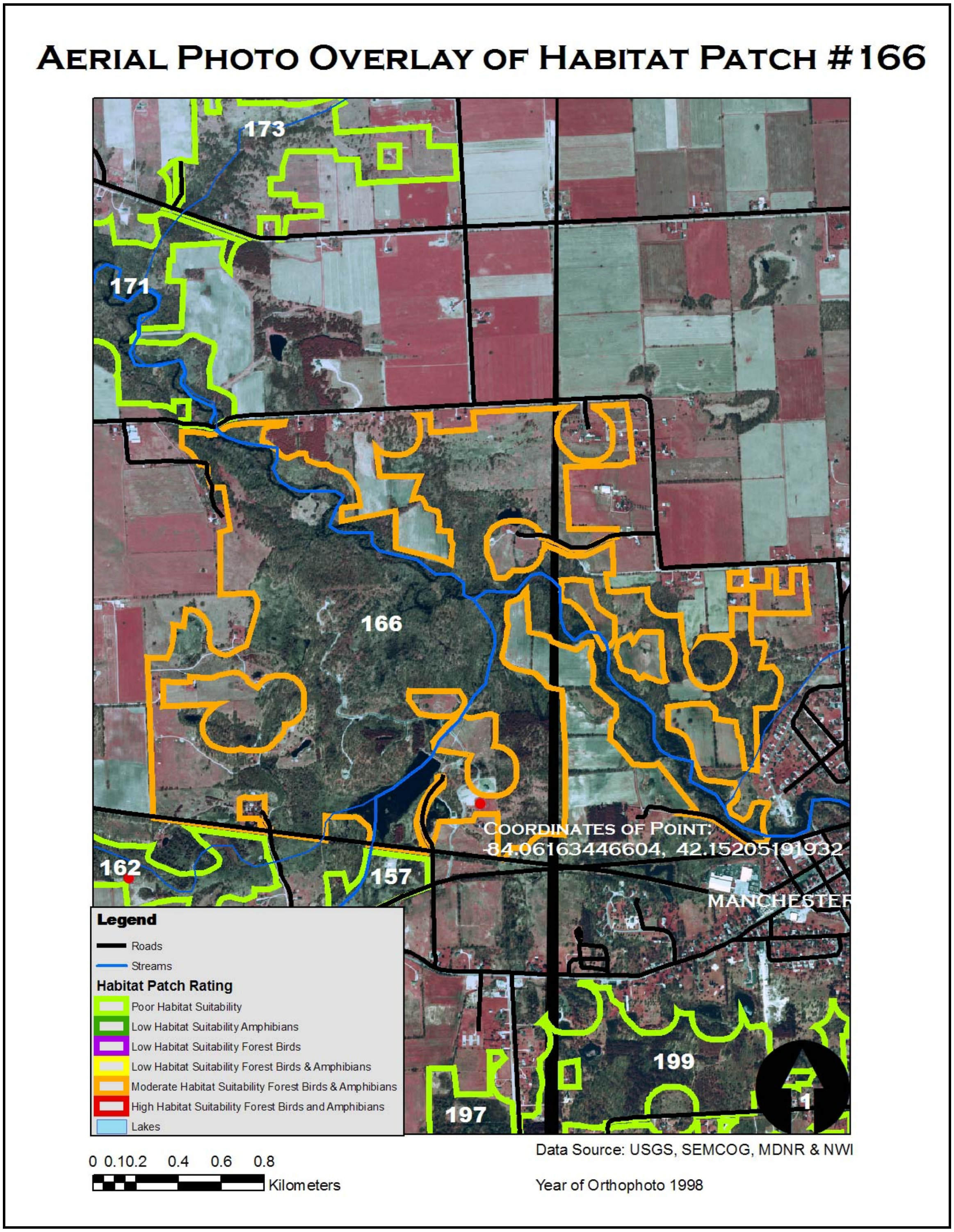
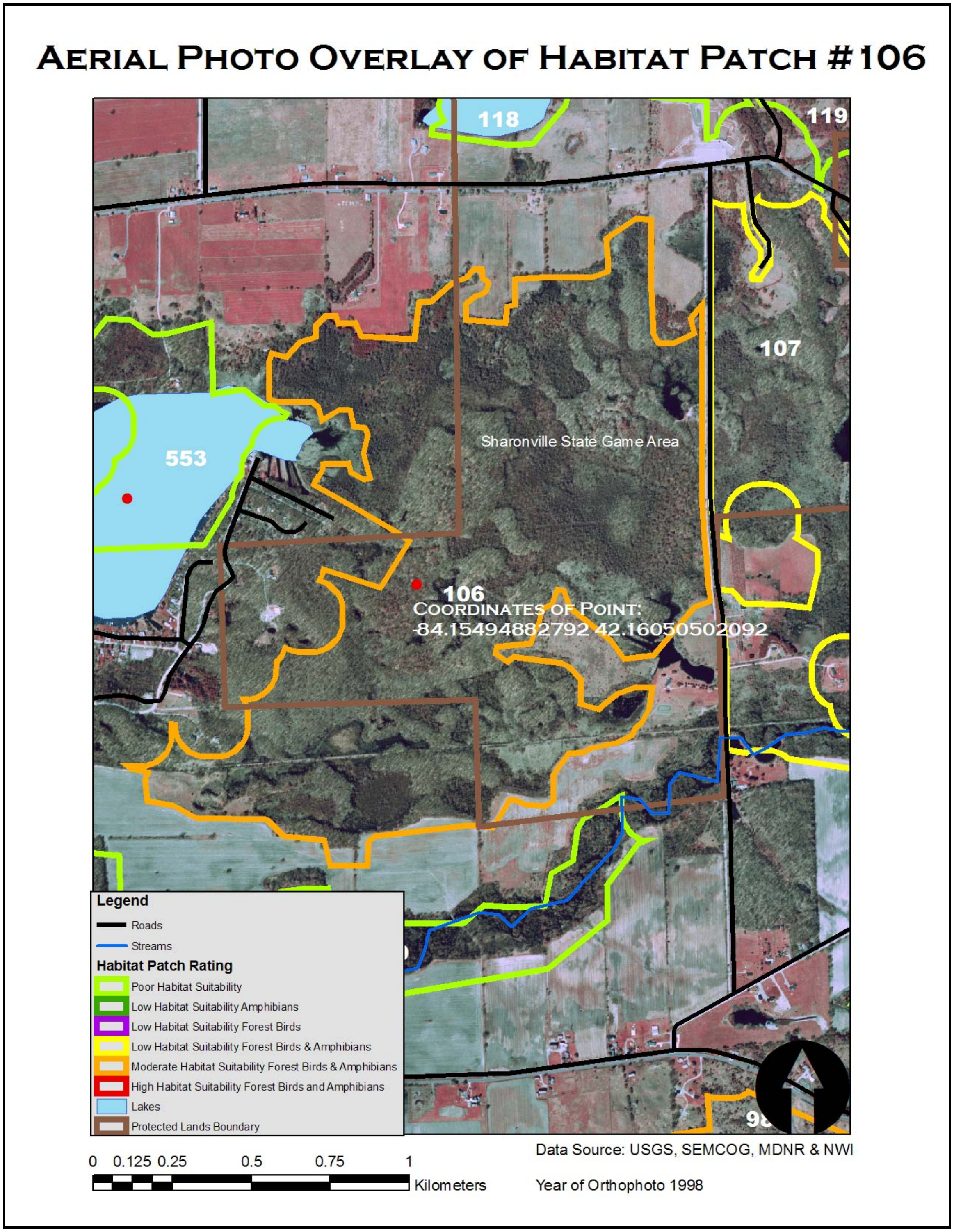
b. Patch #122: Moderate suitability habitat for forest birds, amphibians and reptiles.



