DRAFT

LAKE JEAN
TMDL

LOW pH DUE TO ATMOSPHERIC DEPOSITION

PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION

SPRING 2004

Lake Jean TMDL
Table of Contents

Introduction

This report represents the Total Maximum Daily Loads (TMDLs) developed for Lake Jean in the Fishing Creek watershed. Lake Jean has been identified by the Pennsylvania Department of Environmental Protection (PA DEP) as not supporting its designated uses for the pH criteria on the state’s 1996, 1998 and 2002 Section 303(d) list of impaired waters. A water quality criterion, as described in PA Code § 93.7, requires the pH be between 6.0 and 9.0. These were done to address the impairments noted on the 1996 Pennsylvania Section 303(d) list of impaired waters, required under the Clean Water Act, and covers one segment on this list (shown in Table 1). Low pH level is the cause for these impairments. All impairments resulted from atmospheric deposition of acidic material. The TMDL addresses the pH by analyzing the balance between acidity and alkalinity.

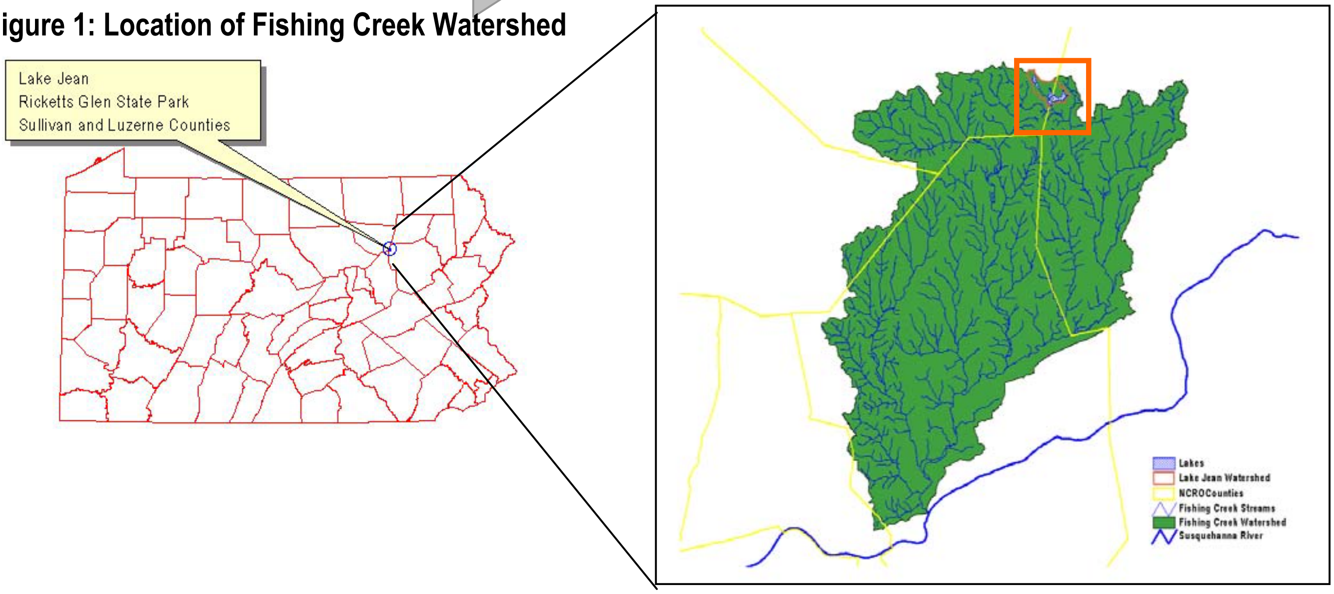
Table 1: Lake Jean Listings on 303(d) List

State Water Plan (SWP) Subbasin: 5-C							
Year	Acres	Name	Segment ID	Designated Use	Data Source	Source	Cause
1996	245	Lake Jean		HQ-CWF	Phase I Clean Lakes Study	Atmospheric Deposition	pH
1998	245	Lake Jean		HQ-CWF	Phase I Clean Lakes Study	Atmospheric Deposition	pH
2004[1]	245	Lake Jean	19920001-0001-LAK	HQ-CWF	Phase I Clean Lakes Study	Atmospheric Deposition	pH

Directions to Lake Jean

Lake Jean is completely contained within Ricketts Glen State Park, which stretches across Luzerne, Sullivan and Columbia Counties. The park is located 30 miles north of Bloomsburg on PA Route 487, between the cities of Wilkes-Barre and Williamsport. The village of Red Rock sits approximately 3 miles to the south of Lake Jean where Route 487 intersects Route 118. The US Department of Labor Red Rock Job Corp Center is located one mile north of the park on Route 487.

Figure 1: Location of Fishing Creek Watershed



---

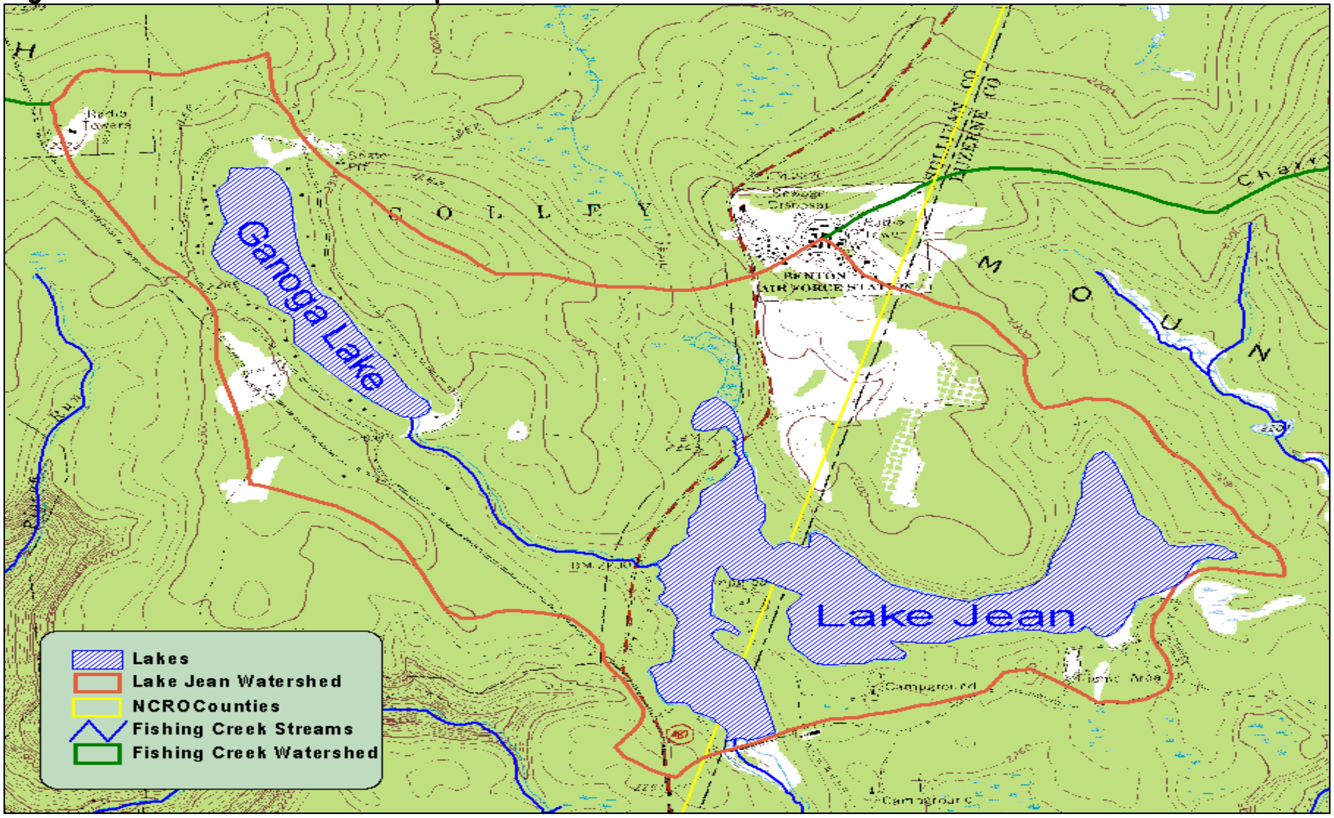
[1] Pennsylvania’s 1996, 1998, and 2002 Section 303(d) lists were approved by the Environmental Protection Agency (EPA), the 2004 list is still in draft form. The 1996 Section 303(d) list provides the basis for measuring progress under the 1996 lawsuit settlement of *American Littoral Society and Public Interest Group of Pennsylvania v. EPA*

Lake Jean Background

Lake Jean is contained within the headwaters of the Fishing Creek watershed. The lake stretches across the border between Sullivan and Luzerne Counties. In Sullivan County, the lake is located in Colley Township and in Luzerne County, Fairmount Township. The existing lake was created by the construction of an earth-filled dam across the outlet of the former Lake Jean in 1956. The dam elevation allowed for the flooding of a narrow tract of land between the former Lake Jean and Mud Pond.

