TARGETING AREAS AS A COST-EFFECTIVE METHOD OF AGRICULTURAL NONPOINT SOURCE POLLUTION CONTROL

By

Leah Concepcion Marquez-Cuyno

PLAN B PAPER

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Agricultural Economics

1995

PROF. SANDRA S. BATIE

TABLE OF CONTENTS:

LIST OF TABLES

LIST OF FIGURES

Section I

INTRODUCTION

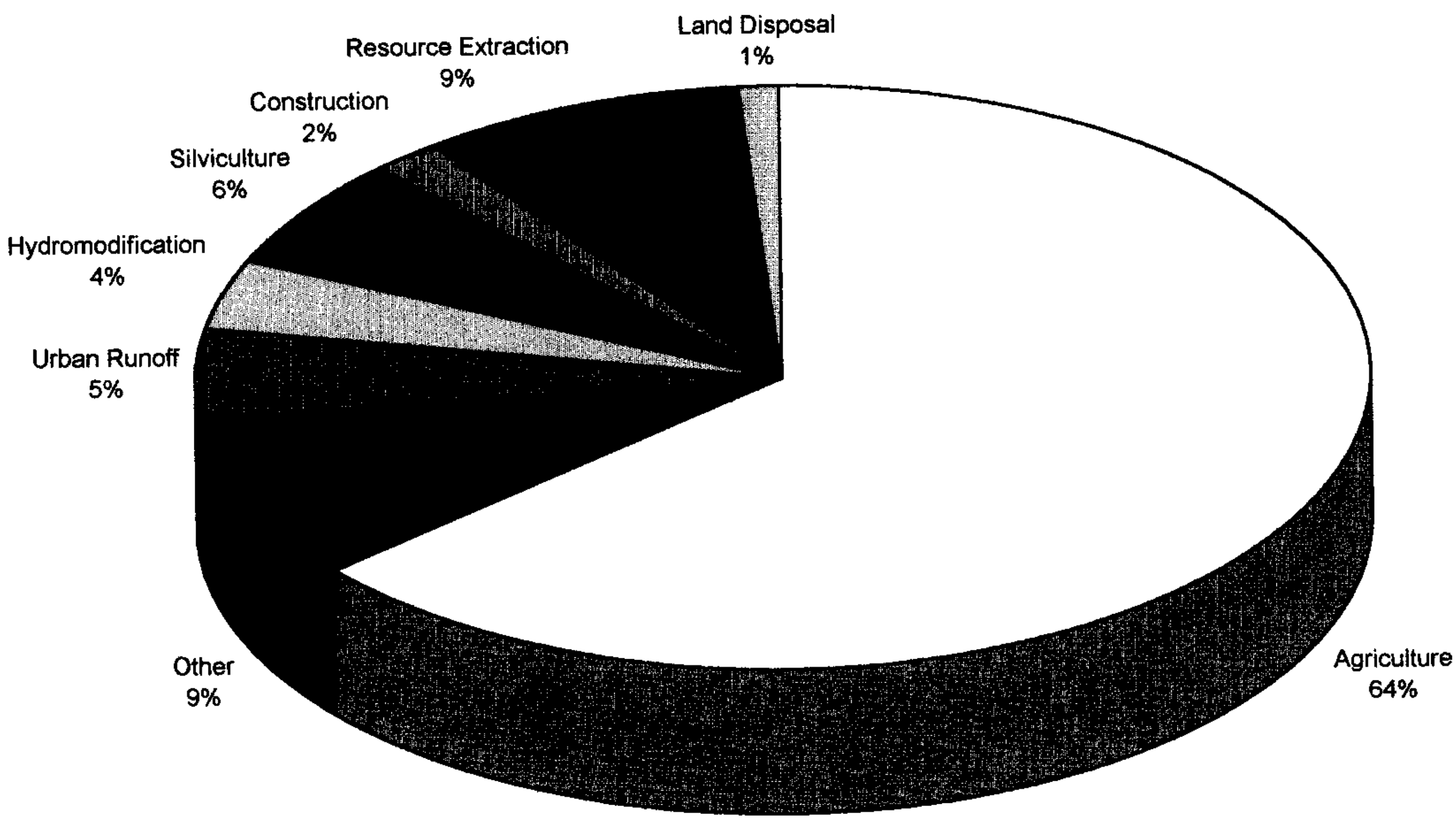
The following section is a discussion of the importance of the problem of agricultural nonpoint source pollution, the conceptual framework and methods, and the research objectives of this study.

Significance of the Study:

Agricultural nonpoint source pollution is an important environmental concern. Agricultural nonpoint sources have been identified as the major contributors to sediments, nutrients, pathogenic bacteria, and pesticides affecting surface water quality (NRC, 1993). Severe soil degradation from erosion, compaction, or salinization, can damage the productive capacity of the soil and exacerbate water pollution. Sediments from eroded croplands interfere with the use of bodies of water for transportation; reduce the life of dams, locks, reservoirs, and other water developments; and degrade aquatic ecosystems. Nutrients accelerate the rate of eutrophication of lakes, streams, and estuaries; and nitrogen may cause health problems if ingested by humans in drinking water. Pesticides in drinking water, may become a human health concern and have been accused of disrupting reproduction of life in aquatic ecosystems (Overcash and Davidson, 1980).

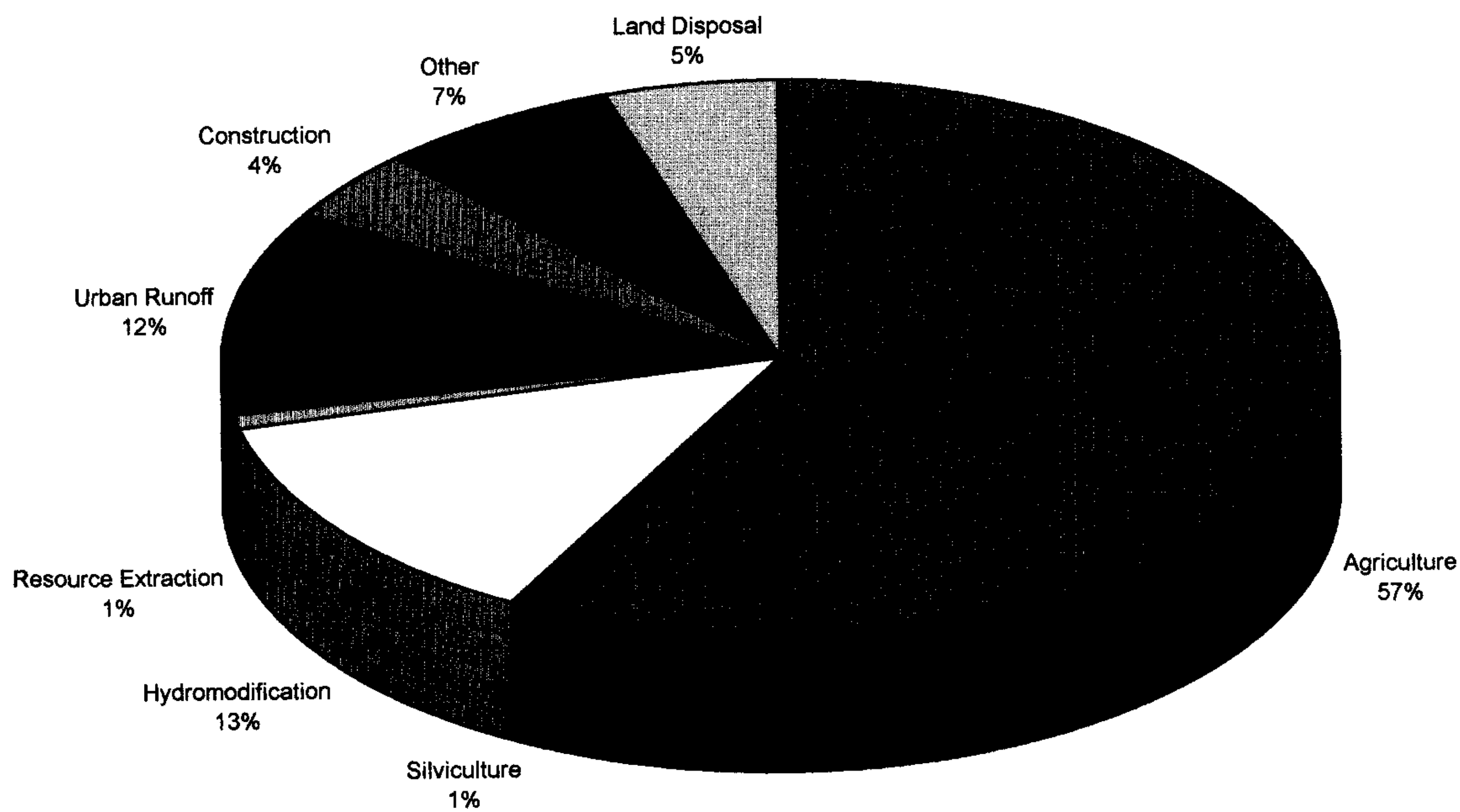
Statistics suggest that agriculture is the primary source of nonpoint pollution, affecting 64 percent of polluted U.S. rivers and 57 percent of impaired U.S. lakes (Figures 1-2). Nutrients (nitrogen and phosphorous) and sediments, the major types of pollutants closely associated with agricultural production, severely affect surface water quality in the United States (Figures 3-4) and loadings of these pollutants have increased in agricultural watersheds. These nutrients account for 13 percent of the destruction in U.S. rivers and 59 percent in U.S. lakes, making it the leading source of impairment in U.S. lakes (Smith et al., 1987).

Figure 1. Primary Sources of Pollution Affecting 266,000 kilometers of Assessed U.S. Rivers



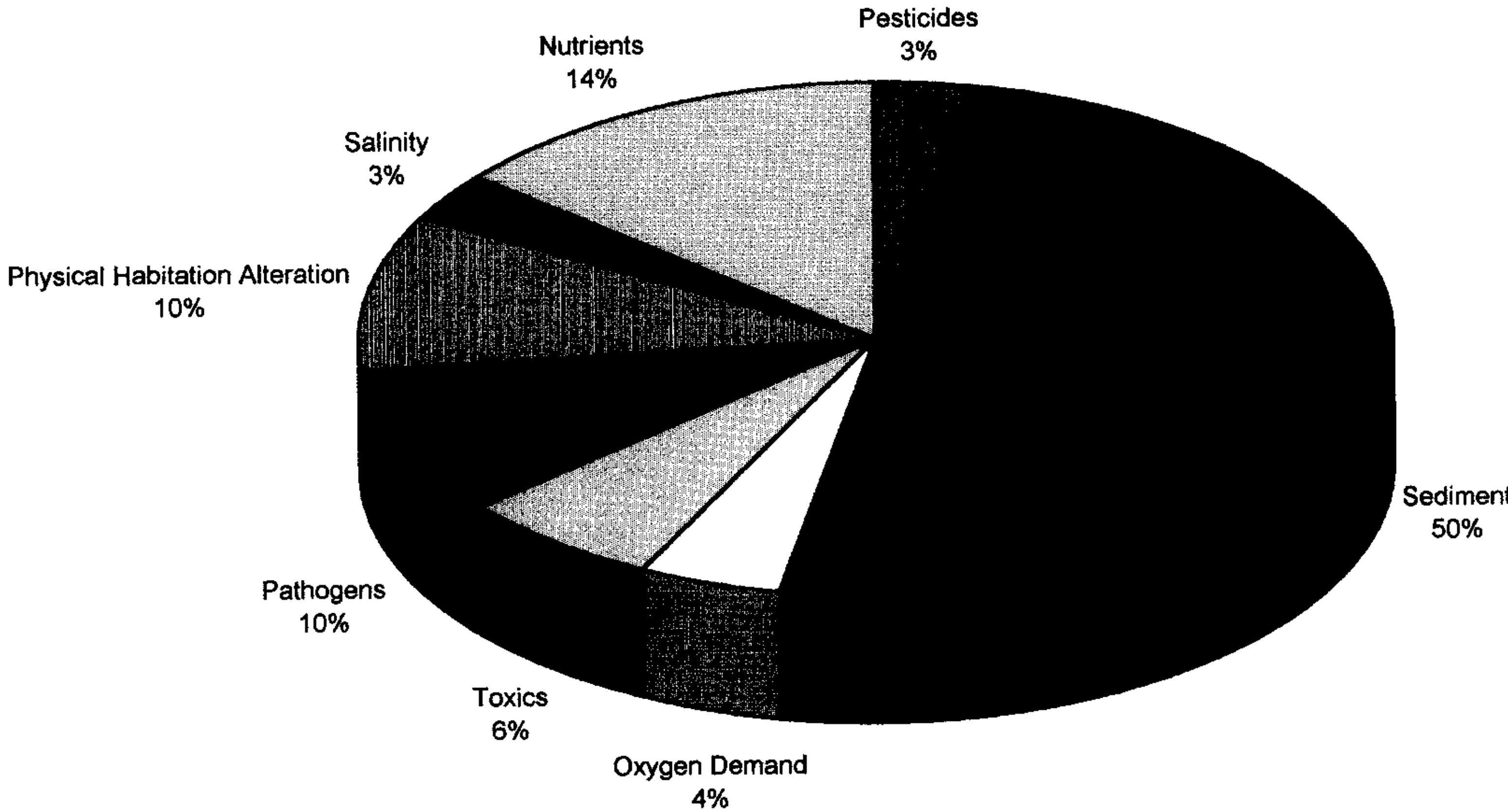
Source: R.A. Smith, et al. 1987. "Water Quality Trends in the Nation's Rivers". Science.

Figure 2. Primary Sources of Pollution Affecting 3.3 Million hectares of Assessed U.S. Lakes



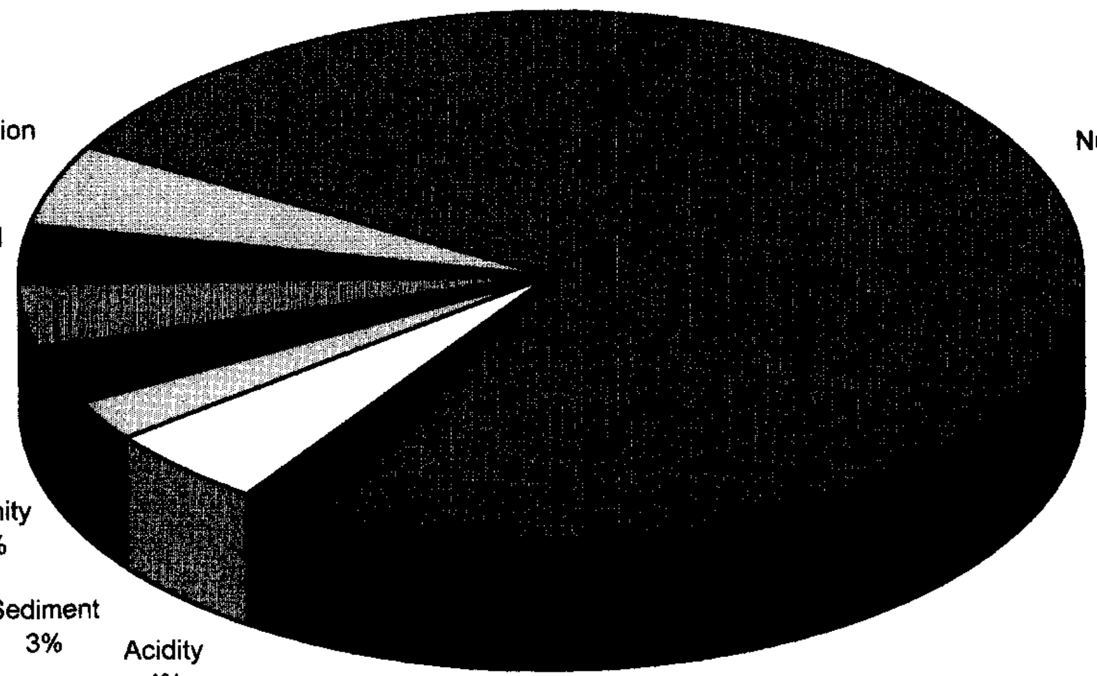
Source: R.A. Smith, et al. 1987. "Water Quality Trends in the Nation's Rivers". Science.

Figure 3. Primary Types of Pollution Affecting 266,000 kilometers of Assessed U.S. Rivers



Source: R.A. Smith, et al. 1987. "Water Quality Trends in the Nation's Rivers". Science.

Figure 4. Primary Types of Pollution Affecting 3.3 Million hectares of Assessed U.S. Lakes



Source: R.A. Smith, et al. 1987. "Water Quality Trends in the Nation's Rivers". Science.

Major pollutants are transported to surface waters via agricultural runoff. As reported in the National Water Quality Inventory (1988), agricultural runoff impairs or threatens more than 100,000 assessed river miles, 2 million acres of lakes, and about 5,000 square miles of estuarine waters nationwide; and because of agricultural runoff, 1.2 million acres of coastal waters are not fully supporting one or more of their designated uses[1] (USEPA, 1990).

The State of Michigan, which supports 10.7 million acres of total farm land and more than 8 million acres (8,156,388) of total cropland, has nonpoint source water quality problems. The State's 1994 Section 305(b) report reveals that 491 significant public lakes with a total combined surface acreage of 119,283 acres (24 percent acreage assessed) are considered to be threatened[2] for overall designated uses, and 78 significant lakes, with a combined surface acreage of 49,644 acres (10 percent of acreage assessed) are classified as impaired[3] (Table 1). The most affected category among Michigan public lakes classified as threatened and not supporting designated uses is aquatic life and wildlife habitat (Table 2). The major causes of impairment of Michigan public lakes are: organic enrichment, metals, priority organics, and nutrients (Table 3).

