Preliminary Economic Analysis of Water Quality Trading Opportunities in the Great Miami River Watershed, Ohio

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ABSTRACT

A preliminary economic analysis evaluates biophysical and economic aspects of the Great Miami River watershed, Ohio to assess water quality trading opportunities in this 3,800 square mile watershed. The Miami Conservancy District is leading an effort to achieve significant nutrient load reductions in this tributary of the Ohio River. The Great Miami has over 80% of its land in agricultural uses. Driven by the pending nutrient standards for the state's surface waters, a 10-year pilot trading program focuses on point source/non-point source trading for nutrients (total phosphorus and total nitrogen) between permitted wastewater dischargers and agriculture.

To determine the potential viability of such a program, the economic analysis focused on:

- Conducting a non-point source modeling analysis to assess agricultural credit supply on the subwatershed level for the Great Miami River watershed using the GIS-interfaced SWAT model;
- Assessing and comparing the costs of point source load reductions via traditional in-plant facility upgrades to the costs of comparable load reductions by agricultural non-point source management practices; and
- Analyzing cost savings and load reductions potentially achieved through the proposed point source/non-point source trading program.

Results indicate that phosphorus credit demand and most of the nitrogen credit demand by point sources can be met by non-point sources through the implementation of the no-till management practices on 50% of the row crops in the watershed. If needed, additional agricultural management practices such as fertilizer management and conversion from corn-soybean rotation to hay-only operations, can supply additional non-point source credits. Current trading program design will require point sources to purchase credits only from upstream non-point sources. Some point sources located in headwater areas may have difficulty securing sufficient credits to meet their load reduction requirements. In these cases, locally-oriented and site-specific non-point source load reduction opportunities, such as streambank erosion mitigation, septic system management, and impervious area stormwater runoff mitigation, should be considered to generate non-point source load reductions.

Treatment plant upgrades to biological nutrient removal technologies for all point sources are estimated at $422.5 million. Costs for implementation of no-till practices to meet point source watershed demand are $37.8 million providing a $384.7 million savings compared to treatment plant upgrades. It is estimated that on average, point sources will pay $23.37 to reduce one pound of phosphorus with biological nutrient removal compared to $1.08 for agriculture with no-till. For nitrogen, point source unit costs are $4.72/pound compared to $0.45/pound for agriculture. This analysis has concluded that water quality trading in the Great Miami River watershed has the potential to provide significant cost savings over traditional command and control approaches.

Disclaimers

This preliminary economic analysis was not intended to be an exhaustive and comprehensive evaluation of point source and non-point source loads in the Great Miami River watershed. Predicted loads from modeling results vary from other published or available works, though loads do fall within the range of these reported values. There is no intended nor inferred use of these results for current or future TMDLs developed in the watershed. Point source data were carefully scrutinized against other published sources but may not be accurate given limitations with available compilations. Current agricultural practices in place within the watershed were assumed based on data provided by MCD and OEPA.

CHAPTER 1

INTRODUCTION

1.0 Overview

This report has been completed by Kieser & Associates of Kalamazoo, Michigan at the request of the Miami Conservancy District, Dayton, Ohio. It presents a preliminary economic analysis of the potential viability of a water quality trading program being contemplated for the Great Miami River watershed of Ohio. Chapter 1 provides an introduction to water quality trading, background information for this study, an overview of the Great Miami River watershed and an introduction to the pilot trading program currently under consideration. The purpose and scope of the study, and the biophysical and economic analyses conducted as part of this analysis are also summarized here.

1.1 Water Quality Trading

Water quality trading is a flexible tool offering a mechanism to achieve additional economic and environment benefits when used in conjunction with traditional command and control approaches. A permitted wastewater treatment plant facing high costs to accommodate new growth or meet more stringent discharge requirements can "trade" for discharge reduction credits generated by another source having lower costs (e.g., an agricultural producer implementing conservation practices). A portion of the reductions traded can be retired to address uncertainty or to create a net reduction of pollutants (nitrogen, phosphorus, sediments) discharged to the receiving water.

In January of 2003, U.S. EPA issued their final Water Quality Trading Policy (U.S. EPA, 2003) that identifies the purpose, objectives and limitations of trading opportunities. The policy provides flexibility to states, interstate agencies and others to develop their own trading programs that meet Clean Water Act (CWA) requirements and localized needs. The release of this policy has motivated watershed stakeholders and policy makers across the country to examine and develop new, innovative trading programs to address the costly challenges of restoring and protecting America's waterways.

1.2 The Pilot Project in the Great Miami River Watershed

The Great Miami River (GMR; Figure 1-1), located in southwest Ohio, drains a 3,800 mi^2 watershed of the Ohio River basin. The portions of the watershed examined here include U.S. Geological Survey Hydrologic Unit Codes 05080001—the Upper Great Miami River and 05080002—the Lower Great Miami River. Over 80% of the land in the watershed is agricultural while 70% of the population lives in urban areas constituting 5% of the land cover. The four major subwatersheds of the river system are the Upper Great Miami River, the Stillwater River, the Mad River, and the Lower Great Miami River. Among the assessed river miles in the watershed, about 58.8% are in full attainment of their designated uses, 19.8% are in partial-attainment, and 21.4% are in non-attainment.

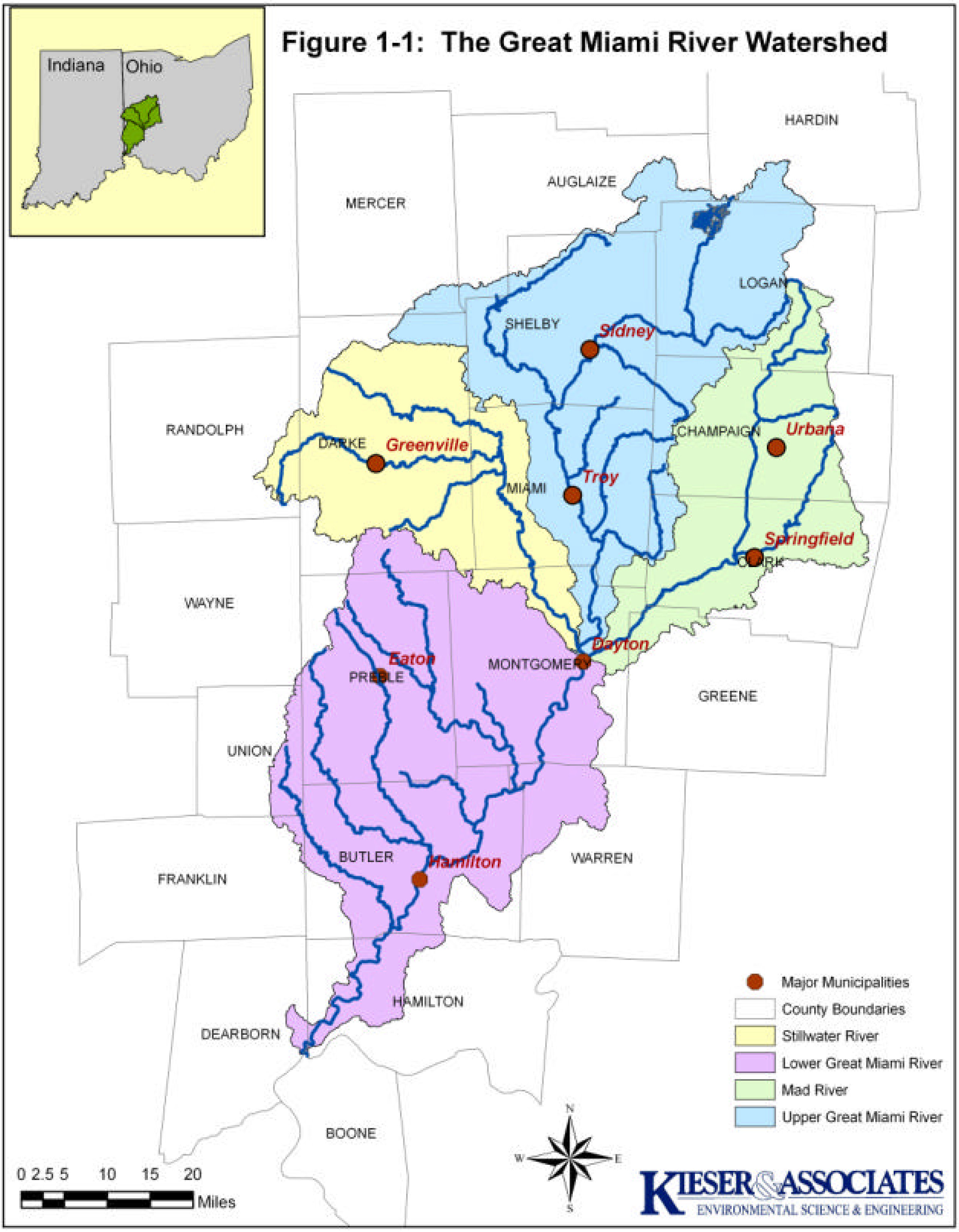

Figure 1-1: The Great Miami River Watershed

Phosphorus loading and hydraulic modification are the two leading causes of non-attainment. In addition, the GMR watershed is one of the largest nitrogen contributors to the Ohio River.

The Miami Conservancy District (MCD) is currently examining opportunities to develop a point source/non-point source trading program in the Great Miami River watershed to improve locally impaired waterways and to provide constructive alternatives to address forthcoming nitrogen and phosphorus standards for all waters in Ohio. Municipal, industrial and other permitted point sources will be required to meet more stringent effluent requirements under the pending standards to be implemented for impoundments and reservoirs in 2005 and rivers and streams in 2007. Such limits will require significant capital investments and increase annual operation and maintenance costs. The intent of the trading program is for agriculture to supply cost-effective nutrient reductions in lieu of anticipated point source reductions associated with expensive wastewater treatment plant upgrades. As agriculture is the predominant land use in the watershed, it is envisioned that trading opportunities in a water quality market with significant demand will motivate producers to participate. Robust participation by agriculture in a trading program can overcome common challenges in traditional programs that lack the authority or incentives to engage producers in water quality initiatives.

1.3 Purpose and Scope of the Study

Water quality trading programs are a preferred alternative to technology-based pollution control standards when: 1) there is sufficient supply to meet the demand for pollutant reduction credits; and 2) there is potential for improving the overall cost-effectiveness in pollution control. These two conditions should be studied before any trading program is implemented.

As part of MCD's effort in developing a pilot point source/non-point source trading program in the GMR watershed, this economic analysis examined the two conditions for the watershed by answering the critical questions of: 1) is there an adequate supply of agricultural non-point source reductions of phosphorus and nitrogen to meet point source demand; and 2) are the cost differentials between point source upgrades and trading sufficient to support a trading program? This analysis addresses these questions by:

- Conducting a rudimentary non-point source loading analysis to assess agricultural credit supply in the Great Miami River watershed and its subwatersheds.
- Comparing the costs of incremental point source load reductions via traditional controls to the costs of comparable load reductions by agricultural non-point sources.
- Analyzing cost savings and load reductions potentially achieved through a proposed point source/non-point source trading program.

MCD and the Ohio Environmental Protection Agency (OEPA) have developed specific trading rules, such as credit eligibility and trading ratios, for the trading program. Chapter 2 of this report discusses these rules in greater detail. These have significant implications to the supply and demand of trading credits in the program. For example, buyers (point sources) are required to purchase credits only from upstream non-point sources. This limitation for upstream credit purchases has two major ramifications for the trading program. First, credit supply and demand becomes localized. In other words, any geographic location in the watershed has its own credit market and all the local markets on the same stream are interconnected. Second, point sources located in the upstream (headwater) areas of the watershed are in a more competitive market for credits because as one moves upstream, potential credit supply diminishes. This study incorporated these rules into its analyses to derive realistic biophysical and economic results for the intended trading program in the GMR watershed.

1.4 This Report

This document consists of four chapters. After this introductory section, Chapter 2 details the methodological approach for assessing market demand and supply. Study findings and discussion on their implications to the trading program are presented in Chapter 3. Chapter 4 highlights key findings from the study and outlines some recommendations for the development of the trading program. To present this study and its findings with focus and continuity, some technical details and results were omitted from this report and are included in a separate Technical Memorandum (K&A, 2004). Interested readers should contact MCD at (937) 223-1271 to obtain a copy of this memo.

CHAPTER 2

METHODOLOGY

2.0 Overview

This chapter describes each step taken in the process to assess demand and supply of nutrient credits in the Great Miami River watershed. Figure 2-1 illustrates the conceptual approach used to assess point source and non-point source components in this analysis. This approach and this chapter are organized under two major strategies: calculation of credit demand attributable to point sources and assessment of credit supply through implementation of agricultural management practices. Expanded explanations for certain methods and approaches used for these calculations are available in the companion Technical Memorandum (K&A, 2004).

2.1 Credit Demand Calculations

Pending state-wide nutrient standards will result in total phosphorus (TP) and total nitrogen (TN) limits for wastewater discharges at 1 mg/L and 10 mg/L, respectively. Available data suggest that few point sources in the Great Miami River (GMR) watershed currently discharge below these limits. If opting for trading, point sources will be required to reduce their TP and TN loadings by the amount (Q) determined by their actual discharge flow rate (F) and the difference between their current discharge concentrations (C) and the new limits (L).[*] These reduction needs are then translated into credit demand from point sources after trading ratios are taken into consideration. This section of the chapter presents the procedures used to determine credit demand in the watershed from all point sources with available flow information. Also included is a subsection explaining the derivation of cost information of point source treatment upgrades. This information is crucial for point source decision-making on whether to participate in the trading program. Point sources will opt for trading over treatment upgrades if the cost of trading is lower than costs for treatment system upgrades.

2.1.1 Point Source Load Reduction Needs

This subsection describes sources of data used for the calculation of point source load reduction needs and costs based on forthcoming nutrient limitations for NPDES dischargers. Data gaps, assumptions made to close these gaps, and calculation procedures are described.

2.1.1.1 Sources of Data

The Miami Conservancy District provided a list from the Ohio Environmental Protection Agency (OEPA) of 334 point source dischargers in the GMR watershed. Design flow and actual flow information were provided for 314 dischargers. Effluent TP and TN concentration data were obtained for a limited number of point sources through U.S. EPA's *Envirofacts* on-line database

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[*] $Q = F \times (C - L)$.

