ABSTRACT

For the past two decades, water quality of both natural and man-made lakes has been a major environmental concern. Numerous studies suggest that land use patterns and/or storm water runoff are major factors in nutrient loading and bacterial contamination of freshwater lakes. In 1986, the Property Owners Association at Lake Latonka in Jackson Center, Pa., installed three sediment control structures in an attempt to reduce the amount of nonpoint-source pollution entering the lake. The Association installed a fourth structure in 1988. It has yet to be determined if any improvement in the water quality has occurred due to the control structures or to the possible changes in the agricultural activities surrounding the development.

From nine years of water quality monitoring data acquired from the consulting firm hired by the Property Owners Association, the percent reduction was determined by calculating the difference between the influx and outflow, dividing by the influx and multiplying by 100. The percent reduction was determined for each of the five water quality parameters (fecal coliform bacteria, ammonia, nitrate, phosphate and total solids). The mean percent reduction over the nine year monitoring period for each Sediment Control Structure and four "control" streams (Manito, Mohican, Park and Apache) were compared for each parameter. The total inorganic nitrogen and phosphate was also determined to provide a basis of comparison to other wetland systems recieving agricultural runoff.

Throughout the nine year monitoring period, there was a gradual improvement in the water quality entering the lake. All four sediment control structures demonstrated varying abilities to reduce coliform bacteria, nitrate, phosphate and suspended sediment. The structures were not able to reduce ammonia concentrations, most likely due to vegetative decay within the retention basins.

EFFECTIVENESS OF SEDIMENT CONTROL STRUCTURES: REDUCING NONPOINT-SOURCE POLLUTION ENTERING A RURAL HOUSING DEVELOPMENT LAKE IN MERCER COUNTY, PENNSYLVANIA

by
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TABLE OF CONTENTS

Chapter		Page
1	INTRODUCTION TO NONPOINT-SOURCE POLLUTION PROBLEM AND POLICY	1
	1.1 Introduction	1
	1.1.1 Overview	1
	1.1.2 Current Land-Use Practices	5
	1.1.3 Factors Affecting Constructed Systems for Nonpoint-Source Abatement	7
	1.2 Policy	11
	1.3 Nonpoint-Source Control Ssytems	13
	1.4 Research Objective and Significance	14
	2.1 Objective	14
	2.2 Significance of Study	15
2	SITE LOCATION AND DESCRIPTION	16
	2.1 General Site Description	16
	2.2 Water Quality Problem Assessment	17
	2.3 Control Structure Description	17
	2.4 Latonka Subwatersheds	21
	2.4.1 Control Subwatersheds	22
	2.4.1.1 Manito	23
	2.4.1.2 Mohican	23
	2.4.1.3 Park	29
	2.4.1.4 Apache	29
	2.4.2 Sediment Control Structures	32

TABLE OF CONTENTS (cont.)

Chapter		Page
	2.4.2.1 Structure 1	32
	2.4.2.2 Structure 2	38
	3.4.2.3 Structure 3	38
	3.4.2.4 Structure 4	39
	2.5 Other Sample Areas	44
	2.5.1 Coolspring Creek	44
	2.5.2 Dam	44
3	STUDY DESIGN	46
	3.1 Data Collection	46
	3.1.1 Water Quality Data	46
	3.1.2 Sediment Sample Collection and Analysis	47
	3.1.3 Precipitation Data	47
	3.1.4 Land-Use Data	48
	3.1.5 Drainage Basin Area, Vegetation and Retention Time	48
	3.2 Sample and Data Analysis	49
	3.2.1 Water Quality Analysis	49
	3.2.2 Sediment Sample Analyis	50
	3.3.3 Structure Effectiveness	50
4	RESULTS AND DISCUSSION	52
	4.1 Results	52
	4.1.1 Water Quality Data and Percent Reductions	52

TABLE OF CONTENTS (cont.)

Chapter		Page
	4.1.2 Controlling Factors	55
	4.2 Discussion	60
5	CONCLUSIONS, RECOMMENDATIONS AND IMPLICATIONS	63
	5.1 Conclusions	63
	5.2 Recommendations	64
	5.3 Implications	65
	APPENDIX	67
	REFERENCES	85

LIST OF TABLES

Table		Page
1	Stream Subwatershed Land-Use at Lake Latonka, Mercer County, Pennsylvania	22
2	Stream Subwatershed Area, Soil Types, Slope Ranges, and Control Structures Retention Basin Areas at Lake Latonka, Mercer County, Pennsylvania	31
3	Stream Subwatershed Dominant Vegetation at Lake Latonka, Mercer County, Pennsylvania	33
4	Water Quality Parameter and Testing Method Used at Lake Latonka, Mercer County, Pennsylvania	49
10	Mean Percent Reduction in Five Water Quality Parameters from 1986 to 1994 at Lake Latonka, Mercer County, Pennsylvania	54
22	Mean Monthly Retention Times for the Four Sediment Control Structures at Lake Latonka, Mercer County, Pennsylvania	56
23	Mean Retention Times, Retention Basin Area, Subwatershed Area, and Flow Rates for the Four Sediment Control Structures at Lake Latonka, Mercer County, Pennsylvania from 1988 to 1994	57
24	Sediment Loading Rates (g/yr) for each of the Four Sediment Control Structures at Lake Latonka, Mercer County, Pennsylvania	57
27	Total Precipitation 24 hours, 5 days, 14 days and 30 days Prior to Sampling at Lake Latonka, Mercer County, Pennsylvania	59
28	Total Precipitation 24 hours, 5 days, 14 days, and 30 days Prior ro Sampling at Lake Latonka, Mercer County, Pennsylvania	59
5	Mean Coliform Concentrations in Nine Subwatersheds and Lake Discharge Point from 1985 to 1994 at Lake Latonka, Mercer County, Pennsylvania	60

LIST OF TABLES (cont.)

6 Mean Total Solids Concentrations in Nine Subwatersheds and Lake Discharge Point from 1985 to 1994 at Lake Latonka, Mercer County, Pennsylvania 69

7 Mean Ammonia Concentrations in Nine Subwatersheds and Lake Discharge Point from 1985 to 1994 at Lake Latonka, Mercer County, Pennsylvania 70

8 Mean Nitrate Concentrations in Nine Subwatersheds and Lake Discharge Point from 1985 to 1994 at Lake Latonka, Mercer County, Pennsylvania 71

9 Mean Phosphate Concentrations in Nine Subwatersheds and Lake Discharge Point from 1985 to 1994 at Lake Latonka, Mercer County, Pennsylvania 72

11 Yearly Percent Coliform Reduction in Seven Subwatersheds and Lake Discharge Point from 1986 to 1994 at Lake Latonka, Mercer County, Pennsylvania 73

12 Yearly Percent Ammonia Reduction in Seven Subwatersheds and Lake Discharge Point from 1988 to 1994 at Lake Latonka, Mercer County, Pennsylvania 74

13 Yearly Percent Nitrate Reductions in Seven Subwatersheds and Lake Discharge Point from 1988 to 1994 at Lake Latonka, Mercer County, Pennsylvania 75

14 Yearly Percent Phosphate Reductions in Seven Subwatersheds and Lake Discharge Point from 1993 to 1994 at Lake Latonka, Mercer County, Pennsylvania 76

17 Monthly Percent Reduction in Coliform Concentrations for Seven Subwatersheds from May to October at Lake Latonka, Mercer County, Pennsylvania 77

18 Monthly Percent Reduction in Ammonia Concentrations for Seven Subwatersheds from May to October at Lake Latonka, Mercer County, Pennsylvania 78

19 Monthly Percent Reduction in Nitrate Concentrations for Seven Subwatersheds from May to October at Lake Latonka, Mercer County, Pennsylvania 79

20 Monthly Percent Reduction in Phosphate Concentrations for Seven Subwatersheds from May to October at Lake Latonka, Mercer County, Pennsylvania 80

List of Figures

Figure		Page
1	Nonpoint pollution flow diagram demonstrating the flow of nutrients, bacteria and solids within a watershed from source to reception	4
2	Location of Lake Latonka in Mercer County, Pennsylvania	19
3	Schematic Diagram of the Sediment Control Structure in Place at Lake Latonka, Mercer County, Pennsylvania	20
4	Subwatersheds of the Lake Latonka Watershed, Mercer County, Pennsylvania	25
5	Photograph of the Manito Subwatershed as Taken from Latonka Drive circumnavigating the Lake in Central Mercer County, Pennsylvania	26
6	Photograph of the Mohican Subwatershed as Taken from Latonka Drive circumnavigating the Lake in Central Mercer County, Pennsylvania	26
7	Photograph of the Park Subwatershed as Taken from Latonka Drive circumnavigating the Lake in Central Mercer County, Pennsylvania	27
8	Photograph of Sediment Control Structure 1 Retention Basin as Taken from Latonka Drive circumnavigating the Lake in Central Mercer County, Pennsylvania	27
11	Schematic Diagram of the Retention Basin for Sediment Control Structure 1 at Lake Latonka, Mercer County, Pennsylvania	28
12	Schematic Diagram of the Retention Basin for Sediment Control Structure 2 at Lake Latonka, Mercer County, Pennsylvania	34
13	Photograph of Sediment Control Structure 2 Retention Basin as Taken from Latonka Drive circumnavigating the Lake in Central Mercer County, Pennsylvania	35

LIST OF FIGURES (cont.)

14 Photograph of Sediment Control Structure 3 Retention Basin as Taken from Latonka Drive circumnavigating the Lake in Central Mercer County, Pennsylvania 35

15 Schematic Diagram of the Retention Basin for Sediment Control Structure 3 at Lake Latonka, Mercer County, Pennsylvania 36

16 Schematic Diagram of the Retention Basin for Sediment Control Structure 4 at Lake Latonka, Mercer County, Pennsylvania 42

17 Photograph of the Coolspring Subwatershed as Taken from Latonka Drive circumnavigating the Lake in Central Mercer County, Pennsylvania 43

18 Photograph of Sediment Control Structure 4 Retention Basin as Taken from Latonka Drive circumnavigating the Lake in Central Mercer County, Pennsylvania 43

9 Photograph of the Apache Subwatershed as Taken from Latonka Drive circumnavigating the Lake in Central Mercer County, Pennsylvania 44

10 Photograph of Lake Latonka as Taken from a Public Dock just North of the Spillway 44

CHAPTER 1

INTRODUCTION TO NONPOINT-SOURCE POLLUTION PROBLEM AND POLICY

1.1 Introduction

1.1.1 Overview

Deterioration of surface water quality within watersheds is a major concern throughout the United States (Schlosser and Karr 1981, 1082). Nonpoint-source pollution is identified as a major cause of deteriorating water quality (Federal Water Pollution Control Act (PL 92-500)(1972), as amended by the 1977 Clean Water Act, Frey et al. 1994,80-100, Brenner et al. 1990, 482, 1987, 295, Humenick et al. 1987, 737, Adler and Raucher 1986, 234, Worthington 1986, 342). Land-use practices, however, have been proven ineffective in addressing nonpoint source pollution. Because additional measures, such as sediment control structures, as a secondary control are being employed to protect sensitive water bodies further, the present research was undertaken.

Activities such as lumbering, road construction, mining, and agriculture have adversely impacted both soil and aquatic systems (Simons and Li 1980, 342). Pollution due to such activities are commonly referred to as nonpoint-source pollution, because it originates form diffuse sources (Harper *et al*. 1992, 778, Worthington 1986, 342). Nonpoint pollution is difficult to control because there is no fixed discharge point, and therefore no means of enforcing discharge standards (Worthington 1986, 342).

While much research has been conducted on the contamination of both surface and groundwater, concerning the nutrients, little research has been conducted on microbial contamination from nonpoint sources, such as agriculture (Burge and Parr 1980, 117). The main concern of nonpoint microbial contamination is the pathogenic organisms, which can be divided into four groups: viruses, bacteria, protozoans, and helminths (intestinal worms).

Agricultural land-uses are responsible for contributing more phosphorous and nitrogen than any other form of land-use per unit area (Hopkinson and Day 1980, 319). Agriculture has been cited as contributing, on average, 75 percent of the nitrate, 92 percent of the total solids (dissolved and suspended solids), 73 percent of the biochemical oxygen demand and 83 percent of the bacterial load from nonpoint-source pollution nationwide (Payne 1986, 334). The high bacterial loads in freshwater systems receiving agricultural runoff is most often due to either the presence of livestock in direct contact with a stream or runoff from manure storage areas (Brenner and Mondok 1995, 13, Brenner et al. 1995, 7, Burge and Parr 1980, 117).

Agriculture is a principal source of contamination (fecal coliform, nutrients and sediment) affecting 58 percent of the nearly 2.7 million acres of lakes in the United States (National Research Council 1992, 90). Within Pennsylvania—the site of the study— agriculture is responsible for degrading nearly 700 miles of streams and rivers (although only half the miles of streams and rivers in the state have actually been accessed). Of these nearly 700 miles, 50 miles are in the Ohio River watershed, which accounts for nearly 20 percent of the streams affected by nonpoint source pollution in the watershed.

