EAGLE CREEK WATERSHED MANAGEMENT PLAN: AN INTEGRATED APPROACH TO IMPROVED WATER QUALITY

Eagle Creek Watershed Alliance
A coalition including:

Eagle Creek Watershed Taskforce
Central Indiana Water Resources Partnership
2008

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This report should be referenced as:

Tedesco, L.P., Pascual, D.L., Shrake, L.K., Hall, R.E., Casey, L.R., Vidon, P.G.F., Hernly, F.V., Salazar, K.A., Barr, R.C., Ulmer, J., Pershing, D., Hoffmann, J., 2009. Eagle Creek Watershed Management Plan: An Integrated Approach to Improved Water Quality. Eagle Creek Watershed Alliance, CEES Publication 2005-07, IUPUI, Indianapolis, 182p.

Also available online at: www.cees.iupui.edu

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ACRONYMS

BMP	-	Best Management Practices
CAFO	-	Concentrated Animal Feeding Operation
CEES	-	Center for Earth and Environmental Science, IUPUI
CIWRP	-	Central Indiana Water Resources Partnership
CUPE	-	Center for Urban Policy and the Environment, IUPUI
ECW	-	Eagle Creek Watershed
ECWA	-	Eagle Creek Watershed Alliance
ECWTF	-	Eagle Creek Watershed Task Force
EPA	-	Environmental Protection Agency
FCA	-	Fish Consumption Advisory
GIS	-	Geographic Information Systems
IBI	-	Index of Biotic Integrity
IDEM	-	Indiana Department of Environmental Management
IHMIP	-	Indiana Heartland Model Implementation Project
INCAA	-	Indiana Community Action Association
IUPUI	-	Indiana University - Purdue University at Indianapolis
LUCI	-	Land Use in Central Indiana
MCHD	-	Marion County Health Department
NAWQA	-	National Water Quality Assessment
NPDES	-	National Pollutant Discharge Elimination System
PCB	-	Polychlorinated Biphenyls
POTW	-	Publicly Owned Treatment Works
USGS	-	United States Geological Survey

Section I: Executive Summary

The Eagle Creek Watershed Management Plan:
An Integrated Approach to Improved Water Quality

The Eagle Creek Watershed Management Plan is the result of combined efforts of the Eagle Creek Watershed Task Force and the Central Indiana Water Resources Partnership (a long-term research and development partnership between the Center for Earth and Environmental Science at IUPUI and Veolia Water Indianapolis, LLC). The groups have joined forces to create the Eagle Creek Watershed Alliance (ECWA), a group of citizens, researchers, and managers working together to improve water quality in Eagle Creek Watershed.

Eagle Creek Watershed is located in Central Indiana approximately 10 miles northwest of downtown Indianapolis. The watershed is relatively flat and has a 162 mi^2 drainage area upstream of the Eagle Creek Reservoir dam. The Eagle Creek Reservoir, which is used as a public drinking water supply for the City of Indianapolis, is located completely within Marion County, while the rest of Eagle Creek Watershed runs through parts of Marion, Hendricks, Boone, and Hamilton counties. The dominant land-cover in Eagle Creek Watershed (approximately 60%) is agriculture (mostly corn and soybean) with some portions of the watershed, particularly those close to the reservoir, undergoing urbanization.

The ECWA seeks to bring a fresh approach and new energy to solving watershed problems by increasing the scientific basis for watershed management decisions while incorporating stakeholder concerns and views. This approach is apparent in the *Eagle Creek Watershed Management Plan: An Integrated Approach to Improved Water Quality*. The development of the Plan consisted of:

1. <u>Investigating and Assessing Water Quality Issues in Eagle Creek Subwatersheds</u> – The investigation of water quality issues used historical and recent datasets to assess water quality conditions of subwatersheds and develop problem statements and locate critical areas. A comprehensive Subwatershed Assessment was conducted utilizing several layers of information. The subwatersheds were then ranked against each other to determine those most impacted.

2. <u>Developing Concerns and Problem Statements</u> – Concerns and problem statements were based on a multi-parameter, systematic process, allowing areas of greatest concern to be chosen by the degree of water quality degradation and the possible causes of such degradation. This approach led to the determination of the best course of remediation and insight into the possible outcomes of proposed remediation. Five primary areas of concern have been identified:
    a. Streams in the Eagle Creek watershed exceed the Indiana single sample daily maximum of 235 colonies per 100 milliliters for *Escherichia coli* (*E. coli*) bacteria.
    b. Concentrations of Atrazine in Eagle Creek watershed streams are resulting in elevated Atrazine levels in Eagle Creek Reservoir that exceed the USEPA standard of 3.0 µg/L (.003 mg/L) for drinking water supplies.

   c. Sediment loads in the subwatersheds of Eagle Creek are high during event flows, eventually transporting large pulses of sediment to the reservoir and potentially degrading aquatic habitat.
   d. Nutrient concentrations in all streams in Eagle Creek watershed frequently exceed the national average for watersheds with 50-75% agricultural use.
   e. An adequate educational outreach program is not in place to inform the residents in the Eagle Creek Watershed about their role in maintaining the overall quality of the watershed.

3. <u>Identifying and Prioritizing Critical Areas</u> - A Critical Areas Evaluation tool was developed and a List of Priorities was created for Eagle Creek Watershed. A Subwatershed Prioritization list was then created for subwatersheds chosen for best management implementation. The Critical Area Evaluation took into consideration:
   a. The level of water quality degradation based on benchmark assessment of water quality.
   b. The identification of land-use/land-cover assessments that showed specific areas particularly vulnerable to on-going and future degradation (vulnerability).
   c. The feasibility of remediation.
   d. The opportunity of a given geographic area, best management practice, or pollution source to serve as a key educational tool or demonstration model.

4. <u>Developing Goals and Action Items</u> - Goal achievement was parsed into short-term and long-term target outcomes with each having an associated objective, action item, and indicator(s) of success.

5. <u>Implementing the Watershed Management Plan</u> - A multi-pronged approach to water resource sustainability will be taken to achieve and maintain the water quality goals of the management plan. The first approach is through a series of watershed Best Management Practices and associated demonstration projects. The second approach is through several complimentary watershed education projects.

6. <u>Determining Indicators of Success</u> - Measuring success involves tracking several indicators which have been divided into two major categories: Water Quality Improvements and Education and Outreach Achievements.

The ECWA intends to carry out the goals of this Plan. With the assistance of implementation grants, the ECWA proposes to accomplish a series of initiatives including implementation and demonstrations of best management practices, water quality monitoring, watershed education, and public information and outreach. The ECWA believes that this Watershed Management Plan will provide a sound foundation from which more ambitious and holistic management initiatives can be developed.

Section II: Project Introduction

Designating the Study Area

Eagle Creek Watershed is located approximately 10 miles northwest of downtown Indianapolis within the Eastern Corn Belt Ecoregion (Central Till Plain Natural Region) in the Upper White River Watershed, IN (Figure II-1). Topography of the watershed is relatively flat and consists of productive soils developed in glacial till and loess. It has a drainage area north of the Eagle Creek Reservoir dam of 162 mi^2. The Eagle Creek Reservoir, which is part of the Indianapolis' public drinking water system, is located completely within Marion County, while the rest of the watershed runs through parts of Marion, Hendricks, Boone, and Hamilton counties (Figure II-1). The watershed is divided into 10 subwatersheds varying in size from 10.4 mi^2 to 20.9 mi^2. The town of Zionsville is the largest urban community within the watershed located approximately 5 miles north-northeast of the reservoir and with a population of approximately 8,800 in 2000 (IBRC, 2002). In 2000, 52% of the watershed land cover was agriculture, 29.9% was herbaceous land cover, 9.3% was forested, and 4.3% was high and low density development. Agriculture and herbaceous land cover has declined while high/low density and herbaceous land cover has increased since 2000. The greatest percent of agricultural land is located at the northern portions of the watershed while the portions closer to Eagle Creek Reservoir are undergoing significant urbanization. Subwatersheds transitioning to suburban development the fastest are Little Eagle Branch-Woodruff Branch, Eagle Creek-Long Branch/Irishman Run, Eagle Creek/Jackson Run, School Branch, and Fishback Creek.

Building Partnerships

In 1995, in response to growing Atrazine concerns in Eagle Creek Watershed, a group of concerned citizens led primarily by a watershed coordinator, who was hired by the Indiana Farm Bureau, began to address water quality issues in the Watershed. Funded by an EPA 319 grant, this group, the Eagle Creek Watershed Taskforce (ECWTF), held monthly meetings with stakeholders such as Veolia Water Indianapolis, LCC (formerly USFilter Indianapolis Water, formerly the Indianapolis Water Company) and the Marion County Health Department (MCHD) and developed a monitoring program for the Watershed **(**Appendix A).

In 2003, the Center for Earth and Environmental Science (CEES) and USFilter Indianapolis Water (now Veolia Water Indianapolis, LCC), joined to form the Central Indiana Water Resources Partnership (CIWRP), a long-term research and development partnership focused on creating a center of excellence in water quality and watershed research. In 2004, building on the work of the ECWTF, CIWRP joined the citizens group to begin implementation of best management practices in Eagle Creek Watershed. The combined efforts of the ECWTF and CIWRP resulted in the creation of the Eagle Creek

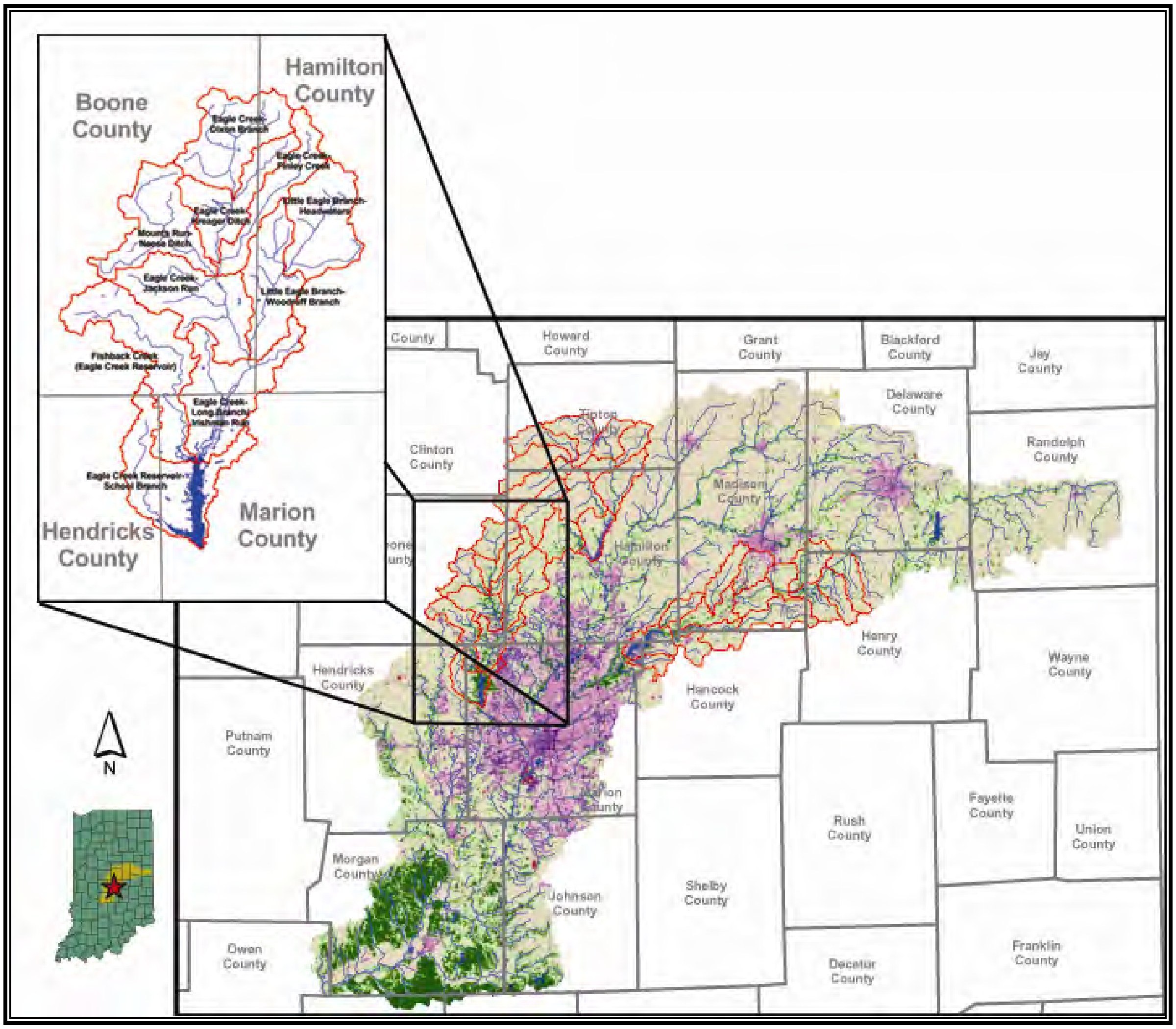


Figure II-1: Eagle Creek Watershed in relation to the Upper White River Watershed

Watershed Alliance (ECWA), a group of citizens, researchers, and managers working together to improve water quality in Eagle Creek Watershed (Appendix B).

Missions

The Eagle Creek Watershed Task Force

The mission of the Eagle Creek Watershed Taskforce is to improve water quality and the environment of Eagle Creek Watershed by working cooperatively with those who impact, and are impacted by watershed activities.

The Eagle Creek Watershed Alliance

The Eagle Creek Watershed Alliance is a broad coalition of individuals, volunteers, foundations, local organizations, utilities, county, state and federal agencies, and universities whose mission is to utilize a holistic approach to watershed management with the ultimate goals of improving water quality, increasing public awareness of watershed water quality, and encouraging stewardship of the watershed's resources.

The ECWA will coordinate watershed research, water quality monitoring, BMP implementation, and watershed education and outreach programs in an effort to boost community awareness and involvement in local watershed issues

History of Eagle Creek Watershed Management Efforts

1995 and 1996

In 1995 and 1996, due to the timing and intensity of spring rains in relation to the agricultural producers' activities in the fields, the levels of triazines in the Eagle Creek Reservoir's untreated water exceeded the Environmental Protection Agency's (EPA's) drinking water quality standard (3 ppb or 0.003 mg/L) for most of each year. To maintain drinking water quality, the Indianapolis Water Company added powder-activated carbon to their water treatment process, an expensive necessity to ensure safe drinking water for the 80,000 customers whose source water is Eagle Creek Reservoir.

The knowledge of high Atrazine levels in the watershed coupled with an increased public concern that was not always grounded in "solid science", catalyzed a dialogue between Novartis (formerly Ciba), a company that utilizes Atrazine in some of their products, the (then) Indianapolis Water Company , and the Indiana Farm Bureau. These three organizations expressed a strong desire to make permanent changes within Eagle Creek Watershed that would result in better quality water; not only in terms of Atrazine, but also in terms of all water quality parameters.

From the beginning, initial efforts were hampered by the lack of consistent data. With the exception of Indianapolis Water Company records from their raw water intake (located in the reservoir itself) and the 1982 Indiana Heartland Model Implementation Project Report, little more than general, discontinuous data existed, especially for the watershed.

In the spring of 1997, meetings were held with individuals from various technical agencies such as Soil and Water Conservation Districts, the Natural Resources Conservation Service, and other successful watershed protection groups. From these contacts, a model based on other successful efforts came forth.

1997

In 1997, Indiana Farm Bureau hired a watershed coordinator to focus the work of the ECWTF. This year, the ECWTF with the help of the Indianapolis Water Company began a detailed monitoring study of the Watershed. This would provide crucial bench marking from with which to measure future progress. So while efforts were underway to develop a contact list of potential stakeholders for the steering committee, a monitoring program was established in the watershed.

The monitoring program was a cooperative venture between Indiana Farm Bureau and the Indianapolis Water Company. The Indianapolis Water Company ran chemical analyses on water samples free of charge for eight different water quality parameters (i.e. Triazines, Ammonia, Nitrates, Nitrites, Turbidity, Fecal Coliform (*E. Coli*.), Total Coliform, and Hetrotropic Plate Counts. In later years, sulfates and chlorides were added.

Samples were collected at ten sites scattered throughout the four-county watershed. The sample sites and frequency where chosen to assess tributary water quality during the agricultural/construction season. Generally, the sampling was intended to be every week for the months of April through June (when lawn, agricultural, and construction impacts are most likely to be intensified due to early season rains), and then every other week until the end of October. With only a few isolated exceptions, this schedule was followed every year since 1997. These samples provided a valuable baseline water quality data for the watershed.

At this time, the Steering Committee submitted an application for an EPA 319 grant application.

1997 – 2002

ECWTF data collection and watershed educational programs continued in the watershed. This included mailings and articles in local newspapers and public tours of septic fields and ECWTF sample sites. At this time, the EPA 319 grant was approved for funding and work on a Watershed Management Plan began.

2002 – 2003

ECWTF submitted and received an EPA 319 grant to support an *E. coli* DNA ribotyping study in Eagle Creek Watershed. This grant was also supported by funding from the Sierra Club. Another 319 grant was submitted to begin Phase I Implementation for best management practices in the watershed. This grant wasn’t successful due to lack of supporting data in the Watershed Management Plan.

2004 – 2005

ECWTF began work with the Center for Earth and Environmental Science at Indiana University – Purdue University, Indianapolis (IUPUI) to submit another EPA 319 grant to begin Phase I Implementation for best management practices, detailed loading studies in the watershed, and collaboration to complete the Watershed Management Plan.

2006 – 2008

The Eagle Creek Watershed Alliance (ECWA) began the 319 Phase I Implementation grant. Three active committees were established (Technical, Education, and Communication Committees). Cost-share projects were installed throughout the watershed and several educational events and materials were produced. A Phase II Implementation 319 grant was submitted to IDEM/EPA for continued BMP implementation and watershed coordination services.

A History of Eagle Creek Watershed Research Efforts

IDEM Assessment Information Management System (AIMS): Documented 23 watershed stations in Eagle Creek Watershed and 20 stations in Eagle Creek Reservoir. Water samples are analyzed for nearly 50 chemical parameters; however, not all sites are monitored for all 50 parameters.

Indiana Heartland Model Implementation Project (1982): Examined watershed data from 1971 – 1980 and reservoir data from 1980-1981; showed that non-point source pollution is a problem in Eagle Creek Watershed and the affects of best management practices.

IDEM Lake Water Quality Assessment Program: Sampling occurred on Eagle Creek Reservoir, Geist Reservoir, and Morse Reservoir once in the 1970s, once in the 1980s, 1991, 1995, and 1996. Physical, chemical, and biological data were gathered to determine the lakes trophic status based on the Indiana Trophic State Index.

Marion County Health Department (1995 – Present): Sited 11 stations in Eagle Creek Watershed around Eagle Creek Reservoir and 1 station on Eagle Creek Reservoir. Sampling occurs on a bi-weekly basis during the growing season and includes the measurement of *in-situ* water quality parameters (dissolved oxygen, temperature, pH, conductivity, and total dissolved solids) and the analysis of soluble nitrogen compounds, ortho-phosphorous, and several herbicides and pesticides.

IDEM Zooplankton Study (2000): Zooplankton were sampled from Eagle Creek Reservoir and Geist Reservoir on August 10, 2000 using an underwater light trapping technique. Data showed that algaecide treatment did not affect mid-summer zooplankton community over the period of the study.

Eagle Creek Watershed Taskforce, ECWTF (1997 – 2003): Funded through an IDEM 319 Grant, the ECWTF sited 10 stations in Eagle Creek Watershed for bi-weekly sampling for chemical and biological analysis during the growing season; showed that *E. coli* and Atrazine contamination is a problem in Eagle Creek Watershed.

Veolia Water Indianapolis (formerly USFilter and Indianapolis Water Company): Two watershed sampling stations were sited in Eagle Creek Watershed and monitored from October 2002 to present. Water samples are collected bi-weekly and analyzed for chemical water constituents (e.g., nutrients). Water from the T.W. Moses Drinking Water Plant intake on Eagle Creek Reservoir intake also sampled bi-weekly and analyzed for *E. coli*, Atrazine, nutrients, and other chemical water constituents.

Central Indiana Water Resources Partnership: Several studies on the watershed and reservoir have been completed, initiated, and proposed through the CIWRP partnership:

2002 – Geologic and Climatological Setting Analysis for Eagle Creek Reservoir, Geist Reservoir, and Morse Reservoir (Tedesco et al., 2002-2003)
2002 – Surficial Sediment Characterization for Eagle Creek Reservoir, Geist Reservoir, and Morse Reservoir (Tedesco et al., 2002-2003)
2003 – Eagle Creek Reservoir: Responses to Algaecide Treatment (Pascual and Tedesco, 2003-2004)
2003 – Phytoplankton Ecology of Eagle Creek Reservoir, IN (Pascual and Tedesco, 2003-2004)
2003 – Eagle Creek Reservoir Zooplankton Growth Responses to the Blue-green Algae Microcystis and Anabaena (Trierweiler and Pascual, 2003-2006)
2003 – Seasonal Loading Contributions to Eagle Creek Reservoir, Geist Reservoir, and Morse Reservoir from Non-point Watershed Sources (Shrake, Hall, Tedesco and Atekwana, 2003-2005)
2003 – *E. coli* distribution in Eagle Creek Watershed (Kuhn Master's Project)
2004 – Eagle Creek Reservoir Nutrient Mass Balance (Pascual, Shrake, Tedesco, Hall, 2004-2006)
2004 – Watershed Input Tracking of Allochthonous Organic Matter and Nutrients to Eagle Creek, Geist, and Morse Reservoirs (Mattox and Filley, 2004-2005)
2005 – Eagle Creek Watershed Alliance: Phase 1 Watershed BMP Implementation, Education and Public Outreach Grant (Eagle Creek Watershed Alliance, IDEM 319 Grant, 2005-2009)
2005 – Nutrient and Sediment Stream Budgets of Streams Under the Influence of Agriculture, Urbanization, and In-transition areas in Eagle Creek Watershed, IN (Vidon, Tedesco, Pascual, Campbell, Casey, Wilson, Gray, 2005-2008)
2005 – Nutrient Limitation and Phytoplankton Succession in Eagle Creek Reservoir (Pascual,et al., 2005-2006)
2005 – Multi-Reservoir Survey Showing the Relationship between Nitrogen Limitation and Nuisance Algal Bloom Formation (Pascual, 2005-2006)
2005 – Mapping Blue-Green Algae with Hyperspectral Imagery in Central Indiana Reservoirs (Li, Wilson, Tedesco, Randolph, Sengpiel, Valleley, Robertson, 2005-2009).
2005 – Watershed-Scale Evaluation of BMP Effectiveness and Acceptability: Eagle Creek Watershed, Indiana (Tedesco, Wilson, Turco, Barr, and Hall, 2005-2009)
2006 – Quantifying Blue-Green Algae of Central Indiana Reservoirs Using Hyperspectral Reflectance (Li, Tedesco, and Wilson, 2006-2007)
2006 – Development of Time-Series Models for Water Quality Management in Eagle Creek Reservoir (Kelson and Wittman, 2006)
2006 – Stream Nitrate and Organic Carbon Dynamics during Storms in Eagle Creek Watershed (Wagner, Vidon, Tedesco, and Gray, 2006-2008)
2007 – Empirical and Bio-optical Modeling of Hyperspectral Reflectance for Improved Mapping of Water Quality Parameters in Central Indiana Reservoirs (Li, Tedesco, and Wilson, 2007-2008)

2007 – Contaminant Transport Dynamics During Storms in Medium to Large River Systems of the Midwest (Vidon, Tedesco, Johnstone, and Stouder, 2007-2009)
2007 – Internal Phosphorus Cycling in an Urban Drinking Water Reservoir (Raftis Master's Thesis)
2007 – Remote Sensing of Phytoplankton Using Optically Active Pigments, Chlorophyll a and Phycocyanin (Randolph Master's Thesis)
2007 – Effects of Land Cover on Water Quality and Nutrient Loading (Casey Master's Thesis)
2008 – Measurement of Cyanobacterial Toxins in Three Central Indiana Drinking Water Reservoirs (Tedesco and Clercin, in progress)
2008 – Cyanobacterial Ecology and Toxicology of Central Indiana Reservoirs (Tedesco and Clercin, in progress)
2008 – Using Hyperspectral Remote Sensing To Estimate Chlorophyll a and Phycocyanin in Central Indiana Reservoirs (Sengpiel Master's Thesis)
2008 – Nutrient Specific Flow Paths during Storm Events in a Glaciated, Artificially Drained Landscape (Wagner Master's Thesis)
2009 – Mitigation of Contaminants in Rural and Semi-Rural Environments to Protect Surface and Groundwater (Tedesco, Moreau-Le Golvan, Matzinger, Grutzmacher, Soyeux, Babbar-Sebbens, and Jacinthe, in progress)
2009 – Algal Ecology and Toxicity (Tedesco and Clercin, in progress)

Section III: Physical Setting of Eagle Creek Watershed

Geological and Climatological Description of Central Indiana and Eagle Creek Watershed

To better characterize the water resources of Eagle Creek Watershed, it is important to consider them within their overall geologic and climatologic setting.

Indiana's Climate Setting and Climate Change

Indiana's climate is classified as temperate continental and humid. Continental climates have a pronounced difference in average seasonal temperatures between summer and winter. Humid climates are those where the normal annual precipitation exceeds annual evapotranspiration. The average annual temperature varies across the state from 48°F (8.7°C) in the northeast to 57°F (13.7°C) in the southwest. The Central Indiana area has an average annual temperature of ~52°F (Figure III-1; Newman, 1997; Clark, 1980).

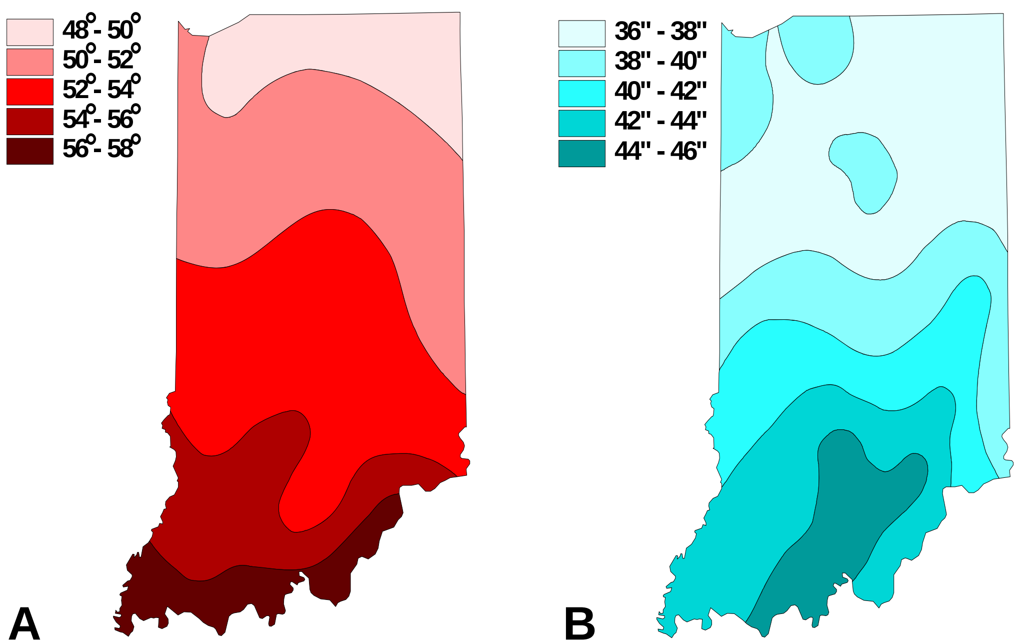


Figure III-1: (A) Average annual temperature in degrees Fahrenheit (ºF). (B) Average annual precipitation in inches (1931-1980). Modified from Clark, 1980.

The average annual precipitation for Central Indiana is 38" to 40" (97 to 102 cm) (Figure III-2; Newman, 1997). In central areas of the state, the wettest seasonal period is late spring; the driest is February (Figure III-2; Newman, 1997). In central Indiana, more than half (54%) of the average annual precipitation occurs during the five-to-six month frost-free growing season. This distribution of rainfall affects the timing and magnitude of water recharge to groundwater resources as well as the timing and magnitude of surface runoff (Figure III-3; Clark, 1980). Using the average values, about 68 % of the precipitation is lost as evaporation, while approximately 9% will recharge groundwater reserves, and the remaining 23% becomes surface runoff (Figure III-4; Clark, 1980).

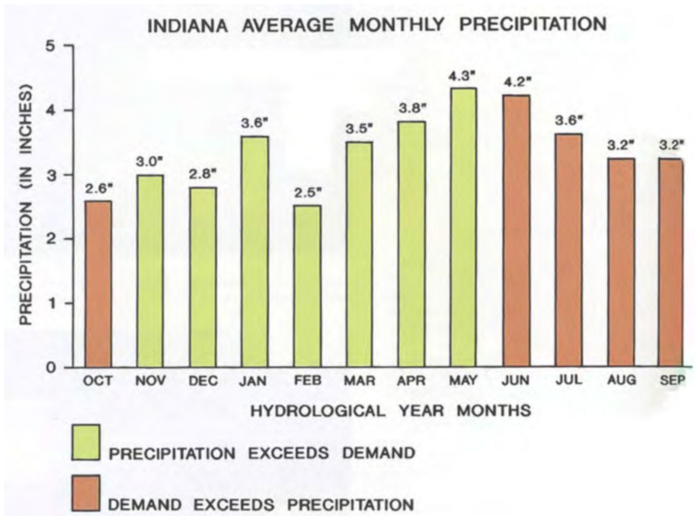


Figure III-2: Average Monthly Precipitation in Indiana. Demand is defined as Evapotranspiration. Newman, 1997.

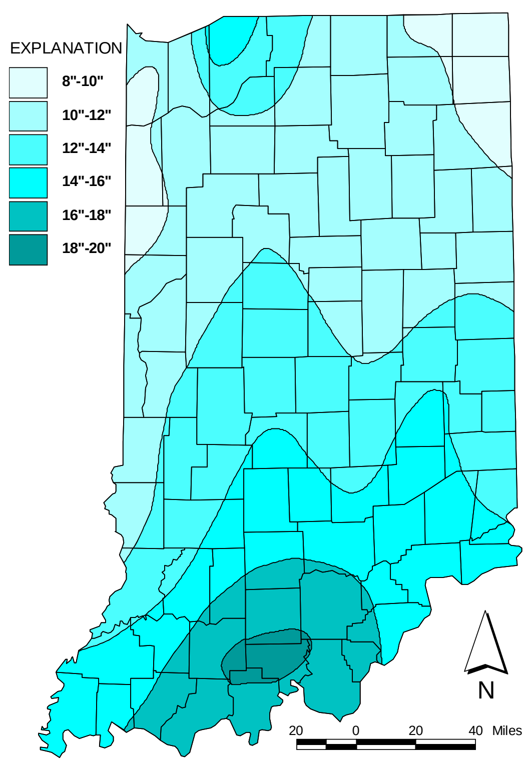


Figure III-3: Average Precipitation Runoff in Indiana. Clark, 1980.

Evidence of climate change is present in Indiana. Continuous and accurate climatological records have existed since about the middle of the nineteenth century. They show that climate has changed over the past century and that detectable shifts have occurred over decadal time scales. Analyses of nine Central Indiana climate records are similar to century long climate trends on global and hemispherical scales (Figure III-5A; EPA, 1998, Newman, 1997). Central Indiana records showed a warming trend of nearly 3°F in annual mean temperature between the 1890s and the 1930s, followed by a cooling trend of about 2°F from the 1940s through the 1970s. A sharp increase occurred in the 1980s, giving rise to the warmest decadal mean annual temperatures since the 1930s (Figure III-5B; Newman, 1997). Other regional observations also suggest that global climate may be changing and the effects of these changes on drinking water supplies and the ecosystem dynamics of lakes and reservoirs should be considered (IPCC, 1995). These observations include:

a) the 20th century's ten warmest years all occurred in the last fifteen years of the century;
b) 1995 record warmth was eclipsed by 1997 record warmth;
c) 1998 was the warmest year on record (since 1860); and
d) the 1990s were the first decade on record with three years featuring nine or more hurricanes which develop over warm ocean water (EPA, 1998).

In Indiana, El Niño climate disturbances result in extended periods of above normal precipitation (e.g. 1993). The 1980s and 1990s had an unusual number of El Niño events (1982-83, 1986-87, 1991-92, 1993, 1994, 1997-98). In Indiana, La Niña results in below normal seasonal precipitation and above-normal seasonal temperature (e.g., 1983, 1988). Other La Niña years included a weak event in 1995-96 and events in 1998-99. The decade with the most summer droughts was the 1930s, followed by the 1980s.

As watershed managers continue to face challenges of harmful algal blooms in Eagle Creek Reservoir and changes in overall water quality, consideration of the role of climate and climate change will need to be taken into account.

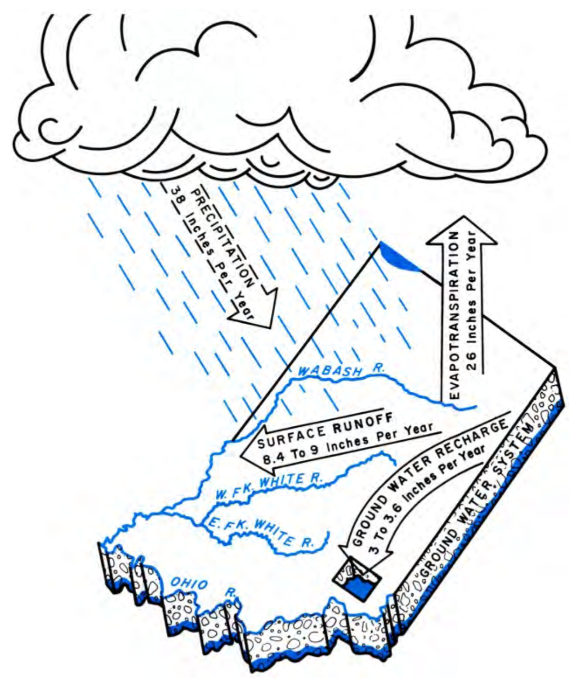
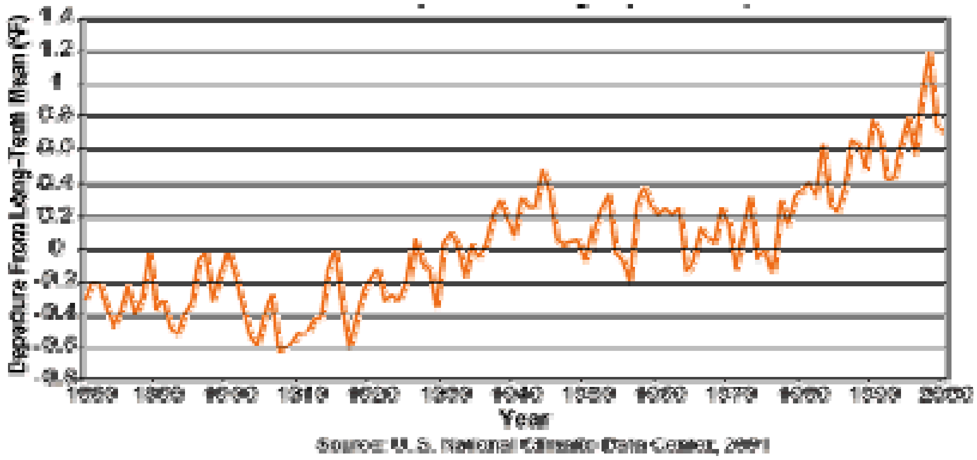


Figure III-4: Indiana's Hydrologic Cycle. Clark, 1980

A



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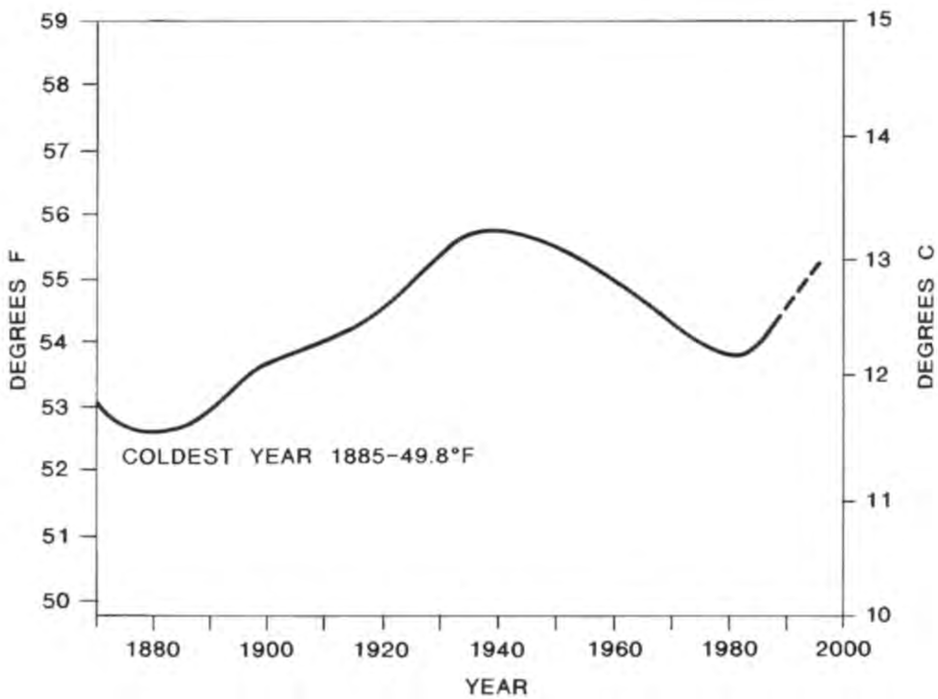


Figure III-5: Climate Change Data (A) Global Temperature Changes (EPA, 1998), (B) Climate Change Trends for Central Indiana (Newman, 1997).

Central Indiana's Geologic and Physiographic Setting

Bedrock Geology

In Central Indiana, the bedrock trends from northwest to southeast with units of increasing age progressing from southwest to northeast across the state. In the study area, the youngest bedrock includes Mississippian-age carbonates (limestone and dolomite), siltstones, and shales (Shaver *et al*., 1986; Gray *et al*., 1987; Gray, 1989; and Rupp, 1991). To the northeast, Devonian-age limestones, dolomites, and black shales occur. In the easternmost portion of the study, Siluirian-age limestones and dolomites prevail. A generalized bedrock geology map of Indiana is shown in Figure III-6 (Clark, 1980).

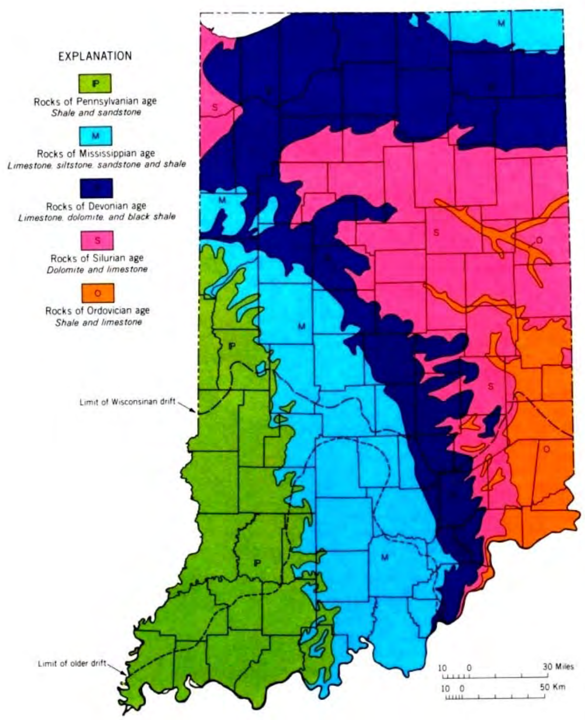


Figure III-6 Bedrock Geology Map for Indiana. Clark, 1980.

Glacial History

Most of Indiana was covered and reshaped by glaciers during at least three separate glacial episodes of the Pleistocene Epoch (Wayne, 1966; Figure III-7). The materials deposited in Central Indiana during glaciation consist primarily of till (a poorly sorted mixture of gravel, sand, silt, and clay), sand and gravel along streams, and silty lake deposits. Materials of the most recent glaciation (Wisconsinian, Figure III-7C-F) were deposited above and covered most of the materials of previous glaciations, except in the far southwest and southeast portions of the state. Unconsolidated deposits may be several hundred feet thick.

Natural Regions and Landscape

Much of Central Indiana lies within the Tipton Till Plain Section of the Central Till Plain region (Gray, 2000; Figure III-8). The Tipton Till Plain Section is topographically uniform and of very low relief with slope angles of mostly 1-2°, with some 2-6° slopes (Figure III-9; Waldrip and Roberts, 1972). The downstream portions of the Eagle Creek Watershed exhibit some areas of higher relief. This is caused by glacial incision of major valleys during deglaciation of the ice sheet. These deep narrow valleys that are now occupied by Eagle Creek, its tributaries, and Eagle Creek Reservoir are much deeper than the surrounding uplands and provide dramatic relief compared to the headwater areas of the watershed.

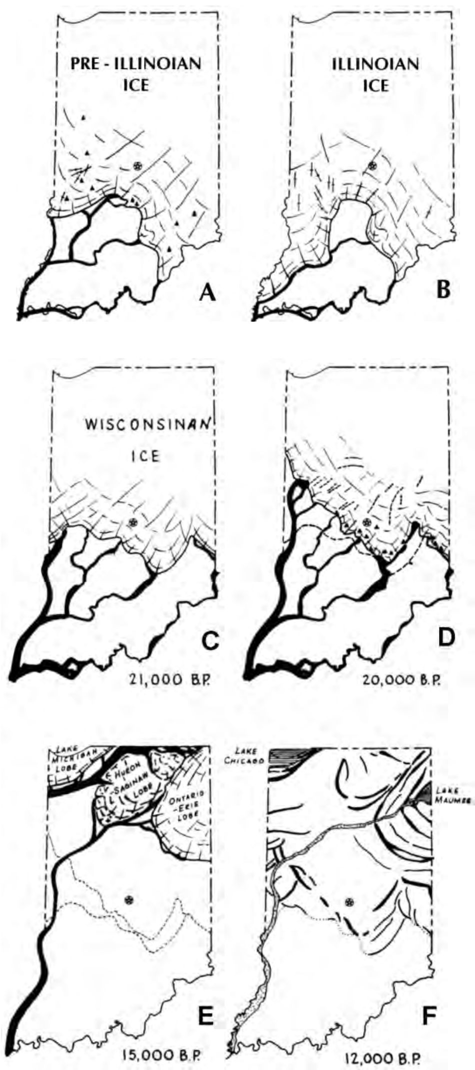


Figure III-7: Extent and Retreat of Glacial Ice in Indiana. A and B Depict the Maximum Extent of Two Previous Glaciations. The Glacial Ice Completely Retreated from Indiana Between these two Glaciations and the Wisconsinan Glaciations Depicted in image C, D, & E. Image C depicts the Maximum Extent of the Last Glaciation. Images D-F Depict the Retreat of Glacial Ice and Generalized Deposits (Wayne, 1966).

Soils

The soils within the Tipton Till Plain are generally poorly draining soils (Figure III-10) developed in glacial materials and include thin loess over loamy glacial till (Clark, 1980; Hall, 1999) and alluvial materials deposited since the last glaciation. These soils formed under dense pre-settlement forests of beech and maple, oak, ash and elm (Newman, 1997). These soils have profiles characterized by an A Horizon, an E Horizon (where it hasn't been mixed by cultivation), and a B Horizon that is underlying horizons (Hall, 1999). The B Horizon is yellowish-brown when the soil is well drained and gray with mottles if the soil is poorly drained (Hall, 1999). These alfisols are excellent for farming but many require artificial drainage in the nearly flat Tipton Till Plain. Soil erosion, however, is not as severe as in most of southern Indiana where slopes are steeper (Figure III-10 and Figure III-11; Clark, 1980).

Eagle Creek Watershed's Geologic and Physiographic Setting

Bedrock Geology

The rock units underlying the Eagle Creek Watershed range in age from Upper Silurian (~420 my) to Lower Mississippian (~345 my; Figure III-12). The far northeastern portion of the watershed is underlain by the upper members of the Silurian-aged Wabash Formation. These rocks are generally brown, fine-grained dolomite to dolomitic limestone. Moving southwest, the area is underlain by the Middle Devonian-aged Muscatatuck Group. It consists of brown sandy dolomite to sandy dolomitic limestone and gray, shaley fossiliferous limestone. The north-central and southern areas of the watershed are underlain by the Upper Devonian to Lower Mississippian-aged New Albany Shale. It consists of brownish-black carbon-rich shale, greenish-gray shale, and minor amounts of dolomite and dolomitic quartz sandstone. Underlying the far western portion of the watershed is the lower portion of the Lower Mississippian-aged Borden Group consisting of dark gray shale to claystone (Shaver *et al*., 1986; Gray *et al*., 1987).

Surficial Deposits

The surficial deposits within the Eagle Creek Watershed are overwhelmingly dominated by loam till of the Trafalgar Formation (Figure III-13). Outwash of the Atherton Formation consists of sand and gravel along major valleys and was deposited by glacial meltwater during the deglaciation of the area. Large areas of outwash can be found along Fishback Creek in Boone County and within Eagle Creek Valley and Reservoir in Marion County. A small area of lake deposits consisting of silt and clay can be found in the uppermost reaches of Fishback Creek in Boone County. Modern alluvium consisting of sand, silt and minor clay can be found along most of the streams throughout the watershed. The surficial deposits range in thickness from 50 feet to 350 feet and average approximately 200 feet.

Soils

Soil associations ("landscapes that have a distinctive pattern of soils in defined proportions", NRCS) within the Eagle Creek Watershed are mapped in Figure III-14.

The dominant soil associations are the Crosby-Treaty-Miami association in the headwaters, and Miami-Crosby-Treaty association along the downstream areas. Minor soil associations include the Sawmill- Lawson- Genesee association within the Eagle Creek Valley and two associations, the Fincastle-Brookston-Miamian association and Mahalasville-Starks-Camden association, along the northwestern watershed boundary.

The Crosby– Treaty- Miami association consists of a deep, poorly drained, nearly level to gently sloping soils formed in a thin silty layer overlying glacial till. This association occurs on the gently undulating upland till plains at the headwaters of the watershed.

The Miami- Crosby- Treaty association consists of deep well drained to somewhat poorly drained, nearly level to moderately steep soils formed in a thin silty layer and the underlying glacial till. This association occurs on slightly to moderately dissected upland plains between the uplands (Crosby-Treaty-Miami association) and the bottomlands (Sawmill- Lawson-Genesee association). The Sawmill-Lawson- Genesee association consists of deep, well drained to very poorly drained, nearly level soils formed in loamy alluvium. This association occurs within the bottomlands or floodplain of the lower half of Eagle Creek including that area which is now flooded by Eagle Creek Reservoir. The Fincastle-Brookston-Miamian association consists of deep, poorly drained, fine to medium textured, nearly level soils formed in silts and silt-covered glacial till on uplands. This association is found in the headwater uplands of the far western portion of the watershed where the silt overlying the glacial till is substantially thicker (22-40 inches) than elsewhere in the watershed (generally less than 20 inches). The Mahalasville-Starks-Camden association consists of deep, poorly drained, moderately fine to medium textured, nearly level soils formed in glacial outwash and lake deposits on outwash plains. This association is found in the headwater uplands of the far western portion of the watershed where silty loess or lake deposits overlie loamy to sandy outwash.

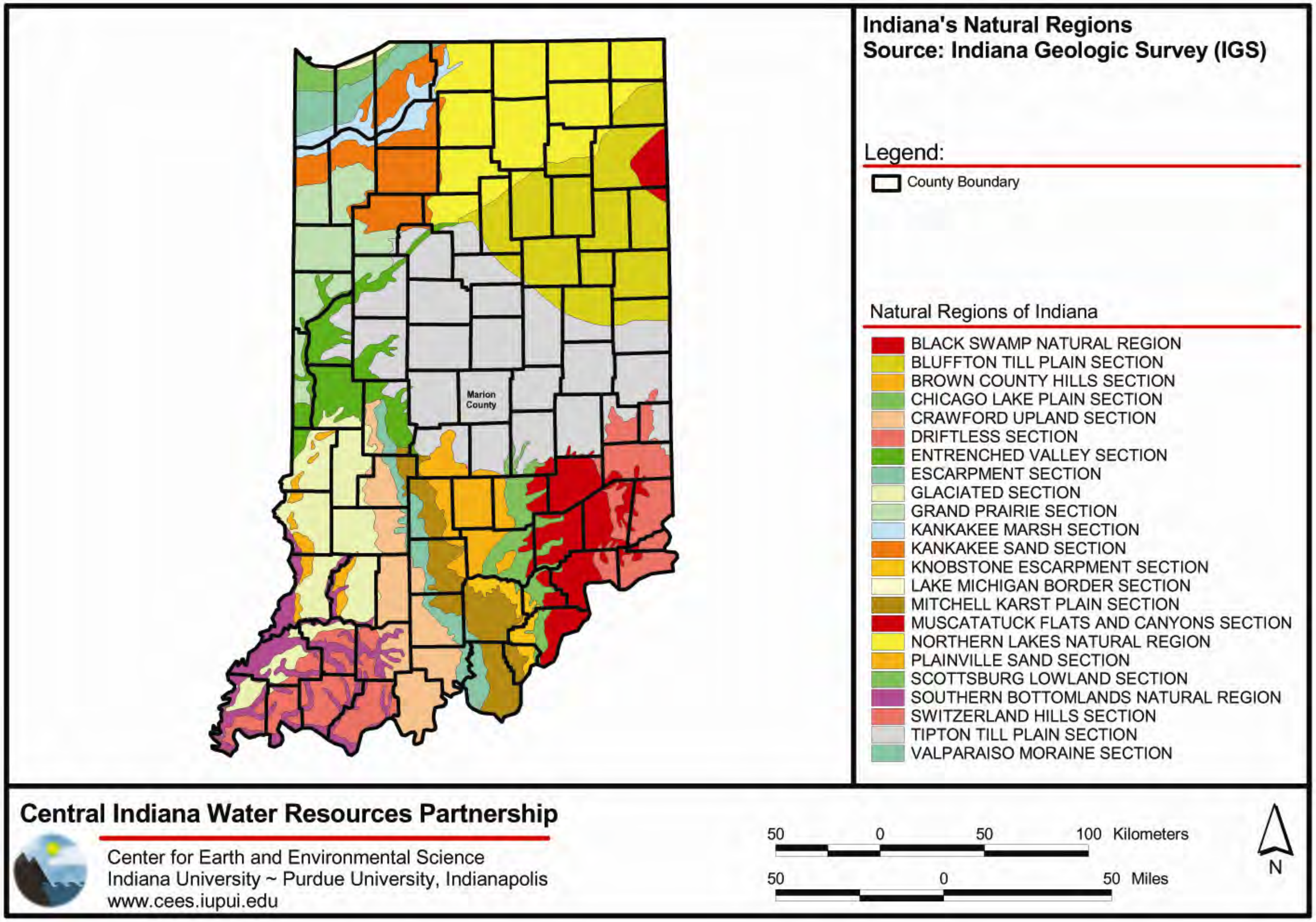


Figure III-8: Indiana's Natural Regions

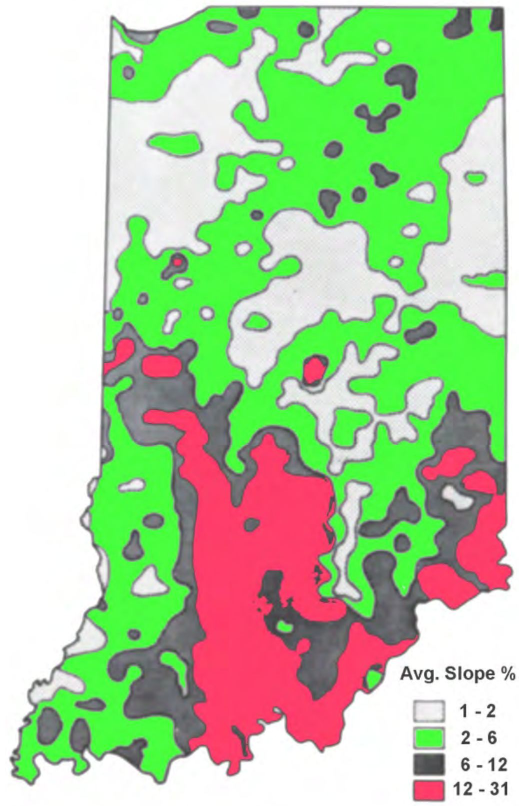


Figure III-9: Average slope in Indiana. Waldrip and Roberts, 1972

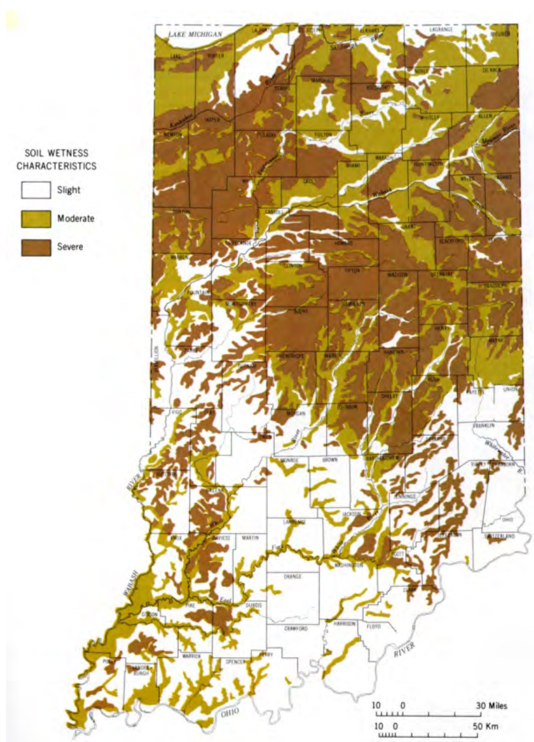


Figure III-10: Drainage Characteristics of Indiana Soils. Clark, 1980

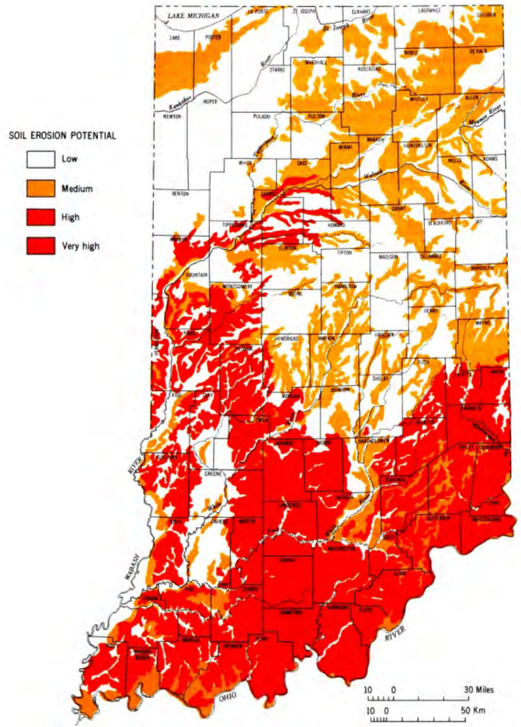


Figure III-11: Erosion Potential of Indiana Soils. Clark, 1980.