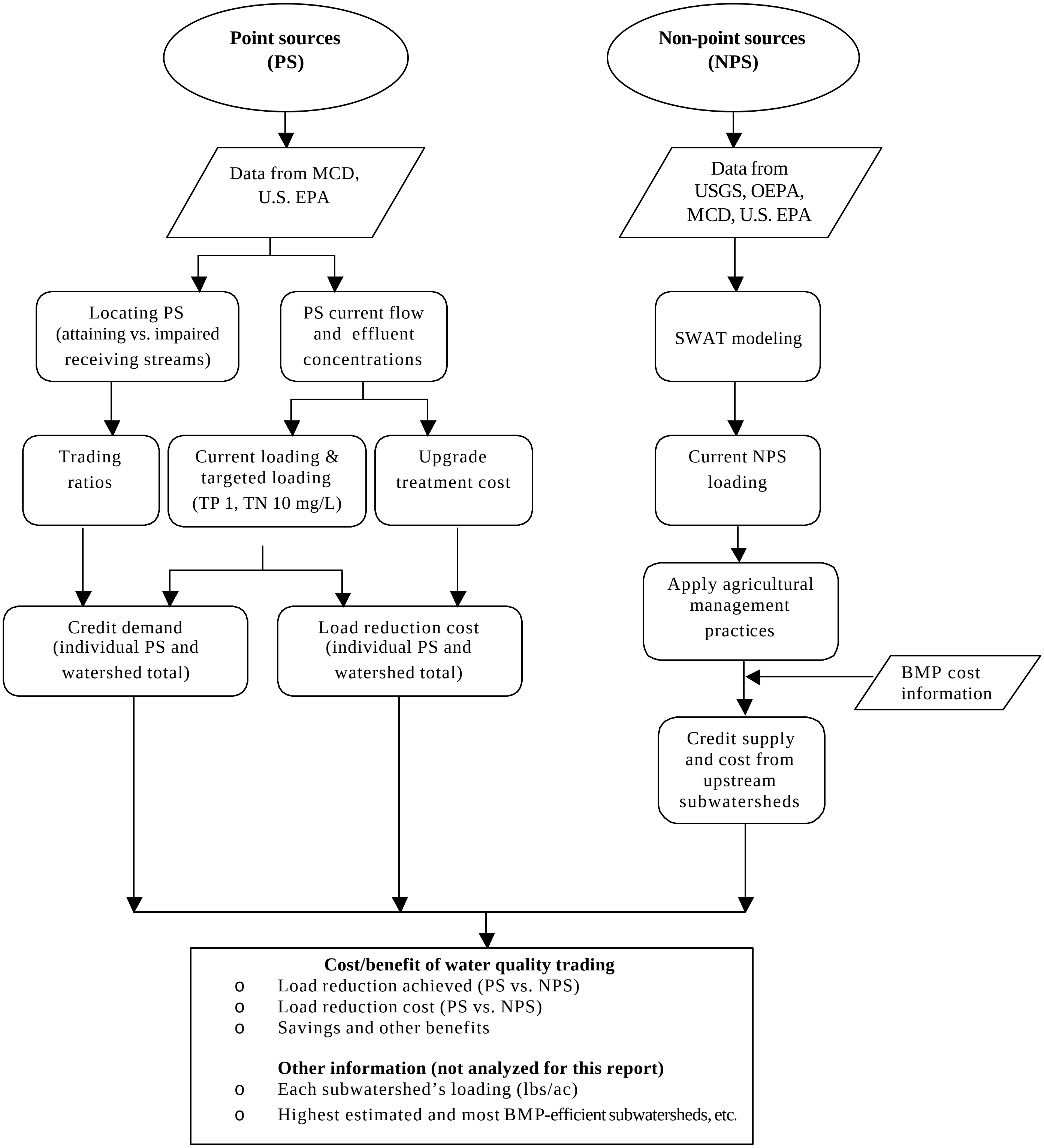


Figure 2-1: Flow chart of the analysis procedure for a preliminary economic analysis of the proposed water quality (point source/non-point source) trading program in the Great Miami River watershed, Ohio. (MCD: Miami Conservancy District; OEPA: Ohio Environmental Protection Agency; SWAT: Soil and Water Assessment Tool; TN: Total Nitrogen; TP: Total Phosphorus; U.S. EPA: U.S. Environmental Protection Agency.)

(http://www.epa.gov/enviro/index_java.html). Point sources included as major active dischargers through the U.S. EPA Permit Compliance System (PCS) were selected for data query. Locational data (latitude/longitude) were obtained for 109 selected point sources from U.S. EPA's *Envirofacts* and PCS databases. Nine additional point sources were also located from published reports (OEPA, 2001, 1997, and 1996). Costs for point source upgrades to meet new effluent limits were obtained from available literature sources. Part A of the Technical Memorandum for this study (K&A, 2004) details the sources utilized to determine upgrade costs.

2.1.1.2 Data Gaps

Actual and design flow data were provided for 314 point sources in the list of 334 supplied by MCD. However, discharge nutrient concentration data for these point sources were not available. Querying U.S. EPA's *Envirofacts* database produced concentration data for thirty point sources, with some of them only having ammonia-N data. TP concentration data were found for twenty point sources, and TN data were available for sixteen (Table 2-1). Thus, the necessary data were not available to calculate actual TP and TN loads for all point sources, or even all large point sources. Of the seven largest point sources (design flow ≥20 MGD), TP and TN data were available for five. Treatment upgrade cost data in the literature were not readily identifiable for point sources smaller than 0.028 MGD, of which there are 122 in the watershed (see K&A [2004] for more information).

Table 2-1: Point sources for which actual concentration data were used in load calculations[1].

Point Source Name[2]	Actual Flow[3] (MGD)	Average TP Concentration (mg/L)	Average TN Concentration (mg/L)	Number of Reported Measurements[4]	Dates of Measurements
Appleton Papers	6.7	0.59	N/A	5 (TP)	9/03 – 1/04
Bellefontaine WWTP	2.65	1.59	10.26	21	2/02 – 12/03
Dayton WWTP	52.69	1.4	16.5	5	8/03 – 12/03
Eaton WWTP	1.37	2.13	12.25	54 (TP) 53 (TN)	3/99 – 1/04
Englewood STP	2.06	1.16	9.44	18	5/02 – 13/03
Fairfield WWTP	5.71	1.97	12.65	3	8/03 – 12/03
Greenville STP	2.06	2.69	N/A	11 (TP)	1/03 – 12/03
Hamilton WWTP	20.72	0.37	3.9	5	8/03 – 1/04
Harrison STP	1.01	4.23	N/A	3 (TP)	11/03 – 1/04
Lesourdsville Water Reclamation	7.78	0.78	6	6	8/03 – 1/04
Logan County Indian Lake SSD	1.63	1.5	16.56	24	11/01 – 12/03
Miamisburg STP	2.45	2.22	17.8	5	8/03 – 12/03
Middletown WWTP	17.16	0.23	12.9	4	8/03 – 1/04
Montgomery County W. Regional WWTP	13.65	2.2	11.8	5	8/03 – 12/03
Oxford WWTP	2.5	3.06	15	47	3/00 – 1/04
Piqua WWTP	3.347	3.14	12.5	12	4/02 – 12/03
Sidney STP	5.06	3.18	9.82	16	5/02 – 12/03
Springboro WWTP	2.19	1.3	N/A	17 (TP)	8/02 – 01/04
Springfield STP	15.49	1.95	10.86	29	8/01 – 12/03
Troy WWTP	6.26	2	12.62	23	2/02 – 12/03

[1] Based on queries conducted in the U.S. EPA *Envirofacts* database. [2] Based on list provided by MCD. [3] Provided by MCD. [4] If shown, parentheses indicate the measured nutrient. Otherwise, both TP and TN were measured.

2.1.1.3 Assumptions

Because of these data gaps, assumptions had to be made to enable appropriate calculations for point source credit demand. It was assumed that the twenty point sources with no flow data were temporary permits or very small point sources. Because no effluent limits for nutrients are currently required, it was also assumed that most point sources do not utilize treatment methods to specifically reduce nutrients to the proposed future levels of 1 mg/L for TP and 10 mg/L for TN. With the exceptions noted in Table 2-1, point sources with design flow smaller than 0.09 MGD discharge were assigned TP concentrations of 3 mg/L while greater than or equal to 0.1 MGD discharge were assigned TP concentrations of 2 mg/L. For all point sources, discharge concentrations for TN were set at 15 mg/L. These assumptions were based on the limited available data found in the *Envirofacts* database. Costs for point sources smaller than 0.028 MGD were assumed to be equal to those costs for plants sized 0.03 – 0.1 MGD. One plant, Martin Marietta Materials (OEPA Number 1IJ00014), has a reported design flow of 0.05 MGD in the unpublished OEPA database, well below the reported actual flow of 9.9 MGD. Therefore, the design flow was assumed to be 10 MGD.

2.1.1.4 Calculation Strategy for Point Source Load Reduction Needs

Actual concentration data, when available, were used in loading calculations for point sources. Available TP and TN concentration data (Table 2-1) were averaged over time to determine whether a point source was already meeting future effluent limits. If the average concentration for either of the two nutrients was below the respective future limit, a point source was considered in this study as not needing load reduction credits for that nutrient. Although the load reduction need was not included in the credit demand analysis, upgrade costs may still occur to the point source if load reduction was still needed for the other nutrient. Consequently, such a point source was still included in the cost analysis. Two point sources, the City of Hamilton WWTP and the Lesourdsville Water Reclamation Plant, were found to be meeting both the TP and TN limits (Table 2-1). For these two plants, no load reductions are required and no costs of treatment upgrades were included in this study.

For all other point sources, assumed TP and TN concentrations were used based on those concentrations observed for active dischargers (TP is 2 mg/L for point sources smaller than 0.1 MGD and 3 mg/L for point sources larger than 0.1 MGD; TN is 15 mg/L for all). Therefore, the current annual load and annual load reduction needed for most point sources were calculated based on actual flows and assumed concentrations. A table of those calculated loads can be found in K&A (2004). Individual loads were summed within each point source size category in order to illustrate the loading contributions from various sized point sources. The annual target loads, based on the proposed effluent limits of 1 mg/L for TP and 10 mg/L for TN were also calculated based on each point source's actual flow. The current assumed load for each nutrient was subtracted from the target load established by pending permit limits to compute the annual load reduction needed for each point source.

2.1.2 Cost for Point Source Upgrades

Costs for point sources to meet effluent standards of 1 mg/L for TP and 10 mg/L for TN were calculated based on design flow. This is because in general, designs for treatment plant upgrades are based on the plant's current design flow. A set of equations developed by Doran (as quoted in Faeth [2000]) for facility upgrades using biological nutrient removal (BNR) technology were used to estimate total capital and annual operation and maintenance (O&M) costs for each point source in the watershed greater than 0.1 MGD. Equations cited by Faeth (2000) were specific to phosphorus reductions. However, the capital cost predicted by these equations for the City of Dayton WWTP for BNR matched a similar cost projection by Black and Veatch (1999) for upgrading this plant to meet both TP and TN effluent limits with BNR. The Black and Veatch cost was based on a detailed study of the Dayton plant. Therefore, equations by Doran are believed to be representative and were used in this study. Doran's cost calculations were published in 1997 and, therefore, assumed to be based on 1997 dollar values. The costs were adjusted to 2001 dollar values by the Producer Price Index (i.e., increased by 1.1%).

The smallest point sources (<0.1 MGD), of which there are 190, were estimated to need to spend $40,000 annually for capital costs and O&M. This was based on published estimates (Senjem, 1997) for small point sources (see K&A [2004]). Additionally, those point sources whose calculated annual costs were less than $40,000 were assigned a cost of $40,000. Such costs were also increased by 1.1% to reflect 2001 dollar values (i.e., increased to $40,440). The net present worth of total upgrade costs for each point source was calculated over a 20-year facility life, with the capital investments occurring in the first year and the O&M costs accruing every year. A five percent interest rate was also assumed (Black and Veatch, 1999). The cost per pound of nutrient reduction was calculated for each point source by dividing the net present worth of the total cost by the total load reduction needed over a 20-year period.

2.1.3 Point Source Credit Demand

Trading credits are defined in this study as pounds of TP or TN load reduction generated by a non-point source and purchased by a point source. One credit, therefore, equals one pound of TP or TN load reduction.

2.1.3.1 Trading Ratios

Trading ratios are used in water quality trading programs to account for scientific uncertainties and to attain additional environmental benefits with each credit exchange. A trading ratio specifies how many units of pollutant reduction a source must purchase to compensate for one unit of required load reduction. According to the currently targeted program design for the Great Miami River point source/non-point source trading program, various trading ratios will be applied to trades depending upon the location of the point source and whether it discharges into waters that fully meet use attainment standards (attaining waters) or to impaired (non-attaining) waters (see Table 2-2). Trading ratios are also dependent on the timing of trades. If the trades take place before the point source (the buyer) is required by its next permit to meet the new effluent limits of 10 mg/L for TN and 1 mg/L for TP ("before requirement"), trading ratios of 1:1 or 2:1 will apply for attaining and non-attaining waters, respectively. These ratios will increase if

Table 2-2: Trading ratios defined in the pilot program.

Trading period	Ratio for Buyer with Discharge to Fully Attaining Waters	Ratio for Buyer with Discharge to Impaired Waters
Before requirement	1:1	2:1
After requirement	2:1	3:1

point sources wait to trade until they are required by their permit to meet the new limits ("after requirement"). For example, a point source in need of 1,000 pounds of annual TP load reduction to meet its effluent TP concentration at 1 mg/L may actually need to buy 1,000, 2,000, or even 3,000 pounds of trading credits, depending on the location of the point source and the timing of the trade. In addition, in the currently targeted program design, trading ratios will apply to credits generated (i.e., pounds of nutrient reduced) at the edge-of-field application of agricultural management practices.

2.1.3.2 Receiving Water Attainment Status

Biological assessments and water quality reports prepared by OPEA for surveys conducted in the Great Miami River watershed in mid to late 1990s were used to identify the attainment status of receiving waters (OEPA, 2001, 1997, and 1996). A use attainment status map provided by OEPA (unpublished, 2004) was also used. Of the 314 point sources in the watershed, 109 were mapped using available latitude/longitude data to ascertain the appropriate trading ratios. The attainment status of their receiving waters was identified using either the reports or the OEPA map. The water quality reports specified the attainment status of the receiving waters of surveyed point sources. The OEPA map was used for point sources not surveyed in these reports. Point sources were considered discharging into attaining waters if they are located within one-half mile of a fully attaining water as indicated by the OEPA map. All other point sources were considered discharging to impaired waters. These 109 mapped point sources included most of the large dischargers (with a flow greater than 0.5 MGD) in the watershed, accounting for 86% of the total actual point source flows. Applying the trading ratios in Table 2-2, credit demand of each of these 109 point sources was calculated.

2.1.3.3 Upstream-only Trading

In the currently targeted program design, buyers (point sources) can purchase credits only from upstream non-point sources. This upstream-only limitation is protective of water quality downstream of the point source. Economically, the limitation for upstream credit purchases has two major ramifications for the trading program. First, credit supply and demand becomes localized. In other words, any geographic location in the watershed has its own credit market and all the local markets on the same stream are interconnected. Second, point sources located in the upstream (headwater) areas of the watershed are in a more competitive market for credits because as one moves upstream, potential credit supply diminishes. For purposes of this study, point sources can trade with any upstream non-point sources AND those non-point sources in the same subwatershed as delineated for this study (see Section 2.2.1.1). This assumption was made because the non-point source model used in this assessment treats all point sources in a particular subwatershed as if they are all located at the outlet of the subwatershed.

2.1.3.4 Calculation Strategy for Point Source Credit Demand

Because point sources can trade only with upstream non-point sources and trading ratios vary with the use attainment status of receiving waters, both credit supply and demand of each point source depends crucially on its location in the watershed. The 109 point sources with their exact location (latitude/longitude) identified in this study are shown in Figure 2-2. Among these point sources, 74 discharge into impaired waterways and 35 into attaining waterways. Credit demand for each of these 109 point sources was calculated based on: 1) the trading ratio applicable to the particular point source as a result of the use attainment status of the receiving water; and 2) the trading period in consideration. For example, located in central Darke County on the Stillwater River, Greenville Sewage Treatment Plant (Figure 2-2) needs an annual TP reduction of 10,604 pounds in order to reach an equivalent 1 mg/L effluent TP level. Because it discharges to Greenville Creek, a non-attaining water, the plant would need 21,209 pounds of TP credits based on a trading ratio of 2:1 if it opts for "before requirement" trading. If the plant decides to take part in the program "after requirements" within the new permit, then the credit requirement would be 31,813 pounds due to a higher trading ratio of 3:1 (Table 2-2).

For the remaining 205 point sources that did not have readily available latitude/longitude information, the attainment status of their receiving waters is unknown. Therefore, it was assumed that 32% of them discharge to attaining waters and 68% to non-attaining waters. This ratio is based on the receiving water attainment status of the 109 point sources with known latitude and longitude information. This was believed to be a reasonable assumption as the 109 mapped point sources accounted for over 80% of the total annual flow, TP load, and TN load of all point sources in the watershed (Table 2-3).

Table 2-3: Comparisons of point sources (PS) information.