Furthermore, the report on the trophic status of Michigan's significant public lakes shows that 201 lakes (28 percent of total number of lakes assessed and 24 percent of total surface area) are classified as eutrophic (high nutrient level) and 33 lakes (5 percent of assessed lakes and 4 percent of

---

[1]Designated uses for Michigan surface waters include: agricultural, industrial, and public water supply; navigation; body contact recreation; and use by aquatic life and wildlife (MDEQ, 1995).

[2]Significant public lakes were assessed as threatened for overall designated use support if all designated uses were currently met, but water quality conditions had deteriorated, compared to earlier assessments (e.g., increased oxygen deficit, low pH, etc.).

[3]Significant public lakes that failed to meet one or more of the state's water quality standards or designated uses were considered to be impaired.

Table 1. Overall Designated Use Support (acres) for Michigan's Significant Public Lakes

	Assessment Category		
Degree of Use Support	Evaluated	Monitored	Total
Fully Supporting	1,551	319,347	320,898
Fully Supporting but Threatened	724	118,559	119,283
Partially Supporting[1]	---	---	---
Not Supporting	0	49,644	49,644
Total Size Assessed	2,275	487,550	489,825
Total Number Assessed	(5)	(704)	(709)

[1] Michigan does not use this use support category.

Source: State of Michigan's 1994 Section 305 (B) Report

Table 2. Individual Designated Use Support Summary (acres) for Michigan's Significant Public Lakes

	DEGREE OF SUPPORT					
Designated Use	Supporting	Supporting but Threatened	Partially Supporting[a]	Not Supporting	Not Attainable	Unassessed
RECREATION						
Swimming	489,825	0	--	0	0	0
Sec. Contact	489,825	0	--	0	0	0
AQUATIC LIFE AND WILDLIFE						
Aquatic Life	484,747	4,286	--	792	0	0
- Warmwater Fish	484,747	5,078	--	0	0	0
- Coldwater Fish	46,146	120,804	--	25,206	0	0
Fish Consumption[b]	0	466,008	--	23,817	0	0
WATER SUPPLY						
Drinking Water	489,825	0	--	0	0	0
Agriculture	489,825	0	--	0	0	0
Industrial	489,825	0	--	0	0	0
NAVIGATION	489,825	0	--	0	0	0

[a] Michigan does not use this support category.
[b] Not a defined designated use in Michigan Water Quality Standards, but included by inference.

Source: State of Michigan's 1994 Section 305 (B) Report

Table 3. Acres of Michigan's Significant Public Lakes Not Supporting Designated Uses by Cause Category.

	Impact	
Cause	Major	Moderate/Minor
Pesticides	2,571	4,865
Priority Organics	8,056	415
Metals	10,481	7,060
Nutrients	7,853	17,353
pH	418	374
Organic Enrichment/DO	25,206	0
Total Toxics	4,351	5,280

Source: State of Michigan's 1994 Section 305 (B) Report

total surface area) are classified as hypereutrophic (very high nutrient level). The largest number of lakes and surface area classified as eutrophic and hypereutrophic are located in Region III where Michigan's most fertile soil and large population centers are located (Michigan Department of Natural Resources, 1994). This suggests that there is correlation between the trophic status of certain areas and high agricultural and economic activity.

In another USDA report, it was acknowledged that 75 percent of Michigan's lakes are seriously affected by nonpoint pollution (USDA, 1991). Nonpoint source pollution also includes non-agricultural sources like construction sites and septic systems. Because runoff is the leading cause of lake eutrophication in the U.S., there is a need to examine how agricultural runoff of nutrients can be controlled effectively.

Conceptual Framework and Methods:

This research paper attempts to provide an in-depth review of the existing literature on the problem of agricultural nonpoint source pollution and targeting as a cost-effective strategy to control this problem. It particularly focuses on the importance of nitrogen as an effective nutrient and pollutant. It is the main assumption of this paper that substantial, cost-effective water quality improvements can be made by carefully targeting control and prevention activities. This assumption is substantiated with economic theory and empirical studies.

This research extends to a case study analysis of the nonpoint source pollution program of the State of Michigan (Michigan's Section 319 of the Clean Water Act).

The paper starts off with an overview of the major research issues. Then a discussion of the economic rationale for the use of targeting as a cost effective strategy for implementation of agricultural nonpoint source programs follows. An "ideal" targeting model will be presented and will be the basis for evaluating Michigan's agricultural nonpoint source pollution control policies and programs. The *Section 319 of the Clean Water Act* program will be reviewed and recommendations for cost-effective targeting of 319 funds will be identified.

Another important research issue to be reviewed is the use of geographic information systems with models that simulate nitrogen runoff as a method of identifying priority areas. Data requirements and data availability to support these models for effective agricultural nonpoint source management in Michigan will also be explored. Conclusions will then be drawn based on the review of the literature and the case study of Michigan's nonpoint source program.

Research Objectives:

The research objectives of this study are:

1. To examine targeting as a cost-effective way of dealing with agricultural nonpoint source pollution management;
2. To review existing literature on targeting schemes;
3. To describe an "ideal" targeting model and compare Michigan's targeting programs to this "ideal" model;
4. To describe existing or potential selection criteria and procedures that can effectively identify priority watersheds and priority farms in Michigan;
5. To examine Michigan's Section 319 activities based on its cost-effectiveness, selection criteria, procedures and effective policy instruments to control nitrogen runoff; and
6. To derive recommendations for the effective targeting and control of nonpoint source pollution in Michigan surface waters.

Section II

AN OVERVIEW OF THE RESEARCH ISSUES

The following is an overview of the major issues and research questions of this paper. These issues include water quality problems brought about by nitrogen runoff, the targeting of priority areas--including priority watersheds and priority farms within priority watersheds, existing Michigan legislation, policy instruments designed to cost-effectively control nitrogen runoff, and the use of models and geographic information systems to manipulate and process data in order to facilitate the identification of priority areas.

Water Quality Problems due to Runoff of Nutrient Pollutants:

Agricultural production inevitably generates residual products including nutrients that can become pollutants. Animal manure is one important source of nitrogen runoff. Nitrogen and phosphorous are important inputs to agricultural production systems. However, they are also important pollutants when delivered to water, causing eutrophication.

Eutrophication refers to the process of enrichment of water with nutrients such as nitrogen and phosphorous. An obvious effect of eutrophication is an increase in the biomass which can be supported in a body of water. The effects of eutrophication of waters are often undesirable. Generally, the aesthetic value of a lake is lowered through excessive growth of aquatic weeds and algae and production of floating algal scums which are a nuisance to those who use the water for recreational purposes. Other effects include undesirable odors and tastes, and impairment of water treatment operations such as the clogging of filters by algae.

Eutrophication, however, is a process affected not only by nutrient levels but also by the interrelationships of climatic, physical, chemical, and biological factors. The control of eutrophication has, for the most part, focused on limiting the amounts of nutrients entering the water.

The success of this approach depends on whether the available nutrient supply can be reduced to the extent that growth of aquatic plants is limited. Nutrients which have received the most attention are nitrogen and phosphorous because, following carbon, they are required in the greatest amounts for the production of green plants (Armstrong and Rohlich, 1970). Nitrogen in the form of nitrate is extremely mobile in the environment, making some losses of nitrogen into the environment inevitable. Indeed, nitrogen cycles are important part of our natural systems. Nitrogen can leave the soil-crop system in the harvested crop, or they can be lost through erosion, runoff, leaching, or volatilizing.

Targeting Priority Areas:

The nonpoint source pollution literature recognizes the need for targeting policies toward priority areas--priority watersheds and priority farms (Thornton and Ford, 1985; Maas et al., 1985; Harrington et al., 1985; Duda and Johnson, 1985 and 1987; Nielson, 1986; Gianessi et al., 1986; Ribaudo, 1986, 1989; Setia and Magleby, 1987; MacGregor et al., 1991). Appendix A provides a review of empirical studies on targeting.

Targeting programs, whether voluntary or not, at priority areas, can reduce the cost and increase the effectiveness of soil and water quality programs. The need for targeting stems from the realization that, because of the nature of nonpoint source pollution, and, because of shrinking budgets, it is a cost-effective way to manage agriculturally related water quality problems. Targeting involves directing technical assistance, educational efforts, financial resources, or regulations to those regions or farm enterprises that cause a disproportionate portion of soil and water quality problems or areas where water quality improvements are most demanded (NRC, 1993).

To be cost-effective, soil and water quality policies designed to control nitrogen runoff should be targeted at the areas where the greatest water quality improvement can be accomplished per dollar spent. These may be farms that, because of their location, production practices, or management, have greater potential to cause soil degradation or water pollution, or, these may be watersheds that are most severely affected by nitrogen enrichment. It may be that the greatest return however may be found with a watershed with great demand for high water quality (e.g. recreation demand for high quality waters).

The Nitrogen Problem and Priority Areas:

Available empirical studies stress the benefits of targeting programs to priority farms. Priority farms are defined here as those farms that are prone to nitrogen losses because of certain farm and soil characteristics, production practices, and farm management practices, making those areas as sources of pollutants that contribute to the eutrophication of surface waters. Priority watersheds are those that are severely affected by eutrophication due to excessive nutrient loads that have the potentially largest net benefits from pollution control.

Previous research on the problems of nutrient management suggests that there is frequently a problem of excess nutrient application (nitrogen and phosphorous) on farms, thereby increasing the amount of pollutants that can reach surface waters through runoff and erosion. Padgitt (1989) found, for example, that about 25 percent of the Iowa farmers surveyed applied fertilizer at a level of 28 kg/ha (25 lb/acre) above recommended levels. Similarly, in the Central Platte Natural Resource District in Nebraska, 14 percent of the land received nitrogen in excess of 100 kg/ha (89 lb/acre) of the recommended amounts (NRC, 1993). A number of other studies support the thesis that some producers apply excessive nutrients: Hallberg et al. ,1991; Bosch et al., 1992; Parsons et al.,1994; Supalla et al., 1995.

The Supalla et al. (1995) study addressed the reasons why a significant number of producers continue to apply agricultural inputs, especially nitrogen fertilizers, above recommended levels.

Some of the factors that were considered in his analysis were: financial incentives, environmental attitudes, socioeconomic characteristics such as education, experience, and financial health of the farm, technical knowledge, and recommended nitrogen rate.

In a related study by Parsons et al. (1994), site and farm characteristics were related to simulated nitrogen losses on Virginia cropland sites. The regression results identified commercial and manure nitrogen applications, tillage, soil water capacity, and slope to be significant explanatory variables of nitrogen losses. The farm characteristics related to manure nitrogen application were confined livestock, manure importation, manure nitrogen per crop acre and gross income per acre. The research results indicated that policy makers should target manure-source nutrient abatement programs toward farms having confined livestock operations, high animal densities, and farms importing manure.

The problem with nitrogen is that it must be applied in excess of the amount actually harvested in grain and residues because the efficiency of nitrogen uptake by the crop is less than 100 percent and because precise crop needs vary with time and weather (NRC, 1993). It has often been alleged that producers apply more than the recommended amount of nitrogen for financial or economic reasons. Proponents of this view contend that there may be a potential gain from "over" application in some years and/or that producers manage economic risk by applying extra nitrogen to insure maximum potential yield at all times (Supalla et al., 1995). While farmers have an interest in retaining nutrients on cropland for plant use, the cost of replacing lost nitrogen from runoff and leaching often is low relative to the perceived cost of reduced crop yields from nutrient deficiencies (Maas et al., 1985).

Data from the studies mentioned above demonstrate the importance of recognizing that there are problem farms that should be prioritized and targeted. Because of these farms' location, production practices and management techniques, they tend to cause more soil and water problems than others. It is just as important to recognize that many farms cause no water quality problems and that some are probably improving soil and water quality. Targeting programs at the set of farms that are responsible for most soil and water quality degradation will reduce the cost and increase the effectiveness of soil and water quality programs. Targeting can also prevent placing unnecessary burdens on those producers who are not causing damages and recognize those producers who are making positive contributions to improving soil and water quality.

On the other hand, there are also problem watersheds (areas drained by rivers and lakes) that have more severe water quality problems than others, and therefore command greater attention in terms of remediation.

Policies Designed to Control Nitrogen Runoff:

Prior to the 1980s, onsite erosion was the primary emphasis of nonpoint pollution policy. From the mid-80's on, attention shifted to offsite impacts of agricultural runoff. In 1987, Congress created *Section 319 of the Clean Water Act* to encourage states to identify waters damaged or threatened by runoff sources and to develop comprehensive programs to reduce pollution from those land-based sources. The *Nonpoint Sources Assessment Reports and Management Programs* developed by the states under *Section 319 of the Clean Water Act* are a critical element of the Environmental Protection Agency's (EPA) nonpoint source program. The reports are considered to be of value in providing direction and funds for nonpoint source activities in the states, among other Federal agencies, and within EPA. These reports identify nonpoint source-related problems in all media (air, surface water, sediments, ground water) and assist in setting priorities and targeting funds for mitigation. The reports also identify areas requiring storm water discharge permits and develop management plans for national priority areas such as the Great Lakes, Puget Sound, and the

Chesapeake bay. Section 319 of the Clean Water Act has the potential to be developed as a major water quality targeting program.

The Use of Physical Models and Geographic Information Systems for Targeting:

Targeting requires spatial information on the location of the pollution problems, the severity of the problem, and proxies for demand for water quality improvement (e.g. population centers). Geographic information systems (GIS) have the potential to increase the usefulness of existing data in the analysis of environmental problems. A geographic information system is a combination of computer hardware and software designed to collect, manage, analyze, and display spatially referenced data. The GIS approach to handling vast amounts of data while preserving spatial detail has been enthusiastically received by many of the scientific disciplines and agencies working on environmental issues (Fletcher and Phipps,1991).

Examples of GIS applications include such diverse activities as describing and managing natural resources like forests, soils, water, and minerals. Geographic information systems could also be used to facilitate identification of priority areas when linked with programming models that simulate phenomenon like runoff of nutrients, soil erosion, percolation, etc.

Section III

TARGETING PRIORITY WATERSHEDS AND PRIORITY FARMS

Agricultural policy has traditionally been concerned with the maintenance and stability of farm income, and the provision of a stable food supply at low relative prices (Hrubovcak, Le Blanc, and Miranowski, 1990). Because commodity program payments are based on quantities produced, there has been an incentive to increase the productivity of farms. For this reason and others (e.g., the need to reduce input costs), the use of chemical fertilizers and pesticides became widespread, and agricultural production extended even to marginal lands. In some cases, the increase use of inputs resulted in environmental degradation.

Despite the existence of nonpoint pollution from agriculture, federal efforts in controlling pollution of water bodies were initially concentrated on point sources of pollution. The few earlier efforts in controlling agricultural nonpoint source pollution were not effective because they were mostly just "stop gap" measures and piecemeal in nature (Adler et al., 1993). In addition, the nonpoint source problem was viewed as a "land-use issue"--suggesting that it was mainly a problem for the localities and states. Therefore, federal efforts to address nonpoint source pollution were lacking. Other significant reasons for the policy vacuum in nonpoint source efforts include: (1) the inability to identify the source areas for control; (2) the variation of nonpoint source pollution unpredictably over time and space as a result of weather and geography; and (3) the difficulties of regulating the politically powerful agricultural sector (Harrington, Krupnick, and Peskin, 1985).

The Food Security Act of 1985 was the first farm legislation to directly tie farm income and environmental concerns. This coupling was achieved through the Conservation Reserve Program

(CRP), Conservation Compliance, Sodbuster, and Swampbuster provisions.[4] But most of the federal policies with respect to agro-environmental problems are found outside the farm programs.

In regard to the water quality problem from agricultural pollutants, the important piece of legislation is the Water Quality Act of 1987, which was designed to control agricultural nonpoint source pollutants that affect water quality. The Section 319 amendments were established as a provision under the *1987 Water Quality Act*. Later on The Water Quality Act was renamed the *Clean Water Act.*

Section 319 is a comprehensive framework for accelerated efforts to control nonpoint source pollution. Under the 319 provision, states are required to submit to the Environmental Protection Agency (EPA), a nonpoint source Assessment Report and Management Program. The Assessment Report must identify (1) state waters that will not attain or maintain water quality standards without additional nonpoint source controls; (2) the categories of nonpoint sources or particular nonpoint sources responsible; (3) the process to identify best management practices (BMPs) for each nonpoint source category or particular nonpoint source; and (4) the state and local programs that would implement controls. The Management Program, must identify the following: (1) actual BMPs to address the problems documented in the Assessment Report and programs to implement the BMPs; (2) sources and proposed uses of all nonpoint source control funding; and (3) Federal programs and projects that states wish to review for consistency with their own nonpoint source programs (National Research Council, 1993). For most states, the 319 program is the heart of their nonpoint pollution control efforts. Michigan is no exception. However, the program has suffered from

---

[4]Although there were other programs in earlier Farm Bills that idled land (e.g., the Soil Bank) these were not connected with environmental criteria, and thus were mainly supply control mechanisms.

limited budgets.

The Economic Case for Targeting:

The challenge facing the agricultural sector and water quality management communities now is to implement cost-effective policies which are attuned with the guidelines set forth in the *Clean Water Act* (particularly the Section 319 program) to control nonpoint source pollution control. Targeting, is gaining wide acceptance particularly as a means to overcome the challenge.

