Seneca Lake Watershed Management Plan

Characterization and Subwatershed Evaluation

May 2012

Written by

Hobart and William Smith Colleges
Finger Lakes Institute at Hobart & William Smith Colleges
Genesee/Finger Lake Regional Planning Council
Southern Tier Central Regional Planning and Development Board

An update of *Setting a Course for Seneca Lake: The State of the Seneca Lake Watershed 1999*

Local Waterfront Revitalization Program Grant

Awarded to

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With Local Match Provided By

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Seneca Lake Area Partners in Five Counties
Schuyler County Watershed Protection Agency
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See Appendix A for full membership list

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The *Seneca Lake Watershed Characterization and Subwatershed Evaluation* provides a description of Seneca Lake's watershed area and the condition of natural resources and the built environment within that area. This characterization is the first component of a comprehensive watershed management plan for the Seneca Lake watershed. Seneca Lake is the largest of the eleven Finger Lakes that make up a complex system of lakes and rivers in central New York State known as Oswego River Basin. The lake's surface area is 66.3 square miles, and the watershed is approximately 457 square miles. The Seneca Lake watershed encompasses 42 municipalities and five counties, including parts of Chemung, Ontario, Schuyler, Seneca, and Yates Counties.

The watershed community has shown strong support for watershed planning; various partnerships and stakeholders have been cooperatively operating since the mid-1990's. The watershed planning process built upon these relationships and previous studies and reports, including *Setting a Course for Seneca Lake, the State of the Seneca Lake Watershed* (1999). The Seneca Lake Watershed Management Plan process establishes a consensus among the watershed municipalities, State agencies, and non-governmental organizations on actions needed to protect the lake's water quality. The plan identifies characteristics of the watershed, sources of impairment, priority projects and necessary actions.

Project History and Previous Report

Seneca Lake Area Partners in Five Counties (SLAP-5) was formed July 3, 1996 as area mayors, supervisors, state legislators, county agency staff and others pledged to work together:

> *To develop a watershed management plan for Seneca Lake that will protect and improve water quality and is supported by the citizens and communities in the watershed. To provide representation of all important sectors in the Seneca Lake Watershed and to keep in contact with people in their areas of expertise to ensure the watershed program reflects and responds to the people represented.*

The Seneca Lake management planning process began in 1996 with the development of a Seneca Lake Watershed Study. Designed to determine the state of the watershed lands that send water to the Lake, the Study identified the following factors to be investigated:

- Description of the Watershed
- Existing Land Uses and Trends
- Limnology and Water Quality
- Sources of Pollution: (listed alphabetically)
    - Agriculture
    - Chemical Bulk Storage
    - Forestry and Forest Practices
    - Landfills, Dumps, Inactive Hazardous Waste Sites
    - Mined Lands
    - Petroleum Bulk Storage
    - Roadbank Erosion
    - Salt Storage and Deicing materials
    - Shoreline Residences
    - SPDES Permits
    - Spills
    - Streambank Erosion

The study was funded by various sources including NYS DEC, NYS Soil and Water Conservation Committee, the NYS Environmental Bond Acts and Environmental Protection Funds, Finger Lakes-Lake Ontario Watershed Protection Alliance, Great Lakes Aquatic Habitat Fund, Open Space Institute, The Tripp Foundation, County SWCDs, Cornell Cooperative Extension Offices, Regional Planning Councils, Hobart and William Smith Colleges and Seneca Lake Pure Waters Association.

Marion Balyszak, SLPWA Executive Director provided leadership and coordination for the work. An Oversight Committee included representatives of funding sources, state and multicounty agency personnel, SLPWA staff and directors, the Farm Bureau, Hobart and William Smith Colleges, representatives of watershed municipalities, and citizen volunteers.

The extensive investigations required to compile necessary information took over two years to complete. Contributors to the work included Oversight Committee members, college interns, Cornell University staff and other interested parties.

Formation of Seneca Lake Area Partners in 5 Counties (SLAP-5) to conduct education and outreach activities, was an outcome of the Study, as well as publication of the two-volume report of findings: *Setting a Course for Seneca Lake: The State of the Seneca Lake Watershed 1999*. Barbara Demjanec served as the first SLAP-5 Coordinator.

The necessity for public education and outreach, research and analysis and response to new challenges to water quality within the watershed area continues. These efforts are currently being carried forward by SLAP-5 and the Seneca Lake Watershed Management Plan Project Advisory Committee through creation of the *Seneca Lake Watershed Management Plan* to address threats to water quality in Seneca Lake.

Project Oversight

The draft *Seneca Lake Watershed Characterization and Subwatershed Evaluation* was prepared for the New York State Department of State with funds provided under Title 11 of the Environmental Protection Fund and prepared by the Project Partners including Genesee/Finger Lakes Regional Planning Council, the Finger Lakes Institute, Hobart and William Smith Colleges, and Southern Tier Central Regional Planning and Development Board through consultant services procured by the City of Geneva and overseen by the Project Advisory Committee. County agencies and organizations and others provided assistance with various project components.

Outreach and Education

In September 2010 an Outreach and Education sub-committee, composed of representatives of the project advisory committee, was created to draft a Community Outreach and Education Plan that would guide public outreach during preparation of the Seneca Lake Watershed Management Plan. The *Outreach and Education Plan* identified key individuals, organizations, and entities to involve in the planning process, and identified the visioning process and the roles and responsibilities in coordinating the entire outreach process, logistics, and the proposed schedule of public meetings and educational opportunities. Components of the Community Outreach and Education Plan included:

- regular Project Advisory Committee meetings;
- creation of a project website;
- identification of watershed stakeholders;
- consultations, discussions, and reporting;
- public information meetings; and
- stakeholder focus groups, meetings, and key contact interviews.

Chapter 2: General Description of the Watershed and Subwatersheds

Watershed and Subwatershed Delineation

A watershed is the geological, geomorphological and geographical area of land that contributes water thought its springs, seeps, ditches, pools, culverts, marshes, swamps, and streams to a body of water. Seneca Lake's watershed is drained by a number of streams and overland runoff draining (known as "direct drainage") to the Lake. The subwatershed delineation appearing in this watershed characterization and Evaluation report follows the delineation used in *Setting a Course for Seneca Lake: The State of the Seneca Lake Watershed, 1999*.

Table 1. Subwatershed characteristics in the Seneca Lake Watershed.

