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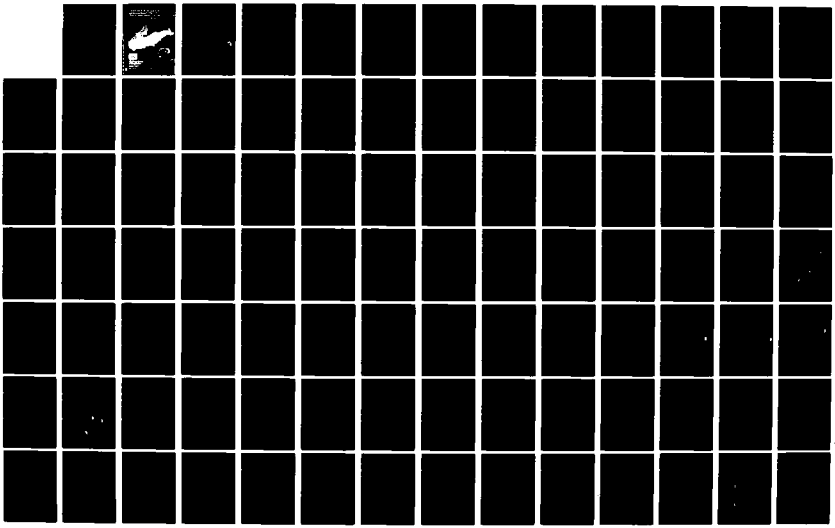

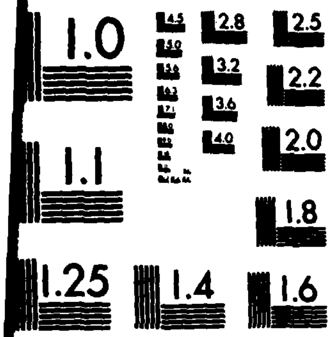

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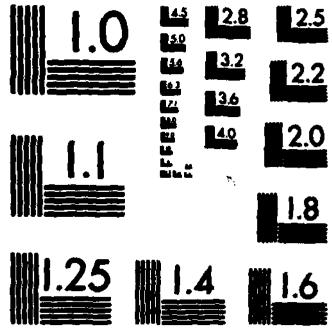

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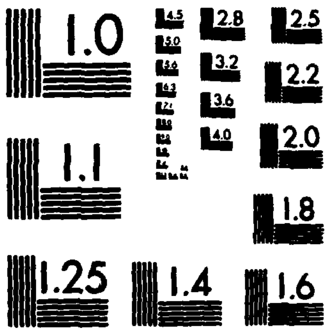

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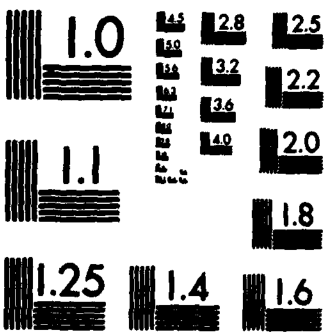

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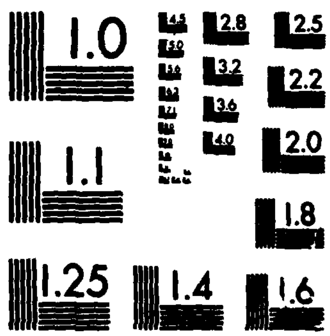

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This summary provides an overview of the findings from LEWMS. After nearly a decade of investigation, considerable information has been obtained concerning the extent of Lake Erie's water quality problems, the causes of these problems, and a cost-effective strategy to improve Lake Erie's water quality. Numerous questions remain unanswered about the exact relationship between land use and water quality and about the effectiveness of the proposed management strategy. However, enough information has been assembled in order to project that Lake

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Erie can be rehabilitated with the recommended program at a relatively low cost.

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LAKE ERIE WASTEWATER MANAGEMENT STUDY

FINAL REPORT

U. S. Army Corps of Engineers District, Buffalo
1776 Niagara Street
Buffalo, New York 14207

September 1982

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This report could not have been completed without the assistance of the following members of the LEWMS staff: David A. Melfi, who developed the three basin phosphorus budget model, the data management system and made the loading calculations; John R. Adams who was responsible for the Land Resource Information System and developed the phosphorus loading reduction scenarios; Fred Boglione who developed the cost of phosphorus reduction at municipal wastewater treatment plants and by urban diffuse source control; and Richard Leonard who wrote several chapters of the report. Sophia Baj, April Zimmerman and Tom Adolph also made contributions to the production of the report.

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Donald R. Urban, George Stem and Bruce Julian of the Soil Conservation Service were assigned to this study at different times. Their advice was valuable and they made a large contribution to the success of the demonstration projects. John Crumrine, Project Manager of the Honey Creek Project, showed that a technical assistance program for conservation tillage was a feasible approach for reducing phosphorus loads from agriculture.

A special thanks goes to Mrs. Freda Soper who prepared this manuscript.

Stephen M Yaksich

STEPHEN M. YAKSICH
Project Manager

SYLLABUS

Introduction.

Congress directed the Corps of Engineers to design and develop a demonstration wastewater management program for the rehabilitation and environmental repair of Lake Erie (PL 92-500, Sections 108(d) and 108(e)). At the time this legislation was enacted, it was recognized that excessive phosphorus loadings were the principal cause of accelerated eutrophication in Lake Erie. The Lake Erie Wastewater Management Study (LEWMS) was directed at (a) identifying and quantifying sources of phosphorus and sediment entering the lake, (b) developing a management strategy for control of these sources, and (c) projecting the economic impact of implementing this management strategy.

Early in the study, it was determined that approximately 44 percent of the phosphorus loadings originated from diffuse or nonpoint sources, and most of this from cropland. It was concluded that management of point sources alone would not achieve the desired improvement in the quality of Lake Erie water. Federal water quality programs had focused on reducing point source loadings such as those from municipal waste treatment facilities. Therefore, the focus of LEWMS became diffuse sources of phosphorus.

LEWMS was divided into three phases. The first phase, initiated in 1973, described water quality conditions in Lake Erie and estimated nutrient loadings from the lake's tributaries, and from particular sources within each tributary. The second phase began in 1976 and investigated those factors affecting diffuse source loadings. During the third phase, which started in 1978, cost-effective management strategies for reducing diffuse source phosphorus loadings were developed and demonstrated.

This summary provides an overview of the findings from LEWMS. After nearly a decade of investigation, considerable information has been obtained concerning the extent of Lake Erie's water quality problems, the causes of these problems, and a cost-effective strategy to improve Lake Erie's water quality. Numerous questions remain unanswered about the exact relationship between land use and water quality and about the effectiveness of the proposed management strategy. However, enough information has been assembled in order to project that Lake Erie can be rehabilitated with the recommended program at a relatively low cost.

Land Use and Land Resources in the Lake Erie Basin.

The United States portion of the basin includes 12.5 million acres (5.06 million hectares), of which over half is cropland. In the western portion of the basin, nearly 70 percent of the land is devoted to cropland. The area is in a relatively favorable location to take advantage of the improved grain export market. As a result, row crop production has been encouraged with corn and soybeans dominating cropland usage.

The trend toward more intensive usage of cropland has resulted in increased sheet and rill erosion and most of the diffuse source phosphorus loadings to Lake Erie. It is estimated that two-thirds of the diffuse source phosphorus loadings are from agricultural land use.

A computer based information system was developed to provide a basin-wide inventory of the land. In this computerized system, the basin was divided into over one million cells, and characteristics were recorded for each cell. These characteristics included attributes of the soil mapping unit (e.g. slope, soil type, erodibility, drainage) which influence soil and phosphorus losses. Some of the other characteristics recorded for each cell were the political boundary (minor civil divisions) within which the cell was located, the watershed in which the cell was located, and land use.

This computerized system, called the Land Resources Information System (LRIS), provided a valuable tool in describing current conditions and in developing strategies for reducing diffuse source pollution. For example, LRIS generated tabular summaries and maps describing land attributes (land use, soil texture, slope, soil erodibility, soil drainage) for particular drainage basins or counties. These products helped planners, soil conservationists, extension agents and farmers in better understanding the land resources of their area.

LRIS information was used in conjunction with the Universal Soil Loss Equation to provide estimates of soil loss under existing land management practices. Thus, areas where soil losses were relatively large were identified.

A major use of LRIS was to compare soil losses under a variety of management scenarios. For example, LRIS was used to estimate the reductions in soil erosion and phosphorus losses if conservation tillage systems were adopted. This information was generated by county, and by major and minor watershed.

Economic analyses indicated that most cropland in the Lake Erie Basin is amenable to reducing soil erosion using conservation tillage. Conservation tillage replaces conventional moldboard plowing with either no tillage or reduced tillage. With conservation tillage, labor and fuel costs are reduced and equipment costs also may decrease. However, some soils are more conducive to conservation tillage than others. Some soils, especially those which are well drained, have produced crop yield increases with conservation tillage. Obviously, reduced costs and increased production make conservation tillage economically attractive on these soils. On other soils, crop yields decline slightly with conservation tillage, and it remains marginally attractive since lower costs more than offset these small yield reductions. However, some of the basin's soils yield reductions associated with reduced tillage make it economically unattractive. Using LRIS, it was projected that adopting conservation tillage on those soils where it was economically advantageous could produce substantial reductions in soil loss and phosphorus loadings. Thus, the concept of accelerating the adoption of conservation tillage to improve Lake Erie water quality was born.

Conservation tillage's usage has expanded rapidly in the basin throughout the last decade. In the early 1970's little conservation tillage was seen. In 1981, reduced tillage was being practiced on 22 percent of the basin's cropland, and no tillage was used on 4 percent. Throughout this period, those adopting conservation tillage have found that fertility management and pest (weeds and insects) control are crucial to successfully adopting these practices. Besides changing tillage practices, several practices (e.g. the method of fertilizer application, pesticide usage, and planting techniques) may have to be altered.

Basin land resources, markets, and agricultural technology have combined to provide farmers with incentives for intensive cropland use. Soil loss and phosphorus loadings to Lake Erie have been a by-product. However, most of these soil resources are amenable to conservation tillage, which would enable cropland use to remain intensive while sharply curtailing soil loss and phosphorus loadings.

Pollutant Export from Watersheds.

Water quality was monitored for 78 watersheds from December 1974 to September 1981. This monitoring program included all tributaries draining to Lake Erie from the United States side. Ten parameters including total and dissolved phosphorus were measured. The Maumee, Portage, Sandusky, and Huron Rivers were intensively studied. This monitoring program was established to quantify the pollutant contributions from various watersheds and to investigate (a) relationships between pollutants and land use activities and (b) the transportation of these pollutants to downstream water bodies.

The effects of land use activities on water quality is a very complex relationship. It was implied above that reducing soil loss through conservation tillage would improve Lake Erie water quality. While this simple statement is true, it hides many of the complexities involved.

First, there are large variations in sediment and nutrient concentrations in streams and rivers. Thus, there is a need for monitoring over several years to accurately determine nonpoint source loadings and their relationship to land use.

Second, the characteristics of runoff from land are dependent on several conditions. For example, runoff from snowmelt has much lower sediment concentration than runoff associated with rainfall. The runoff associated with rainfall in the late winter-early spring period on exposed, saturated, soils would be much different than the runoff from an identical late summer rainfall occurring on dry soil covered by crops.

Third, several types of phosphorus are present in water. Much of the phosphorus native to soils is chemically bound and either unavailable or slowly available for biological assimilation. The proportion of phosphorus which is available varies between watersheds. For example, sediments from high clay agricultural basins in western Ohio have the highest proportions of bioavailable phosphorus.

These complexities made precise descriptions of pollutant export difficult; however, several general relationships were confirmed. Reducing sediment concentrations lessens sediment yields and phosphorus loadings from large river basins. The mean ratio of total phosphorus to suspended solids for 1974-79 was 2.17 g/kg in northwestern Ohio. Of this total phosphorus, 25 percent was soluble phosphorus (which is readily available for plant growth) and 75 percent was particulate phosphorus. However, there was some variation in the ratio of total phosphorus to suspended solids. Generally, higher concentration of suspended solids resulted in lower phosphorus to suspended solids ratios.

Another finding was that particulate and soluble phosphorus entering stream systems disappears rapidly from flowing water. However, it is resuspended and transported downstream as particulate phosphorus during later storm events. Particulate phosphorus may be transported from basin cropland to Lake Erie over a considerable period of time as it is deposited in streams and rivers and then is resuspended during subsequent storm events.

Evidence accumulated during this study indicates that phosphorus from nonpoint sources is more bioavailable when reaching Lake Erie than phosphorus from point sources located on tributaries. Most of the soluble phosphorus, which reaches the lake from tributaries, is derived from nonpoint sources.

The study's findings pointed to an indirect relationship between soil erosion and phosphorus delivery or sediment delivery. The calculated sediment delivery ratios (i.e. sediment delivered as a proportion of gross erosion) was 6.2 to 11.9 percent. Soil characteristics affect this ratio. For example, areas with sandy soils have sediment with higher proportions of coarse particles resulting in lower sediment delivery ratios than areas with fine textured soils. Gross erosion rates poorly represent the sediment or phosphorus actually delivered to Lake Erie.

Along with phosphorus and sediment parameters, pesticide concentrations in tributaries also were monitored. Use of pesticides has expanded rapidly in the basin, and conservation tillage technologies would further increase their usage. Relatively small amounts of pesticides reach water bodies as the runoff of pesticides generally is 1 to 2 percent of applied materials. However, it may be as high as 6 percent when intense rainfall immediately follows application. Many pesticides are tied tightly to soil particles upon application. The increased usage of pesticides with conservation tillage is not expected to result in increased pesticide runoff, since erosion and runoff would decrease.

Pesticides generally used in the Lake Erie Basin are not inhibitory to invertebrates or fish at runoff concentrations found in the LEWMS study. Algae and aquatic macrophytes may be inhibited at the observed stream concentrations. Continued studies are recommended for the ecological impact of herbicide and insecticide runoff from conservation tillage cropland.

In-Lake Effects of Phosphorus Loadings.

Lake Erie's water quality has undergone considerable degradation during the past half century. Eutrophic lakes are characterized by their excessive plant growth which is stimulated by over enrichment of nutrients such as phosphorus. Dead and dying plant matter decays through bacterial decomposition. This process consumes oxygen, and the depletion of oxygen stress fish and other aquatic life. The critical oxygen depletion rate (0.093 mg 02/1/day) in Lake Erie's central basin has been exceeded since 1960.

Point source phosphorus loadings decreased dramatically during the 1970's as a result of improved wastewater treatment. In 1970, point source loadings to Lake Erie were 11,900 metric tons per year (mt/yr). In 1980, they were 4,500 mt/yr. Nonpoint source loadings varied from a low of 5,700 mt/yr to a high of 11,900 mt/yr during the 1970's. The variation was a result of different weather conditions during these years.

Total phosphorus loadings for the base year of 1980 were estimated at 16,500 mt/yr. If wastewater treatment continues to improve as expected, loadings would decline to 15,000 mt/yr. This assumes that all plants treating over 1 million gallons per day achieve effluent phosphorus concentrations of 1.0 mg/l.

The target phosphorus load called for in the 1978 Great Lakes Water Quality Agreement between the United States and Canada is 11,000 mt/yr. This would reduce the area of anoxia in the Central Basin by 90 percent within a few years. Thus, based on the new base year/loading estimate, reductions in nonpoint loadings of 4,000 mt/yr would be required. The U.S. share of this reduction would be 2,800 mt/yr. Present agreements between the United States and Canada call for a nonpoint source reduction objective of 2,000 mt/yr with the U.S. reduction being 1,700 mt/yr.

Land Management Alternatives for Erosion Control and Phosphorus Reduction.

Emphasis has been placed on conservation tillage as a cost effective method of achieving acceptable levels of nonpoint phosphorus loadings. Other management practices (e.g. ban on fall plowing, using cover crops, changing cropping patterns) were considered, but all involved expense to the farmer with less phosphorus loading impact than adoption of conservation tillage on suitable soils. Approximately 53 percent of the U. S. Lake Erie Basin cropland is considered economically suitable for no tillage, and 80 percent is considered economically suitable for reduced tillage.

For the basin, the maximum soil erosion reduction which could be achieved by applying no tillage and reduced tillage to all suitable soils would be 69 percent. Application of only reduced tillage to suitable soils would reduce soil erosion by 46 percent. Of course, expecting complete adoption of conservation tillage on suitable soils is unrealistic, but these estimates provide an indication of the potential impact of conservation tillage.

Conservation tillage has been adopted by basin farmers over the past decade and will continue to be adopted, with or without a program to encourage it. Under the existing program, conservation tillage practice is expected to be employed on 59 percent of Lake Erie Basin cropland. An accelerated program developed in this study is projected to increase conservation tillage adoption to 76 percent of the basin's cropland by the year 2002. The adoption of conservation tillage may be even higher with rising fuel costs and/or shortages.

The present (1982) basin-wide erosion rate is 18 million tons per year. With the accelerated program, erosion will ultimately decline to 9.4 million tons per year.

As previously stated, there is not a perfect correlation between phosphorus and erosion reductions. Reduction of particulate phosphorus in runoff is 90 percent as effective as reductions of soil loss. There is no reduction in the transport of soluble forms of phosphorus using conservation tillage.

Over a 20-year period (1982-2002), total U. S. phosphorus loadings to Lake Erie from the recommended accelerated conservation tillage program will be reduced by 33,000 metric tons compared to 12,600 metric tons under the existing program. The existing program would provide an average U. S. reduction of 630 mt/yr and 980 mt/yr in the final year. The accelerated program would produce an average U. S. reduction of 1,640 mt/yr and 2,030 mt/yr in the final year.

Besides a conservation tillage emphasis, the accelerated program would also stress fertilization management. Surface applied phosphorus fertilizer builds up high levels of available phosphorus at the soil surface. Part of this available phosphorus is transported into tributaries during runoff. Evidence shows that phosphorus application in excess of crop needs and maintenance levels results in high levels of soluble and bioavailable phosphorus in runoff. Furthermore, many basin farmers appear to be applying excess phosphorus.

Based on various economic analyses during LEWMS, it is concluded that widespread adoption of conservation tillage on suitable soils and better fertilization management practices will not be detrimental to net farm income. In fact, these practices should improve net incomes if recommended management practices are followed.

Twenty basin counties have been selected as priority areas for promoting the accelerated adoption of conservation tillage. Selection was based on the relative potential for reducing soil erosion and phosphorus losses and the total area suited for conservation tillage. The selected counties account for 65 percent of the estimated soil loss reduction under the accelerated program and 80 percent of the IJC targeted 1,700 mt/yr reduction in U. S. nonpoint source phosphorus loadings to Lake Erie. Additional phosphorus reductions would result from spillover effects in other counties.

Past and Existing Related Projects.

The LEWMS program and other Federal agencies have carried on several projects to promote conservation tillage adoption. Thus, the accelerated program would build on a well developed base. The existing program mentioned previously assumes an effort similar to these recent projects.

The Corps of Engineers activites included the 3-year Honey Creek Watershed demonstration project emphasizing no tillage. Several economic analyses of tillage practices were conducted in Honey Creek as well as elsewhere in the basin. The Honey Creek Program was highly successful in demonstrating that conservation tillage practices will be adopted by farmers if adequate information and technical assistanace are provided. No-tillage production acreage in the vicinity of the project increased from 2,400 acres in its first year to more than 16,000 acres in its third and final year.

Five watershed management studies were developed to promote the application of conservation tillage in representative Lake Erie watersheds. The Corps used information developed throughout LEWMS program to formulate programs for the accelerated adoption of conservation tillage in the five watersheds.

County resource information system packages (CRISP) have been prepared by the Corps for 28 counties in the basin. These packages include maps and tabular summaries of resource information (soils, slopes, gross erosion, land use, etc.) which are valuable aids for land resource planning.

The U.S. Environmental Protection Agency funded five demonstration projects in 1980 through its Great Lakes National Program Office. These projects were to accelerate adoption of no-tillage systems in the western basin of Lake Erie. Technical and educational assistance was provided by U.S. Department of Agriculture (USDA) agencies, State agencies, and the Corps of Engineers. These projects along with an earlier Allen Co., Indiana project were authorized under PL 92-500, Section 108.

USDA efforts have included the provision of Agricultural Conservation Program (ACP) funds in many counties as cost share incentives for conservation tillage and other best management practices. Other USDA cost share funds have been received in Washtenaw and Monroe Counties in Michigan, through the Rural Clean Water Program (RCWP). These funds have been used to promote best management practices, including conservation tillage. Technical assistance has been provided by the Soil Conservation Service, and educational assistance has been provided by the Cooperative Extension Service. In addition, Land Grant Universities have played an important part in investigating Lake Erie's quality problems and methods of combating them.

Finally, LEWMS program's Land Resource Information System (LRIS) has proven to be a valuable aid in selecting areas for effective RCWP fund deployment and other planning efforts.

Conclusions.

THE WESTERN BASIN AND WESTERN CENTRAL BASIN OF LAKE ERIE HAVE ALGAL GROWTH PROBLEMS WHICH WILL REQUIRE PHOSPHORUS REDUCTIONS IN ADDITION TO THOSE PROVIDED BY POINT SOURCE REMOVAL.

This conclusion is based on our current knowledge of tributary loadings to Lake Erie, the reductions we know can be achieved through point source control programs being implemented at this time and our understanding of the Lake's response to phosphorus inputs. The 11,000 metric tons per year total phosphorus loadings, now felt to be the level at which satisfactory conditions can be achieved, will be reached through diffuse source control or additional point source control.

THE RIVER BASINS WHICH DRAIN INTO THE WESTERN BASIN AND WESTERN CENTRAL BASIN OF LAKE ERIE ARE CONTRIBUTING AREAS OF DIFFUSE PHOSPHORUS LOADS.

This conclusion is based upon results of intensive stream monitoring which showed that these areas contribute high unit area phosphorus loads.

THE ENTIRE WATERSHEDS OF THESE RIVERS ARE HYDROLOGICALLY ACTIVE AREAS AND CONTRIBUTE DIFFUSE PHOSPHORUS LOADS TO LAKE ERIE.

This conclusion is based on the following observations:

a. Most of the phosphorus export occurs in late winter and early spring periods when soils are saturated and runoff occurs over the entire basin.

b. Fine textured soils occur throughout this area and are the major contributing source of high runoff and phosphorus transport.

c. Soil phosphorus levels are high throughout this area.

d. Intensive row crop agriculture is the predominant land use throughout the area.

A PROGRAM FOR CONTROL OF PHOSPHORUS FROM DIFFUSE SOURCES SHOULD BE BASED ON PRACTICES WHICH HAVE THE LOWEST COST PER TON OF PHOSPHORUS STOPPED FROM REACHING THE LAKE.

This conclusion is based on our findings that many agricultural soil conservation practices although vital to the preservation of the long-term productivity of the soil, do not contribute significantly to the reduction of phosphorus transport. Such practices are too costly to receive emphasis in a diffuse source phosphorus control program.

CONSERVATION TILLAGE ON SUITABLE SOILS IS THE MOST COST-EFFECTIVE MEANS OF REDUCING SEDIMENT PHOSPHORUS LOADS TO LAKE ERIE.

This conclusion is based on research and field demonstrations which show that practices which preserve crop residues on the surface of the land, and prevent the impact of raindrops on bare soil, are highly effective in reducing sediment and phosphorus transport. Conservation tillage is such a practice, and has been shown to be implementable at minimal net cost to the farmer.

A MAJOR NEED FOR IMPLEMENTATION OF DIFFUSE SOURCE POLLUTION CONTROL IN THE LAKE ERIE WATERSHED IS ADDITIONAL TECHNICAL ASSISTANCE AT THE FIELD LEVEL TO INCREASE USE OF CONSERVATION TILLAGE PRACTICES.

This conclusion is based on the following observations:

a. The provision of high quality technical assistance at the field level was found to be the most important precursor for accelerated adoption of conservation tillage.

b. Special training programs for conservation tillage specialists are needed.

c. Technical assistance is needed in addition to cost-sharing, education, and information programs.

FERTILITY MANAGEMENT WILL AID IN THE REDUCTION OF THE DIFFUSE PHOSPHORUS LOAD TO LAKE ERIE.

This conclusion is based on the following observations:

a. Dissolved phosphorus losses from agricultural land are directly proportional to plant available phosphorus levels in cropland soils.

b. Plant available phosphorus levels in Michigan and Ohio soils have been increasing steadily and are generally in excess of levels necessary for optimum crop production.

c. Reduction of plant available phosphorus levels to the level necessary for optimum crop production will reduce dissolved phosphorus losses from cropland.

d. Plant available phosphorus levels would increase in the surface layer through conservation tillage.

ALTHOUGH INCREASED ADOPTION OF CONSERVATION TILLAGE WILL RESULT IN GREATER PESTICIDE USAGE, PESTICIDE LOSSES TO THE ENVIRONMENT WILL DECREASE SLIGHTLY OR REMAIN CONSTANT.

This conclusion is based on research findings that the pesticides recommended in conservation tillage systems are associated with soil and organic

matter retained on the land surface. Also, runoff may be reduced in conservation tillage systems. Pesticide losses in the runoff are effectively reduced.

THE HONEY CREEK DEMONSTRATION CONFIRMS THE VALIDITY OF THE PROJECT APPROACH IN ADDRESSING WATER QUALITY PROBLEMS.

Specific findings of the Honey Creek Watershed Management Study which have been incorporated in the Recommended Program include:

a. A start-up period, lasting as long as 2 years in some cases, is a necessary step to insure uniform awareness of the program, and to establish the required organization and staffing for full implementation.

b. Additional county personnel qualified to provide technical assistance in agronomic practices are essential for success.

c. A high level of exposure of the project goals and early implementation efforts are necessary to create the climate for landowner and agency support.

d. A project-wide monitoring and evaluation effort should be used to reinforce the commitment to the goals of the project.

MONITORING OF CONSERVATION TILLAGE ADOPTION, AS WELL AS TRIBUTARY WATER QUALITY MONITORING, IS NECESSARY TO DOCUMENT THE SUCCESS OF A DIFFUSE SOURCE PHOSPHORUS CONTROL PROGRAM.

This conclusion has been reached through the understanding of tributary pollutant transport we have gained as a result of this study. Annual variability in transport is several times greater than the reduction in mean annual transport which can ultimately be achieved through the Recommended Program. Monitoring the adoption of conservation tillage is necessary to document the success of the program and predict its impact on Lake Erie. Long-term water quality monitoring will be required to verify actual reductions in transport.

THE LAND RESOURCES INFORMATION SYSTEM (LRIS) HAS BEEN SUCCESSFULLY USED TO IDENTIFY 20 OF THE 62 COUNTIES IN THE LAKE ERIE BASIN AS PRIORITY AREAS WHERE DIFFUSE SOURCE PHOSPHORUS CONTROL PROGRAMS HAVE A HIGH PROBABILITY OF SUCCESS. THE LRIS CAN ALSO BE USED TO MONITOR ADOPTION.

Twenty counties in the Lake Erie Basin have been selected for direct participation in the recommended program based on the absolute amount of soil loss reduction which can be achieved, the total acreage of cropland suitable for conservation tillage and the ranking of each county based on the flow weighted mean concentration of total phosphorus of the major river basin to which it is tributary. Remote sensing techniques and the LRIS can be used to monitor adoption.

REDUCTION OF IN-LAKE PHOSPHORUS CONCENTRATIONS WILL NOT ELIMINATE ALL LOCAL IN-STREAM WATER QUALITY PROBLEMS.

The bulk of the tributary phosphorus load is transported to Lake Erie during a few major storm events each year. It is this phosphorus which the Recommended Program will control. The program will not control septic tank discharges, runoff from barnyards and other minor sources which control the concentration of phosphorus and other pollutants during low flow periods. It is, however, expected that the programs of other agencies will address these problems.

THE RECOMMENDED PROGRAM WILL ULTIMATELY ACHIEVE A REDUCTION IN TOTAL PHOSPHORUS TRANSPORT TO LAKE ERIE OF 2,030 METRIC TONS PER YEAR. THE TOTAL COST OF THIS PROGRAM IS $12.25 MILLION (1982 DOLLARS) OR $612,400 ANNUALLY OVER A 20-YEAR PROJECTION PERIOD.

This conclusion has the following implications for Great Lakes Water Quality Management Programs:

a. The Great Lakes Water Quality Agreement of 1978 between the United States and Canada calls for an additional target phosphorus reduction for Lake Erie of 2,000 metric tons per year beyond the achievement of a 1.0 milligram per liter effluent concentration for all municipal wastewater treatment plants currently discharging more than 1 million gallons per day. The Unites States allocation of this reduction is 1,700 metric tons per year. The Recommended Program will exceed this allocation. Relative to achieving the reduction by means of additional point source control the Recommended Program has a benefit/cost ratio of 10:1.

b. It is a finding of this study that a new base-year tributary phosphorus load to Lake Erie should be recognized. Inclusion of tributary monitoring data from 1978, 79, and 80 in the computation gives a base-year total phosphorus load of 16,455 metric tons per year. When the 1.0 milligram per liter effluent limitation has been achieved the total phosphorus load to Lake Erie will be 15,025 metric tons per year. At that time an additional phosphorus reduction of 4,025 metric tons per year (not 2,000 metric tons per year as stated above) will be required to meet the 11,000 metric tons per year total loading objective of the Agreement. The United States allocation of this reduction objective should be approximately 2,800 metric tons per year. To reach this reduction objective an additional 770 metric tons per year in reductions beyond the Recommended Program must be achieved through point source controls beyond the 1.0 milligram per liter effluent limitation, and at a cost of $5 million annually. The benefit/cost ratio of the Recommended Program is 17:1 compared to a program requiring the entire reduction to be achieved by point source control.

Recommendations.

In fulfillment of international agreements and because of widespread benefits to water quality and fisheries the following Federal participation in response to Section 108(d) of PL 92-500 costing $12.5 million and administered by the Corps of Engineers, is recommended:

a. A proposed Accelerated Conservation Tillage Program consisting of individual projects of 5 years duration in each of 20 counties, phased in over a 10-year period.

b. A tributary monitoring program at six stations located on the Maumee, Portage, Sandusky, and Huron Rivers and on Honey Creek and the Upper Honey Creek Subbasin.

c. Update and use the Land Resources Information System to produce additional County Reource Information System Packages and to monitor the adoption of conservation tillage.

The funding for this program would be administered by the Corps of Engineers and distributed to appropriate local and Federal agencies. The bulk of the money would be allocated at the local level and used to accelerate existing programs.

As called for in the 1978 Great Lakes Water Quality Agreement, the United States Environmental Protection Agency and appropriate local units of government should ensure that all municipal wastewater treatment plants in the Lake Erie Basin discharging in excess of 1 million gallons per day are designed and operated so that the total phosphorus concentrations in their effluents will not exceed a maximum concentration of 1.0 milligrams per liter.

The United States Department of Agriculture, Soil Conservation Service should view the Lake Erie Basin as a high priority area and continue to fund the provision of technical assistance to county soil and water conservation districts at current levels. Current programs should be continued because of the important role that existing rates of soil loss play in the eutrophication of Lake Erie.

The United States Environmental Protection Agency, Great Lakes National Program Office's Accelerated Conservation Tillage Projects and high flow monitoring of key tributaries in the Lake Erie Basin should be continued.

The Great Lakes International Surveillance Plan which presents the basic framework for surveillance activities in the Great Lakes Basin as required in the 1978 Great Lakes Water Quality Agreement between Canada and the United States should be continually funded by the cooperating State and Federal agencies.

LAKE ERIE WASTEWATER
MANAGEMENT STUDY
FINAL REPORT

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CHAPTER 1 - INTRODUCTION

It has been recognized for many years dating back to the 1960's that the Lower Great Lakes and in particular Lake Erie, have been damaged as a result of cultural activities within the Great Lakes Basin. The problem of accelerated eutrophication, resulting in oxygen depletion, especially within the central basin of Lake Erie, has historically been of great concern. Numerous studies have identified accelerated phosphorus loading of Lake Erie as a principal cause of algal proliferation and attendant oxygen depletion. More recently, inputs of toxic heavy metals and toxic organic compounds have been recognized as serious problems in the Great Lakes ecosystem. At the time this Corps of Engineers Lake Erie Wastewater Management Study (LEWMS) was authorized and during the study period, phosphorus control was acknowledged as the greater problem. This study was therefore directed at development of a phosphorus management strategy which can reverse the historical eutrophication and oxygen depletion experienced in Lake Erie.

1.1 STUDY AUTHORIZATION

The authority for the Lake Erie Wastewater Management Study (LEWMS) is contained in Sections 108(d) and 108(e) of the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500). Section 108(d) recognized the serious conditions which exist in Lake Erie and directed the Secretary of the Army acting through the Chief of Engineers to design and develop a demonstration wastewater management program for the rehabilitation and environmental repair of Lake Erie.

This program was developed in cooperation with the U.S. Environmental Protection Agency, the Soil Conservation Service, other interested agencies of the U.S. Government, and interested States and political subdivisions thereof.

1.2 SCOPE OF STUDY

This study was directed at identifying and quantifying diffuse sources (i.e., nonpoint) of phosphorus and sediment into Lake Erie and its tributaries. A management strategy for control of these diffuse sources was developed along with recommendations for implementation. The economic impact of implementation was projected both for individuals who may be affected (i.e., farmers) and the public as a whole through possible Government-funded programs. No separate environmental impact statement has been prepared since the study itself is one.

The Lake Erie Wastewater Management Study (LEWMS) was organized into three phases. The first phase, initiated in 1973, described conditions relating to water quality in Lake Erie and presented estimates of tributary nutrient loads to the lake. Mathematical models were examined, developed and used to evaluate the effect of phosphorus loadings on Lake Erie water quality.

An interagency technical advisory group consisting of members from the State Environmental Agencies (Indiana, Michigan, New York, Ohio, and

Pennsylvania), the Great Lakes Basin Commission, U.S. Department of Agriculture, U.S. Environmental Protection Agency, other interested Federal agencies, and the Canada Centre for Inland Waters was instituted.

Methodology and results of the Phase 1 study were reported in the three volume report entitled Lake Erie Wastewater Management Study, Preliminary Feasibility Report, prepared by the Buffalo District Corps of Engineers in December 1975 (Ref 1).

Phase II concentrated on identifying factors affecting rural diffuse sources of phosphorus and the relationship of these phosphorus loads to watershed conditions, and the management of rural diffuse sources of phosphorus. Little attention was given to management of point sources or urban nonpoint sources since these sources are being dealt with by other programs. The 1972 Canada-United States Great Lakes Water Quality Agreement called for the reduction of effluent phosphorus concentrations to 1 mg/l for all municipal wastewater treatment plants, with an average flow greater than one million gallons per day. Over $5.3 billion was spent between 1971 and 1980 for municipal waste treatment in the Great Lakes Drainage Basin in the United States (Ref 2). Programs to control urban diffuse sources have been and are being developed by designated 208 agencies. Over $11.4 million was spent on Areawide Waste Treatment Management Planning in the Lake Erie drainage basin.

Phase II studies initiated in 1976 elaborated on the relative importance of nonpoint (diffuse) sources to point sources of pollution as they effect in-lake water quality and availability of phosphorus for biological uptake in the lake. The use of land in the Lake Erie drainage basin was inventoried and described, and its role in the generation of pollutants was evaluated. The process by which pollutants are removed from the land and transported by the tributary system to the lake was investigated. Sediment was found to be an important agent for transport of nutrients. Therefore, land management options designed to reduce sediment export from the drainage basin were analyzed and evaluated. An economic analysis demonstrated how land management can lead to reduction in pollutant export from the drainage basin to the lake, while at the same time not decreasing net farm income.

Methodologies and results of the Phase II studies are described in the report entitled Lake Erie Wastewater Management Study Methodology Report (Ref 3), prepared by the Buffalo District Corps of Engineers in March 1979.

Phase I and II of this study provided valuable baseline data and suggested agricultural land management practices that could substantially reduce the amount of sediment and phosphorus reaching Lake Erie and its tributaries. These practices will be referred to as "Best Management Practices" (BMP's). A major effort was made in Phase III to implement Best Management Practices in a selected watershed and to test and demonstrate their effectiveness for crop production.

In November 1978, the U.S. Army Corps of Engineers contracted with the Honey Creek Joint Board of Soil and Water Conservation District Supervisors in Crawford, Seneca and Huron Counties of Ohio, to carry out a 3-year demonstration project to test the effectiveness of agricultural best management practices (BMP's) in reducing diffuse source pollutant loading to Lake Erie and to test an administrative approach to the implementation of programs which promote accelerated farmer adoption of successful BMP's. The project included information-education activities, technical and cost-sharing assistance to farmers, and the demonstration of BMP's.

Within the scope of the Lake Erie Wastewater Management Study, it was deemed necessary to address more specifically the unique problem areas in the Lake Erie drainage basin. Watershed problems had to be further refined and more precisely identified if diffuse sources of phosphorus are to be controlled. Therefore, five implementation demonstration programs were developed which were: (1) geared to localized problems in the watersheds; (2) included appropriate land treatment practices to address these land problems; and (3) actively involved local people within the particular watershed areas.

A basin-wide educational program using a Land Resources Information System (LRIS) was undertaken. Adoption rates over a 3-year period were measured for the entire lake Erie Basin and the effect of BMP's on crop yields and costs of implementation were closely monitored.

The final product of Phase III and of the entire Lake Erie Wastewater Management Program which is described in this report is the development of a cost effective management strategy for reducing Lake Erie Basin diffuse source phosphorus loadings, which along with targeted point source reductions, will result in restoration of acceptable water quality in Lake Erie. The targeted phosphorus reduction from diffuse sources for the United States portion of the Lake Erie Basin as stipulated by Annex 3 of the 1978 Great Lakes Water Quality Agreement is 1,700 mt/yr.

1.3 STUDY APPROACH

This study was planned to develop a wastewater management strategy that would bring about significant improvement in the quality of Lake Erie water. The degradation of Lake Erie water has resulted from accelerated cultural eutrophication. In short, the growth of human populations, urbanization, industrialization, and intensive agriculture has developed rapidly in the Lake Erie Drainage Basin during the past century. Many of the waste by-products of man's activities in the drainage basin ultimately enter Lake Erie. The addition of nutrients to the lake was of particular importance to the process of eutrophication. These chemical substances are essential to plant growth (i.e., algae), which in turn forms the building block for the aquatic food chain. The overenrichment of the lake with nutrients stimulated excessive plant growth which led to taste and odor problems, the appearance of unsightly scum and turbidity, and depletion of oxygen in the bottom waters of the lake where the dead plant material decomposes. Thus, the physical, chemical, and biological equilibria of the lake were affected. Fisheries have been damaged and recreational use has been impaired. The nutrient of primary concern was phosphorus which is believed by many scientists to be the growth-limiting nutrient in Lake Erie.

Heavy metals and toxic organic substances have been and will continue to be of concern in Lake Erie and the other Great Lakes. However, the management approach to them will continue to be the same: either a ban on use of the material or a ban on release of the material to the lake and pathways to the lake (i.e., land, rivers, and air). Therefore, this study focused on the development of a strategy that would reduce the phosphorus input to Lake Erie.

The following seven basic steps have been used to develop a practical, cost-effective, and technically sound phosphorus load reduction program.

- Reliable Estimation of Phosphorus Loads to the Lake.

- Identification of Factors Affecting Nutrient Loads.

- Relationship of Nutrient Loads to Watershed Conditions.

- Relationship of In-Lake Conditions to Nutrient Loading.

- Development of Alternative Phosphorus Load Reduction Programs.

- Demonstration and Evaluation of Phosphorus Load Reduction Practices.

- Program for Basin Implementation.

The Lake Erie Wastewater Management Study concluded that the land management practices of reduced tillage and no tillage can be successfully applied to a significant percentage of the cropland in the Lake Erie Basin, thereby significantly reducing soil and phosphorus losses. It became highly advantageous to develop a model program which would encourage the voluntary adoption of these practices where applicable throughout the basin. This program includes the identification of croplands in the United States portion of the basin upon which no tillage and reduced tillage can be successfully applied at no cost to farmers. The reductions in soil losses and concomitant reductions in phosphorus loading to Lake Erie which can be expected from various degrees of implementation were projected. Impacts were projected on major crop (i.e., corn, soybeans) yields as well as the economics of crop production.

1.4 STUDY PROCESS

1.4.1 LEWMS Phase I.

The conclusions of the 1975 Preliminary Feasibility Report are summarized here along with commentary based on new knowledge and findings obtained during Phase II and Phase III.

During Phase I it was determined that the preponderance of diffuse phosphorus loads to Lake Erie was carried by streamflows resulting from storm runoff events and that for most streams sampled, a significantly high correlation was evident between phosphorus loading and stream discharge. There was also a high correlation between phosphorus loading and suspended solids carried by the streams. The flow interval method developed during Phase I for estimating phosphorus loading from streams was used with measurements made during Phase II and Phase III to verify tributary loading estimates. The estimates that have been developed for diffuse source phosphorus loading to Lake Erie are thought to be the most reliable and comprehensive now available.

A mathematical model based on the conservation of mass principle was developed during Phase I for the phosphorus budget of Lake Erie. The model provided a means of relating phosphorus loading to the level of phosphorus concentration in the lake. Phosphorus budget analysis for Lake Erie indicated that reduction of phosphorus loadings to the lake would bring about new and lower equilibrium values of phosphorus concentrations in the lake, a necessary step in improving the trophic status of the lake, and in accomplishing the rehabilitation and environmental repair of Lake Erie. This new equilibrium would be established in about 1 year in the Western Basin, 3 years for the Central Basin, and 4 years for the Eastern Basin. The phosphorus budget model was used to project the in-lake effects that would result from phosphorus loads to Lake Erie. The model has also served as a framework for understanding the significance of the uncertainty in estimates of phosphorus loads and measurements of in-lake water quality.

During Phase I it was determined that approximately 44 percent of the phosphorus loading to Lake Erie from its drainage basin originated from diffuse sources. It was concluded that management of point sources alone would not achieve the desired improvement in the quality of Lake Erie Water Management of diffuse sources would also be required. Phase I recommended objectives for total phosphorus concentration for in-lake water (i.e., 0.020 mg/l for western basin, and 0.015 mg/l for central and eastern basins). While these concentrations are still desirable, Phase II modified these objectives by recommending total phosphorus loading to Lake Erie as the objective of the study. This loading objective was designed to reduce the anoxic area in the Central Basin of Lake Erie by 90 percent, and will nearly eliminate the release of phosphorus from the sediments.

The Phase I conclusion that total phosphorus loading to Lake Erie be reduced to 12,500 metric tons was revised downward to 11,000 metric tons upon conclusion of Phase II. This new phosphorus loading objective was recommended by an international technical group to review phosphorus loadings (4). This technical group's recommendations were used as a basis for the Great Lakes Water Quality Agreement of 1978 (5). Based on the phosphorus budget analysis, the revised total phosphorus loading objective of 11,000 metric tons was projected to achieve the in-lake phosphorus concentrations previously recommended in Phase I, except in the Western Basin of Lake Erie. The ongoing plan to reduce point source loading in the drainage basin greatly reduced phosphorus loadings, but was not enough to achieve the desired total phosphorus loading objective of 11,000 metric tons; management of diffuse source loading was required. Inputs from Lake Huron and the atmosphere are assumed to be uncontrollable and constant.

Although wastewater management plans for reduction of point source phosphorus loading are still not fully implemented, the study analysis was based on all municipal point sources with flows greater than 1 million gallons per day having their effluent total phosphorus concentrations reduced to at least 1 mg/l.

In Phase I it was concluded that a methodology was needed for estimating the effect that control of diffuse sources would have on export of total phosphorus from a watershed and ultimately on the reduction of total phosphorus loading originating from diffuse sources in the drainage basin. Such a methodology was developed during Phase II. It was also concluded in Phase I that a determination was needed of the proportion of total phosphorus originating from diffuse sources available for biological uptake in the lake. A better estimate is now possible based on work undertaken during Phase II and Phase III.

The final conclusion in the Preliminary Feasibility Report was that the wastewater management plan eventually recommended for Lake Erie be based on an analysis of the economic, social, and environmental impacts of the proposed plan. This conclusion is still valid. The ramifications of managing diffuse sources of phosphorus in the drainage basin received special study during Phase II and Phase III.

1.4.2 <u>LEWMS Phase II</u>.

Phase II of the Lake Erie Wastewater Management Study concentrated on identifying factors affecting rural diffuse sources of phosphorus and the relationship of these phosphorus loads to watershed conditions. Little attention was given to management of point sources or urban nonpoint sources since these sources are being dealt with by other programs.

Phase II of the study attempted to answer the following questions: How does the use of land affect phosphorus export from a watershed? What percentage of eroded soil ultimately gets to the lake and how long does it take to get there? Where in the Lake Erie drainage basin could erosion control measures be applied? What management practices have the most potential for control of phosphorus loss from land? What is the biological availability of phosphorus associated with soil loss once it enters the lake? What would be the costs of erosion control measures to agriculture?

To help answer these questions, a Land Resource Information System (LRIS) was developed for the entire U.S. portion of the Lake Erie Drainage Basin. This data base contains information on soils, land use and cover, and political and watershed boundaries. It serves as an important basis for relating watershed nutrient loads and net farm returns to soil characteristics and land management practices.

An extensive monitoring program was undertaken which characterized pollutant export from 72 watersheds within the drainage basin. These data were used along with the information generated by LRIS to investigate relationships between land use and water quality. A mathematical model was developed to analyze how phosphorus is transported in a river. Phosphorus availability was measured both chemically and biologically. A prototype report was developed for a specific small watershed in the Lake Erie drainage basin (i.e., Honey Creek) describing soil conserving agricultural techniques that could be applied in that watershed. Phase II resulted in development of methodologies and acquisition of data that answer most of the questions posed above.

Results of the Phase II studies reinforced the conclusion that diffuse source control of phosphorus is necessary to achieve the Lake Erie loading objective of 11,000 mt/yr. It was further estimated that diffuse source phosphorus loading would have to be reduced by 47 or 33 percent depending on whether municipal point sources (i.e. sewage treatment plants) attained concentrations of 1.0 mg/l or 0.5 mg/l phosphorus. Under the above conditions, the anoxic area of the Central Basin would be reduced by 90 percent but the Western Basin would remain eutrophic.

Using the Universal Soil Loss Equation (USLE) in combination with the inventoried land uses, it was determined that reduced tillage and no tillage practices were the most cost effective methods of obtaining needed sediment and phosphorus reductions. Attainable sediment reductions using these methods were estimated as ranging from 47 percent to 69 percent. Little or no costs needed to be imposed on agriculture to achieve these reductions (Ref 6). The tributary diffuse source loading of phosphorus to Lake Erie was estimated as 9,710 mt/yr (Ref 3). Phase II analyses indicated that maximum achievable reductions using reduced tillage would be 2,800 to 3,400 mt/yr, whereas a maximum conservation tillage program (i.e. combination of reduced and no tillage) has a potential for reducing phosphorus loadings by 4,100 to 5,100 mt/yr. Other tillage conservation practices including the use of cover crops or elimination of fall plowing had only minimal efficiency in reducing sediment and phosphorus losses.

Adoption of reduced tillage or no tillage on selected soils, was found to be economically feasible for farmers. Approximately 75 percent of the basins soils were estimated to offer farmers marginal economic incentives for the adoption of reduced tillage or no tillage. A study was conducted in 1979 to determine the current degree of adoption of these technologies. Approximately one-fourth of the row crop acreage was tilled by reduced tillage or no tillage. This proportion was up sharply from a decade earlier when little reduced tillage or no tillage was used. Apparently, many farmers have recognized the benefits of reduced tillage and have been slowly adopting it. Unfortunately, the benefits have not been large enough to encourage rapid adoption of this technology.

Phase II analyses showed that the Western Basin is the greatest contributor of sediment and phosphorus to Lake Erie with an estimated 66 percent of existing potential gross erosion in the Western Basin. The intensive agricultural land use and relatively high clay content of Western Basin soils account for greater losses of sediment and phosphorus. For this reason Western Basin watersheds were targeted for demonstration and implementation of conservation tillage in the Phase III program.

It is known that much of the phosphorus native to soils is chemically bound and either unavailable or slowly available for biological assimilation. Fertilizer phosphorus is readily available when first applied but quickly becomes "fixed" by the soil. Long-term soil fertility research has shown that only about 10-20 percent of fertilizer remains available for crop growth after addition (Ref 7). A study commissioned under Phase II of LEWMS (Ref 8) concluded that sediments from the high clay agricultural basins in western Ohio should have the highest proportions of bioavailable phosphorus, more apt to contribute to algal blooms. In the Central and Eastern Basins the contribution of sediment phosphorus to algal growth is diminished because of lower sediment loads, lower bioavailable sediment phosphorus and shorter contact time between algae and sediment because of more efficient settling in the deeper waters. This conclusion reinforced selection of the Western Basin for Phase III emphasis.

During Phase II Study, Logan (Ref 7) found that phosphorus levels in Lake Erie Basin soils were often at or above requirements for optimum crop yields. It was concluded that overfertilization of basin soils could result in inordinately high levels of bioavailable phosphorus in runoff.

The methodologies developed during Phase II of LEWMS enabled the identification of priority watersheds and counties where the application of Best Management Practices can be most effective in reducing soil and phosphorus losses. It was concluded that education, demonstration, and technical assistance programs were needed to accelerate the adoption of practices in these areas.

Finally, it was concluded that environmental benefits of erosion control extended well beyond phosphorus reduction. Other benefits included: reduced sedimentation and reduced dredging costs in Lake Erie harbors and drainage ditches, lower water treatment costs for sediment removal from domestic water supplies, less movement and transport of other sediment attached pollutants such as insecticides and herbicides, and reduced in-stream sedimentation which benefits the fishery resources.

1.4.3 LEWMS Phase III.

Phase III of LEWMS involved implementation, evaluation, and demonstration of phosphorus reduction techniques in selected watersheds using knowledge and methodologies developed during Phases I and II.

A special demonstration project, The Honey Creek Watershed Management Program (HCWMP) was initiated in 1978 as part of LEWMS. Through contracts with a Joint Board of Supervisors of Huron, Crawford and Seneca SWCD's of Ohio, funds were provided for technical assistance manpower, education programs, and application of conservation tillage and other management practices. Objectives were to demonstrate that the local agricultural agencies and Soil and Water Conservation District's (SWCD's) working with individual farmers could bring about changes in agricultural land management practices. Major thrusts were directed towards conservation tillage with increased one-to-one technical assistance and demonstration plots. A comprehensive inventory of needed management practices and identification of priority critical areas for the 120,000-acre watershed was completed. Two monitoring stations were established and are being maintained.

The HCWMP has been used extensively as a showcase and model for other conservation districts, other States, other projects, and even several Canadian agricultural groups. Emphasis has been placed on local farmer and local agricultural agency participation through county task forces in the planning and implementation of the entire project. Additional funding support for conservation tillage and other BMP's was provided by a special Agricultural Conservation Program (ACP) water quality project. Results of the HCWMP are detailed in Section 6.1 of this report.

Five additional Watershed Management Studies were undertaken as a part of LEWMS. The studies were scattered throughout the Lake Erie basin to look at different critical land forms, land uses, soils, and geographic areas. These watersheds were selected to represent various conditions in the basin. The five basins are: the South Branch of Cattaraugus Creek (NY); West Branch Rocky River (OH); Bean Creek (MI); Ottawa River (OH); and the Sandusky River (OH). The studies involved local agricultural agencies and agricultural interest groups in the study process. Each study included baseline water quality monitoring, identification of major problems, needed BMP's for watershed treatment, and proposed implementation work programs. Educational programs, technical assistance and administration, estimates of costs, and proposed implementation schedules are a part of each report. These studies are described in more detail in Chapter 6.

County Resource Information System Packages (CRISPS) were prepared for 28 counties in the U.S. portion of the basin. These are compendia of information derived from the Lake Erie Wastewater Management Study's Land Resources Information System. They consisted of maps and tabular information summaries which depicted current conditions and projected conditions under alternative land management strategies. A county listing of CRISP packages and description of information in them are contained in Chapter 6.

The profitability of alternative tillage systems were evaluated on a sample of farms within the basin. Results supported the contention that adoption of reduced tillage and no t llage on appropriate soils need not significantly reduce net income.

Findings of the HCWMP, the five watershed managements studies, plus other information and data from water quality projects and special tillage programs were instrumental in the development of the final LEWMS conclusions and recommendations included in this report.

A strategy for widespread implementation of agricultural practices for reducing phosphorus and sediment loadings to Lake Erie was developed. The potential economic, physical and biological impacts of the proposed program are described in this report.

1.4.4 Public and Agency Coordination.

Newsletters, press releases, a special public involvement mailing, conferences, membership in outside working groups, and an interagency technical advisory group have been used to advise the public of this study.

In place of a public meeting to discuss alternatives, a special mailing of a Public Information Fact Sheet was made in October 1977. Over 6,000 people received this special mailing. The purpose of the fact sheet was to inform the public about the Lake Erie Wastewater Management Study and to elicit comment from the public on the status and proposed conduct of LEWMS. The comments received were compiled and are available for review at the Buffalo District Office. A mailing of the information bulletin Phosphorus Management in the Lake Erie Basin was made in 1980. This bulletin described Phase II results.

In addition to presentations to farm organizations and civic groups, LEWMS staff planned and participated in a series of three research coordination conferences held at Heidelberg College in Tiffin, OH. The purpose of these conferences was to exchange information on nutrient transport in rivers, land use - water quality relationships and Sandusky River basin research in particular. Out of these meetings came a consensus that a research demonstration program was the only way to answer many unresolved questions. The Honey Creek basin in the Sandusky River basin was a logical area because of the excellent data base which existed there. From these meetings Seneca, Crawford, and Huron Counties Soil and Water Conservation Districts formed the Honey Creek Watershed Joint Board of Supervisors. This Joint Board provided the institutional and legal means of carrying out the demonstration project in Honey Creek. A major emphasis of this project was conservation tillage.

Phase III of LEWMS involved extensive coordination with groups at local, State and Federal levels of Government. At the grass roots level, the cooperation and efforts of local Soil Conservation Districts (SCD) or Soil and Water Conservation Districts (SWCD's) was most effective in explaining the merits of conservation tillage to the local farmers and encouraging their participation. Since the numerous watershed programs included more than one county, individual SCD's or SWCD's formed ad hoc joint boards for the special purpose of promoting program goals.

Numerous USDA agencies provided valuable technical, educational and promotional assistance, and worked closely with the Corps of Engineers to develop the watershed management programs for the five watershed study areas. The Soil Conservation Service provided soils and land use inventory data, soil erosion data, and erosion control data. The Agricultural Stabilization and Conservation Service (ASCS) provided information of crop acreages and yields, and provided Agricultural Conservation Program (ACP) funds for inducing individual farmers to participate in early demonstration programs (i.e., allotments for acreage in conservation tillage).

The Cooperative Extension Service (CES) offices provided needed educational assistance to inform farm organizations and individual farmers of the technical details of conservation tillage practices, and the benefits and potential problems associated with conservation tillage. Researchers from Land Grant Universities provided agronomic and economic information and assisted LEWMS staff in designing and implementing the study.

Coordination between the Federal/State agencies and the Corps was facilitated through the formation of an "Interagency Technical Advisory Group" (ITAG) which met once or twice each year to clearly establish direction of the LEWMS and the participatory roles of each agency in meeting objectives and goals of the study. Members of ITAG kept the LEWMS staff informed on current policies of Government or agencies which they represented.

Important coordination and joint effort with USEPA was carried out through the Great Lakes National Program Office (GLNPO). Under Section 108(a) of the Clean Water Act, EPA funded no till demonstration programs in 22 counties in Ohio, counties in Indiana and two counties in Michigan. The Corps has made the land resources inventory data acquired during the LEWMS study available to the local agencies.

The Corps of Engineers County Resource Information System Packages previously described, have been provided as planning aids to 28 local agencies including SCS offices, SCD's, SWCD's, ASC offices, and regional planning and development organizations.

The staff of LEWMS has served on several work groups concerned with controlling diffuse sources of phosphorus. These groups are: (1) Task Group III, a technical group to review phosphorus loadings for the Fifth Year Review of Canada-United States Great Lakes Water Quality Agreement; (2) Phosphorus Management Strategies Task Force under the Research Advisory Board of the International Joint Commission; (3) Technical Advisory Group for Task C, River Basin Studies; under the Pollution from Land Use Activities Reference Group (PLUARG) of the IJC; (4) Nonpoint Source Work Group for the Fifth Year Review of Canada-United States Great Lakes Water Quality Agreement; (5) Public Consultation Panel for PLUARG; (6) State of Ohio's Undesignated Area 208 Technical Advisory Committee; and (7) the Great Lakes Basin Commission's work group on coordination of Areawide Water Quality Management Planning activities with Great Lakes water quality objectives.

1.5. RELATED PROGRAMS

Public Law 92-500 (Federal Water Pollution Control Act Amendments of 1972) which authorized the Corps of Engineers Lake Erie Wastewater Management Study stated that the study was to be in addition to other waste studies aimed at eliminating pollution from sources around Lake Erie. A number of programs complementary to this study and their interaction with LEWMS are discussed in this section. These include the Pollution from Land Use Activities Reference Group (PLUARG) studies initiated by the International Joint Commission in 1972, Section 208 studies authorized by Public Law 92-500 as amended by Section 35 of the Clean Water Act of 1977, and Section 108(a) projects authorized by Public Law 92-500.

Section 208 of the 1972 Federal Water Pollution Control Act involving Areawide Waste Treatment Management was amended by Section 35 of the 1977 Clean Water Act to include a new subsection 208(j). This subsection enabled the Secretary of Agriculture to enter into contracts with individual landowners (farmers) to incorporate best management practices (BMP) on the land to control nonpoint pollution for improving water quality. In return, the Government provides technical assistance and cost sharing for implementation of BMP's. Administration of the program is carried out through soil conservation districts, State soil and water conservation agencies or State water quality agencies. Authority for 208 expires on 30 September 1982. USDA and EPA are not recommending an extension.

Section 108(a) of the 1972 Federal Water Pollution Control Act enabled the Administrator of the USEPA to enter into agreements with other Federal agencies to demonstrate new methods and techniques and develop plans for control of pollution within the Great Lakes watersheds. Progress made under Sections 108 and 208 legislation and relationship to the LEWMS Program are discussed in Chapter 6.

1.5.1 Pollution From Land Use Activities Reference Group (PLUARG).

The Governments of Canada and the United States requested, in a reference dated April 1972, that the International Joint Commission study and make recommendations on the extent and cause of pollution from land use activities in the Great Lakes Basin and on possible remedies. The basic questions asked by the Governments were: are the boundary waters of the Great Lakes system being polluted by land drainage from land use activities? If such pollution is occurring, by what causes, to what extent, and where is the pollution taking place? What remedial measures would be most practicable to deal with such pollution, and what would be their probable cost? The Commission was also asked to assess the adequacy of existing programs and control measures for addressing nonpoint pollution.

The IJC concluded in its final report that the Great Lakes are being polluted from land drainage sources (Ref 9). Such pollution occurs most seriously from land areas of intensive agricultural and urban use. The most significant pollutants from these sources are phosphorus, sediments, a number of industrial organic compounds, pesticides, and some heavy metals.

PLUARG estimated that land use activities contribute from a third to a half of the total phosphorus loads to the various lakes. The highest loadings are associated with the most heavily polluted lakes, Erie and Ontario. The movement of phosphorus downstream from one lake to another, and deposition of phosphorus from the atmosphere are also significant sources in some lakes.

Cropland was found to be the major source of nonpoint loads, especially in areas characterized by high density row crops and fine-grained (clay) soils, notably northwestern Ohio, southwestern Ontario and southern Wisconsin, and where insufficient attention is paid to soil conservation and drainage practices.

PLUARG's conclusions reaffirmed the LEWMS Phase I conclusion that diffuse sources must be controlled to restore Lake Erie, and prioritized Lake Erie as a problem area. PLUARG also concluded that the most important land related factors affecting the magnitude of pollution from land use activities in the Great Lakes Basin were found to be soil type, land use intensity, and materials usage. Areas of high phosphorus loading from intensive agricultural activities such as northwestern Ohio are examples of these areas.

PLUARG pointed out the need to further study the cost effectiveness and socio-economic tradeoffs of various remedial alternatives available for nonpoint source control as well as the short and long-term effectiveness of various remedial measures, or alternatives for controlling erosion and sedimentation of fine-textured soils.

PLUARG recommended a methodology whereby problem areas are defined on a priority basis to which the most practicable control means for a particular source are applied. It also recommended the development and implementation of information, education, and technical assistance programs.

The Land Resources Information System (LRIS), developed during Phase II has been the ideal method to carry out PLUARG recommendations. With it, LEWMS identified problem areas in the Lake Erie drainage basin in which available resources could be most cost-effectively directed to reduce sediment and phosphorus losses.

LEWMS has been able to determine the economics of alternative tillage methods and will be able to develop cost-effective programs. LRIS was used in development and implementation of information, education, and technical assistance programs of Phase III. PLUARG provided a Great Lakes-wide perspective. LEWMS provided the detail and focus needed to develop an effective plan for Lake Erie.

1.5.2 Phosphorus Management Strategies Task Force.

During the period of the negotiation of the 1978 Great Lakes Water Quality Agreement by the Governments of the United States and Canada (Ref 5), the Task Force on Phosphorus Management Strategies was established by the Great Lakes Science Advisory Board to assess alternative phosphorus management strategies for the Great Lakes. Staff from the LEWMS were included on this Special Task Force. The Terms of Reference and membership of the Task Force were expanded in 1979, becoming a joint activity of the Great Lakes Science Advisory and Water Quality Boards, in order to address a number of additional related topics. These included certain inconsistencies between the findings on present and target phosphorus loads by PLUARG, the Water Quality Board, and Task Group III which was the binational governmental working group established to review these matters in preparation for the negotiation of the 1978 Great Lakes Water Quality Agreement.

An interim report addressing several specific questions asked by the Governments was provided by the Task Force to the Commission in December 1979, and was forwarded without comment to the Governments. Subsequent to this interim report, the Commission's Report, Pollution in the Great Lakes Basin from Land Use Activities (Ref 9), contained interim findings on phosphorus inputs and appropriate target loads, but the Commission withheld its final conclusions and recommendations on optimal phosphorus management strategies pending its receipt of the final report of the Task Force.

The final report of the Task Force entitled, Phosphorus Management for the Great Lakes (Ref 10), was completed in July 1980, and was forwarded to the Governments of the United States and Canada, at their request, immediately following its receipt and prior to its review by the Commission. The report was reviewed by the Science Advisory Board, the Water Quality Board, and the Commission in order to provide recommendations on phosphorus management strategies for the Great Lakes Basin.

The Commission concurred with the Task Force in confirming the earlier finding that the "future phosphorus load" (i.e., 11,000 mt/yr for Lake Erie) in Annex 3 of the 1978 Agreement is a valid target load for phosphorus control efforts.

For Lake Erie, the goal in Annex 3 is the restoration of year-round aerobic conditions in the bottom waters of the Central Basin. The target load of 11,000 metric tons, however, is predicted by Task Group III to reduce the anoxic area in the hypolimnion by 90 percent. If the goal for Lake Erie is the complete elimination of the anoxic area, the annual phosphorus load should not exceed 9,500 metric tons. The Task Group stated that this lower target load would "ensure optimum conditons for fish in the Central Basin hypolimnion," with respect to oxygen.

Most recently, a draft supplement to Annex 3 of the 1978 Great Lakes Water Quality Agreement, prepared by the USEPA in November 1981, reaffirmed the Lake Erie target load of 11,000 mt/yr. This supplement estimated that if all municipal wastewater treatment plants over 1 million gallon/day achieve 1 mg/1 phosphorus concentration in effluents, loadings to Lake Erie would be reduced to 13,000 mt/yr. Therefore, further reductions totaling 2,000 mt/yr would be required to achieve the targeted goal of 11,000 mt/yr. The targeted further phosphorus reductions in the U.S. part of the basin is 1,700 mt/yr. Information compiled during the LEWMS program and presented in this report suggests that all of this reduction can be achieved through reasonably reducing phosphorus losses from agricultural land in the basin.

1.5.3 Position Paper on the Great Lakes.

This paper was signed in April 1981 by the Regional Administrator of USEPA Region V, the Chief of Soil Conservation Service and the Division Engineer, North Central. Its purpose was to establish a framework for the coordination of the activities of the agencies in the Great Lakes Basin. The focus of this coordination is to foster accelerated implementation of agricultural nonpoint source pollution control programs where nonpoint sources preclude the achievement of the target goals contained in the Great Lakes Water Quality Agreement of 1978. The points of agreement and the new agricultural nonpoint source initiative follow.

- A coordinated effort is desirable and necessary to meet the phosphorus target loads required by the Great Lakes Water Quality Agreement of 1978.

- The initial focus should be on the lower Great Lakes. The Lake Erie Basin will be targeted because nonpoint sources are proportionately larger contributors of phosphorus and because of the availability of the Lake Erie study data base.

- The Public Law 92-500, Section 108, Black Creek, Indiana, demonstration and the Corps of Engineers demonstration area in the Honey Creek, Ohio, sub-basin have demonstrated that effective nonpoint source phosphorus control is feasible and that excellent acceptance of a voluntary program can be obtained.

- Although these demonstrations have been useful in gaining knowledge about how to approach the problem, the geographic areas involved have been small. There is sufffficient information available now, and being developed by other demonstrations within the basin and the Saline River 1980, Rural Clean Water Project, to begin a coordinated nonpoint implementation program.

- There are other agencies within the Department of Agriculture that need to be included in future discussions, and their active participation solicited.

- The USDA Work Group on Water Quality will be utilized by SCS to inform and coordinate involvement by USDA agencies.

- Maximum use will be made of the water quality management plans developed under Public Law 92-500, Section 208.

- The State and areawide water quality management agencies and State agricultural nonpoint source committees will be made aware of this initiative, and their active support solicited by Region V EPA.

- An interagency project review team should be established to effectively coordinate targeted resources, if the States endorse this position paper.

- The Great Lakes National Program office of EPA should take the facilitator role in the development of the framework plan for the coordination of the agencies' activities in the Great Lakes Basin."

<u>A new agricultural nonpoint initiative</u>. Representatives of USEPA, Corps of Engineers and U.S. Department of Agriculture have been working together to mount a joint effort to address critical sources of agricultural nonpoint sources of phosphorus in the Lake Erie Basin. Enough has been learned through demonstration projects. New management practices can now be implemented on a wider scale.

There were two themes running through the new interagency initiative: immediate implementation of low cost, high yield measures and the identification of critical areas. Both themes resulted from the recommendation of PLUARG and the Phosphorus Management Strategies Task Force.

The southwestern portion of Lake Erie, from approximately the Cuyahoga River westward to the Detroit River, is an area of high priority concern. This is due to the naturally high levels of phosphorus present in the fine textured; easily erodible soils in the Defiance Moraine. Also within the area, most soils are amenable to erosion and phosphorus control through tillage practices, which leave crop residues sufficient to significantly reduce the erosive force of rainfall and runoff events.

As a consequence of extensive evidence documented by the Corps of Engineers, it is concluded that a major effort should be made to obtain acceptance of reduced tillage practices throughout the Defiance Moraine on suitable soils.

Beyond treating the general area of the Defiance Moraine as an area critical to Lake Erie there is a need to identify hydrologically active areas where additional practices should be implemented. This effort will go forward along with limited monitoring and modeling for prediction and evaluation."

REFERENCES

1. U.S. Army Corps of Engineers, Buffalo District, "Lake Erie Wastewater Management Study, Preliminary Feasibility Report," Volumes I, II, III, Buffalo, NY, December 1975.

2. Great Lakes Water Quality Board, "1981 Report on Great Lakes Water Quality, Appendix III, Agreement Progress," Cleveland, OH, 1981.

3. U.S. Army Corps of Engineers, Buffalo District, "Lake Erie Wastewater Management Study Methodology Report," Buffalo, NY, March 1979.

4. Task Group III, "A Technical Group to Review Phosphorus Loading, Fifth Year Review of Canada-United States Great Lakes Water Quality Agreement, February 1978.

5. International Joint Commission, "Great Lakes Water Quality Agreement of 1978" (agreement with annexes and terms of reference between the United States and Canada signed at Ottawa), 22 November 1978.

6. Forster, D. L., "Economic Impacts of Changing Tillage Practices in the Lake Erie Basin," LEWMS Technical Report, U.S. Army Corps of Engineers, Buffalo District, August 1978.

7. Logan, T. J., "Levels of Plant Available Phosphorus in Agricultural Soils in the Lake Erie Drainage Basin," LEWMS Technical Report, U.S. Army Corps of Engineers, Buffalo District, December 1977.

8. Logan, T. J., Verhoff, F. H., DePinto, J. V., "Biological Availability of Total Phosphorus" LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo District, January 1979.

9. International Joint Commission, "Pollution in the Great Lakes Basin from Land Use Activities," March 1980.

10. International Joint Commission, Phosphorus Management Strategies Task Force, "Phosphorus Management for the Great Lakes," July 1980.

CHAPTER 2 - LAND USE, LAND RESOURCES AND LAND MANAGEMENT IN THE LAKE ERIE BASIN

2.1 ORIGIN OF POLLUTANTS

The manner in which pollutants are introduced into the water environment can be broadly classified into point source and nonpoint (diffuse) sources. A reliable determination of diffuse source loading is difficult because of the complex transport processes involved in moving pollutants from their source to the receiving waterbody. Included in this category of diffuse sources are sediment production from rural areas, urban runoff, and atmospheric fallout. These processes are not easily quantified; however, their importance should not be underestimated.

A common factor in the generation of diffuse source loading is the precipitation-runoff event. The physical transport process begins with the initial material detachment from the earth's crust resulting from the impact of atmospheric precipitation and the erosive transport during runoff. Atmospheric loading is also enhanced by the natural scavenging of precipitation as it falls through the air mass above a waterbody and its drainage basin. It can be imagined that diffuse source pollutants are transported intermittently through a drainage basin by each precipitation-runoff event and that the larger and less frequent runoff events would be the most significant in terms of moving pollutants ever closer to the receiving waterbody.

The precipitation-runoff event does not discriminate between naturally occurring materials and those introduced by man's activities. Thus, measurements of diffuse source loading will inevitably include a "background" portion that could be attributed to the natural occurrence of some substances. There are, however, unmistakable increases due to the activities of man that depend upon the way he has chosen to use land and the materials that are deliberately or inadvertently spread on the land surface. The application of deicing salts on streets and highways and the application of fertilizers on agricultural land are examples of deliberate spreading. The fallout of lead onto streets and the adjacent lands from automobile exhausts could be classified as inadvertent spreading.

Thus, the determination of the origins of diffuse source loading is complicated by two factors. The first relates to the complexity of the transport processes that ultimately produce a measureable quantity of pollutant and the second relates to the difficulty in discriminating between the "background" portion of this measured load and that which can be attributed to man's activities.

It is apparent from this discussion why point sources have received the most attention in water quality management. The origins of pollutants contained in point source loadings are more easily determined and are almost always the result of man's activities. Point source wastewater streams frequently are carried by man-made conduits and lead either to specific treatment sites or directly to a receiving waterbody. Most of the resources expended to the present for water pollution control have been devoted to the management of point source loading.

Diffuse source loading is now recognized as a significant contributor to the overall balance of pollutants in the water environment. It has been demonstrated as a result of the findings of this study that diffuse sources account for more than one-half of the total phosphorus loading to Lake Erie. In the Maumee River Basin, approximately 80 percent of the total phosphorus loading discharged to Lake Erie originates from diffuse sources. In some other areas of the U.S. Lake Erie drainage basin, diffuse sources make up a smaller fraction of the total loading.

The relationships between land use activities, the physiography of the land resource, and pollutant production will be discussed in this chapter.

2.1.1 Land Use and Point Source Loading.

The historical development of population centers on navigable waterways is the most important factor relating land use to point source loading. The availability of the same water for domestic and industrial use has resulted in the creation of numerous point sources of pollutant loadings where the degraded water is returned to the waterbody. These point source discharges are generally directed into the lake or tributary river. These direct discharges into the lake are of particular concern because pollutants can impact on the Lake Erie ecosystem without opportunity for intermediate processes that tend to mitigate the effect of the pollutant. For instance, soluble phosphorus contained in near-lake point source loadings is immediately available for biological uptake, while inland phosphorus discharges interact with suspended sediments in the stream and are only partially available for direct biological uptake when they enter the lake. Similarly, biochemically-oxidizable pollutants contained in the point source discharges of these inland communities exert a demand for instream dissolved oxygen which is generally satisfied before reaching the lake.

Another tier of communities has developed which frequently do not make direct use of a water course. Most of these communities are without industry and are too small to have installed sewage collection systems and central waste treatment facilities. Many residences in these communities utilize septic systems with leach fields, often where soils are unsuitable for such uses. In many instances, widespread failure of septic systems causes severe effects on local streams and water bodies, however, it has a relatively small contribution to Lake Erie water quality problems.

2.1.2 Land Use and Diffuse Source Loadings.

In contrast to the point sources which originate from a discrete number of locations and contribute a relatively small volume of water, pollutant loading from diffuse sources originates from all parts of the drainage basin and the water volume is very large. Diffuse source pollution is not amenable to treatment in the usual sense of the word. The only practicable approaches to reducing diffuse source loading are reduction in the application of the pollutant to the land surface and/or reduction in the quantity of the pollutants being transported to the lake by the precipitation-runoff process.

Although the first approach has merit and is part of the fertility management program, the focus of the present study has been on devising control measures which either prevent or reduce the amount of pollutants leaving the initial application site.

To this end, it has been necessary to identify land use and land resource characteristics and to assess areas in terms of potential gross erosion and potential for erosion control. The study concentrated on soil erosion as a source and sediment as a carrier of phosphorus. This identification process reduced the land area to be considered in terms of active contribution of phosphorus to Lake Erie. The portion of the drainage basin that is active in terms of its contribution of phosphorus, although large in extent, can be dealt with much more effectively than the entire drainage basin tributary to Lake Erie.

Diffuse source loading from urban land areas is, in general, not related to soil erosion. The urban landscape is usually dominated by extensive areas of impervious surfaces. Runoff from such surfaces is rapid and the washing of waste residues from streets, parking lots, and roof tops generates the diffuse source pollutant load. The magnitude of this load will depend in large part on the type of land use, the intensity of use (particularly automobiles), and the housekeeping practices of the community.

The IJC PLUARG Study (Ref. 1) estimates that 21 percent of diffuse phosphorus loadings to Lake Erie are from urban sources, whereas 66 percent of diffuse phosphorus loadings are from agricultural land use. This study focuses on describing and quantifying sediment and phosphorus loadings to Lake Erie from agricultural lands under existing conditions and under improved land management practices.

2.1.3 The Erosion Process.

In order to describe and estimate sediment and phosphorus losses from agricultural land, it is first necessary to understand erosion processes. Soil erosion can be divided into three categories: gully, rill, and sheet. Gully erosion occurs when concentrated surface runoff is allowed to flow over unprotected areas and cause excessive soil detachment and loss of soil particles. As volumes and rates of flow increase, the resultant erosion scar becomes deeper and wider. Normally, gully erosion is described as those eroded areas which cannot be easily crossed with farm equipment or cannot be eliminated with conventional tillage methods.

Although very damaging to farm operations and a cause of sedimentation in streams, the subsurface horizons of soil removed by gully erosion do not contain significant amounts of biologically available phosphorus, nor is the mass of gully eroded soil large compared to the mass contributed from the other categories. While gully erosion is not considered to be a significant contributor to the Lake Erie phosphorus load, it is a part of the entire erosion-sediment-nutrient loading process that must be addressed.

Streambank erosion can be considered to be an extended case of gully erosion. Studies in the United States drainage to the Great Lakes have shown that it accounts for 1 to 10 percent of the total sediment yield (Ref 2).

Sheet and rill erosion are considered together and include the bulk of eroded soil mass and the soil fraction containing the biologically available phosphorus. Sheet and rill erosion is defined as the detachment and transport of soil particles by raindrop impact and unconcentrated water runoff. The largest component of sheet erosion occurs with the initial raindrop impact. Soil particles are dislodged and suspended in the water. When this water runs overland it may detach additional soil particles or drop some of the previously suspended soil. As this water collects into concentrated channels its kinetic energy is again increased to the point that it can erode soil, and rills are formed as the flow cuts into the soil. These channels are considered rills until they can no longer be obliterated by annual tillage operations. Beyond this point rills become gullies. Sheet and rill erosion of agricultural lands account for most of the diffuse source loading of total phosphorus to Lake Erie. The factors which affect sheet and rill erosion from agricultural lands involve land use intensity, land form, soil type, and climate. The vegetative cover on a particular parcel of land can easily dominate all other factors in assessing the potential and the rate of sheet and rill erosion. The details of land form, such as slope and length of slope, and soil texture, are important variables determining the rate of erosion and the quantity of sediment produced. The frequency, duration, and intensity of precipitation events are the primary climatic factors that interact with the seasonal soil cover variations on agricultural lands to produce greater or lesser quantities of sheet and rill erosion. Winter rains on uncovered soils can produce erosion and sediment delivery far in excess of that produced during summertime periods when the soil is covered with vegetation and infiltration is greater.

2.2 THE LAND RESOURCE INFORMATION SYSTEM (LRIS)

The factors which in concert determine the loss of soil, phosphorus, and other materials of concern from the land were discussed in general in the previous section. In order to develop a system which can predict sediment and phosphorus (or other materials) losses, it becomes necessary to systematically inventory these factors as they are spatially distributed on the land. Because of the many combinations of factors which occur on the land surface and frequent changes from one area to another, it was necessary to develop a computerized system for encoding the combinations or "cooccurrences" of land resource features as they occur on the lands of the Lake Erie Basin. This section describes the Land Resource Information System (LRIS) developed under the LEWMS program and its application for inventory and evaluation of land management practices for reducing sediment and phosphorus loadings to Lake Erie. Although the system is applied to the Lake Erie Basin at this time, it can be universally adapted to the entire Great Lakes or indeed to all major or minor river and lake basins throughout the United States.