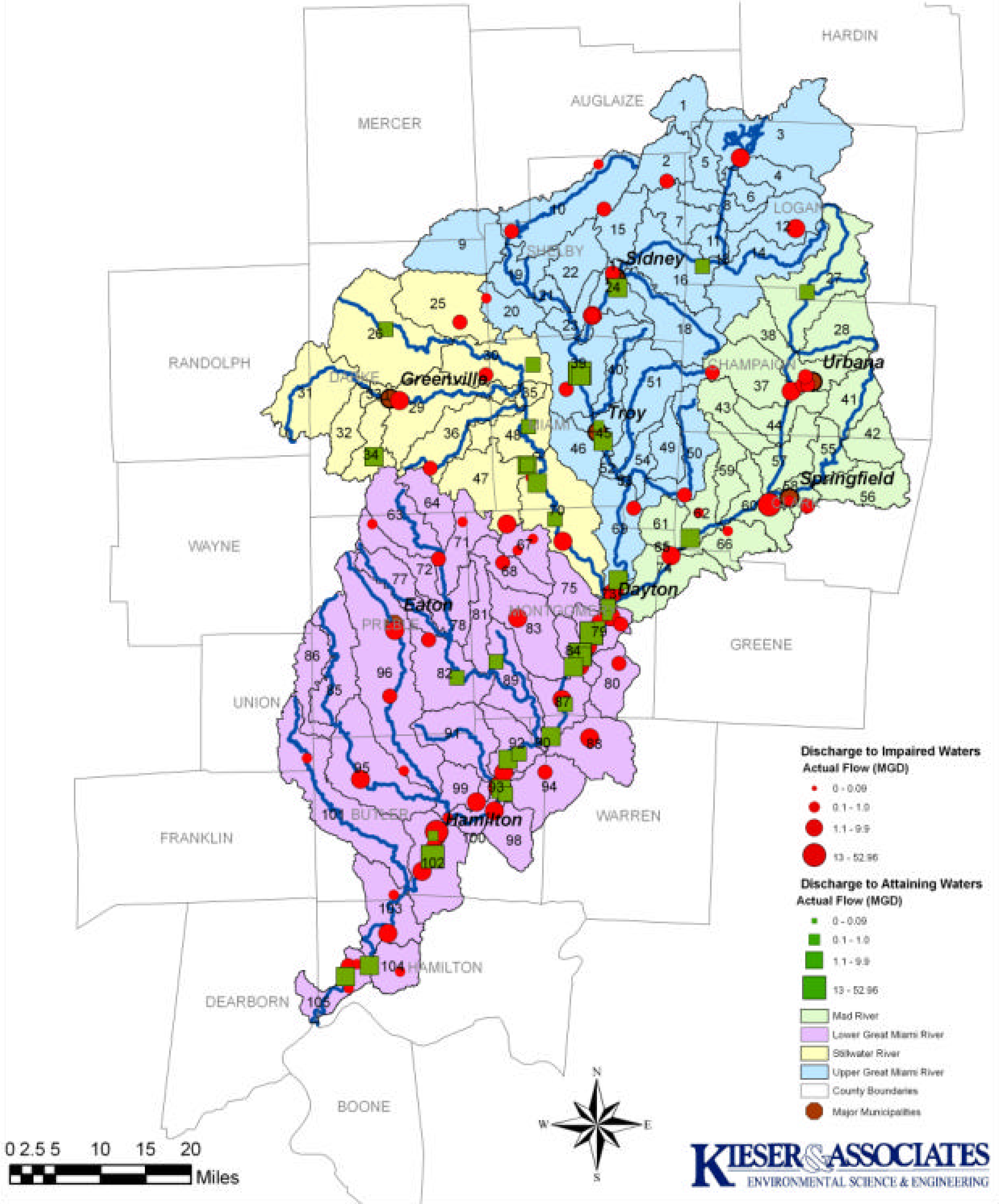
	Mapped PS	Unmapped PS	All PS	% of Mapped PS
Number of Point Sources	109	205	314	35
Flow (MGD)	300	51	351	86
Annual TP Load (pounds)	1,521,814	357,602	1,879,416	81
Annual TN Load (pounds)	12,364,543	2,314,989	14,679,532	84

2.2 Credit Supply Calculations

In order to assess the economic benefits of point source/non-point source trading, it is necessary to understand how effective agricultural management practices are in reducing loadings of TP and TN from agricultural land in the GMR watershed. This, in turn, requires an evaluation of the current and future (after the application of agricultural management practices) loadings of these two nutrients from various assessment locations in the watershed. Due to the lack of water quality monitoring data for the watershed, and its large size (3,800 mi^2), a modeling approach was necessary for such an evaluation.

The Soil and Water Assessment Tool (SWAT) model was selected for this modeling application. SWAT is a river basin, or watershed scale model developed by Dr. Jeff Arnold for the USDA Agricultural Research Service (ARS). SWAT was developed to predict the impact of land management practices on water, sediment, and agricultural chemical yields in large complex

Figure 2-2: Mapped Point Source Dischargers in the Great Miami River Watershed



watersheds with varying soils, land use and management conditions over long periods of time (Neitsch et al., 2002). SWAT has been used extensively in the U.S. for TMDL applications. The OEPA employed SWAT for its TMDL development for the Stillwater River watershed, a subwatershed of the GMR. The U.S. EPA has accepted SWAT as a major modeling tool for TMDL development (OEPA, 2003). SWAT has also been incorporated into U.S. EPA's BASINS (Better Assessment Science Integrating point and Non-point Sources) system, developed for watershed and water quality-based assessment and integrated analysis of point and non-point sources. BASINS integrates a geographic information system (GIS), national watershed and meteorological data, and environmental assessment and modeling tools into one convenient package. The SWAT modeling in this study was conducted within the BASINS platform.

2.2.1 SWAT Modeling

This section outlines the modeling approach using SWAT. Part B of the Technical Memorandum (K&A, 2004) provides a more detailed description of the SWAT modeling.

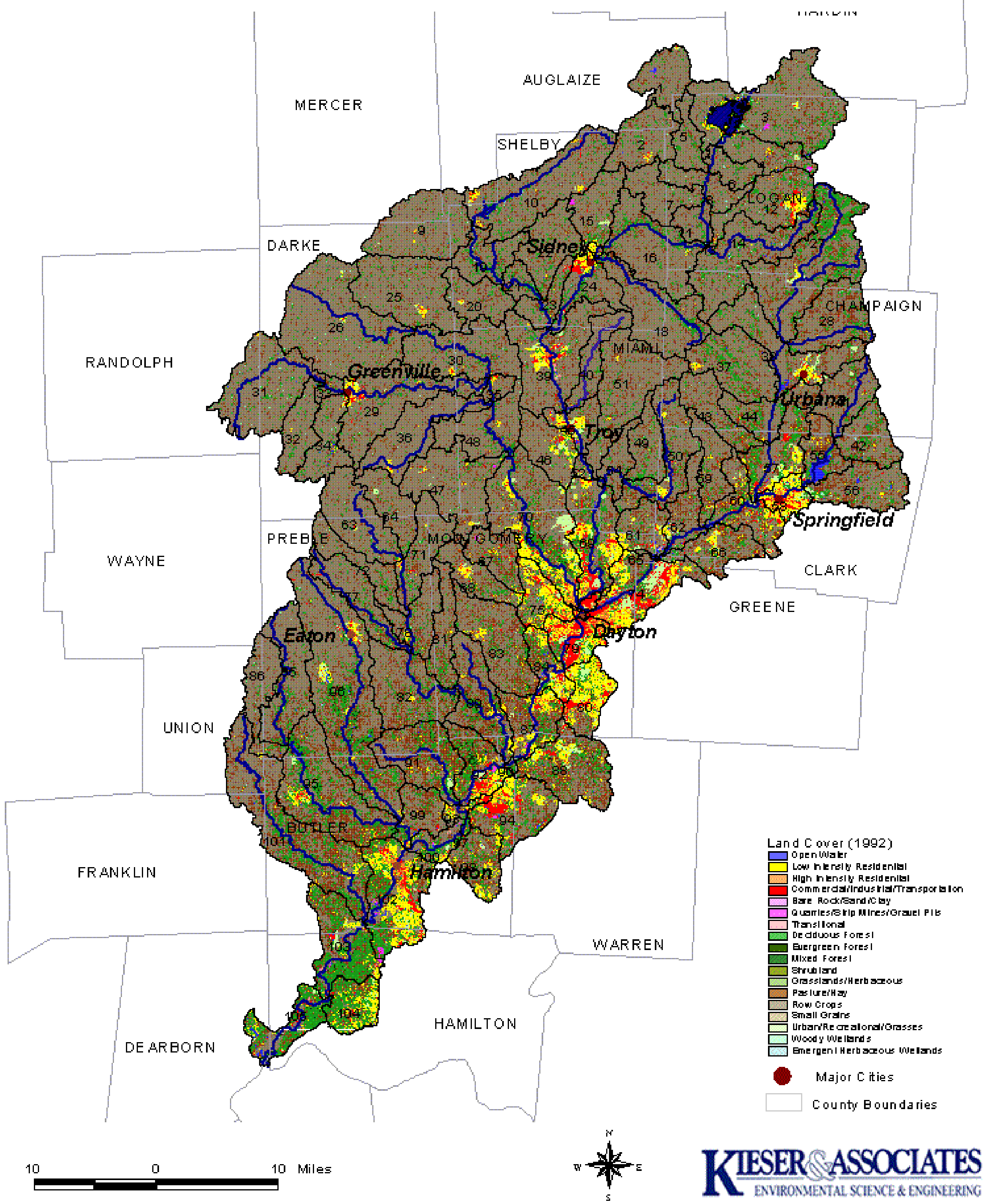
2.2.1.1 Data Input

The U.S. Geological Survey (USGS) has compiled 1992 land cover data in its National Land Cover Data Set for the entire contiguous United States. These data are available on the web in a GIS format (http://landcover.usgs.gov/natllandcover.asp) at a 30-meter resolution. Data for the area encompassing the GMR watershed were downloaded from USGS and processed for incorporation into the BASINS-SWAT interface. Figure 2-3 shows the land cover distribution for the GMR watershed.

USGS has also developed a Digital Elevation Model (DEM) data set with a 30-m resolution for the contiguous United States. Areas in and around the Great Miami River Watershed were downloaded from the USGS website (http://edc.usgs.gov/guides/dem.html). The resulting GIS grid file was utilized in SWAT modeling to delineate subwatersheds of the Great Miami River watershed. For purposes of this study, 105 subwatersheds were defined to form the basic hydrologic response units in SWAT. These subwatersheds also formed the basis of subwatershed level analyses on trading economics in this study. Figure 2-3 shows the boundaries and assigned serial numbers of these subwatersheds. Note here that these numbers are simply SWAT model designations. They are nothing more than random codes for the identification of the model-delineated subwatersheds and do not relate to any other designations that various state and federal agencies use to refer to the geographic areas covered by these subwatersheds.

BASINS built-in state soil data layers (Indiana and Ohio) were used in the modeling. Dr. Dale White from Ohio EPA provided weather and agricultural management information for the model from a recent TMDL modeling effort in the Stillwater River subwatersheds (OEPA, 2003). Point source flow and nutrient loading data (monthly or constant daily loadings, dependent on data availability) were obtained for 30 active major point sources (as defined by U.S. EPA's PCS system) from U.S. EPA's *Envirofacts* on-line database.

Figure 2-3. Land Cover of the Great Miami River Watershed



2.2.1.2 Model Calibration

SWAT models the in-stream processes of pollutants, which is essential for the simulation of pollutant loading in the watershed. Flow calibration of the SWAT model was based on USGS gage station data at station No. 03266000 (Stillwater River at Englewood) and No. 03274000 (GMR near Hamilton). Calibration procedures were formed following Arnold et al. (2000), Santhi et al. (2002), and Neitsch et al. (2002). Dr. Dale White also provided some key suggestions on the calibration according to his experience with the Stillwater River TMDL development (personal communication, 2004). Cursory sediment and nutrients calibrations were also attempted in this study based on limited USGS monitoring data.

2.2.2 Current Non-point Source Loading

Agricultural land management scenarios in the GMR watershed were assigned according to the USGS 1992 land cover data. Tillage practices (conventional or conservation) data on the county level were provided by MCD (unpublished data, 2004). To segregate county level data into subwatershed levels, an algorithm based on randomly assigned numbers and manual adjustment was used (K&A, 2004). The endpoint of this algorithm was reached when the percentage of area in no-till (conservation tillage) in each county in SWAT matched within 10% of the data provided by MCD.

Model simulations of current non-point source loadings (to which reduced loadings from applying agricultural management practices are compared) were conducted for the entire GMR watershed from October 1989 through September 2001 using available weather station data. It was also assumed here that corn-soybean rotation was the only crop production practice in the agricultural land in the GMR watershed. For this 12-year period, simulation results from the first four years (the model set-up period) were discarded and the average annual loadings from the last 7 years (October 1994 through September 2001) were used as the current loadings.

2.2.3 Agricultural Management Practice Simulations

Three watershed-wide agricultural management practices were simulated successively in this study: 1) converting conventional tillage practices to no-till; 2) nutrient management (excluding animal feedlot management) resulting in a 50% reduction of phosphorus and nitrogen fertilizer usage in all the cropland in the watershed; and 3) converting agricultural land from corn-soybean rotation to hay-only operations in subwatersheds where the first two BMPs did not provide sufficient credits for local point source needs. No site-specific simulations of other non-point source management practices were attempted given the limited scope of the project and lack of site-specific reference information.

For purposes of this preliminary economic study, the application of agricultural management practices in SWAT was simulated on the subwatershed scale. In the Great Miami River watershed, approximately 50% of croplands are currently under no-till practices while less than 5% are employing nutrient management plans. Accordingly, the no-till practice was applied to agricultural subwatersheds that are not currently in no-till while nutrient management was applied to all the agricultural subwatersheds after all were considered to be 100% no-till, and assuming that none of them are currently under nutrient management.

Nutrient load reductions calculated for the outlet of each subwatershed were compared to credit demand of point sources in each subwatershed. For those subwatersheds that did not meet the credit demand, particularly TN demand, the corn-soybean to hay-only conversion was applied. This hay-only conversion simulation is an artificially formulated management practice based on the corn-soybean-wheat-grass rotation currently used by some farmers in the watershed. It was used in this study as a representation of those management practices requiring substantial changes in traditional agricultural operation activities. The hay-only operation involves the planting of perennial hay on formerly corn-soybean cropland. No fertilizer and tillage operations were simulated in these select subwatersheds and hay harvest was allowed four times a year.

Exactly how much reduction in fertilizer/manure application can be achieved through nutrient management is highly dependent on local conditions. Generally, soil nutrient tests will be conducted before a nutrient management plan is made for a particular farm. The test results, along with other pieces of site-specific information such as soil properties, yield expectations for the crops to be grown, and environmental susceptibility of the surrounding landscape features, will then decide how much fertilizer/manure should be applied. Because it was not feasible to obtain such site-specific information in this study, a 50% reduction in fertilizer application was used here for all phosphorus and nitrogen-related fertilizer and manure applications to simplify the model simulation. This reduction rate, although implemented in other parts of the nation (e.g., Magdoff et al., 1984 [Vermont] and Bouldin et al., 1971 [New York]), was quite aggressive. However, because nutrient management was added in addition to no-till in this study, benefits of lower reduction rates in fertilizer application provided limited reductions or proved to be insignificant in some subwatersheds. The 50% reduction was used in this study mainly to show the potential of the agricultural sector in reducing nutrient loadings. In practice, nutrient management may well be adopted by landowners before no-till and lower application reduction rates can yield large nutrient load reductions (U.S. EPA, 1993).

It should be noted here that the three agricultural management practices selected for this analysis represent broad scale management applications that were easily accommodated by the limited scope of non-point source modeling. These types of management practices lend themselves to broad-based programmatic implementation. They do not, however, account for additional nutrient load reductions that can accompany site-specific application of buffer strips, wetlands, animal management practices, etc. (that could not be assessed within the scope of this project). These additional management practices will likely create more nutrient load reductions than derived from the current SWAT model simulations.

The above three practices were also chosen in this study because no-till and nutrient management represent some of the most widely applied and probably most cost-effective agricultural management practices in the nation. Converting to hay-only operations, on the other hand, may well be one of the less cost-effective strategies. Therefore, using these three practices yields reduction estimates with a range of cost-effectiveness that also encompass a wide range of potential agricultural management practices. Such information will be valuable in guiding the operation of the pilot trading program.