The targeting approach grew out of the realization that many natural resource problems are concentrated in limited geographic areas. This fact first became evident with soil erosion data assembled and made available for the 1985 Farm Bill debate. USDA's previous conservation efforts were spread widely and uniformly throughout the nation's agricultural areas. Targeting was offered by the environmental community as a way to increase the effectiveness of federal expenditures for conservation.

Prior to 1985, support for targeting and data necessary for targeting was quite limited and only a few county Agricultural Stabilization and Conservation committees gave targeting a high priority (Nielson, 1986). Targeting is not a politically popular exercise for several reasons. It is often more politic to spread benefits over a majority of recipients, even though this practice is not cost-effective. Federal, state and local agencies rely on political support for their continued existence and broadly distributing benefits strengthens their political base. Second, until the last decade, information that would allow cost effective targeting was, the most part, unavailable.

Currently, more policy makers and water quality managers are realizing that nonpoint pollution is not only a serious environmental quality problem causing damage to sensitive water bodies, but is also a significant drain on their budgets. Funds do, and probably will always, limit the number of environmental actions that can be implemented, thus, it makes sound fiscal sense to cost-effectively reduce nonpoint inputs rather than to continue spending billions of dollars each year to treat symptoms of the problems (Duda and Johnson, 1987). Cost-effectiveness can be improved and budgets economized by prioritizing problem areas and tailoring site-specific solutions or best management practices to these areas.

Indeed, the need for refined targeting has been made more urgent as federal, state, and local policy makers have struggled to stretch shrinking budgets to keep up with the increasing list of items on the environmental agenda. Adler and his colleagues (1993) reported that although polluted runoff causes more than half of our nation's water quality impairments, it receives a small fraction of all U.S. clean water funds. Congress authorized $400 million under the 319 program for the 1987-1992 cycle, but cumulative appropriations through FY 1993 totaled slightly under $200 million, or less than 50 percent of the authorization. A 1990 EPA report projected that annual federal spending on runoff controls would decline to less than 2 percent of the estimated $58 billion in water quality control costs in the year 2000. Obviously, agricultural runoff reduction is a neglected concern in the Environmental Protection Agency's (EPA) budget, despite its role as a major water pollution source.

The nature of agricultural nonpoint source pollution also justifies the need for targeting water quality management funds. Nonpoint sources, by definition, are diffuse and not easily identified or quantified. Not all areas of the watershed contribute equally to the nonpoint source loads because of the variation in watershed slopes, soils, and vegetative cover. Because of these geographical differences (including, differences in soil characteristics, production practices, management approaches, climate, and topography) among the different watersheds and the different farms within the watersheds, it is costly and impractical to tailor specific solutions for each of this areas without prioritizing the areas with severe water quality problems or areas where improvement/alleviation of the problems is possible. It is even more costly and ineffective to implement uniform or blanket solutions to all the areas including those which do not contribute to the problem substantially, especially because control technologies and BMPs are generally expensive to implement[5].

To be low cost, agricultural nonpoint source pollution control policies must be cost-effective. The reason for the pursuit of cost-effective policies rather than "optimal policies" with the highest net benefits, stems from the difficulties of measuring actual benefits from cleaner water.

Cost effectiveness is a subset of economic efficiency. To achieve full economic efficiency, a regulatory strategy must:

- allocate control efforts within a source to minimize the cost of achieving any given reduction in damages from that source;
- allocate control efforts across sources in a manner that minimizes the cost of achieving any given reduction in overall damages; and
- strike an appropriate balance between the costs of control and the benefits of damage reduction (Nichols, 1984).

Economic efficiency requires an assessment of the benefits from a reduction in water pollution and onsite and off-site costs plus transaction costs (i.e., information, administrative, and enforcement). The benefits that can be derived from an improvement in water quality can be proxied by factors like the number of recreation user days or similar measures. In lieu of a complete economic efficiency analysis, cost-effectiveness can be used as a good criterion for prioritizing resources.

There is reasonable empirical evidence to support cost-effectiveness of targeting (see

[5]This argument assumes that the administration, information, and enforcement costs of targeting are not so large as to swamp the savings from changing a uniform, non-targeted approach to a targeted one.

Appendix A). In general, the literature put more emphasis on on-site criteria for micro-targeting than off-site studies for macro-targeting. Micro-targeting refers to farm-level targeting, that is--identifying priority farms within priority watersheds based on the farms' contribution to the nonpoint source problem and trying to direct resources to alleviate the problem at the source. On the other hand, macro-targeting involves prioritization on a watershed-basis--watersheds with the highest water quality impact on surface waters within the state are identified for preventive and remedial actions.

The Conservation Foundation estimates that more than 6 billion dollars in off-site damages are caused each year by sediment and its associated pollutants, mainly from soil erosion on agricultural land (Clark et al., 1985). If damages to fish and wildlife and wildlife were included, the estimate would be substantially higher.

Aside from the offsite costs of nutrient and sediment pollution that farmers share with the general public, there are also onsite farm costs caused by wastage of nutrients lost from (soil) fields and by lowered crop yields. In fact, soil productivity loss is a widespread problem. Millions of acres likely have been permanently lost to production of row crops because of this damage (Duda and Johnson, 1985). Consumers and growers spend a substantial amount of dollars each year to replace the lost productivity. This is because the costs of producing a crop on eroded soils rise. The costs include more expensive chemicals, fertilizer, and hybrid seeds needed to maintain yields and replace eroded nutrients and higher fuel costs to work damaged land. USDA estimated that each ton of eroded soil carried with it about $4.00 (1974 dollars) worth of plant-available nitrogen, phosphorous, and potassium (Duda and Johnson, 1985).

The level of damages ultimately depends on the presence of water users. Water provides services of value, and these services include the benefits from recreational and industrial water uses.

The impacts of improved water quality to uses such as recreational fishing, navigation, water storage, irrigation ditches, water treatment, recreational boating, would need to be assessed to completely satisfy the economic efficiency criterion. Without a demand for water, or for water quality, there can be no economic damages from poor water quality.

The Targeting Framework:

Ideally, the decision to target programs at particular regions or enterprises should be based on the following (NRC, 1993):

1. An articulation of national or state goals for soil and water quality--

The Clean Water Act establishes such articulation of the goals for the nation's waters. Although the goals as stated are subjective, the primary goal of the Clean Water Act is to restore and protect the chemical, physical, and biological integrity of the nation's surface waters. In order to achieve this objective, subsidiary and interim goals were also created stating that it is the national goal that--the discharge of pollutants into the navigable waters be eliminated; wherever attainable, an interim goal of water quality which provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water be achieved; and that the discharge of toxic pollutants in damaging amounts be prohibited (Adler et al., 1993).

In particular, Section 319 of the Clean Water Act provides more specific guidelines and direction for states to implement soil and water quality programs. As required by Section 319, states are to identify priority watersheds for treatment of nonpoint source pollution problems. The criteria for such identification could serve as the basis for ranking and prioritizing those areas for targeting state efforts. In designing such criteria, factors like: the severity of the water quality problem, magnitude of pollutant loads likely causing the pollution and the potential to significantly reduce the pollutant load, landowners' willingness to participate in nonpoint source management programs, and the potential public use and benefits that will result from watershed projects, should be considered.

2. Identification of regions where the benefits from achieving the goals per dollar invested are greatest--

Proper identification of these regions where the benefits from achieving the goals per dollar invested are greatest, involves the use of economic criteria. Criteria must be set to identify the agricultural watersheds that have large pollutant (nutrient) loadings, those that contribute most to the degradation of the state's surface waters, and those where the net benefits of improvement are the greatest. For example, areas of large numbers of confined livestock may be creating a nitrogen pollution problem unique to only a few counties, but in these counties high quality water may be greatly valued, therefore, more returns per dollar spent will be realized if these counties are targeted.

3. Identification of the linkages among farm practices , soil quality, and water quality--

Identification of the linkages among farm practices, soil quality, and water quality involves an interplay of a wide range of factors from crop cycles, nutrient cycles to soil and water characteristics. The delivery of agricultural pollutants to waterways from agricultural land depends on factors such as, the size of the watershed, average slope, amount of ground cover, and stream density. Water quality in the receiving waterway depends not only on the agricultural pollutants discharged, but also on pollutants from other sources, as well as on the physical, chemical, and biological characteristics of the waterway and farming practices. These various inter-relationships need to be understood fully in order to determine what factors significantly contribute to the problem of nutrient runoff, and then consequently facilitate the implementation of the proper criteria to be used in the selection of priority regions. The use of models (i.e. simulation models) can be employed to be able to provide a clearer picture of the interrelationships among these factors.

4. Identification, within a targeted region, of those enterprises that contribute to the problem as well as their barriers to changing their farming systems--

This objective requires identification of priority farms within the priority watersheds (a micro-targeting approach). With some knowledge of the factors that cause nitrogen losses, priority farms can be identified based on their potential to contribute to the problem.

5. Tailoring policies and programs designed to control agricultural nonpoint source pollution to specific priority areas and priority farms--

Once priority areas have been identified, proper incentive schemes should be designed to influence farmer behavior in these priority areas to conform with set policies.

Section IV

AN ASSESSMENT OF THE AGRICULTURAL NONPOINT SOURCE POLLUTION POLICIES AND MANAGEMENT PROGRAMS: THE CASE OF MICHIGAN

The state of Michigan is blessed with abundant water resources. Often referred to as the "Great Lakes State", Michigan is the focal point of the Great Lakes basin. Geographically, Michigan consists of two peninsulas surrounded by four of the five Great Lakes, and it is the only U.S. state or Canadian province to lie almost entirely within the Great Lakes basin. Of the state's official total water and land area of 96,791 square miles, roughly 40 percent (38,504 square miles) is covered by the Lakes, and 1,505 square miles consists of inland lakes and ponds. There are about 35,000 mapped lakes and ponds in Michigan, and 201 of these waterbodies have surface areas larger than 500 acres. Michigan leads the nation with 3,288 miles of freshwater coastal shoreline and also has 56,094 miles of rivers and streams in 65 river basins (MDNR, 1994).

These waters are important sources of public drinking water, recreational opportunities, and aesthetic beauty as well as industrial and agricultural water supply for the 9.3 million residents of Michigan. The deterioration of these water resources impacts not only the residents of Michigan, but also the residents of any of the other territories beyond Michigan as well. Because all rivers in the state flow into the Great Lakes, pollutant loads delivered to Michigan lakes and streams may eventually affect other states or Canadian provinces. Because of the significance of these valuable water resources, the state has reason to effectively control pollutant inputs and maintain good water quality.

Considerable improvements in water quality have been obtained since the first formal water pollution control efforts began in 1913 with the passage of Public Act 98[6]. Despite the considerable investment and progress made in Michigan's water quality programs, the state still faces substantial challenges in achieving full protection of the water resources. For example, all desirable/designated uses[7] have not yet been attained for most of the Michigan waters.

There is also increasing public concern regarding the source, fate and effects of toxic materials found in the Great Lakes and inland waters. Most importantly, nonpoint source pollution still contributes substantially to degraded water quality conditions. Although several billion dollars have already been spent to reduce the impact of point source pollution, many Michigan waterbodies are still unable to meet water quality standards because of nonpoint source pollution (MDNR, 1994).

The magnitude of the nonpoint problem varies among areas of the state and is strongly affected by such factors as land use practices, soil types, and topography. Runoff from agricultural lands, particularly those with fine textured soils that are highly erodible, contributes nutrient and sediment loads to receiving waters. It is difficult to quantify nonpoint source inputs, and thus assessment and control efforts are hampered. Cause and effect relationships between nonpoint sources and particular water quality problems are often hard to establish. Since nonpoint sources are by nature diffuse and result from many different land use activities, it is difficult to quantify the relationship between runoff and water quality degradation. Also, nonpoint pollutant loads are generated in different volumes, combinations and concentrations dependent upon storm frequency, intensity, duration, and seasonality (MDNR, 1994). Therefore, it is difficult to effectively control

[6]Public Act 98 required larger communities to construct and operate sewers, sewage treatment facilities, and treatment and distribution systems for drinking water (Michigan Department of Natural Resources, 1994).

[7]These uses include agricultural, industrial and public water supply, the provision of warm water fish habitat, other aquatic life and wildlife habitat, navigation, and body contact recreation.

agricultural nonpoint source pollution. These characteristics must be considered in the design of state policies and programs.

The nitrogen problem is a classic example of an agricultural nonpoint pollution source. As indicated in the previous section, the nitrogen problem results from the "over application" of nitrogen fertilizer and improper manure management practices, thus contributing to nutrient runoff and eventually causing water quality problems. In Michigan, nitrate and nitrite concentrations continue to increase throughout the Great Lakes Basin. The increase in nitrate-nitrite concentrations in the open waters of the Great Lakes is of concern because it has the potential to impact phytoplankton community structure. These impacts could alter important food web dynamics and disrupt existing ecosystems (MDNR, 1994). Most observers agree that agricultural nonpoint sources of pollution in Michigan must be effectively controlled to further improve water quality and to meet the recreational, commercial and drinking water needs of the state (MDNR,1994).

The desired future for Michigan's water quality as stated in legislation, is that all state waters will support the designated uses, meaning Michigan's water quality standards are met, and fish consumption and swimming advisories eliminated. All degraded areas will have to be restored to acceptable water quality.

The desired future will also embody the federal Clean Water Act goal of "zero" discharge of pollutants and the U.S.-Canada Great Lakes Water Quality Agreement goal that the discharge of persistent toxic substances to the Great Lakes be virtually eliminated (MDNR, 1994).

An important question to investigate at this point is, how does Michigan manage its agricultural nonpoint source problems in order to attain the state's vision for the future—that of attaining designated uses for all of it's surface waters? A review of existing policies and programs to control agricultural nonpoint source is presented below.

Agricultural Nonpoint Source Pollution Control Policies and Programs in Michigan:

Despite long standing concerns in Michigan about the magnitude and impacts of nonpoint source pollution, no statewide assessment had been done to determine which waterbodies were impacted by nonpoint sources until 1985 (MDNR, 1994). In 1987, amendments to the federal Clean Water Act required all states to conduct a statewide assessment of waters impacted by nonpoint sources. Subsequently, in 1988, the Michigan Department of Natural Resources conducted a more detailed assessment than in 1985 and developed the Michigan Nonpoint Pollution Assessment Report. From 1989 through 1993, a significant amount of effort was devoted to documenting water quality impacts from nonpoint sources of pollution and verifying information included in the assessment report. Chemical, biological and physical surveys were conducted to identify water quality standards violations and biologically degraded communities in many watersheds. Based on these assessments, the state designed strategies to control nonpoint source problems.

Thus, Michigan's Nonpoint Source Management Plan came to fruition. The plan identified programs and best management practices that will be implemented in Michigan to solve the nonpoint source problems identified in the assessment report. One of the priority programs identified was the Watershed Demonstration Program, which has become the major emphasis of the state's nonpoint source efforts in Michigan (MDNR, 1994). The following is a review of the State's water quality programs and nonpoint source pollution policies and regulations:

Michigan's Surface Water Quality Standards:

To protect water quality, Michigan has developed Water Quality Standards pursuant to Part 31, Water Resources Protection, of the Natural Resources and Environmental Protection Act (P.A. 451) of 1994. This legislation authorizes promulgation of Water Quality Standards for Michigan waters. The purpose of the water quality standards is to (1) establish water quality requirements applicable to the Great Lakes, their connecting waterways, and all other surface waters of the state; (2) protect public health and welfare; (3) enhance and maintain the quality of water; (4) protect the state's natural resources; and (5) serve the purposes of the Michigan Water Resources Commission Act, the Federal Clean Water Act, and the U.S.- Canada Great Lakes Water Quality Agreement.

The water quality standards designate specific uses for which all Michigan surface waters must be protected at a minimum. These uses include agricultural, industrial and public water supply; use by aquatic life and wildlife; navigation; and body contact recreation. In addition to describing designated uses, the water quality standards also define parameters and criteria levels necessary to protect a waterbody for its designated uses. For example, as stated in the water quality standards, nutrients shall be limited to the extent necessary to prevent stimulation of growths of aquatic rooted, attached, suspended and floating plants, fungi or bacteria, which are, or may become, injurious to the designated uses of the waters of the state.

Michigan's Section 319 Nonpoint Source Program:

Congress added Section 319 to the Clean Water Act in 1987, directing states to assess their waters for runoff damages and create watershed-based programs to repair the damages and prevent further pollution. The primary purposes of the program are to address nonpoint source problems on a watershed basis, and to facilitate inter-agency cooperation towards addressing nonpoint source problems.

Since watersheds are land areas that drain to a common waterbody, watershed-level efforts offer a means for developing comprehensive site-specific control programs. Nonpoint sources of pollution in a watershed can often be individually identified, and, then, based on site-specific problems, recommendations for remedial actions and control measures can be implemented. One of Michigan's Section 319 Program priorities is to encourage and emphasize implementation of nonpoint source pollution activities on a watershed basis.

In 1989, the Surface Water Quality Division staff in collaboration with other state agencies developed the Michigan Nonpoint Source Management Plan under the Section 319 program. One of the key elements of the plan with major emphasis on nonpoint source problems is the Watershed Demonstration Program.