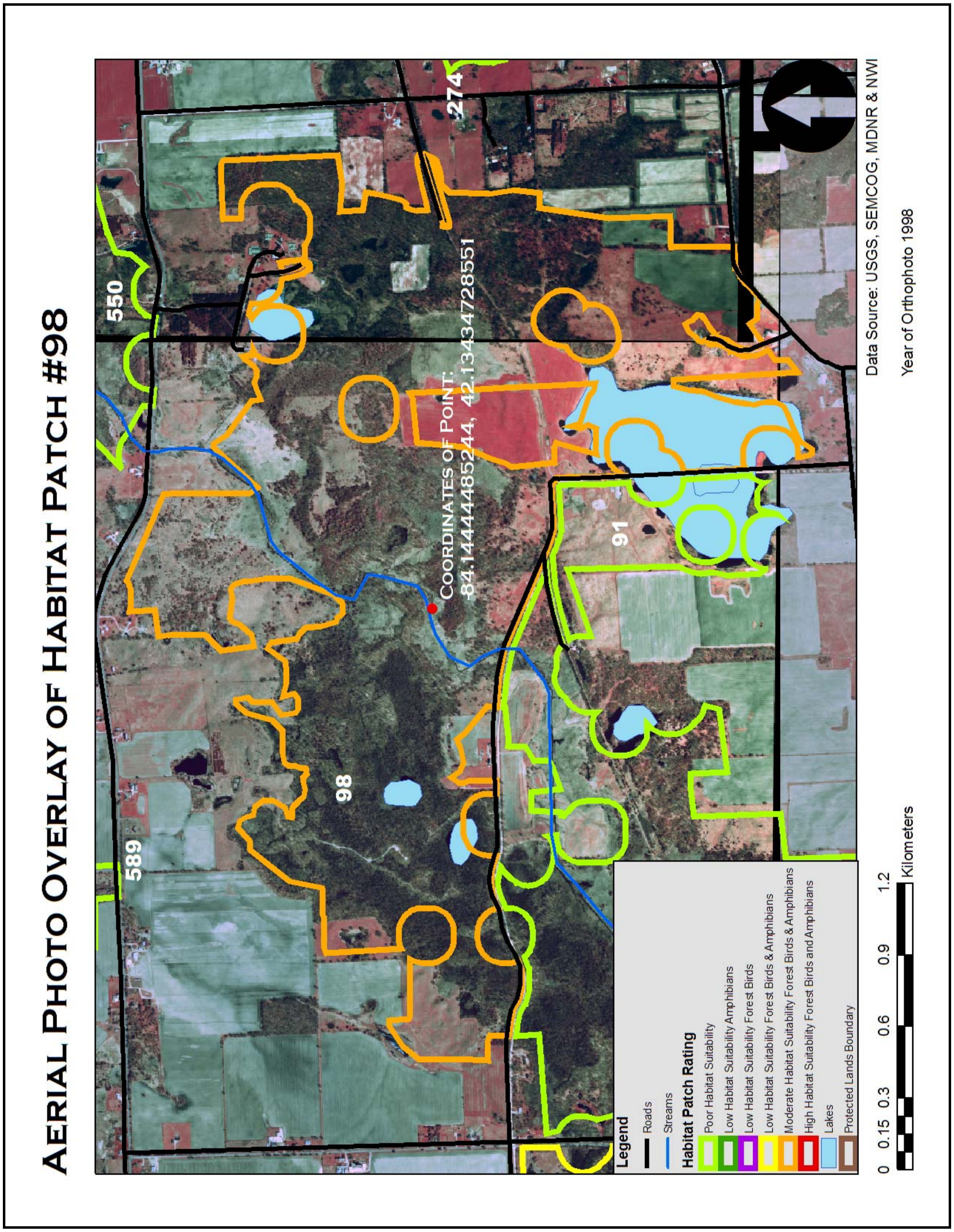
c. Patch #166: Moderate suitability habitat for forest birds, amphibians and reptiles.