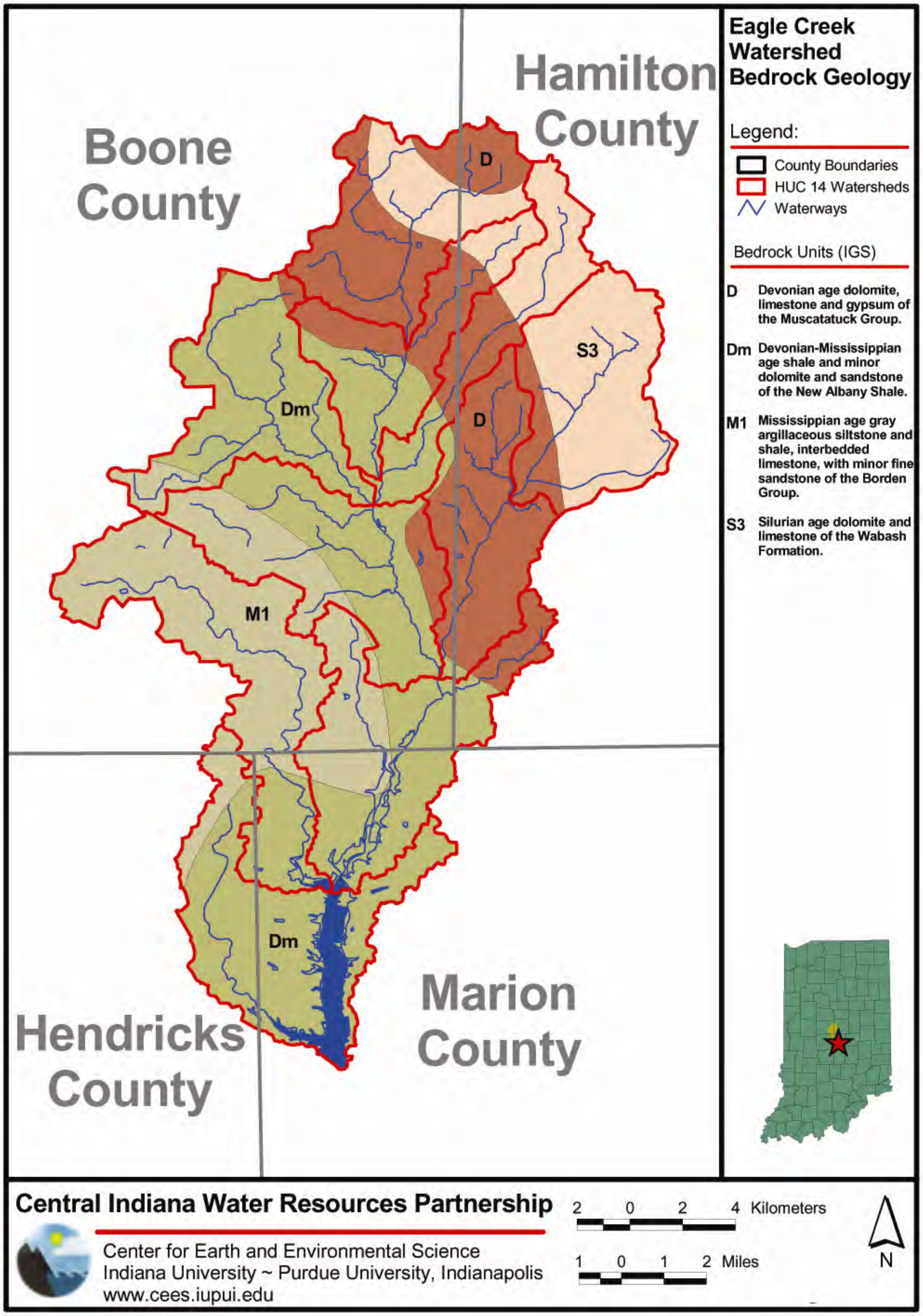


Figure III-12: Eagle Creek Watershed - Bedrock Geology

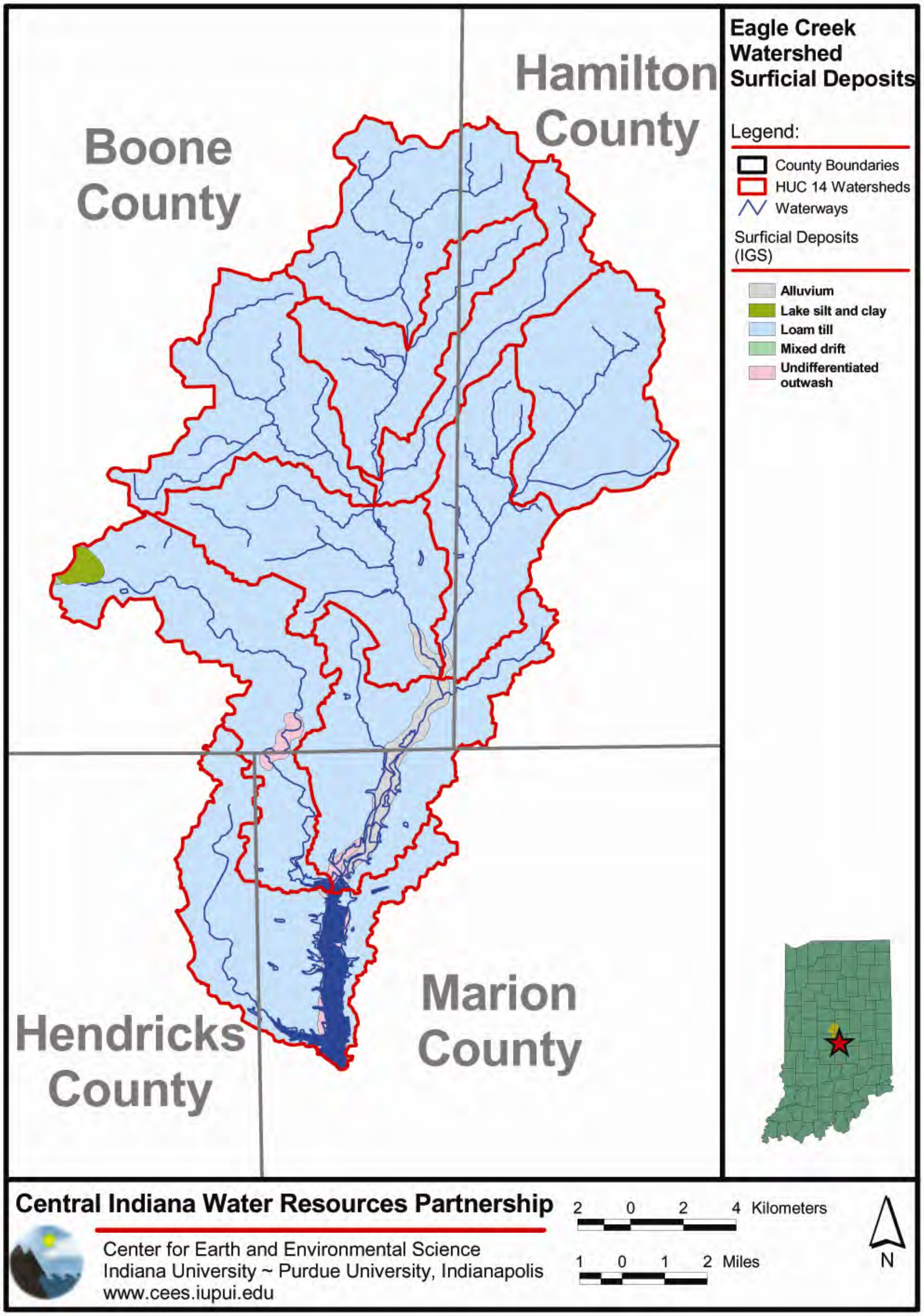


Figure III-13: Eagle Creek Watershed – Surficial Deposits

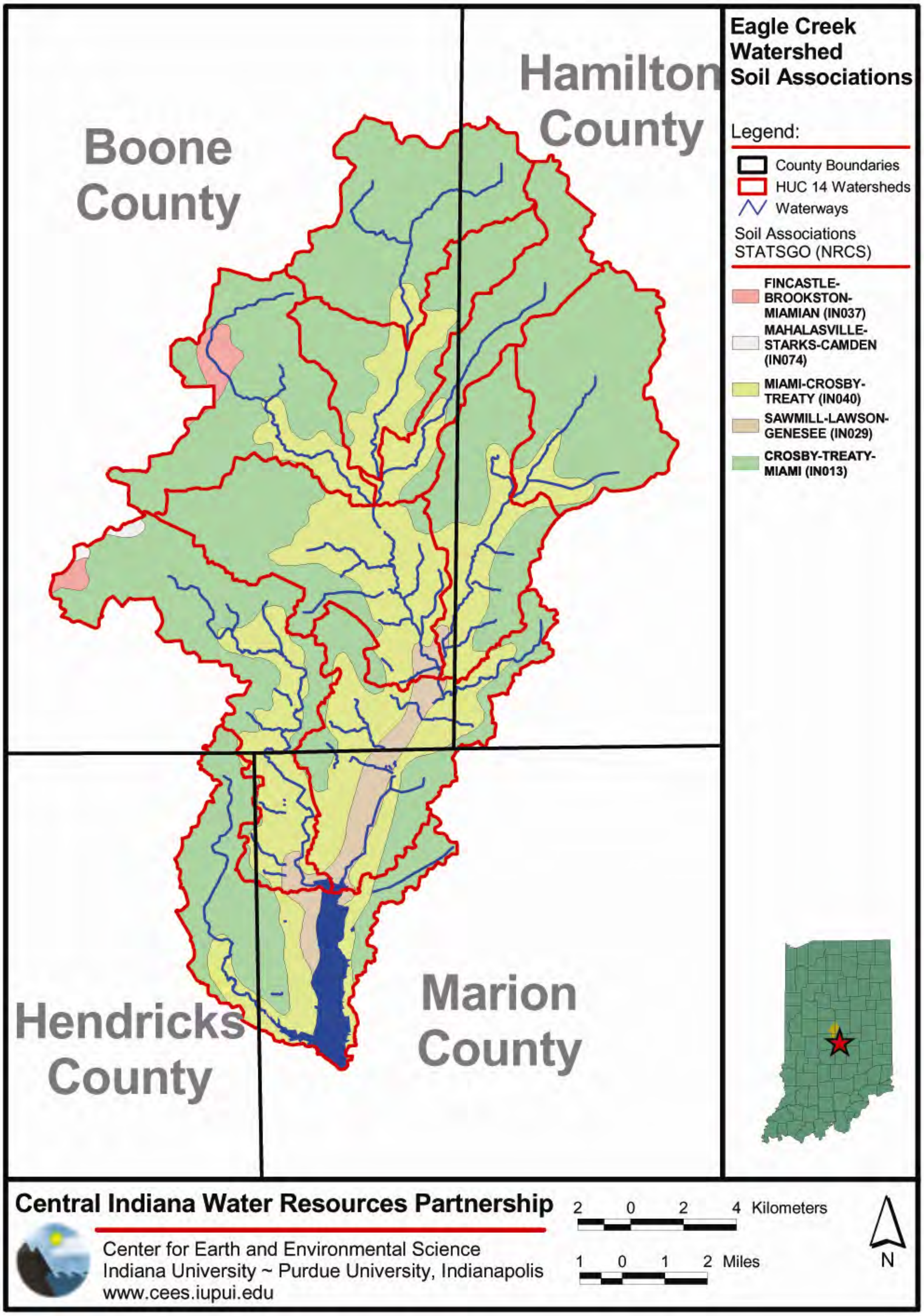


Figure III-14: Eagle Creek Watershed – Soil Associations

Description of Eagle Creek Watershed and Reservoir

The majority of the surface water in Marion County is derived from the Upper White River Watershed (Figure III-15). The Indianapolis drinking water system is fed primarily by the White River and three central Indiana watersheds and three reservoirs (Figure III-16), one of which is Eagle Creek Reservoir.

Eagle Creek Watershed and Reservoir

Watershed and Setting

Eagle Creek Watershed (ECW), HUC#05120201120, is located approximately 10 miles northwest of downtown Indianapolis within the Eastern Corn Belt Plains Ecoregion in the state. It has a drainage area north of the Eagle Creek Reservoir dam of 162 mi^2, which runs through parts of Marion, Hendricks, Boone, and Hamilton counties (Figure III-17) with majority of the watershed lying within the southeastern portions of Boone County. The watershed can be divided into 10 subwatersheds varying in size from 10.4 mi^2 to 20.9 mi^2 (Figure III-17 and Table III-1). The main tributaries joining Eagle Creek above the reservoir include Dixon Branch, Finley Creek, Kreager Ditch, Mounts Run, Jackson Run, Woodruff Branch, Little Eagle Branch, and Long Branch. School Branch and Fishback Creek, along with Eagle Creek flow directly into the reservoir. Flow apportionment shows that Eagle Creek with an average measured flow of 100 ft^3/s (USGS Gage # 03353200; Figure III-17; and Figure III-18) contributes 79% of the water to Eagle Creek Reservoir while Fishback Creek has an average calculated flow rate of 37 ft^3/s and contributes 14% and School Branch has an average calculated flow of 17 ft^3/s and contributes 7%.

Streamflow measured in Eagle Creek Watershed at Zionsville (U.S. Geological Survey streamflow gaging station 03353200) shows that flow highest in March with a monthly average of 192 ft^3/s and lowest in September with a monthly average of 21 ft^3/s (Figure III-18). Monthly averages are taken from a 1957-2002 record (USGS, 2003). Average annual runoff in Eagle Creek at Zionsville for the 1958-97 water years is about 13 inches (Stewart *et al*., 1998).

Agriculture is the dominant land use within the subwatersheds, with the exception of Little Eagle Branch-Woodruff Branch and Eagle Creek-Long Branch/Irishman's Run which are transitioning to suburban development (Figure III-17).

Climate

Monthly precipitation normals for the Eagle Creek Watershed taken from 1971-2000 Whitestown, IN data show lowest precipitation occurring in February with an average of 2.35 inches, and highest precipitation occurring in July with an average of 4.54 inches of rainfall. The mean annual precipitation for the Eagle Creek Watershed area is 41.37 inches. Monthly mean temperatures for this area from 1971-2000 show January as having the lowest average temperature of 26.0°F and July as the being the warmest month with an average temperature of 74.7°F (PAMG, 2003).

Eagle Creek Reservoir History, Use, and Morphological Data

History –
The City of Indianapolis constructed the Eagle Creek Reservoir, prior to and through 1967. The primary purpose for its development was flood control on Eagle Creek. Historically, Eagle Creek would seasonally flood areas of Indianapolis and the Town of Speedway as it approached its confluence with the White River. In 1976, the Reservoir began use as a drinking water supply for the City and the 56th St. causeway was built. The causeway had the effect of creating two basins: a northern and southern basin in which flow is constricted to a 50 yard opening (Figure III-19).

Use –
The Reservoir is a small (2.1 mi^2) impoundment located on the Northwest side of Indianapolis (86.31W 39.83N, 86.30W 39.87N) located completely within Marion county. The Indiana Department of Environmental Management has listed Eagle Creek Reservoir's designated uses (as defined by IAC 327) for Full Body Contact Recreation, Warm Water Aquatic Life, and Public Water Supply. The reservoir's multiuse designation complicates reservoir management. Eagle Creek Park, which surrounds the northern end of the reservoir, utilizes it for recreational purposes, including swimming, boating, fishing, and sporting events such as rowing competitions. Eagle Creek Park also manages the abandoned quarry on the northeastern section of the reservoir which serves as a bird sanctuary. The City of Indianapolis uses the reservoir as a drinking water source water for the T.W. Moses Drinking Water Plant, which provides drinking water for over 80,000 Indianapolis residents.

Morphological Description –
The reservoir has a mean depth 18 ft and a calculated residence time of 51 days. Characterization of Eagle Creek Reservoir using Indiana's Trophic State Index (ITSI) showed that the reservoir is in the mesotrophic to eutrophic range; however, characterization of the reservoir using 2003 data show that the reservoir is currently in a eutrophic to hypereutrophic state: with an average Total Phosphorous concentration of 93.5 µg P/L (R: 14 – 680 µg P/L; N = 127), an average Secchi Disk Depth of 1.0 meters (R: 0.35 – 4.2 m; N = 48), sustained hypolimnetic anoxia, and the occurrence of blue-green algae, assessment of Eagle Creek Reservoir using the ITSI resulted in a score of 55, an ITSI score in eutrophic to hypereutrophic state (Pascual and Tedesco, 2004). Morphological data for Eagle Creek Reservoir are summarized in Table III-2.

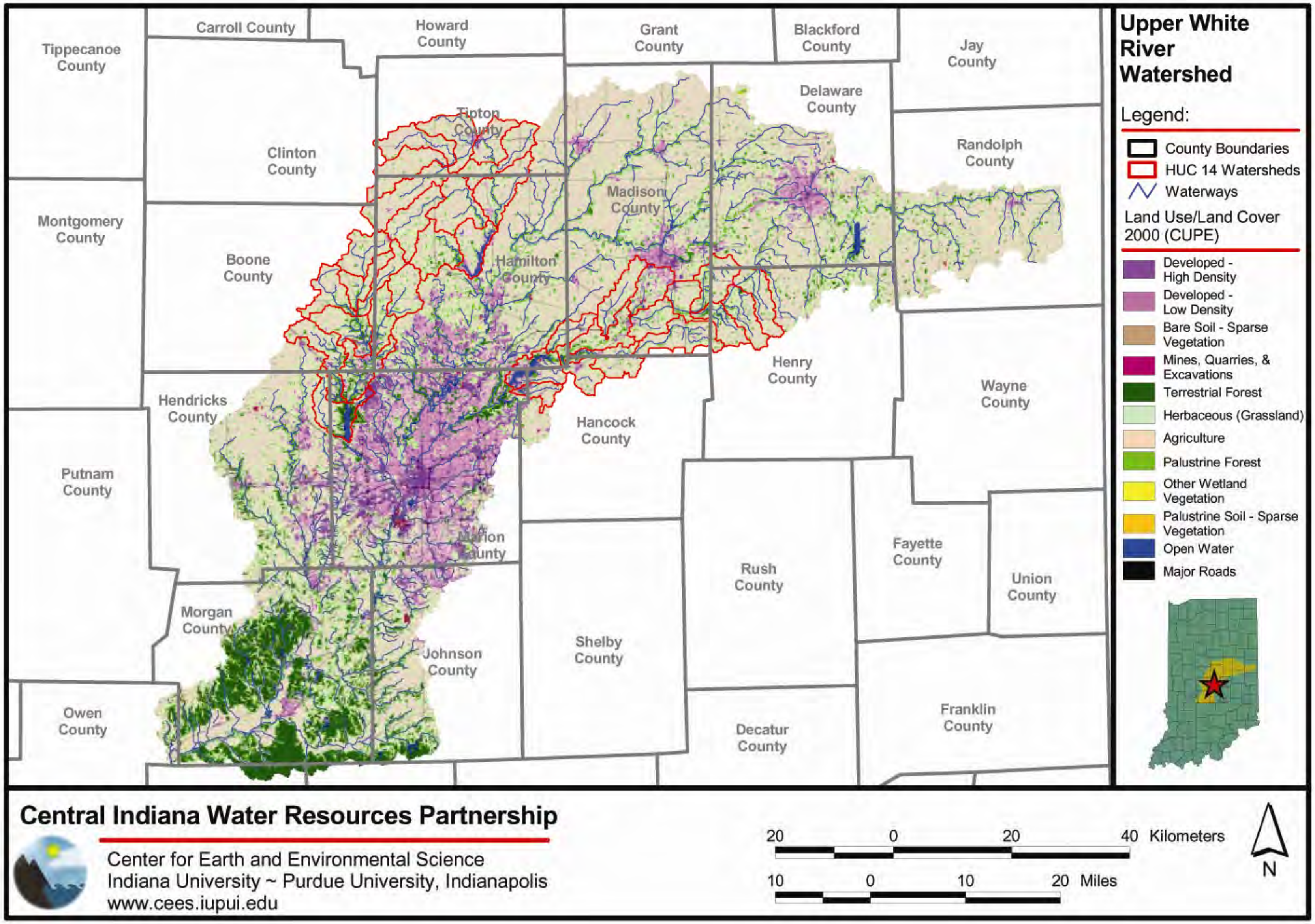


Figure III-15: Upper White River Watershed

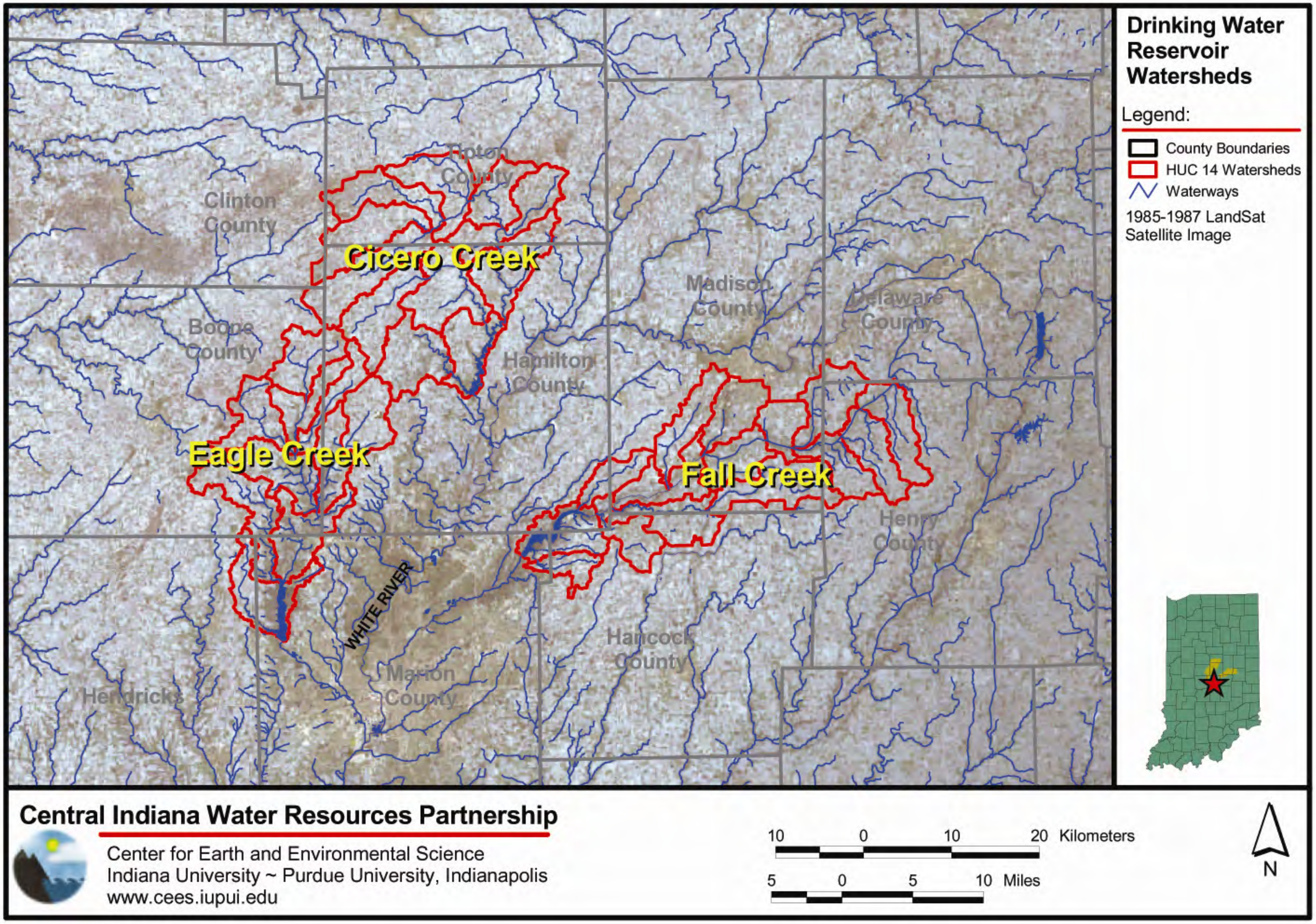


Figure III-16: Indianapolis Drinking Water Reservoirs and Their Watersheds

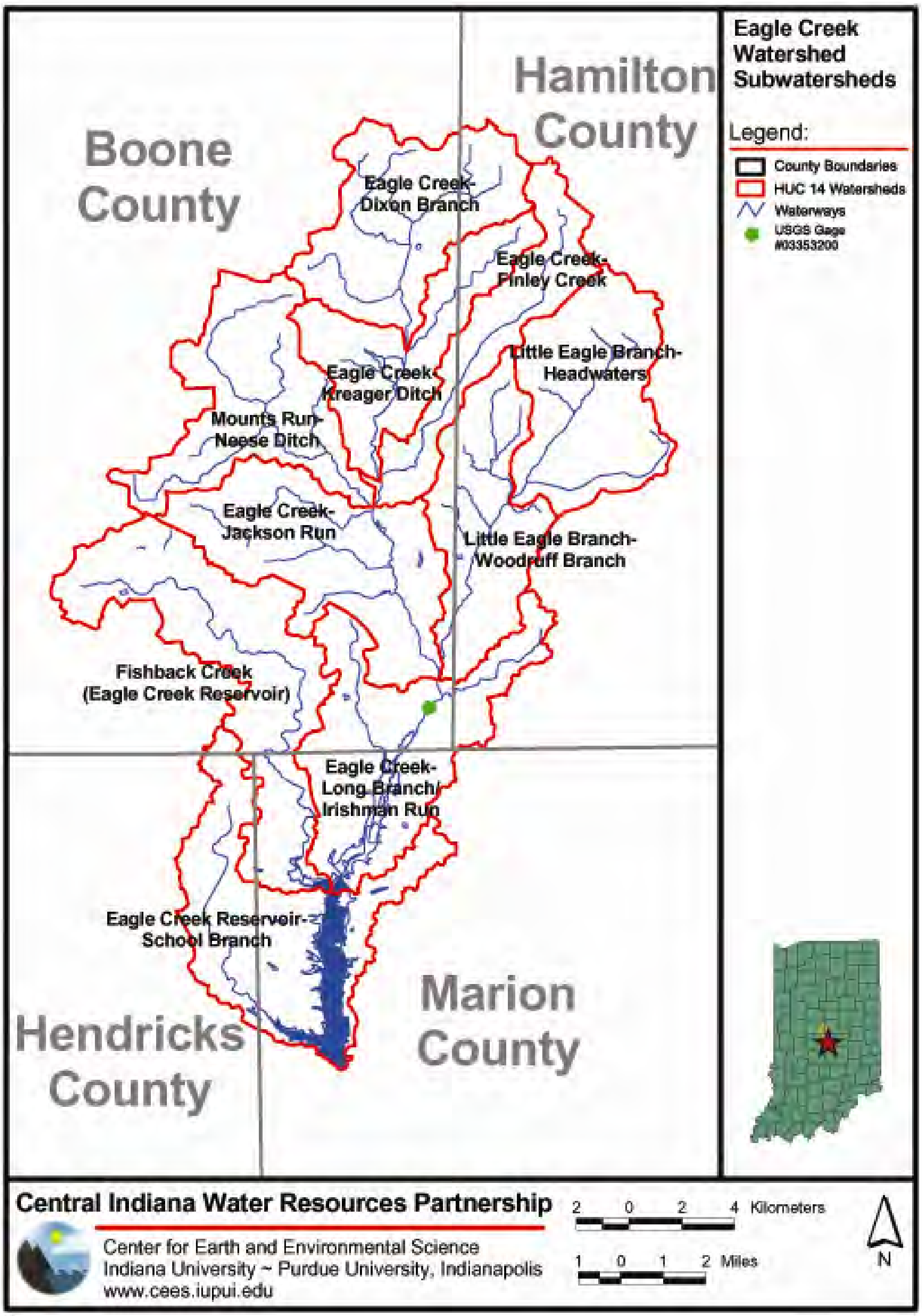


Figure III-17: Eagle Creek Watershed – Subwatersheds, Political Boundaries, and location of USGS Gage # 03353200 on Eagle Creek.

Table III-1: Eagle Creek Subwatersheds and the Associated Drainage Area

Subwatershed	Area *(km^2)*	Area *(mi^2)*	Area *(Acres)*
Eagle Creek-Dixon Branch	42.5	16.4	10,492
Eagle Creek-Finley Creek	26.9	10.4	6,638
Eagle Creek-Kreager Ditch	31.3	12.1	7,727
Little Eagle Branch-Headwaters	40.6	15.7	10,034
Mounts Run-Neese Ditch	41.2	15.9	10,183
Little Eagle Branch-Woodruff Branch	35.1	13.6	8,680
Eagle Creek-Jackson Run	48.5	18.7	11,991
Fishback Creek (Eagle Creek Reservoir)	54.1	20.9	13,353
Eagle Creek-Long Branch/Irishman Run	48.5	18.7	11,978
Eagle Creek Reservoir-School Branch	51.0	19.7	12,591
Eagle Creek Watershed Total	419.7	162.0	103,667

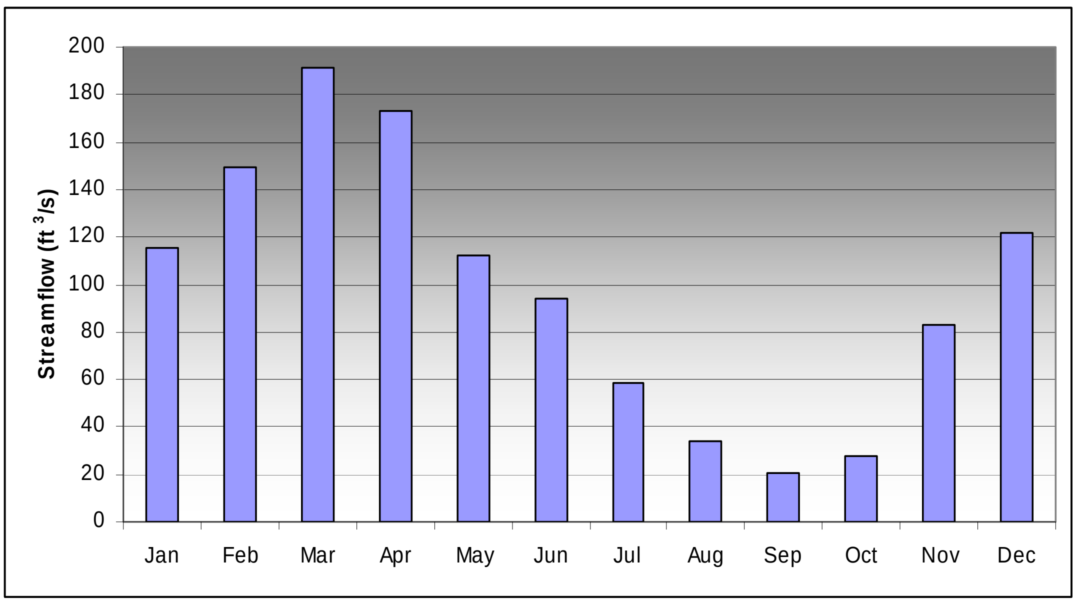


Figure III-18: Eagle Creek Monthly Mean Streamflow (Zionsville, IN; USGS Gage 03353200; 1957-2002; Figure III-17)

Figure III-19: Eagle Creek Reservoir overlay of Eagle Creek and valley (1941), showing the location of the 56th St. Causeway opening and the original location of streambed. Black arrow shows location of land bridge opening. Yellow arrow shows pre-flood Eagle Creek streambed.

Table III-2: Morphological Data for Eagle Creek Reservoir

Lake surface area	1.9	km^2
Northern Basin	0.8	km^2
Southern Basin	1.1	km^2
Quarry	0.2	km^2
Mean Depth	5.5	m
Lake Volume	5,500	million gallons
Calculated Residence Time	51	days

As a eutrophic reservoir, nuisance algal blooms are a common occurrence, threatening all of the Reservoir's designated uses. Of particular concern is the protection of the Reservoir as a drinking water supply. As the T.W. Moses Drinking Water Plant uses Eagle Creek Reservoir as its source water, algal blooms of nuisance (e.g., taste and odor or filter-clogging algae) or harmful (toxin producing algae) create challenges to maintaining finished drinking water quality: this treatment plant is not technologically equipped with a process that can adequately address the levels of algal produced taste and odor compounds historically measured in the Reservoir. Water conditions in Eagle Creek Reservoir define the parameters for treatment at the TWM plant (there is no groundwater or additional surface water source with which to blend and, therefore, amend Reservoir water). Therefore, protecting Eagle Creek Reservoir is critical to protecting drinking water resources in Indianapolis.

EAGLE CREEK RESERVOIR – AT A GLANCE

- Ownership – The City of Indianapolis
- Original purpose – Flood control
- Date into service – 1968
- Water surface area – 1,350 acres
- Maximum depth – 40 feet; 54 feet
- Watershed area above dam – 162 square miles
- Storage capacity – 7.8 billion gallons
- Dependable water supply yield – 15.4 MGD
- Rated capacity of TWM plant – 16 MGD
- Permanent pool elevation – 790.0 feet M.S.L.
- Overall dam length – 4,200 feet
- Dam height above valley – 75 feet
- Water depth at dam – 40 feet
- Type of embankment structure – Earthen fill
- Type of outlet structure – Six Tainter Gat

Section IV: Land-use and Land Cover Description of Eagle Creek Watershed

Surface water quality is inherently related to the land over and through which the water flows. As such, land-use[1] and land cover[2] descriptions of Eagle Creek Watershed are important to understanding surface water quality: slope, soil characteristics, and ground cover (e.g., impervious surfaces) will affect water velocity and quality. Therefore land-use/land cover assessments of Eagle Creek Watershed can give insight into the possible sources of contaminants to Eagle Creek Watershed streams.

Landuse History

Eagle Creek Watershed, like most of Indiana prior to the mid-1700s was a temperate deciduous forest. However by the late 1800s and into the 1900s the watershed was dominated by farmland. This decrease in forested land and increase in farmland occurred with a loss of wetland areas (Figure IV-1). By the 20th Century, more than 80% of Indiana's pre-settlement wetlands were being drained by agricultural tiles, and the converted land was transformed to farmland, a practice that continues today with land being further transformed to suburban low and high density housing.

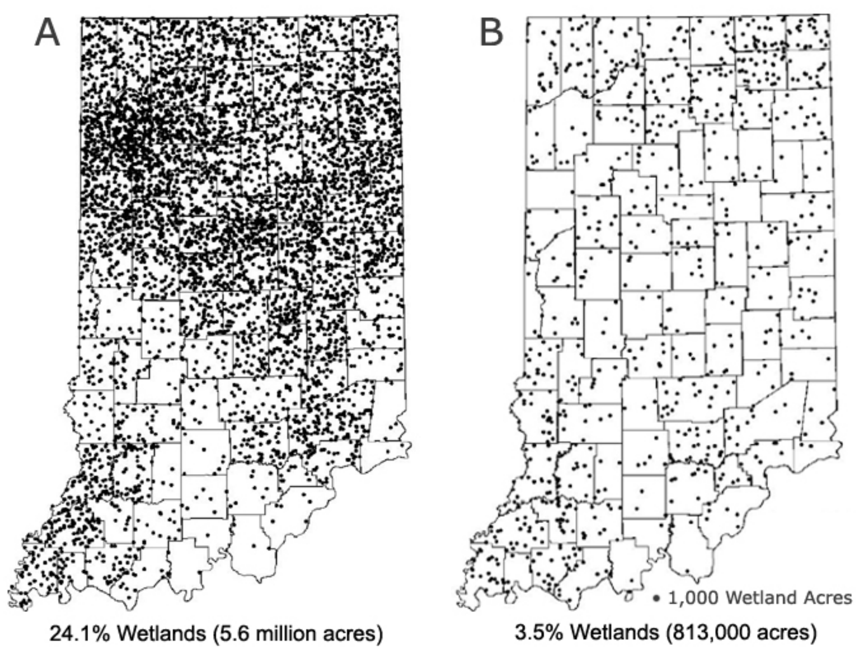


Figure IV-1: Indiana Wetland Losses (A) Historic Wetlands in Indiana[3] and (B) 1986 Wetlands in Indiana[4] (Robb, 2002).

[1] **Land-use** is defined as the activity for which a parcel of land is used (e.g., agriculture).
[2] **Land cover** is defined as the physical description of the land surface (e.g., forest)
[3] Hydric soils acreage from NRCS County Soil Surveys

Demographic History

Eagle Creek Watershed lies within four counties: Boone, Hamilton, Hendricks, and Marion. Boone County covers the largest portion of the watershed with 53.5% of Eagle Creek watershed within its county boundaries. Hamilton, Hendricks, and Marion counties contain 26.5%, 5.5%, and 14.5% of the watershed, respectively (Figure III-17). Population density ranges from 30 people per square mile in Marion Township in the northern part of the basin to about 1100 people per square mile in Clay and Pike townships in the southeastern part of the basin, where population is the most concentrated due to the suburban expansion of Indianapolis. Suburban expansion of Sheridan, and Zionsville have also added to the basin's population. Sheridan, Zionsville, and Whitestown are the three towns located within Eagle Creek Watershed. Sheridan is located in Hamilton County and has had a 14.5% increase in population from 1980-2000. The population of Zionsville has increased dramatically by 122% from 1980–2000, which is important due to its central location in the watershed. Whitestown is the only town in Eagle Creek watershed that has seen a slight decline in population (IBRC, 2002) (Table IV-1). Overall, the estimated population in the watershed has more than tripled in the last 40 years. (The watershed population was estimated by pro-rating the township population by the percent of that township in the basin.)

Much of the watershed land-use is agriculture, but high and low density land-use is on the rise as a result of increased development. Increasing population and the associated development can have a dramatic impact on the water quality. Population of the four counties has shown a steady rise since the early-1900's (IBRC, 2002). The growth within the watershed and surrounding areas are largely a result of the close proximity to the city of Indianapolis. Work/residence patterns show high commuting trends between Boone, Hamilton, Hendricks, and Marion counties (IBRC, 2003).

Land-use Data

Under contract by CEES, the Center for Urban Policy and the Environment (CUPE) conducted a study to use GIS to analyze historic, current, and future land-use in and around Eagle Creek Watershed. Historic and current land-use patterns were identified by evaluating 1985 and 2000 Indiana land cover data previously developed by CUPE. The land cover data were created from supervised classification of satellite imagery and cover the entire state of Indiana at a spatial resolution of 30 meters. Using a geographic information system (GIS) coverage of Eagle Creek Watershed provided by CEES, CUPE staff used spatial analytical tools to identify grid cells located in the watershed and subwatersheds.

Using the Land-use in Central Indiana (LUCI) model, a tool created by CUPE to evaluate the effects of policy choices on the conversion of vacant land to residential use over time, CUPE staff projected future land-use in and around the watershed areas (Tedesco *et al.*, 2003). The database from which the model was developed was created from satellite

[4] Rolley, 1991

imagery for 1985 and 2000 from the Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) sensors on the Landsat series of earth observation satellites. Image pixels were resampled to a spatial resolution of 30 meters during the georeferencing process. Image processing and GIS operations were performed using selected elements of ERDAS Imagine 8.5 and ESRI ArcGIS 8.1. to enable researchers to use the data for specific applications and analyses.

Table IV-1: Eagle Creek Watershed Demographic History

	Population Census Counts					% Change
	1900	**1950**	**1980**	**1990**	**2000**	**1980-2000**
Counties						
Boone	26,321	23,993	36,446	38,147	46,107	27%
Hamilton	29,914	28,491	82,027	108,936	182,740	123%
Hendricks	21,292	24,594	69,804	75,717	104,093	49%
Marion	197,227	551,777	765,233	797,159	860,454	12%
Townships in Watershed						
Boone County						
Center	7,497	9,596	14,376	14,538	17,102	19%
Eagle	1,883	2,762	7,995	9,864	13,910	74%
Marion	2,370	1,369	1,214	1,191	1,359	12%
Perry	1,015	609	1,144	1,162	1,166	2%
Union	1,087	750	1,634	1,707	2,014	23%
Worth	1,116	999	1,378	1,378	1,292	-6%
Hamilton County						
Adams	4,415	3,691	4,307	4,504	4,892	14%
Clay	1,283	2,311	32,606	43,007	64,709	98%
Washington	3,696	3,032	7,425	9,272	18,358	147%
Hendricks County						
Brown	1,032	769	4,176	4,617	8,142	95%
Lincoln	1,474	2,600	13,351	14,008	18,967	42%
Marion County						
Pike	2,006	3,316	25,336	45,204	71,465	182%
Towns in Watershed						
Boone County						
Whitestown	na	550	497	476	471	-5%
Zionsville	765	1536	3948	5281	8775	122%
Hamilton County						
Sheridan	1795	1965	2200	2046	2520	15%

1985 Land-use Data

In 1985, Eagle Creek Watershed was 2.1% High and Low Density Urban, 13.4% Forest (Forest and Wetland Forest), and 65.9% Agriculture land cover (Figure IV-2 and Table IV-2).

2000 Land-use Data

By 2000, the Eagle Creek Watershed was 4.3% High and Low Density Urban, 10.6% Forest (Forest and Wetland Forest), and 52% Agriculture land cover (Figure IV-2 and Table IV-2).

Land-Cover Change Analysis 1985-2000

Comparing Eagle Creek Watershed land-cover characterizations between 1985 and 2000, the Watershed showed a 21% (-22.61 mi^2) decrease in the amount of agricultural land-use accompanied by a 25% (-5.04 mi^2) loss in Forest cover (Table IV-2). The greatest amount of percent change occurred with the increase of High Density Urban +147% (1.34 mi^2) and Herbaceous (Grassland) +98% (24.03 mi^2) with the greatest percent land-cover losses occurring in the Bare Soil/Sparse Vegetation -73% (-0.91 mi^2) , Wetland Other Vegetation -48% (-0.13 mi^2), and Wetland Bare -57% (-0.04 mi^2) land-covers.

Land-use Change Predictions 2000-2040

Using the LUCI model, the percent change in urbanization was predicted for each subwatershed between 2000 and 2040 (Tedesco *et al*., 2003). Urbanization appears to be expanding the most in areas surrounding Eagle Creek Reservoir and the town of Zionsville (Figure IV-3).

Table IV-2: Eagle Creek Watershed Area Change by Land Cover Type (1985 & 2000)

	1985		2000		Change	% Change
Land Cover Type	*(mi^2)*	*(%)*	*(mi^2)*	*(%)*	*(mi^2)*	*(mi^2)*
High Density	0.91	0.6	2.25	1.4	1.34	147%
Low Density	2.53	1.6	4.72	2.9	2.19	87%
Bare Soil/Sparse Vegetation	1.24	0.8	0.33	0.2	-0.91	-73%
Excavations	0.00	0.0	0.53	0.3	0.52	
Forest	20.06	12.4	15.02	9.3	-5.04	-25%
Herbaceous (Grassland)	24.40	15.1	48.43	29.9	24.03	98%
Agriculture	106.82	65.9	84.21	52.0	-22.61	-21%
Wetland Forest	1.70	1.1	2.14	1.3	0.44	26%
Wetland Other Vegetation	0.27	0.2	0.14	0.1	-0.13	-48%
Wetland Bare	0.07	0.0	0.03	0.0	-0.04	-57%
Water	2.76	1.7	2.97	1.8	0.21	8%
Roads	1.28	0.8	1.28	0.8	0.00	0%
Total Area	162.05	100	162.05	100	0.00	0%

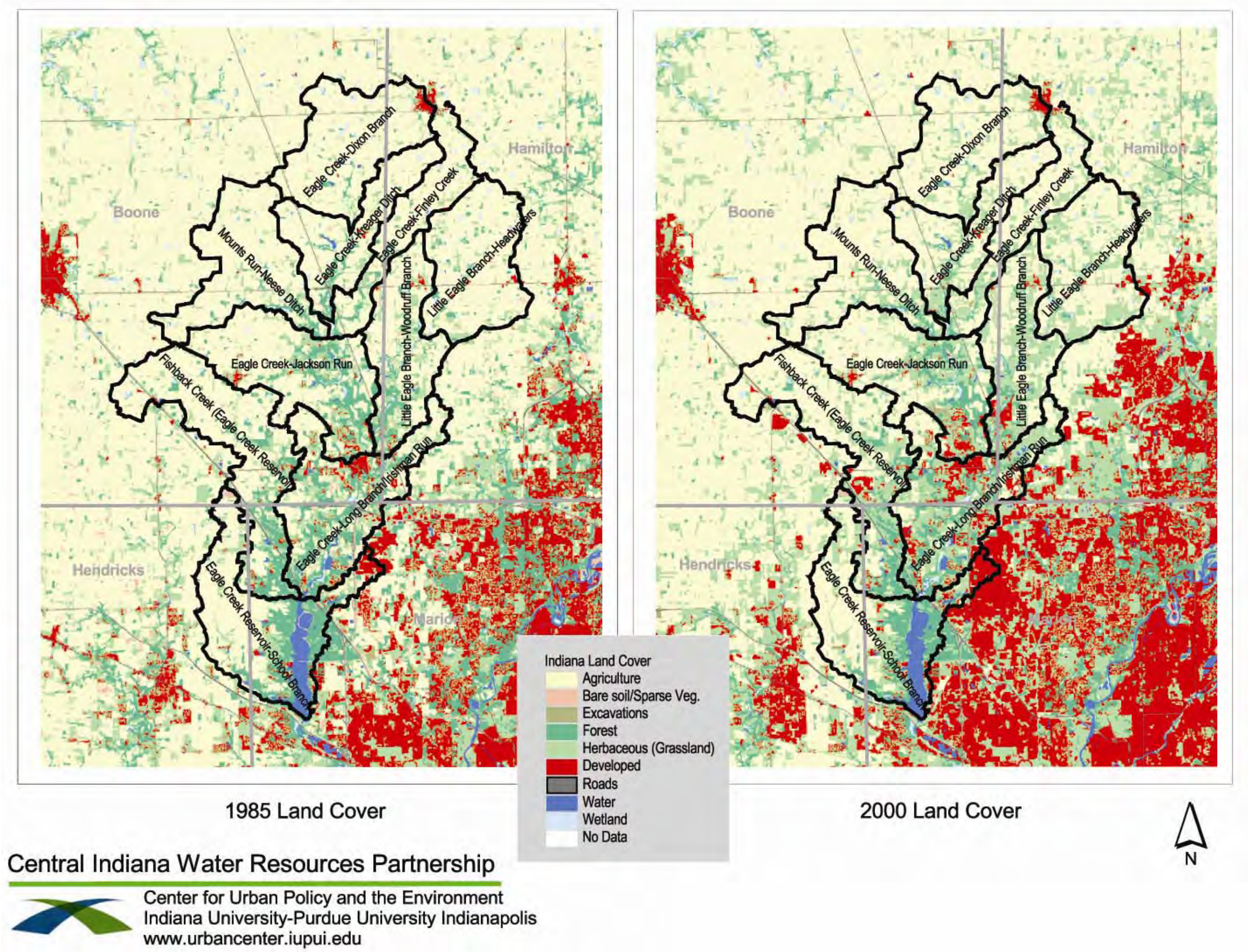


Figure IV-2: Eagle Creek Subwatershed Areas by Land Cover Type (1985 & 2000)

Table IV-3: Predicted Urbanization by Subwatersheds (2000-2040)

Subwatershed	% Urban* 2000	% Urban* 2040	Change in % Urbanization
Eagle Creek-Dixon Branch	3%	7%	4%
Eagle Creek-Finley Creek	2%	23%	21%
Eagle Creek-Kreager Ditch	2%	13%	11%
Little Eagle Branch-Headwaters	3%	57%	55%
Mounts Run-Neese Ditch	1%	12%	11%
Little Eagle Branch-Woodruff Branch	10%	75%	66%
Eagle Creek-Jackson Run	15%	64%	49%
Fishback Creek (Eagle Creek Reservoir)	10%	59%	49%
Eagle Creek-Long Branch/Irishman Run	31%	85%	54%
Eagle Creek Reservoir-School Branch	18%	65%	47%

* low and high density land cover

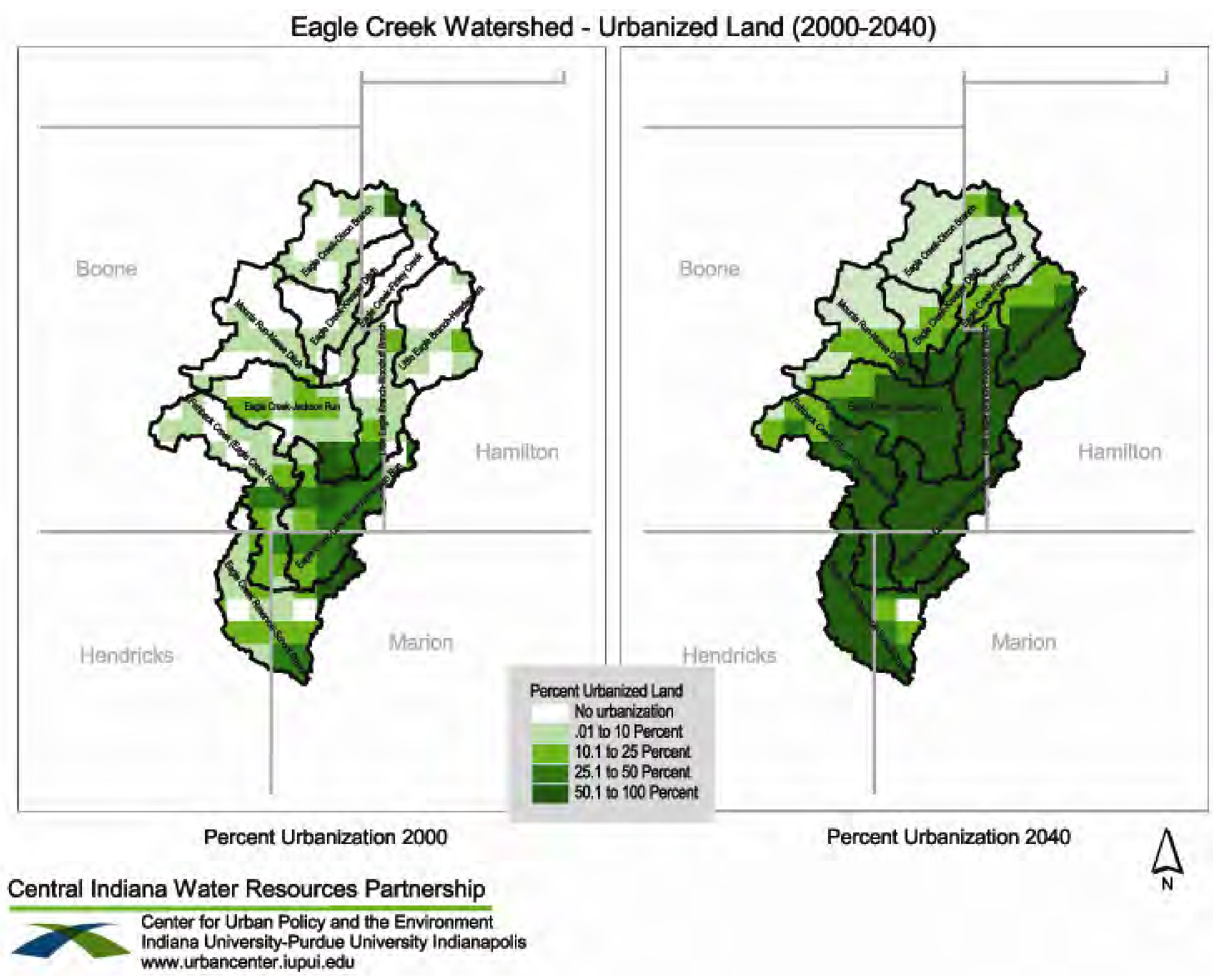


Figure IV-3: LUCI Model Prediction of Urbanization in Eagle Creek Watershed (2000 – 2040)

2002 – 2003 Land-use Data

In 2004, Eagle Creek Watershed's land-use was reassessed using multiple images from various seasons (winter, spring, summer, and fall) to determine the difference between herbaceous, grassland, and farmland land cover types. This reassessment utilized 2002-2003 land cover data created by CUPE from supervised classification of satellite imagery and cover at a spatial resolution of 25 meters and resulted in a more precise delineation of herbaceous, grassland, and farmland land cover types. By comparing land cover over the seasons, researchers were able to delineate land cover that was once assessed to be herbaceous cover into three categories: herbaceous, grassland, and farmland. This reclassification of the Eagle Creek Watershed resulted in an increase in the amount of land classified under agricultural land cover and a decrease in the amount of land classified under herbaceous land cover (Table IV-4). The 2002-2003 land cover data show that Eagle Creek Watershed was 10% low and high density urban, 13.7% forest, 23% herbaceous, and 61% agriculture land cover. This new method for classifying herbaceous land cover was also used to determine land cover area for each Eagle Creek Subwatershed (Table IV-5 and Figure IV-4). These data show that the northernmost Eagle Creek Subwatersheds (Dixon Branch, Mounts Run-Neese Ditch, Kreager Ditch, Finley Creek, and Little Eagle Branch Headwaters) are dominated by agriculture; at least 70% of the land cover was classified as agriculture land-use. Comparatively, the subwatersheds closer to Eagle Creek Reservoir have a larger percentage of urbanized land and less farmland. Of the subwatersheds located around the reservoir, Eagle Creek-Irishman Run (located just north of the reservoir) has the least percent agriculture (25%) and the most percent urbanization (25%), while Fishback Creek (located just north west of the reservoir) has the most percent agriculture (59%) and the least percent urbanization (9.3%).