The below figure shows the approximate watershed that drains to Lake Jean, outlined in red.

Figure 2: Lake Jean Watershed Map



Lake Jean Characteristics

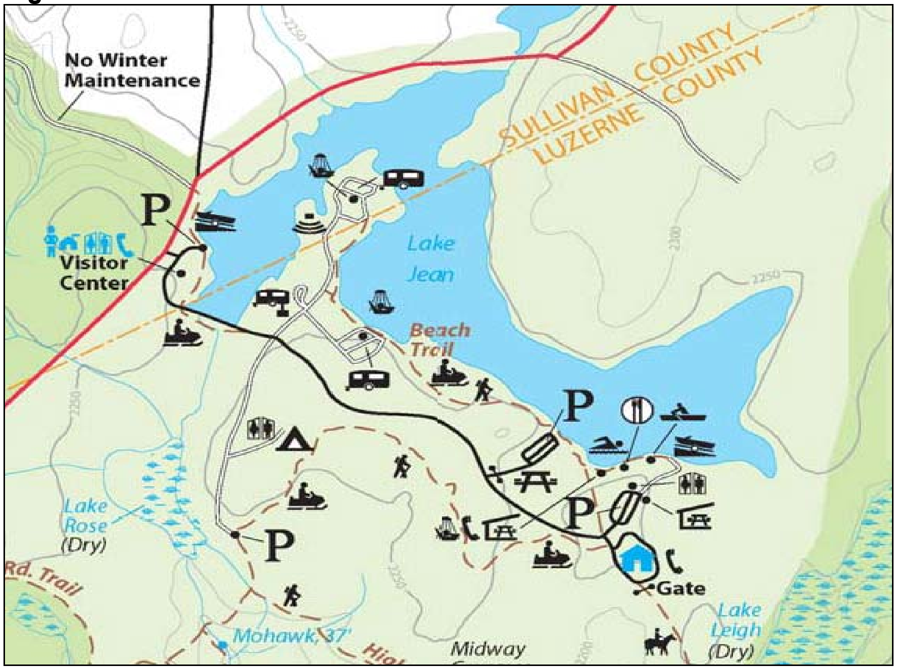
The watershed of Lake Jean is 1,745 acres in size and is in eastern Sullivan and western Luzerne Counties. This watershed is predominantly hardwood forest. The lake is fed by two sources: the outlet of Ganoga Lake and the drainage from an upstream wetland area. This watershed area is found on the United States Geological Survey Red Rock 7.5-minute quadrangle.

Lake Jean is a 253-acre lake, completely contained in Ricketts Glen State Park. The 13,050-acre park offers a variety of recreational activities, including hiking, swimming, hunting, boating, fishing, and horseback riding trails.

The outlet from Ganoga Lake, located approximately 0.4 miles north-northwest of Lake Jean, forms the largest tributary (see above figure).

The figure below shows the variety of recreational opportunities at and around Lake Jean.

Figure 3: Lake Jean Recreation



The outlet of Lake Jean feeds Rose Lake, which in turn feeds Kitchen Creek. This eventually flows into the Susquehanna River near Bloomsburg, PA via Huntington and then Fishing Creeks.

Table 2 identifies the characteristics of Lake Jean.

Table 2: Characteristics of Lake Jean

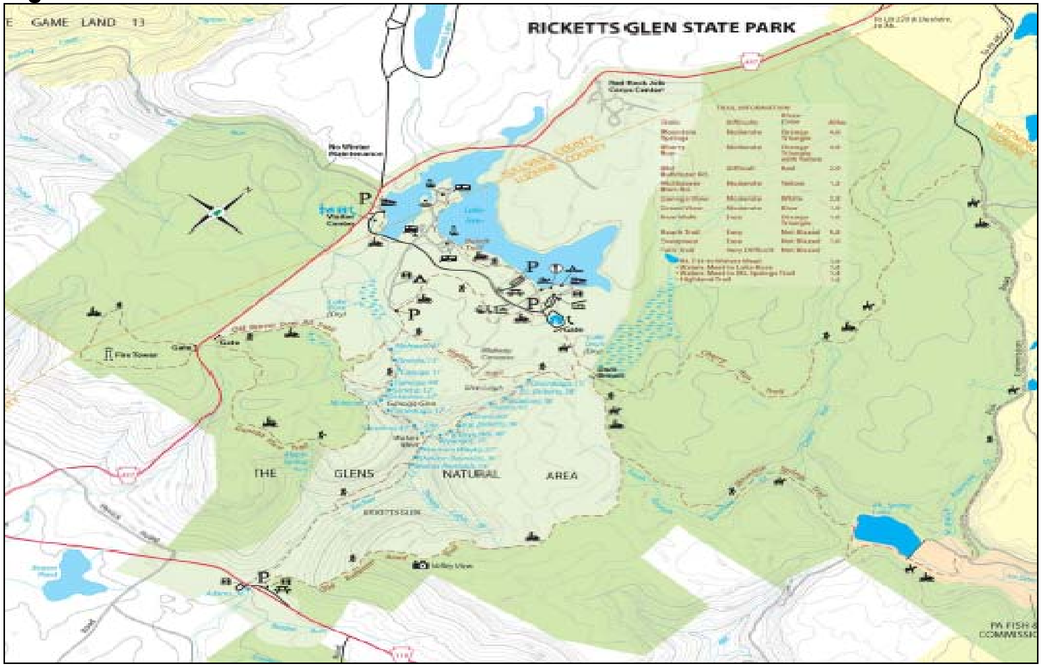
Surface Area	253 acres
Volume	486,000,000 gallons
Depth – Average	5.9 feet
Depth – Maximum	19.5 feet
Hydraulic Retention Time	0.6 years
Average Discharge	3.62 ft^3/sec
Basin Drainage Area	1,745 acres

Ricketts Glen State Park

The 13,050-acre park offers a variety of recreational activities, including hiking, swimming, hunting, boating, fishing, and horseback riding trails. The Glens Natural Area, a registered National Natural Landmark since October 12, 1969, is the main scenic attraction in the park. Many of the magnificent trees in this area are over 500 years old and ring counts on fallen trees have revealed ages as high as 900 years. Diameters of almost four feet are common and many trees tower to 100 feet in height. The area is the meeting ground of the southern and northern hardwood types, creating an extensive variety of trees. In 1993, the Glens Natural Area became a State Park Natural Area and will be protected and maintained in a natural state.

The figure below shows the lake, the surrounding park and associated hunting lands.

Figure 4: Ricketts Glen State Park



Lake Jean Fishery

Acid tolerant species have proliferated in the lake. These species include yellow perch, pumpkinseed, and brown bullhead. The adults of acid intolerant species, such as fathead minnows, largemouth bass, chain pickerel, walleye and muskellunge, appear to have good growth rates, but very poor reproductive success.

In 1958, the Fish Commission determined that the lake's fish population was unbalanced and of no value to anglers. The lake was reclaimed chemically. Fishing was not permitted during the next three years. In the winter of 1959, the Department of Environmental Resources, in an attempt to increase lake alkalinity and pH, applied 106 tons of cement stack dust to the frozen surface. Following the dust application, the Fish Commission stocked the lake with forage and game fish in an attempt to re-establish the fishery. The lake was re-opened to anglers in 1961. The only period when game fish successfully reproduced was after the first year of in-lake adjustment with the cement dust.

A 2003 fish survey of the lake by the Fish & Boat Commission indicated an improvement to the fishery since the 1960s, but the numbers, size and catch rates were less than desirable.

Watershed Characteristics

The total watershed area of Lake Jean is 1,998 acres, including the 253 acres of the lake. The remaining 1,745 acres drain to the lake.