2.2.1 Requirements of System.

It was determined early in the LEWMS study that the LRIS data base had to spatially express the existing natural and cultural features within the Lake Erie Basin in a format that would satisfy the various study objectives. Within given time and funding constraints, the system was designed to satisfy three basic needs of the LEWMS data base.

a. Coverage of the entire U.S. portion of the Lake Erie Drainage Basin.

b. Measurement of land features in a manner which will allow the generation of statistics for all desired combinations of features (cooccurrences) which characterize a watershed, political division or planning unit.

c. Generation of output from the LRIS must meet the requirements of input parameters for all modeling components, including hydrologic, chemical, and land use management modeling.

While the primary objective in developing this data system was the restoration of Lake Erie water quality, the Corps was well aware of its broad potential as a long range planning tool for other applications, from air quality and solid waste studies to economic and demographic analysis. For this reason and the fact that data inputs are continuing over time, the LRIS should be viewed as a dynamic rather than a static system, to be expanded upon and improved as the needs of the Lake Erie community evolve.

2.2.2 Data Sources and General System Design.

It would have been impossible in the timeframe and dollar constraints to complete the development of a data base for the Lake Erie Basin if major sections had not already been completed by other agencies. These existing data base sets, including the Toledo Metropolitan Area Council of Governments (TMACOG), Southeast Michigan Council of Governments (SEMCOG) and the State of Ohio's Ohio Capability Analysis Program (OCAP), (Map II-1) serve as the foundation of this system and were integrated with the remaining portions of the basin. While various details are slightly different within each system, the basic structure and composition were sufficiently similar to allow the merging of data systems.

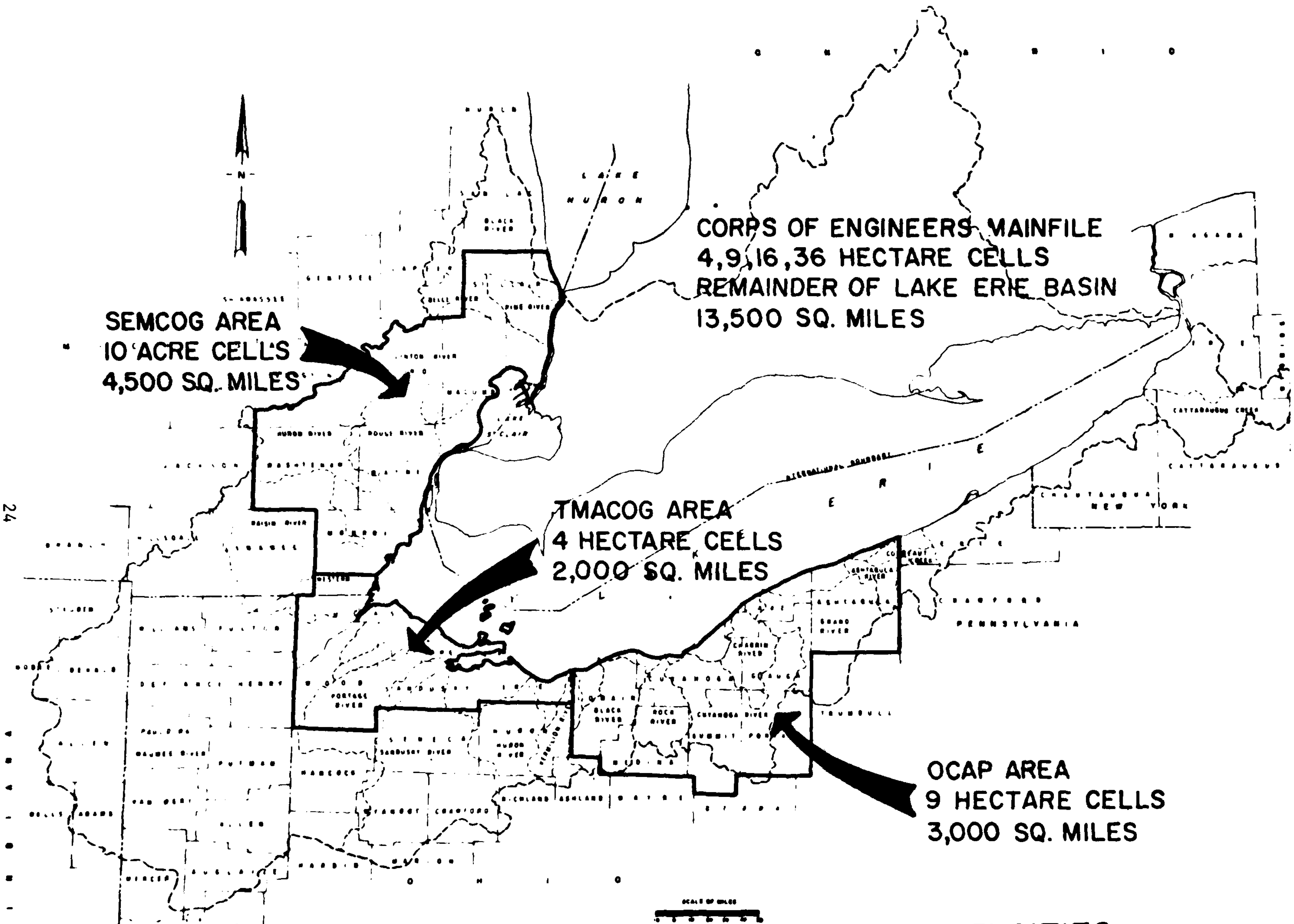
Characteristics of the four major data sources employed were as follows:

a. Toledo Metropolitan Area Council of Governments (TMACOG) uses a 200-meter square/UTM (Universal Transverse Mercator) grid and includes data on land use, soils, watershed, and political unit;

b. Southeast Michigan Council of Governments (SEMCOG) uses a 660-foot square grid referenced to Michigan State Plan coordinates and includes data on soils, watersheds, political units and land use. Much of the original data was digitized as polygons and converted to cells in this study.

c. Ohio Capability Analysis Program by ODNR (OCAP) uses a line digitizing method which has been converted to approximately a 9-hectare cell. It is not tied directly to any coordinate system, but orientation is based on latitude and longitude. Data includes land use, soils, watershed, and political unit; and

d. Corps of Engineers (COE) Main File, uses a variable cell size with either 200-, 300-, 400-, or 600-meter square cells. Reference is to the UTM coordinate system. Data is included on land use, soils, watershed, and political unit.



MAP II-1 LRIS DATA SOURCES AND SAMPLING DENSITIES

The Lake Erie LRIS is a variable cell size, multiparameter system for encoding spatial data by a random point/cell digitizing procedure. That is, each cell or unit of land surface (varying from 4 to 36 hectares) is encoded for each parameter (soil type, land use, etc.) at a randomized point location within each cell (Map II-1).

In order to keep the costs of data collection within limits, the size of grid cells varies over the basin, depending primarily on the size of drainage basins above chemical sampling stations (Map II-1), and on the complexity of data encoded. Thus, the Sandusky Basin Tributary of Honey Creek, a pilot research project area with subbasins of less than 15 square miles, was coded at four hectares and the Auglaize River (2,900 square miles), a tributary of the Maumee Basin, was coded at 36 hectares. The smallest cells are those comprising the TMACOG system (200 meters on the side) and the largest (600 meters on a side) were used in much of the Maumee River Basin.

A fundamental objective followed in design of LRIS, was to allow the development of statistics, aggregated by drainage basin, political unit or other spatial boundary, summarizing the combinations of factors which comprise an area. The use of information in this format was of great importance, both from a water quality analysis and a land management planning point of view.

After the data had been compiled from TMACOG, SEMCOG, and OCAP and reorganized into a format which allowed manipulation it was decided that that data organization was very cumbersome. The various parts of the data base still retained their original cell sizes and geographic coordinate system references. Since the parts of the data base were generally established along political boundaries it was easy to do work on units such as counties, but extremely difficult to manipulate hydrologic units which obviously transcend political boundaries.

In order to solve this problem, and to begin to organize the LRIS into an information system which could be manipulated by noncomputer specialists, the six different "pieces" of the LRIS were resampled into a common cell size on the geodetic (latitude and longitude) coordinate system.

In this new structure any hydrologic or political unit can easily be retrieved from the LRIS by simply specifying the latitude and longitude of a rectangular window which surrounds the area of interest within the data base.

Details of the computer system used for land resource inventory under the LEWMS study are given in the report entitled "Lake Erie Basin Land Resource Information System" and accompanying "User's Manual" (Ref 3).

2.2.3 Elements of Data Base.

This section describes the land resource information which comprises the data files for the United States portion of the Lake Erie Basin. Data files include the following:

a. Soil Phase and Auxiliary Soils Properties Files

b. Land Cover

c. Drainage Boundaries

d. Political Boundaries

2.2.3.1 Soil Phases and Auxiliary Soils Properties Files - Probably the most important natural feature determining the amount of sediment and runoff generated by agricultural and other land use activities is the soil type on which these activities are located. Soils information is therefore the most critical element of the LRIS. Soils properties were used in the analysis of land management alternatives with the Universal Soil Loss Equation (USLE) and to determine values for parameters of the hydrologic model.

The U.S. Department of Agriculture Soil Conservation Service (SCS) Soil Survey information is the primary data source for soils information. The SCS map soil type information on a county basis. Map II-1 shows the 63 counties in New York, Pennsylvania, Ohio, Indiana, and Michigan that are partially or totally within the Lake Erie Basin. The status of SCS mapping in these counties is reported in the User's Manual. Approximately half of the county surveys are in published form, but nearly all of the remainder are either in draft or underway.

Where modern soil surveys were published or in progress the unit of coding was soil phase, which defines the soil series name, its texture and the slope upon which the mapping unit was observed. Soil phases are the best soil data available in the LRIS. In some counties only older reconnaissance soil surveys were available. These surveys make only the soil series and sometimes slope available for coding. In other counties no soil survey has ever been completed. In these areas it was possible only to obtain the soil maps for individual farm surveys. In all counties where it was necessary to use old surveys SCS soil scientists were consulted to assess the quality of the survey and update the soil naming conventions used in the old surveys so that modern soil properties information could be utilized.

The code for each soil which is stored in the LRIS data base is actually a reference address for the location of the properties of that soil. Obtaining all of the data for a soil is a two-step process. The first file accessed includes data which is county dependent, including the symbol used in that county's survey, the computed soil loss for cropland on that soil in that county, a best management practice, any notes about the soil, and the address of additional noncounty dependent data in the Soil Properties File. This first file called the Phase File contains the records for 8,739 mapping units found in the soil surveys of the 62 counties in the Lake Erie Basin.

The Soil Properties File contains highly detailed information about the soils of the basin. This file was established by sorting and merging the Soil Phase File to eliminate all duplicate entries (i.e. the same soil phase occurring in two or more counties). Even with most of the redundancy eliminated this file still contains 3,131 records. Each of these records includes 31 properties of the soil. They are listed in Table 2.1.

Table 2.1 - Variables in the Soil Properties File

Sequence Number	Land Capability Class
Soil Series Name	Crop Yield for up to 7 Crops
Texture	Depth to Seasonal High Water Table Range
Slope Range	Depth to Bedrock Range
Number of Horizons	Soil Management Group*
Identity of Horizons Present	LS Factor*
Erosion Status	Median of Observed Slopes*
Variant Descriptor	Median of Observed Slope Lengths*
Horizon Data:	Soil Drainage Class
Depth Range	Numeric Soil Texture Code
Particle Size Range	
Permeability Range	Suitability for Land Treatment of Municipal Wastewater, Method*
Erodability	
Soil Loss Tolerance (uneroded)	
Soil Loss Tolerance (eroded)	Wastewater Loading Rate*
(Horizon Data is given for up to six horizons)	Suitability for Land Application of Municipal Sludge*

* Derived Variables not in SCS-5 National Properties File

2.2.3.2 Land Cover - The emphasis on diffuse source phosphorus generation in the LEWMS study dictated that the LRIS describe existing land use, and in particular, agricultural land use, throughout the lake basin.

Photo interpretation of high altitude infrared photography was the primary data source to digitize land use information for the LRIS. In June 1976, false color infrared photography covering the Sandusky Basin and contiguous watersheds (approximately 2,000 square miles), was photographed by NASA, Lewis, Cleveland, at a 1:70,000 scale. This data was photointerpreted using a relatively dense grid of four hectare cells (200 meters per side), for portions of the basin and nine hectare cells for the balance. The Honey Creek Basin, in the Sandusky Basin with an area of 177 square miles was done as a pilot effort at the four hectare density (11,483 cells), and the balance of the area finished primarily at the nine hectare density. Relatively dense sampling within the Sandusky Basin was necessary for development and calibration of the hydrologic and chemical transport models.

The balance of the Lake Erie Basin was photographed (false color IR) by NASA, Ames, IA, at a 1:120,000 scale. The land use photointerpretation of this data was done at varying densities, either 16 or 36 hectare cells.

2.2.3.3 Political Boundaries - A political jurisdiction code was included for every point in the data base. The code indicates both the county and minor civil division (e.g., township), and the codes can be aggregated to the State coding scheme. First, each of the 62 counties with area within the Lake Erie Basin was assigned a two-digit identification number. Next, all the municipalities in each county were alphabetized and assigned consecutive two-digit numbers starting with the number one. The county identification code number was then prefixed to each municipality code number within the county to form the four-digit political jurisdiction code numbers found in the data file.

2.2.3.4 Drainage Basin - The primary unit of analysis for the LEWMS program is the watershed or subwatershed. The LRIS, therefore, is capable of aggregating data at this level. Watershed and subwatershed boundaries have been digitized in addition to the land and soil characteristics for each point sampled. In this manner, any hydrologic unit, from a subwatershed to a larger river basin of which it is a part, can be aggregated for analysis or modeling.

The drainage subbasins were defined on 7½-minute quad sheets and this set of watershed boundary maps comprised the source of data for basin digitization. Once the boundaries were traced onto a set of topographic maps, they were coded and digitized. In addition, the chemical sampling stations monitored during 1977 were located on these quads to facilitate summarizing factors for the basins subtended by the stations.

For the SEMCOG region, drainage basins were originally digitized as polygons under a prior study and converted to a cell structure under this study. For this portion of the LRIS, the drainage basins were generally much smaller in size and were aggregated to larger subbasins in the User's Manual. For the other areas, the unique raw basin codes are listed. The User's Manual also contains the information necessary to aggregate subbasins to drainage areas subtended by sampling stations.

2.2.4 LRIS Data Outputs and Products.

It is possible to provide a description of the soils, land uses and their cooccurrences within the various basins. This means that the area and/or percent of a basin falling into each soil and land use category is summed. For management modeling, it is felt that counties might provide a useful aggregation of political boundary data. Thus, a summary file is provided in the LRIS, by basin, county, land use and soils, to allow any necessary aggregation to be made.

In describing a land area, be it a watershed, a township or some other planning unit, it is frequently beneficial to summarize the composition of a descriptive factor, such as land use or soils. The counted files discussed previously do this for major subdivisions of the LRIS by counting the number of occurrences or point/cells in a given area. Most natural processes, however, are a function of combinations of ingredients or land factors. For example. the runoff or hydrologic response of a watershed is dependent not only on the type of soils in the basin, but also on what land uses occur on the various soils, determining the degree of vegetative cover or imperviousness. Other factors, such as the slope of land or degree of relief, also enter into the picture, especially when the question of sediment production by soil erosion is raised. Man's use of land also reflects the consideration of combinations of factors, from cultivation to construction. Thus, it is important that the LRIS have the capacity to quantify selected combinations of land resource factors and cooccurrences as descriptive statistics of any land area in the data base.

Land resource statistics can be used in a variety of ways for analysis of land use-water quality relationships, for mathematical modeling, for zoning and ordinance drafting, comprehensive plan formulation, land treatment of wastewater effluent and many other planning applications. Special software was written for each application or study to produce tabular data summarizing the selected factors one with another (called a two-way count) or grouped by additional factor combinations (three or four way counts). Such aggregations increased in complexity with additional dimensions in the array to a point of diminishing returns. That is, for comparative purposes among data sets or land areas, cooccurrences of more than three dimensions were generally difficult to comprehend. For this reason statistical outputs of cooccurrence variables has been restricted to a maximum of three for the LEWMS study. The system could be modified for generating cooccurrences statistics for a larger number of variables, if necessary.

Cooccurrence tables prepared under LEWMS included the following variables (Tables 2.2 and 2.3) for each of the 62 counties in the basin, the 72 chemical sampling stations in the basin, as well as the direct drainage area and ungaged portions of basins. The User's Manual summarizes the program steps, program names, and data sets developed to produce these tables.

Table 2.2 - Two-Way Cooccurrence Tables

Variable		Variable
Basin	by	Permeability
Basin	by	Land Use
Basin	by	Slope
Basin	by	Texture
Basin	by	Drainage Code
Basin	by	Intrinsic Erodibility

Examples of two-way and three-way cooccurrence tables are given in Table 2.4 and 2.5, respectively.

Table 2.4 shows the breakdown of slope categories, from "less than 0.2 percent" to "13 percent or greater" that occur in major basins. For example, the first basin listed, the Maumee River at Waterville, OH, contains 2,262 square miles of land whose slope is less than 0.2 percent. This represents 42.7 percent of all the measured land in the basin.

Table 2.5 summarizes the cooccurrence of two other factors, land use and soil texture, as they exist within Basin No. 34, the Cattaraugus Creek, Gowanda, NY. This table shows that cropland in the basin occurring on soils with a loam surface texture is 22 square miles, or 55.7 percent of all loam soil is in cropland, which is 12.7 percent of all cropland and 5.4 percent of all land. Note that this table is considered a three-way cooccurrence because two variables, texture and land use, are sorted by a third variable, drainage basin.

Table 2.3 - Three-Way Cooccurrence Tables
Variables Summarized by Basin

Variable	Variable
Slope	by Land Use
Soil Texture	by Land Use
Soil Texture	by Slope
Soil Texture	by Intrinsic Erodibility
Land Use	by Intrinsic Erodibility
Slope	by Intrinsic Erodibility
Permeability	by Slope
Land Use	by Drainage Class
Land Use	by Land Capability Class
Permeability	by Land Use

The row totals give the total areas of each soil texture in the basin and the percent of the total basin area in each soil texture class (i.e., there are 39 square miles of soils with a loam surface texture comprising 9.7 percent of the total basin area). The column totals show the total areas in each land use class and the percentages of the basin in each land use class (i.e., there are 173 square miles of cropland comprising 42.8 percent of the basin land area). The aforementioned types of tables are of great utility for resource inventory, planning, and land management.

Table 2.4 - Example of Two-Way Cooccurrence Basin and Slope Class

Basin Location		Slope Class: Less than 0.5		1.0	2.0	3-5	6-8	9-11	12-14	15-17	18 or Greater
		0.2	0.5	1.0	2.0	4.0	7.0	10.0	13.0	16.0	18.0
Maumee at Waterville, OH	Square Mile	2,262	524	992	81	1,259	7	124	11	26	14
	Percent Basin	42.7	9.9	18.7	1.5	23.8	0.1	2.3	0.2	0.5	0.3
Portage at Woodville, OH	Square Mile	221	54	6	5	91	6	3	0	0	0
	Percent Basin	57.2	13.9	1.5	1.4	23.5	1.7	0.9	0.0	0.0	0.0
Sandusky at Fremont, OH	Square Mile	169	73	346	7	256	1	27	0	6	6
	Percent Basin	19.0	8.2	38.8	0.8	28.8	0.1	3.1	0.0	0.7	0.6
Sandusky at Mexico, OH	Square Mile	110	46	177	0	150	0	20	0	5	5
	Percent Basin	21.4	8.9	34.4	0.1	29.2	0.0	3.9	0.0	1.1	1.0
Sandusky at Upper Sandusky, OH	Square Mile	43	22	74	0	82	0	11	0	2	2
	Percent Basin	18.4	9.3	31.3	0.0	34.7	0.0	4.6	0.0	0.8	0.9
Sandusky at Bucyrus, OH	Square Mile	13	7	28	0	27	0	4	0	0	1
	Percent Basin	15.9	8.6	35.2	0.0	33.7	0.0	4.8	0.0	0.6	1.1
Tymochtee at Crawford, OH	Square Mile	41	10	43	0	22	0	3	0	1	1
	Percent Basin	34.0	8.4	35.7	0.1	17.9	0.0	2.4	0.0	1.0	0.6

Table 2.5 - Three-Way Cooccurrence Table-Basin
(Cattaraugus Creek, Gowanda, NY) Soil Texture and Land Use*

Soil Surface Texture		Cropland	Vineyard	Pasture/	Forest/	Water/	Other	Row
		1	2	3	4	5	6	Total
Silt, Clay, Loam	Sq. Mi.	0	0	0	0	0	0	0
	Percent	0.0	0.0	50.0	50.0	0.0	0.0	0.0
	Percent	0.0	0.0	0.3	0.1	0.0	0.0	
	Percent	0.0	0.0	0.0	0.0	0.0	0.0	
Loam	Sq. Mi.	22	0	2	8	1	6	39
	Percent	55.7	0.0	5.3	21.4	2.3	14.3	9.7
	Percent	12.7	0.0	7.1	5.4	12.3	16.6	
	Percent	5.4	0.0	0.5	2.1	0.2	1.5	
Silt Loam	Sq. Mi.	147	1	27	142	6	28	35.2
	Percent	41.8	0.3	7.7	40.5	1.8	7.9	87.3
	Percent	85.3	100.0	92.2	90.9	84.9	77.3	
	Percent	36.5	0.3	6.7	35.3	1.5	6.9	
Very Fine Sandy Loam	Sq. Mi.	0	0	0	1	0	0	2
	Percent	21.1	0.0	0.0	68.4	0.0	10.5	0.5
	Percent	0.2	0.0	0.0	0.8	0.0	0.6	
	Percent	0.1	0.0	0.0	0.3	0.0	0.0	
Sandy Loam	Sq. Mi.	2	0	0	3	0	1	5
	Percent	32.7	0.0	0.0	49.1	3.6	14.5	1.4
	Percent	1.0	0.0	0.0	1.7	2.7	2.2	
	Percent	0.4	0.0	0.0	0.7	0.0	0.0	
Fine Sandy Loam	Sq. Mi.	1	0	0	1	0	0	2
	Percent	57.1	0.0	0.0	33.3	0.0	9.5	0.2
	Percent	0.7	0.0	0.0	0.4	0.0	0.6	
	Percent	0.3	0.0	0.0	0.2	0.0	0.0	
Muck	Sq. Mi.	0	0	0	1	0	1	2
	Percent	4.5	0.0	4.5	45.5	0.0	45.5	0.5
	Percent	0.1	0.0	0.3	0.6	0.0	2.8	
	Percent	0.0	0.0	0.0	0.2	0.0	0.2	
Column Total	Sq. Mi.	173	1	29	157	7	36	40.3
	Percent	42.8	0.3	7.3	30.8	1.8	9.0	100.0

*See text for explanation.

2.3 UNIVERSAL SOIL LOSS EQUATION

Probably the most important work which has been done with the LRIS has involved the computation of soil loss from cropland in the basin. This application required the use of the Universal Soil Loss Equation (USLE):

$$A = RKLSCP$$

where:
A = the average annual soil loss per year (tons/acre/year)
R = the rainfall erosion intensity factor
K = the soil erodability factor
LS = the combined slope/slope length factor
C = the cropping management factor and
P = the soil erosion control practice

In assigning values for each factor in the USLE the United States Department of Agriculture, Handbook 537, Predicting Rainfall Erosion Losses, and its predecessor Handbook 282 (Ref 4) served as guides.

The factors R and C were assigned on a county basis. R values were obtained from the isoerodant maps in Handbook 282. Assigning the C factor on a county basis was not the most desirable level at which to work, but it was the only level at which cropping patterns could be established for an area as large as the Lake Erie Basin. The annual reports prepared by the Agriculture Statistical Reporting Service in each State were used to determine crop planting and yield statistics for each county in the basin. Crops used in the determination included corn, soybeans, wheat, oats, and hay. Using the acreage of these crops and seven typical rotations in which they are grown, it was possible to estimate a "typical" C factor for each county. The methodology used in the computation of the C factor is given in Urban, et al (Ref 5).

The K factor for the soil in each cell was derived directly from the Soil Properties File. The L, length of slope used in this study was derived from the results of a study by SCS, the National Erosion Study. During this study the SCS District Conservationists from each county in the basin went into the field and cumulatively made many thousands of observations of the actual slope and length of slope for the soils of the Lake Erie Basin. Results from this study were used to calculate observed mean slope length value. This study yielded information for length of slope which would simply not otherwise have been available. Finally, the soil survey staff of the Ohio SCS office reviewed the information which had been compiled and offered many useful suggestions for improvement. They also assisted in filling in data where none was otherwise available.

Many of the additional applications of the LRIS have involved the use of the data developed in this application of the Universal Soil Loss Equation.

2.4 LAND USE AND LAND RESOURCES OF LAKE ERIE BASIN

Previous sections of this report have described the mechanics of the Land Resource Information System (LRIS) and application of the Universal Soil Loss Equation. This section presents some of the cartographic and summary tabular data which have been produced on a basinwide basis from the LRIS data base and exercising of the soil loss model.

2.4.1 Land Use.

Land use for the subbasins and total United States drainage to Lake Erie is given in Table 2.6. This table is derived from an inventory of the LRIS. Map II-2 shows the spatial distribution of land use in the United States drainage to Lake Erie. The Western Basin is dominated by cropland use (69 percent). None of the other basin areas has any specific land use category greater than 50 percent, although the Central Basin is close with 48 percent of the land in agriculture. Cropland accounts for about 39 percent in both the Detroit River/Lake St. Clair Basin and the Eastern Basin. However, these latter two differ in that the Detroit/St. Clair Basin exhibits urban land uses, principally the city of Detroit, while in the Eastern Basin, forest dominates. In the Western Basin, the most agriculturally oriented area, grassland is least abundant, while the Detroit River/Lake St. Clair Basin has the highest percentage of grassland. Transportation and utilities which includes roads, railroads, and airports, accounts for 3 to 6 percent in any of the basins.

2.4.2 Soil Texture.

Map II-3 portrays the various surface textures of Lake Erie Basin soils. Because of its large size, the central portion of the Maumee River Basin contains most of the clay and silty clay-textured soils found in the Lake Erie Basin. This area originally drained the lakes which formed as the glaciers of 8,000 to 16,000 years ago receded to the north and before the Niagara River outlet was established. The remainder of the Lake Erie Basin is comprised of clay and silt loam soils in ground and end moraines formed as the glaciers advanced and receded. The Defiance Moraine in the northwest part of the Maumee Basin has steep slopes of clay loam and silt loam soils.

Throughout the remainder of the western portion of the basin, there are extensive areas of sand formed in offshore sand bars of the glacial lakes. In the southwestern part of the basin there are many sandy beach ridges formed at the shorelines of many stages of the glacial lakes. East of Sandusky Bay, the terrain is generally higher than any of the glacial lake stages. Along the eastern shoreline, there is only a narrow bank of lake-deposited sands. The remainder of the eastern half of the basin soils are formed of glacial till and outwash and generally silt loam and clay loam soils.

2.4.3 Slope.

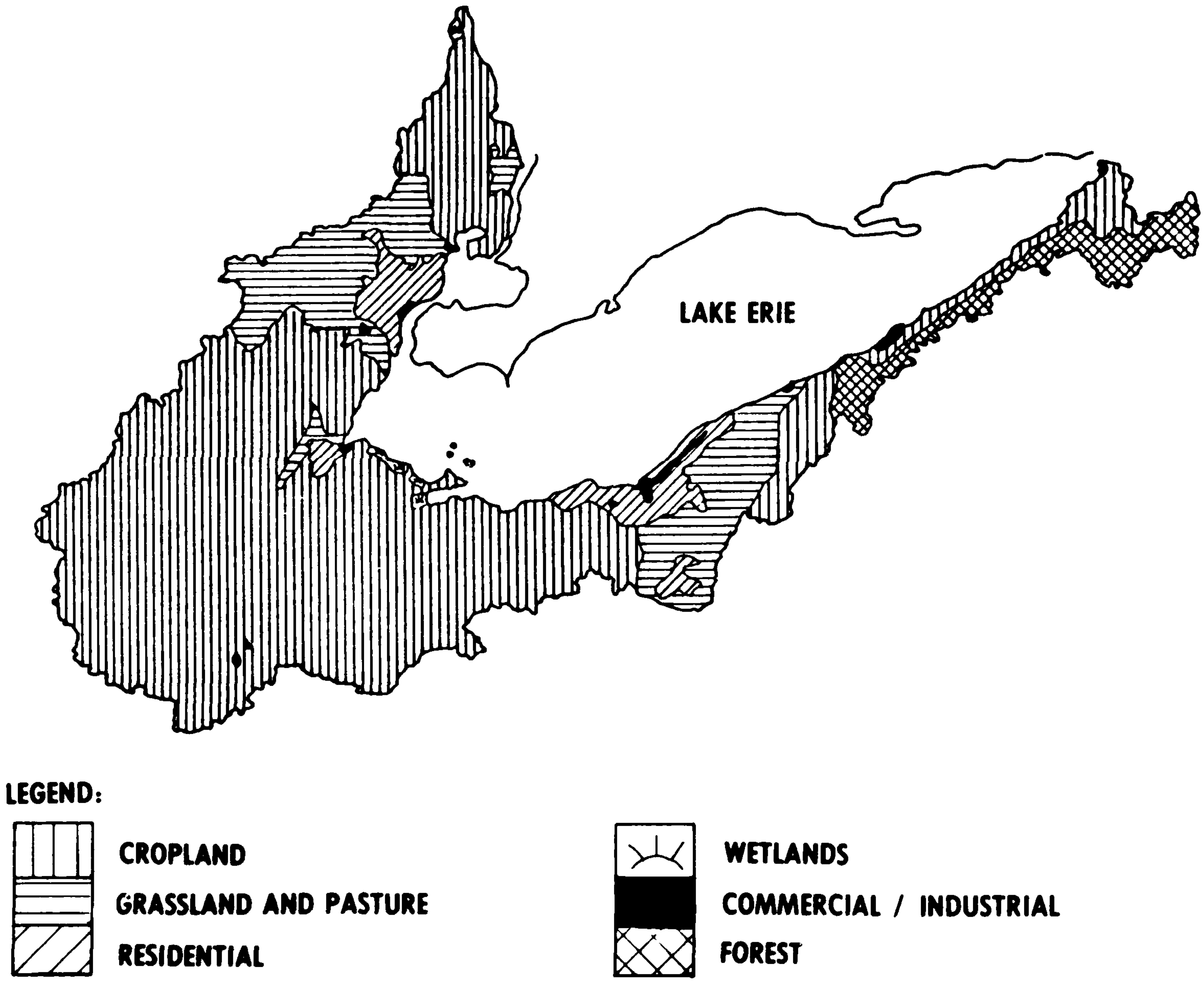
Map II-4 shows the slope of lands in the Lake Erie Basin. The indicated slopes were obtained from the soil phase coded at each location in the LRIS. Each soil phase entry in the LRIS has a slope range. The unique values shown on Map II-4 are the median of the slope range for each soil phase. Additional adjustments were made for poorly drained soils in the zero to two percent range. Depending upon the soil type, a value of either 0.2 or 0.5 percent was used. A value of 0.5 percent was used for flood plain soils.

Table 2.6 - Land Use in the United States Drainage to Lake Erie

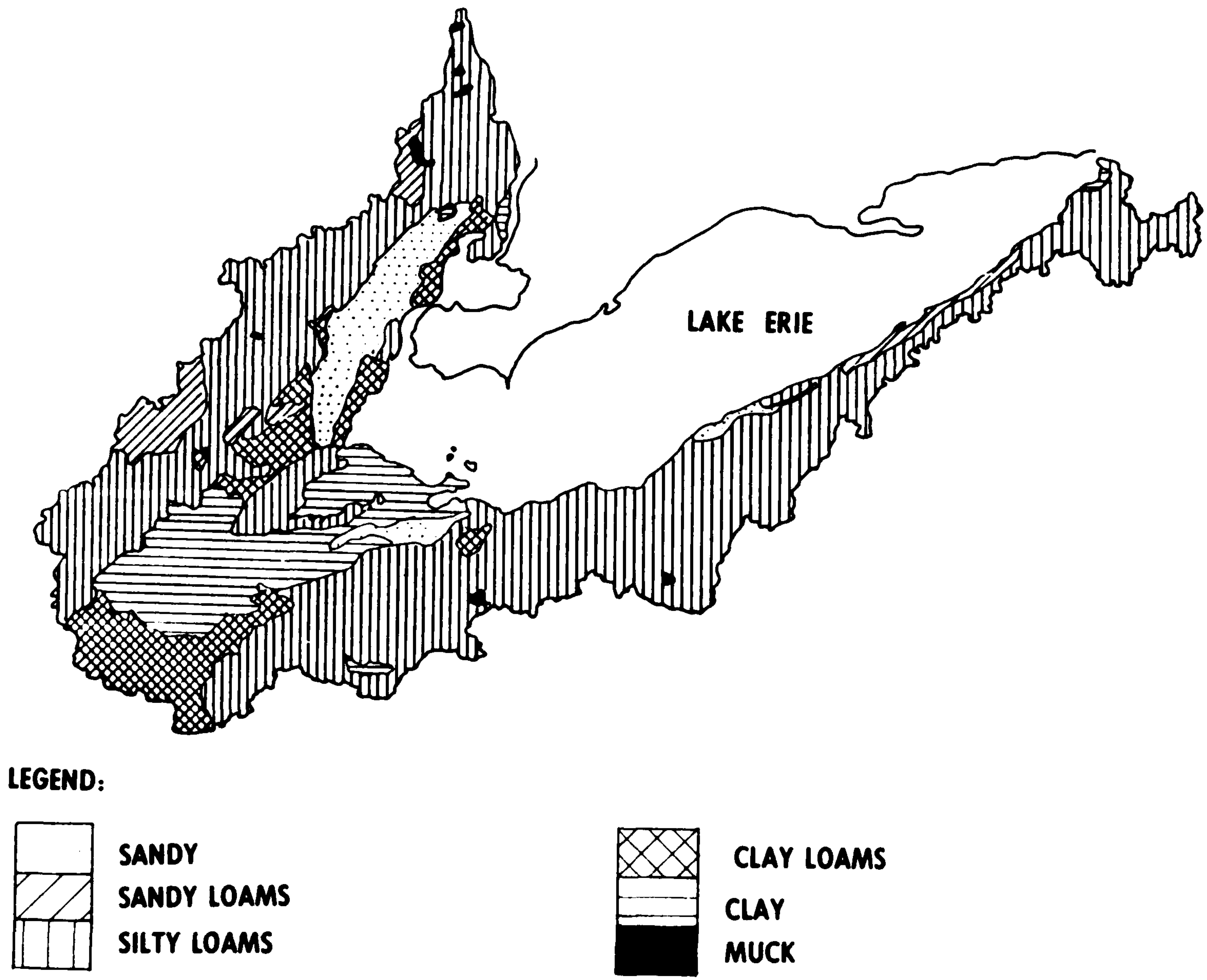
Basin Land Use	Detroit River/St. Clair Hectares (1)	Percent	Western Below Detroit River Hectares	Percent	Central Hectares	Percent	Eastern Hectares	Percent	Total Hectares	Percent
Cropland	272,474	39.2	1,792,096	69.2	694,916	48.1	128,602	38.4	2,888,088	57.0
Vineyards/Orchards	1,672	0.2	2,108	0.1	5,768	0.4	2,781	0.8	12.329	0.2
Grasslands	94,364	13.6	98,958	3.8	149,366	10.3	18,149	5.4	360,837	7.1
Forest	43,480	6.3	220,992	8.5	298,333	20.6	119,529	35.7	682,334	13.5
Water	14,960	2.2	87,144	3.4	29,608	2.0	7,596	2.3	139,308	2.8
Other	310	0.0	679	0.03	301	0.0	486	0.1	1,776	0.0
Residential	121,189	17.5	128,116	4.9	131,327	9.1	19,357	5.8	399,989	7.9
Industrial/Comm.	33,748	4.9	21,605	0.8	[illegible],347	1.7	5,382	1.6	85,082	1.7
Missing	6,091	0.9	30	0.0	0	0	0	0	6,121	0.1
Institutional	104	0.0	5,344	0.2	9,847	0.7	1,341	0.4	16,636	0.3
Urban Mixed	36	0.0	671	0.03	6,926	0.5	162	0.0	7,795	0.2
Trans/Util	25,170	3.6	129,800	5.0	44,596	3.1	19,679	5.9	219,245	4.3
Extr/Mine/Const	12,075	1.7	10,279	0.4	7,349	0.5	1,341	0.4	31,044	0.6
Wetlands	54,509	7.9	62,105	2.4	16,576	1.1	6,192	1.8	139,382	2.8
Urban Open Space	13,540	2.0	30,360	1.2	25,551	1.8	4,149	1.2	73,600	1.5
Total	693,722	100.0	2,590,287	100.0	1,444,811	100.0	334,746	100.0	5,063,566	100.0

(1) One hectare equals 2.47 acres.

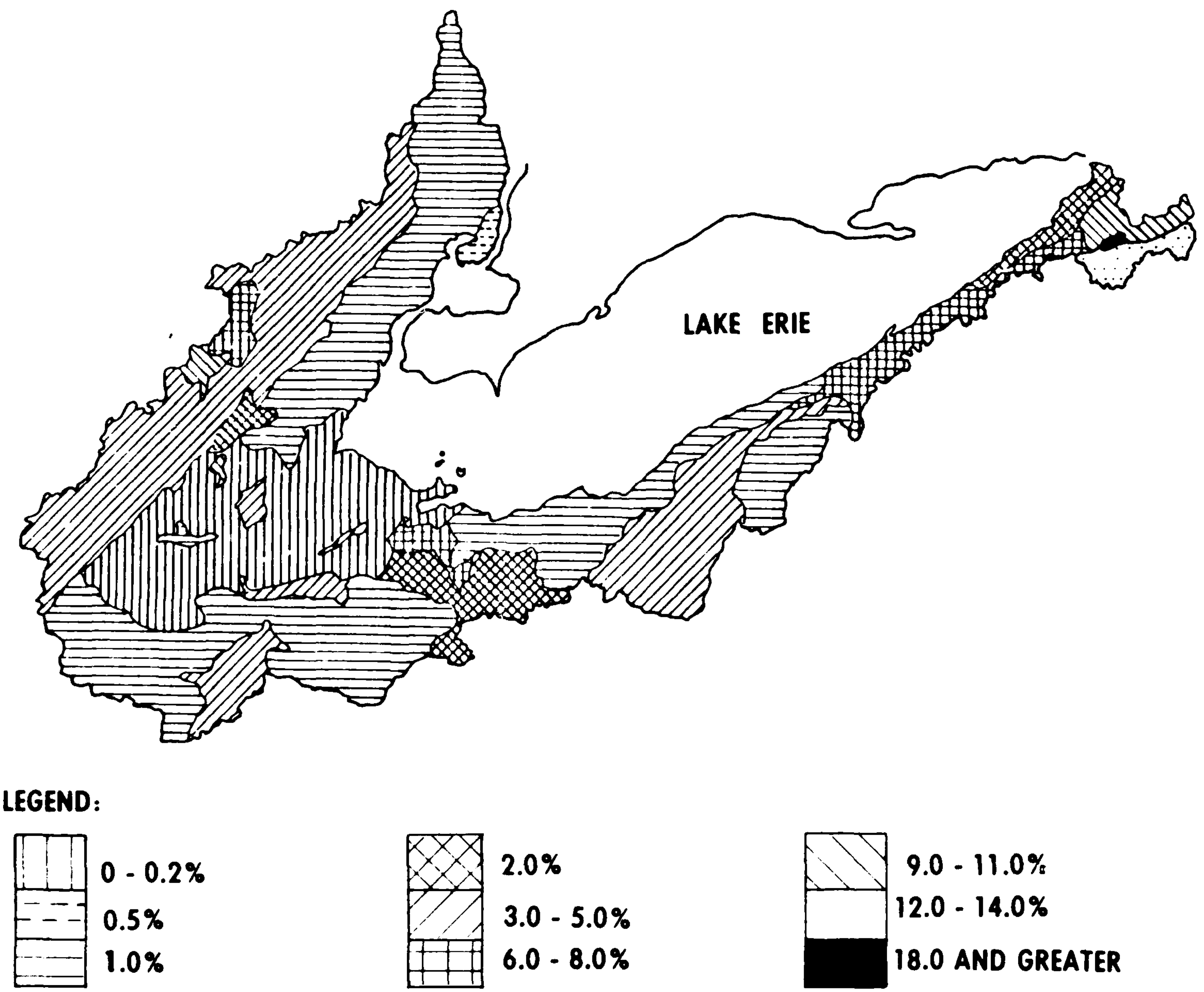
MAP II - 2 LAND USE IN THE UNITED STATES DRAINAGE OF LAKE ERIE



MAP II - 3 SURFACE TEXTURE OF SOILS IN THE UNITED STATES DRAINAGE OF LAKE ERIE



MAP II - 4 SLOPE OF LANDS IN THE UNITED STATES DRAINAGE OF LAKE ERIE



The steepest sloping areas in the U.S. portion of the Lake Erie Basin are concentrated along the eastern end. Sloping areas are on glacial end moraines and glacier-carved valleys. The area south of Buffalo, NY, which includes the area of the greatest slopes in the basin, is a series of parallel moraines extending in a north-south direction. To the west, in northwest Ohio, the land becomes generally flat. The central portions of the Maumee River Basin and the Portage River Basin have slopes that are predominantly less than 0.2 percent. This area was the bottom of the glacial lakes; the soils are clay and silty clay lacustrine deposits over glacial till. Along the northwestern boundary of the Lake Erie Basin, the Defiance and Wabash Moraines give relief to usually gently rolling lands.

2.4.4 Tabular Summaries of Combinations of Features.

Tabular summaries of combinations of features have also been prepared for all areas in the Lake Erie Basin. The tables are organized according to sampling station drainage basins. Tables 2.4 and 2.5, presented previously in Section 2.2.4, are examples of such cooccurrence tables. Tables 2.2 and 2.3 list all of the information summaries which have been prepared. These information summaries are published as separate LEWMS Technical Reports (Ref. 6-9).

2.5 POTENTIAL GROSS EROSION

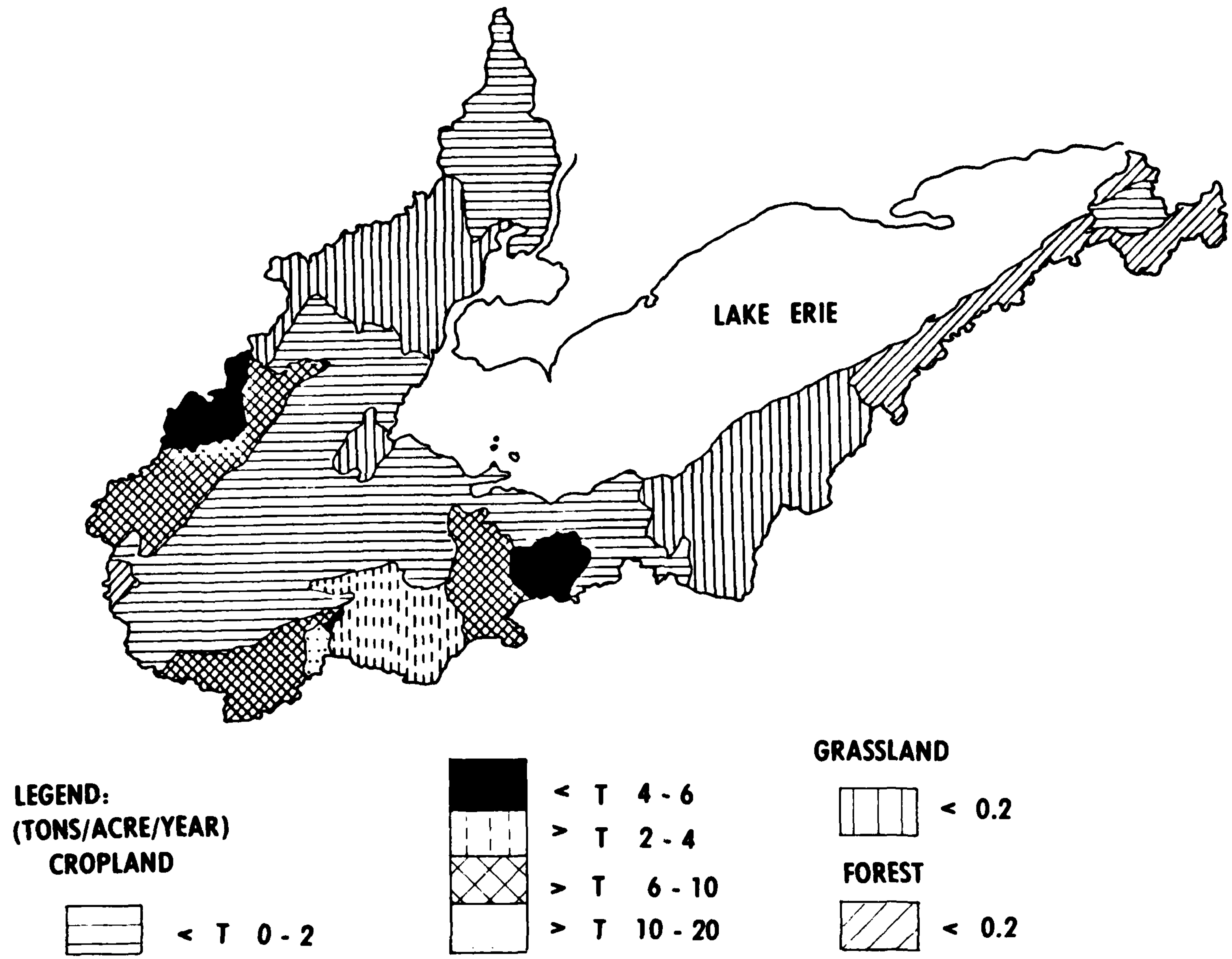
In the previous section, maps of single properties of the Lake Erie drainage basin were presented. There are, however, combinations of land resource properties which, when taken together, give added information. An example of a combination of land resource properties is Potential Gross Erosion (PGE) calculated by the Universal Soil Loss Equation. The results of the equation represent an estimate of the long-term annual soil loss based on local climatic conditions, soil erodibility, topography, land use, and management conditions.

Map II-5 shows a generalization of the detailed LRIS PGE map for the U.S. drainage of Lake Erie. Soil loss from cropland is expressed as a range (tons/acre/year) below and above the soil loss tolerance factor (T). Soil loss for grassed lands and forested areas is predominantly less than 0.2 tons per acre. Land areas dominated by these cover types are shown.

A map such as this is more valuable for some purposes than the tabular reports when considered as a management tool from an erosion control program. It graphically identifies the location of areas where land use and local conditions indicate a high potential for soil loss and, therefore, the areas where attention should be directed in an erosion control program.

It can be seen from Map II-5 that most of the land drainage into Lake St. Clair and the Detroit River has PGE rates less than T. However, land in Michigan, Indiana, and the western Ohio portion of the Western Basin have large areas with PGE rates several times greater than T. Land south of Sandusky Bay also has areas where PGE rates exceed T. Most of the land drainage into the remainder of the Central Basin does not exceed T with the exception of some land southwest of Cleveland. There are also some areas of

MAP II- 5 POTENTIAL GROSS EROSION IN THE UNITED STATES DRAINAGE OF LAKE ERIE



high PGE in the Cattaraugus Creek drainage into the Eastern Basin. It should be remembered when viewing this map that no estimates for PGE have been made for land uses such as urban, industrial-commercial, residential, and transportation.

2.6 CULTURAL PRACTICES THAT ALTER THE SYSTEM

2.6.1 Cultivation.

In Section 2.3.5, the influence of crop rotation systems on soil erosion in the Lake Erie Basin was discussed at some length. In general rotations with greater inclusion of row crops (or continuous row crop) will result in greater erosion than rotations with greater inclusion of small grains or hay and pasture. Within the same rotation, however, there can be large differences in erosion rates depending on cultivation practices. The most prevalent tillage systems historically employed in the United States include the use of the moldboard plow which incorporates plant residues into the plow layer leaving a bare ground surface. Plowing is usually followed by disking and leveling operations which prepare the seed bed. After seed planting, spraying and/or cultivating for weed control is done as necessary.

During the period of time that the land is bared to the kinetic energy of wind and water, the soil is most vulnerable to erosion. As the crop becomes established the above ground vegetation and roots provide increasing erosion protection. Pasture provides more complete cover and greater protection than row crops.

Plowing is often done in the fall of the year especially on the wetter soils in the low-lying lake plains of the basin because it is difficult to plow in the spring. In these areas the melting snow and rains of late winter and early spring are particularly effective in detaching and transporting sediment.

Intuitively, and through countless research investigations and demonstrations conducted over the past 100 years throughout the United States, it is known that maintenance of vegetation residue on the soil surface effectively reduces soil erosion. Vegetation accomplishes this by reducing raindrop impact, increasing water intake, decreasing runoff velocity and decreasing soil detachability. Rotation and cover crops help to maintain vegetative residues on the soil surface but have limited application for economic reasons. The possibility of leaving crop residues on the surface for erosion protection must then be examined as an alternative to traditional moldboard plowing. Cultivation practices which result in increased amounts of residues on the soil surface are collectively referred to as "conservation tillage." The ultimate conservation tillage practice is referred to as "no till," wherein no tillage or plowing is done. Weed control is accomplished with chemicals. In "reduced tillage" practices moldboard plowing is replaced by chisel plowing, disking, field cultivation, chemical weed control or similar minimum tillage practices. Conventional plowing and cultivation systems generally result in less than 1,000 lbs. of crop residue per acre on the soil surface at planting time. Reduced tillage results in approximately 1,000 to 3,000 lbs. of crop residue per acre on the soil surface at planting time. No till results in virtually all previous crop residue remaining on the soil surface - in the range of 3,000 to 6,000 lbs. per acre expressed as corn residue equivalent. Detailed study under LEWMS on a representative watershed in the Western Lake Erie Basin showed that soil erosion could be reduced by approximately 30 percent by employment of reduced tillage and by 75 percent or more using no till (Ref 10). Table 2.7 lists the operations involved in typical conventional tillage and conservation tillage systems.

The use of conservation tillage methods is admittedly a highly significant departure from traditional farming methods and has been viewed with justified skepticism by the farming community. Problems associated with weed control, plant emergence and establishment, insect and pest control, and cold, wet soils resulting in reduced yield and reduced income immediately come to mind. It has been demonstrated within the LEWMS program, however, and throughout the United States that the above problems can be overcome and that under good management practices, crop yields and net income are not adversely affected using conservation tillage systems for adaptable soils (Ref 11).

Table 2.7 - Typical Conventional and Conservation Tillage Operations

	Conservation Tillage	
Conventional Tillage	Reduced Tillage	No Till
Fertilize	Fertilize	Fertilize
Plow	Chisel Plow	Plant
Disk	Disk	Pesticide Application
Level	Pesticide Application Cultivate	Harvest
Plant	Harvest	
Pesticide Application		
Cultivate		
Harvest		

It has been shown that under good management practices yields of some crops (i.e. corn, soybeans) and net income may be increased using reduced and no-tillage on suitable soils. The projected economic impacts of adopting conservation tillage on suitable soils of the Lake Erie Basin are presented in Chapter 5 of this report.

2.6.2 Fertilization.

Most cropping systems in the Lake Erie Basin rely on the addition of the major plant nutrients (N, P, K) as determined through fertility assessment (i.e. soil tests) and specific crop needs. Significant amounts of applied fertilizer are removed from the soil, dissolved in runoff water, attached to sediments entrained in the runoff, and by crop removal. Although losses of nitrogen, phosphorus, and potassium are of concern to the agricultural community, the LEWMS program has focused principally on phosphorus losses because phosphorus control can reverse the eutrophication of Lake Erie.

It is known that fertilizer phosphorus applied in soluble forms becomes rather quickly fixed in mineral soil in much less soluble forms. The greater percentage of phosphorus loss which occurs from cropland is associated with soil bound phosphorus. This implies that control of soil erosion can be an effective means of limiting phosphorus inputs into Lake Erie. Logan and Adams (Ref 12) estimate that 80 percent of the total tributary load to Lake Erie is sediment bound phosphorus. Logan and Adams also conclude that conservation tillage practices are approximately 90 percent as effective in reducing total particulate phosphorus losses as in reducing soil loss. The results of their analysis of various researchers work on transport of sediment and phosphorus from conservation tillage plots is detailed in Chapter 5 of this report. The LEWMS program has used this and related data along with the soil loss equation and land use inventory to estimate soil and phosphorus losses throughout the U. S. Lake Erie Basin.

2.7 TRENDS THAT SUGGEST MANAGEMENT ALTERNATIVES

From the previous section it is clear that the use of reduced tillage and no-till farming practices can substantially reduce sediment and phosphorus losses, however, individual farmers by necessity must be able to adopt conservation tillage without undue disruption to their overall farm management operations and avoid economic impairment. Indeed, farmers would be more disposed to adopt conservation tillage if there are management and economic advantages.

2.7.1 Growth of Conservation Tillage.

Significant adoption of conservation tillage has occurred in the past two decades. It is estimated that conservation tillage covered about 40 million hectares of cropland in the United States in 1980. Thus, conservation tillage was used on over 1/4 of the nation's cropland. In 1972 only 12 million hectares were covered with conservation tillage, and in 1963 it was less than 1 million hectares. Nationwide, conservation tillage appears to be expanding by about 1.2 million hectares annually or about 3-4 percent. It is projected that nearly half of the U.S. cropland will be under conservation tillage by the year 2000 (Ref 13).

The 1970's experienced severe inflationary trends resulting in accelerated fuel, labor, and equipment costs to the farmer. Since conservation tillage offers opportunities to significantly reduce these costs, many farmers have turned their attention to these methods. Tables 2.8 and 2.9

illustrate typical savings in fuel and labor which may be realized from conservation tillage operations. Since conservation tillage systems normally require fewer trips across the field and move less soil than plow-based systems, direct fuel savings are often realized. Table 2.8 shows fuel usage for various operations in crop establishment. These are average figures and individual experience will be influenced by tractor and implement size, soil type, and soil moisture status. The figures show that moldboard plowing consumes far more fuel than other tillage operations. The farmer who plows, disks, plants, sprays, and cultivates once may put 3.5 gallons of fuel per acre into tillage and planting while the farmer who plants and sprays may use only 0.7 gallons per acre to do the same. Conservation tillage can result in more timely crop establishment. Reducing the number of trips across the field and modifying the intensity of tillage can speed the planting operation considerably, as shown in Table 2.9. Since yields of corn and soybeans generally decrease as planting is delayed later into May, conservation tillage can increase yields of these crops if the system enables the farmer to plant more land at the proper time. Forster (Ref 11) estimates that the producer's labor input may be reduced by approximately 10 percent when changing from conventional tillage to no tillage.

It is difficult to predict whether or not the individual farmer will incur increased overall equipment costs for conservation tillage. Much depends on what equipment he has on hand and how well it can be adapted to conservation tillage.

Table 2.8 - Estimated Fuel Requirements for Various Field Operations

Operation	Diesel Fuel (gal/A)
Moldboard Plow	1.82
Chisel Plow	1.12
Heavy Tanden Disk	0.77
Field Cultivator	0.70
Standard Disk	0.56
Row Cultivator	0.39
Plant	0.63
Spray	0.11

SOURCE: Fuel requirements for selected farming, OSU Ag. Engr. Department Farm Machinery No. 10 (Ref 14).

Table 2.9 - Time Required to Establish Corn or Soybeans Using Various Tillage Systems

System	Rate* (A/hr)	Time (hr/100 A)
Plow Disk Plant	1.61	62
Chisel Plow Plant	3.06	33
Disk Plant	2.96	34
No Till	4.44	22

* Planting rate may be higher or lower than stated, depending on size of Equipment.

SOURCE: Farm Machinery and equipment, 1980 cost estimates. ESO 663. OSU Dept of Agriculture, Economic and Rural Society (Ref 14).

Some farmers may find it necessary to acquire chisel plows, while others may be able to adapt disks or field cultivators to their operations. One of the most important adaptations to be made and one which often requires additional capital investment is the planter equipment. It is of paramount importance to place seed below the surface crop residue and in good contact with the soil at proper planting depth.

Conservation tillage planters in general consist of "coulters" which cut the organic surface residue and loosen the soil. The coulter is followed by a disk opener which prepares the furrow for seed placement. After seed placement, a press wheel closes the furrow and firms the seed bed. It is very important for the farmer to insure that the planter equipment is properly calibrated and synchronized so as to maintain correct seeding depth. Generally more care and time is required for proper planting with conservation tillage systems than with conventional planting systems. Eckert and Schmidt (Ref 14) provide an excellent discussion of planting, cultivation, and other considerations for conservation tillage in Ohio.

Forster (Ref 11) provides overall estimates of approximately 8 percent less costs for minimum tillage equipment compared to conventional tillage equipment, and approximately 10 percent less costs for no till equipment.

2.7.1.1 Conservation Tillage Adoption - Forster and Stem (Ref 15) conducted a study to identify baseline data on the adoption of conservation tillage and other conservation practices in the Lake Erie Basin and identification of factors explaining their implementation. This study, completed in 1979 found that conservation tillage had occurred in 23 percent of the basin's row crop acreage. In approximately 21 percent of this area, moldboard plowing had been replaced by chisel plowing, disking, field cultivating or other reduced tillage practices. On approximately 2 percent of this cropland, moldboard plowing had been replaced by no till farming. The 1981 revision of these estimates (Ref 16) indicated that reduced tillage was now employed on 22.2 percent of the row crop acreage while no till was practiced on 3.8 percent of the row crop acreage resulting in overall increases in conservation tillage from 23 percent of the row crop acreage in 1979 to 26 percent of the row crop acreage in 1981.

In addition to fuel and labor considerations discussed previously, Forster and Stem learned of other factors influencing adoption of conservation tillage in the Lake Erie Basin. They found that basin farms in northwest Ohio, Indiana, and southeast Michigan tended to have larger proportions of tillable acres, and higher proportions of these acres in row crops. Furthermore, farms with larger amounts of row crop acreage tended to favor conservation tillage, apparently because labor efficiency is improved using reduced tillage during the critical planting periods. Land with improved drainage on poorer drained soils was also more apt to have conservation tillage applied. Interestingly, the researchers found little pattern to adoption - counties thought to be more suitable for adoption had less adoption than some counties thought to be less suitable as in glacial lake plain counties of northwest Ohio. Forster and Stem found conservation tillage was more often practiced by farmers with higher education levels. Demonstration programs needed to be in place for a period of 5 to 10 years before they resulted in increased adoption tendencies. This reflects the understandable basic resistance to long-standing proven crop production methods employed by the farming community. Establishment of trust and belief in conservation tillage must then necessarily be established over a period of perhaps decades.

2.7.2 Changes in Pest Management with Conservation Tillage - Using conservation tillage technology, close management of weed and insect control becomes highly important. In essence much or all of the weed control traditionally carried out through cultivation is replaced by chemical control. This is done through the use of short-term contact sprays and residual herbicides to give longer term control of germinating and emerging weeds. It is beyond the scope of this study to detail the array of materials and programs which may be used for effective weed control in conservation tillage. It is clear that effective weed control can be secured through chemical control, and equally clear that individual farmers must closely monitor their particular operations and work with agricultural extension service agents and chemical suppliers for development of programs that fit their situations. Farmers must be able to identify the types of weeds present in their fields and monitor their growth and spread so that the proper chemical controls are selected and timely applications are made. Management of weed control may well be the most important aspect of conservation tillage.

As with conventional farming, insect and other pest control must be closely controlled in conservation tillage. Here again, individual farmers should work closely with extension service agents and others in monitoring insect infestations on individual fields and selection and timing of proper and effective insecticide/herbicide agents. Fields should be monitored frequently to identify problems before they cause major damage. Pest scouts working out of local County Extension offices or private scouting services can often provide valuable guidance in this area.

2.8 INFLUENCE OF CONSERVATION TILLAGE ON USE AND FATE OF HERBICIDES AND INSECTICIDES IN THE GREAT LAKES BASIN

It has been well established that conservation tillage can greatly reduce soil erosion and phosphorus loadings to Lake Erie and its tributaries.

However, increased use of herbicides and possibly insecticides will accompany the increased implementation of conservation tillage. This section will attempt to describe how the increased adoption of conservation tillage may influence the current pattern of pesticide usage in the basin and possible ecological impacts of changes which may occur.

2.8.1 Influences on Types and Amounts of Herbicide and Insecticide Use.

Any analyses of the impact of conservation tillage on herbicide and insecticide use must examine this impact within the context of the existing patterns of use. Logan (Ref. 17) summarized the use of herbicides and insecticides for the Basin States of Ohio, Indiana, and Michigan in 1978 (Table 2.10). The three most widely used herbicides (atrazine, alachlor, and butylate) accounted for 77 percent of herbicide use while carbofuran, fonofos, and terbufos accounted for 86 percent of insecticide use. Much larger quantities of herbicides than insecticides were used (8 times as much herbicide as insecticides). Corn and soybeans receive the bulk of herbicides and insecticides applied in the basin and are, of course, the principal target crops for conservation tillage.

A shift from conventional tillage to conservation tillage and especially no till will have some predictable effects on pesticide use according to Logan. First, preplant herbicides which require immediate soil incorporation will no longer be used. These include butylate (Sutan) and EPTC (Eptam, Eradicane) which are two of the 10 compounds most used in Ohio. The insecticide chlordane is also primarily incorporated. Secondly, there will be an increase in the use of nonselective herbicides for weed and mulch cover control. Paraquat and glyphosate (Roundup) are the two most commonly used compounds in this category and their use, especially paraquat, would increase greatly from the present. In 1978, paraquat was only 0.19 percent of all herbicides used in Ohio and glyphosate use was 0.14 percent of the total.

Logan foresees an increase in the use of postemergent herbicides with yet unknown increases in total annual per acre herbicide applications.

Methods for the control of above-ground insects such as armyworms or European corn borer are not expected to change with a shift to conservation tillage, but the rate of infestation by these pests may increase with no till and also the use of insecticides to control them. Soil-borne insects may increase with conservation tillage, and insecticides which require preplant soil incorporation cannot be used. Control will have to be by seed or band placement, or surface application.

There may be tendency to shift to broad spectrum insecticides with some residual effect such as toxaphene. These compounds are highly toxic and the environmental hazards and restrictions on their use may prevent their widespread use in the Corn Belt.

It is not possible at this time to predict with any degree of accuracy the change in the total amount of pesticides which might be associated with adoption of conservation tillage. Logan concludes there may be increases in

Table 2.10 - Summary of Herbicide and Insecticide Use in Ohio, Indiana and Michigan in 1978

	Quantities of Material (1,000 pound) Used On:			
	Ohio	Michigan	Indiana	Total
Herbicides				
Alachlor	7,074	2,791	9,159	19,024
Atrazine	4,451	3,349	7,916	15,716
Butylate	1,175	1,091	3,328	5,594
Trifluralin	-	779	1,553	2,332
Cyanazine	1,142	840	635	2,617
Metribuzin	780	-	975	1,755
Linuron	784	290	670	1,744
EPTC	365	306	623	1,294
Chloramben	981	205	-	1,186
Metolachlor	-	-	776	776
Total				52,038
Insecticides				
Carbofuran	922	549	1,601	3,072
Fonofos	342	648	683	1,673
Terbufos	461	94	433	988
Carbaryl	77	111	172	360
Phorate	51	81	76	208
Chlorpyrifos	43	-	101	144
Ethoprop	-	-	91	91
Chlordane	43	-	35	78
M+M	44	-	19	63
Malathion	35	-	-	35
Total				6,712

application rates for some compounds or increased number of applications but, in general, pesticide usage will not change markedly with a shift to conservation tillage.

2.8.2 Characteristics of Herbicides and Insecticides Commonly Used in Basin.

Table 2.11 summarizes some of the properties of the herbicides and insecticides most commonly used and those expected to increase significantly in use (i.e. paraquat, glyphosate). Solubility is of interest as it gives an indication of the tendency of the substance to dissolve in rainfall and runoff water. Persistence is of importance since it indicates the length of time after application that the active ingredient is available for entrainment and transport in runoff.

The toxicological behavior of the substances is summarized in the last column. All of the substances are considered of relatively low toxicity to fish and mammals. Carbofuran is considered hazardous to fish, and data on terbufos and fonofos was not available.

It is of interest that the herbicides expected to increase in use (i.e. paraquat, glyphosate) are of high solubility, moderate persistence, and relatively low toxicity to fish. Paraquat is somewhat more toxic to mammals.

2.8.3 Herbicides and Pesticides in Runoff.

The amount of pesticide compound lost in runoff will depend on the degree to which the compound has degraded or infiltrated before runoff occurs, the amount of runoff, water solubility, relative affinity for soil and soil loss. Since most of the pesticide used in the Lake Erie Basin is applied within 2 weeks before or after planting, pesticide losses in runoff would be primarily in the period April-June. This is a period of high runoff potential, but it does not include the earlier spring thaw runoff which accounts for a significant part of the total flow and sediment load from the basin.

Weber et al (Ref 20) have recently summarized runoff losses of pesticides in watershed and plot studies and these are given in Table 2.12 for those compounds used in the Lake Erie basin as well as overall means for all compounds grouped by chemical form. Atrazine runoff losses were higher than other compounds included and methoxychlor was the lowest.

Overall, about 1 percent of the pesticide applied was lost in runoff. Weber also reported on rainfall simulator studies where rain was applied immediately after the pesticide application to simulate "catastrophic" events, and about 7 percent of the compound was lost. These types of "catastrophic" events are probably of very low frequency and their impact on total losses of pesticides to Lake Erie is probably insignificant. However, the effect on stream biota in the immediate drainage area of the event could be significant for the more toxic compounds.

Table 2.11 - Characteristics of Herbicides and Insecticides Most Commonly Used in Great Lakes Basin or Expected to Have Increased Use With Conservation Tillage

Common Name	Trade Name	Class	Solubility (2) (ppm)	Persistence in Soil (3) (months)	Application Method (4)	Toxicity (6)
Herbicides						
Alachlor	Lasso	Anilide Herbicide	242	2	PE, PPI	2 (1,200)
Atrazine	Aatrex & Others	Triazine Herbicide	33	12	POE, PE, PPI	2 (3,080)
Butylate	Sutan	Thiocarbamate Herbicide	-	-	PPI	2 (4,000)
Paraquat (5)	Paraquat Gramoxone	Herbicide	Completely	>18	POE	1 (150)
Glyphosate (5)	Roundup	Acidic Herbicide	V. Soluble	MP (7)	API	1 (4,320)
Insecticides						
Carbofuran	Furadan	Carbamate Insecticide	700	<1	API	3
Terbufos	Counter	Organophosphous Insecticide	15	MP (7)	API	-
Fonofos	Dyfonate	Organophosphorus Insecticide	13	<1	API	-

(1) Taken in part from Wauchope (Ref 18) Logan (Ref. 17).
(2) Solubility in water at 20-25° C.
(3) Approximate time for 90 percent disappearance; times vary depending on climate and soil (see Ref. 17).
(4) Preplant incorporated (PPI), preemergence (PE), postemergence (POE), at planting incorporation (API)
(5) Use expected to increase greatly with conservation tillage systems.
(6) Toxicity scale of Weber (Ref. 19) based on fish toxicity. 1 = nonhazardous; 2 = slightly hazardous; 3 = hazardous; 4 = toxic; numbers in parenthesis are mammalian toxicity (LD_{50}ug/ml).
(7) Moderately persistent 0 half life of 20-100 days.

Table 2.12 - Runoff Losses of Herbicides and Insecticides Used in the Lake Erie Basin (Weber *et al*, 1980)

Class	Compound	Crop	Tillage or Cover	Rate Applied (kg/ha)		Percent of Application Lost in Runoff	
				Range	Mean	Range	Mean
Basic	Atrazine	Corn	Cultivated	0.6-9.0	2.77	0.00-15.9	2.39
Basic	Atrazine	Turf	Sod	2.24-3.92	3.08	0.04-0.84	0.44
Basic	Cyanazine	Corn	Cultivated	1.35-1.61	1.48	0.07-1.00	0.54
Basic	Metribuzin	Soybean	Cultivated	0.56	0.56	0.90-2.10	1.50
Acidic	2, 4-D	Corn	Cultivated	0.56-1.68	0.98	0.01-1.00	0.33
Acidic	2, 4-D	Forest	Litter	9.35	9.35	<0.1	<0.1
Nonionic, High Solubility	Carbofuran	Corn	Cultivated	3.11-5.41	4.23	0.47-1.90	1.08
Nonionic Moderate Solubility	Carbaryl	Corn	Cultivated	5.03	5.03	0.15	0.15
Nonionic, Low Solubility	Methoxychlor	Turf	Sod	22.5	22.5	0.0047	0.0047

Reference 20

2.8.4 Effect of Conservation Tillage on Pesticide Losses.

The effect of increased residue cover on runoff losses of pesticide will depend on the solubility of the compound and its affinity for soil particles. If the effect of residue is to reduce soil loss with no change in runoff volume, then losses of compounds with a high affinity for soil such as paraquat will be reduced, but there will be little effect on soluble compounds with low soil affinity. Logan and Adams (Ref. 12) have shown that in some cases no till can reduce runoff or increase it relative to conventional tillage depending on soil properties. Therefore, runoff losses of water-soluble compounds could either increase or decrease depending on the soil. More significant, however, may be the timing between pesticide application and runoff-causing rainfall. Heavy rains immediately after pesticide application may produce the "catastrophic" losses reported by Weber, but more gentle rains may wash the material off of the residue and into the soil.

Several researchers (Ref. 20, 21, 22) reported lower pesticide losses with increased surface cover, and all attribute the reductions to decreased runoff and soil loss. Baker and Johnson (Ref. 23) measured the runoff losses of fonofos, alachlor, atrazine, and cyanazine under natural rainfall in six 0.55 to 1.75 ha watersheds planted to continuous corn with conventional, till-plant, and ridge-plant systems. They found that pesticide losses decreased in conjunction with decreased runoff and erosion with the conservation tillage systems relative to the conventional system, but that concentrations in the sediment and water were sometimes higher under the conservation tillage systems. Wauchope (Ref. 18) concluded that erosion control practices can be expected to have little effect on runoff of pesticides with solubilities greater than about 1 mg/l, or with extreme clay-binding capacities, except where these practices control water as well as sediment losses. Although most pesticides are more concentrated (by 2 to 3 orders of magnitude) in the sediments than in the water, the pesticides are lost primarily in the water because sediment is such a small fraction of total runoff. To the extent that pesticides are associated with sediments and organic matter retained on the land surface by conservation tillage, losses in runoff are effectively reduced.

Although increased use of conservation tillage will result in greater pesticide usage, pesticide loss to the environment will decrease or remain constant.

REFERENCES

1. International Reference Group on Great Lakes Pollution from Land Use Activities, "Environmental Management Strategy for the Great Lakes System," Report to the International Joint Commission, Windsor, Ontario, July 1978.

2. Knap, K. M. and W. F. Mildner, "Streambank Erosion in the Great Lakes," Report to PLUARG, Windsor, Ontario, June 1978.

3. Cahill, Thomas H. "Lake Erie Basin Land Resource Information System" Resources Management Associates for U. S. Army Corps of Engineers, Buffalo District, January 1979

4. Wischmeier, W. H. and D. D. Smith "Predicting Rainfall - Erosion Losses from Cropland East of the Rocky Mountains" ARS - USDA Handbook No. 282 1965.

5. Urban, D. R., J. R. Adams, and T. J. Logan, "Application of the Universal Soil Loss Equation in the Lake Erie Drainage Basin," Lake Erie Wastewater Management Study Technical Report, U. S. Army Corps of Engineers, Buffalo, NY, November 1978.

6. Resource Management Associates, "Land Resource Information for the Lake Erie Drainage Basin, Vol. I - Land Resource Summary," LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY, March 1980.

7. Resource Management Associates, "Land Resource Information for the Lake Erie Drainage Basin, Co-occurence of Land Resource Features, Vol II - Major River Basins," LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY, March 1979.

8. Resource Management Associates, "Land Resources Information for the Lake Erie Drainage Basin, Co-occurrence of Land Resources Features, Vol. III - Sandusky River Basin," LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY, March 1979.

9. Resource Management Associates, "Land Resources Information for the Lake Erie Drainage Basin, Co-occurrence of Land Resource Featues, Vol IV - Small Watersheds," LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY, March 1979.

10. Crumrine, J. "Honey Creek Watershed Project Final Program Evaluation Report" LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY, January 1982.

11. Forster, L., "Economic Impacts of Changing Tillage Practices in the Lake Erie Basin," LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY, August 1978.

12. Logan T. J., and Adams, J. R., "The Effects of Reduced Tillage on Phosphate Transport from Agricultural Land," LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY, January 1981.

13. Phillips, R. E., R. L. Blevins, G. W. Thomas, W. W. Frye and S. H. Phillips "No Tillage Agriculture," Science 208: pp 1108-1113, 1980.

14. Eckert, D. J. and Schmidt, W. H. "Using Conservation Tillage in north-central Ohio," Bulletin FAC 10, Cooperative Extension Service, The Ohio State University, January 1981.

15. Forster, L. and Stem, G. "Adoption of Reduced Tillage and Other Conservation Practices in the Lake Erie Basin," LEWMS Technical Report, U.S. Army Corps of Engineers, Buffalo, NY, November 1979.

16. Forster, L., unpublished report for LEWMS, February 1982.

17. Logan, T. J., "Pesticide Use in the Lake Erie Basin and the Impact of Accelerated Conservation Tillage on Pesticide Use and Runoff Losses" LEWMS Technical Report, U.S. Army Corps of Engineers, Buffalo, NY, January 1981.

18. Wauchope, R. D., "The Pesticide Content of Surface Water Draining From Agriculture Fields -- A Review." J. Environmental Quality. 7 (4) 459-472, 1978.

19. Weber, J. B., "Agricultural Chemicals and Their Importance as a Non-Point Source of Water Pollution" in Nonpoint Sources of Water Pollution. P. M. Ashton and R. C. Underwood, Eds. Virginia Water Resources Res. Center, Blacksburg, VA, pp. 115-129, 1975.

20. Weber, J. B., P. J. Shea and H. J. Strek. An evaluation of nonpoint sources of pesticide pollution in runoff. In Environmental Impact of Nonpoint Source of Pollution. M. J. Overcash and J. M. Davidson, Eds. Ann Arbor Science, Ann Arbor, MI, pp. 69-97, 1980.

21. Triplett, G. B., B. J. Connor and W. M. Edwards. Herbicide runoff from conventional and no-tillage cornfields. Ohio Report. 63: 70-73

22. Baker, J. L., and H. P. Johnson. "The Effects of Tillage Systems on Pesticides in Runoff From Small Watersheds." Trans. Amer. Soc. Agricultural Engineering. 22: 554, 559, 1979.

CHAPTER 3 - POLLUTANT EXPORT FROM WATERSHEDS

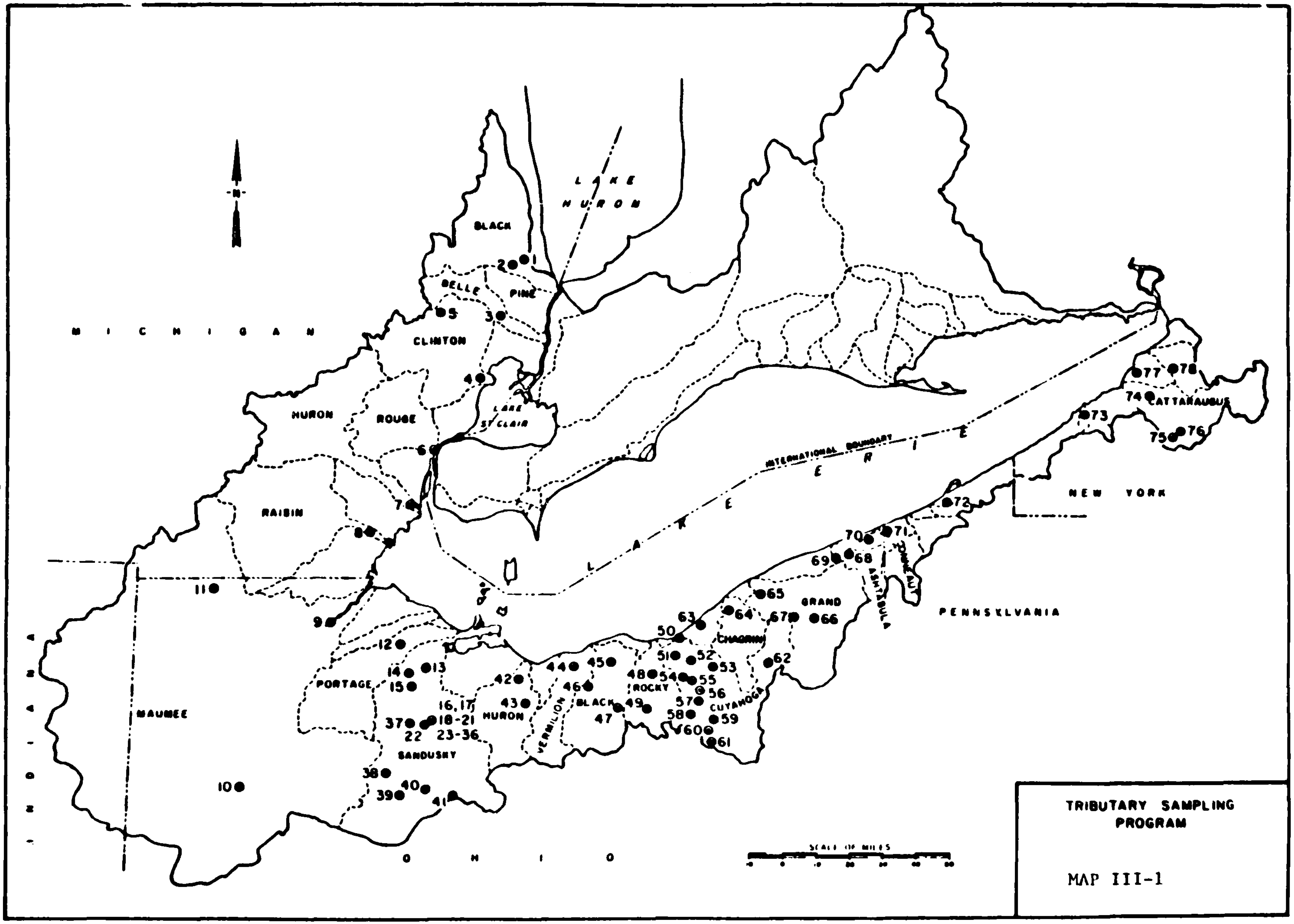
3.1 INTRODUCTION

This chapter describes the results of the tributary monitoring activities conducted by LEWMS. Phase I activities were directed at developing reliable nutrient loads to Lake Erie. These results showed that the bulk of the sediment and nutrient transport to the lake occurred during high flow events. These events were not monitored in previous studies and as a result total phosphorus loads to Lake Erie from diffuse sources were underestimated (Ref. 1). Studies conducted during Phase II were designed to: (1) characterize the spatial and temporal variability of the annual tributary loads to Lake Erie; (2) study the effects of mainstream transport processes on the delivery of both point and nonpoint derived pollutants to the lake; and (3) characterize pollutant export for a variety of watersheds with different land use. Phase II results were summarized in the Methodology Report (Ref. 2) and References 3, 4, 5, 6, 7, and 8. Tributary monitoring activities conducted during Phase III of this study had four objectives: (1) establish baseline data and monitor water quality changes in Honey Creek; (2) establish baseline data for the five watershed studies; (3) provide calibration data for watershed response models, and (4) characterize pesticide transport. These studies have been summarized in References 9, 10, 11, and 12.