Table IV-4: Comparison of 1985, 2000, and 2002-2003 Land Cover Assessment

	1985		2000		2002-2003	
Land Cover Type	*(mi^2)*	*(%)*	*(mi^2)*	*(%)*	*(mi^2)*	*(%)*
High Density	0.91	0.6	2.25	1.4	2.32	1.4
Low Density	2.53	1.6	4.72	2.9	13.90	8.5
Bare Soil/Sparse Vegetation	1.24	0.8	0.33	0.2	n/a	n/a
Excavations	0.00	0.0	0.53	0.3	0.98	0.6
Forest	20.06	12.4	15.02	9.3	22.22	13.5
Herbaceous (Grassland)	24.40	15.1	48.43	29.9	22.78	13.9
Agriculture	106.82	65.9	84.21	52.0	98.78	60.1
Wetland Forest	1.70	1.1	2.14	1.3	n/a	n/a
Wetland Other Vegetation	0.27	0.2	0.14	0.1	n/a	n/a
Wetland Bare	0.07	0.0	0.03	0.0	n/a	n/a
Water	2.76	1.7	2.97	1.8	3.44	2.1
Roads	1.28	0.8	1.28	0.8	n/a	n/a
Total Area	162.05	100.0	162.05	100.0	164.42	100.0

Table IV-5: Eagle Creek Subwatersheds 2002-2003 Land-use Data

Land Cover Type	Total Eagle Creek Watershed		Eagle Creek Dixon Branch		Eagle Creek-Finley Creek		Eagle Creek - Kreager Ditch		Little Eagle Branch-Headwaters		Mounts Run-Neese Ditch	
	(mi^2)	*%*	*(mi^2)*	*%*	*(mi^2)*	*%*	*(mi^2)*	*%*	*(mi^2)*	*%*	*(mi^2)*	*%*
High Density	2.32	*1.4%*	0.07	*0.4%*	0.02	*0.2%*	0.01	*0.1%*	0.04	*0.3%*	0.02	*0.1%*
Low Density	13.90	*8.5%*	0.50	*3.0%*	0.44	*4.1%*	0.32	*2.6%*	0.88	*5.6%*	0.19	*1.2%*
Excavations	0.98	*0.6%*	0.01	*0.0%*	0.11	*1.1%*	0.00	*0.0%*	0.14	*0.9%*	0.00	*0.0%*
Forest	22.22	*13.5%*	0.81	*4.9%*	0.88	*8.3%*	1.11	*9.1%*	1.18	*7.5%*	1.11	*6.9%*
Herbaceous	22.78	*13.9%*	1.26	*7.6%*	1.55	*14.6%*	1.44	*11.8%*	2.38	*15.0%*	1.22	*7.6%*
Agriculture	98.78	*60.1%*	13.88	*83.6%*	7.56	*71.3%*	9.32	*75.8%*	11.16	*70.4%*	13.57	*84.0%*
Water	3.44	*2.1%*	0.06	*0.4%*	0.05	*0.5%*	0.08	*0.7%*	0.06	*0.4%*	0.03	*0.2%*
Total Area	**164.42**		**16.60**		**10.60**		**12.29**		**15.84**		**16.15**	

Land Cover Type	Little Eagle Branch-Woodruff		Eagle Creek-Jackson Run		Fishback Creek (Eagle Creek Reservoir)		Eagle Creek-Long Branch/Irishman Run		Eagle Creek Reservoir-School Branch	
	(mi^2)	*%*	*(mi^2)*	*%*	*(mi^2)*	*%*	*(mi^2)*	*%*	*(mi^2)*	*%*
High Density	0.10	*0.7%*	0.14	*0.7%*	0.28	*1.3%*	0.86	*4.5%*	0.78	*3.9%*
Low Density	1.53	*11.1%*	2.18	*11.5%*	1.70	*8.0%*	3.97	*20.9%*	2.19	*10.9%*
Excavations	0.09	*0.7%*	0.10	*0.5%*	0.15	*0.7%*	0.36	*1.9%*	0.02	*0.1%*
Forest	2.11	*15.3%*	3.40	*17.9%*	3.24	*15.3%*	4.68	*24.6%*	3.69	*18.5%*
Herbaceous	2.47	*17.9%*	2.62	*13.8%*	3.10	*14.6%*	3.99	*21.0%*	2.74	*13.7%*
Agriculture	7.41	*53.8%*	10.41	*54.9%*	12.58	*59.3%*	4.68	*24.6%*	8.22	*41.1%*
Water	0.05	*0.4%*	0.13	*0.7%*	0.15	*0.7%*	0.47	*2.5%*	2.35	*11.8%*
Total Area	**13.76**		**18.98**		**21.20**		**19.01**		**19.98**	

Table IV-5: Eagle Creek Subwatersheds 2002-2003 Land-use Data

Land Cover Type	Total Eagle Creek Waterhsed		Eagle Creek Dixon Branch		Eagle Creek-Finley Creek		Eagle Creek - Kreager Ditch		Little Eagle Branch-Headwaters		Mounts Run-Neese Ditch	
	(acres)	*%*	*(acres)*	*%*	*(acres)*	*%*	*(acres)*	*%*	*(acres)*	*%*	*(acres)*	*%*
High Density	1,485	*1.4%*	45	*0.4%*	13	*0.2%*	6	*0.1%*	26	*0.3%*	13	*0.1%*
Low Density	8,896	*8.5%*	320	*3.0%*	282	*4.1%*	205	*2.6%*	563	*5.6%*	122	*1.2%*
Excavations	627	*0.6%*	6	*0.0%*	70	*1.1%*	0	*0.0%*	90	*0.9%*	0	*0.0%*
Forest	14,221	*13.5%*	518	*4.9%*	563	*8.3%*	710	*9.1%*	755	*7.5%*	710	*6.9%*
Herbaceous	14,579	*13.9%*	806	*7.6%*	992	*14.6%*	922	*11.8%*	1,523	*15.0%*	781	*7.6%*
Agriculture	63,219	*60.1%*	8,883	*83.6%*	4,838	*71.3%*	5,965	*75.8%*	7,142	*70.4%*	8,685	*84.0%*
Water	2,202	*2.1%*	38	*0.4%*	32	*0.5%*	51	*0.7%*	38	*0.4%*	19	*0.2%*
Total Area	**105,229**		**10,624**		**6,784**		**7,866**		**10,138**		**10,336**	

Land Cover Type	Little Eagle Branch-Woodruff		Eagle Creek-Jackson Run		Fishback Creek (Eagle Creek Reservoir)		Eagle Creek-Long Branch/Irishman Run		Eagle Creek Reservoir-School Branch	
	(acres)	*%*	*(acres)*	*%*	*(acres)*	*%*	*(acres)*	*%*	*(acres)*	*%*
High Density	64	*0.7%*	90	*0.7%*	179	*1.3%*	550	*4.5%*	499	*3.9%*
Low Density	979	*11.1%*	1,395	*11.5%*	1,088	*8.0%*	2,541	*20.9%*	1,402	*10.9%*
Excavations	58	*0.7%*	64	*0.5%*	96	*0.7%*	230	*1.9%*	13	*0.1%*
Forest	1,350	*15.3%*	2,176	*17.9%*	2,074	*15.3%*	2,995	*24.6%*	2,362	*18.5%*
Herbaceous	1,581	*17.9%*	1,677	*13.8%*	1,984	*14.6%*	2,554	*21.0%*	1,754	*13.7%*
Agriculture	4,742	*53.8%*	6,662	*54.9%*	8,051	*59.3%*	2,995	*24.6%*	5,261	*41.1%*
Water	32	*0.4%*	83	*0.7%*	96	*0.7%*	301	*2.5%*	1,504	*11.8%*
Total Area	**8,806**		**12,147**		**13,568**		**12,166**		**12,787**	

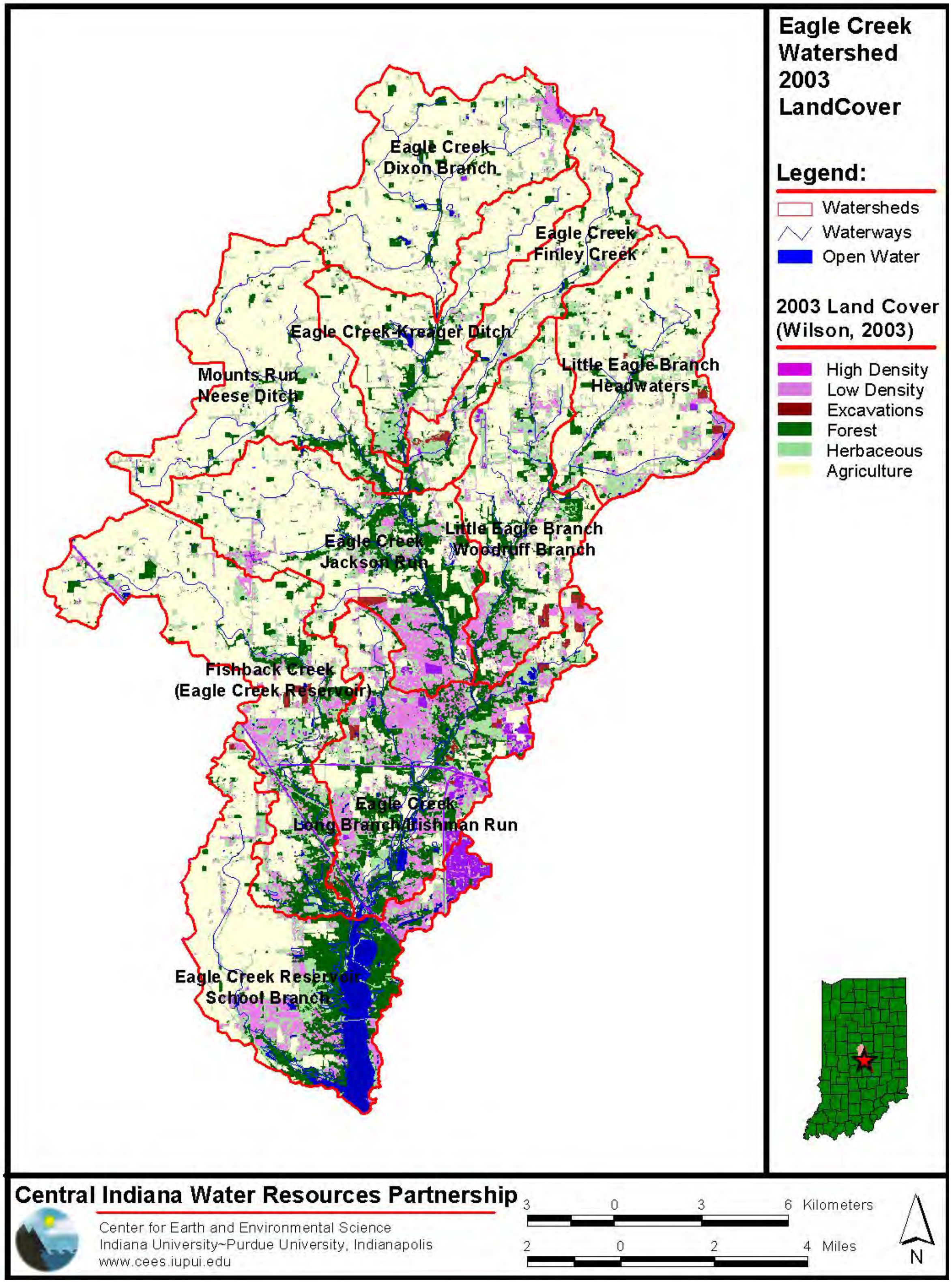


Figure IV-4: Eagle Creek Watershed 2002-2003 Land Cover

Slope and Elevation

A general topographic survey in Eagle Creek Watershed Sub-watersheds was completed using digital elevation model (DEM) data (USGS, 2002) to investigate elevation variations (Figure IV-5). Elevations in the watershed ranged from 240 m above sea level in School Branch to 299 m above sea level in Fishback Creek Watershed. Additionally, GIS surface analysis tools (ESRI, 2003) were used to model slope in the watersheds from the DEM dataset (Figure IV-5). In Eagle Creek Watershed, percent slope ranges from 0 to 44% in the lower reaches of Fishback Creek. However, the vast majority of Eagle Creek Watershed has a low percent slope; mean slopes of the sub-watersheds range from 0.85% in Dixon Branch to 2.43% in School Branch watershed (Figure IV-5and Table IV-6). The slope of the watersheds typically increases from the headwaters toward the outflow of the watershed, and the highest slopes in Eagle Creek Watershed are found nearest Eagle Creek Reservoir (Figure IV-5). The slope of the land surface is an important watershed characteristic, as the slope of the land surface increases, both soil erosion and runoff rise, increasing the delivery of sediment, nutrients, and pollutants to nearby streams (NRCS, 1994 and NRCS, 2002). Slope is not the only factor controlling erosion and runoff, soil type and permeability also play a significant role, but land surfaces with greater than just 1.00 % slope have been shown to have increased erosion and runoff rates (NRCS, 1994 and NRCS, 2002).

Table IV-6 Elevation and Percent slope statistics for all sub-watersheds in Eagle Creek Watershed.

	Elevation Statistics				Percent Slope Statistics			
	Mean (ft)	σ (ft)	Min (ft)	Max (ft)	Mean (%)	σ (%)	Min (%)	Max (%)
Eagle Creek-Dixon Branch	947	12	899	971	0.9	1.2	0.0	13.0
Eagle Creek-Finley Creek	933	18	860	961	1.3	1.8	0.0	28.2
Eagle Creek-Kreager Ditch	933	18	866	961	1.5	2.1	0.0	26.1
Little Eagle Branch-Headwaters	919	15	869	951	0.9	1.3	0.0	11.4
Mounts Run-Neese Ditch	944	14	860	974	1.2	1.9	0.0	23.1
Little Eagle Branch-Woodruff Branch	902	21	823	938	1.7	2.0	0.0	18.3
Eagle Creek-Jackson Run	915	28	823	971	2.1	2.7	0.0	33.0
Fishback Creek (Eagle Creek Reservoir)	921	31	791	981	2.3	3.7	0.0	44.1
Eagle Creek-Long Branch/Irishman Run	876	34	791	951	3.3	3.4	0.0	32.1
Eagle Creek Reservoir-School Branch	868	40	787	935	2.4	4.0	0.0	38.0

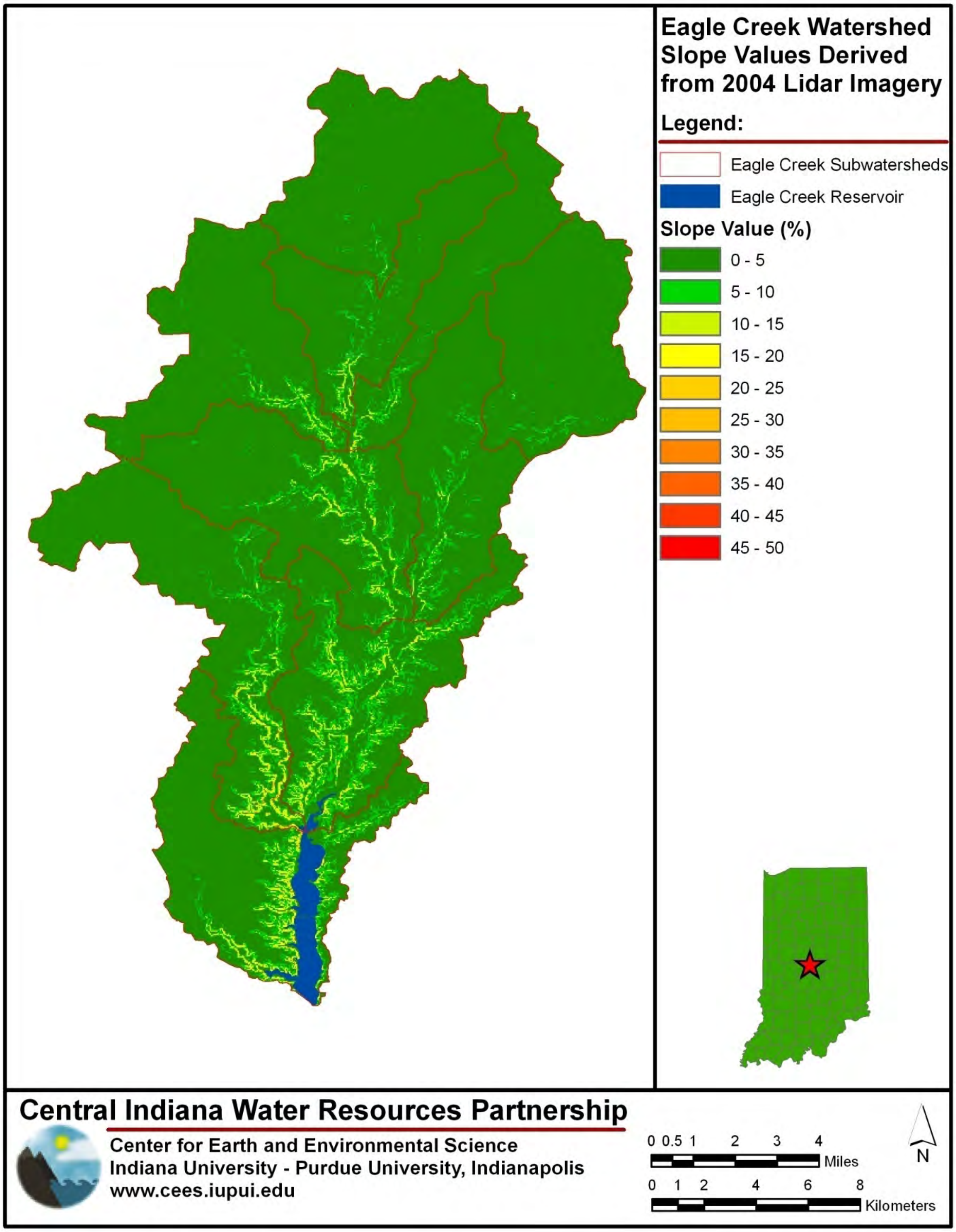


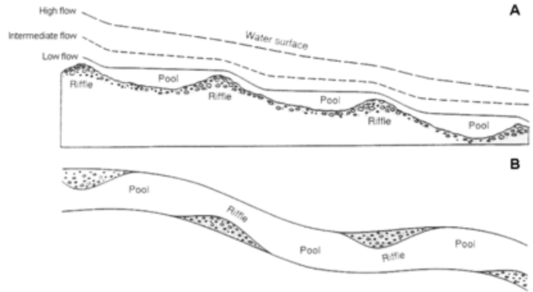
Figure IV-5: Eagle Creek Watershed – Slope Delineation

Impervious Surface Analysis

Using 2003 land-use/land cover data CEES researchers estimated impervious land cover for each subwatershed. EPA defines an impervious surface as any "hard surface area that either prevents or retards the entry of water into the soil mantle or causes water to run off the surface in greater quantities or at an increased rate of flow." Examples of impervious surfaces are streets and roads, rooftops, and parking lots. Therefore, this analysis was completed using the convention that forest and natural ground cover were the least impervious, allowing for the greatest amount of water infiltration and retention, and high density urban was the most impervious, allowing for the least amount of water infiltration and retention (Table IV-7 and Figure IV-6).

As impervious surfaces facilitate the overland flow of water and decrease infiltration and retention of water, areas with a high surface area of impervious surfaces cause detrimental effects to their adjoining stream ecosystems. For example, impervious surface can alter the shape of stream channels, raise water temperature, augment the transport of trash and pollutants "washing" into the stream, and increase the frequency and magnitude of surface runoff event such as storm run-off. Therefore, increasing the amount of watershed impervious surfaces results in a decrease in stream water quality. Work published by Elvidge *et al.*, (2004) on small (0.2 to 10 square mile area) urban watersheds in the mid-Atlantic showed that stream water quality decreased as a function of increased watershed percent impervious surface cover, whereby, watersheds with 11 – 25% impervious cover had streams that exhibited clear signs of degradation (i.e., downcutting and widening of the stream channel, streambank erosion, and degraded water quality) and watersheds with 25 – 30% impervious cover had streams that consistently exhibited severe degradation (i.e., severe widening, downcutting, and streambank erosion, a significant loss of riffle-pool stream structure[5], and degraded water quality).

[5] Riffle and pool stream structure describes the longitudinal transects of a stream that alternate between shallow areas with high water velocity and mixed gravel-cobble substrates and deeper areas with slow water velocity and finer substrates (Allan, 1995). These alternating areas provide essential habitats for fish and aquatic macroinvertebrate communities.



Stream-Riffle Structure (reproduced from Allan, 1995)
A – Longitudinal View
B – Plan view

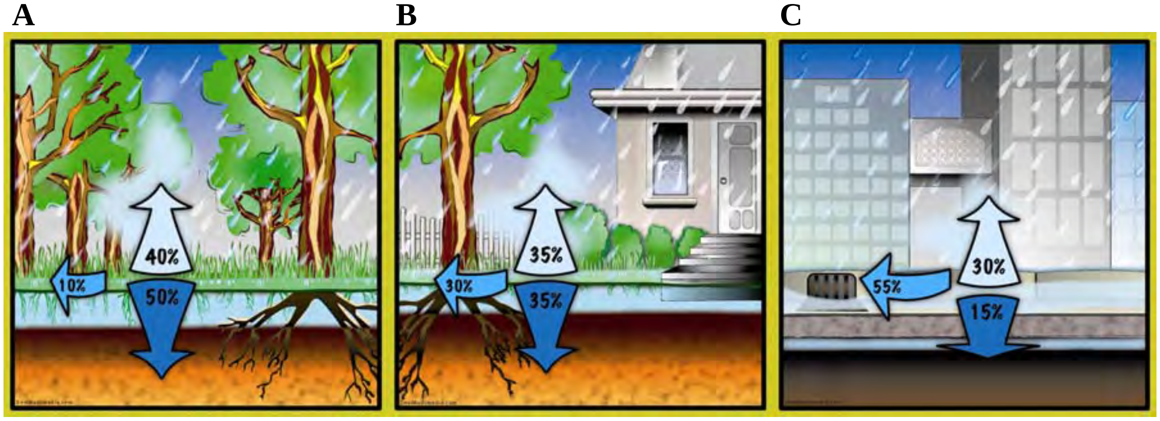
Table IV-7: Continuum of Land-use/Land Cover Imperviousness

Land-use/Land Cover	Imperviousness
Forest	Least Impervious
Herbaceous	↓
Agriculture	↓
----------------------------------	----------------------------------
Excavations	↓
Low Density Urban	↓
High Density Urban	Most Impervious

--- Dashed lines represent delineation between an impervious surface and permeable surface.

The impervious surface analysis for Eagle Creek Watershed showed that the upper subwatersheds (e.g., Dixon Branch, Kreager Ditch, and Mounts Run –Neese Ditch) have the least amount of impervious surfaces while the lower subwatersheds (e.g., Long Branch/Irishman Run and School Branch) have the greatest amount of impervious surfaces (Table IV-8 and Figure IV-7). Therefore, the streams in these lower subwatersheds are susceptible to downcutting and widening, streambank erosion, and degraded water quality.

A B C



Least Impervious → → → → → → → → → → → → → → → → → Most Impervious

Figure IV-6: Diagram showing the effect of increasing urbanization on run-off (©IUPUI Visual and Interactive Spaces Lab/CEES 2005). A – Natural land cover of forest and herbaceous plants. B – Low density urban land cover. C – High density urban land cover. ⇧ = evapotranspiration; ⇩ = infiltration; and ⇦ = run-off.

Table IV-8: Eagle Creek Subwatersheds – Impervious Surface Analysis

	Impervious		Pervious	
Subwatershed	*(mi^2)*	*%*	*(mi^2)*	*%*
Eagle Creek Dixon Branch	0.6	3.4%	16.0	96.1%
Eagle Creek-Finley Creek	0.6	5.4%	10.0	94.2%
Eagle Creek -Kreager Ditch	0.3	2.7%	11.9	96.7%
Little Eagle Branch-Headwaters	1.1	6.8%	14.7	92.9%
Mounts Run- Neese Ditch	0.2	1.3%	15.9	98.5%
Little Eagle Branch- Woodruff	1.7	12.5%	12.0	87.0%
Eagle Creek- Jackson Run	2.4	12.7%	16.4	86.6%
Fishback Creek (Eagle Creek Reservoir)	2.1	10.0%	18.9	89.2%
Eagle Creek- Long Branch/Irishman Run	5.2	27.3%	13.4	70.2%
Eagle Creek Reservoir-School Branch	3.0	14.9%	14.7	73.3%
Total Eagle Creek Watershed	17.2	10.5%	143.8	87.5%

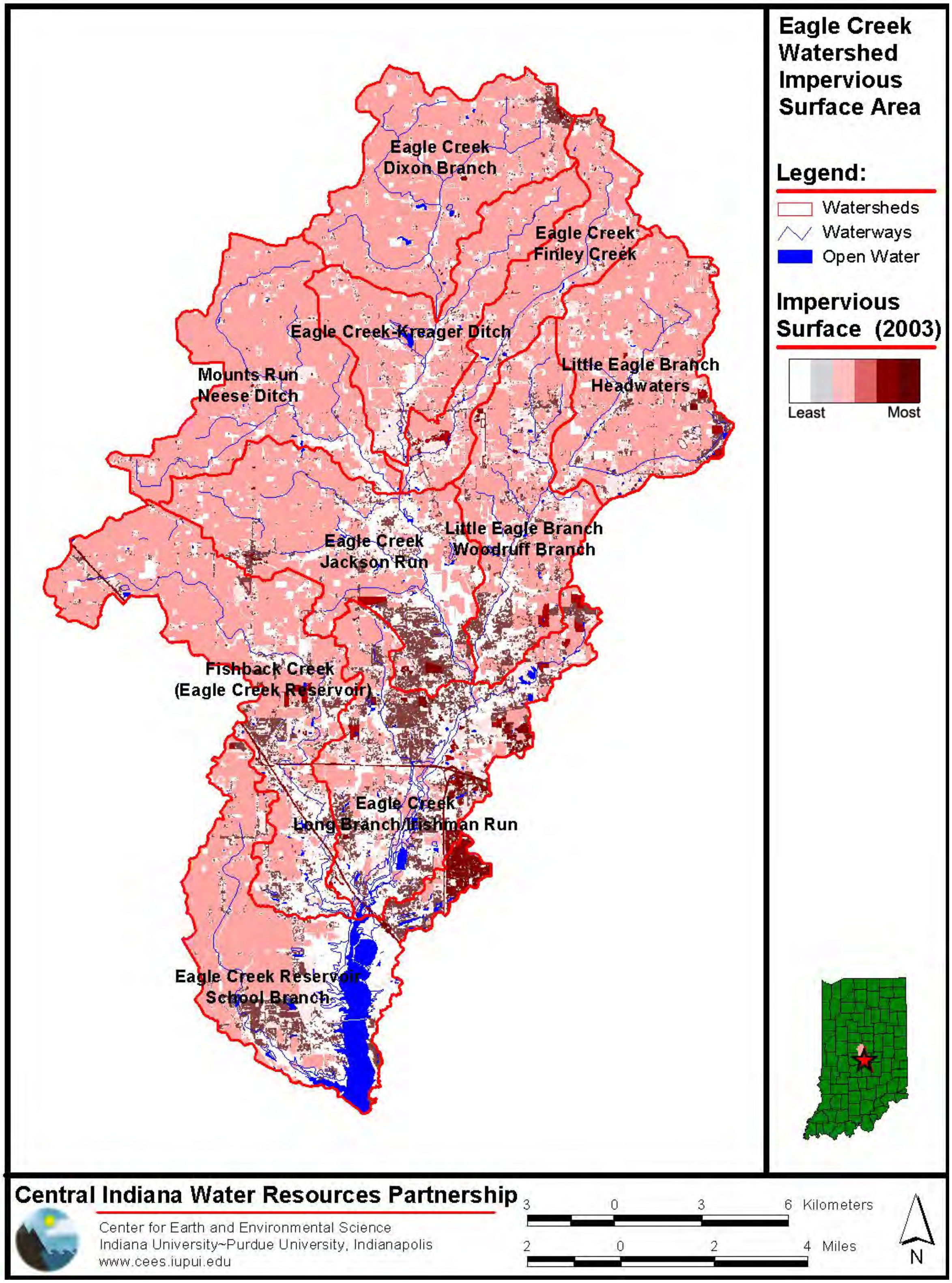


Figure IV-7: Eagle Creek Watershed – Impervious Surfaces

Recreation Areas

While the streams in Eagle Creek Watershed and Eagle Creek Reservoir are designated for use for Full Body Contact Recreation, much of the upstream reaches are bordered by agricultural land, making access to the streams limited. Public Access to Eagle Creek is limited to a few parks: Eagle Creek Park (Indianapolis), Starkey Nature Park (Zionsville), Creekside Nature Park (Zionsville), and Lions Park (Zionsville) (Table IV-9).

The main trunk of Eagle Creek in the Long Branch & Irishman Run subwatersheds are sufficiently deep to allow for shallow drafting, low horsepower or paddle driven water craft such as jon boats, kayaks and canoes. Boaters can access this area of the stream via under bridge put-ins or Eagle Creek Park.

Table IV-9: Recreational Areas in Eagle Creek Watershed

Park	City	Size	Amenities
Eagle Creek Park	Indianapolis	3,900 acres	Bait shop, Sailboat Marina, Outdoor Theater, Concession Stands, Fishing Areas, Fitness Course, Nature Center, Retreat Centers, Picnicking, Boat Ramps and Slips, Swim Beach,, Boat Rentals, Cross-Country Ski Paths, Marsh & Bird Sanctuary, Pistol/Archery Range, Woodland Wildlife Preserve
Starkey Nature Park	Zionsville	77 acres	Hiking Trails, Nature Study, Picnicking, Access to Stream
Creekside Nature Park	Zionsville	18 acres	Hiking Trails, Access to Stream
Lions Park	Zionsville	18 acres	Baseball and Softball Diamonds, Sand Volleyball, Picnicking

Farming Practices

Corn and soybeans are the predominant crops in Boone, Hamilton, and Hendricks Counties, the three agricultural counties in which Eagle Creek Watershed lies (Figure III-17). (The area of Marion County in which Eagle Creek Watershed lies does not have a significant amount of agriculture). In 2000, approximately 53,900 acres of land in Eagle Creek Watershed were used for agriculture (Tedesco *et al.*, 2003). In 2004, 221,014 acres in Boone County, 106,430 acres in Hamilton County, and 114,085 acres in Hendricks County were used for the production of corn and soybean (Table IV-10).

Tillage Practices

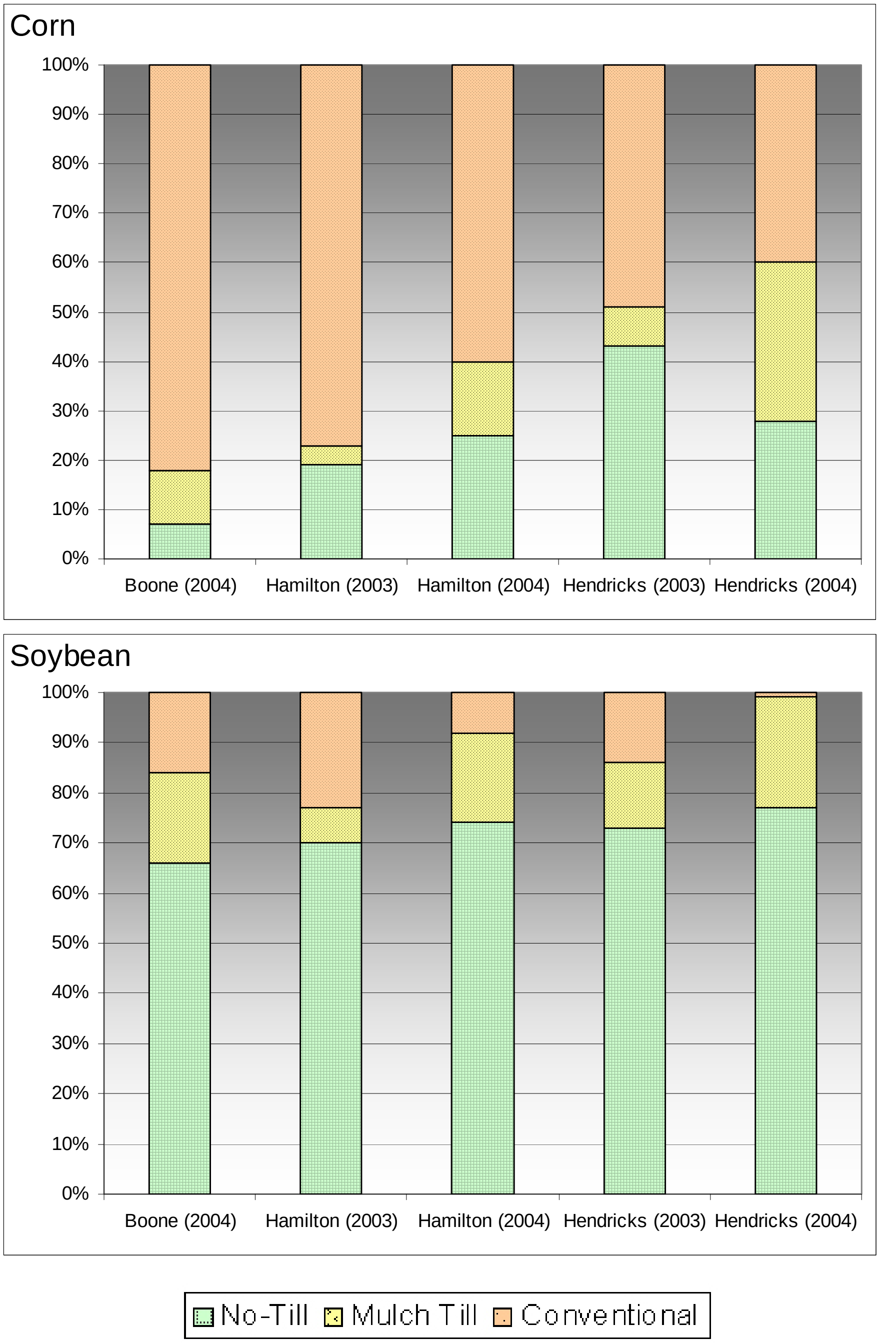
Tillage practices can affect water quality by influencing the amount of sediment that is eroded from fields and transported to streams, lakes, and reservoirs. Agricultural chemicals, such as nutrients and pesticides, are often transported along with eroded sediments, which can increase concentrations of these contaminants in surface water. Soil erosion and runoff are considered (by volume) the greatest surface water contaminant in Indiana watersheds (Evans *et al*., 2000). No-till, a conservation-tillage system, which leaves more than 30% crop residue cover on the fields, is the most effective soil conservation practice for reducing soil erosion and improving water quality. Leaving more than 30% crop cover increases infiltration rates, thus reducing the amount of soil lost to agricultural runoff. As such, conservation tillage[6] along with filter strips and buffers is recognized as a management practice necessary for reducing agricultural runoff and improving water quality (Evans *et al*., 2000) however, no-till practices can result in an increased use of agricultural chemicals.

Table IV-10: Corn and Soybean Acreage and Tillage Practices

			Corn					
		Total Acres	**No Till**		**Mulch Till**		**Conventional**	
Year	**County**	*(acres)*	*(acres)*	*%*	*(acres)*	*%*	*(acres)*	*%*
2004	Boone	114,543	8,018	*7%*	12,600	*11%*	93,925	*82%*
2003	Hamilton	59,058	11,221	*19%*	2,362	*4%*	45,475	*77%*
2004	Hamilton	48,372	12,093	*25%*	7,256	*15%*	29,023	*60%*
2003	Hendricks	68,679	29,532	*43%*	5,494	*8%*	33,653	*49%*
2004	Hendricks	49,525	13,867	*28%*	15,848	*32%*	19,810	*40%*

			Soybean					
		Total Acres	**No-Till**		**Mulch Till**		**Conventional**	
Year	**County**	*(acres)*	*(acres)*	*%*	*(acres)*	*%*	*(acres)*	*%*
2004	Boone	106,471	70,271	*66%*	19,165	*18%*	17,035	*16%*
2003	Hamilton	55,161	38,613	*70%*	3,861	*7%*	12,687	*23%*
2004	Hamilton	58,058	42,963	*74%*	10,450	*18%*	4,645	*8%*
2003	Hendricks	57,736	42,147	*73%*	7,506	*13%*	8,083	*14%*
2004	Hendricks	64,560	49,711	*77%*	14,203	*22%*	646	*1%*

[6] Any tillage system leaving at least 30% of the crop residue cover on the soil surface after planting.



<u>No-till</u>: Any direct seeding system including strip preparation with minimal soil disturbance.
<u>Mulch Till</u>: Any tillage system leaving greater than 30% of the crop residue cover after planting, excluding no-till.
<u>Conventional</u>: Any tillage system leaving less than 30% crop residue cover after planting.

Figure IV-8: Tillage Practices by County (Percent) (Indiana Division of Soil Conservation, 2003 and 2004)

Indiana's Division of Soil Conservation 2003 and 2004 data show that corn field tillage practices in the counties in which Eagle Creek Watershed lies are dominated by conventional tillage, while soybean crop tillage practices are dominated by no-till practices (Table IV-10 and

Figure IV-8). That corn is the most heavily fertilized of soybean and corn crops (see following section on Agricultural Chemicals) and that corn is most often farmed using conventional tillage practices suggests that corn field run-off is a possible source of nutrients and herbicides into Eagle Creek Watershed's streams.

Agricultural Chemicals

Agricultural fertilizers, herbicides, and pesticides are used extensively in crop production in Indiana. Soil erosion, runoff, and tile drainage from agricultural fields is a source of contaminants in Indiana watersheds; therefore, a major source of plant limiting nutrients (nitrogen and phosphorous), herbicides, and pesticides in the surface and ground water is from chemical applications to row crops.

As information on agricultural chemical use is not available for Eagle Creek Watershed, usage was estimated. Estimates of acres planted of each crop within Eagle Creek Watershed were based on the statewide percentages of soybean and corn acres. The state total acreage of soybean and corn fields was added to obtain the Total Agricultural Acreage. (Other crops such as wheat, hay, and oats were not included in the calculation as visual assessments of the Eagle Creek Subwatersheds show that they are negligible.) The acreage of soybeans was divided by the Total Agricultural Acreage to determine the percentage of agricultural land used for soybean production and the same calculation was completed for corn. These calculations resulted in an estimated annual state agricultural land-use average of 48% soybean and 52% corn production. These percentages were applied to the acreage of agricultural land delineated in 2002-2003 land cover assessment for each Eagle Creek Subwatershed to estimate acres of soybean and corn in the subwatersheds. (Visual assessment of the subwatersheds verifies that agricultural land is approximately 50% soybean fields and 50% corn fields.) To estimate the amount of agricultural chemicals used in Eagle Creek Basin, the total mass of chemicals applied in the state was divided by the total acreage of crop (soybean or corn) to determine an average statewide application rate (lbs/acre-year or ton/acre-year Mass of applied chemicals was based on NASS USDA 2002 Chemical Usage Reports. This rate was then applied to the Eagle Creek Subwatersheds to estimate mass of agricultural chemicals applied to agricultural fields in Eagle Creek Watershed (Table IV-11 and Table IV-12).

Of the crops to which fertilizer is applied (e.g., corn, soybean, and wheat) most is applied to corn—it receives 90 percent of the nitrogen and 76 percent of the phosphorus. One percent of the nitrogen and 13 percent of the phosphorus is applied to soybeans. Application methods and the types of fertilizer applied in Indiana varies depending on the weather, soil fertility, tillage systems, crop types, crop rotations, yield goals, and farmer preferences. Anhydrous ammonia, 28-percent-liquid nitrogen, and urea in solid form are the most widely used nitrogen-based fertilizers for corn (Schnoebelen and others, 1996). Typically, two applications of nitrogen based fertilizer are applied in Indiana to corn per year (Indiana Agricultural Statistics Service, 1992). The initial treatment is anhydrous ammonia applied 1 to 2 weeks before planting or liquid nitrogen or urea applied at planting. After corn is about 1 foot tall (usually early to mid-June), a second, larger treatment is applied. Some farmers also apply nitrogen-based fertilizers after harvest, especially if they plan to grow winter wheat. As estimated fertilizer usage was based on acreage, those subwatersheds with the greatest amount of land in soybean and corn production (Dixon Branch, Mounts Run-Neese Ditch, and Fishback Creek) consistently show the highest estimated fertilizer application (Table IV-11– shaded rows).

Herbicides applied to corn and soybeans dominate herbicide and pesticide use in Indiana and, therefore, it is reasonable to believe that, this is also true for the Eagle Creek Basin. Herbicides are applied in the spring during planting to virtually all corn and soybean crops. In Indiana, herbicide with the highest statewide average application rate are Sulfosate (1.22 lb/acre-year) and Glyphosate (1.58 lb/acre-year). Corn herbicides with the highest statewide average application rate are Atrazine (1.32 lb/acre-year), Dimethenamid (1.18 lb/acre-year), Metolachlor (1.66 lb/acre-year), and S-Metolachlor (1.23 lb/acre-year) (Table IV-12). Because of increased use of no-till farming practices in Indiana, there has been a significant increase in the use of glyphosate, 2,4-D, and pendimethalin in the last 7 years. These herbicides are used prior to planting to kill all plant growth. Insecticides are applied during the summer to about 25 percent of the corn crop and typically are not applied to soybeans (National Agricultural Statistics Service, 1998). As estimated herbicide usage was based on acreage, those subwatersheds with the greatest amount of land in soybean and corn production (Dixon Branch, Mounts Run-Neese Ditch, and Fishback Creek) consistently show the highest estimated herbicide application (Table IV-12– shaded rows).

Table IV-11: Estimated 2002 Fertilizer Application in Eagle Creek Subwatersheds

	Soybean N*	Soybean P†	Soybean Potash	Corn N*	Corn P†	Corn Potash
Application Rate (lbs/acre/yr)‡	2	52	111	147	71	125

Subwatershed	Acres Planted° Soybean	Acres Planted° Corn	Soybean N* (tons)	Soybean P† (tons)	Soybean Potash (tons)	Corn N* (tons)	Corn P† (tons)	Corn Potash (tons)
Eagle Creek Dixon Branch	4,600	4,283	4.1	121	256	315	151	268
Eagle Creek-Finley Creek	2,504	2,332	2.2	66	139	172	82	146
Eagle Creek -Kreager Ditch	3,088	2,875	2.8	81	172	212	101	180
Little Eagle Branch-Headwaters	3,698	3,443	3.3	97	205	253	121	215
Mounts Run- Neese Ditch	4,497	4,187	4.0	118	250	308	148	262
Little Eagle Branch-Woodruff	2,455	2,286	2.2	64	136	168	81	143
Eagle Creek- Jackson Run	3,451	3,213	3.1	90	192	236	113	201
Fishback Creek (Eagle Creek Reservoir)	4,170	3,882	3.7	109	232	286	137	243
Eagle Creek- Long Branch/Irishman Run	1,550	1,443	1.4	41	86	106	51	90
Eagle Creek Reservoir-School Branch	2,724	2,536	2.4	71	151	187	89	159
Total Applied in Eagle Creek Watershed	32,738	30,480	29.3	858	1,819	2,243	1,075	1,905

* Nitrogen

† Phosphorous

‡ Application rate based on total mass applied in Indiana divided by total acres of land in Indiana used for each crop (NASS USDA 2002 Chemical Usage Reports).

° Acres Planted was estimated based on statewide averages for corn and soybean production. In Indiana, annual averages show that 52% of farmland is used for corn production while 48% is used for soybean production. These percentages were applied to the acreage of agricultural land delineated in 2002-2003 land cover assessment for each subwatershed to estimate how many acres were planted for each crop. Visual assessment of the subwatersheds verifies that agricultural land is approximately 50% corn fields and 50% soybean fields and that other crops (e.g., wheat, hay, and oats) were negligible.

Table IV-12: Estimated 2002 Herbicide Application in Eagle Creek Subwatersheds

	Soybean						
	2,4-D	**Chlorimuron-ethyl**	**Fenoxaprop**	**Fluazifop-P-butyl**	**Fomesafen**	**Glyphosate**	**Glyphosate, diam. Salt**
Common Name(s)		(Canopy, Classic, Authority)	(Fusion)	(Fusilade, Typhoon, Fusion)	(Reflex, Flextar, Typhoon)	(Roundup, Protocol, Extreme, Bronco)	(Touchdown)
Application rate (lbs/acre/yr)*	0.29	0.02	0.14	0.04	0.31	1.22	0.90

Subwatershed	**2,4-D** *(lbs)*	**Chlorimuron-ethyl** *(lbs)*	**Fenoxaprop** *(lbs)*	**Fluazifop-P-butyl** *(lbs)*	**Fomesafen** *(lbs)*	**Glyphosate** *(lbs)*	**Glyphosate, diam. Salt** *(lbs)*
Eagle Creek Dixon Branch	1,348	79	650	206	1,428	5,590	4,142
Eagle Creek-Finley Creek	734	43	354	112	777	3,043	2,255
Eagle Creek -Kreager Ditch	905	53	437	138	958	3,753	2,781
Little Eagle Branch-Headwaters	1,084	64	523	166	1,148	4,494	3,330
Mounts Run- Neese Ditch	1,318	78	636	202	1,396	5,465	4,049
Little Eagle Branch- Woodruff	720	42	347	110	762	2,984	2,211
Eagle Creek- Jackson Run	1,012	60	488	155	1,071	4,194	3,107
Fishback Creek (Eagle Creek Reservoir)	1,222	72	590	187	1,294	5,067	3,754
Eagle Creek- Long Branch/Irishman Run	454	27	219	69	481	1,883	1,395
Eagle Creek Reservoir-School Branch	798	47	385	122	845	3,310	2,453
Total for Eagle Creek Watershed	**9,596**	**564**	**4,628**	**1,468**	**10,160**	**39,784**	**29,477**

* Application rate based on total mass applied in Indiana divided by total acres of land in Indiana used for each crop (NASS USDA 2002 Chemical Usage Reports). These estimates show the amount of herbicide possibly applied if all farms used all herbicides at all times. This is not the case: each farm utilizes only one to a few chemicals for each crop. Therefore, these estimates only give the possible amount of herbicide used in each watershed.

Table IV-12: Estimated 2002 Herbicide Application in Eagle Creek Subwatersheds (continued)

	Soybean					
	Imazaquin	**Imazethapyr**	**Metribuzin**	**Pendimethalin**	**Sulfentra zone**	**Sulfosate**
Common Name(s)	(Scepter, Squadron, TriScept, Steel)	(Pursuit, Lightnight, Steel, Extreme, Res.)	(Canopy, Turbo, Sencor, Aziom, Boundary)	(Prowl, Steel, Pursuit Plus, Squadron)	(Authority , Canopy, Gauntlet)	(Touchdown) (2001 Data)
Application rate (lbs/acre/yr)*	0.07	0.06	0.16	0.90	0.10	1.58

Subwatershed	**Imazaquin** *(lbs)*	**Imazethapyr** *(lbs)*	**Metribuzin** *(lbs)*	**Pendimethalin** *(lbs)*	**Sulfentra zone** *(lbs)*	**Sulfosate** *(lbs)*
Eagle Creek Dixon Branch	337	262	730	4,124	465	7,257
Eagle Creek-Finley Creek	184	142	397	2,245	253	3,951
Eagle Creek -Kreager Ditch	226	176	490	2,769	312	4,872
Little Eagle Branch-Headwaters	271	210	587	3,315	373	5,834
Mounts Run- Neese Ditch	330	256	713	4,032	454	7,094
Little Eagle Branch- Woodruff	180	140	389	2,201	248	3,874
Eagle Creek- Jackson Run	253	196	547	3,094	349	5,445
Fishback Creek (Eagle Creek Reservoir)	306	237	661	3,738	421	6,578
Eagle Creek- Long Branch/Irishman Run	114	88	246	1,389	156	2,445
Eagle Creek Reservoir-School Branch	200	155	432	2,442	275	4,297
Total for Eagle Creek Watershed	**2,399**	**1,863**	**5,193**	**29,351**	**3,306**	**51,647**

* Application rate based on total mass applied in Indiana divided by total acres of land in Indiana used for each crop (NASS USDA 2002 Chemical Usage Reports). These estimates show the amount of herbicide possibly applied if all farms used all herbicides at all times. This is not the case: each farm utilizes only one to a few chemicals for each crop. Therefore, these estimates only give the possible amount of herbicide used in each watershed.

Table IV-12: Estimated 2002 Herbicide Application in Eagle Creek Subwatersheds (continued)

	Corn						
	Acetamide	**Acetochlor**	**Atrazine**	**Clopyralid**	**Dicamba**	**Dicamba, Dimet. Salt**	**Dimethenamid**
Common Name(s)	(Axiom, Epic, Definte, Domain).	(Harness Plus, Surpass, TopNotch)	(Atrazine, Bicep, Degree, Xtra)	(Curtail, Stinger, Hornet)	(Banvel, North Star, Celebrity, Op Till)	(Distinct, Range Star, Sterlin)	(Guardsman, Frontier, Op Till)
Application rate (lbs/acre/yr)*	0.44	0.19	1.32	0.10	0.12	0.10	1.18

Subwatershed	**Acetamide** *(lbs)*	**Acetochlor** *(lbs)*	**Atrazine** *(lbs)*	**Clopyralid** *(lbs)*	**Dicamba** *(lbs)*	**Dicamba, Dimet. Salt** *(lbs)*	**Dimethenamid** *(lbs)*
Eagle Creek Dixon Branch	1,903	807	5,640	419	529	416	5,036
Eagle Creek-Finley Creek	1,036	439	3,071	228	288	227	2,742
Eagle Creek -Kreager Ditch	1,278	542	3,787	281	355	280	3,381
Little Eagle Branch-Headwaters	1,530	649	4,534	337	425	335	4,049
Mounts Run- Neese Ditch	1,861	789	5,514	410	517	407	4,923
Little Eagle Branch- Woodruff	1,016	431	3,011	224	282	222	2,688
Eagle Creek- Jackson Run	1,428	605	4,232	315	397	312	3,779
Fishback Creek (Eagle Creek Reservoir)	1,725	731	5,113	380	479	377	4,565
Eagle Creek- Long Branch/Irishman Run	641	272	1,900	141	178	140	1,697
Eagle Creek Reservoir-School Branch	1,127	478	3,340	248	313	247	2,982
Total for Eagle Creek Watershed	**13,547**	**5,743**	**40,141**	**2,984**	**3,763**	**2,963**	**35,842**

* Application rate based on total mass applied in Indiana divided by total acres of land in Indiana used for each crop (NASS USDA 2002 Chemical Usage Reports). These estimates show the amount of herbicide possibly applied if all farms used all herbicides at all times. This is not the case: each farm utilizes only one to a few chemicals for each crop. Therefore, these estimates only give the possible amount of herbicide used in each watershed.