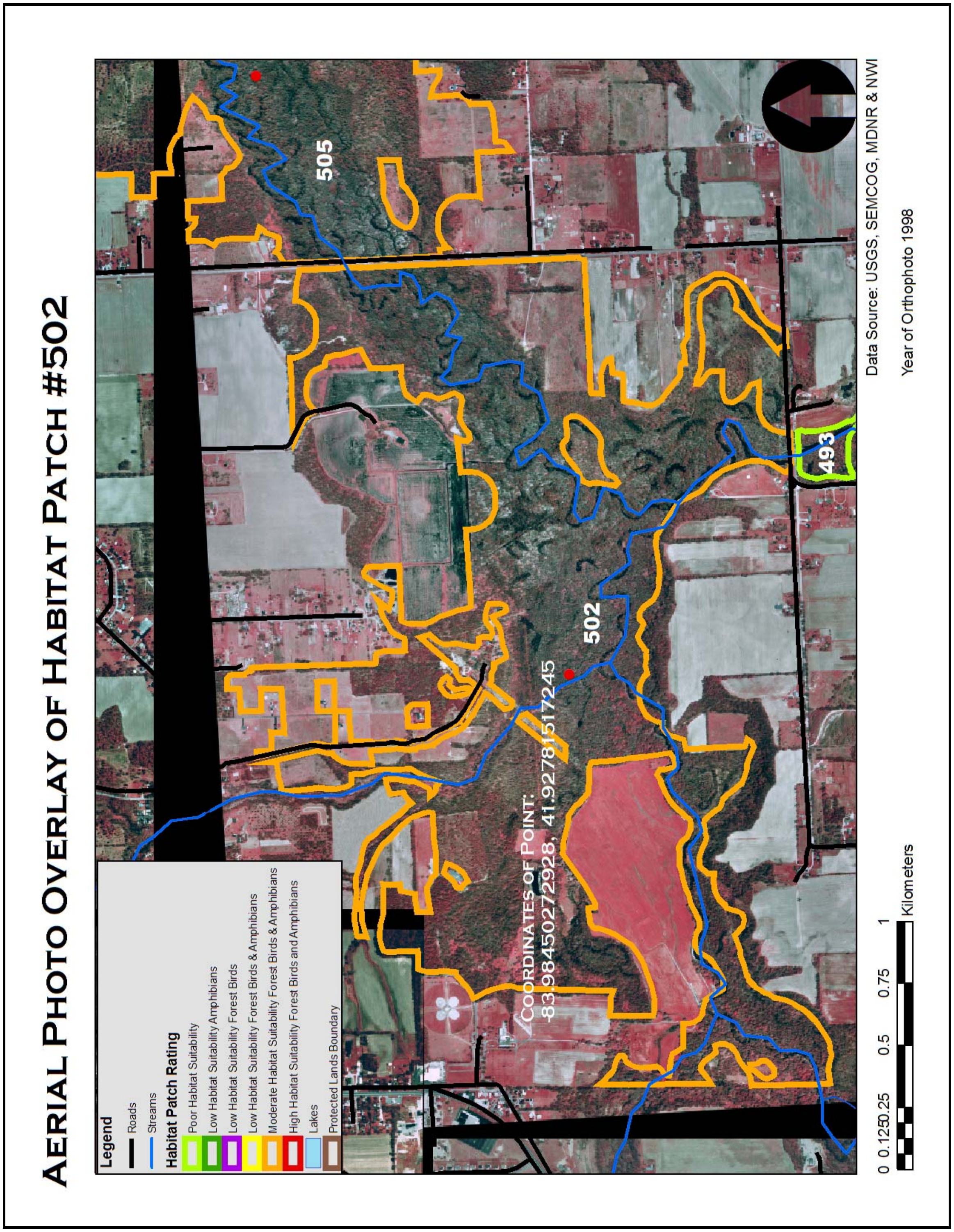
d. Patch #106: Moderate suitability habitat for forest birds, amphibians and reptiles.