Watershed/ Subwatershed	Area (km^2)	Residential & Urban (%)	Agriculture (%)	Forest & Shrubs (%)	Lakes & Wetlands (%)	Stream Length (km)	Stream Density (L/A)	Max Order (# Tribs)	Relief (m)
Catharine Creek Subwatershed	329.8	4.3	36.7	57.2	1.4	535.0	1.62	4 (1)	502
Reading Drainage	50.5	2.9	49.6	47.1	0.3	119.5	2.36	2 (30)	380
Rock Stream Drainage	20.1	0.0	49.1	50.9	0.0	34.0	1.69	3 (1)	401
Big Stream Drainage	96.3	1.8	53.1	45.0	0.2	135.7	1.41	4 (1)	378
Starkey Drainage	48.6	2.1	63.1	34.2	0.5	74.8	1.54	3 (13)	295
Plum Point Subwatershed	15.5	2.9	53.0	43.7	1.0	24.7	1.59	3 (1)	278
Long Point Drainage	38.3	2.9	72.8	24.3	0.0	77.7	2.03	2 (19)	220
Keuka Lake Outlet Subwatershed	80.1	7.4	76.9	15.6	0.1	119.9	1.50	4 (1)	266
Benton Drainage	21.3	2.6	82.6	14.8	0.0	23.9	1.12	1 (8)	136
Kashong Creek Subwatershed	80.5	0.9	83.3	15.7	0.1	105.4	1.31	4 (1)	236
Reed Point Drainage	22.2	2.3	87.0	10.6	0.0	25.2	1.13	1 (5)	142
Wilson Creek Subwatershed	46.7	1.3	78.6	18.4	1.6	59.0	1.26	3 (1)	203
Geneva Drainage	55.6	30.2	54.3	14.4	1.2	65.6	1.18	2 (5)	132
Sunset Bay Drainage	18.8	6.6	78.0	15.4	0.0	17.0	0.91	2 (11)	60
Reeder Creek Subwatershed	12.7	56.3	17.3	22.9	3.5	24.8	1.95	2 (1)	83
Wilcox Creek Drainage	13.7	5.8	51.0	41.9	1.2	15.7	1.15	1 (5)	77
Kendaia Subwatershed	10.1	61.6	9.9	27.3	1.2	9.1	0.90	1 (1)	96
Sampson State Park Drainage	14.0	17.4	9.1	49.4	24.0	12.3	0.88	1 (3)	76
Indian Creek Subwatershed	22.9	20.5	38.7	39.9	0.9	23.4	1.02	2 (2)	169
Simpson Creek Subwatershed	8.4	26.3	54.1	19.1	0.5	10.8	1.29	2 (1)	188
Sixteen Falls Creek Drainage	31.3	1.3	69.6	28.9	0.3	41.3	1.32	2 (8)	238
Lodi Point Subwatershed	5.0	9.6	62.4	28.0	0.0	9.7	1.94	1 (1)	255
Mill Creek Subwatershed	25.6	0.9	58.6	40.3	0.2	38.3	1.50	3 (1)	382
Lamoreaux Landing Drainage	26.7	1.5	59.4	38.3	0.0	51.3	1.92	2 (19)	276
Valois Drainage	28.4	2.3	51.1	43.5	1.4	51.2	1.80	3 (10)	432
Sawmill/Bullhorn Creek Subwatershed	17.2	1.4	36.2	62.4	0.0	33.3	1.93	3 (2)	433
Satterly Hill Drainage	22.5	0.4	38.5	60.6	0.5	52.1	2.32	2 (23)	303
Glen Eldridge Subwatershed	20.1	1.4	28.8	69.0	1.4	31.3	1.55	2 (1)	428
Hector Falls Creek Subwatershed	33.5	2.1	26.5	70.2	1.2	59.0	1.76	3 (1)	447
Keuka Lake Watershed*	415.6	2.9	39.0	46.8	11.3	*This watershed flows into Keuka Lake Outlet			

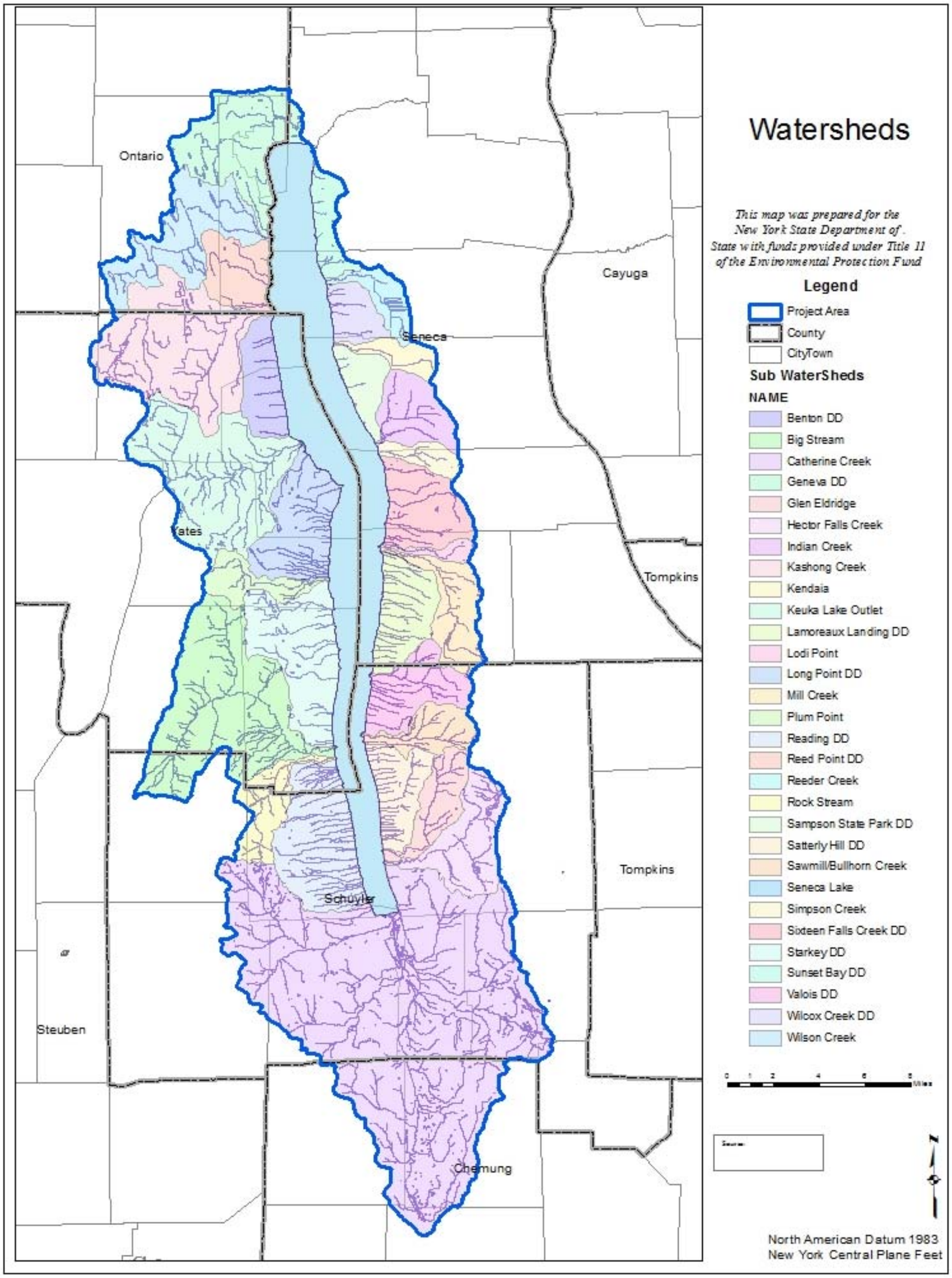
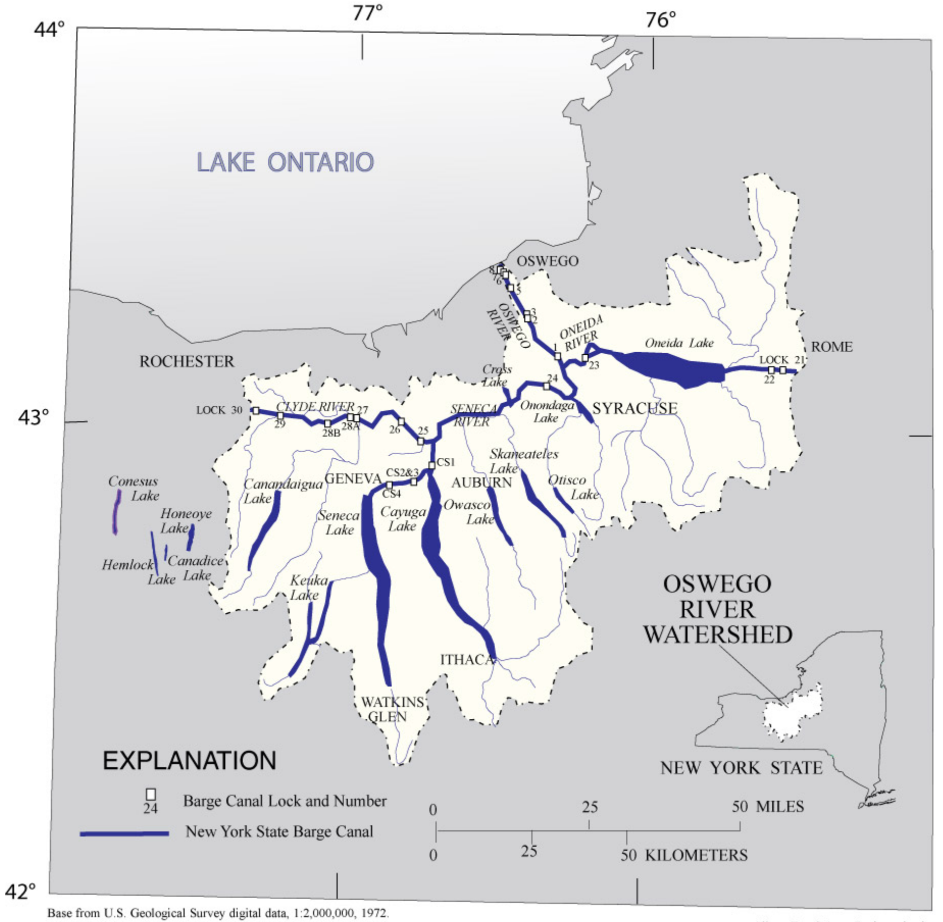


Fig. 1. Subwatersheds and drainages in the Seneca Lake watershed.