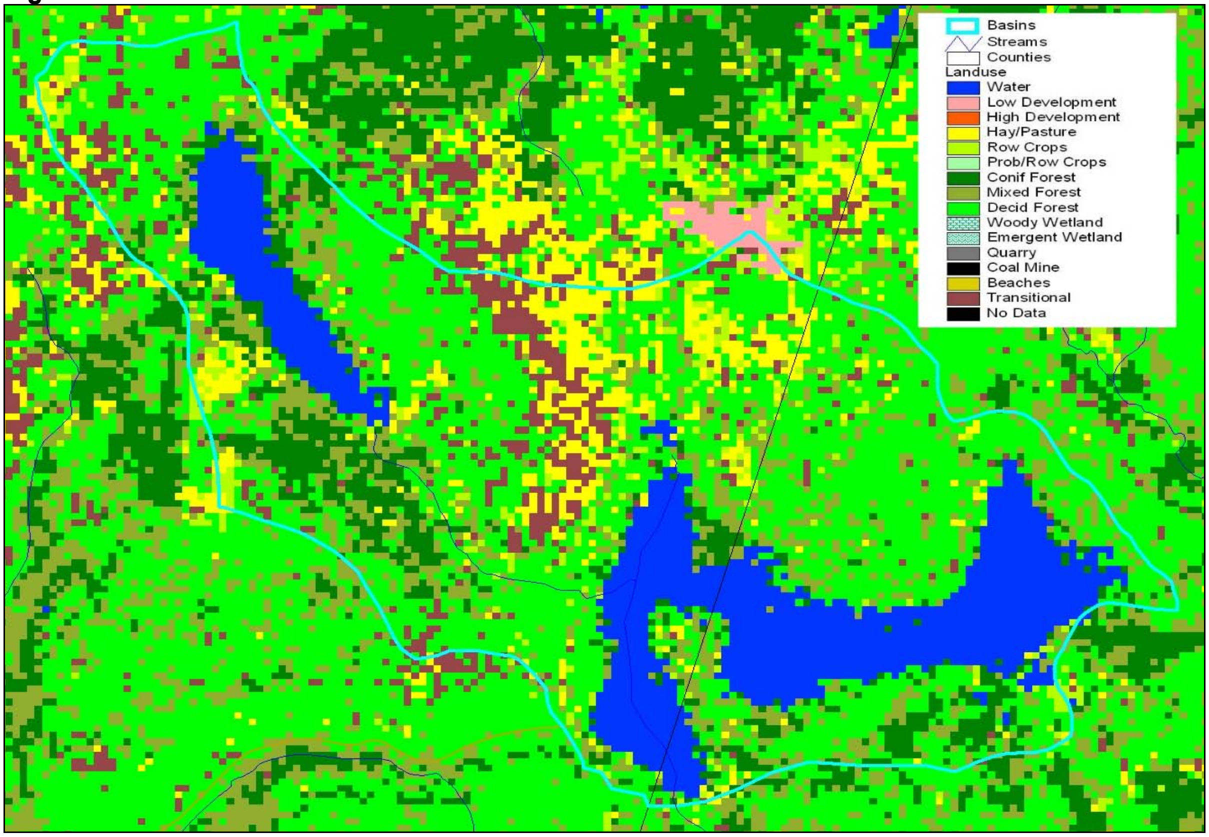
Table 3 identifies the different land uses within the watershed and the approximate percentages of each.

Table 3: Lake Jean Watershed Land Use

Land Use Type	Area (acres)	Percent (%)
Forested	1,414	81.0
Field	220	12.6
Other Lakes	82	4.7
Wetlands	29	1.7
TOTAL	**1,745**	**100**

The various land uses of the Lake Jean watershed are shown in the figure below, as generated by the AV-GWLF model.

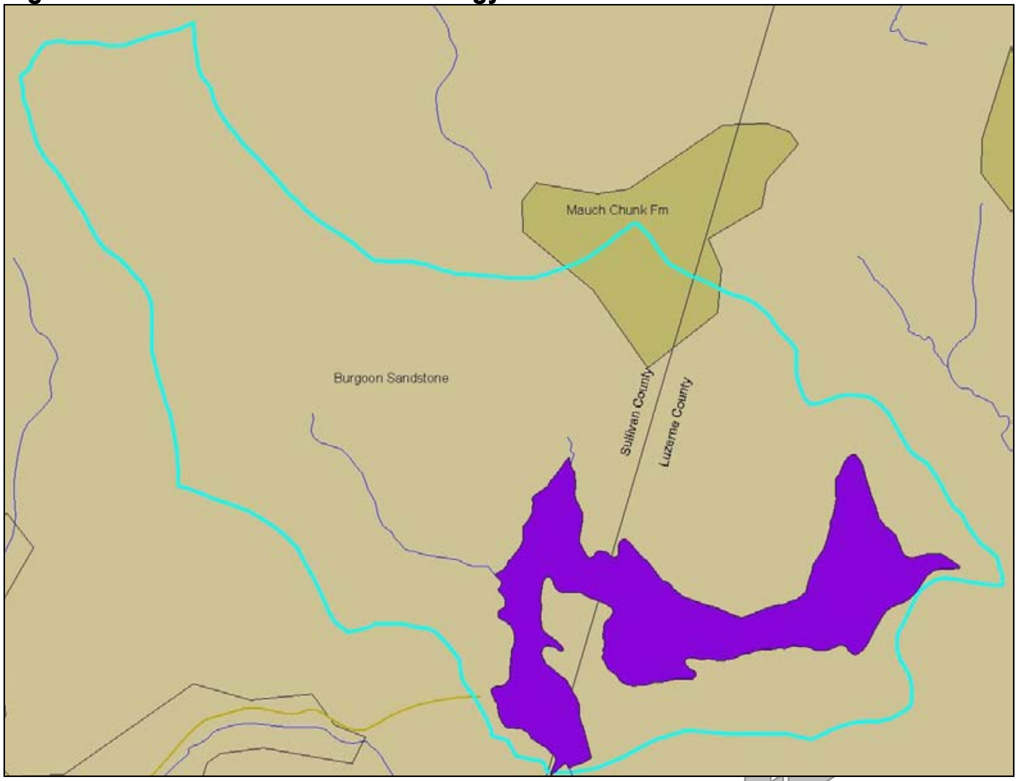
Figure 5: Lake Jean Watershed Land Use



The watershed is situated on Colley Mountain, which is located in the Allegheny High Plateaus Section of the Appalachian Plateaus Province of Pennsylvania. The general topography in the region consists of rolling hills, deeply entrenched streams, and very steep mountains. The highest elevation in the watershed is to the east of Ganoga Lake at 2,380 feet (above MSL). The elevations of Lake Jean and Ganoga Lake are 2,222 and 2,266, respectively. The watershed area is located in the Appalachian Physiographic Province, and is underlain with red and grey sandstone (Devonian, Mississippian and Pennsylvanian bedrock).

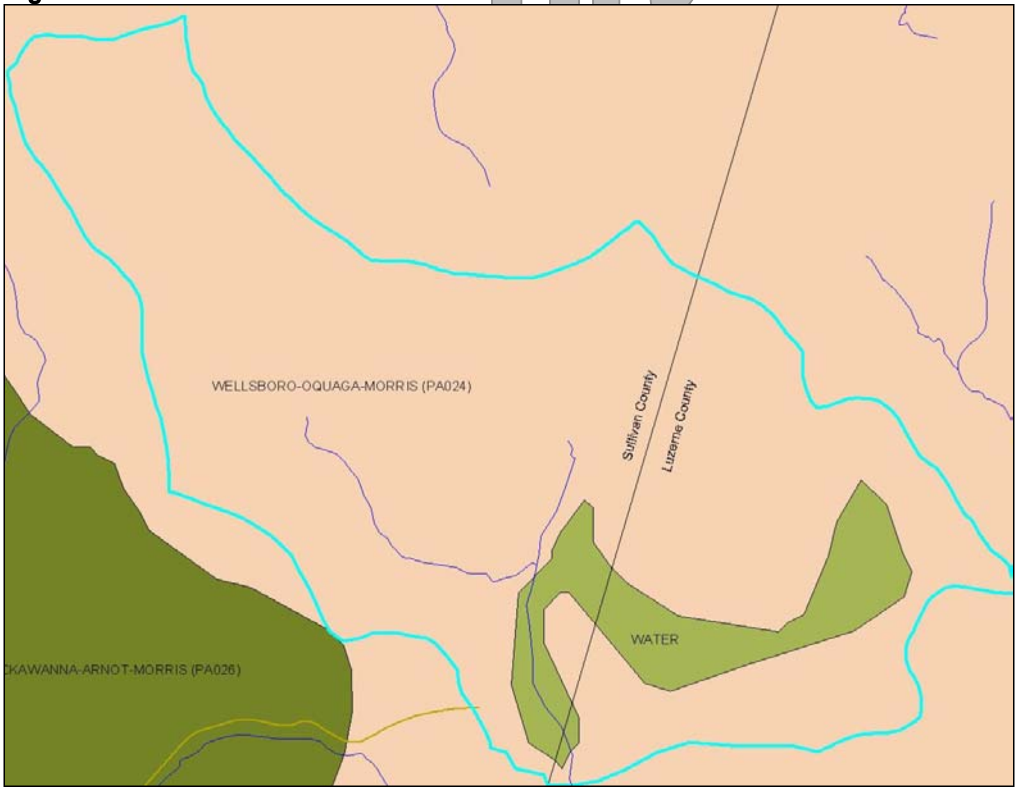
Geology of the Lake Jean watershed is predominately Burgoon Sandstone as shown in Figure 6. Burgoon Sandstone consists of sandstone with minor interbedded gray shale, conglomerate, and mudstone; upper member is light-gray, fine- to medium-grained orthoquartzite.