The sampling program was conducted from December 1974 to September 1981. The 78 watersheds which were monitored are shown on Map III-1. It can be seen from this map that all tributaries draining into Lake Erie from the U.S. side were monitored. The heavy concentration of stations in the Sandusky River reflects the special studies carried out there. Table 3.1 shows the station identification number, locations, watershed area, sampling dates, and number of samples analyzed.

The strategy used to sample the watersheds was event sampling. A minimum of two high flow events with samples collected on the rising and falling stages of the hydrograph were monitored. From 23 to 3,472 samples were used to characterize pollutant export from a watershed. The parameters measured were total phosphorus, soluble reactive phosphorus, nitrite-nitrate nitrogen, ammonia nitrogen, total Kjeldahl nitrogen, suspended solids, chlorides, silica, and conductivity. Numerous pesticides were monitored and are listed in Table 3.8.

As can be seen from Table 3.1 the Maumee, Portage, Sandusky and Huron Rivers were the sites of extensive studies. The large data base available for these rivers allows one to examine annual variation in sediment and nutrient export. This chapter will summarize this information. It will also present what has been learned about fluvial transport of both point and diffuse sources. The pesticide studies are presented as well as the potential for use of models in estimating program effects.



TRIBUTARY SAMPLING PROGRAM

MAP III-1

Table 3.1 - Water Quality Monitoring Stations in the Lake Erie Drainage Basin

Station Location (USGS Gage No.)	Drainage Area	Map Code	Sampling Dates		Number of Samples
Michigan					
Black River Near Fargo (04159500)	480	1	3- 4-77	6-27-77	63
Mill Creek Near Avoca (04159900)	169	2	3- 4-77	6-27-77	65
Belle River at Memphis (04160600)	151	3	3- 4-77	6-27-77	65
Clinton River at Mt. Clemens (04165500)	734	4	3- 4-77	6-27-77	63
Sashabaw Creek Near Drayton Plains (04160800)	20.9	5	3- 3-77	6-27-77	62
River Rouge at West Jefferson Bridge	467	6	3- 3-77	6-27-77	63
Huron River at South Metropolitan Parkway	849	7	3- 3-77	6-27-77	63
River Raisin Near Monroe (04176500)	1,042	8	3- 3-77	6-27-77	63
Ohio					
Maumee River at Waterville (04193500)	6,330	9	1-10-75	9-30-78	2,181
Ottawa River at Allentown (04187500)	160	10	3-25-80	7- 1-80	211
			2-16-81	6-25-81	164
Bean Creek at Powers (04184500)	206	11	3-20-80	6-29-80	167
			2-17-81	7- 6-81	197
Portage River at Woodville (04195500)	428	12	12-19-74	9-30-78	1,976
Sandusky River Near Fremont (04198000)	1,251	13	12- 7-74	9-29-81	3,472
West Branch Wolf Creek at Bettsville (04197300)	66.2	14	2- 2-76	10- 6-80	2,344
			2-23-81	8- 2-81	236
East Branch Wolf Creek Near Bettsville (04197450)	82.3	15	1-28-76	10- 6-80	2,295
			1-30-81	8- 2-81	307
Rock Creek West at County Road 16	13.6	16	9-17-76	8- 2-77	36
Rock Creek East at County Road 16	7.0	17	9-17-76	8- 2-77	36
Mohawk Lake Tributary Below Mohawk Lake	5.3	18	8- 6-76	8- 2-77	42
Mohawk Lake Tributary Above Mohawk Lake	3.7	19	2-13-77	8- 2-77	23
Honey Creek at Route 231	171	20	8- 6-76	8- 2-77	42
Buckeye Creek at Route 67	5.6	21	8- 6-76	8- 2-77	43
Honey Creek at Melmore (04197100)	149	22	1-29-76	9-29-81	3,454
Silver Creek Confluence with Honey Creek	24.4	23	8- 6-76	9-17-77	43
Silver Creek Downstream from Marsh	16.4	24	8- 6-76	8- 2-77	43
Silver Creek Upstream from Marsh	12.1	25	8- 6-76	8- 2-77	43
Honey Creek Upstream from Silver Creek	121.6	26	8- 6-76	8- 2-77	42
Aichholz Ditch at County Road 49	16.3	27	8- 6-76	6-23-77	40
Honey Creek Upstream from Aichholz Ditch	95.6	28	8- 6-76	8- 2-77	43
Honey Creek at Attica at Route 4	75.6	29	8-11-76	8- 2-77	41
Broken Knife Creek at County Line Road	20.5	30	8- 6-76	9-17-77	43
Tributary to Honey Creek at Weis Road	10.1	31	8- 6-76	8- 2-77	43
Tributary to Honey Creek at RR North at Scott Road	3.4	32	8- 6-76	9-17-77	34
Honey Creek Upstream from Broken Knife Creek	26.8	33	8- 6-76	8- 2-77	43
Honey Creek Near New Washington (04197020)	17	34	2-23-79	9-29-81	1,453
Honey Creek at Route 103	15.7	35	8- 6-76	8- 2-77	42
Ackerman Ditch	4.4	36	8- 6-76	8- 2-77	39
Sandusky River Near Mexico (04197000)	774	37	1- 1-76	7-18-77	914
			10- 9-78	10- 6-80	1,049
			2- 2-81	9-29-81	330
Tymochtee Creek at Crawford (04196800)	229	38	1- 9-76	7- 2-79	1,731
Sandusky River Near Upper Sandusky (04196500)	298	39	1- 9-76	9-30-80	1,542
			2-25-81	8- 1-81	256
Broken Sword Creek Near Nevada (04196200)	83.8	40	1-29-76	9- 1-80	2,478
			2-23-81	8- 2-81	225
Sandusky River Near Bucyrus (04196000)	88.8	41	1- 1-76	9-30-80	2,495
			2- 5-81	8- 2-81	256
Huron River at Milan (04199000)	371	42	12-15-74	6- 6-79	2,318
Norwalk Creek Near Norwalk (04198100)	4.9	43	3-11-77	6- 7-77	63
Vermilion River Near Vermilion (04199500)	262	44	2-23-75	5-27-75	113
			3-11-77	7- 3-77	63
Black River at Elyria (04200500)	396	45	2-22-75	5-27-75	115
			3-11-77	7- 3-77	63
Plum Creek at Oberlin (04200100)	4.8	46	3-11-77	6-28-77	67
Neff Run Near Litchfield (04199800)	0.8	47	3-11-77	6- 7-77	63
Rocky River Near Berea (04201500)	267	48	1- 6-77	10- 9-77	145
West Branch Rocky River Near Valley City (04201300)	119	49	3-22-80	7- 2-80	200
Cuyahoga River at West Third Street Bridge (04208506)	798	50	1- 8-75	5-25-75	127
Big Creek at Cleveland (04208502)	35.3	51	3-18-77	6- 7-77	62
Cuyahoga River at Independence (04208000)	707	52	2-22-75	5-27-75	114
			12- 1-76	11-30-77	408
Tinkers Creek at Bedford (04207200)	83.9	53	11-30-76	12- 1-77	321
Chippewa Creek Near Brecksville (04206450)	17.7	54	2- 2-77	11-29-77	156
Brandywine Creek at Jaite (04206420)	27.2	55	2- 2-77	11-29-77	179
Cuyahoga River at Peninsula (04206400)	494	56	12-15-76	11-30-77	457
Furnace Run Near Everett (04206370)	17.7	57	2- 2-77	11-29-77	178
Yellow Creek Near Botzum (04206220)	30.7	58	2- 2-77	11-29-77	177
Mud Brook Near Akron (04206050)	29.3	59	2- 2-77	11-29-77	173
Cuyahoga River at Old Portage (04206000)	404	60	12- 4-76	11-30-77	374
Little Cuyahoga River at Akron (04205700)	59.2	61	3-29-77	11- 9-77	31
Cuyahoga River at Hiram Rapids (04202000)	151	62	2-22-75	5-27-75	116
Euclid Creek Near Euclid (04208690)	22.6	63	7- 9-77	6-11-78	215
Chagrin River at Willoughby (04209000)	246	64	2-22-75	5-25-75	98
			11-20-76	10-10-77	173
Grand River at Painesville (04212200)	701	65	3-12-77	6- 8-77	63
Hoskins Creek at Hartsgrove (04210100)	5.4	66	3-12-77	6- 7-77	43
Montville Ditch at Montville (04210090)	0.3	67	3-12-77	6- 7-77	43
Ashtabula River Near Ashtabula (04212500)	121	68	3-12-77	5-24-77	23
Hubbard Run at Ashtabula (04212600)	0.9	69	3-12-77	6- 7-77	44
Conneaut Creek at Conneaut (04213000)	175	70	3-12-77	5-24-77	23
Pennsylvania					
Raccoon Creek Near West Springfield (04213040)	2.5	71	2-16-77	5- 6-77	54
Mill Creek at Erie (04213200)	9.2	72	2-16-77	6- 6-77	54
New York					
Canadaway Creek at Fredonia	34.9	73	1- 1-75	2-18-75	43
Cattaraugus Creek at Gowanda (04213500)	432	74	1-11-75	5-27-75	188
			2-16-77	6- 7-77	80
South Branch Cattaraugus Creek Near Cattaraugus	67.5	75	3-21-80	6-21-80	73
South Branch Cattaraugus Creek Near Otto (04213490)	25.6	76	2-16-77	6- 7-77	78
Delaware Creek Near Angola (04214040)	8.2	77	2-16-77	6- 7-77	90
Eighteen Mile Creek at North Boston (04214200)	37.2	78	2-16-77	6- 6-77	77

3.2 SEDIMENT AND NUTRIENT EXPORT

3.2.1 Annual Variations.

The loading of sediments and nutrients into Lake Erie from major tributaries varies substantially from year to year as illustrated in Table 3.2. In this table, the annual discharge, as measured by the U.S. Geological Survey, and the annual flux weighted mean concentrations are shown in addition to the annual loading values. Flux weighted concentrations are obtained by dividing the total measured flux by the associated discharge. Both variations in annual discharge and variations in average annual concentration contribute to the variations in annual loading.

The largest annual loads are not necessarily associated with the largest annual discharges. The data for the Sandusky River at Fremont for 1975, 1978, and 1979 illustrate the importance of pollutant concentration in annual loading. Although in 1978 the annual discharge exceeded the discharges in both the 1975 and 1979 water years, the annual flux weighted concentrations of suspended solids and total phosphorus in 1975 and 1979 were much higher than in 1978. Consequently the loadings of these parameters in 1975 and 1979 exceeded the loading in 1978.

The large annual variability in flux weighted concentrations makes it difficult to estimate mean annual loadings of nutrients and sediments based on short-term, intensive studies. Although mean annual discharge data based on long-term flow records are often available for large rivers, long-term chemical measurements, upon which reliable mean annual flux weighted mean concentrations can be determined, are seldom available. For many water quality management decisions, mean annual tributary loadings are desirable, rather than the loading in any particular year. Only through multiyear, intensive sampling programs can reliable estimates of mean annual loadings be obtained for the major Lake Erie tributaries.

3.2.2 Seasonal and Storm Variability.

Most of the pollutant loading into Lake Erie from tributaries occurs during runoff events. The peak discharge during these runoff events can range from low values associated with frequently recurring small events to high values accompanying infrequent major floods. The flux weighted concentrations of sediments and nutrients for individual storms also varies widely. In Figure 3.1 the relationship between the flux weighted suspended solids concentration and peak flows for 52 individual storms at the Upper Sandusky station is illustrated. Storms with equal peak flows can be accompanied by widely varying average suspended solids concentrations over the entire range of peak flows.

In Figure 3.1 the month of occurrence of the individual runoff events is also shown. In general events occurring during the winter months (12 = December; 1 = January; 2 = February, etc.) have much smaller average concentrations than do events occurring during spring and summer periods. Most runoff events during the winter and early spring are associated with snow melt, and contain relatively low sediment and phosphorus concentrations.

Table 3.2 - Annual Variations in Flux Weighted Mean Concentrations and Yields of Sediments and Nutrients at Selected Northwestern Ohio Gaging Stations

Station	Water Year	Discharge 10^6 m^3	Suspended Solids Flux Wt. Con. mg/L	Suspended Solids Yield 10^3 m.tons	Total Phosphorus Flux Wt. Con. mg/L	Total Phosphorus Yield m. tons	Sol.Reactive Phos Flux Wt. Con mg/L	Sol.Reactive Phos Yield m. tons	Nitrate-Nitrite N Flux Wt Con mg/L	Nitrate-Nitrite N Yield m. tons
Maumee	1975	4,763	279	1,329	.577	2,748	.114	543	6.72	32,000
	1976	5,035	315	1,588	.554	2,739	.107	538	3.58	18,000
	1977	3,053	404	1,233	.739	2,256	.098	299	6.82	20,000
	1978	6,166	138	851	.396	2,442	.111	684	4.40	27,000
Portage	1975	290	275	80	.496	144	.133	39	8.14	2,360
	1976	326	161	52	.400	130	.111	36	3.82	1,245
	1977	241	128	31	.389	94	.140	34	8.86	2,140
	1978	444	132	59	.359	159	.100	44	4.84	2,150
Sandusky,	1975	1,030	294	303	.513	528	.067	69	4.99	5,140
Fremont	1976	772	198	153	.401	309	.072	56	3.82	2,950
	1977	629	160	100	.416	261	.106	67	4.96	3,120
	1978	1,391	148	206	.357	497	.075	104	4.12	5,730
	1979	1,088	272	296	.531	578	.104	113	4.87	5,300
Huron	1975	306	281	86	.403	123	.080	24	3.66	1,120
	1976	267	232	62	.293	78	.141	38	2.31	617
	1977	254	279	71	.436	111	.088	22	5.30	1,346
	1978	405	119	48	.291	117	.108	43	2.99	1,210
Honey	1976	69	226	16	.484	33	.053	3.6	3.71	256
Creek,	1977	73	87	6.3	.284	20	.092	6.7	5.82	424
Melmore	1978	148	67	9.9	.252	37	.083	12	3.78	559
	1979	150	271	41	.524	79	.081	12	5.17	775

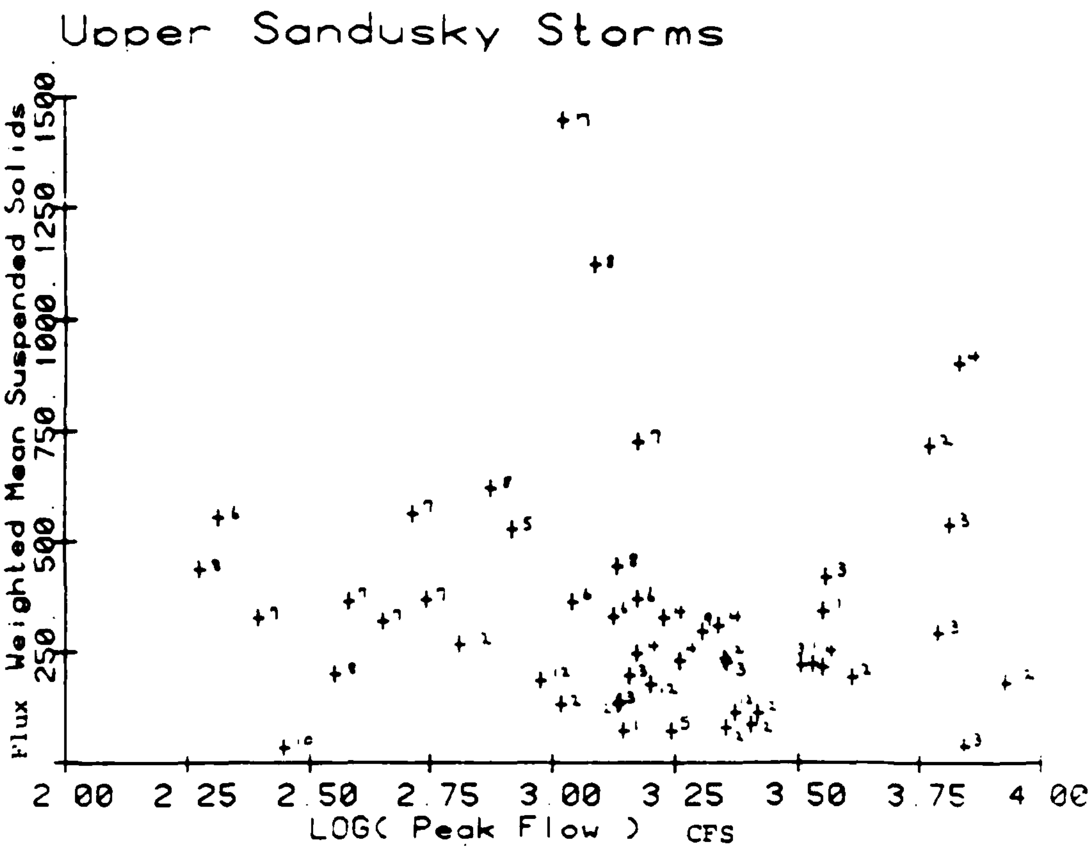


Figure 3.1 Flux Weighted Mean Concentrations of Suspended Solids in Relation to Peak Flow with Months of Occurrence Marked for Individual Storms (Jan +1, Feb +2, etc.)

SOURCE: Reference 12

Table 3.3 - Monthly Variations in Yields and Flux Weighted Concentrations of Nutrients and Sediments at the Melmore Gaging Station for the Period between February 1976 and September 1981

		Total Phosphorus		Suspended Solids		Nitrate-Nitrite N	
Month	No. of Samples	Yield m ton	Flux Wt. Con mg/L	Yield m tons	Flux Wt. Con mg/L	Yield m ton	Flux Wt. Con mg/L
Jan	172	7.618	.213	1,409	39.76	193	5.419
Feb	277	48.75	.461	19,000	179.81	477	4.515
Mar	330	36.69	.266	10,883	78.74	530	3.86
Apr	318	49.67	.5069	22,353	227.	462	4.709
May	252	12.307	.2929	6,382	151.8	395	9.402
Jun	383	78.04	.939	66.828	796.6	656	7.83
Jul	360	9.48	.461	6,379	311.93	128.5	6.25
Aug	276	6.93	.348	3,026	152.11	49.3	2.50
Sep	222	10.44	.372	3,534	116.2	82.75	2.72
Oct	149	.88	.107	75	10.4	16.95	2.24
Nov	145	7.87	.343	1,759	77.3	89.6	3.90
Dec	182	16.67	.265	4,072	64.9	338	5.39

Spring and summer runoff events, where raindrops impact on bare soil, have the highest sediment concentrations.

In Table 3.3 the monthly distribution yields and flux weighted concentrations of total phosphorus, suspended sediments and nitrate plus nitrite nitrogen are shown for Honey Creek at Melmore. The table shows the total yield and flux weighted concentration for all of the samples collected in each month during a 5.5 year sampling period. June storms had the highest sediment and total phosphorus concentrations, while May storms had the highest nitrate plus nitrite-N concentrations.

The seasonal patterns of suspended solids concentrations provide an explanation for the large differences in flux weighted sediment concentrations in the Sandusky River at Fremont between the 1978 and 1979 water years. In 1978 the December through March period accounted for 76.1 percent of the annual discharge at Fremont while in 1979 this period accounted for only 45.5 percent of the annual discharge. Although both years had high discharges the predominantly winter runoff of 1978 had much smaller annual average sediment concentration (148 mg/L) than in 1979 with its much smaller proportion of winter runoff at much higher concentration (272 mg/L).

In runoff events during the spring and early summer periods that result from sustained, low-intensity rains, the sediment and nutrient concentrations differ substantially from the concentrations in events produced by more intense rainstorms. The former conditions produce runoff water with relatively low suspended solids concentrations but exceptionally high nitrate concentrations. Apparently with prolonged, low intensity rains the proportion of stream flow derived from tile effluent increases while the proportion from surface runoff decreases. This would account for the elevated nitrate levels during this condition, as well as the lower sediment concentrations.

The large variability in suspended sediment concentrations for storms with similar peak flows leads to the following conclusions:

a. Most of the time the sediment transport in the streams is less than the sediment carrying capacity of the streams at a given flow. There apparently is not a ready source of erodible sediment from stream banks or bottom that replace sediment "deficits" in surface runoff water entering the stream network. Thus programs that reduce the sediment concentration in surface runoff water should reduce the sediment yield from large river basins.

b. The interaction between watershed factors and precipitation intensity, duration, and distribution have major impacts on the concentration of sediments and nutrients present in runoff water. During the time period of the study at Upper Sandusky there were no significant changes in farming practices that would have accounted for variations in stream chemistry. The seasonal changes of ground cover associated with the prevalent rotations and tillage practices coupled with variations in precipitation patterns were sufficient to cause the observed variations.

c. The extent of the variability illustrates the complexity of calibrating models where output includes sediment graphs and chemographs for individual storms from large watersheds. The inputs for such models must include the major variables which cause the variation in concentrations within storms with equal peak flows.

3.2.3 Phosphorus Sediment Ratios.

A large portion of the total phosphorus transported in a river system is associated with suspended solids. Often phosphorus loading is estimated through first estimating sediment yields and then multiplying by a phosphorus-sediment ratio. The latter can be obtained from empirical determinations or the use of phosphorus enrichment ratios and soil phosphorus values. In Table 3.4 the nutrient-sediment ratios as measured for the northwestern Ohio river basins using the entire data sets for each station are listed. The highest ratios of phosphorus to sediment were observed at the Bucyrus station. This station was located a short distance downstream from the Bucyrus sewage treatment plant and the high ratios observed at that station undoubtedly reflected the effect of phosphorus derived from point sources.

The most constant of the phosphorus-sediment ratios was the particulate phosphorus fraction. This is estimated by subtracting the soluble reactive phosphorus from the total phosphorus values. The lowest value for this ratio was found at the Nevada station, which has the highest gross erosion rates. One important aspect of the data on phosphorus-sediment ratios was variability. This variability is shown in the data of Table 3.2. At the Melmore station in 1978, the TP/SS and PP/SS ratios were 3.76 and 2.52 while in 1979 the ratios were 1.93 and 1.63. Both years had similar total discharges of water. Sediment concentration was lower in 1978 resulting in a higher phosphorus sediment ratio.

Table 3.4 - Nutrient-Sediment Ratios for Agricultural Watersheds of Northwestern Ohio, 1974-1979

Gaging Station	TP/SS (1)	OP/SS (2)	PP/SS (3)
	g/kg	g/kg	g/kg
Maumee, Waterville	2.13	0.48	1.65
Portage, Woodville	2.45	0.73	1.72
Huron, Milan	1.64	0.47	1.17
Sandusky, Fremont	2.09	0.43	1.66
Sandusky, Mexico	1.79	0.29	1.50
Sandusky, Upper S.	2.20	0.57	1.63
Sandusky, Bucyrus	3.31	1.26	2.05
Tymochtee, Crawford	2.04	0.34	1.71
Honey Cr., Melmore	2.24	0.56	1.68
Broken Sword, Nevada	1.64	0.25	1.39
Wolf Cr., East Br.	2.30	0.65	1.65
Wolf Cr., West Br.	2.15	0.55	1.61
Mean	2.17	0.55	1.62
St. Dev.	0.44	0.26	0.21

SOURCE: Reference 12

(1) Mean annual total phosphorus load divided by the mean annual suspended sediment load.

(2) Mean annual soluble reactive phosphous load divided by the mean annaul suspended sediment load.

(3) Mean annual total phosphorus load minus soluble reactive phosphorous load divided by the mean annual suspended sediment load.

For individual samples there is a great amount of variability in both TP/SS and PP/SS ratios. This variability is illustrated for the Melmore station in Figure 3.2. The TP/SS ratios for individual samples are plotted as a function of stream flow in Figure 3.2a. In Figure 3.2b, the same data is presented with the ratios plotted as a function of suspended solids concentrations. In this form it is evident that higher suspended solids concentrations are associated with lower phosphorus-sediment ratios. The same is true for particulate phosphorus ratios (Figure 3.2c). One possible explanation for the above would be that higher sediment concentrations may tend to have larger average particle size distributions. Since smaller particles have larger surface areas, and often mineralogies suited to adsorption, they may have more phosphorus per unit weight than finer particles. Organic matter which contains higher phosphorus concentrations than the mineral fraction of soils and sediments is concentrated in the smaller particle size fractions.

The variability in nutrient sediment ratios for individual samples points out the difficulties that may be encountered when attempting to measure such ratios based on the collection of a small number of samples. For individual stations the flux weighted suspended solids concentrations can vary from year to year and the accompanying ratios of TP/SS can also have large annual variations. At Melmore, the TP/SS values in mg/g varied from 2.52 in 1978 to 1.63 in 1979 (data from Table 3.2). Since control programs aimed at reducing phosphorus loading from agricultural sources are based on erosion control programs and such programs may have different degrees of effectiveness for different particle sizes, a better understanding of nutrient-sediment ratios in relation to particle size distribution is needed.

3.3 FLUVIAL TRANSPORT

3.3.1 Point and Non-Point Source Components of Stream Phosphorus Transport.

The entire data sets for each station have been used to calculate the mean annual phosphorus transport (Ref 12). These mean annual nutrient loads are presented in Table 3.5. The loads include the contributions of both point and nonpoint source inputs. A standard procedure for calculating the nonpoint source components of the transport is to subtract upstream point source inputs from the total stream transport. This assumes that all of the point source inputs are transported through the stream system. By assuming 100 percent transmission of point source inputs and subtracting this value from the total stream transport, the resulting value for nonpoint components represents a minimum value.

Calculations of nonpoint phosphorus loading for the study watersheds are shown in Table 3.5. Point source loading estimates for the study watersheds were taken from sewage treatment plant records where available and estimated in other cases. Plants with flows both greater than and less than 1 million gallons per day were included in the point source summaries (Ref. 1). Table 3.5 also includes data which suggests that point source inputs do not have 100 percent transmission through the stream system. The watersheds with the highest percentage of point source phosphorus (Bucyrus, Portage and Huron) have the lowest unit area nonpoint phosphorus yields. These same watersheds,

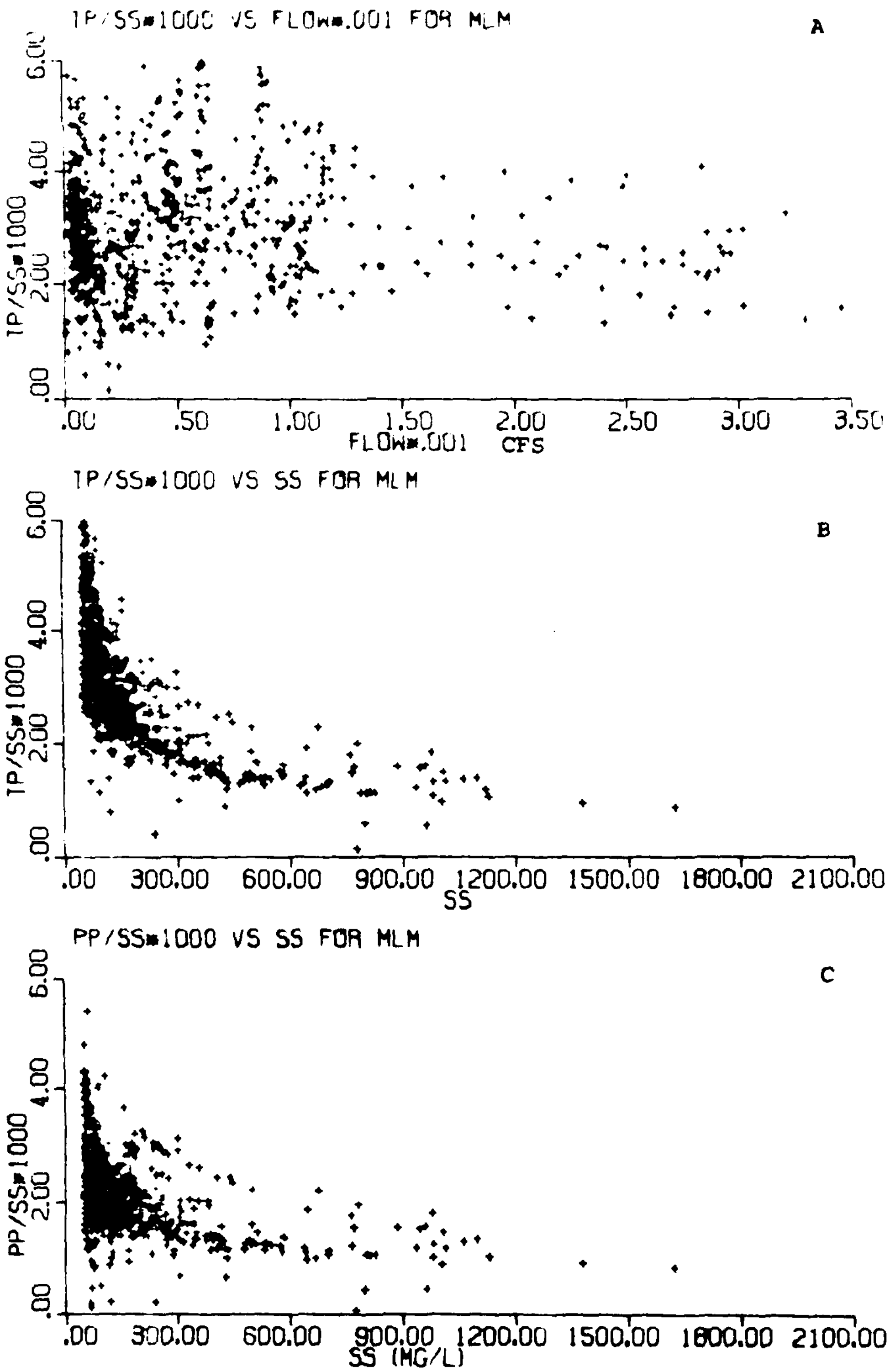


Figure 3.2 Phosphorus/Sediment Ratios (X 1000) for Individual Samples Plotted in Relation to Stream Flow (A) and Suspended Sediment Concentrations (B+C) for Honey Creek at Melmore

SOURCE: Reference 12

Table 3.5 - Minimum Nonpoint Source Phosphorus Yields for the Study Watersheds

Watershed	Mean Annual Phosphorus Transport (t/yr)	Point Source Input (t/yr)	Maximum Nonpoint Yield (t/yr)	Unit Area Nonpoint Yield (kg/ha/yr)	Suspended Solids Yield (Mt/ha/yr)	Nonpoint TP/SS Ratio (g/kg)	Point Source % of Total Phosphorus Yield (%)	Watershed Population Density (#/km^2)
Maumee	2,200	321	1,879	1.14	.63	1.81	14.6	-
Portage	108	40	68	.61	.40	1.52	37.0	-
Huron	98.4	44	54.4	.57	.59	.97	44.7	-
Sandusky Basin Stations								
Fremont	355	45	310	.96	.52	1.85	12.7	31
Mexico	234	37	197	.98	.65	1.51	15.8	26
Upper Sandusky	112	32	80	1.04	.63	1.65	28.5	46
Bucyrus	42.6	27	15.6	.68	.54	1.25	63.3	96
Nevada	31.1	-	31.1	1.43	.87	1.64	0	16
Tymochtee	62.9	-	-	1.06	.54	1.96	0	8
Melmore	42.2	3.5	39.0	1.01	.49	2.06	8.3	18
Wolf, East	29.8	-	29.8	1.40	.61	2.29	0	29
Wolf, West	17.6	-	17.6	1.03	.48	2.13	0	29

SOURCE: Reference 12

AD-A120 625 LAKE ERIE WASTEWATER MANAGEMENT STUDY(U) CORPS OF ENGINEERS BUFFALO NY BUFFALO DISTRICT SEP 82 2/4

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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

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however, have unit area sediment yields comparable to adjacent watersheds lacking point source inputs. Consequently, the nonpoint phosphorus to sediment ratios are relatively low for the watersheds with higher percentages of point sources. The explanation could be a transmission of point source phosphorus inputs of less than 100 percent. Even if point source inputs have 100 percent transmission through the stream systems they would account for only 16.3 percent of the total loads observed at the river mouth stations (Maumee, Portage, Huron, and Sandusky at Fremont).

Septic tank systems are another potential source of phosphorus in the stream system. Within the Sandusky Basin upstream from Fremont the total population is about 99,600 (preliminary 1980 census data). Approximately 50 percent of the population is served by centralized sewage collection systems and treatment plants, while the other 50 percent is served by septic tanks. Although some septic tank effluents containing phosphorus enter the stream systems, studies conducted below the town of Tyro in the Honey Creek watershed indicated that stream loading associated with septic tank inputs was quite small (Ref. 10).

The dominance of agricultural land use within the study watersheds suggests that the bulk of this nonpoint phosphorus loading is derived from rural, rather than urban land uses. The unit area nonpoint phosphorus loading rates are actually higher in watersheds which lack urban areas (Nevada, Tymochtee, Melmore, Wolf East and Wolf West) than for watersheds containing urban areas.

3.3.2 Stream Processing of Point Source Phosphorus Inputs.

During nonstorm flow condition, point source phosphorus entering stream systems rapidly disappears from the water column. Biological uptake by the periphytic and benthic communities, adsorption onto sediments, and chemical precipitation could all be involved in the removal of total phosphorus from the flowing water. (Ref. 6 and 8).

The extent of phosphorus deposition below point sources in the Sandusky Basin has been analyzed using both concentration data and flux data (Ref. 13). The combined point source loading rate in the Sandusky Basin upstream from Fremont is about 5.3 kg/hr. The phosphorus flux at Fremont averaged 1.79 kg/hr and was less than 5.3 kg/hr for 55 percent of the time and the cumulative flux during that time accounted for only 2.14 percent of the total phosphorus flux observed at the Fremont station (Ref 12). This flux includes both phosphorus from point sources and "background" phosphorus following the hydrological pathways of water under these flow conditions.

The average flow during the 55 percent of the time with the lowest flows was 145 cfs. Since the combined flow from all the sewage treatment plants is only about 14 cfs, it is clear that the bulk of the flow (131 cfs) during this portion of the time is derived from hydrological pathways such as ground water, tile effluent and surface water rather than point sources. In the watersheds lacking point sources, the total phosphorus concentrations averaged about 0.12 mg/l during the 55 percent of the time with the lowest flows. Assuming that this concentration characterized the nonpoint or "background" concentration of the stream flow, the average nonpoint loading rate would be about 1.6 kg/hr. Since at Fremont, the average total loading during this time period is 1.8 kg/hr, it is clear that most of this phosphorus can be attributed to nonpoint rather than point source inputs. With point source phosphorus input rates of 5.3 kg/hr, and with only about 0.2 kg/hr of the average output for 55 percent of the time allocable to point sources, it is clear that these streams are capable of removing most of the point source phosphorus inputs from the flowing water. The 55 percent time period in the above calculations was selected because in the flux exceedency tables, 55 percent of the time the fluxes at Fremont were below the point source input rate of 5.3 kg/hr. Since much of that phosphorus loading would be due to nonpoint sources, deposition of point source phosphorus must also be occurring at higher flows and fluxes.

Municipal point sources which load phosphorus into tributaries upstream from gaging stations nearest Lake Erie are considered indirect point sources with respect to phosphorus loading. Direct point sources are those whose outfalls enter streams below the gaging station nearest the lake, or enter estuaries or the nearshore zone of the lake. The effectiveness of phosphorus control programs at indirect point sources in reducing eutrophication in Lake Erie depends on the extent of resuspension and eventual delivery of this phosphorus to the lake, and on its bioavailability upon reaching the lake.

Analysis of hydrograph patterns at Sandusky gaging stations coupled with wave and water routing techniques indicate that sediment resuspension is an important component of sediment transport in this basin (Ref. 7). Phosphorus derived from point sources becomes part of the particulate phosphorus which is resuspended and moved downstream by the passage of wave fronts associated with storm flows. Soluble phosphorus is not released from this particulate phosphorus during the passage of storm events. The question of the transmission of point source phosphorus to the lake becomes a question of the instream transmission or delivery of particulates to the lake. Reservoir sedimentation or flood plain deposition could transfer point-source-derived phosphorus into long-term sinks and consequently reduce the transmission of this phosphorus below 100 percent. It is also possible that phosphorus could be removed from stream systems through food chains or other biological means.

With respect to bioavailability, some evidence indicates that the point-source-derived phosphorus that does reach the lake as particulate phosphorus has no greater bioavailability than nonpoint particulate phosphorus. This assumes that point-source-derived particulate phosphorus which is bioavailable would be present in the NaOH extractable-P fraction. Baker (Ref. 14), has measured the available particulate phosphorus (NaOH-P) for the 12 Sandusky stations. The results are presented in Table 3.6. The percentage of the particulate phosphorus that is available is approximately the same along both mainstem stations and agricultural tributary stations. This would not be expected if point-source-derived phosphorus became largely incorporated into the bioavailable particulate fraction. At the Fremont station, the mean annual particulate phosphorus loading is 278 metric tons per year. Assuming 25 percent of this is bioavailable, the bioavailable particulate phosphorus loading would be 64 metric tons per year. If all of the point source phosphorus inputs upstream from Fremont (45 metric tons per year), 75 percent of which can be assumed to be available, were exported as bioavailable particulate phosphorus, the point source inputs would make up 53 percent of the total export of bioavailable phosphorus from the basin. It would then be expected that the percent bioavailability would be much greater along the mainstream of the river below point sources than from watersheds lacking or with very small point source inputs. Data presented in Table 3.6 do not support this. Instead, the data suggest that, as a result of instream processing along the mainstem of the river, point source phosphorus that is discharged to the stream system does not alter the availability of particulate phosphorus that is subsequently exported from the basin even though the amounts processed are large relative to the loading of NaOH-P. The fate of this point-source-derived phosphorus remain to be determined. It is clear that the forms of phosphorus reaching Lake Erie from indirect point sources will be quite different from phosphorus derived from direct point sources.

Table 3.6 - Average Bioavailability of Particulate Phosphorus in Storm Runoff Samples Collected in the Sandusky Basin as Measured by NaOH Extraction

Station	Number of Samples	Average Bioavailability (%)	Standard Deviation
Sandusky River, Fremont	64	23.1	1.77
Sandusky River, Mexico	48	24.4	4.73
Sandusky River, Upper Sandusky	54	23.3	1.96
Sandusky River, Bucyrus	16	24.1	2.82
Wolf Creek, East Branch	31	21.4	3.26
Wolf Creek, West Branch	39	20.8	4.87
Honey Creek, Melmore	59	24.9	3.84
Honey Creek, New Washington	44	23.4	3.51
Tymochtee Creek, Crawford	32	23.2	3.79
Broken Sword Creek, Nevada	23	22.1	5.30

SOURCE: Reference 14

It should also be noted that most of the soluble reactive phosphorus delivered to the lake from tributaries is derived from nonpoint sources. The flux exceedency tables for the Fremont gage indicate that 70 percent of the soluble phosphorus flux is delivered in 10 percent of the time. On an annual basis this corresponds to 53.5 metric tons of soluble reactive phosphorus during 10 percent of the year. Since point source inputs are relatively constant year round, they could account for only 4.5 metric tons during the time when the total export was 53.5 metric tons (Ref 12). Even if during periods of high streamflow soluble phosphorus from point sources moved directly through the stream system without processing, it could account for only a small portion of the soluble phosphorus loading to the lake.

Of the total bioavailable phosphorus entering Lake Erie from tributaries approximately 50 percent is soluble reactive phosphorus and 50 percent is bioavailable (NaOH-extractable) particulate phosphorus. Since most of the soluble reactive phosphorus is exported during floods and is derived from nonpoint sources, and since point source derived phosphorus does not appear to enrich the particulate phosphorus, in terms of the NaOH-extractable fraction, the tributary phosphorus from nonpoint sources actually has a greater bioavailability upon reaching the lake than does phosphorus from indirect point sources.

3.3.3 Relative Deliveries of Phosphorus to Lake Erie.

Research in northwestern Ohio rivers suggests that temporal, spatial and hydrodynamic aspects of phosphorus loading could also be very important in comparing the effects of point and nonpoint inputs on open-lake phosphorus level. As described above, point source inputs are processed extensively in streams resulting in deposition and probable reduction in subsequent bioavailability. Direct point source phosphorus inputs into the lower section of rivers, estuaries, bays, and even the near shore zone of the lake, may also be subject to rapid processing, resulting in deposition and/or conversion to less bioavailable forms. The susceptibility of point source inputs to efficient processing may be associated with the constant rather than pulsed nature of these inputs. The annual point source inputs are delivered to aquatic systems at approximately constant daily rates. The processing of this phosphorus may be associated with significant localized water quality problems.

In contrast, the nonpoint phosphorus is delivered in association with runoff events. Large portions of the annual loads are delivered in a small percentage of the time. During periods of nonpoint loading the retention time of water in the lower sections of rivers, estuaries, bays and even the nearshore zone of the lake would be much shorter. Consequently, soluble nonpoint phosphorus may be much less susceptible to processing within these zones than point-source-derived phosphorus. Since much of the particulate phosphorus of nonpoint origin is associated with clay-sized particles, this material may also be delivered rather efficiently through the estuaries, bays and the nearshore zone to the open lake.

It should also be noted that the concentrations of both soluble and total phosphorus in rivers during periods of high flows are much higher than the phosphorus concentrations in lake water. Also, point source phosphorus from the Detroit area enters the Western Basin of Lake Erie at much lower concentrations than nonpoint phosphorus, due to the large volume of water with low phosphorus concentration entering the Detroit River from the Upper Lakes.

3.3.4 Gross Erosion, Sediment Delivery and Critical Area Identification.

Potential gross erosion rates were calculated for all the agricultural lands in the Lake Erie Basin (see Section 2.5). Using the LRIS system, these data were aggregated for each of the study watersheds, producing an average gross erosion rate under current cropping management systems. The resulting average gross erosion rates are shown in Table 3.7. Dividing the mean annual suspended sediment yields, as determined from the water quality monitoring program, by the average gross erosion rates gives the average sediment delivery ratios for each watershed (Table 3.7). The sediment delivery ratios ranged from 6.2 to 11.9 percent.

Table 3.7 - Sediment Delivery Ratios for Northwestern Ohio Agricultural River Basins

Gaging Station	Watershed Area km^2	Mean Annual Flow (cm/yr)	Gross Erosion Tons/ha/yr	Sediment Yield (Tons/ha/yr)	Delivery Ratio Percent
Maumee	16,395	26.3	6.84	0.63	9.2
Portage	1,109	25.1	5.00	0.40	8.0
Huron	961	27.9	7.51	0.59	7.9
Sandusky	3,240	26.3	8.25	0.52	6.3
Mexico	2,005	25.7	9.37	0.65	6.9
Upper Sandusky	772	28.0	9.35	0.63	6.8
Bucyrus	230	32.9	7.85	0.54	6.9
Tymochtee	593	25.8	8.41	0.52	6.2
Honey Creek	386	27.1	6.86	0.49	7.1
Nevada	217	35.6	9.39	0.87	9.2
Wolf, East	213	33.5	5.11	0.61	11.9
Wolf, West	171.5	26.0	4.19	0.48	11.5

SOURCE: Reference 12

The delivery ratios were so variable among the watersheds that they masked any clear relationship between gross erosion rates and sediment yields or nonpoint phosphorus yields. The lack of correlation between gross erosion and nonpoint phosphorus yields is illustrated in Figure 3.3. The three stations with the lowest nonpoint phosphorus yields are those with relatively large point source inputs. For these stations the nonpoint yield has probably been underestimated.

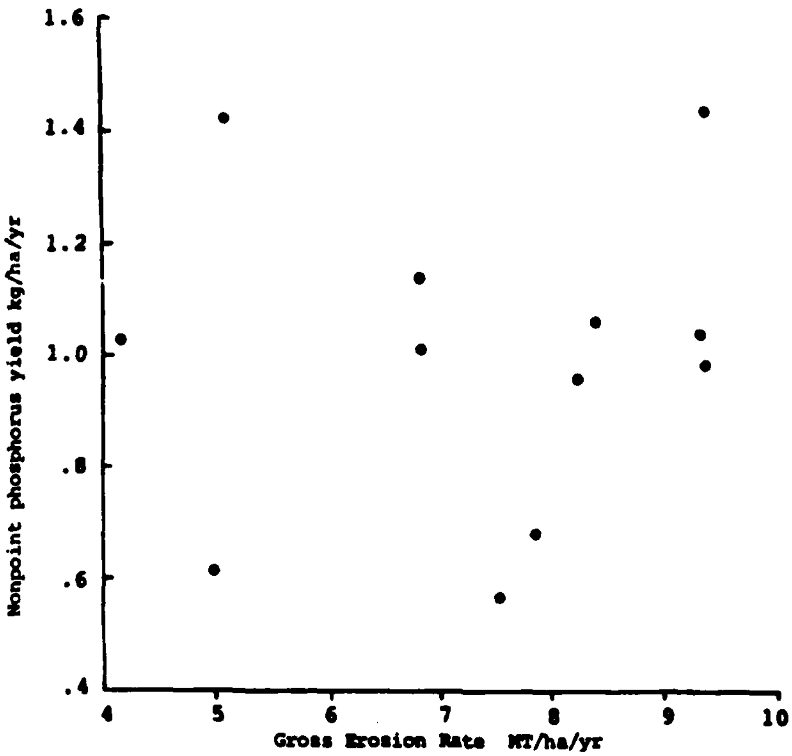


Figure 3.3 Relationship between Nonpoint Phosphorous Export and Gross Erosion Rates in the Study Watersheds.

SOURCE: Reference 12

The data illustrated in Figure 3.3 raises a basic question about the potential effectiveness of programs aimed at reducing nonpoint phosphorus yields by reducing gross erosion. The data illustrate no clear relationship between these two variables in the study watersheds. The control programs outlined in subsequent sections of this report are based on the following interpretation of the above data:

1. The variability in average gross erosion in the study watersheds under current and predominantly conventional tillage is largely a consequence of varying soils (K factors). The unit area phosphorus yields are largely related to the export of clays and fine silts from the watersheds. For these watersheds the unit area export of these smaller particle sizes is apparently rather uniform. The watersheds with higher gross erosion rates have generally lower sediment delivery ratios due in large part to downslope deposition of large particle size fractions.

2. The reductions in gross erosion rates, upon which the proposed nonpoint phosphorus control program is based, will be achieved through increasing the ground cover and surface roughness (decreasing the C factor). These reductions in gross erosion should be accompanied by a decrease in the entrainment of clay particles and their loss by surface runoff. Consequently, these reductions in gross erosion should be accompanied by decreased suspended sediment and phosphorus yields.

The above interpretation has considerable significance for water quality management programs. From the standpoint of agricultural nonpoint phosphorus problems, calculations of average gross erosion rates are of little value in identifying critical areas. In watersheds characterized by high nonpoint phosphorus yields, adoption of conservation tillage programs which increase ground cover or decrease surface runoff could be equally effective in reducing phosphorus yield when applied to areas of low gross erosion as when applied to areas of high gross erosion. Thus with respect to reducing sediment and particulate phosphorus yields to Lake Erie from northwestern and northcentral Ohio tributaries, "critical areas" may not exist. Instead, efforts should concentrate on implementing various conservation tillage practices wherever the combination of suitable soils and technology are present. The benefits to the lake could be proportional to the areal extent of conservation tillage implementation rather than to the reduction in gross erosion per se. It is quite possible that the proportional reduction in phosphorus yields could be greater than the reduction in gross erosion for a large watershed.

3.4 PESTICIDE TRANSPORT

3.4.1 Introduction.

Currently-used agricultural pesticides pose a much smaller environmental hazard than the pesticides in common use in the 1960's (Ref. 15). Most of the currently-used compounds have lower mammalian and fish toxicities, lower environmental persistence, and smaller tendencies for bioaccumulation.

Through pesticide registration requirements, currently used formulations all receive extensive testing to assure that they will not behave in the environment in a similar fashion to the chlorinated hydrocarbons such as DDT.

Environmental studies of currently-used compounds have largely centered on studies of the factors which affect edge-of-field losses to stream systems (Ref. 15). The intensity and amount of rainfall, the timing of rainfall relative to pesticide application, the method of pesticide application, and the properties of the individual pesticides all greatly affect both the amounts and concentrations of pesticides in runoff. Generally, the runoff losses are 1 to 2 percent or less of the applied materials, although under "catastrophic" conditions of high rainfall immediately following pesticide application, 6 percent or more of certain compounds may be exported in the runoff (Ref. 16). Because of the small percentage of runoff losses and their relatively low environmental hazard, little priority has been given to studies of the occurrence, transport and environmental effects of these compounds in stream systems and lakes.

Logan (Ref. 17) has reviewed current pesticide use and projected the impact of conservation tillage on pesticide use and runoff losses. He concludes that there may be an increase in contact herbicides, but in general, pesticide use and runoff losses, will not change markedly with a shift to conservation tillage. This study further investigated the basic characteristics of pesticide loss in order to have an environmental baseline before major shifts to conservation tillage occur.

In order to study some basic characteristics of pesticide transport in streams draining large agricultural watersheds, detailed measurements of chemograph patterns for currently-used pesticides were obtained at the Melmore gaging station in Honey Creek. The detailed sampling program was augmented by a grab sampling program at 11 additional sites in northwestern and north-central Ohio to examine the extent of geographical variability in pesticide concentrations. Selection of pesticides for analysis was based primarily on the quantities applied within the region rather than on the relative hazard posed by the compounds. The pesticides included in the study are listed in Table 3.8.

An automatic sampler was used to collect samples at 12-hour intervals at the Melmore gaging station on Honey Creek and a grab sampling program was operated at the other sites. Analytical methods are detailed in Baker et al (Ref. 11).

3.4.2 Results.

The 1981 water year was characterized by unusually high rainfall and runoff during the month of June. Rainfall at 19 daily recording stations in the Honey Creek Watershed averaged 23.8 cm for the month and ranged from 14.9 to 37.2 cm. The average June rainfall at seven stations in or near the Sandusky River Basin for the period 1951 - 1975 was 8.7 cm. Most of June, 1981 rainfall occurred during four storm periods centering on June 8 and 9, June 13, June 21, and June 23. Hourly totals of 4.93 cm and 2.67 cm were recorded at two recording gages in the basin on 13 June.

Table 3.8 - Characteristics of the Pesticides Measured in this Study (1)

Common Name	Trade Name	Class	Solubility (2) (mg/L)	Persistence in Soil (3) (months)	Application Method (4)
Alachlor	Lasso	Anilide Herbicide	242	2	PE, PPI
Atrazine	Aatrex & Others	Triazine Herbicide	33	12	POE, PE, PPI
Butylate	Sutan	Thiocarbamate Herbicide	-	-	PPI
Cyanazine	Bladex	Triazine Herbicide	171	12	PE, PPI, POE
Fonofos	Dyfonate	Organophosphorus Insecticide	13	<1	API
Metolachlor(5)	Dual	Chloroacetamide Herbicide	530	4 (6)	PPI, PE
Metribuzin	Sencor, Lexone	Triazine Herbicide	1,220	5	PE, POE
Phorate	Thimet	Organophosphorus Insecticide	80-85	<1	API
Simazine	Princep & Others	Triazine Herbicide	5	12	PE, PPI
Terbufos	Counter	Organophosphorus Insecticide	15	-	API

(1) Taken in part from Reference 16 and 17.

(2) Solubility in water at 20-25° C.

(3) Approximate time for 90 percent disappearance; times vary depending on climate and soil (Ref 16).

(4) Preplant incorporated (PPI), preemergence (PE), postemergence (POE), incorporated in planting (API).

(5) CIBA-GEIGY Tech. CGA480-003.

(6) Calculated from half-life in soil of 30-50 days in northern U.S.A.

Approximately 90 percent of the corn and 50 percent of the soybeans had been planted prior to the 7 June storm. Much of the planting was concentrated in the 3 weeks immediately prior to the first storm. Low ground cover resulted in extensive erosion problems throughout the watershed in June. This is reflected, in part, by the large sediment yields for the 1981 water year in comparison with previous years. Eighty percent of the 1981 sediment yield occurred during the month of June. Although the total runoff volume for 1981 ranked third from the largest during 6 years, the 1981 sediment and total phosphorus yields were the largest. The extreme nature of the June storms in the watershed should be kept in mind while interpreting the pesticide runoff studies.

The concentrations of five of the pesticides along with the sediment and nitrate concentrations for the month of June are shown in Figure 3.4, A-F. In each case the hydrograph is also shown. Sediment concentrations (Figure 3.4A) illustrate the advanced peak relative to the hydrograph that is characteristic of sediment transport in northwestern Ohio rivers. The advanced peak is attributed to a combination of surface runoff routing and sediment resuspension associated with the passage of the wave fronts through the stream system (Ref. 6). Nitrate concentrations (Figure 3.4B) peak during the downside of the hydrograph. This is attributed to the delayed routing of tile effluent through the stream system relative to surface runoff.

The concentration of atrazine (Figure 3.4C) peaks just prior to the peak discharge for the first June storm. It decreases during the declining limb of the hydrograph for the first storm and during the first part of the second storm. It then increases slightly and remains rather constant during the second half of the first storm. A secondary peak in atrazine concentration occurs during the rising stage of the third storm, after which concentration drops below those for the second storm. Concentrations continued to decrease during the fourth storm.

The pattern of changing concentrations of metribuzin during the June storms (Figure 3.4D) is similar to atrazine. Metribuzin concentrations drop more rapidly after the initial peak concentration than those for atrazine. For the first storm the concentration patterns for alachlor (Figure 3.4E) are more like those of atrazine while the pattern for metolachlor (Figure 3.4F) are more like metribuzin. The greater solubility of metribuzin and metolachlor than alachlor and atrazine could account for the slight differences in patterns.

In Table 3.9 the flux weighted concentrations during the first and second halves of the water masses for each of the first three storms is listed. A gap in the sampling program prevented similar calculations for

Figure 3.4 Hydrographs (+) and Chemographs (•) for June 1981 Storms at the Melmore Gaging Station on Honey Creek. A-suspended, B-nitrate-nitrogen, C-atrazine, D-metribuzin, E-alachlor, F-metolachlor.

SOURCE: Reference 11

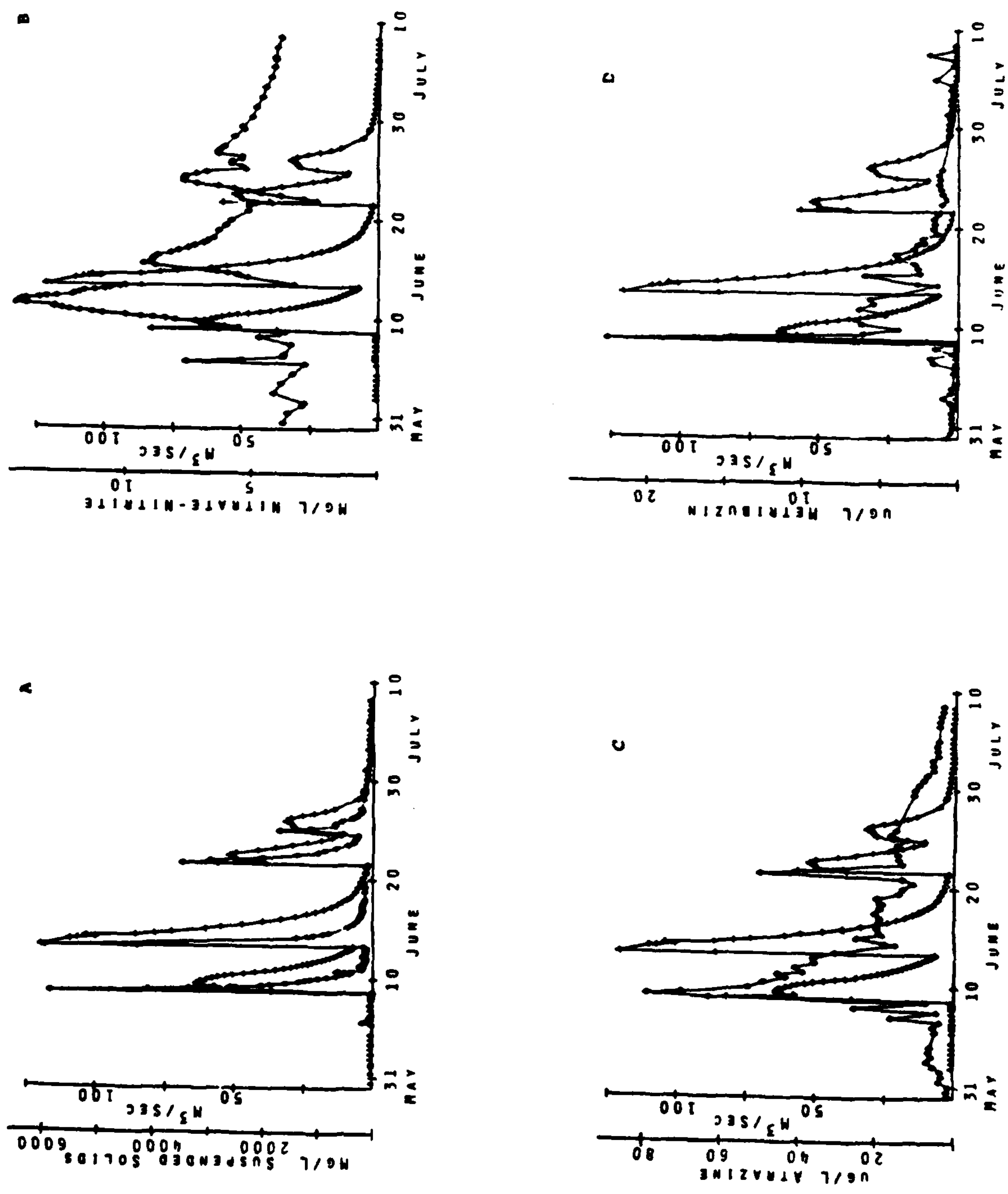


Figure 3.4 Continued

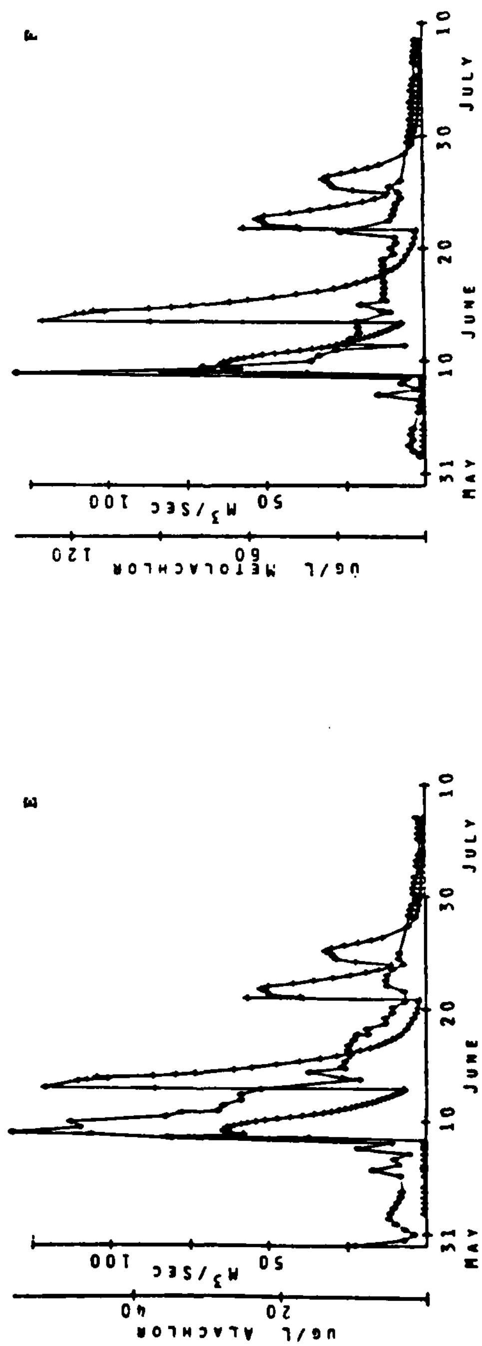


Table 3.9 - Flux Weighted Mean Concentrations of Pesticides, Sediments and Nutrients During First and Second Halves of Water Masses for Three Consecutive June Storms at Honey Creek, Melmore, Ohio

	Storm I		Storm II		Storm III	
	First Half	Second Half	First Half	Second Half	First Half	Second Half
Volume $10^6 m^3$	7.66	7.66	11.83	11.83	4.80	4.80
Duration, days	1.25	3.21	1.24	6.82	1.05	1.95
Sediment, mg/l	2,268	392	2,479	399	2,194	633
Total Phosphorus, mg/l	2.30	.669	2.42	.615	2.10	.906
SRP, mg/l	0.049	.079	0.056	0.073	0.042	0.057
Nitrate-N, mg/l	6.53	11.86	4.33	7.78	3.44	6.54
Atrazine, ug/l	69.5	38.8	17.2	22.6	14.4	14.7
Alachlor, ug/l	51.9	31.0	10.7	11.9	3.8	5.8
Metolachlor, ug/l	75.6	23.8	13.4	15.8	11.4	8.9

SOURCE: Reference 11

the fourth storm. Sediment and total phosphorus consistently showed much higher concentrations during the first half of each storm and did not decline much in successive storms. Soluble reactive phosphorus was higher during the second half of each storm and also did not decline much in the successive storms. Nitrates had much higher concentrations during the second half of each storm and the concentrations of nitrate declined during successive storms. For the first storm the pesticides showed higher concentrations during the first half of the water mass. For the second and third storms the second half of the water masses had higher concentrations. In all cases the concentration dropped rapidly from the first to the second storm and somewhat more slowly from the second to the third storm.

The importance of the first storm and especially the first half of the first storm is evident in the data. The difficulties in accurately monitoring pesticide export from watersheds in this size range is underscored by the fact that the first half of the water mass for the first storm moved past the gaging station in 1.25 days. This period accounted for 48 percent of the total export of metolachlor during the three storms.

3.4.3 Discussion.

The pesticide chemographs from Melmore suggest that both surface runoff and tile effluent are important in pesticide loading into streams. The high pesticide concentrations during the first half of the first storm, which coincided with high sediment concentrations, suggest that surface runoff was the primary pathway of pesticide movement during the first storm. In a detailed survey of pesticide usage in Ohio in 1978, surface application was used for 99 percent of the alachlor, 76 percent of the atrazine and 75 percent of the metolachlor. In each case the remainder of the pesticide was incorporated into the soil profile. Assuming similar application procedures were used in the Honey Creek Watershed in 1981, large quantities of pesticides would have been available on or near the soil surfaces for dissolution and runoff in surface waters. Portions of these compounds would also have leached into the soil and moved with the tile effluents into the stream systems. Also those portions of the pesticides that were incorporated into the soil would have contributed to the tile effluent concentrations.

During the second and third storms tile effluents appear to be more important than surface runoff, based on the higher concentrations during the second half of the water masses. Alachlor showed the greatest decline in concentrations during the three storms. This may be attributed to the fact that, unlike the other compounds, it is primarily applied to the soil surface.

The type of storms which occurred in June 1981 may well have resulted in extreme losses of pesticides in terms of the proportions of applied material which moved into stream systems. Although the total amount of atrazine applied in 1981 in the watershed is unknown, estimates can be made based on corn acreage, as estimated by the Extension Service, and mean application rates based on Statewide surveys. Assuming that corn was grown on 33 percent of the cropland (i.e. 10,600 hectares) and the application rate was 1.81 kg/ha (1.62 lb/acre) a total of 19,100 kg of atrazine would have been applied. The atrazine export measured at the Melmore station during the 38-day period encompassing the June runoff was 1,440 kg or 7.5 percent of the applied atrazine. Such losses would be large for individual fields or plot studies (Ref. 16) and consequently are unexpected for a watershed the size of Honey Creek. Atrazine application would have been distributed throughout the three to four week period preceding the first storm.

Although the June storms may have resulted in maximum amounts of pesticide export, they are not the types of storms which result in maximum runoff concentrations in field and plot studies (Ref. 16). The amounts of runoff in these storms were so large that they probably diluted the pesticide concentrations which could have been present from smaller storms. The nitrate concentration at Melmore in 1980 often reached 30 mg/l during smaller runoff events while in 1981 they did not exceed 15 mg/l. If soluble pesticides parallel nitrates in behavior, higher pesticide concentrations than those observed in 1981 can be expected at the Melmore station.

The reported effects of atrazine and simazine on aquatic biota suggest that levels of these herbicides, even during runoff events, are not inhibitory to invertebrates and fish. The levels observed are, however, well above inhibitory levels for weeks at a time for some (perhaps all) of the algal species which comprise the normal stream flora of northwestern Ohio. Submersed aquatic macrophytes, where they occur in the streams, may also be measurably inhibited by the concentrations attained. When the total concentration of all of the measured herbicides is considered, it becomes evident that adverse effects may be more pronounced than with a single herbicide.

3.5 POTENTIAL FOR USE OF MODELS IN ESTIMATING PROGRAM EFFECTS

Earlier sections discussed the annual variability in sediment and nutrient yields and the variations associated with season and rainfall intensity. As a result, changes measured in annual yields may have nothing to do with conservation measures. This chapter discusses the use of a hydrologic response model to estimate program effect, both before and after a program.

Because a watershed's hydrologic response to a storm event is the controlling mechanism for transporting sediment, nutrients, and pollutants to a drainage network, ANSWERS (Areal Nonpoint Source, Watershed Environment Response Simulation) evolved as a distributed parameter, deterministic computer model which is intended to simulate the behavior of small primarily agricultural watersheds during and immediately following a rainfall event. This model was developed and is constantly being modified and updated by the Agricultural Engineering Department at Purdue University (Ref. 18 and 19) and is envisioned to be a planning tool for evaluating various strategies for controlling nonpoint source pollution from intensively cropped areas and for identifying areas which contribute high unit area loads.

A watershed to be modeled is described as a group of cells or elements for which rainfall, soil, cropping, land use, physical, and surface information along with channel and stream flow characteristics are available. Model output consists of a basin outflow hydrograph, a chemograph for suspended sediment, and amounts of sediment deposited or eroded from each cell. Originally ANSWERS was developed for small watersheds usually less than 10,000 hectares in area with element sizes normally less than four hectares. These watersheds have hydrographs which usually last less than a day. The smaller the cell size the more accurate the results. Of course, as the size of the cells become smaller the costs for preparing an elemental data file and computer running time and memory increase. Rainfall data must be available that adequately describes the distribution and intensity over the watershed of interest. For small basins a continuous record taken every half minute to a minute over the rainfall event is needed, and for good modeling results the computer computational time step is kept between one-half to two minutes, with the smaller time steps giving the best results.

ANSWERS has been applied to some watersheds with apparent success even though verification of the accuracy of such a model is impossible in the strictest sense. The model is capable of simulating the storm response of a watershed under actual or hypothetical conditions without requiring "calibration" only if the base results compare fairly well with any measured field data, namely a hydrograph and chemograph for suspended sediment. Small watersheds where ANSWERS has been applied are: Black Creek, Allen County, Indiana, area of 714 hectares, cell size of 1.0 hectare (Ref 20); Marie Delarme Watershed, Allen County, Indiana, area of 487 hectares, cell size of 2.6 hectares (Ref 21); Finley Creek Watershed, area of 1942 hectares, cell size of 2 hectares; and the Lower Stotts Creek Watershed, area of 7,283 hectares, cell size of 2 hectares, both outside Indianapolis (Ref 22). These are small areas mostly agricultural watersheds with less than 2 percent slopes. They were modeled with small cells and small time step computational intervals. The lengths of average storm hydrographs were about a day or shorter in length. It was stated in the reports that the model output hydrographs and chemographs compared well with measured field data. In cases where this was not true, the deviations were said to be explained by changes in soil characteristics due to moisture changes.

It was hoped that ANSWERS could be applied to larger watersheds by using larger cell sizes and time steps in the computations. Originally it was going to be extended to the small demonstration watersheds with hopeful extension to larger areas such as Honey Creek which has an area of approximately 38,600 hectares. Plans were to run specific storms on each watershed and compare model results to measured field data. Once the model parameters were adjusted within specific realistic parameter ranges so the output closely matched the measured field data, the storms would be rerun with best management practices to evaluate changes in runoff and sediment yield. It was deemed necessary to change the transport, resuspension, and deposition model mechanisms for stream channel transport of the sediment in order to obtain a more realistic approximation of what was actually measured at sampling stations on the larger watersheds. For each watershed, once the model parameters were adjusted to calibrate a storm for the runoff portion, then the sediment transport portion would be calibrated. It was hoped that once calibrated for a storm, little or no tuning would be needed to run additional storms on the same watershed.

The Upper Honey Creek and South Branch Cattaraugus Creek Watersheds were tried as test pilot projects because of their vastly different slopes, agriculture, and land use. Upper Honey Creek is about 4,300 hectares in area, relatively flat with less than 2 percent slope, and moderately agricultural. The cell size chosen was 4 hectares. On the other hand, the Cattaraugus Creek Watershed is about 18,000 hectares, hilly with over 50 percent of the area with slopes in excess of 8 percent, and 25 percent of the area with slopes exceeding 18 percent. About half the watershed is forested and half agricultural. Here a cell size of 36 hectares was tried. Four rain gages were located in the Cattaraugus Creek Watershed and one in Upper Honey Creek. It was found that these gages did not truly represent the rainfall distribution. To save computer time because of the number of runs needed to tune in on the measured field data, time steps of 5, 10, and 15 minutes were tried for the calculations. Also for Honey Creek cell sizes of 16 and 36 hectares were tried. By adjusting the soil and land use parameters within specified valid limits, the measured field data could not be approximated.

Even a smaller time step did not improve the results. Only one storm for Upper Honey Creek was approximately reproduced, but the hydrograph peak time and flow did not match the total runoff volume. Because of the nature of the sediment transport calculations, even this reproduction was deemed not good enough. A large number of computer runs were made for similar storms with different time steps, soil and land use parameters on the two basins, and because of the lack of significant success in the modeling effort, this part of the study was abandoned.

REFERENCES

1. U.S. Army Corps of Engineers, Buffalo District, "Lake Erie Wastewater Management Study, Preliminary Feasibility Report," Vol. I, II and III, Buffalo, NY, December 1975.

2. U.S. Army Corps of Engineers, "Lake Erie Wastewater Management Study Methodology Report." Buffalo, NY. 1979.

3. U.S. Army Corps of Engineers, Buffalo District, Lake Erie Wastewater Management Study, "Water Quality Data - Sandusky River Material Transport," Buffalo, NY, 1978.

4. U.S. Army Corps of Engineers, Buffalo District, Lake Erie Wastewater Management Study, "Water Quality Data - Lake Erie Tributary Loading," Buffalo, NY, 1978.

5. U.S. Army Corps of Engineers, Buffalo District, Lake Erie Wastewater Management Study, "Water Quality Data - Small Watersheds and Special Studies," Buffalo, NY, 1979.

6. Verhoff, F. H., S. M. Yaksich, D. A. Melfi, and D. B. Baker, "Phosphorus Transport in Rivers," LEWMS Technical Report, U.S. Army Corps of Engineers, Buffalo, NY, November 1978.

7. Melfi, D. A. and F. H. Verhoff, "Material Transport in River Systems During Storms Events by Water Routing" LEWMS Technical Report, Buffalo, NY, November 1978.

8. Yaksich, S. M., D. A. Melfi, and J. R. Adams, "Sediment and Phosphorus Transport" Seminar on Water Quality Management Trade-Offs, USEPA, Chicago, IL, September 1980.

9. Setzler, J. V., "Atrazine Residue in Northern Ohio Streams - 1980." LEWMS Technical Report, Buffalo, NY, September 1980.

10. Krieger, K. A., R. P. Richards, P. A. Kline, and D. A. Baker, "Environmental Quality of Upper Honey Creek: A Preliminary Assessment," LEWMS Technical Report, Buffalo, NY.

11. Baker, D. B., K. A. Krieger, and J. V. Setzler, "The Concentrations and Transport of Pesticides in Northwestern Ohio Rivers - 1981," LEWMS Technical Report, Buffalo, NY, November 1981.

12. Baker, D. B., "Fluvial Transport and Processing of Sediment and Nutrients in Large Agricultural River Basins," LEWMS Technical Report, Buffalo, NY, February 1982.

13. Baker, D. B., "Upstream Point Source Phosphorus Inputs and Effects," Seminar on Water Quality Management Trade-Offs, USEPA, Chicago, IL, September 1980.

14. Baker, D. A., "Characteristics of the Transport of Bioavailable Particulate Phosphorus in the Sandusky River Basin," submitted for publication March 1982.

15. Weber, J. B., P. J. Shea and H. J. Strek "An Evaluation of Nonpoint Sources of Pesticide Pollution in Runoff." In: Overcash, M. R. and J. M. Davidson Eds.), Environmental Impact of Nonpoint Source Pollution, Ann Arbor Science Publishers Inc., Ann Arbor, MI, 1980.

16. Wauchope, R. D., "The Pesticide Content of Surface Water Draining from Agricultural Fields--A Review," J. Environ. Qual.: 7(4):459-472, 1978.

17. Logan, T. J., "Pesticide Use in the Lake Erie Basin and the Impact of Accelerated Conservation Tillage on Pesticide Use and Runoff Losses," LEWMS Technical Report, Buffalo, NY, January 1981.

18. Beasley, D. B., "ANSWERS: A Mathematical Model for Simulating the Effects of Land Use and Management on Water Quality," PhD Thesis, Purdue University, West Lafayette, IN, 1977.

19. Beasley, D. B., and L. F. Huggins, "ANSWERS Users Manual," Agricultural Engineering Department, Purdue University, West Lafayette, IN, 1980.

20. Lake, James and James Morrison, "Environmental Impacts of Land Use on Water Quality, Final Report on the Black Creek Project," U.S. Environmental Protection Agency, Chicago, IL, October 1977.

21. Allen Co. Soils & Water Conservation District, "Planning and Evaluating BMP's, Black Creek Project," Brochure, Fort Wayne, IN.

22. Indiana Heartland Model Implementation Project, "Insights into Water Quality, Status Report," March 1981.

CHAPTER 4 - IN-LAKE EFFECTS OF PHOSPHORUS LOADS

4.1. INTRODUCTION

This chapter summarizes the estimates of phosphorus loadings and in-lake phosphorus concentrations for Lake Erie during the period 1970-1980. The phosphorus loadings have been separated into contributions from point and nonpoint sources. Using these available data and assuming equilibrium between historical loadings and in-lake concentrations for selected periods, a long-term phosphorus model has been calibrated and used to project future in-lake phosphorus concentrations for various reduced loading scenarios. The results of this model application are summarized in this chapter, and a discussion of the significance of the model results is presented. The model output enables a projection of the possible improvement in the trophic status of Lake Erie as a result of reducing phosphorus loadings. The scenarios are also evaluated using results from models developed by others for the projected effect on chlorophyll a concentrations and dissolved oxygen in the hypolimnion of the Central basin. Finally, a discussion is presented on the biological availability of the phosphorus loads to Lake Erie.

4.2. IN-LAKE CONDITIONS

Lake Erie's water quality has undergone considerable degradation during the past half century as a result of increasing pollutant loads. Normally, the time scales associated with the natural trophic evolution of a waterbody are very long. However, high intensity agricultural development, growth of human populations, urbanization, and industrialization have proceeded very rapidly in the Lake Erie drainage basin. As a result, the time scale for trophic evolution has been greatly accelerated. This phenomenon is often referred to as cultural eutrophication. Eutrophic lakes are characterized by excessive plant (or algae) growth that is stimulated by the over enrichment of nutrients such as phosphorus. Dead and dying plant matter settles to the bottom where decay takes place through bacterial decomposition. Oxygen is consumed by this aerobic decay process and, in stratified lakes such as the central basin of Lake Erie, depletion of dissolved oxygen can stress other aquatic life that inhabits the bottom waters.

The oxygen depletion rate of the hypolimnetic waters of the Central Basin of Lake Erie has been measured and the findings are summarized in Figure 4.1.

The critical oxygen depletion rate which brings about anoxia in the Central Basin bottom waters has been estimated as 0.093 mg O_2/l/day(Ref 1). This critical rate has been exceeded in Lake Erie since 1960. The oxygen depletion rate in the Eastern Basin is about 0.060 mg O_2/l/day (Ref 2). Although the oxygen demand in the Western Basin is high, the basin does not stratify or become anoxic except in rare cases.