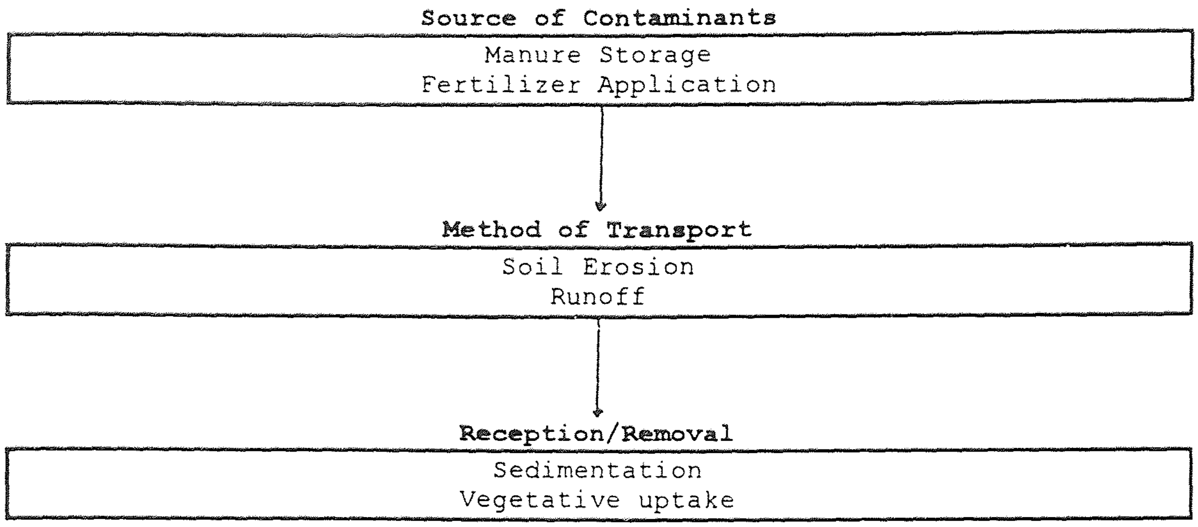

Figure 1 Nonpoint pollution flow Diagram demonstrating the flow of nutrients, bacteria and solids within watershed from source to reception

Unlike industrial discharges, which have a fixed discharge pipe, nonpoint pollution has no definitive discharge point. Agricultural activity, such as feedlots and crop cultivation activities, is one of the principal forms of land use creating nonpoint source pollution; this type of pollution contributes sediment, nutrients (phosphate, nitrate and ammonia) and coliform bacteria to receiving waters—a process which leads to eutrophication, closing of recreational areas and decreased diversity of aquatic life. Spreading of commercial fertilizers or manures increases both the nutrient and coliform bacterial loads (Humenick et al. 1987, 738, Payne 1986, 334-340, Worthington 1986, 344). Agriculture contributes over 200 metric tons of nutrients (Fontaine 1994).

Nonpoint contaminants (fecal coliform bacteria, nutrients and sediment) are commonly transported to receiving waters by means of either soil erosion or surface runoff. Soil erosion is responsible for contributing primarily sediments to surface waters. Surface runoff, to the contrary, contributes both bacteria and nutrients as well as sediment.

The receptors of nonpoint source pollution are commonly freshwater systems, either streams, rivers, or lakes/reservoirs. Within these systems, contaminants are typically removed by either sedimentation or vegetative uptake. Sedimentation involves the settling out of suspended materials (primarily sediment within the water column). The removal of nutrients is commonly accomplished by vegetation using the nutrient to grow. This process is known as vegetative uptake.

1.1.2 Current Land-Use Practices to Control Nonpoint Source Pollution

Land-use practices, such as strip cropping, contour farming, no-till agriculture, and terrace farming—all known as Best Management Practices (BMPs)— are currently the only accepted way of combating nonpoint-source pollution. Strip cropping involves the alternating of crop rows (i.e. corn-soybeans-corn), while no-till farming typically involves cultivating a crop without disturbing the soil to a large extent. Both strip cropping and no-till farming involve reducing the amount of bare soil exposed for erosion, thereby reducing erosion and soil loss. Contour farming and terracing are used on steep slopes to control erosion. Contour farming involves tilling along the natural slope or contour, while terracing involves breaking the slope into a series of stair steps or terraces. Both contour farming and terracing attempt to reduce the volume and velocity of water leaving the field.

These methods are only relatively successful in controlling soil erosion and have not completely eliminated sedimentation problems. Concentrations of total solids have been shown to be as much as 20 times greater in nonforested agricultural watersheds under BMPs when compared to forested nonagricultural watersheds (Hill 1987, 140). Park et al. (994, 1019-1022) cited 42 percent reductions in Kjeldahl (organic) nitrogen, 35 percent reduction in total phosphorous and 20 percent reduction in sediment with strip cropping in the Midwest United States. Such comparisons indicate that while these methods may reduce erosion, they are not completely effective. In addition, many of these BMPs are only seasonally effective in reducing sedimentation because of changes in precipitation and other climatic factors (Brenner et al. 1990. 484).

1.1.3 Constructed Systems for Nonpoint Source Abatement

Technological applications such as fencing, riparian (those trees and woody shrubs associated with a stream channel) buffer zones, constructed wetlands and wetland restoration, and sediment basins, are being developed to be used in addition to BMPs for the control of nonpoint source pollution. For example, Brenner et al. (1995, 13), determined that fencing cattle out of the stream channels and restoring a riparian wetland resulted in a 40 to 60 percent reduction in phosphate and coliform bacteria, respectively. These practices have recently been added to the recommended land use practices in Mercer County, Pennsylvania.

The degree to which sediment basins and constructed wetlands reduce concentrations has not been adequately addressed. These systems function by increasing retention time and decreasing flow velocity to settle out suspended material. The two parameters commonly associated with sediment—bacteria and nutrients (Brenner et al. 1990, 484, 1987, 298)—are transported by sediments to receiving streams.

Research by Brenner et al. (1995, 7) determined that restoring riparian areas along stream channels resulted in reduced velocity of runoff and allowed for increased retention time for sediments to settle. The result was a reduction in the concentration of bacteria nutrients and sediment entering the stream. The reduction in bacteria, nutrients and sediment resulted because the riparian buffer acted as a trap and reduced the velocity.

Wetlands, natural or constructed, have a natural ability to remove contaminants, and contain four components that function as water purifiers (Hammer 1993, 73-75). These are vegetation, substrate, the microbial population, and the water column itself (Hammer 1993, 75). Wetlands increase settling time, and are nutrient traps. Within wetlands (either natural or constructed), phosphorous is removed primarily through deposition and adsorption to sediments (Cooke 1992, 733, Reed et al 1988, 85). Nitrogen, on the other hand, is removed through not only adsorption and deposition but also vegetative uptake, nitrification/denitrification and volatilization of ammonia to the atmosphere (Hammer 1993, 75). The removal of fecal coliform is dependent on retention time and temperature (Reed et al. 1988, 70). Wetland systems receiving surface runoff from agricultural areas display one of the highest sediment accumulation rates (Johnson 1991, 498). The concentration of nutrients, bacteria and total solids within the water column also determine how well a wetland system can remove these materials. For example, if a wetland receives higher concentrations of total solids than it can remove the system becomes saturated and fails to remove any addition solids (Hammer 1993, 154).

Previous studies by Johnson (1991, 493), Brenner et al. (1995, 7), and Sikora (1994, 4-6) indicate the value of riparian vegetation and wetland systems. The vegetation associated with both of these systems plays a dual role: as sediment/nutrient traps and as a mechanism for nutrients uptake. The presence or absence of such systems has an impact on the ability of constructed systems to reduce nutrients and total solids.

An earlier study at Lake Latonka (Brenner and Brenner 1995, 6) indicated that the size of the subwatershed determined the concentration of total solids, bacteria and nutrients entering the lake from each subwatershed. These concentrations are due to the fact that the volume of water within a stream is related to the size of the watershed from which it is drawn.

The watershed area, then, determines the loading rate of each parameter (sediment, coliform bacteria, and nutrients). It is this loading rate that determines whether or not a constructed wetland or constructed sediment control structure functions according to design (Hammer 1992, 154, Hedin 1991, 10).

Similarly, the size of the retention basin, a small impoundment designed to retard flow and settle out suspended materials--also determines how well a constructed system operates to control water quality. The size of the basin is determined by the loading rate. The loading rate is calculated according to the following formula:

Load=C*R*T

where Load=loading rate (mg/yr)
C=Concentration of contaminant (mg/L)
R=Flow rate (L/sec)
T=3,153,600, which is the conversion factor from per second to per year

Likewise, the retention time is a factor of the size of the retention basin: the larger the basin, the longer the retention time. The retention basin area is an important factor since increased retention time results in more time for suspended materials to settle out and more time for microbial activity to reduce nutrient concentrations (Fifield 1994, 39). These authors suggest that increasing the retention time of agricultural runoff entering a lake or reservoir would reduce the concentration of suspended materials and allow time for microbial action. Increasing the retention time would reduce not only sediment concentrations, but bacteria and nutrient concentrations as well.

1.2 Policy

Within Mercer County, as elsewhere in Pennsylvania, there is a voluntary policy to control nonpoint pollution coming from agricultural areas. Land-use education and making use of both natural systems and technological innovations are the only actions being undertaken at this time in an effort to control agricultural runoff. There are two natural systems currently employed—restoration of riparian buffer zones and the use of natural wetland systems as purifiers. The list of technological innovations is larger--soil erosion prevention measures, manure storage facilities and fencing cattle out of streams—are all part of the current land-use education currently in place in Mercer County. Also included in this category are constructed wetlands and in-stream structures (control structures within the stream channel), such as sediment control structures. Constructed wetlands and in-stream structures are currently being utilized on an experimental basis.

Two factors come into play with any nonpoint-source abatement policy in Pennsylvania: economics and culture.

Some farmers argue that to address nonpoint-source pollution at its source would be too costly, so the more cost effective solution would be to treat the pollution at reception. The second problem involves the Amish culture. As a subculture of American society, the Amish are unique. They resist modern culture entirely, having no electricity, telephone, or indoor plumbing. To them, our modern culture is evil (Savells 1988, 130, Ediger 1986, 286). Within their own communities, the Amish utilize a barter economic systems, trading goods and/or services for whatever they need. As a result, the only means of obtaining cash for their community is by selling their goods and/or services to the outside (this is the term they give to those who are not Amish)(Olsham 1991, 380).

The Amish farming methods have not changed since the early 1800's. They use horse drawn plows and reapers. Also they harvest a large portion of their crops by hand rather than with animal power (Cosgel 1993, 325). The Amish do adhere to the law of the land (lights and reflectors on their buggies, for example) as long as it does not interfere with their own culture and/or beliefs (Ediger 1986, 286).

It is still to early too determine if these methods alone will be enough to significantly reduce agricultural runoff, since the program is only two years old. Since soil erosion methods have been ineffective in controlling nonpoint pollution (only 20 percent reduction in total solids), other policy recommendations may need to be undertaken, such as in-stream structures and/or wetland systems.

1.3 Nonpoint Source Control Systems

There are three methods currently employed in stream systems within Mercer County, Pennsylvania--jack dams, constructed wetlands and sediment control structures. Jack dams are small wooden dams placed in stream channel, usually in pairs, to improve the aeration of the water. Constructed wetlands have been used as a tertiary step in wastewater treatment, and are currently being used as a buffer around stream channels (Brenner and Mondok 1995). Constructed sediment control structures, like the ones installed at Lake Latonka (in Mercer County, Pennsylvania) operate by damming a stream channel, forming a sediment or retention basin behind it. This retention basin allows for increased retention time; more suspended materials can settle out.

1.4 Research Objective and Significance

1.4.1 Objective

The purpose of this study was three fold:

- To determine the percent reduction in five water quality parameters (fecal coliform, ammonia, nitrate, phosphate and total solids) of constructed sediment control structures at Lake Latonka, Mercer County, Pennsylvania.
- To see if, in addition to reducing total solids (as the Sediment Control Structures were designed to do), the fecal coliform bacteria, nitrate, ammonia, and phosphate concentrations entering the lake were likewise reduced.
- To determine if the constructed sediment control structures were any better at reducing nonpoint-source pollution than similar land-use streams without such structures.

The key to reducing any of these concentrations is increasing the retention time, which can be accomplished by any combination of vegetation and retention basin area (the size of which is determined by the loading rate). The longer the retention time, the higher the percent reductions in these concentrations.

Hypotheses:

- The constructed sediment control structures have higher percent reductions for all five water quality parameters than similar streams without such structures.
- The retention time influences how well a constructed sediment control structure will reduce nonpoint pollution with retention basin area and percent wetland vegetation influencing the retention time.

1.4.2 Significance of Study

Land-use practices are having little effect in addressing the problem of nonpoint-source pollution; therefore additional measures are needed as a secondary control to protect sensitive water bodies. Few studies exist that determine the conditions under which constructed sediment basins are effective in reducing nonpoint pollution in receiving streams. Constructed sediment control structures are a relatively new technology to combat nonpoint pollution—how well such structures function had not been investigated until now. Consequently, research in this area provides greater insight into the means of combating this common and probably most difficult type of nonpoint pollution. From the results of this study guidelines can be established to improve the functioning of constructed sediment control structures.

CHAPTER 2

SITE LOCATION AND DESCRIPTION

2.1 General Site Description

Lake Latonka is located approximately 3 km north of U.S. Route 62 and 3 km west of Interstate 79 (Figure 2) in Western Pennsylvania. The lake was formed by constructing a dam across Coolspring Creek in the early 1960's; since construction, the lake has had problems with eutrophication and sedimentation. Coolspring Creek is classified as a cold water fishery (maximum summer temperature of 20°C) by the Pennsylvania Department of Environmental Resources. The portion of the stream below the dam supports a stocked-trout fishery.

Surrounding the lake is a 405-unit rural housing development managed by a Property Owners Association. The Property Owners initiated a water quality monitoring program in 1973 to monitor bacteria concentrations. The program was expanded to include nutrients in 1988, due to concerns about the sedimentation and eutrophication of the lake.

In 1986, the Association installed three sediment control structures consisting of a perforated stand pipe, gravel and a discharge pipe (Figure 3) on the east side of the lake; and a fourth was added on the west side of the lake in 1988. The objective was to reduce the amount of sediment, and eventually other nonpoint-source pollution parameters such as coliform bacteria, phosphate, and ammonia—entering the lake from the agricultural lands in the watershed.

2.2 Water Quality Problem Assessment

Water quality monitoring began at Lake Latonka in 1973, in order to help identify malfunctioning septic systems on the lots surrounding the lake. Initially, only coliform bacteria concentrations were determined at 11 sites around the lake, from May through October, when the lake was at its peak usage. In 1988, with the installation of the fourth and final control structure, monitoring was expanded to include nutrient and sediment concentrations as well, at a total of 20 sites. In 1993 and 1994, this program was further expanded to include virus detection to determine the origin of contamination, as being either from agriculture or human sources.

2.3 Control Structure Description

The sediment control structures installed at Lake Latonka consist of an earthen embankment with a perforated steel stand pipe, gravel and a discharge pipe (Figure 3). These structures were installed in tributary streams approximately 100 m from the shore of the lake. The water is retained behind the embankment within the stream channel at the stand pipe, creating a retention basin. This basin allows time for the sediment along with associated nutrients and bacteria within the water column to settle or precipitate out.