Figure 6: Lake Jean Watershed Geology



Soils in the watershed consist of the Wellsboro-Oquaga-Morris Association, primarily derived from the Catskill Formation. The soils from the watershed are shown in Figure 7.

Figure 7: Lake Jean Watershed Soils



There are currently no point source discharges in the watershed above the lake that may contribute to the low pH condition.

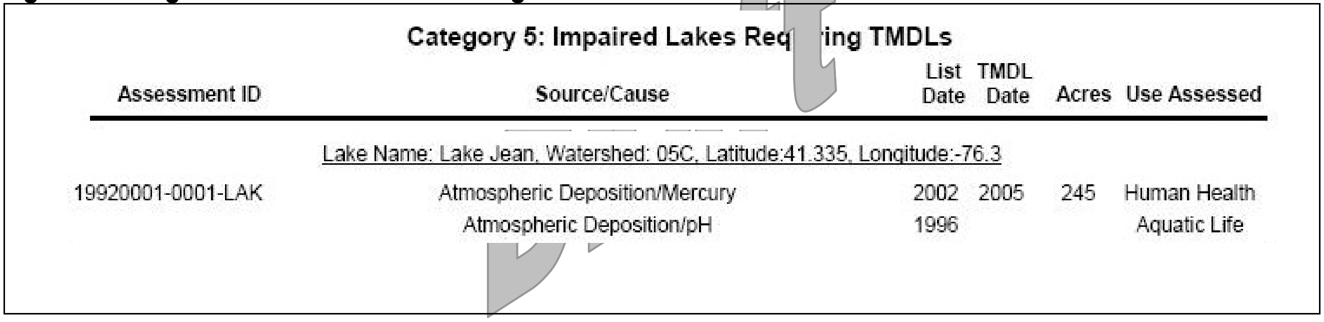
Watershed History

Ricketts Glen was named for Colonel Robert Bruce Ricketts, who led Battery F, which aided the repulsion of the famed “Picketts Charge” during the Battle of Gettysburg. At one time, Ricketts owned over 80,000 acres in and around the current park. His heirs sold 48,000 acres to the PA Game Commission from 1920 to 1924. The area around the lakes and the Glen was planned to become a national park in the 1930s, but that plan was abandoned at the onset of World War II. In 1942 and 1943, Ricketts’ heirs sold additional land to the Commonwealth for the purposes of establishing a state park. The park was officially opened as Ricketts Glen State Park in 1944.

Lake Jean was listed on the 1996 303(d) List as impaired by low pH due to acid deposition. The data source for this listing was the Phase One Diagnostic-Feasibility Study of Lake Jean conducted by Coastal Environmental Services, Inc. in 1993 and 1995 (also referred to as Clean Lakes Study). This study, completed under a grant from the U.S. EPA Clean Lakes Program, was funded under Section 314 of the Federal Clean Water Act. The study was the result of an application submitted to EPA by the then Department of Environmental Resources, which was concerned with the water quality of the lake. The mercury listing will be addressed in a future TMDL.

The listing, from the 2004 Integrated List, is shown below.

Figure 8: Integrated List Lake Jean Listing



Category 5: Impaired Lakes Requiring TMDLs

Assessment ID	Source/Cause	List Date	TMDL Date	Acres	Use Assessed
	Lake Name: Lake Jean, Watershed: 05C, Latitude:41.335, Longitude:-76.3				
19920001-0001-LAK	Atmospheric Deposition/Mercury	2002	2005	245	Human Health
	Atmospheric Deposition/pH	1996			Aquatic Life

Acid Precipitation

Acid rain, more properly called acid deposition, is caused by the emission of various pollutants to the air. The principle sources are the smokestacks of fossil fuel power plants, other industrial facilities and automotive exhausts. These emissions contain sulfur dioxide (SO2), the major contributor to the problem, and nitrogen oxide (NOx). These gases combine with oxygen and water vapor in the air to form sulfuric and nitric acids. The acids fall to the earth in two forms of deposition. When precipitation such as rain, sleet or snow containing dissolved sulfuric or nitric acid falls to the ground, it is termed wet deposition or “acid rain.” If the acids descend as sulfate or nitrate particles, it is labeled dry deposition.

These acids, suspended high above the earth, may be carried hundreds of miles by the wind before they eventually drop or wash down. That’s why acid rain is a problem that has no borders or territories. Compounding the problem is the fact that emissions are not spread out evenly. In the United States, almost half of all SO2 and NOx emissions produced come from seven states in the coal-burning Ohio River Valley and Missouri and Tennessee. The wind carries the gases in a northeasterly direction toward the Mid-Atlantic States, New England and Canada.

When acids enter lakes and streams, the effects on aquatic life can be devastating. Organisms ranging from fish and frogs down to microscopic plankton cannot survive in highly acidic waters. The low pH level can halt or disrupt the reproductive cycles of these organisms. The Pennsylvania Fish and Boat Commission warns that acid rain poses a threat to over 5,000 miles of streams it stocks annually.

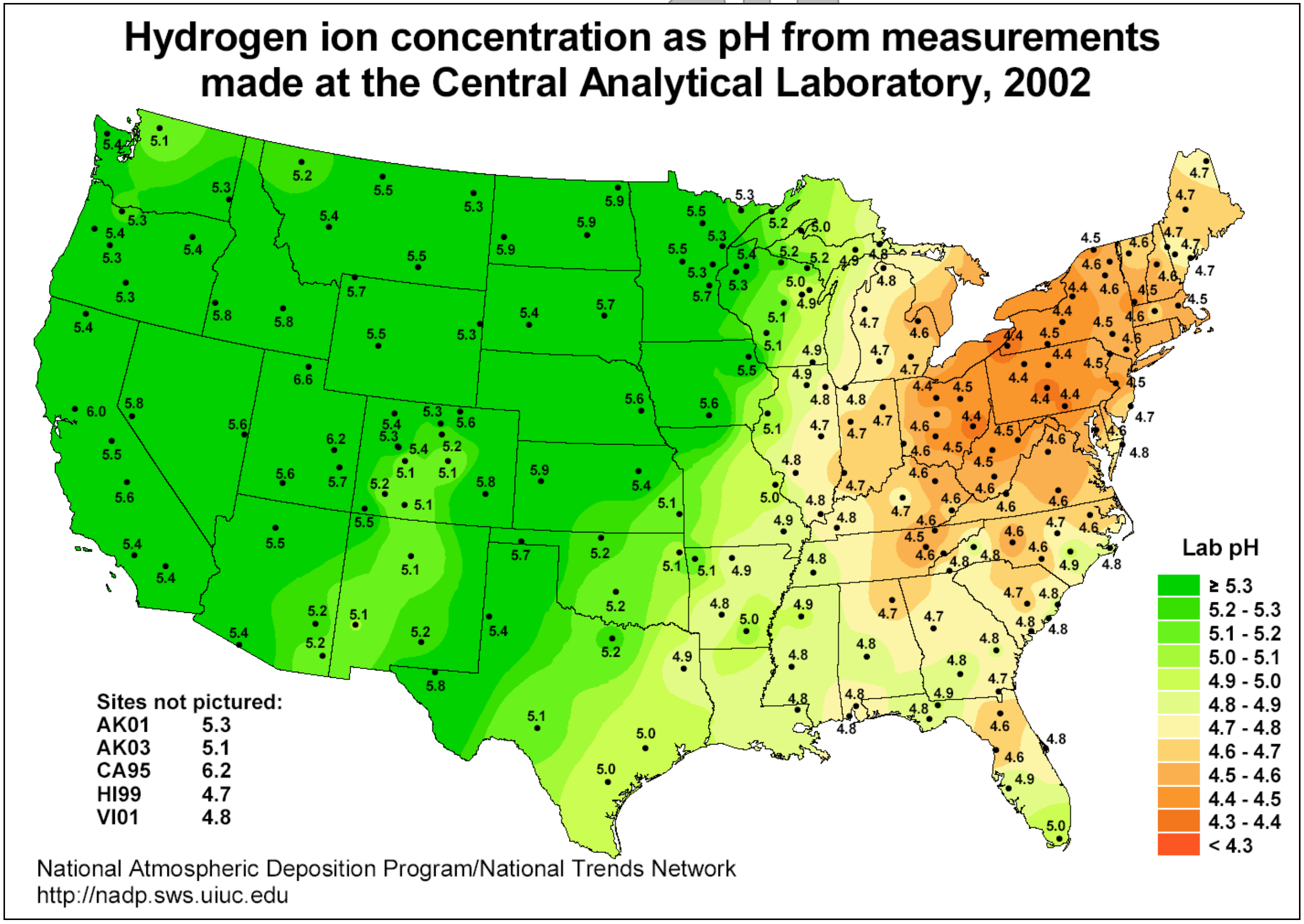
Many of PA's sandstone ridge watersheds, like that of Lake Jean, are susceptible to acid runoff events, due to the lack of buffering offered by the geology.