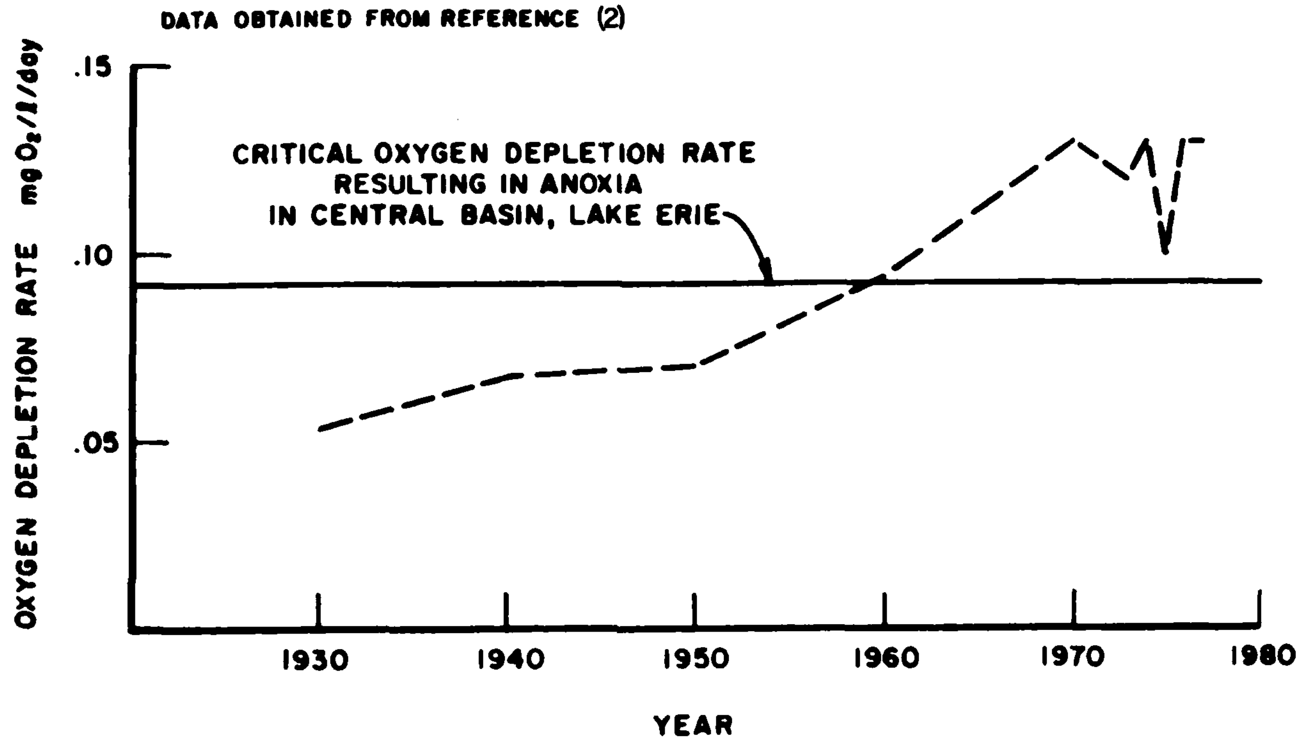


FIGURE 4.1
OBSERVED OXYGEN DEPLETION RATES IN THE HYPOLIMNION WATERS OF THE CENTRAL BASIN, LAKE ERIE

Figure 4.2 shows the variation of the mean annual concentration of total phosphorus in the Western, Central, and Eastern Basins of Lake Erie for the period 1970-1980. No trends in the annual concentration can be seen for any of the basins for the period 1970 to 1977. The primary reasons for the annual variations in this period were the variations in hydrology and the timing of the sampling from which the averages were determined. In Figure 4.3, the seasonal variation of total phosphorus concentration is shown for the Western Basin of Lake Erie. It can be seen from this figure that the concentrations are higher in early spring and in the fall. Spring values reflect increases due to increased phosphorus loading during the spring runoff period. Higher fall concentrations are partly due to resuspension of phosphorus bearing lake sediments during fall storms and enrichment by phosphorus released into the hypolimnetic waters during the period of anoxia. If sampling cruises are not made during these periods, as was the case in 1973 and 1974, reported annual phosphorus concentrations could be expected to be lower.

Total phosphorus concentrations have decreased in all three basins during the period 1978 to 1980. The reason for this decrease has been the reduction in total phosphorus loads to the lake. The theoretical response of the lake to these load changes are shown by lines A and B on Figure 4.2. These lines were calculated from the total phosphorus model (Ref 4) and will be discussed in the following sections.

4.3. NUTRIENT LOADINGS

Phosphorus enters the surface of Lake Erie from the atmosphere, at the lake boundaries from shoreline erosion of phosphorus-bearing sediments, in the tributary inflows that drain the watershed, and in direct discharges from wastewater outfalls. Data obtained from the sampling program described in Chapter Three were used to estimate tributary loadings for the period 1970 to 1980. Municipal and industrial loadings were obtained from surveillance data obtained by the States and the Province of Ontario. Atmospheric loadings were estimated from data extrapolated from measurements taken within the Great Lakes Basin (Ref 5). Phosphorus contained in shoreline eroded materials has been estimated to be 6,936 mt/yr; however, it has been excluded from the analysis because it is not considered available for biological uptake (Ref 6). A detailed discussion of the methods used to calculate nutrient loadings to Lake Erie is contained in a separate technical report of this study entitled, "Lake Erie Nutrient Loads 1970-1980" (Ref 7).

Estimated total phosphorus loads to Lake Erie for the period 1970 to 1978 are presented in Figure 4.4. It can be seen in the figure that the estimated total phosphorus loading decreased during the 1970 to 1980 period. The point source loading decreased from 11,900 mt/yr in 1970 to 4,500 mt/yr in 1980, as a result of the implementation of the phosphorus effluent limitation to 1 mg/l at wastewater treatment plants. The nonpoint source load has varied from a low of 5,700 mt/yr in 1971 to a high of 11,900 mt/yr in 1977.

The annual variation in tributary loads, which reflect the contribution from diffuse sources, makes it important to determine if hydrologic conditions are unusual in the year in which loadings are estimated. In an

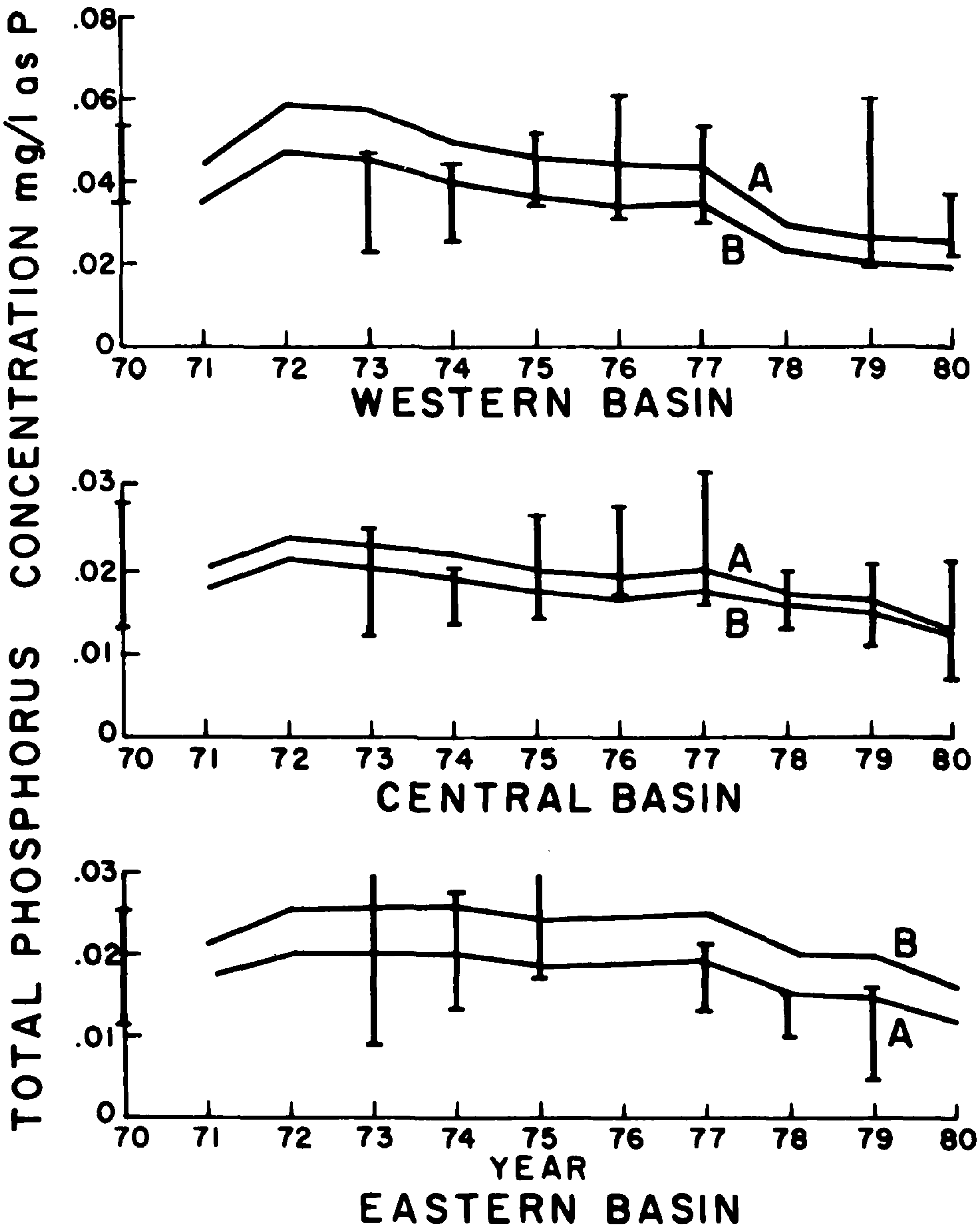
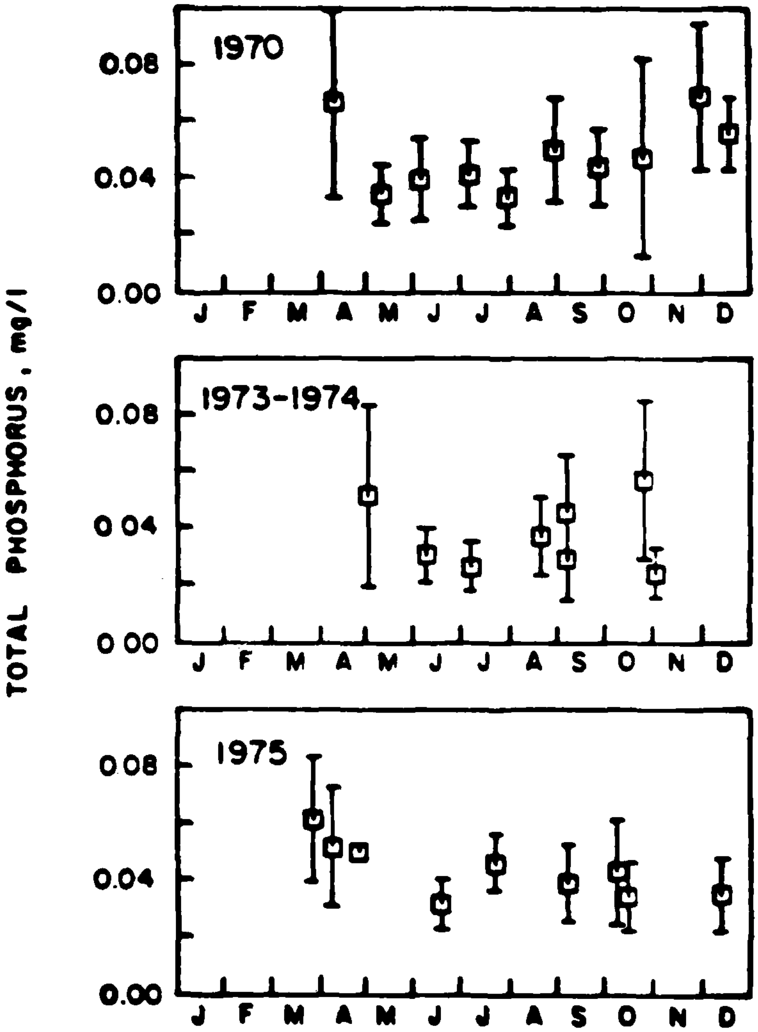


Figure 4.2 Lake Erie Total Phosphorus Concentrations
A - Model Prediction for 1970 Loadings and Concentrations
B - Model Predictions for Average 1970-1975 Loadings, and Concentrations Data points and error bars showing $\pm$ 1 standard deviation from actual mean concentrations are presented



WESTERN BASIN

Figure 4.3 - Seasonal Variation in Total Phosphorus Concentrations in the Western Basin of Lake Erie

Source: Reference 3

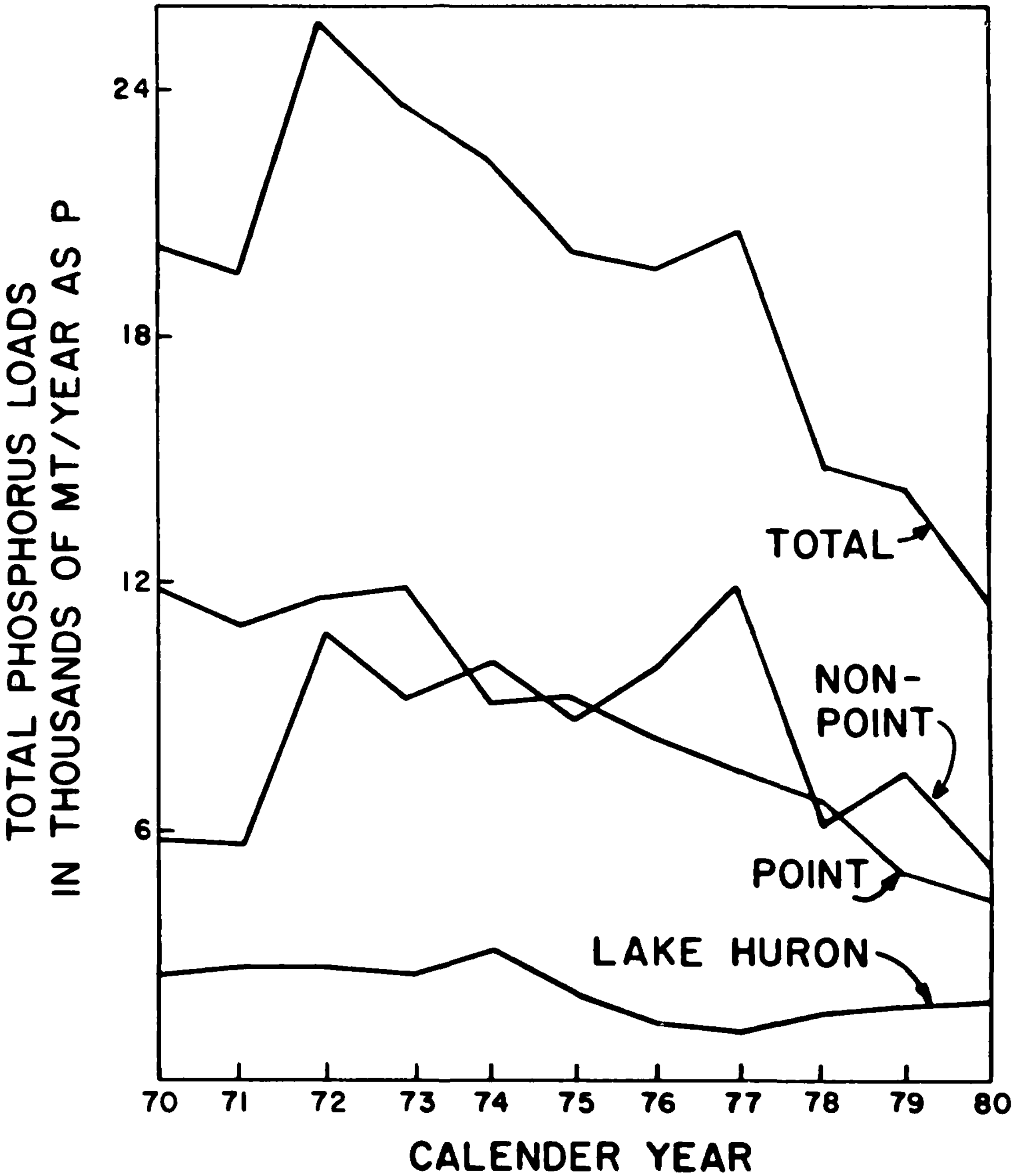


Figure 4.4 Lake Erie Total Phosphorus Loadings, Atmospheric Input and Shoreline Erosion are not included.

effort to "smooth out" the hydrologic variations, "base year" loads were developed in the Methodology Report (Ref 8) using historical average data for the tributary flows. The tributary loadings computed in this manner were combined with the 1975 estimates for point source loadings and atmospheric loadings to give the estimated total loadings for the so-called "base year." These estimates and the 1974-1975 estimates from the Preliminary Feasibility Report (Ref 9) are presented in Table 4.1.

Table 4.1 - Estimates of Total Phosphorus Loadings to Lake Erie (1)
(metric tons per year)

	1974-1975	Base Year	Scenario 1(2)	Scenario 2(3)
Western Basin	13,389	14,499	10,799	9,785
Central Basin	5,096	4,007	3,352	3,096
Eastern Basin	2,022	1,463	1,370	1,281
Whole Lake Total	20,507	19,969	15,521	14,162

(1) Shoreline erosion loadings excluded. Only point sources with flows greater than one million gallons per day are controlled.

(2) Scenario 1 is based on point sources at 1 mg/l.

(3) Scenario 2 is based on point sources at 0.5 mg/l.

The "base year" loading estimates were used in the Methodology Report to estimate the total phosphorus loads remaining after municipal point sources with flows greater than one million gallons per day reached effluent concentration of 1.0 and 0.5 mg/l P. These estimates are also shown in Table 4.1. It can be seen from this table that the total phosphorus loads will be reduced to 15,500 and 14,200 mt/yr for each scenario. Scenario 1 will require an additional reduction of 4,500 mt/yr if the phosphorus loading objective for Lake Erie of 11,000 mt/yr is to be reached. Scenario 2 will require an additional 3,200 mt/yr reduction.

During Phase III of this study additional data have been collected which allows a better base year estimate to be made. Tributary monitoring programs were carried out during 1978, 1979 and 1980. New flow measurements were made at the wastewater treatment plants. Wastewater flows increased at some plants while others were taken off line. Additional atmospheric load measurements were made. This new information has been used to calculate a new base year. The diffuse source phosphorus load estimate for this new base year is an average of the diffuse load for the years 1970 to 1980. The point source estimate is what was measured in 1980. This new base year is presented in Table 4.2.

Table 4.2. - Base Year Total Phosphorus Loads to Lake Erie
(metric tons per year)

	Upper Lake	Point(1)	Diffuse	Atmospheric(2)	Total
WESTERN					
Base Year	1,080	2,693	5,390	186	9,349
Scenario 1		1,960			8,616
Scenario 2		1,225			7,881
CENTRAL					
Base Year		1,510	2,441	992	4,943
Scenario 1		880			4,313
Scenario 2		614			4,047
EASTERN					
Base Year		294	1,497	372	2,163
Scenario 1		226			2,095
Scenario 2		144			2,013
TOTAL					
Base Year	1,080	4,497(3)	9,328	1,550	16,455
Scenario 1		3,066(4)			15,025
Scenario 2		1,983(5)			13,941

(1) Only point sources with flows greater than one million gallons per day are controlled.

(2) 1980 Estimate of IJC Surveillance Committee.

(3) 1980 Loads.

(4) Scenario 1 is based on point sources at 1.0 mg/l.

(5) Scenario 2 is based on point sources at 0.5 mg/l.

Also shown in this table are the total phosphorus loads remaining after municipal point sources with flows greater than one million gallons per day reached effluent concentrations of 1.0 and 0.5 mg/l as P. With this new base year the total phosphorus loads will be 15,000 mt/yr and 13,900 mt/yr after implementation of these point source controls. Scenario 1 will now require an additional reduction of 4,000 mt/yr if the phosphorus loading objective for Lake Erie of 11,000 mt/yr is to be reached. Scenario 2 will require an additional 2,800 mt/yr reduction.

4.4. PHOSPHORUS BUDGET MODEL

The long-term phosphorus model adopted in this study was basically the application of a material balance on total phosphorus incorporating the exchange of phosphorus at the sediment-water interface and the retention of phosphorus in the sediments. Phosphorus loading to the lake basin and phosphorus discharge (or export) from the basin are also accounted for. The lake basin is assumed to be continuously stirred and the effect of varying internal lake circulation is presumably averaged out by considering a time step of one year in model application. Lake Erie was simulated using this model by treating it as three separate basins arranged in series. Model output provides phosphorus concentrations in the lake basin water and in the sediment interstitial water as a function of time measured in years. A detailed description of the long-term phosphorus model and comparison with other modeling approaches is contained in a separate technical report to this study (Ref 4).

The application of the model required the estimation of rate constants and knowledge of the physical characteristics of the lake basin. One basic assumption made in arriving at the above estimates of rate constants was that the in-lake phosphorus concentrations were at equilibrium with the estimated phosphorus loadings for the period selected for calibration. The model constants were determined for two cases: Case A - 1970 estimated loadings with 1970 in-lake total phosphorus concentrations; Case B - 1970-1975 average loadings with the 1970-1975 average in-lake total phosphorus concentrations.

Figure 4.2 shows the predicted response of the lake for the model constants calculated for Cases A and B. It can be seen from this figure that Case A using 1970 conditions has predicted the response of the basins to changes in loads. Case B using average 1970-75 conditions underestimated the 1980 concentration in the Western Basin. It gave a good representation for the Central Basin and overestimated the concentrations for 1977-79 in the Eastern Basin.

4.5. PROJECTED FUTURE LAKE CONDITIONS

The projected in-lake total phosphorus concentrations for the various whole lake loadings given by scenarios 1 and 2 using the new base year and the 11,000 mt/yr loading objective can be determined from Figure 4.5. It can be seen from this figure that even at the 11,000 mt/yr loading objective, the Western Basin will have total phosphorus concentrations between 0.015 and 0.019 mg/l as P. The Central Basin will be between 0.011 and 0.012 mg/l and the Eastern Basin will be between 0.012 and 0.015 mg/l when the loading objective is reached.

Other Lake Erie modeling efforts have been summarized in the Report of Task Group III (Ref 10). The various model projections all indicated that in-lake chlorophyll a will be reduced as annual loading of total phosphorus to the lake is decreased. According to these model projections, the levels of chlorophyll a in the Western, Central, and Eastern Basins will decrease as shown in Figure 4.6. The prediction of chlorophyll a although uncertain as to specific magnitude, clearly has a downward trend as phosphorus loading is reduced.

According to analysis of oxygen levels in the Central Basin of Lake Erie, the recommended objective whole lake loading of 11,000 mt/yr is estimated to result in a mean hypolimnetic dissolved oxygen level during the

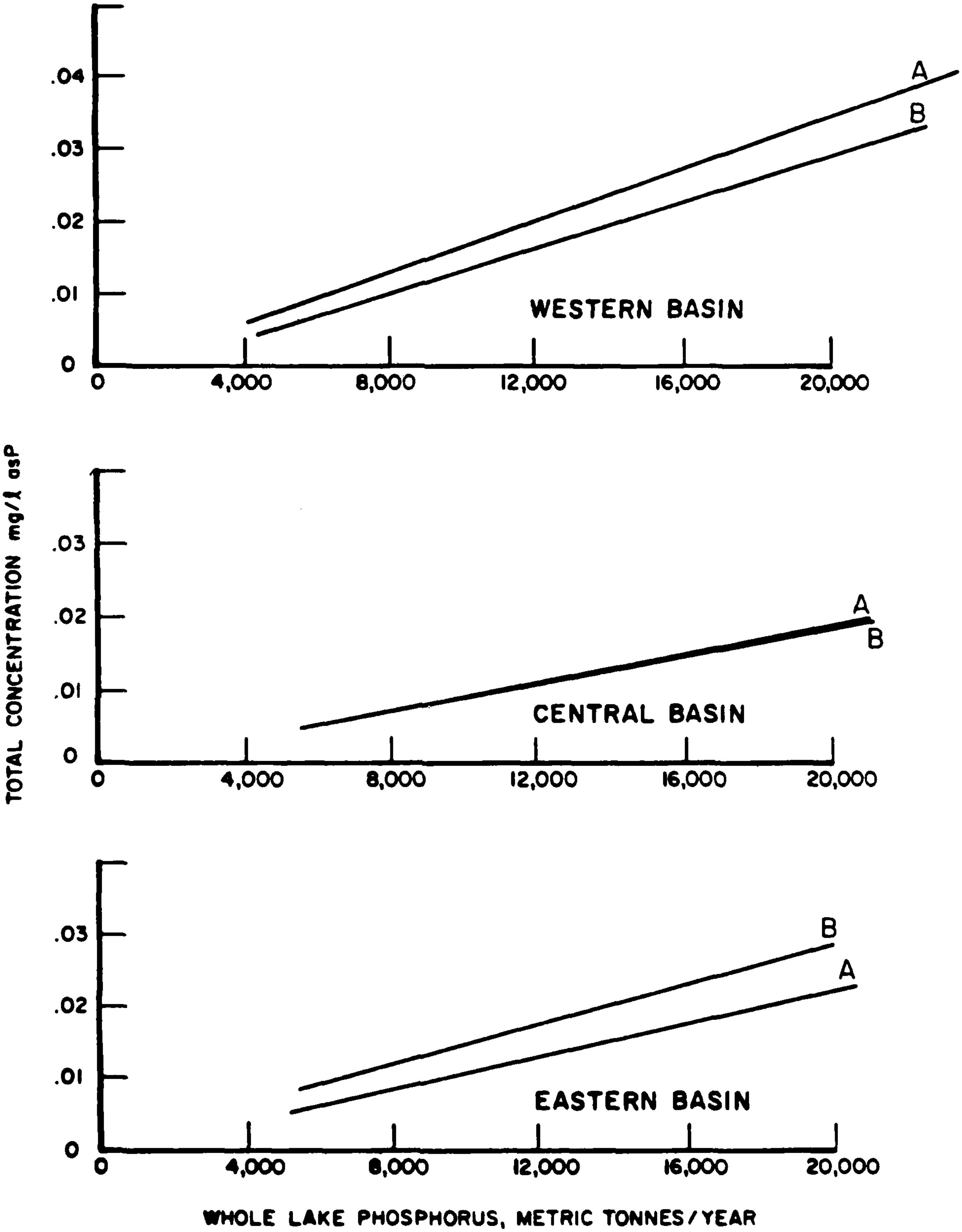


Figure 4.5 Projected In-Lake Total Phosphorus Concentrations for Indicated Whole-lake Loading Using Base Year Data

Case A = Model results using 1970 Loads and 1970 concentrations

Case B = Model results using 1970-1975 average loading and concentration data

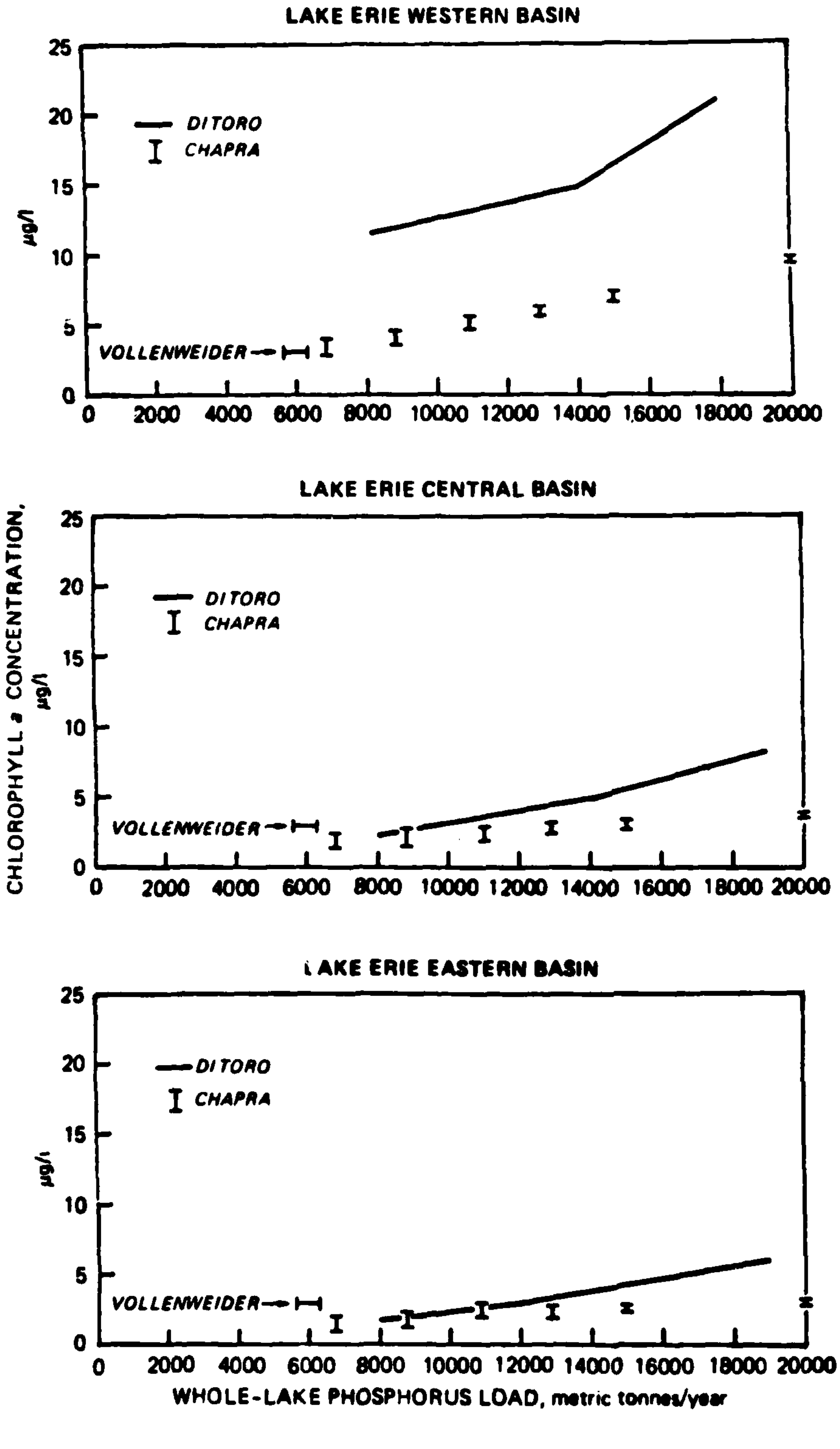


Figure 4.6 - Relationship Between Chlorophyll A Concentration and Whole-lake Phosphorus Load in Lake Erie for the Vollenweider, DiToro, and Chapra models.

Source: Reference 10

summertime stratification period of no less than one mg/l. These results are shown in Figure 4.7, which shows the projected recovery of the dissolved oxygen level in the Central Basin as phosphorus loading is reduced. The model projections indicated that if a phosphorus loading of 11,000 metric tons is achieved, the level of hypolimnetic dissolved oxygen in the Central Basin would remain above one mg/l and could be as high as four mg/l.

It was also estimated that this objective loading would lead to a reduction in the area of anoxia in the Central Basin by 90% in the short-term (say within five years after the objective loading has been achieved and maintained), and ultimately lead to elimination of anoxia completely (Figure 4.8). The application of the presently constituted long-term phosphorus model does not permit estimates of oxygen levels based on computed in-lake concentrations of total phosphorus.

These reductions in chlorophyll a and summertime oxygen deficits in the Central Basin are the desired effects of a phosphorus reduction program and should lead to improvement in the trophic status of Lake Erie.

4.6. AVAILABILITY OF PHOSPHORUS FOR BIOLOGICAL UPTAKE

In the Methodology Report (Ref 8), the algal bioavailability of tributary sediment P was addressed. Based on an analysis of 66 water samples from tributary stations in the Lake Erie Basin (Ref 11), the algal uptake study of Verhoff and Heffner (Ref 12), and other studies in the Great Lakes Region (Ref 13 and 14), the following conclusions were made:

a. Phosphorus extracted by NaOH was immediately bioavailable, while CDB-P* is potentially bioavailable after the sediment has undergone anaerobic conditions followed by resuspension and reaeration.

b. Sediments from the New York tributaries draining into the Eastern Basin of Lake Erie had lower NaOH-P and higher HCl-P (apatite) than Central and Western Erie Basins. This difference was attributed to the lower use of commercial fertilizer, the lower extent of point sources and the higher content of coarse-sized sediments in the New York area compared to the Ohio and Michigan regions of the Lake Erie Basin.

c. Algae utilized sediment P at the rate of 0.4% per day, and more P was extracted by algae from the NaOH-P fraction than from the CDB-P or HCl-P fractions.

In the three years since the Methodology Report, there have been several additional bioavailability studies on Lake Erie Basin tributary sediments.

DePinto et al. (Ref 15) used chemical fractionation similar to that of Logan et al. (Ref 11) together with algal bioassay to study the bioavailability of Lake Erie tributary sediment P. They confirmed the findings of Logan et al. that Ohio tributary sediments had higher bioavailable P than sediments

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Phosphorus extracted with citrate-dithionite-bicarbonate (CDB).

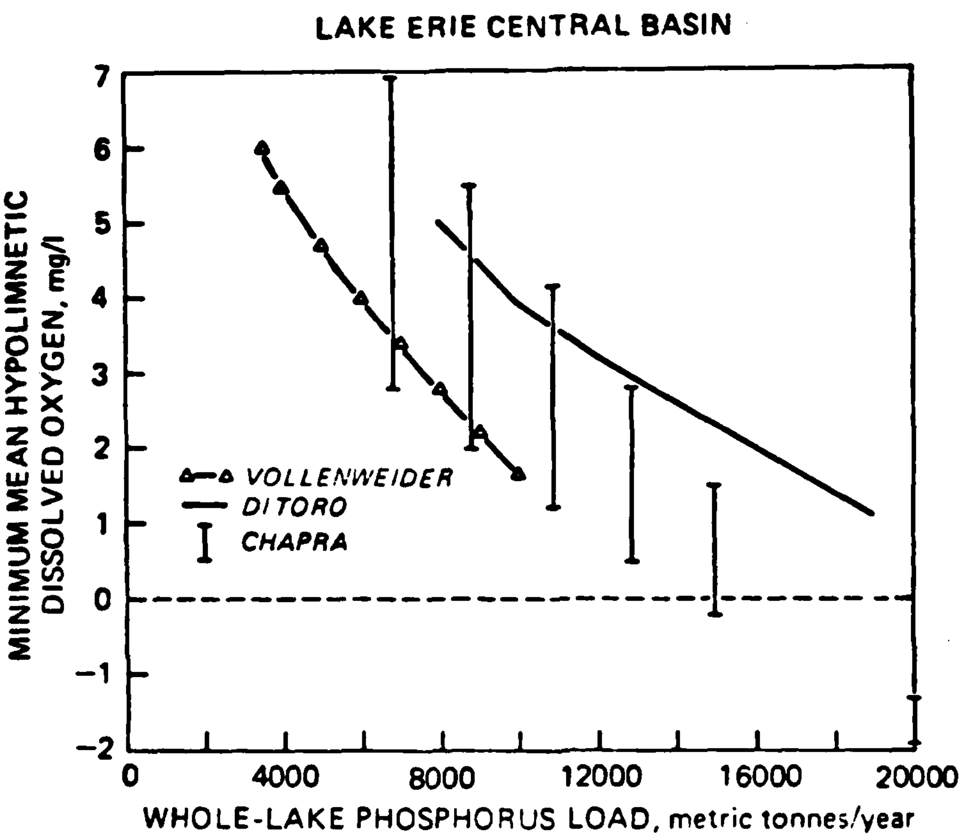


Figure 4.7 - Relationship Between Minimum Mean Hypolimnetic Dissolved Oxygen Concentration and Whole-lake Phosphorus Load in the Central Basin of Lake Erie for the Vollenweider, DiToro, and Chapra models.

Source: Reference 10

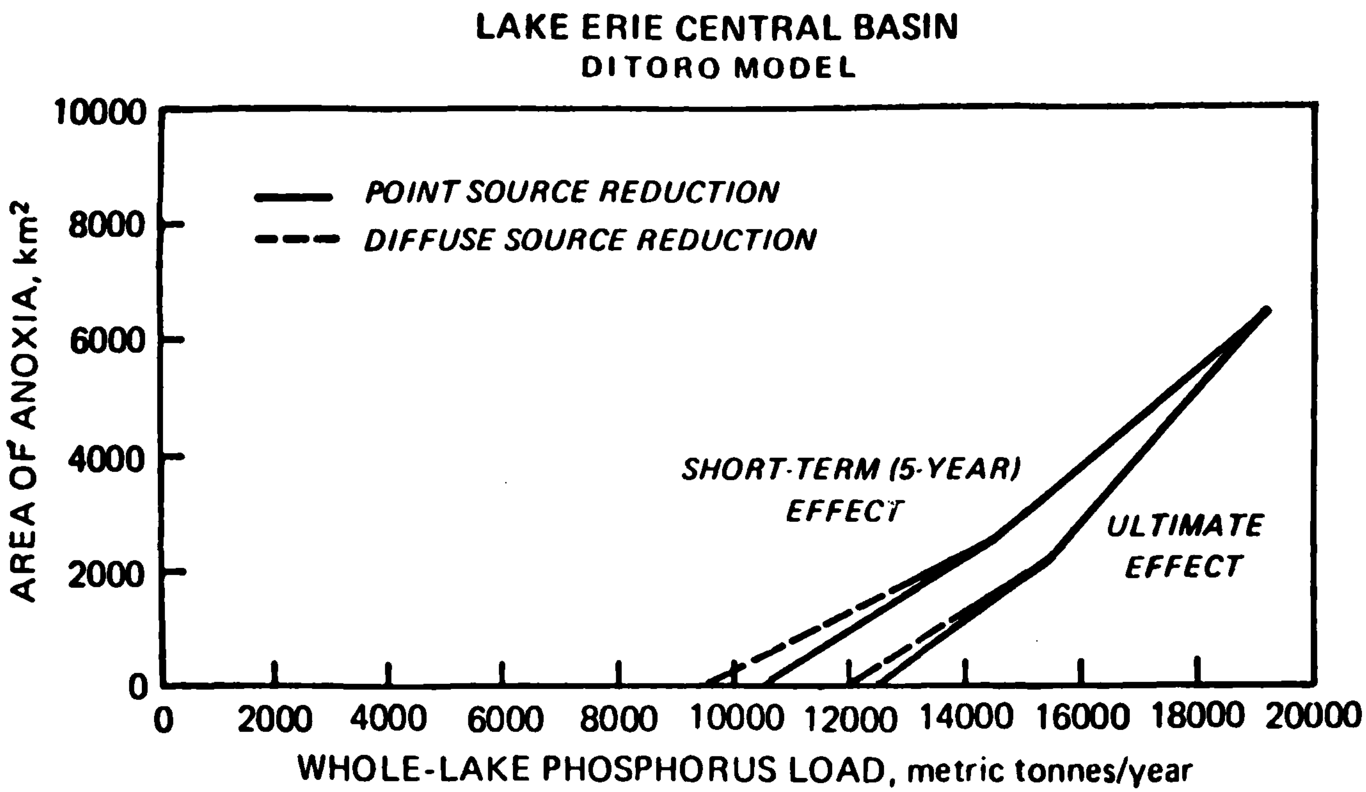


Figure 4.8 Relationship Between Area of Anoxia and Whole-lake Phosphorus Load in the Central Basin of Lake Erie for the DiToro Model.

Source: Reference 10

from New York tributaries. They found that both non-apatite inorganic P fractions (NaOH-P, CDB-P) correlated well with sediment bioavailable P, and they also determined that algae utilized sediment P at a rate of approximately 15 percent/day. This is considerably higher than the 0.09-0.4 percent/day obtained by Verhoff and Heffner (Ref 12).

Young et al. (Ref 16) studied the effects of anaerobic preincubation and subsequent reaeration on the algal uptake of sediment P. Their major conclusion was that anaerobic conditions followed by reoxidation had no effect on the subsequent uptake of sediment P by algae.

Baker (Ref 17) measured NaOH-P on a total of 410 sediments from the Sandusky River and its tributaries in 1981. He found that the concentrations of total particulate P (TPP) and NaOH-P decreased with increasing sediment concentration. This is due to the increasing content of coarse particles at higher sediment concentrations, and the lower concentration of TPP normally found in the coarser particle sizes. However, Baker found that the percentage of TPP as NaOH-P did not vary with sediment concentration and was remarkably consistent for all samples. Baker also noted that there was no increase in the percent NaOH-P of sediments below sewage treatment plant outfalls in agricultural river basins, and indicated that this point source P may be biologically processed in the stream rather than adsorbed onto stream sediments.

Dorich and Nelson (Ref 18) used a number of different chemical and resin extraction procedures together with algal bioassay to determine the bioavailability of sediment-P from the Black Creek watershed in northeastern Indiana. They found, as have others, that NaOH extraction gave the best correlation with algal available sediment P. They found, as did Baker (Ref 17), that the percent of TPP as NaOH-P did not vary with different particle sizes, and they also observed that about 78% of the sediment P utilized by algae in 14 days was taken up in the first two days.

The percent bioavailability of sediment P (NaOH-P as percent of TPP) for Lake Erie Basin tributaries determined in the studies discussed here is summarized in Table 4.3. The results for the three studies in the Western Basin are very consistent and show bioavailability of about 25%. Michigan, Indiana and Eastern Ohio gave similar results, while the two studies on New York sediments indicated much lower NaOH-P and higher HCl-P (which is considered to be relatively unavailable).

Lee et al. (Ref 19), in their review of phosphorus bioavailability, speculated that not all of the point source phosphate in sewage treatment plant effluents would be bioavailable. They suggested that P precipitated with Fe and/or Al as well as refractory organic P could constitute a significant fraction of the phosphate in effluents from plants with P removal to 1 mg/l, and questioned whether further reductions below 1 mg/l would have any cost-effective impact on Great Lakes eutrophication. Since that review, however, DePinto et al. (Ref 20) have reported on their bioassay studies of lower Great Lakes municipal treatment plant effluents. They found that 82% of the dissolved phosphorus and 55% of the particulate P was taken up by test algae using the incubation procedure they developed for tributary samples. These values indicate that, at 1.0 mg/l, municipal wastewater effluents are

Table 4.3. - Percent Bioavailability of Sediment-P in Lake Erie Basin Tributaries

	No. of Samples	NaOH-P	CDB-P	HCl-P
		Michigan		
Logan et al. (11)	24	30.9	46.3	15.3
		Western Ohio		
Logan et al. (11)	28	28.3	24.2	9.7
DePinto et al. (15)	11	21.4	21.6	6.9
Baker (17)	410	23.2	-	-
		Eastern Indiana		
Dorich and Nelson (18)	4	26.0	-	-
		Eastern Ohio		
Logan et al. (11)	8	32.8	55.8	6.8
DePinto et al. (15)	3	32.3	23.6	15.3
		New York		
Logan et al. (11)	5	11.5	23.6	36.9
DePinto et al. (15)	6	9.3	14.6	46.9

more bioavailable than tributary loads. In addition, Baker (Ref 17) found that point source phosphorus discharges to tributaries are processed in the stream and there is no detectable change in the bioavailability of tributary sediments below point source discharges. This would indicate that, if additional reductions in point source phosphorus concentrations below 1.0 mg/l might be required to meet target loads to Lake Erie, the most cost-effective reductions in bioavailable P would be obtained by additional P removal at those plants which discharge directly to the Lake. The tributaries themselves are essentially providing additional phosphorus removal at no monetary cost.

Based on current findings, the following conclusions can be drawn:

a. NaOH extractable inorganic P is a reliable estimate of bioavailable sediment P although lesser amounts are available from other extractable fractions.

b. Sediment P bioavailability is higher in the Ohio-Indiana-Michigan portions of the Lake Erie Basin and lower in New York tributary sediments.

c. For a given region, the percent of TPP as NaOH-P is relatively constant over a wide range of sediment concentrations and particle sizes.

d. A large fraction of the NaOH-P is immediately available to algae and utilization rates as low as 0.04 percent/day and as high as 15 percent/day have been reported.

e. Discharge of point-source P to streams that have watersheds that are predominantly agricultural does not appear to be incorporated into the NaOH-P fraction of sediments.

f. About 25 percent of the sediment P of tributary sediments in the Western Basin of Ohio are bioavailable.

g. Anaerobic incubation of stream sediments followed by reoxidation did not increase sediment P bioavailability.

REFERENCES

1. Dobson, H. H. and M. Gilbertson, "Oxygen Depletion in the Hypolimnion of the Central Basin of Lake Erie 1929 to 1970," in Project Hypo, February 1972.

2. International Joint Commission, "Great Lakes Water Quality, 1977 Annual Report, Appendix B," July 1978.

3. DiToro, D. M. and J. P. Connolly, "Mathematical Models of Water Quality in Large Lakes, Part 2: Lake Erie," Manhattan College, Bronx, New York.

4. Rumer, R. R., "Methodology for Evaluating In-Lake Effect Resulting from Phosphorus Management in the Lake Erie Drainage Basin," Lake Erie Wastewater Management Study Technical Report, U. S. Army Corps of Engineers, Buffalo, New York, July 1978.

5. Great Lakes Water Quality Board, "1981 Report on Great Lakes Water Quality," Report to the International Joint Commission, Windsor, Ontario, November 1981.

6. International Reference Group on Great Lakes Pollution from Land Use Activities, Environmental Management Strategy for the Great Lakes, Final Report to the International Joint Commission. Windsor, Ontario, July 1978.

7. Yaksich, S. M., D. A. Melfi, D. A. Baker and J. A. Kramer, "Lake Erie Nutrient Load, 1970-1980" Lake Erie Wastewater Management Study Technical Report, U. S. Army Corps of Engineers, Buffalo, New York, September 1982.

8. U. S. Army Corps of Engineers, "Lake Erie Wastewater Management Study - Methodology Report," Buffalo, New York, March 1979.

9. U. S. Army Corps of Engineers, "Lake Erie Wastewater Management Study - Preliminary Feasibility Report," Buffalo, New York, December 1975.

10. Task Group III, A Technical Group to Review Phosphorus Loading, Fifth Year Review of Canada-United States Great Lakes Water Quality Agreement, February 1978.

11. Logan, T. J., T. O. Oloya and S. M. Yaksich, "Phosphate Characteristics and Bioavailability of Suspended Sediments from Streams Draining into Lake Erie " J. Great Lakes Res. 5:112-123, 1979.

12. Verhoff, F. H. and M. R. Heffner. "Rate of availability of total phosphorus in river waters," Environ. Sci. Technol. 13:844-849, 1979.

13. Armstrong, D. E., J. J. Perry and D. E. Flatness, "Availability of Pollutants Associated with Suspended or Settled River Sediments Which Gain Access to the Great Lakes," USEPA Region V, Technical Report, EPA905/4-79-028, 1979.

14. Nelson, D. W. "Algal Studies," In Environmental Impact of Land Use on Water Quality, EPA Tech. Rep. EPA 905/9-77-007B pg. 221, 1977.

15. DePinto, J. V., T. C. Young and S. C. Martin. "Algal-available phosphorus in suspended sediments from lower Great Lakes tributaries," J. Great Lakes Res. 7:311-325, 1981.

16. Young, T. C., J. V. DePinto and J. P. McAuliffe. "Effects of anaerobic conditions on particulate phosphorus availability in lower Great Lakes tributaries, "LEWMS, Technical Report Series". Buffalo, NY, 1982.

17. Baker, D. B., "Characteristics of the transport of bioavailable particulate phosphorus in the Sandusky River Basin," Final Report, Environmental Safety Department. Procter and Gamble Corp., Cincinnati, Ohio. (unpublished report), 1982.

18. Dorich, R. A. and D. W. Nelson, Bioavailability of sediment P in the Black Creek watershed, (unpublished report), 1982.

19. Lee, G. F., R. A. Jones and W. Rast, "Availability of phosphorus to phytoplankton and its implications for phosphorus management strategies," In Phosphorus Management Strategies for Lakes, R. C. Loehr, C. S. Martin and W. Rast, Eds. Ann Arbor Science, 1980.

20. DePinto, J. V., J. K. Edzwald, M. S. Switzenbaum and T. C. Young, "Phosphorus removal in lower Great Lakes municipal treatment plants," Final Report, Municipal Environmental Research Laboratory, ORD, USEPA, Cincinnati, Ohio, 1980.

CHAPTER 5 - LAND MANAGEMENT ALTERNATIVES FOR EROSION CONTROL AND PHOSPHORUS REDUCTIONS

Chapter 2 of this report described the nature and extent of the soil erosion problem in the Lake Erie Basin and its relationship to phosphorus transport. The use of the Land Resources Information System (LRIS) and the Universal Soil Loss Equation for quantifying and mapping soil loss was described in detail. Cultural practices that either increase or decrease soil and phosphorus losses were described.

This chapter will apply the methodologies and concepts described in Chapter 2 to arrive at quantitative estimates of reductions in soil and phosphorus losses which may be achieved by application of conservation cropping management practices within individual counties, major subbasins of Lake Erie (i.e. Western, Central and Eastern Basins) and finally the entire United States portion of the Lake Erie Watershed.

Using crop yield data, and cost data compiled during the LEWMS program, the costs, benefits, and overall economic impacts of conservation tillage will be discussed. Preferred areas for the application of conservation tillage practices are identified, and adoption rates are projected.

5.1 BEST MANAGEMENT PRACTICES

Best Management Practices (BMP's) are those soil and water conservation practices or combination of practices, both cultural land management and structural, which provide for the best production and conservation protection on a particular parcel of land while also effectively serving to reduce sediment and phosphorus transport from diffuse sources of pollution. R. M. Davis, a former Administrator of the USDA, Soil Conservation Service has said "What farmers and conservationists need are new, integrated farming systems, including recommendations for: capital requirements; machinery; fertilizer needs; weed, insect and disease control; suitable plant varieties; soil and water management; fuel needs, and tillage systems." In effect, Best Management Practices, when used in association with other crop management factors, are equivalent to "integrated farming systems." BMP's are an effective and practicable (including technological, economic, and institutional considerations) means of reducing the amount of pollution generated by nonpoint sources to a level compatible with water quality goals.

For purposes of the LEWMS, the list of BMP's are categorized according to their effect in the erosion process, and in relation to the treatment of the land surface, erosion control, runoff collection and disposal, sediment retention, and other related nonpoint source control practices. The categories are:

a. Cultural and Land Management Practices

b. Runoff Collection and Disposal Practices

c. Sediment Retention and Trapping Practices

d. Other Related Practices

While it is recognized that all the above categories of soil conservation practices are important for erosion control the LEWMS program has focused on cultural and land management practices as cost effective means of attaining the program goal of reducing Lake Erie diffuse phosphorus loadings to acceptable levels. These cultural practices can be applied to the greatest basin cropland area, and can effectively reduce sheet and rill erosion.

5.1.1 Cultural and Land Management Practices.

The practices in this category deal principally with cultural and land management decisions made by the land owner, operator, or user. These decisions effect primarily the soil surface and its protection from the impact of falling raindrops. Included are decisions related to crop planning, planting, harvest and the management of crop residues.

5.1.1.1 Conservation Tillage - The class of noninversion tillage systems that retain protective amounts of residue mulch on the surface throughout the year (minimum of 1,000 pounds surface residue at planting time). Conservation tillage methods vary greatly. A few accepted methods are as follows:

a. No Till - Planting the crop with a minimum of seedbed disturbance in the remaining residue of the *previous* crop. Seedbed is normally prepared by a coulter, single chisel, disc-opener or similar tool with the seed placement occurring at the same time.

b. Reduced Tillage - Maintaining a majority of the crop residues on the soil surface. Reduced tillage is accomplished by chisel, disk, rotary tiller, or other similar tools which retain a high percentage of residue on the surface. Seedbed preparation and planting may be either single or separate operations.

c. Ridge Planting, Strip Tillage - Creating a ridge for seedbed preparation and planting with special equipment while maintaining surface protection. Special ridge preparation and planting equipment is available for this system.

d. Combinations of the above systems may also be utilized (e.g. - no till planting on ridges).

Suitability - Conservation tillage is applied to those lands where crop residues or annual vegetation is available. Soil must be adequately drained either naturally or artificially to permit planting, crop growth, and harvesting.

Relative Water Quality Impact - Major benefits result from surface cover and protection against erosion caused by impact of falling raindrops. The volume and velocity of runoff water may be reduced due to increased infiltration and improved soil structure.

5.1.1.2 Winter Cover Crops (Crop Residue Use) - The growing of grasses, legumes, or small grains for seasonal soil surface protection and soil improvements, usually grown for one year or less. Existing plant residues (crop residue use) may also be maintained and used to provide this seasonal erosion protection. Cover crops are normally used for winter protection and crop residues are normally used for protection of cultivated fields during the erosion seasons, both may be used for summer and winter protection.

Suitability - Cover crops are suited primarily for cropland, however, other land uses can be treated. Crop residue use is suited wherever adequate surface residue cover is produced.

Relative Water Quality Impacts - Controls erosion during periods of inadequate crop protection against raindrop impact. There are also benefits of moisture conservation, increased infiltration, less soil loss, improved soil structure, and reduced nutrient transport.

5.1.1.3 Conservation Cropping Systems (Rotations) - The growing of crops, or combinations of crops, with needed cultural and management practices, in a system of rotation which provides adequate protection against soil erosion to maintain soil productivity. Small grains, grasses, and legumes are included with row crops in these cropping systems.

Suitability - Crop rotation systems help improve and maintain soil conditions and provide natural control of weed, insect and disease problems. Other factors such as livestock demands, equipment limitations, market prices or other economic influences may dictate the crops to be grown in rotations.

In western Lake Erie Basin, soils technology and markets have resulted in expanded incentives for row crop (corn, soybean) production. Soils lend themselves to continous row crops. Commercial fertilizers and other technology have made continous row cropping practical. Basin farmers' ready access to export markets have given them a relative advantage in satisfying increased U. S. grain export demand. These factors have made rotations less economically attractive for many farmers in the western basin.

Relative Water Quality Impacts - Erosion is decreased and infiltration is increased during periods when row crops are not present.

5.1.1.4 Critical Area Planting - The planting of adequate vegetative cover such as grasses and legumes or other cover such as trees, shrubs and vines on critical erosion areas. Included are adequate seed bed preparation, proper species selection, necessary lime and fertilizer, and mulch cover protection to insure erosion control, seed germination, and plant growth.

Suitability - This practice applies to all highly eroding, sediment producing areas. Normally these are smaller isolated areas such as roadsides, cut and fill slopes, spoil areas and other eroding areas outside of cropland areas.

Relative Water Quality Benefits - Reduced erosion, sediment yield, and runoff to downstream areas are major benefits of this practice.

5.1.2 Runoff Collection and Disposal Practices.

Runoff collection and disposal practices are those which collect and dispose of excessive runoff water at nonerosive velocities. Any time high amounts of water are allowed to accumulate and concentrate, the rate of flow increases, and excessive soil erosion occurs unless adequate erosion protection is provided. Normally these concentrated flows result in gully formations as opposed to sheet and rill erosion caused by raindrop impact and diffuse overland surface flows. Practices in this category disperse and control surface runoff; collect and concentrate flows for safe, nonerosive runoff; and provide protection against gully erosion where runoff flows concentrate. Practices include:

a. Contour Farming and Stripcropping

b. Terraces

c. Diversions

d. Grassed Waterways

e. Outlet Protection Structures

f. Subsurface (Tile) Drainage

5.1.3 Sediment Retention and Trapping Practices.

When the combination of land management and runoff disposal practices are inadequate, sediment and attached particulate phosphorus may be prevented from entering streams, rivers, and lakes through sediment retention and trapping practices. From an erosion and sediment transport standpoint, the use of sediment trapping practices is probably the last resort. Sediment retention and trapping practices function under the principle of slowing runoff waters (including ponding) to increase sediment deposition. However, sediment trapping is ineffective for phosphorus control since finer, phosphorus rich sediments are not easily trapped.

With controlled sediment deposition and trapping, phosphorus and other attached pollutants are prevented from entering streams, rivers, and lakes. Practices include:

a. Sediment Basins

b. Ponds and Impoundments

c. Vegetative Filter Strips

5.1.4. Other Factors.

In addition to those practices discussed above, there are certain other practices which have a beneficial effect on water quality. These other practices must be considered essential BMP's to effectively control the broad cross section of diffuse source water quality problems. These practices relate to other types of problems and controls which cannot be reasonably classified in the other categories.

5.1.4.1 Waste Management Systems (WMS) - Waste Management Systems are facilities to manage liquid and solid waste, including runoff from concentrated waste areas, with ultimate disposal in a manner which does not degrade air, soil, and water resources, and which protect public health and safety. Generally applicable in rural agricultural areas, the systems are planned to preclude discharge of pollutants to surface or ground water, and where possible to recycle waste through soil and plants. There are many BMP component practices which may go into a complete WMS, including diverting clean water away from other barn yards. Likewise, there are several major considerations such as design, installation, operation, and maintenance of component practices. The principal waste management structures include: waste storage ponds and structures, and waste treatment lagoons.

5.1.4.2 Windbreaks (Field, Farmstead and Feedlot) - Windbreaks are belts of trees and/or shrubs established in specific locations for the primary purpose of reducing the adverse effects of high winds. They may be used to protect fields from soil erosion by winds or to protect farmsteads and feedlots from wind damage.

5.1.4.3 Streambank Protection - This practice is the protection of streambanks, lakes, estuaries, or excavated channels from the scour and erosion of soil particles caused by flowing waters or wave action. Methods of protection may include either vegetative or structural techniques, or a combination of both.

5.1.5 Other BMP Considerations.

In addition to benefits and protection provided by BMP's as discussed above, it should be noted that these BMP's may offer many secondary benefits. Many of the practices discussed earlier, when used in conjunction with other practices, provide opportunities for wildlife enhancement. For example, vegetative filters and diversions may provide wildlife habitat cover. Used in conjunction with conservation cropping systems, adequate food would also be available. This type of example is true in numerous other combinations of practices.

Energy conservation is another significant secondary benefit. With reduced and no tillage systems, there are less horsepower and fuel requirements. With windbreak protection around farmsteads, there are considerable energy savings in domestic heating requirements.

Economic benefits are also realized with many BMP's. It is recognized that these benefits must be present in order to realize widespread adoption of BMP's. All landowners and operators prefer to have the flexibility and option to select the cropping system or tillage methods which are demanded by market forces and soil conditions. Studies indicate that conservation tillage systems when used properly on suitable soils provides a net increase in farm income.

The flexibility to mix and match the many possible combinations of practices and still achieve the desired result is likely the most significant hidden secondary benefit. No one set of practices is necessary if the combinations of practices can achieve the desired gross erosion reduction and eventual phosphorus load reductions in the Lake Erie Basin.

Table 5.1 summarizes those conservation practices which were considered BMP's for the reduction of sediment and phosphorus transport in the Lake Erie Basin. The BMP list (Table 5.1 depicts the mode and relative effectiveness of each practice in reducing gross erosion, sediment delivery, and phosphorus delivery).

In application of the USLE for assessment of present potential gross erosion conditions, soil loss attributable to gully and wind erosion is not estimated. The USLE is a predictive tool for average annual soil loss via sheet and rill erosion by water. There is no credit given to gully erosion soil losses nor is there any method to predict average annual gully erosion without detailed field inventory. No calculations or values have been developed for wind erosion. Where appropriate, measures to control gully and wind erosion must be applied.

Gully erosion, along with other diffuse source problems such as urban construction sites and animal feed lot wastes, may be classified as identifiable nonpoint sources. While they cannot be classified specifically as point source discharges, they are often times readily visible and easily identified. Control of these highly eroded sediment sources and waste disposal problems cannot be accomplished with cultural land management practices. These problems and numerous other problems will require the unique blending and application of other BMP's.

5.2 ALTERNATIVE SCENARIOS FOR EROSION AND PHOSPHORUS REDUCTIONS

The previous section identified a number of candidate cultural and land management practices for controlling soil and phosphorus losses from agricultural crop lands including conservation tillage, rotations, cover crops, and spring rather than fall plowing. Unfortunately these practices cannot be universally applied in the Lake Erie Basin because of soil limitations, climatic factors, and economic limitations of cropping systems. To have reasonable expectation of successful implementation of a conservation program it is necessary therefore to provide alternatives which can best fit the exact set of natural and man-induced conditions on the land, and at the same time be cost-effective. Thus a number of scenarios were developed which provide alternatives for achieving desired reductions.

Table 5.1 - The Effects of Best Management Practices on Erosion, Sedimentation, and Phosphorus Transport

	Practices Which Affect			Sediment Retention Point			Effect (H, M, L) (1)		
	Raindrop Impact	Reduced Runoff Volume	Reduced Runoff Velocity	On Field	Swale	Stream	Gross Erosion Reduction	Sediment Delivery Reduction	Phosphorus Delivery Reduction
Cultural and Land Management									
Conservation Tillage									
No Till	X	X	X	X			H	H	H
Reduced Tillage	X	X	X	X			M	H	H
Ridge, Strip Tillage	X	X	X	X			M	M	M
Winter Cover Crop - Crop Residue Use	X	X	X	X			M	M	M
Conservation Cropping System	X	X	X	X			H-L	H-L	H-L
Critical Area Planting	X	X	X	X			H	H	L
Runoff Collection and Disposal									
Contour Farming		X	X	X			M	M	L
Contour Strip Cropping	X	X	X	X	X		H	M	M
Terrace		X	X		X		M	M	L
Diversion		X	X		X		M	M	L
Parallel Tile Outlet Terrace		X	X	X	X		M	H	M
Grassed Waterways			X		X		H	L	L
Outlet Protection Structure						X	L	L	L
Subsurface Tile Drainage		X	X	X			L	M	L
Sediment Retention and Trapping									
Sediment Detention Basins			X			X	-	H	L
Ponds and Impoundments			X			X		H	L
Filter Strip - Vegetative			X	X	X		M	L	L
Other Practices									
Waste Management Systems									
Storage Pond									H
Storage Structure									H
Treatment Lagoon									H
Windbreaks									
Field				X			M	L	L
Farmstead				X			L	L	L
Stream Bank Protecion			X			X	L	L	L

(1) H = High, M = Medium, L = Low

5.2.1 Scenario Development.

5.2.1.1 Tillage Systems - The scenarios developed in this program were designed to evaluate reductions in gross erosion which can be achieved by application of cultural and land management practices to cropland. The baseline against which the scenarios are compared is the estimated potential gross erosion for the base year, 1975. The methodology for the use of the Universal Soil Loss Equation with the Land Resources Information System was detailed in Chapter 2.

For these scenarios, only those practices which will not adversely impact on crop yields have been considered. The tillage systems considered and the methodology for this application are described briefly below. An excellent discussion of tillage systems is given in Reference 1.

The following tillage systems were used to develop the scenarios:

a. Conventional Tillage utilizes the moldboard plow (fall or spring) plus preplanting cultivation for soil smoothing. Planting is in a smooth bare soil surface.

b. Reduced Tillage is any tillage system which is not based on the use of the moldboard plow. For the purpose of the scenarios, reduced tillage is defined as the use of a noninversion chisel plow-based system in the fall or spring plus spring leveling operations. The chisel plow tills and mixes the soil to a depth of 8 to 12 inches, but retains at least 1,000 lbs. of crop residue on the surface.

c. No Tillage requires planting directly in the residue of the previous year's crop. There is minimal disruption of the soil. Planting is accomplished with a planter which is specially equipped to operate in previous crop residues. Weed and turf control is achieved strictly with herbicides. A minimum of 3,000 lbs. of crop residue is retained on the surface.

5.2.1.2. Soil Management Groups (SMG) - Triplett et. al. (Ref 2) has grouped soils according to their crop responses to no till.

The first five soil groups as described by Triplett et al are:

Soil Management Group 1 - With good management, soils included in this group should have yield response to no tillage equal to or greater than conventional tillage. Soils in this group are moderately well, well, and excessively well drained. They have silt loam, loam, sandy loam, or loamy fine sand surface textures. These soils are relatively low in organic matter and include glaciated, residual, and terrace soils. No recent alluvial soils are included.

Soil Management Group 2 - With good management, soils in this group should have yield response to no tillage nearly equal to conventional tillage, provided soil drainage has been improved by surface or subsurface drainage. These soils are somewhat poorly to poorly drained in the natural state. They have silt loam, loam, sandy loam, or loamy fine sand surface textures. Soil permeability is equal to or greater than 0.2 inches per hour within the top 2 feet of the profile. Soils in this group are relatively low in organic matter and include glaciated, residual, and terrace soils. No recent alluvial soils are included.

Mulch cover is important to proper performance of no tillage on the lower organic matter soils (1.5 to 2.5 percent organic matter) in this grouping, as is the case with SMG 1. No tillage corn following sod, or delaying planting with no tillage until the latter part of the optimum planting period in areas where continuous row cropping is practiced, are excellent choices on these soils.

Soil Management Group 3 - Soils in this group may yield less with no tillage in comparison to conventional tillage and should not be considered for no tillage under most circumstances. These soils are somewhat poorly to very poorly drained. Internal water movement is so slow that even tile does not provide adequate drainage. Surface texture is primarily loam, silt loam, or silty clay loam. These soils are derived from glacial till or residual parent material. No recent alluvial soils are included. Most of these soils are relatively low in organic matter content.

Soil Management Group 4 - Soils in this group may yield less with the no tillage system in comparison to conventional tillage. These soils are very poorly drained and have surface textures of silty clay loam, clay loam, silty clay, or clay. They contain relatively high amounts of organic matter in the surface. Soils developed in glacial till and residue are included in this group, but alluvial soils are not. Corn on these soils does not respond to mulch cover where no tillage is used, except perhaps for slower growth in cool, wet springs where mulch is present.

Soil Management Group 5 - This group includes organic soils, recent alluvial soils, strip mine land, and certain fine-textured soils that are not recommended for no tillage. There has been little or no experience with no tillage on organic soil. Corn grown on well drained, recent alluvial soils should respond satisfactorily to no tillage, but in a small number of tests, this has not been observed. No reason is known for this poor response at this time.

Yields on poorly drained clays, such as Paulding, have not been satisfactory with no tillage. Well drained soils where erosion has exposed a high clay subsoil probably should not be planted to row crops. No tillage may do as well on these soils as any other system, but planter function with no tillage has been a problem. Strip mine land is so variable that decisions for crop production must be made on an individual site basis.

Soil Management Groups 6-9 - These groupings correspond directly to SMG's 2 through 5. SMG 6 responds to no tillage cropping as does SMG 2, SMG 7 responds as does SMG 3, etc. The division of each group is by surface texture classification. SMG 6-9 include all soils which might have been included in SMG's 2-5, except that they have clay or silty clay surface horizon textures. The purpose for breaking out these fine-textured surface horizon soils involves the sediment phosphorus delivery characteristics of fine clays. Since such soils have been identified as having a more significant effect on water quality, it is useful to know the degree to which a reduced tillage conservation program will be applied to them.

Soil Management Group 10 - SMG 10 includes all cropland on soils with slopes greater than 18 percent. This grouping is made because it is not recommended that lands with slopes of this magnitude should be in cropland. However, if these lands are presently in cropland, they would experience the lowest achievable level of soil loss if a no tillage management system were employed.

Since the soil management groups are formed around the potential crop yield response of each group, they are also useful for economic impact analysis for the scenarios. Forster (Ref 3) has evaluated the costs and benefits of a range of cropping management schemes for soils representative of each of the groups. The same approach has been used in this study. The results of the economic impact analysis are discussed in Section 5.4.

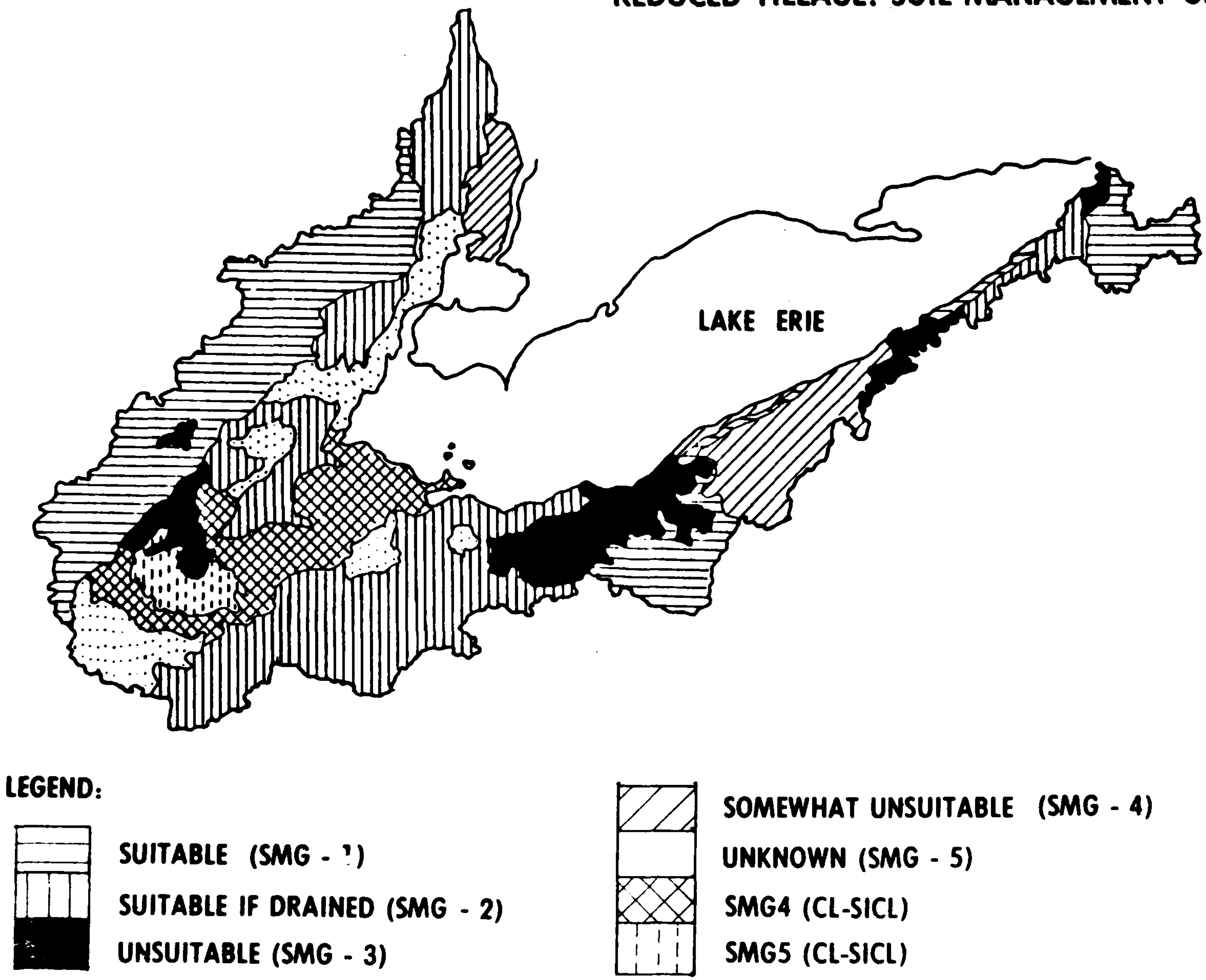
Using the LRIS system, the distribution of soil management groups in the Lake Erie Basin has been mapped and is shown in Map V-1.

Table 5.2 gives the acreages of each soil management group in each of the Lake Erie subbasins and in the entire basin. Since SMG's 1, 2, 6, and 10 are believed amenable for no till farming it may be estimated that 53 percent of the Lake Erie Basin cropland ultimately can be no tilled. Soil management groups 1, 2, 4, 6, 8, and 10 or approximately 80 percent of the basin cropland acreage is considered suitable for reduced tillage farming. However, these soils sometimes occur in fields with soils that are not suitable and it would not be practical to use conservation tillage in those instances.

Table 5.2 - Acres of Cropland in Lake Erie Basin by Soil Management Group

SMG	St. Clair	Western	Central	Eastern	Total
1	331,662	458,642	299,093	108,426	1,197,823
2	469,052	1,127,426	711,907	39,440	2,347,825
3	25,298	194,341	311,518	89,590	620,747
4	94,472	776,192	211,774	5,620	1,088,058
5	82,752	157,155	178,185	4,732	422,824
6	0	0	110	0	110
7	0	2,243		0	2,243
8	318	661,291	91,243	0	752,852
9	4,527	273,983	4,538	0	283,048
10	6,837	4,735	8,997	14,371	34,940
	1,014,918	3,656,008	1,817,365	262,179	6,750,470

MAP V - 1 SUITABILITY OF SOILS IN THE UNITED STATES DRAINAGE OF LAKE ERIE FOR REDUCED TILLAGE: SOIL MANAGEMENT GROUPS



5.2.2 Scenarios for Potential Gross Erosion Control.

The scenarios which have been evaluated for potential gross erosion reduction are summarized in Table 5.3. In the scenarios, tillage and cover conditions for cropland SMG's are evaluated. Vineyards, orchards, pastureland, and woodlands essentially remain the same in all scenarios.

Scenario 1 is the base year condition scenario. PGE is calculated for each of the 62 counties in the Lake Erie drainage basin for the best estimate of prevailing conditions in each. The methodology for determining current C, cropping management practice (C) factors and rainfall erosivity (R) factors, is described in Chapter 2 and a separate technical report (Ref 4).

Scenario 2 evaluates the effect of limiting PGE across the basin to T, the soil loss tolerance factor. The T factor is the upper limit of PGE which a soil in crop production can withstand over the long-term without reduction in crop yield. For any given soil resource unit, it is the standard or goal to reach in the development of conservation plans for farm units. Thus, in Scenario 2, the assumption is made that all farms in the Lake Erie Basin have fully implemented conservation plans in effect. For any cell in which the present PGE is less than T, the present condition is unaltered.

Scenario 3 alters the present condition by eliminating the practice of fall plowing.

Scenario 4 is the inverse of Scenario 3 in that the soil loss equation is evaluated for fall plowing only. Although this is a scenario which increases PGE, it was necessary to assess the range of soil loss which might be expected from an increase in fall plowing and a decrease of the spring plowing.

Scenario 5 requires the introduction of a winter cover crop planted in the residue of the previous crop. Spring tillage precedes the next crop.

Scenario 6 is the most extreme of the scenarios. It requires the maximum PGE reduction practically achievable through the use of tillage modification. Before tillage modification is allowed on a particular soil in this scenario, that soil must be identified as "suitable" or not having significant adverse impacts on net farm income. The no till crop production system is applied on SMG's 1, 2, 6, and 10; reduced tillage (fall or spring, depending on current timing) is utilized on SMG's 4 and 8; and present practices (predominantly fall moldboard plowing) are continued on SMG's 3, 5, 7, and 9.

Scenario 7 is an intermediate reduced tillage scenario which requires the use of reduced tillage plow (again, in fall or spring as presently used) on SMG's 1, 2, 4, 6, 8, and 10, while continuing the allowance of present practices on SMG's 3, 5, 7, and 9.

In addition to the cropland, vineyards and orchards, pastureland, and woodland soil loss values, there are soil loss values developed for those areas which appear as missing data. Missing data represents those cells for which no soils information is available due to lack of available published soil survey maps.

Table 5.3 - Potential Gross Erosion Sc narios for the Lake Erie Drainage Basin Cropland

Scenario	Soil Management Group Code									
	1	2	3	4	5	6	7	8	9	10
Present Condition	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
Reduce Soil Loss to T and Existing	T=PC T=T	T=PC T=T	T=PC T=T	T=PC T=T	T=PC T=T	T=PC T=T	T=PC T=T	T=PC T=T	T=PC T=T	T=PC T=T
Spring Plow Only	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP
Fall Plowing Only	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP
Winter Cover Crop	WC	WC	WC	WC	WC	WC	WC	WC	WC	WC
Maximum Reduction - Tillage	NT	NT	PC	CP	PC	NT	PC	CP	PC	NT
Reduced Tillage - Chisel Plow	CP	CP	PC	CP	PC	CP	PC	CP	PC	CP

PC - Present Condition

T=PC - If the existing potential gross erosion (PGE) calculated for a cell is less than the soil loss tolerance factor (T), PGE remains as the present condition.

T=T - If the existing PGE calculated for a cell is greater than the soil loss tolerance factor for the soil, PGE is set equal to T.

SP - Implies the use of spring moldboard plow tillage only as an alternative to present conditions.

FP - Implies the use of fall moldboard plow tillage as an alternative to present conditions. This will usually imply an increase in PGE.

WC - Requires the introduction of a winter cover crop planted in the residue of the previous crop. Spring tillage precedes the next crop.

NT - No tillage. Crop is planted directly in the residue of the previous crop.

CP - Chisel plow. Applied as spring or fall reduced tillage as an alternative to present use of moldboard plow tillage systems.

For areas with missing soil data, the assumption was made that land use distribution for missing data was the same as the land use distribution for which soils information was available. The average soil loss values in tons per acre per year for the particular land use with soils data was assigned to those assumed land uses with missing soil data.

Excluded from the soil loss totals for the various scenarios are soil losses from water areas which have no soil loss and soil losses from "other" land use areas. These other areas include such land uses as: commercial, industrial, residential, public utilities, developing areas, extractive, and transportation lands. While it is known that these areas do indeed erode, there was no methodology established to estimate the extent of soil loss. In many cases, these land uses have more gully erosion problems which can be considered "identifiable nonpoint sources." Where other land use categories represent a high percentage of the land area, for example, in the river basins draining the Detroit or Cleveland metropolitan areas, this problem is significant. However, on a lakewide basis it is not important.

When evaluating the results of the following scenarios, keep in mind these points: each data point represents a landscape cell of between 10 and 90 acres, each scenario option is assumed to be adapted totally for those soil management groups where it is suitable. Scenario 6 assumes that adequate subsurface drainage has been installed in all SMG 2 and 6 soils.

The object was to determine the total possible reduction in PGE that could be accomplished under ideal conditions using only tillage and cover modifications. Ideal conditions will not be achieved for a number of reasons. The normal intermingling of both adapted and unadapted soils for a given scenario within a field precludes total adoption. All SMG 2 and 6 soils do not have adequate subsurface drainage. None of the scenarios tested will achieve the allowable soil loss limits for Group 10 soils. A land use change, rotation change or structural measures will be required for SMG 10 soils.