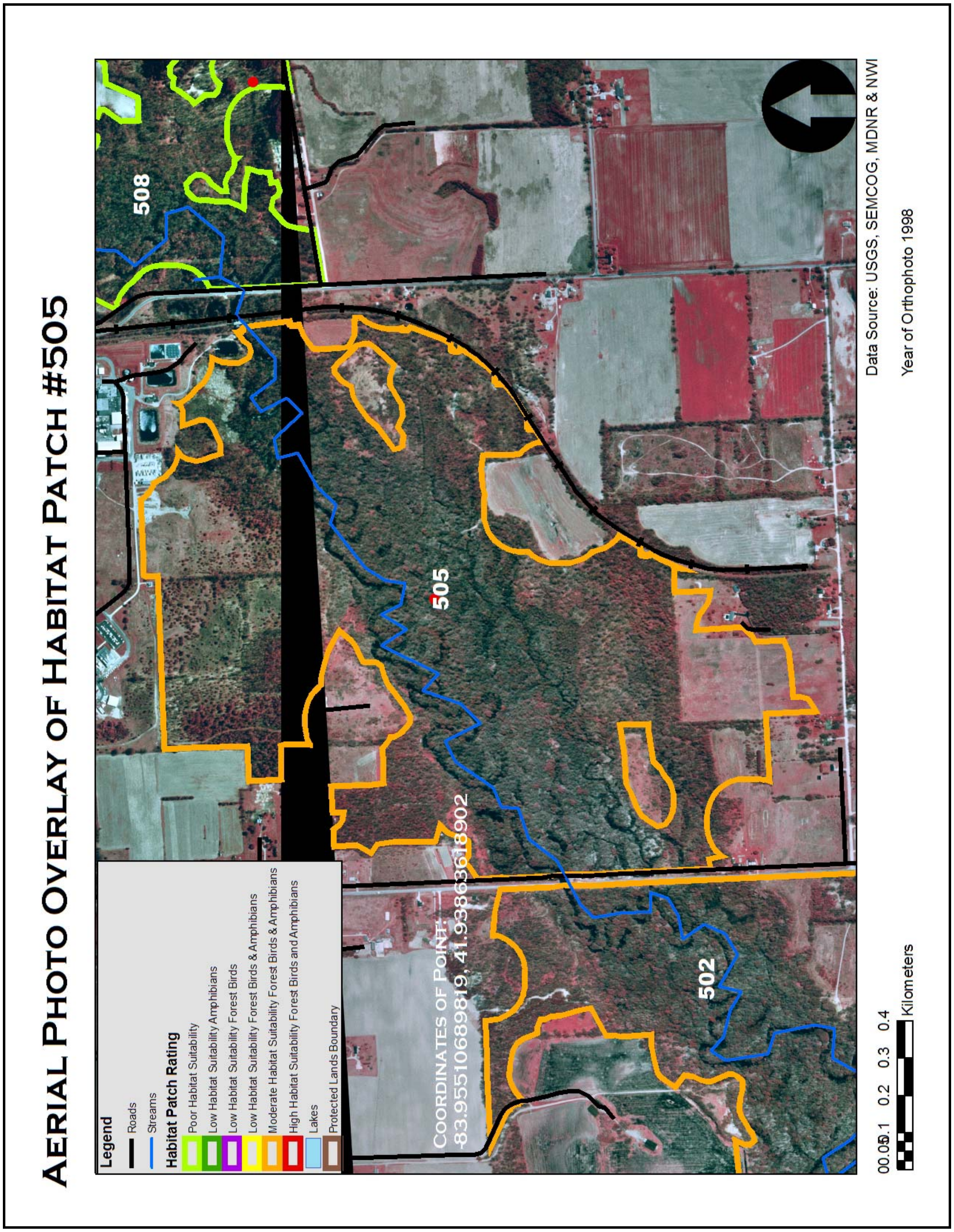
e. Patch #98: Moderate suitability habitat for forest birds, amphibians and reptiles.