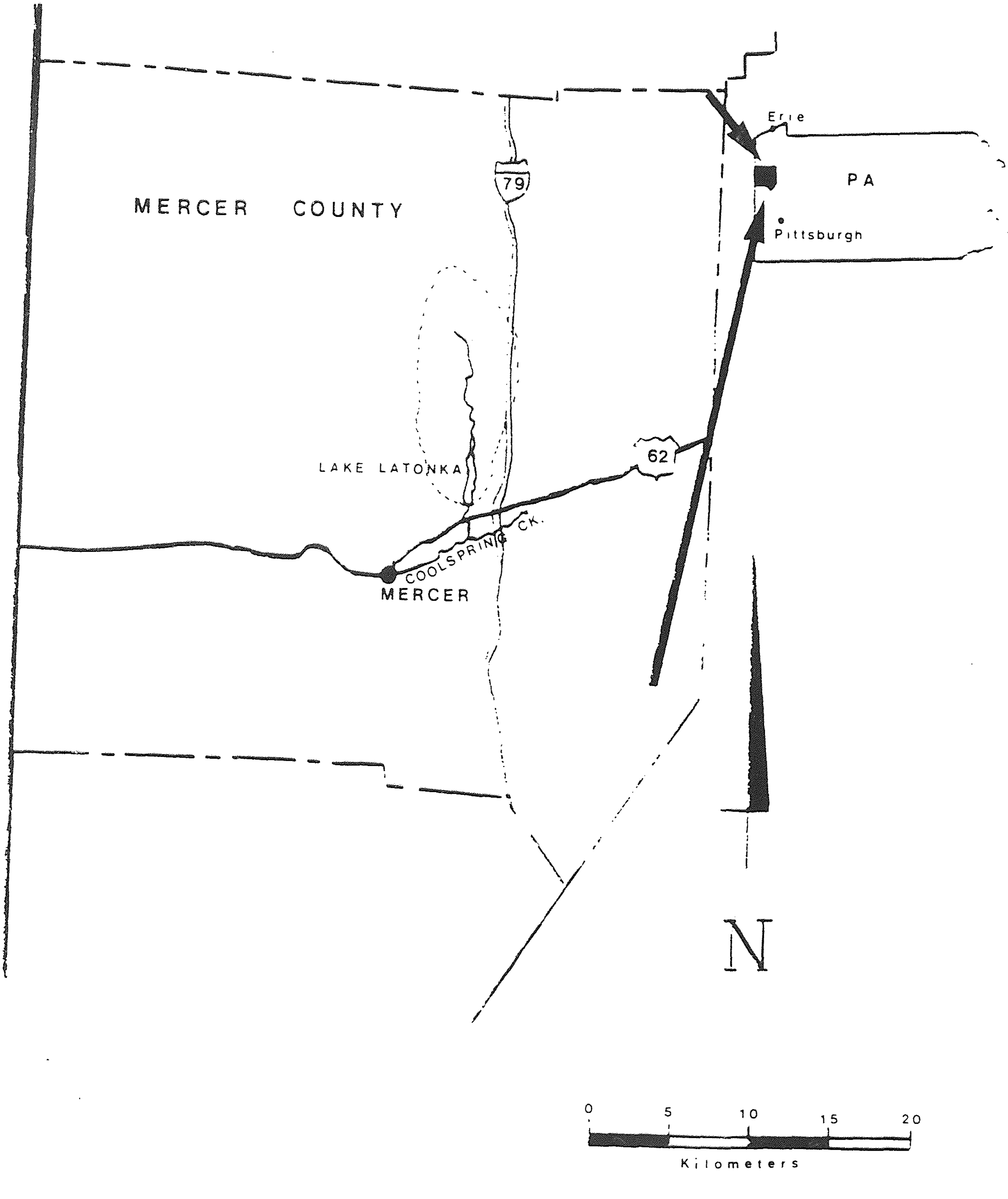

Figure 2 Location of Lake Latonka in Mercer County, Pennsylvania

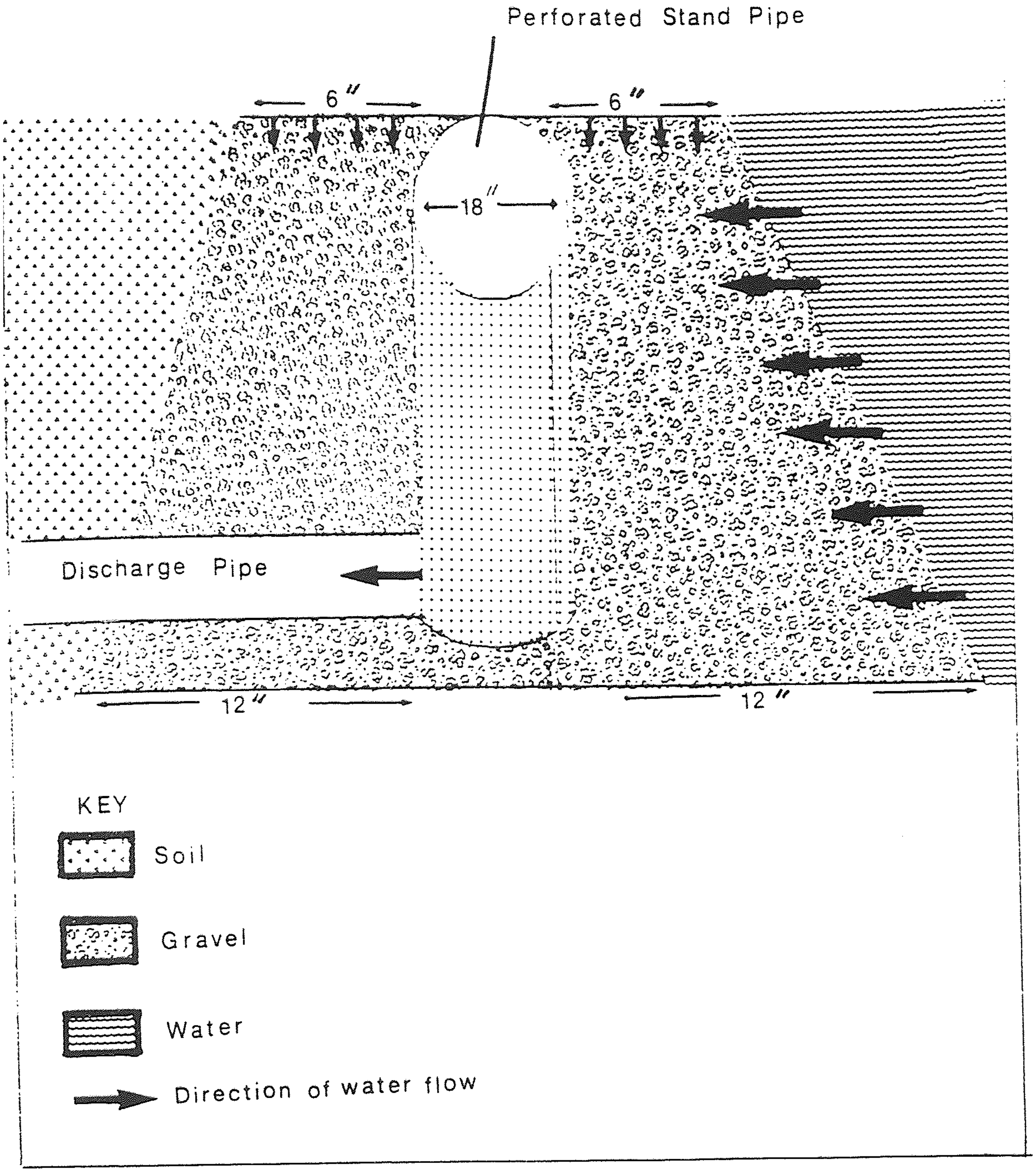

Figure 3 Schematic diagram of the Sediment Control Structure in place at Lake Latonka, Mercer County, Pennsylvania

2.4 Latonka Subwatersheds

The Latonka watershed consists of approximately 25 subwatersheds draining an area of approximately 1200 hectacres (ha). Only twelve of these subwatersheds are monitored monthly from May to October (Figure 4). Nine of these (Park, Manito, Mohican, Coolspring (above the lake), Apache, and the four Sediment Control Structures) were utilized for this study. Manito, Mohican, and Park are located on the east side of the lake, and Apache is located on the west side of the lake (Figure 4). Manito, Mohican, Park, and Apache were selected to serve as comparisons for the sediment control subwatersheds based on drainage area, land-use, and the presence or absence of wetlands within the subwatershed. Coolspring was used to provide base-line concentrations entering the lake, since it is the largest single subwatershed.

The soil types and hydric (soils with seasonally high water tables and reduced permeability) characteristics, combined with the hydrology and vegetation, determine if an area is indeed a wetland. For an area to be a wetland, two of the three (hydric soil, vegetation and hydrology) must exist. In Pennsylvania, the hydrology is rarely questioned since most areas are typically wet for a month or more. Because of the vegetation requirement for wetland determination, it is necessary with any site now to determine the dominant vegetation in the watershed. It is also necessary to determine the soil characteristics.

Table 1. Stream Subwatershed Percent Land Use at Lake Latonka, Mercer County, Pennsylvania (1988)

Watershed	**Riparian Wetland**	**Upland Forest**	**Cropland**	**Pasture**	**Urban**
Manito	18.6	25.0	12.5	0.0	43.8
Mohican	17.4	11.6	29.1	41.8	0.0
Park	23.5	22.2	63.6	28.9	0.0
Structure 1	33.3	33.3	0.0	0.0	33.4
Structure 2	23.0	38.0	9.5	23.1	0.0
Structure 3	35.0	45.0	0.0	20.0	0.0
Coolspring	26.1	33.7	29.8	10.4	0.0
Structure 4	26.8	31.0	24.3	17.1	0.0
Apache		42.6	13.0	35.2	9.3

2.4.1 Control Subwatersheds

The control subwatersheds consist of three stream watersheds on the east side of the lake--Manito, Mohican and Park; and one stream watershed on the west side of the lake--Apache. Each of these streams have similar land-use characteristics to one particular Sediment Control Structure subwatershed. In addition, each of these subwatersheds is larger than their respective Sediment Control Subwatershed, but for comparison purposes, land-use was the factor that was considered predominantly.

2.4.1.1 Manito

Manito is located on the east side of the lake and has the smallest subwatershed area of all the streams, at slightly over 16 ha. The predominant land use within this subwatershed is residential, comprising 43.8 percent of the land area (Figure 5). The remaining land use is divided between riparian wetlands, upland forest and cropland (Table 1). There is no commercial livestock present within the watershed. Canfield, Frenchtown and Ravenna are the only soil types present in the watershed with an average slope of four percent (Table 2). The forested areas are dominated by red maple (*Acer rubrum*) and quaking aspen (*Populus tremulodies*) and the riparian areas are dominated by quaking aspen and cattail (*Typha latifolia*)(Table 3). Manito is not considered a wetland due to the presence of nonhydric soils within the subwatershed, and the lack of wetland vegetation present.

2.4.1.2 Mohican

Mohican is located on the east side of the lake, approximately 100 m north of Manito with a subwatershed area of 42.9 ha (Figure 6). Croplands and pastures comprise the majority of the watershed, with 29 and 42 percent of the land use, respectively. The remaining 29 percent is evenly divided between riparian and upland forest (Table 1). Livestock within this watershed is primarily cattle, accounting for a large percentage of the fecal coliform load. Four soil types exist within this subwatershed: Canfield, Frenchtown, Ravenna and Wayland, with an average slope of six percent (Table 2). The riparian areas are dominated by quaking aspen and black willow (*Salix nigra*). Wetlands are dominated by skunk cabbage (*Symplocarpus foetidus*) and black willow (*S. nigra*) (Table 3).

LAKE LATONKA SUBWATERSHEDS

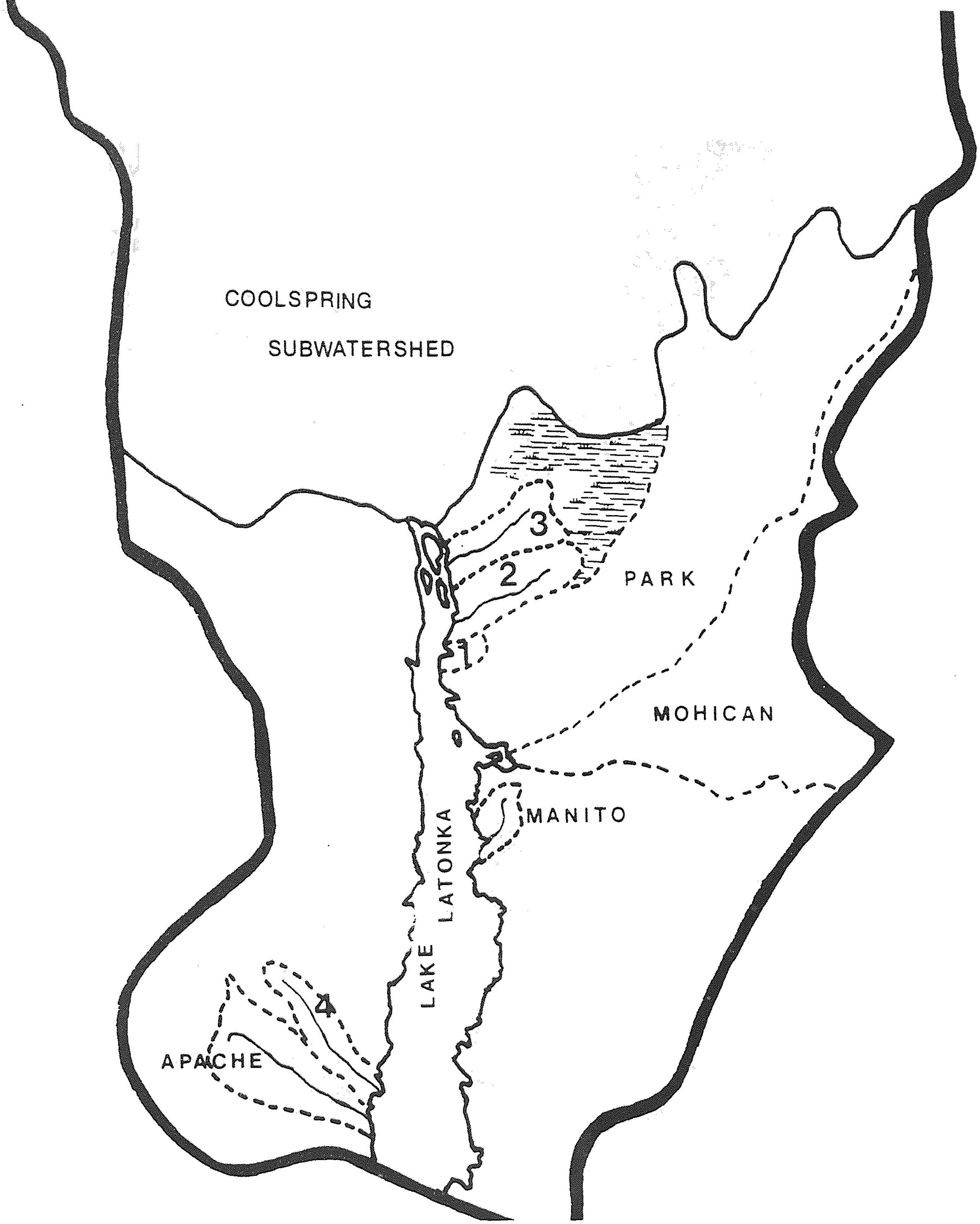

Figure 4 Subwatersheds of the Lake Latonka Watershed, Mercer County, Pennsylvania

Figure 5 Photograph of Manito Subwatershed as taken from Latonka Drive circumnavigating the Lake in Central Mercer County Pennsylvania.