The **National Atmospheric Deposition Program/National Trends Network** (NADP/NTN)is a nationwide network of precipitation monitoring sites. The network is a cooperative effort between many different groups, including the State Agricultural Experiment Stations, U.S. Geological Survey, U.S. Department of Agriculture, and numerous other governmental and private entities.

The purpose of the network is to collect data on the chemistry of precipitation for monitoring of geographical and temporal long-term trends. The precipitation at each station is collected weekly according to strict clean-handling procedures. It is then sent to the Central Analytical Laboratory where it is analyzed for hydrogen (acidity as pH), sulfate, nitrate, ammonium, chloride, and base cations (such as calcium, magnesium, potassium and sodium).

An evaluation of these data reveals that the area of Pennsylvania that includes the Lake Jean Watershed has persistent low pH precipitation. The average pH values are in the 4.3 to 4.4 range, which is consistent with the instream sampling data that was collected as part of this study. Figure 8 shows a map of pH values collected by NADP in 2002.

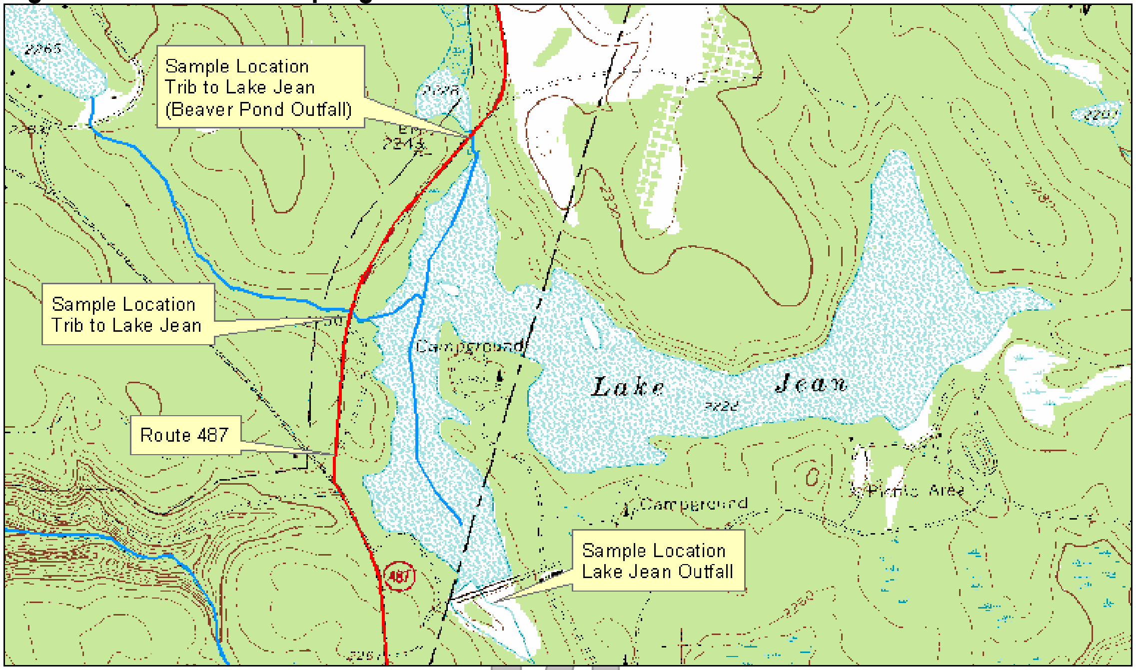
Figure 8: pH Values from NADP



Sampling

Sampling was conducted at two sites. These sites include the outfall of the Beaver Pond and the tributary on Route 487. Additional data came from the GWLF model, for the eastern portion of the Lake Jean watershed (1.51 square miles) and the surface area of the lake. Chemical samples were taken at each sampling location, and sent to the Pennsylvania Department of Environmental Protection laboratory for analysis. Below is a map that shows the sample locations. Samples were collected in January 2004, May and July 2003 to represent the most critical seasonal conditions. Data was also collected at the outlet for comparison purposes.

Figure 9: Lake Jean Sampling Locations



Clean Water Act Requirements

Section 303(d) of the 1972 Clean Water Act requires states, territories, and authorized tribes to establish water quality standards. The water quality standards identify the uses for each waterbody and the scientific criteria needed to support the uses. Uses can include drinking water supply, contact recreation (swimming), and aquatic life support. Minimum goals set by the Clean Water Act require that all waters be “fishable” and “swimmable.”

Additionally, the federal Clean Water Act and the U.S. Environmental Protection Agency’s (USEPA) implementing regulations (40 CFR Part 130) require:

- States to develop lists of impaired waters for which current pollution controls are not stringent enough to meet water quality standards (the list is used to determine which streams need TMDLs);
- States to establish priority rankings for waters on the lists based on severity of pollution and the designated use of the waterbody; states must also identify those waters for which TMDLs will be developed and a schedule for development;
- States to submit the list of waters to USEPA every two years (April 1 of the even numbered years);

- States to develop TMDLs, specifying a pollutant budget that meets state water quality standards and allocate pollutant loads among pollution sources in a watershed, e.g., point and nonpoint sources; and

- USEPA to approve or disapprove state lists and TMDLs within 30 days of final submission.

Despite these requirements, states, territories, authorized tribes, and USEPA had not developed many TMDLs. Beginning in 1986, organizations in many states filed lawsuits against the USEPA for failing to meet the TMDL requirements contained in the federal Clean Water Act and its implementing regulations. While USEPA has entered into consent agreements with the plaintiffs in several states, other lawsuits still are pending across the country.

In the cases that have been settled to date, the consent agreements require USEPA to backstop TMDL development, track TMDL development, review state monitoring programs, and fund studies on issues of concern (e.g., AMD, implementation of nonpoint source Best Management Practices (BMPs), etc.).

The TMDLs in this report were developed in partial fulfillment of the 1996 lawsuit settlement of *American Littoral Society and Public Interest Group of Pennsylvania v. EPA*.

Section 303(d) Listing Process

Prior to developing TMDLs for specific waterbodies, there must be sufficient data available to assess which streams are impaired and should be on the Section 303(d) list. With guidance from the USEPA, the states have developed methods for assessing the waters within their respective jurisdictions.

The primary method adopted by the Pennsylvania Department of Environmental Protection (DEP) for evaluating waters changed between the publication of the 1996 and 1998 Section 303(d) lists. Prior to 1998, data used to list streams were in a variety of formats, collected under differing protocols. Information also was gathered through the Section 305(b)[2] reporting process. DEP is now using the Unassessed Waters Protocol (UWP), a modification of the USEPA Rapid Bioassessment Protocol II (RPB-II), as the primary mechanism to assess Pennsylvania's waters. The UWP provides a more consistent approach to assessing Pennsylvania's streams.

The assessment method requires selecting representative stream segments based on factors such as surrounding land uses, stream characteristics, surface geology, and point source discharge locations. The biologist selects as many sites as necessary to establish an accurate assessment for a stream segment; the length of the stream segment can vary between sites. All the biological surveys included kick-screen sampling of benthic macroinvertebrates, habitat surveys, and measurements of pH, temperature, conductivity, dissolved oxygen, and alkalinity. Benthic macroinvertebrates are identified to the family level in the field.

After the survey is completed, the biologist determines the status of the stream segment. The decision is based on the performance of the segment using a series of biological metrics. If the stream is determined to be impaired, the source and cause of the impairment is documented. An impaired stream must be listed on the state's Section 303(d) list with the source and cause. A TMDL must be developed for the stream segment. In order for the process to be more effective, adjoining stream segments with the same source and cause listing are addressed collectively, and on a watershed basis.