5.2.3 Potential Gross Erosion Reductions.

This section presents potential gross erosion and potential achievable reductions estimated for each of the scenarios. The results are summarized for the Western, Central and Eastern Basins and total Lake Erie and are given in Table 5.4. A much more detailed breakdown of PGE calculations exists for each major river basin, sub-basins, and county portions of the river basins. This information is contained in a separate technical report (Ref 5) and was used in selecting five basins for more intense study during Phase III.

a. Western Basin - The Western Basin of Lake Erie has the largest drainage area, as well as the highest sediment and phosphorus loadings. Table 5.4 shows the PGE in the Western Basin for the scenarios. It can be seen from this table that existing Potential Gross Erosion (PGE) averages about 2.3 tons per acre per year (t/a/y). It must be recognized that the average PGE figure actually camouflages the extremely high and low PGE areas. With the average PGE figures, it is impossible to identify specific problem areas and critical erosion areas.

Table 5.4 - Existing and Potential Achievable Reduction of Potential Gross Erosion
United States Drainage to Lake Erie

Basin	Existing PGE Scenario 1	Reduce Soil Loss to T and Existing Scenario 2	Spring Plowing Only Scenario 3	Fall Plowing Only Scenario 4	Winter Cover Scenario 5	Maximum Reduction Tillage Scenario 6	Reduced Tillage (Chisel) Scenario 7	Cropland Grassland and Forest (Acres)	Other Land Use (Acres)
Western									
Average PGE(tons)	16,558,689	9,652,224	15,762,305	17,511,751	15,859,357	4,519,203	8,323,693	7,340,043	909,368
(t/a/y)	2.3	1.3	2.1	2.4	2.2	0.6	1.1		
Percent Reduction		42.	5.	(-6.)*	4.	73.	50.		
Central									
Average PGE(tons)	6,730,579	4,396,989	6,468,333	7,230,668	6,569,516	2,368,456	3,892,375	3,406,608	313,209
(t/a/y)	2.0	1.3	1.9	2.1	1.9	0.7	1.1		
Percent Reduction		35.	4.	(-7.)*	2.	65.	42.		
Eastern									
Average PGE(tons)	1,808,952	1.098,794	1,781,211	2,033,528	1,805,904	926,274	1,275,956	810,538	129,216
(t/a/y)	2.2	1.4	2.2	2.5	2.2	1.1	1.6		
Percent Reduction		39.	2.	(-12.)*	0.	49.	29.		
Lake Erie Total	25,048,220	15,148,007	24,011,849	26,775,947	24,234,777	7,813,933	13,492,024	11,557,189	1,351,793
Average PGE									
(t/a/y)	2.2	1.3	2.1	2.3	2.1	0.7	1.2		
Percent Reduction		40.	4.	(-7.)*	3.	69.	46.		

*Denotes negative impacts where soil loss is actually increased instead of reduced.

In order to provide adequate protection against soil erosion for pur-es of maintaining productivity and the soil resource base, 42 percent uction in PGE would be needed on those soils where PGE exceeds the erable soil loss limits. These values are reflected in Scenario 2.

Potential achievable reductions under the various scenarios show that spring plow, fall plow, and winter cover crop scenarios yield essentially same PGE, ranging from 2.1 to 2.4 t/a/y. While the differences in PGE ear to be rather insignificant, it is important to recognize that winter er crops (Scenario 5) and crop residue protection (spring plow, Scenario afford surface protection against soil detachment from raindrop impact ing winter and early spring months. Infiltration is likely to be improved er these conditions also. Another consideration is that delivery of sedi-t eroded in the winter and early spring months is high. The USLE tends to erestimate potential gross erosion because losses from winter runoff are erestimated.

There are large reductions in PGE realized from using reduced tillage tems as applied in Scenarios 6 and 7. By applying no till and reduced lage (chisel plow) on those soils suited to these tillage techniques, PGE reduced 73 percent (Scenario 6). A 50 percent reduction is realized under "chisel plow" reduced tillage scenario.

b. Central Basin - The PGE rate of 2.0 t/a/y for the Central Basin is s than the Western Basin. In Scenario 2, a 35 percent reduction in PGE ld be needed on those soils exceeding the tolerable soil loss to ade-tely protect the soil resource base. This type of soil loss reduction not be achieved under the spring plow or winter cover scenarios. Here in, the range in PGE from 1.9 to 2.1 t/a/y is essentially negligible. or PGE reductions are also potentially achievable under reduced tillage, narios 6 and 7. Scenario 6 reductions of 65 percent and Scenario 7 reduc-ns of 42 percent are both significant, yet slightly lower than the same narios for the Western Basin.

c. Eastern Basin - Table 5.4 shows potential gross erosion in the tern Basin for the scenarios. The Eastern Basin has a PGE rate of 2.2 /y, which is similar to the Western Basin. In Scenario 2, a 39 percent luction in PGE is needed on those soils exceeding tolerable soil loss limits adequately protect the soil resource base. As in the other basins, this luction cannot be achieved with conventional tillage system unless there is otation change. Some type of reduced tillage system will be needed for se areas.

The PGE rates of 2.2 to 2.5 t/a/y for spring plow, fall plow, and winter er crops are not significantly different from the present condition.

Scenarios 6 and 7 show reasonable reductions in PGE (49 percent and 29 cent, respectively), but not nearly as significant as in the Western and tral Basins. Reduced tillage systems are, however, viable erosion control sures for the Eastern Basin and should be further developed.

d. Lake Erie Summary - Basically, the same holds true for the Lake Erie basinwide summary as applies in the individual basins. Average PGE of 2.2 t/a/y still distorts the true picture because of the averaging. There are many areas where soil loss is well below the tolerable limits. In fact, in many cases, existing PGE is less than 1.0 t/a/y while in other areas soil loss is well over "T." It is not uncommon to find soil losses in some areas ranging from 6 to 12 t/a/y or higher. It is these high PGE areas which must be identified and treated if sediment and nutrient loading reduction objectives are to be achieved.

Throughout the Lake Erie Basin, it holds true that, on the average, where soil loss exceeds tolerable limits, merely a change to conventional spring plow or winter cover crops will not bring soil loss to within tolerable limits. The reduced tillage Scenarios (6 and 7) indicate that throughout the Lake Erie Basin significant reduction in PGE can be achieved. It should be stressed that Scenarios 6 and 7 use no till and chisel plow tillage systems only where practical. It is recognized that a voluntary approach to reducing cropland nonpoint pollution is only feasible if incomes remain nearly the same or are enhanced by the pollution reducing technologies. Thus, these scenarios depict the potential practical reduction in PGE with the adoption of reduced tillage practices on all suitable soils.

It should also be remembered that the estimates of PGE in Table 5.4 do not include any values for soil losses attributable to streambank and shoreline erosion, gully erosion, or other land use areas previously identified. Control measures and conservation treatments to reduce erosion and sediment problems from these areas must be appropriately applied where needed.

5.2.4 Projected Potential Gross Erosion Reductions.

The previous section provided estimates of erosion reductions which could be achieved using various conservation practices, principally conservation tillage. These estimates assumed 100 percent adoption, however, and do not provide insight into what adoption rates and levels may realistically be expected, or the reductions which would be realized at the projected levels of adoption.

A panel consisting of LEWMS technical staff, university and Extension Service personnel intimately involved with conservation tillage in the Lake Erie Basin for the last 5 to 10 years was convened for the purpose of making best estimates of future adoption of conservation tillage in the basin. The consensus results of these estimates are given in Table 5.5. The first three columns of Table 5.5 gives the estimated percentage of cropland soil management group acreages presently (1982) in reduced tillage, no-till or remaining under conventional plow tillage methods. The second set of columns gives the best estimate of the predicted adoption of reduced tillage and no-till assuming that adoption rates follow recent trends, and demonstration programs or other special incentives to accelerate adoption are available. For the most abundant soil management group acreages (see Table 5.2) predicted increases in percent adoption of conservation tillage over the period would be as follows:

SMG	Reduced Tillage	No-Till
1	30	25
2	40	15
4	25	9

An accelerated program encompassing education, technical assistance and demonstration programs is expected to increase adaptation over the same period as follows.

SMG	Reduced Tillage	No-Till
1	20	45
2	30	35
4	35	19

Table 5.5 - Estimated Percent Adoption of Conservation Tillage Practices Under Existing and Accelerated Programs

	Present (1982)			Existing Program Ultimate			Accelerated Program Ultimate		
SMG	Plow	Reduced Till	No Till	Plow	Reduced Till	No Till	Plow	Reduced Till	No Till
1	75	20	5	20	50	30	10	40	50
2	75	20	5	20	60	20	10	50	40
3	90	10	0	75	25	0	50	50	0
4	84	15	1	50	40	10	30	50	20
5	90	10	0	75	25	0	60	30	10
10	85	10	5	20	50	30	10	20	70

It is seen that the accelerated program is expected to result in much greater increases in adoption of the greater soil saving no-till practices. Much of the SMG 2 area which may come under reduced tillage under the present program could be converted to no-till under an accelerated program which promotes improved soil drainage to increase crop responses under no-till management.

The poor response of SMG 3 soils to artificial drainage is expected to preclude the application of no-till in the long-term, although reduced tillage with perhaps ridge-furrow practices could increase significantly (i.e., 40 percent) under an accelerated program.

Based on the projected increases in adoption of conservation tillage and the inventory of existing practices, projections have been made of the acreages of cropland expected to be affected and resultant reductions in soil losses. These projections are contained in Tables 5.6 through 5.10 for the St. Clair, Western, Central, Eastern, and entire United States portion of the Lake Erie Basin. Present conditions are also given so as to enable the quantification of progress achieved to date and projected future achievements.

Data from Tables 5.6 through 5.10 indicate that significant progress in erosion reduction has been made from 1975 to 1982 with overall reduction in the basin of 13 percent. Under the existing program Scenario, ultimate reductions are expected to range from 32 percent in the Eastern Basin to 48 percent in the Western Basin, with a basin-wide reduction of 45 percent. With an accelerated program, reductions are estimated as ranging from 39 percent in the Eastern Basin to 58 percent in the Western Basin with basin-wide reductions of 55 percent.

The present (1982) basin-wide erosion rate is estimated as 18,000,000 tons/yr. The estimated basin-wide cropland erosion by the year 2002 under the existing program will ultimately be 11,700,000 tons/yr. With an accelerated program, the estimated erosion is 9,400,000 tons/yr. Thus, the accelerated program is expected to increase soil loss reduction by 20 percent compared to the unaugmented program.

It is assumed that cropland area will remain constant over this period, although some conversion of cropland to urban use is expected to occur. High grain export demand is expected to shift some pasture and woodland to cropland.

It is of interest to estimate the acreage of cropland which will ultimately have conservation practices by the year 2002. Estimates for the existing and accelerated programs are given in Table 5.11. This table was produced by applying the figures in Table 5.5 to the mix of soils actually found in the basin (Table 5.2). Under the existing program, it is expected that 59 percent of the cropland in the Lake Erie Basin will have conservation tillage practices with a breakdown of 44 percent reduced tillage and 15 percent no-till. Under the accelerated program these percentages should be increased to 46 percent for reduced tillage and 30 percent for no-till, for a total of 76 percent of the cropland under conservation tillage. In addition to reduced soil and phosphorus losses under the accelerated program, runoff of other nutrients, pesticides and other diffuse source pollutants should be commensurately reduced.

Table 5.6 - Estimated Cropland Soil Losses for the United States Drainage of Lake Erie

Land Use	Base Year Soil Loss 1975 (Tons) (Tons/Acre)	Existing Soil Loss 1982 (Tons) (Tons/Acre)	Existing Program (Tons) (Tons/Acre)	Accelerated Program (Tons) (Tons/Acre)	Soil Management Group Land Area (Acres)
Cropland	7,681,295	6,558,263	3,751,535	2,868,912	1,197,857
SMG 1	6.4	5.5	3.1	2.4	
Cropland	6,807,908	5,778,582	3,431,784	2,649,786	2,347,826
SMG 2	2.9	2.5	1.5	1.1	
Cropland	2,187,637	2,075,619	1,907,592	1,627,547	620,747
SMG 3	3.5	3.3	3.1	2.6	
Cropland	931,018	843,494	638,823	505,642	1,088,058
SMG 4	0.9	0.8	0.6	0.5	
Cropland	497,866	470,969	430,625	375,133	422,824
SMG 5	1.2	1.1	1.0	0.9	
Cropland	22	21	18	16	110
SMG 6	0.2	0.2	0.2	0.1	
Cropland	4,102	3,865	3,509	2,916	2,243
SMG 7	1.8	1.7	1.6	1.3	
Cropland	828,116	748,491	562,970	442,673	572,851
SMG 8	1.1	1.0	0.7	0.6	
Cropland	336,797	316,949	287,177	248,116	283,048
SMG 9	1.2	1.1	1.0	0.9	
Cropland	1,336,046	1,216,229	682,286	684,630	34,939
SMG 10	38.2	34.8	19.5	19.6	
Cropland	20,610,808	18,012,842	11,696,320	9,405,370	6,750,503
	3.1	2.7	1.7	1.4	
Percent Reduction		13	45	55	

Table 5.7 - Estimated Cropland Soil Losses for The United States Eastern Basin of Lake Erie

Land Use	Base Year Soil Loss 1975 (Tons) (Tons/Acre)	Existing Soil Loss 1982 (Tons) (Tons/Acre)	Existing Program (Tons) (Tons/Acre)	Accelerated Program (Tons) (Tons/Acre)	Soil Management Group Land Area (Acres)
Cropland	363,163	321,886	211,672	170,211	108,426
SMG 1	3.3	3.0	2.0	1.6	
Cropland	91,931	81,487	57,113	46,644	39,440
SMG 2	2.3	2.1	1.4	1.2	
Cropland	325,355	312,922	294,272	263,190	89,590
SMG 3	3.6	3.5	3.3	2.9	
Cropland	6,003	5,619	4,647	3,966	5,620
SMG 4	1.1	1.0	0.8	0.7	
Cropland	3,280	3,156	2,969	2,658	4,732
SMG 5	0.7	0.7	0.6	0.6	
Cropland	272,440	252,067	160,255	171,899	14,371
SMG 10	19,0	17.5	11.2	12.0	
Cropland	1,062,172	977,138	730,928	658,568	262,179
	4.1	3.7	2.8	2.5	
Percent Reduction		10	32	39	

Table 5.8 - Estimated Cropland Soil Losses for The United States Central Basin of Lake Erie

Land Use	Base Year Soil Loss 1975 (Tons) (Tons/Acre)	Existing Soil Loss 1982 (Tons) (Tons/Acre)	Existing Program (Tons) (Tons/Acre)	Accelerated Program (Tons) (Tons/Acre)	Soil Management Group Land Area (Acres)
Cropland	2,277,194	1,940,797	1,102,480	841,608	299,093
SMG 1	7.6	6.5	3.7	2.8	
Cropland	2,250,308	1,925,205	1,181,685	924,324	711,907
SMG 2	3.2	2.7	1.7	1.3	
Cropland	1,101,106	1,044,646	959,956	818,805	311,518
SMG 3	3.5	3.4	3.1	2.6	
Cropland	217,716	197,608	150,449	119,677	211,774
SMG 4	1.0	0.9	0.7	0.6	
Cropland	245,112	232,238	212,927	185,997	178,185
SMG 5	1.4	1.3	1.2	1.0	
Cropland	22	21	18	16	110
SMG 6	0.2	0.2	0.2	0.1	
Cropland	94,791	85,485	63,863	49,878	91,243
SMG 8	1.0	0.9	0.7	0.5	
Cropland	5,152	4,850	4,398	3,802	4,538
SMG 9	1.1	1.1	1.0	.8	
Cropland	574,172	520,844	283,635	279,859	8,997
SMG 10	63.8	57.9	31.5	31.1	
Cropland	6,765,573	5,951,695	3,959,411	3,223,966	1,817,364
	3.7	3.3	2.2	1.8	
Percent Reduction		11	41	51	

Table 5.9 - Estimated Cropland Soil Losses for the United States Western Basin of Lake Erie

Land Use	Base Year Soil Loss 1975 (Tons) (Tons/Acre)	Existing Soil Loss 1982 (Tons) (Tons/Acre)	Existing Program (Tons) (Tons/Acre)	Accelerated Program (Tons) (Tons/Acr)	Soil Management Group Land Area (Acres)
Cropland	3,911,947	3,294,107	1,775,892	1,324,368	458,642
SMG 1	8.5	7.2	3.9	2.9	
Cropland	4,189,939	3,521,920	2,004,263	1,520,987	1,127,426
SMG 2	3.7	3.1	1.8	1.3	
Cropland	729,824	687,984	625,224	520,623	194,341
SMG 3	3.8	3.5	3.2	2.7	
Cropland	678,305	613,157	461,380	362,970	776,192
SMG 4	0.9	0.8	0.6	0.5	
Cropland	235,247	221,714	201,415	174,328	157,155
SMG 5	1.5	1.4	1.3	1.1	
Cropland	4,102	3,865	3,509	2,916	2,243
SMG 7	1.8	1.7	1.6	1.3	
Cropland	733,276	662,959	499,071	392,764	661,291
SMG 8	1.1	1.0	0.8	0.6	
Cropland	330,746	311,224	281,941	243,551	273,983
SMG 9	1.2	1.1	1.0	0.9	
Cropland	340,574	305,841	152,164	140,714	4,735
SMG 10	71.9	64.6	32.1	29.7	
Cropland	11,153,959	9,622,771	6,004,858	4,683,220	3,656,009
	3.1	2.6	1.6	1.3	
Percent Reduction		16	48	58	

Table 5.10 - Estimated Cropland Soil Losses for the United States St. Clair Basin of Lake Erie

Land Use	Base Year Soil Loss 1975 (Tons) (Tons/Acre)	Existing Soil Loss 1982 (Tons) (Tons/Acre)	Existing Program (Tons) (Tons/Acre)	Accelerated Program (Tons) (Tons/Acre)	Soil Management Group Land Area (Acres)
Cropland	1,128,865	1,001,723	661,425	532,673	331,662
SMG 1	3.4	3.0	2.0	1.6	
Cropland	275,731	249,970	188,723	157,831	469,052
SMG 2	0.6	0.5	0.4	0.3	
Cropland	31,351	30,067	28,140	24,928	25,298
SMG 3	1.2	1.2	1.1	1.0	
Cropland	28,995	27,110	22,348	19,029	94,472
SMG 4	0.3	0.3	0.2	0.2	
Cropland	14,227	13,862	13,314	12,150	82,752
SMG 5	0.2	0.2	0.2	0.1	
Cropland	50	46	37	31	318
SMG 8	0.2	0.1	0.1	0.1	
Cropland	900	875	838	763	4,527
SMG 9	0.2	0.2	0.2	0.2	
Cropland	148,860	137,477	86,232	92,159	6.837
SMG 10	21.8	20.1	12.6	13.5	
Cropland	1,628,978	1,461,130	1,001,057	839,564	1,014,917
	1.6	1.4	1.0	0.8	
Percent Reduction		13	38	50	

Table 5.11 - Estimated Areal Extent of Conservation Tillage for the Future

	Total Cropland (Acres)	Reduced Tillage (Acres)	Reduced Tillage (Percent)	No Tillage (Acres)	No Tillage (Percent)	Total Conservation Tillage (Percent)
Existing Program						
Western	4,670,926	2,147,856	46	713,112	15	61
Central	1,817,364	691,442	38	265,131	15	53
Eastern	262,179	110,822	42	45,289	17	60
Total	6,750,469	2,950,120	44	1,023,532	15	59
Accelerated Program						
Western	4,670,926	2,149,501	46	1,400,187	30	76
Central	1,817,364	839,530	46	519,529	29	75
Eastern	262,179	114,989	44	72,592	28	72
Total	6,750,469	3,104,020	46	1,992,308	30	76

5.2.5 Projected Adoption Rates for Conservation Tillage.

The estimates of rate of adoption of conservation tillage systems include estimates for both an "Existing Program" and the recommended "Accelerated Program." To repeat, the figures for ultimate adoption under these two programs were arrived at as the result of the deliberation of a panel of experts. In order to estimate the pattern of adoption, and subsequent annual reduction in phosphorus, of conservation tillage from the present (1982) to a point 20 years in the future, it was necessary to estimate potential rates of adoption on an annual basis. This was done by study of the rates of adoption of conservation tillage currently being experienced in the Lake Erie Basin. In order to compute rates for both the existing and accelerated program a surrogate had to be developed for each. In this analysis, the rate of adoption of conservation tillage systems for the Lake Erie Basin counties of Ohio was used to develop the existing program. The Ohio Counties of Seneca, Huron, and Crawford, all involved in the Honey Creek Watershed Management Study represent the accelerated program. Tables 5.12 and 5.13 include the inventories of conservation tillage in all Ohio, the Lake Erie Basins of Ohio and Seneca, Huron and Crawford Counties, Ohio respectively.

Table 5.12 - Adoption of Reduced Tillage Production Practices for Corn and Soybeans

	1979 (Acres)	1979 (Percent)	1980 (Acres)	1980 (Percent)	1982 (Acres)	1982 (Percent)
Corn						
All Ohio Counties	833,322	22	979,902	23	833,322	22
Basin Ohio Counties	343,810	20.6	389,976	22.2	383,988	21.9
Honey Creek Counties	38,000	18.9	52,311	25.2	61,405	29.5
Soybeans						
All Ohio Counties	899,333	24.5	991,933	26	999,413	27
Basin Ohio Counties	438,176	21.6	459,654	21.7	451,542	21.7
Honey Creek Counties	25,000	10.1	38,420	15.1	44,803	17.6

Table 5.13 - Adoption of No-Tillage Production Practices for Corn and Soybeans in Ohio (OCES, 1980, 1981, 1982).

	1979 (Acres)	1979 (Percent)	1980 (Acres)	1980 (Percent)	1982 (Acres)	1982 (Percent)
Corn						
All Ohio Counties	202,490	5.4	252,277	6.5	344,560	9.0
Basin Ohio Counties	35,455	2.3	58,814	3.4	86,662	4.9
Honey Creek Counties	1,600	0.7	7,412	3.6	11,526	5.5
Soybeans						
All Ohio Counties	68,893	1.9	70,392	1.9	74,230	1.9
Basin Ohio Counties	8,190	0.4	16,098	0.8	28,232	1.4
Honey Creek Counties	200	0.1	1,471	0.6	2,558	1.0

Adoption of conservation tillage is expected to increase on the basis of normal growth which will have the form

$$p = \frac{k}{1 + e^{-(a + bt)}} \qquad (1)$$

where
p = the percentage adoption at some point in time
k = the ultimate percentage adoption
a = a constant
b = a constant
t = time from beginning of program.

The constants a and b are determined for a variety of programs for which p has been measured over a period of time and for which k has been estimated. In order to estimate a and b in a linear regression, equation (1) is first expressed in linear form:

$$a + bt = -\ln\left(\frac{k}{p} - 1\right) \qquad (2)$$

The constants a and b are estimated by linear regression of the data presented in Tables 5.12 and 5.13 and are then substituted back into equation (1). Equation (1) is then solved over time to compute the projected percentage adoption of conservation tillage at any time in the future.

The data in Tables 5.12 and 5.13 which represent the current adoption of conservation tillage in the Lake Erie Basin counties of Ohio was used to estimate rate of adoption for the entire Lake Erie Basin under the Existing Program. The end points, k in equation (1) are 44 percent for reduced tillage and 15 percent for no-tillage. For the Accelerated Program, the rates of adoption experienced in the Honey Creek Watershed Management Study counties, were used to project increases in adoption for the entire Lake Erie Basin. The end points, k, are 46 percent and 30 percent for reduced and no-tillage, respectively. Figures 5.1 and 5.2 are the projected adoption rate curves.

For no-tillage, the ultimate adoption rates are reached under either program well before the end of the 20 years. However, under the Accelerated Program adoption of no-tillage achieves double the rate of the Existing Program in half the time. This observation indicates that the ultimate adoption rates for no-tillage under both programs may be low. If the cost of fuel increases dramatically over the next 20 years, the adoption of no-tillage may far exceed the estimates. If this happens, it will be especially important that a high level of technical assistance be available to farmers learning how to use this new conservation cropping management system.

In order to translate these adoption rate curves into reductions in soil loss which will take place over the next 20 years, it is necessary to compute the soil loss reduction which will be realized in each year by the incremental adoption of conservation tillage. This is done by computing a potential

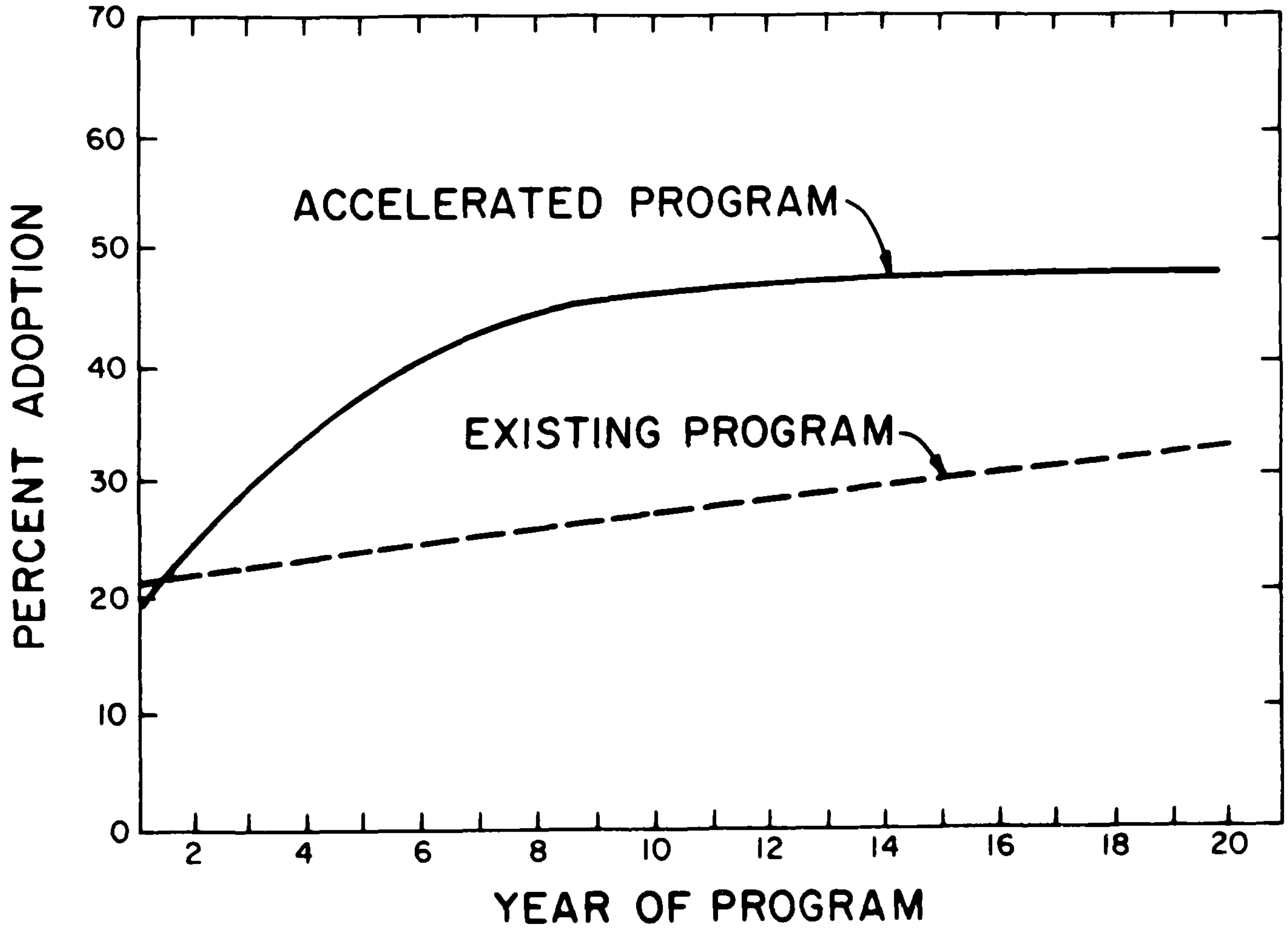


Figure 5.1 Projected Rate of Adoption of Reduced Tillage Production Practices in the Lake Erie Basin

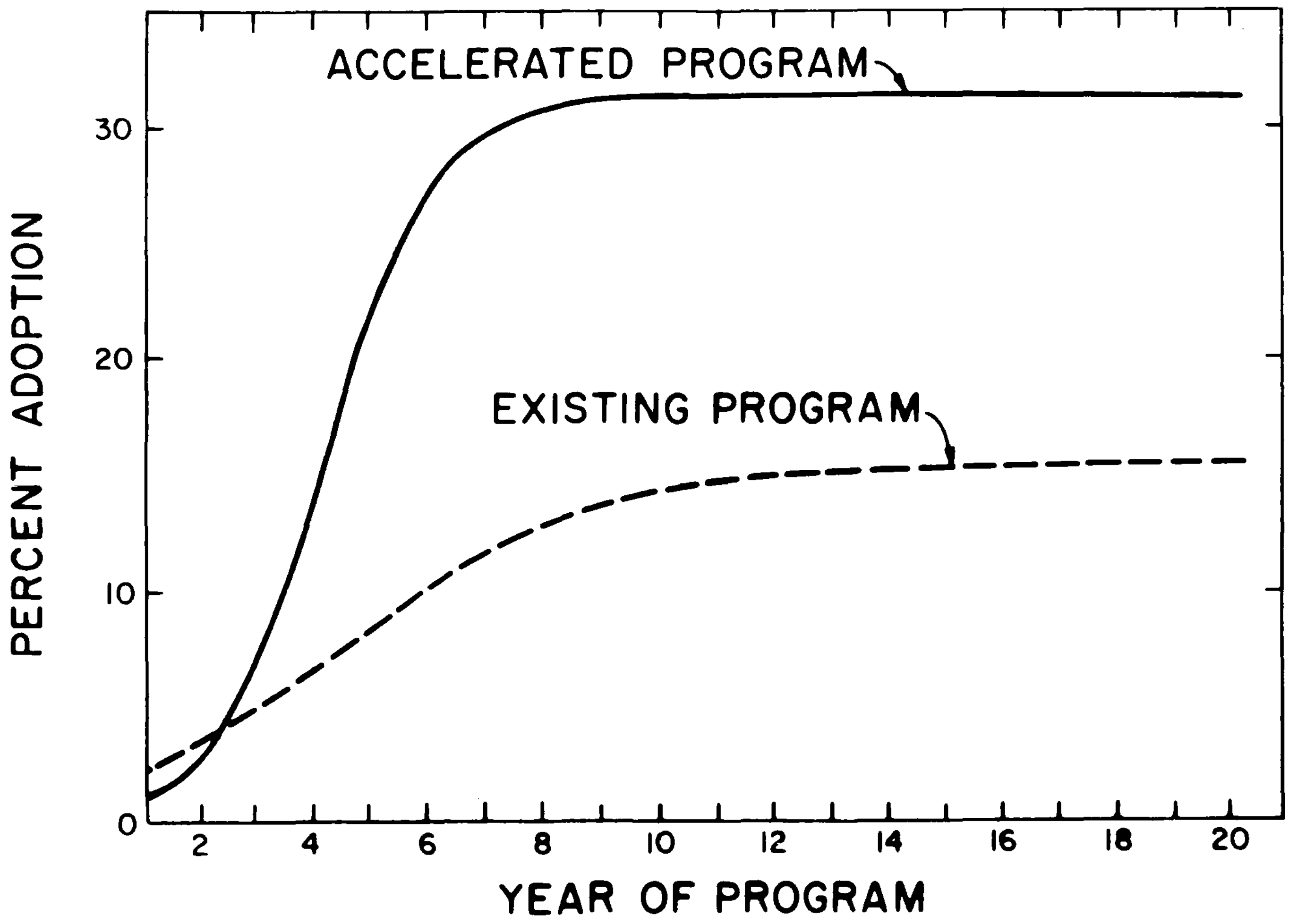


Figure 5.2 Projected Rate of Adoption of No-Tillage Production Practices in the Lake Erie Basin

ɔss erosion rate for land in reduced tillage, no-tillage and conventional ɔpping management patterns; area weighting each rate by the amount of land timated for each system in a given year; and finally computing a total soil ss for the basin in each year. The results of this computation are plotted Figure 5.3 for both the Existing and Accelerated Programs. The celerated Program will achieve a soil loss reduction of approximately 51 rcent within 12 years while the existing rates of adoption of conservation llage will achieve a reduction of only 25 percent within 20 years.

3 REDUCTIONS IN PHOSPHORUS TRANSPORT THROUGH AN EROSION CONTROL PROGRAM

The previous section has provided estimates of the total sediment ero- ɔn reductions which may be realized by applying various soil conservation nagement practices to agricultural land. It is necessary to estimate the ount of phosphorus associated with these sediments which reaches Lake Erie, d the potential of the various chemical forms of phosphorus to impact on gal growth and water quality of Lake Erie.

5.3.1 Relationships Between Erosion Control and Phosphorus Transport ductions

Table 5.4, given previously, gives percentage estimates of erosion ductions which may be realized by application of best management practices. rresponding reductions in phosphorus transport associated with the soil uld not be as great. This is because sheet and rill erosion as experienced the Lake Erie Basin preferentially remove finer grained sediments (i.e., ay and silt) which are more enriched in phosphorus. Thus the land derived diments transported by the stream are likely to contain higher phosphorus ncentrations than the soil from the eroded watersheds.

Research has shown that reduced tillage land management practices cause further increase in the proportion of clay sized particles carried by noff and an accompanying increase in the phosphorus sediment ratio (Ref 8). Even though these studies indicate that it is possible for the ratio phosphorus to sediment in runoff to increase by use of reduced tillage actices, significant reductions in phosphorus transport would still be hievable. The "relative effectiveness" of management practices in reducing osphorus relative to soil loss expresses the efficiency of conservation llage in reducing phosphorus transport.

Data available at the time the Phase II LEWMS Report was completed indi- ted that application of best management practice technology would be from percent to 90 percent effective in reducing phosphorus transport relative reduction of potential gross erosion. More recent data compiled by Logan d Adams (Ref. 9) and shown in Figure 5-4 indicates that the ratio of reduc- on in total particulate phosphorus to reduction in soil loss is in the der of 89 percent. This ratio will be used in this LEWMS final report for re accurate calculations of particulate phosphorus loss reductions.

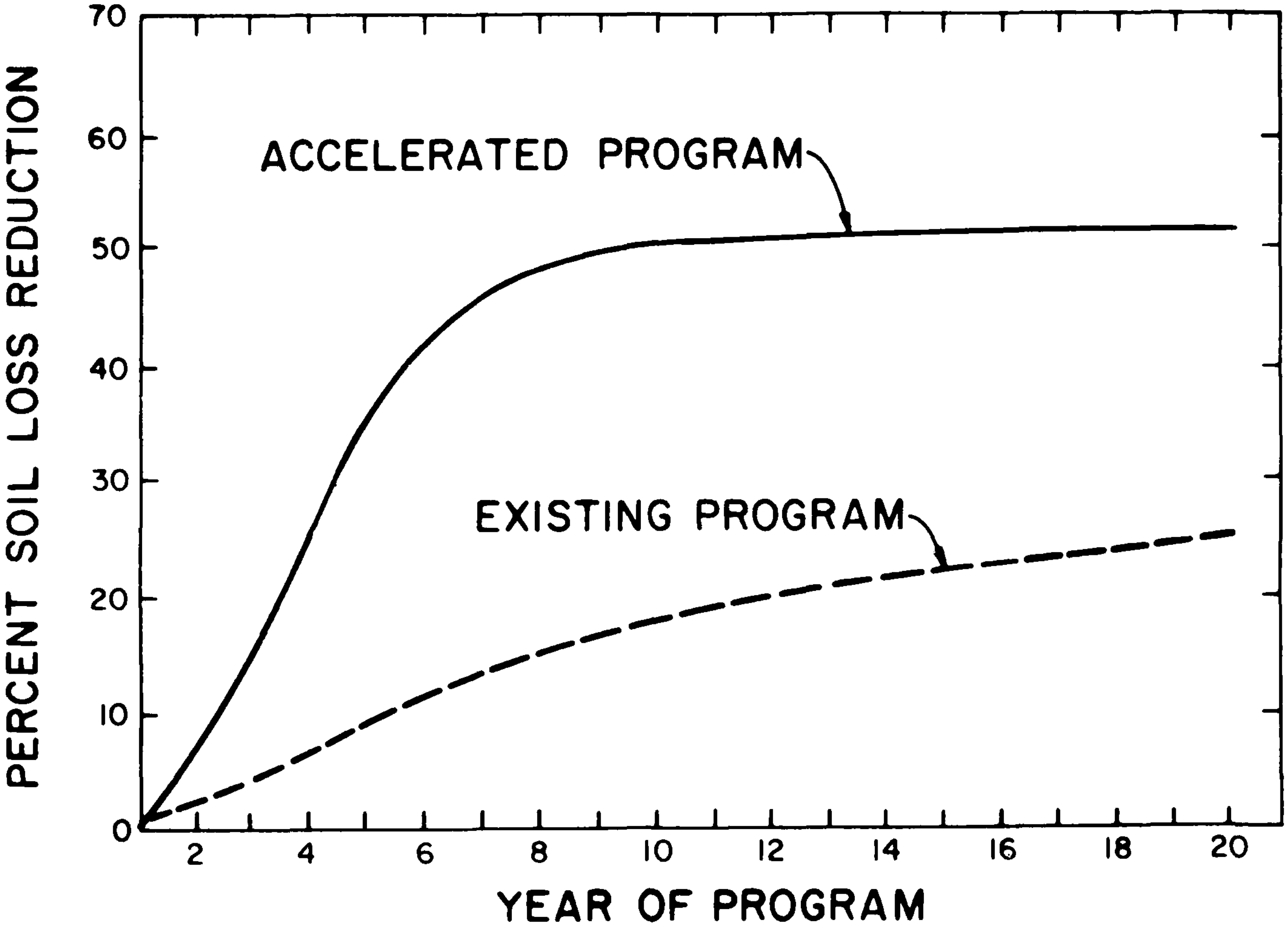


Figure 5.3 Soil Loss Reductions Achievable Under Existing and Accelerated Conservation Tillage Programs

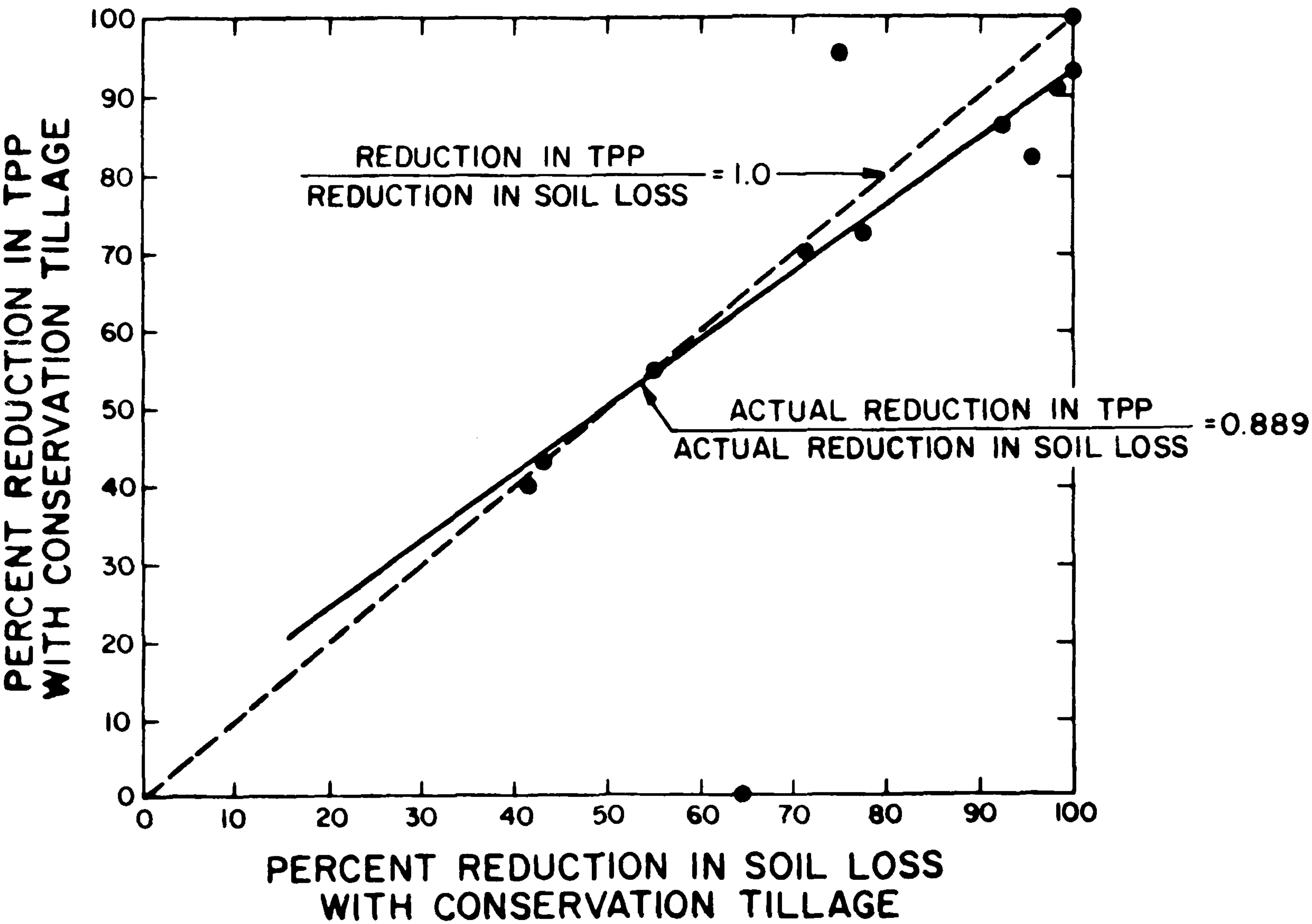


Figure 5-4 Reduction in Total Particulate Phosphorus (TPP) with Conservation Tillage as a Function of Soil Loss Reduction

5.3.1.1 Effect of Conservation Tillage On Reduction of Soluble Inorganic Phosphorus - Data gathered by Logan and Adams (Ref. 9) showed that reductions in sediment particulate phosphorus losses using no-till often result in slightly increased losses of soluble phosphate. There are several reasons for this effect. In a fertilized soil where the phosphate added has not reacted completely with the soil minerals, there are significant amounts of soluble P held in soil pores, precipitated as soluble compounds or adsorbed on soil surfaces. During runoff some of this soluble P is removed and comes to equilibrium (or near equilibrium) with the sediment in the runoff. When no till is used, the amount of sediment in the runoff decreases dramatically but the runoff volume is little changed. Therefore, the amount of soluble P initially removed during runoff is similar to that with conventional tillage. However, there is less sediment in the no-till runoff to buffer the soluble P load and it, therefore,increases relative to conventional tillage. Another reason for higher soluble P levels with no till is the buildup of fertilizer P on the surface of no-till soils (discussed in the next section) and the leaching of soluble P from decaying plant residues.

While no-till can be expected to greatly decrease soil loss on land previously tilled, the main effect on phosphorus loads will be to significantly decrease the particulate P with no change or slight increase in soluble P. If this is true, then other management options for controlling soluble P must be considered including fertilizer use.

5.3.2 Fertility Management.

When fertilizer P is added to soil, it is generally 100 percent orthophosphate, 100 percent available. It reacts immediately with the small volume of soil that it contacts, and much of it is rendered insoluble and unavailable. Long-term soil fertility research has shown that only about 10-20 percent of fertilizer P remains available after addition. The unavailable forms include highly insoluble precipitates of P with soil cations such as Fe, Al, Mg, Ca, and others, and P which has sorbed and diffused into soil mineral surfaces. The available forms include soluble P in soil pores and labile P sorbed onto soil surfaces. The chemistry and mineralogy of a particular soil will determine the extent to which fertilizer P is converted to available and unavailable forms, and the distribution of P between these forms will affect the amounts of particulate and soluble phosphorus in runoff. But for a particular soil, any increase in P fertilizer over and above the needs of the crop will increase the levels of available P in the soil, and the levels of soluble P as well.

Since P fertilization in excess of crop removal rates will increase the total P level in the surface soil, it should also increase TPP losses in runoff if erosion remains the same. More important, however, is the effect of P fertilization on the loss of "available" particulate phosphorus. In the studies reported here, "available" means available to crops and is determined by a standard chemical extraction such as Bray P1 (Ref. 10). However, it also reflects the pool of particulate phosphorus that would be available to algae. Studies have shown that while TPP in runoff increased with fertilization, the increase in available sediment P loss was proportionately much greater and can be explained by the higher available P levels of the clay fraction of the soils, the fraction that is selectively transported during runoff (Ref. 11 and 12).

5.3.2.1 Effect of Fertilizing No-Till Soils On Soluble P Losses - No till soils are commonly fertilized by broadcasting on the soil surface, or as a starter application with the planter if available P levels are high enough. Since the soil is not disturbed and since soluble fertilizer P reacts rapidly with the small volume of soil it contacts, P broadcast on the surface of no-till soils will accumulate there. Agronomic studies (Ref. 7, 13) have demonstrated that under the no-till condition although there were large reductions in soil and total phosphorus losses, runoff of soluble phosphorus was greater than from conventional tilled plots. Further research (Ref. 13) has shown that fertilizer P placement on the soil surface either above or below the crop residue gave much higher soluble P losses than non-fertilized plots, or plots where the fertilizer was injected below the soil surface. It may be concluded that surface-applied fertilizer P builds up high levels of available P at the soil surface and part of this is desorbed during runoff as soluble P.

5.3.2.2 Phosphorus Levels and Fertilization Practices for Lake Erie Drainage Basin Soils - In light of the fertilizer phosphorus behavior as discussed in the previous section, it is of interest to examine phosphorus fertilization practices for Lake Erie Basin soils and resultant phosphorus forms and levels. Logan (Ref. 14) investigated levels of available-P in agricultural soils of the basin, described phosphorus fertilization practices, and related these practices to best management practices for reducing phosphorus losses, particularly bioavailable forms of phosphorus. This data was updated in a later report (Ref 15).

Extensive total phosphorus and available phosphorus (Bray P1 method) measurements were made on representative agricultural soils in Defiance County, OH. The overall mean total phosphorus content of these soils was 700 mg/kg. Levels of P in lacustrine (i.e., glacial lakebed) soil were generally higher than in soils of glacial till origin.

Levels of available phosphorus varied widely with a mean of 23 mg/kg including some inordinately high values over 100 mg/kg. Thus about 3 percent of total phosphorus was available. Since the field measurements of available phosphorus were similar to statewide soil test data from the Ohio State Cooperative Extension Service, it was assumed that statewide data and data from Michigan and Indiana which use the same test procedure (Bray P1) could be used for more extensive data analysis.

Ohio soil test data for 1961, 1971, and 1976 was compared to ascertain trends in levels of available phosphorus in surface soils. Data was separated with the Maumee-Portage-Sandusky drainage basin data comprising one group, and the Eastern Ohio data comprising a second group. This was done because the former basins have high-lime glacial till and lacustrine soils with a large proportion of row crops, while Eastern Ohio has a considerably greater proportion of soils derived from sandstone and shale till, and greater amounts of hay and pasture.

Figure 5.5 gives the mean and standard deviation of Bray P1 soil test levels for Ohio counties in the Maumee-Portage-Sandusky Basin from 1961 to 1980. Levels have increased steadily, and are now well above the sufficiency level of 20 mg/kg ($\sim$40 lbs/acre) for corn and soybeans. The trends for the eastern Ohio counties were identical. Figure 5.6 gives the distribution of soil test values by range for the same data shown previously in Figure 5.5. It clearly shows that the number of soil samples testing in the low ranges have declined since 1961, while samples in the highest ranges have increased. The largest percentage of the samples have fallen in the range of 30-59 lbs/acre in each of the three years.

Similar soil test data were obtained for the Lake Erie Basin counties in Michigan. However, these were only given as percentages of samples testing in different ranges so means could not be calculated. The ranges (Figure 5.7) show the same trend as seen for Ohio counties. The higher ranges reported by Michigan illustrate the number of samples with very high soil test values.

Because of inherently low available phosphorus soil levels and the rapid conversion of applied fertilizer to unavailable forms of phosphorus, Lake Erie Basin States encourage the immediate buildup of available P levels, and annual maintenance applications thereafter based on annual soil tests. The data presented previously suggests that annual phosphorus applications in excess of that required for maintenance of available phosphorus levels sufficient for crop demands is occurring on significant acreage of basin soils. Annual applications of maintenance recommendations without supporting soil test verification may result in over fertilization. As discussed previously, excess fertilizer applications would result in disproportionately higher levels of soluble and bioavailable phosphorus in runoff. Logan and Forster (Ref 15) calculated the reduction in particulate and dissolved phosphorus loads which could be achieved through maximum implementation of a fertility management program. Reductions were 64 and 33 metric tons of nonlabile particulate phosphate under existing conditions and maximum adoption of conservation tillage, respectively, and 16 and 1.6 metric tons of labile particulate P and soluble orthophosphate, respectively. These reductions are low compared to those that can be achieved with conservation tillage alone, but the major impact of a fertility management program will be to slow down the increase in available P levels in Lake Erie Basin soils.

5.3.2.3 Implications for Available Phosphorus Control With No-Till - This study has shown a strong relationship between P fertilization practices and loss of both available particulate phosphorus and also soluble phosphorus in runoff. Therefore, P fertilization management may be required. Management practices which could reduce available P losses with no-till include:

a. Keep available P levels in the soil no higher than is necessary for optimum crop production. This requires an annual soil test to monitor soil fertility levels.

b. When soil test levels are above the sufficiency level, no phosphate fertilizer is required.

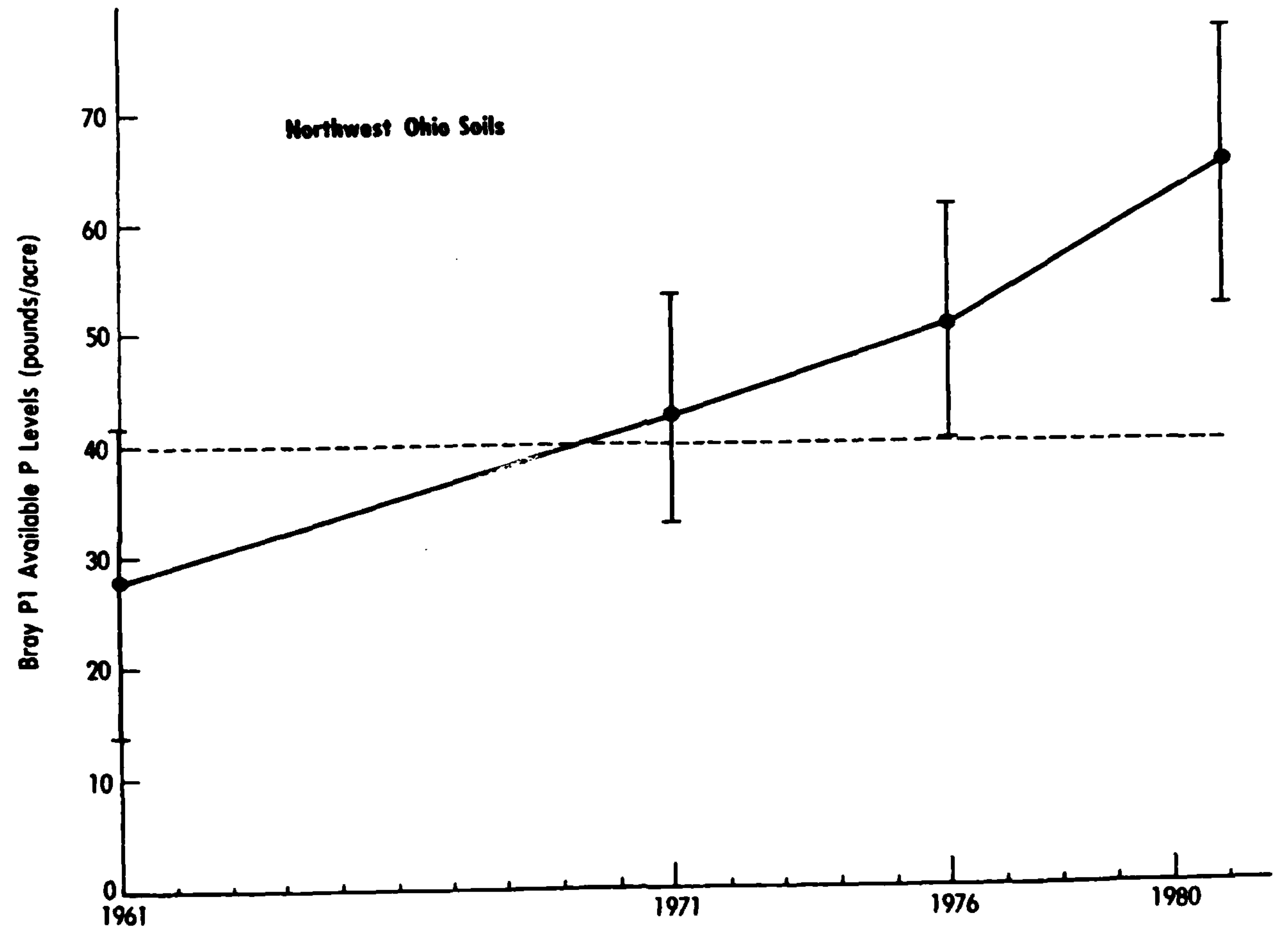


Figure 5.5
Mean Bray P1 available phosphorus soil test levels for agricultural soils in the Maumee-Portage-Sandusky basin counties of Ohio for 1961-1980. The standard deviation of individual county means about the overall mean for each year is also given.

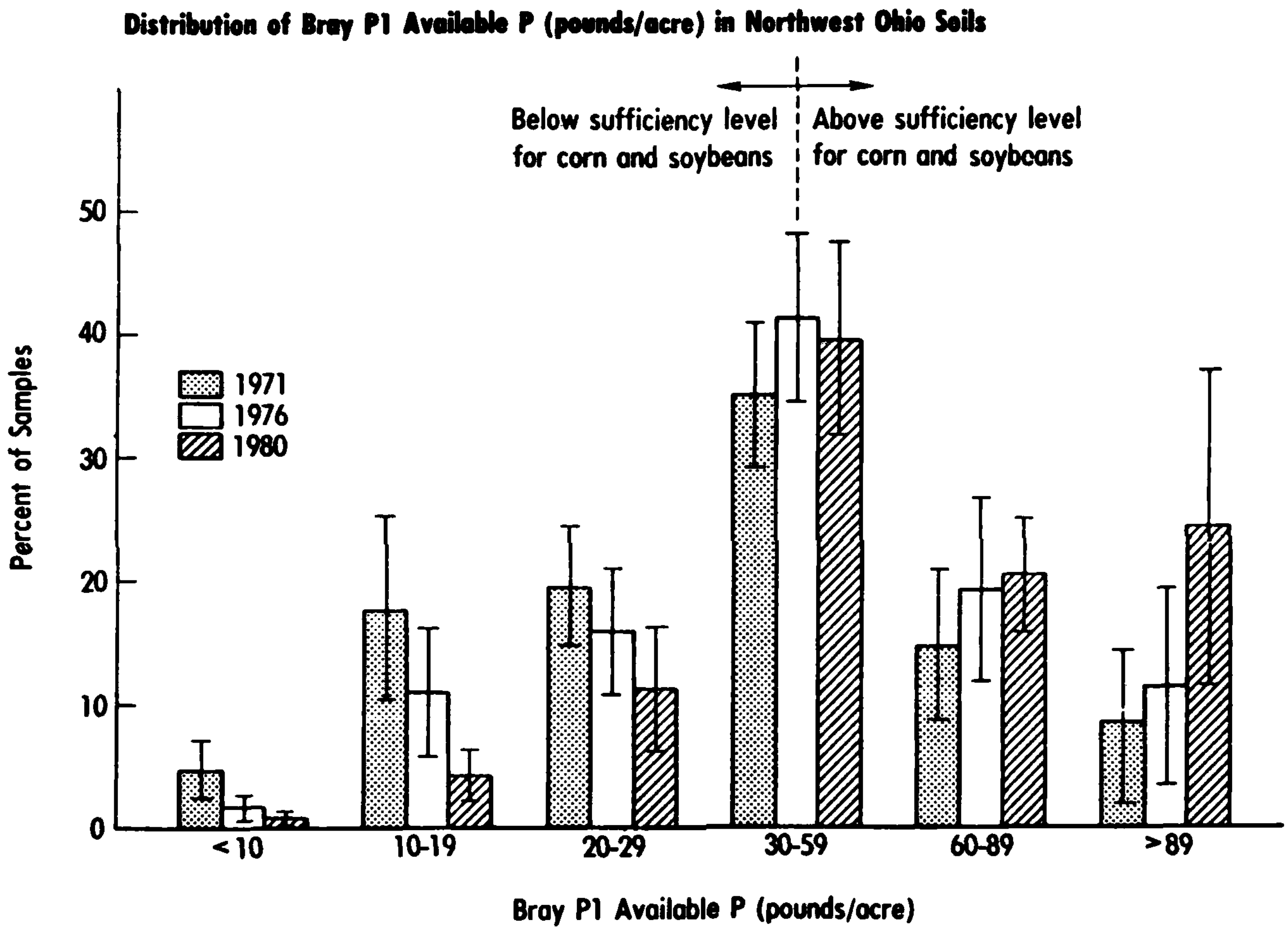


Figure 5.6
Distribution of agricultural soil samples testing at different Bray P1 available phosphorus levels in the Maumee-Portage-Sandusky basin counties of Ohio for 1961-1980. Standard deviation for individual county means about the overall mean are also given.

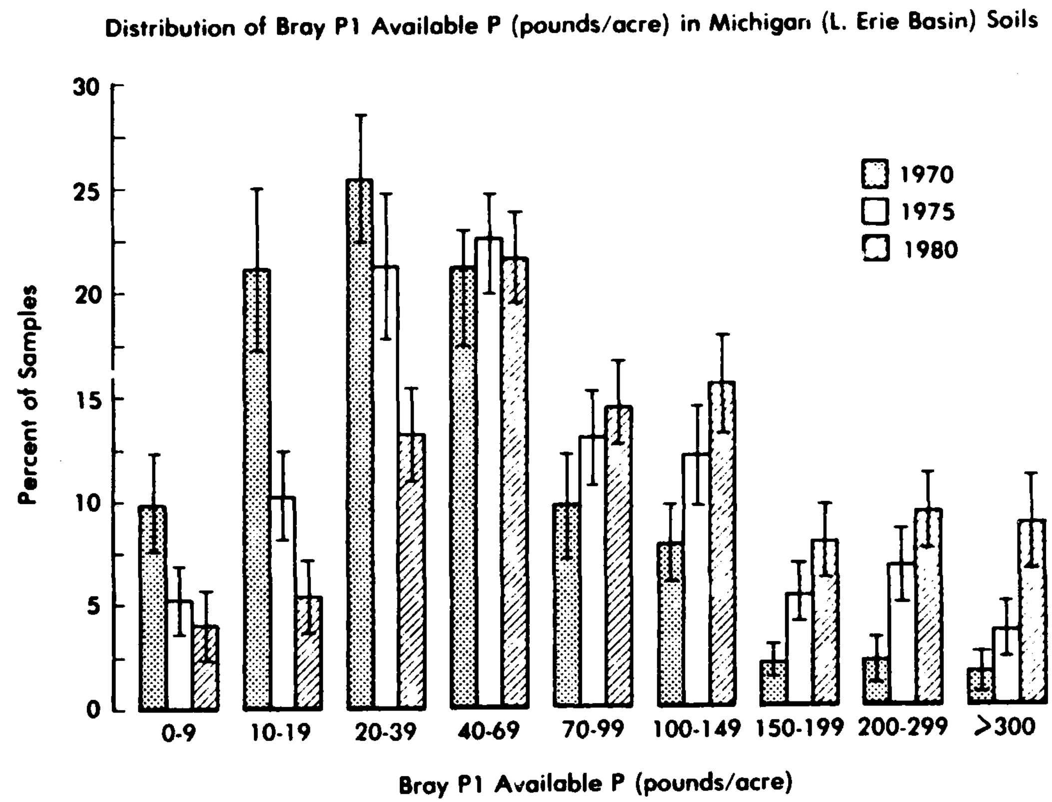


Figure 5.7
Distribution of agricultural soil samples testing at different Bray P1 available phosphorus levels in the Lake Erie basin counties of Michigan for 1970-1980. Standard deviations for individual county means about the overall mean are also given.

c. If soil test levels are below the sufficiency level, two options are possible: build-up the level by broadcasting P and incorporate it in before going to no-till or apply all P in the row at planting.

5.3.3 Achievable Phosphorus Reductions.

Reductions in total phosphorus transport achievable by the continuation of the Existing Program or the Accelerated Program are computed using the annual gross erosion reduction figures shown in Figure 5.3. Reductions are computed for both the United States and Canadian basins as an illustration of the total potential impact of the program.

The achievable reductions will be applied against the mean annual total phosphorus transport figures shown in Table 5.14. These loadings represent the best estimate of mean annual loading calculated from the tributary loadings for the entire base period 1970 to 1980. The reductions are applied only against the rural diffuse particulate phosphorus load. Total urban and rural dissolved phosphorus are unaffected by the program. An estimate of the urban total phosphorus load was made by applying a unit area load of 0.9 kg/ha to all of the urban land in both the United States and Canadian basins. Partition of rural dissolved and particulate phosphorus is made by applying a partition coefficient, measured during the tributary monitoring program earlier in this project. Expressed as the ratio of rural particulate to rural total phosphorus these coefficients are for the Western Basin, 0.81, for the Central Basin, 0.77, and for the Eastern Basin, 0.89.

Table 5.14 - Distribution of Diffuse Sources of Phosphorus to Lake Erie for the Base Record 1970-1980 (metric tons per year)

	Urban (1)	Rural Dissolved(2)	Rural Sediment	Total
Western				
United States	470	658	2,803	3,931
Canada	43	269	1,147	1,459
Central				
United States	361	382	1,281	2,025
Canada	8	94	315	417
Eastern				
United States	31	49	393	473
Canada	26	110	889	1,025
Total				
United States	862	1,089	4,477	6,428
Canada	77	473	2,351	2,900

(1) 0.9 kg/ha for urban land diffuse sources.

(2) Sediment fractions of diffuse sources calculated to be 0.81, 0.77 and 0.89 for the Western, Central and Eastern Basins, respectively based on tributary monitoring for 1976 and 1977.

The annual reduction of particulate phosphorus achievable is then determined by applying the relative effectiveness factor, 0.89, against the percentage reductions in potential gross erosion for each scenario. The resultant phosphorus reduction percentage is then applied against the rural particulate phosphorus load to give the achievable reduction.

A sample calculation illustrates the method: The potential gross erosion reduction for the 10th year in the Existing Program scenario is 17.9 percent (from Figure 5.3). If the computation is made for the U.S. tributaries to the Western Basin, the diffuse source total phosphorus load is 3,931 metric tons per year in the base period, the urban load is 470 metric tons per year and Western Basin particulate phosphorus partition coefficient is 0.81. The rural diffuse source particulate phosphorus load in the base period is:

(3,931 mt/y -470 mt/yr) X 0.81 = 2,803 mt/yr.

Using a relative effectiveness factor of 0.89 the reduction from the base year is:

(0.89 X 0.179 X 2,803 mt/yr) = 447.5 mt/yr.

The results of the computation for annual reduction in transport of rural particulate phosphorus for the United States basin are shown on Figure 5.8.

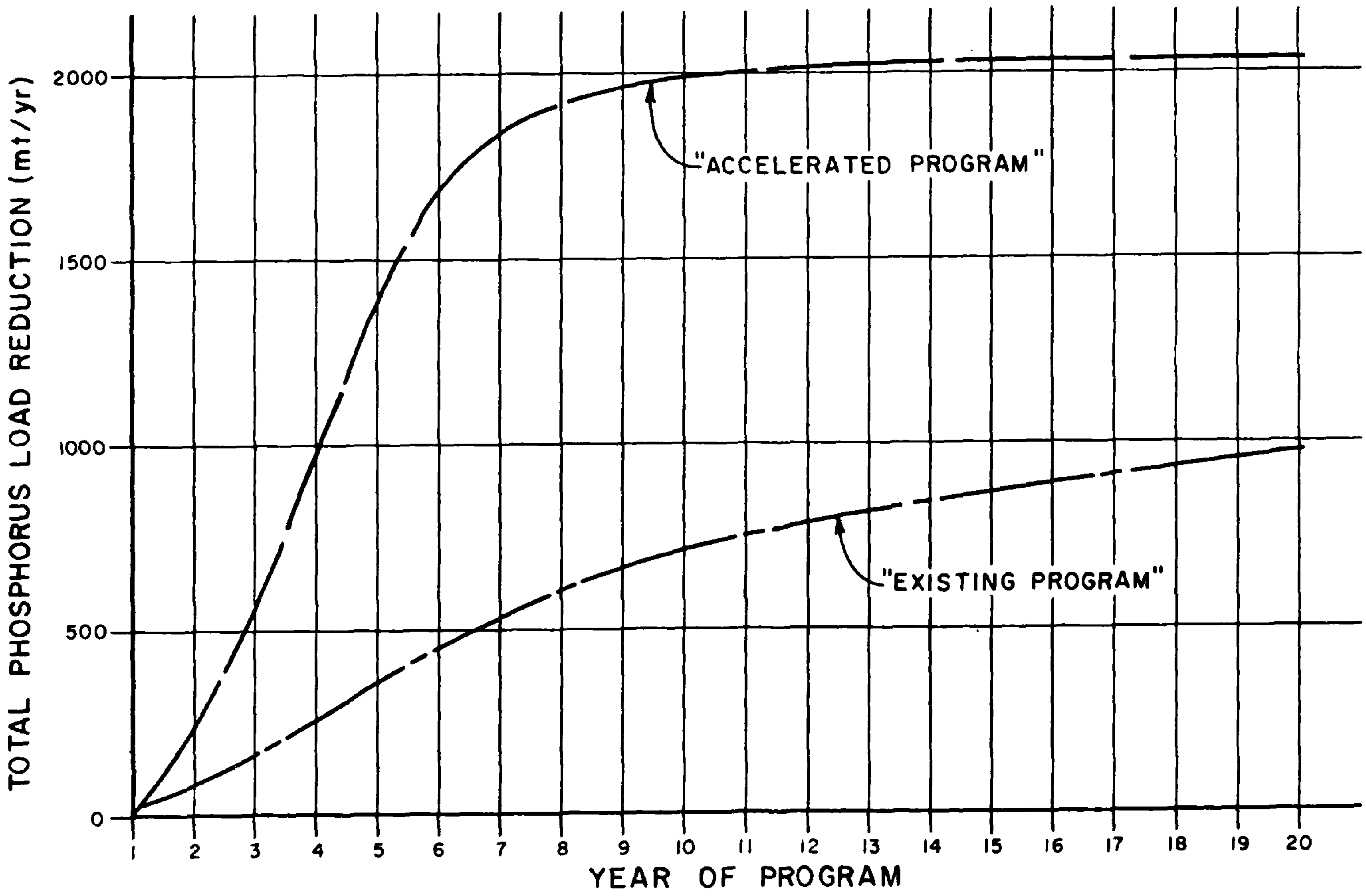
Over the 20-year period the Existing Program saves 12,600 metric tons while the Accelerated Program saves 32,900 metric tons of total phosphorus transport, 20,300 metric tons more than the Existing Program. The average annual reduction for the Existing Program is 630 metric tons per year and 980 metric tons per year by the final year. The Accelerated Program yields an average annual savings of 1,640 metric tons per year and 2,030 metric tons per year after 20 years.

The Existing Program will achieve a 15 percent reduction in the U.S. diffuse source phosphorus load, with the reduction coming fairly steadily over the 20 years. The Accelerated Program produces a reduction of 32 percent with 90 percent of the reduction being achieved within the first 7 years of the program.

5.4 ECONOMIC IMPACTS OF CONSERVATION TILLAGE

Previous sections in this chapter have demonstrated that highly significant reductions in soil and phosphorus losses may be realized by implementation of conservation tillage practices. However, individual farmers cannot provide these overall societal benefits if their net returns are adversely affected. The economic benefits of maintaining future soil productivity are small for individual farmers. Although maintaining soil productivity in the long run may be a proper societal goal and of concern to farmers, it is often a minor economic factor for a farmer choosing between various farming systems; such as between conventional or conservation tillage.

Figure 5.8 UNITED STATES DIFFUSE SOURCE TOTAL PHOSPHORUS LOAD REDUCTIONS UNDER EXISTING AND ACCELERATED CONSERVATION TILLAGE PROGRAMS



5.4.1 Impact on Crop Yields.

One of the most important factors to be considered is the impact of alternative tillage systems on crop yields. Research of various universities indicate that with proper management it is possible to produce yields using conservation tillage on many basin soils which equal or exceed those produced using conventional tillage. Extensive data was gathered from farmers during the LEWMS Program to determine actual on-farm yields from alternative tillage systems. This data was acquired through numerous demonstration plots as well as farmer surveys (Ref 16-17).

5.4.1.1 Results of Basin Demonstration Projects - Demonstration plots under the LEWMS and other programs were established at various locations throughout the basin and monitored for crop yields over the time period generally extending from 1977 to 1980. Soil conditions and management practices were not subject to as strict control as at research sites, but would be expected to reflect the variability which might be expected in the real world conditions of the basin. The areas containing the demonstration plots were the Honey Creek Watershed in Crawford, Huron and Seneca Counties, OH, the Allen SWCD Demonstration Project in Allen County, OH and the Maumee Valley Project in Defiance, Fulton, Henry, Paulding and Williams Counties.

In each program, crop yield comparisons were made (Table 5.15). Since the programs were initiated to demonstrate practices under a variety of farm settings, there was not a valid experimental design to allow statistical inferences from the results.

Descriptive "success rate" statistics have been calculated for the projects, however, indicating the percentage of plot comparisons in which yields from a given tillage practice equaled or exceeded those of plow-based, conventional tillage. In Table 5.15, the first success rate represents absolute success, that is, cases where reduced or no-till yields were actually equal to or greater than plow based yields. Since variation is inevitable in any plot work, a second percentage is given, also, which allows for some error of measurement. "Least significant differences" in replicated plot studies of tillage are often in the ranges of 5-10 bu/A for corn and 2-4 bu/A for soybeans. The upper limits of these ranges were used to determine a second success rate percentage. By incorporating such a criterion, conservation tillage corn yields which were less than plow yields by fewer than 10 bu/A were judged equal to those yields (similarly for soybeans at 4 bu/A less). Such success rates will obviously be higher than absolute rates and the true success rate of a project probably lies somewhere between them.

Generally, reduced tillage yields were about the same as those with conventional tillage. In the Honey Creek program, reduced tillage corn yields were 8 bushels per acre higher than the conventional tillage yields. However, in the Maumee Valley program, reduced tillage yields were slightly lower on soil management Groups 1 and 2. It should be noted that Hoytville and Latty soils are very poorly drained, thus the relatively poor reduced tillage performance on these soils was expected. It was quite unexpected that no till yields would be comparable to conventional tillage on these soils. On other sites, no tillage yields generally were lower than conventional tillage yields.

Table 5.15 Plot Yields for Basin Demonstration Projects

Demonstration Site	Years	Number of Plots	Comparison Yields: Plow	Reduced Till	No Till	Success Rate*: SR_A	SR_E
Honey Creek							
Corn	1980-81	30	124		109	17	47
Corn	1980-81	11	111	119		64	82
Soybeans	1980-81	11	45		47	45	91
Soybeans	1980-81	3	46	44		33	67
Allen Co.							
Corn	1978-80	24	116		111	38	67
Corn	1978-80	9	103	102		56	77
Maumee Valley Group 1&2 Soils							
Corn	1978-80	19	109		97	37	58
Corn	1978-80	17	105	101		53	76
Maumee Valley Hoytville and Latty Soils							
Corn	1978-80	6	106		104	50	66
Corn	1978-80	5	94	86		40	60

* An SR_A is the absolute success rate or proportion of plots where conservation tillage yields equalled or exceeded conventional tillage yields. SR_E is the success rate with error or proportion of plots where conservation tillage yields were greater than conventional tillage yields, or less than conventional tillage yields, by fewer than 10 bu/acre for corn and 4 bu/acre for soybeans.

5.4.1.2 Survey Study Results - Hemmer and Forster (Ref 16) conducted a survey of 96 farmers covering 10 counties in the Western Lake Erie Basin. The average corn yields by tillage systems were as follows:

	bu/ac
Conventional Plow	121.9
Chisel Plow	121.2
Minimum till	124.4
No-till	120.8

With conventional tillage, fall or spring, moldboard plowing is followed by secondary tillage. With chisel plowing, fall or spring, chisel wing is followed by secondary tillage. Minimum till implies that only :ondary tillage operations are performed. Neither plowing nor secondary .lage operations are performed with no till.

There was a 2.5 bushel per acre difference between minimum and conven- nal tillage yields and slight differences between chisel plow, no-till and ventional tillage yields. However, none of these yield differences were tistically significant. As with the demonstration plot studies pre- usly discussed, conventional plow yields from this survey exceeded no-till n yields, although the difference (1.1 bu/a) is insignificant.

It may be concluded that corn and soybean yields using reduced tillage minimum tillage should be comparable to yields using conventional plow .1 practices. Comparable yields were also obtained by using no-till ctices. However attention must be placed on proper field selection e. good drainage) and careful management practices (i.e. fertilizer .ection, proper weed control and use of rotations) to obtain comparable lds with no till.

5.4.2 Impact On Crop Production Costs.

In order to fully evaluate the economic impact of conservation tillage crop production it is necessary to ascertain the costs of crop production, well as effects on crop yields as given in the previous section. In his iew, Forster (Ref 18) concluded that reduced tillage reduces fuel and labor ts while increasing herbicide costs compared to conventional tillage. No- .l has the potential for even greater reductions in fuel, labor and equip- t costs, but generally results in greater herbicide and insecticide costs. ster estimated that equipment costs for reduced tillage are approximately ercent less than for conventional moldboard plow and associated equipment, .le equipment for no-till is approximately 10 percent less. As discussed Section 2.7.1 equipment costs to individual farmers can vary widely. cent reductions in labor costs were estimated to be about the same as for ipment. Tables 2.8 and 2.9 presented previously in Section 2.7.1 gave ical time savings and fuel savings (gallons) which could be realized from servation tillage operations.

Detailed records of material and machinery costs were kept for the LEWMS ey Creek demonstration plots (Ref 19). Material costs included seed, lime, tilizer, herbicides, insecticides, and interest on operating capital. hinery costs included custom rates for tillage, planting, harvesting, cking and application of fertilizers, herbicides and insecticides. The raged 3-year (1979-1981) costs are summarized in Table 5.16.

Material and machinery costs varied considerably with tillage system for h corn and soybeans. For corn, material costs were about $16 per acre ater for no-till than for reduced tillage or conventional. In most cases, s added cost was due to recommended use of a contact herbicide plus the of an insecticide (usually Toxaphene) for armyworm control in plots with cover crops. On the other hand, machinery costs for no till were $10 per e less than for reduced tillage and $22 per acre less than for conven- nal.

Table 5.16 - Comparative Costs for Tillage Systems

Tillage System	Costs $/A					
	Material		Machinery		Total	
	Corn	Soybeans	Corn	Soybeans	Corn	Soybeans
No till	197	106	50	42	247	148
Reduced Till	179	94	60	47	239	141
Conventional	183	95	72	60	255	155

These cost differences were a direct function of the type and intensity of tillage performed. For soybeans, material costs were about $11 per acre greater for no till than for reduced tillage or conventional. This added cost was almost always due to the recommended use of a contact herbicide. Machinery costs for no till soybeans were $5 per acre less than for reduced tillage and $18 per acre less than for conventional. Again, differences were a function of degree of tillage. In summary, increased material costs for no-till crops were more than offset by reduced machinery costs when compared to conventional tillage systems. Optimal savings occurred in reduced tillage systems where both material and machinery costs tended to be lower.

5.4.3 Impact on Net Farm Income.

The ultimate indicator of the economic viability of new farming systems is the net return to individual farmers and in the target area (i.e., Lake Erie Basin) as a whole. During the LEWMS program, careful attention has been given to ascertaining, as well as possible, the impact of conservation tillage to the farmer. This effort consisted of determination of net returns for demonstration plots in the Honey Creek program (Ref. 19), development of a predictive model for basin-wide impact (Ref. 18), and farmer surveys (Ref. 16).

5.4.3.1 Predictive Model for Changes in Basin Net Farm Income - A model was developed under the LEWMS program to predict the changes in net farm income in the Lake Erie Basin based on Soil Management Groups (SMG) and their associated yield characteristics along with commodity prices and production costs.

Specific objectives were:

a. To estimate gross return and costs of production for major crops on each soil series in the basin;

b. To determine the effect of conservation tillage technologies on gross returns and cost of production for corn and soybeans;

c. To develop a simulation model which represents the economic impacts of alternative crop management practices in the Lake Erie Basin; and

d. To estimate the economic impacts for the basin of adopting minimum tillage and no-tillage technologies on selected soils.

For the model development, the soil series acreages in the basin were assigned to the LEWMS Soil Management Groups 1-5 as described in Section 5.2.1. Numerous sources, mainly from State agricultural colleges, were used to develop "yield indices" for corn and soybeans on soils in each management group. Yield indices are the expected yields under the conservation tillage systems expressed as a percentage of the yields using conventional plow tillage. Yield indices tables are given in reference 18.

Commodity prices used in the model were projected for 1978-1981 using various sources. Corn and soybean production costs for conventional, reduced and no-tillage systems were estimated separately for each State and are given in Reference 18. Cost items included seed, fertilizer, weed control chemicals, fuel, drying, repairs, labor, and management. Interest on operating capital and depreciation and interest on machinery were also included.