Figure 6 Photograph of the Mohican Subwatershed as taken from Latonka Drive circumnavigating the Lake in Central Mercer County, Pennsylvania.

Figure 7 Photograph of the Park Subwatershed as taken from Latonka Drive circumnavigating the Lake in Central Mercer County, Pennsylvania.

Figure 8 Photograph of Sediment Control Structure 1 retention basin as taken from Latonka Drive circumnavigating the Lake in Central Mercer County, Pennsylvania.

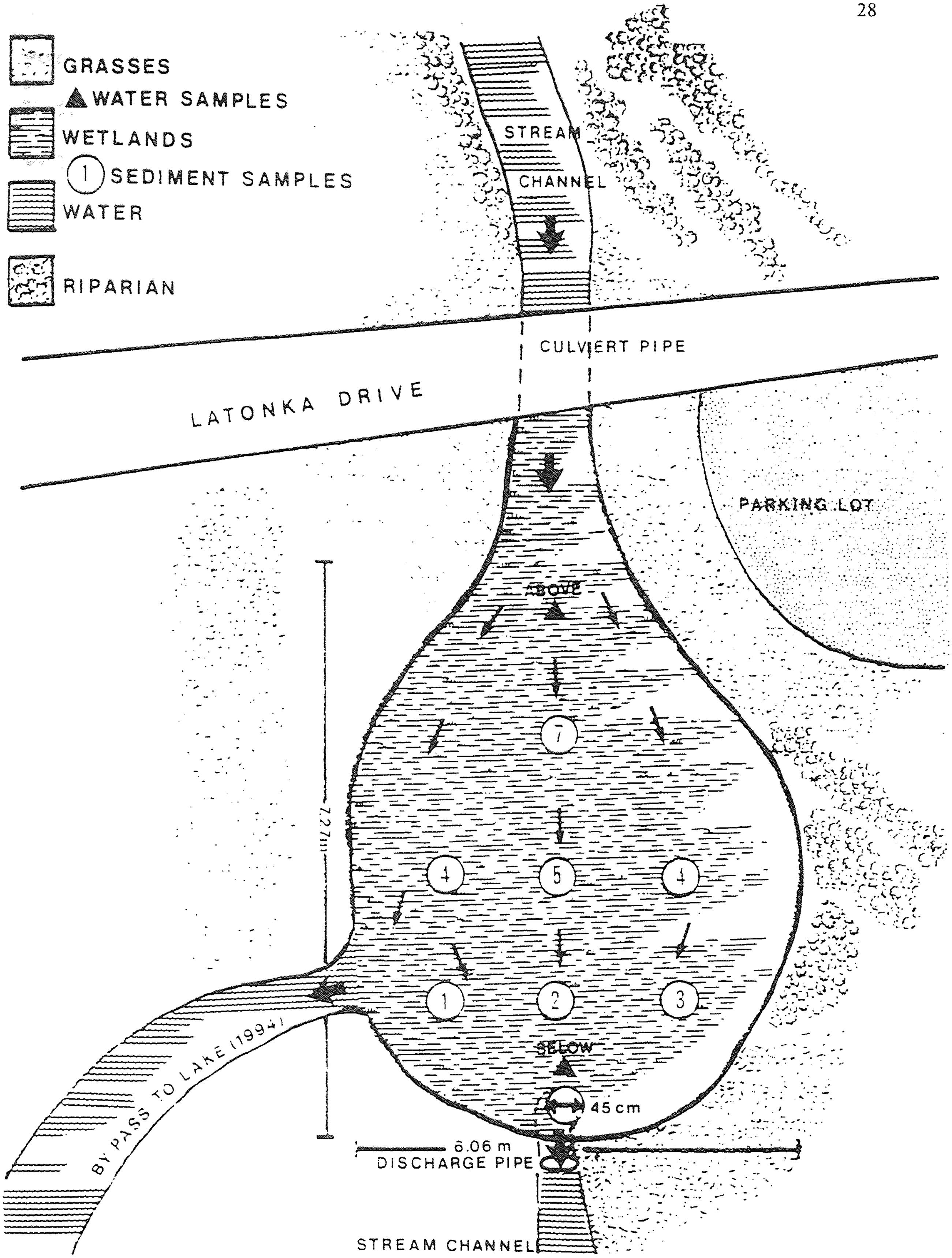

Figure 11 Schematic diagram of the retention basin for Sediment Control Structure 1 at Lake Latonka, Mercer County, Pennsylvania

Portions of Mohican are wetlands because of the presence of hydric soils (Frenchtown and Wayland) and wetland vegetation (black willow and skunk cabbage) present.

2.4.1.3 Park

Park is located on the east side of the lake, approximately 120 m north of Mohican, and has the second largest subwatershed area at 231 ha (Figure 7). The land use is a combination of riparian wetlands, upland forests, croplands and pastures (23.5, 22.2, 63.6 and 28.9 percent, respectively) (Table 1). Dairy is the major agricultural enterprise, with corn being the principal row crop. The major soil types include Braceville, Canfield, Frenchtown, Ravenna and Wayland, with an average slope of six percent (Table 2). The vegetation within the riparian and upland forest areas are dominated by red maple (*Acer rubrum*) and quaking aspen (*Populus tremuloides*) (Table 3). The only wetland possibilities within Park are within the stream channel and floodplain; however, due to the lack of wetland vegetation present within the subwatershed, it is unlikely that any significant wetlands exist.

2.4.1.4 Apache

Apache is the only monitored stream on the west side of the lake, draining a 36 ha area, with upland forests and pastures comprising 43 and 35 percent of the watershed, respectively (Figure 9)(Table 1). Red Hook and Ravenna are the only soil types present with an average slope of six percent (Table 2). The vegetation canopy is dominated by shagbark hickory (*Carya lacinosa*), black cherry (*Prunus serotina*), white oak (*Quercus alba*), cucumber magnolia (*Magnolia acuminata*) and red maple (*Acer rubrum*). The understory is dominated by smooth alder (*Alnus serrulata*), and witchhazel (*Hamamelis virginiana*) (Table 3). Apache is considered an upland forest subwatershed because the dominant vegetation is not of wetland designation, and there are no hydric soils present.

Table 2. Stream Subwatershed Area, Soil Types, Slope Ranges and Control Structure Retention Basin Areas at Lake Latonka, Mercer County, Pennsylvania

Watershed	Area (ha)	Retention Basin (m^2)	Mean Slope (%)	Soil Type	Hydric[1]
Manito	16.1		2	Frenchtown	Yes
			4	Ravenna	Inclusions
			5	Canfield	No
Mohican	42.9		2	Frenchtown	Yes
			5	Ravenna	Inclusions
			variant	Wayland	Yes
Park	231.3		variant	Wayland	Yes
			4	Frenchtown	Yes
			5	Ravenna	Inclusions
			5	Canfield	No
			9	Braceville	No
Structure 1	7.7	36.5	8	Halsey	Yes
			12	Braceville	No
			5	Ravenna	Inclusions
Structure 2	14.9	77.8	6	Braceville	No
			5	Ravenna	Inclusions
Structure 3	32.6	58.4	12	Braceville	No
Coolspring	585.8		5	Braceville	No
			5	Canfield	No
			5	Chenango	No
			5	Frenchtown	Yes
			8	Ravenna	Inclusions
			5	Red Hook	No
			variant	Wayland	Yes
Structure 4	30.0	668.8	5	Canfield	No
			8	Ravenna	Inclusions
			5	Red Hook	No
Apache	36.0		6	Ravenna	Inclusions
			5	Red Hook	No
Dam (Latonka)	1200.0		5	Braceville	No
			5	Canfield	No
			5	Chenango	No
			8	Frenchtown	Yes
			8	Halsey	Yes
			8	Ravenna	Inclusions
			5	Red Hook	No
			variant	Wayland	Yes

[1] Hydric: Such soils have seasonal high water tables and reduced permeability

2.4.2 Sediment Control Subwatersheds

There are four Sediment Control Subwatersheds (hereafter referred to as Structures 1,2,3, and 4). Three are on the east side of the lake and one is on the west side. All four of these subwatersheds are relatively small and have as a part of them a retention basin. The land-uses in two of these subwatersheds (Structures 2 and 3) are similar to each other.

2.4.2.1 Structure 1

This 7.65 ha watershed located on the east side of the lake is the smallest of the structure watersheds (Figures 8 and 11). The settling basin associated with this structure has an area of 36.49 m^2. Like Manito, its land use is a combination of riparian wetland, upland forest and urban, divided evenly with 33 percent each (Table 1). Three soil types occur within the watershed: Braceville, Halsey and Ravenna, with an average slope of eight percent (Table 2). The wetland is dominated by cattail (*Typha latifolia*), soft rush (*Juncus effusus*), and slender rush (*Juncus tenus*), but numerous other wetland species occur as well, including nut sedge (*Cyperus spp.*), jewelweed (*Impatiens capenis*) and three square rush (*Scirpus fluviatillus*). The forested areas, like Manito, are dominated by red maple and quaking aspen. The dominant vegetation within the urban areas is bluegrass (*Poa pratensis*) (Table 3). Structure 1 has a sizable wetland, based on dominant vegetation and hydric soil characteristics present, within its retention basin.

Table 3. Stream Subwatershed Dominant Vegetation at Lake Latonka, Mercer County, Pennsylvania

Watershed	Vegetation	Scientific Name	Designation
Manito	red maple	*Acer rubrum*	Facultative[2]
	quaking aspen	*Populus tremulodies*	Facultative[3] upland
	cattail	*Typha latifolia*	Obligate wetland[4]
Mohican	black willow	*Salix nigra*	Obligate wetland
	quaking aspen	*Populus tremulodies*	Facultative upland
	skunk cabbage	*Symplocarpus foetidus*	Obligate wetland
Park	red maple	*Acer rubrum*	Facultative
	quaking aspen	*Populus tremulodies*	Facultative upland
Structure 1	cattail	*Typha latifolia*	Obligate wetland
	soft rush	*Juncus effusus*	Facultative wetland
	slender rush	*Juncus tenus*	Facultative wetland
	three square rush	*Scirpus fluviatillus*	Facultative wetland
	nut sedge	*Cyperus spp.*	Facultative and Obligate wetland
	bluegrass	*Poa pratensis*	Facultative upland
Structure 2	cattail	*Typha latifolia*	Obligate wetland
	rice cutgrass	*Leersia oryzoides*	Facultative upland
	nut sedge	*Cyperus spp.*	Facultative and Obligate wetland

[2] Facultative: Equally likely in wetlands and non-wetlands (34-66 percent)

[3] Facultative upland: 67 to 99 percent occurrence in non-wetlands
1-33 percent occurrence in wetlands

[4] Obligate wetland: estimated 99 percent probability of occurrence in wetlands

Table 3. Stream Subwatershed Dominant Vegetation (cont.)

	three square rush	*Scirpus fluviatillus*	Obligate wetland
	skunk cabbage	*Symplocarpus foetidus*	Obligate wetland
	red maple	*Acer rubrum*	Facultative
	quaking aspen	*Populus tremulodies*	Facultative upland
Structure 3	red maple	*Acer rubrum*	Facultative upland
	quaking aspen	*Populus tremulodies*	Facultative upland
	bluegrass	*Poa pratensis*	Facultative upland
	fescue	*Festuca arundinacea*	Facultative upland
	timothy	*Phleum pratense*	Facultative upland
Coolspring	red maple	*Acer rubrum*	Facultative
	American elm	*Ulmus americana*	Facultative wetland
	black willow	*Salix nigra*	Obligate wetland
	elderberry	*Sambucus canadensis*	Facultative wetland
	skunk cabbage	*Symplocarpus foetidus*	Obligate wetland
Structure 4	red maple	*Acer rubrum*	Facultative
	American elm	*Ulmus americana*	Facultative wetland[5]
	black cherry	*Prunus serotina*	Facultative upland
	raspberry	*Rubus idaeus*	Facultative upland
	hawthorne	*Crataegus phaenopyrum*	Facultative upland
	may apple	*Podophyllum peltatum*	Facultative upland
Apache	white Oak	*Quercus alba*	Facultative upland
	shagbark hickory	*Carya laciniosa*	Facultative upland
	black cherry	*Prunus serotina*	Facultative upland
	red maple	*Acer rubrum*	Facultative
	cucumber magnolia	*Magnolia acuminata*	Facultative upland
	smooth alder	*Alnus serrulata*	Obligate wetland
	witchhazel	*Hamamelis virginiana*	Facultative