As noted in Figure 1, the Seneca Lake watershed has been divided into twenty-nine sub-watersheds and direct drainages (Table 1). The Lake's principal tributaries are Catharine Creek and Keuka Lake Outlet. Catharine Creek is located at the southern end of Seneca Lake and drains more than one quarter of the entire watershed. Keuka Lake Outlet enters Seneca Lake in the middle of the western shore. Keuka Lake Outlet drains the Keuka Lake watershed, a different watershed, and thus is subject to a separate watershed plan, but mentioned here as it still influences the hydrology and water quality of Seneca Lake. Table 1 also includes the areas, land use percentages, stream lengths, stream densities, max stream order (and number of tribs in drainages), and topographic relief for each delineated subwatershed and direct drainages (boundaries initially defined in the Setting a Course for Seneca Lake: The State of the Seneca Lake Watershed, 1999).

Geographic Setting

Seneca Lake, located in the Finger Lakes region of central New York, is the largest of the eleven Finger Lakes. These Finger Lakes and the systems of rivers and streams that feed into the Finger Lakes are part of the Oswego River Basin (Fig. 2). Water flows from uplands, into streams and rivers to the Finger Lakes, then out to low-gradient rivers, which are part of the New York State Barge Canal and then ultimately to Lake Ontario.



Base from U.S. Geological Survey digital data, 1:2,000,000, 1972.
Standard parallels 29 30' and 45 30', central meridian -96 00'.

Albers Equal-Area Conic projection

Fig. 2. The Oswego River Basin – Finger Lakes Watershed.

Affecting this flow of water are three physiographic features:

- Appalachian plateau, located to the south of the Finger Lakes
- Tug Hill Plateau, located directly northeast of the Finger Lakes
- Lake Ontario Plain located between the northern end of the Finger Lakes and Lake Ontario

A total of 5,100 square miles makes up the Oswego River Basin. Critical to the flow of water is the Clyde/Seneca River and Oneida Lake Troughs. These areas of lowlands run west-to-east and collect the water from the lakes and deliver it to Lake Ontario. This area was first carved out by glaciers during the last Ice Age and then filed with clay, silt, sand and gravel from receding glaciers. In the 1800's the New York State Barge Canal was constructed within these troughs due to their low grade. All of the eastern Finger Lakes drain into this trough and unfortunately water in the Barge Canal is very slow moving due to the low gradient, occasionally causing flooding issues at the confluence of the Seneca, Oneida and Oswego Rivers (Fig.2, 3, and 4).

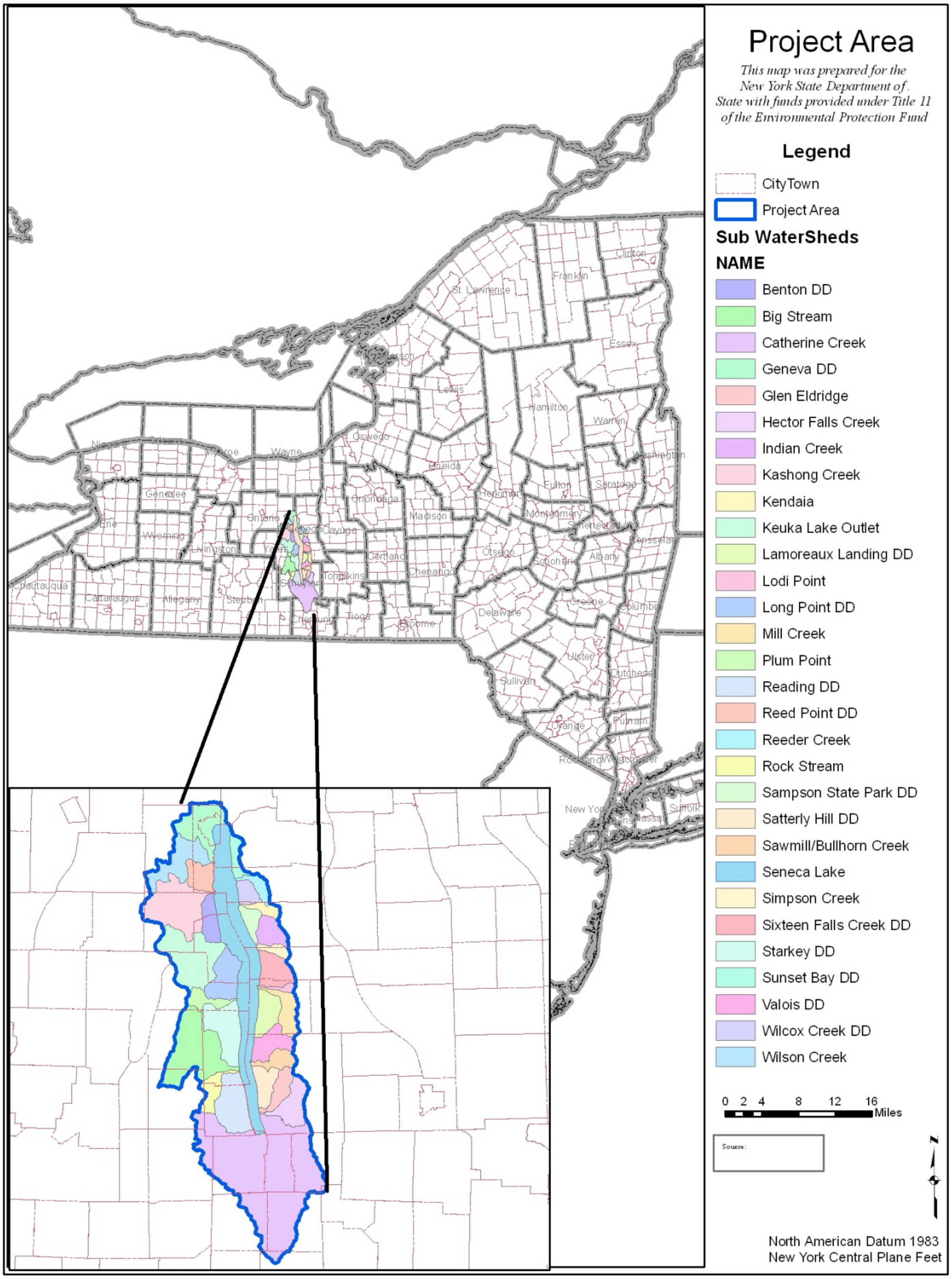


Fig. 3. Seneca Lake watersehd project area in central New York State.