---

[2] Section 305(b) of the Clean Water Act requires a biannual description of the water quality of the waters of the state.

Basic Steps for Determining a TMDL

Although all watersheds must be handled on a case-by-case basis when developing TMDLs, there are basic processes or steps that apply to all cases. They include:

1. Collection and summarization of pre-existing data (watershed characterization, inventory contaminant sources, determination of pollutant loads, etc.);
2. Calculation of TMDL for the waterbody using USEPA approved methods and computer models;
3. Allocating pollutant loads to various sources;
4. Determining critical and seasonal conditions;
5. Public review and comment period on draft TMDL,
6. Submittal of TMDL to EPA.,
7. USEPA approval of the TMDL

TMDL Elements (WLA, LA, MOS)

A TMDL equation consists of a wasteload allocation, load allocation and a margin of safety. The wasteload allocation is the portion of the load assigned to point sources. The load allocation is the portion of the load assigned to nonpoint sources. The margin of safety is applied to account for uncertainties in the computational process. The margin of safety may be expressed implicitly (documenting conservative processes in the computations) or explicitly (setting aside a portion of the allowable load).

Targeted TMDL values were than used as the basis for load allocations and reductions in the Lake Jean Watershed, using the following equation:

1. $TMDL = WLA + LA + MOS$

where:

TMDL = Total Maximum Daily Load
WLA = Waste Load Allocation (point sources)
LA = Load Allocation (nonpoint sources)
MOS = Margin of Safety

Allocation Summary

The allocation of the TMDL in this report is based on available data. These TMDLs will focus remediation efforts on the identified numerical reduction targets for each watershed. As changes occur in the watershed, the TMDLs may be re-evaluated to reflect current conditions. Table 3 presents the estimated reductions identified for all points in the watershed. The TMDLs by Segment section gives detailed TMDLs by segment analysis for each allocation point.

Consideration of Critical Conditions

The AVGWLF model was used to calculate average flows that were used in the development of the TMDL. The AVGWLF model is a continuous simulation model, which uses daily time steps for weather data and water balance calculations. Monthly calculations are made based on the daily water balance accumulated to monthly values. Therefore, all flow conditions are taken into account for loading calculations. Because there is generally a significant lag time between the introduction of low pH atmospheric deposits to a waterbody and the resulting impact on beneficial uses, establishing this TMDL using average annual conditions is protective of the waterbody.

Additionally, the concentration of acid instream is varied through the seasons, thus the timing of sampling was spread over a year.

Margin of Safety

For this study, the margin of safety is applied implicitly. The allowable concentrations and loadings were simulated using Monte Carlo techniques and employing the @Risk software. Other margins of safety used for this TMDL analysis include the following:

- The data were analyzed to determine if there was reason to suspect any samples were significantly different than the rest of the data set. If it were determined that there was reason to suspect that any of the data were outliers, those data were processed through Chauvenet's Criterion algorithms to determine if they were statistical outliers (Kennedy 1964.) Because the 99 percent level of protection is designed to protect for the extreme event, it was pertinent not to filter the data set unless there is reason to believe that the sample is statistically different from the rest of the samples. Some of the reasons for a sample being statistically different may lie in the sampling procedures and equipment, the laboratory procedures or equipment, or the sample may have been compromised at any stage of processing.

Low pH Atmospheric Deposition TMDLs Methodology

A two-step approach is used for the TMDL analysis of atmospheric deposition impaired stream segments. The first step uses a statistical method for determining the allowable instream concentration at the point of interest necessary to meet water quality standards. This is done at each point of interest (sample point) in the watershed. The second step is a mass balance of the loads as they pass through the watershed. Loads at these points will be computed based on average annual flow.

The statistical analysis describes below can be applied to situations where all of the pollutant loading is from non-point sources as well as those where there are both point and non-point sources. The following defines what are considered point sources and non-point sources for the purposes of our evaluation; point sources are defined as permitted discharges or a discharge that has a responsible party, non-point sources are then any pollution sources that are not point sources. For situations where all of the impact is due to nonpoint sources, the equations shown below are applied using data for a point in the stream. The load allocation made at that point will be for all of the watershed area that is above that point. For situations where there are point-source impacts alone, or in combination with nonpoint sources, the evaluation will use the point-source data and perform a mass balance with the receiving water to determine the impact of the point source.

Allowable loads are determined for each point of interest using Monte Carlo simulation. Monte Carlo simulation is an analytical method meant to imitate real-life systems, especially when other analyses are too mathematically complex or too difficult to reproduce. Monte Carlo simulation calculates multiple scenarios of a model by repeatedly sampling values from the probability distribution of the uncertain variables and using those values to populate a larger data set. Allocations were applied uniformly for the watershed area specified for each allocation point. For each source and pollutant, it was assumed that the observed data were log-normally distributed. Each pollutant source was evaluated separately using @Risk[3] by performing 5,000 iterations to determine the required percent reduction so that the water quality criteria, as defined in the *Pennsylvania Code. Title 25 Environmental Protection, Department of Environmental Protection, Chapter 93, Water Quality Standards,* will be met instream at least 99 percent of the time. For each iteration, the required percent reduction is:

---

[3] @Risk – Risk Analysis and Simulation Add-in for Microsoft Excel, Palisade Corporation, Newfield, NY, 1990-1997.

PR = maximum {0, (1-Cc/Cd)} where (1)

PR = required percent reduction for the current iteration

Cc = criterion in mg/l

Cd = randomly generated pollutant source concentration in mg/l based on the observed data

Cd = RiskLognorm(Mean, Standard Deviation) where (1a)

Mean = average observed concentration

Standard Deviation = standard deviation of observed data

The overall percent reduction required is the 99th percentile value of the probability distribution generated by the 5,000 iterations, so that the allowable long-term average (LTA) concentration is:

LTA = Mean * (1 – PR99) where (2)

LTA = allowable LTA source concentration in mg/l

Once the allowable concentration and load for each pollutant is determined, mass-balance accounting is performed starting at the top of the watershed and working down in sequence. This mass-balance or load tracking is explained below.

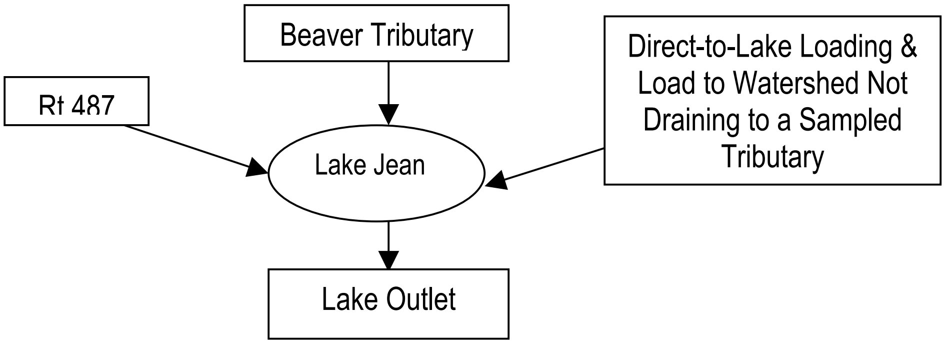
Load tracking through the watershed utilizes the change in measured loads from sample location to sample location, as well as the allowable load that was determined at each point using the @Risk program.

There are two basic rules that are applied in load tracking; rule one is that if the sum of the measured loads that directly affect the downstream sample point is less than the measured load at the downstream sample point it is indicative that there is an increase in load between the points being evaluated, and this amount (the difference between the sum of the upstream and downstream loads) shall be added to the allowable load(s) coming from the upstream points to give a total load that is coming into the downstream point from all sources. The second rule is that if the sum of the measured loads from the upstream points is greater than the measured load at the downstream point this is indicative that there is a loss of instream load between the evaluation points, and the ratio of the decrease shall be applied to the load that is being tracked (allowable load(s)) from the upstream point.

Tracking loads through the watershed gives the best picture of how the pollutants are affecting the watershed based on the information that is available. The analysis is done to insure that water quality standards will be met at all points in the stream. The TMDL must be designed to meet standards at all points in the stream, and in completing the analysis, reductions that must be made to upstream points are considered to be accomplished when evaluating points that are lower in the watershed. Another key point is that the loads are being computed based on average annual flow and should not be taken out of the context for which they are intended, which is to depict how the pollutants affect the watershed and where the sources and sinks are located spatially in the watershed.