[5] Facultative wetland: 67 to 99 percent probability of occurrence in wetlands

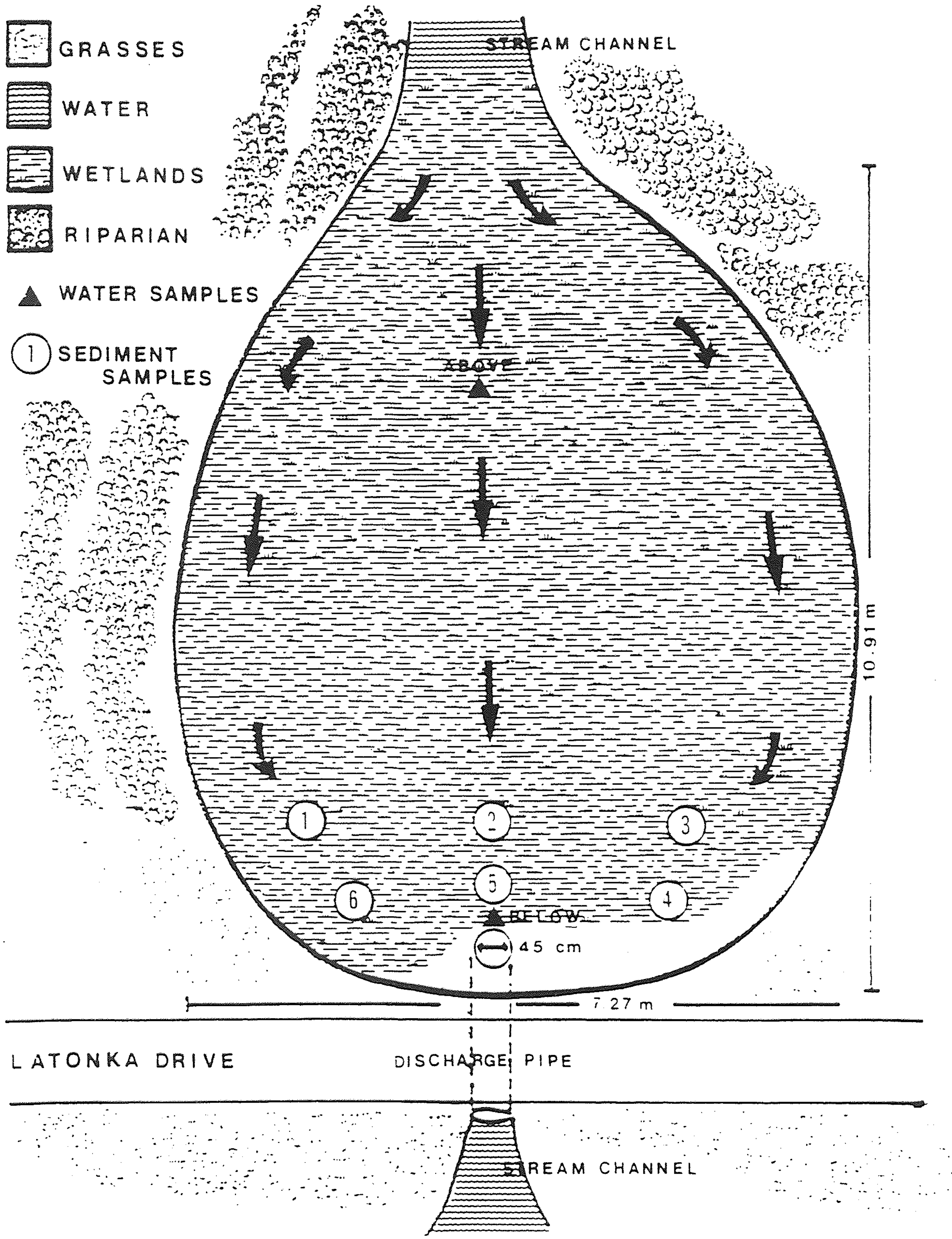

Figure 12 Schematic diagram of the retention basin for Sediment Control Structure 2 at Lake Latonka, Mercer County, Pennsylvania

Figure 13 Photograph of Sediment control Structure 2 retention basin as taken from Latonka Drive circumnavigating the Lake in Central Mercer County, Pennsylvania.

Figure 14 Photograph of Sediment Control Structure 3 retention basin as taken from Latonka Drive circumnavigating the Lake in Central Mercer County, Pennsylvania.

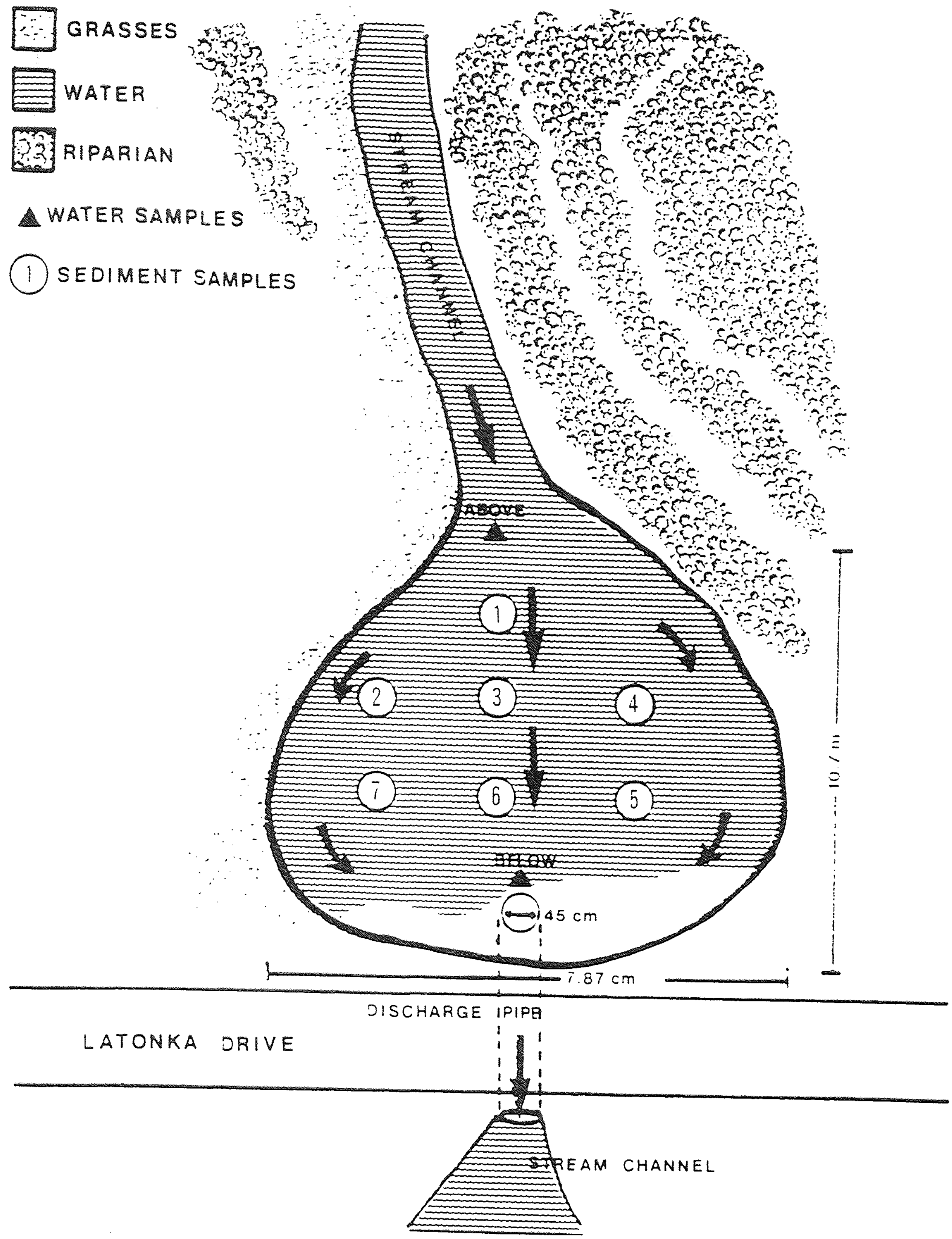

Figure 15 Schematic diagram of the retention basin for Sediment Control Structure 3 at Lake Latonka, Mercer County, Pennsylvania

2.4.2.2 Structure 2

The second control structure is located on the east side of the lake, approximately 100 m north of Structure 1 and has a 77.76 m^2 retention basin (Figures 12 and 13). This subwatershed drains an area of 14.86 ha, and 60 percent of the land consists of riparian wetlands and upland forests (Table 1). Pastures and cropland, with row crops such as corn, make up the remaining portion of the watershed. Braceville and Ravenna silt loams are the only soils found in this subwatershed, and the average slope is six percent (Table 2). The forested areas, like Structure 1, are dominated by red maple and quaking aspen. The wetland is dominated by cattail (*Typha latifolia*), nut sedge (*Cyperua spp.*) and rice cutgrass (*Leersia oryzoides*). Skunk cabbage (*Symplocarpus foetidus*) and three square rush (*Scirpus fluviatillus*) are also present, but not widely distributed (Table 3). Like Structure 1, Structure 2 also has a large wetland present within its retention basin, again based on dominant vegetation and the hydric inclusions present with Ravenna soils.

2.4.2.3 Structure 3

The third structure is located on the east side of the lake, approximately 200 m north of Structure 2. This subwatershed drains the largest area of the four structure subwatersheds and comprises 32.59 ha (Figure 14). It has the second smallest retention basin area at 58.35 m^2 (Figure 16). The land use consists of riparian wetlands, upland forest and pasture (Table 1), with upland forest being the dominant land-use. A large portion of the pasture lands have been abandoned in recent years. Braceville is the only soil type present within the watershed (Table 2). The forested areas are dominated by red maple (*Acer rubrum*) and quaking aspen (*Populus tremulodies*), as in Structures 1 and 2. There is a small grassland directly north of the structure dominated by bluegrass (*Poa pratense*), timothy (*Phleum pratense*), and fescue (*Fesuca arundinacea*)(Table 3). Structure 3, to the contrary, is not considered a wetland because there are no hydric soils or dominant wetland vegetation present within the subwatershed.

2.4.2.4 Structure 4

The fourth structure is the only one on the west side of the lake. It is located approximately 500 m north of the dam spillway and has the second largest subwatershed, draining an area of 30 ha (Figure 18). The settling basin, however, is the largest, at slightly less than 670 m^2 (Figure 16). The land-use within this subwatershed is a combination of riparian wetlands, upland forests, croplands and pastures (Table 1). Riparian wetlands and upland forests are the dominant land-uses. There are a few cattle located at the headwaters of this stream. Canfield, Ravenna and Red Hook are the only three soil types present in this subwatershed with an average slope of six percent (Table 2). The riparian and forested areas are dominated in the canopy by red maple (*Acer rubrum*) and American elm (*Ulmus americana*), and in the understory by black cherry (*Prunus serotina*), raspberry (*Rubus idaeus*), hawthorne (*Cratagus phaenopyrum*) and may apple (*Podophyllum peltatum*)(Table 3). Like Apache, Structure 4 is not considered a wetland, but rather an upland forest subwatershed based on dominant vegetation and soil characteristics.

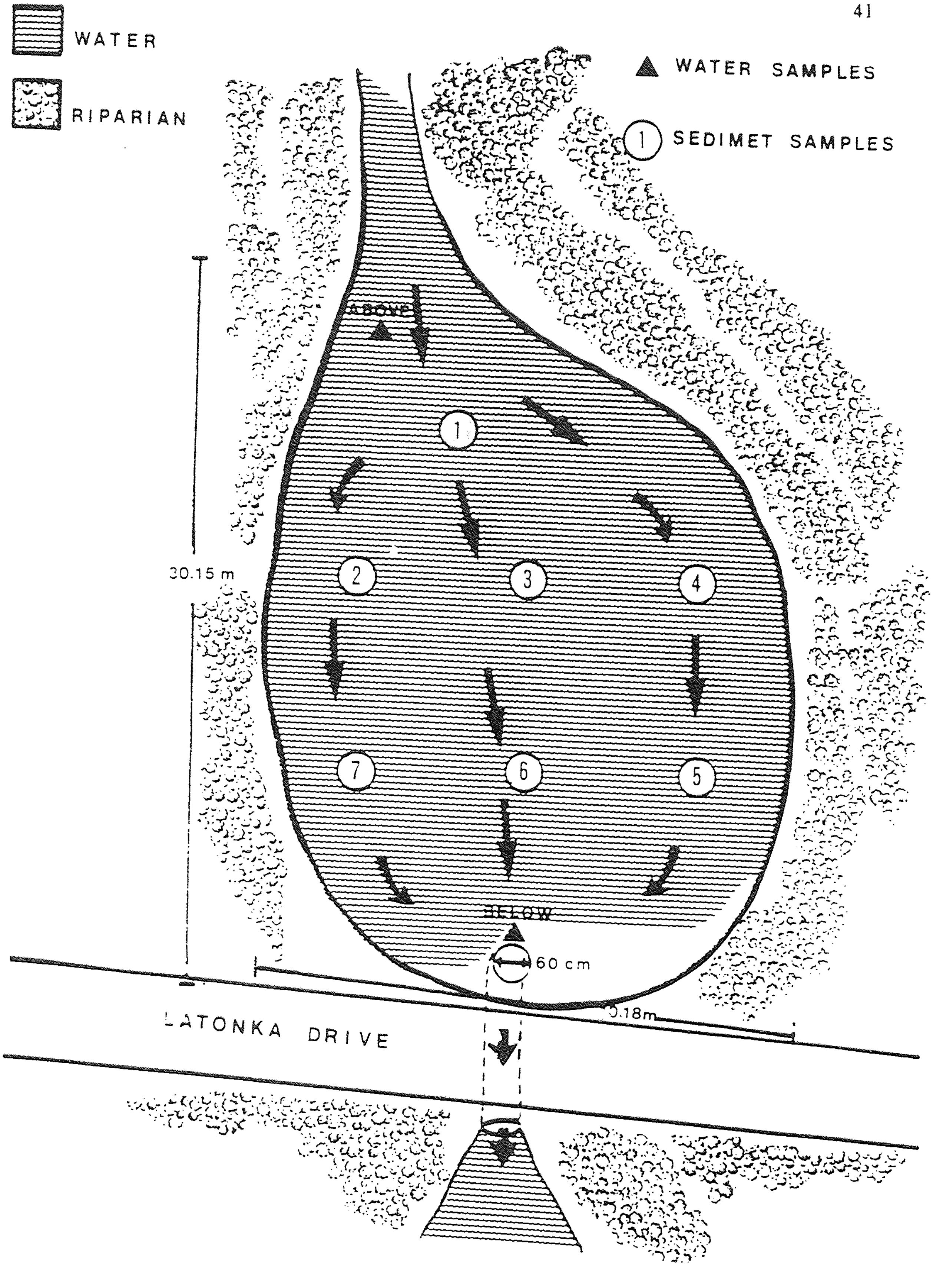

Figure 16 Schematic diagram of the retention basin for Sediment Control Structure 4 at Lake Latonka, Mercer County, Pennsylvania

Figure 17 Photograph of the Coolspring Subwatershed as taken from Latonka Drive circumnavigating the Lake in Central Mercer County, Pennsylvania.