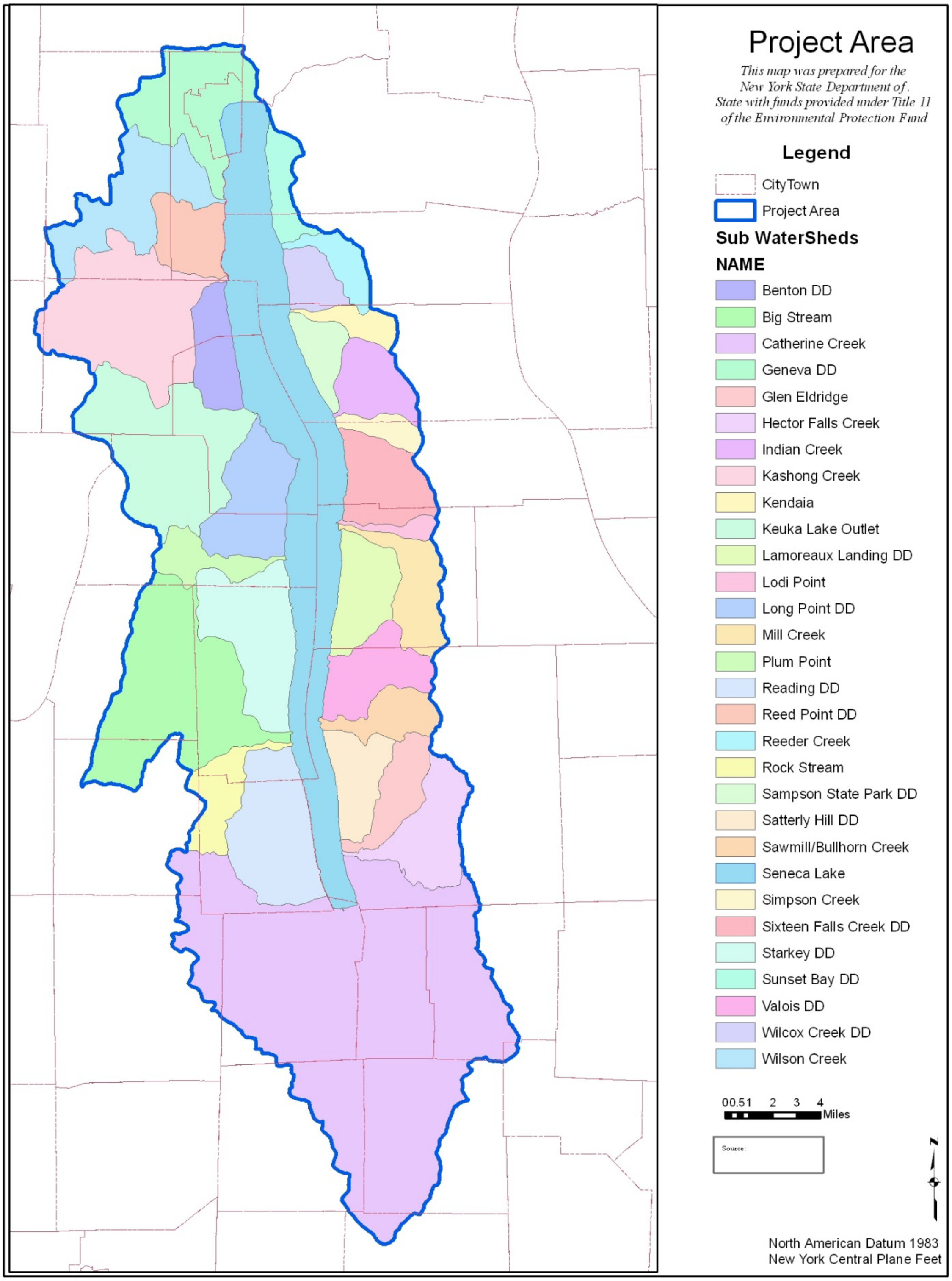


Fig. 4. Seneca Lake watershed project area.

The elevations of each of the lakes, rivers and the locks along the Barge Canal are show in Figure 5. This diagram illustrates the topographic relationships of the lakes to one another and to their receiving streams and summarizes the cumulative percentages of watershed that drains into the Oswego River basin. The physiography of the basin, combined with human settlement and related activities, has resulted in flooding and navigational problems that prompted the establishment of programs which attempt to control lake levels and alleviate flooding.

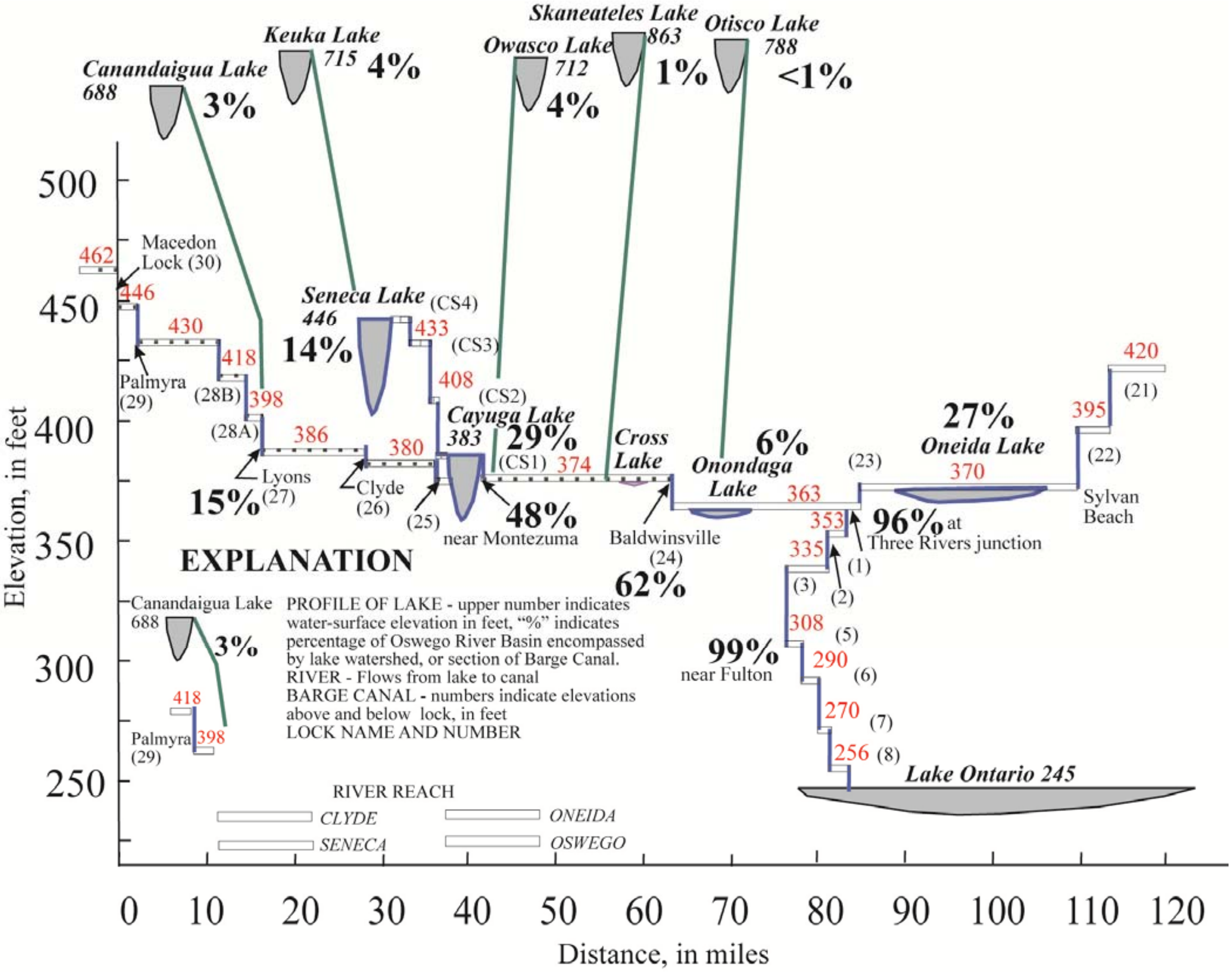


Fig.5. Elevations and flood potential in the Oswego River watershed.

According to Seneca Lakes Pure Waters Association, in 2008 and 2009 Seneca Lake water levels were very low. This low water lever caused health and safety issues, as well as endangered the wildlife and fish of the lake. Low water levels directly impact residents that rely on the lake for drinking water, fish and wildlife, loss of revenue from marinas, damage to resident's boats and additional erosion and down-cutting of existing stream channels.

Municipalities

The Seneca Lake watershed contains forty-one municipalities, located within five counties. Chemung, Ontario, Schuyler, Seneca and Yates County surround Seneca Lake (Fig. 6).