Table IV-12: Estimated 2002 Herbicide Application in Eagle Creek Subwatersheds (continued)

	Corn						
	Flumetsulam	**Glyphosate**	**Imazapyr**	**Imazethapyr**	**Isoxaflutole**	**Metolachlor**	**Nicosulfuron**
Common Name(s)	(Broadstrike, Accent Gold, Bicep)	(Roundup, Protocol, Extreme, Glyphomax)	(Lightning, Pursuit, Steel)	(Pursuit, Lightning, Steel)	(Balance, Epic)	(Dual, Dual II, Bicep, Turbo)	(Accent Gold, Celebrity, Steadfast)
Application rate (lbs/acre/yr)*	0.10	0.68	0.00	0.01	0.06	1.66	0.02

Subwatershed	**Flumetsulam** *(lbs)*	**Glyphosate** *(lbs)*	**Imazapyr** *(lbs)*	**Imazethapyr** *(lbs)*	**Isoxaflutole** *(lbs)*	**Metolachlor** *(lbs)*	**Nicosulfuron** *(lbs)*
Eagle Creek Dixon Branch	412	2,895	16	32	256	7,112	79
Eagle Creek-Finley Creek	225	1,576	9	17	140	3,872	43
Eagle Creek -Kreager Ditch	277	1,944	11	21	172	4,775	53
Little Eagle Branch-Headwaters	332	2,327	13	26	206	5,717	64
Mounts Run- Neese Ditch	403	2,830	16	31	250	6,952	78
Little Eagle Branch- Woodruff	220	1,545	8	17	137	3,796	42
Eagle Creek- Jackson Run	309	2,172	12	24	192	5,336	60
Fishback Creek (Eagle Creek Reservoir)	374	2,624	14	29	232	6,446	72
Eagle Creek- Long Branch/Irishman Run	139	975	5	11	86	2,396	27
Eagle Creek Reservoir-School Branch	244	1,714	9	19	152	4,211	47
Total for Eagle Creek Watershed	**2,935**	**20,602**	**113**	**226**	**1,824**	**50,612**	**564**

* Application rate based on total mass applied in Indiana divided by total acres of land in Indiana used for each crop (NASS USDA 2002 Chemical Usage Reports). These estimates show the amount of herbicide possibly applied if all farms used all herbicides at all times. This is not the case: each farm utilizes only one to a few chemicals for each crop. Therefore, these estimates only give the possible amount of herbicide used in each watershed.

Table IV-12: Estimated 2002 Herbicide Application in Eagle Creek Subwatersheds (continued)

	Corn						
	Primisulfuron	**S-Metolachlor**	**Chlorpyrifos**	**Clyfluthrin**	**Fipronil**	**Teupirimphos**	**Tefluthrin**
Common Name(s)	(Exceed, North Star, Beacon)	(Gual Mag, Dual II, Bicep Mag, Bound	(Lorsban, Dursban)	(Baythroid, Leverage, Aztec)	(Regent)	(Aztec)	(Force)
Application rate (lbs/acre/yr)*	0.02	1.23	0.90	0.00	0.13	0.11	0.12

Subwatershed	**Primisulfuron** *(lbs)*	**S-Metolachlor** *(lbs)*	**Chlorpyrifos** *(lbs)*	**Clyfluthrin** *(lbs)*	**Fipronil** *(lbs)*	**Teupirimphos** *(lbs)*	**Tefluthrin** *(lbs)*
Eagle Creek Dixon Branch	99	5,289	3,847	20	544	466	523
Eagle Creek-Finley Creek	54	2,879	2,094	11	296	254	285
Eagle Creek -Kreager Ditch	67	3,551	2,583	13	365	313	351
Little Eagle Branch-Headwaters	80	4,251	3,092	16	437	375	421
Mounts Run- Neese Ditch	97	5,170	3,760	19	532	455	512
Little Eagle Branch- Woodruff	53	2,823	2,053	11	290	249	279
Eagle Creek- Jackson Run	74	3,968	2,886	15	408	350	393
Fishback Creek	90	4,794	3,487	18	493	422	474
Eagle Creek- Long Branch/Irishman Run	33	1,782	1,296	7	183	157	176
Eagle Creek Reservoir-School Branch	59	3,132	2,278	12	322	276	310
Total for Eagle Creek Watershed	**706**	**37,638**	**27,376**	**141**	**3,870**	**3,316**	**3,725**

* Application rate based on total mass applied in Indiana divided by total acres of land in Indiana used for each crop (NASS USDA 2002 Chemical Usage Reports). These estimates show the amount of herbicide possibly applied if all farms used all herbicides at all times. This is not the case: each farm utilizes only one to a few chemicals for each crop. Therefore, these estimates only give the possible amount of herbicide used in each watershed.

Herbicides are the most commonly occurring agricultural pesticides in surface waters in the White River Basin (Crawford, 1995; Crawford, 1996). Typically, 1 percent of the applied herbicide is washed into surface water (Crawford, 1995). Most of this wash off usually occurs during the first rainfall after application. The percentage of the herbicides applied that wash off increases as the time between pesticide application and the next rainfall decreases. Concentrations of herbicides in streams are usually elevated for a several week to several month period from mid-May to early July (Crawford, 1995). Herbicides washed into Eagle Creek Reservoir can accumulate there because of the reservoir residence time (51 days) and the persistence of some chemicals. For example, depending on temperature, pH, and organic matter content, Atrazine has a half-life of 64 days. Given an increase in organic matter, degradation can be twice as fast; however, given a pH of 7-9 (typical of Eagle Creek Watershed Streams), degradation can be 2-3 times as slow. In general, herbicide persistence is dependent on the degradation kinetics of the particular herbicide and the presence of bacteria capable of facilitating degradation.

Tile Drains

Water quality in many parts of Indiana is affected by tile drains. Since the beginning of the 20th Century many poorly drained soils in Indiana have been improved for farming by the installation of tile-drain systems (Figure IV-1). Newer tile drains commonly consist of perforated, flexible tubes buried in trenches in fields beneath the plow zone. Older systems are usually clay tile. Tile drains short circuit the natural flow of water through soil by removing standing water in fields, draining excess soil moisture in the unsaturated zone, draining seasonally high ground-water tables, and transporting water to nearby ditches or streams. Information on the number and location of tile-drain systems in Indiana is not available, but agricultural experts expect that nearly all poorly drained farmlands contain tile-drain systems (Schnoebelen *et al*., in press) which would include much of the Eagle Creek Watershed. As tile drains are a transport mechanism that often bypasses riparian buffers, tile drainage can be particularly problematic to surface-water quality if rainfall occurs immediately following application of fertilizers or pesticides. Tile drains have been shown to be a significant pathway for nutrient and herbicide transport to streams in central Indiana (Fenelon, 1998; Fenelon and Moore, 1998).

Section V: Investigation of Water Quality Issues in Eagle Creek Watershed

Water quality data in Eagle Creek Watershed is available from many sources. Since the mid-1990s groups such as the Marion County Health Department (MCHD) and the Eagle Creek Watershed Taskforce (ECWTF) have maintained a database on stream water quality for Eagle Creek Watershed streams. In 2002, the Center for Earth and Environmental Science (CEES) began detailed study of the streams and reservoir as part of the Central Indiana Water Resources Partnership. These data with several historical data sets were used to assess the water quality conditions in the Eagle Creek Subwatersheds to develop Problem Statements and locate Critical Areas.

This assessment process takes into account several indicators of water quality, ranging from concentrations of contaminants to loads of contaminants, and remotely sensed land-use/land cover data to visual assessments. This robust assessment allowed the ECWA to formulate Problem Statements and identify Critical Areas based on a multi-parameter, systematic process, allowing areas of greatest concern to be chosen not only by the degree of water quality degradation, but also by the possible causes of such degradation. This approach allowed the ECWA to determine the best course of remediation and develop insight into the possible outcomes of proposed remediation.

The water quality indicators were compiled from the many data resources and studies on Eagle Creek Watershed. Given the availability of data each subwatershed was assess based on the following information:

- Water Quality Data
- Biomonitoring Study
- Nutrient and Suspended Sediment Load Data
- Adequate Woody Riparian Buffer Zone Determination
- Land Cover Assessment
- Land-Use Perturbation Study
- Watershed Visual Assessment Survey
- Point Source Location Data
- Unsewered Community Report
- Stream Order Classification

The following sections summarize the water quality information that has been collected or is currently being collected on, about, or regarding Eagle Creek Watershed and/or Reservoir that was used in the Subwatershed Assessment.

Indiana Department of Environmental Management Data

Under the provisions of the Clean Water Act, the Indiana Department of Environmental Management (IDEM) regularly compiles data and assesses information on Indiana's surface waters. This assessment results in the creation of the 303(d) Impaired Water Bodies list for the state. Impairment is defined by a waterbodies ability to support its designated uses, therefore, the state must first assign each water body a designated use.

Designated Uses

Under the provisions of the Clean Water Act, the Indiana Water Pollution Control Board, part of the Indiana Legislative Services Agency (1997) has designated state waters, except those waters within the Great Lakes System (327 IAC 2-1.5), for the following uses (327 IAC 2-1-3):

- *Agricultural Use* – "All waters which are used for agricultural purposes are designated as an agricultural use water body;"
- *Full Body Contact* – "Surface waters of the state are designated for full-body (complete submergence) contact recreation;"
- *Human Health and Wildlife* – "Protection of human health and wildlife;"
- *Industrial Water Supply* – "All waters which are used for industrial water supply must meet the standards for those uses at the points where the water is withdrawn. Industrial water supply includes water which is withdrawn (either with or without treatment) for industrial cooling and processing;"
- *Limited Use* – "All waters in which naturally poor physical characteristics (including lack of sufficient flow), naturally poor chemical quality, or irreversible man-induced conditions, which came into existence prior to January 1, 1983, and having been established by use attainability analyses, public comment period, and hearing may qualify to be classified for limited use and must be evaluated for restoration and upgrading at each triennial review of this rule. Specific waters of the state designated for limited use are listed in section 11(a) of the standards document';
- *Put and Take Trout Fishery/Cold Water Fishery* – "Where natural temperatures permit, waters will be capable of supporting put-and-take trout fishing. All waters capable of supporting the natural reproduction of trout as of February 17, 1977 shall be so maintained;"
- *Public Water Supply* – "All waters which are used for public water supply must meet the standards for those uses at the points where the water is withdrawn. Public waters supply means any wells, reservoirs, lakes, rivers, sources of supply, pumps, mains, pipes, facilities, and structures through which water is obtained, treated as may be required, and supplied through a water distribution system for sale to or consumption by the public for drinking, domestic, or other purposes, including state-owned facilities even though the water may not be sold to the public;" and
- *Warm Water Aquatic Life* – "All waters, except those listed as limited use or designated for a cold water fish community, will be capable of supporting a well-balanced, warm water aquatic community (US EPA, 1997)."

Indiana Department of Environmental Management (IDEM) has designated all the streams in Eagle Creek Watershed for Agricultural Use, Full Body Contact Recreation, and Aquatic

Life Use; and designated Eagle Creek Reservoir for Full Body Contact Recreational Use, Aquatic Life Use, and use as a Public Water Supply.

Impaired Waterbodies

Under the Clean Water Act, IDEM is required to assess the water quality of its surface water for compliance with the state's water quality standards, a set of thresholds used to protect the water body for its designated use. This assessment is then made public via the states 303(d) list, or The Impaired Waters List, which includes the portion of the waterbody that is impaired and the pollutant(s) not meeting water quality standards thus causing the impairment. In the case of multiple use water bodies, such as those in Eagle Creek Watershed, the Designated Use with the most sensitive threshold, such as the lowest level of pollutant concentration, is the threshold that must be exceeded for the waterbody to be listed as impaired. Therefore, while the streams in Eagle Creek Watershed are designated for use in agricultural purposes, the water quality thresholds for maintaining full body contact recreation or a well-balanced, warm water aquatic community often are more sensitive than thresholds for Agricultural Use and will take precedence.

The designation of impaired, therefore, denotes that water quality analysis has shown that the waterbody is no longer able to support its designated use. For instance, *E. coli* concentrations are used as a proxy for human pathogens. As such, concentrations of *E. coli* in excess of 235 colony forming units per liter (CFU/100mL) are considered above a safe level for full body human contact. Any stream consistently exceeding this level of *E. coli* is considered impaired by not being fit for full body human contact.

In Eagle Creek Watershed, all streams are impaired due to *E. coli* concentrations higher than those recommended for full body human contact. Additionally, Eagle Creek - Kreager Ditch is also listed as impaired due to low biotic integrity which suggests that it is not able to support a well-balanced, warm-water aquatic community. Eagle Creek Reservoir is listed as impaired due to the presence of nuisance algae which impair the use of the Reservoir as a Public Water Source. Eagle Creek Reservoir also has a Fish Consumption Advisory (FCA) for PCBs, a toxin that poses a human health risk when high concentrations are consumed (Table V-1).

Eagle Creek Watershed Task Force (ECWTF) Monitoring Study

The Eagle Creek Watershed Taskforce has maintained weekly to bi-weekly monitoring efforts on streams in Eagle Creek Watershed during the growing season (roughly May – October) from 1997 – 2003 (Figure V-1). At each of the 10 stations, sampling involved taking grab samples from the stream but did not include the determination of stream discharge. This data set includes measurements of stream turbidity, ammonia (NH_3), nitrite (NO_2), nitrate (NO_3), chloride (Cl), sulfate (SO_4), *E. coli*, fecal coliform, and heterotrophic plate count concentrations, and Atrazine. Major ions (chloride and sulfate) were added to the data set in May of 1998. Measurements of ortho-phosphate were reported only in 2001 with the majority of measurements (92%) being below detection limit (0.060 mg P/L). However, in 2001, 10 stations (Mounts Run, Finley Creek, Little

Eagle Creek, and Eagle Creek at CR 300N, CR 200S, Holiday Rd., and Zionsville Lions Club Park) had ortho-phosphate concentrations exceeding 0.060 mg P/L. These high measurements were found in samples taken in the Spring (May) and late Fall (October) sampling dates. Parameters with greater than 100 measurements over the course of the sampling period were summarized as means (Table V-2). Based on mean water quality measurements, the upper subwatersheds (Mounts Run – Neese Ditch, Eagle Creek - Kreager Ditch, Eagle Creek - Dixon Branch, and Eagle Creek - Finley Creek) showed the highest mean turbidity; Mounts Run – Neese Ditch showed the highest mean concentrations of ammonia and *E. coli*; Eagle Creek Reservoir - School Branch showed the highest mean concentration of nitrate; and Fishback Creek (Eagle Creek Reservoir) showed the highest mean concentration of atrazine. This data set provides a good longitudinal data set for most streams (School Branch, Fishback, Irishman Run, Little Eagle Creek, Mounts Run, and Finley Creek) and the main trunk of Eagle Creek. These data were used with other data sets to determine stream water quality in the Subwatershed Assessment.

Table V-1: Eagle Creek Watershed 14 Digit HUC Subwatershed 303(d) Listing (IDEM 2002, 2004).

HUC 14	Subwatershed	Status	Parameter
05120201120010	Eagle Creek-Dixon Branch	Impaired	*E. coli*
05120201120020	Eagle Creek-Kreager Ditch	Impaired	*E. coli*: impaired biotic community
05120201120030	Eagle Creek-Finley Creek	Impaired	*E. coli*
05120201120040	Mounts Run-Neese Ditch	Impaired	*E. coli*
05120201120050	Eagle Creek-Jackson Run	Impaired	*E. coli*
05120201120060	Little Eagle Branch-Headwaters	Impaired	*E. coli*
05120201120070	Little Eagle Branch-Woodruff Branch	Impaired	*E. coli*
05120201120080	Eagle Creek-Long Branch/Irishman Run	Impaired	*E. coli*
05120201120090	Fishback Creek (Eagle Creek Reservoir)	Impaired	*E. coli*
05120201120100	Eagle Creek Reservoir-School Branch*	Impaired	Taste and Odor, Algae and FCA-PCBs

* School Branch is not included in the 2004 303(d) list of impaired waterways for *E. coli*. However, information provided by IDEM (J. Arthur, IDEM, personal communication) and data presented in this Watershed Management Plan show that the stream often has high concentrations of *E. coli* in excess of the 235 CFU/L threshold and will be listed on the next 303(d) list.

Table V-2: Mean Water Quality Values for ECWTF Data (May 1997 – October 2003)

Site	Subwatershed	Turbidity *NTU*	NH_3 *mg N/L*	NO_3 *mg N/L*	*E. coli* *CFU/100mL*	Cl^- *mg/L*	Atrazine *ppb*
10	Eagle Creek-Dixon Branch	26.6	0.13	4.4	1,982	28	2.4
9	Eagle Creek-Finley Creek	19.9	0.13	3.3	1,778	36	1.7
6	Mounts Run, Kreager Ditch, Dixon Branch, and Finley Creek	50.1	0.06	4.0	2,384	32	1.7
8	Mounts Run	19.6	0.27	5.3	7,114	39	1.5
7	Little Eagle Creek-Woodruff Branch	18.0	0.18	2.1	1,581	74	1.5
5	Jackson Run	31.0	0.10	3.5	1,413	31	1.9
2	Fishback Creek (Eagle Creek Reservoir)	19.2	0.13	3.2	1,762	64	9.1
4	Long Branch	29.3	0.10	2.7	1,447	41	1.9
3	Irishman Run	13.3	0.12	4.7	1,971	84	1.4
1	Eagle Creek Reservoir-School Branch	18.1	0.10	5.4	969	43	2.0

Central Indiana Water Resources Partnership (CIWRP) Studies

In 2003, the Central Indiana Water Resource Partnership undertook a study in Eagle Creek Watershed to determine the contribution of suspended sediment and dissolved loads to Eagle Creek Reservoir during seasonal base and event flow (Figure V-1). At each of the 8 stations, sampling involved taking grab samples from the middle of the stream bed in wadeable conditions or from the bridge in non-wadeable conditions. Stream discharge was measured with a SonTek Doppler flow meter during wadeable conditions and estimated using a linear least-squares regression relating measured stream discharge to the USGS gage (03353200) during non-wadeable conditions. These measured and estimated discharge data were used for instantaneous and yearly stream loading calculations. This data set includes *E. coli*, fecal coliform and heterotrophic plate count concentrations; nutrients (total phosphorous (Total P), ortho-phosphorous, total Kjeldahl nitrogen (TKN), nitrate (NO_3), nitrite (NO_2), ammonia (NH_3), total and dissolved silicate (SiO_4), total organic carbon (TOC), and dissolved organic and inorganic carbon (DOC and DIC)); major anions (Cl^- and SO_4^-); major cations (Na^+, Ca^+, Mg^+, and K^+); alkalinity and hardness (as $CaCO_3$); turbidity; chlorophyll *a*; and *in-situ* measurements of temperature, pH, conductivity, total dissolved solids (TDS), salinity, and dissolved oxygen.

All parameters measured a minimum of eight times over the course of the sampling period were summarized as means (Table V-3). Based on mean water quality measurements, the lower subwatersheds Fishback Creek (Eagle Creek Reservoir) and Eagle Creek - Long Branch/Irishman Run had the highest mean turbidity and highest mean total suspended sediment (TSS) concentrations. Fishback (Eagle Creek Reservoir) subwatershed also showed the highest mean concentrations of Total P and *E. coli*.

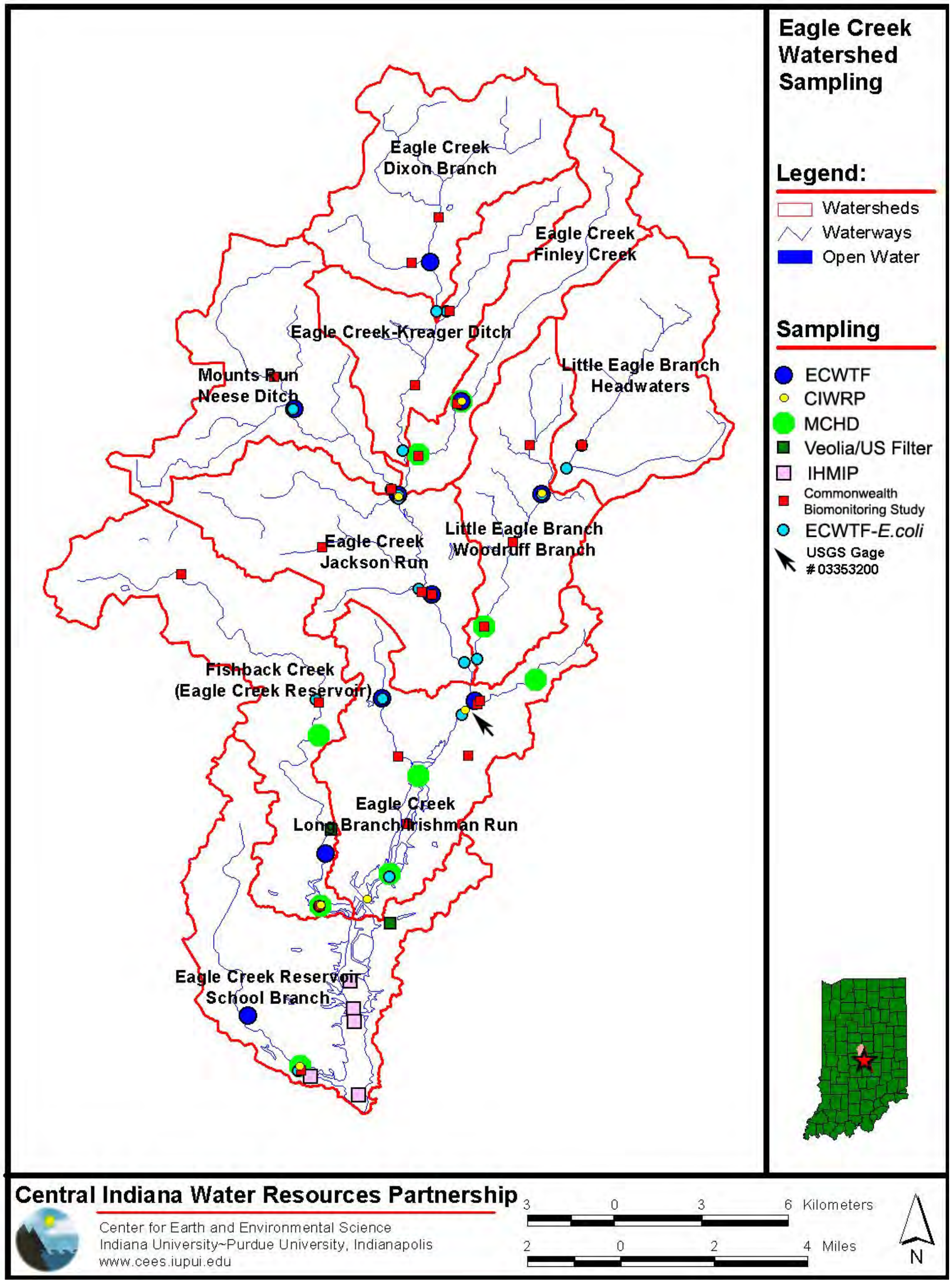


Figure V-1: Eagle Creek Watershed Sampling Stations

ECWTF = Eagle Creek Watershed TaskForce
CIWRP = Central Indiana Water Resources Partnership
MCHD = Marion County Health Department
IHMIP = Indiana Heartland Model Implementation Project

Annual load at each station was estimated using seasonal event and base flow measurements. To obtain a water balance, the relationships between measured stream discharge and the Zionsville Gage (USGS 03353200) was used to determine daily discharge at each sample station for 2003. As samples were only taken seasonally at base and event flow where event was defined as three times the 40 year average stream flow at the Zionsville Gage (USGS 03353200) for each month, the station's seasonal base flow concentration for each parameter was assigned to all days within the season when flow was not greater than three times the monthly base flow. This approach was used for event flow as well, whereby the station's seasonal event flow concentration for each parameter was assigned to all days within the season when flow was greater than three times the monthly base flow. These concentrations were then multiplied by the daily water discharge to obtain a daily load. The daily loads were summed to calculate the yearly load for each parameter. These data were then stratified by Base and Event Flow and by Season (Winter, Spring, Summer, and Fall) and assigned to accountable subwatersheds through a simple mass balance.

2003 Mass Balance data show that station ECW-3 at Lafayette Road experienced reservoir backflow during high flow (Event and Spring). In subsequent studies (2004 and 2005), ECW-3 was moved upstream to 96th and Ford Road where backflow from the reservoir is not likely to occur. Despite this errant data point, the annual Tot P load was verified using an independent data set: down core sequential P extractions yielded a 35 year average organic P accumulation rate of 30 (R: 22-39) tons/year in Eagle Creek Reservoir (Raftis, in press). 2004 Eagle Creek Reservoir Mass Balance resulted in a P-retention coefficient of 0.597, showing that 60% of P entering the reservoir is retained in the reservoir (CIWRP). Therefore, 2003 Total P watershed loads of 58 tons of Total P is consistent with downcore organic P sedimentation rates: given 60% Total P retention, this results in 35 tons of P being retained in Eagle Creek Reservoir sediment. While this is on the high end of the range, higher than normal rainfall in 2003 may account for this higher than average Total P load.

The watershed mass balance shows that the majority of the load for all parameters (i.e. total suspended solids, nitrogen, phosphorous, carbon, *E. coli*, and chloride) in the watershed comes from Event flow and during Spring and Summer. This is consistent with loading caused from non-point sources such as agricultural run-off. Loading as a function of run-off is confirmed by data for Eagle Creek Reservoir - School Branch Subwatershed, which had the lowest percent run-off (Depth of Run-off/annual rainfall) and the lowest flux (lb/acre-year) for most parameters (i.e., TSS, ammonia, TKN, Tot N, Tot P, TOC, and *E. coli*); and by data for the subwatershed group of Little Eagle Branch - Woodruff Branch and Eagle Creek – Jackson Run which had the highest percent run-off and the highest flux for most parameters (i.e., TSS, ammonia, TKN, Tot P, TOC, and *E. coli*).

Such loading analyses can be used to give further insight into the sources of loading. In Little Eagle Branch – Woodruff Branch and Eagle Creek – Jackson Run subwatersheds, all parameters follow a run-off loading pattern except ammonia: Ammonia loading is highest at base flow. This suggests that ammonia is entering the stream from a point source. This point source is also discernible through chloride loading. As there is no natural source of chloride ions in the watershed, chloride can be used as a tracer for municipal run-off (from road salts) via storm drains and direct run-off, waste water treatment plants, and septic outfalls. As point sources would be a constant source (as opposed to run-off which would be an episodic source), the occurrence of high base flow loadings of ammonia and chloride in the Little Eagle Branch – Woodruff Branch and Eagle Creek - Jackson Run subwatersheds suggests that point sources are responsible for those loadings.

Overall, the CIWRP data set provides an excellent basis for the determination of stream loads for School Branch, Fishback Creek, Little Eagle Creek, Finley Creek, and the main trunk of Eagle Creek. However, based on sample locations, not all subwatersheds could be parsed and some were grouped according to what subwatershed area could be accounted for by the sample location. Both water quality data and loading data were used to determine stream water quality in the Subwatershed Assessment.

Table V-3: Mean Water Quality Values for CIWRP Data (February 2003 – December 2003)

		Turbidity	**TSS**	**NH_3**	**NO_3**	**TKN**	**Tot P**	***E. Coli***	**Cl**
Site	**Subwatershed**	*NTU*	*mg/L*	*mg N/L*	*mg N/L*	*mg N/L*	*mg P/L*	*CFU/100mL*	*mg/L*
ECW8	Eagle Creek-Finley Creek	100	37	0.15	3.2	1.1	0.23	3345	20
ECW6	Mounts Run-Neese Ditch	86	52	0.13	4.4	1.0	0.18	2641	23
ECW7	Little Eagle Branch - Woodruff Branch	121	46	0.14	2.5	1.0	0.22	2540	39
ECW2	Fishback Creek (Eagle Creek Reservoir)	377	198	0.12	2.7	1.6	0.25	5014	40
ECW3	Long Branch & Irishman Run	117	74	0.13	2.3	1.3	0.22	3139	38
ECW4	Long Branch & Irishman Run	239	100	0.14	2.6	1.2	0.20	3093	28
ECW1	Eagle Creek Reservoir-School Branch	54	63	0.08	5.7	0.8	0.18	1686	27

Marion County Health Department (MCHD) Water Quality Data

Marion County Health Department has maintained weekly to bi-weekly monitoring efforts on streams in Eagle Creek Watershed during ice-free conditions since 1995 (Figure V-1). At each station, sampling involved taking grab samples from the bridges over the streams and did not include the determination of stream discharge. This data set includes the analysis of water for *E. coli*, pesticides (Atrazine, Simazine, Cyanazine, ala/metolachlor, and Alachlor), nutrients (nitrate, ammonia, and phosphate), metals (barium, cadmium, chromium, copper, mercury, lead, zinc, and nickel), major ions (chloride, sulfate, and calcium carbonate); as well as, in-situ measurements of temperature, pH, conductivity, total dissolved solids (TDS), and dissolved oxygen. While the data set is robust, all analyses are not performed on all streams and stations at all times and some stations are only sporadically sampled or have been terminated from the sampling program while others have been added. Despite these inconsistencies, the data set provides a good longitudinal data set of the streams in Eagle Creek Watershed, specifically, Finley Creek, Long Branch, Fishback Creek, School Branch Creek, and Big Eagle Creek. At these stations, *in-situ* water quality parameters, pesticides, nutrients, metals, and major ions were consistently measured. *E. coli* was measured most consistently in Big Eagle Creek starting in February of 2003. These data were used with other datasets to determine stream water quality in the Subwatershed Assessment.

Veolia Water/USFilter/IWC Data

Veolia Water Indianapolis, LLC (VWI), formerly US Filter Indianapolis Water (USFIW) and Indianapolis Water Company (IWC), has a continuous compliance data set of Eagle Creek Reservoir from 1976 when the T.W. Moses Drinking Water Plant came on line. This data set from the drinking water intake includes concentrations of such parameters as NH_3, NO_2, NO_3, PO_4, and total phosphorus, as well as pH and dissolved oxygen. Recent atrazine concentrations show that atrazine concentrations in the reservoir are, on average, near or above the 3 ppb (0.003 mg/L) drinking water standard (Table V-4). Since October 2002, Veolia Water Indianapolis has also conducted biweekly sampling in the Eagle Creek Watershed. The sampling and analysis is ongoing. Two sampling sites exist in the Eagle Creek Watershed and are located north of intersection 71st Street and Lafayette Rd. and at Ford Bridge (Figure V-1). Each biweekly sample collected is analyzed for the following parameters: cations (Na, Ca, Mg, K, NH_3), anions (Cl^-, SO_4, NO_2, NO_3, PO_4), total phosphorus, alkalinity, turbidity, and pH.

Table V-4: T.W. Moses Drinking Water Intake Atrazine (0.003 mg/L) Levels

	Sample Dates		Range				
Year	**Start**	**End**	**Min.**	**Max.**	**Ave.**	**σ**	**N**
2001	8-Jan	30-Oct	0.14	8.50	2.74	2.04	46
2002	13-Feb	10-Dec	0.10	8.20	4.00	1.47	111
2003	7-Jan	27-Oct	0.13	18.00	3.05	4.13	132

Indiana Heartland Model Implementation Project (IHMIP)

Existing water quality data of the reservoirs and watersheds can provide important historical records for comparison. The Indiana Heartland Model Implementation Project (1982) defined a problem in Eagle Creek watershed as nonpoint source pollution and examined water quality and impacts of best management practices. One station in the Eagle Creek Watershed and four in Eagle Creek Reservoir were monitored for physical and chemical water quality (Figure V-1). The Holcomb Research Institute performed spatial and statistical analysis on the data. They provided analysis of water quality data from 1971-1980 of an Eagle Creek station located near Zionsville, IN. Water quality parameters included biochemical oxygen demand (BOD), pH, specific conductance (SpC), temperature, chloride, phosphorus, fecal coliforms, dissolved oxygen (DO), nitrates, and suspended solids. Biological studies (benthic macroinvertebrate and fish) were conducted by researchers from DePauw University. Limnological analysis concluded Eagle Creek to be a hardwater eutrophic system. Algal assay tests suggested phosphorus was the nutrient that is limiting algal growth in the reservoir.

Indiana Department of Environmental Management Zooplankton Study

In response to a fish kill on Eagle Creek Reservoir in July 2000, IDEM conducted a comparison study to determine the impact of algaecide usage on zooplankton communities. Using an underwater light trapping technique to gather zooplankton, investigators identified and enumerated the free-living planktonic organisms captured at three sites. This same technique was used to gather zooplankton on non-algaecide treated reservoirs: Geist Reservoir and Morse Reservoir. Major zooplankton found in Eagle Creek Reservoir on August 10, 2000 include the following taxa: Dipterans, i.e. Chaoboridae and Chironomidae (larvae and pupae); Crustaceans, i.e. Branchiopoda (Calanoida, Cyclopoda, and Cladocerans) and some Ostrocoda; and Anthropods, i.e. *Hydracarina*. After comparing Eagle Creek Reservoir to Geist Reservoir, it was shown that the samples “were statistically the same and taxonomically and structurally comparable to each on a multivariate scale” (Newhouse and Stahl, 2000). Therefore, conclusions stated that algaecide treatment did not affect the mid-water zooplankton community over the period of the study.

Eagle Creek Watershed Biomonitoring Study

In 2000, Commonwealth Biomonitoring undertook a study in Eagle Creek Watershed to determine the watershed’s biological integrity using macroinvertebrate and fish surveys (Bright and Cutler, 2000). Investigators collected macroinvertebrates from 24 stream riffle areas in October 2000 using kick samplers and collected fish from the same sites from August 28 – September 15, 2000. In-situ measurements of temperature, pH, conductivity, and dissolved oxygen were taken at time of macroinvertebrate and fish collection. Using EPA’s Protocol III for macroinvertebrates and Protocol V for fish, each sampled stream (and its associated subwatershed) was classified along gradients of water quality, sediment impairment, nutrient impairment, and low dissolved oxygen.

Commonwealth Biomonitoring's 2000 study (Bright and Cutler, 2000) showed that all ECW subwatersheds scored Poor to Fair for macroinvertebrates and Poor to Good for fish using the Index of Biotic Integrity (IBI) classes for biological integrity. As several subwatersheds were sampled at different sites within the subwatershed, report scores are averages for each subwatershed. Average macroinvertebrate normalized IBI scores[7] for each subwatershed ranged from Mounts Run at 39 (very poor/poor) to School Branch at 67 (fair) (Table V-5 and Table V-6). Average fish normalized IBI scores for each subwatershed ranged from Dixon Branch at 47 (poor) to Kreager Ditch at 80 (good) (Table V-5 and Table V-6). Most subwatersheds scored between Poor and Fair for both benthos and fish. These low biotic index values for benthos and fish throughout ECW indicate that the habitat in these streams is not able to support diverse, clean-water macroinvertebrate and fish communities. The lack of clean-water taxa and abundances of tolerant taxa indicate that ECW may be undergoing degradation such that it is will not be capable of supporting a well-balanced, warm water aquatic community. These data were used along with other datasets to determine stream water quality in the Subwatershed Assessment.

Table V-5: Subwatershed Normalized IBI Scores

Subwatershed	Macroinvertebrates Ave. Score*	Fish Ave. Score*
Eagle Creek - Dixon Branch	49	62
Eagle Creek - Finley Creek	55	70
Eagle Creek - Kreager Ditch	52	70
Little Eagle Creek (Woodruff Branch & Headwaters)	41	49
Mounts Run – Neese Ditch	39	47
Eagle Creek - Jackson Run	46	60
Fishback Creek (Eagle Creek Reservoir)	44	56
Eagle Creek - Long Branch/Irishman Run	46	62
Eagle Creek Reservoir - School Branch	67	80

* Biotic indices for macroinvertebrates and fish are scored out of a different maximum values. A normalized score is the actual score divided by the total possible score multiplied by 100 (Actual Score/Maximum Possible X 100).

Table V-6: Normalized IBI Scores

Normalized IBI Score	Integrity Class	Description
97 -100	Excellent	Comparable to the best situation without human disturbance
80 – 87	Good	Some loss of the most intolerant forms
67 – 73	Fair	Increasing frequency of omnivores and tolerant species
47 – 57	Poor	Dominated by omnivores and tolerant species
20 – 37	Very Poor	Few present; mostly tolerant forms

[7] Biotic indices for macroinvertebrates and fish are scored out of a different maximum values. A normalized score is the actual score divided by the total possible score multiplied by 100 (Actual Score/Maximum Possible X 100).

E. coli Impairment Study

From 1997-2003, the Eagle Creek Watershed Task Force (ECWTF) collected grab samples for *E. coli* analysis on 118 different days from ten sites in Eagle Creek Watershed (Figure V-1). *E. coli* data was analyzed by CEES and compared to IDEM's *E. coli* guidelines for impaired waterbodies.

In 1990, IDEM adopted a geometric mean of 125 CFU/100 mL of water (five samples over a 30-day period). Additionally, IDEM adopted a single sample daily maximum of 235 CFU/100 mL of water, stating that no more than 10% of the grab samples could be substantially greater than this value. Finally, IDEM noted that no samples should exceed 2,400 CFU/100 mL of water. If any of these three criteria are not met, then the waterbody is considered impaired. ECWTF data analyzed by CEES showed that all sites in Eagle Creek Reservoir have been impaired for full body recreational contact.

Over the 1997-2003 sampling period, nine sampling periods met the criteria for geometric mean calculation. For all ten sites, a geometric mean was calculated and compared to the IDEM guidelines. The results of the data analysis revealed that none of the ten sampling sites fully supported the IDEM criteria for *E. coli*, indicating that all sites should be listed as impaired waterbodies during the period from 1997-2003. Additionally, the data analysis revealed that the highest median concentrations of *E. coli* were typically measured at Sample Sites 3, 7, and 8. Site 3 is Irishman's Run near State Road 334; site 7 is Little Eagle Creek, near 156th Street in Hamilton County; and Site 8 is Mounts Run, near State Road 32 (Figure V-1).

E.coli DNA-Ribotyping Study

In 2002, Biological Consulting Services of Northern Florida, Inc. undertook a study in Eagle Creek Watershed to construct an *E. coli* DNA fingerprint database containing fingerprints from *E. coli* isolated from animal and human sources in Eagle Creek Watershed and to use those watershed specific *E. coli* fingerprints (also called ribotypes) to apportion *E. coli* contamination to sources within the watershed. Investigators collected samples from known fecal sources (humans, cattle, chickens, sheep, horses, swine, and turkeys) and analyzed the cultured *E. coli* DNA from these source samples to discern strains that are specific to each source, a process called DNA ribotyping. This resulted in genetic *E. coli* fingerprints for the specific sources of *E. coli*. While statistical analysis of the *E. coli* isolates' banding patterns showed good separation of cattle, chicken, horse, sheep, and turkey *E. coli* and, thus, allowed for correct classification of these *E. coli* to their sources, human and swine *E. coli* were not as easily discerned. Despite this shortcoming, researchers concluded that correct classification of human and swine *E. coli* did occur at levels greater than can be attributed to chance alone, and that the low degree of separation of human and swine *E. coli* could be attributed to contamination of human sewage with other fecal material and contamination of swine fecal material collected from a possibly mixed sewage retention pond (Lukasik and Scott, 2003).

Using the developed fingerprints, *E. coli* isolated DNA from samples collected at 20 sites in Eagle Creek Watershed over a 12 week period (8 weeks high water and 4 weeks low water) were analyzed to classify the *E. coli* sources. Overall, 44% of all *E. coli* was classified using the developed fingerprints. Data are summarized in Table V-7 where the major known sources are shaded. While some *E. coli* can be attributed to known sources, in each subwatershed the amount of *E. coli* from unknown sources is the highest percentage, therefore, DNA ribotyping did not prove to be a good *E. coli* sourcing tool in the Eagle Creek subwatersheds.

Table V-7: Apportionment of *E. coli* to sources based on DNA Ribotyping

Subwatershed	Site #s	Cattle	Chicken	Horse	Human	Sheep	Swine	Turkey	UK*
Eagle Creek - Dixon Branch	4,5	9%	0%	2%	9%	25%	2%	16%	36%
Eagle Creek - Kreager Ditch	7	5%	5%	14%	0%	10%	0%	0%	67%
Little Eagle Branch- Headwaters	1,2	5%	0%	13%	8%	15%	3%	3%	55%
Mounts Run – Neese Ditch	6,8,9,10	14%	4%	3%	4%	1%	4%	4%	64%
Little Eagle Branch - Woodruff Branch	3,13	5%	5%	3%	8%	5%	3%	8%	65%
Eagle Creek - Jackson Run	11,12,14	10%	0%	4%	10%	8%	4%	4%	60%
Fishback Creek (Eagle Creek Reservoir)	17,19	20%	5%	0%	20%	5%	0%	9%	41%
Eagle Creek - Long Branch / Irishman Run	15,16,18	15%	0%	7%	9%	11%	0%	2%	56%
Eagle Creek Reservoir - School Branch	20	9%	0%	4%	4%	4%	4%	9%	65%

* UK = Unknown. In all cases the amount of *E. coli* from unknown sources was the highest.

U.S. Geological Survey National Water Quality Assessment: White River Basin, Indiana

From 1992 to 1996 the U.S. Geological Survey (USGS) completed a study on the White River Watershed in Indiana as a part of the National Water Quality Assessment program. The goal of the NAWQA study was to describe the quality and trends of the nations ground and surface waters and to understand the primary natural and human factors affecting these resources. Eagle Creek Watershed (above the Eagle Creek Dam) comprises 162 mi^2 of the White River Basin 11,349 mi^2 of drainage area and was a part of this large study. The study focused on pesticide, herbicides, and nitrate concentrations, in addition some phosphorus and ammonia work was also completed.

The study concludes that pesticide and herbicide concentrations in White River Basin streams are among the highest in the nation, and that pesticide and herbicide concentrations are highest where use is the greatest, differ with respect to landuse (lawn insecticides are found in urban areas, while agricultural insecticides are found in areas with large amounts of cropland), and differ based on soil drainage properties (well-drained, permeable soils and tile drained regions have the highest in-stream concentrations). Stream nitrate concentrations ranged from 2 to 6 ug/L over the course of the study, which is higher than most other NAWQA sites, but samples did not exceed any Federal standards. The study also found that nitrate concentrations are highest during the non-growing season, January through March (Figure V-2), most nitrogen input (61%) is attributed to commercial fertilizer (Figure V-3), and that watersheds with naturally and artificially moderately well and well-drained soils have higher median nitrate concentrations (Figure V-4). The study further concludes that urban areas are major contributors to elevated in-stream phosphorus and ammonia concentrations (Figure V-5), to volatile organic compounds (VOCs) in the groundwater supply (Chloroform being the most common VOC), and to elevated levels of industrial compounds and metals in streambed sediments (Fenelon, 1998).

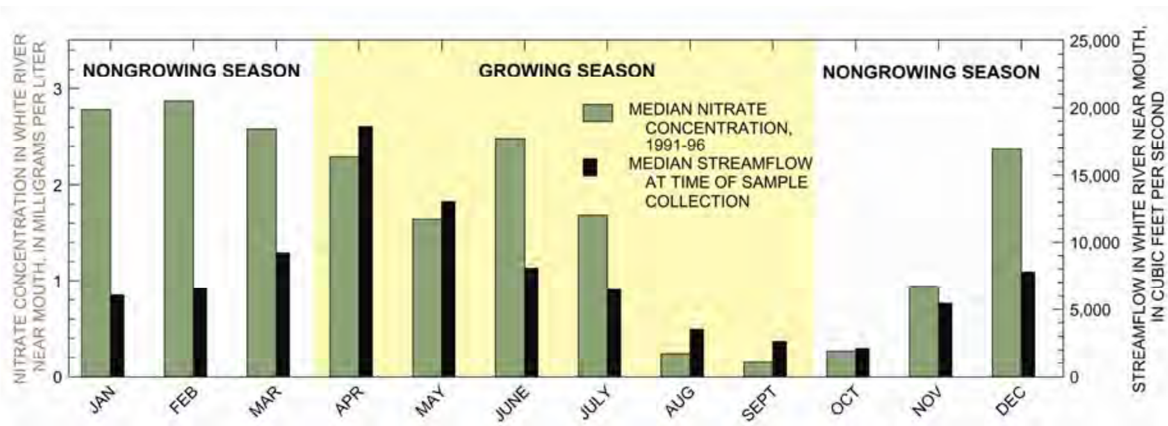


Figure V-2: Seasonal concentration of nitrate near mouth of White River (reproduced from Fenelon, 1998)

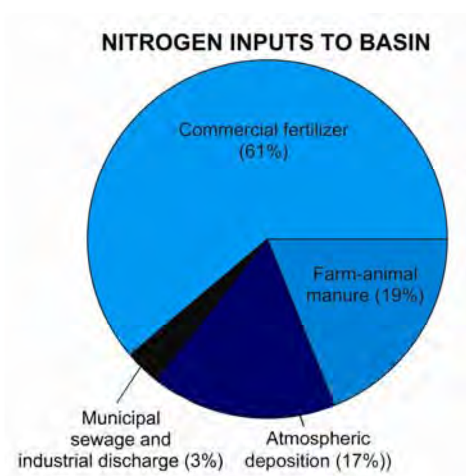


Figure V-3: Sources of nitrogen to White River Basin (reproduced from Fenelon, 1998)

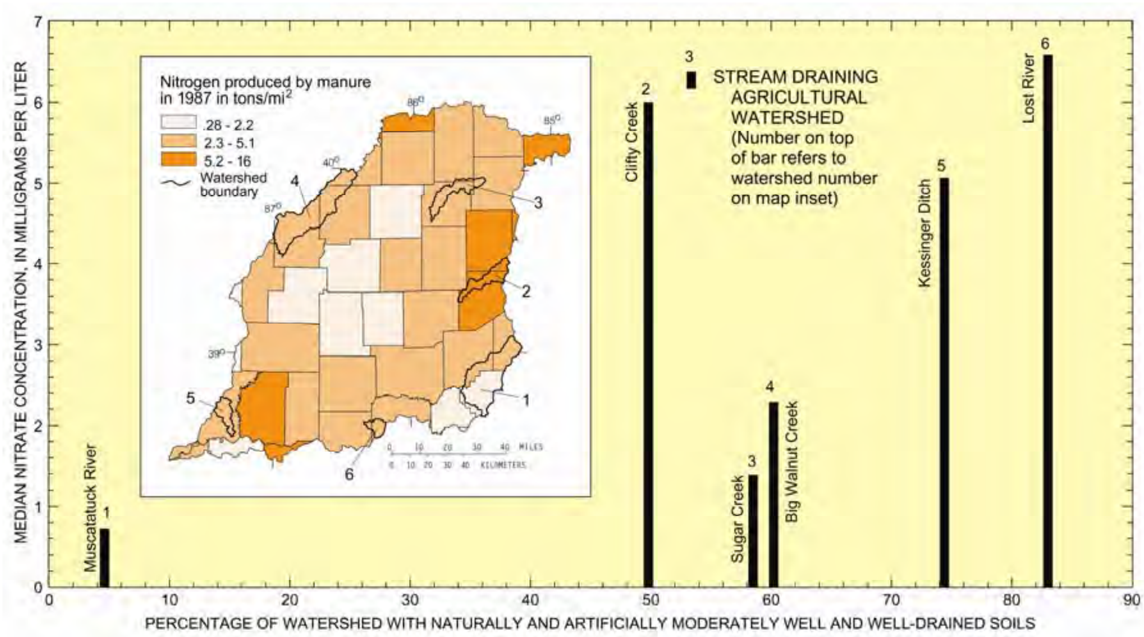


Figure V-4: Nitrate concentrations in soils related to soil drainage (reproduced from Fenelon, 1998)

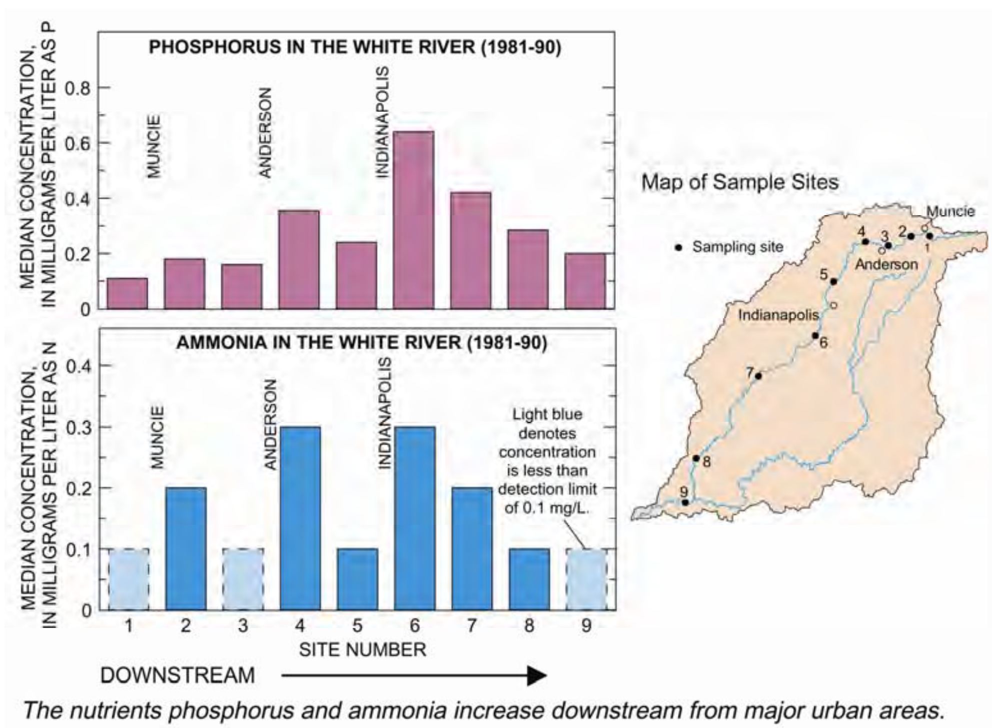


Figure V-5: Phosphorous and ammonia concentrations in urban areas (reproduced from Fenelon, 1998)

Adequate Woody Riparian Buffer Assessment Study (ArcView GIS)

Vegetated and woody stream buffers are an important component of the overall watershed landscape. They are beneficial to stream water quality because they slow water runoff, trap sediment, enhance filtration, and reduce channel erosion. When stream buffers are inadequate or removed from the landscape, runoff increases and can therefore result in increased chemical and nutrient loads as well as increased bank erosion.

Adequate woody riparian stream buffer was determined using the NRCS minimum standard for assessing the buffering needs for Zone 1 (streamside forest) 1st and 2nd order streams. The standard is equal to 25 feet (NRCS, 2004). The streams of Eagle Creek watershed were visually assessed using ArcView GIS with 2003 NRCS aerial photography. Although slight error is associated with this form of assessment, it allows for the identification of critical areas in need of buffers over a large area. The critical areas identified can then later be visually assessed to determine what areas are of greatest concern.

The ArcView GIS assessment for Eagle Creek watershed concluded that all 10 of the subwatersheds had less than 60% adequate woody buffer. Some stream segments were mowed or farmed up to the stream bank with no woody vegetation cover at all. The watersheds of greatest concern are Eagle Creek/Dixon Branch, Little Eagle Branch headwaters, Mounts Run Creek, and School Branch Creek with 20%, 26%, 29% and 34% of stream segments with adequate woody buffer, respectively (Table V-8).