Figure 18 Photograph of Sediment Control Structure 4 retention basin as taken from Latonka Drive circumnavigating the Lake in Central Mercer County, Pennsylvania.

Figure 9 Photograph of Apache Subwatershed as taken from Latonka Drive circumnavigating the Lake in Central Mercer County, Pennsylvania.

Figure 10 Photograph of Lake Latonka as taken from a Public Dock just north of the Dam Spillway.

2.5 Other Sample Areas

2.5.1 Coolspring Creek

Coolspring Creek serves as the headwaters for Lake Latonka. It has the largest drainage area of any subwatershed encompassing nearly 600 ha (Figure 17). This subwatershed is dominated by agricultural and forested areas (Table 1), with cropland and upland forests dominant. Most of the livestock within the Latonka watershed are located within this subwatershed. The croplands are predominately row crops, such as corn. There are seven different soil types within this subwatershed: Braceville, Canfield, Chenango, Frenchtown, Ravenna, Red Hook, and Wayland, with an average slope of six percent (Table 2). The forested and riparian areas are dominated in the canopy by red maple (*Acer rubrum*) and American elm (*Ulmus* americana) and in the understory by black willow (*Salix* nigra) and elderberry (*Sambucus canadensis*). The flood plain itself is dominated by skunk cabbage (*Symplocarpus foetidus*)(Table 3). The floodplain of Coolspring is considered a wetland based on the dominant vegetation and soil characteristics.

3.5.2 Dam

The dam encompasses the entire 1200 ha Latonka watershed (Figure 10). Land-use within this watershed is predominately agricultural row crops (46.9%) with corn being the principal row crop occurring on over 34 percent of the agricultural lands. Riparian and abandoned fields account for the remaining 20 percent and 33.1 percent, respectively, of the drainage basin. Of the remaining agricultural lands, pasture and haylands account for 24.9 and 24.5 percent of the land use, respectively, with small grains, soybeans, alfalfa, vegetables and orchards accounting for the remaining 16.3 percent of the croplands. Livestock within the watershed is predominately cattle, accounting for nearly 75 percent of the animal population, while swine account for the second largest percentage with slightly more than 11 percent. The remaining percentage is comprised of sheep, poultry and horses (Mercer County Conservation District, Mercer, PA).

CHAPTER 3

STUDY DESIGN

The Sediment Control Structures have been in place since 1986. Despite the continued water quality monitoring at these structures no study has yet been conducted to determine if these structures are indeed functioning as designed.

To gain a clear understanding of how effective (percent reduction) these structures are, all nine years of monitoring data needed to be analyzed in the present study. It was also necessary in the present study to use the monitoring data from streams with the Latonka watershed that had similar land-uses to the Control Structure subwatersheds but without any in-stream structures as controls.

3.1 Data Collection

3.1.1 Water Quality Data

Water samples were collected during the first half of each month from May to October when the lake was intensely used for recreation (swimming, water skiing, etc.) Samples were collected in 250 ml sterile polyethylene bottles at the headwaters of the settling basin and in the standpipe of each structure (referred to as above and below), the dam, the mouth of Coolspring Creek and Manito, and source and mouth of Mohican, Park and Apache streams, for a total of 17 samples per month.

3.1.2 Sediment Sample Collection and Analysis

Sediment samples were collected along a series of transects from inlet to outflow of each of the retention basins for the Sediment Control Structures: one at the inlet to the basin, three across the center of the basin and three across the outlet of the basins, for a total of seven samples per basin (the only exception was the basin for Structure 2 because the inlet was inaccessible for a sediment sample). There was no sediment collection prior to June of 1994, and samples were collected once in June and again in August of 1994. The samples were collected using a small trowel at the surface and at a depth of greater than 5 cm (depending on the depth of the sediment accumulation in the basin). These samples were then placed in polyethylene bags for transport to the laboratory.

3.1.3 Precipitation Data

Since nonpoint-source pollution from agricultural lands generally occurs in the form of runoff, it was necessary to obtain seasonal precipitation data from the Mercer County Conservation District from 1986 to 1994. Mean and total precipitation were determined for 30, 14, and 5 days and 24 hours prior to each sample date (Mercer County Conservation District, Mercer, PA).

3.1.4 Land-use Data

Land-use data were determined from aerial photographs (1988)(1 in = 400 ft) obtained from the Mercer County Conservation District. The land use was expressed in terms of the percent of forest, urban and agricultural land. The agricultural land use was further delineated for various types of row crops, haylands and pasture.

3.1.5 Drainage Basin Area, Vegetation and Retention Time

Drainage basin area was determined from aerial photographs (1988)(1 in = 400 ft) by using a polar planimeter. The soil type and mean slope of the slope range were based on soil characteristics as described in the Mercer County Soil Survey (U.S. Soil Conservation Service 1971). The dominant plant species within the drainage basin was determined by a vegetative survey at each site in 1994. The retention time (1994) within each sediment basin was during the months of May, June and August, determined by placing a dye in the intake of each structure and recording the time in minutes for 90 percent of the dye to discharge.

3.2 Sample and Data Analysis

3.2.1 Water Quality Analysis

Beginning with the installation of the first three control structures in 1986, the samples were analyzed for coliform bacteria using the multiple fermentation analysis and expressed as the most probable number of bacteria per milliliter (MPN)(Table 4). With the installation of the fourth and final control structure in 1988, samples were also analyzed for PO_4 and NH_3 using colorimetric method and total solids by means of evaporation method, in addition to coliform bacteria as described above (Table 4). In 1993, these samples were also analyzed colormetrically for NO_3 (Table 4). All procedures were conducted in accordance with Standard Methods for the Examination of Water and Wastewater (Greenberg et al.. 1992, 1980). These results were obtained from the consultant hired by the Property Owners Association to monitor water quality.

Table 4 Water Quality Parameters and Testing Method Used at Lake Latonka

Water Quality Parameter	Testing Method
Fecal Coliform (MPN)	Multiple Fermentation Tube
Ammonia	Direct Nesslerization
Nitrate	Chromotropic Acid
Phosphate	Vanadomolybdate
Total Solids (Sediment)	Evaporation
Redox Potential (Sediment)	Conductivity meter

3.2.2 Sediment Sample Analysis

To determine nutrient concentration in the sediments, 2.5g of dry soil (dried at 60°C for 24 hours) was dissolved in 50ml of 5 molal sodium bicarbonate solution, and analyzed according to the procedures described by Carter (1993). This soil/acid solution was then analyzed by colorimetric method for nitrogen, phosphorous and soil pH. The organic content and Redox potential in accordance to the procedures described (Carter 1993). The Redox potential is a measure of the oxidative/reductive potential of a system, which indicates if the system is oxidizing or reducing and therefore indicates the predominant bacterial action within the system.

3.2.3 Structure Effectiveness

The effectiveness of the sediment control structures was determined by calculating the percent change in the mean concentration of each parameter per year. This was accomplished by the following equation:

$$\frac{\text{Influx-Outflow}}{\text{Influx}} \times 100\% = \%\ \text{Reduction}$$

where Influx=concentration at either the headwaters of a stream or the headwaters of a retention basin

Outflow=concentration entering the lake

The percent reduction for Manito, Coolspring and the Dam (at lake discharge) was calculated using the same formula, except using consecutive years as influx and outflow respectively. The the water quality means were then compared to Title 25 of the Commonwealth of Pennsylvania Code (1989), Chapter 23 Water Quality Standards for nitrate, ammonia and coliform bacteria concentrations, are 10 mg/l, 0.1 mg/l, and 2000 organisms/100 ml. No standards currently exist for phosphate and sediment.

Manito, Mohican, Park and Apache have similar land-use patterns to Sediment Control Structures 1, 2, 3 and 4, respectively, and hence provide good comparisons for the effectiveness of these structures. As noted earlier, all four structures have different subwatershed areas and different retention basin areas. Structures 1 and 2 have wetlands as part of their retention basins, while Mohican and Manito have wetlands at their sources.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Results

4.1.1 Water Quality Data and Percent Reductions

Overall, there has been a gradual improvement in water quality entering Lake Latonka over the last nine years. The most dramatic improvements were in the reduction of fecal coliform (38.4%) and total solids concentrations (94.5%)(Tables 5 and 6, appendix B). Only minimal reductions (<1 percent) occurred in ammonia and nitrate concentrations (Tables 7 and 8, appendix B) and moderate reductions (<10 percent) in phosphate concentrations over the nine year monitoring period (Table 8, appendix B).

Overall, the four Sediment Control Structures had lower concentrations of all five water quality parameters, and hence had better reductions than the control subwatersheds (Table 10). Structure 2 overall had slightly higher percent reductions than Structure 1. The reason for the better coliform reductions at Structure 2 is unclear; it may possibly be due to the slightly less wetland vegetation present in the retention basin compared to Structure 1 (90 percent versus 95 percent). Likewise, Structure 2 was also slightly better than Structure 1 in

reducing phosphate concentrations. Again, the better phosphate reduction at Structure 2 was most likely due to the amount of wetland vegetation present. Structure 4 was the worst at reducing the ammonia concentration, possibly due to the decay of leaf litter within the basin.
Structure 3 was the best at reducing nitrate concentrations, most likely due to the reduced agricultural activity within the subwatershed (one large farm went bankrupt between 1991 and 1994). Structure 4 was overwhelmingly the best at reducing the total solid concentrations due to the long retention time.
The four structures were overall better at reducing the nonpoint parameters than were the streams.

Table 10 Mean Percent Reduction in Five Water Quality Parameters from 1986 to 1994 in Nine Subwatersheds and Lake Latonka (at Dam Discharge Point)

Watershed	**Coliform**	**Ammonia**	**Nitrate**	**Phosphate**	**Sediment**
Manito	10.4 (N=6)	-143.3* (N=6)	-700* (N=1)	-145.7* (N=6)	-29.9* (N=6)
Mohican	15.5 (N=9)	-10.3* (N=3)	71.3 (N=2)	43.3 (N=3)	3.96 (N=3)
Park	5.55 (N=9)	38.2 (N=3)	-2.63* (N=2)	-14.9* (N=3)	21.8 (N=3)
Struct. 1	12.6 (N=9)	2.59 (N=7)	37.1 (N=2)	20.0 (N=7)	24.1 (N=7)
Struct. 2	20.1 (N=9)	0.76 (N=7)	12.1 (N=2)	29.1 (N=7)	31.8 (N=7)
Struct. 3	10.0 (N=9)	35.4 (N=7)	56.5 (N=2)	11.4 (N=7)	16.6 (N=7)
Coolspring	21.7 (N=8)	77.0 (N=1)	47.4 (N=1)	-65* (N=1)	-1.7* (N=1)
Struct. 4	-1.6* (N=9)	-116.9* (N=7)	-26.2* (N=3)	15.7 (N=7)	63.1 (N=7)
Apache	9.78 (N=9)	-2.73* (N=3)	27.5 (N=2)	33.1 (N=3)	-2.42* (N=3)
Dam	48.9 (N=8)	83.3 (N=1)	100 (N=1)	-68.2* (N=1)	20.1 (N=1)

*Negative percentages indicate that the concentrations of these parameters actually increased through the system.

The degree to which the concentration of the various water quality parameters (fecal coliform, ammonia, nitrate, phosphate and total solids) were reduced varied among subwatersheds as well as among the different years. There was also variation among the different parameters (the highest average percent reductions in fecal coliform in 1986, the highest individual yearly reduction at

Structure 1 in 1988)(Tables 11-15, appendix B). Likewise, there was also a considerable variation among the months and among the parameters. August was the best month for reducing fecal coliform, while July was the best for three of the other four parameters (ammonia, phosphate and total solids)(Tables 17-21, appendix B) due to higher 30 day total precipitation during these months which tended to dilute the concentrations.

4.1.2 Controlling Factors

There are several factors that can and do influence how well a constructed system functions. These include retention time, retention basin area, percentage of wetland vegetation in the basin, watershed area, flow rates, and loading rates. The retention time is a factor of the retention basin area: the larger the retention basin, the longer the retention time. The percentage of wetland vegetation can also play a role in the retention time to the extreme of making it virtually impossible to determine, which was the case at Structures 1 and 2 in August of 1994 (Table 23). The area of the watershed influences the flow rate, which in turn influences the loading rate. The flow rate factors into the sizing of the retention basin. All these factors--retention time, retention basin area, percentage of wetland vegetation in the basin, watershed area, flow rate and loading rate--all determine how well constructed systems function.

The retention time varied greatly among the various Sediment Control Structures, ranging from 0.5 hours for Structure 3 to over 3.5 hours for Structure 4, due to the varying sizes of the retention basins (Table 23). The retention basins would completely flush out (all traces of dye removed) in 3 hours (Structure 3) to 24 hours (Structure 4)(Table 23). The large percentage of wetland vegetation in both basins 1 and 2 accounted for the inability to determine the retention time for these structures in August, since the dye used was unable to flow through these systems.

Table 22 Subwatershed areas, Retention basin area, Percent Wetland Vegetation within the basin, Monthly q Retention Times (hrs) and Flush Times (hrs) for the Sediment Control Structures at Lake Latonka, Mercer County, Pennsylvania for 1994.