- Chemung County
    - Towns of: Big Flats, Catlin, Horseheads, Veteran
    - Villages of: Horseheads, Millport
- Ontario County
    - City of: Geneva
    - Towns of: Geneva, Gorham, Phelps, Seneca
- Schuyler County
    - Towns of: Catharine, Cayuta, Dix, Hector, Montour, Orange, Reading, Tyrone
    - Villages of: Burdett, Montour Falls, Odessa, Watkins Glen
- Seneca County
    - Towns of: Covert, Fayette, Lodi, Ovid, Romulus, Seneca Falls, Varick, Waterloo
    - Villages of: Lodi Point, Ovid
- Yates County
    - Towns of: Barrington, Benton, Milo, Potter, Torrey, Starkey,
    - Villages of: Dresden, Dundee, Penn Yan

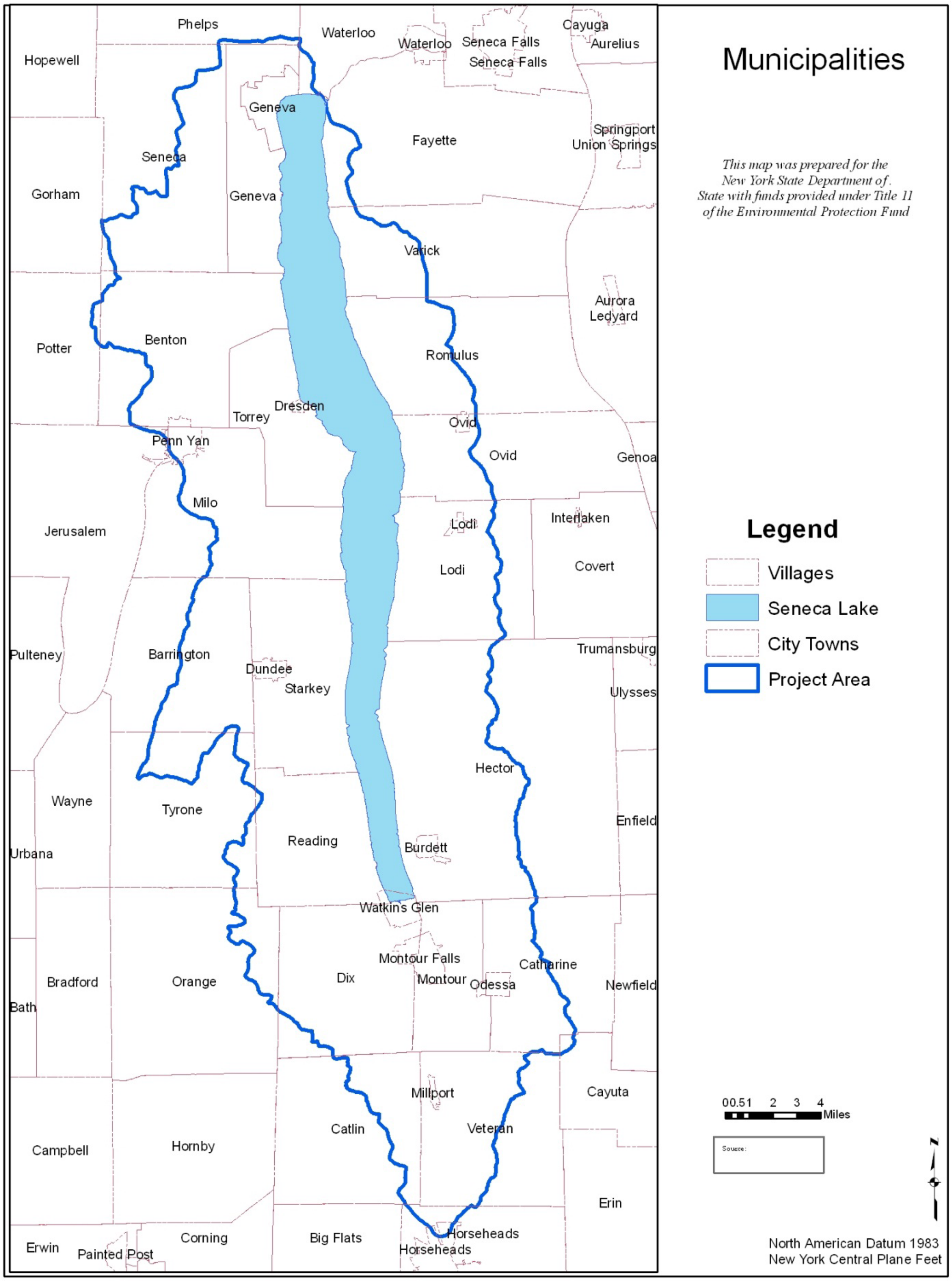


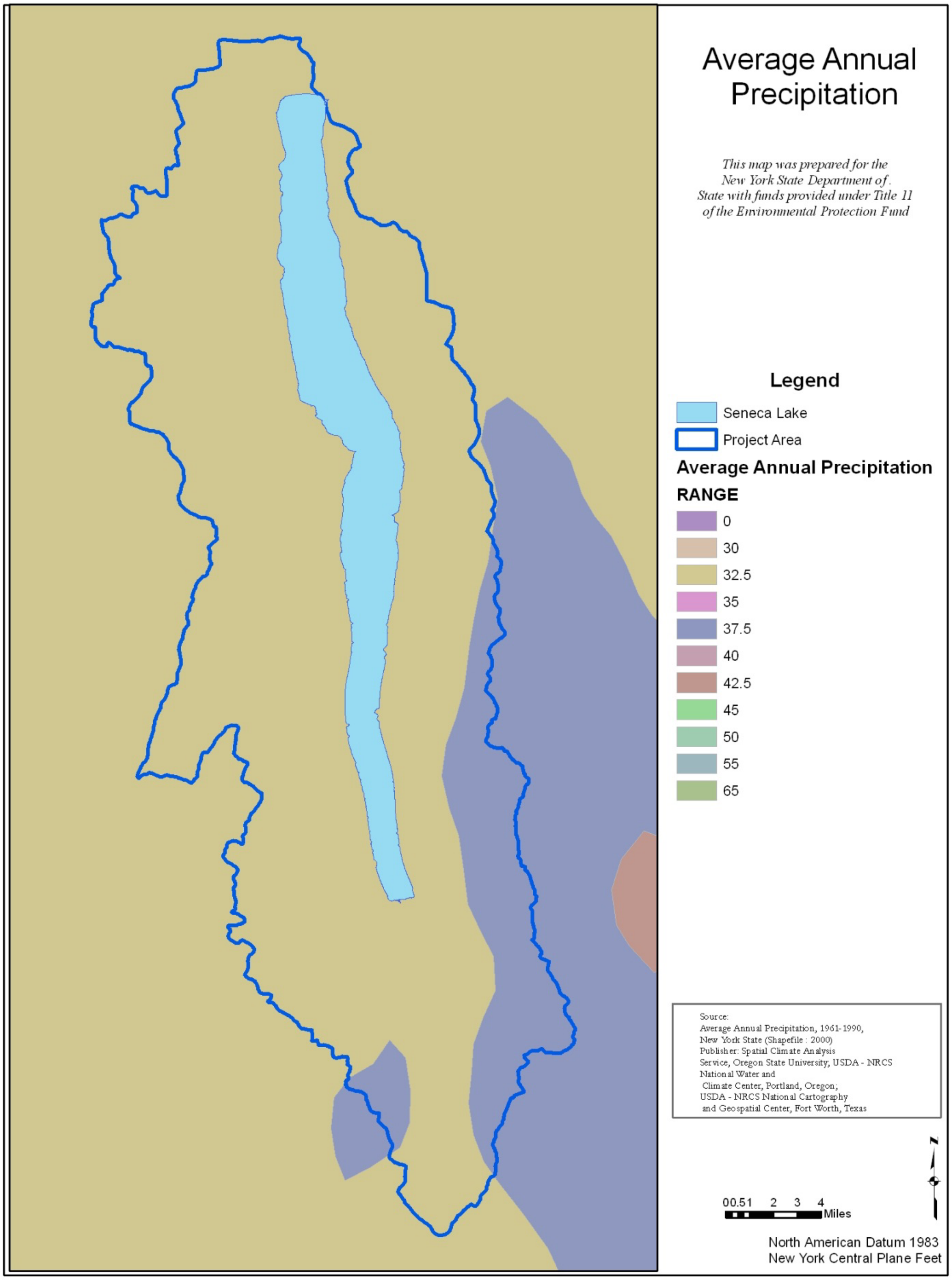
Fig. 6. Municipalities in the Seneca Lake watershed.