Michigan's Watershed Demonstration Program:

The primary purposes of the Michigan Watershed Demonstration Program are to address nonpoint source problems on a watershed basis; to facilitate interagency cooperation in addressing nonpoint source problems; to improve water quality in specific watersheds; and to ensure that limited resources are directed to the highest priority areas (MDNR, 1994).

As defined in the 319 Plan, priority watersheds are selected based on the expected ability of the applicant to demonstrate the following water quality and project success criteria:

A. Water quality criteria are based on the extent to which:

1) Water quality standards are being violated in the watershed;
2) Water quality problems can be controlled or prevented;
3) Designated uses are not being maintained;
4) Potential public use and benefit will result;
5) Current and potential surface water and groundwater quality problems exist within the watershed; and,
6) The watershed includes high quality waters that should be protected.

B. Project success criteria are based on the:

1) Capability of applicant (and/or assisting local agencies) to plan and implement necessary control practices;

2) Landowner/local government's willingness to participate;

3) Willingness and capability of local/state agencies to control other sources of pollution;

4) Ongoing local/state/federal nonpoint source initiatives;

5) Transferability, of the planning or implementation methods used, to similar projects at other locations.

The priority watershed process begins with the Nonpoint Source (NPS) district staff of the Michigan Department of Environmental Quality (MDEQ) working with local agencies and communities to help them identify nonpoint sources and inform them of what they can do to correct these problems. This local/state working relationship initiates with the NPS district staff contacting the appropriate local agency in a watershed where they feel there are waters that need protecting. This contact is also initiated by the local agency when they feel there is a problem in a watershed or there is a high quality watershed they wish to protect. This initial stage is considered a most important step because it establishes a working relationship between the state and the local community, and, because it shows the NPS district staff how committed the community is to a watershed project. Landowners and local government official's willingness to participate is key in determining priority watersheds within the Michigan 319 Plan.

NPS district staff use previously conducted biological surveys to determine what current conditions exist in a watershed. Biological surveys are conducted by the Surface Water Quality Division of the Michigan Department of Environmental Quality mainly to determine present water quality, identify impaired designated uses of waterbodies, and determine the pollutants of concern within a watershed. Biological community surveys are those related to determining if the biological community present at a site is adversely impacted by water pollution, those evaluated as not healthy are further studied to identify causes of the impacts. If a biological survey has not been completed for the watershed the district staff can request that a survey be done in the future. Biological surveys are important in determining what types of nonpoint source pollution exist in the watershed, and to verify that there actually is a water quality problem. The biological surveys will also give good baseline data that can be compared with future data.

The Nonpoint Source (NPS) district staff then works with the local government units, landowners, and communities to assist them in preparing proposals to be submitted in the state's Request for Proposals (RFP) process for Section 319 funding.

The NPS Unit will send the RFP to the appropriate local units of government statewide, that have the authority and expertise to address nonpoint source problems. Criteria for judging applications are those listed above. In addition to the previously mentioned criteria, certain types of projects may receive higher considerations. The types of projects that will receive higher considerations may change from year to year depending on the state's and EPA's priorities. Higher priority is given to those projects that demonstrate cooperation between local and state agencies, and those projects that show high local support and acceptance of the watershed project.

The Request for Proposals (RFP) review process consists of an extensive review of the proposals by the Surface Water Quality Division staff from the Nonpoint Source Unit, Nonpoint Source district staff, Administrative Unit, chemical and biological monitoring staff, as well as a Nonpoint Source Advisory Committee—all are in the Michigan Department of Environmental Quality (MDEQ). The advisory committee is comprised of federal, state and local representatives.

This process results in the state selecting priority watersheds on a yearly basis, a process which easily adapts to changing priorities. This process allows all local communities who have an interest in preserving and protecting their water resources the opportunity to do so. Supporters of this approach believe that this priority will result in the highest quality projects, with the most water quality improvements, and considerable educational value locally as well as statewide. However, this approach has the potential for neglect of longer term projects as well as the neglect of serious pollution problems where there is little local support for pollution control. Changing project priorities annually may undermine any benefits from systematic targeting.

Implementation of the nonpoint source priority watershed projects occurs in four phases. Phase 1 consists of a watershed assessment. Phase 2 is the development of a detailed watershed plan, Phase 3 is the implementation of the watershed plan and Phase 4 is the evaluation of the implemented project.

Michigan's Surface Water Assessment:

The goal of the surface water assessment program is to provide water quality data that can be used to meet eight primary objectives: define water quality conditions statewide; identify degraded waterbodies; document water quality trends; detect emerging trends; determine pollutant loads to the Great Lakes; assess impacts of pollutant inputs; track effects of pollution abatement programs; and provide data in support of discharge permit development and wasteload allocation.

The quality of Michigan waters including the Great Lakes, inland lakes, rivers, and wetlands are continuously being monitored and assessed by the Surface Water Quality Division (SWQD). For the years 1990-1995, approximately 40 percent of Michigan streams have been assessed for designated use support and about 50 percent of the state's significant public lakes have also been assessed. Michigan's 1994 Section 305(b) report indicated up-to-date water quality conditions for the state. Tables 1-3 show water quality assessment data on significant public lakes.

State Laws to Control Nutrient Runoff:

There are four laws that address the problem of nutrient runoff, specifically, from commercial fertilizer and manure, and which complement the Michigan Watershed Demonstration Program. These are (1) The Michigan Water Resources Act (P.A. 245); (2) The Right to Farm Act (P.A. 93); (3) The Environmental Response Act (P.A. 307); and (4) The Michigan Groundwater and Freshwater Protection Act.

A. *The Michigan Water Resources Act (P.A. 245):*

The Michigan Water Resources Act (P.A. 245) of 1929, as amended in 1990 is the cornerstone law to protect the state's water quality. Under this Act, it is unlawful for any person, directly or indirectly, to discharge into the waters of the state any substance which is or may become injurious to the public health or ecosystem. Violations of this Act subject the violator to civil fines up to $25,000 per day, and criminal penalties. One drawback to this law is that there has to be a discharge before a violation is committed. Also, there are no numerical limits provided in the law by which to determine a violation.

B. *The Michigan Right to Farm Act (P.A. 93):*

This Right to Farm Act (P.A. 93) of 1981 provides the Generally Accepted Agricultural and Management Practices (GAAMPS) that, if followed, will protect farmers from nuisance lawsuits. These agricultural and management practices under GAAMPS are based on technical recommendations that are a consensus of agricultural engineers and professionals working in the agricultural nonpoint source management field. If the GAAMPS are not followed, the farmer is liable for pollution cleanup under P.A. 307, the Environmental Response Act. The Right to Farm Act provides for an agency response to reported violations. The response component is administered by the Michigan Department of Agriculture, and if the violation is not corrected, it is then referred to the Michigan Department of Natural Resources for enforcement action, such action may include fines and penalties under the Water Resources Commission Act. The Right to Farm Act is not regulatory; it is voluntary in nature. Critics charge that major limitations of the Right to Farm Act are that compliance with this law is not required of the producer, it is complaint driven, and the GAAMPS are not as effective as they could be in preventing pollution. However, if the farmer chooses to voluntarily follow GAAMPS as a nonpoint pollution strategy, the producer is protected from nuisance suits.

C. *The Environmental Response Act (P.A. 307):*

The purpose of the Environmental Response Act (P.A. 307) of 1982 is to shift the burden of cleanup costs onto polluters rather than the public taxpayers. Farmers who do not follow the GAAMPS for nutrients and who thereby cause contamination of the environment are responsible for cleanup activities. Farmers who follow the GAAMPS for nutrients are not liable under the Environmental Response Act. The limitation of this Act is that it is reactive in nature--it deals with the clean-up of contaminated sites and does not require proactive prevention approaches such as following a nutrient management plan.

D. *Groundwater and Freshwater Protection Act*

The Groundwater and Freshwater Protection Act assists producers in developing groundwater protection plans and provides educational resources, technical assistance and cost sharing. One component is the concept of groundwater stewardship practices. A second concept is the availability of local stewardship teams which aid assessment and problem solving. The main concept that makes this act effective is that by adhering to groundwater stewardship practices, the farmer is guaranteed liability protection from groundwater contamination. By following groundwater stewardship practices, the producer has access to continued technical assistance and funding. Groundwater and freshwater protection programs are funded by producers through pesticide and fertilizer registration fees.

Other Voluntary Programs, Regulations, Policies and Special Initiatives:

A number of new programs, regulations, and policies have been implemented to control the problem of agricultural nonpoint source pollution. The Michigan Environmental Protection Act supplements existing regulatory programs and may be used to effectively prevent pollution of the state's waters from nonpoint pollution sources. Many other statutes protect wetlands, lakes and streams, including the Wetlands Protection Act, the Inland Lakes and Streams Act, the Great Lakes Submerged Lands Act and the Shorelands Protection and Management Act. These statutes protect the state's natural resources and assist in reducing the impact of nonpoint sources of pollution (MDNR, 1994).

Other statewide watershed programs that involve nutrient management practices are: the Water Quality Incentives Program and the Natural Resources and Conservation Service (formerly the Soil Conservation Service) PL 566 Water Quality Project. These programs are voluntary and are watershed-based. All have a water quality focus and deal with structural, vegetative and managerial practices, or a combination of all these elements. Technical and financial assistance is available through these programs.

In addition to these programs, Michigan State University runs soil testing and tissue analysis labs for state citizens. There is a charge for the soil testing and tissue analysis and only a limited number are conducted through Michigan State University. Private soil testing labs are readily available to growers in the state and a large number of growers have their soil tested by these private labs. Michigan State University also provides educational and technical assistance, and initiates research activities directed at nutrient use reduction.

An Assessment of Michigan's Section 319 Nonpoint Source Program:

The state of Michigan has been consistent in its efforts to protect its valuable water resources, as proven by the above enumeration of the State of Michigan's various environmental programs and policies.

Through the Nonpoint Source Program, authorized by Section 319 of the Clean Water Act, the MDEQ has sought to identify priority watersheds and to provide technical and financial assistance to landowners to reduce the effects of nonpoint sources of pollution. In addition, the Michigan Coastal Management Program and the Section 319 Nonpoint Source Program have supported efforts of the Saginaw Bay Watershed Initiative to identify and reduce nonpoint sources of pollution which are diminishing the water quality of the Saginaw Bay. Similar efforts are underway to protect the high quality water of Grand Traverse Bay and to prevent deterioration of water quality from both point and nonpoint sources of pollution. Finally, refinements are being made to the state's education and outreach efforts to provide improved technical information on the effects of land use activities on nonpoint sources of pollution. All of these programs combined will indeed improve Michigan's ability to reduce the nonpoint source problem.

A review of the Section 319 Program was done by the Environmental Protection Agency in 1992. EPA officials examined ten state programs and management policies (not including Michigan) and found out that "the majority of the ten states do not have nonpoint source programs oriented toward improving water quality on a watershed-specific basis, and that the majority of state management programs do not identify strategic plans or goals for specific waters identified in the assessment reports. The conclusion arrived at by the EPA is that the Section 319 (b) requirement that states shall, to the maximum extent practicable, develop and implement management programs on a watershed-by-watershed basis has not been effectively enforced (Adler, 1990).

Michigan's nonpoint source control efforts have been relatively successful compared to the 1990 national assessment of the Section 319 program, although the Michigan nonpoint source program only started in 1990. The state's water quality managers saw the need and importance of the watershed approach to solving water quality problems, an approach which is currently being used in Michigan's Section 319 program. The state's nonpoint source control efforts incorporate both statewide and watershed activities, including incentives for landowners and municipalities, technical assistance, and information/education.

With the Watershed Demonstration Program, Michigan is an exception to the "majority" states that do not adopt a watershed approach to water quality management. Furthermore, Michigan is also an exception to the majority, in that Michigan has strategic plans and water quality goals.

The state has identified its water quality goals. Surface water quality standards are set based on water quality levels needed to support designated uses of the specific waterbody. The state's goal is to have all waterbodies fully support their designated uses. The water quality standards also define parameters and criteria levels necessary to protect the waterbody for it's designated uses. However, it does not necessarily follow that with set strategies and water quality goals, the state is able to effectively implement these strategies and successfully realize its water quality goals.

There are constraints and drawbacks in the implementation of some of the state's agricultural nonpoint source programs. One major constraint is the lack of funding, especially for program staff at all levels. For fiscal years 1990-1995, the 319 program has received through Section 319 of the Clean Water Act a total of $11.5 million, but $9.4 million as of 1994 have already been granted to local government units to support the planning and implementation of 88 watershed projects. Available information on the economic costs of achieving the objectives of the federal Clean Water Act in Michigan is limited. Past expenditures have included over $3.5 billion spent on nearly 1,100 municipal wastewater treatment plant improvement projects since 1972. It has been projected that $900 million more is necessary to meet federal and state requirements for municipal wastewater treatment, and that an additional $1.9 billion would be needed to meet optimal conditions that reflect water quality enhancement, growth capacity and economic development (MDEQ, 1995). Clearly, more funds are needed to support other water quality initiatives and programs. Because monitoring and assessment projects entail considerable government outlays, not all surface waters in the state can be effectively monitored. And, since most of the policies are voluntary, participation in water quality programs are often times low.

Another meaningful approach in evaluating a program is to determine whether program objectives and goals are realized. For example, the primary purposes of the Watershed Demonstration Program are:

1. <u>To address nonpoint source problems on a watershed basis</u>--

The state has developed strategies using the watershed approach. The priority watershed project implementation process starts from the assessment of the nonpoint source problem through monitoring activities, biological, chemical, and physical surveys. As discussed earlier, priority watersheds are identified based on two sets of criteria, the water quality (e.g., violation of water quality standards) and project success criteria (e.g.,landowners' willingness to participate). Proposals for remedial actions are drawn for each of these priority watersheds and these proposals are reviewed for 319 funding.

2. <u>To facilitate inter-agency cooperation in addressing nonpoint source problems to improve water quality in specific watersheds</u>--

One of the strengths of the state's nonpoint source program comes from the importance placed on inter-agency cooperation. Because of the nature of nonpoint source pollution and the extensiveness of the problem, collaborative efforts in the implementation of abatement programs among different agencies and institutions are imperative. It is recognized by the state that solving nonpoint source pollution problems in Michigan requires the implementation of abatement programs through the cooperation of federal, state, and local interests. Thus, coordinating efforts to reduce nonpoint source pollution needs is a priority in the state's nonpoint source pollution management plan. Collaborative work is exchanged among the following Michigan agencies, institutions, and professionals for nonpoint source pollution control: Michigan Department of Agriculture, Michigan Department of Transportation, Natural Resources and Conservation Service, and Water Conservation Districts, Cooperative Extension Service, Farm Service Agency, drain commissioners, universities, watershed councils, environmental councils, local units of government, groundwater specialists, hydrologists, and the staff of the Soil Erosion and Clean Lakes programs.

3. To ensure that limited resources are directed to the highest priority areas--

Michigan's Section 319 Program is the primary source of funding for the state's site-specific (watershed-basis) nonpoint source control efforts. However, the definition of highest priority areas need to be refined and revised so as to be more attuned with obtaining water quality objectives from its program funds at the least cost. The state's selection of priority areas is dependent on landowners' or government officials' willingness to participate in the water quality program, and these areas are not necessarily the ones that have the greatest water quality problem. Furthermore, these areas are not necessarily the areas that will get the most benefit from an improvement in water quality.

A Comparison of Michigan's Nonpoint Source Targeting Program with the Ideal Targeting Model:

To assess Michigan's nonpoint source targeting program, it is useful to compare it with an ideal targeting model. As mentioned in an earlier section, ideally, the decision to target programs at particular regions or enterprise should be based on the following:

1. An articulation of national or state goals for soil and water quality--

The Clean Water Act provides an articulation of national water quality goals. The state of Michigan also identified its water quality goals-- that of attaining all of its surface waters' designated uses.

2. Identification of regions where the benefits from achieving the goals per dollar invested are greatest—

This criteria involves targeting priority watersheds or "macro-level" targeting. While Michigan does have a prioritization strategy, the criteria by which watersheds are targeted appears to be based mainly on the parties' willingness to participate. While this approach minimizes the transaction costs of designing, implementing, and monitoring an agreement, nevertheless, selection of areas on the basis where landowners and government officials are willing to participate may not necessarily be the areas where benefits are maximized per dollar invested to improve water quality.

3. Identification of linkages among farm practices, soil quality, and water quality--

Improved information systems are needed in order to fully understand the linkages among farm practices, soil quality, and water quality. The use of physical models and geographic information systems to facilitate understanding these linkages, thereby enhancing targeting efforts is not yet the norm and should be explored by the state. As it is, only one study has been conducted using GIS for water quality evaluation within Michigan (He, et al. 1993).

4. Identification, within a targeted region, of those enterprises that contribute to the problem as well as their barriers to changing their farming systems—

This identification involves micro-level targeting. As mentioned previously, Michigan's nonpoint source program seems to be less aggressive in trying to identify the root source of the agricultural nonpoint source problems. Identification of farms where nitrogen fertilizer is being "over used" and where there are large livestock operations contributing to water pollution should be carefully done so that proper best management practices can be implemented on these targeted priority farms.

5. Policies and programs designed to control agricultural nonpoint source pollution should be tailored to specific priority areas and priority farms—

Once priority farms are identified, what is also needed is a set of incentives and/or regulations that will induce the farmers/landowners to employ environmentally friendly agricultural practices that will help prevent nutrient runoff. The problem with nonpoint source pollution and nutrient runoff in particular is that normally the onsite costs are lower than off-site costs. The impact of nutrient runoff on surface water quality is greater than its on-farm impacts, and since the water resource (watershed) is a public good, the costs of environmental degradation are not internalized by the farmers who are "polluters". Thus, the tendency is to allow more pollution than is "optimal" even with full information. The problem is usually exacerbated with imperfect information as many farmers do not recognize the magnitude of their own farm's pollution contribution (Batie, 1994).