2.2.4 Agricultural Management Practice Costs

Watershed specific costs of conducting various agricultural management practices in the GMR watershed were difficult to determine absent direct local information from USDA. It was therefore decided that for purposes of this preliminary economic study, literature values would be used. Direct payments to farmers to induce no-till vary widely among different localities and individual farmers. Many farmers in the upper Midwest have adopted no-till even without any incentive payment. In addition, farm-level economic cost-benefit analyses often indicate a net profit with the adoption of conservation tillage or no-till (e.g., Haper, 1996; Massey, 1997; and Forster, 2002). A recent study on the cost of nutrient and sediment reduction in the Chesapeake Bay watershed (U.S. EPA, 2003b) cited a net farm cost of $2.72/acre/year for applying conservation tillage. Kurkalova et al. (2003) used a modeling approach based on the contingent valuations literature that computed directly the subsidies needed for adoption of conservation tillage in Iowa. They incorporated an adoption premium related to uncertainty in addition to changes in expected profit because the adoption premium may exceed the profit gain. Consequently, the farmer would require a subsidy to adopt the practice. They concluded that it would need an annual subsidy of $2.40 per acre for corn and $3.30 per acre for soybeans (1992 dollars).

Among the literature reviewed for this study, the Kurkalova et al. (2003) estimate represented the most rigorous evaluation of subsidies for inducing conservation tillage (including no-till) in the upper Midwest. Therefore, the average of the annual subsidies for corn and soybean ($2.85) from their study was used for this analysis. Applying a Producer Price Index increase of 8.2% from 1992 to 2001, this number was translated into $3.08 in 2001 dollars.

Costs for implementing nutrient management on cropland correspond to equipment and labor for soil testing, hiring a consultant to design the plan, and the costs of any additional passes over the field to fertilize. Assuming a 3-year useful life for a plan once it is developed, and including the costs of soil testing, implementation, (and in some cases, cost savings and yield increases), net cost estimates range from -$30/acre/yr (i.e., a net cost savings) to $14/acre/yr in 2001 dollars (U.S. EPA, 2003b). In this study, a cost of $2.65/acre/yr in 2001 dollars was used as cited by U.S. EPA in its *National Management Measures for the Control of Non-point Pollution from Agriculture* (U.S. EPA, 2003c).

Converting agricultural land from a corn-soybean rotation to the hay-only operation was considered in this study because it was an easy agricultural management practice to simulate in SWAT with the available information on agricultural practices in the GMR watershed. Cost information for such conversion, however, was not readily available. USDA's Farm Service Agency in its fiscal year 2002 summary for the Conservation Reserve Program (CRP) reported an average annual rental payment of $43.80 per acre. This number was adopted in this study for the hay-only operation. Land enrolled in CRP is generally taken out of production while conversion from corn-soybean production to hay-only would still allow hay harvest. Therefore, $43.80 per acre payment for hay-only operation is likely an overestimate. Consequently, the per pound nutrient reduction costs calculated based on this payment amount are likely to be conservative.

In order to compare cost of non-point source agricultural reductions with costs of point source load reductions (see Section 2.1.2), net present worth values were calculated for these annual agricultural management practices based on the acreage of practice adoption, a 20-year practice implementation time, and a five percent interest rate. Cost-effectiveness of these practices on a per pound basis was then calculated by dividing the net present worth by the total load reduction achieved over the 20-year period.

CHAPTER 3

RESULTS AND DISCUSSION

3.0 Overview

This chapter presents the results of the economic analysis for point source/non-point source trading in the Great Miami River watershed. It compares pounds of demand to available supply for the entire GMR watershed, its subwatersheds, and individual point sources. It then examines costs of meeting demand with BNR and then with trading. Potential implications of these findings are highlighted in the context of future trading program applications and implementation. Interested readers are referred to the companion Technical Memorandum (K&A, 2004) for a more detailed and complete presentation of the results.

3.1 Demand and Supply

This section deals with the estimated demand and supply of nutrient credits. Demand from point sources is presented on the watershed, subwatershed and individual point source levels. Supply is described according to the three agricultural management practices simulated in this study. Comparisons between demand and supply are then conducted to reveal the balance of potential credit markets on the watershed, subwatershed, and individual point source levels.

3.1.1 Credit Demand

Credit demand by a point source is determined by the difference between current loads and future required loads with application of the appropriate attainment or non-attainment trading ratio for the "before requirement" application.

3.1.1.1 Point Source Load Reduction Needs

Figure 3-1 illustrates the distribution of point sources in the Great Miami River (GMR) watershed according to natural breaks in actual discharge volumes. The greatest proportion of point sources (40%) are those with reported discharges smaller than 0.03 MGD. There are only seven point sources with flows greater than 13 MGD and only fifty-three point sources greater than 1 MGD.

Over 90% of the estimated nutrient loads are from dischargers with reported flows greater than 1 MGD. Currently estimated annual watershed loads from point sources are 1,879,416 pounds of TP and 14,679,532 pounds of TN. Figures 3-2 and 3-3 illustrate current loads and target loads with future effluent criteria for TP (1 mg/L) and TN (10 mg/L), respectively.

The total required annual point source load reductions associated with the more stringent effluent limits are 904,015 pounds for TP and 4,47,978 pounds for TN (Figure 3-4). The majority of the load reduction is attributed to point sources greater than 1 MGD. Point sources in the 1.01-9.9 MGD category (actual flow) require the greatest TP reduction (505,462 pounds annually or 56%

of the total). Forty-six percent of the TN load reduction need is from point sources in the 1.01-9.9 MGD size category (2,062,140 pounds annually). The largest point source size category only contains six plants that need to reduce their nutrient loadings according to available monitoring data, but accounts for 31% of the TP load reduction and 43% of the TN load reduction needs in the watershed.

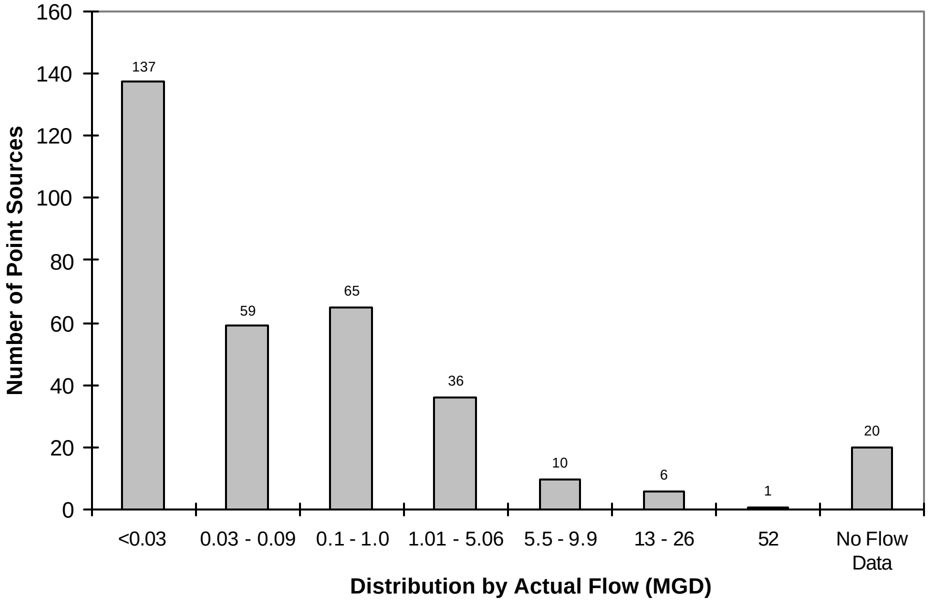


Figure 3-1: Distribution of point sources by actual flows in the Great Miami River watershed.

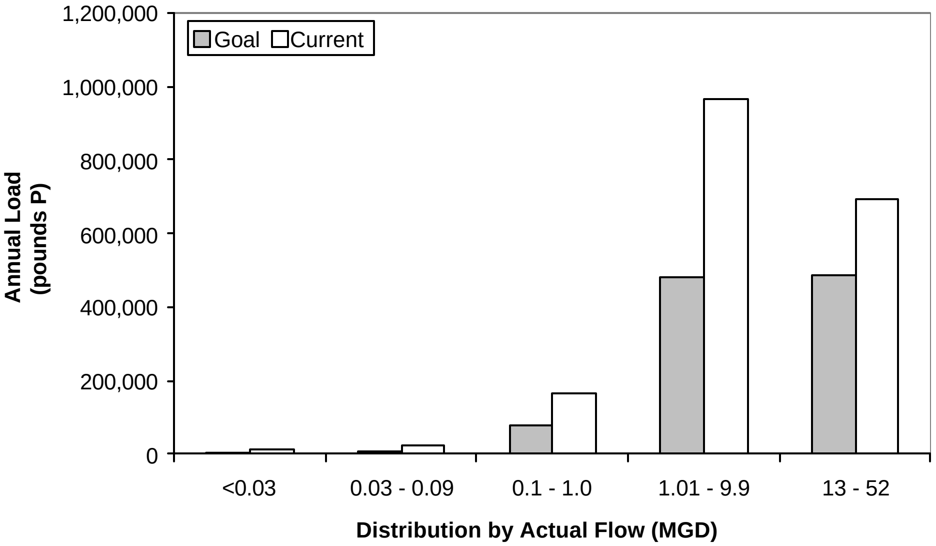


Figure 3-2: Distribution of point source current and goal annual TP loads by actual flows.

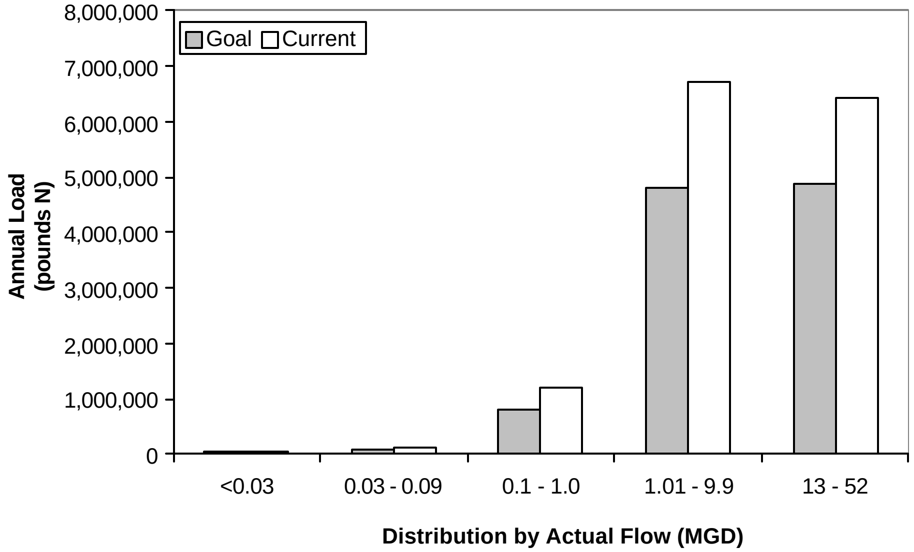


Figure 3-3: Distribution of point source current and goal annual TN loads by actual flows.

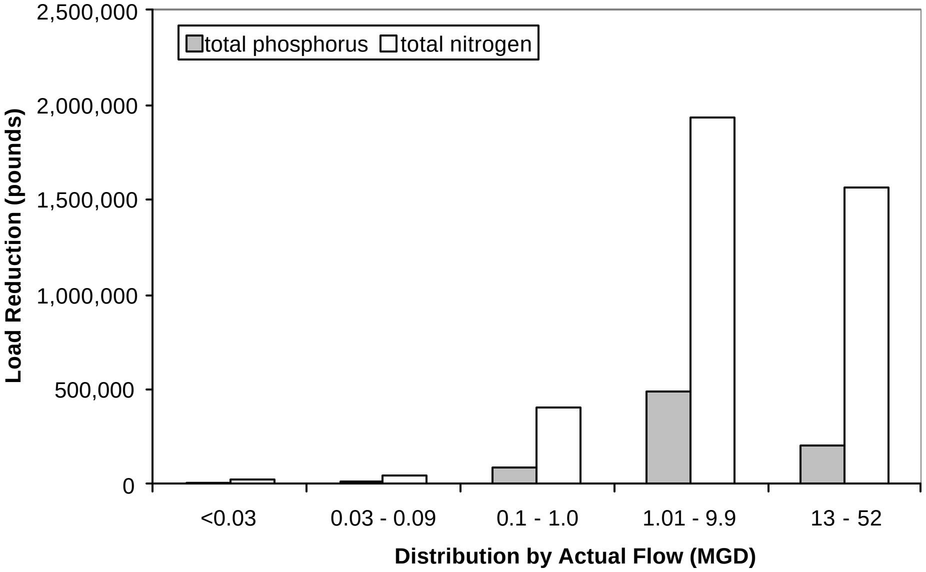


Figure 3-4: Distribution of point source annual total load reduction needs by actual flows.

3.1.1.2 Point Source Credit Demand

Credit demand is a function of a point source's actual flow, current treatment efficiency, and the use attainment status of the receiving waters. Calculations based on data provided by MCD, U.S. EPA's *Envirofacts* and assumptions described in Chapter 2, yielded the nutrient load reduction and credit demand information for the entire GMR watershed shown in Table 3-1.

Table 3-1: Point source nutrient load reduction needs and credit demand for the entire GMR watershed.

Trading Period	Current Load (lbs)	Load reduction needed [1] (lbs)	Reduction percentage	Credit Demand (lbs)
Total Phosphorus				
Before requirement	1,879,416	904,015	48%	1,349,207
After requirement				2,253,222
Total Nitrogen				
Before requirement	14,679,532	4,475,978	31%	6,380,721
After requirement				10,865,700

[1] Not including Hamilton WWTP, as recent monitoring data indicate that it meets the effluent nutrient concentration goals.

Point sources in the GMR watershed would need to reduce TP load by nearly one half of the estimated current load and TN by one third. Credit demand, reflecting the impact of trading ratios, is over 40% higher than the load reduction needed for both TP and TN before load reductions become mandatory in the next permit ("before requirement") and nearly 150% higher "after requirement". The fact that more TN credits would be needed by the point sources than TP credits is the result of the substantially higher TN reduction requirements. This, in turn, is a result of the larger difference between the current TN effluent level (15 mg/L) for point sources in the watershed and the target TN nutrient criterion (10 mg/L).

3.1.1.3 Subwatershed Level Demand

The upstream-only trading limitation for point sources results in variable credit supply from subwatershed to subwatershed. Consequently, when studying the balance between supply and demand, it is also important to know credit demand on the subwatershed level.

With exact locations of 205 point sources in the watershed not determined, subwatershed level demand was only analyzed for the 109 mapped point sources (Figure 2-2). As a result, demand from some subwatersheds will be higher than what is presented in this report. However, Table 3-2 shows that credit demand of these 109 analyzed point sources accounts for over 75% of the total demand of all the point sources. In addition, the seven largest point sources with design flow equal to or greater than 20 MGD were all included in the 109 mapped point sources. As these plants are likely to be major credit buyers in this trading program, results from this subwatershed level credit demand analysis should produce a fairly accurate picture of subwatershed credit markets. More importantly, results illustrate the effects of upstream-only trading on the supply and demand balance in individual subwatershed credit markets in the watershed. This is believed to be a crucial demonstration of how this preliminary economic study can guide future implementation of a trading program. Several examples of these issues are presented in this section of the report.

Table 3-2: Estimated credit demand for point sources (PS).