Table V-8: Percent of Stream with Adequate Woody Riparian Buffer

Subwatershed	% of Stream With Adequate Woody Buffer
Eagle Creek - Dixon Branch	20
Eagle Creek - Finley Creek	51
Eagle Creek - Kreager Ditch	45
Little Eagle Branch - Headwaters	26
Mounts Run – Neese Ditch	29
Little Eagle Branch - Woodruff Branch	43
Eagle Creek - Jackson Run	54
Fishback Creek (Eagle Creek Reservoir)	57
Eagle Creek - Long Branch/Irishman Run	57
Eagle Creek Reservoir - School Branch	34

Land-Use Perturbation Study

Using 1985 and 2000 satellite imagery with 30 meter resolution of the State of Indiana, a land cover change assessment was performed by the Center for Urban Policy and the Environment at IUPUI using the LUCI model (Tedesco *et al.*, 2003). This land cover change assessment was used concomitant with 2003 Single Family Home Permit information stratified by township to determine each Eagle Creek Subwatershed's susceptibility to land-use perturbation. Watershed land-use analysis done utilizing the LUCI model for Eagle Creek Watershed projected that School Branch Creek, Fishback Creek, Irishman Run, Jackson Run, and Little Eagle Branch would be more than 50% urbanized by 2040 (Tedesco *et al*., 2003) (Figure IV-3). According to 2003 Single Family Home Permits issued per township data, new home building is currently focused in the following subwatersheds: School Branch Creek, Fishback Creek (in July of 2004 Boone County approved a large development along the upper reaches of Fishback Creek), Irishman Run, Jackson Run, and Little Eagle Creek Branch (Figure V-6). Therefore, these subwatersheds are considered as having a high susceptibility to land-use perturbations and associated sediment loading to their respective streams.

Watershed Survey

A windshield survey was conducted in Spring 2005 to assess streams of Eagle Creek watershed and their adjacent lands. Observations were made upstream and downstream from bridge crossings at most stream segments over a series of several days and photographed. A section of Big Eagle Creek near Zionsville was assessed using a kayak to allow for greater detail in observations at the southern portion of the watershed before it flowed into Eagle Creek Reservoir. Survey forms assisted in the assessment (Appendix C). Observations were made for: bank erosion, livestock access to streams, trash in streams, adequate woody and/or grassy buffer, surrounding land use, animal feeding operations, and pipes flowing into streams. Parameters recorded on the survey sheets were then entered into a spreadsheet and mapped in ArcView GIS. The following sections summarize the visual observations made in Eagle Creek Watershed.

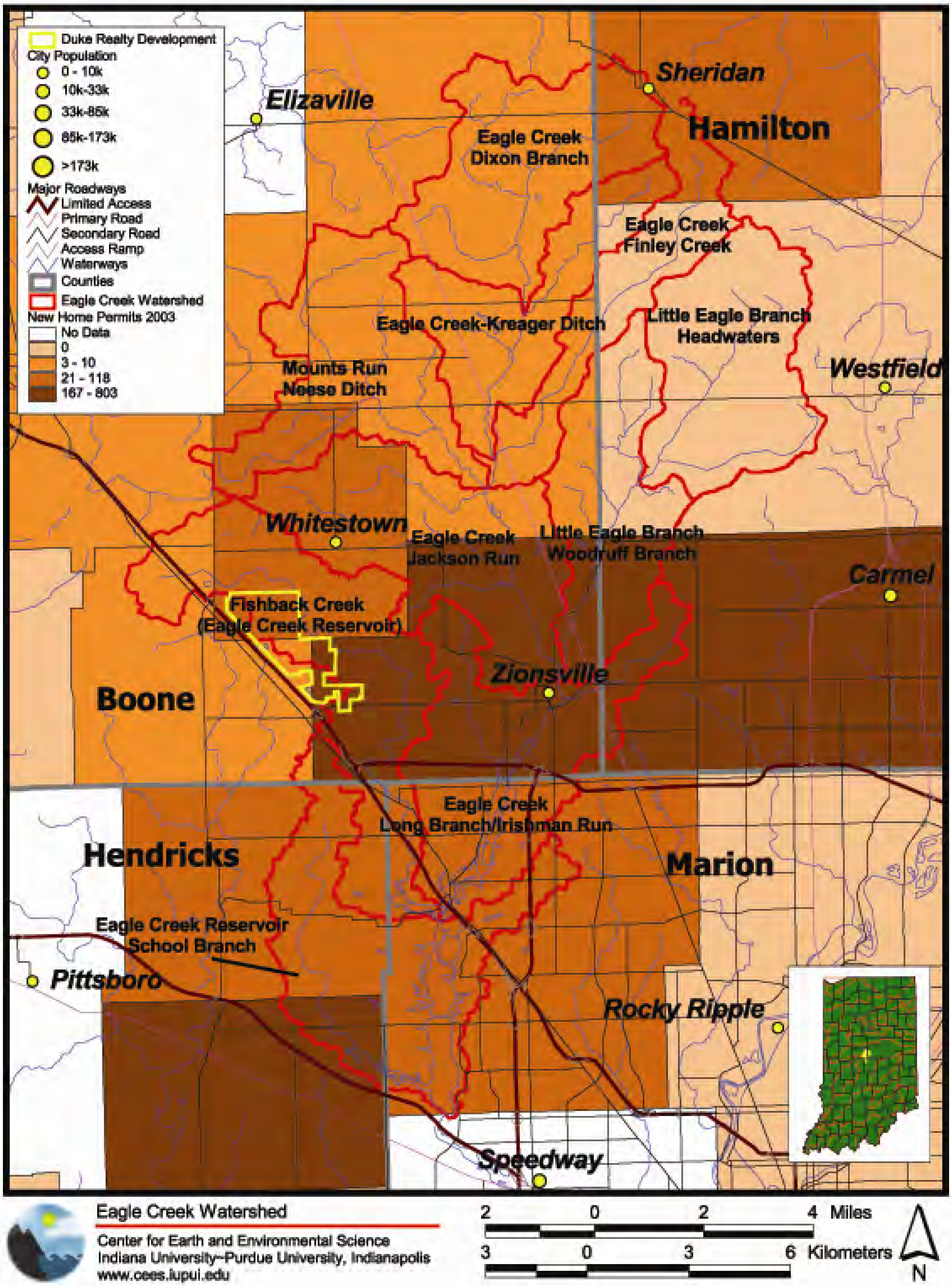


Figure V-6: 2003 single family permits issued per township. Yellow borders denote location of 3,000+ home development in Fishback Creek (Eagle Creek Reservoir) subwatershed.

Streambank Erosion

Streambank erosion is the removal of sediment from the stream's banks and beds by flowing water and is part of a stream's natural process. It becomes a problem, however, when the stream is carrying large loads (usually during high stream flow) of the eroded sediment and depositing the loads downstream. Sedimentation in downstream waterways and reservoirs can negatively affect water clarity and aquatic vegetation and habitat. Other problems induced by erosion include reduction in water quality due to contaminants associated with the sediment, damage to public utilities and roadways, and costs incurred with erosion prevention. Keeping streambanks vegetated and livestock away from the streams can help slow down the erosion process.

Areas of greatest concern in Eagle Creek Watershed are the stream trunks closest to the reservoir. These areas are also experiencing the highest rates of development, which can limit the streams natural area to meander and increase streambank erosion. Headwater erosion also poses an area of concern as it is a source fine grain sediments (silts and clays). Figure V-7 shows the visual assessment sites and their ranking for streambank erosion. The sites were ranked as: little to no erosion, moderate, moderate to severe, and severe erosion. Rankings were based on slope, slumping, undercutting of vegetation, and size of the eroded streambank.

Big Eagle Creek

Fishback Creek

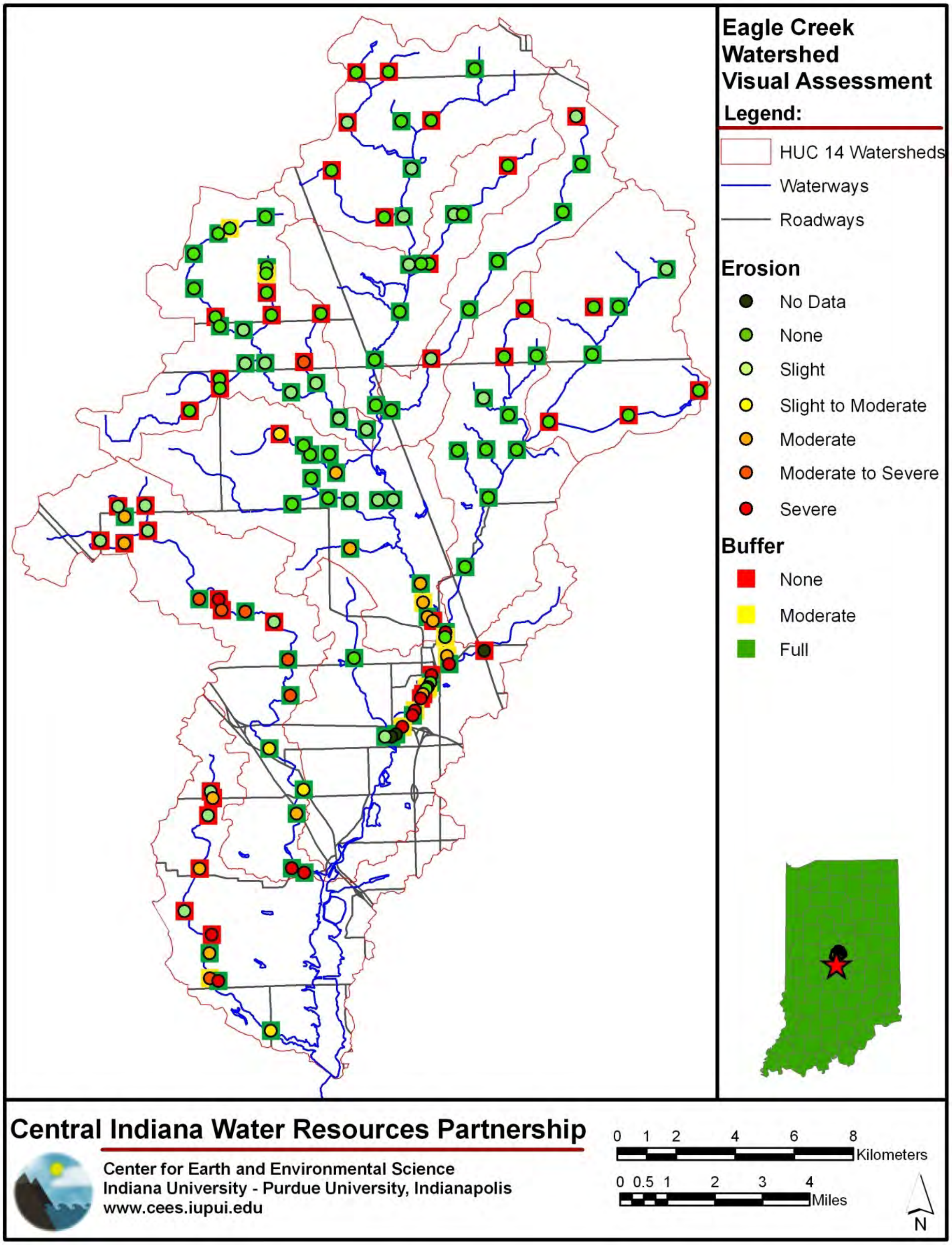


Figure V-7: Visual Assessment – Stream Buffer and Streambank Erosion

Adequate Stream Buffer

Vegetated stream buffers are natural boundaries between the waterway and the land surrounding it. Stream buffers are important in protecting our water resources by filtering pollutants, providing flood control, reducing streambank erosion, and maintaining aquatic habitat. A woody riparian buffer can also provide shade that is important for stream quality by reducing the surface water temperature. Lack of adequate stream buffers can result in increased runoff of nutrients and pollutants and increased bank erosion.

The windshield survey provided information on which areas in the watershed were lacking adequate buffers. Grassy buffers as well as woody riparian buffers were noted and taken into consideration when determining whether an adequate amount of buffer was present to prevent stormwater runoff. A width of 25’ was used to measure adequate buffer width, although ideally more than 25’ buffer should be present, especially if it is grassy buffer without woody species. Results in Figure V-7 show that most streams in Eagle Creek Watershed lack adequate vegetated buffer in the stream headwaters. Stream buffer generally increases downstream with the exception of Big Eagle Creek near the town of Zionsville. Some segments along the trunk stream were observed to have rip rap and little to no vegetation along the streambanks.


Big Eagle Creek

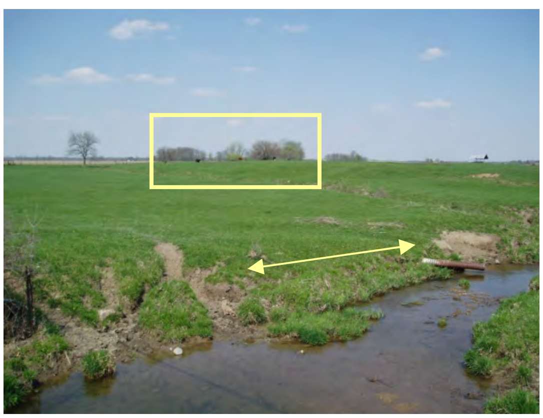

Mounts Run


School Branch

Livestock Access

Livestock access to streams is a concern because of the negative impacts it has on water quality as well as human and aquatic health. Uncontrolled animal access to a water source can result in fecal contamination of the stream and facilitate streambank erosion, resulting in water quality degradation. For example, influxes of nitrogen and phosphorous rich animal waste can contribute to excess algae and plant growth; fecal material can introduce human pathogens (such as *E. coli*, *cryptosporidiu*m, and *giardia*) to the water source, turning the stream into a mechanical vector of disease; and livestock trampling of streambanks and beds can increase rates of erosion, resulting in elevated levels of suspended sediments in the stream.

Areas where livestock had direct access to waterways were observed during the visual assessment. School Branch, Fishback Creek, and Eagle Creek – Long Branch/Irishman Run subwatersheds had one site each where animals were observed with stream access. Eagle Creek/Jackson Run, Mounts Run, and Eagle Creek/Kreager Ditch had multiple sites with direct animal access to the streams. Cattle and horses were the most common animals observed with stream access. When animals were not viewed directly in the stream at the time of the windshield survey, tracks and trampling were noted if present (Figure V-8).



School Branch – Cows in distance. Arrow shows aresa of streambank erosion possibly due to livestock access.

School Branch – Cow in stream.

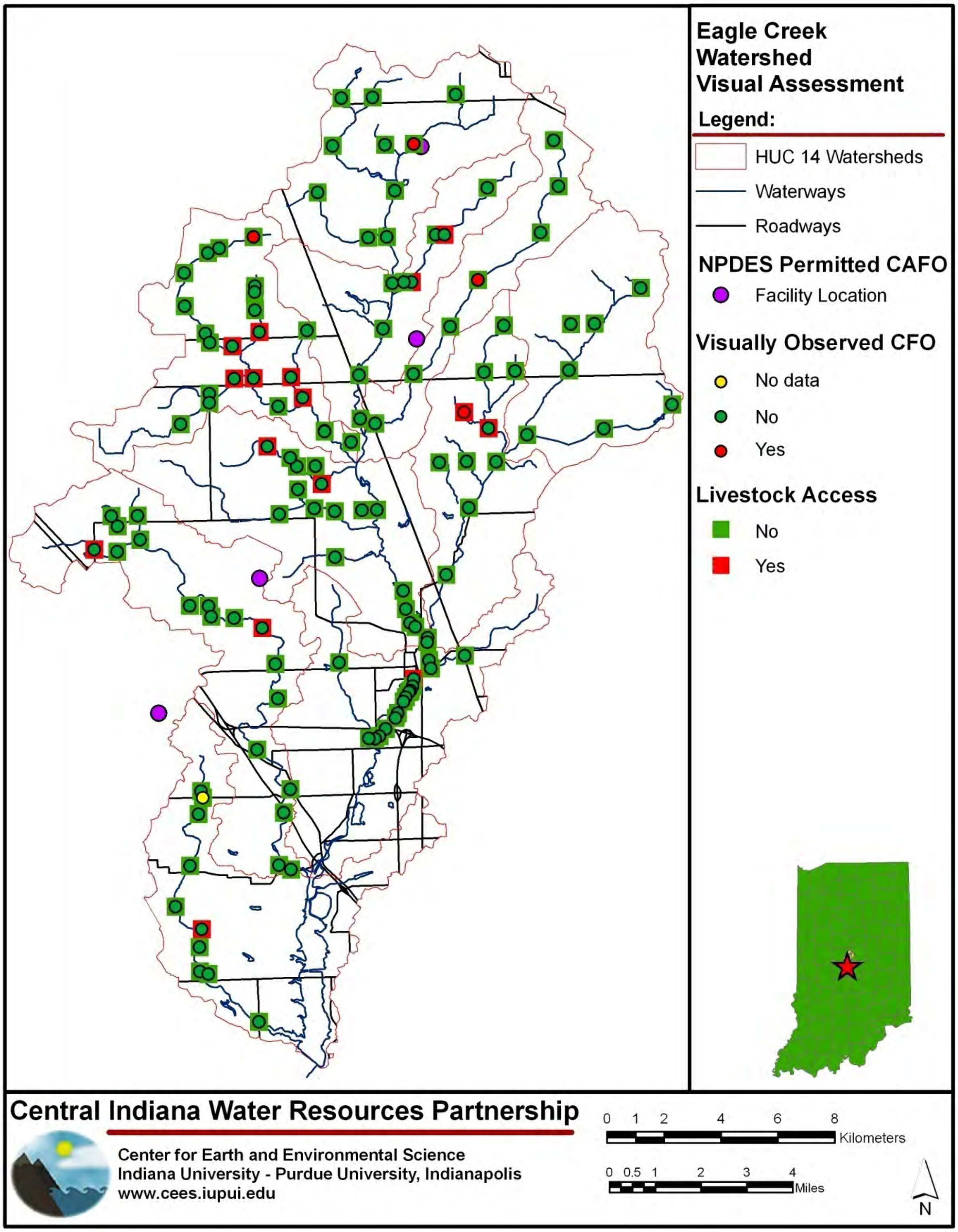


Figure V-8: Visual Assessment – Livestock Access, Observed Confined Feeding, NPDES Confined Animal Feeding Operations (CAFOs)

Trash

The presence of trash was noted in streams during the visual assessment. Trash not only ruins the aesthetically pleasing appearance of the stream, but it can also disrupt wildlife and aquatic habitat. Trash can also add unwanted contaminants into the watershed as it begins to break down. Trash did not appear to pose a large threat to Eagle Creek Watershed. It was observed in a few areas shown on Figure V-9. During the visual assessment, each site was ranked for trash as: None, Slight, Moderate, or Severe.

Fishback Creek – Bucket in stream.

School Branch – Tire and scrap metal in stream.

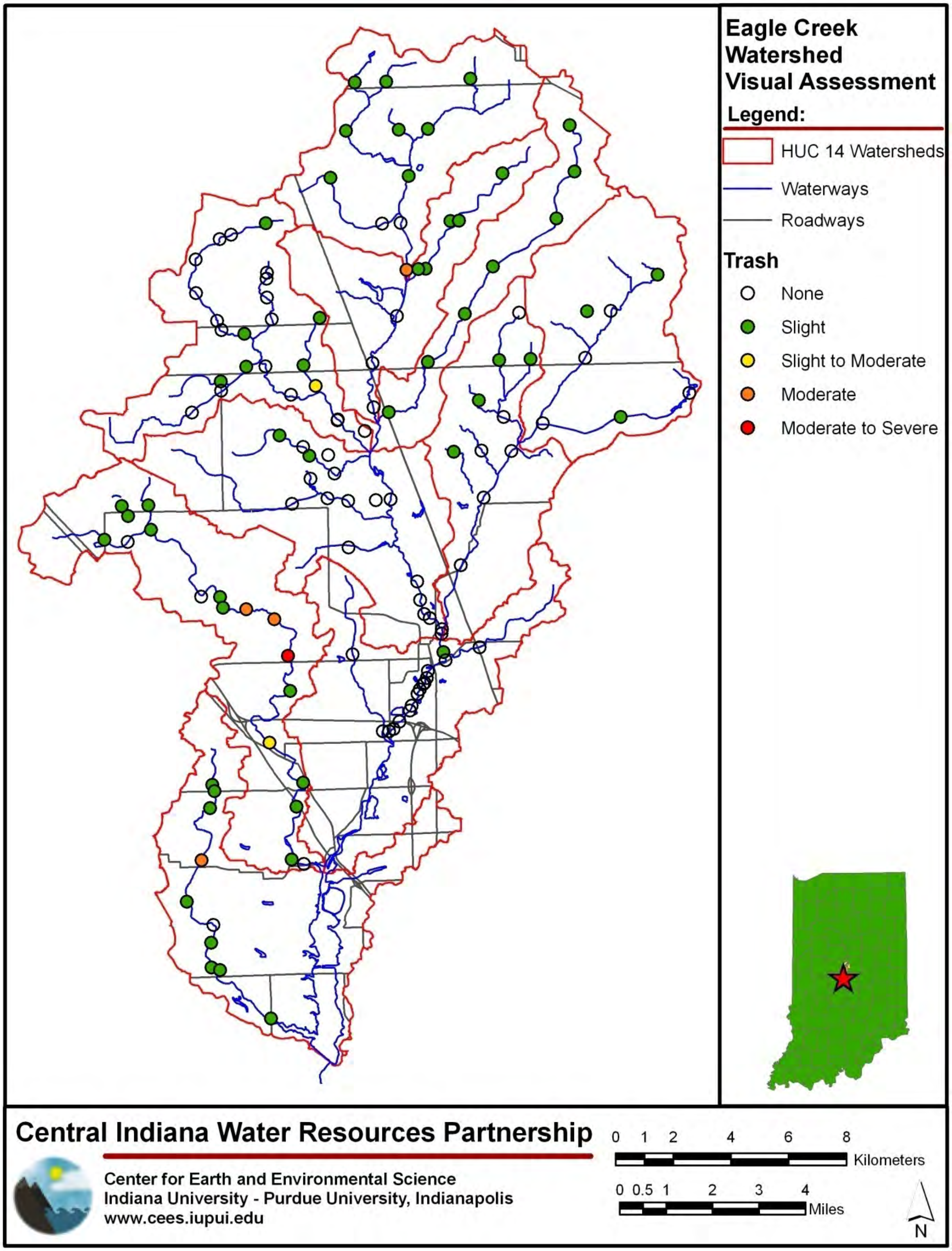


Figure V-9: Visual Assessment - Trash

Tile/Pipe Discharge

The presence of pipes was noted in all subwatersheds of Eagle Creek watershed. Many of the pipes observed represent agricultural tiles, although a few are stormwater and other regulated drainage pipes. Agricultural tiles have been common practice in the Midwest since the 19th century. Their purpose is to drain excess surface water from farm fields to enhance crop production. When managed properly, the agricultural tile drainage network can be a beneficial practice for environmental farm management. However, when improperly managed, tile outflow can carry contaminants and pollute nearby waterways. Increased nitrogen, pesticides and pathogens have been found to move through tile drains impacting water quality.

During the windshield survey, tiles were noted in all subwatersheds. Eagle Creek/Dixon Branch, Fishback Creek, Mounts Run, and School Branch subwatersheds had pipes noted at 60% or more of the survey sites. Eagle Creek/Finley Creek subwateshed had the least amount of pipes observed with only one site out of nine with a pipe in viewing range. Figure V-10 shows the survey sites with pipes observed.

Mounts Run – Pipe discharging into stream.

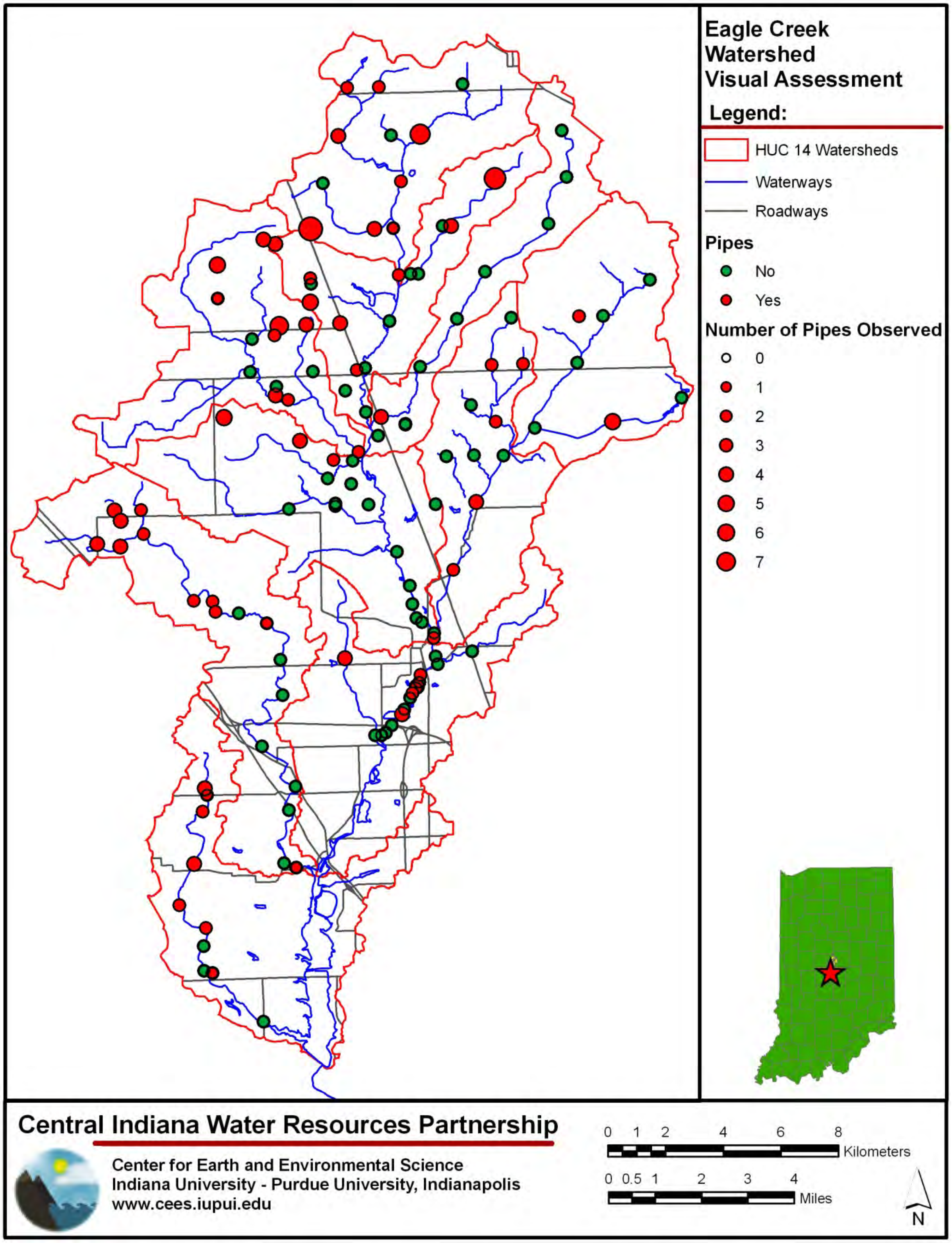


Figure V-10: Visual Assessment – Location of Tile/Pipes Observed in Watershed

NPDES Point Source Data

The National Pollutant Discharge Elimination System (NPDES) Program was established by the Federal Water Pollution Control Act Amendments of 1972. Under this program, all facilities that discharge pollutants from a point source into any US waterway must obtain a permit. The permit regulates the amount of allowable pollutants discharged from a point source. Point sources are specific locations of discharge such as pipes or man-made ditches and include “discharges from publicly owned treatment works (POTWs), discharges from industrial facilities, and discharges associated with urban runoff” (USEPA, www.epa.gov/npdes/pubs/101pape.pdf). Concentrated animal feeding operations (CAFOs) are also considered a point source and require NPDES permits, although most other agricultural activities are non-point sources.

Fifteen NPDES permitted pipes are located within Eagle Creek Watershed (Table V-9). Eagle Creek–Long Branch/Irishman Run subwatershed has eight of the fifteen permitted discharge pipes (outfalls). Little Eagle Branch–Headwaters and Little Eagle Branch–Woodruff Branch subwatersheds each have two and Eagle Creek–Dixon Branch, Eagle Creek–Jackson Run, and Fishback Creek (Eagle Creek Reservoir) subwatersheds each have one permitted discharge pipe. Table V-9 lists the NPDES pipe discharge sources and the type of discharge that is permitted with each pipe. The permit number and outfall number in Table V-9 for which GPS data are available correlate with the pipes mapped in Figure V-11.

Four confined animal feeding operations (Figure V-12 and Table V-10) are located in Eagle Creek Watershed. These operations are permitted through the NPDES program to ensure they comply with the Clean Water Act. Although Clark’s Pork Farm is shown to fall outside of the Eagle Creek Watershed boundary, it is important to note the location of this CAFO with respect to Eagle Creek Watershed because of it close proximity to the watershed and the possibility of the tile drainage system transporting water across watershed boundaries.

Table V-9: NPDES Point Sources in Eagle Creek Watershed

Permit Number	Outfall Number	Subwatershed	Facility Name	Waste Description
INP000025	001A	Eagle Creek – Dixon Branch	Biddle Screw Products Co.	Process Water
IN0055280	001A	Little Eagle Branch – Headwaters	Eagletown Treatment Plant	Sanitary
IN0109762	001A	Little Eagle Branch – Headwaters	Eagletown Estates M.H.P.	Sanitary
ING340063	001A	Little Eagle Branch – Woodruff Branch	Jolietville Terminal - Country Mart Cooperative	Stormwater Runoff
ING340063	002A	Little Eagle Branch – Woodruff Branch	Jolietville Terminal - Country Mart Cooperative	Stormwater Runoff
IN0020796	001A	Eagle Creek – Jackson Run	Whitestown Municipal STP Waste Water Treatment Plant	Sanitary
ING080130	001A	Fishback Creek (Eagle Creek Reservoir)	Stuckey's Gas Station	Groundwater Treatment
ING080225	001A	Eagle Creek – Long Branch/Irishman Run	Village Pantry 471	Groundwater Treatment
IN0055760	001A	Eagle Creek – Long Branch/Irishman Run	Clay Township Regional Waste District	Sanitary
IN0060054	001A	Eagle Creek – Long Branch/Irishman Run	DOW Chemical Biological Lab	Groundwater Treatment
IN0045209	001A	Eagle Creek – Long Branch/Irishman Run	Buckeye Terminals LLC Zionsville	Other
IN0045209	002A	Eagle Creek – Long Branch/Irishman Run	Buckeye Terminals LLC Zionsville	Other
IN0045209	003A	Eagle Creek – Long Branch/Irishman Run	Buckeye Terminals LLC Zionsville	Other
IN0043559	001A	Eagle Creek – Long Branch/Irishman Run	Shady Hills Utility Company, Inc.	Sanitary
ING080082	001A	Eagle Creek – Long Branch/Irishman Run	Traders Point #1 IDOT Garage	Groundwater Treatment
IN0061832	001A	Eagle Creek Reservoir - School Branch	Lewis Group Wastewater Treatment Plant	Sanitary
IN0059544	001A	Little Eagle Breek – Headwaters	Westfield Municipal Wastewater Treatment Plant	Sanitary
IN0059544	001T	Little Eagle Branch – Headwaters	Westfield Municipal Wastewater Treatment Plant	Sanitary
IN0025569	001A	Eagle Creek – Jackson Run	Pine Ridge Mobile Home Park	Sanitary
IN0036951	001A	Eagle Creek – Long Branch/Irishman Run	Zionsville Wastewater Treatment Plant	Sanitary

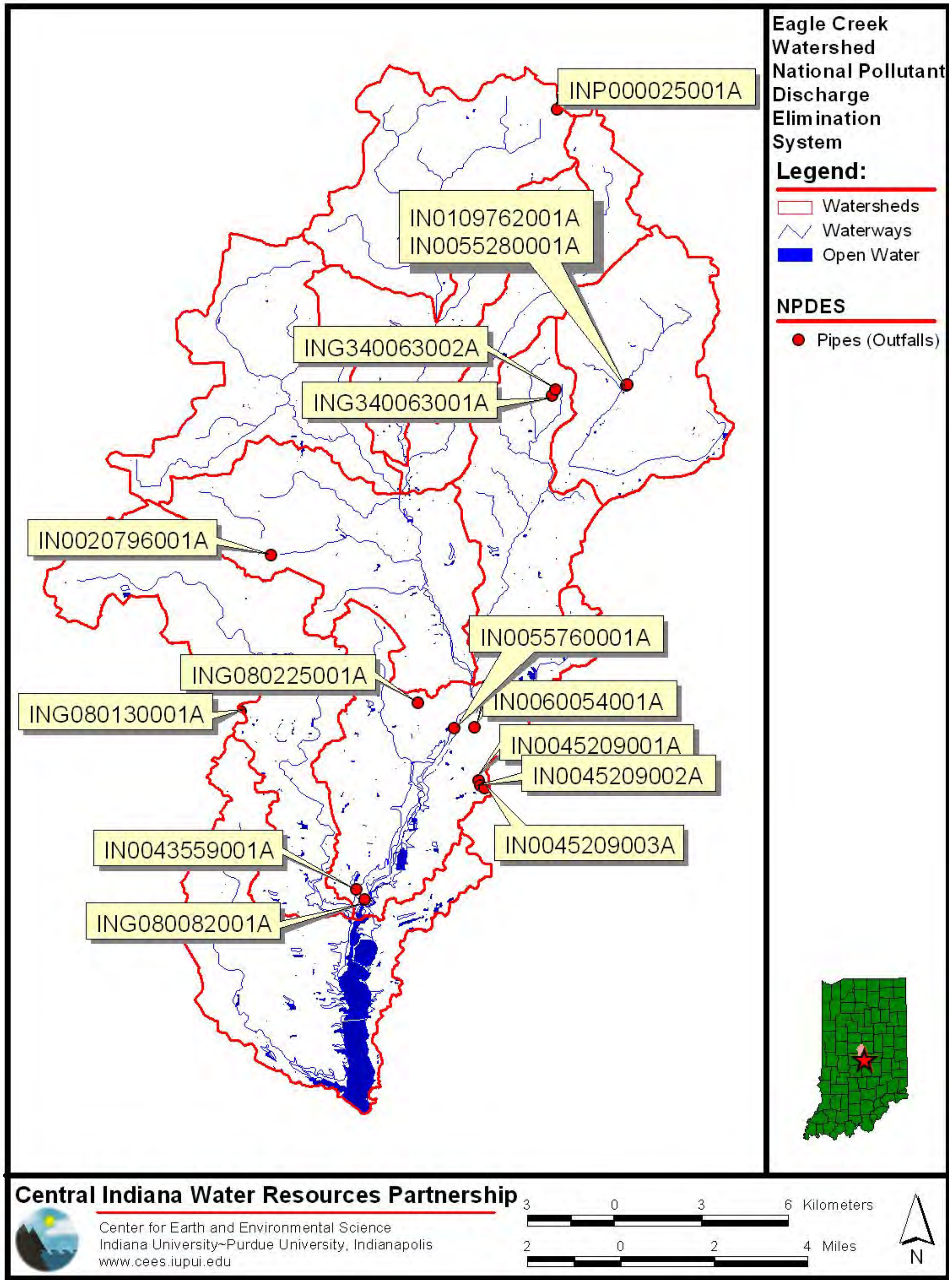


Figure V-11: NPDES Point Sources in Eagle Creek Watershed

Table V-10: Confined Animal Feeding Operations in Eagle Creek Watershed

Permit Type	Subwatershed	Facility Name
CAFO	Eagle Creek – Dixon Branch	Double Bridge Farm
CAFO	Eagle Creek – Kreager Ditch	Tom's Place - Primary
CAFO	Eagle Creek – Kreager Ditch	Kouns Farms Incoroporated
CAFO	Fishback Creek (Eagle Creek Reservoir)	Kaser Farm Partnership
CAFO	White Lick Creek - Wiley Thompson Ditch (*outside Eagle Creek Watershed*)	Clark's Pork Farm Number 1

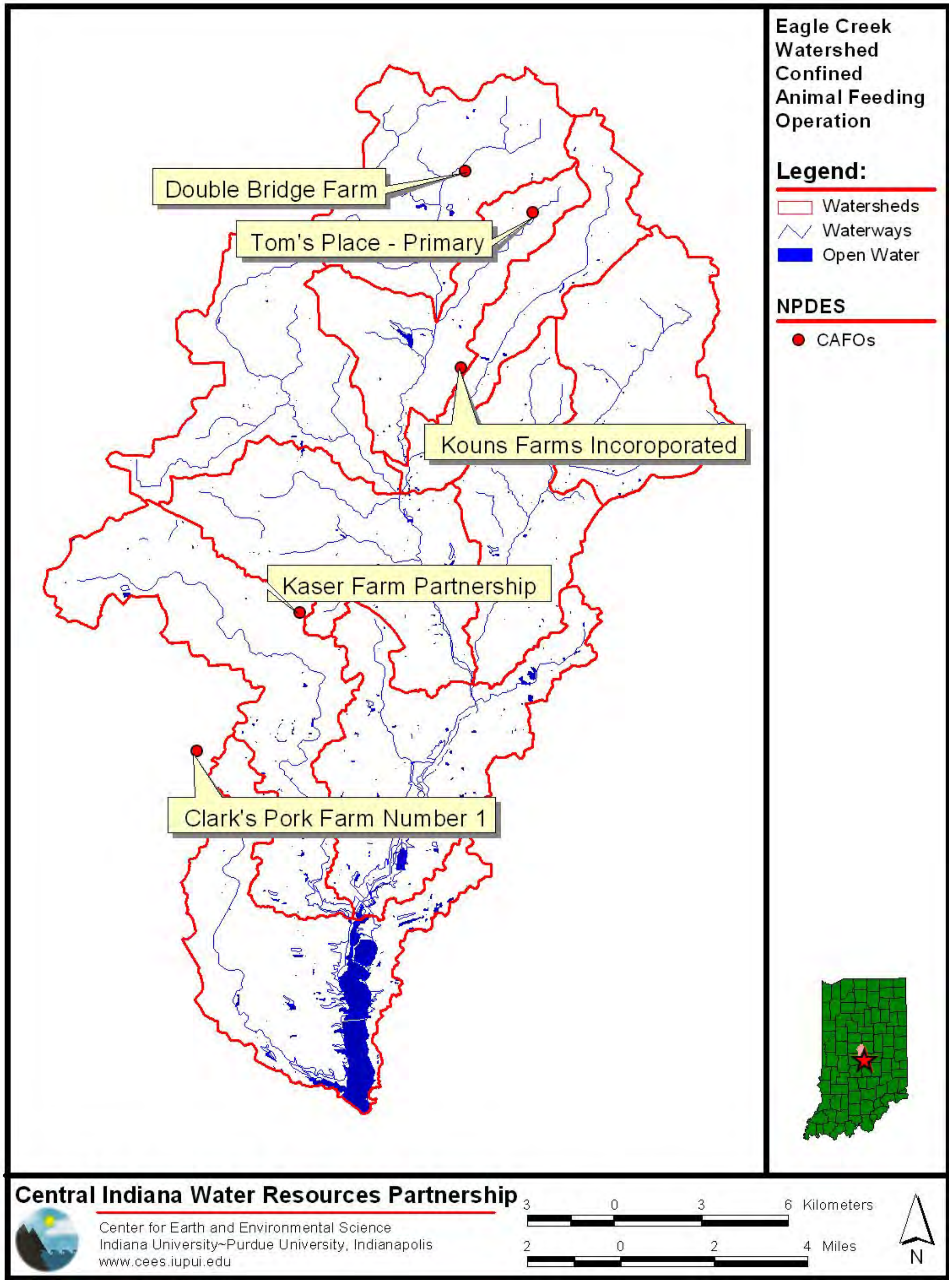


Figure V-12: Confined Animal Feeding Operations in Eagle Creek Watershed

Septic Systems

Unsewered communities are a possible source of human waste contamination into streams. Contaminants such as *E. coli*, ammonia, and phosphorous are associated with human waste. While well-maintained septic systems can remove most contaminants before the waste enters the stream, septic system failures can release excess *E. coli* and nutrients, especially ammonia and ammonia compounds into surface waters. In Indiana, common causes of septic system failure are soil wetness (seasonally high water table), undersized systems, system age, and limited space for the soil absorption field (Taylor *et al*., 1977).

As septic systems can be a source of contamination to the streams in Eagle Creek Watershed, the location and efficiency of septic systems is important to Watershed health. However, septic system location and function information is difficult to obtain. Sources of information are often limited to permits that were issued during or prior to building, and these permits are often imbedded in county records that are not easily accessed or searched. While work on developing a map of septic systems in Eagle Creek Watershed is on-going, preliminary data show that, of the homes in each county that lie within Eagle Creek Watershed, most of the homes located outside of the major urban areas (e.g., Indianapolis and Zionsville) rely on septic systems for waste disposal: the majority of the homes within the Watershed in Marion county are sewered, and the majority of homes within the Watershed in Hamilton county, Boone county (outside of Zionsville), and Hendricks county are on septic systems.

Previous data collected on septic systems in Eagle Creek Watershed were compiled by the Indiana Community Action Association (INCAA) and the Boone County Department of Health.

INCAA Unsewered Communities Report

As unsewered communities present a concern to surface water quality, the Indiana State Department of Health and the Rural Community Assistance Program conduct regular surveys to identify communities needing assistance with resolving outstanding sewage disposal problems. This information is published by the INCAA as the "Unsewered Community Survey Report."

Work by the Center for Urban Policy and the Environment at IUPUI suggests that approximately 31 percent of Indiana households are on septic systems (Lindsey, 2003). The Indiana State Department of Health estimates that 25 percent of the septic systems in the state are inadequate or failing, and that for every failing septic system over 82,000 gallons of untreated wastewater is released into the environment annually (Lee *et al*., 2004). A common cause of septic system failure stems from the placement of septic systems in improper soils: soils that do not allow for proper drainage.

A list of unsewered communities in Eagle Creek Watershed are shown in Table V-11 and Figure V-13. This is only a partial list of the number of unsewered homes in watershed and includes Hortonville despite that the community lies just outside the

Watershed boundaries. Preliminary studies by the ECWA indicate that many other homes exist outside community boundaries that are also unsewered. The ECWA is currently mapping the location of all known unsewered homes and businesses in the watershed.

Table V-11: List of Unsewered Communities in Eagle Creek Watershed by County

County	Community*	Subwatershed	Residences	Businesses	Community Type
Boone	Big Springs	Eagle Creek – Kreager Ditch	16	1	Unincorporated
	Rosston	Eagle Creek – Kreager Ditch	10	0	Unincorporated
	Royalton	Fishback Creek (Eagle Creek Reservoir)	22	1	Unincorporated
Hamilton	Eagletown*	Little Eagle Branch – Headwaters	48	4	Unincorporated
	Hortonville[†]	Little Eagle Branch – Headwaters	57	4	Unincorporated
	Jolietville	Little Eagle Branch – Woodruff Branch	62	2	Unincorporated
Hendricks	None				
Marion	None				

* On June 12, 2003, Eagletown was issued an NPDES permit for a sanitary treatment plant.

[†] While Hortonville lies just outside of the watershed boundaries, the extent of tile drainage could direct septic system outfalls into Little Eagle Branch –Headwaters (Figure V-13). However, as the amount of this is unknown, this unsewered community was not used in the subwatershed ranking.

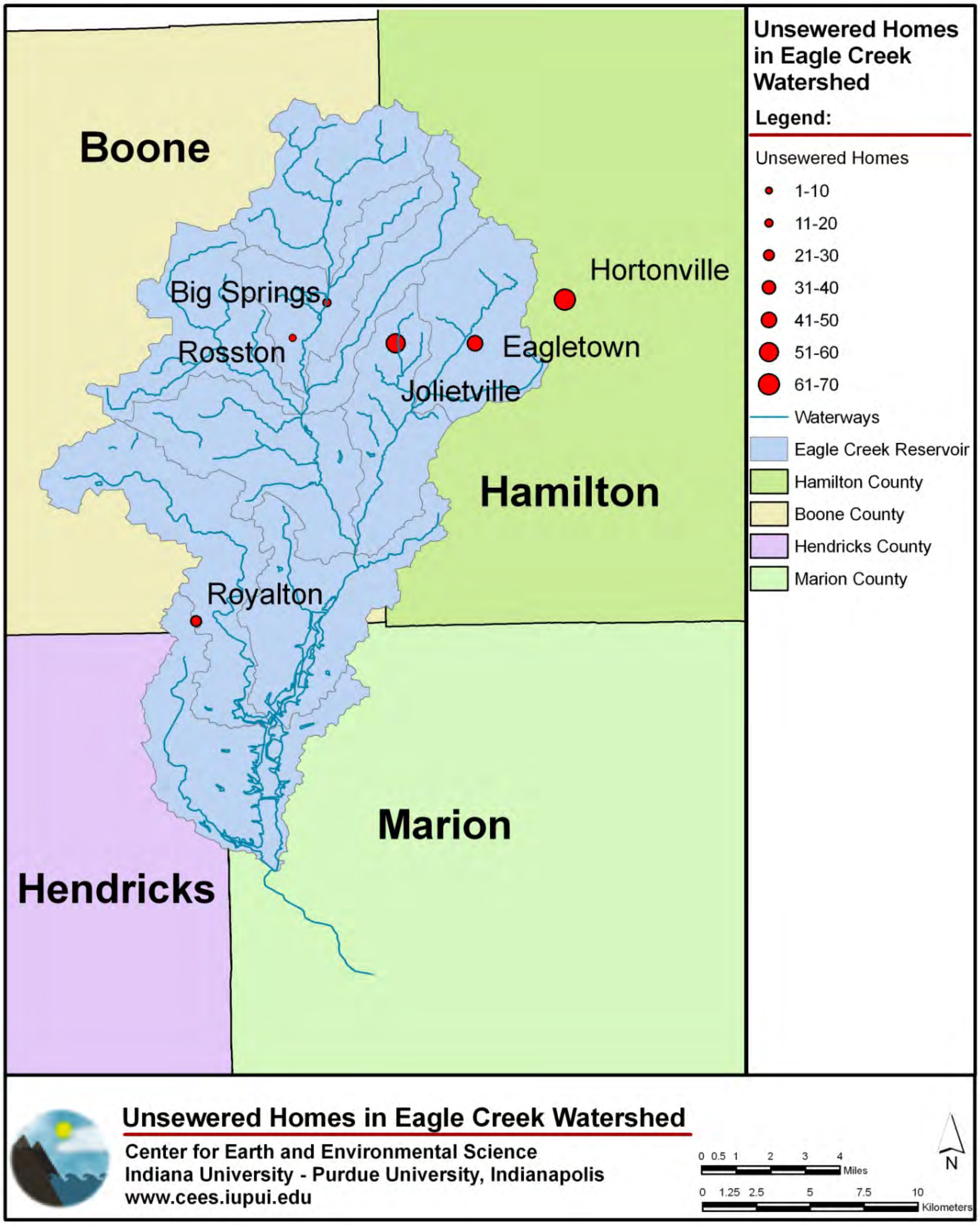


Figure V-13: Unsewered Homes in Eagle Creek Watershed

Boone County Department of Health Septic System Field Survey

In 1999, the Boone County Health Department conducted a septic system field survey in response to concerns regarding the pathogen levels in Eagle Creek Watershed. To determine how well septic systems were working, field surveys were taken in area of Boone County which overlaps Eagle Creek Watershed. (Fifty percent of Eagle Creek Watershed lies within Boone County.) The field surveys recorded the age, size of the system, and the type of soil in which each system is located. Additionally, a total of 324 houses were asked to complete informational questionnaire surveys while surveyors were on their property. Homeowners either answered the questionnaires in an interview with the surveyor or were given the questionnaire to be answered and mailed in later. Fifty-seven homeowners (17.5%) responded that their septic system had undergone some replacement or repair. The questionnaire also revealed that some homeowners were not aware of the history of the septic system on their land before their ownership. That many septic systems have failed shows that education on septic system maintenance is needed in the Watershed (Griggs, 1999).

In terms of soil data, the field survey showed that soil type was integral to properly functioning septic systems. In Eagle Creek Watershed, the three primary soil associations are Brookston-Crosby (55%), Miami-Crosby (35%), and Genesee-Shoals (10%) (Griggs, 1999). Brookston-Crosby soil associations tend to have poor drainage and are, therefore, poor for septic systems. Miami-Crosby is good for septic system use because they provide efficient drainage. Genesee-Shoals soils are problematic in that while they are well drained, they are floodplain soils which can drain very quickly into nearby surface water bodies. As only 35% of the Watershed is Miami-Crosby, a soil type suitable for properly functioning septic systems, the remaining 65% of the Watershed is ill-suited for septic systems.

In addition to field and informational surveys, water samples were taken to determine septic influence on stream bacteria loads. Samples were taken once a week on Irishman's Run Creek and Fishback Creek. The study showed that *E. coli* concentrations increased at locations downstream of residential areas and then decreased as the stream flowed through agricultural lands. This suggests that *E. coli* was entering the streams from residential areas and not agricultural areas (Griggs, 1999). However, these preliminary results require further study to confirm these findings. The Central Indiana Water Resources Partnership is currently collecting data on the distribution of septic systems throughout the Eagle Creek Watershed to provide additional location information.

Stream Order Classification

Using the hierarchical classification developed by Horton (1945) as modified by Strahler (1952, 1964) (Figure V-14), all streams in Eagle Creek Watershed were categorized by stream order. This allowed for the delineation of headwater streams which are defined as 1st and 2nd order streams. In Eagle Creek Watershed, stream classification and length measurement were done using a combination of high resolution maps and visual assessments of stream locations (Table V-12). This classification showed that more than 80% of the stream miles in Eagle Creek Watershed can be designated headwater streams.

In most watersheds, like Eagle Creek Watershed, headwater streams are the most abundant stream class in a watershed – in the Midwest most people live within 1 – 2 miles of a headwater stream. As these streams supply all downstream reaches, headwater streams are particularly important to watershed ecosystem health as their water quality affects downstream water quality. Properly functioning headwater streams, particularly primary head water streams[8], with adequate buffers are important in controlling downstream sediment, nutrient, and contaminant loads: As these small streams have a close connection to groundwater, subsurface flows, and wetlands, a healthy headwater stream will also mitigate flooding by allowing water to be recharged into groundwater or be retained in wetlands. In addition to contaminant and flood control, headwater streams play a crucial role in the ecological health of a watershed: using the River Continuum Concept (Vannote *et al*., 1980), the wooded area of a healthy headwater stream is the site of transported nutrient inputs to a stream, a critical source for nutrients (carbon, phosphorus, and nitrogen) to the upstream community as well as downstream communities which receive these nutrients from downstream transport. Therefore, protecting these small 1st and 2nd order streams is critical to the overall water quality of the watershed.

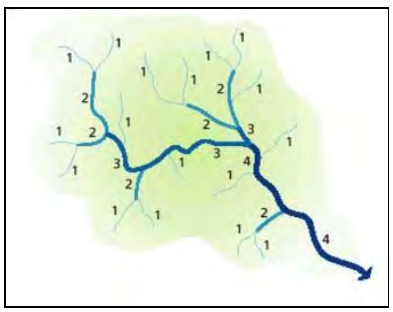


Figure V-14: Hierarchical stream classification developed by Horton (1945) as modified by Strahler (1952, 1964).

[8] Ohio EPA(2003) defines primary head water streams as ephemeral, intermittent, or perennial streams that have a watershed area generally less than one square mile.

Table V-12: Stream Classification and Stream Length

Subwatershed	Total	1st Order		2nd Order		3rd Order		Trunk		Trunk Order*
	mi	*mi*	*%*	*mi*	*%*	*mi*	*%*	*mi*	*%*	
Eagle Creek - Dixon Branch	28.7	15.8	*55%*	8.3	*29%*			4.6	*16%*	3rd Order
Eagle Creek - Finley Creek	15.2	15.2	*100%*							
Eagle Creek - Kreager Ditch	19.4	13.1	*68%*					6.3	*32%*	3rd Order
Little Eagle Branch - Headwaters	20.6	13.4	*65%*	7.3	*35%*					
Mounts Run - Neese Ditch	36.2	26.5	*73%*	2.9	*8%*	6.9	*19%*			
Little Eagle Branch - Woodruff Branch	26.2	15.9	*61%*	2.8	*11%*	7.5	*29%*			
Eagle Creek - Jackson Run	30.9	19.5	*63%*	3.1	*10%*			8.3	*27%*	4th Order
Fishback Creek (Eagle Creek Reservoir)	31.2	8.0	*26%*	23.2	*74%*					
Eagle creek - Long Branch/Irisman Run	22.1	12.1	*55%*					10.0	*45%*	4th Order
Eagle Creek Reservoir - School Branch	12.1	12.1	*100%*							
Eagle Creek Watershed Total	242.7	151.5	*62%*	47.7	*20%*	14.4	*6%*	29.1	*12%*	

* Based on Horton (1945) as modified by Strahler (1952, 1964) hierarchical stream classification system.

Section VI: Subwatershed Assessment

In an effort to characterize water quality throughout Eagle Creek Watershed using multiple data sets collected over several years, a comprehensive Subwatershed Assessment was conducted utilizing several layers of information ranging from water quality data to land cover analysis. Given the large suite of data with different spatial and temporal values, the assessment focused at a subwatershed scale with some subwatersheds being grouped based on location of the sampling stations.