The State of Michigan should develop the proper incentive schemes designed to influence farmer behavior in identified priority areas to conform with set policies. All the policies and programs designed to alleviate the agricultural nonpoint source program mentioned in the previous section, if implemented on the identified priority areas should make a big impact on the state's targeting efforts.

Cost-Effective Targeting and Control of Agricultural Nonpoint Source Pollution in Michigan Surface Waters:

Michigan's efforts in targeting of priority watersheds as described in the previous section has been ongoing for several years. Refinement in response to future policy initiatives will no doubt be forthcoming. What appears to be lacking in the state's nonpoint source management initiatives is a more aggressive identification of priority farms within priority watersheds--the root source of most of the agricultural nonpoint source problem. Identifying these sources would enable preventive measures to be employed and thereby save on pollution control expenditures.

On the nitrogen runoff problem, a comprehensive assessment of all nonpoint sources prior to implementing a priority watershed project is needed to effectively identify and target pollution sources. There are several factors that make farms major contributors of agricultural pollutants like nitrogen. Farm practices, soil characteristics, topography, and climate are some of these factors. Parsons et al. (1994) identified commercial and manure nitrogen applications, tillage, soil water capacity, and slope to be significant explanatory variables of total nitrogen losses.

Possible criteria for selection of priority farms include:

- use of suspected pollutant (e.g. nitrogen);
- distance to nearest watercourse;
- distance to the impaired water resource;
- application method and timing
- farming practices like tillage and use of conservation measures (i.e. strip cropping, terracing, etc.);
- erosion and runoff rate
- soil type
- slope

These factors that are known or suspected to affect nitrogen runoff and water quality can be entered in a geographic information system for processing and mapping. The intersection of several of these factors would indicate potential problem areas. After the potential priority areas are identified, potential runoff or transport processes could be evaluated using runoff models to determine the contributing flow areas to the receiving waters. Or simpler runoff formulations could be used to determine potential transport to the watershed (He et al., 1993).

GIS and agricultural watershed models are important analytical tools in planning water quality programs. By integrating GIS and watershed models such as the Agricultural Nonpoint Source Model (AGNPS), management agencies can identify critical areas within a watershed and promote the most appropriate agricultural management practices in the targeted areas to control soil erosion and nutrient runoff. Consequently, resources could be used more effectively in reducing agricultural nonpoint source pollution (He et al., 1993).

The collection of data and the development of GISs will greatly increase the ability to implement integrated approaches at the state and local levels. Improvements in data collection, particularly the collection of systematic data on production practices, are needed to implement a systems approach to developing and directing national policy.

Bosch (1995) reported that much work remains to be done to exploit the potential for GIS to assist in socioeconomic research and planning. Social scientists and planners are frequently concerned with how systems adjust over time to policy changes or other exogenous shocks. Yet GISs are not well suited to dealing with time series data that are continually being updated (Harris and Batty, 1993). Given the present state of the art of GIS and the needs of social scientists and planners, several things can be said about future research needs. First, careful thought should be given to the types of data and data processing functions to be included in GIS. Designers must consider more than simply how GIS can make mapping and record keeping more efficient. Designers must consider what likely decisions will be made by users and what types of information will be needed to support such decisions (Bromley and Coulson, 1991).

Despite the difficulties, more aggressive efforts on the part of the state in identifying and prioritizing farms that contribute most to surface runoff of nutrients seems possible. Currently, although the state's efforts in identifying priority watersheds are laudable, micro-targeting (farm-level) efforts appear to be minimal. Some of the programs wait until somebody files a complaint or a report to MDNR before any measure is undertaken to control the discharge.

A more proactive approach is possible. The importance of preventing water pollution, rather than treating problems after they have occurred, is usually the lower cost way to solving water quality problems caused by agricultural runoff. It will be more effective to identify the source and then priority be given to this source in terms of cost-share projects and the implementation of best management practices. According to a Surface Water Quality Division staff (Thad Cleary, 1995), what frequently happens is that the Michigan Department of Agriculture (MDA), accepts complaints/reports on nonpoint source pollution problems (caused by harmful agricultural practices) then reports this situation to MDNR, and only then will the problem be acted on, usually by requesting voluntary BMP implementation. This procedure is basically complaint-driven and reactive and relies solely on someone reporting the situation, otherwise no action will be done to correct the problem.

One of the major issues raised in the Michigan Section 305(b) Report (MDNR, 1994) was the lack of funds for the implementation of the state's agricultural nonpoint source control programs. It is precisely because of limited funds that the state should try to evaluate the effectiveness of the nonpoint source programs being implemented to ensure that the maximum benefit is attained at the least cost. New and cost-effective technologies and programs are needed for addressing Michigan's agricultural nonpoint source pollution problem primarily because water quality problems remain.

Identification of critical areas, prioritization of projects, and targeting these priority areas for Best Management Practices implementation[8] are cost-effective strategies to control the agricultural nonpoint source problem and therefore should be an integral part of the state's comprehensive agricultural nonpoint source control plan if water quality goals are to be achieved at least cost. Cost-effective agricultural nonpoint source pollution management is dependent on the proper identification of watershed areas that should be prioritized and targeted for remedial and preventive actions as well as farms within watersheds. By locating and targeting specific farms within a priority watershed that have high potential for nutrient losses, available federal and state funds (i.e., Section 319 funds) can be used more efficiently to alleviate potential pollution problems and protect water quality. Once priority watersheds and priority farms within these watersheds are identified, Section 319 funds can be targeted to these areas for proper remedial and preventive measures. Doing so will enhance the cost-effectiveness of the Section 319 Nonpoint Source Program. Imposing universal solutions to site-specific problems ("one-size-fits-all") will not only be ineffective in solving the pollution problem, but will also drain federal and state budgets.

Effective nonpoint source management is heavily dependent upon accurate, current land resource information. In Michigan, detailed land use data is being compiled in a computerized geographic information system (GIS) under the Michigan Resource Inventory Program (MIRIS). The overall intent of the program is to gather the best available information about the state's land and water resources, place it in a format that allows many users access to the data, and to provide that data to public and private land resource managers. Base maps and county land use inventories have been entered for the entire state. Modern soil surveys are also being entered into the system,

[8]As used here, BMP implementation can and usually should involve whole farm system planning.

along with other information relevant to nonpoint source management (e.g. location of prime farmlands, unique natural features, inland lake watershed boundaries).

Because the costs of gathering information (record keeping, testings, land uses, weather information, etc.,) to effectively control agricultural nonpoint source pollution are normally high, new technologies like metamodelling and geographic information systems could also facilitate the processing of information (NRC, 1993).

Nutrient Management Plans:

An effective voluntary and yet proactive approach in controlling nitrogen runoff that could be aggressively pursued in line with Michigan's nonpoint source program is the implementation of nutrient management plans. Implementation of the plans can be embedded in the Michigan Right to Farm Act's GAAMPS. The nutrient management plan as proposed under the Coastal Zone Act Reauthorization Amendment (CZARA) of 1990 could be adopted as part of the nonpoint source program.

For nutrient management, farmers are required under proposed CZARA requirements to develop, implement, and periodically update a nutrient management plan to:(1) apply nutrients at rates necessary to achieve realistic crop goals; (2) improve the timing of nutrient application; and (3) use agronomic crop production technology to increase nutrient use efficiency. The nutrient management plans contain the following core components:

(1) Farm and field maps showing acreage, crops, soils, and waterbodies

(2) Realistic yield expectations for the crops grown, based primarily on the producer's actual yield history, State Land Grant University yield expectations for the soil series, or SCS Soils-5 information soil series

(3) A summary of the nutrient resources available to the producer, which at a minimum include:

- Soil tests for pH, phosphorous, nitrogen, and potassium;
- Nutrient analysis of manure, sludge, mortality compost (birds, pigs, etc.);
- Nitrogen contribution to the soil from legumes grown in the rotation (if applicable); and
- Other significant nutrient sources (e.g., irrigation water).

(4) An evaluation of field limitations based on environmental hazards or concerns, such as:

- Sinkholes, shallow soils over fractured bedrock, and soils with high leaching potential;
- Lands near surface water;
- Highly erodible soils; and
- Shallow aquifers.

(5) Use of the limiting nutrient concept to establish the mix of nutrient sources and requirements for the crop based on a realistic yield expectation.

(6) Identification of timing and application methods for nutrients to: provide nutrients at rates necessary to achieve realistic crop yields; reduce losses to the environment; and avoid applications as much as possible to frozen soil and during periods of runoff.

(7) Provisions for the proper calibration and operation of nutrient application equipment.

By implementing nutrient management plans (at the farm-level), cost savings are realized. According to the Coastal Zone Act Reauthorization Amendments (CZARA) report, most of the costs of the nutrient management plan are associated with additional technical assistance to landowners to develop their own nutrient management plans. It was further cited in the report that, in many instances, landowners can actually save money by implementing nutrient management plans. For example, Maryland has estimated (based on over 750 nutrient management plans that were completed prior to September 30, 1990) that if plan recommendations are followed , the landowners will save an average of $23 per acre per year. The average savings may be even higher because most plans were for farms using animal waste. Future savings may be reduced as more farms using commercial fertilizer are included in the program. In another study, assuming a cost of $0.15 per pound of nitrogen, the savings in fertilizer cost due to improved nutrient management on Iowa corn was about $2.25 per acre as rates dropped from 145 pounds per acre in 1985 to about 130 pounds per acre in 1989 and 1990 (CARD, 1991).

Other studies suggest additional costs. In South Dakota , the total cost (1982-1991) for implementing fertilizer management on 46,571 acres was $50,109, or $1.08 per acre (USDA-ASCS, 1991). In a similar project in Minnesota, the average cost for fertilizer management for 1982-1988 was $20.00 per acre (Wall et al., 1989).

Section V

GEOGRAPHIC INFORMATION SYSTEMS AND MODELS AS TOOLS FOR COST-EFFECTIVE TARGETING

Controlling agricultural nonpoint source pollution poses a particular challenge to policy makers because by its nature, nonpoint pollution sources are difficult to pinpoint and eliminate. The discharges from nonpoint sources enter surface waters in a diffuse manner and at intermittent intervals and travel over land before reaching surface waters. The extent of the pollution is affected by uncontrollable events, such as storms as well as geographic and geologic conditions, and may differ greatly from place (e.g., spatially) to place and year to year (e.g., temporally). The impact of a given agricultural activity (i.e., tillage practices, nitrogen application rates, manure management, etc.) varies greatly with the characteristics of the site on which it is applied.

Spatial analysis is increasingly being recognized in dealing with the problem of agricultural nonpoint source pollution to account for site-specific and inter-locational differences among regions (Bosch, 1995). Geographic information systems and programming models are tools that can be tapped to facilitate the identification of these priority areas. The geographic information system gives a description of site characteristics and effectively presents a snapshot of a given area at a particular point in time. The use of geographic information systems is of considerable assistance in saving time and thus cost in data management and presentation. Its capability to process a large volume of data, create maps that pinpoint specific geographic areas of concern (i.e. priority areas) in a timely fashion makes it more efficient than manipulating various data using stand alone database systems, mapping systems, and other mathematical models. The use of geographic information systems also saves substantial resources by minimizing the need for a more detailed on-site inspection of the whole geographical area. According to a study cited in He et al. (1993), time savings for data preparation, processing, and map production was in the order of 50 percent. However, the costs of establishing a GIS to manage land resource data in a large project can be considerable. and careful consideration has to be given to the potential use of the system.

Programming models, can be used to simulate impacts of surface runoff. Various models are already being used for estimating runoff, percolation, sedimentation, soil erosion, etc. (i.e., Agricultural Nonpoint Source (AGNPS) Model and Expert Systems are some of the tools that are being used for this purpose). These models will be reviewed in succeeding sections

An Overview of Geographic Information Systems:

Geographic Information Systems have the potential to greatly increase the usefulness of existing data in the analysis of agricultural nonpoint source pollution. GISs are designed to collect, manage, analyze and display data spatially; they can be used in combination with other models as a way to enhance targeting, planning, and directing programs.

A geographic information system is a computerized information management system where data entries are tied to specific geographical locations, identified by latitude and longitude. It is designed to facilitate working with data that are ordered spatially. Theoretically, any data with a spatial dimension can be incorporated into a GIS. Obvious examples include physical land characteristics such as soils, topography, and underlying geology; land use characteristics such as industrial land, residential land, cropland and forest land; and the location of specific markers such as roads, rivers, historical sites, and political boundaries. These data are entered in one of three forms: (1) point data for characteristics keyed to a specific point such as the site data of a drinking-water well; (2) linear data for characteristics with a linear dimension such as rivers; and (3) area data for characteristics with two dimensions such as land use. The level of resolution, or the size of a discernible area, depends upon how the data were collected. For example, some satellite-generated data may have a minimum resolution size of about 30 square meters, so that anything smaller than 30 square meters is not discernible. For other data sources, the resolution may be 20 to 30 feet, about the size of a road.

The data in a GIS system can be viewed as a computerized version of the data normally presented on a map. These computerized versions have several advantages over the use of paper maps. First, by geo-referencing the data, the data from different sources can be combined in a consistent manner and used for calculations. If observations in two different data sets are both tied to specific geographic locations, the observations, can be matched to generate a single, larger data set. For example, soils data collected by the National Resources Conservation Service can be combined with land-use data from the U.S. Geological Survey (USGS) to provide a richer data set for site characteristics. From such a data set, information about the joint distribution of site characteristics can be determined.

Second, unlike paper maps, use of the GIS creates digitized maps that can be easily overlaid. Thus, the geographical locations having a combination of several characteristics can be easily determined. This combination is equivalent to finding the intersection of several sets comprising the locations with the individual characteristics. For example, if the GIS contains data on soil types, depth to groundwater, and land use, then the three maps can be combined to produce a map of sites that have any combination of these characteristics.

Third, given that the data are digitized, they are readily available for performing a variety of calculations. For example, the computerized system could be used to calculate acreage in various land uses or the acreage of the intersection between various land uses and characteristics associated with susceptibility to groundwater contamination and/or nitrogen runoff (Opaluch and Segerson, 1991).

Agricultural Nonpoint Source Pollution Models:

Research and modeling efforts involving nonpoint source pollution have been concerned primarily with soil erosion. More recently, research has broadened its scope to include the movement of pesticides and nutrients in addition to soil movement. Most of the models developed are lumped parameter models such as the Universal Soil Loss Equation (USLE)[9]; however, distributed parameter models have become more prevalent in recent years. A lumped parameter approach uses some type of averaging technique to approximate characteristics of each parameter needed for computation in the model.

---

[9]The USLE (Wischmeier and Smith, 1978) estimates annual sheet and rill erosion, as affected by six factors: rainfall erosivity, soil erodibility, slope length, slope steepness, cover and management, and conservation practices. Values for each factors are determined by averaging or lumping factor values within the area for which an erosion estimate is desired (Engel et al.,1993). The USLE equation is: $A = RKLSCP$

where A= average soil loss for the time interval represented by factor $R[ML^{2}T^{-1}]$,

R = combined erosivity of rainfall and runoff $[FT^{-2}]$,

K = soil erodibility factor $[MTL^{-2}F^{-1}]$,

L = slope length factor,

S = slope steepness factor,

C = cover management factor,

P = supporting practices factor

The Agricultural Nonpoint Source Model (AGNPS):

Distributed parameter watershed models such as the Agricultural Nonpoint Source (AGNPS) are able to incorporate the influences of the spatially variable controlling parameters (e.g., topography, soils, land use, etc.) in a manner internal to computational algorithms. AGNPS is a single storm-event based model developed by Young et al. (1989). It simulates runoff, sediment, and nutrient yields in surface runoff from primarily agricultural watersheds. The model operates on a cell basis. It can be used to examine the runoff estimates from individual cells, problem areas within the watershed can be identified. Consequently, impacts of upstream agricultural practices on downstream water quality can be evaluated and BMPs can be selected to minimize agricultural nonpoint source pollution.

AGNPS creates tabular and spatial outputs (not georeferenced). It provides estimates of runoff volume (inches), sediment yield (tons), sediment generated within each cell (tons), mass of sediment attached and soluble nitrogen in runoff (lbs/acre), mass of sediment attached and soluble phosphorous in runoff (lbs./acre), and oxygen demand (lbs/acre). These results can be used by decision makers to prioritize the entire watershed for implementation of remedial measures to control runoff. Output from this model can be geo-referenced by incorporating it to a geographic information system. By overlaying data on, say volume of runoff with other existing farm data on vegetative cover, crops produced, amount and timing of nitrogen application, weather variables, etc., one can identify priority areas in terms of susceptibility to environmental degradation.