County crop acreage data (USDA) was used to develop the proportions of each county's cropland in corn, soybeans, oats, hay, wheat, tomatoes, and sugar beets. Every crop acre in the county was assumed to grow these proportions of crops. While not completely accurate, this assumption was necessary since data was not available to estimate all crops actually grown in each county.

Output from the model includes: (a) net return per acre by crop, by tillage system, by county, and by soil series; (b) acres in each county by soil management group, (c) net return for each county by "management scenario;" and (d) net return for the Lake Erie Basin by "management scenario."

The primary purpose of the model is to analyze the economic impacts of each of these management scenarios. However, the model is structured to accommodate many other types of analyses. Basic assumptions might be modified to test the sensitivity of results to changes in these assumptions. For example, critical parameters in the model are the response of crop yields to reduced tillage and no tillage.

Model Results - Over 3.76 million hectares (9.3 million acres) in the basin were modeled, including 53 counties. Reference 18 summarizes the net income model outputs under conventional tillage and the percent changes in net income under alternative conservation tillage scenarios for each county. Net income in the basin was calculated as $338.2 million under conventional tillage. With the implementation of reduced and no-tillage technologies on Soil Management Groups, net income in the basin changes as predicted by the model are shown in Table 5.17.

Table 5.17 - Change in Basin Net Income with a Change to Conservation Tillage

Scenario	Change in Basin Net Income (percent)	
Soil Management Group	Reduced Tillage	No Tillage
1	+1.3	+2.2
2	+4.9	+5.9
3	-3.7	-
4	-1.2	-

The economic impacts of conservation tillage systems on Soil Management Groups 1, 2, 3, and 4 are relatively minor. In the case of soils in Management Groups 1 and 2, net income actually improves with the adoption of reduced and no-tillage. With soils in SMG's 3 and 4, net income declines when reduced tillage is implemented.

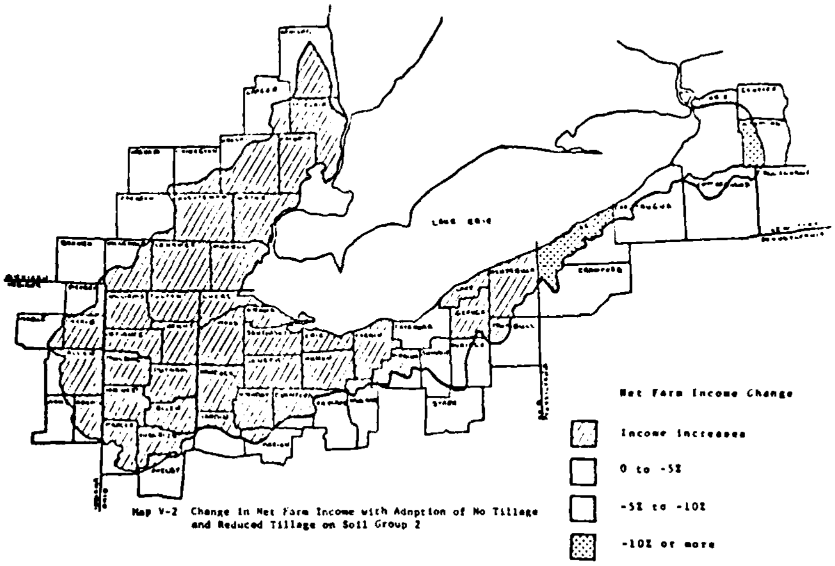
If reduced tillage was adopted on 100 percent of the soils in the four management groups, net income change is predicted to be +1.3 percent by the model. While basin net income actually improves with conservation tillage, the distribution of the income change is crucial. First, the adoption of reduced tillage or no tillage on SMG 1 soils is beneficial to all counties. Adoption of reduced tillage and no tillage on SMG 2 soils does have adverse impacts on eastern counties (Map V-2). Even though the basin's net income is improved dramatically with adoption of conservation tillage technologies on Group 2 soils, some counties' incomes are lowered.

Most counties would experience income loss when reduced tillage is used on Group 3 soils (Map V-3). Western counties not facing an income loss are those without Group 3 soils.

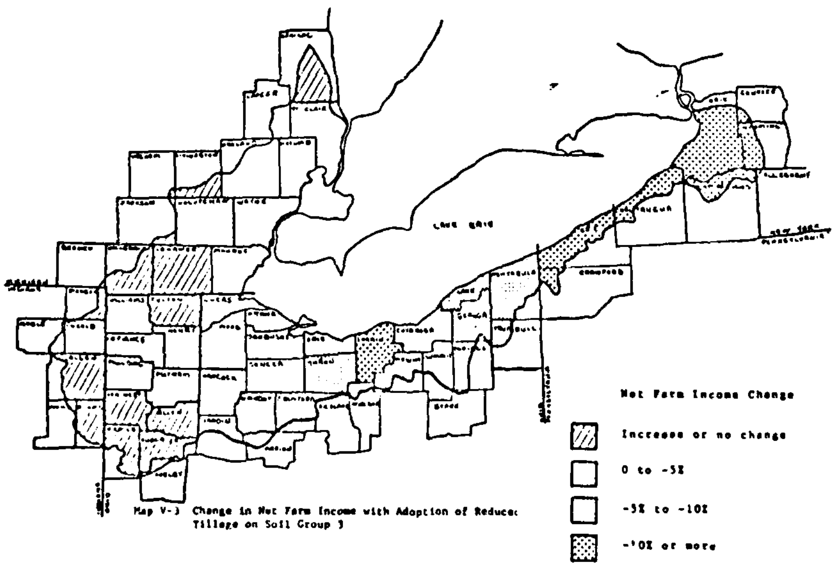
Finally, using reduced tillage on Group 4 soils would affect counties in the western part of the basin (Map V-4). Eastern counties would be relatively unaffected due to the absence of Group 4 soils.

A critical assumption made in the model is the response of corn and soybean yields to reduced and no-tillage. Yield indices are used which are based on research plots. These indices could be criticized as being biased in favor of conservation tillage systems. Conservation tillage may take a high level of management which exists on university experimental plots, but which does not exist on the average farm.

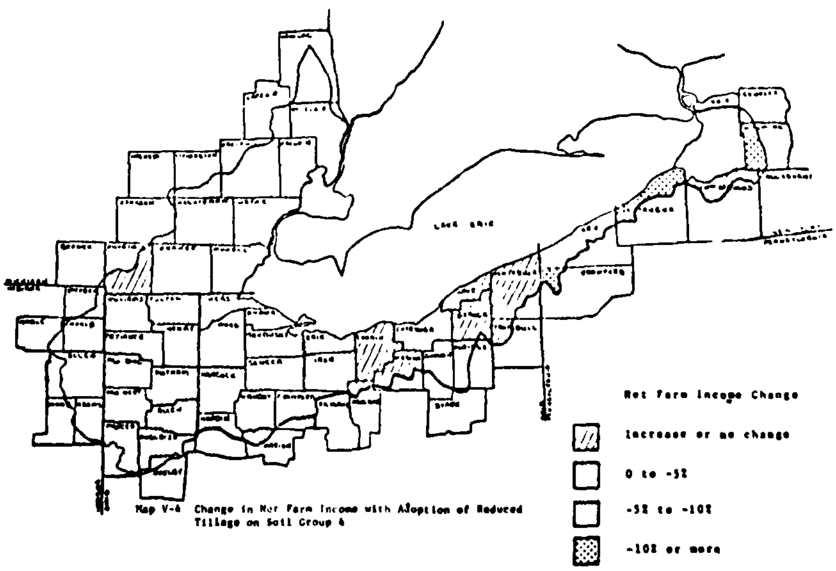
To test the sensitivity of model results, yield indices are constrained to a maximum of 100. That is, no yield advantage is allowed for conservation tillage systems even though research results clearly show yield advantages for conservation tillage systems on some soils. Results are shown in Table 5.18.



Map V-2 Change in Net Farm Income with Adoption of No Tillage and Reduced Tillage on Soil Group 2



Map V-3 Change in Net Farm Income with Adoption of Reduced Tillage on Soil Group 3



Map V-4 Change in Net Farm Income with Adoption of Reduced Tillage on Soil Group 4

Table 5.18 - Change in Basin Net Income with Yield Indices at 100 Percent

Scenario	Change in Basin Net Income (percent)	
Soil Management Group	Reduced Tillage	No Tillage
1	+1.3	+2.3
2	+2.5	4.4
3	-3.7	
4	-1.2	

If reduced tillage would be adopted on all soils in Groups 1, 2, 3, and 4, net income under these assumptions would decrease by -1.1 percent. This contrasts with an increase in net income of 1.3 percent under expected yield responses.

Results of the model studies indicated that conservation tillage systems have an impact on yields, costs of production, and net income. However, net incomes for the Lake Erie Basin change only slightly with the advent of these systems. It is estimated that overall net incomes would increase 0 to 3 percent if conservation tillage technologies were used on Soil Management Groups 1, 2, 3, and 4.

Not every soil series is suitable economically for conservation tillage. If reduced tillage is used only on Group 3 soils, basin net income declines by about 4 percent. If reduced tillage is used only on SMG 4 soils, basin net income declines by about 1 percent. Conservation tillage on SMG 5 is excluded from the analysis since it is thought to have severe negative income effects.

Group 1 soils are suitable for reduced and no tillage technologies throughout all the basin. Yields remain the same or improve, and costs are reduced when conservation tillage is used on SMG 1 soils. Almost all SMG 2 soils produced improved profits with conservation tillage. The exception is in the northeastern regions where yields may be adversely affected on SMG 2 soils.

5.4.3.2 Honey Creek Economic Evaluation - The Honey Creek Demonstration Project provides another comparison of net returns from alternative tillage systems. Over the 3-year period of the project, net returns for corn plots were highest under conventional tillage (Table 5.19). Production costs were lower with reduced than with conventional tillage, but yields also were lower. No tillage returned the least on these corn plots and had the lowest yields. For soybeans the highest net returns were achieved by the no tillage plots. Like the corn plots, soybean plots with reduced tillage had the least production costs; however, yields from the reduced tillage plots were low (Table 5.20).

Care should be taken in interpreting these results. The demonstration plots were established to demonstrate tillage technologies to farmers and the agricultural community. They were not research plots, and they lacked sufficient controls in their design to allow inferences from these results. The highest net returns (i.e.conventionally tilled corn, and no till soybeans) may be due to many factors besides tillage. For example, the inherent productivity of the soil could have been highest on the conventionally tilled corn and the no tillage soybean plots, or planting dates might have favored a particular system. The plots were not designed to prevent these biases, and the small number of observations magnifies the impact of these biases.

Table 5.19 - Mean Gross Returns, Production Costs and Net Return of Land for Corn, by Tillage Systems, Honey Creek Demonstration Plots, 1979-81

	Conventional Tillage	Reduced Tillage	No Tillage
Gross Return ($/Acre)	312	277	271
Production Costs [a] ($ Acre)	255	239	247
Net Return to Land ($/Acre)	57	38	24
Number of Plots	27	28	71

[a] Excludes land costs.

Table 5.20 - Mean Gross Return, Production Costs, and Net Return of Land for Soybeans, by Tillage System, Honey Creek Demonstration Plots, 1978-81

	Conventional Tillage	Reduced Tillage	No Tillage
Gross Return ($/Acre)	306	268	318
Production Costs [a] ($ Acre)	155	141	148
Net Return to Land ($/Acre)	151	127	170
Number of Plots	12	6	18

[a] Excludes land costs.

5.4.3.3 Survey Study Results - Hemmer and Forster (Ref. 16) conducted a comprehensive survey of farmers using conventional conservation tillage systems for corn production in the Western Basin of Lake Erie over the period 1978-1980. A total of 96 farmers participated in the 3-year study.

On nearly every farm in the sample, more than one tillage system was being used. Various systems were being tried because of the farmer's interest in comparing for themselves the results of several systems. The use of multiple observations from one farm operation has advantages in that it removes some of the differences due to many unidentified factors. For example, management practices such as plant population, seed variety, harvesting technology, and time of harvest may strongly affect the results of a comparison of tillage practices. These factors, however, tend to be constant among the multiple tillage systems used on a particular farm.

Because a farmer's investment in field equipment is difficult to obtain and compare with investment data from other farmers, standard custom rates for field operations were used. These standard custom rates included cash operating costs (fuel, oil, repairs, and maintenance) as well as labor costs and fixed cost (depreciation, interest and insurance). In order to calculate the cost of the fertilizer and pesticide inputs, the amount and analysis of each fertilizer and pesticide were obtained for all observations. Standard fertilizer and pesticide prices were then used to compute the input cost for each observation.

Drying costs were calculated on the basis of reducing the reported moisture to 15.5 percent. Interest on operating capital was determined by taking the sum of variable input costs (seed, fertilizer, herbicide, and insecticide) at the average rate of interest for that crop year over a 7-month growing season. Corn prices, based on the average prices paid to farmers for each crop year, were used with the farmer's actual yields in computing returns.

Net return was computed for each tillage observation by subtracting the costs of field operations, fertilizer, seed, pesticides, drying, and interest from gross returns. Land and management charges were omitted; thus, calculated net return was to land and management. The analysis was constructed in such a way as to remove variations due to the differences in inherent soil productivities. Results are summarized in Table 5.21.

Net returns per acre and yields were nearly the same for all tillage systems. The results showed slightly higher net returns for chisel plow and no-till than conventional tillage, but these differences were not significant. Net return with minimum tillage was significantly higher than that of conventional tillage. There was a 2.5 bushel per acre difference between minimum and conventional tillage yields and slight differences between chisel plow, no till, and conventional tillage yields. However, none of these yield differences were statistically significant.

It is hypothesized that using reduced tillage systems on selected soils in the Lake Erie Basin does not adversely affect producers' net returns and, at the same time, substantially reduces soil loss and improves water quality in Lake Erie. The soils that are thought to be best suited for reduced tillage systems are soil series in Soil Management Groups 1, 2, and 4 of the classification identified by Triplett, et al. (Ref. 2) and used in the LEWMS program.

Table 5.21 - Net Return and Yield by Tillage System for a Sample of Western Lake Erie Basin Farmers, 1978-1980

Tillage System (1)	Number of Observations	Net Return to Land and Management	Corn Yield
		($/Acre)	(bu./acre)
Conventional	111	141.75	121.9
Chisel Plow	63	159.96	121.2
Minimum Till	74	156.96 (2)	124.4
No-Till	168	142.22	120.8

(1) With conventional tillage, fall or spring, moldboard plowing is followed by secondary tillage. With chisel plowing, fall or spring, chisel plowing is followed by secondary tillage. Minimum till includes only secondary tillage operations. Neither plowing nor secondary tillage operations are performed with no-till.

(2) The difference between minimum till and conventional till net return is statistically significant at the 0.01 level.

The results of this analysis support the contention that reduced tillage technologies could be utilized as an economical method of reducing gross erosion from a majority of the basin's cropland. For the 3-year period, net returns under minimum tillage were shown to be significantly higher than those of conventional tillage. Returns from chisel plow tillage and no tillage were not statistically different from those of conventional tillage.

5.4.3.4 Comparison of Economic Studies - The model projections of impacts on net incomes discussed in Section 5.4.3.1, and the field survey results discussed in the previous section were in good agreement regarding the impact of conservation tillage on net returns to the farmer. However, the Honey Creek demonstration project results were not consistent with the model and survey study, especially with respect to net returns on corn. Although average yields of corn, using reduced tillage and no-till approached yields from conventional plow (97 and 95 percent of conventional, respectively), net returns using conservation tillage were substantially less. On the other hand, average net returns from no-till soybeans exceeded those of conventional soybeans.

Observations made during Honey Creek field trials explains some of the problems. During the project growing season, rainfall was above average in each of the 3 years: 1979 - +6.0 inches; 1980 - +1.8 inches; 1981 - +9.3 inches. As a result, some of the more poorly drained fields of corn exhibited a predictable adverse response to conservation tillage which may have been avoided by drainage improvements. This problem was accentuated on plots having previous cover crops. The problem of nitrogen losses from high surface residue plots when urea forms of nitrogen were used, has been mentioned previously. Drainage of wet fields, selection of drier fields for no-till corn, and management of residues to minimize excesses are steps that would lead to consistently improved no-till corn yields in the future.

Soybeans which are generally planted later in the growing season than corn are not as subject to problems associated with soil drainage. In addition, since soybeans are legumes, nitrogen would not be limiting.

Considering the overall results of the various investigations under the LEWMS program in addition to the established research findings of State agricultural colleges, it is concluded that the wide-spread adoption of conservation tillage should not result in reduced net income to farmers within the Lake Erie Basin. Farmers would need to carefully match tillage practices with the soil and drainage characteristics of individual fields, and employ management practices (rotations, fertilizers, seed placement, herbicides, etc.) which assure acceptable crop yields.

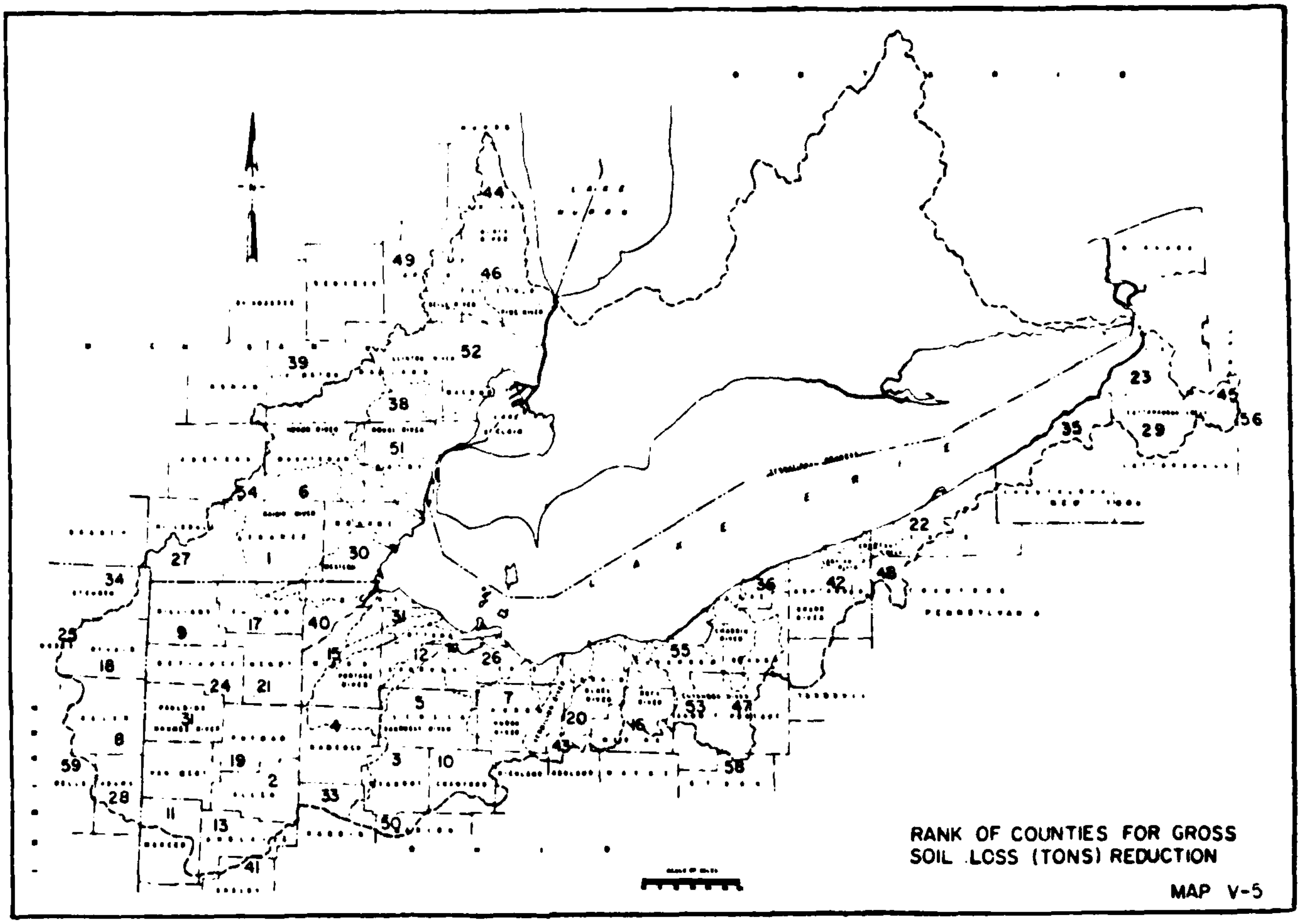
5.5 SELECTION OF PRIORITY AREAS FOR IMPLEMENTATION OF CONSERVATION TILLAGE PROGRAMS

The Accelerated Conservation Tillage Program will achieve the greatest return if target counties for implementation are chosen to maximize both the land area which can be covered in those counties and the soil loss reduction which can be achieved. Further benefit will be realized if the selection of the counties includes consideration of the amount of phosphorus transported from the counties. An earlier report (Ref. 20) ranked counties on the basis of soil loss and on the economic advantages of conservation tillage. In the ranking scheme used here, economics are not a direct consideration. Of course, conservation tillage is still considered to be implementable only if there is an economic advantage to crop production.

The ranking scheme has been developed as follows: the first factor to be considered is the gross reduction in soil loss which can be achieved in a county through implementation of the program. Counties are ranked from 1 through 59 for the gross difference in tons of soil loss between the base year condition and the estimated soil loss at the end of the 20-year program. The county with the greatest reduction receives a rank of 1, the county with the least, a 59. This element of the ranking insures that counties with high gross erosion rates which are amenable to control through conservation tillage receive high consideration.

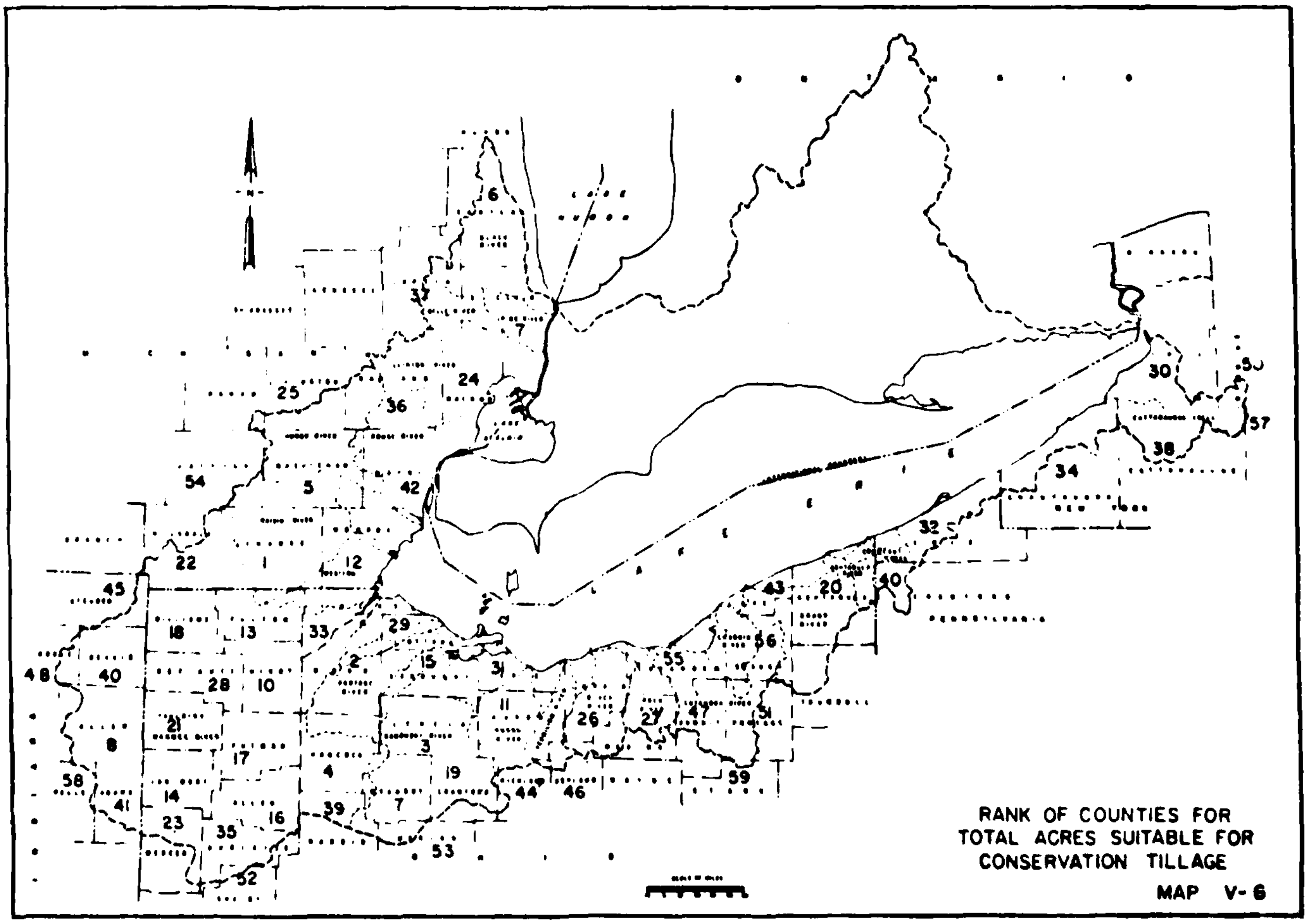
Map V-5 presents the results of ranking the counties for gross soil loss reduction. The number given within each county represents its ranking with No. 1, Lenawee County, MI, having the greatest potential for reduction. Many of the counties with large number rankings (39, Wells, IN; 54, Jackson, MI; 58 Stark, OH; 56, Alleghany, NY) are so rated because such small portions of their areas lie within the Lake Erie drainage, and not because these counties as a whole do not have a potential for soil loss reduction.

The second element of the ranking scheme measures the absolute amount of land in a county which is amenable to conservation tillage. Counties with especially large acreages of Soil Management Group 1, 2, and 4 are weighted heavily whether or not high erosion rates are occurring. This element was



RANK OF COUNTIES FOR GROSS SOIL LOSS (TONS) REDUCTION

MAP V-5



RANK OF COUNTIES FOR TOTAL ACRES SUITABLE FOR CONSERVATION TILLAGE

MAP V-6

felt to be important, because high erosion rates are not the only factor in the transport of phosphorus. In fact, sediment and phosphorus delivery was found to be independent of gross erosion as discussed in Chapter 3. Phosphorus yield is thought to be determined by the amount of surface cover. Also, those counties with high proportions of soils suitable for conservation tillage will have the greatest likelihood for successful programs.

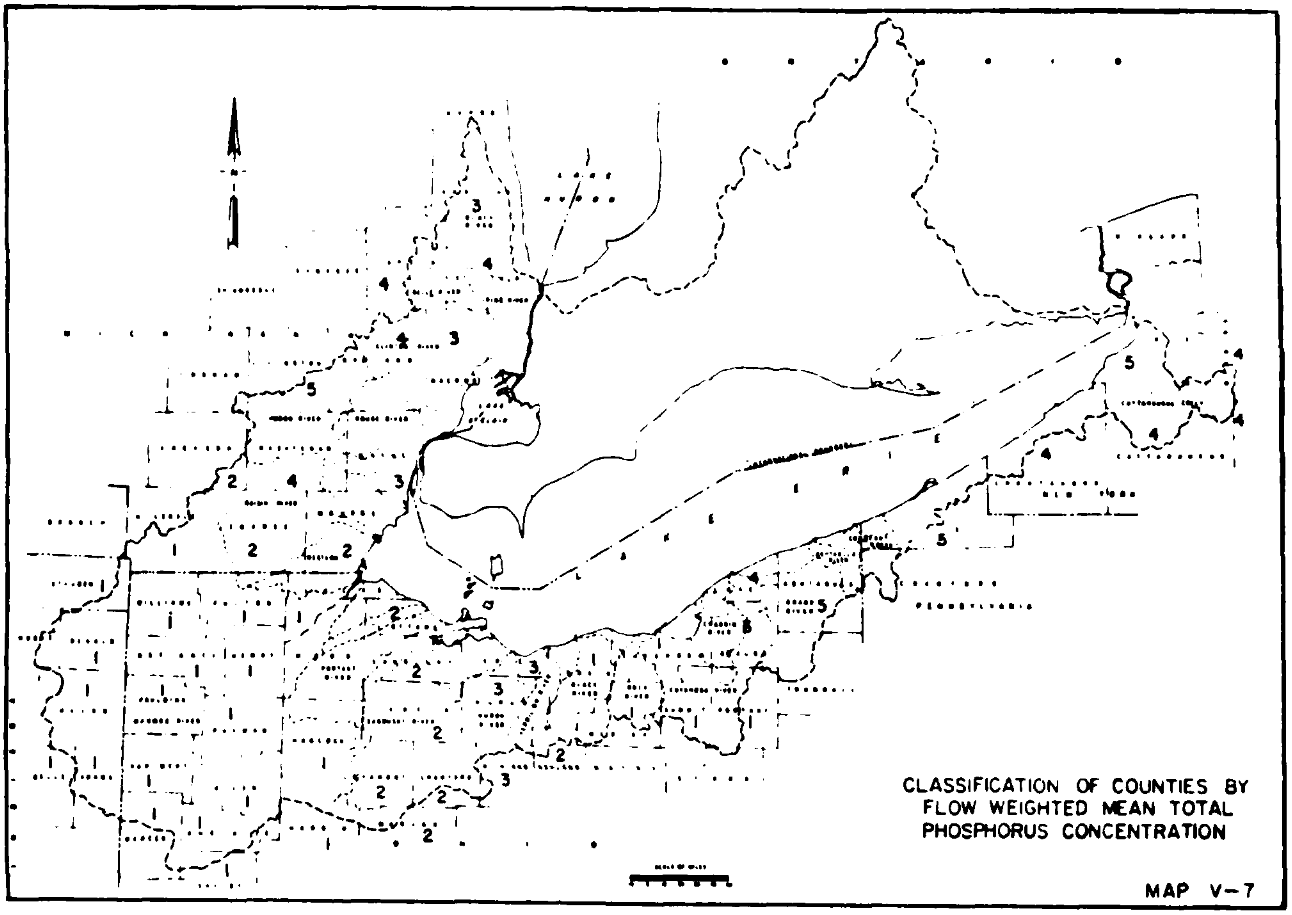
Map V-6 presents the rankings of counties for total acreage of soils suitable for conservation tillage. Again, Lenawee County, MI has received the highest ranking. It is interesting to note that Wood County, OH, ranked No. 15 for soil loss reduction, is ranked No. 2 for total land suitable for conservation tillage. In Wood County, the conservation tillage method most used will be reduced tillage on 29,920 acres of SMG 4 and 190,226 acres of the clay or silty clay surface textured SMG 8. This represents 68 percent of the total cropland. No tillage will be the less important practice on 91,020 acres. It is significant that much of the land in Wood County can be treated, because although it is not eroding at high rates, the soils of this county are very fine textured and have been shown to produce very high sediment and phosphorus delivery ratios (Ref. 21).

The third element of the ranking is a measure of the effectiveness that the program will have on reduction in the transport of phosphorus. For the purposes of the implementation program it will be considered very important, in addition to reducing soil loss and covering the landscape with conservation tillage, that the program be targeted toward areas which are currently producing the largest loads of phosphorus. Each county was rated in one of five classes based on the flow weighted mean total phosphorus concentration measured in the major river basins to which each county drains: Class 1, 0.4 mg/l or greater; Class 2, 0.3 to 0.4 mg/l; Class 3, 0.2 to 0.3 mg/l; Class 4, 0.1 to 0.2 mg/l; and Class 5, 0.0 to 0.1 mg/l total phosphorus. Map V-7 presents the results of this ranking.

In order to combine all three of the previously discussed ranking factors to provide an overall ranking factor, the individual factors were added together. To give an appropriate weight to the total tributary phosphorus concentration, the class number was reduced by 1 and the result multiplied by 15. The resulting scores for the counties were then ranked from 1 to 59. They are shown in Map V-8.

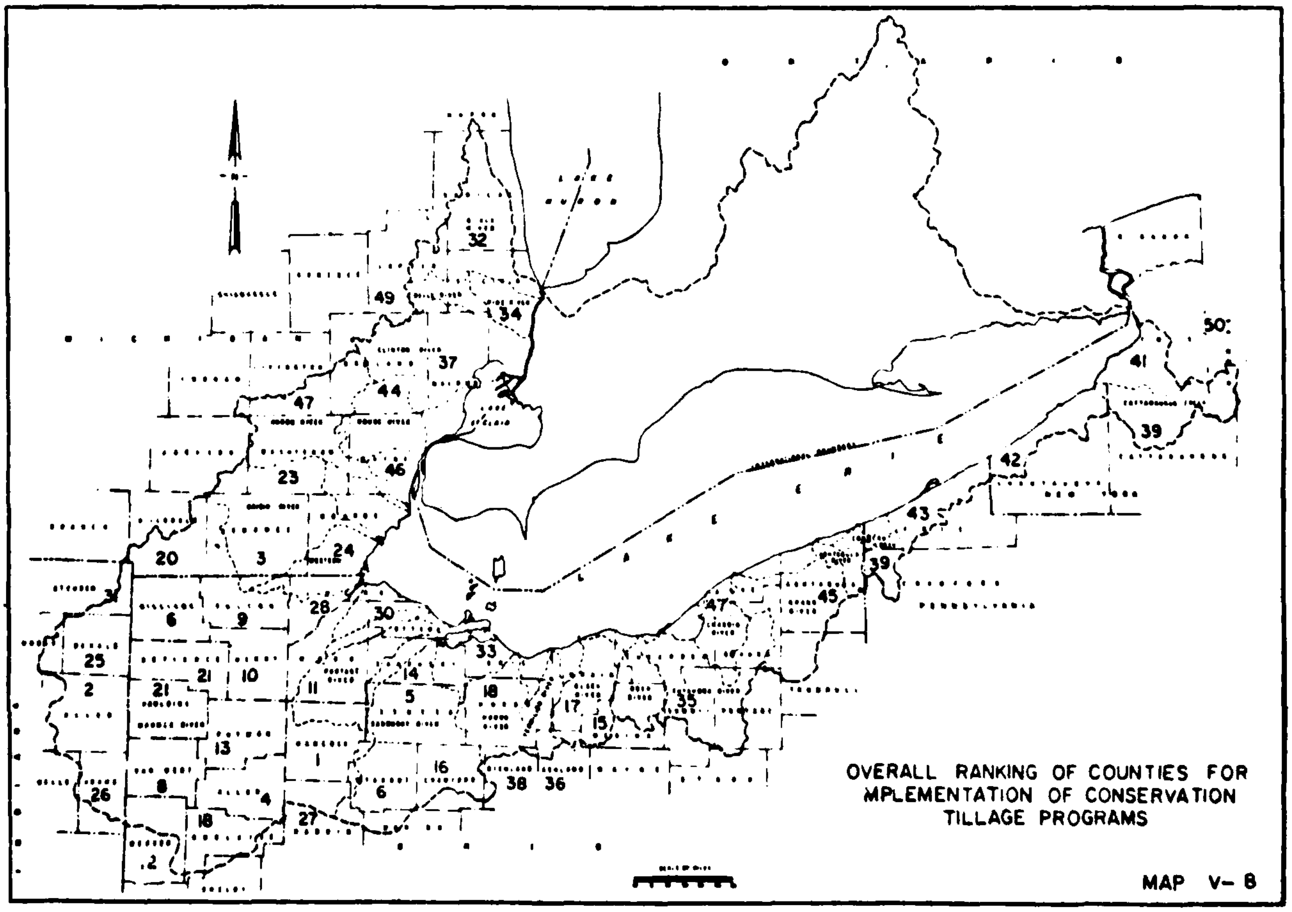
The benefits of the recommended program will not be limited to these counties alone. Accelerated adoption of conservation tillage should occur in other Lake Erie counties so that the phosphorus reduction presented in Section 5.3.3 are reached.

The top 20 ranked counties are listed in Table 5.22, with their base year soil loss, soil loss after program implementation, and resulting change in soil loss. Considered together these 20 of the 62 total counties in the Lake Erie drainage account for 60 percent of the total base year soil loss. During the course of the program they will account for 65 percent of the total achievable soil loss reduction.



CLASSIFICATION OF COUNTIES BY FLOW WEIGHTED MEAN TOTAL PHOSPHORUS CONCENTRATION

MAP V-7



OVERALL RANKING OF COUNTIES FOR MPLEMENTATION OF CONSERVATION TILLAGE PROGRAMS

MAP V- 8

If the recommended program is implemented a reduction in total phosphorus transport of approximately 1,320 mt/yr will be achieved in these counties alone. Spinoff benefits will result in additional phosphorus reduction of 710 mt/yr. throughout the rest of the Lake Erie Basin.

Table 5.22 - Soil Loss Reductions Achieveable Through Implementation of the Accelerated Conservation Tillage Program in 20 Priority Counties

Rank	County	Base Year Soil Loss	2002 Soil Loss	Reduction
1	Hancock, OH	879,627	330,726	548,901
2	Allen, IN	772,462	287,953	484,509
3	Lenawee, MI	1,580,064	568,681	1,011,383
4	Allen, OH	1,110,854	399,938	710,916
5	Seneca, OH	887,850	345,083	542,767
6	Williams, OH	789,876	177,265	612,611
7	Wyandot, OH	1,084,292	427,224	657,068
8	Van Wert, OH	453,501	185,247	268,254
9	Fulton, OH	431,054	170,260	260,794
10	Henry, OH	392,439	189,633	202,806
11	Wood, OH	513,658	250,773	262,885
12	Mercer, OH	554,965	218,290	336,675
13	Putnam, OH	532,964	316,082	216,882
14	Sandusky, OH	626,901	323,335	303,566
15	Medina, OH	504,950	242,825	262,125
16	Crawford, OH	628,215	241,413	386,802
17	Lorain, OH	533,352	322,589	210,763
18	Huron, OH	907,856	413,388	494,468
19	Auglaize, OH	471,847	180,417	291,430
20	Hillsdale, MI	219,836	146,568	73,268
		13,876,563	5,737,690	8,138,873

REFERENCES

Bone, S. W, D. M. Van Doren, and G. B. Triplett, "Tillage Research in Ohio," Bulletin 620, Cooperative Extension Service, the Ohio State University, January 1977.

Triplett, G. B., D. M. Van Doren, and S. W. Bone, "An Evaluation of Ohio Soils in Relation to No-Tillage Corn Production," Research Bulletin 1068, Ohio Agricultural Research and Development Center, Wooster, OH, December 1973.

Forster, D. L., N. Rask, S. W. Bone, and B. W. Schurle, "Reduced Tillage Systems for Conservation and Profitability," Department of Agricultural Economics and Rural Sociology, the Ohio State University, April 1976.

Urban, D. R., J. R. Adams, and T. J. Logan, "Application of the Universal Soil Loss Equation in the Lake Erie Drainage Basin," Lake Erie Wastewater Management Study Technical Report, U.S. Army Corps of Engineers, Buffalo, NY, November 1978.

U.S. Army Corps of Engineers, Buffalo District, Lake Erie Wastewater Management Study," Land Management Alternatives in the Lake Erie Drainage Basin, Buffalo, NY, March 1979.

Schwab, G. O., E. O. McLean, A. C. Waldron, R. K. White, D. W. Michener, "Quality of Drainage Water from a Heavy Textured Soil," Transactions of the ASAE, Vol. 16, No. 6, St. Joseph, MI, 1973.

Romkens, M. J. M., D. W. Nelson, and J. V. Mannering, "Nitrogen and Phosphorus Composition of Surface Runoff as Affected by Tillage Method," J. Environmental Quality, Vol. 2, No. 2, 1973.

Mannering, J., C. B. Johnson, and D. Nelson, "Simulated Rainfall Study Results," in "Environmental Impact of Land Use on Water Quality," Final Report on the Black Creek Project-Technical Report, Allen County Soil and Water Conservation District, U.S. Environmental Protection Agency, Chicago, IL, October 1977.

Logan, T. J., and Adams, J. R. "The Effects of Reduced Tillage on Phosphate Transport from Agricultural Land" LEWMS Technical Report, U.S. Army Corps of Engineers, Buffalo, NY, January 1981.

0. Bray, R. H. and L. T. Kurtz "Determination of Total, Organics and Available Forms of Phosphorus in Soils" Soil Science: 59, 39-45, 194[illegible]

1. Smith, G. E., R. Blanchar and R. E. Burwell. Fertilizers and pe[illegible] in runoff and sediment from claypan soil. Completion Report. [illegible] Missouri Water Resources Research Center, Columbia, 1979.

2. Lake, J. L. and J. Morrison, "Environmental Impact [illegible] Quality." Black Creek Progress Report. USEPA Regi[illegible] 005, 1975.

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NATIONAL BUREAU OF STANDARDS-1963-A

13. Baker, J. L. and J. M. Laflen, "Effects of Corn Residue and Chemical Placement on Chemical Runoff Losses" Trans Am. Soc. Agric. Eng, 1980.

14. Logan, T. J. "Levels of Plant Available Phosphorus in Agricultural Soils in the Lake Erie Drainage Basin" LEWMS Technical Report, U.S. Army Corps of Engineers, Buffalo, NY, December 1977.

15. Logan, T. J. and D. L. Forster. "Alternative Management Options for the Control of Diffuse Phosphorus Loads to Lake Erie." LEWMS Technical Report. U. S. Army Corps of Engineers, Buffalo, NY. 1982.

16. Hemmer, R. F. and D. L. Forster, "Farmer Experiences with Alternate Tillage Practices in the Western Lake Erie Basin," LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY.

17. Eckert, Donald, J. "Effects of Conservation Tillage on Crop Yields in the Lake Erie Basin" LEWMS Technical Report, U.S. Army Corps of Engineers, Buffalo, NY, December 1981.

18. Forster, D. L., "Economic Impacts of Changing Tillage Practices in the Lake Erie Basin," LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY, August 1978.

19. Honey Creek Joint Board of Supervisors (John Crumrine, Project Manager) "Honey Creek Watershed Project Final Program Evaluation Report, 1979-1981." LEWMS Technical Report, U.S. Army Corps of Engineers, Buffalo, NY, January 1982.

20. Forster, D. L. "Preferred Areas for Reduced Tillage - Technical Assistance Programs in the United States Drainage to Lake Erie," LEWMS Technical Report, U.S. Army Corps of Engineers, Buffalo, NY, July 1979.

21. Logan, T. J., and Stiefel, R. C., The Maumee River Basin Pilot Watershed Study, Volume 1, The Ohio State University, Columbus, OH, March 1979, EPA-905/9-79-005-A.

CHAPTER 6 - EVALUATION OF PAST AND EXISTING RELATED PROJECTS

There have been a number of projects both within the LEWMS program and by other Federal agencies which have been initiated to stimulate interest and result in application of agricultural best management practices to reduce sediment and nutrient runoff into the waters of the Lake Erie Basin. This chapter summarizes these programs and their relationship to overall LEWMS objectives.

6.1 HONEY CREEK WATERSHED MANAGEMENT PROJECT

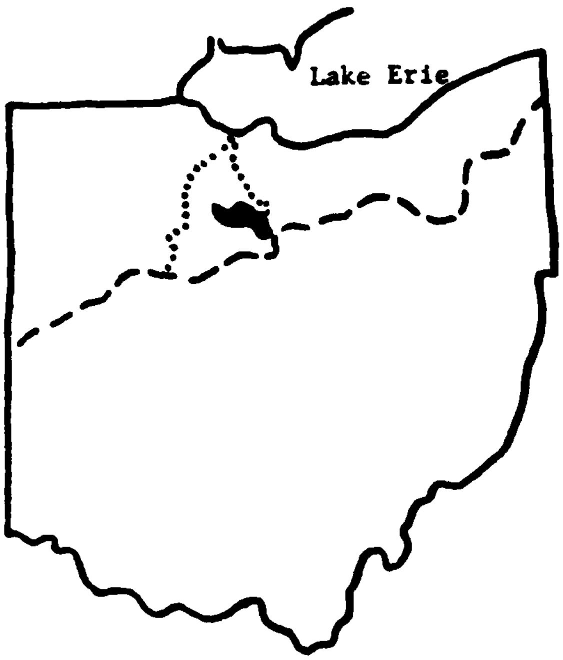
In November, 1978, the Corps of Engineers, Buffalo District contracted with the Honey Creek Joint Board of Supervisors (Crawford, Huron, and Seneca Soil and Water Conservation Districts, Ohio) to carry out a three year pilot program to demonstrate and promote the use of conservation tillage and other management practices which result in reduction of soil and phosphorus losses. Details of this program are reported in the Honey Creek Joint Board of Supervisors final report issued in January 1982 (Ref. 1). Location of the project area is shown in Map VI-1. This watershed was chosen for a number of reasons: (1) Land use in the 176 sq. mi. watershed was predominantly cropland (82 percent) with a large percentage devoted to row crops (mainly corn and soybeans) which are targeted for application of conservation tillage; (2) high local interest existed in demonstration of conservation tillage and other Best Management Practices (BMP); and (3) variety of soils and physiographic areas had significant erosion problems and potential for conservation tillage (Ref. 2). The program included information and education activities, technical assistance to landowners and the demonstration of BMP's on farms within the basin. Work was accomplished in two phases: (I) 1979, Upper Honey Creek watershed, Crawford County, 11,000 acres and (II) 1980-1981, entire Honey Creek watershed, Crawford, Huron and Seneca Counties, 120,000 acres. Over the 3-year period of the program, there were significant increases in conservation tillage both within the Honey Creek watershed and in the three-county area outside the watershed as shown below:

	Within Honey Creek Watershed (ac)	Rest of Three-County Area (ac)
1979 -	1183	1184
1980 -	2669	3422
1981 -	8350	7820

In 1981 conservation tillage was applied to about 9 percent of the cropland in the watershed. About 2/3 of all conservation tillage was no till, with the remainder some form of reduced tillage. Thus the emphasis was on promotion of no till which has the greater potential for sediment and phosphorus reduction.

6.1.1 Estimated Sediment and Phosphorus Reductions.

Estimates of reductions in soil erosion and phosphorus losses from the study area were made to provide guidance on what benefits may be realized from instituting conservation tillage. Estimates were made for



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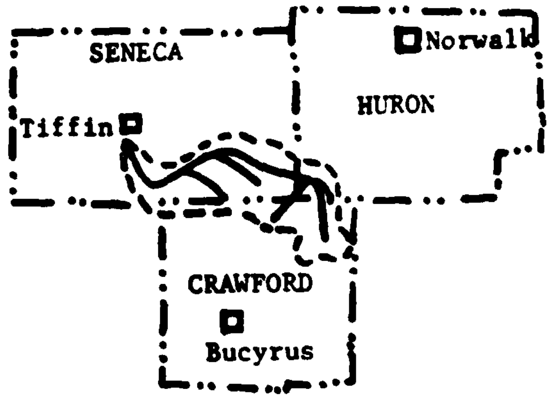
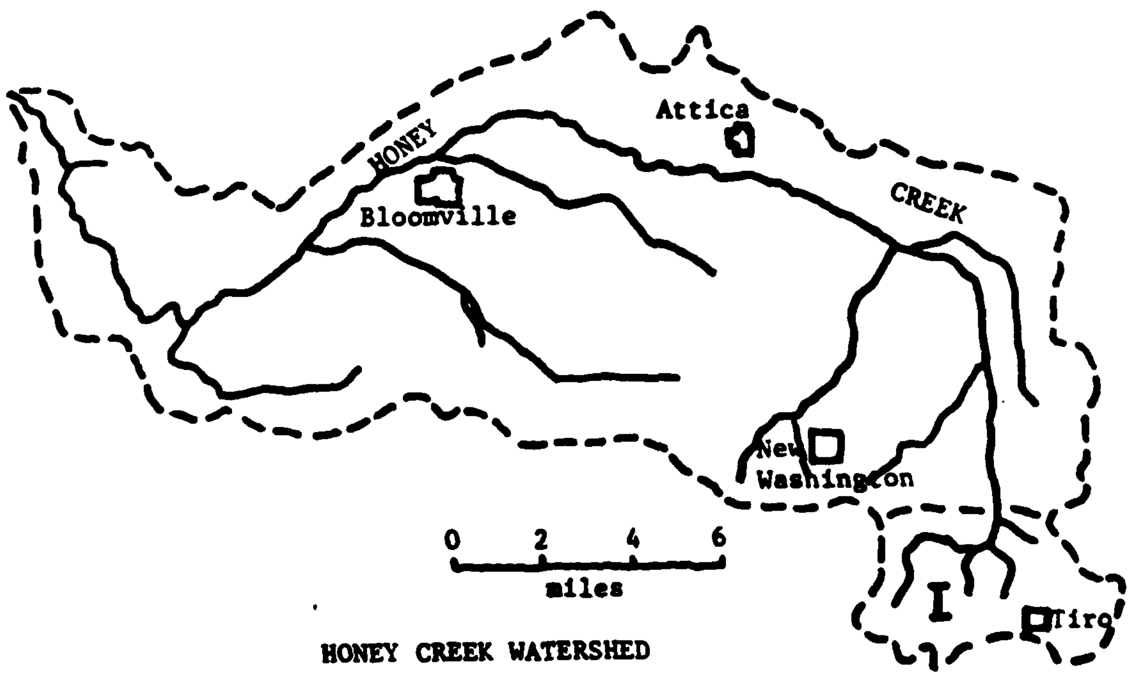


RELATION TO COUNTIES
AND COUNTY SEATS



HONEY CREEK WATERSHED

Map VI-1 **Honey Creek watershed as located in Seneca, Crawford, and Huron Counties in the State of Ohio.**

Area I is the Upper Honey Creek Watershed

10-20 acre demonstration plots using the Universal Soil Loss Equation as described in Section 2.3. Calculations showed that reduced tillage systems decreased erosion rates from 6-7 tons per acre per year (T/ac/Yr) to 4-5 T/ac/Yr or by about 30 percent over the conventional plow systems. On the same soils, but often different fields, no till decreased erosion rates from 6-7 T/ac/Yr to 1-2 T/ac/Yr or about 75 percent.

For a relative effectiveness then of 89 percent, reduced tillage systems in the Honey Creek Watershed would potentially decrease phosphorus transport from a present watershed condition of 0.84 kilograms per hectare per year (kg/ha/yr) to 0.63 kg/ha/yr or by 26 percent. No till would decrease phosphorus transport from 0.84 to 0.30 kg/ha/yr or by 64 percent.

As part of the Honey Creek Project, a field inventory of the 11,000 acre Upper Honey Creek (UHC) Watershed was conducted to validate similar data within the Land Resources Information System (LRIS), described in Chapter 2. Validation of LRIS files, containing data gathered or estimated from existing records or maps, was necessary to insure that predictions or calculations made using LRIS were reliable. Key conclusions were:

Manual calculations comparing most of the UHC field inventory data with LRIS data showed that, for the watershed as a whole, erosion predictions using either data base were similar. However, for specific soil types, LRIS data tended to under-estimate soil losses on flatter soils and over-estimate soil losses on steeper soils.

Because of higher UHC cropping-management ("C") factors, application of conservation tillage practices will have a greater impact on soil loss than would be expected using LRIS data base "C" factors. Thus, programs designed to accelerate implementation of conservation tillage may potentially have a far greater impact on reducing erosion and improving water quality than originally thought.

6.1.2 Crop Yields Using Conservation Tillage.

Table 6.1 presents average corn and soybean yields from Honey Creek tillage demonstration plots using conventional, reduced, and no-tillage systems. For corn, during 1979-1981, conventional system yields averaged 3.4 bu/ac above reduced tillage yields and 13.1 bu/ac above no-till yields in field sized demonstration plots. The surface application of urea as the sole nitrogen source in three plots in 1979 and the introduction of rye cover crops into corn after corn, and corn after soybeans clearly reduced yields. When plots employing these practices were excluded, no-till yields averaged only 6 bu/ac less than plow system yields. However, for side by side comparison plots, no-till yields were within 10 bushels (plus or minus) of conventional plow yields more than half (57 percent) of the time.

Yield variations from plow averages were in large part due to a combination of drainage plus the type and amount of crop residue on the soil surface at planting. Under cool, wet conditions, in fields of less than

Table 6.1 - Average Corn and Soybean Yields by Tillage System and Rotation, Honey Creek Watershed Management Project

Tillage System and Rotation	CORN Yield, bu/ac (No. of Plots) 1979	1980	1981	Three-Year Average
No till Corn After:				
Corn	135.3 (5)	120.3 (9)	113.4 (9)	120.9
Corn, cover crop	-	-	96.2 (4)	96.2
Soybeans	117.1 (1)	118.9 (4)	118.0 (2)	118.4
Soybeans, cover crop	-	107.9 (9)	92.9 (7)	101.3
Wheat, clover sod	123.3 (9)	127.8 (4)	93.7 (4)	117.4
Alfalfa	117.7 (1)	143.7 (1)	136.3 (1)	132.6
Rye crop	-	-	103.7 (1)	103.7
No till, all rotations	126.3 (16)	118.0 (27)	103.8 (28)	114.3
No till, excluding Urea-N and cover crop plots	134.1 (13)	123.0 (18)	110.1 (17)	121.4
Reduced	140.8 (9)	118.0 (7)	114.8 (12)	124.0
Plow	137.8 (2)	135.6 (13)	116.9 (12)	127.4
No till success ratio (1): all comparisons plots	-	58 percent	56 percent	57 percent

Tillage System and Rotation	SOYBEANS Yield, bu/ac (No. of Plots) 1979	1980	1981	Three-Year Average
No till, Soybeans After:				
Corn	49.1 (1)	50.9 (6)	41.3 (4)	47.2
Corn, cover crop	-	-	-	47.2
Soybeans	42.1 (1)	48.2 (2)	38.9 (1)	44.4
No till, all rotations	45.6 (2)	50.2 (8)	43.2 (8)	46.6
Reduced	39.9 (3)	40.8 (1)	45.2 (2)	41.8
Plow	41.0 (1)	48.2 (5)	43.2 (6)	45.1
No till success ratio (2): all comparison plots	-	100 percent	80 percent	90 percent

(1) No till yield equal to plow yield ± 10 bu/ac in side by side comparisons.

(2) No till yield equal to plow yield ± 4 bu/ac in side by side comparisons.

ideal drainage, excessive amounts of crop residues (previous crop mulch plus cover crop, unbaled wheat, straw, etc.) caused surface soil to remain cooler and wetter than in conventional comparisons, resulting in greater denitrification than in plow plots. Under dry conditions, in other years, excessive amounts of crop residues promoted nitrogen losses through volatilization. Plots having reduced amount of crop residues through either tillage or residue management (bale straw, plant no cover crop, etc.) normally produced corn yields approximating those of conventional plow yields. Apparently, under these conditions, reduced amounts of residue maintained conservation tillage yields due to improved conditions for soil warming and drying during spring, and greater opportunity for surface applied nitrogen to contact and be held by the soil.

For soybeans, 1979-1981, no till yields averaged 4.8 bu/ac above reduced tillage yields and 1.5 bu/ac above conventional plow yields. In no till rotations, beans after corn produced yields typically higher than beans after beans. In 1981, no till beans into a rye cover crop after corn increased yield over beans after corn alone. Rye residue on the soil surface during a dry August appeared to reduce moisture stress on plants and, as a result, improved crop maturation. For side by side comparison plots, no till yields were within 4 bushels (plus or minus) of conventional plow yields almost all the time (90 percent).

Avoidance of problems relating to drainage was a key factor in the success of no till soybeans. Beans, normally planted later than corn, were not subject to the stress of cool, wet seedbeds, nor, like nitrogen for corn, were beans subject to loss of a critical plant nutrient. As well, moisture conservation resulting from the presence of crop residues in late summer may have helped improve no till yields over conventional.

6.1.3 Economic Analyses of Honey Creek Tillage Systems.

The economic indicator of success of new tillage systems is net return, or how do costs of one system vary with another? Table 6.2 shows that for corn, 1979-1981, net return per acre for conventional, reduced and no tillage systems averaged \$57, \$38 and \$24, respectively, for demonstration plots within the Honey Creek Watershed. While production costs ran from \$239 per acre for reduced tillage, to \$247 per acre for no till to \$255 per acre for conventional, crop value ranged from \$271 per acre for no till, to \$277 per acre for reduced tillage to \$312 per acre for conventional. Low production costs for conservation tillage crops did not offset high crop values for conventional crops, resulting in an average 3-year economic advantage to conventional corn, \$19 per acre over reduced tillage, \$33 per acre over no till.

However, when urea and rye cover crop plots were excluded from analysis, no till economics improved significantly. Crop value increased by \$18 to \$289 per acre, while average production cost decreased by \$4 to \$243 per acre. As a result, net return increased by \$22 to \$46 per acre, a return only \$11 per acre less than that from conventional corn.

Table 6.3 shows that for soybeans, 1979-1981, net return per acre for conventional, reduced and no-tillage systems averaged \$151, \$127 and \$170,

Table 6.2 - Average Per Acre Crop Values, Production Costs and Net Returns Using Conservation Tillage, and Conventional Systems for Corn, Honey Creek Demonstration Plot Data

Tillage System	Conventional			Reduced			No Till			No Till (2)		
Year	1979	1980	1981	1979	1980	1981	1979	1980	1981	1979	1980	1981
No. of Plots	2	13	12	9	7	12	16	27	28	13	18	17
Crop value, $/ac	288	387	235	300	335	226	270	335	209	286	350	228
Range - low	269	321	162	253	271	127	166	231	84	235	281	166
- high	307	506	314	381	418	331	324	438	295	324	438	295
3-Year Average		312			277			271			289	
Production Costs $/Ac (1)	224	253	263	193	255	265	208	251	267	210	249	263
Range - low	220	225	210	150	227	237	157	216	205	157	216	205
- high	228	290	293	228	295	286	245	299	305	245	299	305
3-Year Average		255			239			247			243	
Net Return, $/ac	64	134	-28	107	80	-39	62	84	-58	76	101	-35
Range - low	42	55	-108	63	19	-130	-36	-10	-186	40	35	-90
- high	87	224	56	179	191	71	129	200	40	129	200	40
3-Year Average		57			38			24			46	

(1) Excludes land cost.

(2) Excludes plots where either Urea-N only was surface applied as the sole nitrogen source or plots where rye cover crops were seeded the fall before planting.

Table 6.3 - Average Crop Values, Production Costs and Net Returns Using Conventional and Conservation Tillage Systems for Soybeans, Honey Creek Demonstration Plot Data

Tillage System	Conventional			Reduced			No Till		
Year	1979	1980	1981	1979	1980	1981	1979	1980	1981
No. of Plots	1	5	6	3	1	2	2	8	8
Crop value, $/ac	253	360	269	246	306	283	284	376	269
Range - low	-	322	162	156	-	269	263	334	243
- high	-	389	314	293	-	297	306	409	312
3-Year Average		306			268			318	
Production Costs $/ac (1)	127	139	175	139	118	156	124	149	152
Range - low	-	116	137	124	-	154	124	111	129
- high	-	176	234	169	-	158	124	182	239
3-Year Average		155			141			148	
Net Return, $/ac	126	221	94	107	188	127	161	227	117
Range - low	-	161	12	-13	-	115	139	178	4
- high	-	269	196	169	-	139	182	291	183
3-Year Average		151			127			170	

(1) Excludes land cost.

respectively. While production costs varied from $141 per acre for reduced tillage, to $148 per acre for no-till to $155 per acre for conventional, crop value ranged from $268 per acre for reduced tillage, to $306 per acre for conventional to $318 per acre for no-till. Relatively low production costs and high crop value combined to give the average 3-year economic advantage to no-till soybeans, $19 per acre over conventional, $43 per acre over reduced tillage beans.

Regardless of final farmer successes, certain production costs were required to help insure achievement of yield goals and related profits. Table 6.4 shows that for both corn and soybeans, material and machinery costs varied considerably with tillage system. For corn, material costs were about $16 per acre greater for no till than for reduced tillage or conventional. In most cases, this added cost was due to recommended use of a contact herbicide* plus the use of an insecticide (usually Toxaphene) for armyworm control in plots with rye cover crops. On the other hand, machinery costs for no till were $10 per acre less than for reduced tillage and $22 per acre less than for conventional. These cost differences were a direct function of the type and intensity of tillage performed. For soybeans, material costs were about $11 per acre greater for no-till than for reduced tillage or conventional. This added cost was almost always due to the recommended use of a contact herbicide. Machinery costs for no till soybeans were $5 per acre less than for reduced tillage and $18 per acre less than for conventional. Again, differences were a function of degree of tillage. In summary, increased material costs for no till crops were more than offset by reduced machinery costs when compared to conventional tillage systems. Optimal savings occurred in reduced tillage systems where both material and machinery costs tended to be lower.

Table 6.4 - Average Material and Machine Costs for Conservation, Tillage Systems, Honey Creek Demonstration Plot Data 1979-1981

Tillage System		Three-Year Average ($/acre) Corn	Soybeans
No-till	Material (1)	197	106
	Machinery (2)	50	42
Reduced	Material	179	94
	Machinery	60	47
Conventional	Material	183	95
	Machinery	72	60

(1) Material costs include seed,lime, fertilizer, herbicides, insecticides and interest on operating capital.
(2) Machinery costs include custom rates for tillage, planting, harvesting, and trucking and application of fertilizers, herbicides and insecticides.

*Contact herbicides such as Paraquat or Roundup, much like plowing, provide initial control of existing vegetation. Residual herbicides, applied in all tillage systems, subsequently provide control of all new or sprouting weeds.

Average net returns from no till soybeans even exceeded those of conventional soybeans, and returns from no till corn approximated those of conventional where poor drainage and/or excessive amounts of crop residues did not combine to reduce yields. Thus tillage demonstrations within the Honey Creek Watershed have shown that a change to conservation tillage need not necessarily harm farm income. Drainage of wet fields, selection of drier fields for no-till corn and management of residues to minimize excesses are steps that would lead to consistently improved no-till corn yields in the future.

6.1.3.1 Program Cost - Table 6.5 summarizes the conservation tillage program costs in the Honey Creek Watershed in relationship to erosion and phosphorus reductions. Annual costs included information/education, technical assistance, labor costs, and landowner conservation tillage crop acreage payments made to cooperating landowners. Scrutiny of the table shows that unit costs were greatest during 1979, $10/ton of sediment and $270/kg of phosphorus. Unit costs were lowest in the final project year, 1981, $3/ton of sediment and $56/kg of phosphorus. Average unit costs for the 3-year period were $4/ton of sediment and $89/kg of phosphorus.

Realistically, investment costs would be less than those given above since, as a result of the special effort, farmers are expected to continue conservation tillage farming to some degree even after project discontinuation. Several scenarios can be developed to portray the extent of conservation tillage continuation for some fixed period, say 20 years after project conclusion. These scenarios may then be used to revise downward unit investment costs of the 3-year implementation effort:

Scenario 1 - Application will remain constant.

Over the next 20 years, acres treated with conservation tillage (no till and reduced tillage) will remain at a level to maintain the soil and phosphorus loss reductions for project year 1981: 61507 tons and 2896 kilograms, Table 6.5.

Scenario 2 - Application will decrease by half.

Over the next 20 years, acres treated with conservation tillage will decrease to a level to reduce by one-half the soil and phosphorus loss reductions for project year 1981.

Scenario 3 - Application will double.

Over the next 20 years, acres treated with conservation tillage will expand to a level to increase by 2 times the soil and phosphorus loss reductions for project year 1981.

Scenario 4 - Application will expand five-fold.

Over the next 20 years, acres treated with conservation tillage will expand to a level to increase by 5 times the soil and phosphorus loss reductions for the project year 1981.

Assuming, then, these ben[illegible] be largely a function of the Honey Creek demonstration effort alon[illegible] unit costs over the 20 year period would change as shown in Table 6.6.

Table 6.5 - Conservation Tillage Program Costs in Relationship to Erosion and Phosphorus Reductions

	Total Program Costs (1)	Total Erosion(2) Reduction (Tons)	Total Phosphorus Reduction (kg)(2)	Program Costs ($/Ton)	Program Costs ($/kg)
	$				
1979	110,000	10,504	407	10	270
1980	121,000	22,711	1,107	5	109
1981	161,000	61,507	2,896	3	56
Totals	392,000	94,722	4,410	4	89

(1) Annual costs include: $25,000 information/education, $35,000 technical assistance plus landowner payment amounts from the Honey Creek Joint Board.

(2) Reductions from both no till and reduced tillage practices. Combines acreage data with erosion and phosphorus reduction as discussed in Section 6.1.1.

Table 6.6 Program Cost Effectiveness

Scenario		Program Cost Effectiveness $/ton Soil	$/kg P
1	Implementation remains constant	0.32	6.77
2	Implementation decreases by half	0.64	13.54
3	Implementation doubles	0.16	3.38
4	Implementation increases five-fold	0.06	1.35

Thus, under the most optimistic scenario, program cost effectiveness could be as low as $.06/ton of soil or $1.35/kg of phosphorus kept on the land and out of the water. The least optimistic scenario would still measurably increase program cost effectiveness, reducing costs to $.64/ton of soil and $13.54/kg of phosphorus. The LRIS analysis of the Honey Creek Watershed shows that about 85% of the cropland is suitable for application of conservation tillage (Ref. 3). Since the current adoption is only 9 percent, a five-fold increase to 45 percent in about 20 years is an entirely reasonable expectation.

6.2 WATERSHED MANAGEMENT STUDIES

Within the scope of the Lake Erie Wastewater Management Study (LEWMS), it was deemed necessary to address more specifically the unique problem areas in the Lake Erie drainage basin. Watershed problems and candidate remedies had to be further refined and more precisely identified if diffuse sources of sediment and phosphorus are to be controlled. Therefore, five demonstrational implementation programs were developed which: (1) included appropriate watersheds; (2) were geared to land treatment practices to address local problems; and (3) allowed for active involvement of local people within the particular watershed areas. The five selected watershed management studies are logical steps to bring the concepts of land stewardship identified in this report to fruition in the Lake Erie Basin. Major overall objectives were:

a. To identify and document critical problems within the selected watersheds.

b. To establish and/or continue baseline water quality monitoring for evaluating benefits of future implementation programs.

c. To inform and involve local people in the watershed management study activities.

d. To develop model education and technical assistance management programs for each watershed.

e. To prepare watershed management study plans for future demonstration and implementation programs.

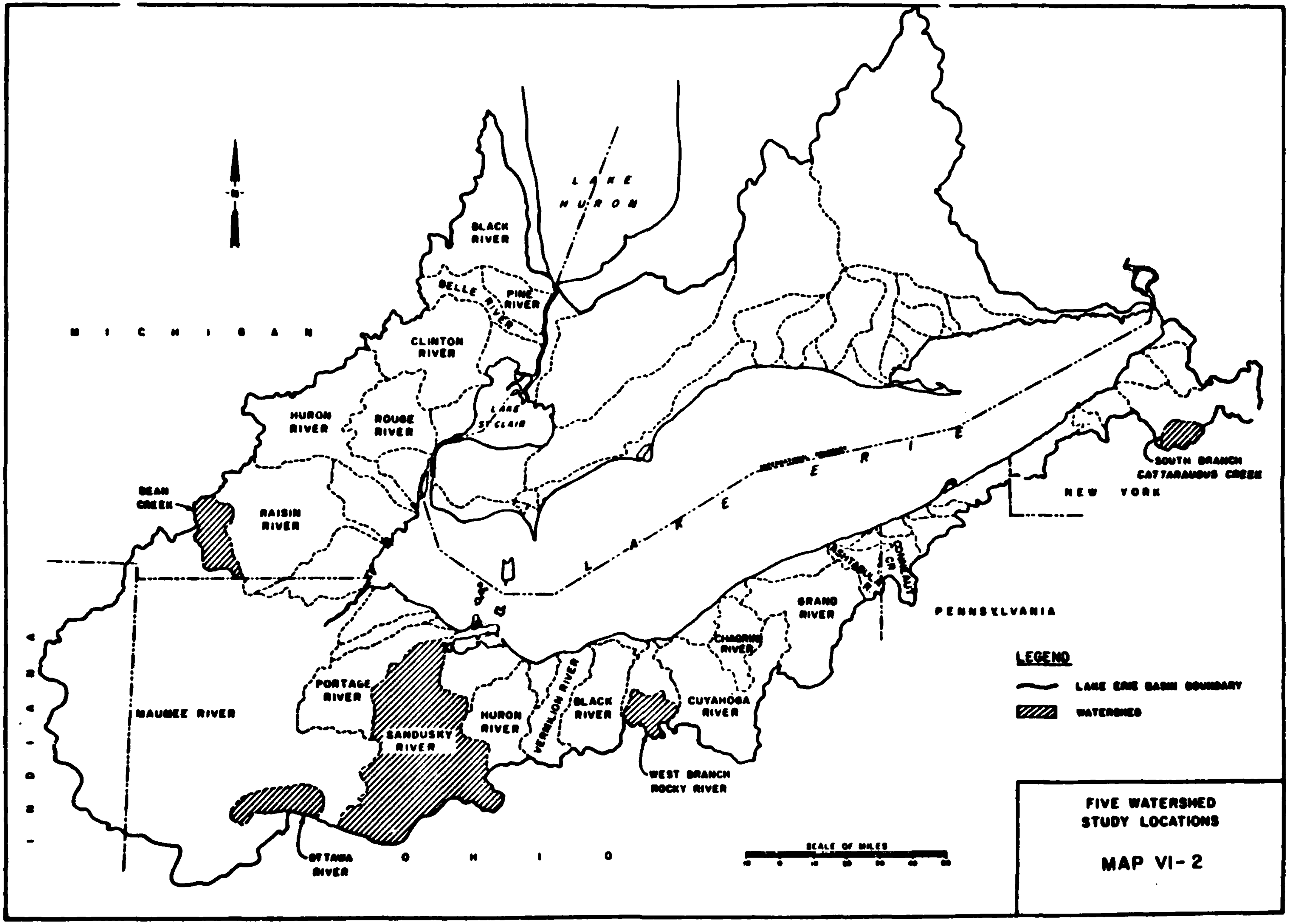
These five watershed management studies present programs which will control diffuse (non-point) sources of pollution and phosphorus. They are consistent with and complimentary to ongoing water quality planning efforts under Section 208 of the Clean Water Act. Watershed problems, treatment needs, and alternative land management solutions are identified.

Much of the information concerning the five watershed studies is based on the Lake Erie Wastewater Management Study's Land Resource Information System described in Chapter 2. The computerized LRIS watershed maps, reduced for inclusion in this report, are available in their original (1/48,000) size from the Buffalo District, Water Quality Section.

6.2.1. Descriptions of Watershed Study Areas.

The five watershed areas selected for study were the following: (1) Sandusky River (OH); (2) West Branch Rocky River (OH); (3) Bean Creek (MI); (4) Ottawa River (OH); and (5) South Branch Cattaraugus Creek (NY). The locations of these watersheds are shown on Map VI-2. More detailed maps and descriptions of these watersheds including identification of subbasins, and locations of gaging and sampling locations are given in the individual reports for each watershed (Ref. 4-8). The reader is referred to these reports for detailed information on soils, geology, physiography, and land use. Table 6.7 summarizes information on land use within the study watersheds as derived from the LRIS system.

With the exception of the Cattaraugus Creek watershed, agriculture is the major land use in the study watersheds. The Cattaraugus Creek watershed


LAKE HURON
BLACK RIVER
BELLE RIVER
PINE RIVER
CLINTON RIVER
MICHIGAN
HURON RIVER
ROUGE RIVER
LAKE ST CLAIR
BEAN CREEK
RAISIN RIVER
LAKE ERIE
SOUTH BRANCH CATTARAUGUS CREEK
NEW YORK
PENNSYLVANIA
CONNEAUT CR
ASHTABULA R
GRAND RIVER
CHAGRIN RIVER
CUYAHOGA RIVER
WEST BRANCH ROCKY RIVER
BLACK RIVER
VERMILION RIVER
HURON RIVER
SANDUSKY RIVER
PORTAGE RIVER
MAUMEE RIVER
OTTAWA RIVER
INDIANA
OHIO
SCALE OF MILES
LEGEND
LAKE ERIE BASIN BOUNDARY
WATERSHED
FIVE WATERSHED STUDY LOCATIONS
MAP VI-2

is heavily wooded (approximately 49%) and contains a more rugged terrain than the other study watersheds. The LRIS analysis showed that 75 percent of the Cattaraugus Creek watershed contains slopes greater than 8 percent, while 25 percent of the watershed contains slopes greater than 18 percent. The other watersheds contained much flatter terrain. Thus inclusion of the Cattaraugus Creek watershed enabled analysis and application of management practices on much steeper terrain.

In addition, much of the Cattaraugus Creek area has highly impermeable subsoils which increase runoff and erosion. Soils in all the study watersheds have evolved from unconsolidated earth material of glacial origin. The soil parent material in these basins is predominantly glacial till with minor percentages of glacial outwash, glacio-lacustrine, and recent alluvial deposits. Surface soil textures in four of the basins (Cattaraugus Creek, Ottawa River, Rocky River, Sandusky River) are predominantly medium textured (silt loams, loams, silty clay loams). The Bean Creek watershed has somewhat coarser textured surface soils (loams, sandy loams) and a higher percentage of better drained soils.

Table 6.7 - Percentage Land Use Distribution in Study Basins

Study Basin	Total Area: (Sq Miles)	Cropland	Pasture	Forest and Brushland	Water	Other
Sandusky	1,251	79.9	2.3	8.9	2.0	6.8
West Branch Rocky River	119	33.2	30.0	17.1	0.9	18.8
Bean Creek	206	64.2		20.4	5.0	10.4
Ottawa River	159.6	65.2		12.3	3.6	18.9
South Branch Cattaraugus Crk.	67.5	41.8		49.4	2.5	6.3

6.2.2 Watershed Problems and Needs.

6.2.2.1 Soil Erosion and Stream Sedimentation and Transport - The separate reports detail the nonpoint watershed problems peculiar to each of the study areas. However, there are problems which are common to all of the areas. These include soil erosion from cropland, stream sedimentation and transport of elevated suspended sediment and phosphorus loads, drainage problems, and soil fertility management. Accelerated erosion from the study watersheds generally results from intensive row crop cultivation (generally corn and soybeans). Sheet and rill erosion are experienced much more than gully erosion, generally as a result of the predominance of flatter terrain. Sheet and rill erosion are aggravated to a great extent by the often-used practice of fall plowing with no winter cover. It has been estimated that 70-90 percent of the annual sediment runoff in many Lake Erie watersheds occurs between February and May when rainfall is incident on saturated sometimes partially frozen ground. To a lesser extent, continuous row crop cultivation without inclusion of field crops or meadow in rotations is seen to aggravate soil losses.

The extent of the gross erosion problem in the study watersheds is quantified by application of the Universal Soil Loss Equation (USLE) which is described at length in Chapter 2 of this report. Approximately 21 percent of the Ottawa River Watershed was calculated to have PGE exceeding 6 T/ac/yr and 30 percent exceeds the established soil loss tolerance values (T value - the estimated upper limit of erosion rate which can be experienced without loss in soil productivity).

Approximately 22 percent of the Bean Creek watershed area is estimated to experience soil losses greater than 6 T/ac/yr, while 30 percent of the watershed experiences soil losses greater than T. Approximately 35 percent of the Sandusky River Basin is estimated to have soil losses greater than 9 T/acYr and 31 percent greater than T. The West Branch Rocky River is estimated to have 10 percent exceeding 10 T/ac/Yr and 41 percent of the area exceeding T. The South Branch Cattaraugus Creek watershed is estimated to have erosion exceeding T on 27 percent of the area while only 9 percent of the area had estimated erosion rates exceeding 6 T/ac/Yr. Analysis of land use data shows that the predominant uses of the rugged sloping uplands of the Cattaraugus watershed is woodland, pasture or meadow resulting in effective erosion control. The aforementioned percentages of the basin with severe erosion were based on total areas. These percentages increase significantly when eroded lands are calculated as percentages of cropland.

Sediment, phosphorus, and nitrogen loadings were determined at numerous locations in the study watersheds for many storm events especially during peak runoff periods. The reader is referred to the individual watershed reports for details on loading measurements and analyses. In general, suspended sediment and total phosphorus were observed to increase with flow. Soluble phosphorus was not always observed to increase with flow but was present at significant concentrations during periods of high flow. Concentrations of nitrogen forms (i.e., nitrate-nitrite, ammonia, kjeldahl-N) varied widely and exhibited different patterns with flow. A summary of suspended sediment, total phosphorus and soluble phosphorus loadings for the study periods is contained in Table 6.8.

6.2.2.2 Soil Drainage - All of the studied watersheds have areas with soil drainage problems associated either with low lying flat terrain and/or slowly permeable glacial till or lacustrine soils. This problem is particularly evident in an 8,000 acre area of the upper Ottawa River watershed. Poor drainage often prompts tillage in the drier fall months rather than the wet spring, thereby leaving the soil unprotected during the winter months. Poor drainage often delays plant establishment and affects yields under standard plow tillage systems. Poor drainage can be an even more serious problem with conservation tillage systems. Poor internal drainage on land with even low slope gradients (i.e., less than 4 percent) can aggravate sheet and rill erosion because of low infiltration and increased water runoff and sediment entrainment.

Table 6.8 - Summary of Suspended Sediment and Phosphorus Loadings

Watershed	Sampling Period	Loadings for the Sampling Period (kg/hec) Suspended Sediment	Total Phosphorus	Soluble Phosphorus
W. Branch Rocky R.	22 Mar-2 Jul 80	1,390	1.43	0.22
Ottawa River	25 Mar-1 Jul 80	1,110	1.70	-
Bean Creek	20 Mar-29 Jul 80	2,850	3.55	-
Sandusky River	Mean Annual 1976-1979	470	1.12	0.23
South Branch Cattaraugus Creek	1 Nov, 1979 - 30 June, 1980	3,680	2.51	0.17

Thus the use of artificial drainage on many of the soils in the study basins is viewed as a high priority need. The high density of improperly designed drainage ways and ditches in many of the low lying areas often increases ditch bank erosion and can lead to gully erosion on areas of sufficient gradient. Intensive cultivation adjacent to drainways and ditches was observed to result in greater erosion. There is a need therefore for properly designed and maintained grassed waterways and drainage district ditches in the study areas along with the establishment of vegetative buffer strips along some of these.