Assessment Methodology

To identify Concerns and Critical Areas, several categories of data were analyzed. These include:

- IDEM's 303(d) Impaired Waterbodies List
- Water Quality Assessment (Benchmark Analysis)
- Atrazine Application Assessment
- Nutrient, Suspended Sediment, and *E. coli* Load Assessment
- Biological Assessment
- Land –Use Perturbation Assessment
- Watershed Visual Assessments
    - Streambank Erosion Assessment
    - Adequate Buffer Zone Assessment
    - Livestock Access Assessment
    - Trash Assessment
    - Tile/Pipe Drain Assessment
- Adequate Woody Riparian Buffer Zone Assessment
- Impervious Surface Land Cover Assessment
- Point Source Assessment
- Unsewered Communities Assessment
- Headwater Stream Assessment

For each category, the subwatersheds were ranked against each other in the order of most impacted to least impacted.

IDEM's 303(d) Impaired Waterbodies List

All streams in Eagle Creek Watershed except School Branch were listed as impaired in the 2004 303(d) list. As, Kreager Ditch was listed as impaired for both *E. coli* and biotic community, this stream received the lowest rank of 1 with all other streams receiving a rank of 2 (Table VI-1).

Table VI-1: Subwatershed Ranking Based on IDEM 303(d) List

Subwatershed	Status	Parameter	Rank
Eagle Creek-Dixon Branch	Impaired	*E. coli*	**2**
Eagle Creek-Kreager Ditch	Impaired	*E. coli*: impaired biotic community	**1**
Eagle Creek-Finley Creek	Impaired	*E. coli*	**2**
Mounts Run-Neese Ditch	Impaired	*E. coli*	**2**
Eagle Creek-Jackson Run	Impaired	*E. coli*	**2**
Little Eagle Branch-Headwaters	Impaired	*E. coli*	**2**
Little Eagle Branch-Woodruff Branch	Impaired	*E. coli*	**2**
Fishback Creek (Eagle Creek Reservoir)	Impaired	*E. coli*	**2**
Eagle Creek-Long Branch/Irishman Run	Impaired	*E. coli*	**2**
Eagle Creek Reservoir – School Branch*		*E. coli*	**2**

* School Branch is not included in the list of impaired waterways for *E. coli*. However, data is now available showing that School Branch is also impaired and will be listed in the upcoming 303d listing (J. Arthur, IDEM, personal communication).

Water Quality Data

To allow for comparability between several data sets, water quality data was analyzed using a Benchmark Assessment. Three data sets were used for this assessment: Marion County Health Department (MCHD {1995 – 2004}), Eagle Creek Watershed Task Force (ECWTF {1997 – 2003}), and Central Indiana Water Resources Partnership (CIWRP {2003 and 2004}). Data sets are summarized in Table VI-2. Each sample site was apportioned to a specific Hydrologic Unit Code (HUC) 14-digit subwatershed of Eagle Creek Watershed (HUC 05120201120). Collected data was compared against known water quality thresholds (Table VI-3). These thresholds were categorized into tiers.

- Tier 1: standards mandated by Indiana Administrative Code (IAC);
- Tier 2: standards mandated by US EPA and other states' environmental protection agencies but not the IAC; and
- Tier 3: standards based on criteria for the protection of ecosystem health.

Table VI-2: Summary of ECW data sets used in Benchmark Assessment

MCHD Data Stream	Subwatershed	Street	**LOCATION†** Easting	Northing	**SAMPLE PERIOD*** From	To
Finley Creek	Finley Creek	SR32	n/a	n/a	09/02/99	10/15/03
Finley Creek	Finley Creek	SR421	n/a	n/a	04/09/98	06/30/04
Long Branch	Long Branch	116th	565628.57087	4423098.48995	04/09/98	06/30/04
Fishback Creek	Fishback Creek	Hunt Club	558202.25081	4421129.65161	04/09/98	06/30/04
Fishback Creek	Fishback Creek	Wilson	558248.30551	4415301.42958	06/16/95	06/30/04
School Branch	School Branch	Maloney Rd	555098.16417	4415264.58582	04/09/98	06/30/04
School Branch	School Branch	County Line Rd	557539.06316	4409682.75642	06/16/95	06/30/04
Little Eagle Creek	Little Eagle Creek - Woodruff Branch	SR421	563901.51969	4424917.65052	04/09/98	06/30/04
Little Eagle Creek	Little Eagle Creek	Vermont Rd.	n/a	n/a	06/05/96	04/01/02
Eagle Creek	Long Branch & Irishman Run	Ford Rd.	561679.38051	4419863.14742	06/16/95	06/30/04
Eagle Creek	Long Branch & Irishman Run	79th	560643.14981	4416397.53139	06/16/95	06/30/04
Eagle Creek	Reservoir	56th	559418.09484	4411570.99904	06/16/95	06/30/04

ECWTF Data Stream	Subwatershed	Street	**LOCATION†** Easting	Northing	**SAMPLE PERIOD**** From	To
School Branch	School Branch	Count Road 600 N	555749.04613	4411534.05146	05/13/97	10/22/03
Fishback Creek	Fishback Creek	82nd Street	558418.37444	4417103.76243	05/13/97	10/22/03
Irishman Run	Irishman Run	State Road 334	560359.40433	4422446.72932	05/13/97	10/22/03
Eagle Creek	Long Branch	Lions Club Park	563546.61288	4422361.63773	05/13/97	10/22/03
Eagle Creek	Jackson Run	Holiday Road	562081.62516	4426012.51540	05/13/97	10/22/03
Eagle Creek	Mounts Run & Finley Creek	Couny Road 200 S	560909.93950	4429444.01374	05/13/97	10/22/03
Little Eagle Creek	Little Eagle Creek - Woodruff Branch	156th Street	565842.86712	4429485.12365	05/13/97	10/22/03
Mounts Run	Mounts Run	State Road 32	557336.99427	4432413.19220	05/13/97	10/22/03
Finley Creek	Finley Creek	State Road 32	563093.64337	4432680.81784	05/13/97	10/22/03
Eagle Creek	Dixon Branch	Count Road 300 N	562022.40269	4437445.01387	05/13/97	10/22/03

Table VI-2: Summary of ECW data sets used in Benchmark Assessment (continued)

CIWRP 2003 Data Stream	Subwatershed	**LOCATION†** Street	Easting	Northing	**SAMPLE PERIOD***** From	To
School Branch	School Branch	Raceway Rd	557518.214	4409810.485	02/25/03	12/03/03
Fishback Creek	Fishback Creek	Wilson Rd	558258.702	4415347.485	02/25/03	12/03/03
Eagle Creek	Long Branch & Irishman Run	Lafayette Rd	559837.775	4415552.825	02/25/03	12/03/03
Eagle Creek	Long Branch & Irishman Run	Zionsville Rd	563219.929	4422038.412	02/25/03	12/03/03
Eagle Creek	Mounts Run	County Rd 200 S	560924.380	4429383.957	02/25/03	12/03/03
Little Eagle Creek	Little Eagle Creek - Woodruff Branch	County Rd 200 S	565844.616	4429497.815	02/25/03	12/03/03
Finley Creek	Finley Creek	County Rd 1100 E	563098.508	4432659.226	02/25/03	12/03/03
Eagle Creek	Eagle Creek Watershed – South of ECR Dam	Near 38th St	n/a	n/a	02/25/03	12/03/03

† GPS coordinates are given in UTM: NGD 1983; Zone 16.

* Samples were taken regularly throughout this time period, usually beginning in late Winter/Early Spring and ending in Late Fall/Early Winter.

** Samples were taken regularly throughout this time period, usually April - October (2002: June - September; 1997 & 1998: May - November).

*** Samples were taken relative to event (3x 40 year stream discharge average) or base flow (40 year stream discharge average) as measured by the USGS Zionsville Gage (USGS 03353200).

Table VI-3: Tiers for Water Quality Benchmark Assessment

Tier 1			
Parameter	*Threshold*	*Units*	*Reference*
E. coli	Max: 235	CFU	IAC Title 327 – Full Body Contact
DO	Min: 4.0	mg/L	IAC Title 327 – Protect Aquatic Life
TDS	Max: 750	mg/L	IAC Title 327
pH	Range: 6 - 9		IAC Title 327 – Protect Aquatic Life

Tier 2			
Parameter	*Threshold*	*Units*	*Reference*
Atrazine	Max: 3.0	ppb	EPA Drinking Water Standard (Human Toxicity)
Nitrate	Max: 10	mg/L	EPA Drinking Water Standard (Human Toxicity) IAC Title 327
TSS	Max: 263	mg/L	Utah and South Dakota Standard for Warm Water Streams – Protect Aquatic Life
Total P	Max: 0.125	mg/L	National Average for US Watersheds 50-75% Agriculture (Omernik, 1977) & Ohio EPA
Total N	Max: 2.75	mg/L	National Average for US Watersheds 50-75% Agriculture (Omernik, 1977) & Ohio EPA

Tier 3			
Parameter	*Threshold*	*Units*	*Reference*
DIN / NO_3-N	Max: 1.0	mg/L	Levels leading to periphyton and macrophyte control (Dodds and Welch, 2000)
DO	>125%	DO_{sat}	Indication of excessive algal activity (indication of nutrient enrichment) (CB*, 2001)
pH	>8.3		Indication of excessive algal activity (indication of nutrient enrichment) (CB*, 2001)

* Commonwealth Biomonitoring

The thresholds were used to discern areas of poor water quality. If the measured parameter did not meet the threshold requirement, the sample was counted as exceeding the threshold. Each of the data sets was analyzed to determine how many times a subwatershed did not meet the threshold requirement and, subsequently, how many times a subwatershed indicated poor water quality based on each specific parameter. For instance, in all data sets and for all subwatersheds, the *E. coli* threshold (235 CFU/100mL) was exceeded more than 50% of the time sampled and the Atrazine threshold (3 ppb or 0.003 mg/L) was exceeded approximately 10% of the time sampled (Appendix D). This analysis allowed for a comparison of subwatersheds using multiple data sets taken over different spatial and temporal frequencies.

Based on the number of times each threshold was not met, each subwatershed was ranked against the others to determine a continuum of most impacted to least impacted according to each parameter. Based on this continuum, each subwatershed was assigned a rank with the lowest number rank representing the subwatershed that was the most impacted and a highest number representing the subwatershed that was the least impacted.

For each subwatershed, the ranks for each parameter within a Tier were averaged to obtain a Tier Score. A low tier score indicates a high percentage of times that the subwatershed did not meet the benchmark criteria. Because all parameters were not measured in all subwatersheds, three subwatersheds (Eagle Creek - Dixon Branch, Eagle Creek - Kreager Ditch, and Eagle Creek - Jackson Run) were not included in this analysis. According to Tier Scores, Mounts Run – Neese Ditch and Eagle Creek Reservoir - School Branch subwatersheds scored consistently the lowest in all Tiers (Table VI-4).

Table VI-4: Subwatershed Ranking by Tier Scores

	Tier 1		**Tier 2**		**Tier 3**	
Subwatershed	*Score*	*Rank*	*Score*	*Rank*	*Score*	*Rank*
Eagle Creek Dixon Branch	n/a	**n/a**	n/a	**n/a**	n/a	**n/a**
Eagle Creek-Finley Creek	4	**4**	5	**5**	2	**1**
Eagle Creek -Kreager Ditch	n/a	**n/a**	n/a	**n/a**	n/a	**n/a**
Little Eagle Branch-Headwaters	3	**3**	4	**1**	3	**5**
Mounts Run- Neese Ditch	2	**1**	4	**1**	2	**1**
Little Eagle Branch- Woodruff Branch	3	**3**	4	**1**	3	**5**
Eagle Creek- Jackson Run	n/a	**n/a**	n/a	**n/a**	n/a	**n/a**
Fishback Creek (Eagle Creek Reservoir)	4	**4**	5	**5**	2	**1**
Eagle Creek- Long Branch/Irishman Run	5	**6**	4	**1**	3	**5**
Eagle Creek Reservoir-School Branch	2	**1**	4	**1**	2	**1**

n/a – insufficient data to perform rank analysis.

This assessment was also used for the baseline or benchmark assessment of each subwatershed. The number of times a subwatershed does not meet the requirements of a water quality threshold can be used as a measurement of improvement. Given the implementation of better management practices, the number of times a subwatershed exceeds a water quality threshold should decrease.

Atrazine Application Assessment

Using Indiana statewide average application rates for Atrazine (1.32 lbs/acre-year) and estimated acreage of corn in each subwatershed, the amount of Atrazine applied in each watershed was estimated. This was compared to Tier 2 Benchmark Ranks of Atrazine exceedence whereby the subwatershed exceeding the Atrazine concentration of 3 ppb the most received the highest rank and the subwatershed with the least number of exceedences received the lowest rank. Then, each subwatershed was ranked against each other such that the subwatershed having the greatest estimated Atrazine load applied was assigned the lowest rank and the subwatershed with the lowest estimated Atrazine load applied was assigned the highest rank. The two ranks were then combined to give an overall Atrazine Rank. This analysis showed that Eagle Creek – Dixon Branch, Eagle Creek – Finley Creek, Mounts Run – Neese Ditch, and Little Eagle Branch – Woodruff Branch were the most impacted by Atrazine (Table VI-5).

Table VI-5: Subwatershed Ranking by Atrazine

Subwatershed	Atrazine Applied* (lbs)	Atrazine Applied* Rank	Tier 2 Benchmark Analysis† N	# Exceed 3 ppb	%	Rank	Overall Rank‡
Eagle Creek Dixon Branch	5,640	1	122	33	27%	1	**1**
Eagle Creek-Finley Creek	3,071	6	342	42	12%	5	**4**
Eagle Creek -Kreager Ditch	3,787	5					**n/a**
Little Eagle Branch-Headwaters	4,534	3					**n/a**
Mounts Run- Neese Ditch	5,514	2	122	9	7%	7	**2**
Little Eagle Branch- Woodruff	3,011	7	261	42	16%	2	**2**
Eagle Creek- Jackson Run	4,232	4					**n/a**
Fishback Creek (Eagle Creek Reservoir)	731	8	410	54	13%	4	**5**
Eagle Creek- Long Branch/Irishman Run	272	10	581	65	11%	6	**7**
Eagle Creek Reservoir-School Branch	478	9	418	61	15%	3	**5**

* Estimated using statewide average application rates.
† Benchmark Analysis is from combined MCHD and ECWTF data sets (Appendix D).
‡ Overall Rank determined by Atrazine Applied Rate + Tier 2 Benchmark Rank.
n/a – insufficient data to perform rank analysis.

Nutrient, Suspended Sediment, and *E. coli* Loading Assessment

After loading for each subwatershed was calculated, each subwatershed was ranked against each other such that the subwatershed having the greatest estimated annual load was assigned the lowest rank and the subwatershed with the lowest estimated annual load was assigned the highest rank. Subwatersheds were accordingly ranked based on their loading per acre. Normalizing load to surface area allowed determination of which subwatersheds were loading disproportionately higher loads compared to their size. This with the land-use data and estimated fertilizer application can be used to determine possible sources of nutrient loads. This analysis showed that the subwatershed group of Little Eagle Branch - Woodruff Branch and Jackson Run, and Little Eagle Branch – Headwaters contributed the greatest per acre load of Total Organic Carbon (TOC) and Total P, and the upper subwatershed group of Eagle Creek – Dixon Branch, Eagle Creek - Kreager Ditch, and Mounts Run-Neese Ditch, and Little Eagle Branch – Headwaters contributed the greatest per acre load of Total N. Similarly, total suspended sediment (TSS) load was also normalized to surface area. These data show that the lower subwatersheds such as Little Eagle Branch - Woodruff Branch and Jackson Run, and Fishback Creek (Eagle Creek Reservoir) contribute the greatest amount of TSS load to the watershed (Table VI-6).

While *E. coli* themselves are not persistent – individual bacteria cells do not survive for more than a few days in a stream environment – the application of manure based fertilizers or point sources of fecal contamination can cause *E. coli* numbers to follow similar transport dynamics as other water contaminants such as total suspended solids. Therefore, loads of *E. coli* were used to determine if any subwatershed contributed a disproportionate amount of *E. coli* to the watershed. This analysis shows that the subwatershed group of Eagle Creek – Little Eagle Branch – Woodruff Branch and Jackson Run contributed the most *E. coli* per acre, more than 100,000 cfu/acre (Table VI-7).

Table VI-6: Subwatershed Ranking by Load

	TSS		Tot N		TOC		Tot P	
Accountable Subwatersheds	*tons/yr*	*Rank*	*tons/yr*	*Rank*	*tons/yr*	*Rank*	*tons/yr*	*Rank*
Total Eagle Creek Watershed	**26,000**		**1,500**		**60**		**890**	
Eagle Creek – Dixon Branch and Eagle Creek - Kreager Ditch and Mounts Run-Neese Ditch	4,200	**4**	420	**4**	10	**4**	350	**1**
Eagle Creek - Finley Creek	670	**5**	60	**5**	3	**4**	40	**6**
Little Eagle Branch-Headwaters	2,300	**3**	230	**2**	10	**2**	120	**2**
Little Eagle Branch - Woodruff Branch and Jackson Run	12,900	**1**	480	**1**	20	**1**	150	**4**
Fishback Creek (Eagle Creek Reservoir)	6,600	**2**	210	**3**	8	**3**	140	**3**
Eagle Creek - Long Branch and Irishman Run		**n/a**		**n/a**		**n/a**		**n/a**
Eagle Creek Reservoir - School Branch	1,200	**6**	90	**6**	3	**6**	90	**5**

n/a – insufficient data to perform rank analysis.

Table VI-7: Subwatershed Rank by *E. coli* Load

	E. coli	
Accountable Subwatersheds	*mCFU/yr*	*Rank*
Eagle Creek Watershed	**8,000**	
Eagle Creek – Dixon Branch and Eagle Creek - Kreager Ditch and Mounts Run-Neese Ditch	1,900	**4**
Eagle Creek - Finley Creek	370	**5**
Little Eagle Branch - Headwaters	1000	**2**
Little Eagle Branch - Woodruff Branch and Jackson Run	2,800	**1**
Fishback Creek (Eagle Creek Reservoir)	930	**3**
Eagle Creek - Long Branch and Irishman Run		**n/a**
Eagle Creek Reservoir - School Branch	290	**6**

n/a – insufficient data to perform rank analysis.

Biological Assessment

Biological assessment of ECW was summarized from the Commonwealth Biomonitoring report to the ECWTF in 2001. Normalized Index of Biological Integrity (IBI) scores for each subwatershed were ranked. A low number rank refers to the most impaired and a high rank refers to the least relatively impaired. Rank analysis showed that Mounts Run – Neese Ditch, Little Eagle Branch (Headwaters and Woodruff Branch), and Fishback Creek (Eagle Creek Reservoir) subwatersheds scored lowest for macroinvertebrate and fish biological integrity (Table VI-8).

Table VI-8: Subwatershed Ranking by Bioassessment

	Macroinvertebrates		Fish	
Subwatershed	**Ave. Score***	**Rank**	**Ave. Score**	**Rank**
Eagle Creek - Dixon Branch	49	**6**	62	**5**
Eagle Creek - Finley Creek	55	**8**	70	**7**
Eagle Creek - Kreager Ditch	52	**7**	70	**7**
Little Eagle Branch (Headwaters and Woodruff Branch)	41	**2**	49	**2**
Mounts Run – Neese Ditch	39	**1**	47	**1**
Eagle Creek - Jackson Run	46	**4**	60	**4**
Fishback Creek (Eagle Creek Reservoir)	44	**3**	56	**3**
Eagle Creek - Long Branch/Irishman Run	46	**4**	62	**5**
Eagle Creek Reservoir - School Branch	67	**9**	80	**9**

* Macroinvertebrates were sampled twice in May and October for each station in each subwatershed. The average score is the average for all stations in the subwatershed for both sample dates.

Land-use Perturbation Assessment

Land-use perturbation potential was measured using the LUCI model and the number of single family home permits issued in 2003. Again, subwatersheds were ranked from most impacted to least impacted with the lowest number representing the subwatershed that was the most impacted and a highest number representing the subwatershed that was the least impacted. Using the LUCI model, degree of impact was determined by the predicted % change in urbanization.

Based on the LUCI model and on the number of single family home permits issued in 2003, subwatersheds were ranked according to their susceptibility to land-use perturbations and subsequent sediment loading to their streams. Eagle Creek - Long Branch/Irishman Run, Eagle Creek Reservoir - School Branch, Little Eagle Branch (Headwaters and Woodruff Branch), and Eagle Creek - Jackson Run subwatersheds are predicted to be the most susceptible to land-use perturbation based on land-use change by 2040 and single family home development in 2003. Mounts Run – Neese Ditch, Eagle Creek - Finley Creek, and Eagle Creek - Dixon Branch are expected to be the least impacted by land-use perturbation (Table VI-9, Figure IV-3, and Figure IV-4).

Table VI-9: Subwatershed Ranking by Land-use Perturbation

Subwatershed	Land-use Perturbation LUCI 2040 Rank	Land-use Perturbation 2003* Rank
Eagle Creek - Dixon Branch	**9**	**6**
Eagle Creek - Finley Creek	**6**	**6**
Eagle Creek - Kreager Ditch	**7**	**6**
Little Eagle Creek (Headwaters and Woodruff Branch)	**1**	**5**
Mounts Run – Neese Ditch	**7**	**9**
Eagle Creek - Jackson Run	**3**	**3**
Fishback Creek (Eagle Creek Reservoir)	**3**	**4**†
Eagle Creek - Long Branch/Irishman Run	**2**	**2**
Eagle Creek Reservoir - School Branch	**5**	**1**

* Based on the number of single family home permits issued in 2003 for townships within ECW.

† In July of 2004, a 3000+ home development was approved by Boone County (Figure V-6).

Watershed Visual Assessment

A windshield survey was conducted to provide a visual assessment of Eagle Creek Watershed. Observations were made to determine the condition of streambank erosion, the adequacy of stream buffers, the stream accessibility for livestock, the condition of trash in streams, and the presence of tile/pipes in the watershed. Each subwatershed was ranked based on the occurrence of parameters observed and the degree or severity of which they were observed. For example, each subwatershed visual assessment site was ranked individually for the degree of impact. The sites for each subwatershed were totaled, averaged and then ranked against the other subwatersheds to provide an overall ranking of the Eagle Creek subwatersheds. This was done for each parameter (erosion, buffer, livestock access, trash, tile/pipes) visually assessed. The lower ranked numbers represent the subwatersheds that are most impacted while the higher rankings represent subwatersheds that are less critically impacted by the particular parameter observed.

<u>Stream Bank Erosion</u>

Visual assessments of stream bank erosion showed that the upper subwatersheds such as Little Eagle Branch – Headwaters, Eagle Creek – Dixon Branch, and Mounts Run – Neese Ditch showed the least amount of stream bank erosion, while the lower subwatersheds such as Fishback Creek (Eagle Creek Reservoir), Eagle Creek Reservoir – School Branch, and Eagle Creek – Long Branch/Irishman Run showed the greatest amount of stream bank erosion (Figure V-7, Table VI-10). This corresponds well with the slope assessments (Figure IV-5): stream reaches closer to the reservoir showed higher slopes, which, if left bare, are more susceptible to stream bank erosion.

Table VI-10: Subwatershed Ranking by Degree of Stream Bank Erosion

Subwatershed	Average		# Sites Assessed	Rank
Eagle Creek – Dixon Branch	5.7	(Slight)	12	**9**
Eagle Creek – Finley Creek	5.6	(Slight)	9	**7**
Eagle Creek – Kreager Ditch	5.6	(Slight)	14	**7**
Little Eagle Branch – Headwaters	5.9	(Slight)	7	**10**
Mounts Run – Neese Ditch	5.7	(Slight)	14	**9**
Little Eagle Branch – Woodruff Branch	5.5	(Slight)	13	**5**
Eagle Creek – Jackson run	4.6	(Slight to Moderate)	15	**4**
Fishback Creek (Eagle Creek Reservoir)	3.1	(Moderate)	18	**1**
Eagle Creek – Long Branch/Irishman Run	3.4	(Moderate)	16	**3**
Eagle Creek Reservoir – School Branch	3.2	(Moderate)	10	**2**

Adequate Buffer Zone Assessment

Visual assessments of adequate buffer zone showed that upper subwatersheds where land use is predominantly agricultural rank the lowest for adequate stream buffer zone: Little Eagle Branch – Headwater and Eagle Creek – Dixon Branch have the least amount of adequate buffer (Figure V-7, Table VI-11). This visual assessments match well with ArcView GIS land cover assessments which showed that these two subwatersheds had the least amount of adequate buffer zone (page 110).

Table VI-11: Subwatershed Ranking by Percent of Stream with Adequate Buffer

Subwatershed	Average		# Sites Assessed	Rank
Eagle Creek – Dixon Branch	1.5	(Moderate)	12	**2**
Eagle Creek – Finley Creek	1.8	(Moderate)	9	**6**
Eagle Creek – Kreager Ditch	1.7	(Moderate)	14	**5**
Little Eagle Branch – Headwaters	1.4	(Moderate)	7	**1**
Mounts Run – Neese Ditch	1.8	(Moderate)	14	**6**
Little Eagle Branch – Woodruff Branch	1.9	(Moderate)	13	**8**
Eagle Creek – Jackson Run	1.9	(Moderate)	15	**8**
Fishback Creek (Eagle Creek Reservoir)	1.6	(Moderate)	18	**4**
Eagle Creek – Long Branch/Irishman Run	2.0	(Moderate)	15	**10**
Eagle Creek Reservoir – School Branch	1.5	(Moderate)	10	**2**

Livestock Access

Visual assessments of livestock access showed that Eagle Creek – Kreager Ditch and Mounts Run – Neese Ditch have the greatest amount of places where livestock had free access to the streams (Figure V-8, Table VI-12).

Table VI-12: Subwatershed Ranking by Livestock Access to Stream

Subwatershed	# Sites w/ Livestock Access	# Sites Assessed	Rank
Eagle Creek - Dixon Branch	0	9	**8**
Eagle Creek - Finley Creek	0	9	**8**
Eagle Creek - Kreager Ditch	4	16	**1**
Little Eagle Branch - Headwaters	0	7	**8**
Mounts Run – Neese Ditch	4	13	**1**
Little Eagle Branch - Woodruff Branch	2	11	**3**
Eagle Creek - Jackson Run	2	17	**3**
Fishback Creek (Eagle Creek Reservoir)	2	18	**3**
Eagle Creek - Long Branch/Irishman Run	1	16	**6**
Eagle Creek Reservoir - School Branch	1	9	**6**

Trash

Visual assessments of trash in the streams showed that overall Eagle Creek Watershed is relatively clean, with some exceptions such a sofa in the lower reaches of Fishback Creek. Subwatersheds that had the greatest amount of trash were Fishback Creek (Eagle Creek Reservoir), Eagle Creek Reservoir – School Branch, and Eagle Creek – Dixon Branch (Figure V-9, Table VI-13).

Table VI-13: Subwatershed Ranking by Trash in Stream

Subwatershed	Average		# Sites Assessed	Rank
Eagle Creek - Dixon Branch	4.1	(slight)	12	6
Eagle Creek - Finley Creek	4.2	(slight)	9	4
Eagle Creek - Kreager Ditch	4.3	(slight)	15	5
Little Eagle Branch - Headwaters	4.6	(slight – none)	7	6
Mounts Run – Neese Ditch	4.8	(slight – none)	13	8
Little Eagle Branch - Woodruff Branch	4.6	(slight – none)	11	6
Eagle Creek - Jackson Run	4.9	(slight – none)	17	9
Fishback Creek (Eagle Creek Reservoir)	3.8	(mod. – slight)	18	1
Eagle Creek - Long Branch/Irishman Run	4.9	(slight – none)	16	10
Eagle Creek Reservoir - School Branch	4.0	(slight)	10	2

Tile/Pile Drains

Visual assessment of the number of tile and/or pipe discharges into the streams showed that two subwatersheds with the greatest percent land-use for agriculture were also two of the lowest ranking subwatersheds for tile and/or pipe discharges into the streams: Eagle Creek – Dixon Branch and Mounts Run – Neese Ditch. School Branch also ranked as one of the lowest for tile and/or pipe discharges directly into the stream (Figure V-10, Table VI-14).

Table VI-14: Subwatershed Ranking by Number of Tile/Pipe Discharges

Subwatershed	# Sites with Tile/Pipe Observed	# Sites Assessed	%	Rank
Eagle Creek – Dixon Branch	9	12	75%	**1**
Eagle Creek – Finley Creek	1	9	11%	**10**
Eagle Creek – Kreager Ditch	6	14	43%	**6**
Little Eagle Branch – Headwaters	2	7	29%	**8**
Mounts Run – Neese Ditch	10	14	71%	**3**
Little Eagle Branch – Woodruff Branch	6	13	46%	**5**
Eagle Creek – Jackson run	3	15	20%	**9**
Fishback Creek (Eagle Creek Reservoir)	11	18	61%	**4**
Eagle Creek – Long branch/Irishman Run	6	16	38%	**7**
Eagle Creek Reservoir – School Branch	7	10	70%	**2**

Adequate Woody Riparian Zone Assessment (ArcView GIS)

After ArcView GIS assessment of each subwatershed using aerial photography, all subwatersheds were ranked against each other such that the subwatershed with the least adequate buffer received the lowest rank that the subwatershed with the most adequate buffer received the highest rank. Adequate buffer was measured as approximately 25' of woody riparian buffer on both sides of the stream. Eagle Creek - Dixon Branch, Little Eagle Branch - Headwaters, Mounts Run – Neese Ditch, and Eagle Creek Reservoir - School Branch Creek ranked the lowest amongst the subwatersheds, showing that these streams have the lowest percent adequate buffer of the Eagle Creek Subwatersheds (Table VI-15).

Table VI-15: Subwatershed Ranking by Adequate Woody Riparian Zone

Subwatershed	% of Stream With Adequate Buffer	Rank
Eagle Creek - Dixon Branch	20	**1**
Eagle Creek - Finley Creek	51	**7**
Eagle Creek - Kreager Ditch	45	**6**
Little Eagle Branch - Headwaters	26	**2**
Mounts Run – Neese Ditch	29	**3**
Little Eagle Branch - Woodruff Branch	43	**5**
Eagle Creek - Jackson Run	54	**8**
Fishback Creek (Eagle Creek Reservoir)	57	**9**
Eagle Creek - Long Branch/Irishman Run	57	**9**
Eagle Creek Reservoir - School Branch	34	**4**

Impervious Surface Assessment

After assessment of each subwatershed, all subwatersheds were ranked against each other such that the subwatershed with the most impervious surfaces by surface area (mi^2) received the lowest rank and the subwatershed with the least impervious surfaces by surface area received the highest rank (Table VI-16). In the case that two subwatersheds had the same amount of impervious surface area, percent surface area broke the tie, as in the case of Eagle Creek – Dixon Branch and Eagle Creek – Finley Creek which both had 0.6 mi^2 of impervious surfaces. As Eagle Creek – Finley Creek had a greater percent surface area of impervious surfaces, it received the lower rank (Table VI-16). Using this analysis, the subwatersheds closest to Eagle Creek Reservoir show the greatest amount of impervious surfaces in both surface area and percentage: Eagle Creek – Long Branch/Irishman Run and Eagle Creek Reservoir – School Branch rank the lowest while the subwatersheds such as Mounts Run – Neese Ditch, Eagle Creek – Kreager Ditch, and Eagle Creek- Dixon Branch ranked the highest. This suggests that the lower subwatersheds are the most susceptible to degradation from stormwater run-off.

Table VI-16: Subwatershed Ranking by Impervious Surface Assessment

Subwatershed	Impervious *(mi^2)*	Impervious *%*	Rank
Eagle Creek Dixon Branch	0.6	3.4%	**8**
Eagle Creek-Finley Creek	0.6	5.4%	**7**
Eagle Creek -Kreager Ditch	0.3	2.7%	**9**
Little Eagle Branch-Headwaters	1.1	6.8%	**6**
Mounts Run- Neese Ditch	0.2	1.3%	**10**
Little Eagle Branch- Woodruff	1.7	12.5%	**5**
Eagle Creek- Jackson Run	2.4	12.7%	**3**
Fishback Creek (Eagle Creek Reservoir)	2.1	10.0%	**4**
Eagle Creek- Long Branch/Irishman Run	5.2	27.3%	**1**
Eagle Creek Reservoir-School Branch	3.0	14.9%	**2**

Location of Point Sources Assessment (NPDES)

Using the location of each NPDES permit (point source and combined animal feeding operation, CAFO) located within Eagle Creek Watershed, the number of point sources within each subwatershed was counted (Figure V-11, Figure V-12). Subwatersheds were then ranked against each other such that the subwatershed with the most NPDES permitted point sources received the lowest rank and the subwatershed with the least received the highest rank (Table VI-17).

Table VI-17: Subwatershed Rank by Number of NPDES and CAFO Sources that Discharge into the Stream

Subwatershed	# Point Sources* and CAFOs	Rank
Eagle Creek - Dixon Branch	1 NPDES 1 CAFOs	**2**
Eagle Creek - Finley Creek	0 NPDES 0 CAFOs	**8**
Eagle Creek - Kreager Ditch	0 NPDES 2 CAFOs	**2**
Little Eagle Branch - Headwaters	4 NPDES 0 CAFOs	**1**
Mounts Run - Neese Ditch	0 NPDES 0 CAFOs	**8**
Little Eagle Branch - Woodruff Branch	2 NPDES 0 CAFO	**2**
Eagle Creek - Jackson Run	2 NPDES 0 CAFO	**2**
Fishback Creek (Eagle Creek Reservoir)	0 NPDES 1 CAFO	**7**
Eagle Creek - Long Branch/Irishman Run	2 NPDES 0 CAFOs	**2**
Eagle Creek Reservoir - School Branch	0 NPDES 0 CAFOs	**8**

* Only NPDS permits classified as Process Water, Sanitary, or Stormwater Run-off were used in the ranking.

Unsewered Communities Assessment

Using the location of each unsewered community found within Eagle Creek Watershed, each unsewered community was assigned to a subwatershed. Subwatersheds were then ranked with the subwatershed with the greatest number of known unsewered homes receiving the lowest rank and the subwatershed with the lowest number of unsewered homes receiving the highest rank. Using data from the Indiana Community Action Association's "Unsewered Community Survey Report" (2003), this assessment showed that Little Eagle Branch – Woodruff Branch has the most unsewered homes in Eagle Creek Watershed.

Table VI-18: Subwatershed Rank by Number of Unsewered Homes

Subwatershed	# Unsewered Homes	Rank
Eagle Creek - Dixon Branch	*	**5**
Eagle Creek - Finley Creek	*	**5**
Eagle Creek - Kreager Ditch	26	**3**
Little Eagle Branch - Headwaters	48	**2**
Mounts Run - Neese Ditch	*	**5**
Little Eagle Branch - Woodruff Branch	62	**1**
Eagle Creek - Jackson Run	*	**5**
Fishback Creek (Eagle Creek Reservoir)	22	**4**
Eagle Creek - Long Branch/Irishman Run	*	**5**
Eagle Creek Reservoir - School Branch	*	**5**

* According to the INCAA report, no unsewered communities were surveyed in these watersheds as of April 18, 2003.

Headwater Stream Assessment

Using the classifications discussed in Section V:, subwatersheds were ranked according to the percentage of stream miles that could be designated as a headwater stream (1st and 2nd order). Subwatersheds with a larger percentage of stream reach classified as headwater streams received the lowest rank and subwatersheds with the lowest percentage of stream reach classified as headwater streams were ranked the highest. This analysis showed that Eagle Creek-Finley Creek, Little Eagle Branch –Headwaters, Fishback Creek (Eagle Creek Reservoir), and Eagle Creek Reservoir – School Branch had the greatest amount of headwater streams: all stream reaches (100%) in these subwatersheds were classified as headwater streams.

Table VI-19: Subwatershed Rank by Headwater Stream Classification

Subwatershed	Headwater Streams*		Rank
	mi	*%*	
Eagle Creek - Dixon Branch	24.1	84%	5
Eagle Creek - Finley Creek	15.2	100%	1
Eagle Creek - Kreager Ditch	13.1	68%	9
Little Eagle Branch - Headwaters	20.6	100%	1
Mounts Run - Neese Ditch	29.4	81%	6
Little Eagle Branch - Woodruff Branch	18.7	71%	8
Eagle Creek - Jackson Run	22.6	73%	7
Fishback Creek (Eagle Creek Reservoir)	31.2	100%	1
Eagle creek - Long Branch/Irisman Run	12.1	55%	10
Eagle Creek Reservoir - School Branch	12.1	100%	1

* A headwater stream was defined as a 1st and/or 2nd order stream.

Results of Assessment

Once all subwatersheds were ranked for all parameters, parameters were parsed into two major categories: (1) Level of Degradation based on water quality parameters and (2) Level of Vulnerability to on-going and future degradation based on land-use/land cover assessments and other pertinent aspects of the subwatersheds. Then, with all parameters equally weighted, the average for each category was calculated and the subwatersheds were ranked according to their Level of Degradation (Category 1) and Vulnerability (Category 2). The subwatershed ranks of these two categories were then averaged. This average was then used to determine the subwatersheds overall rank, or Rank Score. This provided insight into how subwatersheds compared in terms of Level of Degradation (Category 1), Level of Vulnerability (Category 2), and overall. As with the individual parameter rankings, the most impacted subwatershed received the lowest rank and the least impacted received the highest rank (Table VI-20 and Table VI-21).

This assessment showed that Mounts Run – Neese Ditch, Little Eagle Branch – Woodruff Branch, and Little Eagle Branch – Headwaters showed the highest level of overall water quality degradation (Category 1 Evaluation Table VI-20), and that Eagle Creek Reservoir – School Branch, Fishback Creek (Eagle Creek Reservoir), and Little Eagle Branch – Woodruff Branch exhibits the greatest amount of overall subwatershed vulnerability to on-going and future degradation (Category 2 Evaluation Table VI-20). Overall Rank Scores showed that Little Eagle Branch – Woodruff Branch, Fishback Creek (Eagle Creek Reservoir), Little Eagle Branch – Headwaters, and Mounts Run – Neese Ditch ranked the lowest for all parameters in all categories.

This overall analysis demonstrates the importance of an integrated approach to improving water quality in Eagle Creek Watershed: All subwatersheds pose serious challenges for remediation as there are multiple contaminants of concern and multiple land-use/land cover stressors that may be contributing to the subwatersheds degraded water quality.

Summary of Findings:

- According to IDEM 303(d) listings and water quality data, most Eagle Creek Subwatersheds do not meet criteria to support the Watershed’s designated uses. This is supported by the Benchmark Assessment which showed that most subwatersheds exceeded *E. coli* thresholds designated for water bodies to support full body contact recreation (235 cfu/100 mL) more than 50% of the time sampled (Tier 1:Appendix D). 2003 load data show that the subwatersheds with the greatest contribution of *E. coli* (cfu/acre-year) are Little Eagle Branch – Woodruff Branch and Eagle Creek - Jackson Run, and Little Eagle Branch Headwaters. As ECR has a designated use as a drinking water resource, subwatersheds were characterized for Atrazine and nitrate concerns based on the number times they exceeded IAC 327 and US EPA Primary Drinking Water Regulations of 3 ppb of Atrazine. Benchmark Analysis show that the Tier 2 threshold of 3 ppb of Atrazine is exceeded approximately 10% of the time, with some subwatersheds such as Eagle Creek – Long Branch/Irishman Run and Little Eagle Branch -

Woodruff Branch exceeding the threshold 35% and 24% of the time, respectively (Tier 2:Appendix). Recent storm flow data from an on-going 2005 study show that Atrazine concentrations can exceed 75 ppb in Eagle Creek Watershed.

- Tier 2 Benchmark Analysis of Total N and Total P show that nutrient concentrations often exceed the national averages for Total N and Total P in US watersheds with at least 50% agricultural land-use: both were exceeded at least 50% of the time sampled. Load analysis shows that over 880 tons of Total N and 58 tons of Total P are transported in Eagle Creek Watershed streams annually. This load divided by the total acreage of Eagle Creek Watershed results in an average watershed Total N flux of approximately 500 lb/acre-year and a Total P flux of approximately 1 lb/acre-year. These nutrients are most likely sourced from agricultural production, inadequate septic systems, animal waste and residential area runoff, NPDES point source discharges and uncontrolled stormwater in tributary streams and in ECR. Land cover and land-use perturbation assessments show that ECW is under pressures from agriculture, urban development, and increasing population demands. A watershed land-use analysis done utilizing the LUCI model for ECW projected that Eagle Creek Reservoir - School Branch, Fishback Creek (Eagle Creek Reservoir), Eagle Creek – Long Branch/Irishman Run, Eagle Creek - Jackson Run, and Little Eagle Branch – Woodruff Branch would be more than 50% urbanized by 2040 (Tedesco *et al.*, 2003). Using 2003 Single Family Home Permits issued per township, new home building is currently focused in Eagle Creek Reservoir - School Branch, Fishback Creek (Eagle Creek Reservoir), Eagle Creek – Long Branch/Irishman Run, Eagle Creek - Jackson Run, and Little Eagle Branch – Woodruff Branch, making these subwatersheds highly susceptible to land-use perturbations and sediment loading, which threaten the sustainability of the watershed's designated uses.
- Total suspended sediment data, Adequate Buffer Assessments, Streambank Slope Analysis, Streambank Erosion Assessments, Land-use Perturbation Assessments, and Impervious Surfaces Assessments show that the watershed is susceptible to suspended sediment contamination from streambanks, cropland, construction sites, and ditches.
    - For example, Fishback Creek (Eagle Creek Reservoir) which contributed 985 lbs/acre-year of suspended sediment has adequate woody riparian buffers on only 57% of its stream, relatively steeply sloped streambanks, moderate visually assessed streambank erosion, a high level of land-use perturbation due to the transformation of farmland to suburban land-use, and impervious surfaces covering 10% of the watershed. All of these can contribute to total suspended sediment loading. All other subwatersheds show similar multiple vulnerabilities to suspended sediment loading.
    - During Spring runoff events (CIWRP 2003 data), all subwatersheds except Eagle Creek Reservoir - School Branch exceeded TSS benchmark criteria of 263 mg/L (Utah and South Dakota standard for warm water streams) for protection of aquatic life.
    - Total suspended solids load analysis showed that the combined subwatersheds of Little Eagle Branch – Woodruff Branch and Eagle Creek - Jackson Run contributed the greatest TSS load: 1,250 lb/acre-year.

- All subwatersheds are lacking adequate buffer along many of the stream reaches: Eagle Creek - Dixon Branch (80%), Little Eagle Branch – Woodruff Branch (74%), Mounts Run – Neese Ditch (71%), and Eagle Creek Reservoir - School Branch (67%) have the highest percent of stream reach with inadequate buffers.
- Streambank Slope Analysis, Streambank Erosion, and Land-use Perturbation, and Impervious Surface Assessments show that the three lower subwatersheds closest to the Reservoir (i.e., Eagle Creek – Long Branch/Irishman Run, Eagle Creek Reservoir – School Branch, and Fishback Creek (Eagle Creek Reservoir)) have the highest streambank slope, the greatest amount of streambank erosion, are most susceptible to land-use perturbation, and the highest amounts of impervious surfaces.

- Commonwealth Biomonitoring’s 2001 report showed that Fishback Creek (Eagle Creek Reservoir), Mounts Run – Neese Ditch, and Little Eagle Branch – Woodruff Branch had low biotic index values for fish or benthos, indicating that habitat in these streams was not able to support diverse fish and macroinvertebrate communities. The lack of clean-water taxa and abundances of tolerant taxa indicate that the watershed may be undergoing degradation such that it will not be capable of supporting a well-balanced, warm water aquatic community.

Table VI-20: Determination of Subwatershed Rank Score

Category 1: Level of Water Quality Degradation

Subwatershed	# Parameters	Average	Category 1 Rank
Eagle Creek - Dixon Branch	8	3.38	6
Eagle Creek - Finley Creek	11	4.64	9
Eagle Creek - Kreager Ditch	7	4.00	7
Little Eagle Branch - Headwaters	10	2.40	3
Mounts Run - Neese Ditch	11	2.00	1
Little Eagle Branch - Woodruff Branch	11	2.18	2
Eagle Creek - Jackson Run	7	2.43	4
Fishback Creek (Eagle Creek Reservoir)	11	3.09	5
Eagle Creek - Long Branch/Irishman Run	7	4.29	8
Eagle Creek Reservoir - School Branch	11	4.64	9

Category 2: Level of Vulnerability to On-going and Future Degradation

Subwatershed	# Parameters	Average	Category 2 Rank
Eagle Creek - Dixon Branch	11	5.45	5
Eagle Creek - Finley Creek	11	6.09	9
Eagle Creek - Kreager Ditch	11	5.82	7
Little Eagle Branch - Headwaters	11	4.55	3
Mounts Run - Neese Ditch	11	6.09	9
Little Eagle Branch - Woodruff Branch	11	4.73	4
Eagle Creek - Jackson Run	11	5.64	6
Fishback Creek (Eagle Creek Reservoir)	11	3.45	2
Eagle Creek - Long Branch/Irishman Run	11	5.91	8
Eagle Creek Reservoir - School Branch	11	2.91	1

Rank Score and Evaluation

Subwatershed	1 & 2 Sum	Rank Score	Evaluation* Level of Degradation	Level of Vulnerability
Eagle Creek - Dixon Branch	11	7	6 - Moderate	5 - Moderate
Eagle Creek - Finley Creek	18	10	9 - Low	9 - Low
Eagle Creek - Kreager Ditch	14	8	7 - Moderate	7 – Moderate
Little Eagle Branch - Headwaters	6	1	3 - High	3 – High
Mounts Run - Neese Ditch	10	4	1 - High	9 – Low
Little Eagle Branch - Woodruff Branch	6	1	2 - High	4 – Moderate
Eagle Creek - Jackson Run	10	4	4 - Moderate	6 – Moderate
Fishback Creek (Eagle Creek Reservoir)	7	3	5 - Moderate	2 – High
Eagle Creek - Long Branch/Irishman Run	16	9	8 - Low	8 – Low
Eagle Creek Reservoir - School Branch	10	4	9 - Low	1 – High

* 1 – 3 = High; 4 – 7 = Moderate; and 8 – 10 = Low

Table VI-21: ECW Subwatershed Rankings. Lowest ranking subwatersheds are shaded.

Category 1: Level of Water Quality Degradation											
Subwatershed	303(d)	Tier 1	Tier 2	Tier 3	Atraz.	TSS	TotN	TOC	TotP	Mac*	Fish
Eagle Creek - Dixon Branch	2	n/a	n/a	n/a	1	4	1	4	4	6	5
Eagle Creek - Finley Creek	2	4	5	1	4	5	6	5	4	8	7
Eagle Creek - Kreager Ditch	1	n/a	n/a	n/a	n/a	4	1	4	4	7	7
Little Eagle Branch - Headwaters	2	3	1	5	n/a	3	2	2	2	2	2
Mounts Run - Neese Ditch	2	1	1	1	2	4	1	4	4	1	1
Little Eagle Branch - Woodruff Branch	2	3	1	5	2	1	4	1	1	2	2
Eagle Creek - Jackson Run	2	n/a	n/a	n/a	n/a	1	4	1	1	4	4
Fishback Creek (Eagle Creek Reservoir)	2	4	5	1	5	2	3	3	3	3	3
Eagle Creek - Long Branch/Irishman Run	2	6	1	5	7	n/a	n/a	n/a	n/a	4	5
Eagle Creek Reservoir - School Branch	2	1	1	1	5	6	5	6	6	9	9

Criteria 2: Level of Vulnerability to On-going and Future Degradation												
Subwatershed	LUCI 2040	2003 Permits	Erosion	Stream Buffer	Live-stock Access	Trash	Tile/ Drain Pipe	ARB†	Imp. Surf.	NPDES	USC°	HW□
Eagle Creek - Dixon Branch	9	6	9	2	8	6	1	1	8	2	5	5
Eagle Creek - Finley Creek	6	6	7	6	8	4	10	7	7	8	5	1
Eagle Creek - Kreager Ditch	7	6	7	5	1	5	6	6	9	2	3	9
Little Eagle Branch - Headwaters	1	5	10	1	8	6	8	2	6	1	2	1
Mounts Run - Neese Ditch	7	9	9	6	1	8	3	3	10	8	5	6
Little Eagle Branch - Woodruff Branch	1	5	5	8	3	6	5	5	5	2	1	8
Eagle Creek - Jackson Run	3	3	4	8	3	9	9	8	3	2	5	7
Fishback Creek (Eagle Creek Reservoir)	3	4	1	4	3	1	4	9	4	7	4	1
Eagle Creek - Long Branch/Irishman Run	2	2	3	10	6	10	7	9	1	2	5	10
Eagle Creek Reservoir - School Branch	5	1	2	2	6	2	2	4	2	8	5	1

Shaded cells represent subwatershed that were combined in that category to determine a rank. Thus, the rank is for all highlighted subwatersheds.

* Mac = Macroinvertebrate Ranking

† Adequate Riparian Buffer Analysis done using ArcView GIS.

‡ Headwater Stream Assessment

° Unsewered Communities

□ Headwater Stream

Section VII: Development of Problem Statements and Threat Identification

Concerns and Problem Statements

The Subwatershed Assessment and ongoing watershed research and monitoring has allowed the Eagle Creek Watershed Alliance to determine the scope of each water quality concern and from those concerns develop problem statements to summarize the primary watershed concerns.

Concerns

Based on the results of the Subwatershed Assessment, five areas of primary concern have been identified. They are:

1. *E. coli* loading within the watershed exceeds acceptable levels in many areas of the watershed for considerable amounts of time. Given that *E. coli* is an indicator organism, concerns exist that other pathogens may also be present at elevated levels in the watershed. All watersheds in Eagle Creek Watershed are listed for *E. coli* impairment with the exception of School Branch (IDEM 2004 303 d List). Data is now available showing that School Branch is also impaired and will be listed in the upcoming 303d listing (J. Arthur, IDEM, personal communication). Both *Giardia lamblia* and *Cryptosporidium* are present in area streams as evidenced by measurements in Eagle Creek Reservoir (Veolia Water Indianapolis 2003 data).
2. Atrazine loading (measured as triazine) within the watershed has been shown to exceed USEPA and IAC drinking water standards in several areas of the watershed. Although drinking water standards are based on an annual average of atrazine in treated water, high atrazine loads in the watershed can pose a problem and are a concern. Given the source of triazines is agricultural applications, other herbicides, pesticides and metals may also exceed acceptable standards.
3. Sedimentation/Turbidity, low dissolved oxygen, and elevated nutrients may be causing degradation of aquatic habitats. Riparian habitats in many portions of the watershed have been degraded by stream erosion and/or loss of riparian buffer. These combinations of factors are resulting in poor habitat quality in some portions of the watershed.
4. Nutrient (nitrogen and phosphorous) loading within the watershed is frequently at or above levels that promote algal blooms in Eagle Creek Reservoir, taste and odor problems in finished drinking water and potential health risks associated with elevated nitrate in source waters and the toxins from algal blooms in both Eagle Creek Reservoir and in the drinking water supply.
5. The public’s level of understanding about and stewardship of the watershed, drinking water resources, and the value as a natural resource need to be increased.

Problem Statements

Problem:
Streams in the Eagle Creek watershed exceed the Indiana single sample daily maximum of 235 colonies per 100 milliliters for *Escherichia coli* (*E. coli*) bacteria.

Discussion:
All Eagle Creek subwatersheds, with the exception of Eagle Creek Reservoir - School Branch, are listed as impaired for *E. coli* (IDEM 2004 303d list); however, data is now available that show this subwatershed to also be impaired. Sampling of Eagle Creek subwatersheds by CEES between January 2003 and March 2005 indicated concentrations of *E. coli* exceed the Indiana single sample daily maximum of 235 colonies per 100mL at least 65% of the time based on 107 samples collected throughout the Eagle Creek watershed. A benchmark analysis prepared by CEES using 1995-2004 data from the Marion County Health Department, Eagle Creek Watershed Task Force, and the Central Indiana Water Resources Partnership showed an exceedence of the 235 CFU daily maximum between 52-100% of the times sampled. Land-use/Land-cover data assessments show that streams with high *E. coli* loads such as Dixon Branch, Little Eagle Branch – Headwaters have subwatersheds with CAFOs and unsewered communities, respectively. Additionally, windshield surveys completed in the spring of 2005 revealed that there are still areas where livestock have access to the streams. *E. coli* in water is indicative of fecal contamination by warm-blooded animals, and may also be an indicator that other pathogens are present in the water. Both *Giardia lamblia* and *Cryptosporidium* are present in area streams as evidenced by measurements in Eagle Creek Reservoir (Veolia Water Indianapolis 2003 data).