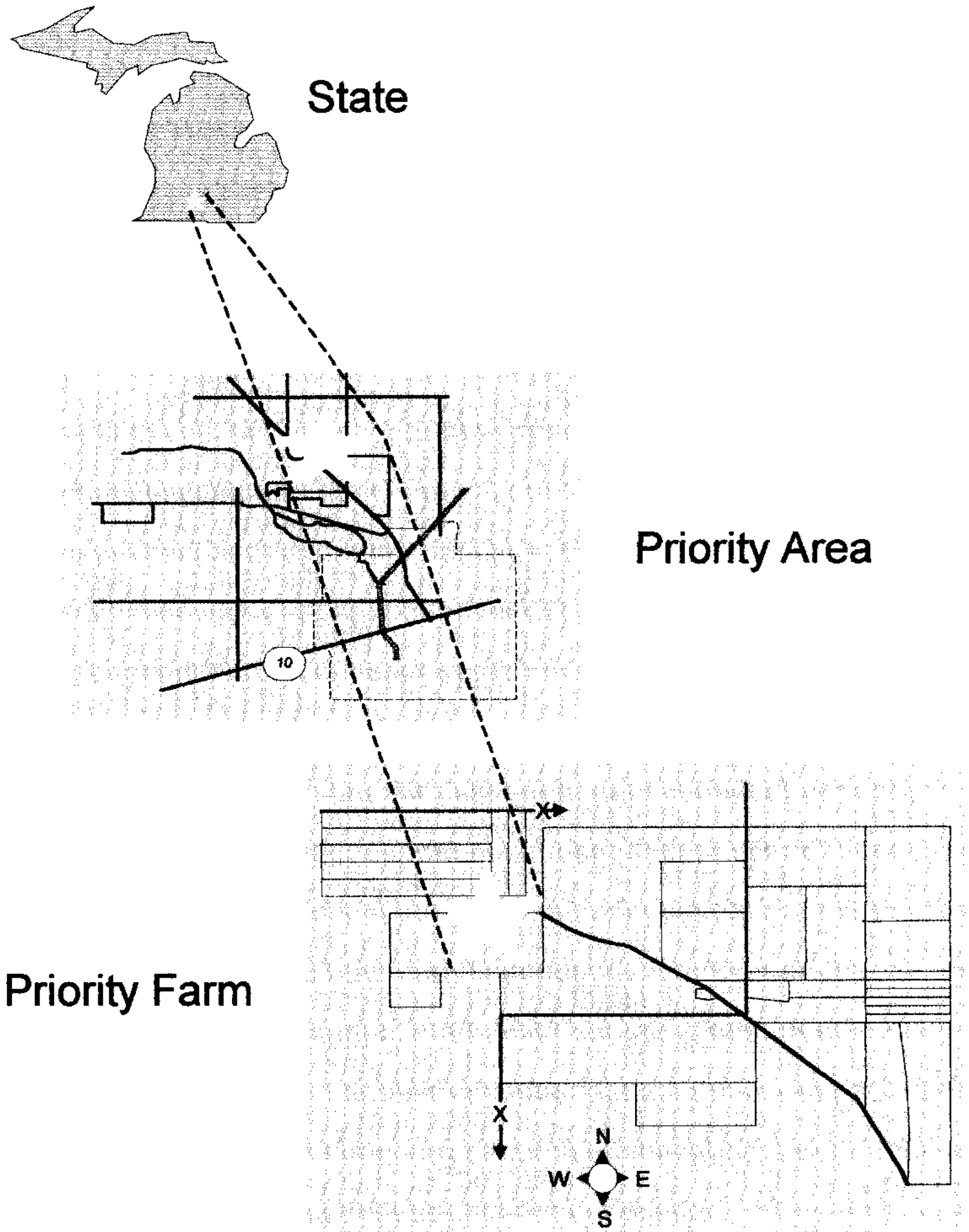
Expert Systems:

A rule-based expert system may be used to obtain information from the decision maker about the problem and determine what data are required from the GIS. For example, Wright used an expert system as part of a spatial decision support system to assist the Army Corp of Engineers in locating training sites. The Corp's objectives were assumed to be minimizing the cost of acquiring and developing sites and minimizing disruption to the natural environment. The expert system queries the user as to the land attributes affecting site development cost and potential for environmental damage and the ratings and weights to be given to each factor. For example, the user might identify land slope as a particularly important factor affecting environmental damage. Ratings might be given to various slope categories and a weight given to slope to determine its relative importance in environmental damage from a specified activity. The expert system writes a program that determines what data layers are required from the GIS and assigns appropriate weights to cells in the layers based on their attribute values (Wright, 1990). Multi-objective integer programming is used to determine the location and size of training sites and the environmental damage and economic cost of training activities.

Using Geographic Information Systems to Identify Priority Areas:

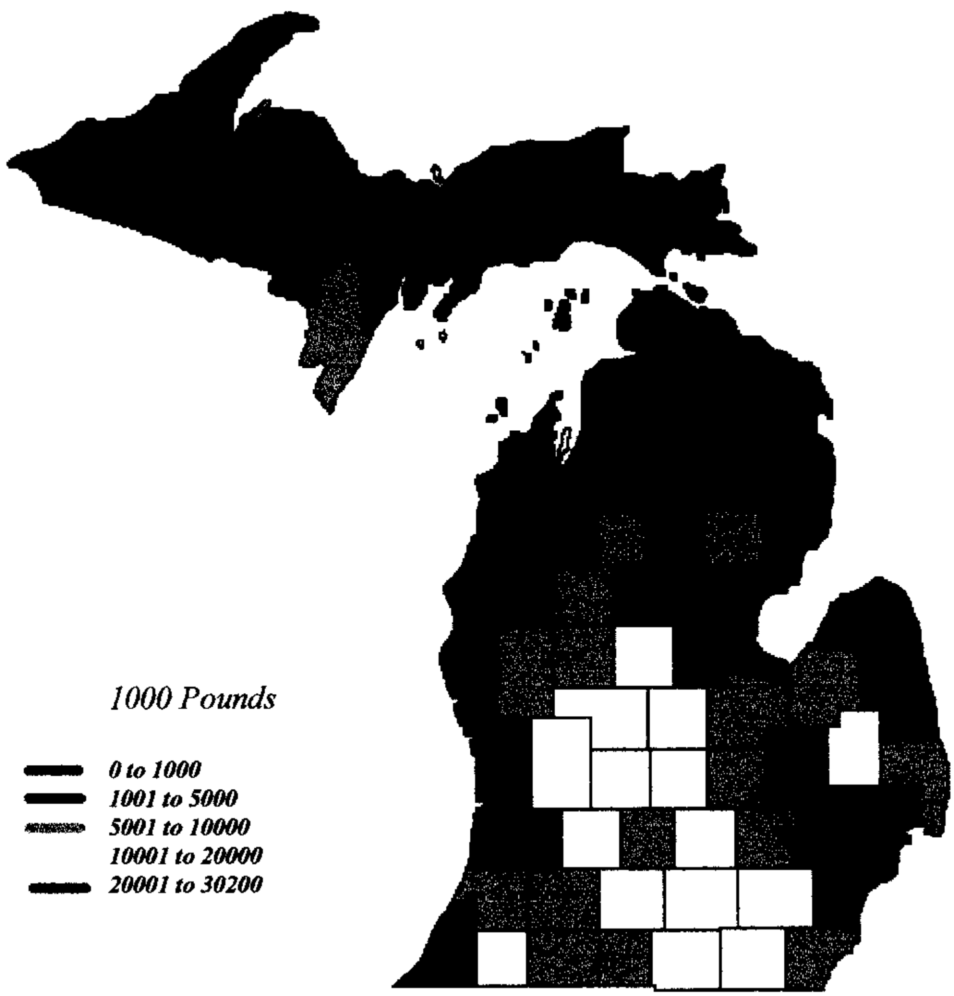
Federal and state agencies are increasingly recognizing the potential of GIS for both information presentation and policy analysis. Geographic information systems and the AGNPS model as demonstrated in past studies (refer to Appendix B) are effective tools in identifying critical areas or priority areas. At the national level, using the STATSGO (soil series maps), slope maps, land uses, and weather data, high risk areas in terms of nitrogen runoff can be identified. Resources for the Future researchers have conducted such an analysis and were able to identify which states have problems in surface runoff (Gianessi et al., 1986). Federal funds can be targeted towards those states that have the most severe water quality problems. At the state level, similar analysis can be conducted. Figure 5 provides an illustration of how targeting for nonpoint source prevention is done from the state level priority regions (macro-level targeting) to priority watersheds and then down to micro-level targeting at priority farms. Figure 6 and 7 (combined) on the other hand illustrate a

Figure 5. Selecting Priority Areas and Priority Farms for Nonpoint Source Pollution Prevention



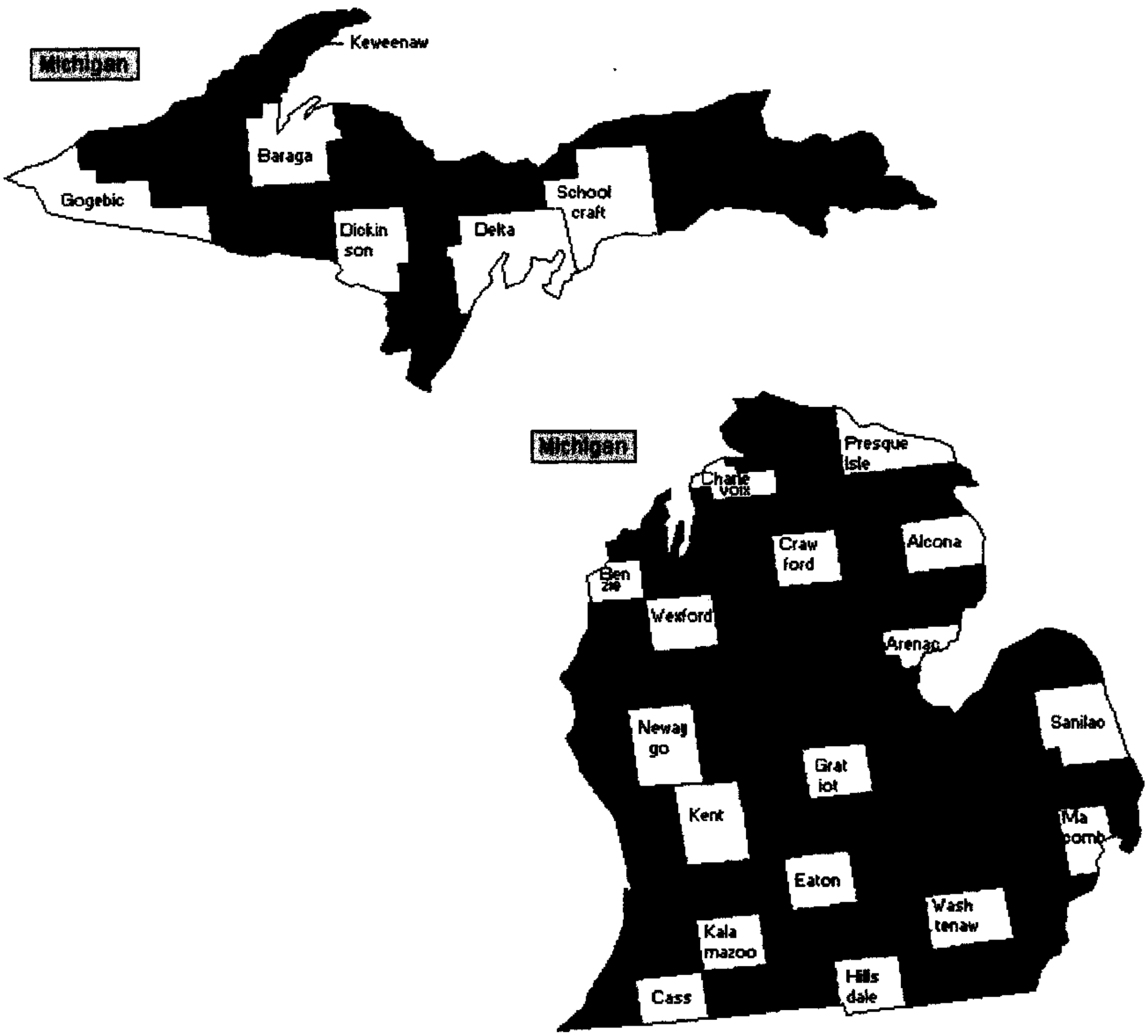
Source: Michigan Department of Environmental Quality, 1995.

Figure 6. Total Animal Manure Produced in Michigan (1992)



Source: Day, Esther. 1995. The Distributional Impacts on Michigan Counties of Alternative Targeted Federal Green Support Programs. Department of Agricultural Economics. Michigan State University.

Figure 7. Michigan Counties



Source: Day, Esther. 1995. The Distributional Impacts on Michigan Counties of Alternative Targeted Federal Green Support Programs. Department of Agricultural Economics. Michigan State University.

targeting scheme based on a specific problem like nitrogen runoff. The Michigan counties--Huron, Sanilac, and Ottawa--have been identified through GIS analysis as areas with severe nitrogen problems specifically due to high volumes of manure from livestock operations.

A detailed land use data is being compiled in a computerized geographic information system (GIS) under the Michigan Resource Inventory Program (MIRIS). The overall intent of the program is to gather the best available information about the state's land and water resources, place it in a format that allows many users access to the data, and to provide that data to public and private land resource managers. Base maps and county land use inventories have been entered for the entire state. Modern soil surveys are also being entered into the system, along with other information relevant to nonpoint source management (e.g., location of prime farmlands, unique natural features, inland lake watershed boundaries). This information can be downloaded to personal computers for use by local agencies.

The basic data sets required for the AGNPS model includes: land use/cover, digital elevation model, water features (lakes, rivers, and drains), soils, and watershed boundary. Land use/land cover data can be obtained from the Michigan Resource Information System database, although this was last updated in 1979. Water resource features as well as watershed boundaries can also be obtained from the MIRIS data. Data on topography can be generated from a digital elevation model (DEM), originally from the U.S. Defense Mapping Agency through the USGS. Soils data, can be obtained from the USDA, National Resources Conservation Service's STATSGO database and county soil surveys. These data sets can be used to determine dominant texture, dominant hydrologic group, and weighted soil erodibility values--necessary for the AGNPS model. Once all these data layers are converted into a single GIS format and overlaid, priority areas can be pinpointed and targeted based on environmental criteria.

Data Availability and Requirements:

The U.S. Geological Services has several data sets/maps digitized. In many cases, coverage is not comprehensive, but is instead limited to isolated locations or regions. The USGS has, however, compiled digital data on land use/land cover and hydrological units for most of the United States. The mapping system units used for these data have a minimum size of 10 to 40 acres, depending upon the land-use category. Unfortunately, however, the current maps are based on 1972 data and there are no plans to update them systematically. In addition, the categories within "agricultural land" are defined broadly as cropland and pasture land; orchards, groves, etc.; confined feeding operations; and other agricultural land. Thus, the crop-specific information necessary to link farming practices with physical characteristics at a given site is not available in these data sets.

The National Resources Conservation Service (NRCS) also has an extensive GIS effort underway. For example, detailed information from soil surveys has been aggregated across sites and the aggregates are being digitized for most of the United States in the STATSGO data set. Recognizing the value of small-scale maps for regional and national analysis, NRCS has undertaken a national program to produce the STATSGO database. STATSGO data will be useful for many types of regional, statewide, and national studies The USGS is cooperating with NRCS to investigate how the data can be used in a GIS and to explore potential mechanisms for archiving and distributing the data. However, the detailed data, which might be more useful than the aggregates for linking production decisions and groundwater quality with soil characteristics, have been digitized for only about 1 percent of the country.

NRCS also conducts the National Resources Inventory (NRI) survey every five years, which collects site-specific data regarding land use and other characteristics. The NRI provides information on condition of the nation's soil, water, and related natural resources, and is considered as one of the most important sources of information for soil and water conservation services. Examples of data collected include, land cover, land use, soil characteristics and interpretations, erosion data, land treatment, conservation treatment needs, vegetative conditions and the potential for conversion to wetlands. While the data collected for each site have been digitized, the site locations have not yet been geo-referenced, they will provide a potentially useful data source for the joint distribution of site characteristics (Opaluch and Segerson, 1991).

Due to data limitations, policy analysts have not been able to take full advantage of the available technology. However, the up-front costs of data collection and conversion can be allocated over multiple applications. Because of the potential for economies of scale in the use of GIS data sets, the more technology is used, the more it is likely to be extended, making it even more useful for other applications. Thus, one may expect accelerating progress in these data-collection efforts, given a critical mass of applications.

Section VI

SUMMARY AND CONCLUSIONS

Michigan is blessed with valuable water resources that are beset with water quality problems. Most of the state's rivers and lakes are not supporting their designated uses because of agricultural nonpoint source pollution. For example, 69% of Michigan lakes assessed were considered to be threatened for their overall designated uses. This paper looked at the problem of nitrogen runoff , one of the leading causes of eutrophication of surface waters. Nitrogen runoff to surface waters is usually caused by over application of nitrogen fertilizer in the field and improper manure management in livestock operations. The problem of nitrogen runoff however is not universal to all farms. In the same manner, not all surface waters are impacted by nutrient pollutants. It is important that only those areas that have considerable contributions to the water quality problems be singled out for proper actions (e.g., best management practices) if programs are to be low-cost. Moreover, because of shrinking federal and state budgets macro-level and micro-level targeting should be the primary cost-effective strategy employed to manage agricultural nonpoint source pollution problems.