f. Patch #502: Moderate suitability habitat for forest birds, amphibians and reptiles.



g. Patch #166: Moderate suitability habitat for forest birds, amphibians and reptiles.



Appendix 13. Codes and Ordinances Worksheet

1. Street Width

a. What is the minimum pavement width allowed for streets in low density residential developments that have less than 500 average daily trips (ADT)?

If the answer is between 18-22 feet, award 4 points

b. At higher densities are parking lanes allowed to also serve as traffic lanes (i.e., queuing streets)?

If the answer is YES, award 3 points

2. Street Length

a. Do street standards promote the most efficient street layouts that reduce overall street length?

If the answer is YES, award 1 point

3. Right-of-Way Width

a. What is the minimum right-of-way (ROW) width for a residential street?

If the answer is less than 45 feet, award 3 points

b. Does the code allow utilities to be placed under the paved section of the ROW?

If the answer is YES, award 1 point

4. Cul-de-Sacs

a. What is the minimum radius allowed for cul-de-sacs?

If the answer is less than 35 feet, award 3 points
If the answer is 36 feet to 45 feet, award 1 point

b. Can a landscaped island be created within the cul-de-sac?

If the answer is YES, award 1 point

c. Are alternative turn arounds such as "hammerheads" allowed on short streets in low density residential developments?

If the answer is YES, award 1 point

5. Vegetated Open Channels

a. Are curb and gutters required for most residential street sections?

If the answer is NO, award 2 points

b. Are there established design criteria for swales that can provide stormwater quality treatment (i.e., dry swales, biofilters, or grass swales)?

If the answer is YES, award 2 points

6. Parking Ratios

a. What is the minimum parking ratio for a professional office building (per 1000 ft^2 of gross floor area)?