Trading Period	Mapped PS (lbs)	Unmapped PS (lbs)	All PS (lbs)	Portion of Mapped PS (%)
Total Phosphorus				
Before requirement	1,007,918	341,288	1,349,207	75
After requirement	1,708,665	544,557	2,253,222	76
Total Nitrogen				
Before requirement	5,085,099	1,295,622	6,380,721	80
After requirement	8,798,414	2,067,286	10,865,700	81

Calculations indicate that subwatersheds Nos. 102, 39, and 84 have the highest TP credit demand (Table 3-3). These are all located on the GMR main stem (Figure 2-2) and have major point sources discharging to the river, including Smart Papers and Fairfield WWTP in subwatershed No. 102, Piqua WWTP in No. 39, and Appleton Papers in No. 84. In addition, none of five subwatersheds with the greatest demand for TP credits are located in a headwater area and three of them (Nos. 102, 84, and 79) are dominated with urban land uses (Figure 2-3), reflecting the fact that major point sources in the GMR watershed are generally located in urban centers along large streams and rivers. The top five subwatersheds for TP credits also include the top four subwatersheds for TN credits. The only exception is Subwatershed No. 60, where Springfield STP is located. According to *Envirofacts* data (Table 2-1), Springfield STP currently discharges TN at a concentration of 10.86 mg/L, very close to the 10 mg/L target. As a result, it would not need many TN credits in the trading program.

Table 3-3: Examples of subwatershed credit demand (before load reduction requirement).[1]

Subwatershed number	**Headwater subwatersheds (Yes/no)**	**Number of Identified Point Sources**	**Major County Name**	**TP Credit Demand (lbs)**	**TN Credit Demand (lbs)**
Subwatersheds with largest TP credit demand					
102	No	5	Butler	126,066	553,802
39	No	3	Miami	103,267	432,738
84	No	5	Montgomery	93,604	395,432
60	No	1	Clark	89,647	81,154
79	No	6	Montgomery	87,722	1,164,535
Subwatersheds with smallest TP credit demand					
100	No	1	Butler	0	0
101	Yes	1	Butler	91	228
20	Yes	1	Shelby	146	366
72	Yes	1	Preble	305	1,523
48	No	1	Miami	366	1,828
Subwatersheds with median TP credit demand					
62	No	2	Clark	4,021	19,799
50	Yes	1	Champaign	4,082	20,408
68	Yes	1	Montgomery	4,618	23,089
3	Yes	1	Logan	4,965	65,141
Watershed average	--	*2*	--	*18,665*	*94,169*

[1] Tables C-2 and C-3 in K&A (2004) provide complete lists of subwatershed credit demands.

Each of the five subwatersheds with the lowest TP credit demand has only one small mapped point source. Most of these subwatersheds are in headwater areas. Located in Subwatershed No.

100, the Butler County Lesourdsville Water Reclamations plant has zero TP and TN demand because available data (Table 2-1) indicate that the plant is currently meeting the 10 mg/L TN and 1 mg/L TP effluent nutrient limits.

For individual point sources, Dayton Wastewater Treatment Plant, which is located in subwatershed No. 79, downstream of the three major branches of the GMR (the Stillwater River, the Mad River, and the Upper GMR), is the largest plant in the entire watershed in terms of design flow (72 MGD) and reported actual flow (53 MGD). Dayton WWTP currently has an average effluent TP concentration of 1.4 mg/L and TN of 16.5 mg/L (Table 2-1). Because the segment of the GMR that receives discharge from Dayton WWTP is a fully attaining water as evaluated in the 1995 survey (OH EPA, 1997), a trading ratio of 1:1 is applicable. This results in an annual TP credit demand of 64,526 pounds and a TN demand of over 1.0 million pounds for the "before requirement" condition. Table 3-4 illustrates these demand scenarios along with other select point sources. These point sources were chosen to represent a variety of actual flow, receiving stream attainment status, and subwatershed location conditions. If Dayton WWTP decides to trade "after requirement", these numbers would double due to a higher trading ratio of 2:1. The substantially higher TN credit demand than TP is a result of the plant's current much higher TN effluent concentration reduction need (6.5 mg/L, vs. 0.4 mg/L for TP). In fact, Dayton WWTP has the highest TN credit demand among all the point sources in the entire GMR

Table 3-4: Examples and statistics of point source TP and TN credit demands in the Great Miami River watershed before load reduction are required by the next permit (before requirement).[1]

NPDES Number	**Receiving Water Status** [2]	**Sub-watershed No.**	**Head-water? (Yes/no)**	**Plant Name**	**Actual Flow (MGD)**	**TP Credit Demand (lbs)**	**TN Credit Demand (lbs)**
OH0024881	Att.	79	No	Dayton WWTP	52.96	64,526	1,048,555
OH0025445	Att.	102	No	Hamilton WWTP	20.27	0	0
OH0026522	Imp.	93	No	Middletown WWTP	17.16	0	303,162
OH0027481	Imp.	60	No	Springfield STP	15.49	89,647	81,154
OH0010065	Imp.	102	No	Smart Papers	15	91,380	456,900
OH0026638	Att.	84	No	Montgomery Co. W. Reg. WWTP	13.65	49,893	74,840
OH0025071	Imp.	102	No	Fairfield WWTP	5.71	33,742	92,181
OH0009644	Imp.	47	Yes	Martin Marietta Troy Gravel	4.1	24,977	124,886
OH0024066	Imp.	12	Yes	Bellefontaine WWTP	2.65	9,525	4,197
OH0026930	Imp.	95	No	Oxford WWTP	2.5	31,374	76,150
OH0036641	Imp.	3	Yes	Logan Co. Indian Lake SSD	1.63	4,965	65,141
OH0020605	Imp.	68	Yes	Brookville STP	0.758	4,618	23,089
OH0029343	Imp.	66	Yes	Enon WTP	0.03	366	914
OH0030465	Imp.	20	Yes	Bradford WTP	0.012	146	366
IN0038911	Imp.	101	Yes	Indian Hills MHP	0.0075	91	228
Statistics [3]				*Maximum*	*52.96*	*91,380*	*1,048,555*
				Minimum	*0.0075*	*0*	*0*
				Average	*2.75*	*9,247*	*46,652*
				Median	*0.49*	*2,008*	*9,443*

[1] Examples were selected to include

[2] Receiving water use attainment status: Imp.—impaired and Att.—attaining.

[3] Based on the 109 mapped point sources.

watershed. The point source with the largest flow in Subwatershed No. 102 is Hamilton WWTP (20.27 MGD). However, recent concentration data indicate that this plant is actually meeting the nutrient criteria of 1.0 mg/L for TP and 10 mg/L for TN (Table 2-1). As a result, Hamilton WWTP does not have any credit demand for TP or TN. Nevertheless, Subwatershed No. 102 has two other large point sources, Smart Papers and Fairfield WWTP (Table 3-4) that have high flows (15 and 5.71 MGD, respectively), and two very small point sources (0.16 MGD in total). Combined these four point sources make up the largest subwatershed TP demand in the GMR watershed with an assumed TP effluent concentration of 2 mg/L for Smart Papers and the two small sources, and a measured 1.97 mg/L for Fairfield WWTP (Table 3-3).

For TN, Subwatershed No. 93 is a major source of credit demand because monitoring data indicate that Middletown WWTP, a 17.16 MGD point source, is meeting its TP effluent level target but not the level for TN (Table 3-4). There is also another significant point source (Crystal Tissue) in the same subwatershed contributing both TN and TP credit demand (See Part A of the Technical Memorandum).

3.1.2 Credit Supply with Agricultural Management Practices

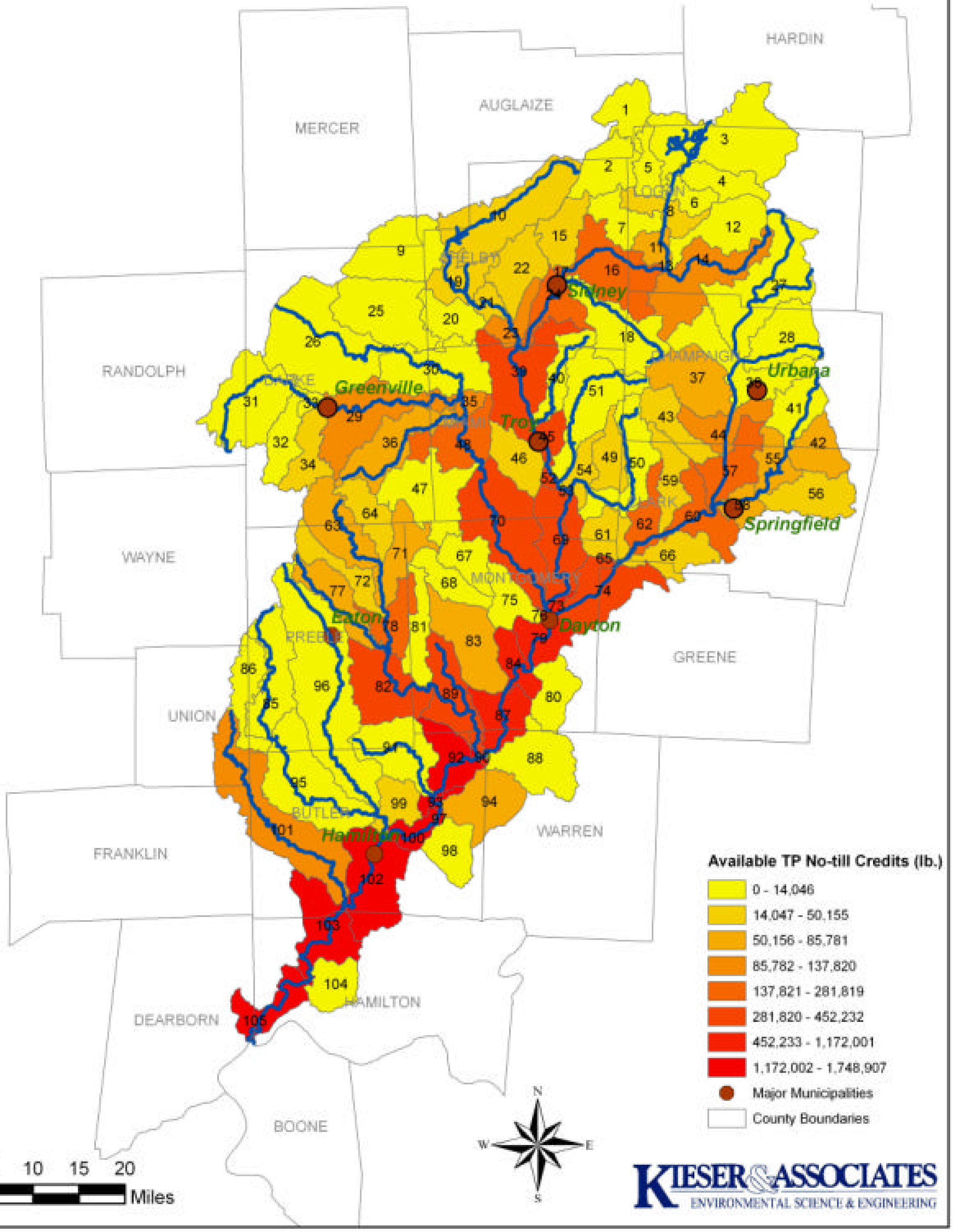
This study successively simulated three agricultural management practices. This subsection presents results and discussion on credit supplies of TP and TN predicted from each of these three management practices.

3.1.2.1 No-till Cropland Management Practice

To generate sufficient no-till load reduction credits, a subwatershed must possess two conditions. First, its land use pattern must be agriculturally dominated. This is necessary because no-till can only be applied to row crop agricultural land and in this study, SWAT assigned and modeled the land use category of each subwatershed according to its dominant land use. Second, a subwatershed must be currently assigned a conventional tillage management scenario in the model so that switching from conventional tillage to no-till is possible (see K&A [2004] for further descriptions).

Of the 105 subwatersheds delineated for purposes of this study, 45 are already in no-till practice; 19 are non-agricultural land (including pastures); and 41 are available to be converted to no-till from conventional tillage. Figure 3-5 shows the estimated amount of available upstream no-till TP credits for all the subwatersheds in the GMR watershed. Subwatershed-level TN credit availability exhibits the same subwatershed distribution pattern as TP. Tables C-1 and C-2 in K&A (2004) show available TP and TN credits, respectively, accumulated at the outlet of each subwatershed. There were 33 subwatersheds with zero no-till TP credit supply. They fall into one of the following three situations:

Figure 3-5: Estimated Annual TP No-till Credits Available for Each Subwatershed



- headwater subwatersheds already in no-till practice (e.g., Nos. 2, 50, and 98);
- non-headwater subwatersheds that are already in no-till practice AND all their upstream subwatersheds are also already in no-till practice (e.g., Nos. 30 and 38)
- headwater subwatersheds with non-agriculturally dominated land uses (e.g., Nos. 80 and 104, which are urban low density residential and deciduous forest, respectively).

It is clear from Figure 3-5 that available credits accumulate towards the downstream sections of all waterways. Subwatersheds located on the lower reaches of a waterway generally have higher available credits than those on the upper reaches. Not surprisingly, Subwatershed No. 103 and 105, which are the two subwatersheds closest to the mouth of the GMR at the Ohio River, have the greatest amount of TP credits (over 1.7 million pounds) available to their point sources. (Subwatershed No. 104 is a forested tributary subwatershed and did not contribute any agricultural management practice credits.)

In the currently targeted program design, credits are calculated at the edge of the field where agricultural management practices are applied. The SWAT model, as it was used in this study, applied agricultural management practices on a subwatershed scale (see Section 2.2.3). In addition, SWAT simulates the in-stream processes of pollutant movement downstream through the watershed, which was necessary for model calibration. The resulting credit value of any particular agricultural management practice in a subwatershed was then presented at the outlets of the subwatershed and each of its downstream subwatersheds. These differences in credit quantification between the program design and SWAT modeling lead to the conservative estimates of credit supply (i.e., underestimates) for downstream point sources in this study. This is due to the in-stream pollutant attenuation processes applied in the modeling.

Precise watershed level credit supplies cannot presently be determined due to the difference in credit quantification in trading program design and current SWAT modeling. Accumulated TN and TP credits at the outlet of the most downstream Subwatershed No. 105 (Figure 3-5) are therefore used in this report as approximates to assist the reader to gain an overall understanding of the credit supply and demand for the entire GMR watershed. At the outlet of Subwatershed No. 105, no-till can generate 1,743,657 pounds of annual TP credits with a watershed-wide average TP load reduction efficiency of 1.77 pounds/acre. These values for TN are 4,226,431 pounds and 4.30 pounds/acre. No-till generates more TN credits than TP based on modeled applications.

Because higher trading ratios would be applied if point sources decide to participate in the trading program after load reductions become mandatory (“after requirement”), credit demand for TP and TN would also change. On the other hand, these changes would not affect credit supply by no-till estimated in this study because all the potential no-till credits have been generated with the conversion of all conventionally tilled subwatersheds to no-till.

3.1.2.2 No-till and Nutrient Management

After nutrient management (50% fertilizer reduction) is applied across the watershed in row crop subwatersheds in addition to no-till, all subwatersheds gain additional TP credits from this additional management practice with three exceptions. Non-row crop headwater subwatersheds (Nos. 80, 91, and 104) have none of the three management practices considered in this study. Results for TN were generally similar except that six subwatersheds (Nos. 15, 20, 22, 67, 75, and 83) showed a slight loss (<1,000 pounds/year) of TN credits after nutrient management. This was likely due to the reduction of biomass and thus increased erosion in these mostly small- to mid-sized headwater subwatersheds simulated by SWAT. Tables C-1 and C-2 in Part C of the Technical Memorandum (K&A, 2004) list the total credits availability for each subwatershed under all three management practices.

At the outlet of the most downstream Subwatershed No. 105, accumulated TP and TN credits stand at 2,007,489 million and 4,428,096 million pounds, respectively. The additional credits generated from applying nutrient management on top of no-till are 263,831 pounds for TP and 201,665 pounds for TN. With nutrient management applied across the watershed in all agricultural row crop subwatersheds (2.1 million acres), the additional efficiency of this management practice in reducing nutrient loadings is only 0.12 pounds/acre for TP and 0.09 pounds/acre for TN. These values are considerably lower than those of no-till. This is because no-till already substantially reduces erosion and nutrient runoff, i.e., most of the nutrient loss pathways to streams have been reduced. As a result, additional nutrient management (fertilizer/manure application) provided a limited benefit in simulations.