Since the late 1990's these municipalities have banded together, acknowledging they are inevitably linked by being located within the Seneca Lake watershed. Currently two multi-jurisdictional organizations exist. SLAP-5 (Seneca Lake Area Partners – 5 Counties), which began with the *Setting a Course for the Seneca Lake Watershed* and consist of all five county Soil and Water Conservation Districts and municipal representatives. Another organization located within the watershed is, Seneca Lake Pure Waters Association, which is made up of lake association members, water quality advocates and municipal representatives. These and other organizations (Appendix A) are vital in educating the public about water quality issues. They work to advocate for better policy within their respective counties, as well as New York State and encourage research throughout the region.

Climate

The Finger Lakes climatic region is characterized by cold, snowy winters and warm, dry summers although major flooding events may occur at any time, usually the product of tropical storm remnants entering the region from the south or rapid snow pack melt in the spring. At the extreme, flooding has been known to raise the Lake level to a maximum of 450.2 feet. As a whole the central Finger Lakes is one of New York State's driest regions; however, precipitation is adequate to support most horticulture, especially that of deep rooted plants such as grapes.

Average precipitation for the Seneca Lake watershed is 32.5 inches per year throughout most of the watershed. (Fig. 7) The southeastern corner of the watershed receives slightly higher amounts of precipitation with an average of 37.5 inches per year. The smallest amount of precipitation falls in the December to March period (Fig. 8, Table 2). Winter snowmelt commonly occurs in late March to early April. Air temperature averages are consistent throughout the watershed (Fig. 8, Table 2). The average July temperature is 70.4 degrees Fahrenheit and a 22.4 degree average in January. From the mid-nineteenth century to early twentieth century local records indicate that Seneca Lake froze over during February-March on four different years. Since 1912, ice has apparently covered only localized, near shore areas.



Source:
Average Annual Precipitation, 1961-1990,
New York State (Shapefile : 2000)
Publisher: Spatial Climate Analysis
Service, Oregon State University; USDA - NRCS
National Water and
Climate Center, Portland, Oregon;
USDA - NRCS National Cartography
and Geospatial Center, Fort Worth, Texas

Fig. 7. Average annual precipitation in the Seneca Lake watershed.

Table 2. Mean monthly maximum and minimum tempertuares and mean monthly precipitation for Geneva, NY, 1970 through 2009. Data from Cornell's Agricultural Research Station, Geneva, NY.

Month	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Mean Max Temp (F)	30.2	32.3	41.0	54.4	66.7	75.5	79.9	78.4	70.9	58.6	47.1	35.8
Mean Min Temp (F)	15.4	16.6	24.6	24.6	46.6	56.1	56.1	59.2	51.8	41.0	32.4	22.1
Precipitation (in)	1.6	1.6	2.3	2.8	3.1	3.7	3.2	3.2	3.6	3.2	2.8	2.4

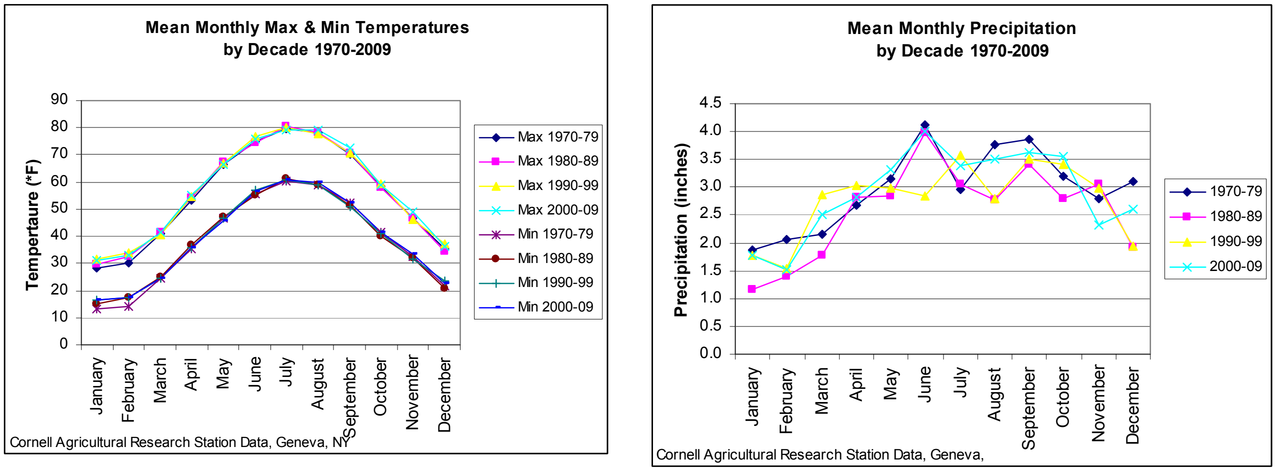


Fig.8. Maximum and minimum mean temperatures (left) by decade and mean monthly precipitation (right) by decade, 1970 through 2009 for Geneva, NY. Data from Cornell's Agricultural Research Station, Geneva, NY.

Geology

During the Paleozoic time period, 220-600 million years ago, the region now containing Seneca Lake was part of a vast inland sea (Fig. 9). Evaporation of water and precipitation of salts, along with deposition of muds and sands produced sediments that were compressed into sedimentary rocks with a depth of some 8,000 feet. The remnants of this rock, after repeated periods of uplifting and down cutting by erosion are present as today's sandstones and shales of the Hamilton, Genesee, Sonyea, Java, and West Falls formations characterizing the southern part of the basin and the Tully and Onondaga limestones further north.