If the answer is less than 3.0 spaces, award 1 point

b. What is the minimum required parking ratio for shopping centers (per 1,000 ft^2 gross floor area)?

If the answer is 4.5 spaces or less, award 1 point

c. What is the minimum required parking ratio for single family homes (per home)?

If the answer is less than or equal to 2.0 spaces, award 1 point

d. Are the parking requirements set as maximum or median (rather than minimum) requirements?

If the answer is YES, award 2 points

7. Parking Codes

a. Is the use of shared parking arrangements promoted?

If the answer is YES, award 1 point

b. Are model shared parking agreements provided?

If the answer is YES, award 1 point

c. Are parking ratios reduced if shared parking arrangements are in place?

If the answer is YES, award 1 point

d. If mass transit is provided nearby, is the parking ratio reduced?

If the answer is YES, award 1 point

a. What is the minimum stall width for a standard parking space?

If the answer is 9 feet or less, award 1 point

b. What is the minimum stall length for a standard parking space?

If the answer is 18 feet or less, award 1 point

c. Are at least 30% of the spaces at larger commercial parking lots required to have smaller dimensions for compact cars?

If the answer is YES, award 1 point

d. Can pervious materials be used for spillover parking areas?

If the answer is YES, award 2 points

a. Are there any incentives to developers to provide parking within garages rather than surface parking lots?

If the answer is YES, award 1 point

a. Is a minimum percentage of a parking lot required to be landscaped?

If the answer is YES, award 2 points

b. Is the use of bioretention islands and other stormwater practices within landscaped areas or setbacks allowed?

If the answer is YES, award 2 points

a. Are open space or cluster development designs allowed in the community?

If the answer is YES, award 3 points
If the answer is NO, skip to question No. 12

b. Is land conservation or impervious cover reduction a major goal or objective of the open space design ordinance?

If the answer is YES, award 1 point

c. Are the submittal or review requirements for open space design greater than those for conventional development?

If the answer is NO, award 1 point

d. Is open space or cluster design a by-right form of development?

If the answer is YES, award 1 point

e. Are flexible site design criteria available for developers that utilize open space or cluster design options (e.g, setbacks, road widths, lot sizes)

If the answer is YES, award 2 points

12. Setbacks and Frontages

a. Are irregular lot shapes (e.g., pie-shaped, flag lots) allowed in the community?

If the answer is YES, award 1 point

b. What is the minimum requirement for front setbacks for a one half (½) acre residential lot (=21,780 square feet)?

If the answer is 20 feet or less, award 1 point

c. What is the minimum requirement for rear setbacks for a one half (½) acre residential lot?

If the answer is 25 feet or less, award 1 point

d. What is the minimum requirement for side setbacks for a one half (½) acre residential lot?

If the answer is 8 feet or less, award 1 points

e. What is the minimum frontage distance for a one half (½) acre residential lot?

If the answer is less than 80 feet, award 2 points

13. Sidewalks

a. What is the minimum sidewalk width allowed in the community?

If the answer is 4 feet or less, award 2 points

b. Are sidewalks always required on both sides of residential streets?

If the answer is NO, award 2 points

c. Are sidewalks generally sloped so they drain to the front yard rather than the street?

If the answer is YES, award 1 point

d. Can alternate pedestrian networks be substituted for sidewalks (e.g., trails through common areas)?

If the answer is YES, award 1 point

14. Driveways

a. What is the minimum driveway width specified in the community?

If the answer is 9 feet or less (one lane) or 18 feet (two lanes), award 2 points

b. Can pervious materials be used for single family home driveways (e.g., grass, gravel, porous pavers, etc)?

If the answer is YES, award 2 points

c. Can a "two track" design be used at single family driveways?

If the answer is YES, award 1 point

d. Are shared driveways permitted in residential developments?

If the answer is YES, award 1 point

15. Open Space Management

a. Does the community have enforceable requirements to establish associations that can effectively manage open space?

If the answer is YES, award 2 points

b. Are open space areas required to be consolidated into larger units?

If the answer is YES, award 1 point

c. Does a minimum percentage of open space have to be managed in a natural condition?

If the answer is YES, award 1 point

d. Are allowable and unallowable uses for open space in residential developments defined?

If the answer is YES, award 1 point

e. Can open space be managed by a third party using land trusts or conservation easements?