Targeting involves prioritizing watersheds (macro-level) and farms within the watersheds (micro-level) in terms of funding for remedial and preventive measures. Targeting is a cost-effective strategy to control agricultural nonpoint source pollution, unless the transaction costs necessary for targeting outweigh the revenues from more accurate identification of the location of problem areas. Targeting can obtain the greatest maximum benefit that can be achieved per dollar spent. Identification of priority areas to be targeted for preventive and remedial actions of on-site and off-site costs (damages/ severity of the water quality problem when compared to water quality standards) involves evaluation of the severity of the water quality problem as well the benefits that can be derived from an improvement in water quality. Benefits of an improvement in water quality can be measured by an increase in aesthetic value of the water resource, increase in recreational activities like sport fishing and swimming, and an improvement in drinking water conditions.

Empirical studies (as presented in Appendix A and throughout the paper) support the hypothesis of this study--that targeting is cost-effective. Ribaudo (1989) and McGregor (1991) discussed targeting schemes that given a more complete information on costs and benefits could be used by environmental and watershed managers in terms of successfully identifying priority areas.

Fortunately, with advancement in technology, identification of priority areas can be done using physical models that simulate surface runoff and using geographic information systems to facilitate data processing. The use of these models should be tapped to facilitate identification of priority areas. With the proper selection criteria taking into consideration inter-relationships between farm practices, soil and water characteristics, and surface runoff, a more refined identification process can be achieved.

However, the lack of systematic data on production practices, land and water resource information is a particularly serious obstacle to targeting, monitoring, and designing water quality programs. When such information is available, it is often not geographically based or linked to physical information about soil and water quality degradation (NRC, 1993). The lack of linkage between relevant natural resource data, production practices, and socioeconomic data, limits the ability to realize improved targeting and program direction.

If the state of Michigan can invest further in setting up geographic information systems and developing technical skills to evaluate what types of data are needed to facilitate the use of geographic information systems, much improvement in targeting will be achieved. There are some GIS projects already underway in some areas in Michigan. The Michigan Information Resource

System (MIRIS) is a good start in terms of providing data for use in geographic information systems. Targeting on the basis of technical measures of soil erosion alone , such as tons of soil loss per hectare could be readily implemented by the state via geographic information systems. Furthermore, gaining from conclusions in the study by Mapp, et al. (1994)—it could be more effective to target nitrogen restrictions on production systems than on soil types. These kinds of data that either exist already or are relatively easy to gather should go into geographic information systems now, as a first "cut" for macro/micro targeting.

An "ideal" targeting framework was presented. This ideal targeting framework requires :1) an articulation of national or state goals for water quality; 2) identification of regions where the benefits from achieving the goals per dollar invested are greatest (macro-targeting); 3) identification of the linkages among farm practices, soil quality, and water quality; 4) identification within a targeted region, of those enterprises that contribute to the problem as well as their barriers changing their farming systems; and 5) policies and programs designed to control agricultural nonpoint source pollution should be tailored to specific priority areas and priority farms.

A review of the agricultural nonpoint source policies and management programs of the state of Michigan was presented and assessed by comparing the state's targeting program to that of the ideal model. While all actual situations will fail in comparison to an "ideal", the "ideal" model should provide guidance for improvement in the cost-effectiveness of nonpoint pollution policies. In the evaluation of the state of Michigan's nonpoint source program, it was concluded that the state would benefit from more aggressive efforts in micro-targeting. While the state had strategies and criteria on identifying priority watersheds, the criteria being used is mainly dependent on willingness of landowners' and government officials to participate in the water quality projects. Willingness to participate and being worthy of limited program funds are two separate things. Priority in terms of remedial and preventive actions should be given to those areas that contribute most to the problem and will have the greatest benefit from a dollar spent on water quality improvement.

In conclusion, it is worthy to note that Michigan has been consistently ranked high in terms of its institutional capability to carry out environmental programs and water quality programs in particular. Inter-agency cooperation among the various units involved in agricultural nonpoint source pollution control programs has been identified as one of the strengths of the Watershed Demonstration Program. The state should capitalize on this strength but needs to redefine targeting strategies in order to increase the cost-effectiveness of their nonpoint source pollution programs. There is also a need for evaluating all nonpoint source programs and policies and bring them under one coordinated program. As it is, programs and policies at the state and federal level do not quite fit into one coordinated umbrella program where funds can be allocated to areas where the problems are more pressing. Appendix C presents further recommendations for improvement of Section 319 programs.

The question then is how onsite and offsite impacts can be measured, linked to land use practices and on-site and off-site remediation options, and mitigated in a cost-effective manner. More importantly, how is it possible to increase the cost-effectiveness of Michigan's Section 319 program through targeting for nitrogen pollution? The onsite damages primarily impacts soil productivity. Ideally, factors that affect soil productivity like farm practices and soil characteristics must be studied in order to refine the criteria to be used in selecting farms to be targeted. On the other hand, offsite damages are manifested in the deterioration of the valued services of the water resource, specifically, the agricultural watersheds that are drained by surface waters. Water quality standards for nitrogen need to be established in order to determine which watersheds need immediate attention for nitrogen pollution control. Aside from these costs considerations, the benefits from pollution prevention must also be assessed. Water uses must be determined and valued, because without the demand for improved water quality, there are no economic impacts.

APPENDICES

APPENDIX A

A Literature Review on Targeting

Interest in targeting began as a way of increasing cost-effectiveness of federal soil erosion control programs. Early targeting efforts involved: (1) a shift from single-field, production-oriented plans to whole-farm, conservation-oriented plans; (2) an effort to identify critical watersheds where erosion control would be most cost-effective; and (3) a policy in selected counties of offering higher rates of cost share for practices on fields where greater amounts of erosion reduction are likely to be obtained from the practice (Park and Sawyer, 1985).

There is empirical evidence to support the cost-effectiveness of targeting (NRC, 1993). In a case study of a highly erodible watershed, Park and Sawyer (1985) found that per ton costs of erosion reduction were 34 percent lower than the national average implying greater cost-effectiveness from targeting more highly erodible regions. They also reported that cost-effectiveness of erosion control can be substantially increased by offering more cost sharing for sites and practices with higher potential for erosion reduction. In another study, Setia and Magleby (1987) found that targeting conservation tillage practices to the 4,452 ha (11,000 acres) that cause the most damage within the targeted watershed could reduce the cost of improving water quality from $139,000 to between $9,000 to $32,000 for each percentage point reduction in the amount of sediments. And, targeting the farms that contribute the largest nutrient loadings in the watershed could reduce cost of improving water quality from $151,000 to between $11,000 and $43,000 for each percentage point reduction in nutrient loads. In a similar study, Lee and colleagues (1985) found that directing improvement efforts to critical areas within a targeted watershed could reduce costs of improving water quality 5- to 10-fold.

Finally, as reported by Nielson (1986) in an analysis of the entire targeting effort completed by the Agricultural Research Service and the Economic Research Service Center in 1985, targeting was deemed imperative, and it was recommended that USDA should concentrate its efforts on priority farms. The study indicated that progress had been made in targeting objectives, that targeting was cost-effective, and that targeting improved efficiency in the use of federal conservation resources. In the four states studied for the analysis, the percentage of land in targeted areas that was eroding at rates greater than 2T (soil loss tolerance) and receiving conservation technical assistance was 51 percent in Alabama, 76 percent in Missouri, 39 percent in Tennessee, and 53 percent in Washington. All of these percentages represented substantial increases in efficiency in the use of funds over pre-targeting figures. The report further reiterated that targeting improved information and education programs. That is, farmers became more aware of the consequences of erosion and were more inclined to do something about it. Two-thirds of those surveyed said farmers in their counties were more concerned about erosion than before the county was targeted. In fact, USDA surveys indicated that, nationwide, use of conservation tillage has increased 10 per cent per year.

Most of the earlier studies that implemented targeting schemes focused on soil productivity as the criterion for targeting. Runge, Larson, and Roloff (1986) compared soil loss tolerance (T) values with a quantitative soil vulnerability measure as a basis for conservation set-asides in six major land use areas of the Upper Midwest. They proposed using the soil vulnerability criterion as the basis for targeting. Soil vulnerability was calculated from soil profile characteristics and the suitability of the soil to root growth under simulated erosion conditions. Because soil vulnerability was based on measured soil characteristics, it was quantitatively related to productivity losses and, therefore, less subjective than the usual T values. They reported that soil vulnerability was a more sensitive criterion to productivity losses from erosion than T values. The results suggested that substantially less area could be shifted from row crops to forage if targeting policies for soil and water conservation were based on soil vulnerability to productivity losses rather than the customary T value.

In a more recent study, Mapp et al. (1994) developed and applied an analytical framework to evaluate the potential economic and environmental effects of broad versus targeted nitrogen use policies in five unique regions within the Central High Plains. The broad policies analyzed included restrictions on the total quantity of nitrogen that can be applied and restrictions on per-acre nitrogen applications. Targeted policies included restricting nitrogen use on course soils likely to produce nitrate losses in percolation and restricting nitrogen use on crops produced under furrow irrigation. The policies were analyzed in terms of their impacts on cropping patterns, income, and the complete distribution of potential nitrate losses in runoff and percolation. They concluded that the targeted policies' effectiveness depends on the distribution of the soils within a subregion and on the current allocation of cropping systems across soil types. Because of the distribution of soils within subregions, targeting nitrogen reductions to more permeable soils may not produce the anticipated reductions in percolation. They concluded that it may be more effective to target nitrogen restrictions on production systems than on soil types.

Soil diversity and the lack of predominance of highly erodible soils and in many fields limits the efficiency with which targeted soil conservation programs can be implemented. Although significant economic gains can be achieved by targeting erosion control programs to highly erodible soils, the diverse nature of soils still can cause significant constraints in treating each soil with the most cost-effective treatment. For regions having more homogenous distributions of soils, the prescribed cost-effective treatment may be implemented with a higher level of efficiency. However, for areas with diverse soils occurring within cropland fields, some significant implementation inefficiencies can be anticipated (Padgitt, 1989). Regional/aggregate level studies have shown that targeting on the basis of on-site criteria alone can result in serious misallocation of erosion mitigation funds when off-site damages are significant (Ervin and Blase 1986; Gianessi et al 1986; Ribaudo 1986, 1989).

Interest in targeting has expanded to considering the off-site benefits of reduction in agricultural pollution. Ribaudo (1986, 1989) using available data, demonstrated that ignoring the offsite effects of erosion resulted in a misallocation of resources. The allocation of program funds based on estimates of off-site damages from erosion as well as on-site erosion rates resulted in a much different regional allocation of soil erosion control efforts than when only on-site erosion was considered. MacGregor et al. (1991), on the other hand, developed an operational model for targeting erosion remediation on the basis of partial off-site damage assessments. The conclusion of the study indicated that targeting on the basis of technical measures of soil erosion alone, such as tons of soil loss per hectare, while they may result in substantial improvements in off-site environmental quality, may still be economically suboptimal. Fields with relatively low erosion rates may be important to treat simply because of their proximity to watercourses and impoundments that support highly valued uses.

Targeting Schemes:

In this section, examples of two methods of targeting analysis will be presented. These studies exemplify the proper framework for the implementation of a targeting scheme using economic criteria.

<u>The Ribaudo Study (1989):</u>

The goal of this study was to demonstrate how economic efficiency of a program might be increased. The Conservation Reserve Program was used for the targeting analysis. The targeting objective was to identify 22 million acres that can be enrolled in the Conservation Reserve Program. There were several criteria mentioned available for targeting acres to be enrolled in the CRP to address water quality issues. One possible approach mentioned was the use of a physical measure of water quality (such as dissolved oxygen levels or other water quality parameters) to identify regions where water quality is unacceptable. The CRP could be directed to these regions with the expectation that improvements in water quality will be generated. A drawback of this approach, from an economic standpoint, is water quality improvements may occur in areas where there is little demand for such improvements because of a lack of in stream and off stream water users. If water quality benefits are to be maximized , the demand for water quality must also be considered when identifying critical areas.

Three Scenarios used:

Three different scenarios were used in the analysis. These include the water quality scenario, damage per ton scenario, and the damage per acre scenario.

I. *Water Quality Scenario*-- assumes that the marginal impact of soil conservation on water quality differs between regions. Average concentrations of the agricultural pollutants' TSS (Total Suspended Solids), TKN (Total Kjeldahl Nitrogen) , and TP (Total Phosphorous) where used to identify regions where targeting the CRP would do the most to improve water quality. Data can be obtained from the USGS- National Stream Quality Monitoring Network (NASQUAN). Aggregated Sub-Areas (ASA's) are hydrologic units, generally the basins of major rivers, for which pollution delivery data exist and which are relevant for studying water quality issues. The drawback of only using NASQUAN data is that no monitoring stations are located on lakes, which are important recreational resources (however, there is really no consistent national database for lake water quality, and steps were taken to try to account for lake quality within the targeting scheme). Water quality standards were-- .9 mg/liter for TKN, 90 mg/liter for TSS and .1 mg/liter for TP. These water quality standards are based on the concentrations where adverse impacts on the aquatic environment can be expected in streams (Ribaudo, 1989). Aggregated Sub-Areas' in "violation" of the standard were identified. The concentrations of TKN, TP, and TSS are functions of the amounts of material discharged into waterways. Agriculture is only one source of these materials. Nitrogen and phosphorous can originate from point sources, such as sewage treatment plants.

The likelihood that reducing agriculture's share of pollutant discharge will actually improve water quality depends on its share of the total discharge load. If the majority of discharged material comes from sources other than agriculture, then controlling agricultural sources will probably not make a significant impact on water quality. A simple way of identifying regions where a reduction in agricultural pollution is likely to result in noticeable water quality improvements is to compare the percentage share of pollutant loading from agriculture and the percentage reduction in concentrations required to meet water quality goals. If agriculture's share of loadings is greater than the percentage reduction required, then improvements in water quality are likely.

II. *Damage Per Ton Scenario* (DT): Targeting regions for CRP enrollment on the basis of water quality improvements assumes that the marginal economic benefits from water quality improvements are the same among watersheds. However, there is no reason to expect that this is the case. Agricultural regions with poor water quality may be relatively unpopulated, having little potential demand for the instream and off-stream services of water. Even though water quality improvements from controlling agricultural runoff may be significant, the economic benefits are small. If the goal of agricultural pollution control is to maximize economic benefits, then targeting should take into account potential benefits. The damages per ton approach uses damages per ton of erosion as a proxy for potential benefits. Estimates of off-site damages from soil erosion were available at the Farm Production Region level. Differences in estimates of damages per ton of erosion reflect varying levels of demand for water quality, and demonstrate the error of assuming that soil erosion causes the same damages everywhere.

III. *Damage Per Acre Scenario* (DA): The damage per ton scenario implicitly assumes that removing an acre of cropland will generate the same level of erosion reduction regardless of the region. However, sheet and rill erosion varies widely between regions, due mainly to differences in topography, climate, and soil type. Benefits from removing an acre of cropland from production will therefore also differ, even if the damages per ton are the same. The region with the greatest per acre erosion reductions would generate the greatest benefits, given identical DT. Targeting on the basis of damages per acre of cropland would account for differences in demand for water quality. The off-site water quality damages from erosion on cropland were estimated from each Farm Production Region by multiplying offsite water quality damages from all sources of erosion by the percentage of erosion originating on cropland, as determined from the National Resource Inventory data (USDA, 1984). Cropland damages were then divided by total crop acreage. Differences reflect varying levels of demand for water quality and erodibility of cropland.

Benefit Estimation:

The economic benefits from the reduction in the discharge of pollutants to waterways were estimated for 9 impact categories: recreational fishing; navigation; water storage; irrigation ditches; roadside ditches; water treatment; municipal and industrial water use; steam cooling; and flooding. Benefits were defined in terms of changes in defensive expenditures, changes in production costs, or changes in consumer surplus, depending on the damage category and the data available (see

Ribaudo, 1989 for more details).

The reductions in the discharge of sediment, nitrogen, and phosphorous were estimated from each Aggregated Sub-Area (ASA). Reductions in sediment discharge to waterways were calculated by applying cropland sediment delivery ratios that were estimated for each Aggregated Sub-Area by Resources for the Future researchers to the erosion reductions expected from the CRP (Gianessi, Peskin, and Puffer, 1985).

When damage estimates are not available, proxies such as recreation visits, tons of sediment dredged, and gallons of drinking water withdrawn could be used.

The MacGregor et al. Study (1991):

MacGregor et al. (1991) measured the response of offsite receptors to environmental damage and evaluated marginal response by using offsite use values generated in other studies. Because recreation was the highest-valued category of offsite losses due to agricultural pollution in reports by Clark and associates (1985), the preliminary test of the modeling approach was to explain in recreational activity (boating, fishing, or swimming participation) due to sedimentation in 46 state park lakes in Ohio for which visitation data were available. They chose recreational boating for the initial analysis because of the conviction that it would provide the earliest indication of offsite damage. This choice was because sedimentation begins to interfere with small boat navigation and access before biochemical interactions--increases in nutrient, pesticide, or herbicide loadings are reflected in major damage to fishing or swimming qualities. The model they developed explained annual boater participation by using the following explanatory variables: surface water area of the lake in hectares, average depth in meters of the lake at normal pool--proxy for sedimentation; a dummy variable that differentiates between lakes that have both fuel and docking facilities, and aggregate area of all public recreational lakes within 40 kilometers of the target lake and with at least 75 percent of the surface area of that lake. All the four explanatory variables were significant at the .05 probability level or above.

To estimate the value of lost boater participation, a recreational visitor-day value was taken from a U.S. Forest Service study that estimated the value of recreational boating in the region, which includes Ohio, to be approximately $20.00 per recreational visitor in 1984. On the basis of the boater-response model, the total estimated annual loss of boater value for all of the 46 state park lakes studied exceeded $564,000, $331,200 of which was due to agricultural sedimentation.