Struct No.	Watershed Area (ha)	Retention Basin Area (m^2)	% Wetland Vegetation	May	June	August	Flush
1	7.65	36.5	90	0.75	1.25	N/A*	6-12
2	14.86	77.8	95	0.58	1.25	N/A*	6-12
3	32.59	58.4	1	0.5	1.00	2.25	3-6
4	30.00	668.8	2	1.3	2.00	3.5	12-24

* Retention times were unable to be determined due to the failure of the dye to flow through the systems

Table 23 Mean Retention Times, Retention Basin Area, Subwatershed Area and Flow Rates for the Four Sediment Control Structures at Lake Latonka, Mercer County, Pennsylvania from 1988 to 1994

Structure	Watershed Area (ha)	Retention Basin Area (m^2)	Retention Time (hr)	Flow Rates (L/min)
1	7.65	36.49	1.00	0.03
2	14.86	77.76	0.92	0.10
3	32.59	58.35	1.25	0.14
4	30.00	668.83	2.27	0.13

Sediment loading rates and flow rates varied among subwatershed areas. Loading rates also varied among the different years, with the highest rates occurring in the first year of operation of each structure, due to construction in the area.

Table 24 Sediment Loading Rates (g/yr) for each of the Four Sediment Control Structures at Lake Latonka, Mercer County, Pennsylvania from 1988 to 1994.

Year	Structure 1	Structure 2	Structure 3	Structure 4
1988	2412.5	4888.1	2906.6	7242.8
1989	211.7	466.7	346.7	670.0
1990	87.5	286.7	318.3	253.3
1991	100.7	338.3	410.0	1380.0
1992	90.5	305.0	316.7	475.0
1993	86.7	324.8	340.3	1005.0
1994	88.1	249.7	459.2	373.8

Of the retention basins for the four Sediment Control Structures, Structure 2 had the highest orthophosphate (inorganic phosphate) in the sediments, while Structure 4 had the lowest. Among the streams, Park and Mohican had the highest and lowest orthophosphate concentration in the sediments, respectively (Table 26, appendix B) for the Structures. The orthophosphate concentrations averaged 1.54 mg/gdw (milligram per gram dry weight) at the surface and 1.30 mg/gdw greater than 5 cm below the surface (Table 27, appendix B). Similarly, Structure 2 also had the highest total inorganic nitrogen concentration, while Structure 4 had the lowest. Likewise, Park had the highest total inorganic nitrogen concentrations, with Mohican having the lowest (Table 26, appendix B). The total inorganic nitrogen concentrations in the surface sediment averaged 1.37 mg/gdw and 1.31 greater than 5 cm (Table 27, appendix B) for the Structures.

All four sediment control structures displayed varying degrees of effectiveness for fecal coliform, ammonia, nitrate, phosphate and total solids reduction. Over the nine year monitoring period, Structure 4 was the most effective at reducing the total solids concentrations. Similarly, Structure 2 was the most effective at reducing both phosphate and fecal coliform concentrations, whereas, Structures 1 and 3 were most effective at reducing ammonia and nitrate concentrations, respectively (Table 10).

The total precipitation 24 hours, 5 days, 14 days and 30 days prior to sampling, plays a role not only in the volume and flow rates of water in streams but also in the

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Also during the nine year monitoring period, there was a considerable variation in the percent reductions of each of the five water quality parameters (fecal coliform bacteria, ammonia, nitrate, phosphate, and total solids). The fluctuations in the effectiveness of the four structures from year to year appear to be closely related to the fluctuations in total precipitation in the 24 hours, 5 days, 14 days and 30 days prior to sampling over the nine years.

4.2 Discussion

The four Sediment Control Structures at Lake Latonka are better at reducing nonpoint-source pollution contaminants than streams without such structures. The reason for the improved reductions at the structures is most likely due to a combination of wetland vegetation, retention basin area, and retention time. The amount of wetland vegetation and retention basin area both influence the retention time; the greater the wetland vegetation and/or the larger the retention basin area, the longer the retention time. The longer the retention time the more time allowed for suspended materials to settle out (Hammer 1992, 154). The retention basin size is determined by the loading rate. Structure 4 had the best retention time and also had the largest retention basin area. Structure 4 also had the best total solids reduction as well, due to the high retention time. The high percent reductions in total solids at Structure 4 could possibly also be attributed to the riparian buffer around the retention basin (Brenner and Mondok 1995). The high percent reductions observed at Structures 1 and 2 for phosphate can most likely be attributed to the presence of wetland vegetation (Johnson 1992).

The concentrations of inorganic nitrogen and phosphate in the sediments were consistent with the concentration commonly found in wetlands receiving agricultural runoff (Johnson 1991, 495-498). This indicates the accumulation of these nutrients within the sediments. This accumulation is of particular concern with phosphate, since phosphate associated with sediments can easily return to solution.

The fact that the percent reductions appeared to follow closely the total precipitation was not unexpected. In an earlier study at Lake Latonka (Brenner and Brenner 1995), total precipitation 5 to 30 days prior to sampling determined the concentration of fecal coliform bacteria, ammonia, nitrate, phosphate, and total solids, so it would logically follow that the total precipitation would also influence the percent reductions. The total precipitation did influence the percent reductions. The influence of precipitation on percent reductions is most likely attributed to the concentrations of nonpoint pollution parameters.

While retention time, retention basin area and percent of wetland vegetation are all important in determining how well a constructed sediment control system functions, the subwatershed area is an important factor determining the loading rate since the concentration of any nonpoint parameter is a factor of the subwatershed area. Given the fact that the loading rate factors into the construction of the retention basin, it follows that the ratio of retention basin area to subwatershed area is an important factor. The ratio of retention time area to subwatershed area does appear to influence the performance of constructed sediment control systems. As a result, this ratio needs to be considered in determining whether or not to install such a structure in a stream.

Since only one year of land-use data was available, it is difficult to know what, if any influence land-use changes may have had in the overall water quality improvements at Lake Latonka. It is likely that the bankruptcy of some farms resulting in their closure has had a positive impact on the water quality of the lake. At this point it is only speculation as to the degree of that positive impact.

CHAPTER 6

CONCLUSIONS, RECOMMENDATIONS, AND IMPLICATIONS

6.1 Conclusions

Constructed sediment control structures, like the ones erected at Lake Latonka, are effective in reducing all nonpoint-source pollution parameters (fecal coliform, nitrate, phosphate and total solids) except ammonia. The effectiveness of these structures depends on the size of the retention basin in relation to the subwatershed area (RA/WA ratio) and the amount of wetland vegetation present in the retention basin, since these two factors influence the retention time. Of the four structures, Control Structure 3 was the least effective because of the lack of wetland vegetation in the retention basin and the small RA/WA ratio.

It is unclear at this time if there is a limit to the size of the subwatershed for which these systems will work, although it does appear that the optimal RA/WA ratio is at least 3 m^2 per hectacre. More research is needed with varying subwatershed areas to determine if such a limit exists. Varying watershed area research is not possible at

Lake Latonka due to the size constraints of the housing development itself.

6.2 Recommendations

There are several recommendations to be made to the Lake Latonka Property Owners Association. (1) Although wetland vegetation is an important factor in the effective operation of constructed sediment control structures, this vegetation should be harvested yearly during the dormant season. This harvesting will help prevent the basin from becoming choked with vegetation and hence restricting the water flow. The new growth in the spring will take up more nutrients and improve percent reductions. (2) The retention basin for Sediment Control Structure 3 needs to be enlarged to at least twice (Hammer 1992, 163) its current area. By enlarging the retention basin, the generally poor performance of Structure 3 would be improved by increasing the retention time for the structure. In addition, wetland vegetation, such as sedges (*Cyperus spp.*) and rushes (*Juncus spp.*), should be planted around the perimeter of the retention basin to increase retention time and allow for vegetative uptake of nutrients. (3) Finally, the retention basins should be dredged out every 3 to 5 years to prevent the accumulation and recycling of phosphate (Faulkner and Richardson 1989, Richardson 1985, 1426). The dredge material could than be composted to be later sold as fertilizer to local farmers.

6.3 Implications

Prior to the 1970's, water quality problems associated with nonpoint pollution, agricultural runoff in particular were not a major concern. This was because, with the exception of some pesticides, the contaminants are not highly toxic to humans. As a result, prior to the passage of the Federal Water Pollution Control Act (1972) nonpoint-source pollution was a forgotten item. Once industrial point source pollution was addressed and thought to be brought under control, the issue of nonpoint pollution could then be addressed. Addressing agricultural runoff was thought to be accomplished through soil erosion control practice such as strip cropping and contour farming.

The soil loss prevention measures were thought to be effective in reducing sedimentation of waterways until the 1980's when researchers such as Brenner and Mondok (1995, 13), Park et al. (1994, 1019-1022) and Hill (1987, 140), among other, began to demonstrate that these measures were not as effective as once believed. Their research has led to a cry to do more to control agricultural pollution. Nationwide, one problem to getting any additional measures in place to control agricultural measures in place to control agricultural runoff is the economic cocerns of the agricultural lobby. Some farmers feel that by requiring them to treat their runoff on-site like any other industry would inflict financial hardship. Another problem, particularly in Lancaster and Mercer Counties in Pennsylvania, is cultural. These two have large populations of Amish. The Amish reject all outside influence and particularly despise any influence by the government in how they farm their land. Both the economic and cultural factors would make it difficult for any additional restrictions on agricultural discharges to be enacted.

Therefore, the only real option is to treat agricultural pollution at it reception (where it ultimately ends up). Any reception treatment needs to be combined with agricultural Best Management Practices. The constructed sediment control structures at Lake Latonka are able to reduce all nonpoint source pollution parameters except ammonia. Such structures will work on watersheds less than 40 ha. It is unclear at this point in time if these structures would work on larger watersheds. It is possible that they would, given a large enough retention basin (at least 3 m^2/ha).

APPENDIX B

Table 5 Mean Fecal Coliform Concentrations in Nine Subwatersheds and Lake Discharge Point From 1985 to 1994 at Lake Latonka

	Sediment Control Structures					Control Streams				
Year	**1**	**2**	**3**	**4**	**Manito**	**Mohican**	**Park**	**Apache**	**Coolspring**	**Dam**
1985	N/A	N/A	N/A	N/A	N/A	2153	1413	2153	958	31
1986	1421	1272	2254	N/A	N/A	1807	1804	1560	1708	811
1987	1155	1592	1791	N/A	N/A	2334	1742	2005	1907	765
1988	1295	1726	2267	1163	2400	1184	1693	2156	680	483
1989	1394	1341	2029	1012	2200	1835	1548	2219	839	743
1990	2143	2212	2267	1192	2133	2400	2067	2267	2006	343
1991	2168	2130	2000	1813	2400	2267	2300	2400	1116	142
1992	1307	1171	1217	1819	1829	1320	1867	2400	909	161
1993	1177	1162	1564	1693	1860	1641	1634	2210	1099	61
1994	765	955	608	634	1092	1326	1411	1707	750	498

Table 6 Mean Total Solids Concentrations in Nine Subwatersheds and Lake Discharge Point From 1985 to 1994 at Lake Latonka

	Sediment Control Structures				Control Streams					
Year	**1**	**2**	**3**	**4**	**Manito**	**Mohican**	**Park**	**Apache**	**Coolspring**	**Dam**
1988	13.5	54.8	30.5	61.3	231	N/A	N/A	N/A	N/A	N/A
1989	10.36	8.99	6.58	7.3	7.35	N/A	N/A	N/A	N/A	N/A
1990	5.39	4.69	3.75	2.77	1.6	N/A	N/A	N/A	N/A	N/A
1991	5.77	6.14	4.49	11.75	5.9	N/A	N/A	N/A	N/A	N/A
1992	4.61	5.57	4.39	5.8	7.8	5.43	9.24	5.81	N/A	N/A
1993	4.77	5.03	3.69	9.72	17.3	8.06	7.01	4.14	5.93	4.38
1994	5.59	4.75	6.24	6.13	5.47	5.51	4.68	4.38	5.98	4.4

Table 7 Mean Ammonia Concentrations in Nine Subwatersheds and Lake Discharge Point From 1985 to 1994 at Lake Latonka

	Sediment Control Structures				**Control Streams**					
Year	**1**	**2**	**3**	**4**	**Manito**	**Mohican**	**Park**	**Apache**	**Coolspring**	**Dam**
1988	0.07	0.08	0.05	0.29	0.56	N/A	N/A	N/A	N/A	N/A
1989	0.04	0.02	0.03	0.03	0.03	N/A	N/A	N/A	N/A	N/A
1990	0.18	0.04	0.03	0.12	0.03	N/A	N/A	N/A	N/A	N/A
1991	0.04	0.02	0.08	0.03	0.08	N/A	N/A	N/A	N/A	N/A
1992	0.27	0.25	0.23	0.34	0.05	0.33	0.09	0.12	N/A	N/A
1993	0.45	0.53	0.51	0.85	0.47	0.78	0.73	0.82	0.62	0.72
1994	0.23	0.26	0.15	0.16	0.32	0.21	0.26	0.37	0.14	0.1

Table 8 Mean Nitrate Concentrations in Nine Subwatersheds and Lake Discharge Point From 1985 to 1994 at Lake Latonka

	Sediment Control Structures				Control Streams					
Year	**1**	**2**	**3**	**4**	**Manito**	**Mohican**	**Park**	**Apache**	**Coolspring**	**Dam**
1993	0.02	0.02	0.32	0.07	0.13	0.11	0.06	0.09	0.25	0.08
1994	0.85	0.59	0.55	0.98	1.04	0.93	0.39	1.15	1.75	1.33

Table 9 Mean Orthophosphate Concentrations in Nine Subwatersheds and Lake Discharge Point From 1985 to 1994 at Lake Latonka

	Sediment Control Structures				Control Streams					
Year	**1**	**2**	**3**	**4**	**Manito**	**Mohican**	**Park**	**Apache**	**Coolspring**	**Dam**
1988	4.3	2.8	2.76	2.67	4.5	N/A	N/A	N/A	N/A	N/A
1989	4.66	4.13	4.08	3.77	10.5	N/A	N/A	N/A	N/A	N/A
1990	1.61	1.64	1.45	2.45	1	N/A	N/A	N/A	N/A	N/A
1991	2.77	3.33	1.65	2.01	2.5	N/A	N/A	N/A	N/A	N/A
1992	0.7	1.55	1.16	1.74	0.2	1.26	1.06	1.12	N/A	N/A
1993	1.37	0.72	1.11	2.1	1.9	1.13	1.35	1.63	0.8	1.1
0.23	0.64	1.88	1.08	1.23	0.44	1.28	0.62	1.41	1.32	1.85

Table 11 Yearly Percent Reduction in Fecal Coliform Concentrations for Seven Subwatersheds from 1986 to 1994 at Lake Latonka, Mercer County Pennsylvania

	Sediment Control Structures				Control Streams		
Year	**1**	**2**	**3**	**4**	**Mohican**	**Park**	**Apache**
1986	34.8	55.7	2.96	N/A	6.86	13.3	33.3
1987	57.0	12.5	5.80	N/A	-5.87	-20.6	0.00
1988	66.7	47.5	11.1	0.34	23.2	-13.6	0.00
1989	-5.83	9.14	9.93	-1.78	47.1	15.2	0.00
1990	11.1	13.7	0.00	11.0	0.00	-1.00	0.00
1991	-24.0	-17.8	7.69	-0.78	11.1	7.14	0.00
1992	4.93	28.0	7.21	-6.41	37.9	0.00	0.00
1993	-39.0	16.4	6.94	0.43	-19.3	10.6	-5.29
1994	7.7	15.9	38.8	-14.0	38.1	38.9	39.9

Table 12 Yearly Percent Reduction Reduction in Ammonia Concentrations for Seven Subwatersheds from 1988 to 1994 at Lake Latonka, Mercer County.