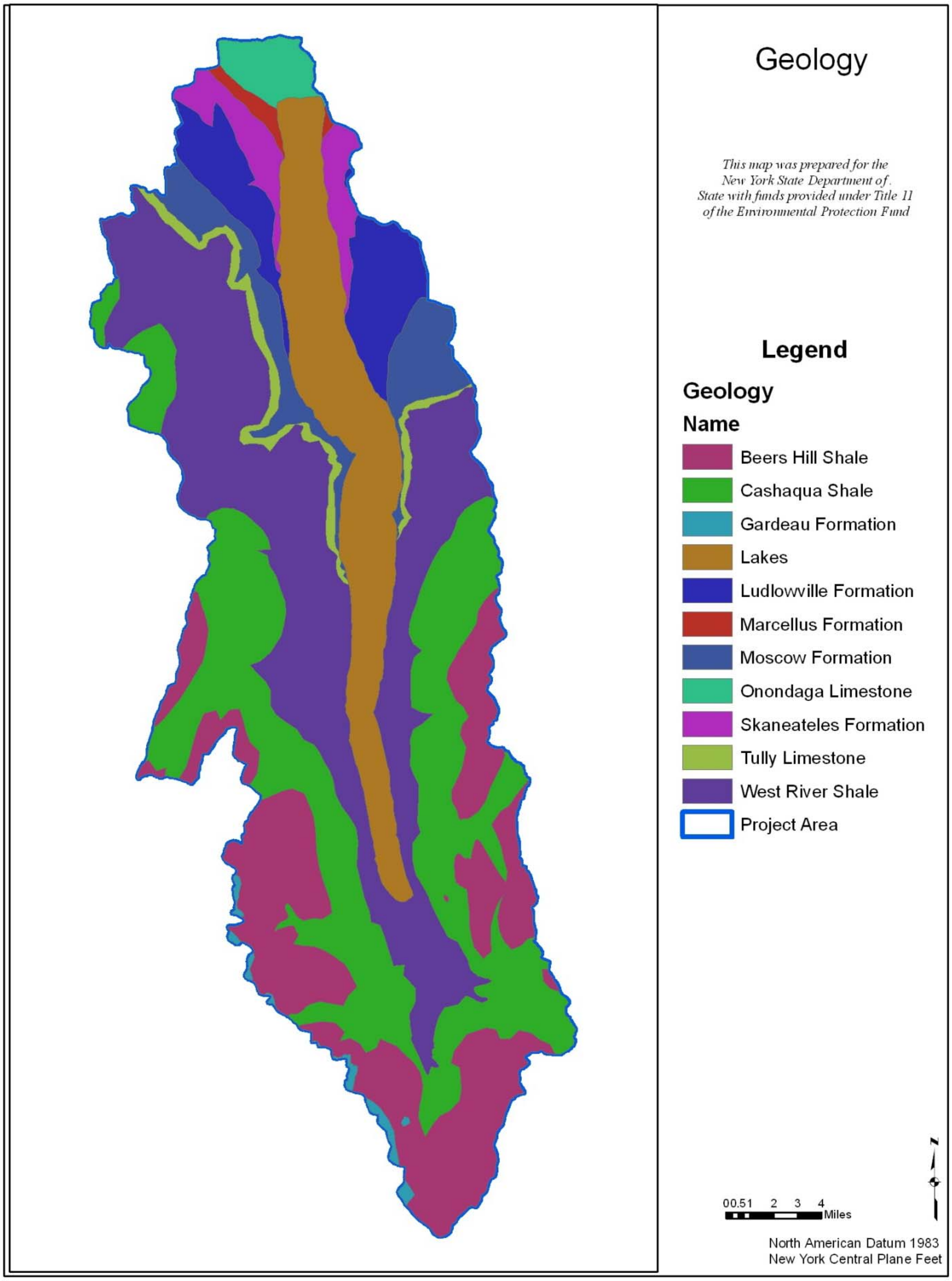


Fig. 9. Generalized geology in the Seneca Lake watershed.

The present day lake basins, gorges, and other geomorphological features resulted from repeated glacial activity in the region. The last major ice age began about 2 million years ago. Twenty massive glaciers invaded the Finger Lakes region. These advances occurred in 100,000 year cycles beginning with a slow glacial advance over 80,000 years, a rapid melt back over 10,000 years, followed by a 10,000 year warm interglacial period as warm or warmer than today's climate. A million tourists a year visit the famous gorges around the south end of Seneca Lake. Each gorge is a tangled skein of buried gorges, degraded relic falls, secondary side channels and partially excavated old gorges. The rich gorge diversity is due to multiple glacial advances covering the gorges, and then glacial retreats to excavate debris from old channels or cut new gorges.

Soils

As the most recent glacial ice sheet retreated some 9,000-10,000 years ago, glacial debris, mostly tills were left behind. Recessional moraines, ground moraines and other glacial deposits mantled the region (moraines are the sand and gravel left by the glacier). The largest sand and gravel deposits are located at the southern end of the watershed. Proglacial lakes, lakes dammed by the ice sheet to the north with drainage to the south, left glacial clay deposits next to and within 300 to 400 feet of the modern lake level. In the subsequent 10,000 years, soils developed on this glacial deposits and have, in many places, been overlaid by and mixed with other material deposited by wind and water, and by humus derived from forest that covered the area. One early (1778) traveler to this region describes the soil's upper layer as composed of 8 to 10 inches of black organic loam. This was undoubtedly a great boon to the earliest agriculturists but one soon lost due to erosion and oxidation.

The soils in the watershed are complex (Fig. 10a, 10b). The northern portion of Seneca Lake's basin contains moderately coarse-textured soil with calcareous substrata and better suited for agriculture. These soils are typically classified as Howard, Langford, Valosia and Honeoye-Lima soils. Southward these give way to complex assemblages of more acidic, less drained soils, such as Volusia, and Mardin-Lordstown. The combination of steeper topography and soils less well suited to many types of agriculture in the south compared with better buffered, better drained soils on less steep topography northwards is strongly reflected in land use patterns and in the price of farmland.

Volusia Channery silty loam at a 0 to 3 percent slope and at 8 to 15 percent slope are the most commonly occurring soils within the watershed, occurring approximately 1,500 times each. These soils are considered to have an only slight risk of erosion. Within the watershed, only a very few areas are underlain by highly erodible soils. Further, the highly erodible soils do not occur on the steeper slopes within the watershed.

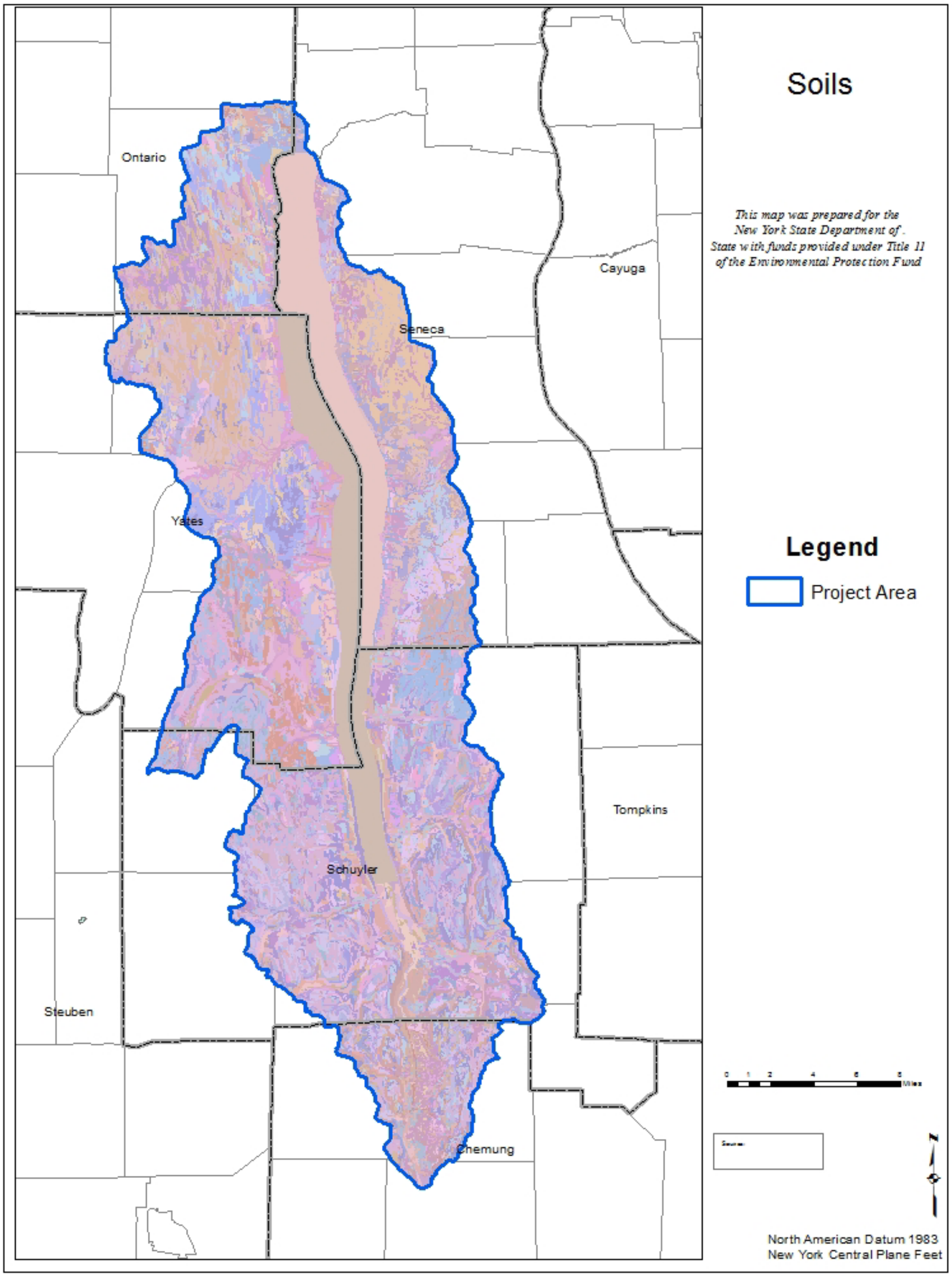


Fig. 10a. Soils in the Seneca Lake watershed. See Figure 10b for map legend.