Poorly functioning septic systems and package plant operations are additional sources of *E. coli* to Eagle Creek Watershed streams. Other potential sources of *E. coli* and pathogens in the watershed include: runoff of manure applications to cropland, regulated confined feeding operations and smaller non-regulated private livestock farms.

Problem:
Concentrations of Atrazine in Eagle Creek watershed streams are resulting in elevated Atrazine levels in Eagle Creek Reservoir that exceed the USEPA standard of 3.0 ug/L (.003 mg/L) for drinking water supplies.

Discussion:
Eagle Creek Reservoir frequently exceeds the Atrazine maximum contaminant level of 3.0 ug/L for a drinking water supply (USEPA, National Primary Drinking Water Regulations; http://www.epa.gov/safewater/mcl.html#2). Although the maximum contaminant level (MCL) of 3.0 µg/L for atrazine is based on an annual average of atrazine in treated water, the importance of keeping atrazine levels low in the watershed and reservoir is recognized. Water collected from Eagle Creek Reservoir by the Indianapolis Water Company in 1996, 1998 and 2002 indicated peak levels of atrazine

typically occur between April and September. In 2002, 75% of the 111 samples collected from Eagle Creek Reservoir exceeded the drinking water standard. Calculations based on USDA 2002 chemical usage reports for corn and soybean, indicate approximately 448,100 pounds of pesticide were applied in Eagle Creek Watershed, of which 40,140 pounds and 88,250 pounds were atrazine and metolachlor, respectively (USDA, 2002). Furthermore, the windshield survey in Spring 2005 revealed that there are numerous agricultural drainage pipes discharging into the watershed streams and ditches. Adequate riparian buffer was noted to be missing in the subwatersheds, which is crucial to prevent runoff of agricultural and lawn chemicals applied to the adjacent lands from entering the streams. Grassy buffers were observed in many parts of the watershed but still lacked the acceptable width of 150’ (Kovacic, 1994) needed to remove 80% of nitrate. In 1991, the U.S. Geological Survey began the National Water Quality Assessment (NAWQA) Program to describe the status and trends in the quality of the Nation’s water resources. The USGS noted that there was a significantly greater frequency of detections and much higher concentrations of atrazine and metolachlor observed in samples of river water than groundwater (Crawford and others, 1995). Low pesticide concentrations in ground water and high concentrations in nearby stream waters suggests that pesticides may move quickly from agricultural fields to streams via tile drain discharge and surface runoff. An estimated 52% of Eagle Creek Watershed is tiled, but the number is likely higher from farmlands that were developed but still have functioning tile systems.

<u>Problem</u>:
Sediment loads in the subwatersheds of Eagle Creek are high during event flows, eventually transporting large pulses of sediment to the reservoir and potentially degrading aquatic health.

<u>Discussion</u>:
Although base flow does not contribute excessive amounts of suspended sediment in the watershed, storm events have high suspended sediment loads, particularly in the spring. Samples collected by CEES during a spring runoff event in 2003 indicate all subwatersheds exceeded the TSS benchmark criteria of 263 mg/L for protection of aquatic life, with the exception of School Branch which had 235 mg/L TSS during spring event flow. Many areas of moderate stream bank erosion in Eagle Creek Watershed were noted during the windshield survey, an indicator that these areas are sensitive to high flowing water removing the stream’s bank. Lack of adequate buffer was observed and can also influence stream bank erosion, making the banks less stable and more vulnerable. Steep slopes are another stressor and lead to higher rates of sedimentation as well as runoff. Although much of Eagle Creek Watershed has a low percent slope (mean slopes range from 0.85% in Dixon Branch to 2.43% in School Branch), some of the areas had as high as 44.12% slope (Fishback Creek). Areas of highest slope are located near the reservoir where development is rapidly occurring. More impervious surfaces are associated with development, increasing runoff and therefore, increasing discharge of the streams. Much of the suspended sediment transport occurs during pulses of higher discharge in Eagle Creek and its tributaries.

Chemicals, nutrients and other pollutants are carried with the sediment during these pulses which also threaten the stream's health. CEES studies have shown phosphorus may be bound to the suspended sediment particles. These phosphorous-laden particles are transported to the reservoir where anoxic conditions can release the bound phosphorus and become a phosphorous source for reservoir algal blooms (Pascual *et al*., 2004; Raftis *et al*., 2004).

Problem:
Nutrient concentrations in all streams in Eagle Creek watershed frequently exceed the national average for watersheds with 50-75% agricultural use.

Discussion:
Despite that Eagle Creek Watershed's land-use is 52% agricultural use, Eagle Creek Watershed streams frequently exceed nutrient concentrations that are found in US watersheds with 50-75% agriculture. Using the Total P concentration of 0.125 mg P/L, the Total N concentration of 2.75 mg N/L, and nitrate concentration of 1.0 mg N/L from the EPA's 1977 nationwide study on non-point source stream nutrients (Omernik, 1977), the streams in Eagle Creek Watershed exceed these concentrations at least 60% of the time sampled, with stations in School Branch and Irishman Run & Long Branch subwatersheds exceeding nitrate threshold more than 75% of the time sampled. Excess amounts of phosphorous and nitrogen, plant growth limiting nutrients, have detrimental affects down stream in Eagle Creek Reservoir. 2004 estimated total P and total N load entering the reservoir showed that total P load exceeds 40 metric tons/year and total N load exceeds 550 metric tons/year. These high nutrient loads spur algal blooms that adversely affect the water quality of the reservoir, a designated public water supply for over 80,000 Indianapolis residents. Nutrient concentrations in water are generally related to landuse in the upstream watershed or the area overlying an aquifer (USGS, 1996). This was demonstrated in the USGS White River Basin study that showed nitrate concentrations were low in ground water, but high is streams, indicating that the tile drains were rapidly directing nitrate into nearby streams. The 2004 detailed stream reach sampling study on School Branch and Fishback Creek Watersheds showed that portions of watersheds with intense agriculture (90 to 100 percent agriculture landcover) contribute high total P and total N loadings relative to water contribution during both eventflow and baseflow conditions, whereas stream reaches with less intense agriculture landuse showed total N and total P loading typically equals or is less than water contribution (Jackson *et al*., 2004). The study demonstrates that intense agricultural areas are loading extraneous amounts of total N and total P to streams. Additionally, all CEES studies completed from 2003 to 2004 find increased loads of phosphorous and nitrogen with increasing streamflow is consistent with nonpoint sources (Tedesco *et al*., 2003; Shrake *et al*., 2003; Shrake *et al*., 2004).

Problem:
An adequate educational outreach program is not in place to inform the residents in the Eagle Creek Watershed about their role in maintaining the overall quality of the watershed.

Discussion:
While difficult to quantify, many of the observed water quality problems in the Eagle Creek Watershed suggest that the residents do not fully understand how their actions can impact water quality. Personal contact with Boone County Health Department and the County NRCS District Conservationists confirm that no formal educational outreach programs are currently in place for the Eagle Creek Watershed community. Residents encountered during the 2003-2005 stream sampling, however, often expressed interest in knowing more about the overall state of their watershed. As development continues in the watershed, a considerable outreach effort will be required to integrate newer watershed scale practices into these areas.

Section VIII: Critical Areas Identification and Prioritization

Based on the concerns and problem statements elucidated in the previous sections, the ECWA has developed a Critical Areas Evaluation tool and created a list of Priorities for Eagle Creek Watershed. Based on the Critical Areas Evaluation, and developed Priorities, subwatersheds were chosen for best management implementation. This listing is called the Subwatershed Prioritization.

Critical Areas Identification

Citing Critical Areas was accomplished through a Critical Areas Evaluation Tool. For this evaluation, Critical Areas were defined as specific stream reaches within a subwatershed that showed a high level of water quality degradation, and/or showed a high level of vulnerability to on-going and future degradation, and were practical for remediation implementation. As water quality degradation and vulnerability are equally important in deciding remediation type, these criteria were considered equally important but not exclusive, meaning that a subwatershed with a high level of water quality degradation and vulnerability, a subwatershed with a high level of water quality but low level of vulnerability, and a subwatershed with a low level of water quality degradation but a high level of vulnerability could be designated as a Critical Area given the feasibility of remediation. Thus, Critical Areas Evaluation was determined by:

(1) the level of water quality degradation based on benchmark assessment of water quality; *and/or*
(2) the identification of land-use/land cover assessments that showed specific areas particularly vulnerable to on-going and future degradation (vulnerability); and
(3) the feasibility of remediation (Figure VIII-1).

After the first two years of implementing a best management practice cost-share program, a fourth consideration was added to the Critical Evaluation Tool. It was quickly realized that the feasibility of remediation was also affected by social acceptance and knowledge of given conservation practices and remediation techniques. To this end, demonstration sites and educational opportunities along with opportunities to monitor effectiveness of remediation practices are key to making progress with landowners or affecting land use planning into the future. Since a shortage of demonstration sites exists, an additional consideration was added into the identification of Critical Areas to help increase educational opportunities. The Criterion is as follows:

(4) The opportunity of a given geographic area, best management practice, or pollution source to serve as a key educational tool or demonstration model.

Criteria 1 and Criteria 2: Level of Degradation and Level of Vulnerability

The first two criteria, (1) the level of water quality degradation and (2) vulnerability were determined by the Subwatershed Assessment (Section VI: Subwatershed Assessment). The third criterion was determined by a Feasibility Assessment (Figure VIII-1). This method allowed the ECWA to weigh the need for remediation, the practicality of remediation, and the efficacy of remediation in determining Areas of Concern.

After Criteria 1 Evaluation to identify the major contaminants of concern and Criteria 2 Evaluation to identify possible sources of the contaminants for the subwatersheds, the ECWA discerned the feasibility of remediation. Through literature reviews of best management practices, the ECWA determined what type of remediation (e.g., fencing, increased stream buffer, created wetland, and/or education and outreach) was necessary to reduce or control the contaminant from its respective source. Once a type of remediation was selected, visual assessments were used to determine the best possible stream reach locations for the proposed remediation. Once these areas have been mapped, discussions with landowners or stakeholders will be held to determine those landowners and stakeholders most amenable to work with the ECWA to implement best management practices on their land. Therefore, while the Feasibilty Assessment is not complete as talks with landowners and stakeholders have not yet been held, the ECWA has mapped out areas for which remediation is practical and would have short-term and long-term benefits.

For example, Criteria 1 Evaluation of Fishback Creek (Eagle Creek Reservoir) showed that the major contaminants of concern for the subwatershed are *E. coli*, TSS, Total P, and Total Organic Carbon. Criteria 2 Evaluation showed that this subwatershed is vulnerable to contamination from agricultural run-off, impervious surfaces, stream bank erosion, an unsewered community, a confined animal feeding operation, tiles and/or pipe discharges directly into the stream, and land-use perturbation (Table VIII-1). Based on these contaminants of concern and the possible sources of contamination, remediation using conventional best management practices in Fishback Creek is plausible. However, best management practice implementation must be an integrated effort, comprising whole farm planning, grass strips in stream bottoms, woody riparian buffers, constructed wetlands, stormwater management, whole community planning (e.g., low impact development practices), education and outreach, and point source reductions (page 130) which require the participation of landowners and stakeholders. Therefore, while remediation in Fishback Creek is plausible, the feasibility of implementing remediation will depend upon the identification of landowners and stakeholders amenable to participating in remediation efforts.

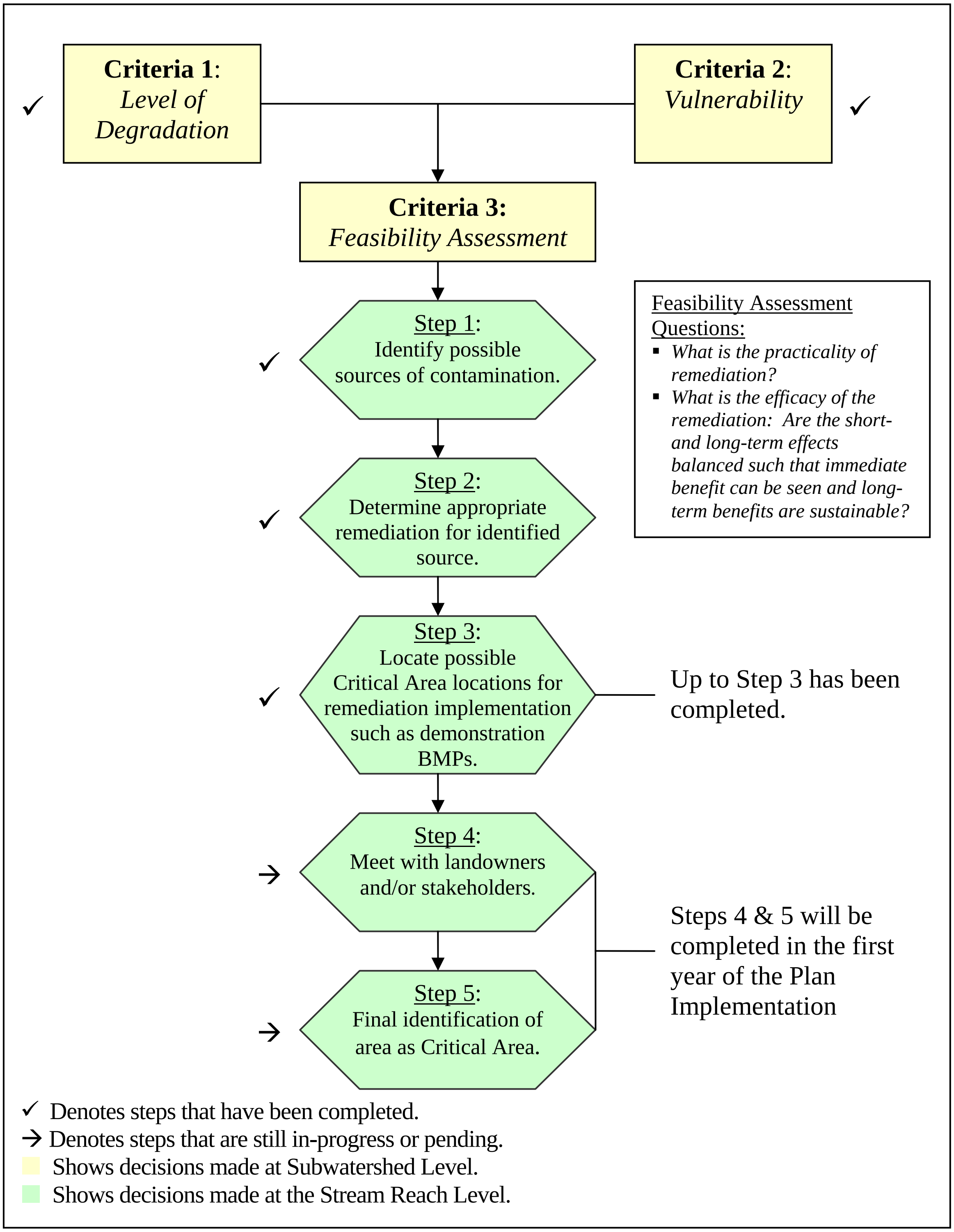


Figure VIII-1: Determination of Critical Areas Evaluation Tool (Flow Chart)

Table VIII-1: Identifying Critical Areas Based on Criteria 1 and Criteria 2

Subwatershed	Criteria 1: Level of Degradation*	Criteria 2: Vulnerability[†]	Possible Remediation Type(s)[‡]
Eagle Creek - Dixon Branch	▪ *E. coli* ▪ Atrazine (1) ▪ TSS (4) ▪ Total N (1) ▪ Total Organic Carbon (1)	▪ Agricultural Run-off (84%) ▪ An NPDES Processed Water Point Source ▪ CAFO (1) ▪ Tile and/or Pipes into Stream (9)	⇒ Whole Farm Planning ⇒ Grass Strips in Channel Bottom ⇒ Point Source Reduction ⇒ Education/Outreach ⇒ Grass and Tree Buffers ⇒ Constructed Wetlands
Eagle Creek - Finley Creek	▪ *E.coli* ▪ Atrazine (4)	▪ Agricultural Run-off (71%)	⇒ Whole Farm Planning ⇒ Grass Strips in Channel Bottom ⇒ Education/Outreach ⇒ Constructed Wetlands
Eagle Creek - Kreager Ditch	▪ *E. coli* ▪ TSS (4) ▪ Total P (4) ▪ Total N (1) ▪ Total Organic Carbon (4)	▪ Agricultural Run-off (76%) ▪ Livestock Access ▪ Unsewered Communities (2) ▪ CAFO (2) ▪ Tile and/or Pipes into Stream (6)	⇒ Whole Farm Planning ⇒ Grass Strips in Channel Bottom ⇒ Stream Protection (Fencing) ⇒ Education/Outreach ⇒ Grass and Tree Buffers ⇒ Constructed Wetlands
Little Eagle Branch - Headwaters	▪ *E. coli* ▪ TSS (3) ▪ Total P (2) ▪ Total N (2) ▪ Total Organic Carbon (2)	▪ Agricultural Run-off (70%) ▪ NPDES Sanitary Point sources (4) ▪ Unsewered Communities (2)	⇒ Whole Farm Planning ⇒ Grass Strips in Channel Bottom ⇒ Grass and Tree Buffers ⇒ Point Source Reduction ⇒ Constructed Wetlands
Mounts Run - Neese Ditch	▪ *E. coli* ▪ Atrazine (2) ▪ Total N (1) ▪ Total Organic Carbon (4)	▪ Agricultural Run-off (84%) ▪ Livestock Access ▪ Tile and/or Pipes into Stream (10)	⇒ Whole Farm Planning ⇒ Grass Strips in Channel Bottom ⇒ Education/Outreach ⇒ Grass and Tree Buffers ⇒ Stream Protection (Fencing) ⇒ Constructed Wetlands

Table VIII-1: Identifying Critical Areas Based on Criteria 1 and Criteria 2 (continued)

Subwatershed	Criteria 1: Level of Degradation*	Criteria 2: Vulnerability[†]	Possible Remediation Type(s)[‡]
Little Eagle Branch - Woodruff Branch	▪ *E. coli* ▪ Atrazine (2) ▪ TSS (1) ▪ Total P (1) ▪ Total N (4) ▪ Total Organic Carbon (1)	▪ Agricultural Run-off (54%) ▪ Impervious Surfaces (1.7 mi^2) ▪ NPDES Stormwater Run-off Point Sources (2) ▪ Tile and/or Pipes into Stream (6) ▪ Unsewered Communities (2)	⇒ Whole Farm Management ⇒ Grass Strips in Channel Bottom ⇒ Education/Outreach ⇒ Grass and Tree Buffers ⇒ Point Source Reduction ⇒ Whole Community Planning (e.g., low impact development practices and stormwater management) ⇒ Constructed Wetlands
Eagle Creek - Jackson Run	▪ *E. coli* ▪ TSS (1) ▪ Total P (1) ▪ Tot N (4) ▪ Total Organic Carbon (1)	▪ Agricultural Run-off (55%) ▪ Impervious Surfaces (2.4 mi^2) ▪ Land-use Perturbation ▪ NPDES Sanitary Point Source (2)	⇒ Whole Farm Management ⇒ Grass Strips in Channel Bottom ⇒ Education/Outreach ⇒ Tree and Shrub Buffer ⇒ Point Source Reduction ⇒ Whole Community Planning (e.g., low impact development practices and stormwater management) ⇒ Constructed Wetlands
Fishback Creek (Eagle Creek Reservoir)	▪ *E. coli* ▪ TSS (2) ▪ Total P (3) ▪ Total N (3) ▪ Total Organic Carbon (3)	▪ Agricultural Run-off (59%) ▪ Impervious Surfaces (2.1 mi^2) ▪ Stream Bank Erosion (moderate) ▪ Unsewered Community (1) ▪ CAFO (1) ▪ Tiles and/or Pipes into Stream (11) ▪ Land-use Perturbation	⇒ Whole Farm Management ⇒ Grass Strips in Channel Bottom ⇒ Grass and Tree Buffers ⇒ Education/Outreach ⇒ Point Source Reduction ⇒ Whole Community Planning (e.g., low impact development practices and stormwater management) ⇒ Constructed Wetlands

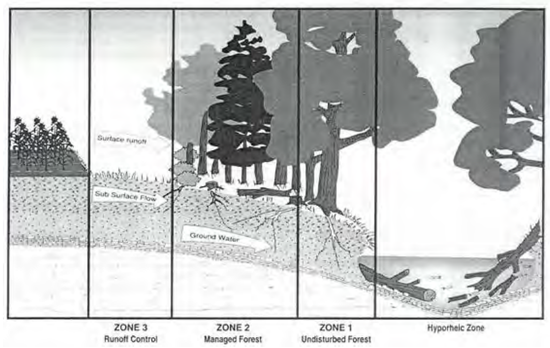
Subwatershed	Criteria 1: Level of Degradation*	Criteria 2: Vulnerability†	Possible Remediation Type(s)‡
Eagle Creek - Long Branch/Irishman Run	▪ *E. coli*	▪ Agricultural Run-off (25%) ▪ Impervious Surfaces (5.2 mi^2) ▪ Stream Bank Erosion (moderate) ▪ NPDES Sanitary Point Sources (2) ▪ Tiles and/or Pipes into Stream (6) ▪ Land-use Perturbation	⇒ Whole Community Planning (e.g., low impact development practices and stormwater management) ⇒ Whole Farm Management ⇒ Grass Strips in Channel Bottom ⇒ Education/Outreach ⇒ Grass and Tree Buffers ⇒ Point Source Reduction ⇒ Constructed Wetlands
Eagle Creek Reservoir - School Branch	▪ *E. coli*	▪ Agricultural Run-off (41%) ▪ Impervious Surfaces (3.0 mi^2) ▪ Stream Bank Erosion (moderate) ▪ Tiles and/or Pipes into Stream (7) ▪ Land-use Perturbation	⇒ Whole Community Planning (e.g., low impact development practices and stormwater management) ⇒ Whole Farm Management ⇒ Grass Strips in Channel Bottom ⇒ Education/Outreach ⇒ Grass and Tree Buffers ⇒ Constructed Wetlands

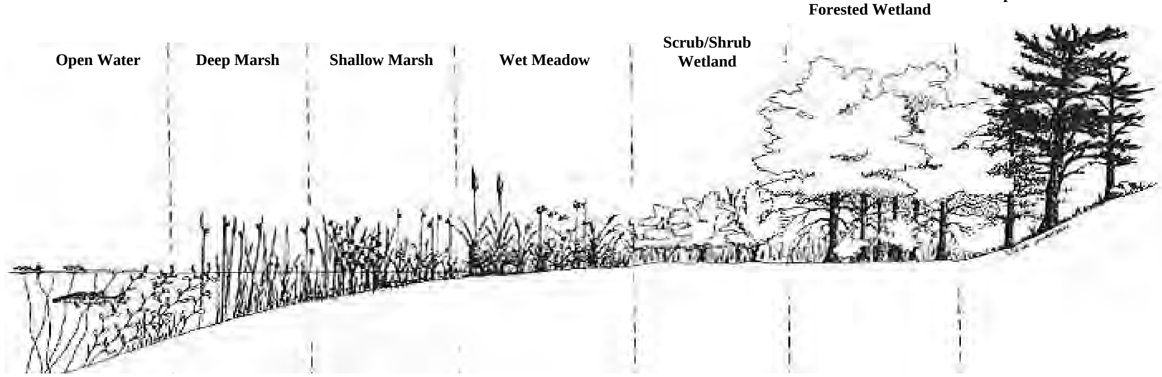
* Based on Subwatershed Assessment: All subwatersheds are listed as impaired by *E. coli* by IDEM 303(d) listings except Eagle Creek Reservoir – School Branch; however, *E. coli* concentrations in School Branch often exceed 235 CFU/100 mL (page 99). TSS, Total P, Total N, and Total Organic Carbon were listed if loads from the Subwatershed exceeded the average load for the entire Eagle Creek Watershed (Table VI-6 and Table VI-7). Parenthetical note after Atrazine, TSS, Total P, Total N, and Total Organic Carbon represents Rank for that parameter assessment.

† Based on a land-use/land cover and point source identification data. Parenthetical note after possible source refers to: % of agricultural land-use; mi^2 of impervious surfaces; number of NPDES point sources; visually assessed level of stream bank erosion; number of unsewered communities; number of CAFOs; and number of tiles and/or pipes found discharging directly into the stream.

Table VIII-1: Identifying Critical Areas Based on Criteria 1 and Criteria 2 (continued – notes)

‡ Remediation Type Explanations (Alphabetical Order)

Buffers	Buffers are areas or bands of natural or planted vegetation located between agricultural land and water bodies. These zones of permanent vegetation are generally covered with grasses or with a combination of grasses, shrubs, and trees. They help to reduce flooding, serve as areas for ground water recharge and discharge, reduce sedimentation and conserve topsoil, and retain nutrients and curb their transport into water bodies. Buffers have been shown to reduce sediment loads by 50 – 90% , Total P by 20 – 90% , Total N by 63 – 76%, Atrazine by 32% – 68%, depending on the type and width of installed buffer (Coote and Gregorich, 2000), and nitrate in subsurface flow by more than 90% in most riparian zones (Vidon and Hill, 2004).  (Reproduced from Lowrance *et al*., 1997) 
Education and Outreach	Education through public speaking, open discussions, BMP demonstrations, service programs, and literature dissemination that raises public awareness of environmental issues to promote informed environmental decision-making and stewardship, which is critical to modern urban development and community well-being. By combining research, education, and service, citizens gain the knowledge, skills and experience they need to make a positive impact on their natural surroundings.
Grass Strips in Channel Bottom (Grassy Swales)	Swales are natural or man-made low lying areas (depressions) where surface run-off collects before entering the stream. These areas intermittently flood. Planting grass or other permanent vegetation in these areas helps to slow surface water run-off from agricultural land and impervious surfaces, allowing infiltration of surface water into the ground and reducing sediment and nutrient export into streams.  Grassy swale in a corn field.
Point Source Reduction	Point source reduction is the concerted effort by users and dischargers to decrease the amount (load) of contaminants released into streams.

Stream Protection (Fencing)	Protecting the stream from livestock entails the use of physical barriers that curtail the movement of livestock into the stream. Livestock can disrupt the natural vegetation along the stream bank and increase erosion. For example, fencing is a simple barrier that decreases livestock access to the stream.  www.epa.gov/watertrain Livestock in stream.  Livestock damage to stream.
Wetlands (natural and constructed)	Wetlands are areas saturated with water for long enough periods to significantly alter soils and vegetation such that aquatic processes are the dominant factor determining the nature of soil development and the types of plant and animal communities living in the soil and on its surface (EPA Regulations listed at 40 CFR 230.3(t)). They provide wildlife habitat, act as biological filters and allow for mechanical settling and filtering which help to remove contaminants from water, recharge groundwater, augment low flow in streams and buffer against droughts, reduce risk and damage of flooding by storing water during heavy rainfall, rapid thaws, or other run-off events, and stabilize shorelines (Coote and Gregorich, 2000). Wetlands have been found beneficial in reducing nutrient and *E. coli* concentrations to flowing streams (DeBusk, 1999).
	

Whole Farm Planning	Whole farm planning is a holistic approach to farm management which encourages land stewardship and sustainable practices. These practices include conservation tillage, crop nutrient management, pest management, conservation buffers, irrigation water management, grazing management, animal feeding operations management, and erosion and sediment control. US EPA recognizes these practices as a method for water quality protection.
Whole Community Planning (Low Impact Development and Stormwater Management)	Whole community planning is a holistic approach to urban planning which encourages land stewardship and sustainable practices (also called "smart growth" strategies). These practices include a comprehensive stormwater program, such as conservation based zoning decisions; minimizing impacts before, during, and after building; protecting and maintaining natural areas (e.g., riparian buffers and wetlands) and/or restoring natural areas; directing run-off to natural areas; using small-scale controls (e.g., rain gardens, vegetated swales, cisterns, greenroofs, and amended soils for better infiltration); and pollution prevention and education. These practices are aimed at mitigating flooding and reducing pollution (Northern Virginia Regional Commission, 2005 and US EPA, 2000).

Feasibility Evaluation

The Area of Concern Evaluation has been completed to the subwatershed level for all Eagle Creek Subwatersheds (Figure VIII-1 and Table VIII-1). Results showed that remediation in all Subwatersheds must be multi-faceted as most subwatersheds had multiple (Criteria 1) contaminants of concern and multiple (Criteria 2) vulnerabilities. However Criteria 3 Feasibility evaluation to determine specific stream reaches for remediation is on-going. As feasibility is dependent upon the type of remediation, it is necessary to determine what types of remediation would result in the greatest benefit to the Watershed. As benefit is a relative measure, benefits were based on Priorities developed through stakeholder meetings. Furthermore, as location of specific remediation methods that alter the landscape (e.g. buffers, fencing, and wetlands) would determine the success of the remediation, feasibility evaluations also took into account the areas of the subwatersheds that would result in the best possible outcomes. For instance, while erosion is a source of total suspended sediments in the lower watershed, it is not always feasible to place woody riparian buffers on some lower watershed streambanks as slopes are too great to allow successful planting of woody and herbaceous plants.

Priorities

Section IX: To determine the types of remediation projects which would result in the greatest benefit to the Watershed, goals and objectives were developed based on Concerns and Problem Statements. These goals were formulated to address *E. coli*, Atrazine, Total Suspended Solids, Nutrients, and Education and Outreach issues in the Watershed. (These Goals and Objectives are explained in greater detail in Section IX: Watershed Management Goals

on page 137.)

Goals and Objectives for Eagle Creek Watershed

(1) Reduce *E. coli* load in Eagle Creek Watershed.
   a. Reduce *E. coli* load from livestock with access to streams. (ST)[9]
   b. Reduce *E. coli* load from event flow run-off. (ST)
   c. Reduce *E. coli* load from malfunctioning septic systems. (LT)[10]
   d. Reduce *E. coli* load from agricultural stormwater run-off. (LT)
   e. Reduce *E. coli* load from unsewered communities. (LT)

(2) Reduce Atrazine loads in Eagle Creek Watershed.
   a. Reduce Atrazine run-off from agricultural fields from entering the trunk streams of Eagle Creek Watershed. (ST)
   b. Reduce Atrazine usage on agricultural fields. (LT)
   c. Reduce Atrazine load from agricultural stormwater run-off. (LT)

(3) Reduce sediment loads in Eagle Creek Watershed.

[9] (ST) – Short-term Objective
[10] (LT) – Long-term Objective

a. Reduce fine-grain sediment load from headwater erosion. (ST)
b. Reduce sediment load from agricultural run-off. (ST)
c. Reduce sediment load from stormwater run-off from impervious surfaces and urbanized areas. (LT)
d. Reduce sediment load from bank erosion in lower reaches of Eagle Creek Watershed. (LT)

(4) Reduce nutrient loads in Eagle Creek Watershed.
a. Reduce nutrient load from agricultural run-off. (ST)
b. Reduce nutrient load from tile drainage. (LT)
c. Reduce nutrient load from point sources. (LT)
d. Reduce nutrient load from non-point sources other than agricultural run-off. (LT)
e. Reduce nutrient load from stormwater run-off from impervious surfaces and urbanized areas. (LT)
f. Reduce suburban and urban phosphorous lawn fertilizer application. (LT)

(5) Increase watershed education and outreach in Eagle Creek Watershed.
a. Raise public awareness of watersheds and their role in water quality. (ST)
b. Raise public awareness of watershed and water quality issues. (ST)
c. Continue to build on and expand watershed outreach activities. (LT)

As goals can be parsed into short-term (ST) and long-term (LT) objectives, priorities were developed based on timelines necessary to achieve the outcomes within a reasonable time frame. These priorities were then ranked by the amount of goals they would address: the greater number of goals an objective addressed, the higher its priority rank (Table IX-1). These priorities were then used in Criteria 3: Feasibility evaluations for the subwatersheds to determine which subwatersheds would be the focus for remediation implementation.

Table IX-1: Priorities for Eagle Creek Watershed

Rank	Priority	Goal(s)
1	Implement demonstration riparian buffers.	1, 2, 3, 4, and 5
1	Implement other demonstration best management practices (e.g., stream protection – fencing, grass strips in channel bottom, and constructed wetlands).	1, 2, 3, 4, and 5
1	Promote implementation of Whole Farm Planning.	1, 2, 3, 4, and 5
2	Develop and distribute septic system educational brochure.	1, 4, and 5
2	Promote implementation of Whole Community Planning (Low Impact Development and stormwater management).	3, 4, and 5
3	Create watershed education programs.	3 and 5
4	Work with point source dischargers to reduce nutrient loading.	4
4	Develop watershed education plan (e.g., ECWA website, semi-annual paper, activities, and Water Quality Awareness Day program).	5

Locating Sites for Remediation

Due to their inherent importance to stream ecosystem health, headwater stream vulnerability is a threat to the entire watershed's health. Therefore, remediation efforts concentrated in vulnerable headwater streams will affect and benefit the whole watershed. In Eagle Creek Watershed, subwatersheds with the most miles of headwater streams (1^{st} and 2^{nd} order streams) were compared using Criteria 1 and Criteria 2 Evaluations to determine Subwatershed Prioritization.

Subwatershed Prioritization

Based on the Critical Areas Evaluation and given the identified Priorities, subwatersheds were prioritized for remediation implementation (Table IX-2).

Table IX-2: Subwatershed Prioritization

Priority Rank	Subwatershed	Remediations
1	Little Eagle Branch – Headwaters % Headwater Streams: **100%** Level of Degradation: **High** Level of Vulnerability: **High**	(1) Promote implementation of BMPs (2) Promote Whole Farm Planning (3) Education/Outreach (specifically septic system maintenance) (4) Work with point source dischargers to reduce nutrient loading
2	Fishback Creek (Eagle Creek Reservoir) % Headwater Streams: **100%** Level of Degradation: **Moderate** Level of Vulnerability: **High**	(1) Grass and Tree Buffers (Demonstration BMP) along 1 mile on each side of stream (2) Grass Strips in Channel Bottom (Demonstration BMP) (3) Whole Farm Planning (4) Whole Community Planning (5) Education/Outreach (specifically development suspended sediment prevention and septic system maintenance) (6) Point Source Reduction (7) Constructed Wetlands
3	Mounts Run – Neese Ditch % Headwater Streams: **100%** Level of Degradation: **High** Level of Vulnerability: **Low**	(1) Grass and Tree Buffers (Demonstration BMP) along 1 mile on each side of stream (2) Fencing (Demonstration BMP) (3) Grass Strips in Channel Bottom (Demonstration BMP) (4) Whole Farm Planning (5) Whole Community Planning (6) Education/Outreach (7) Constructed Wetlands
4	Eagle Creek Reservoir – School Branch % Headwater Streams: **100%** Level of Degradation: **Low** Level of Vulnerability: **High**	(1) Grass and Tree Buffers (Demonstration BMP) along 1 mile on each side of stream. (2) Fencing (Demonstration BMP) (3) Grass Strips in Channel Bottom (Demonstration BMP) (4) Whole Farm Planning (5) Whole Community Planning (6) Education/Outreach (specifically development suspended sediment prevention)

Table IX-2: Subwatershed Prioritization (continued)

Priority Rank	Subwatershed	Remediation
5	Eagle Creek – Dixon Branch % Headwater Streams: **84%** Level of Degradation: **Moderate** Level of Vulnerability: **Moderate**	(1) Promote implementation of BMPs (2) Promote Whole Farm Planning (3) Education/Outreach (4) Work with point source dischargers and CAFO to reduce nutrient loading
6	Little Eagle Branch – Woodruff Branch % Headwater Streams: **71%** Level of Degradation: **High** Level of Vulnerability: **Moderate**	(1) Promote implementation of BMPs (2) Promote Whole Farm Planning (3) Promote Whole Community Planning (4) Education/Outreach (specifically septic system maintenance) (5) Work with point source dischargers to reduce nutrient loading
7	Eagle Creek – Jackson Run % Headwater Streams: **73%** Level of Degradation: **Moderate** Level of Vulnerability: **Moderate**	(1) Promote implementation of BMPs (2) Promote Whole Farm Planning (3) Promote Whole Community Planning (4) Education/Outreach (specifically development suspended sediment prevention) (5) Work with point source dischargers to reduce nutrient loading
8	Eagle Creek – Kreager Ditch % Headwater Streams: **68%** Level of Degradation: **Moderate** Level of Vulnerability: **Moderate**	(1) Promote implementation of BMPs (2) Promote Whole Farm Planning (3) Work with CAFOs to reduce loading (4) Education/Outreach (specifically septic system maintenance)
9	Eagle Creek – Finley Creek % Headwater Streams: **100%** Level of Degradation: **Low** Level of Vulnerability: **Low**	(1) Promote implementation of BMPs (2) Promote Whole Farm Planning (3) Education/Outreach
10	Eagle Creek – Long Branch/Irishman Run % Headwater Streams: **55%** Level of Degradation: **Low** Level of Vulnerability: **Low**	(1) Work with point source dischargers to reduce loading (2) Promote implementation of BMPs (3) Promote Whole Farm Planning (4) Promote Whole Community Planning (5) Education/Outreach (specifically development suspended sediment prevention)

Social Acceptance and Educational Opportunities

While the initial three Criteria included tangible assessments, the addition of a fourth criterion simply recognizes that not all elements of watershed planning and implementation can be based on formal analysis of physical features or feasibility of technical solutions. One of the goals for the Eagle Creek Watershed is to 'Increase Watershed Education and Outreach.' Critical Areas, as defined by this Plan, must then be flexible enough to accommodate projects that can:

- demonstrate remediation techniques in highly visible places, or

- serve as future outreach opportunities (such as tour locations) for hard to reach audiences, or
- allow for unique monitoring or educational opportunities to further understand or document scientific or engineering results.

Projects that arise serving any of these important functions will be viewed as critical to helping achieve the above stated educational goal for this Plan. When these unique opportunities present themselves they will, by their nature, define that particular location to be a Critical Area.

Section X: Watershed Management Goals

Based on the concerns and problem statements elucidated in the previous sections, a set of goals were developed. Goal achievement was parsed into short-term and long-term target outcomes with each having an associated objective, action item, and indicator(s) of success listed.

These goals listed in their order of importance are;

(1) Reduce *E. coli* loads in Eagle Creek Watershed.

Problem: Streams in the Eagle Creek Watershed exceed the Indiana single sample daily maximum of 235 colonies per 100 milliliters for *Escherichia coli* (*E. coli*) bacteria.
Short-term Target: Reduce the number of times in which streams in Eagle Creek Watershed exceed 10,000 CFU/100mL during event flow. By eliminating the number of times E. coli exceeds 10,000 CFU/100mL, the overall load will be reduced by 81%.
Long-term Target: Eliminate *E. coli* concentrations of greater than 1,000 CFU/100mL from occurring in Eagle Creek Watershed with the ultimate goal of meeting the single sample standard of 235 CFU/100 mL.

(2) Reduce Atrazine loads in Eagle Creek Watershed.

Problem: Concentrations of Atrazine in Eagle Creek Watershed streams result in elevated Atrazine levels in Eagle Creek Reservoir that exceed the USEPA standard of 3.0 ug/L (0.003 mg/L) for drinking water supplies.
Short-term Target: Reduce Atrazine concentrations in Eagle Creek Watershed streams such that concentrations of Atrazine in Eagle Creek Reservoir do not exceed 3.0 ug/L (0.003 mg/L). A total atrazine load reduction of 40% is expected when the number of times atrazine exceeds 3.0 ug/L is eliminated.
Long-term Target: Reduce application of Atrazine in Eagle Creek Watershed.

(3) Reduce sediment loads in Eagle Creek Watershed.

Problem: Sediment loads in the subwatersheds of Eagle Creek are high during event flows, eventually transporting large pulses of sediment to the reservoir and potentially degrading aquatic health.
Short-term Target; Reduce fine-grained sediment (silt and clay) loading into headwater (first order) streams in Eagle Creek Watershed.

Long-term Target: Reduce sediment loading to Eagle Creek Watershed to enhance aquatic habitats.

(4) Reduce nutrient loads in Eagle Creek Watershed.

Problem: Nutrient concentrations in all streams in Eagle Creek watershed frequently exceed the national average for watersheds with 50-75% agricultural use.

Short-term Target: Reduce stream nutrient concentrations such that Total P does not exceed 0.125 mg P/L and Total N does not exceed 2.75 mg N/L. By eliminating such exceedences, Total P loads can be reduced by 58% and Total N loads can be reduced by 36%.

Long-term Target: Reduce nutrient loading to Eagle Creek Reservoir such that reservoir trophic status reverts from its current eutrophic state to a mesotrophic state.

(5) Increase watershed education and outreach in Eagle Creek Watershed

Problem: An adequate educational outreach program is not in place to inform the residents in the Eagle Creek Watershed about their role in maintaining the overall quality of the watershed.

Short-term Target: Raise awareness of watershed and water quality issues, especially septic system maintenance, agricultural best management practices, and urban storm water management.

Long-term Target: Change attitudes and behaviors to foster environmental stewardship.

(1) Reduce *E. coli* loads in Eagle Creek Watershed.

Problem: Streams in the Eagle Creek Watershed exceed the Indiana single sample daily maximum of 235 colonies per 100 milliliters for *Escherichia coli* (*E. coli*) bacteria.

Short-term Target: Reduce the number of times that streams in Eagle Creek Watershed exceed 10,000 CFU/100mL during event flow[11].

Objective	Action Item	Stakeholders	Responsible Party	Schedule	Indicators of Success
Reduce *E. coli* load from livestock with access to streams.	Work with NRCS and SWCDs to identify partners.	Landowners with livestock	Boone Co. SWCD ECWA	Present – Year 2	✓Identification of landowners with livestock amenable to fence installation
	Install fencing	Landowners with livestock	Boone Co. SWCD ECWA	Present – Year 3	✓Miles of fencing installed ✓Visual confirmation of fewer animals with stream access.
	Monitor fencing effectiveness		ECWA	Year 2 – Year 3+	✓Reduction in the number of event flows[11] with *E. coli* concentrations higher than 10,000 CFU/100mL. ✓Creation of BMP effectiveness database.
Reduce *E. coli* load from event flow run-off.	Work with NRCS and SWCDs to identify partners.	Agricultural landowners	ECWA	Present – Year 2	✓Identification of agricultural landowners amenable to buffer installation.
	Install buffers	Agricultural landowners	ECWA	Year 1 – Year 3	✓Number of implemented buffers.
	Monitor buffer effectiveness		ECWA	Year 2 – Year 3+	✓Reduction in the number of event flows with *E. coli* concentrations higher than 10,000 CFU/100mL. ✓Creation of BMP effectiveness database.

[11] An "event" is defined as the duration of time at which discharge at the Eagle Creek Gage in Zionsville (USGS 03353200) was greater than three times the 40 year average base flow for that month

Long-term Target: Eliminate *E. coli* concentrations of greater than 1,000 CFU/100mL from occurring in Eagle Creek Watershed.

Objective	Action Item	Stakeholders	Responsible Party	Schedule	Indicators of Success
Reduce *E. coli* load from malfunctioning or absent septic systems. Reduce *E. coli* load from unsewered communities.	Determine the number of un-sewered areas near stream	Landowners with septic systems or no waste disposal system	ECWA County Health Departments	Present – Year 3	✓Creation of a map showing the location of unsewered areas in Eagle Creek Watershed.
	Develop an educational brochure and distribute throughout the watershed.	Landowners throughout the watershed Septic maintenance businesses	ECWA County Health Departments	Year 2 – Year 3+	✓Number of educational packets distributed. ✓Number of attendees to educational events.
	Eliminate failing septic systems and sewer un-sewered areas.	Landowners Rural Community Assistance Program	County Health Departments Indiana Community Action Association	Year 3+	✓Number of un-sewered homes sewered. ✓Number of rehabilitated septic sytems. ✓Reduction in *E. coli* concentrations greater than 1,000 CFU/100mL.
Reduce *E. coli* load from agricultural stormwater run-off.	Work with NRCS and SWCDs to increase whole farm planning practices	Agricultural landowners	ECWA SWCDs	Year 1 – Year 3+	✓Increase in the amount of agricultural fields using whole farm practices..

(2) Reduce Atrazine loads in Eagle Creek Watershed.

Problem: Concentrations of Atrazine in Eagle Creek Watershed streams result in elevated Atrazine levels in Eagle Creek Reservoir that exceed the USEPA standard of 3.0 ug/L (0.003 mg/L) for drinking water supplies.

Short-term Target: Eliminate Atrazine concentrations in Eagle Creek Watershed streams such that concentrations of Atrazine in Eagle Creek Reservoir do not exceed 3.0 ug/L (0.003 mg/L).

Objective	Action Item	Stakeholders	Responsible Party	Schedule	Indicators of Success
Reduce Atrazine run-off from agricultural fields from entering the trunk streams of Eagle Creek Watershed.	Work with Boone Hendricks, and Hamilton SWCDs to identify partners	Agricultural landowners	ECWA	Year 1 – Year 2	✓Identification of landowners amenable to accommodating BMP implementation.
	Provide cost-sharing-funding, education, and demonstration projects (e.g., buffers, constructed wetlands, and controlled drainage).	Landowners throughout the watershed	ECWA	Year 1 – Year 3+	✓Miles of installed buffers or enhanced buffers. ✓Area of land rededicated to wetland land-use.
	Monitor effectiveness of demonstration projects.		ECWA	Year 2 – Year 3+	✓Reduction in Atrazine loading to Eagle Creek Reservoir. ✓Creation of BMP effectiveness database.
	Work with NRCS and SWCDs to increase the use of Whole Farm Planning practices.	Agricultural landowners	ECWA	Year 1 – Year 3+	✓Increase in the amount of agricultural fields using Whole Farm Planning practices.

Long-term Target: Reduce application of Atrazine in Eagle Creek Watershed.

Objective	Action Item	Stakeholders	Responsible Party	Schedule	Indicators of Success
Reduce Atrazine usage on agricultural fields.	Identify specific agricultural landowners using Atrazine and the quantities they use	Agricultural landowners	SWCD	Year 3+	✓ Development of Atrazine application rates specific to agricultural land in Eagle Creek Watershed.
	Monitor Atrazine Application	Agricultural landowners	ECWA	Year 3+	✓ Creation of Atrazine application database
	Work with NRCS to determine feasible alternatives to Atrazine	Agricultural landowners	ECWA	Year 3+	✓ Inclusion of information into educational brochure, educational programs. ✓ Increase in the amount of agricultural fields using whole farm practices.
	Develop brochure on Atrazine application	Agricultural landowners	ECWA	Year 2 – Year 3+	✓ Number of educational brochures distributed. ✓ Number of meetings with agricultural landowners. ✓ Reduction in Atrazine application
Reduce Atrazine load from agricultural stormwater run-off.	Work with NRCS and SWCDs to increase whole farm planning practices	Agricultural landowners	ECWA SWCDs	Year 1 – Year 3	✓ Increase in the amount of agricultural fields using whole farm practices.

(3) Reduce sediment loads in Eagle Creek Watershed.

Problem: Sediment loads in the subwatersheds of Eagle Creek are high during event flows, eventually transporting large pulses of sediment to the reservoir and potentially degrading aquatic health.

Short-term Target: Reduce fine-grained sediment (silt and clay) loading into headwater (first order) streams in Eagle Creek Watershed.

Objective	Action Item	Stakeholders	Responsible Party	Schedule	Indicators of Success
Reduce fine-grain sediment load from headwater erosion.	Work with NRCS, SWCDs and County Drainage Board to identify partnerships	Agricultural landowners, NRCS, SWCDs, County Drainage Board	ECWA SWCDs NRCS	Present – Year 2+	✓Development of common goals between NRCS, County Drainage Board, and ECWA. ✓Identification of landowners amenable to buffer installation.
	Quantify extent of headwater erosion	Landowners throughout the watershed	ECWA	Present – Year 1	✓Development of a detailed baseline map showing headwater erosion.
	Provide cost-sharing-funding, education, and demonstration projects (e.g. buffers and fencing)	Landowners throughout the watershed	ECWA	Year 1 – Year 3	✓Number of implemented buffers. ✓Miles of fencing installed. ✓Visual confirmation of fewer animals with stream access and less animal-caused bank erosion.
	Monitor effectiveness of demonstration projects.		ECWA	Year 2 – Year 3+	✓Reduction in total suspended sediment loading ✓Creation of BMP effectiveness database.
Reduce sediment load from agricultural run-off.	Work with NRCS and SWCDs to increase conservation tillage practices.	Agricultural landowners	ECWA SWCDs	Year 1 – Year 3+	✓Increase in the amount of agricultural fields using conservation tillage practices.

Long-term Target: Reduce sediment loading to Eagle Creek Watershed to enhance aquatic habitats.

Objective	Action Item	Stakeholders	Responsible Party	Schedule	Indicators of Success
Reduce sediment load from stormwater run-off from impervious surfaces and urbanized areas.	Promote whole community planning and begin storm drain marking.	Homeowners	ECWA	Year 1 – Year 3+	✓Implemented whole community planning practices. ✓Number of marked storm drains
Reduce sediment load from bank erosion in the lower reaches of Eagle Creek Watershed.	Create and deliver watershed education programs.	Schools, Homeowners, Park Patrons, and Developers	IndyParks, Veolia Water CEES, ECWA	Present – Year 3	✓Number of educational events held. ✓Attendance at educational events.
	Work with developers to ensure that sediment traps are being used and are properly functioning.	Developers and Homeowners	ECWA, Co. Commissioners, NRCS, SWCDs, IN Green Building Council	Present – Year 3+	✓Visual Assessments HHEI and QHEI scores. ✓Number of developers that agree to participate.
	Develop sustainable development practices	Developers and Homeowners	County Commissioners, NRCS, SWCDs, ECWA, Indiana Green Building Council	Present – Year 3+	✓Development of common goals between land developers, Indiana Green Building Council and ECWA ✓Number of developments using sustainable development practices.

(4) Reduce nutrient loads in Eagle Creek Watershed.

Problem: Nutrient concentrations in all streams in Eagle Creek watershed frequently exceed the national average for watersheds with 50-75% agricultural use.

Short-term Target: Reduce stream nutrient concentrations such that Total P does not exceed 0.125 mg P/L and Total N does not exceed 2.75 mg N/L.

Objective	Action Item	Stakeholders	Responsible Party	Schedule	Indicators of Success
Reduce nutrient loads from agricultural run-off.	Work with NRCS and SWCDs to identify partners	Agricultural landowners	ECWA	Present – Year 1	✓ Identification of agricultural landowners amenable to buffer and/or wetland installation.
	Work with NRCS and SWCDs to educate agricultural landowners to reduce fertilizer applications and/or change fertilizer application practices.	Agricultural landowners	ECWA	Present – Year 1	✓ Decrease in the amount of agricultural fertilizers applied in Eagle Creek Watershed and/or improve fertilizer retention on farms. ✓ Increase in the amount of farms with developed and implemented Whole Farm management.
	Work with NRCS to increase conservation tillage practices.	Agricultural landowners	ECWA	Present – Year 3	✓ Increase in the amount of agricultural fields using conservation tillage practices.
	BMP installation	Agricultural and Residential landownders	ECWA	Year 2 – Year 3+	✓ Number of BMPs installed.

Long-term Target: Reduce nutrient loading to Eagle Creek Reservoir such that reservoir trophic status reverts from its current eutrophic state to a mesotrophic state.

Objective	Action Item	Stakeholders	Responsible Party	Schedule	Indicators of Success
Reduce nutrient load from tile drainage.	Work with NRCS and SWCDs to increase controlled drainage practices	Agricultural landowners	ECWA SWCDs	Year 3+	✓Increase in the amount of agricultural fields using controlled drainage practices.
Reduce nutrient load from point sources.	Work with point source dischargers to determine feasibility of load reductions.	Point source Dischargers	ECWA	Year 3+	✓Number of meetings with Point Source Dischargers and CAFOs[12]. ✓Determination of feasible goals ✓Implementation of possible reductions.
Reduce nutrient load from non-point sources other than agricultural run-off.	Identify partners	Landowners throughout the watershed	ECWA	Present – Year 2	✓Identification of landowners amenable to buffer installation.
	Provide cost-sharing-funding, education, and demonstration projects	Landowners throughout the watershed	ECWA	Year 1 – Year 3	✓Number of installed buffers or enhanced buffers.
	Monitor effectiveness of demonstration projects.		ECWA	Year 2 – Year 3+	✓Reduction in nutrient loading ✓Creation of BMP effectiveness database.
Reduce nutrient load from stormwater run-off from impervious surfaces and urbanized areas.	Promote whole community planning and begin storm drain marking.	Homeowners	ECWA	Year 1 – Year 3	✓Implemented whole community planning practices. ✓Number of marked storm drains
					✓

[12] CAFO = Confined Animal Feeding Operation

Long-term Target: Reduce nutrient loading to Eagle Creek Reservoir such that reservoir trophic status reverts from its current eutrophic state to a mesotrophic state (continued).

Objective	Action Item	Stakeholders	Responsible Party	Schedule	Indicators of Success
Reduce suburban and urban lawn phosphorous fertilizer application.	Begin education and outreach program regarding sustainable fertilizer use.	Landowners throughout the watershed	ECWA	Year 3+	✓Initiation open discussions regarding future reductions and eventual elimination of phosphorous lawn fertilizers applications. ✓Eventual increase in landowners and homeowners using non-phosphorous and low-phosphorus fertilizers.