The dredging cost estimates were derived from full cost accounting of all costs related to dredging, including operations costs, repair and maintenance, and administrative costs. These values were then compared to the measures of boater values lost to determine if dredging was justified on the basis of boater value losses alone. Conceptually, the offsite user response model used was intended to identify linkage between technical measure of damage (i.e., sediment flows, declines in lake depths, and phosphorous and nitrogen loadings) and observable changes in offsite use levels.

APPENDIX B

GIS Applications: Previous Empirical Studies

Some examples from economic literature can demonstrate how GIS and modeling can be used to advance policies' targeting capabilities. Prato et al.(1989) evaluated impacts of various constraints for farms in an Idaho watershed. A GIS was used to assemble and process data including farm boundaries and soil characteristics. The Universal Soil Loss Equation (USLE; Wischmeier and Smith, 1978) was used to estimate soil loss potential by soil characteristics and farming practices. The GIS was used to apply the soil loss calculations to all sites in the watershed. Annualized economic returns were then calculated based on a 20-year planning for each soil and farm practice combination. A linear programming model was used to estimate optimal combinations of practices and farm net return with alternative erosion constraints. The Agricultural Nonpoint Source Pollution (AGNPS) model (Young et al., 1989) was used to evaluate effects of alternative erosion levels on water quality at the outlet of the watershed.

Carpentier (1996) evaluated relationships between costs of reducing nonpoint source pollution and farm characteristics. Farm survey data provided economic and physical characteristics of randomly sampled farms in the Lower Susquehanna watershed in Pennsylvania and Maryland. A GIS was used to estimate flowpath characteristics between each farm and nearest waterbody. Potential to deliver sediment and nutrients to nearby surface water was estimated based on characteristics of the flowpath between the farm and surface water. A farm programming model maximized the net returns subject to constraints on potential runoff and leaching of nitrogen as well as other farm resource limitations. Shadow prices of nitrogen delivery and runoff constraints were used as estimates of farm marginal costs of reducing nitrogen pollution. Estimated shadow prices were entered in a GIS and used to generate maps showing the distribution of farm costs of reducing nitrogen runoff.

Xu, Prato, and Fulcher (1993) developed a watershed model to evaluate broiler litter application practices on cropland. A GIS was used to prepare land cover data relative to potential crop utilization of poultry litter. Litter was found to be an economical alternative to commercial fertilizer after accounting for spreading and handling costs.

He, Riggs, and Kang (1993) integrated the Agricultural Nonpoint Source Pollution Model (AGNPS), the Geographic Resource Analysis Support System (GRASS), a GIS and GRASS WATERWORKS (a hydrologic modeling tool box being developed at Michigan State University for Remote Sensing) to evaluate the impact of agricultural runoff on water quality in the Cass River, a subwatershed of Saginaw Bay. AGNPS was used to estimate the amounts, origin, and distribution of sediment, nitrogen, and phosphorous in the watershed. GRASS and GRASS WATERWORKS were used to generate parameters needed for AGNPS from digital maps, which included soil association, land use, watershed boundaries, water features, and digital elevation. Outputs of the model included spatially distributed estimates of volume and peak runoff, overland and channel erosion, sediment yields, and concentrations of nitrogen and phosphorous. Management scenarios were explored in the AGNPS model to minimize sedimentation and nutrient loading. Scenarios evaluated included variations in crop cover, tillage methods, and other agricultural management practices. In addition, areas vulnerable to runoff were identified for best management practices.

In addition to comparing runoff from varying agricultural scenarios, AGNPS can also be used to identify critical areas within the watershed. In this study, AGNPS outputs were used to create GIS data layers representing the simulated results for the entire Cass River watershed. The combination of cropland and relatively high slopes produces the areas of greatest sediment yield per cell, while agriculture, slopes, proximity to tributaries, and drainage patterns dictate the highest levels of nitrogen runoff per cell. Once identified, these areas can be singled out to maximize NPS pollution control measures.

Engineers working under guidelines of the Galveston Bay National Estuary Program, a multi agency environmental management planning program, have embarked on a three-phase plan for this area to prioritize estuary problems, scientifically characterize the problems and link them with causes, and create a series of action plans to solve these problems. Characterizing these pollutants requires extensive information about area geography and nonpoint sources. A geographic information system database has provided a powerful management tool for this task .

The GIS database designed specifically for this study, helped map the area's geographic characteristics, analyze the land use data, complete the nonpoint source calculations and graphically present the project results. With this database, they were able to identify the areas within the watershed that contribute the highest load concentrations of a given pollutant entering Galveston Bay. These areas could in turn be targeted in action plans aimed at managing the pollutants. The ARC/INFO GIS software (ESRI, 1989) was the basic tool for the entire nonpoint source assessment. This system permitted the storage, manipulation and processing of the several hundred megabytes of electronic data required to calculate nonpoint source pollution.

APPENDIX C

Recommendations to Further Improve Section 319 Programs

The following are the recommendations arrived at based on the EPA assessment of the 319 Program (Adler, Landman, and Cameron, 1993):

1. Reform Section 319 of the Clean Water Act to mandate whole-watershed restoration and protection and site-specific pollution control practices in impaired watersheds. States must create comprehensive target watershed lists that include all significantly degraded and threatened watersheds. These watersheds must be restored on a reasonable timetable.

2. Require site-level planning and adoption of site-level water quality practices. As currently required in coastal areas by the Coastal Zone Management Act, all landowners in the target (impaired) watersheds and anyone who breaks new ground for development around the state must bear their fair share of the responsibility for watershed restoration and protection through adoption of runoff measures tailored to each unique site , based on menus of management measures developed by EPA and the states. Each landowner or operator contributing in a target watershed must create a site-level water quality plan consistent with the watershed goals and must implement that plan within a three- to five-year time frame. Technical assistance in writing and enacting the plans, cost-sharing when necessary to help defray farmers' and other landowners' costs, and adequate implementation time should be made available where needed. As water quality monitoring indicates the need, plans should evolve and practices change over time in an iterative process until the water body is fully restored.

3. Require that federal agencies implement EPA runoff management measure guidance on all lands under their jurisdiction. Significant runoff pollution occurs on lands managed by federal agencies. The same type of site-specific management measures and land use practices should be required for

activities on federal lands as for those on lands owned by private parties or by state and local governments.

4. Require permits for feedlots and irrigation return flows. The conclusion arrived at, is that the national nonpoint source runoff policy is based upon a voluntary, piecemeal approach riddled with inconsistencies, ineffectiveness, and massive gaps in funding, monitoring and staffing. As a result, as of 1990, there were fifty individual runoff assessment and management programs that vary widely in terms of comprehensiveness, stringency, degree of public participation, accountability, funding commitments, and instream effectiveness. And most programs fall on the voluntary side of the spectrum. Major changes are needed to strengthen 319 into a publicly accountable and ecologically and economically effective program. Unfortunately, implementation of 319 has failed to stem the flow of polluted runoff; EPA concluded that the majority of state programs are ineffective and unfocused.

LIST OF REFERENCES

LIST OF REFERENCES

Adler, Robert W., J.C. Landman, and D.M. Cameron. 1993. The Clean Water Act 20 Years Later. Natural Resources Defense Council. Washington, D.C.: Island Press.

Armstrong, D.E. and G.A. Rohlich. 1970. "Plant Nutrients as Water Pollutants." In Agricultural Practices and Water Quality, eds. Ted L. Willrich and George E. Smith. Iowa:Iowa State University Press.

Batie, Sandra S. 1994. "Designing a Successful Voluntary Green Support Program: What Do We Know?" Staff Paper No. 94-65. East Lansing, Michigan, Department of Agricultural Economics, Michigan State University.

Bosch, D.J. 1995. "Integration of Geographic Information Systems and Programming Models for Research and Decision Support". Paper presented at the AAEA Learning Workshop, "GIS as a Research Tool in Applied Economics". Indianapolis, Indiana.

Bosch, D.J., J.W. Pease, S.S. Batie, and V.O. Shanholtz. 1992. "Crop Selection, Tillage Practices, Chemical, and Chemical and Nutrient Applications in Two Regions of the Chesapeake Bay Watershed". Bulletin 176, Virginia Water Resources Research Center. Blacksburg, VA: Virginia Polytechnic Institute and State University.

Bromley, R., and M. Coulson. 1991. "GIS in British Local Government: the Benefits to Resource Management and Planning". In Spatial Analysis and Spatial Policy using Geographic Information Systems. L. Worrall ed. London: Belhaven Press.

Carpentier, L.C. 1996. Value of Information for Targeting Agro-Pollution Control: A Case Study of the Lower Susquehanna Watershed. Doctoral Dissertation. Department of Agricultural and Applied Economics. Virginia Polytechnic Institute and State University.

Center for Agricultural and Rural Development (CARD). 1991. Evaluation of Regulatory Impacts of Externalities: A Project Proposal. Iowa State University. Ames, Iowa.

Clark, E.H. II, J.A. Haverkamp, and W. Chapan. 1985. Eroding Soils: The Off-farm Impacts of Soil Erosion. The Conservation Foundation, Washington, D.C.

Cleary, Thad. Personal Interview. July, 1995.

Duda, A.M., and R.J. Johnson. 1987. "Targeting to Protect Groundwater Quality". Journal of Soil and Water Conservation, 42(5):325-331.

Duda, A.M., and R.J. Johnson. 1985. "Cost-Effective Targeting of Agricultural Nonpoint Source Pollution Control". Journal of Soil and Water Conservation. 20(1):108-111.

Engel, B.A., R. Sirnivasan, J. Arnold, C. Roberts, and S.J. Brown. 1993. "Nonpoint Source Pollution Modeling Using Models Integrated with GIS". Water Science and Technology, 28(2):685-690.

Environmental Systems Research Institute (ESRI). 1989. ARC/INFO User's Manual Version 5.0. Redlands, California.

Ervin, D.E., and M. Blase. 1986. "The Conservation Reserve: Potential Impacts and Problems". Journal of Soil and Water Conservation, 41(2):77-80.

Fletcher, J.J. and T. T. Phipps. 1991. "Data Needs to Assess Environmental Quality Issues Related to Agriculture and Rural Areas". American Journal of Agricultural Economics, 3:926-932.

Gianessi, Leonard P., Henry M. Peskin, Pierre Crosson, and Cindi Puffer. 1986. Nonpoint Source Pollution Controls: Are Cropland Controls the Answer? Resources for the Future, Washington, D.C.

Hallberg, G.R., R.D. Libra, Z.J. Liu, R.D. Rowden, and K.D. Rex. 1993. "Watershed-Scale Water-Quality Response to Changes in Land Use and Nitrogen Management". In Agricultural Research to Protect Water Quality: Proceeding of the Conference, February 21-24. Minneapolis, Minnesota.

Harrington, Winston, Alan J. Krupnick, and Henry M. Peskin. 1985. "Policies for Nonpoint Source Water Pollution Control". Journal of Soil and Water Conservation, 40(1):27-32.

Harris, B. and M. Batty. 1993. "Locational Models, Geographic Information and Planning Support Systems". Journal of Planning Education and Research, 12:184-198.

He, C., J.F. Riggs, and Y. Kang. 1993. "Integration of Geographic Information Systems and a Computer Model to Evaluate Impacts of Agricultural Runoff on Water Quality". Water Resources Bulletin, 29(6):891-100.

Hrubovcak, James, M. Le Blanc, J. Miranowski. 1990. "Limitations in Evaluating Environmental and Agricultural Policy Coordination Benefits". American Economic Review, 80(2):208-212.

Lee, J., Gary S.B. Lovejoy, and D. Beasely. 1985. "Soil Loss Reduction in Finley Creek, Indiana: An Economic Analysis of Alternative Policies". Journal of Soil and Water Conservation, 40(1):132-135.

Maas, R.P., M.D. Smolen, and S.A. Dressing. 1985. "Selecting Critical Areas for Nonpoint Source Pollution Control". Journal of Soil and Water Conservation, 40(1):68-71.

MacGregor, Robert D., Judith A. Maxwell, and Fred J. Hitzhusen. 1991. " An Operational Model for Targeting Erosion Remediation on the Basis of Partial-Off-Site Damage Assessments".

Journal of Soil and Water Conservation, 46(4):301-304.

Mapp, H.P., D.J. Bernardo, G.J. Sabbagh, S. Geleta, and K.B. Watkins. 1994. "Economic and Environmental Impacts of Limiting Nitrogen Use to Protect Water Quality: A Stochastic Regional Analysis". American Journal of Agricultural Economics, 76(4):889-903.

Michigan Department of Environmental Quality (MDEQ). 1995. Water Quality and Pollution Control in Michigan. Unpublished report.

Michigan Department of Natural Resources (MDNR). 1994. Michigan Agricultural Nonpoint Source Pollution Prevention Plan. Unpublished report.

National Research Council. 1993. Soil and Water Quality: An Agenda for Agriculture. Committee on Long-Range Soil and Water Conservation. Board of Agriculture. Washington, D.C. National Academy Press.

Nichols, Albert L. 1984. Targeting Economic Incentives for Environmental Protection. The MIT Press: Cambridge, Massachusetts.

Nielson, James. 1986. "Conservation Targeting Success or Failure?". Journal of Soil and Water Conservation, 41(2):70-76.

Opaluch, J.J., and K. Segerson. 1991. "Aggregate Analysis of Site-Specific Pollution Problems: The Case of Groundwater Contamination from Agriculture". Northeastern Journal of Agricultural Economics, 20(1):83-97.

Overcash, M.R. and J.M. Davidson. 1980. Environmental Impact of Nonpoint Source Pollution. Ann Arbor Science: Ann Arbor, MI.

Padgitt, Merritt. 1989. "Soil Diversity and the Effects of Field Eligibility Rules In Implementing Soil Conservation Programs Targeted to Highly Eroded Land". Journal of Soil and Water Conservation, 44(1):91-95.

Park, W.M. and D.G. Sawyer. 1985. Targeting Soil Erosion Control Efforts in a Critical Watershed. Economic Research Service Staff Report No. AGES850801. Washington D.C.: U.S. Department of Agriculture.

Parsons, L.R., J.W. Pease, and D.J. Bosch. 1994. "Identifying Field and Farm Characteristics Related to Nitrogen Losses: Implications for Water Quality Protection Programs". Paper presented at the 1994 Meetings of the American Agricultural Economics Association. August 9, in San Diego, California.

Prato, T., H.Q. Shi, R. Rhew, and M. Brusven. 1989. "Soil Erosion and Nonpoint Pollution Control in an Idaho Watershed". Journal of Soil and Water Conservation, 44(1): 323-328.

Ribaudo, Marc O. 1989. "Targeting the Conservation Reserve Program to Maximize Water Quality Benefits". Land Economics, 65(4):320-332.

Ribaudo, Marc O. 1986. "Consideration of Offsite Impacts in Targeting Soil Conservation Programs". Land Economics, 62(4):402-411.

Runge, C.F., W.E. Larson, and G. Roloff. 1986. "Using Productivity Measures to Target Conservation Programs: A Comparative Analysis". Journal of Soil and Water Conservation, 41(1):45-49.

Setia, Parveen and Richard Magleby. 1987. "An Economic Analysis of Agricultural Nonpoint Pollution Control Alternatives". Journal of Soil and Water Conservation, 42(6):427-431.

Smith, R.A., R.B. Alexander, and M.G. Wolman. 1987. "Water Quality Trends in the Nation's Rivers". Science, 235:1607-1615.

Supalla, Raymond, R.A. Selley, S. Bredeweg, and D. Watts. 1995. "Adoption of Nitrogen and Water Management Practices to Improve Water Quality". Journal of Soil and Water Conservation. 50(1):77-82.

Thornton, K.W. and D.E. Ford. 1985. Identifying Critical NPS Contributing Watershed Areas. In Perspectives on Nonpoint Source Pollution: Proceedings of a National Conference. Washington, D.C.: U. S. Environmental Protection Agency, Office of Water Regulation and Standards.

U.S. Department of Agriculture (USDA). 1991. A Report on the State of United States' Waters. Agricultural Stabilization and Conservation Service, USDA.

U.S. Environmental Protection Agency. 1990. National Water Quality Inventory, 1988 Report to Congress. Office of Water. Environmental Protection Agency. EPA841-F-88-002.

Wall, David B., S.A. McGuire, and J.A. Magner. 1989. Water Quality Monitoring and Assessment in the Garvin Brook Rural Clean Water Project Area. St. Paul, Minnesota: Minnesota Pollution Control Agency, Division of Water Quality, Program Development Section.

Wischmeier, W.H., and D.D. Smith. 1978. "Predicting Rainfall Erosion Losses. A Guide to Conservation Planning". In Agricultural Handbook #537. Washington, D.C.: USDA.

Wright, J.R. 1990. "ISIS: Toward an Integrated Spatial Information System". In Expert Systems: Applications to Urban Planning. T.J. Kim, L.L. Wiggins, and J.R. Wright eds. New York: Springer-Verlag.

Xu, F., T. Prato, and C. Fulcher. 1993. "Broiler Litter Application to Land in an Agricultural Watershed: A GIS Approach". Water Science and Technology, 28:111-118.

Young, R.A., C.A. Onstad, D.D. Bosch, and W.P. Anderson. 1989. "AGNPS: A Nonpoint Source Pollution Model for Evaluating Agricultural Watersheds". Journal of Soil and Water Conservation, 44(2):168-173.