3.1.2.3 No-till, Nutrient Management, and Hay-only

Conversion from a corn-soybean rotation to the hay-only operation was applied to fourteen agricultural row crop subwatersheds (Nos. 2, 3, 12, 20, 25, 38, 47, 50, 67, 68, 72, 88, 95, and 96). These areas still did not have enough TN credit supply to meet the total demand (with "before requirement" trading ratios) of point sources within these subwatersheds even after the application of no-till and nutrient management. In addition, four more subwatersheds, Nos. 27, 28, 85, and 86, were also converted to the hay-only operation because their immediate downstream subwatersheds, Nos. 38 (27, 28), and 95 (85, 86) are among the list of fourteen. This brought the total hay-only subwatersheds to eighteen. Except Subwatershed Nos. 3 and 72, these eighteen subwatersheds are all located in headwater areas or immediately downstream of such subwatersheds that are already in no-till before management practice changes are simulated. No-till and nutrient management are not able to generate sufficient load reduction credits for these subwatersheds. Subwatershed Nos. 3 and 72 are also headwater reaches. Although they had both no-till and nutrient management applied, high TN credit demand and limited supply result in credit shortages in these subwatersheds. Among the eighteen subwatersheds that were converted to the hay-only operation, Nos. 2, 12, 38, 47, 68, 88, and 95 are also in need of additional TP credits.

At the outlet of Subwatershed No. 105, converting to hay-only operations in the eighteen subwatersheds can produce nearly 500,000 pounds of additional TP and over 895,000 pounds of additional TN credits on 623,000 acres of select cropland. This translates into an additional efficiency of 0.80 pounds/acre for TP and 1.44 pounds/acre for TN. With all three management practices in place, the accumulated credits at the outlet of Subwatershed No. 105 were 2,507,053 million pounds for TP and 5,323,338 million pounds for TN for the entire GMR watershed.

3.1.3 Demand and Supply Comparisons

Demand and supply comparisons are presented in this subsection on all three levels: the entire GMR watershed, individual subwatersheds, and individual point sources.

3.1.3.1 Watershed Level Comparisons

Credit demand and supply identified in this analysis are summarized in Table 3-5. Phosphorus and nitrogen load reductions associated with the three agricultural management practice scenarios are compared to the anticipated point source load reductions expected under point source treatment upgrades as well as credit demand under the envisioned trading program. Current credit demand assumes point sources will trade at 1:1 and 2:1 ratios before being required by a new permit to meet new effluent nutrient criteria of 10 mg/L for TN and 1 mg/L for TP (before requirement). Future (after requirement) credit demand assumes that no trading will occur before point sources are required by their permit to reduce nutrient loadings and thus, trading ratios will be 2:1 and 3:1. As it is anticipated that there will be some level of trading at the lower ratios, it is unlikely that the entire level of predicted future demand will be needed.

Table 3-5 indicates that when applied to about 50% of the subwatersheds in the watershed, no-till alone will be able to generate sufficient credits to meet all the before requirement total TP demand for all point sources in the watershed. If we compare the amount of available credits (1.74 million pounds/yr) to the actual point source load reduction needed (904,000 pounds/yr), there will be a 836,000 pounds/year surplus TP load reduction for the watershed. Select subwatersheds will, however, have potential credit shortages as discussed previously.

For TN, with no-till alone, only 66% of the current (“before requirement”) watershed level TN credit demand can be met. Although not sufficient to meet the credit demand, non-point source TN load reductions generated by no-till alone (4.23 million pounds/year) are, however, very close to meeting the point source load reduction requirement of 4.48 million pounds/year (i.e., 94%). With all three management practices in place, 83% of the current TN credit demand can be met and there will be a net environmental benefit of 847,000 pounds TN per year. However, the future (“after requirement”) watershed TN credit demand is twice as much as all three management practices combined can supply.

3.1.3.2 Subwatershed Level Comparisons

Subwatershed level credit demand and supply under the three management practice scenarios considered in this study is also summarized in Table 3-5. Select subwatersheds, especially those located in headwater areas, are already in no-till and thus not available for additional no-till application. The “no-till on all lands” scenario, therefore, has the most subwatersheds without sufficient credit supply for both TP and TN (Tables 3-6 and 3-7). After nutrient management is added across the watershed, TP credit supply improves substantially with only seven subwatersheds left with potential credit deficit. However, thirteen subwatersheds remain TN credit deficient, a result of both the low TN reduction effectiveness of nutrient management in addition to no-till (see Section 3.1.2.2) and the generally higher TN credit demand from point

Table 3-5: Comparison of nutrient load reductions required with treatment upgrades to credit demand/supply in the Great Miami River watershed under the proposed trading framework.

Total Phosphorus

Agricultural Management Practice Scenarios	Point Source Load Reduction Need (lbs/year)	Watershed Credit Demand [a] (lbs/year)	Watershed Credit Supply (lbs/year) [b]	Percent of Watershed Credit Demand Met (%)	Subwatershed Credit Demand Met? [c]	Future Watershed Credit Demand [f] (lbs/year)
No-till on all lands	904,000	1,349,000	1,744,000	100	No (15 [d, e])	2,253,000
No-till and 50% Fertilizer Reductions			2,007,000	100	No (7)	
No-till, 50% fertilizer reductions, and hay-only in select sub-watersheds			2,507,000	100	Yes	

Total Nitrogen

Agricultural Management Practice Scenarios	Point Source Load Reduction Need (lbs/year)	Watershed Credit Demand [a] (lbs/year)	Watershed Credit Supply (lbs/year) [b]	Percent of Watershed Credit Demand Met (%)	Subwatershed Credit Demand Met? [c]	Future Watershed Credit Demand [f] (lbs/year)
No-till on all lands	4,476,000	6,381,000	4,226,000	66	No (16 [g])	10,865,700
No-till and 50% Fertilizer Reductions			4,428,000	69	No (13)	
No-till, 50% fertilizer reductions, and hay-only in select sub-watersheds			5,323,000	83	No (2)	

[a] Before load reductions are required by the next permit (before requirement), with trading ratio at 1:1 for point sources discharging to fully attaining waters and 2:1 for point sources discharging to impaired waters.

[b] Values are those estimated by SWAT at the mouth of the Great Miami River.

[c] Excluding the two non-agricultural headwater subwatersheds (No. 80 and 104).

[d] Number of subwatersheds that do not have sufficient credit supply.

[e] These 15 (out of 105) subwatersheds are mostly headwater subwatersheds that are already in no-till.

[f] After load reductions are required by the next permit (after requirement); with trading ratio at 2:1 for point sources discharging to fully attaining waters and 3:1 for point sources discharging to impaired waters.

[g] In addition to the above 15 subwatersheds, Subwatershed No. 3 (Figure 3-5) does not have sufficient TN credit supply.

sources (see Section 3.1.1.3). A comparison of credit demand and supply for each of the subwatersheds with identified point sources are presented in Tables C-3 through C-6 in Part C of the Technical Memorandum (K&A, 2004), along with the amount of credit deficit or surplus for these subwatersheds.

TP and TN credit supplies improve substantially on the subwatershed level with the hay-only operation. Excluding those non-row crop headwater subwatersheds (Nos., 80 and 104; No. 91 does not have any known point source), all subwatersheds obtain sufficient TP credits to meet their demand (Table 3-5). Only two remain TN credit deficient (Table 3-7), Nos. 47 and 88, both of which have significant point source TN demand and are headwater subwatersheds without no-

Table 3-6: Subwatersheds with potential agricultural TP credit shortage.

Sub-watershed No.	Head-water? (Yes/no)	Credit demand (before requirement) (lbs P)	No-till credit (lbs P)	No-till & nutrient manage. credits (lbs P)	No-till, nut. manage. & hay-only credits (lbs P)	Overall credit balance[1] (before requirement) (lbs P)	Credit demand (after requirement) (lbs P)	Overall credit balance[1] (after requirement) (lbs P)
2	Yes	2,254	0	1,207	7,788	5,534	3,381	4,407
12	Yes	9,525	0	3,646	41,690	32,165	14,287	27,402
20	Yes	146	0	470	18,982	18,836	219	18,763
25	Yes	2,315	0	3,842	38,946	36,631	3,472	35,474
26	Yes	487	0	7,587	7,587	7,100	975	6,612
27	Yes	1,188	0	9,767	73,030	71,843	2,376	70,655
30	No	2,467	0	18,547	52,915	50,445	4,295	48,617
38	No	21,200	0	19,742	155,607	134,407	31,800	123,807
47	Yes	33,506	0	3,665	36,452	2,946	54,523	(18,071)
50	Yes	4,082	0	4,977	34,338	30,257	6,122	28,216
67	Yes	366	0	781	18,077	17,712	548	17,529
68	Yes	4,618	0	1,114	15,008	10,390	6,927	8,081
80	Yes	1,828	--	--	--	(1,828)	2,741	(2,741)
88	Yes	4,002	0	3,238	39,367	35,364	6,004	33,363
95	No	31,374	0	17,001	105,620	74,246	47,061	58,559
96	Yes	10,964	0	11,681	75,698	64,735	16,446	59,253
104	Yes	731	--	--	--	(731)	1,097	(1,097)

[1] Numbers in parentheses indicate deficit.

Table 3-7: Subwatersheds with potential agricultural TN credit shortage.

Sub-watershed No.	Head-water? (Yes/no)	Credit demand (before requirement) (lbs N)	No-till credit (lbs N)	No-till & nutrient manage. credits (lbs N)	No-till, nut. manage. & hay-only credits (lbs N)	Overall credit balance[1] (before requirement) (lbs N)	Credit demand (after requirement) (lbs N)	Overall credit balance[1] (after requirement) (lbs N)
2	Yes	11,270	0	1,822	14,964	3,693	16,905	(1,942)
3	Yes	65,141	48,181	49,917	65,271	131	97,711	(32,440)
12	Yes	4,197	0	671	70,136	65,939	6,296	63,840
20	Yes	366	0	0	31,911	31,545	548	31,362
25	Yes	11,575	0	5,748	67,672	56,097	17,362	50,310
26	Yes	2,437	0	13,221	13,221	10,784	4,874	8,347
27	Yes	5,940	0	10,751	134,855	128,915	11,879	122,975
30	No	12,336	0	31,378	91,559	79,223	21,474	70,085
38	No	106,001	0	17,883	278,067	172,067	159,001	119,066
47	Yes	167,530	0	7,193	68,491	(99,039)	272,617	(204,126)
50	Yes	20,408	0	3,621	60,644	40,236	30,612	30,032
67	Yes	914	0	0	30,647	29,733	1,371	29,277
68	Yes	23,089	0	97	25,077	1,989	34,633	(9,556)
80	Yes	9,138	--	--	--	(9,138)	13,707	(13,707)
88	Yes	66,707	0	2,074	64,821	(1,886)	100,061	(35,240)
95	No	76,150	0	14,910	177,092	100,942	114,225	62,867
96	Yes	25,809	0	6,834	125,742	99,934	38,713	87,029
104	Yes	1,828	--	--	--	(1,828)	2,741	(2,741)

[1] Numbers in parentheses indicate deficit.

till credits. The TN credit deficit for Subwatershed No. 88 (1,886 pounds) is quite small (only 3%) compared to the total subwatershed demand (66,707 pounds). In practice, it is likely that point sources in this subwatershed will be able to find some additional local agricultural or other general non-point source management practices (e.g., streambank stabilization) to obtain additional credits to address this deficit.

Credit demand for both TP and TN increases substantially after loading reduction becomes mandatory for point sources (after requirement) due to higher trading ratios. However, only Subwatershed No. 47 becomes TP deficient with all three management practices in place. For TN, Subwatersheds Nos. 2, 3, and 68 join Nos. 47 and 88 as TN deficient. Again, all these subwatersheds are located in headwater areas, pointing to the inherent low credit supply available to these reaches. Except Subwatershed No. 2, credit deficits are quite substantial for TN (Table 3-7), ranging from 28% of the demand in Subwatershed No. 68 to 75% in Subwatershed No. 47. These numbers suggest that it is advisable for point sources located in these particular subwatersheds to participate in the trading program early to avoid higher trading ratios and potential credit shortages. Alternatively, they should seek other non-point source credit opportunities.

3.1.3.3 Individual Point Source Considerations

It is apparent from the analysis in Section 3.1.1.3 that large to mid-sized point sources are the major contributors of credit demand for both TN and TP. The location of a point source is a crucial factor in determining its credit supply. If Dayton WWTP (the largest point source in the GMR watershed) makes trades "before requirement" with upstream non-point sources, it will need only 64,526 pounds of TP credits but 1,048,555 pounds of TN credits (Table 3-4) due to its high current average TN effluent concentration (16.5 mg/L). Because it is located on the main stem of the GMR downstream of the entire Stillwater River, the Mad River and the Upper Miami River major subwatersheds, it can theoretically trade with non-point sources anywhere in these areas. This leads to an ample supply of TP and TN credits. Subwatershed No. 79, where Dayton WWTP is located, has a TP no-till credit supply of 1,101,754 pounds and TN of 2,804,333 pounds, more than enough to meet the plant's demand for both types of nutrient credits.

Notably, Dayton WWTP will have sufficient credit supplies from no-till alone even with the trading ratio increased to 2:1 "after requirement". However, Dayton WWTP would consume 75% of the total no-till TN credits produced by the entire Stillwater River, the Mad River, and the Upper Miami River major subwatersheds with an "after requirement" TN credit demand of nearly 2.1 million pounds. This leaves only a few credits available to point sources in these major subwatersheds and other point sources downstream.

Point sources in Subwatershed No. 47 may have difficulties in meeting their credit demand for both TP and TN in most of the simulated management and trading ratio scenarios. This is because of: 1) the presence of three mid-sized point sources (1-4.1 MGD) in the subwatershed generating substantial demands; and 2) the fact that this subwatershed is located in a headwater area and as a result, credit supplies are inherently limited. It is especially important for the point sources in Subwatershed No. 47 to participate in trading early to lock in the lower trading ratios and work with local landowners to come up with more non-point source load reduction options than suggested by current model simulations. Alternatively, in-plant treatment can be considered. It should be noted here that although the nature of these point sources (NPDES IDs: OH0009644, OH0115479, and OH0117479) cannot be clearly identified with the information available to this study, their names appear to reflect construction material manufacturers. Therefore, their actual load reduction needs may not be as high as calculated here based on the assumptions used in this study (see Section 2.1.1).

3.2 Cost Analysis

This section deals with the costs of both point sources and non-point implementing load reduction practices.

3.2.1 Point Source Treatment Upgrades

Upgrade costs to meet the nutrient criteria of 1 mg/L of TP and 10 mg/L of TN were calculated based on design flow. For comparison purposes, unit upgrade costs (per pound of nutrient reduction) were calculated by dividing the upgrade cost for each point source by the load reductions needed. A cost for phosphorus reduction and a cost for nitrogen reduction were calculated for each point source. Five point sources in the watershed were found to have reported design flows smaller than their actual flows. Therefore, the cost per pound of nutrient reduction reported for those plants were not considered accurate. (The reported flows were used for the cost and load calculations [see Section 2.1.1.4]. It was not known whether the design flow or the actual flow was misreported.) Excluding those five plants, upgrade costs per pound of TP reduction range from $73,900 for the smallest point source to $5.74 for one of the largest point sources. Upgrade costs per pound of TN reduction range from $29,500 to $2.21. This suggests an economy of scale for larger point source upgrades using this costing approach. The total annual upgrade cost for all point sources in the watershed (annualized capital + O&M) is estimated to be $33.9 million. The net present value for all upgrade costs is estimated at $422.5 million (based on a twenty-year investment with a 5% interest rate). Cost data are provided for each point source in Part A of the Technical Memorandum (K&A, 2004). Figure 3-6 illustrates the net present value for point source upgrades within size distributions.