(5) Increase watershed education and outreach in Eagle Creek Watershed

Problem: An adequate educational outreach program is not in place to inform the residents in the Eagle Creek Watershed about their role in maintaining the overall quality of the watershed.

Short-term Target: Raise awareness of watershed and water quality issues, especially septic system maintenance, agricultural best management practices, and urban storm water management.

Objective	Action Item	Stakeholders	Responsible Party	Schedule	Indicators of Success
Educate farmers on Whole Farm Planning practices.	Work with NRCS and SWCDs to increase Whole Farm Planning implementation and controlled drainage practices.	Agricultural landowners	ECWA SWCDs	Year 1 – Year 3+	✓Increase in the amount of farmers using Whole Farm Planning and controlled drainage practices.
Raise public awareness of watersheds and their role in water quality.	Install watershed identification signs and storm drain markers for watershed education.	All residents in the Watershed	ECWA	Present – Year 3+	✓Number of signs installed. ✓Number of storm drains marked.
Raise public awareness of watershed and water quality issues.	Create a web site for the ECWA	All residents in the Watershed	ECWA	Present – Year 2	✓Number of hits on the website.
	Establish a semi-annual paper and electronic newsletter	All residents in the Watershed	ECWA	Present – Year 3+	✓Number of residents receiving newsletter.
	Create education materials and activities	All residents in the Watershed	ECWA Watershed Parks Schools, IndyParks	Present – Year 3+	✓Number of educational materials distributed ✓Number of outreach events hosted.
	Watershed and Water Quality Awareness Day program	All Residents in the Watershed	ECWA, Hoosier River Watch	Year 2 – Year 3	✓Number of residents attending event

Long-term Target: Change attitudes and behaviors to foster environmental stewardship.

Objective	Action Item	Stakeholders	Responsible Party	Schedule	Indicators of Success
Continue to build on and expand watershed outreach activities.	Create and install watershed exhibits and educational programs at Eagle Creek Park Nature Center	Eagle Creek Park, Park Visitors	ECWA Eagle Creek Park	Year 2 - Year 3+	✓ An increase in environmental stewardship.

Section XI: Watershed Management Plan Implementation

The overall goal of the Eagle Creek Watershed Alliance is to improve water quality in the Eagle Creek Watershed. Given the rapid rate of urbanization in the watershed, without significant investment in watershed Best Management Practices and education and outreach programs, it is likely that water quality will continue to degrade. Our ultimate goal is to have Eagle Creek Watershed meet state water quality standards, reduce nutrient loads to the point that Eagle Creek Reservoir's trophic status can be improved to mesotrophic with an associated decrease in algal blooms, and improve both riparian and aquatic habitat so that macroinvertebrates and fish populations native to the watershed can thrive.

To achieve these water quality goals and maintain them in a sustainable fashion, the Eagle Creek Watershed Alliance envisions a multi-pronged approach to water resource sustainability. The first approach is through a series of watershed Best Management Practices and associated demonstration projects. BMP installation projects will be implemented throughout Eagle Creek Watershed, with concentrated efforts focused in Little Eagle Branch – Headwaters, Fishback Creek (Eagle Creek Reservoir), Mounts Run – Neese Ditch subwatersheds, and Eagle Creek Reservoir – School Branch.

Water Quality Action Register

Water quality improvement will focus on load reductions (Goals 1 – 4). As the majority of loading for most contaminants in most subwatersheds occurred during event flows, a reduction in the number of times event flow contaminant concentration exceeds water quality indicator thresholds should result in a decrease in the contaminant load and an improvement in watershed water quality. Therefore, water quality improvement in Eagle Creek Watershed focuses on restoring natural stream water filters (riparian buffers) and, ultimately, wetlands. Both of these remediations should slow and/or reduce water run-off to streams and remove *E. coli*, pesticides and herbicides, sediment, and nutrient from the water before the water enters the stream. Water quality improvement will also be achieved through source reductions: reducing sediment load from livestock facilitated bank erosion through the installation of fencing along stream corridors, reducing agricultural chemical usage and run-off through the promotion of Whole Farm Planning, and reducing nutrient load from point sources through cooperative initiatives and improved technology. An action register for implementation details the plan for water quality improvements (Table XI-1).

Education and Outreach Action Register

Concomitant with the *in-situ* remediation projects, several complimentary watershed education projects will be initiated (Goal 5). These will include:

(1) Establishing a Water Quality Awareness Day of watershed-wide water quality testing. The project will be coordinated through CEES' environmental service learning program in partnership with DNR's Hoosier Riverwatch program and the World Water Quality Monitoring Day.
(2) Creating and delivering watershed education programs in cooperation with Indy Parks Hub Naturalist Program and Veolia Water's Watershed Initiative. Education and outreach specialists from Indy Parks, Veolia Water, CEES, and the watershed coordinator will create program materials and partner in program delivery. This program will target schools, homeowner groups, park patrons, and developers in an effort to prevent further degradation of resources.
(3) Raising awareness about watersheds through watershed informational signage at a subset of the 44 major roadway stream crossings in Eagle Creek Watershed. The watershed coordinator and ECWA will work with state, city and county departments of transportation to install signs identifying the stream reach and the watershed name.
(4) Encouraging septic system maintenance through the creation of a septic system information campaign. This program will disseminate information in the form of brochures to homeowners and businesses that service septic systems. The watershed coordinator, ECWA, and county boards of health will work together to educate septic system owners on problems with malfunctioning septic systems and maintenance requirements, ensuring that homeowners are informed and in compliance with septic system regulations adopted by Indiana in 1990 (Rule 410 IAC 6-8.1)
(5) Promoting watershed stewardship by creating and distributing a set of watershed and NPS pollution informational brochures for the general public that address the scope of the problem and the role of the individual in reducing water quality impacts. Distribution will be via mailings, educational program offerings, county park entrance stations and nature centers, libraries, and businesses catering to recreational users. Additional educational materials will be created for the new nature center at Eagle Creek Park via ongoing educational program development.
(6) Increasing the availability of watershed water quality data, issues, and events by upgrading and maintaining an enhanced web presence for the alliance and reestablishing a semi-annual watershed newsletter.
(7) Developing relationships that foster corporate and group stewardship by offering and promoting workshops to developers, planners and homeowners associations focused on the economic value of wetlands and the use of wetlands for watershed management.

An action register for implementation details the plan for education and outreach efforts (Table XI-1).

Table XI-1: Action Register

Timelines (Start/Finish)	Description	Participants	Cost*	Goal(s)
2002-2005+ (pre-grant)	▪ Monitor water quality and land-use/land cover changes in the Watershed (on-going throughout grant period).	CEES, ECWTF, and VWI	100k	n/a
2004 – 2005 (pre-grant)	▪ Assess water quality degradation in the Watershed and determine possible contaminant sources.	CEES and ECWTF	20k	n/a
2004 – 2005 (pre-grant)	▪ Complete update of watershed plan ▪ Enhance Eagle Creek Watershed Alliance (ECWA) partnerships and stakeholder involvement ▪ Begin quarterly ECWA meetings	CEES and ECWTF	20k	n/a
2005 – 2007? (pre-grant)	▪ Partner with IDEM on Eagle Creek EPA Region V Accountability Pilot.	ECWA and IDEM	NA	1, 2, 3, and 4
9/2005 – 12/2005	▪ Create and fill position of Watershed Coordinator. Funded for 3 years.	CEES	134k	1, 2, 3, 4, and 5
9/2005 -12/2005	▪ Create and fill position of "Farmer Promoter." Funded for 3 years.	Coordinator and Boone County SWCD	26k	1, 2, 3, 4, and 5
1/2006	▪ Write first interim report	Coordinator	n/a	n/a
1/2006 – 3/2006+	▪ Launch new website and create connectivity to WINS (on-going updates)	CEES and ECWTF	10k	5
1/2006	▪ Create educational and technical subcommittees for ECWA	ECWA	n/a	5
1/2006 – 3/2006+	▪ Hold quarterly education subcommittee meetings and begin production of educational materials (on-going throughout grant period)	ECWA Education Subcommittee	n/a	5
1/2006 – 3/2006	▪ Hold quarterly technical subcommittee meetings, identify targets (e.g., number and location of unsewered homes and failing septic systems) for education and outreach, and assist in EPA Region V Accountability Pilot (on-going throughout grant period).	Coordinator, Farm Promoter, ECWA Technical Subcommittee, NRCS, and SWCD	n/a	1, 2, 3, 4, and 5
1/2006 – 3/2006 1/2006 – 3/2006+	▪ Complete Criteria 3 Feasibility Evaluation for Critical Areas by identifying landowners and stakeholders amenable to BMP installation (e.g., buffers and fencing) ▪ Promote BMPs and whole farm planning to reduce use of agricultural chemicals and increase no-till tillage practices (on-going throughout grant period).	Farm Promoter, Coordinator, ECWA Technical Subcommittee, County Drainage Boards, NRCS, and SWCD	5k 50k	1, 2, 3, 4, and 5
4/2006 – 11/2006+	▪ Implement demonstration BMPs in Fishback (Eagle Creek Reservoir), Mounts Run – Neese Ditch, and Eagle Creek Reservoir – School Branch subwatersheds: grass and tree riparian buffer projects and fencing.	Farm Promoter, Coordinator NRCS HHRC&D, and CEES	300k	1, 2, 3, 4 and 5

Table XI-1: Action Register (continued)

Timelines (Start/Finish)	Description	Participants	Cost*	Goal(s)
4/2006 – 6/2006+	▪ Initiate on-going BMP monitoring and evaluation program	CEES	50k	1, 2, 3, and 4
4/2006 – 6/2006	▪ Work with land developers to promote proper sediment trap usage.	Coordinator and developers	5k	3
7/2006 – 6/2006	▪ Identify and build relationships with point source dischargers to encourage load reductions	Coordinator	5k	4
7/2006 – 6/2006+	▪ Install watershed educational displays in Eagle Creek Park Nature Center ▪ Begin production of watershed educational materials (such as ECWA newsletter) and prepare for Water Quality Awareness Day, public watershed meetings, watershed and BMP tours, field demonstrations, and other community events such as county fairs (on-going throughout grant period).	CEES, Coordinator, ECWA Education Subcommittee, IndyParks	300k 40k	5
7/2006	▪ Write second interim report	Coordinator	n/a	5
7/2006 – 12/2006	▪ Implement watershed signage program	Coordinator, Indiana Dept. of Transportation	5k	5
1/2007	▪ Write third interim report	Coordinator	n/a	5
1/2007 – 3/2007	▪ Begin production of septic system informational brochures and compile mailing lists of homeowners with septic systems. ▪ Prepare Wetland Workshop.	Coordinator, ECWA Educational Subcommittee, County Health Departments	10k 28k	1, 4, and 5
4/2007 – 6/2007+	▪ Distribute septic system brochures (on-going throughout grant period).	Coordinator, ECWA Educational Subcommittee, County Health Departments	5k	1 and 5
7/2007	▪ Write fourth interim report	Coordinator	n/a	5
7/2007 – 9/2007	▪ Prepare Phase II implementation grant	Coordinator and ECWA	n/a	n/a
10/2007 – 12/2007	▪ Present program results to Upper White River Watershed Alliance Annual Meeting	Coordinator	n/a	5

Table XI-1: Action Register (continued)

Timelines (Start/Finish)	Description	Participants	Cost*	Goal(s)
1/2008	▪ Write fifth interim report	Coordinator	n/a	5
1/2008 – 3/2009	▪ Present results to Upper White River Watershed technical committee	Coordinator and Farm Promoter	n/a	5
4/2008 – 6/2008	▪ Evaluate program	Coordinator, Farm Promoter, and ECWA	n/a	n/a
7/2008 – 9/2008	▪ Write final report.	Coordinator	n/a	5
2008+	▪ Constructed Wetlands plan development and installation	Coordinator, Farm Promoter, ECWA Technical Subcommittee, CEES	1.0 mil	1,2,3, and 4
2008+	▪ Stream Restoration plan development, initiation, and implementation for 50% of headwater streams (~100 miles of stream): - Bank Stabilization (20k/mile)° - Channel Rehabilitation (20k/mile)° - Riparian Reforestation (20k/mile)°	Coordinator, Farm Promoter, ECWA Technical Subcommittee, and CEES	 200k 200k 200k	1,2,3, and 4
2008+	▪ Sustainable Development plan development, initiation, and implementation.	Coordinator, ECWA Technical Subcommittee, and ECWA Educational Subcommittee	150k	1,2,3,4, and 5
2008+	▪ Wetland Workshops plan development, initiation, and implementation.	Coordinator, ECWA Educational Subcommittee, and CEES	112k	5
2008+	▪ Stormwater Management plan development, initiation, and implementation.	Coordinator, ECWA Technical Subcommittee, and ECWA Educational Subcommittee	150k	1,2,3, and 4
2008+	▪ Whole Farm Management plan development, initiation, and implementation.	Coordinator, Farm Promoter, and ECWA Educational Subcommittee	150k	1,2,3, and 4

* k = $1,000

° Blair, 2004. Costs adjusted for Indiana topography and hydrology.

Section XII: Monitoring Indicators

Success in Watershed Planning requires a long-term, multi-faceted, and integrated approach, involving the dedicated involvement of all stakeholders: citizens, landowners, managers, researchers, and businesses that depend on a healthy watershed. Measuring success, therefore, involves tracking several indicators which have been divided into two major categories: Water Quality Improvements (Goals 1 – 4) and Education and Outreach Achievements (Goal 5). While these two categories are not exclusive – benefits from one will affect the other, they are separated for clarity.

Measuring Water Quality Improvements (Goals 1 – 4)

Water quality improvements will be measured using two categories of indicators: Administrative and Ground Truth Indicators.

Administrative Indicators of Success

Administrative Indicators of success track the successful development of an infrastructure for improving water quality in the Watershed. This includes locating areas for best management practice implementation, contacting homeowners amenable to best management practice implementation, and installing best management practices.

Ground Truth Indicators of Success

Ground Truth Indicators of success track the successful improvement of water quality in the Watershed. The success of implemented best management practices will be measured mainly by monitoring water quality (Criteria 1) and documenting changes in land-use/land cover (Criteria 2) in the subwatersheds. Water quality monitoring will begin soon after Criteria 3 Feasibility evaluations have been completed and specific stream reaches have been identified as Critical Areas. This will give the ECWA a baseline (or before remediation) data. Monitoring will continue after installation of the recommended best management practices. While monitoring efforts will focus on Contaminants of Concern, namely, *E. coli*, Atrazine, Total Suspended Solids, and nutrients (Total P, Total N, and Total Organic Carbon), several other water quality parameters will be measured in the streams. These include nitrate, ortho-P, chloride, and dissolved organic carbon. *In-situ* water quality parameters such as pH, dissolved oxygen, conductivity, specific conductance, temperature, total dissolved solids, and salinity will be measured with a YSI multiparameter probe. At the time of sample collection, stream discharge will be measured with a Doppler flow meter while continuously measuring level loggers positioned near the implementation site will record continuous stream stage. These data will allow for the calculation of contaminant loads in the stream and a determination of longitudinal changes in water quality before and after best management implementation.

To determine how effective the implemented best management practice is at reducing contaminants, riparian zone efficiency will be monitored using wells and piezometers placed along a transect of the riparian zone (Vidon and Hill, 2004b). Water samples from these wells will be measured for contaminants (e.g., nitrate, ortho-P, Total P, sulfate, and chloride), water quality parameters such as pH, conductivity, specific conductance, temperature, total dissolved solids, and salinity which will be measured using a YSI multiparameter probe, and dissolved oxygen which will be measured using a Hanna DO meter. These data will be used to determine how efficient riparian zone best management practices are at removing contaminants of concern and will help to guide future decisions on best management practice implementation in the Watershed.

Goal 1: Reduce E. coli loads in Eagle Creek Watershed to meet water quality standards.

Objective 1: Reduce *E. coli* load from livestock with access to streams.

Indicator	How Tracked	Responsible Party
◆ Sufficient number of landowners amenable to fencing installation.	Create a list of landowners whose land overlaps a Critical Area and maintain a list of partners and possible partners.	Coordinator and Farm Promoter
◆ Miles of fencing installed.	Track length of fencing purchased and length of fencing installed in Critical Areas.	Coordinator and Farm Promoter
▸ Reduction in sites with animal access to stream.	Compare before and after visual assessments of sites with animal access to stream.	Coordinator
▸ Reduction in number of event flows with *E.coli* concentrations higher than 10,000 CFU/100 mL.	Event flow water quality sampling upstream and downstream of cited fencing installation to track *E. coli* concentrations will begin as soon as the Critical Area is determined and will be maintained as long as funding is available. These data will be used to create a best management practice database for Eagle Creek Watershed and for further scientific research on and publication.	CEES Research Scientists

◆ Water Quality Administrative Indicator of Success
▸ Water Quality Ground Truth Indicator of Success

Objective 2: Reduce *E. coli* load from event flow run-off.

Indicator	How Tracked	Responsible Party
◆ Sufficient number of landowners amenable to buffer installation.	Create a list of landowners whose land overlaps a Critical Area and maintain a list of partners and possible partners.	Coordinator, Farm Promoter and SWCDs
◆ Number of implemented buffers and a decrease in the amount of stream bank with inadequate riparian buffers.	Document the area of stream bank land converted from inadequate buffer to adequate buffer	Coordinator and CEES Research Scientists
▸ Reduction in number of event flows with *E.coli* concentrations higher than 10,000 CFU/100 mL.	Event flow sampling upstream and downstream of cited fencing installation to track *E. coli* concentrations and loads will begin as soon as the Critical Area is determined and will be maintained as long as funding is available. These data will be used to create a best management practice database for Eagle Creek Watershed and for further scientific research and publication..	CEES Research Scientists, Veolia Water Indianapolis, and Coordinator

◆ Water Quality Administrative Indicator of Success
▸ Water Quality Ground Truth Indicator of Success

Objective 3: Reduce *E. coli* load from malfunctioning septic systems

Indicator	How Tracked	Responsible Party
◆ Location of unsewered areas in Watershed.	Create a timeline toward the development of a map showing the location of the unsewered areas and a list of addresses of homes with septic systems.	Coordinator and ECWA Technical Subcommittee
◆ Reduction in the number of malfunctioning septic systems.	Document the number of homes whose septic systems have been improved due to education and outreach efforts.	Coordinator and ECWA Education Subcommittee
▸ Reduction in *E. coli* concentrations greater than 1,000 CFU/100mL.	Continued water quality monitoring of stream reaches upstream and downstream of unsewered communities for *E. coli* concentrations.	CEES Research Scientists, Veolia Water Indianapolis, and Coordinator
■ Development of septic system informational brochure and the number of copies printed and distributed to the public.	Document the number of copies printed and disseminated.	Coordinator and ECWA Education Subcommittee
■ Number of attendees to educational events.	Document the number of attendees at educational events.	Coordinator and ECWA Education Subcommittee

◆ Water Quality Administrative Indicator of Success
▸ Water Quality Ground Truth Indicator of Success
■ Education and Outreach Indicator of Success

Objective 4: Reduce *E. coli* load from agricultural stormwater run-off.

Indicator	How Tracked	Responsible Party
◆ Increase in the amount of agricultural fields using Whole Farm Planning practices.	Document the number of farmers who have adopted Whole Farm Planning practices	Farm Promoter, SWCDs, ECWA Education Subcommittee, and Coordinator
▸ Reduction in *E. coli* concentrations greater than 1,000 CFU/100mL.	Continued water quality monitoring of stream reaches upstream and downstream of agricultural land-uses for *E. coli* concentrations.	CEES Research Scientists, Veolia Water Indianapolis, and Coordinator

◆ Water Quality Administrative Indicator of Success
▸ Water Quality Ground Truth Indicator of Success

Goal 2: Reduce Atrazine loads in Eagle Creek Watershed.

Objective 1: Reduce Atrazine run-off from agricultural fields from entering the trunk streams of Eagle Creek Watershed.

Indicator	How Tracked	Responsible Party
◆ Sufficient number of landowners amenable to buffer and/or constructed wetland installation.	Create a list of landowners whose land overlaps a Critical Area and maintain a list of partners and possible partners.	Coordinator, Farm Promoter and SWCDs
◆ Number of implemented buffers and a decrease in the amount of stream bank with inadequate riparian buffers.	Document the area of stream bank land converted from inadequate buffer to adequate buffer. Document the number of projects initiated and completed.	Coordinator and CEES Research Scientists
◆ Increase in the amount of agricultural fields using Whole Farm Planning practices.	Document the number of farmers who have adopted Whole Farm Planning practices	Farm Promoter, SWCDs, ECWA Education Subcommittee, and Coordinator
▸ Reduction in Atrazine loading to Eagle Creek Reservoir	Continued monitoring of Atrazine concentrations and loads upstream and downstream of the cited riparian buffer and/or constructed wetland installation will begin as soon as the Critical Area is determined and will be maintained as long as funding is available. These data will be used to create a best management practice database for Eagle Creek Watershed and for further scientific research and publication. Continued monitoring of Atrazine concentrations in Eagle Creek Reservoir will occur on a bi-weekly bases at the raw water intake for the T.W. Moses Drinking Water plant as a part of Veolia Water Indianapolis monitoring of Eagle Creek Reservoir.	CEES Research Scientists, Veolia Water Indianapolis, and Coordinator

◆ Water Quality Administrative Indicator of Success
▸ Water Quality Ground Truth Indicator of Success

Objective 2: Reduce application of Atrazine in Eagle Creek Watershed.

Indicator	How Tracked	Responsible Party
◆ Developed database on Atrazine application rates specific to agricultural land in Eagle Creek Watershed	Create a timeline toward the development of an Atrazine usage database for Eagle Creek Watershed.	Farm Promoter and SWCDs
◆ Creation of list showing Atrazine alternatives with their costs and benefits.	Create a timeline toward the development of Atrazine Alternatives for Eagle Creek Watershed.	Farm Promoter and SWCDs
■ Development of Atrazine informational brochure and the number of copies printed and distributed to the public.	Document the number of copies printed and disseminated.	Farm Promoter and ECWA Education Subcommittee
▸ Reduction in Atrazine application in Eagle Creek Watershed	Document the number of farmers who change Atrazine application practices and maintain Atrazine usage database for Eagle Creek Watershed.	Farm Promoter and SWCDs

◆ Water Quality Administrative Indicator of Success
▸ Water Quality Ground Truth Indicator of Success
■ Education and Outreach Indicator of Success

Objective 3: Reduce Atrazine run-off from agricultural stormwater run-off.

Indicator	How Tracked	Responsible Party
◆ Increase in the amount of agricultural fields using Whole Farm Planning practices.	Document the number of farmers who have adopted Whole Farm Planning practices	Farm Promoter, SWCDs, ECWA Education Subcommittee, and Coordinator
▸ Reduction in Atrazine loading to Eagle Creek Reservoir	Continued monitoring of Atrazine concentrations in Eagle Creek Reservoir will occur on a bi-weekly bases at the raw water intake for the T.W. Moses Drinking Water plant as a part of Veolia Water Indianapolis monitoring of Eagle Creek Reservoir.	CEES Research Scientists, Veolia Water Indianapolis, and Coordinator

◆ Water Quality Administrative Indicator of Success
▸ Water Quality Ground Truth Indicator of Success

Goal 3: Reduce Total Suspended Sediment loads in Eagle Creek Watershed to meet water quality standards.

Objective 1: Reduce fine grain sediment load from headwater erosion.

Indicator	How Tracked	Responsible Party
◆ Development of common goals between NRCS, County Drainage Board, and ECWA.	Create a timeline toward the development of common goals between NRCS, County Drainage Board, and ECWA.	Coordinator, Farm Promoter, and ECWA
◆ Sufficient number of landowners amenable to buffer installation.	Create a list of landowners whose land overlaps a Critical Area and maintain a list of partners and possible partners.	Coordinator, Farm Promoter and SWCDs
◆ Development of a detailed baseline map showing headwater erosion.	Create a timeline toward the development of a baseline map showing headwater erosion.	Coordinator and Farm Promoter
◆ Number of implemented or enhanced buffers and a decrease in the amount of stream bank with inadequate riparian buffers.	Document the area of stream bank land converted from inadequate buffer to adequate buffer.	Coordinator and CEES Research Scientists
▸ Reduction in total suspended sediment loading	Monitoring of Total Suspended Solids concentrations and loads upstream and downstream of cited buffers will begin as soon as the Critical Area is determined and will be maintained as long as funding is available. These data will be used to create a best management practice database for Eagle Creek Watershed and for further scientific research and publication. .	CEES Research Scientists, Veolia Water Indianapolis, and Coordinator

◆ Water Quality Administrative Indicator of Success
▸ Water Quality Ground Truth Indicator of Success

Objective 2: Reduce sediment load from agricultural run-off.

Indicator	How Tracked	Responsible Party
◆ Increase in the amount of agricultural fields using Whole Farm Planning practices.	Document the number of farmers who have adopted Whole Farm Planning practices	Farm Promoter, SWCDs, ECWA Education Subcommittee, and Coordinator

◆ Water Quality Administrative Indicator of Success

Objective 3: Reduce sediment load from stormwater run-off from impervious surfaces and urbanized areas.

Indicator	How Tracked	Responsible Party
▪ Increase in public awareness of whole community planning and low impact development.	Document the number of visitors (hits) to the ECWA website over the course of the grant period. Document the number of ECWA newsletter mailings and e-mailings sent over the course of the grant period. Document the number of educational material distributed over the course of the grant period.	Farm Promoter, SWCDs, ECWA Education Subcommittee, and Coordinator
▪ Number of watershed and stormwater markers installed.	Document the number of signs and markers installed.	Coordinator, ECWA Education Subcommittee

▪ Education and Outreach Indicator of Success

Objective 6: Reduce sediment load from bank erosion in the lower reaches of Eagle Creek Watershed.

Indicator	How Tracked	Responsible Party
◆ Development of common goals between land developers, Indiana Green Building Council and ECWA	Create a timeline toward the development of common goals between land developers, Indiana Green Building Council, and ECWA	Coordinator and ECWA
◆ Number of land developers using sustainable development practices.	Conduct a baseline visual survey on-going developments and the proper use of sediment traps then maintain and update database.	Coordinator and ECWA
▸ Improvements in visually assessed HHEI[13] and QHEI[14] scores.	Measure and document changes in HHEI and QHEI scores at least once each year during the growing season..	Coordinator and ECWA Technical Subcomittee
■ Number of educational events focused on sustainable development practices held	Document the number of educational events held.	Coordinator and ECWA Education Subcommittee
■ Number of attendees at educational events focused on sustainable development.	Document the number of attendees at educational events.	Coordinator and ECWA Education Subcommittee

◆ Water Quality Administrative Indicator of Success
▸ Water Quality Ground Truth Indicator of Success

[13] HHEI = Headwater Habitat Evaluation Index
[14] QHEI = Qualitative Habitat Evaluation Index

Goal 4: Reduce nutrient loads in Eagle Creek Watershed to meet water quality standards.

Objective 1: Reduce nutrient loads from agricultural run-off.

Indicator	How Tracked	Responsible Party
◆ Sufficient number of landowners amenable to buffer and/or constructed wetland installation.	Create a list of landowners whose land overlaps a Critical Area and maintain a list of partners and possible partners.	Coordinator, Farm Promoter and SWCDs
◆ Decrease in the amount of agricultural fertilizers applied in Eagle Creek Watershed.	Create a timeline toward the development of a nutrient usage database for Eagle Creek Watershed	Farm Promoter and SWCDs
◆ Increase in the amount of agricultural fields using Whole Farm Planning practices.	Document the number of farmers who have adopted Whole Farm Planning practices	Farm Promoter, SWCDs, ECWA Education Subcommittee, and Coordinator
▸ Reduction in nutrient loading	Monitoring of nutrient concentrations and loads upstream and downstream of cited buffers will begin as soon as the Critical Area is determined and will be maintained as long as funding is available. These data will be used to create a best management practice database for Eagle Creek Watershed and for further scientific research and publication.	CEES Research Scientists, Veolia Water Indianapolis, and Coordinator

◆ Water Quality Administrative Indicator of Success
▸ Water Quality Ground Truth Indicator of Success

Objective 2: Reduce nutrient load from tile drainage.

Indicator	How Tracked	Responsible Party
◆ Increase in the amount of agricultural fields using Whole Farm Planning practices.	Document the number of farmers who have adopted Whole Farm Planning practices	Farm Promoter, SWCDs, ECWA Education Subcommittee, and Coordinator

◆ Water Quality Administrative Indicator of Success

Objective 3: Reduce nutrient loading from point sources.

Indicator	How Tracked	Responsible Party
◆ Development of common goals between point source dischargers, CAFOs[15], and ECWA.	Create a timeline toward the development of common goals between point source dischargers, CAFOs and ECWA and the implementation of those common goals.	Coordinator, ECWA, point source dischargers, and CAFOs

◆ Water Quality Administrative Indicator of Success

[15] CAFO = Confined Animal Feeding Operation

Objective 4: Reduce nutrient loading from non-point sources other than agricultural run-off.

Indicator	How Tracked	Responsible Party
◆ Sufficient number of landowners amenable to buffer and/or constructed wetland installation.	Create a list of landowners whose land overlaps a Critical Area and maintain a list of partners and possible partners.	Coordinator and ECWA
◆ Number of implemented or enhanced buffers and a decrease in the amount of stream bank with inadequate riparian buffers.	Document the area of stream bank land converted from inadequate buffer to adequate buffer.	Coordinator and CEES Research Scientists
▸ Reduction in nutrient loading	Monitoring of nutrient concentrations and loads upstream and downstream of cited buffers will begin as soon as the Critical Area is determined and will be maintained as long as funding is available. These data will be used to create a best management practice database for Eagle Creek Watershed and for further scientific research and publication. .	CEES Research Scientists, Veolia Water Indianapolis, and Coordinator

◆ Water Quality Administrative Indicator of Success
▸ Water Quality Ground Truth Indicator of Success

Objective 5: Reduce nutrient load from stormwater run-off from impervious surfaces and urbanized areas.

Indicator	How Tracked	Responsible Party
▪ Increase in public awareness of whole community planning and low impact development.	Document the number of visitors (hits) to the ECWA website over the course of the grant period. Document the number of ECWA newsletter mailings and e-mailings sent over the course of the grant period. Document the number of educational material distributed over the course of the grant period.	Coordinator, ECWA Education Subcommittee
▪ Number of watershed and stormwater markers installed.	Document the number of signs and markers installed.	Coordinator, ECWA Education Subcommittee

▪ Education and Outreach Indicator of Success

Objective 6: Reduce and eventually eliminate suburban and urban lawn phosphorous fertilizer application.

Indicator	How Tracked	Responsible Party
▪ Increase in public awareness of their impacts on watershed and reservoir water quality.	Document the number of visitors (hits) to the ECWA website over the course of the grant period. Document the number of ECWA newsletter mailings and e-mailings sent over the course of the grant period. Document the number of educational material distributed over the course of the grant period.	Farm Promoter, SWCDs, ECWA Education Subcommittee, and Coordinator
▪ Number of watershed and stormwater markers installed.	Document the number of signs and markers installed.	Coordinator, ECWA Education Subcommittee

▪ Education and Outreach Indicator of Success

Measuring Education and Outreach Achievements

Education and outreach indicators of success track the successful development of an infrastructure for improving public awareness and education about water quality and water quality issues in the Watershed. This includes placing watershed boundary signs in the watershed, creating educational programs and workshops, developing a website for disseminating information about the watershed to the public, and producing educational material such as brochures and newsletters.

Goal 5: Increase education and outreach in Eagle Creek Watershed.

Objective 1: Educate farmers on Whole Farm Planning practices.

Indicator	How Tracked	Responsible Party
▪ Number of educational materials created for and disseminated to farmers regarding Whole Farm Planning practices.	Document the number of visitors (hits) to the ECWA website page on Whole Farm Planning over the course of the grant period. Document the number of ECWA educational material sent regarding Whole Farm Planning over the course of the grant period.	Farm Promoter, ECWA Education Subcommittee
◆ Increase in the amount of agricultural fields using Whole Farm Planning practices.	Document the number of farmers who have adopted Whole Farm Planning practices	Farm Promoter, SWCDs, ECWA Education Subcommittee, and Coordinator

▪ Education and Outreach Indicator of Success
◆ Water Quality Administrative Indicator of Success

Objective 2: Raise public awareness of watersheds and the public's role in water quality.

Indicator	How Tracked	Responsible Party
▪ Number of storm drain markers installed	Document the number of storm drain markers installed.	Coordinator, ECWA Education Subcommittee
▪ Number of watershed boundary signs installed	Document the number of watershed boundary signs installed.	Coordinator, ECWA Education Subcommittee

- Education and Outreach Indicator of Success

Objective 3: Raise public awareness of watershed and water quality issues.

Indicator	How Tracked	Responsible Party
▪ Number of hits on ECWA website.	Document the number of visitors (hits) to the ECWA website over the course of the grant period.	Coordinator, ECWA Education Subcommittee
▪ Number of residents receiving ECWA newsletter.	Document the number of ECWA newsletter mailings and e-mailings sent over the course of the grant period.	Coordinator, ECWA Education Subcommittee
▪ Number of educational materials distributed.	Document the number of educational material distributed over the course of the grant period.	Coordinator, ECWA Education Subcommittee
▪ Number of outreach events hosted.	Document the number of outreach events hosted over the course of the grant period.	Coordinator, ECWA Education Subcommittee
▪ Number of residents attending outreach events.	Document the number of attendees at each outreach event over the course of the grant period.	Coordinator, ECWA Education Subcommittee

- Education and Outreach Indicator of Success

Objective 4: Continue to build on and expand watershed outreach activities.

Indicator	How Tracked	Responsible Party
▪ Increase in environmental stewardship.		Coordinator, ECWA Education Subcommittee

- Education and Outreach Indicator of Success

Section XIII: Adapting and Evaluating the Plan: Establishing Long-term Sustainability

The Center for Earth and Environmental Science (CEES) as part of the Central Indiana Water Resources Partnership (CIWRP) and in partnership with the Eagle Creek Watershed Task Force applied for a Section 319 grant for Phase 1 implementation, education and public outreach in Eagle Creek Watershed to begin fall 2005. The union of these groups is called the Eagle Creek Watershed Alliance (ECWA); and with the implementation grant, the ECWA proposes to accomplish a series of initiatives including BMP implementation, demonstrations, monitoring, watershed education, and public information and outreach. A watershed coordinator and farm promoter will be funded through the implementation grant. These positions will ensure the coordination of stakeholder meetings, assistance to land owners, and the overall progress of implementation.

The ECWA will hold quarterly meetings to evaluate the plan implementation progress and assess success of the BMP implementation, monitoring and demonstration program, and outreach and education campaign. The management plan will continue to be re-evaluated during the ECWA quarterly meetings and revisions/updates will be made by the watershed coordinator when appropriate. For instance, should a TMDL be developed for Eagle Creek Watershed, the management plan will be updated accordingly.

The ECWA believes that this Watershed Management Plan will provide a good foundation from which more ambitious and holistic management initiatives can be developed. As the current paradigm of stream remediation turns more towards stream restoration, the future initiatives of the ECWA will evolve to reflect this more holistic understanding of improving stream water quality through restoring the natural structure and function of a stream ecosystem. This process includes reestablishing a stream’s natural diversity and aquatic habitats to approximate pre-settlement conditions (Berger, 1990; National Resources Council, 1992) or, more pertinently, the return of a degraded ecosystem to a close approximation of its remaining natural potential (USEPA, 2000). Such an initiative could begin with the reestablishment of stream structure, riparian zones, and wetlands. The ECWA understands that while the proposed remediations detailed in this document may redress some water quality degradation, they fall short of re-creating true sustainable riparian and aquatic ecosystems. This is no small feat. As population demands for drinking water and land continue to stress these ecosystems, a balance must be struck, a common ground between resource use and resource conservation. The ECWA recognizes that creating sustainable riparian and aquatic ecosystems cannot happen unless there is a concerted effort by all stakeholders to change. As Wendel Berry wrote in his essay Getting Along with Nature, “Humans, like all other creatures, must make a difference; otherwise, they cannot live. But unlike other creatures, humans must make a choice as to the kind and scale of the difference they make.” It is the goal of the ECWA that this Watershed Management Plan will provide a catalyst from which long-term, positive change in Eagle Creek Watershed can be made.

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Appendix A

The Eagle Creek Watershed Taskforce

While the monitoring program was in progress, efforts were underway to gather a group of individuals to provide the nucleus of the Eagle Creek Watershed Steering Committee. Individuals were also focused on recruiting individuals to serve on a Technical Committee and an Education/Outreach Committee, and a Public Relations Committee. These would be subcommittees of the Steering Committee. During the later half of the summer and the fall of 1997, this diverse group met monthly to begin the process of melding their urban, suburban, and agricultural viewpoints into a cohesive whole. While the individual-member make-up tended to vary at each meeting, the group had a strong technical component via various agency representations. The next largest representation was from the agricultural community, followed by developers, and a small general homeowner contingent.

This group met monthly through the late summer and fall of 1997, working develop a common vision that could be expressed as a mission statement. This was the crucial first step in melding together the diverse nature of this group. This process was also used to identify the six major items of concern of the Task Force. These would be used as a framework in later meetings to develop a set of specific goals and objectives and during the development of the watershed management plan.

Concurrent with the formation of the Task Force, a database of over 100 individuals from federal, state and local government agencies as well as community associations, environmental groups and agricultural associations was created. This database was primarily used to notify individuals of meetings and current issues. In addition to mailings and articles in local newspapers, public tours of septic fields and ECWTF sample sites provided information on particular areas of environmental concern.

Eagle Creek Watershed Taskforce -- Timeline

1995 & 1996 due to the timing and intensity of spring rains in relation to the agricultural producers' activities in the fields, the levels of triazines in the Eagle Creek Reservoir's untreated water exceeded the Environmental Protection Agency's (EPA's) drinking water quality standard for most of each year.

1997

Spring, Indiana Farm Bureau hired a watershed coordinator to begin a watershed group to investigate water quality issues in the Eagle Creek Watershed

Summer, while a list of stakeholders and steering committee was being developed a water sampling program, with "in-kind" testing by the Indianapolis Water Company was initiated.

Fall & Winter, regular monthly meetings of the steering committee and various technical subcommittees took place. 319 grant for funding the watershed coordinator was approved and work on Watershed Management Plan began.

1998

Data continued to be gathered as well as work on management plan. In the fall the watershed task force in combination with the Heartlands Group of the Indiana Sierra Club sponsored a tour of failing septic systems in the watershed in Boone County

1999

Data collection and work on the management plan continued.

2000 & 2001

319 grant obtained for bio-assay of 20 sites in the Eagle Creek Watershed.

2002

A 319 grant was submitted for a DNA ribotyping study of E. Coli. This grant was also supported by funding from the Sierra Club. Another 319 grant was submitted to begin phase I implementation for BMP's in the watershed. This grant wasn't successful due to lack of supporting data in the watershed management plan.

2003

319 grant for ribotyping of E. Coli study was completed. Work continued on revising the management plan to get it to support the 319 BMP grant that had been conditionally accepted.

2004

The taskforce was unsuccessful in obtaining the 319 BMP grant.

Appendix B
Eagle Creek Watershed Alliance

Eagle Creek Watershed Taskforce

Sharon Adams – Boone County Health Dept. – environmental health
Laura Bieberich – IDEM – grant and department liaison
Greg Bright – Commonwealth Bio-monitoring – bio assays
Chuck Brinkman – Zionsville citizen
Dennis Carrell – Frontier Co-op – GIS Field Support
Bonny Elifritz – IDEM – watershed coordinator
John Pankhurst – Eagle Creek Park Foundation Advisory Committee
Dale Pershing – Veolia Water - Indianapolis – technical water quality
Glenn Pratt – Environmental interests
Jim Ray – Zionsville Town Council – governmental interests
Adam Rickert – Marion County Health Department – level 2 testing
Gerald Shelburne – Boone County SWCD
John South – Hamilton County SWCD – soils and urban components
George Tikijian – Zionsville Parks Dept. – governmental interests
John Ulmer – Sierra Club – citizen/environmental inputs

Central Indiana Water Resources Partnership

Veolia Water Indianapolis
Jhani Laupus – Watershed Initiative
Dale Pershing – Technical Water Quality

Center for Earth and Environmental Science
Lenore P. Tedesco - Director
Lora Shrake – Research Scientist, Watershed Studies
Denise Lani Pascual – Research Scientist, Limnologist
Bob E. Hall – Technologist, GIS and Land-use
Leda R. Casey – Graduate Student, Watershed Studies
Kara Salazar – Education Outreach
Robert C. Barr – Contractor

Appendix C

Windshield Surveys for Eagle Creek Watershed

Subwatershed:
Site Location:

No. Pictures Taken at this site:

1. Is there bank erosion? None Slight Moderate Severe
   Comments:

2. Livestock have access to streams? Yes No
   Comments:

3. Is there trash in stream? None Slight Moderate Severe
   Comments:

4. Is there adequate riparian buffer (25')? Yes No
   Comments:

5. What is surrounding land use? Crops, pasture, development, etc?
   If pasture, what type of animals?

6. Any Confined Animal Feeding Operations? Yes No
   Type of animal:

7. Are there pipes flowing directly into stream? Yes No
   How many?

General Notes/Comments:

Appendix D

Benchmark Analysis: Tier 1

MCHD Data		*[E.coli]* ≥ 235 CFU†			[DO]<4 mg/L			[TDS]>750 mg/L			6 > pH > 9		
Stream	Subwatershed	N	#	%	N	#	%	N	#	%	N	#	%
Finley Creek	Finley Creek	3	3	100%	88	5	6%	88	0	0%	88	0	0%
Finley Creek	Finley Creek	15	4	27%	135	3	2%	133	0	0%	130	0	0%
Long Branch	Long Branch				133	12	9%	133	0	0%	129	0	0%
Fishback Creek	Fishback Creek				136	11	8%	135	0	0%	131	0	0%
Fishback Creek	Fishback Creek				157	8	5%	156	0	0%	154	0	0%
School Branch	School Branch				140	8	6%	140	0	0%	135	0	0%
School Branch	School Branch				158	4	3%	158	0	0%	153	0	0%
Little Eagle Creek	Little Eagle Creek - Woodruff Branch				136	0	0%				131	0	0%
Little Eagle Creek	Little Eagle Creek	37	29	78%	19	7	37%	19	0	0%	18	0	0%
Eagle Creek	Long Branch & Irishman Run	40	22	55%	196	3	2%	196	0	0%	191	0	0%
Eagle Creek	Long Branch & Irishman Run	39	19	49%	197	5	3%	195	0	0%	192	0	0%
Eagle Creek	Reservoir	33	1	3%	191	4	2%	192	0	0%	186	0	0%

ECWTF Data		*[E.coli]* ≥ 235 CFU†			[DO]<4 mg/L			[TDS]>750 mg/L			6 > pH > 9		
Stream	Subwatershed	N	#	%	N	#	%	N	#	%	N	#	%
School Branch	School Branch	122	92	75%									
Fishback Creek	Fishback Creek	119	77	65%									
Irishman Run	Irishman Run	122	95	78%									
Eagle Creek	Long Branch	122	82	67%									
Eagle Creek	Jackson Run	122	64	52%									
Eagle Creek	Mounts Run & Finley Creek	122	76	62%									
Little Eagle Creek	Little Eagle Creek - Woodruff Branch	122	83	68%									
Mounts Run	Mounts Run	122	102	84%									
Finley Creek	Finley Creek	122	89	73%									
Eagle Creek	Dixon Branch	122	92	75%									

CIWRP 2003 Data		*[E.coli]* ≥ 235 CFU†			[DO]<4 mg/L			[TDS]>750 mg/L			6 > pH > 9		
Stream	Subwatershed	N	#	%	N	#	%	N	#	%	N	#	%
School Branch	School Branch	9	6	67%	9	0	0%	9	0	0%	9	0	0%
Fishback Creek	Fishback Creek	9	6	67%	9	0	0%	9	0	0%	9	0	0%
Eagle Creek	Long Branch & Irishman Run	9	6	67%	9	0	0%	9	0	0%	9	0	0%
Eagle Creek	Long Branch & Irishman Run	8	6	75%	8	0	0%	8	0	0%	8	0	0%
Eagle Creek	Mounts Run	8	5	63%	8	1	13%	8	0	0%	8	0	0%
Little Eagle Creek	Little Eagle Creek - Woodruff Branch	8	6	75%	8	0	0%	8	0	0%	8	0	0%
Finley Creek	Finley Creek	7	5	71%	7	1	14%	7	0	0%	7	0	0%
Eagle Creek	Eagle Creek Watershed - South of ECR Dam	2	2	100%	2	1	50%	2	0	0%	2	0	0%

† Threshold set by US EPA and IAC drinking water standard.

Benchmark Analysis: Tier 2

MCHD Data		[Atrazine] ≥ 3 ppb†			[NO3-N] ≥ 10 mg/L†			[TSS] > 263 mg/L			[TotP] > 0.125 mg/L			[TotN > 2.75 mg/L		
Stream	Subwatershed	N	#	%	N	#	%	N	#	%	N	#	%	N	#	%
Finley Creek	Finley Creek	85	7	8%	87	4	5%									
Finley Creek	Finley Creek	135	12	9%	137	4	3%									
Long Branch	Long Branch	136	9	7%	137	2	1%									
Fishback Creek	Fishback Creek	135	14	10%	136	12	9%									
Fishback Creek	Fishback Creek	156	14	9%	155	5	3%									
School Branch	School Branch	139	22	16%	138	23	17%									
School Branch	School Branch	157	19	12%	158	17	11%									
Little Eagle Creek	Little Eagle Creek - Woodruff Branch	139	13	9%	140	1	1%									
Little Eagle Creek	Little Eagle Creek															
Eagle Creek	Long Branch & Irishman Run	162	18	11%	164	5	3%									
Eagle Creek	Long Branch & Irishman Run	161	19	12%	166	3	2%									
Eagle Creek	Reservoir	162	29	18%	166	1	1%									
ECWTF Data		[Atrazine] ≥ 3 ppb†			[NO3-N] ≥ 10 mg/L†			[TSS] > 263 mg/L			[TotP] >0.125 mg/L			[TotN > 2.75 mg/L		
Stream	Subwatershed	N	#	%	N	#	%	N	#	%	N	#	%	N	#	%
School Branch	School Branch	122	20	16%	122	38	31%									
Fishback Creek	Fishback Creek	119	26	22%	119	19	16%									
Irishman Run	Irishman Run	122	42	34%	122	20	16%									
Eagle Creek	Long Branch	122	19	16%	122	14	11%									
Eagle Creek	Jackson Run	122	19	16%	122	15	12%									
Eagle Creek	Mounts Run & Finley Creek	122	18	15%	122	22	18%									
Little Eagle Creek	Little Eagle Creek - Woodruff Branch	122	29	24%	122	6	5%									
Mounts Run	Mounts Run	122	9	7%	122	32	26%									
Finley Creek	Finley Creek	122	23	19%	122	16	13%									
Eagle Creek	Dixon Branch	122	33	27%	122	20	16%									
CIWRP 2003 Data		[Atrazine] ≥ 3 ppb†			[NO3-N] ≥ 10 mg/L†			[TSS] > 263 mg/L			[TotP] >0.125 mg/L			[TotN] > 2.75 mg/L		
Stream	Subwatershed	N	#	%	N	#	%	N	#	%	N	#	%	N	#	%
School Branch	School Branch				9	2	22%	9	0	0%	8	6	75%	9	7	78%
Fishback Creek	Fishback Creek				9	0	0%	9	1	11%	9	5	56%	9	7	78%
Eagle Creek	Long Branch & Irishman Run				9	0	0%	9	1	11%	9	5	56%	9	7	78%
Eagle Creek	Long Branch & Irishman Run				8	0	0%	8	1	13%	8	4	50%	8	5	63%
Eagle Creek	Mounts Run				8	1	13%	8	1	13%	8	4	50%	8	6	75%
Little Eagle Creek	Little Eagle Creek - Woodruff Branch				8	0	0%	8	1	13%	8	5	63%	8	4	50%
Finley Creek	Finley Creek				7	0	0%	7	1	14%	7	4	57%	7	4	57%
Eagle Creek	Eagle Creek Watershed - South of ECR Dam				2	0	0%	2	0	0%	2	0	0%	2	0	0%

† Threshold set by US EPA and IAC drinking water standard.

Benchmark Analysis: Tier 3

MCHD Data		[NO3-N] > 1.0 mg/L			Dosat > 125%			pH > 8.3		
Stream	Subwatershed	N	#	%	N	#	%	N	#	%
Finley Creek	Finley Creek	87	69	79%	88	21	24%	88	2	2%
Finley Creek	Finley Creek	137	102	74%	135	19	14%	130	4	3%
Long Branch	Long Branch	137	61	45%	133	7	5%	129	1	1%
Fishback Creek	Fishback Creek	136	110	81%	136	23	17%	131	7	5%
Fishback Creek	Fishback Creek	155	112	72%	157	6	4%	154	8	5%
School Branch	School Branch	138	114	83%	140	25	18%	135	2	1%
School Branch	School Branch	158	124	78%	158	4	3%	153	7	5%
Little Eagle Creek	Little Eagle Creek - Woodruff Branch	140	8	6%	136	17	13%	131	4	3%
Little Eagle Creek	Little Eagle Creek	0	0		19	0	0%	18	1	6%
Eagle Creek	Long Branch & Irishman Run	164	162	99%	196	10	5%	191	2	1%
Eagle Creek	Long Branch & Irishman Run	166	25	15%	197	4	2%	192	1	1%
Eagle Creek	Reservoir	166	119	72%	191	41	21%	186	79	42%

ECWTF Data		[NO3-N] > 1.0 mg/L			Dosat > 125%			pH > 8.3		
Stream	Subwatershed	N	#	%	N	#	%	N	#	%
School Branch	School Branch	122	83	68%						
Fishback Creek	Fishback Creek	119	86	72%						
Irishman Run	Irishman Run	122	106	87%						
Eagle Creek	Long Branch	122	83	68%						
Eagle Creek	Jackson Run	122	90	74%						
Eagle Creek	Mounts Run & Finley Creek	122	89	73%						
Little Eagle Creek	Little Eagle Creek - Woodruff Branch	122	79	65%						
Mounts Run	Mounts Run	122	93	76%						
Finley Creek	Finley Creek	122	88	72%						
Eagle Creek	Dixon Branch	122	90	74%						

CIWRP 2003 Data		[NO3-N] > 1.0 mg/L			Dosat > 125%			pH > 8.3		
Stream	Subwatershed	N	#	%	N	#	%	N	#	%
School Branch	School Branch	9	9	100%	9	0	0%	9	0	0%
Fishback Creek	Fishback Creek	9	7	78%	9	0	0%	9	0	0%
Eagle Creek	Long Branch & Irishman Run	9	7	78%	9	1	11%	9	0	0%
Eagle Creek	Long Branch & Irishman Run	8	6	75%	8	0	0%	9	0	0%
	Mounts Run	8	7	88%	8	1	13%	8	0	0%
	Little Eagle Creek - Woodruff Branch	8	6	75%	8	0	0%	8	0	0%
	Finley Creek	7	5	71%	7	1	14%	7	0	0%
	Eagle Creek Watershed - South of ECR Dam	2	2	100%	2	0	0%	2	0	0%

Appendix E

Annual Load Reduction Targets for Eagle Creek Watershed

Scenario		Sediment (tons/yr)			Total P (pounds/yr)			Total N (pounds/yr)		
		Mean	% Reduction (from baseline)	% daily samples ≤ benchmark	Mean	% Reduction (from baseline)	% daily samples ≤ benchmark	Mean	% Reduction (from baseline)	% daily samples ≤ benchmark
Baseline		26000	-	90	120000	-	42	1780000	-	36
Target		18628	28.4%	100	50000	58.3%	100	1136000	36.2%	100
Buffer Strips (miles)	2 mi in Boone County	25977	0.1%	-	119964	0.0%	-	1779930	0.0%	-
	2 mi in Hendricks County	25956	0.2%	-	119941	0.0%	-	1779885	0.0%	-
Conservation Tillage (acres)	300 acres in Hendricks County	25635	1.4%	-	119537	0.4%	-	1779075	0.1%	-
	1100 acres in Hamilton County	25205	3.1%	-	118882	0.9%	-	1777767	0.1%	-
	3500 acres in Boone County	24332	6.4%	-	117451	2.1%	-	1774909	0.3%	-

Scenario	E.coli (mCFU/yr)			Atrazine (Kg/yr)		
	Mean	% Reduction (from baseline)	% daily samples ≤ benchmark	Mean	% Reduction (from baseline)	% daily samples ≤ benchmark
Baseline	8000	-	31	299	-	85
Target	1528	80.9%	100	180	39.8%	100