If the answer is YES, award 1 point

16. Rooftop Runoff

a. Can rooftop runoff be discharged to yard areas?

If the answer is YES, award 2 points

b. Do current grading or drainage requirements allow for temporary ponding of stormwater on front yards or rooftops?

If the answer is YES, award 2 points

17. Buffer Systems

a. Is there a stream buffer ordinance in the community?

If the answer is YES, award 2 points

b. If so, what is the minimum buffer width?

If the answer is 75 feet or more, award 1 point

c. Is expansion of the buffer to include freshwater wetlands, steep slopes or the 100-year floodplain required?

If the answer is YES, award 1 point

18. Buffer Maintenance

a. Does the stream buffer ordinance specify that at least part of the stream buffer be maintained with native vegetation?

If the answer is YES, award 2 points

b. Does the stream buffer ordinance outline allowable uses?

If the answer is YES, award 1 point

c. Does the ordinance specify enforcement and education mechanisms?

If the answer is YES, award 1 point

19. Clearing and Grading

a. Is there any ordinance that requires or encourages the preservation of natural vegetation at residential development sites?

If the answer is YES, award 2 points

b. Do reserve septic field areas need to be cleared of trees at the time of development?

If the answer is NO, award 1 point

20. Tree Conservation

a. If forests or specimen trees are present at residential development sites, does some of the stand have to be preserved?

If the answer is YES, award 2 points

b. Are the limits of disturbance shown on construction plans adequate for preventing clearing of natural vegetative cover during construction?

If the answer is YES, award 1 point

21. Land Conservation Incentives

a. Are there any incentives to developers or landowners to conserve non-regulated land (open space design, density bonuses, stormwater credits or lower property tax rates)?

If the answer is YES, award 2 points

b. Is flexibility to meet regulatory or conservation restrictions (density compensation, buffer averaging, transferable development rights, off-site mitigation) offered to developers?

If the answer is YES, award 2 points

22. Stormwater Outfalls

a. Is stormwater required to be treated for quality before it is discharged?

If the answer is YES, award 2 points

b. Are there effective design criteria for stormwater best management practices (BMPs)?

If the answer is YES, award 1 point

c. Can stormwater be directly discharged into a jurisdictional wetland without pretreatment?

If the answer is NO, award 1 point

d. Does a floodplain management ordinance that restricts or prohibits development within the 100 year floodplain exist?

If the answer is YES, award 2 points

TOTAL

Appendix 14. List of Acronyms

AFO	Animal Feeding Operation
APHA	American Public Health Association
BMPs	Best Management Practices
BSD	Better Site Design
CAFO	Concentrated Animal Feeding Operation
CILER	Cooperative Institute for Limnology and Ecosystems Research
CMI	Clean Michigan Initiative
CSO	Combined Sewer Overflow
CSS	Combined Sewer System
CWA	Clean Water Act
CWP	Center for Watershed Protection
DO	Dissolved Oxygen
EPA	Environmental Protection Agency
GIS	Geographic Information System
ha	Hectare
m	Meter
MDEQ	Michigan Department of Environmental Quality
MDNR	Michigan Department of Natural Resources
Mich. Comp. Laws	Michigan Compiled Laws
MIRIS	Michigan Resource Information System
mL	Milliliter
MNFI	Michigan Natural Features Inventory
MS4	Municipal Separate Storm Sewer System
NEMO	Nonpoint Education for Municipal Officials
NOAA	National Oceanic & Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Sources
NREPA	Natural Resources and Environmental Protection Act
NWI	National Wetlands Inventory

PA	Public Act
PCB	Polychlorinated Biphenyls
POTW	Publicly Owned Treatment Works
PUD	Planned Urban Development
RRWC	River Raisin Watershed Council
RVLT	Raisin Valley Land Trust
SEMCOG	Southeast Michigan Council of Governments
SNRE	School of Natural Resources and Environment
SRP	Soluble Reactive Phosphorus
SSO	Separate Sewer Overflow
SSS	Separate (or Sanitary) Sewer System
TDS	Total Dissolved Solids
TMDL	Total Maximum Daily Load
TNC	The Nature Conservancy
TP	Total Phosphorus
TSM	Total Suspended Matter
TSS	Total Suspended Solids
USFWS	United States Fish & Wildlife Service
USGS	United States Geological Survey
µg/L	Microgram per liter