In Low pH Atmospheric Deposition TMDLs, acidity is compared to alkalinity as described in Attachment B. Each sample point used in the analysis of pH by this method must have measurements for total alkalinity and total acidity. Net alkalinity is alkalinity minus acidity, both in units of milligrams per liter (mg/**l**) $CaCO_3$. Statistical procedures are applied, using the average value for total alkalinity at that point as the target to specify a reduction in the acid concentration. By maintaining a net alkaline stream, the pH value will be in the range between six and eight. This method negates the need to specifically compute the pH value, which for streams affected by low pH from atmospheric deposition may not a true reflection of acidity. This method assures that Pennsylvania's standard for pH is met when the acid concentration reduction is met.

Information for the TMDL analysis performed using the methodology described above is contained in the "TMDLs by Segment" section of this report.



Sample sites are evaluated prior to entering the lake. The sample data, for the Beaver Dam Tributary and the Ganoga Lake Tributary, are evaluated using @Risk (explained above) to calculate the existing loads, allowable loads, and a percentage reduction for acidity. Because data were not available for the area of the watershed that does not drain to one of the tributaries, the average of all samples collected in the watershed were used to be representative of a concentration for the this area.

Flows for the Lake Jean Watershed were modeled using AVGWLF, and the flows were divided using an area-weighted method to calculate the flow for each of the areas modeled using @Risk. Modeled flows were compared to flows measured at the time of sampling as a calibration.

At the Ganoga Lake Tributary sample site, the measured load and the allowable load are calculated using the methodology described in the Low pH Atmospheric Deposition TMDLs Methodology section and shown in Table 2. The calculations show that there needs to be a 136.6 lbs/day reduction of acidity at from the Ganoga Lake Tributary as shown in Table 3.

Table 2: Calculation of TMDL Loads at Ganoga Lake Tributary

Ganoga Lake Tributary		Measured		Allowable	
Flow (mgd)=	0.6	Concentration	Load	Concentration	Load
		mg/L	lbs/day	mg/L	lbs/day
	Acidity	29.07	140.60	0.84	4.05
	Alkalinity	1.47	7.09		

Table 3: Calculation of Load Reduction Necessary at Ganoga Lake Tributary

Ganoga Lake Tributary	Acidity (lbs/day)	Flow (mgd)
Existing Load @ Rt 487	140.6	0.6
Allowable Load @ Rt 487	4.1	
Load Reduction @ Rt 487	136.6	
% Reduction Required @ Rt 487	97%	

At the Beaver Dam Tributary sample site, the measured load and the allowable load are calculated using the methodology described in the Low pH Atmospheric Deposition TMDLs Methodology section and shown in Table 4. The calculations show that there needs to be a 29.2 lbs/day reduction of acidity at that point as shown in Table 5.

Table 4: Calculation of TMDL Loads at Beaver Dam Tributary

Beaver Dam Tributary		Measured		Allowable	
Flow (mgd)=	0.2	Concentration	Load	Concentration	Load
		mg/L	lbs/day	mg/L	lbs/day
	Acidity	26.80	33.53	3.46	4.33
	Alkalinity	5.60	7.01		

Table 5: Calculation of Load Reduction Necessary at Beaver Dam Tributary

Beaver Dam Tributary	Acidity (lbs/day)	Flow (mgd)
Existing Load @ Beaver Dam Tributary	33.5	0.2
Allowable Load @ Beaver Dam Tributary	4.3	
Load Reduction @ Beaver Dam Tributary	29.2	
% Reduction Required @ Beaver Dam Tributary	87%	

For the area draining directly to the lake and the watershed not drained by a sampled tributary, the modeled load and the allowable load are calculated using the methodology described in the Low pH Atmospheric Deposition TMDLs Methodology section and shown in Table 6. The calculations show that there needs to be a 173.2 lbs/day reduction of acidity at that point as shown in Table 7.

Table 6: Calculation of TMDL Loads For Area of Watershed Not Draining to a Tributary and Directly to the Lake Surface

Direct to Lake		Measured		Allowable	
Flow (mgd)=	0.8	Concentration	Load	Concentration	Load
		mg/L	lbs/day	mg/L	lbs/day
	Acidity	27.93	184.04	1.65	10.87
	Alkalinity	2.84	18.74		

Table 7: Calculation of Load Reduction Necessary for Area of Watershed Not Draining to a Tributary and Directly to the Lake Surface

Direct to Lake	Acidity (lbs/day)	Flow (mgd)
Existing Load @ Direct to Lake	184.0	0.8
Allowable Load @ Direct to Lake	10.9	
Load Reduction @ Direct to Lake	173.2	
% Reduction Required @ Direct to Lake	94%	

At the lake outlet, the measured load and the allowable loads are calculated and shown in Table 8.

Table 8: Calculation of TMDL Loads at the Lake Outlet

Lake Outlet		Measured		Allowable	
Flow (mgd)=	1.53	Concentration	Load	Concentration	Load
		mg/L	lbs/day	mg/L	lbs/day
	Acidity	15.20	193.96	2.68	34.19
	Alkalinity	3.47	44.24		

The calculated load reductions for all the loads that enter the lake must be accounted for in the calculated reductions at the lake outlet as shown in Table 9. A comparison of measured load between the sum of the loads entering the lake and the lake outlet shows that there is a loss in load of 164.2 lbs/day (194-(358.2)). This shows that the load entering the lake is likely being buffered by the addition of limestone to the lake and results in decrease in the cumulative acid load. Because of the buffering that occurs in the lake the calculations determined that there is no additional reduction necessary to meet the TMDL at this sample location. The final cumulative load that is calculated at the lake outlet is 10.4 lbs/day.

Table 9: Calculation of Load Reduction Necessary at the Lake Outlet

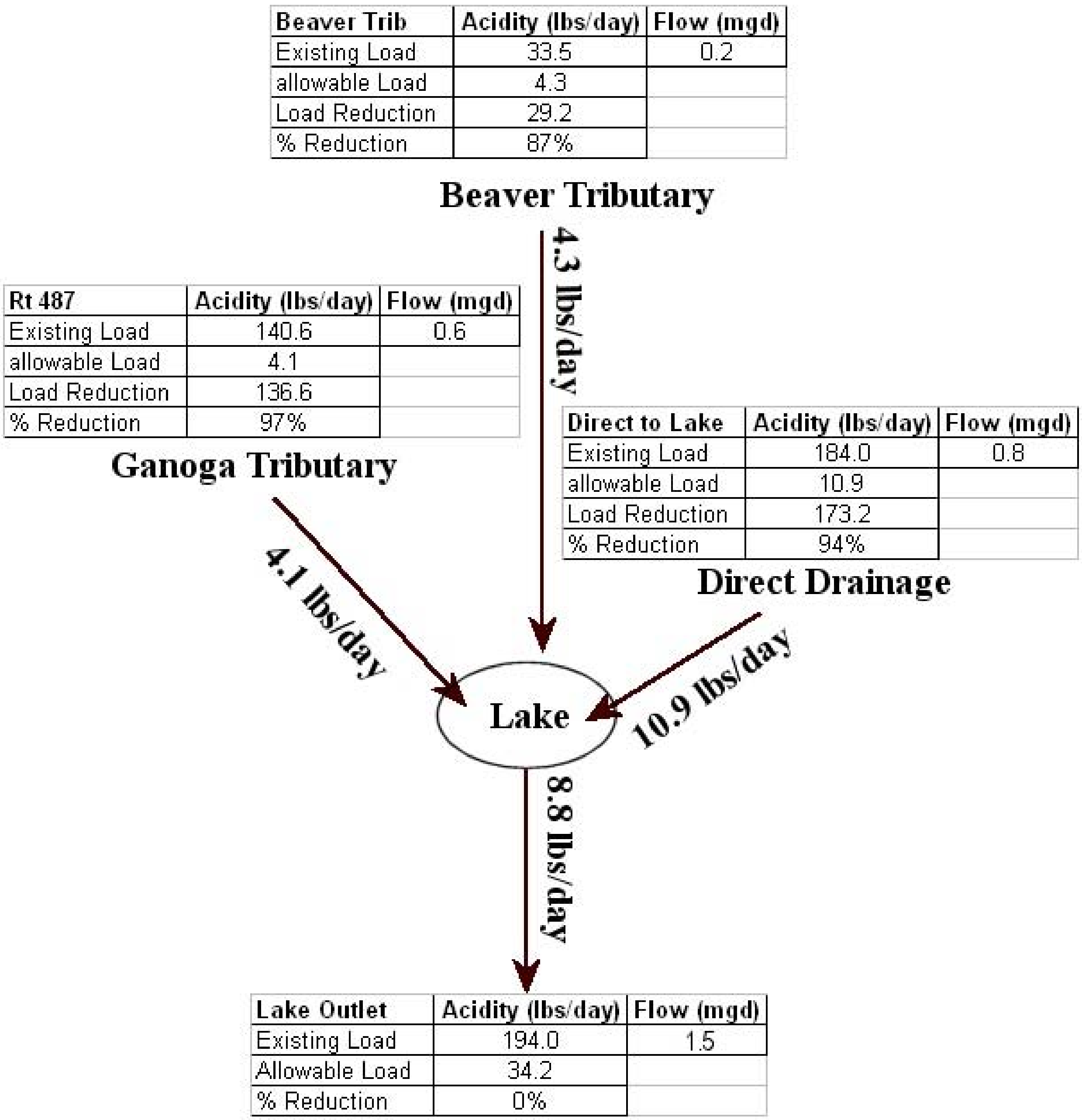
Summary of All Loads That Affect Lake Outlet	Acidity (lbs/day)	Flow (mgd)
Existing Load @ Lake Outlet	194.0	1.5
Difference in Measured Load Between the Loads That Enter the Lake and the Lake Outlet	-164.2	
Percent Loss Due to Buffering in Lake	46%	
Additional Load Tracked from Above Samples	19.2	
Percentage of Upstream Loads That Reach the Outlet	54%	
Total Load Tracked Between Loads That Enter the Lake and Lake Outlet	10.4	
Allowable Load @ Lake Outlet	34.2	
Load Reduction @ Lake Outlet	0.0	
% Reduction Required at Lake Outlet	0%	