	Sediment Control Structures				Control Streams		
Year	**1**	**2**	**3**	**4**	**Mohican**	**Park**	**Apache**
1988	14.3	66.7	0.00	41.7	N/A	N/A	N/A
1989	40.0	0.00	33.3	-33.3	N/A	N/A	N/A
1990	-25.0	40.0	-33.3	-1000	N/A	N/A	N/A
1991	66.7	-50.0	85.7	33.3	N/A	N/A	N/A
1992	28.6	69.0	-37.5	35.7	6.06	50.0	28.6
1993	-16.4	-177	17.7	56.8	-10.8	34.5	17.3
0.23	43.3	24.1	23.5	47.6	-52.9	30.3	32.4

Table 13 Yearly Percent Reduction Reduction in Nitrate Concentrations for Seven Subwatersheds from 1988 to 1994 at Lake Latonka, Mercer County. Pennsylvania

	Sediment Control Structures				Control Streams		
Year	**1**	**2**	**3**	**4**	**Mohican**	**Park**	**Apache**
1993	0.00	0.00	89.5	-100	72.2	0.00	22.2
1994	74.1	24.1	23.5	47.6	70.4	-5.26	32.7

Table 14 Yearly Percent Reduction Reduction in Orthophosphate Concentrations for Seven Subwatersheds from 1988 to 1994 at Lake Latonka, Mercer County. Pennsylvania

	Sediment Control Structures				Control Streams		
Year	**1**	**2**	**3**	**4**	**Mohican**	**Park**	**Apache**
1988	2.27	56.0	19.0	-0.37	N/A	N/A	N/A
1989	4.22	28.10	23.5	17.0	N/A	N/A	N/A
1990	3.07	-4.38	-7.14	9.72	N/A	N/A	N/A
1991	42.8	58.1	-1.22	35.0	N/A	N/A	N/A
1992	0.41	62.2	20.8	1.14	75.4	-96.0	40.7
1993	66.1	-41.7	25.2	43.8	-10.8	2.40	-20.3
1994	20.8	45.7	0.00	-16.7	-52.9	48.8	78.9

Table 17 Monthly Percent Reduction Reduction in Coliform Concentrations for Seven Subwatersheds from 1988 to 1994 at Lake Latonka, Mercer County. Pennsylvania

	Sediment Control Structures				Control Streams		
Month	**1**	**2**	**3**	**4**	**Mohican**	**Park**	**Apache**
May	-5.38	26.4	2.67	45.6	14.6	-5.66	9.25
June	3.80	22.6	-3.14	22.0	3.55	-5.77	0.00
July	19.4	-3.64	4.07	0.00	7.71	4.30	0.00
August	41.9	22.7	11.7	7.7	16.7	14.5	3.49
September	-35.8	41.2	2.36	0.00	0.00	-11.8	13.9
October	0.93	5.12	-17.7	-6.65	35.8	15.7	23.3

Table 18 Monthly Percent Reduction Reduction in Ammonia Concentrations for Seven Subwatersheds from May to October at Lake Latonka, Mercer County. Pennsylvania

	Sediment Control Structures				Control Streams		
Month	**1**	**2**	**3**	**4**	**Mohican**	**Park**	**Apache**
May	-16.7	25	0	33.3	50	25	0
June	-182.6	32.4	-88.5	-34.4	67.5	54.7	30.9
July	16.7	0	76.5	30.6	46.6	22.2	5.77
August	77	-41.7	7.41	61.2	20	85.7	33.3
September	61.5	28.6	-80	-40	-166.7	0	50
October	65.4	66.7	-333.3	50.9	-10	54.2	-34.8

Table 19 Monthly Percent Reduction Reduction in Nitrate Concentrations for Seven Subwatersheds from May to October at Lake Latonka, Mercer County. Pennsylvania

	Sediment Control Structures				Control Streams		
Month	**1**	**2**	**3**	**4**	**Mohican**	**Park**	**Apache**
May	0.00	0.00	0.00	0.00	0.00	0.00	0.00
June	0.00	50.0	16.7	33.3	11.8	-200.0	33.3
July	0.00	0.00	0.00	66.7	20.0	83.3	61.5
August	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	0.00	0.00	96.8	-816.70	0.00	100.0	72.7
October	75.0	50.0	0.00	0.00	75.0	0.00	-34.8

Table 20 Monthly Percent Reduction Reduction in Phosphate Concentrations for Seven Subwatersheds from May to October at Lake Latonka, Mercer County. Pennsylvania

	Sediment Control Structures				Control Streams		
Month	**1**	**2**	**3**	**4**	**Mohican**	**Park**	**Apache**
May	9.49	-7.53	-26.7	-4.19	22.5	-38.8	50.0
June	14.4	58.2	-14.0	12.4	13.0	42.9	18.0
July	28.8	57.8	47.9	30.1	12.5	37.0	2.7
August	15.9	11.6	32.6	21.4	20.0	30.1	-16.8
September	1.15	40.5	39.0	-54.4	13.0	7.8	42.9
October	-11.8	31.9	12.9	31.8	-5.61	48.5	27.1

REFERENCES

Adler, K. and R. Raucher. ASWIPCA's nonpoint assessment. *Journal of Water Pollution Control Federation.* 58(1986):1082-1083.

Brenner, E.K. and F.J. Brenner. Impact of precipitation and drainage area size on water quality in stream systems supplying a rural residential lake. *Journal of the Pennsylvania Academy of Science.* (1995)(In publication)

Brenner, F.J., R.P. Steiner, and J.J. Mondok. Groundwater-surface water interaction in an agricultural watershed. *Journal of the Pennsylvania Academy of Science.* (1995)(In publication).

Brenner, F.J. and J.J. Mondok. Evaluation of non-point pollution potential in an agricultural watershed in Northwestern Pennsylvania. *Water Resources Bulletin.* (1995)(In publication).

Brenner, F.J., J.J. Mondok and R.J. McDonald, Jr. Impact of riparian areas and land use on four nonpoint source pollution parameters in Pennsylvania. *Journal of the Pennsylvania Academy of Science.* 65(1991):65-70.

Brenner, F.J., R.P. Steiner, J.J. Mondok and R.J. McDonald, Jr. Nonpoint-source pollution: a model watershed approach to improve water quality. *In* S.K. Majumdar, E.W. Miller, and R.R. Parizek (eds). *Water Resources in Pennsylvania: Availability, Quality and Management.* Phillipsburg, NJ: Pennsylvania Academy of Science (1990) pp. 483-498.

Brenner, F.J., R.P. Steiner, and J.J. Mondok. Use of water quality models to predict nonpoint-source pollution parameters in an agricultural watershed. *Monitoring, Modeling and Mediating Water Quality.* Bethesda, MD: American Water Resources Association. (1987) pp. 295-301.

Burge, W.D. and J.F. Parr. Movement of pathogentic organisms from waste applied to agricultural lands. *In* M.R. Overcash and J.M. Davidson (eds). *Environmental Impact of Nonpoint Source Pollution.* Ann Arbor, MI: Ann Arbor Science. (1980) pp. 107-124.

Carter, M.R. *Soil sampling and methods of analysis. Canadian Society of Soil Science.* Lewis Publishers. Boca Raton, FL. 1993.

Cooke, J.G. Phosphorous removal process in a wetland after a decade of receiving a sewage effluent. *Journal of Environmental Quality.* 21(1992):733-739.

Cosgel, M.M. Religious culture and economic performance: Agricultural productivity of the Amish, 1850-1880. *Journal Economic History.* 53(1993):319-331.

Ediger, M. Amish adaptations to modern society: technical, medical, and legal. *Social Science Research.* 70(1986):286.

Fifield, J.S. What is required for effective sediment control? *Land and Water.* 38(1994):39-40.

Frey, R.F., R.A. Kime and N.M. Spagenberg (eds) *Commonwealth of Pennsylvania 1994 water quality assessment.* PA Dept. of Environ. Resources, Bureau of Water Quality Management. 1994.

Fontaine, T. The Everglades: Past, present and future. Third Symposium of Biogeochemistry of Wetlands. Orlando, Florida, USA. June 26-29, 1994

Graybow, W.O.K. and P. Croubrough. Practical direct plague assay for coliphage in 100 ml samples of drinking water. *Applied and Experimental Microbiology.* 2(1986):430-433.

Greenberg, A.E. , J.J. Condors, D. Jerkins and M.A.H. Ranson. *Standard Methods for the Examination of Water and Wastewater.* Washington, D.C.: American Public Health Association. 1981.

Groffman, P.M. Denitrification in freshwater wetlands. *Current Topics in Wetland Biogeochemistry.* 1(1994):15-35.

Hammer, D.A. *Creating Freshwater Wetlands.* Ann Arbor, MI: Lewis Publishers. 1992.

Hammer, D.A. Agricultural nonpoint pollution. *In* R.K. Olson (ed). *Created and Natural Wetlands for Controlling Nonpoint Source Pollution.* Boca Raton, FL: C.K. Smoley. (1993) pp. 71-111.

Harper, C.R., W.J. Goetz, and C.E. Willis. Groundwater protection in mixed land-use aquifers. *Environmental Management.* 16(1992):777-783.

Havelaar, A.H. and T.J. Nieuwstad. Bacterialphages and fecal bacteria as indicators of chlorination effectiveness of biologically treated wastewater. *Journal of Water Pollution Control Federation.* 57(1985):1084-1088.

Hedin, R. *Constructing wetlands for treatment of acid mine drainage.* U.S. Bureau of Mines, U.S. Department of Interior, Office of Surface Mining Reclamation and Enforcement. 1991.

Hill, C.L. Monitoring the effects of land management practices on water quality in Gulford County, North Carolina. *In* S.J. Nix and P.E. Black (eds). *Monitoring, Modeling and Mediating Water Quality.* Bethesda, MD: American Water Resources Association. (1987) pp. 137-148.

Humenick, F.J., M.D. Smolen and S.A. Dressing. Pollution from nonpoint-source. *Environmental Science and Technology.* 21(1987):737-742.

Johnson, C.A. Sediment and nutrient retention by freshwater wetlands: effects on surface water quality. *Critical Reviews in Environmental Control.* 21(1991):491-565.

National Research Council. *Restoration of Aquatic Ecosystems: Science, Technology and Public Policy.* Washington, D.C.: National Academy Press. 1992.

Olsham, M.A. The opening of Amish society: cottage industry as Trojan horse. *Human Organization.* 50(1991):378-384.

Olson, R.K. *Created and Natural Wetlands for Controlling Nonpoint Source Pollution.* Boca Raton, FL: C.K. Smoley. 1993.

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

Reed, S.C., E. J. Middlebrooks and R.W. Crites. *Natural Systems for Waste Management and Treatment*. New York: McGraw Hill. 1988.

Park, S.W., S. Mostaghimi, R.A. Cooke, and P.W. McClellan. BMP impacts on watershed runoff, sediment and nutrient yields. *Water Resources Bulletin*. 30.6(1994):1011-1023.

Payne, M. Agricultural pollution-the farmers view. *In* J.F. Solbe' and L.G. Solbe' (eds). *Effects of land use on freshwaters: agriculture, forestry, mineral exploitation, urbanisation*. Chichester, England: Ellis Horwood Publishers. (1986) pp. 329-340.

Savells, J. Economic and social acculturation among the Old Order Amish in select communities: surviving in a high-tech society. *Journal of Comparative Family Studies*. 19(1988):123-135.

Schlosser, I.J. and J.R. Karr. Water quality in agricultural watersheds: impact of riparian vegetation during base flow. *Water Resources Bulletin*. 17(1981):233-240.

Sikora, F.J. Summary of research at the Tennessee Valley Authority's constructed wetlands research and development facility. *Workshop on Constructed Wetlands for Animal Waste Management*. Purdue University. 4-6 April 1994.

Simons, D.B. and R.M. Li. Modeling of sediment nonpoint source pollution from watersheds. *In* M.R. Overcash and J.M. Davidson (eds). *Environmental Impact of Nonpoint Pollution*. Ann Arbor Science. Ann Arbor, Michigan. pp. 341-373.

Solbe', J.F. and L.G. Solbe' (eds). *Effects of land use on fresh waters: agriculture, forestry, mineral exploitation, urbanisation*. Chichester, England: Ellis Horwood Publishers. 1986.

United States Department of Agriculture, Soil Conservation Service. *Mercer County Pennsylvania Soil Survey.* Washington, D.C.: U.S. Government Printing Office. 1971.

Worthington, P. Regulatory remedies for agricultural pollution. *In* J.F. Solbe' and L.G. Solbe' (eds). *Effects of land use on fresh waters: agriculture, forestry, mineral exploitation, urbanisation.* Chichester, England: Ellis Horwood Publishers. (1986) pp. 314-348.