6.2.2.3 Fertility Management - In as much as phosphorus is a major plant nutrient, fertilizer applications of phosphorus are routinely made by farmers in the basins. All soil testing programs and recommendations regarding phosphorus are directed towards (1) providing sufficient phosphorus and other plant nutrients to produce the desired crop yield and (2) building up soil phosphorus levels for future production. Essentially, phosphorus recommendations were "crop production" and soil phosphorus "build up" oriented.

After many years of phosphorus applications at "build-up" rates, high soil phosphorus levels have generally been established in many soils. Therefore, present phosphorus application rates can be reduced to strictly "crop production" rates if the soil phosphorus levels are adequate.

As excessive soil phosphorus levels and excessive rates of phosphorus applications are reduced, water quality benefits will ultimately be realized. Excessive phosphorus not used by growing plants and not "tied-up" as soil particulate phosphorus, is available to be eroded into streams, watercourses, and eventually Lake Erie.

Manure management was found to pose some water quality problems in some of the study watersheds. Manure is often spread on frozen fields with resultant runoff of phosphorus and nitrogen in the spring. The problem is more evident in high density livestock areas such as the Cattaraugus Creek watershed where an estimated 33,000 tons of manure containing 70 tons of phosphorus is spread on fields during winter months.

In two of the study watersheds (Rocky River, Ottawa River) municipal sewage sludge is added as a soil building and fertilizer amendment to agricultural lands. Careful management of this practice is seen as necessary to prevent soil overloading and runoff of the nutrients nitrogen and phosphorus, and heavy metals or other toxics.

6.2.3 Land Management Programs.

As discussed in the previous section, existing potential gross erosion for each of the study watersheds was computed, mapped and tabulated. Figure 6.1 is an example of these outputs for the Ottawa River Watershed.*

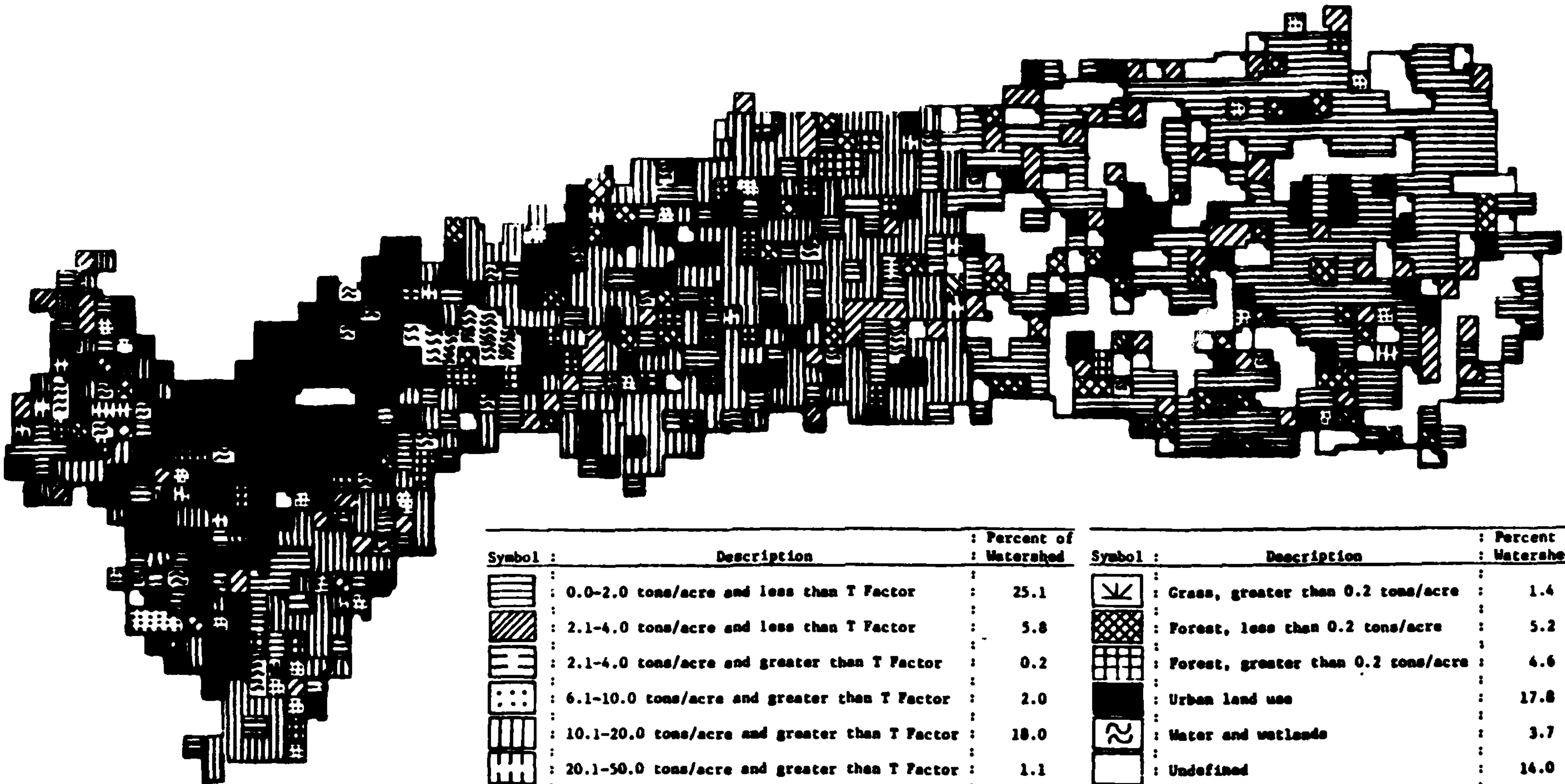
Figure 6.2 presents the distribution of SMG's in the Ottawa River Watershed. Map and tabular outputs for SMG's were prepared for the five watersheds.

Chapter 5 of this report described various conservation tillage and allied land management scenarios which can be applied to soil management groups for the purpose of reducing sediment and phosphorus losses. These Best Management Practice Scenarios were applied to all of the study watersheds for the purpose of obtaining quantitative estimates of erosion and phosphorus which may be realized. This exercise will highlight those areas where the use of limited resources for demonstration and implementation of soil conservation practices could realize the greatest benefits.

Table 6.9 gives the estimated erosion rates before and after application of various BMP's for croplands within the Ottawa River basin and percent reductions (or increases) in PGE for the various scenarios. The average existing cropland potential gross erosion is 5.3 tons/acre/year. Soil Management Groups 1, 2, and 10 exhibit above average PGE rates, and fortunately, these SMG's respond favorably to no tillage and reduced tillage Under the Maximum Reduction Tillage scenario, where no tillage is applied to SMG's 1, 2, and 10, reduced tillage is used on SMG's 4 and 8, and conventional tillage on SMG's 3 and 5, the average cropland PGE rate dramatically decreases from 5.3 to 0.8 tons/acre/year. Similarly, for the reduced tillage scenario, chisel plowing is used on SMG's 1, 2, 4, 8, and 10, while conventional tillage is applied to SMG's 3 and 5; this results in the average PGE

*Larger scale maps (1:48,000) for land use, Gross Erosion, and Soil Management Groups Are on File at the Buffalo District Office, Army Corps of Engineers.

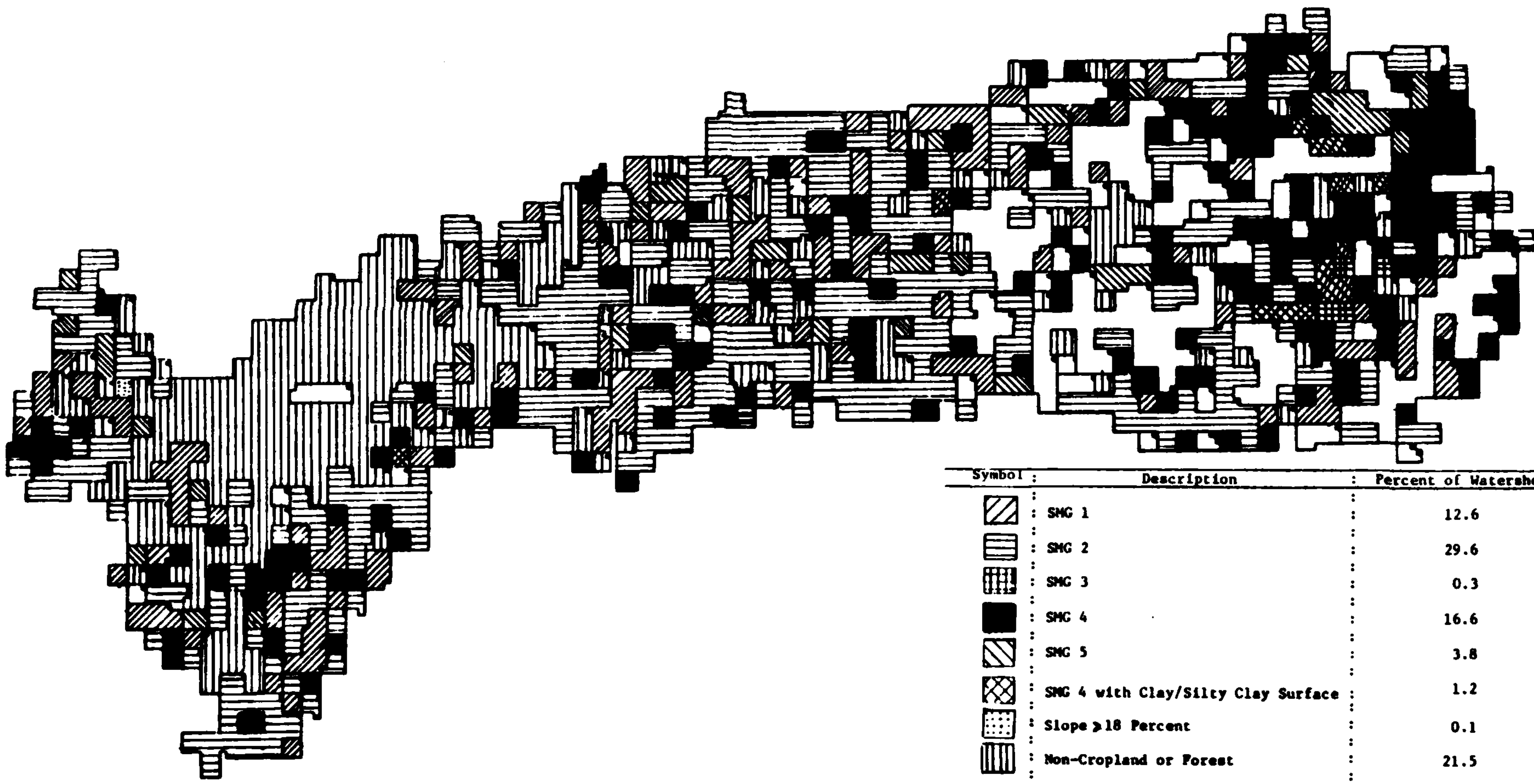
Figure 6.1 Potential Gross Erosion Within the Ottawa River Watershed



Symbol	Description	Percent of Watershed
	0.0-2.0 tons/acre and less than T Factor	25.1
	2.1-4.0 tons/acre and less than T Factor	5.8
	2.1-4.0 tons/acre and greater than T Factor	0.2
	6.1-10.0 tons/acre and greater than T Factor	2.0
	10.1-20.0 tons/acre and greater than T Factor	18.0
	20.1-50.0 tons/acre and greater than T Factor	1.1
	50+ tons/acre and greater than T factor	0.1

Symbol	Description	Percent of Watershed
	Grass, greater than 0.2 tons/acre	1.4
	Forest, less than 0.2 tons/acre	5.2
	Forest, greater than 0.2 tons/acre	4.6
	Urban land use	17.8
	Water and wetlands	3.7
	Undefined	14.0

Figure 6.2 Soil Management Groups Within the Ottawa River Watershed



Symbol	Description	Percent of Watershed
	SMG 1	12.6
	SMG 2	29.6
	SMG 3	0.3
	SMG 4	16.6
	SMG 5	3.8
	SMG 4 with Clay/Silty Clay Surface	1.2
	Slope ≥ 18 Percent	0.1
	Non-Cropland or Forest	21.5
	No Data	14.3

Table 6.9 - Potential Gross Erosion Rates for Various Land Management Alternatives, Ottawa River Basin

Cropland	Existing Pot Gross Erosion (Tons) (Tons/Acre)	Spring Plowing Only (tons) (Tons/Acre)	Fall Plowing Only (Tons) (Tons/Acre)	Winter Cover Crop (Tons) (Tons/Acre)	Maximum Reduction Tillage (Tons) (Tons/Acre)	Reduced Tillage: Mulch Till (Tons) (Tons/Acre)	Land Area (Acres)
SMG 1	99,972	93,959	104,106	93,959	12,778	40,590	10,469
	9.5	9.0	9.9	9.0	1.2	3.9	
SMG 2	149,725	140,719	155,917	140,719	19,137	60,791	23,526
	6.4	6.4	6.6	6.0	.8	2.6	
SMG 3	595	569	619	559	595	595	231
	2.6	2.4	2.7	2.4	2.6	2.6	
SMG 4	14,191	13,338	14,778	13,338	5,762	5,762	14,890
	1.0	.9	1.0	.9	.4	.4	
SMG 5	3,209	3,016	3,342	3,016	3,209	3,209	2,733
	1.2	1.1	1.2	1.1	1.2	1.2	
SMG 8	1,275	1,199	1,328	1,199	518	518.1	1,199
	1.1	1.0	1.1	1.0	.4	.4	
SMG 10	10,517	9,884	10,952	9,884	1,344	4,270	77
	136.4	128.2	142.0	128.2	17.4	55.4	
All Cropland	279,487	262,676	291,045	262,676	43,345	115,736	
(Tons/Acre)	5.3	4.9	5.5	4.9	0.8	2.2	
% Reduction		7.5	-3.8	7.5	85	59	

rate decreasing from 5.3 to 2.2 tons/acre/year. No other scenario, including winter cover crops, can offer the reductions in PGE exhibited by no tillage and reduced tillage. Tables have been prepared for attainable sediment and phosphorus reductions for each of the study watersheds.

Table 6.10 summarizes the average reductions in PGE which can be obtained by application of conservation tillage practices within each of the five watershed study areas. Reductions using reduced tillage range from a low of 37 percent for the West Branch Rocky River to a high of 59 percent for the Ottawa River watershed. The higher reductions attainable from using a combination of reduced tillage and no-tillage (i.e., Maximum Reduction Tillage) range from 54 percent for the Cattaraugus Creek to 85 percent for the Ottawa River watershed.

6.2.4 Implementation Programs - Programs were formulated for accelerated adoption of conservation tillage and other conservation practices in each of the five watershed study areas. These programs consist of proposed administrative frameworks, BMP technical assistance organization, information and education, fertility management, and program monitoring activities. Experience gained from these studies showed that the required programs could best be carried out on a county level and an organization based on watersheds was cumbersome. As a result, LEWMS has recommended county implementation programs and not watershed programs.

Overall program sponsorship and leadership is to be vested with local soil and water conservation districts (SWCD's) since they represent farmers and landowners who must be convinced of the benefits to be realized by implementation of conservation practices on their farms, and ultimately apply these practices. Technical and educational assistance would be provided by USDA agencies including the Soil Conservation Service (SCS) and the Cooperative Agricultural Extension Service (CES). The Agricultural Stabilization and Conservation Service (ASCS) can provide incentive funds to local farmers for incorporation of conservation tillage and other soil conservation practices through the Agricultural Conservation Program (ACP).

Experience gained during the LEWMS program has shown that one or more professionals must be fully committed to conservation tillage and allied practices in each watershed to achieve program objectives. These "conservation tillage specialists" could work out of other U.S.D.A. offices but must be specially funded for their specific work. Soil conservation technicians would work with the farmers in the field and receive technical support from SCS. Soil Conservationists, and Extension Service specialists.

Table 6.10 - Average Percent Reductions in Cropland Potential Gross Erosion Using Conservation Tillage for Five Watershed Studies

Watershed	PGE (T/Ac/Yr)	Reduced Tillage Percent Reduction	Maximum Reduction Tillage Percent Reduction
Sandusky	4.2	50 (45) (1)	80 (72)
West Branch Rocky River	5.4	37 (33)	61 (55)
Bean Creek	7.7	53 (48)	81 (73)
Ottawa River	5.3	59 (53)	85 (77)
South Branch Cattaraugus Creek	7.9	39 (35)	54 (49)

(1) Estimates of phosphorus reductions are shown in the parentheses.

BMP Technical Assistance functions would include planning, survey and design of on-site treatment, as well as the establishment of demonstration plots for conservation tillage, fertility management and any engineering measures. Information dissemination and educational support are viewed as highly important. This includes issuance of brochures (especially on successful demonstration plots), orientation meetings, tours of farms with practices, radio shows and other media contact. These functions would be coordinated through the SWCD's and the Extension Service.

Promotion, demonstration and assistance in soil fertility management are also considered as important adjunct functions of the proposed county and watershed programs. During the course of the LEWMS program, review of soil test data revealed that phosphorus levels are often far in excess of crop needs. Consequently application of excess phosphorus can result in unnecessary losses of the more highly biologically available fertilizer phosphorus. Frequent (i.e. annual) soil testing with application of fertilizer at levels required for crop needs would decrease runoff losses, and at the same time, could reduce farmer costs.

Water quality monitoring in the management program watersheds was recommended to assess the effectiveness of the program in reducing stream sedimentation and transport of phosphorus, other nutrients and other pollutants. Since the implementation of conservation tillage is expected to result in the increased use of herbicides, and may increase the use of pesticides, monitoring of these materials is also recommended.

Baseline data for making comparisons is available from the data collected for the five watershed studies and the Honey Creek Study. Automatic sampling and flow measurements should be done as it was in the LEWMS program.

Careful documentation of program accomplishments such as acreages of various crops in reduced tillage and no-till should be kept. Records should be kept for costs, fertilizer use, herbicide and pesticide use, and crop yields for demonstration plots, and other farm fields as available. It is equally important to document problems that are encountered so as to make program adjustments and corrections. As an example, in cases where conservation tillage results in unsatisfactory crop yields, reasons for reduced yields such as nutrient utilization, poor drainage, weed control, or pests should be documented.

Finally and most importantly, it must be recognized that implementation of the proposed BMP's will take a number of years. Thus five year programs are suggested as a minimum. Benefits such as statistically significant measured reductions in stream sediment and phosphorus loadings may take a number of years to observe after the realization of on-land conservation practice goals.

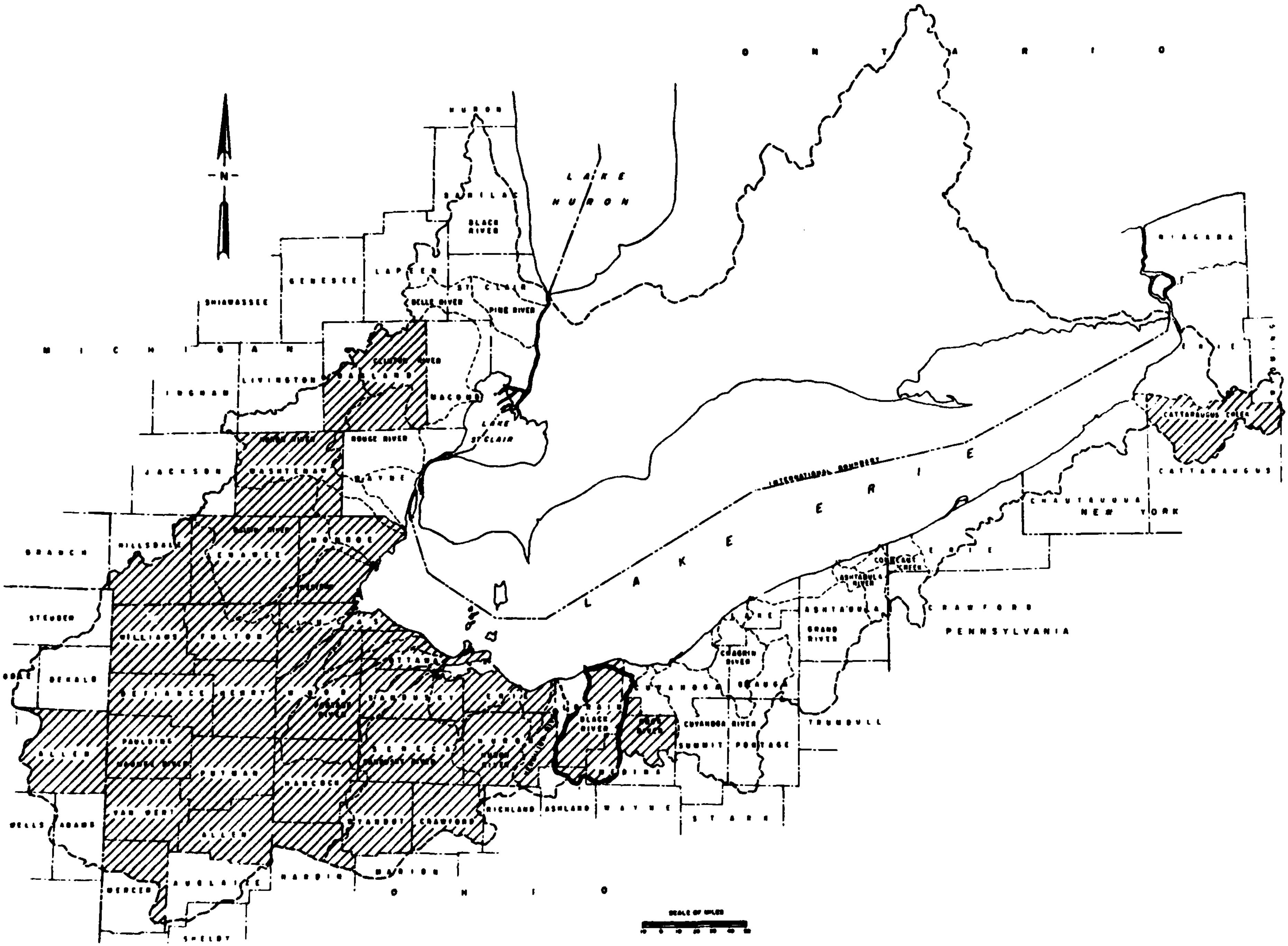
6.3 COUNTY RESOURCE INFORMATION SYSTEM PACKAGES

The County Resource Information System Packages (CRISPS) are compendia of information derived from the Lake Erie Wastewater Management Study's Land Resources Information System. They consist of maps and tabular information summaries for 28 counties in the U.S. portion of the Lake Erie drainage basin. Map VI-3 shows counties for which CRISP packages have been prepared.

One principal function of the CRISP'S is to provide resource information. In both the maps and tables, data on land use, watershed boundaries and areas, political boundaries and areas, and soil physical properties are presented. Some of the information is analytical. For example, one of the maps indicates an estimate of existing potential gross erosion. This map requires the combination of various soil resources features, knowledge of meteorological characteristics, land use, and an analysis of the cultural practices of land management for the county being mapped.

A second function of the CRISP's is to suggest possible alternative land management practices as discussed in Chapter 5 of this report for areas where there may be soil erosion problems. The "Best Management Practices" map has been prepared by evaluating observable land resource characteristics to suggest practices which would reduce soil erosion. The resource base has also been examined to suggest potential sites for land disposal of municipal sewage, effluents, and sludges.

These comprehensive information packages will serve as invaluable tools to assist county Soil and Water Conservation Districts and others in the long-term implementation of controls on diffuse source sediment, phosphorus and ultimately other nutrients and/or pollutants from agricultural land.



MAP VI-3 COUNTIES WITH COMPLETED CRISP REPORTS

6.4 GREAT LAKES NATIONAL PROGRAM OFFICE PROJECTS

USEPA 108 Great Lakes Demonstration Projects have been initiated in different areas of the Lake Erie Basin since 1972. The Black Creek project, a 12,000-acre watershed program in Allen County, IN, was initiated in 1972. It was a demonstration project, supported by detailed research, aimed at understanding agricultural land use impacts on water quality in the Maumee River Basin. This effort preceded the work of PLUARG and the IJC recommendations, but provided a foundation for additional agricultural nonpoint source work through Conservation Districts and USDA supporting agencies. With leadership from the Allen County Soil Conservation District, the Black Creek 108 project focused on cropland and streambank erosion, and movements of sediments and nutrients through the watershed. Research conclusions of the 5-year project were: (1) Many agricultural pollutants can be controlled by control of sediments; (2) Raindrop impact is the major factor on soil detachment; (3) Many water quality improvements can be made by treating critical areas; and, (4) Streambank erosion accounts for less than 10 percent of the sediment load. Administrative conclusions were: (1) Local level administration is important to local acceptance; (2) Voluntary programs, with financial incentive and technical assistance, can achieve significant land treatment; and, (3) Public information is critical for success. While 108 funding was used to continue monitoring efforts, no other 108 projects were initiated in the Lake Erie Basin until 1980, after the final PLUARG report.

In 1980, the EPA Great Lakes National Program Office (GLNPO) began funding five demonstration projects to accelerate the implementation of notillage systems in 30 counties in the Western Basin of Lake Erie. The primary objectives of the no-till demonstration projects are:

a. To make no till farming equipment available for farmers' use on their own land in an effort to secure acceptance in the project area.

b. To provide onsite technical assistance to individual farmers to assist them in using the new tillage techniques and equipment.

c. To provide consultation from professionally-trained agronomists to help farmers select the proper pesticides and fertilizer programs for no-till crop production.

d. To carry out an accelerated information and education program within the project area including no till workshops, field days, tours, etc.

e. To evaluate the effectiveness of the programs with respect to participation, potential water quality improvement, and cost of treatment by comparing the cost of production vs. yields on no till compared to conventional tillage on various soil types (cost sharing will not be a part of the project).

Technical assistance for the projects was provided through the USDA, SCS, ASCS, and CES, as well as the Corps and EPA, to the State and Local Soil and Water Conservation Districts.

The five projects, funded under Section 108(a) of the 1972 Federal Water Pollution Control Act Amendments were:

(1) Allen County SWCD, Ohio

(2) Defiance County SWCD, Ohio

(3) Lenawee and Hillsdale Counties SCD's, Michigan

(4) Allen County SCD, Indiana (6 counties)

(5) Ohio Department of Natural Resources (20 counties)

The Ohio project was channeled through the Ohio Department of Natural Resources (ODNR) Accelerated Conservation Tillage program with funds being passed directly to local soil and water conservation districts. Present plans call for 20 districts to participate with funds being authorized for technical support, lease or purchase of conservation tillage equipment, pest management scouting, demonstration plots, and an education program. Major focus is in North Central Ohio from the Rocky River west to the Maumee River Basin. This special EPA funding was in response to EPA's experience with Great Lakes demonstration grant projects and LEWMS findings that conservation tillage programs may be the most cost effective approach to reducing Lake Erie phosphorus loads.

The Northeast Indiana Conservation Tillage Demonstration project is a joint effort of the Soil and Water Conservation Districts in Adams, Allen, Dekalb, Noble, Steuben, and Wells Counties. Funds were being used for technical manpower, no-till conservation tillage planters, and educational programs. Farm landowners and/or operators in the St. Joseph, St. Mary's and Maumee River drainage basins were eligible to participate.

The Bean Creek Watershed, Hillsdale-Lenawee Conservation Tillage Demonstration project in Michigan focused on Bean Creek but proposed to promote conservation tillage practice throughout each county. With contract provisions being handled by the Lenawee SCD, a joint working agreement was developed with the Hillsdale SCS to coordinate efforts. A conservation tillage specialist was employed and local task forces created for planning and implementation.

The Michigan, Indiana, and ODNR programs are funded for technical and educational support through the 1984 spring planting season. Within the five conservation tillage demonstrations there is approximately $2,300,000 available through 30 cooperating soil and water conservation districts in 3 different states. This represents nearly one-third of the counties in the U.S. portion of the Lake Erie Basin.

One special urban-oriented project was the Lake Erie Tributaries Stormwater Effects Evaluation (LETSEE) program sponsored by the Northeast Ohio Areawide Coordinating Agency (NOACA), a designated 208 water quality planning agency. The LETSEE program included instream evaluations and monitoring to determine effect of stormwater runoff impacts on the channel morphology (cross sections) and instream biological communities (benthos and fish species). Instream sampling and channel cross section surveys were taken on an agricultural stream (Granger Ditch), an urbanized stream (Champion Creek), and an urbanizing transition stream (Plum Creek). Each of these are in the LEWMS West Branch Rocky River Watershed Study. This effort at assessing instream impacts complimented the LEWMS upland watershed management study extremely well. Both efforts should provided valuable information about watershed management and relationships to instream biological communities. Findings of this program are applicable to other urban areas in the Lake Erie Basin.

6.5 USDA PROGRAMS

ACP Special Water Quality Projects, under authority of USDA, Agricultural Stabilization and Conservation Service, were also being used in implementation programs in the Lake Erie Basin. A Honey Creek ACP Special Water Quality Project was approved in 1979 to compliment the Honey Creek Watershed Management project initiated as part of LEWMS. The ACP special funds were used for cost-share incentives with landowners and operators in Honey Creek. Major BMP's included conservation tillage, cover crops, and structural measures such as waterways, chutes or structures, and animal waste management systems. These were additional funds available above and beyond regular ACP funds and Honey Creek Project funds. Technical services were provided by the Soil Conservation Service. Priority critical areas were identified and efforts were coordinated with the Honey Creek project through the County Task Forces.

In Indiana, the Allen County ACP Special Water Quality Project has taken a very unique approach. Special efforts to provide water quality land treatment focuses on small miniwatersheds (1,200 to 2,400 acres) generally within a major group drainage ditch. Priority watersheds within the county were identified using the "ANSWERS" computer model developed in the Black Creek study. Major sediment sources and erosion problems were identified for the 13 priority watersheds. Followup contacts and inquiries were directed towards these priority areas. Ultimately, groups of local landowners and farm operators worked together to develop miniwatershed land treatment plans. A systematic sequence for BMP installation was developed and construction initiated. Major practices include waterways, chutes, drop structures, terraces, debris basins, and streambank protection.

Rural Clean Water Program (RCWP) in Washtenaw and Monroe Counties, Michigan, had a 200,000-acre program initiated in 1980, under Section 208(j) of the Clean Water Act, as amended. The approved BMP's and priority water quality project area were identified in an approved and certified 208 Water Quality Management Plan. The Saline Valley project was one of 13 experimental RCWP programs approved and funded through the USDA Agricultural Stabilization and Conservation Service. Administered through the local ASC County Committee, technical and education manpower support is being provided with RCWP funds along with BMP cost-share incentives. Major problems being addressed were cropland erosion, excessive sedimentation and nutrient loadings, wind erosion, and animal waste management. There are a variety of soils, sloping lands, and drainage conditions in the watershed. Project life expectancy is 6 to 8 years.

The Rural Clean Water Programs provide cost-sharing funds for implementation of best management practices, and are based on 208 Water Quality Plans which are not Lake Erie basinwide, and not tied specifically to phosphorus and water quality program needs of Lake Erie. RCWP money goes to designated basins with water quality problems. The Land Resource Information System could be used to choose these basins.

Although 208 agencies and Soil and Water Conservation Districts can prioritize problems for areas under their jurisdiction, they cannot prioritize problems basinwide for Lake Erie. LEWMS is the required link between the generalized conclusions of PLUARG and the detailed planning required to prioritize areas for implementation under the Clean Water Act of 1977. LEWMS is specifically aimed at lakewide improvement, in contrast to the RCWP which emphasizes improvement on a small regional scale.

6.6 POSSIBLE STRATEGIES FOR CONTROLLING SOIL EROSION AND IMPROVING WATER QUALITY

Soil loss reductions must be made in an economic and technical climate which provides strong incentives for farmers to produce row crops. Traditionally, increased row crop production results in higher soil erosion. Export demand for soybeans, corn, and wheat have grown immensely so that now 51 percent of the soybeans production, 36 percent of the corn production and 64 percent of the wheat production are exported. Lake Erie Basin farmers with their access to markets via the St. Lawrence Seaway have a distinct advantage in this export market. Under any soil loss reduction strategy, it must be remembered that strong economic pressures exist for continued production of row crops.

6.6.1 Cost Sharing.

Cost sharing, a direct subsidy of farmers' conservation practices, has been the heart of Federal soil conservation programs for decades. It promotes investments in conservation practices with the farmer bearing only a portion of the total investment but receiving all the on-farm benefits of the investment. The problem with the device is that Federal dollars are difficult to target on critical areas. Political expediency tends to encourage policy makers to make cost sharing widely available. It tends to be neither focused on areas, on farms within areas, or even problem areas on a farm where it would have the most impact. A recent GAO report was highly critical of past cost sharing conservation programs (Ref 9). The programs were cited for subsidizing profitable practices that farmers would do on their own. Furthermore, most of the funds were spent on practices which had a minor effect on soil erosion.

6.6.2 Technical Assistance and Education.

Along with cost sharing, technical assistance and education have played a large part in past programs. Especially when practices provide potential economic benefits to farms, technical assistance and education can speed the adoption process. The Soil Conservation Service and the Cooperative

Extension Service have had long histories in delivering the conservation message. Yet their work also has been criticized for failing to target programs on critical areas. Too often, too few technical assistance resources are available for a wide geographic area. Similarly, too few education resources are available to direct effective extension programs at the soil erosion problems.

6.6.3 Contracts Between Farmers and Government.

This strategy would allow farmers to contract for a reduction in soil erosion in exchange for a payment. The farmer would pledge to reduce soil erosion by X tons per acre. He would be allowed to select among tillage practices, crop rotations, or other conservation practices to achieve this level of soil erosion reduction. This strategy could target those areas that deserve the most attention. "The public would get what it pays for and only contract for what it needs" (Ref 10). Problems with this strategy would include the large public outlays required for farmers' payments and for monitoring farmers' soil reduction progress.

6.6.4 Soil Loss Tax.

A tax of $X per ton of soil erosion could be charged farmers. Ideally, the amount of the tax would be equivalent to the costs of soil erosion. The farmer would then be forced to internalize these costs into his production process. Theoretically, soil loss tax is attractive initially because it places the off-farm burden on soil loss back on the one producing it. However, a thorny issue surrounding the soil loss tax is property rights and equity. Farmers would argue that imposition of a soil loss tax would amount to the taking without compensation of some of the existing property rights tied to their land ownership. Others argue that equity calls for consumers to bear the burden, not farmers. Consumers vote for "nonconservation" through the market as they buy grain-fed beef and wear cotton clothing. If they had stronger conservation goals, they would buy grass-fed sheep and wear wool. Consumers prefer nonconservation products, and they should pay the cost of conservation, not farmers (Ref 11).

6.6.5 Regulation.

Of course, this is the primary strategy used to reduce environmental degradation in the United States. Setting soil erosion standards and enforcing them would be extremely costly due to the size of the basin (11.6 million acres) and the number of farmers (over 100,000) involved. This strategy would be extremely unpopular because of farmers' perception that rights would be taken without compensation. Furthermore, the politically conservative nature of basin farmers makes government regulation an unacceptable alternative to them (Ref 12).

Evidence points to the possibility of farmers voluntarily adopting soil conserving/water quality improving practices in the near future. The adoption of reduced tillage practices where economically practical appears to provide for improvement in Lake Erie water quality sufficient to meet water quality goals. Given marginal economic incentives, farmers are likely to voluntarily adopt these practices over time. But it seems appropriate to use the strategies which accelerate this adoption process. Technical assistance and education appears to be the best strategy. In addition, limited cost sharing might be used to provide stronger incentives for adoption.

REFERENCES

1. Honey Creek Joint Board of Supervisors, "Honey Creek Watershed Project, Final Program Evaluation Report, 1979-1981" LEWMS Report, U.S. Army Corps of Engineers, Buffalo District, January 1982.

2. Cahill, T.H. and Pierson, R.W., "Honey Creek Watershed Report," LEWMS Technical Report, Buffalo District, NY, March 1979.

3. "Land Management Alternatives In the Lake Erie Drainage Basin" LEWMS Technical Report, U.S. Army Corps of Engineers, Buffalo District, March 1979.

4. "Sandusky River Watershed Management Study," LEWMS Technical Report, U.S. Army Corps of Engineers, Buffalo District, October 1981.

5. "West Branch Rocky River Watershed Management Study" LEWMS Technical Report, U.S. Army Corps of Engineers, Buffalo District, January 1981.

6. "Bean Creek Watershed Management Study," LEWMS Technical Report, U.S. Army Corps of Engineers, Buffalo District, July 1981.

7. "Ottawa River Watershed Management Study," LEWMS Technical Report, U.S. Army Corps of Engineers, Buffalo District, April 1981.

8. "South Branch Cattaraugus Creek Watershed Management Study" LEWMS Technical Report, U.S. Army Corps of Engineers, Buffalo District, January 1981.

9. U.S. General Accounting Office, "Report to the Congress of the United States: To Protect Tomorrow's Food Supply, Soil Conservation Needs Priority Attention," CED-77-30. February 14, 1977b.

10. Brubaker, Sterling, and C. N. Castle "Alternative Policies and Strategies to Achieve Soil Conservation," Symposium on Policy Institutions and Incentives for Soil Conservation, May 1981.

11. Head, Earl O., "Trade Offs Betwen Soil Conservation Energy Use, Exports and Environmental Quality," Symposium on Policy, Institutions and Incentives for Soil Conservation, May 1981.

12. Forster D. Lynn and George L. Stem, "Adoption of Reduced Tillage and Other Conservation Practices in the Lake Erie Basin." LEWMS Technical Report, Corps of Engineers, Buffalo District, November 1979.

CHAPTER 7 - RECOMMENDED PROGRAM

7.1 INTRODUCTION

This chapter presents a program for the reduction of phosphorus loads into Lake Erie. Chapter 5 showed that the 1,700 mt/yr total phosphorus reduction required by Annex 3 of the 1978 Great Lakes Water Quality Agreement could be achieved by a program to accelerate the adoption of reduced tillage and no till. This program is in addition to programs presently in effect for removal of phosphorus to 1 mg/l in the effluent of municipal wastewater treatment plants discharging more than 1 million gallons per day, and the on-going programs described in Chapter 6. It also assumes that the programs now carried out by the U. S. Department of Agriculture will continue at their present level of funding. Any change in this level would increase the recommended program requirement. Also presented in this chapter is a program for monitoring the effects of the recommended program. It includes provisions for measuring acceptance rates, tributary loads and water quality changes in the lake. The costs of the accelerated program are compared with the costs of other methods of keeping phosphorus from entering the lake. Finally the cost of a program which would reach the loading objective is presented.

7.2 ACCELERATED TECHNICAL ASSISTANCE PROGRAM

7.2.1 Introduction.

The recommended program for reduction of sediment phosphorus loadings to Lake Erie is a locally oriented demonstration/implementation program focusing on conservation tillage and fertility management. Reducing the amount of tillage done on basin farms has proven to be the most cost-effective means of controlling erosion and sediment phosphorus transport, both from the standpoints of farm operators and governmental agencies. This type of program will be conducted in 20 counties selected from Land Resource Information System data as having highest priority for treatment. Each county will receive provisional funding for 5 years, and it is expected that all counties will have completed their projects within 10 years of initial funding for the first counties participating.

The projects will involve a locally-based technical staff whose main responsibilities will be to carry out an intensive educational and technical assistance program dealing with conservation tillage. This approach has proven quite effective in accelerating the rate of adoption of conservation tillage practices in the Honey Creek area (Ref 1). Many counties in the basin are currently attempting their own demonstration efforts, but lack sufficient funding to attempt such a concentrated effort. Since interest in conservation tillage is quite high among farmers at the present time and educational-technical assistance programs have proven effective, increased funding in this area would be fully warranted.

7.2.2 Counties Involved.

Twenty counties have been selected to receive project funding under the proposed program. The criteria used to rate the counties was the number of acres in the county on which conservation tillage is projected to be adopted, the reduction in soil loss which could be achieved, and a factor weighting the potential of the county for phosphorus transport. These counties are listed in Table 7.1. Five additional counties are also listed. These counties could replace those counties on the original list where programs could not be developed, or where compatible programs are already in place. Each county would be required to submit a proposal for work to be accomplished during the program. Counties which do not develop adequate proposals would be replaced by lower priority counties.

Selection of these 20 counties effectively encompasses the areas of the Maumee and Sandusky River Basins characterized by soils most easily adopted to reduced tillage. Acceptance of reduced tillage practices should be high in these counties, as will be the reductions in sediment phosphorus transported from them.

Table 7.1 - Counties to be Included in the Sediment Phosphorus Reduction Program

Ohio	Indiana	Michigan
Allen	Allen	Hillsdale
Auglaize		
Crawford	DeKalb (1)	Lenawee
Defiance (1)		
Fulton		Monroe (1)
Hancock		
Henry		Washtenaw (1)
Huron		
Lorain		
Medina		
Mercer		
Paulding (1)		
Putnam		
Sandusky		
Seneca		
Van Wert		
Williams		
Wood		
Wyandot		

(1) Counties not in the top 20.

7.2.3 Project Management.

Choices must be made as to the Federal funding agency which will distribute project allocations, and as to which local agency will receive and administer them. Experiences in the Honey Creek project have shown that the Corps of Engineers would be the logical contracting agency, while local Soil and Water Conservation Districts would be logical recipients.

Despite the agricultural nature of these projects, the Corps of Engineers has proven its ability to carry out a similar project in the Honey Creek watershed. The advantages of contracting directly with local districts have been stated previously (Ref 2), including already established program priorities in the area of soil erosion control. Routing funds from the Corps of Engineers directly to local districts would eliminate many problems. One major reason for the success of the Honey Creek project was that the local Supervisors answered directly to the Corps, an arrangement which improved communication greatly. This approach is a proven one, and should be continued.

7.2.4 Program Staffing.

The major staffing requirements for this program are at the county level and include a project conservationist and a field technician. The conservationist would handle the administration aspects of the project, reporting, organizing activities, and overseeing the duties of the technician. He will also participate directly in activities directed at establishing conservation tillage and allied practices on the land. The technician would be directly responsible for establishing field demonstration plots, collecting and organizing information pertaining to the plots, and for providing technical assistance to local farmers experimenting with conservation tillage practices. The technician should have training in the area of crop production, since this project will focus on management rather than engineering methods for achieving sediment reductions.

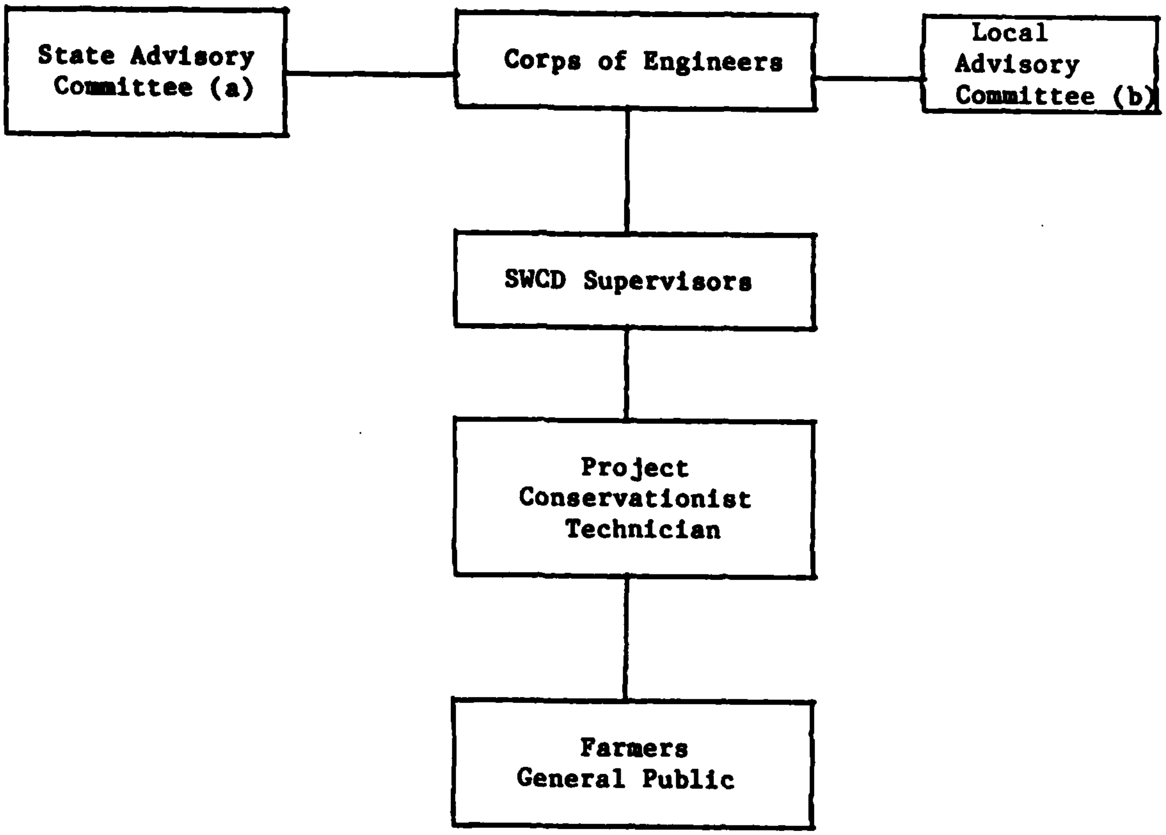
Coordination of the 20 individual projects would best be accomplished through a program office established at the U. S. Army Engineer District at Buffalo. Since Corps involvement would largely be restricted to coordination of projects, and distribution and accounting of funds, one staff member, charged specifically with administering the projects would be sufficient. A basin-wide position will be established for both SCS and the Cooperative Extension Service. Both positions would be responsible for the training of local project personnel and the setting up of administrative frameworks for each county.

7.2.5 Activities of Local and State Agencies.

Though the Federal and State agencies normally associated with agricultural and sediment control activities (ASCS, CES, EPA, SCS) will not be involved in administration, and projects will normally operate independently, the supporting activities of these agencies are vital to program success. The programs cannot maintain credibility or acceptance without interagency support. This support should come in two general ways - formation of advisory groups and providing of ancillary services to amplify the work of the projects. (Figure 7.1)

Project advisory groups should be formed at the local and State levels. At both levels, agency personnel should be willing to allocate time to advising projects on best courses of action. The local advisory groups would meet with the project staff of its own area at least four times per year, while the State advisory group might meet in a joint session with all project staffs in its particular State, once or twice per year.

Figure 7.1 - Organization of County Projects



(a) SCS, ASCS, CES, EPA
(b) SCS, ASCS, CES

The local advisory group would be composed of the local county extension agent, district conservationist, ASCS director, an SWCD administrator, and other interested local leaders, including those from agribusiness. The group would meet with the entire project staff and interested SWCD Supervisors to discuss project direction, performance and needs at the local level.

The State groups would be composed of State and area level representatives of ASCS, CES, EPA, SCS, and State Department of Natural Resources. They would probably meet in joint session with managers from all projects. Such an interaction would enable State agencies to have input to the projects, allow some Statewide coordination of efforts, and would allow project managers to voice concerns best expressed at the Statewide level. The experience in the Honey Creek project has been that these advisory groups were quite important in maintaining good relations between the projects and agencies, and provided for effective guidance.

At the local level, however, the most important functions of the local agencies will be activities in support of, or paralleling, the county project. For the projects to be most effective, the local populace must be aware that their local leaders support the same ends. The local SWCD, of course, will be directly responsible to the Corps of Engineers for project administration through its Board of Supervisors. SWCD would also provide housing for the project, plus publicity and technical assistance.

The Cooperative Extension Service would be a key support agency for the projects because it is the one agency which possesses an expertise in crop management. The extension agents would advise the projects on best methods of managing reduced tillage systems, including pesticide selection and use, cropping systems, fertility management, etc. The extension agents would also hold educational meetings and prepare materials for distribution dealing with reduced tillage, both for the project staff and the public. Providing adequate information to farmers is the best way to maintain adoption.

The Soil Conservation Service would provide information on field suitability for reduced tillage, and also indicate which fields may require further measures to control erosion. Such information is quite important as it will enable the project staff to concentrate on areas which have the greatest need for treatment. SCS would also provide other technical assistance to the project staff.

The Agricultural Stabilization and Conservation Service could provide cost-sharing incentives to those farmers beginning to use reduced tillage. It is hoped that counties involved in the projects would receive enough funding through normal channels to allow for a cost-sharing program which would support most of the farm cooperators in the early start up of a conservation tillage program on an individual farm.

7.2.6 Project Approach.

The majority of the project's initial year will be devoted to laying a firm foundation. During this time, the newly-hired project conservationist will meet with and enlist the cooperation of local agency and agribusiness persons, establish advisory committees, hire the technician, secure necessary equipment, sign up initial farm cooperators, and begin an extensive information/education program.

A strong information education program is critical to project success. This program should have two main objectives - to promote the project itself, and to provide farmers with the best possible information on conservation tillage. The program should include both mass media and meeting approaches and should involve local agency personnel. As the project progresses, the emphasis of the programs will shift from promotion to more education.

Beginning in the second year, the technician will be responsible for establishing demonstration plots and providing technical assistance to other farmers who are interested in conservation tillage, but are not directly involved in demonstrations. Careful records of cultural practices used on demonstration plots will be kept. Results of demonstration plots will be made available to the public on a yearly basis, and demonstration plots will be used as teaching aids at project-sponsored field days throughout the summer.

The combination education/demonstration/technical assistance program will continue for 4 years. During this time, the rate of adoption of reduced tillage will be monitored and reported to the Corps of Engineers by the Supervisors. Continued funding for an individual project during these 4 years will be contingent upon demonstrating increased adoption of reduced tillage. This should pose little problem for a given county, however, since the experience of past projects has been that technicians normally receive more requests than they can honor.

A time table for main project activities is given in Figure 7.2.

7.2.7 CRISPS and LRIS.

County Resource Information System Packages were prepared for 28 counties during Phase II. They have been described in the previous Chapter. CRISPS have proven to be valuable land and water resource planning tools for the local level of government. The potential gross erosion, soil management groups, and best management practice applicability maps are especially useful planning tools for this program. This work element would not only produce CRISPS for the counties in the project, but also for the remaining Lake Erie Counties.

When the data now in the LRIS were originally coded, the best available soil surveys were used. Nine counties had only old reconnaissance surveys, and data from modern soil surveys in progress were coded for 24 counties. Thirteen of the surveys have now been completed and would be available for coding for the LRIS. The LRIS can also be used with LANDSAT imagery to monitor the implementation rates for reduced tillage. Multitemporal scenes have been used to monitor land cover (Ref 3), and these techniques would be used to measure acceptance rate of conservation tillage.

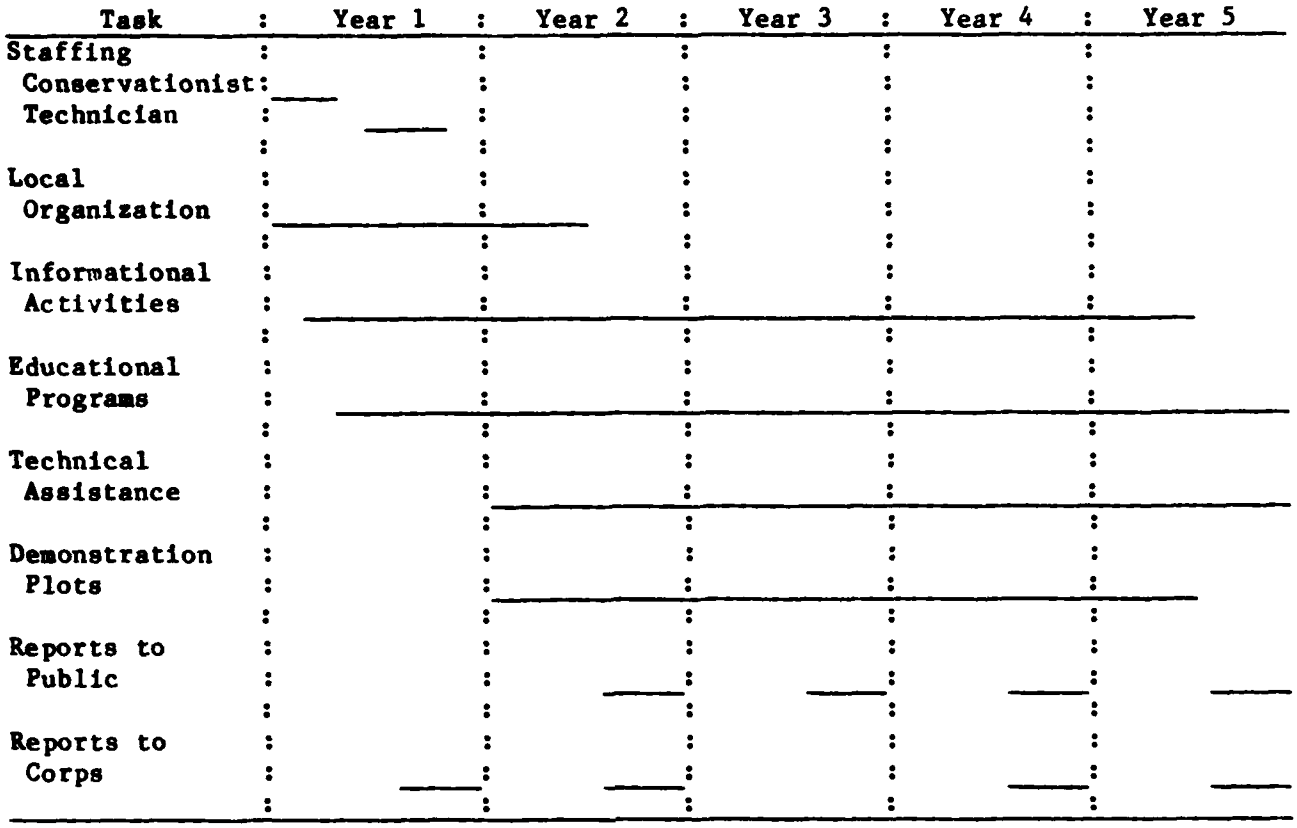


Figure 7.2 Timetable for Program Execution

7.2.8 Program Costs.

The projected costs for a given county project are given in Table 7.2. This budget assumes a 5-year salary for the project conservationist and 4 years for the technician. This represents the bulk of program costs. There is no cost sharing figured into this budget, as it is assumed that cost sharing will be available from ASCS. Table 7.3 shows the costs for the entire project. Included in the total are costs for the involvement of an Extension Agronomist and a Resource Conservationist for the full 10 years of the project. Also included are costs for the Corps of Engineers to administer the project as well as costs for the CRISP packages, the soil updates, and the monitoring of acceptance rates.

Table 7.2 - Costs for County Demonstration/Implementation Projects

Component	5-Year Cost
	$
Personnel Salaries	
Conservationist (5-years, at $25,000)	125,000
Technician (4-years, at $18,000)	72,000
Secretary (5 years, halftime at $7,500)	37,500
Fringe Benefits (at 20 percent of salary)	46,900
Overhead (at 25 percent of salary)	58,600
Publications	10,000
Travel	20,000
Telephone	5,000
Equipment	30,000
County Total	405,000
20-County Program Total	8,100,000

Table 7.3 - Program Costs for 10-Year Period

Program Costs	10-Year Period
$	$
20-County Cost at 405,000	8,100,000
Resource Conservationist SCS at 72,000/yr. (1)	720,000
Extension Agronomist at 64,000/yr. (1)	640,000
Corps of Engineers at 75,000/yr. (1)	750,000
Education Program Publications and Consulting Including Extension and University	650,000
30 CRISP Package at 6,000	180,000
18 Soils Updates at 6,000	108,000
Monitor Land Cover	150,000
Total	11,298,000

(1) Includes fringe benefits, travel, and office overhead.

7.3 MONITORING

7.3.1 Tributary Monitoring.

The tributary monitoring program described here is designed to measure change in sediment nutrient and pesticide loads resulting from the recommended program. In order to accomplish this purpose, acceptable baseline data must be available. The only stations with the required data bases are the Maumee River, Portage, Sandusky (9 Stations), and Huron Rivers. As described in Chapter 3, the annual variability in sediment, nutrient transport are well characterized at these stations. The Honey Creek and Upper Honey Creek are priority areas because it is anticipated that large shifts toward no till and conservation tillage will occur in Honey Creek, thus changes in nutrient loads attributable to the program can be measured there. The costs of the required tributary monitoring program are shown in Table 7.4. The program will monitor six rivers for a total of 5 years. Funds are also included for data interpretation, calculations, report preparation, and contract administration.

Table 7.4 - Annual Cost Estimate for Tributary Monitoring

Tributary	Flow	Continuous Monitoring of Nutrients	Pesticides	Total
	$	$	$	$
Honey Creek	6,500	15,000	6,000	27,500
Upper Honey Creek	6,500	15,000	6,000	27,500
Maumee River	6,500	15,000	6,000	27,500
Portage River	6,500	15,000	6,000	27,500
Huron River	6,500	15,000	6,000	27,500
Sandusky River	6,500	15,000	6,000	27,500
Total	39,000	90,000	36,000	165,000

Five years of Monitoring at $165,000	=	$825,000
Five-year Contract Administration at $15,000	=	75,000
Calculations and Reporting	=	50,000
Total		$950,000

7.3.2 Lake Monitoring.

The Surveillance Subcommittee of the Great Lakes Water Quality Board developed a Great Lakes International Surveillance Plan (GLISP) (Ref 4). The document presents the basic framework for surveillance activities in the Great Lakes Basin as required in the 1978 Water Quality Agreement between the United States and Canada.

The surveillance plan is a long-term strategy to coordinate the monitoring activities of the many participating agencies in a cost-effective manner. In this regard, the plan is characterized by quality assurance programs and the rapid exchange of comparable data among the various jurisdictions.

The plan is a framework to facilitate long-term planning of monitoring programs. It is a planning document which provides a basis for identifying future resource needs for monitoring, and a means for coordinating the monitoring programs of various State, Provincial and Federal agencies. The plan facilitates research planning so that research can make maximum use of monitoring facilities.

The fundamental objective of the Great Lakes International Surveillance Plan is to determine the impact of man's activities on the quality of the Great Lakes ecosystem, particularly the effect of these activities on the desired uses of the lakes. Data obtained from the surveillance program is interpreted:

a. To determine the state of compliance with jurisdictional control requirements and with the general and specific objectives of the 1978 Great Lakes Water Quality Agreement, including an assessment, where possible, of the significance of any violation;

b. To assist managers of remedial programs in the design and implementation of such programs, including an evaluation of their effectiveness;

c. To identify emerging problems; and

d. To identify the need for special studies to improve the understanding of phenomena and/or trends observed as a result of the surveillance program.

The Great Lakes International Surveillance Plan is an important element in the overall Great Lakes water quality process. This process relies on analysis, interpretation and communication of information obtained from monitoring material inputs as well as from observing the immediate and longer term effects of these inputs. Determining the implications of these effects is often dependent on research to provide an understanding of the physical, chemical and biological processes at work in the system, and their interrelationships. Information analysis and interpretation includes evaluating trends, determining compliance with water quality objectives and jurisdictional control requirements, assessing the significance of violations and relating causes (material inputs) to effects (ecosystem quality). Results provide management with the information needed to establish policies, to determine the effectiveness of management actions and to plan future strategies.

Elements in GLISP change annually in response to program resources and information learned in previous years. The USEPA Great Lakes National Program Office carries out the main lake monitoring for Lake Erie. It is essential that this activity continue to be funded if the main lake effects of the recommended program are to be determined.

7.4 BENEFITS AND COSTS OF THE RECOMMENDED PROGRAM

7.4.1 Unit Costs.

This section compares the cost of the recommended program with alternative methods of reducing phosphorus inputs into Lake Erie. Annex 3 of the 1978 Great Lakes Water Quality Agreement requires that the United States reduce the total phosphorus load by 1,700 mt/yr after wastewater treatment plants discharging in excess of 1 million gallons per day reach a maximum effluent total phosphorus concentration of 1 mg/1. It was seen in Chapter 5 that the accelerated program would achieve this reduction by reducing the diffuse source phosphorus load from the United States by 2030 mt/yr. Over the 20-year life of the program, 32,900 metric tons of phosphorus would be prevented from entering Lake Erie. The existing program would account for a

20-year reduction of 12,600 metric tons. Therefore, the incremental reduction which could be attributed to the accelerated program would be 20,300 metric tons. At a total program cost of $12,248,000 (includes the tributary monitoring costs) it would cost $0.60 per kilogram of total phosphorus reduced. This unit cost is compared with alternative methods of phosphorus reduction in Table 7.5. The municipal costs shown in the table were extracted from a report to PLUARG by Drynan (Ref 5). They were computed by utilizing a computer model which developed capital and operating costs to achieve various levels of phosphorus removal at 43 major municipal wastewater treatment facilities in Lake Erie and Ontario drainage basins. Capital costs required to build the facilities in 1975 and expand them as necessary over a 25-year period were simulated. Costs for sludge treatment and disposal were included. The capital costs were updated to the 4th quarter 1981 values using USEPA's construction cost index for wastewater works and an escalation index for operation and maintenance.

The costs for urban diffuse source controls were taken from a report to PLUARG by Johnson et al (Ref 6). Level 1 controls are a program of pollutant reduction at the source. They include an extensive street-sweeping program plus measures to reduce flow. Level 2 controls include detention and sedimentation of stormwater and overflows in addition to the Level 1 measures. Costs for Level 1 activities were updated using the escalation index for operation and maintenance since they involve mostly labor-related activities. The costs for the Level 2 program were updated in the same manner as the costs for point source control. The costs for the rural diffuse source controls were taken from Logan (Ref 7).

The unit costs ($/kg) of total phosphorus controlled were multiplied by the percent of the available phosphorus in order to obtain the unit cost in $/kg of biologically available phosphorus controlled ($/kg BAP). It can be seen from the table that the accelerated program costs $2.40/kg BAP. Conservation tillage, and fertility management which are major elements of the recommended program show zero costs to the farmer. Actually barnyard runoff control is another practice which could be recommended by the program as well as low cost manure storage and spreading practices. However, the phosphorus reduction achievable from these sources is less than 100 mt/yr.

The projected costs of the proposed program probably are overestimated. Adoption of conservation tillage practices on suitable soils may result in an increase in net farm income as discussed previously. In addition, reduced soil erosion through conservation tillage would improve future soil productivity. Research on the economic benefits of soil productivity maintenance shows the returns to be relatively modest for most farmers. When these future benefits are discounted to the present, they become almost insignificant to present land users. But today's protection of soil resources could be important to future generations.

Other economic benefits of the proposed program include reduced "downstream" costs. Reducing soil erosion would decrease sediment deposits in drainage ditches, for example. Research conducted during this study indicated that a one ton per acre decrease in annual gross erosion would be

Table 7.5 - Costs of Phosphorus Reduction Methods

Method	Total Phosphorus $/kg	Percent Biologically Available Phosphorus	$/kg of Biologically Available Phosphorus
URBAN POINT SOURCES (1)			
Reduction of Sewage Treatment Effluent Concentration			
1.0 mg/l to 0.5 mg/l	8.00	75 (4)	10.70
		25 (5)	32.00
0.5 to 0.3 mg/l	121.00	75	161.00
		25	484.00
URBAN NON-POINT SOURCES (2)			
Level 1 - Program of Pollutant Reduction at Source	128.00	25	512.00
Level 2 - Level 1 Measures Plus Detention and Sedimentation	258.00	25	1,030.00
RURAL NON-POINT SOURCES (3)			
No Till and Conservation Tillage	0	25	0
Cover Crops	276.00	25	1,100.00
Critical Area Seeding	326.00	25	1,300.00
Coutour Stripcropping	82.00	25	330.00
Diversions	2,640.00	25	10,600.00
Waterways	97.00	25	390.00
Vegetative Filters	30.00	25	120.00
Runoff Control Structures	368.00	25	1,470.00
Terraces	73.00	25	290.00
Tile Drains	9,180.00	25	36,720.00
Manure Storage and Spreading	4.40	75	5.90-36.3
	27.20		
Barnyard Runoff Control	2.20	75	2.90
Fertility Management	0	25	0
Fertilizer Placement	44.00	25	176.00
ACCELERATED PROGRAM	0.60	25	2.40

(1) Urban Point source costs from Drynan (Ref 5) Capital costs were updated using EPA's construction cost index for wastewater works and an escalation index for operation and maintenance.

(2) From Johnson et. al (Ref 6) Level 1 updated, using an escalation index for operation and maintenance. Level 2 update in the same manner at the point source control.

(3) Rural nonpoint source costs from Logan (Ref 7).

(4) From DePinto et. al (Ref 8).

(5) Point source phosphorus on tributaries is delivered in the same form as tributary nonpoint source.

accompanied by a 0.079 ton decrease in sediment deposits in nearby drainage ditches. The benefit of reducing soil erosion on cropland with a nearby drainage ditch was estimated to be $0.12 per ton of reduced soil erosion.

"Downstream" benefits of the proposed program also includes reduced water treatment costs, reduced harbor dredging, and increased recreational and aesthetic benefits. The value society places on aesthetic and recreational benefits is difficult to determine because they are not traded in the market, and no prices are available. However, one study estimated the impact of Maumee Basin soil erosion on water treatment costs to be $1.90 per ton of soil erosion (Ref 9). Dredging costs for 2.4 million cubic yards of material removed from Lake Erie are approximately $8.0 million per year. Disposal sites for the dredged material added an additional $5.6 million per year, resulting in a total cost of $4.80 per ton of material removed. As seen from the previous chapter, cost of the recommended program could be as low as $0.06 per ton of soil erosion stopped.

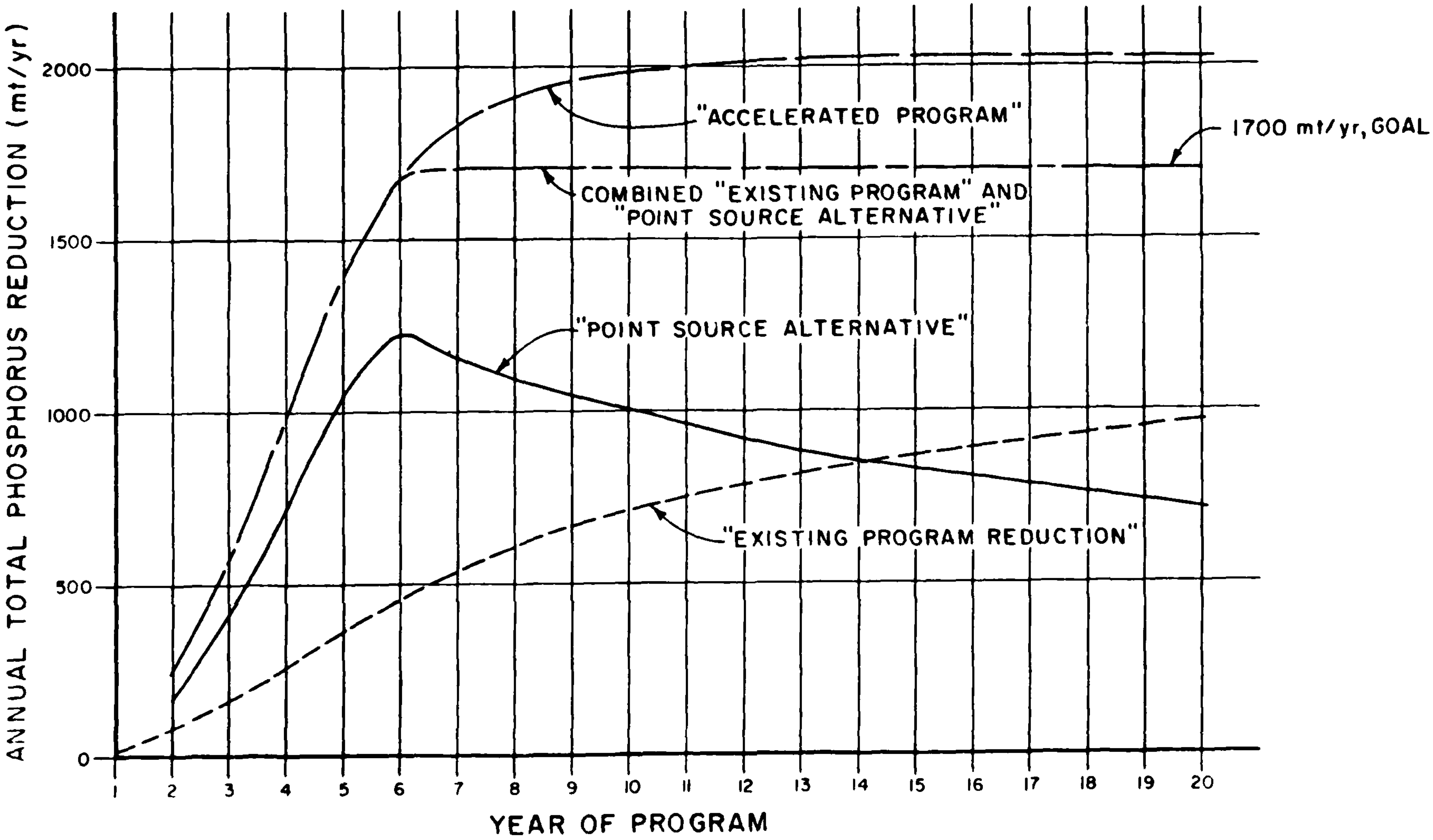
After the recommended program the next most cost effective step would be phosphorus removal at direct point sources to 0.5 mg/l ($10.70/kg BAP followed by vegetative filters ($120/kg BAP) and point source phosphorus removal at direct point sources to 0.3 mg/l ($161/kg BAP). However, if the point sources are located on tributaries the bioavailable phosphorus is in the same form as tributary nonpoint source phosphorus (Chapter 3). Therefore, the unit costs for removal to 0.5 mg/l and 0.3 mg/l increases to $32/kg BAP and $484/kg BAP respectively. Urban non-point source controls range from $512/kg BAP for Level 1 to $1,030/kg BAP for Level 2 practices. The remaining rural non-point source phosphorus control practices range from $176/kg BAP for fertilizer placement to $36,720/kg BAP for tile drains.

7.4.2 Benefit/Cost Ratios.

The accelerated program and phosphorus removal to 0.5 mg/l at point sources located directly on the lake are the only phosphorus control methods which are economically comparable. Additional phosphorus removal to 0.3 mg/l or phosphorus removal at point sources on tributaries are many times more expensive. Other rural nonpoint source controls and urban nonpoint controls are at least an order of magnitude more expensive in terms of control of biologically available phosphorus. This section compares the annual cost for reaching the 1700 mt/yr reduction if achieved by the accelerated program with the cost of phosphorus control at point sources. Figure 7.3 shows the annual phosphorus reductions which result from the existing program, the accelerated program, and the point source reduction required. The required point source reduction was calculated as the difference between the existing program and the accelerated program. When the accelerated program produces a reduction greater than 1,700 mt/yr, the point source reduction required is the difference between the existing program and 1,700 mt/yr. After 6 years the point source reduction required decreases every year because of the increased reduction brought about by the existing rural diffuse program. The total reduction required from point sources over 20 years is 16,090 mt. At a cost of $8.00/kg the 20-year cost of a point source program is $128.7 million or an annual cost of $6.43 million. The annual cost for the accelerated program is $612,400 giving a benefit cost ratio of 10:1.

Figure 7.3 ANNUAL PHOSPHORUS REDUCTIONS RESULTING FROM VARIOUS CONTROL PROGRAMS

(REQUIRED REDUCTION, 1700 mt/yr)



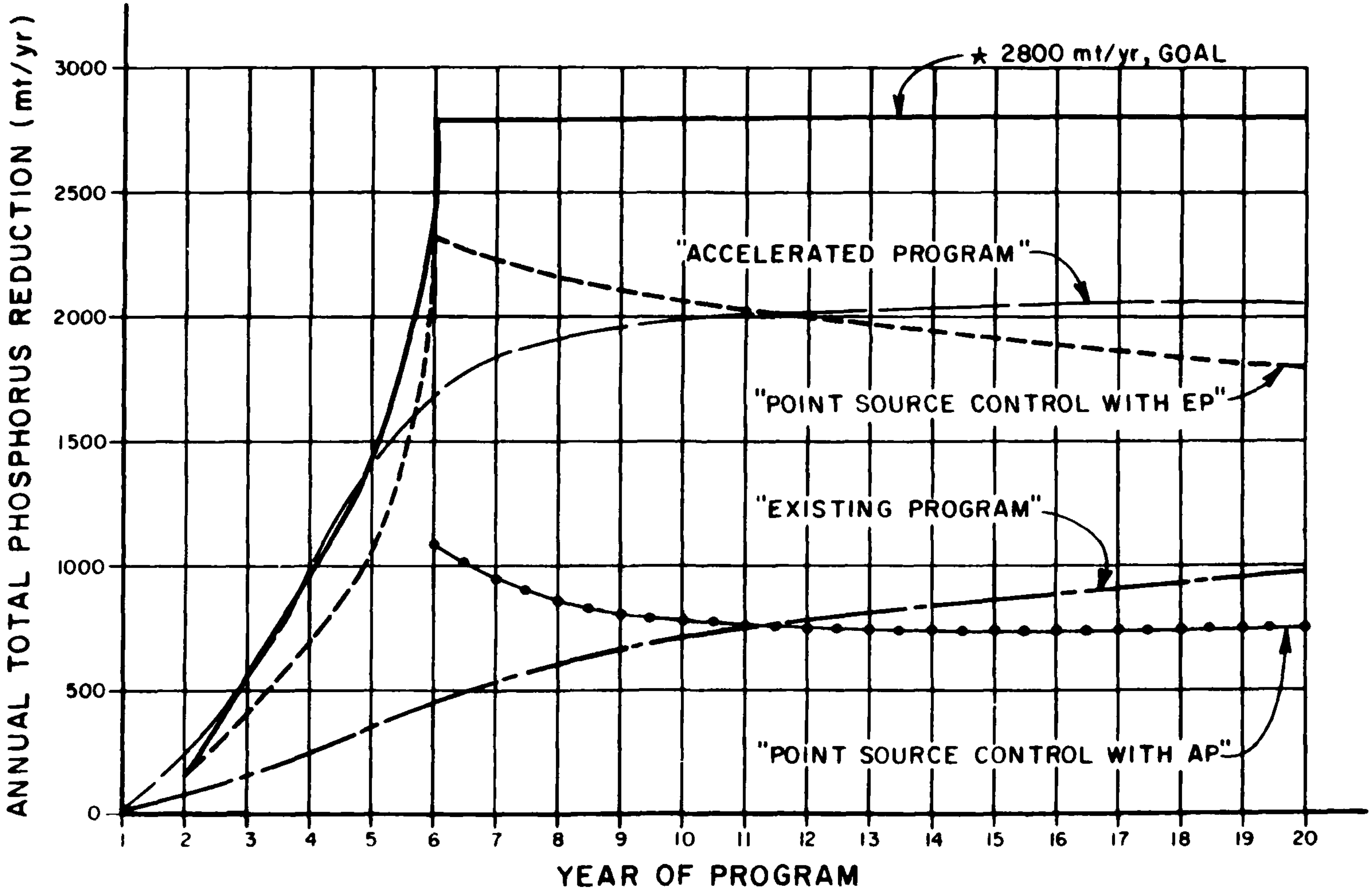
Another scenario for phosphorus reduction is presented in Figure 7.4. In this case it is assumed that a total reduction of 2,800 mt/yr is required on the U. S. side. This increased phosphorus load reduction would result from using the phosphorus loading number shown in Table 4.2 and assuming that the U. S. contribution to reach the 11,000 mt/yr loading objective is proportioned the same as the diffuse source load (a 4,025 reduction required and the U. S. share is 69 percent) It could also result from a decrease in the phosphorus loading objective during the 1983 review of the Great Lakes Water Quality Agreement or population growth resulting in a larger point source load.

Shown in Figure 7.4 are the required reductions in point sources in addition to the accelerated program (a total of 12,345 mt over 20 years) and the point source reduction required if the accelerated program is not implemented (a total of 32,605 mt over 20 years). An additional 20,260 mt are required to be removed at point sources without the accelerated program.

Phosphorus removal to 0.5 mg/l at a cost of $8.00/kg can account for 18,025 mt of the 32,605 mt reduction. The remaining 14,580 mt must be removed by technology which can reach an effluent concentration of 0.3 mg/l at a cost of $121.00/kg. The total cost of the alternate program is $1,908 million or an annual cost of $95.4 million. The additional point source removal for the accelerated program is 12,345 mt at $8.00/kg, a $98.7 million addition to the program costs of $12.88 million or $5.58 million/yr for the total program. The benefit cost ratio for the accelerated program with additional point source removal is 17:1.

Figure 7.4 ANNUAL PHOSPHORUS REDUCTIONS RESULTING FROM VARIOUS CONTROL PROGRAMS

(REQUIRED REDUCTION, 2800 mt/yr)



★ EITHER DIFFUSE SOURCE PROGRAM ACHIEVES GOAL WITH APPROPRIATE POINT SOURCE CONTROL PROGRAM

REFERENCES

1. Honey Creek Joint Board of Supervisors, "Honey Creek Watershed Project, Final Program Evaluation Report 1979-1981," LEWMS Technical Report, Buffalo, NY, January 1982.

2. U. S. Army Corps of Engineers. "Lake Erie Wastewater Management Study Methodology Report." Buffalo, NY, March 1979.

3. Walsh, M. B., "Landsat Eight Band Two Season Land Cover Classification Compared with Aerial Photographic Interpretation of the Toledo, Ohio Area," Environmental Research Institute of Michigan, Ann Arbor, MI, September 1979.

4. Great Lakes Water Quality Board, Surveillance Subcommittee, "The Great Lakes International Surveillance Plan," International Joint Commission, Windsor, Ontario, 1979.

5. Drynan, W. R., "Relative costs of Achieving Various Levels of Phosphorus Control at Municipal Wastewater Treatment Plants in the Great Lakes Basin." Prepared for the Pollution from Land Use Activities Reference Group of the International Joint Commission, Windsor, Ontario, 1978.