The greatest total upgrade cost is for point sources in the 1.1 – 13 MGD size category. Forty-seven point sources are included in this category. One plant in this category, Lesourdsville Water Reclamation Plant, was found to be meeting both the TP and TN effluent limits according to data from the *Envirofacts* database. Therefore, forty-six plants were included in the total cost. The largest size category, 20-72 MGD, contains only seven plants. Among them, the City of Hamilton plant (20 MGD design flow), was also found to be meeting nutrient effluent limits. Therefore, only six point sources were included in the total cost. These point sources constitute 48% of the watershed point source design flow. It should be noted that cost calculations are based on a power function. Therefore, increasing design flows do not increase the costs linearly. Figure 3-7 illustrates the average cost per pound of nutrient reduction within plant size distributions. The economy of size in point source treatment upgrades is clearly demonstrated in this plot, with a rapid decrease of unit costs from small to large plants for both TP and TN load reductions. The cost of nitrogen reduction for the two largest size categories are similar because some large plants were found to be discharging at lower nutrient concentrations than the assumed

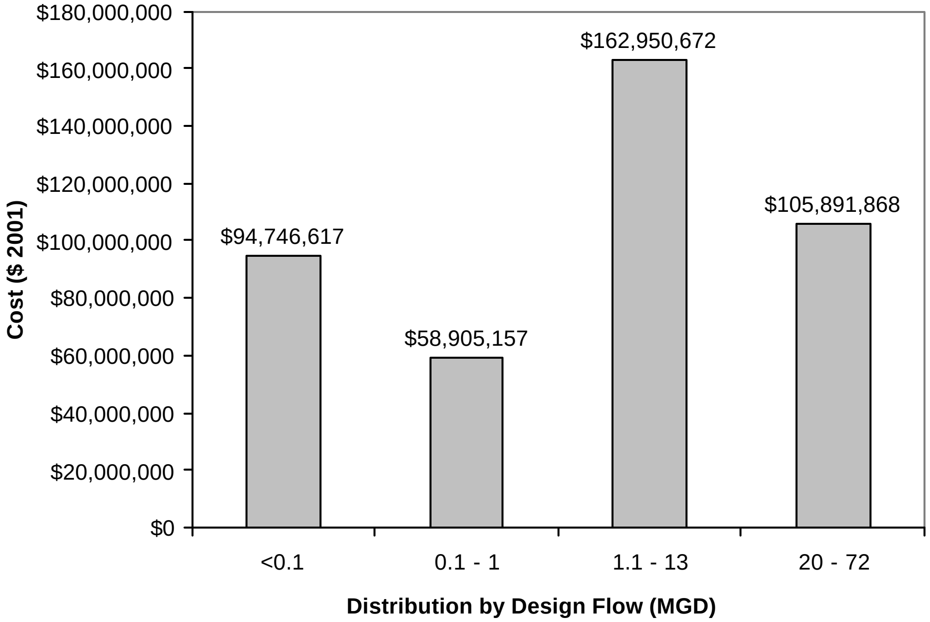


Figure 3-6: Distribution of net present worth for point source BNR upgrades by design flows.

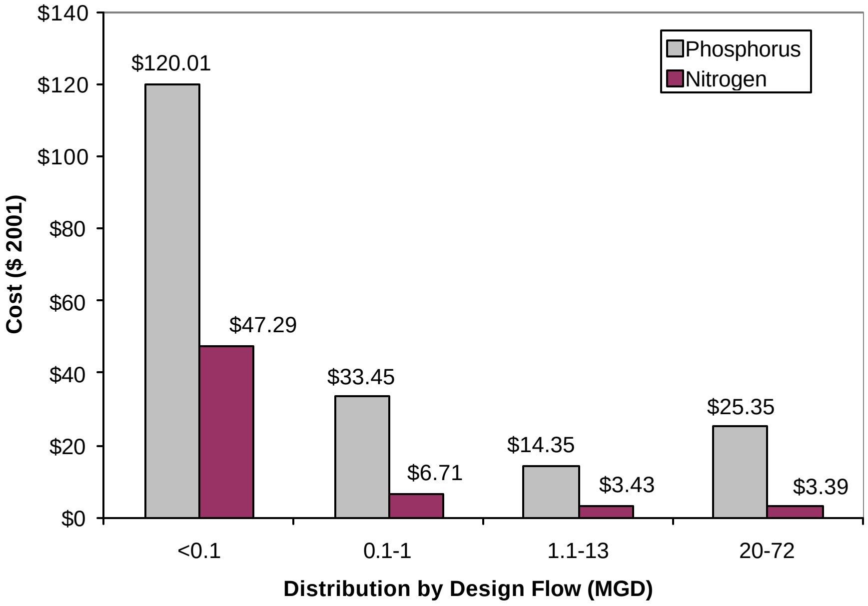


Figure 3-7: Distribution of point source upgrade cost (per pound of nutrient reduction) by design flows.

concentrations. This resulted in smaller load reduction needs, which increased the resulting cost per pound. The 20-72 MGD category has a higher phosphorus reduction cost because the Middletown WWTP, which has 26 MGD design flow, is currently meeting the 1 mg/L TP criterion but not the 10 mg/L TN criterion (see Table 2-1). As assumed in this study, this would require the plant to install BNR treatment facilities that reduces its TN loading but does not induce further TP load reduction. Consequently, the per pound cost of TP rises for the largest design flow category.

3.2.2 Agricultural Management Practices

Costs of the three agricultural management practices are presented in this subsection. Three types of cost information are included: watershed or subwatershed total cost, per acre cost, and per unit cost (cost of per pound of pollutant load reduction).

3.2.2.1 No-till

For the entire GMR watershed, 41 subwatersheds with a total area of 982,802 acres were converted from conventional tillage to no-till. Taking the available no-till credits at the outlet of the subwatershed 105 (Figure 3-5) as the watershed-wide total no-till credits (1,743,654 pounds), no-till has an average load reduction rate of 1.77 pounds TP/acre/year. With a $3.08/acre cost to induce non-point sources to switch from conventional till to no-till, no-till can achieve a cost-effectiveness (unit load reduction cost) of $1.08/lb TP reduction based on the net present worth ($37.8M) of the total incentive payment over a 20-year period (5% interest rate). Individual subwatersheds, as a result of its soil, weather, and landscape conditions, have cost-effectiveness ranging from $0.55/lb TP in Subwatershed No. 42 to $9.83/lb in Subwatershed No. 3. For TN, no-till has an average load reduction rate of 4.30 pounds/acre/year and a cost-effectiveness of $0.45/lb TN. Cost-effectiveness of individual subwatersheds ranges from $0.22/lb in Subwatersheds Nos. 14, 42, and 55 to $2.58 in Subwatersheds No. 3.

3.2.2.2 No-till and Nutrient Management

With the limited load reduction effectiveness of nutrient management, cost-effectiveness of nutrient management shown is much lower than normally might be expected. The total cost (net present worth) of applying nutrient management to all the row crop subwatersheds in the GMR watershed is estimated at $70.5 million over 20 years. For the entire watershed, adding nutrient management to no-till can only bring an additional 0.12 pounds of TP and 0.09 pounds of TN reduction per acre per year. The per pound cost of these additional reductions is $13.41/pound for TP and $17.54/pound for TN. The combined watershed-wide cost-effectiveness for no-till plus nutrient management, however, is still high at $2.70/lb TP and 1.23/lb TN, obviously due to the highly effective no-till practice.

3.2.2.3 No-till, Nutrient Management, and Hay-only

Switching from a corn-soybean rotation to hay-only operations in this analysis is an expensive conservation practice at a cost of $43.80/acre/year. The total cost (net present worth) of applying hay-only operation in the eighteen select subwatersheds in the GMR watershed is estimated at

$340.2 million over 20 years. For TP, the watershed-wide average cost of reducing an additional pound of TP by hay-only in the eighteen select subwatersheds is calculated at $34.05. For individual subwatersheds, it ranges from $16.99/lb in Subwatershed No. 28 to $303.17/pound in No. 3. For TN, the watershed-wide average is $19.00 for an additional pound of TN and the range is from $9.31/pound in Subwatershed No. 28 and $114.88/pound in No. 3. The overall (no-till plus nutrient management plus hay-only) watershed-wide cost effectiveness stands at $8.48/pound for TP and $3.99/pound for TN.

3.2.3 Cost Comparisons of Trading vs. Point Source Treatment

Comparisons of results from previous sections are presented in this subsection to examine potential cost saving opportunities in the trading program. Again, comparisons are performed on all three levels: the entire GMR watershed, individual subwatersheds, and individual point sources.

3.2.3.1 Watershed Level Comparisons

In the trading program studied here, point sources have two options to meet their obligations for nutrient load reduction: treatment system upgrades to BNR or trading with upstream non-point sources. From a pure economic point of view, cost differences are the deciding factor in a point source's choice between these two options. Results from cost comparisons of facility upgrades versus agricultural management practices can give a clear indication on the feasibility of a trading program in the GMR watershed. There are two perspectives from which costs of TP and TN load reductions can be compared: total costs and per pound (unit) costs. Table 3-8 provides a synopsis of such costs for the entire GMR watershed.

To reach the required load reductions for both TP and TN, point sources would collectively need to spend $422.5 million upgrading their treatment facilities. With trading, the cost is $37.8 million paid to landowners to apply no-till to about 50% of the agricultural land in the watershed. One hundred percent of the TP credit demand and 66% of the TN credit demand can be met on a watershed-wide basis with no-till alone. This is savings of $384.7 million or 91% of the total upgrade cost. If only load reduction is considered, no-till alone can provide 94% of the TN load reduction need. To meet the remaining TN load reduction needs, an additional $70.7 million would be required to implement nutrient management across the watershed. This brings the total agricultural practice cost to $108.5 million, still only 26% of the estimated $422.5 million total upgrade cost for point sources or a potential $313 million savings.

Due to the high cost of converting from a corn-soybean rotation to the hay-only operation, further increases in TN credit supply incurs significant increase in cost. By applying hay-only to the eighteen subwatersheds to meet their TN credit demand, an additional $340.2 million payment is needed over 20 years based on a per acre cost of $43.80/year. This brings the total agricultural practice cost to $425.1 million, about 0.6% higher than the estimated total point source upgrade cost. Clearly, other agricultural management practices or non-point source load reduction options should be sought to obtain more TN credits in these subwatersheds rather than hay-only operations.

Table 3-8. Costs of total phosphorus and total nitrogen load reduction in the Great Miami River watershed.

Total Phosphorus				
Agricultural Management Practice Scenarios	Watershed Point Source Load Reduction Cost (million)[a]	Watershed Point Source Unit Reduction Cost (/lb)	Watershed Agricultural Practice Cost (million) [b]	Watershed Agricultural Practice Unit Cost (/lb)
No-till on all lands	$422.5	$23.37	$37.8	$1.08
No-till and 50% Fertilizer Reductions			$108.5	$2.70
No-till, 50% fertilizer reductions, and hay-only in select sub-watersheds			$425.1	$8.48
Total Nitrogen				
Agricultural Management Practice Scenarios	Watershed Point Source Load Reduction Cost (million)[a]	Watershed Point Source Unit Reduction Cost (/lb)	Watershed Agricultural Practice Cost (million) [b]	Watershed Agricultural Practice Unit Cost (/lb)
No-till on all lands	$422.5	$4.72	$37.8	$0.45
No-till and 50% Fertilizer Reductions			$108.5	$1.23
No-till, 50% fertilizer reductions, and hay-only in select sub-watersheds			$425.1	$3.99

[a] Net present worth over 20 years with a 5% interest rate for wastewater treatment upgrades; same value for TP and TN.
[b] Net present worth over 20 years with a 5% interest rate is assumed here for comparison to point source treatment plant upgrades

In terms of cost per pound of reduction, agricultural management practices are lower than that of point source upgrades in all of the three scenarios. No-till is particularly cost-effective at $1.08/pound TP and $0.45/pound TN. Compared to the unit costs of point source upgrades at $23.37/pound TP and $4.72/pound TN (Table 3-8), the potential for cost savings is enormous.

3.2.3.2 Subwatershed Level Comparisons

One way to compare the subwatershed level load reduction costs between point source upgrades and agricultural management practices is to examine the overall descriptive statistics of the cost information. Table 3-9 shows that all statistics (maximum, minimum, and average values) favor agricultural management practices in all three management scenarios for both TP and TN load

Table 3-9: Statistics of subwatershed level unit reduction cost ($/pound) in the Great Miami River watershed. [1]

	Total Phosphorus ($/lb reduction)			**Total Nitrogen** ($/lb reduction)		
	Maximum	Minimum	Average	Maximum	Minimum	Average
Point Source Upgrades [2]	551.51	5.83	62.62	220.60	1.39	18.97
No-till on all lands	9.83	0.68	1.40	2.58	0.26	0.50
No-till and 50% fertilizer reductions	59.66	1.13	7.69	257.82	0.48	10.49
No-till, 50% fertilizer reductions, and hay-only in select sub-watersheds	90.69	1.09	14.19	39.58	0.48	7.06

[1] Statistics for agricultural management practices are for subwatersheds with identified point sources only.
[2] Based on the 109 mapped point sources in the watershed.

reductions. The only exception is the maximum TN unit reduction cost among all the subwatersheds under the no-till and nutrient management (50% fertilizer reductions) scenario, where Subwatershed No. 28 has a cost of $257.82/pound, greater than the highest cost of point source upgrades for Indian Hills MHP (OH EPA permit ID: 1PV00056) located in Subwatershed No. 101. Subwatershed No. 28 is already in no-till and the cost is incurred solely by fertilizer reduction. Because the low load reduction efficiency of fertilizer reduction after no-till has been implemented and the particular soil and landscape conditions of this subwatershed, unit TN load reduction costs are especially high.

It is, however, still helpful to conduct subwatershed by subwatershed cost comparisons because: 1) decisions to trade are made by individual point sources based on subwatershed level credit supply, demand, and cost; and 2) trading can result in local water quality benefits even when watershed-wide results do not show significant cost savings from trading under some agricultural management practice scenarios. Tables C-3 through C-6 in Part C of the Technical Memorandum (K&A, 2004) provide cost information for all the subwatersheds with identified point sources.

All the subwatersheds that can generate no-till credits have no-till TP credit costs (per pound of TP reduction) smaller than their average point source upgrade costs (Table C-3 [K&A, 2004]). Similar conclusions can be reached for the cost of TN reduction by no-till vs. point source upgrades (Table C-5 [K&A, 2004]). All subwatersheds have a lower no-till TN reduction cost. Subwatershed No. 3, with the highest no-till TN cost at $2.58/pound, still compares favorably to the $6.28/pound for facility upgrades in the Logan County Indian Lake SSD plant.

Adding nutrient management to no-till does not change the cost advantage of agricultural management practices for TP reduction. However, the overall cost for TN reduction increases substantially for nine headwater subwatersheds (Table C-5 [K&A, 2004]) so that on average, facility upgrades for point sources in these subwatersheds become more cost-effective than the combination of the no-till and nutrient management. This again points to the fact that point sources in headwater areas in the watershed should consider other non-point source management practices to generate TN credits if trading is to be used to meet the pending TN load reduction requirement.

3.2.3.3 Individual Point Sources Considerations

Costs for point sources to reduce nutrient loads with facility upgrades on a unit basis are very much dependent on the size (flow) of the point source and its current effluent levels. Among the 109 mapped point sources (excluding those with uncertain reported flows [see Section 3.2.1) facility upgrade costs of TP reduction range from $6.45/pound for the 5.1 MGD (actual flow) Sidney STP to $1,500/pound for a 0.01 MGD source. Costs of TN reduction range from $2.21/pound for Dayton WWTP (53 MGD) to $313/pound for the same 0.01 MGD source. If applying BNR upgrades, Dayton WWTP, for example, would incur costs of $35.9/pound TP and $2.21/pound TN. Both of these are higher than the costs of no-till TP and TN credits available to the plant from upstream agricultural sources (at $1.16/pound and $0.46/pound, respectively). Combined with ample supply of credits due to its advantageous location in the watershed, Dayton WWTP is in an excellent position to use trading to meet its nutrient load reduction obligation.