Figure 10 is a diagram of TMDL load tracking through the Lake Jean Watershed. The diagram shows the load reductions necessary at each of the sample points as well as the modeled load that is flowing between sample sites.

Summary of Loading Calculations in the Lake Jean Watershed

Figure 10 and Table 10 show the TMDL load tracking through the Lake Jean Watershed. The diagram shows the load reductions necessary at each of the sample points after mass balance calculation as well as the modeled load that is flowing between sample sites. The results shown in the table are also reflective of the mass balancing of loads tracked through the watershed, which takes credit for upstream reductions at downstream allocation points.

Figure 10: Stream Modeling Diagram with Data



Beaver Trib	Acidity (lbs/day)	Flow (mgd)
Existing Load	33.5	0.2
allowable Load	4.3	
Load Reduction	29.2	
% Reduction	87%	

Rt 487	Acidity (lbs/day)	Flow (mgd)
Existing Load	140.6	0.6
allowable Load	4.1	
Load Reduction	136.6	
% Reduction	97%	

Direct to Lake	Acidity (lbs/day)	Flow (mgd)
Existing Load	184.0	0.8
allowable Load	10.9	
Load Reduction	173.2	
% Reduction	94%	

Lake Outlet	Acidity (lbs/day)	Flow (mgd)
Existing Load	194.0	1.5
Allowable Load	34.2	
% Reduction	0%	

Table 10: Summary of Loading in the Lake Jean Watershed

Loading Location	Parameter	Measured Load	WLA	LA	Load Reduction	Reduction
Ganoga Lake Tributary	Acidity (lbs/day)	104.6	0	4.1	136.6	97%
Beaver Dam Tributary	Acidity (lbs/day)	33.5	0	4.3	29.2	87%
Directly to the Lake Surface	Acidity (lbs/day)	184	0	10.9	173.2	94%
Lake Outlet	Acidity (lbs/day)	194	0	34.2	0	0%

Recommendations

Passive treatment systems for acid impaired waters can be divided into two categories; category I, which neutralize acidity by raising pH and alkalinity and category II, which remove metals (in addition to raising pH and alkalinity)(Schmidt, 2002.)

Category I treatment methods include watershed liming, in-stream limestone sand, wetland liming, pumping of alkaline groundwater, limestone diversion wells and anoxic limestone drains. None of these methods are 100% effective and are very dependent on site-specific characteristics.

Watershed liming consists of spreading ground agricultural limestone over part or all of a watershed to neutralize acidity. The limestone added to the watershed reacts with precipitation moving through the soil and makes it less acidic. This method prevents the acidic water from leaching metals into streams and provides for better forest health. Most studies have shown this method to be appropriate for lake mitigation. For streams, the effects do not last as long.

In-stream limestone sand is placed directly in the streambed of high-gradient headwater streams. The sand dissolves in the water column as it spreads downstream during high-flow periods. $CaCO_3$ is added by the limestone sand, which results in higher pH and acid neutralizing capacity and lowered aluminum concentrations. Factors affecting the use of limestone sand include roads, weather, water quality and type of sand.

Wetland liming involves the direct application of finely ground limestone to wetlands, where it mixes with upper soil layer. Where wetlands make up a significant portion of the watershed, this method is most successful.

Pumping of alkaline groundwater takes groundwater previously stored in limestone bedrock and transfers it to the headwaters of small streams. This method has been used in PA on an episodically acid-impacted stream to restore the seasonal trout- stocked stream.

Limestone diversion wells are large diameter shallow wells, which contain limestone. These are situated in the ground, adjacent to a stream. The fluidized bed of limestone slowly dissolves and is added to the stream. These can treat streams with small flows.

Anoxic limestone drains are buried trenches of limestone that receive acid mine drainage and convert net acidic water to net alkaline water under anoxic conditions. The anoxic conditions prevent the limestone from becoming coated with metals, which occurs when oxygen is present.

Category II treatment methods include aerobic wetlands, anaerobic wetlands and successive alkalinity producing systems. These systems have been used mainly for treating acid mine drainage. Some could be used for acid impaired streams, but the cost-benefit ratio is an important factor. Another factor to consider is that each of these systems is designed to be efficient for a different set of water quality parameters.

Aerobic wetlands are used to treat alkaline mine drainage that contains low to moderate metals concentrations. The wetland aerates the water and removes the metals through oxidation and hydrolysis.

Anaerobic wetlands are similar to aerobic wetlands but have a thick permeable organic substrate that is either mixed with limestone or placed over a limestone bed. The substrate allows the water to move through the system without the addition of oxygen.

Successive Alkalinity Producing Systems combine the characteristics of the anoxic limestone drains with those of the anaerobic wetlands. Water flows vertically through the wetland and an anoxic limestone bed into another bed of underlying drainage pipes, which convey the water to a settling pond or aerobic wetland.

Selection of a method, or combination of methods, is dependent on the chemistry of the impaired water and the treatment objectives. Objectives may vary from restoring a fishery to improving the downstream habitat of aquatic insects.

Public Participation

A meeting was held February 12, 2003, at the Columbia County Conservation District office, where the concept of TMDLs was introduced to the Fishing Creek Watershed Association. Another meeting was held March 24, 2003, at the Columbia County Conservation District, where TMDLs and acid deposition were further explained and the draft Lake Jean TMDL was discussed.

The draft TMDL will be published in the PA Bulletin, with a 30 day comment period. The public meeting will be advertised and held during the comment period.

More Information

The official website for Ricketts Glen State Park is http://www.dcnr.state.pa.us/stateparks/parks/rickettsglen.aspx.

References

Commonwealth of Pennsylvania. 2001. Pennsylvania Code. Title 25 Environmental Protection. Department of Environmental Protection. Chapter 93. Water Quality Standards. Harrisburg, PA.

Drohan, J.R., Schneck, M. and Sharpe, W.E. 1999. Acid Rain: The Pennsylvania Connection. Pennsylvania State University College of Agricultural Sciences.

F.X. Browne Associates, Inc. 1995. Diagnostic Feasibility Study of Lake Jean.

Kennedy, John V. and. Neville, Adam M. 1964. Basic Statistical Methods. Thomas Y. Crowell, Inc., New York, New York.

NADP/NTN. National Atmospheric Deposition Program/National Trends Network. http://nadp.sws.uiuc.edu/

Pennsylvania Department of Environmental Protection. 2002. Acid Rain in Pennsylvania.

Pennsylvania Department of Conservation and Natural Resources. 1998. Trail of Geology – Ricketts Glen State Park.

Pennsylvania Department of Conservation and Natural Resources. 2000. A Recreational Guide to Ricketts Glen State Park.

Pennsylvania Fish & Boat Commission. 2003. Fishery Management Report for Lake Jean. www.state.pa.us/PA_Exec/Fish_Boat/images/fisheries/afm/2003/4_06-12jean.htm

Pennsylvania Department of Conservation and Natural Resources. Ricketts Glen State Park Website. www.dcnr.state.pa.us/stateparks/parks/rickettsglen.aspx.

Schmidt, Katherine L. and Sharpe, William E. 2002. Passive Treatment Methods for Acid Water in Pennsylvania. Pennsylvania State University College of Agricultural Sciences.