6. Johnson, M. G., J. Comeau, W. C. Sonzogni, T. Heidtke and B. Stahlbaum, "Management Information Base and Overview Modeling." Prepared for the Pollution from Land Use Activities Reference Group of the International Joint Commission, Windsor, Ontario, 1978.

7. Logan, T. J., and D. L. Forster, "Alternative Management Options for the Control of Diffuse Phosphorus Loads to Lake Erie," LEWMS Technical Report, Buffalo, NY, July 1982.

8. DePinto, J. V. et al, "Phosphorus Removal in Lower Great Lakes Municipal Treatment Plants," USEPA, Cincinnati, OH, 1980.

9. Abraham, G. "Crop Production, Soil Erosion and the Environment in the Maumee River Basin, A Modelling Approach," PhD Thesis, Ohio State University, Columbus, OH, 1981.

CHAPTER 8 - CONCLUSIONS

8.1 THE WESTERN BASIN AND WESTERN CENTRAL BASIN OF LAKE ERIE HAVE ALGAL GROWTH PROBLEMS WHICH WILL REQUIRE PHOSPHORUS REDUCTIONS IN ADDITION TO THOSE PROVIDED BY POINT SOURCE REMOVAL.

This conclusion is based on our current knowledge of tributary loadings to Lake Erie, the reductions we know can be achieved through point source control programs being implemented at this time and our understanding of the Lake's response to phosphorus inputs. The 11,000 metric tons per year total phosphorus loadings, now felt to be the level at which satisfactory conditions can be achieved, will be reached through diffuse source control or additional point source control.

8.2 THE RIVER BASINS WHICH DRAIN INTO THE WESTERN BASIN AND WESTERN CENTRAL BASIN OF LAKE ERIE ARE CONTRIBUTING AREAS OF DIFFUSE PHOSPHORUS LOADS.

This conclusion is based upon results of intensive stream monitoring which showed that these areas contribute high unit area phosphorus loads.

8.3 THE ENTIRE WATERSHEDS OF THESE RIVERS ARE HYDROLOGICALLY ACTIVE AREAS AND CONTRIBUTE DIFFUSE PHOSPHORUS LOADS TO LAKE ERIE.

This conclusion is based on the following observations:

a. Most of the phosphorus export occurs in late winter and early spring periods when soils are saturated and runoff occurs over the entire basin.

b. Fine textured soils occur throughout this area and are the major contributing source of high runoff and phosphorus transport.

c. Soil phosphorus levels are high throughout this area.

d. Intensive row crop agriculture is the predominant land use throughout the area.

8.4 A PROGRAM FOR CONTROL OF PHOSPHORUS FROM DIFFUSE SOURCES SHOULD BE BASED ON PRACTICES WHICH HAVE THE LOWEST COST PER TON OF PHOSPHORUS STOPPED FROM REACHING THE LAKE.

This conclusion is based on our findings that many agricultural soil conservation practices although vital to the preservation of the long-term productivity of the soil, do not contribute significantly to the reduction of phosphorus transport. Such practices are too costly to receive emphasis in a diffuse source phosphorus control program.

8.5 CONSERVATION TILLAGE ON SUITABLE SOILS IS THE MOST COST-EFFECTIVE MEANS OF REDUCING SEDIMENT PHOSPHORUS LOADS TO LAKE ERIE.

This conclusion is based on research and field demonstrations which show that practices which preserve crop residues on the surface of the land, and prevent the impact of raindrops on bare soil, are highly effective in reducing sediment and phosphorus transport. Conservation tillage is such a practice, and has been shown to be implementable at minimal net cost to the farmer.

8.6 A MAJOR NEED FOR IMPLEMENTATION OF DIFFUSE SOURCE POLLUTION CONTROL IN THE LAKE ERIE WATERSHED IS ADDITIONAL TECHNICAL ASSISTANCE AT THE FIELD LEVEL TO INCREASE USE OF CONSERVATION TILLAGE PRACTICES.

This conclusion is based on the following observations:

a. The provision of high quality technical assistance at the field level was found to be the most important precursor for accelerated adoption of conservation tillage.

b. Special training programs for conservation tillage specialists are needed.

c. Technical assistance is needed in addition to cost-sharing, education, and information programs.

8.7 FERTILITY MANAGEMENT WILL AID IN THE REDUCTION OF THE DIFFUSE PHOSPHORUS LOAD TO LAKE ERIE.

This conclusion is based on the following observations:

a. Dissolved phosphorus losses from agricultural land are directly proportional to plant available phosphorus levels in cropland soils.

b. Plant available phosphorus levels in Michigan and Ohio soils have been increasing steadily and are generally in excess of levels necessary for optimum crop production.

c. Reduction of plant available phosphorus levels to the level necessary for optimum crop production will reduce dissolved phosphorus losses from cropland.

d. Plant available phosphorus levels would increase in the surface layer through conservation tillage.

8.8 ALTHOUGH INCREASED ADOPTION OF CONSERVATION TILLAGE WILL RESULT IN GREATER PESTICIDE USAGE, PESTICIDE LOSSES TO THE ENVIRONMENT WILL DECREASE SLIGHTLY OR REMAIN CONSTANT.

This conclusion is based on research findings that the pesticides recommended in conservation tillage systems are associated with soil and organic

matter retained on the land surface. Also, runoff may be reduced in conservation tillage systems. Pesticide losses in the runoff are effectively reduced.

8.9 THE HONEY CREEK DEMONSTRATION CONFIRMS THE VALIDITY OF THE PROJECT APPROACH IN ADDRESSING WATER QUALITY PROBLEMS.

Specific findings of the Honey Creek Watershed Management Study which have been incorporated in the Recommended Program include:

a. A start-up period, lasting as long as 2 years in some cases, is a necessary step to insure uniform awareness of the program, and to establish the required organization and staffing for full implementation.

b. Additional county personnel qualified to provide technical assistance in agronomic practices are essential for success.

c. A high level of exposure of the project goals and early implementation efforts are necessary to create the climate for landowner and agency support.

d. A project-wide monitoring and evaluation effort should be used to reinforce the commitment to the goals of the project.

8.10 MONITORING OF CONSERVATION TILLAGE ADOPTION, AS WELL AS TRIBUTARY WATER QUALITY MONITORING, IS NECESSARY TO DOCUMENT THE SUCCESS OF A DIFFUSE SOURCE PHOSPHORUS CONTROL PROGRAM.

This conclusion has been reached through the understanding of tributary pollutant transport we have gained as a result of this study. Annual variability in transport is several times greater than the reduction in mean annual transport which can ultimately be achieved through the Recommended Program. Monitoring the adoption of conservation tillage is necessary to document the success of the program and predict its impact on Lake Erie. Long-term water quality monitoring will be required to verify actual reductions in transport.

8.11 THE LAND RESOURCES INFORMATION SYSTEM (LRIS) HAS BEEN SUCCESSFULLY USED TO IDENTIFY 20 OF THE 62 COUNTIES IN THE LAKE ERIE BASIN AS PRIORITY AREAS WHERE DIFFUSE SOURCE PHOSPHORUS CONTROL PROGRAMS HAVE A HIGH PROBABILITY OF SUCCESS. THE LRIS CAN ALSO BE USED TO MONITOR ADOPTION.

Twenty counties in the Lake Erie Basin have been selected for direct participation in the recommended program based on the absolute amount of soil loss reduction which can be achieved, the total acreage of cropland suitable for conservation tillage and the ranking of each county based on the flow weighted mean concentration of total phosphorus of the major river basin to which it is tributary. Remote sensing techniques and the LRIS can be used to monitor adoption.

8.12 REDUCTION OF IN-LAKE PHOSPHORUS CONCENTRATIONS WILL NOT ELIMINATE ALL LOCAL IN-STREAM WATER QUALITY PROBLEMS.

The bulk of the tributary phosphorus load is transported to Lake Erie during a few major storm events each year. It is this phosphorus which the Recommended Program will control. The program will not control septic tank discharges, runoff from barnyards and other minor sources which control the concentration of phosphorus and other pollutants during low flow periods. It is, however, expected that the programs of other agencies will address these problems.

8.13 THE RECOMMENDED PROGRAM WILL ULTIMATELY ACHIEVE A REDUCTION IN TOTAL PHOSPHORUS TRANSPORT TO LAKE ERIE OF 2,030 METRIC TONS PER YEAR. THE TOTAL COST OF THIS PROGRAM IS $12.25 MILLION (1982 DOLLARS) OR $612,400 ANNUALLY OVER A 20-YEAR PROJECTION PERIOD.

This conclusion has the following implications for Great Lakes Water Quality Management Programs:

a. The Great Lakes Water Quality Agreement of 1978 between the United States and Canada calls for an additional target phosphorus reduction for Lake Erie of 2,000 metric tons per year beyond the achievement of a 1.0 milligram per liter effluent concentration for all municipal wastewater treatment plants currently discharging more than 1 million gallons per day. The Unites States allocation of this reduction is 1,700 metric tons per year. The Recommended Program will exceed this allocation. Relative to achieving the reduction by means of additional point source control the Recommended Program has a benefit/cost ratio of 10:1.

b. It is a finding of this study that a new base-year tributary phosphorus load to Lake Erie should be recognized. Inclusion of tributary monitoring data from 1978, 79, and 80 in the computation gives a base-year total phosphorus load of 16,455 metric tons per year. When the 1.0 milligram per liter effluent limitation has been achieved the total phosphorus load to Lake Erie will be 15,025 metric tons per year. At that time an additional phosphorus reduction of 4,025 metric tons per year (not 2,000 metric tons per year as stated above) will be required to meet the 11,000 metric tons per year total loading objective of the Agreement. The United States allocation of this reduction objective should be approximately 2,800 metric tons per year. To reach this reduction objective an additional 770 metric tons per year in reductions beyond the Recommended Program must be achieved through point source controls beyond the 1.0 milligram per liter effluent limitation, and at a cost of $5 million annually. The benefit/cost ratio of the Recommended Program is 17:1 compared to a program requiring the entire reduction to be achieved by point source control.

CHAPTER 9 - RECOMMENDATIONS

9.1 In fulfillment of international agreements and because of widespread benefits to water quality and fisheries the following Federal participation in response to Section 108(d) of PL 92-500 costing $12.5 million and administered by the Corps of Engineers, is recommended:

a. A proposed Accelerated Conservation Tillage Program consisting of individual projects of 5 years duration in each of 20 counties, phased in over a 10-year period.

b. A tributary monitoring program at six stations located on the Maumee, Portage, Sandusky, and Huron Rivers and on Honey Creek and the Upper Honey Creek Subbasin.

c. Update and use the Land Resources Information System to produce additional County Reource Information System Packages and to monitor the adoption of conservation tillage.

The funding for this program would be administered by the Corps of Engineers and distributed to appropriate local and Federal agencies. The bulk of the money would be allocated at the local level and used to accelerate existing programs.

9.2 As called for in the 1978 Great Lakes Water Quality Agreement, the United States Environmental Protection Agency and appropriate local units of government should ensure that all municipal wastewater treatment plants in the Lake Erie Basin discharging in excess of 1 million gallons per day are designed and operated so that the total phosphorus concentrations in their effluents will not exceed a maximum concentration of 1.0 milligrams per liter.

9.3 The United States Department of Agriculture, Soil Conservation Service should view the Lake Erie Basin as a high priority area and continue to fund the provision of technical assistance to county soil and water conservation districts at current levels. Current programs should be continued because of the important role that existing rates of soil loss play in the eutrophication of Lake Erie.

9.4 The United States Environmental Protection Agency, Great Lakes National Program Office's Accelerated Conservation Tillage Projects and high flow monitoring of key tributaries in the Lake Erie Basin should be continued.

9.5 The Great Lakes International Surveillance Plan which presents the basic framework for surveillance activities in the Great Lakes Basin as required in the 1978 Great Lakes Water Quality Agreement between Canada and the United States should be continually funded by the cooperating State and Federal agencies.

Robert R. Hardiman
ROBERT R. HARDIMAN
Colonel, Corps of Engineers
Commanding

GLOSSARY OF TERMS

Adsorption - The taking up of one substance on the surface of another.

Algae - Thallophytes, or rootless plant bodies, possessing chlorophyll, and so capable of photosynthesis.

Anaerobic - Containing no dissolved oxygen.

Anoxic - Anaerobic; depleted of oxygen.

Baseflow - That part of streamflow contributed by groundwater seeping into surface streams.

Benthos - The community of aquatic organisms which live on the bottom.

Best Management Practices - A practice, or combination of practices, that is determined by a State (or designated areawide planning agency) after problem assessment, examination of alternative practices, and appropriate public participation to be the most effective, practicable (including technological, economic, and institutional considerations) means of preventing or reducing the amount of pollution generated by nonpoint sources to a level compatible with water quality goals.

Bioavailable - Can be used by organisms for their growth, also Biologically Available.

Critical Areas - Within a watershed, those areas contributing the largest amounts of sediment and nutrients to streamflow.

Delivery Ratio - A measure of the sediment actually reaching a stream or lake; equal to the quantity of material reaching a point in a stream divided by the quantity of material eroded above that point.

Diffuse Source - Any source which is not a point source. A nonpoint source.

Drainage Basin - An area delineated by a boundary within which runoff drains to a common outlet. A watershed. When used with reference to a lake, the area includes the surface area of tributary streams and lakes and their drainage basins, but not that of the receiving lake.

Dissolved Inorganic Phosphate - That phosphate that is dissolved in water and is in the form of orthophosphate (PO_4). Dissolved by definition means any material that will pass through an 0.45 micron pore size filter. The word "soluble" is synonymous with "dissolved," although not as rigidly defined and "reactive" is essentially the same as "orthophosphate" or "inorganic." When the water sample is filtered through filters with pore size greater than 0.45 micron, the sample is referred to as "filtered."

Eutrophic - Richly supplied with plant nutrients and supporting heavy plant growth. Having high biological production and turbid waters with deeper waters depleted of oxygen at times during the year.

Eutrophication - The enrichment of natural waters by nutrients, resulting in systematic changes in the quality of the waters.

Event - A distinct period of high rainfall over a watershed or high streamflow during a storm.

Flux - Mass per unit of time.

Hypolimnion - The deep, cold, and relatively undisturbed region of a summer stratified lake.

Interstitial Water - Water occupying the pore space between soil or sediment particles.

Lake Basin - The entire area within the drainage boundaries of a lake, including tributaries and the lake itself. (e.g., the Lake Erie Basin.) Also, the depression which holds the lake water body. (e.g., Lake Erie's Central Basin.)

Load - Flux. Mass per unit time.

Mathematical Model - A systematic, logical representation of physical, chemical, or other phenomena by mathematical expressions, which simulate the response of a real system to inputs or changes. Often programmed for computer analysis, hence the term "computer model."

Mesotrophic - Intermediate in characteristics between oligotrophic and eutrophic; that is, having a moderate supply of plant nutrients, and moderate plant growth and biological production.

Nonpoint Source - Diffuse source.

Nutrient - Organic or inorganic chemical necessary for the growth and reproduction of organisms.

Oligotrophic - Poorly supplied with plant nutrients and supporting little plant growth. As a result, biological production is generally low, waters are clear, and deeper waters are well supplied with oxygen throughout the year.

Periphyton - All aquatic organisms which are attached to, or move upon, a submersed substrate but do not penetrate into it.

Phosphorus - Phosphorus in all its forms; total phosphorus reported as phosphorus.

Point Source - Effluent from a municipal or industrial outfall.

Potential Gross Erosion - A measure of the potential for soil to be dislodged and moved from its place of origin; it is not necessarily the amount of soil which actually reaches a stream or lake. Determined with the USLE, same as soil loss.

River Basin - The drainage basin of a given river.

Runoff - That portion of precipitation which drains overland to a receiving body of water with a free surface.

Sediment Phosphorus - The difference between total phosphorus and soluble orthophosphate concentrations measured in a sample of water.

Study - The Lake Erie Wastewater Management Study (Lake Erie Study). The current study, authorized by Section 108 of Public Law 92-500.

Trophic Level - Level of nutrient enrichment of a body of water.

Watershed - Drainage basin.

Water Quality Standard - A regulation on law specifying mandatory quantitative measures of the physical, chemical, bacteriological and sensible qualities of water.

Wastewater - Water which carries the wastes of cultural processes or activities.

ACRONYMS

ACP - Agricultural Conservation Program

ANSWERS - Areal, Nonpoint Source Watershed Environment Response Simulation Model.

ASCS - Agricultural Stabilization and Conservation Service

BAP - Biologically Available Phosphorus

BMP - Best Management Practice

CES - Cooperative Extension Service

COE Corps of Engineers

CRISP - County Resource Information System Package

EPA - Environmental Protection Agency

GAO - General Accounting Office

GLISP - Great Lakes International Surveillance Plan

GLNPO - Great Lakes National Program Office

HAA - Hydrologically Active Area

HCWMP - Honey Creek Watershed Management Program

IJC - International Joint Commission

ITAG - Interagency Technical Advisory Group

LETSEE - Lake Erie Tributaries Stormwater Effects Evaluation

LEWMS - Lake Erie Wastewater Management Study

LRIS - Land Resources Information System

NOACA - Northeast Ohio Areawide Coordinating Agency

OCAP - Ohio Capability Analysis Program

OCES - Ohio Cooperative Extension Service

ODNR - Ohio Department of Natural Resources

OSU - Ohio State University

PGE - Potential Gross Erosion

PLUARG - Pollution from Land Use Activities Reference Group

RCWP - Rural Clean Water Program

SCD - Soil Conservation District

SCS - Soil Conservation Service

SEMCOG - Southeast Michigan Council of Governments

SMG - Soil Management Group

SWCD - Soil and Water Conservation District

T - Soil loss tolerance Factor

TMACOG - Toledo Metropolitan Area Council of Governments

TPP - Total Particulate Phosphorus

UHC - Upper Honey Creek

USDA - United States Department of Agriculture

USEPA - United States Environmental Protection Agency

USLE - Universal Soil Loss Equation

UTM - Universal Transverse Mercator

WMS - Watershed Management Study

CONVERSIONS

1 metric ton	=	1.1 short tons
1 hectare	=	2.47 acres
1 square kilometer	=	0.4 square miles
1 square kilometer	=	247.1 acres
1 kilogram	=	2.2 pounds
1 kilogram/hectare	=	0.9 pounds/acre
1 square mile	=	640 acres
1 ton/hectare	=	809.7 pounds/acre

APPENDIX I

STUDY AUTHORIZATION

The Authority for the Lake Erie Wastewater Management Study is contained in Sections 108(d) and (e) of the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500), which read as follows:

> "Sec. 108(d) (1) In recognition of the serious conditions which exist in Lake Erie, the Secretary of the Army, acting through the Chief of Engineers, is directed to design and develop a demonstration waste water management program for the rehabilitation and environmental repair of Lake Erie. Prior to the initiation of detailed engineering and design, the program, along with the specific recommendations of the Chief of Engineers and recommendations for its financing, shall be submitted to the Congress for statutory approval. This authority is in addition to and not in lieu of, other waste water studies aimed at eliminating pollution emanating from select sources around Lake Erie.
>
> " (2) This program is to be developed in cooperation with the Environmental Protection Agency, other interested departments, agencies and instrumentalities of the Federal Government and the States and their political subdivisions. This program shall set forth alternative systems for managing waste water on a regional basis, and shall provide local and State governments with a range of choice as to the type of system to be used for the treatment of waste water. These alternative systems shall include both advanced waste treatment technology and land disposal systems including aerated treatment-spray irrigation technology, and will also include provisions for the disposal of solid wastes, including sludge. Such a program should include measures to control point sources of pollution, area sources of pollution, including acid-mine drainage, urban runoff and rural runoff, and in place sources of pollution, including bottom lands, sludge banks and polluted harbor dredgings.
>
> " (e) There is authorized to be appropriated $5,000,000 to carry out the provisions of subsection (d) of this section, which sum shall be available until expended."

APPENDIX II

LEWMS TECHNICAL REPORTS

1. Technical Reports.

Apman, R. P., "Historical Trends in Pollutant Loadings to Lake Erie" LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY, November 1975.

Baker, D. B., K. A. Kreiger, and J. V. Setzler, "The Concentrations and Transport of Pesticides in Northwestern Ohio Rivers - 1981, " LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY, November 1981.

Baker, D. B., "Fluvial Transport and Processing of Sediment and Nutrients in Large Agricultural River Basins, "LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY, February 1982.

Cahill, T. H., "Lake Erie Basin Land Resource Information System," LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY, February 1978.

Eckert, D. J., "Effects of Conservation Tillage Practices on Crop Yields in the Lake Erie Basin," LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY, December 1981.

Forster, D. L. and G. S. Becker, "Economic and Land Management Analysis, Honey Creek, Honey Creek Watershed, "LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY, 1977.

Forster, D. L., "Economic Impacts of Changing Tillage Practices in the Lake Erie Basin," LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY, August 1978.

Forster, D. L., "Preferred Areas for Reduced Tillage Technical Assistance Programs in the U. S. Drainage to Lake Erie." LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY, November 1979.

Forster, D. L. and G. L. Stem, "Adoption of Reduced Tillage and Other Conservation Practices in the Lake Erie Basin," LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY, November 1979.

Forster, D. L. and G. Ibrahim, "Sediment Deposits in Drainage Ditches," LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY, November 1980.

Great Lakes Laboratory, "Annotated Bibliography of Limnological and Related Studies Concerning Lake Erie and Influent Tributaries, Vol. I - Biological, Vol. II - Chemical, Vol. III - Engineering, Vol. IV - Physical, Vol. V - Socio-Economic, "LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY, October 1974.

Hemmer, R. F., and D. L. Forster, "Farmer Experiences with Alternative Tillage Practices in Western Lake Erie Basin," LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY, January 1981.

Honey Creek Joint Board of Supervisors, ""Honey Creek Watershed Project - Tillage Demonstration Results 1979," LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY, July 1979.

Honey Creek Joint Board of Supervisors, "Honey Creek Watershed Project - Tillage Demonstration Results 1980," LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY, January 1981.

Honey Creek Joint Board of Supervisors, "Honey Creek Watershed Project - Tillage Demonstration Results 1981," LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY, January 1982.

Honey Creek Joint Board of Supervisors, "Honey Creek Watershed Project - Final Program Evaluation Report 1979-1981," LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY January 1982.

Krieger, K. A., R. P. Richards, P. A. Kline and D. A. Baker, "Environmental Quality of Upper Honey Creek: A Preliminary Assessment." LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY, January 1981.

Logan, T. J., "Levels of Plant Available Phosphorus in Agricultural Soils in the Lake Erie Drainage Basin," LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY, December 1977.

Logan, T. J., "Chemical Extraction as an Index of Bioavailability of Phosphate in Lake Erie Basin Suspended Sediments," LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY, January 1978.

Logan, T. J., F. H. Verhoff and J. V. DePinto, "Biological Availability of Total Phosphorus," LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY, January 1979.

Logan, T. J. and J. R. Adams, "The Effects of Reduced Tillage on Phosphate Transport from Agricultural Land," LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY, January 1981.

Logan, T. J., "Pesticide Use in the Lake Erie Basin and the Impact of Accelerated Conservation Tillage on Pesticide Use and Runoff Losses." LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY, January 1981.

Logan T. J., and D. L. Forster, "Alternative Management Options for the Control of Diffuse Phosphorus Load to Lake Erie," LEWMS Technical Report, U.S. Army Corps of Engineers, Buffalo, NY, July 1982.

McAuliffe, J. P., I. C. Young, J. V. DePinto, "Effects of Anaerobic Conditions on Availability of Particulate Phosphorus from Tributaries to Lake Erie," LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY, June 1982.

Melfi, D. A., "Material Transport in River Systems During Storm Events by Water Routing," LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY, March 1979.

Rescurce Management Associates, "Honey Creek Watershed Report," LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY, December 1976.

Resource Management Associates, "Land Resource Information for the Lake Erie Drainage Basin, Vol. I - Land Resource Summary," LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY, March 1980.

Resource Management Associates, "Land Resource Information for the Lake Erie Drainage Basin, Co-Occurrence of Land Resource Features, Vol. II - Major River Basins," LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY, March 1979.

Resource Management Associates, "Land Resources Information for the Lake Erie Drainage Basin, Co-Occurrence of Land Resources Features, Vol. III - Sandusky River Basin," LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY, March 1979.

Resource Management Associates, "Land Resources Information for the Lake Erie Drainage Basin, Co-Occurrence of Land Resource Features, Vol. IV - Small Watersheds," LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY, March 1979.

Rumer, R. R., "Methodology for Evaluating In-Lake Effects Resulting from Phosphorus Management in the Lake Erie Drainage Basin," LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY, July 1978.

Setzler, J. V., "Atrazine Residues in Northern Ohio Streams - 1980," LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY, September 1980.

U. S. Army Corps of Engineers, Buffalo District, Lake Erie Wastewater Management Study, "Water Quality Data - Sandusky River Material Transport," Buffalo, NY, 1978.

U. S. Army Corps of Engineers, Buffalo District, Lake Erie Wastewater Management Study, "Water Quality Data - Lake Erie Tributary Loading," Buffalo, NY, 1978.

U. S. Army Corps of Engineers, Buffalo District, Lake Erie Wastewater Management Study, "Water Quality Data - Small Watersheds and Special Studies," Buffalo, NY, 1979.

U. S. Army Corps of Engineers, Buffalo District, Lake Erie Wastewater Management Study "Land Management Alternatives in the Lake Erie Drainage Basin," Buffalo, NY, March 1979.

U. S. Army Corps of Engineers, Buffalo District, Lake Erie Wastewater Management Study, "Lake Erie Wastewater Management Study Methodology Report," Buffalo, NY, March 1979.

Urban, D. R., J. R. Adams and T. J. Logan, "Application of the Universal Soil Loss Equation in the Lake Erie Drainage Basin" LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY, November 1978.

Verhoff, F. H., M. Heffner and W. A. Sack, "Measurement of Availability Rate for Total Phosphorus from River Waters," LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY, January 1978.

Verhoff, F. H., S. M. Yaksich and D. A. Melfi, "Phosphorus Transport in Rivers," LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY, November 1978.

Yaksich, S. M., D. A. Melfi, D. A. Baker and J. A. Kramer, "Nutrient Loads to Lake Erie," 1970-80, LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY, September 1978.

Yaksich, S. M. and R. R. Rumer, "Phosphorus Management in the Lake Erie Basin," Information Bulletin, U. S. Army Corps of Engineers, Buffalo District, Buffalo, NY, March 1980.

Young, T. C., J. V. DePinto and J. P. McAuliffe, "Effects of Anaerobic Conditions on Particulate Phosphorus Availability in Lower Great Lakes Tributaries." LEWMS Technical Report, U. S. Army Corps of Engineers, Buffalo, NY, 1982.

2. Unpublished Reports.

Becker, G. S. and D. L. Forster, "A Summary of Economic Data from the Agricultural Practices Survey, Venice Township, Seneca County, Ohio, Unpublished Report to Buffalo District Corps of Engineers, November, 1976.

Brassel, K. and M. Wasilenko, "Lake Erie Wastewater Management Study Phase III Demonstration Program," Unpublished Final Report to Buffalo District Corps of Engineers, Amherst, NY, January 1980.

DePinto, J. V., "Phosphorus Availability of Aquatic Sediment Material: A Review," Unpublished Report to Buffalo District Corps of Engineers, September 1978.

Haack, B. N., "Lake Erie Basin, Land Resources Data Bank - Phase II," Environmental Research Institute of Michigan, Ann Arbor, MI, June 1977.

Kraus, D., "Lake Erie Dredging Operations," Unpublished Report to Buffalo District Corps of Engineers, Buffalo, NY, August 1978.

Resource Management Associates, "Lake Erie Basin Land Resource Information System," Unpublished Report to Buffalo District Corps of Engineers, West Chester, PA, December 1977.

APPENDIX III

PUBLICATIONS

Adams, J. R., Logan, T. J., Cahill, T. H., Urban, D. R. and Yaksich, S. M., "A Land Resource Information System (LRIS) for Water Quality Management in the Lake Erie Drainage Basin," Journal of Soil and Water Conservation, Vol. 37, No. 1, January-February 1982.

Adams, J. R., and C. J. Merry, "Application of a Land Resource Information System (LRIS) and the CAPDET Model to Facilities Planning and Land Treatment of Municipal Wastewater,' Proceedings of the Fourteenth International Symposium on Remote Sensing of Environment," Environmental Research Institute of Michigan, Ann Arbor, MI, April 1980.

Adams, J. R. and Yaksich, S. M., "The Response of Great Lakes Estuaries to Stormwater Runoff," Proceedings of a National Conference on Urban Stormwater and Combined Sewer Overflow Impact on Receiving Water Bodies, Orlando, FL, November 1980.

Baker, D. B., "Upstream Point Source Phosphorus Inputs and Effects. Proceedings of a Seminar on Water Quality Management Trade-offs, USEPA Region V Chicago, IL, September 1980.

Becker, G. and D. L. Forster, "Summary of Survey of Agricultural Practices in Venice Township, Seneca County, Ohio," ESO 377, Department of Agricultural Economics and Rural Sociology, Ohio State University, November 1976.

Cahill, T.H., "Forms and Sediment Associations of Nutrients, Pesticides and Metals" Proceedings of a Workshop on the Fluvial Transport of Sediment Associated Nutrients and Contaminants, Shear, H. and A. E. P. Watson, Kitchener, Ontario, October 1976.

Cahill, T. H., R. W. Pierson, Jr. and B. Cohen, "The Evaluation of Best Management Practices for the Reduction of Diffuse Pollutants in an Agricultural Watershed," Best Management Practices for Agriculture and Silviculture. (Ed) R. C. Loehr et. al., Ann Arbor Science Pub., Ann Arbor, MI, 1979.

Crumrine, J., "Conservation Tillage Practices to Control Agricultural Pollution, "Proceedings of a Seminar for Water Quality Management Trade-offs. Sponsored by Region V, USEPA, Chicago, IL September 1980.

Eckert, D. J. and W. H. Schmidt "Using Conservation Tillage in North Central Ohio" Cooperative Extension Service Bulletin FAC-10, Columbus, OH, .

Forster, D. L., "Farmers' Role in Restoring Lake Erie," SEI No. 618, Department of Agricultural Economics & Rural Sociology.

Forster, D. L. and G. S. Becker, "Costs and Income Effects of Alternative Erosion Control Strategies: The Honey Creek Watershed," North Central Journal of Agricultural Economics, January, 1979.

Hemmer, F. and D. L. Forster, "Farmers' Experiences with Reduced Tillage Systems," Socio-Economic Information, August 1981.

Krieger, K. W., D. B. Baker, J. V. Setzler, "Concentrations and Transport of Pesticides in Northwestern Ohio Rivers - 1981" Submitted for Publication March 1982.

Logan, T. J. "Bioavailability of Phosphorus Sources to Lakes," Proceedings of a Seminar for Water Quality Management Trade-offs, Sponsored by Region V, USEPA, Chicago, IL, September 1980.

Logan, T. J. "Mechanism for the Release of Sediment Bound Phosphate to Water," Second International Symposium on Interactions between Sediment and Fresh Water, Junk Publisher, Amsterdam, Holland, 1982.

Logan, T. J., T. O. Oloya and S. M. Yaksich, "Phosphate Characteristics and Bioavailability of Suspended Sediments from Streams Draining into Lake Erie," Journal of Great Lakes Research, Vol. 5, No. 1, 1979.

Logan, T. J., D. R. Urban, J. R. Adams, S. M. Yaksich, "Erosion Control Potential with Conservation Tillage in Lake Erie Basin," Journal of Soil and Water Conservation, Vol 37, No. 1, January-February 1982.

Logan, T. J. and S. M. Yaksich, "Lake Erie: A New Prognosis," Water Spectrum, Vol. 12, No. 3, 26-34, 1980.

Melfi, D. and F. Verhoff, "Tracing Technique for Stream Chemistry During Storm Events" Submitted for publication August 1981.

Rumer, R. R., "Phosphorus Transport in Lake Erie," Transport Processes in Lakes and Oceans, Advances in Marine Sciences, Plenum Press, 1978.

Verhoff, F. H. and D. B. Baker, "Moment Methods for Analyzing River Models With Application to Point Source Phosphorus," Water Research 1980.

Verhoff, F. H. and M. R. Heffner, "Rate of Availability of Total Phosphorus in River Waters," Environ. Sci. Technol., 13:844-849, 1979.

Verhoff, F. H. and D. A. Melfi, "Total Phosphorus Transport During Storm Events," Journal of the Environmental Division, ASCE, 104,1021, October 1978.

Verhoff, F. H. , D. A. Melfi, and S. M. Yaksich, "Storm Travel Distances Calculation for Total Phosphorus and Suspended Materials in Rivers," Water Resources Research, Vol. 15, No. 6, 1354-1360, December 1979.

Verhoff, F. H., D. A. Melfi and S. M. Yaksich, "An Analysis of Total Phosphorus Transport in River Systems," proceedings of ASCE Hydraulics Division Specialty Conference, College Park, MD, August 1978.

Verhoff, F. H. and S. M. Yaksich, "Storm Sediment Concentrations as Affected by Land Use, Hydrology and Weather." Journal of Environmental Quality, Vol. 11, No. 1, January-March 1982.

Verhoff, F. H., S. M. Yaksich, and D. A. Melfi, "River Nutrient and Chemical Transport Estimation," ASCE, Journal of the Environmental Engineering Division, EE3, 591-608, June 1980.

Verhoff, F. H., S. M. Yaksich, and D. A. Melfi, "The Transport of Sediment and Sediment Related Material in Rivers," Proceedings of Sediment Freshwater Symposium in Kingston, Ontario, Junk Publishers, Netherlands, June 1981.

Yaksich, S. M., D. A. Melfi and J. R. Adams, "Sediment and Phosphorus Transport," Proceedings of Seminar for Water Quality Management Trade-offs, Sponsored by Region V, USEPA, Chicago, IL, September 1980.

Yaksich, S. M. and D. Urban, "Lake Erie Diffuse Source Phosphorus Control," Great Lakes Focus on Water Quality, Vol. 6, No. 3, October 1980.

Yaksich, S. M. and F. H. Verhoff, "Sampling Strategies for Estimating Pollutant Transport in Rivers," Accepted for Publication in the Journal of the American Society of Civil Engineers, Environmental Division, February 1982.

Yaksich, S. M., D. A. Melfi, D. A. Baker and J. A. Kramer, "Lake Erie Nutrient Loads, 1970-1980. Submitted to the Journal of the International Association of Great Lakes Research, September 1982.

APPENDIX IV

PAPERS PRESENTED

Adams, J. R., "Planning Approaches for Diffuse Source Pollution Control," Erosion, Sedimentation and Water Quality Symposium, Ohio Chapter, Soil Conservation Society of America, Wooster, OH, November 1979.

Adams, J. R., "The Land Resources Information System," INFOCORPS 80, U. S. Army Corps of Engineers, Pipestem, WV, October 1980.

Adams, J. R., "Water Quality Sampling and Analysis-Quality Control Procedures in Contracting," 6th Annual NCD Water Quality Workshop, U. S. Army Corps of Engineers, Des Moines, IA, November 1980.

Adams, J. R., "Analysis of the Cause-Effect Relationships Impacting the Water Quality of Lake Erie," 6th Annual North Central Division Water Quality Workshop, U. S. Army Corps of Engineers, Des Moines, IA, November 1980.

Adams, J. R., "Applications of Remote Sensing and a Geographic Information System to an Upland Erosion Control Study," U. S. Army Corps of Engineers Remote Sensing Symposium, Nashville, TN, December 1981.

Adams, J. R., R. H. Rogers and M. B. Walsh, "Evaluation of Multidate Landsat Data for Water Quality Modeling Applications," Remote Sensing Symposium, U. S. Army Corps of Engineers, Reston, VA, October 1979.

Adams, J. R. and D. R. Urban, "A Land Resources Information System for Land Management Planning," Remote Sensing for Resource Management, Soil Conservation Society of America, Kansas City, MO, October 1980.

Adams, J. R. and S. M. Yaksich, "The Response of Great Lakes Tributaries to Stormwater Runoff," National Conference on Stormwater Runoff, U. S. Environmental Protection Agency, Orlando, FL, December 1979.

Adams, J. R., S. M. Yaksich and M. Wasilenko, "Evaluation of Regional Opportunities for Land Treatment of Municipal Wastes," 1981 Annual Conference of the Water Pollution Control Federation, Detroit, MI, October 1981.

Adams, J. R., S. M. Yaksich, Lake Erie Wastewater Management Study, IJC "Phosphorus Management Strategies," Public Hearing, Buffalo, NY, November 1980.

Baker, D. B. and S. M. Yaksich, "Sediment Delivery Ratios and Nutrient-Sediment Yield Ratios for Agricultural River Basins in Northwest Ohio," presented at the 52nd Annual Conference-Water Pollution Control Federation, Houston, TX, October 1979.

Coniglio, A. F. , D. A. Melfi and R. R. Rumer, Jr., "Modeling Phosphorus Transport in Lake Erie" presented at 82nd National Meeting of American Inst. of Chemical Engineers, Atlantic City, NJ, September 1976.

Coniglio, A. F., S. M. Yaksich, D. A. Melfi, B. R. Wallace and F. H. Verhoff, "Calculations and Analyses of Total Phosphorus Loadings to Lake Erie," presented at 19th Conference on Great Lakes Research, Guelph, Ontario, May 1976.

Forster, D. L., "Economic Impacts of Changing Tillage Practices in the Lake Erie Basin," presented at the 22nd Conference on Great Lakes Research, Rochester, NY, May 1979.

Logan, T. J. and J. R. Adams, "Sediment and Phosphorus Transport by Season in NW Ohio from Small and Large Watersheds," presented at the 22nd Conference on Great Lakes Research, Rochester, NY, May 1979.

Logan, T. J. and J. R. Adams, "Management Strategies for Control of Diffuse Sources of Bioavailable Phosphorus to Lake Erie," presented at the 24th Conference on Great lakes Research, Columbus, OH, 1981.

Melfi, D. A., F. H. Verhoff and S. M. Yaksich, "Total Phosphorus Transport in River Basins of the Great Lakes," presented at the 20th Conference on Great Lakes Research, Ann Arbor, MI, 1977.

Melfi, D. A., F. H. Verhoff, "The Transport of Nutrients and Chemicals in the Sandusky River During Storm Events," presented at the 22nd Conference on Great Lakes Research, Rochester, NY, May 1979.

Oloya, T. O., T. J. Logan and S. M. Yaksich, "Phosphate Characteristics and Bioavailability of Suspended Sediments from Streams Draining into Lake Erie," presented at 21st Conference on Great Lakes Research, Windsor, Ontario, May 1978.

Stem, G. and J. Crumrine, "The Honey Creek Watershed Management Project-Demonstration of a Practical Approach to Diffuse Source Pollution Control," presented at the 23rd Conference on Great Lakes Research, Kingston, Ontario, May 1980.

Verhoff, F. H. and S. M. Yaksich, "Analysis of Orthophosphate Dynamics in a River Downstream from an Outfall," presented at 21st Conference on Great Lakes Research, Windsor, Ontario, May 1978.

Verhoff, F. H. and S. M. Yaksich, "The Influence of Parameters on Suspended Sediment Transport in the Maumee River," presented at the 23rd Conference on Great Lakes Research, Kingston, Ontario, May 1980.

Verhoff, F. H. and S. M. Yaksich and D. A. Melfi, "The Transport of Sediment and Sediment Related Material in Rivers," Preceeding of Sediment Freshwater Symposium in Kingston, Ontario, June 1981.

Yaksich, S. M.,"Lake Erie Wastewater Management Study," invited seminar at Corps of Engineers Sanitary Engineering Seminar, Cincinnati, OH, April 1976.

Yaksich, S. M.,"Non Point Source Case Study-Lake Erie," invited seminar at Corps of Engineers Sanitary Engineering Seminar, St. Louis, MO, April 1979.

Yaksich, S. M.,"Eutrophication and Non Point Sources," Ohio Chapter of the Soil Conservation Society of America, Wooster, OH, 1979.

Yaksich, S. M.,"Lake Erie Wastewater Management Study," USEPA National Water Quality Management Conference, Atlanta, GA, June 1980.

Yaksich, S. M.,"Planning Approaches for Diffuse Source Pollution Control," USEPA Non Point Source Modeling Seminar, Ann Arbor, MI, January 1981.

Yaksich, S. M.,"Lake Erie Wastewater Management Study, Briefing for Great Lakes Area Congressmen, Washington, DC, January 1981.

Yaksich, S. M.,"Ingredients of a Diffuse Source Phosphorus Control Program," presented to the Ohio Federation of Soil and Water Conservation Districts, Independence, OH, August 1981.

Yaksich, S. M. and J. R. Adams, "Opportunities for Diffuse Source Control in the Lake Erie Drainage Basin," presented at the Conference of Great Lakes Research, Kingston, Ontario, May 1980.

Yaksich, S. M. and J. R. Adams, "The Lake Erie Wastewater Management Study, the Land Resources Information System and Land Treatment of Municipal Sewage, a briefing for headquarter staff office of the Chief of Engineers and U. S. Environmental Protection Agency, Washington, DC, June 1980.

Yaksich, S. M., A. F. Coniglio, D. A. Melfi, D. B. Baker, J. W. Kramer, T. H. Cahill and F. H. Verhoff, "Water Chemistry and Mass Transport in Erie South Shore Tributaries," presented at 19th Conference on Great Lakes Research, Guelph, Ontario, May 1976.

Yaksich, S. M., D. A. Melfi and J. R. Adams, "Sediment and Phosphorus Transport," Seminar on Water Quality Management Trade-offs, U. S. Environmental Protection Agency, Chicago, IL, September 1980.

Yaksich, S. M. and F. H. Verhoff, "Water Quality Sampling Frequencies for Rivers," presented at 19th Conference on Great Lakes Research, Guelph, Ontario, May 1976.

Yaksich, S. M. and F. H. Verhoff, "Sampling Strategies for Estimating Pollutant Transport in Rivers," presented at Annual Meeting of the American Institute of Chemical Engineers, New Orleans, LA, November 1981.

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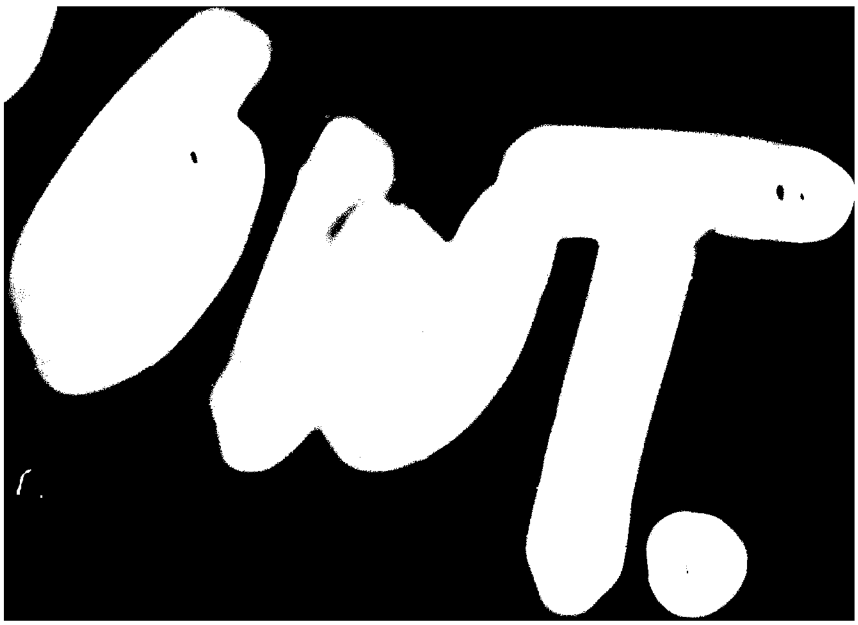

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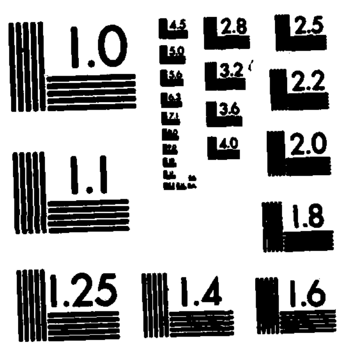
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SUPPLEMENTARY

INFORMATION

Revision Sheets

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REDUCTION OF IN-LAKE PHOSPHORUS CONCENTRATIONS WILL NOT ELIMINATE ALL LOCAL IN-STREAM WATER QUALITY PROBLEMS.

The bulk of the tributary phosphorus load is transported to Lake Erie during a few major storm events each year. It is this phosphorus which the Recommended Program will control. The program will not control septic tank discharges, runoff from barnyards and other minor sources which control the concentration of phosphorus and other pollutants during low flow periods. It is, however, expected that the programs of other agencies will address these problems.

THE RECOMMENDED PROGRAM WILL ULTIMATELY ACHIEVE A REDUCTION IN TOTAL PHOSPHORUS TRANSPORT TO LAKE ERIE OF 2,030 METRIC TONS PER YEAR. THE TOTAL COST OF THIS PROGRAM IS $12.25 MILLION (1982 DOLLARS) OR $612,400 ANNUALLY OVER A 20-YEAR PROJECTION PERIOD.

This conclusion has the following implications for Great Lakes Water Quality Management Programs:

a. The Great Lakes Water Quality Agreement of 1978 between the United States and Canada calls for an additional target phosphorus reduction for Lake Erie of 2,000 metric tons per year beyond the achievement of a 1.0 milligram per liter effluent concentration for all municipal wastewater treatment plants currently discharging more than 1 million gallons per day. The Unites States allocation of this reduction is 1,700 metric tons per year. The Recommended Program will exceed this allocation. Relative to achieving the reduction by means of additional point source control the Recommended Program has a benefit/cost ratio of 10:1.

b. It is a finding of this study that a new base-year tributary phosphorus load to Lake Erie should be recognized. Inclusion of tributary monitoring data from 1978, 79, and 80 in the computation gives a base-year total phosphorus load of 16,455 metric tons per year. When the 1.0 milligram per liter effluent limitation has been achieved the total phosphorus load to Lake Erie will be 15,025 metric tons per year. At that time an additional phosphorus reduction of 4,025 metric tons per year (not 2,000 metric tons per year as stated above) will be required to meet the 11,000 metric tons per year total loading objective of the Agreement. The United States allocation of this reduction objective should be approximately 2,800 metric tons per year. To reach this reduction objective an additional 770 metric tons per year in reductions beyond the Recommended Program must be achieved through point source controls beyond the 1.0 milligram per liter effluent limitation, and at a cost of $5 million annually. The benefit/cost ratio of the Recommended Program is 17:1 compared to a program requiring the entire reduction to be achieved by point source control.

ALL MUNICIPAL WASTEWATER TREATMENT PLANTS IN THE LAKE ERIE BASIN DISCHARGING IN EXCESS OF 1 MILLION GALLONS PER DAY NEED TO BE DESIGNED AND OPERATED SO THAT THE TOTAL PHOSPHORUS CONCENTRATIONS IN THEIR EFFLUENTS WILL NOT EXCEED A MAXIMUM CONCENTRATION OF 1.0 MILLIGRAMS PER LITER.

These controls were called for by the 1978 Great Lakes Water Quality Agreement and are required if the phosphorus loading objective is to be met.

THE UNITED STATES DEPARTMENT OF AGRICULTURE, SOIL CONSERVATION SERVICE SHOULD VIEW THE LAKE ERIE BASIN AS A HIGH PRIORITY AREA.

It is necessary to continue to fund the provision of technical assistance to county soil and water conservation distircts at current levels. Current programs need to be continued because of the important role that existing rates of soil loss play in the euthrophication of Lake Erie.

THE UNITED STATES ENVIRONMENTAL PROTECTION AGENCY, GREAT LAKES NATIONAL PROGRAM OFFICE'S ACCELERATED CONSERVATION TILLAGE PROJECTS AND HIGH FLOW MONITORING OF KEY TRIBUTARIES IN THE LAKE ERIE BASIN NEED TO BE CONTINUED.

These projects have continued and expanded the interest in conservation tillage started by the Honey Creek Demonstration Project. They are filling the gap between the end of the LEWMS study and the start of the recommended program.

THE GREAT LAKES INTERNATIONAL SURVEILLANCE PLAN NEEDS TO BE CONTINUALLY FUNDED BY THE COOPERATING STATE AND FEDERAL AGENCIES.

It provides the basic framework for surveillance activities in the Great Lakes Basin as required in the 1978 Great Lakes Water Quality agreement between Canada and the United States.

Recommendations.

It is recommended that this report be sent to Congress for information and appropriate action on the following program costing $12.5 million.

a. A proposed Accelerated Conservation Tillage Program consisting of individual projects of 5 years duration in each of 20 counties, phased in over a 10-year period.

b. A tributary monitoring program at six stations located on the Maumee, Portage, Sandusky, and Huron Rivers and on Honey Creek and the Upper Honey Creek Subbasin.

c. Update and use the Land Resources Information System to produce additional County Resource Information System Packages and to monitor the adoption of conservation tillage.

This program is in response to Section 108(d) of P.L. 92-500 and is in fulfillment of International Agreements. Program funding could be administered by a managing Federal agency with distribution of monies to appropriate local and other Federal agencies. The bulk of the funds would be allocated at the local level and used to accelerate existing programs.

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Despite the agricultural nature of these projects, the Corps of Engineers has proven its ability to carry out a similar project in the Honey Creek watershed. The advantages of contracting directly with local districts have been stated previously (Ref 2), including already established program priorities in the area of soil erosion control. Routing funds from the Corps of Engineers directly to local districts would eliminate many problems. One major reason for the success of the Honey Creek project was that the local Supervisors answered directly to the Corps, an arrangement which improved communication greatly. This approach is a proven one.

7.2.4 Program Staffing.

The major staffing requirements for this program are at the county level and include a project conservationist and a field technician. The conservationist would handle the administration aspects of the project, reporting, organizing activities, and overseeing the duties of the technician. He will also participate directly in activities directed at establishing conservation tillage and allied practices on the land. The technician would be directly responsible for establishing field demonstration plots, collecting and organizing information pertaining to the plots, and for providing technical assistance to local farmers experimenting with conservation tillage practices. The technician should have training in the area of crop production, since this project will focus on management rather than engineering methods for achieving sediment reductions.

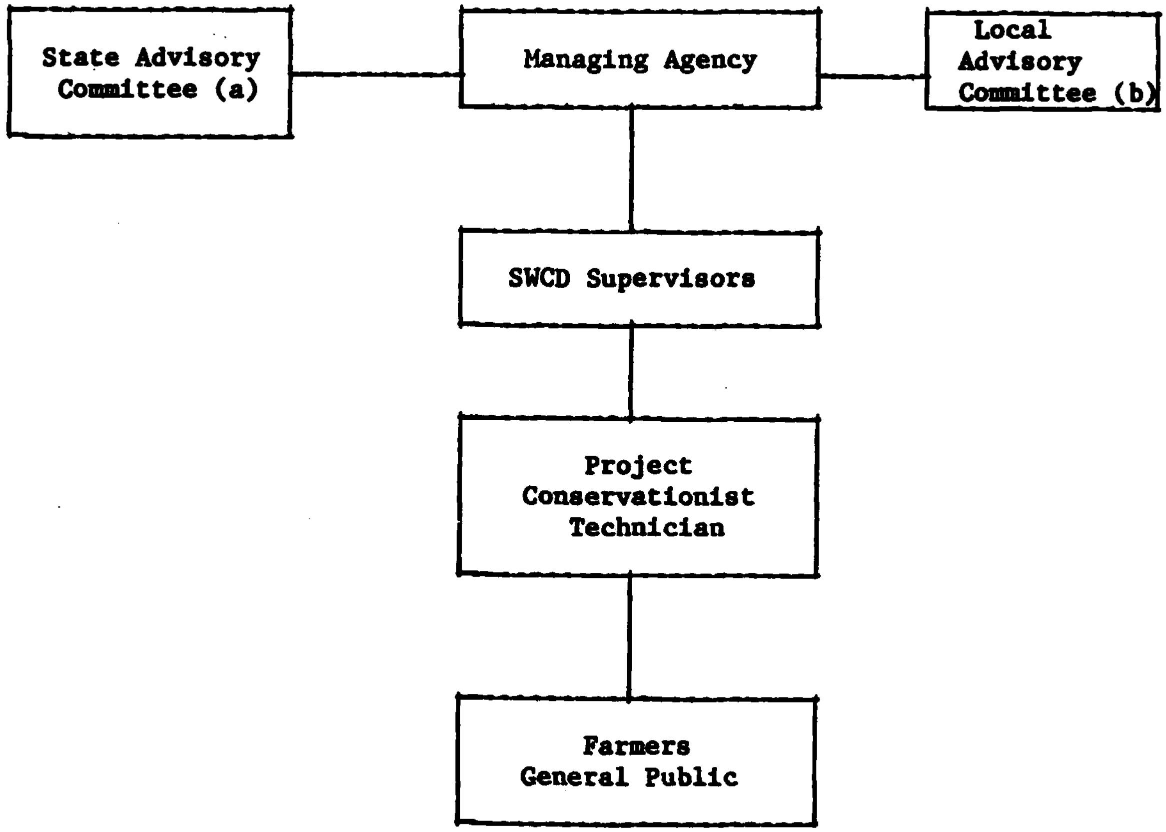
Since the involvement of the Managing Federal Agency would largely be restricted to coordination of projects, and distribution and accounting of funds, one staff member, charged specifically with administering the projects would be sufficient. A basin-wide position will be established for both SCS and the Cooperative Extension Service. Both positions would be responsible for the training of local project personnel and the setting up of administrative frameworks for each county.

7.2.5 Activities of Local and State Agencies.

Though the Federal and State agencies normally associated with agricultural and sediment control activities (ASCS, CES, SCS) may not be involved in administration, and projects will normally operate independently, the supporting activities of these agencies are vital to program success. The programs cannot maintain credibility or acceptance without interagency support. This support should come in two general ways - formation of advisory groups and providing of ancillary services to amplify the work of the projects. (Figure 7.1)

Project advisory groups should be formed at the local and State levels. At both levels, agency personnel should be willing to allocate time to advising projects on best courses of action. The local advisory groups would meet with the project staff of its own area at least four times per year, while the State advisory group might meet in a joint session with all project staffs in its particular State, once or twice per year.

Figure 7.1 - Organization of County Projects



(a) SCS, ASCS, CES, EPA
(b) SCS, ASCS, CES

The local advisory group would be composed of the local county extension agent, district conservationist, ASCS director, an SWCD administrator, and other interested local leaders, including those from agribusiness. The group would meet with the entire project staff and interested SWCD Supervisors to discuss project direction, performance and needs at the local level.

The State groups would be composed of State and area level representatives of ASCS, CES, EPA, SCS, and State Department of Natural Resources. They would probably meet in joint session with managers from all projects. Such an interaction would enable State agencies to have input to the projects, allow some Statewide coordination of efforts, and would allow project managers to voice concerns best expressed at the Statewide level. The experience in the Honey Creek project has been that these advisory groups were quite important in maintaining good relations between the projects and agencies, and provided for effective guidance.

At the local level, however, the most important functions of the local agencies will be activities in support of, or paralleling, the county project. For the projects to be most effective, the local populace must be aware that their local leaders support the same ends. The local SWCD, of course, will be directly responsible to the Managing Agency for project administration through its Board of Supervisors. SWCD would also provide housing for the project, plus publicity and technical assistance.

The Cooperative Extension Service would be a key support agency for the projects because it is the one agency which possesses an expertise in crop management. The extension agents would advise the projects on best methods of managing reduced tillage systems, including pesticide selection and use, cropping systems, fertility management, etc. The extension agents would also hold educational meetings and prepare materials for distribution dealing with reduced tillage, both for the project staff and the public. Providing adequate information to farmers is the best way to maintain adoption.

The Soil Conservation Service would provide information on field suitability for reduced tillage, and also indicate which fields may require further measures to control erosion. Such information is quite important as it will enable the project staff to concentrate on areas which have the greatest need for treatment. SCS would also provide other technical assistance to the project staff.

The Agricultural Stabilization and Conservation Service could provide cost-sharing incentives to those farmers beginning to use reduced tillage. It is hoped that counties involved in the projects would receive enough funding through normal channels to allow for a cost-sharing program which would support most of the farm cooperators in the early start up of a conservation tillage program on an individual farm.

7.2.6 Project Approach.

The majority of the project's initial year will be devoted to laying a firm foundation. During this time, the newly-hired project conservationist will meet with and enlist the cooperation of local agency and agribusiness persons, establish advisory committees, hire the technician, secure necessary equipment, sign up initial farm cooperators, and begin an extensive information/education program.

A strong information education program is critical to project success. This program should have two main objectives - to promote the project itself, and to provide farmers with the best possible information on conservation tillage. The program should include both mass media and meeting approaches and should involve local agency personnel. As the project progresses, the emphasis of the programs will shift from promotion to more education.

Beginning in the second year, the technician will be responsible for establishing demonstration plots and providing technical assistance to other farmers who are interested in conservation tillage, but are not directly involved in demonstrations. Careful records of cultural practices used on demonstration plots will be kept. Results of demonstration plots will be made available to the public on a yearly basis, and demonstration plots will be used as teaching aids at project-sponsored field days throughout the summer.

The combination education/demonstration/technical assistance program will continue for 4 years. During this time, the rate of adoption of reduced tillage will be monitored and reported to the Managing Agency by the Supervisors. Continued funding for an individual project during these 4 years will be contingent upon demonstrating increased adoption of reduced tillage. This should pose little problem for a given county, however, since the experience of past projects has been that technicians normally receive more requests than they can honor.

A time table for main project activities is given in Figure 7.2.

7.2.7 CRISPS and LRIS.

County Resource Information System Packages were prepared for 28 counties during Phase II. They have been described in the previous Chapter. CRISPS have proven to be valuable land and water resource planning tools for the local level of government. The potential gross erosion, soil management groups, and best management practice applicability maps are especially useful planning tools for this program. This work element would not only produce CRISPS for the counties in the project, but also for the remaining Lake Erie Counties.

When the data now in the LRIS were originally coded, the best available soil surveys were used. Nine counties had only old reconnaissance surveys, and data from modern soil surveys in progress were coded for 24 counties. Thirteen of the surveys have now been completed and would be available for coding for the LRIS. The LRIS can also be used with LANDSAT imagery to monitor the implementation rates for reduced tillage. Multitemporal scenes have been used to monitor land cover (Ref 3), and these techniques would be used to measure acceptance rate of conservation tillage.

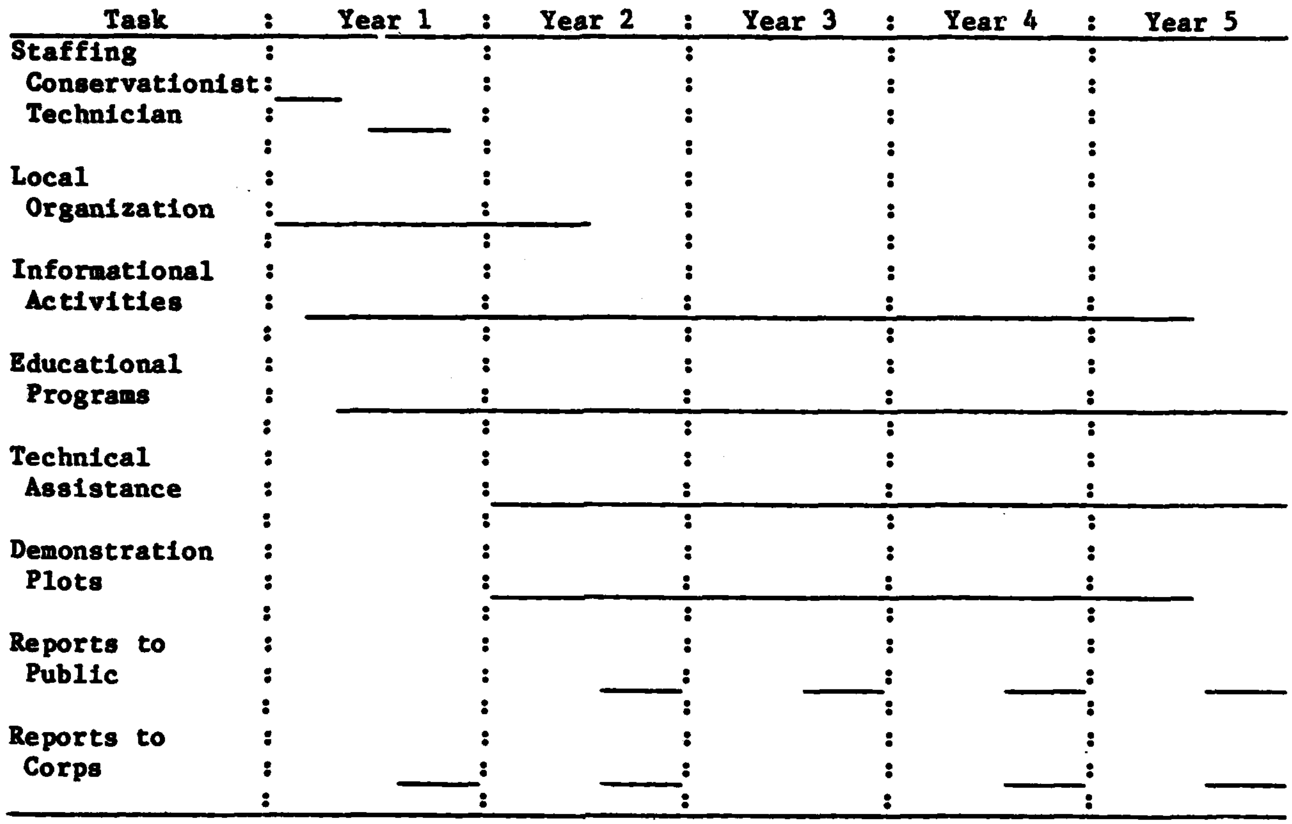


Figure 7.2 Timetable for Program Execution

7.2.8 Program Costs.

The projected costs for a given county project are given in Table 7.2. This budget assumes a 5-year salary for the project conservationist and 4 years for the technician. This represents the bulk of program costs. There is no cost sharing figured into this budget, as it is assumed that cost sharing will be available from ASCS. Table 7.3 shows the costs for the entire project. Included in the total are costs for the involvement of an Extension Agronomist and a Resource Conservationist for the full 10 years of the project. Also included are costs for the Managing Agency to administer the project as well as costs for the CRISP packages, the soil updates, and the monitoring of acceptance rates.

Table 7.2 - Costs for County Demonstration/Implementation Projects

Component	5-Year Cost
	$
Personnel Salaries	
Conservationist (5-years, at $25,000)	125,000
Technician (4-years, at $18,000)	72,000
Secretary (5 years, halftime at $7,500)	37,500
Fringe Benefits (at 20 percent of salary)	46,900
Overhead (at 25 percent of salary)	58,600
Publications	10,000
Travel	20,000
Telephone	5,000
Equipment	30,000
County Total	405,000
20-County Program Total	8,100,000

Table 7.3 - Federal Program Costs for 10-Year Period

Program Costs	10-Year Period
$	$
20-County Cost at 405,000	8,100,000
Resource Conservationist SCS at 72,000/yr. (1)	720,000
Extension Agronomist at 64,000/yr. (1)	640,000
Managing Agency at 75,000/yr. (1) (2)	750,000
Education Program Publications and Consulting Including Extension and University	650,000
30 CRISP Package at 6,000 (2)	180,000
18 Soils Updates at 6,000 (2)	108,000
Monitor Land Cover (2)	150,000
Total	11,298,000

(1) Includes fringe benefits, travel, and office overhead.

(2) Provides an average of $131,300 per year over the 10 years to be expended in technical and administrative support of the recommended program and the monitoring program detailed in Table 7.4. Estimates are based on costs incurred by the Corps of Engineers for similar activities during the study period.

Since the program is a regional project in response to international agreements, no local sponsor is designated and no cost sharing will be required.

7.3 MONITORING

7.3.1 Tributary Monitoring.

The tributary monitoring program described here is designed to measure change in sediment nutrient and pesticide loads resulting from the recommended program. In order to accomplish this purpose, acceptable baseline data must be available. The only stations with the required data bases are the Maumee River, Portage, Sandusky (9 Stations), and Huron Rivers. As described in Chapter 3, the annual variability in sediment, nutrient transport are well characterized at these stations. The Honey Creek and Upper Honey Creek are priority areas because it is anticipated that large shifts toward no till and conservation tillage will occur in Honey Creek, thus changes in nutrient loads attributable to the program can be measured there. The costs of the required tributary monitoring program are shown in Table 7.4. The program will monitor six rivers for a total of 5 years. Funds are also included for data interpretation, calculations, report preparation, and contract administration.

Table 7.4 - Annual Cost Estimate for Tributary Monitoring

Tributary	Flow	Continuous Monitoring of Nutrients	Pesticides	Total
	$	$	$	$
Honey Creek	6,500	15,000	6,000	27,500
Upper Honey Creek	6,500	15,000	6,000	27,500
Maumee River	6,500	15,000	6,000	27,500
Portage River	6,500	15,000	6,000	27,500
Huron River	6,500	15,000	6,000	27,500
Sandusky River	6,500	15,000	6,000	27,500
Total	39,000	90,000	36,000	165,000

Five years of Monitoring at $165,000	= $825,000
Five-year Contract Administration at $15,000	= 75,000
Calculations and Reporting	= 50,000
Total	$950,000

7.3.2 Lake Monitoring.

The Surveillance Subcommittee of the Great Lakes Water Quality Board developed a Great Lakes International Surveillance Plan (GLISP) (Ref 4). The document presents the basic framework for surveillance activities in the Great Lakes Basin as required in the 1978 Water Quality Agreement between the United States and Canada.

The surveillance plan is a long-term strategy to coordinate the monitoring activities of the many participating agencies in a cost-effective manner. In this regard, the plan is characterized by quality assurance programs and the rapid exchange of comparable data among the various jurisdictions.

The plan is a framework to facilitate long-term planning of monitoring programs. It is a planning document which provides a basis for identifying future resource needs for monitoring, and a means for coordinating the monitoring programs of various State, Provincial and Federal agencies. The plan facilitates research planning so that research can make maximum use of monitoring facilities.

The fundamental objective of the Great Lakes International Surveillance Plan is to determine the impact of man's activities on the quality of the Great Lakes ecosystem, particularly the effect of these activities on the

matter retained on the land surface. Also, runoff may be reduced in conservation tillage systems. Pesticide losses in the runoff are effectively reduced.

8.9 THE HONEY CREEK DEMONSTRATION CONFIRMS THE VALIDITY OF THE PROJECT APPROACH IN ADDRESSING WATER QUALITY PROBLEMS.

Specific findings of the Honey Creek Watershed Management Study which have been incorporated in the Recommended Program include:

a. A start-up period, lasting as long as 2 years in some cases, is a necessary step to insure uniform awareness of the program, and to establish the required organization and staffing for full implementation.

b. Additional county personnel qualified to provide technical assistance in agronomic practices are essential for success.

c. A high level of exposure of the project goals and early implementation efforts are necessary to create the climate for landowner and agency support.

d. A project-wide monitoring and evaluation effort should be used to reinforce the commitment to the goals of the project.

8.10 MONITORING OF CONSERVATION TILLAGE ADOPTION, AS WELL AS TRIBUTARY WATER QUALITY MONITORING, IS NECESSARY TO DOCUMENT THE SUCCESS OF A DIFFUSE SOURCE PHOSPHORUS CONTROL PROGRAM.

This conclusion has been reached through the understanding of tributary pollutant transport we have gained as a result of this study. Annual variability in transport is several times greater than the reduction in mean annual transport which can ultimately be achieved through the Recommended Program. Monitoring the adoption of conservation tillage is necessary to document the success of the program and predict its impact on Lake Erie. Long-term water quality monitoring will be required to verify actual reductions in transport.

8.11 THE LAND RESOURCES INFORMATION SYSTEM (LRIS) HAS BEEN SUCCESSFULLY USED TO IDENTIFY 20 OF THE 62 COUNTIES IN THE LAKE ERIE BASIN AS PRIORITY AREAS WHERE DIFFUSE SOURCE PHOSPHORUS CONTROL PROGRAMS HAVE A HIGH PROBABILITY OF SUCCESS. THE LRIS CAN ALSO BE USED TO MONITOR ADOPTION.

Twenty counties in the Lake Erie Basin have been selected for direct participation in the recommended program based on the absolute amount of soil loss reduction which can be achieved, the total acreage of cropland suitable for conservation tillage and the ranking of each county based on the flow weighted mean concentration of total phosphorus of the major river basin to which it is tributary. Remote sensing techniques and the LRIS can be used to monitor adoption.

8.12 REDUCTION OF IN-LAKE PHOSPHORUS CONCENTRATIONS WILL NOT ELIMINATE ALL LOCAL IN-STREAM WATER QUALITY PROBLEMS.

The bulk of the tributary phosphorus load is transported to Lake Erie during a few major storm events each year. It is this phosphorus which the Recommended Program will control. The program will not control septic tank discharges, runoff from barnyards and other minor sources which control the concentration of phosphorus and other pollutants during low flow periods. It is, however, expected that the programs of other agencies will address these problems.

8.13 THE RECOMMENDED PROGRAM WILL ULTIMATELY ACHIEVE A REDUCTION IN TOTAL PHOSPHORUS TRANSPORT TO LAKE ERIE OF 2,030 METRIC TONS PER YEAR. THE TOTAL COST OF THIS PROGRAM IS $12.25 MILLION (1982 DOLLARS) OR $612,400 ANNUALLY OVER A 20-YEAR PROJECTION PERIOD.

This conclusion has the following implications for Great Lakes Water Quality Management Programs:

a. The Great Lakes Water Quality Agreement of 1978 between the United States and Canada calls for an additional target phosphorus reduction for Lake Erie of 2,000 metric tons per year beyond the achievement of a 1.0 milligram per liter effluent concentration for all municipal wastewater treatment plants currently discharging more than 1 million gallons per day. The Unites States allocation of this reduction is 1,700 metric tons per year. The Recommended Program will exceed this allocation. Relative to achieving the reduction by means of additional point source control the Recommended Program has a benefit/cost ratio of 10:1.

b. It is a finding of this study that a new base-year tributary phosphorus load to Lake Erie should be recognized. Inclusion of tributary monitoring data from 1978, 79, and 80 in the computation gives a base-year total phosphorus load of 16,455 metric tons per year. When the 1.0 milligram per liter effluent limitation has been achieved the total phosphorus load to Lake Erie will be 15,025 metric tons per year. At that time an additional phosphorus reduction of 4,025 metric tons per year (not 2,000 metric tons per year as stated above) will be required to meet the 11,000 metric tons per year total loading objective of the Agreement. The United States allocation of this reduction objective should be approximately 2,800 metric tons per year. To reach this reduction objective an additional 770 metric tons per year in reductions beyond the Recommended Program must be achieved through point source controls beyond the 1.0 milligram per liter effluent limitation, and at a cost of $5 million annually. The benefit/cost ratio of the Recommended Program is 17:1 compared to a program requiring the entire reduction to be achieved by point source control.

8.14 ALL MUNICIPAL WASTEWATER TREATMENT PLANTS IN THE LAKE ERIE BASIN DISCHARGING IN EXCESS OF 1 MILLION GALLONS PER DAY NEED TO BE DESIGNED AND OPERATED SO THAT THE TOTAL PHOSPHORUS CONCENTRATIONS IN THEIR EFFLUENTS WILL NOT EXCEED A MAXIMUM CONCENTRATION OF 1.0 MILLIGRAMS PER LITER.

These controls were called for by the 1978 Great Lakes Water Quality Agreement and are required if the phosphorus loading objective is to be met.

8.15 THE UNITED STATES DEPARTMENT OF AGRICULTURE, SOIL CONSERVATION SERVICE SHOULD VIEW THE LAKE ERIE BASIN AS A HIGH PRIORITY AREA.

It is necessary to continue to fund the provision of technical assistance to county soil and water conservation distircts at current levels. Current programs need to be continued because of the important role that existing rates of soil loss play in the euthrophication of Lake Erie.

8.16 THE UNITED STATES ENVIRONMENTAL PROTECTION AGENCY, GREAT LAKES NATIONAL PROGRAM OFFICE'S ACCELERATED CONSERVATION TILLAGE PROJECTS AND HIGH FLOW MONITORING OF KEY TRIBUTARIES IN THE LAKE ERIE BASIN NEED TO BE CONTINUED.

These projects have continued and expanded the interest in conservation tillage started by the Honey Creek Demonstration Project. They are filling the gap between the end of the LEWMS study and the start of the recommended program.

8.17 THE GREAT LAKES INTERNATIONAL SURVEILLANCE PLAN NEEDS TO BE CONTINUALLY FUNDED BY THE COOPERATING STATE AND FEDERAL AGENCIES.

It provides the basic framework for surveillance activities in the Great Lakes Basin as required in the 1978 Great Lakes Water Quality agreement between Canada and the United States.

CHAPTER 9 - RECOMMENDATIONS

9.1 It is recommended that this report be sent to Congress for information and appropriate action on the following program costing $12.5 million.

a. A proposed Accelerated Conservation Tillage Program consisting of individual projects of 5 years duration in each of 20 counties, phased in over a 10-year period.

b. A tributary monitoring program at six stations located on the Maumee, Portage, Sandusky, and Huron Rivers and on Honey Creek and the Upper Honey Creek Subbasin.

c. Update and use the Land Resources Information System to produce additional County Resource Information System Packages and to monitor the adoption of conservation tillage.

9.2 This program is in response to Section 108(d) of P.L. 92-500 and is in fulfillment of International Agreements. Program funding could be administered by a managing Federal agency with distribution of monies to appropriate local and other Federal agencies. The bulk of the funds would be allocated at the local level and used to accelerate existing programs.

for Joseph N Cracken, MAJ
ROBERT R. HARDIMAN
Colonel, Corps of Engineers
District Engineer

GLOSSARY OF TERMS

Adsorption - The taking up of one substance on the surface of another.

Algae - Thallophytes, or rootless plant bodies, possessing chlorophyll, and so capable of photosynthesis.

Anaerobic - Containing no dissolved oxygen.

Anoxic - Anaerobic; depleted of oxygen.

Baseflow - That part of streamflow contributed by groundwater seeping into surface streams.

Benthos - The community of aquatic organisms which live on the bottom.

Best Management Practices - A practice, or combination of practices, that is determined by a State (or designated areawide planning agency) after problem assessment, examination of alternative practices, and appropriate public participation to be the most effective, practicable (including technological, economic, and institutional considerations) means of preventing or reducing the amount of pollution generated by nonpoint sources to a level compatible with water quality goals.

Bioavailable - Can be used by organisms for their growth, also Biologically Available.

Critical Areas - Within a watershed, those areas contributing the largest amounts of sediment and nutrients to streamflow.

Delivery Ratio - A measure of the sediment actually reaching a stream or lake; equal to the quantity of material reaching a point in a stream divided by the quantity of material eroded above that point.

Diffuse Source - Any source which is not a point source. A nonpoint source.

Drainage Basin - An area delineated by a boundary within which runoff drains to a common outlet. A watershed. When used with reference to a lake, the area includes the surface area of tributary streams and lakes and their drainage basins, but not that of the receiving lake.

Dissolved Inorganic Phosphate - That phosphate that is dissolved in water and is in the form of orthophosphate (PO_4). Dissolved by definition means any material that will pass through an 0.45 micron pore size filter. The word "soluble" is synonymous with "dissolved," although not as rigidly defined and "reactive" is essentially the same as "orthophosphate" or "inorganic." When the water sample is filtered through filters with pore size greater than 0.45 micron, the sample is referred to as "filtered."

Eutrophic - Richly supplied with plant nutrients and supporting heavy plant growth. Having high biological production and turbid waters with deeper waters depleted of oxygen at times during the year.

Eutrophication - The enrichment of natural waters by nutrients, resulting in systematic changes in the quality of the waters.

Event - A distinct period of high rainfall over a watershed or high streamflow during a storm.

Flux - Mass per unit of time.

Hypolimnion - The deep, cold, and relatively undisturbed region of a summer stratified lake.

Interstitial Water - Water occupying the pore space between soil or sediment particles.

Lake Basin - The entire area within the drainage boundaries of a lake, including tributaries and the lake itself. (e.g., the Lake Erie Basin.) Also, the depression which holds the lake water body. (e.g., Lake Erie's Central Basin.)

Load - Flux. Mass per unit time.

Mathematical Model - A systematic, logical representation of physical, chemical, or other phenomena by mathematical expressions, which simulate the response of a real system to inputs or changes. Often programmed for computer analysis, hence the term "computer model."

Mesotrophic - Intermediate in characteristics between oligotrophic and eutrophic; that is, having a moderate supply of plant nutrients, and moderate plant growth and biological production.

Nonpoint Source - Diffuse source.

Nutrient - Organic or inorganic chemical necessary for the growth and reproduction of organisms.

Oligotrophic - Poorly supplied with plant nutrients and supporting little plant growth. As a result, biological production is generally low, waters are clear, and deeper waters are well supplied with oxygen throughout the year.

Periphyton - All aquatic organisms which are attached to, or move upon, a submersed substrate but do not penetrate into it.

Phosphorus - Phosphorus in all its forms; total phosphorus reported as phosphorus.

Point Source - Effluent from a municipal or industrial outfall.

Potential Gross Erosion - A measure of the potential for soil to be dislodged and moved from its place of origin; it is not necessarily the amount of soil which actually reaches a stream or lake. Determined with the USLE, same as soil loss.

River Basin - The drainage basin of a given river.

Runoff - That portion of precipitation which drains overland to a receiving body of water with a free surface.

Sediment Phosphorus - The difference between total phosphorus and soluble orthophosphate concentrations measured in a sample of water.

Study - The Lake Erie Wastewater Management Study (Lake Erie Study). The current study, authorized by Section 108 of Public Law 92-500.

Trophic Level - Level of nutrient enrichment of a body of water.

Watershed - Drainage basin.

Water Quality Standard - A regulation on law specifying mandatory quantitative measures of the physical, chemical, bacteriological and sensible qualities of water.

Wastewater - Water which carries the wastes of cultural processes or activities.

END