For all the 109 mapped point sources, the no-till practice, when available, can provide TP and TN credits at a per unit cost that is always lower than in-plant upgrades. However, when nutrient management is added, both TP and TN credits available to two mid-large sized point sources, one located in Subwatershed No. 39 and one in No. 47, became more expensive than in-plant upgrades. For the point source in No. 39 (Piqua Municipal Power System, OH EPA permit ID: 1PD00008), this may not be an issue because credit supply from no-till alone can meet its demand. For the plant in No. 47 (Martin Marietta Troy Gravel, OH EPA permit ID: 1IJ00137), this cost discrepancy, (together with the fact that credit supply in this subwatershed is low in all of the three agricultural management scenarios), suggests strongly that this particular point source should consider other non-point source load reduction opportunities to meet its credit demand in a trading market, or consider plant upgrades as options.

After select subwatersheds are converted to the hay-only operation, eight more point sources have a higher credit cost for TP than facility upgrades. Most of these point sources are mid-sized plants with actual flows great then 1 MGD, highlighting the cost-effectiveness of upgrading treatment plants with higher flows. Four of these eight point sources also depend on the hay-only operations scenario to meet their TP credit demand. All four point sources (Jackson Center STP, OH EPA permit ID: 1PB00018; Barrett Paving Materials [2 permits: 1IJ00048 and 1IN00276]; Oxford WWTP, ID: 1PD00007) are located in headwater areas (Subwatersheds Nos. 2, 47, and 95, respectively), again pointing to the necessity for such point sources to consider more non-point source management options or plant upgrades.

CHAPTER 4

CONCLUSIONS

4.0 Overview

This chapter summarizes findings of this preliminary economic study and discusses the implications of these in the context of the pilot trading program under development in the Great Miami River watershed. Trading program considerations are also highlighted based on results and data gaps identified herein.

4.1 Findings

This preliminary economic analysis for trading in the GMR watershed is the first attempt of its kind to include the consideration of all point source contributions in the watershed. Other water quality studies in the watershed typically consider only a fraction of the total number of point sources (e.g., Reutter, 2003). This has significant implications for: 1) estimating the total point source loading of total phosphorus (TP) and total nitrogen (TN) within the watershed; and 2) understanding the full demand for nutrient credits in a potential trading scheme.

A lack of effluent monitoring data and information on the nature and location of each point source in the watershed has led to several assumptions regarding current nutrient loads and facility upgrade needs of these point sources. Consequently, estimates of credit demand may not be accurate for all point sources in the watershed. Nevertheless, based on reasonable assumptions, these estimates provide a basic assessment on load reduction and associated costs crucial for a preliminary feasibility analysis for a potential trading program.

4.1.1 Credit Demand and Supply

Results from this study indicate that demand and supply for TP and TN credits with the proposed trading schemes (target effluent TP and TN standards, trading ratios, and the upstream-only eligible credit restriction), will be sufficient for a robust trading program. The demand for TP and TN credits can largely be supplied through implementation of agricultural management practices. In total, about 1.35 million pounds of TP credits and 6.38 million pounds of TN credits are needed by the >314 point sources in the watershed. The balance between demand and supply in some subwatersheds will depend upon the number and size of point sources within these reaches.

On the supply side, the three agricultural management practices selected for this analysis, no-till, nutrient management (fertilizer use reduction), and conversion to hay-only operation, represent broad scale management applications that were easily accommodated by the limited scope of non-point source modeling. These types of agricultural management applications lend themselves to broad-based programmatic implementation. They do not, however, account for additional nutrient load reductions that can accompany site-specific application of buffer strips, wetlands, animal management practices, etc. (that could not be assessed within the scope of this project). These additional management practice applications will likely create additional credits. Therefore, predictions for credit supply in this analysis should be considered as conservative estimates.

In addition, the SWAT model simulates instream losses such that an edge-of-field reduction in a headwater area is actually smaller when accounted for at a distant, downstream location such as the confluence of the Great Miami River with the Ohio River. As trading is envisioned to be restricted to upstream credit generation, trades will likely occur between sources within the same or nearby upstream subwatersheds. Thus, localized trading credit supply will be greater than portrayed here for the broader watershed assessment approach. For example, an edge-of-field reduction to a nearby waterbody that is used by a local point source will not necessarily undergo the same instream attenuation that is included in current credit supply estimates for the mouth of the Great Miami River. The net effect of this consideration for trading is greater credit supply and lower overall credit costs than reported here.

Because of the instream losses of credits and the upstream-only restriction on eligible credits, credit supply is highly dependent on the location of demand. The most rigorous study of credit supply and demand in the entire GMR watershed, therefore, would involve the examination of credit supply and demand for each individual point source in the watershed. Though beyond the scope of this preliminary study, such an examination requires knowledge of the precise location of each point source in the watershed; critical information that is not readily available.

A conservative representation of the credit supply from the entire Great Miami River watershed is the available credit at the outlet of the most downstream Subwatershed No. 105; the Great Miami River just upstream of its confluence with the Ohio River (Figure 3-5). (Note here that the Whitewater River watershed is not included in this study). SWAT simulations indicate that at this location, there are 1.74 million pounds of TP credits and 4.23 million pounds of TN credits available from the application of no-till on about 50% of the row crop agricultural land in the watershed. In addition to being able to meet the TP credit demand on the watershed level, no-till can yield an extra 800,000 pounds of TP reduction over the 904,000 pounds of required point source TP load reduction predicted with future permit limits. This 800,000 pounds of TP reduction is one of the potential net environment benefits provided by the trading program compared to the traditional command-and-control approach associated with the lower discharge limits addressed by point source upgrades.

The most credits that the three agricultural management practices combined can generate are 2.51 million pounds of TP and 5.32 million pounds of TN. Comparing demand and supply for the entire GMR watershed (Table 3-5) indicates that there will likely be ample supply of phosphorus credits from agriculture to meet most foreseeable point source demands, both before or after load reductions are required for point sources in the next permit cycle where different trading ratios apply. However, if these trading ratios are similarly applied for TN, agricultural nitrogen reductions generated by the three management practices considered in this study may not fully meet point source trading needs in the watershed. This may especially be the case under a future credit demand scenario with higher trading ratios. Nevertheless, with the no-till and nutrient management practices in place, point source TN load reduction need is close to being fully met (99%). This indicates that even for TN, which is not a pollutant of concern in the GMR watershed related to impairments, a trading program can produce load reductions that fully achieve the point source load reduction goal.

On the subwatershed level, select headwater areas may not have sufficient credit supply primarily due to the lack of upstream agricultural operations. This is particularly true for TN credits in headwater subwatersheds with multiple point sources (e.g., Subwatershed No. 47). When higher trading ratios are applied in the "after requirement" situation, headwater Subwatersheds Nos. 2, 3, 47, 68, and 88 all became deficient in TN credit supply. Headwater subwatersheds Nos. 80 and 104 do not have any agricultural credit supply because their primary land use is non-agricultural (urban residential and forest, respectively).

For large individual point sources, their credit demand can usually be met by supply from agricultural sources because these point sources tend to be located in more developed urban areas around the lower reaches of the GMR main stem. Upstream credits are therefore more readily available than headwaters. For example, the largest point source (Dayton WWTP at a 72 MGD design flow) and the largest TN credit buyer (1.2 million pounds "before requirement") in the watershed is located in Subwatershed No. 79, where it can purchase credits from all agricultural operations in the entire Stillwater River, the Mad River, and the Upper GMR major subwatersheds. TN Credit supply from no-till alone is estimated at 2.8 million pounds for Subwatershed No. 79, more than double the demand from the plant. Mid-sized point sources, such as those located in headwater Subwatershed No. 47 are those whose credit supply may be somewhat limited.

4.1.2 Cost Savings

At an estimated total cost of $422.5 million for treatment upgrades for all point sources, water quality trading in the Great Miami River watershed has the potential to provide significant cost savings over traditional command and control approaches. No-till alone generates sufficient TP credits to meet the point source demand at a total cost of only $37.8 million for the entire watershed. This provides a $384.7 million savings compared to treatment plant upgrades (Table 3-8). Cost savings are further illustrated by comparing the watershed-wide average per unit (pound) cost of TP reduction by no-till ($1.08/pound) to that by treatment upgrades ($23.37/pound). Adding nutrient management to supply additional credits to some of the headwater subwatersheds increases the agricultural management cost substantially to $108.5 million. Compared to the point source upgrades cost, there still is a cost difference of $314 million in favor of these agricultural management practices.

No-till alone can provide 94% of the point sources' total TN load reduction need at a per unit cost of $0.45. This is <10% of that estimated for point source treatment upgrades ($4.72/pound). Even with the relatively high cost hay-only operation implemented in select subwatersheds, the per unit cost of TN load reduction ($3.99/pound) is still lower than that of the point source treatment upgrades.

On the subwatershed level, point sources and agricultural management practices have a wide range of total and per unit load reduction costs. For point sources, this is mainly the result of the computational method and variations in plant size (wastewater flows) among individual sources, and the number of plants in different subwatersheds. For agricultural management practices, initial (or current) management conditions, subwatershed location, and subwatershed hydrological and landscape conditions all contribute to cost variations. However, the three agricultural management practices examined in this study still hold cost advantages in most subwatersheds, including many located in headwater areas.

No-till alone is more cost-effective than point source facility upgrades for both TP and TN in all subwatersheds that receive these nutrient credits. Adding nutrient management does not change the cost advantage of agricultural management practices for TP reduction. However, the overall costs for TN reduction increase substantially for nine headwater subwatersheds so that on average, facility upgrades for point sources in these subwatersheds may be more cost-effective than the combination of no-till and nutrient management. Hay-only operations in select subwatersheds give three subwatersheds (Nos. 2, 47, and 95) higher per unit TP reduction costs with agricultural management than point source upgrades in these areas. Six more subwatersheds (Nos. 3, 25, 38, 50, 68, 88, and 96) join the list for TN. Located in headwater areas, all these subwatersheds are dependent on the hay-only practice to meet (or come close to) their TN or TP credit demand.

4.2 Trading Implications

The implications of study findings are discussed here in the context of the pilot trading program from the perspectives of the three major trading participants: point sources, non-point sources, and the Miami Conservancy District. The District, as the trading market regulator, can improve the trading framework by incorporating these findings into the framework development process.

4.2.1 Point Sources

Whether to take part in a trading program or upgrade treatment systems to biological nutrient removal (or similarly capable treatment) is an economic decision made by individual point sources. At a minimum, two conditions should be satisfied before a point source chooses trading over treatment upgrades. First, there must be sufficient upstream credit supply to meet the demand of the point source. Second, costs of purchasing the required credits must be lower than treatment upgrades. Therefore, point sources should carefully consider the value of joining a trading program to gain a complete understanding of their actual credit needs, credit availability and potential costs. Monitoring their TN and TP effluent concentrations is also a necessary step to reach this understanding. Such monitoring requires point sources to measure more parameters than what current regulations mandate. This study shows that many point sources, particularly smaller ones, lack measurements for various nitrogen components. For example, Kjeldahl-N and nitrate-nitrite-N should be measured to calculate the TN value. TP should also be measured frequently.

As this analysis has demonstrated, the upstream-only credit eligibility requirement determines that trading opportunities for point sources in headwater areas may be limited due to the undeveloped nature of these areas and/or lack of upstream agricultural operations. Early participation for these point sources may be prudent to secure available opportunities for non-point source reduction credits. In headwater subwatersheds, other non-agricultural non-point sources of nutrients (e.g., septic systems, urban runoff, stream bank erosion, and groundwater nitrates) should also be identified and potentially considered for credit generation opportunities. One of the benefits of a trading program is that in a trading credit market, demand for credits will likely provide a mechanism and/or incentive for trading participants to pursue a wide variety of load reduction opportunities.

Trading programs and point source load reduction efforts in other parts of the country have proven that other than capital intensive treatment upgrades, point sources often can reduce TN and TP loadings in their waste streams with improved in-plant management practices. Management changes, for example, enabled many point sources in the Tar-Pamlico basin in North Carolina to operate at a high level of efficiency and reduce loadings (ETN, 2003). Therefore, before considering upgrades or trading, point sources in the GMR watershed may wish to evaluate such management options. It is also likely that some point sources may opt for updating their treatment systems (or seek alternatives) based on growth projections, industry competition and/or available market incentives.

4.2.2 Non-point Sources

Nutrient management and the hay-only operation scenarios examined in this study have inherent limitations in a trading program. Load reduction efficiency with nutrient management is significantly diminished when simulated after no-till has been implemented. Although effective in reducing nutrient loadings, the hay-only operation is expensive to implement in this particular scenario. Thus, many other non-point source load reduction options might be sought to generate lower cost reductions. This will be an important consideration in some headwater subwatersheds where a sufficient supply of nutrient credits cannot be generated from the three agricultural management practices examined. Finding locally efficient non-point source credit opportunities can be the key to the success of the trading markets in these subwatersheds.

4.2.3 Trading Program Framework

Economic and environmental outcomes predicted by this preliminary market assessment can be used to assist with preliminary trading framework development for the GMR watershed. Because such a program will be one of the first of its kind (i.e., the pending nutrient standards serving as the driver), forecasts in this analysis should be re-visited with economic and environmental progress of completed trades. This will allow for fine-tuning of the trading program, and provide a valuable template for spawning additional trading initiatives in the Ohio River basin and beyond. These information updates should be part of the program implementation process. Because of the localized credit markets and interconnection of these markets, the program framework should provide some guidance on where point sources can purchase their credits. For example, because of its advantageous location, Dayton WWTP has ample supply of both TP and TN credits. However, it may be less efficient for the plant to purchase its credits from upstream headwater areas because point sources located in those headwater areas are inherently short of credit supply. If this limited amount of credits is used by other downstream purchasers, such as Dayton WWTP, trading options for these headwater point sources may be eliminated.

Consideration of a 1:1 trading ratio for nitrogen should be made if impairments in non-attaining waters are associated with other pollutants and not specifically nitrogen. A 1:1 trading ratio for nitrogen will likely meet the current point source demand to offset equivalent reductions required under the wastewater treatment upgrade scenario. Analyses indicate that this can be achieved almost entirely through application of no-till on the 50% of agricultural lands not already utilizing this practice. The 1:1 trading ratio in this scenario would suggest that the trading program could be implemented at about 9% of the projected costs for treatment system upgrades. This no-till scenario also generates a large surplus of phosphorus credits under the "before requirement" trading ratios.

It may be economically and environmentally beneficial if point source/point source trading is allowed in this overall trading program. Some point sources that can or are already achieving reductions below the 10 mg/L effluent TN limit, may be able to generate nitrogen credits. For example, Hamilton WWTP at 3.9 mg/L TN and 32 MGD design flow may have 377,000 pounds of annual TN credits already.

Trading infrastructure will likely be necessary to track credit demand, generation and use in the program. Such infrastructure can also serve to track the economic and environmental aspects of the trading program. Easy access to these types of information (e.g., Internet-based searchable databases) will not only reduce transaction costs, but also provide transparency for credit generators, purchasers, administrators, regulators and the public.

The net effect of this trading program will be ecological improvements at the local level that cannot be defined by nutrient sampling alone. Non-point source management practices such as no-till reduce not only nutrient loadings but also other pollutants such as sediment and pesticides. This suggests that additional metrics for monitoring the progress of trading may be useful (e.g., ecological indices). Sampling at strategic locations throughout the watershed will help verify credits as well as the ecological benefits of trading, thus allowing for critical program assessments and future adjustments.

Finally, it should be noted that predictions of annual loading for nitrogen and phosphorus from the Great Miami River watershed vary greatly amongst published sources for the Great Miami River watershed. Though predicted loads from this economic analysis fall within the broad range of reported values, this variability clearly points to the need for better watershed monitoring and updated modeling. These types of efforts, as envisioned for a Great Miami River trading program framework, illustrate the additional benefits of instituting a trading program whereby these evaluation needs might not otherwise be met.

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