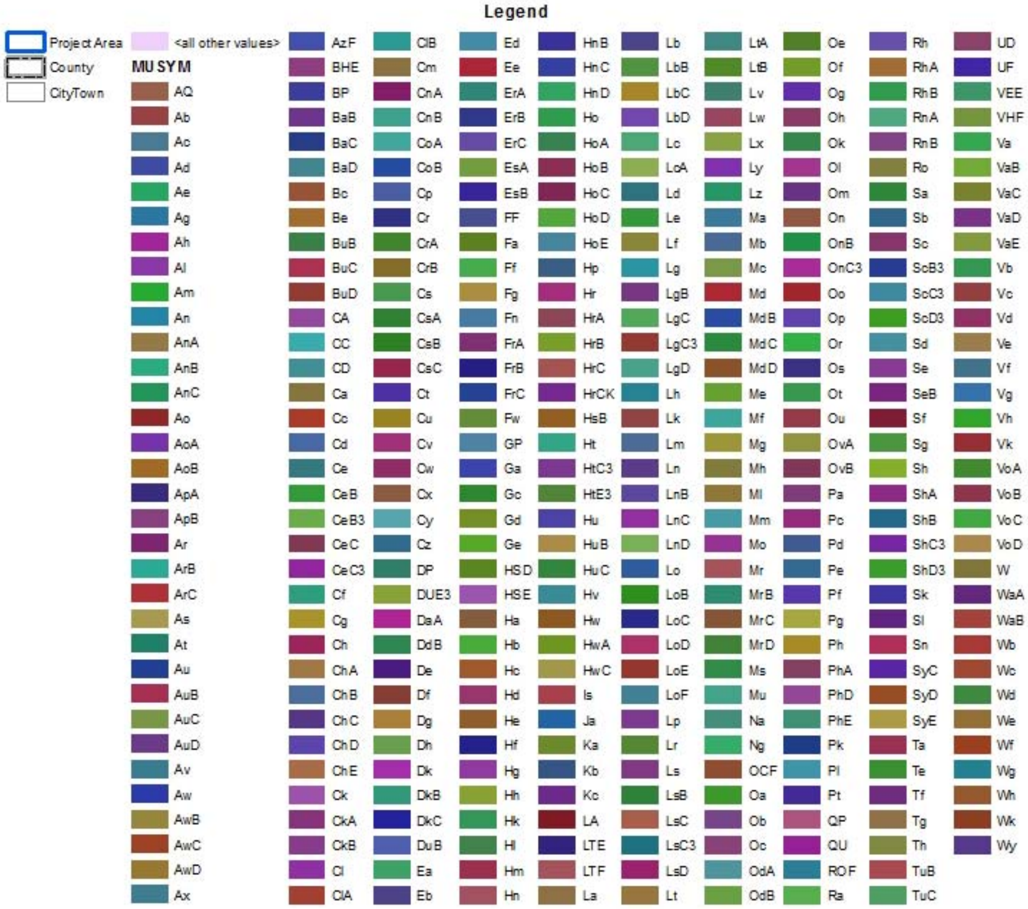


Fig. 10b. Map legend for soils in the Seneca Lake watershed.

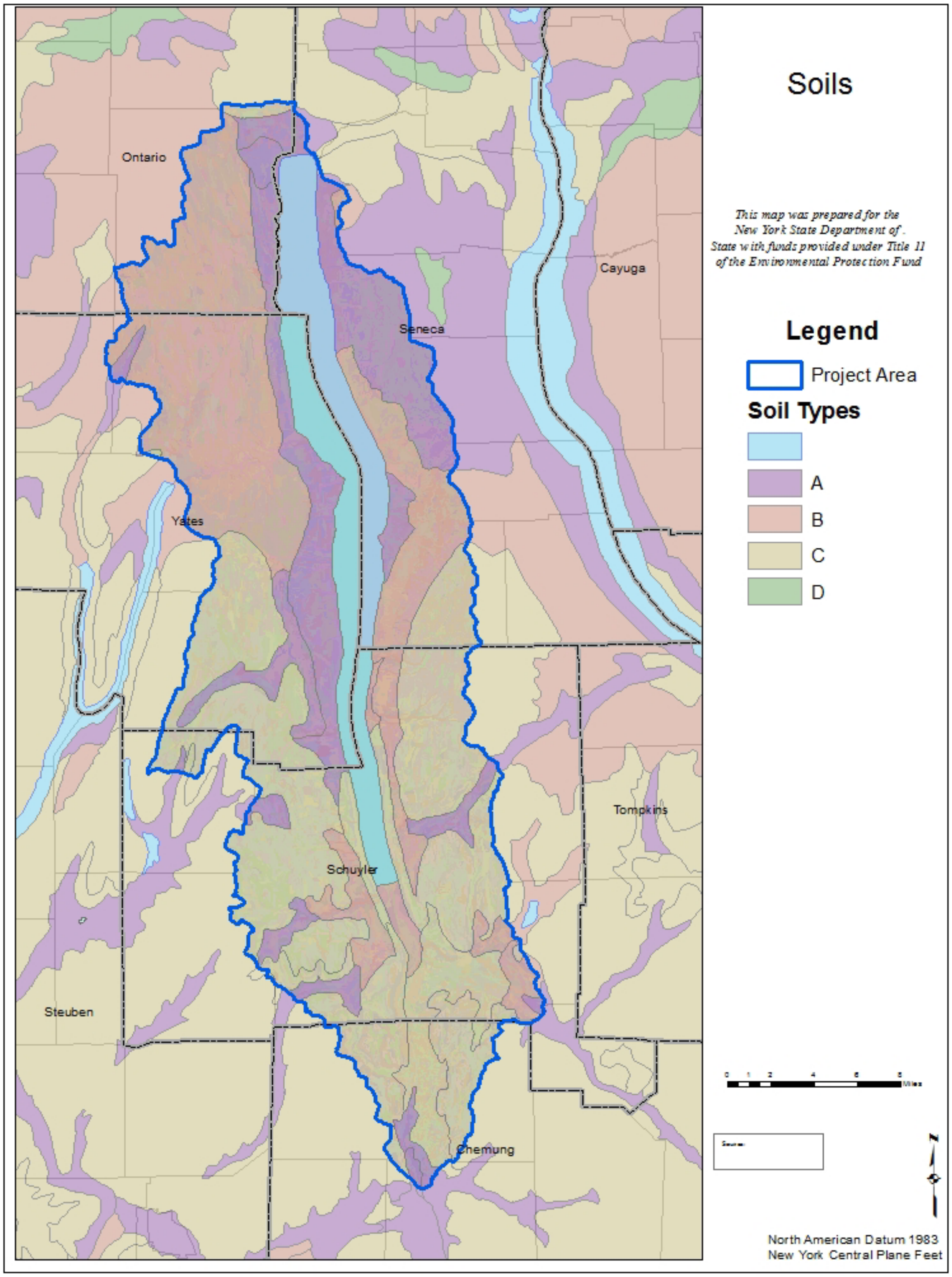


Fig. 11. A generalized soil map based on the soil's infiltration capacity (see text for clarification).

When evaluating the hydrologic soil groups (Fig. 11) four soil groups are revealed: A, B, C, and D. Jim Turenne's definition of each soil group is below.

> ***A**. Soils with low runoff potential. Soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well drained to excessively well-drained sands or gravels.*
>
> ***B**. Soils having moderate infiltration rates even when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well drained to well drained soils with moderately fine to moderately coarse textures.*
>
> ***C**. Soils having slow infiltration rates even when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine textures.*
>
> ***D**. Soils with high runoff potential. Soils having very slow infiltration rates even when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material.*

On the northern end of the lake, type A soils predominate directly adjacent to Seneca Lake and B soils within the northwestern portion of the watershed. "A" soils infiltration is high and B soils is moderate. The southern end of the lake has much slower infiltration with primarily B and C soils. This indicates that runoff issues may be more severe on the southern end of the lake due to such slow infiltration rates. D soils are located just outside the watershed in Seneca County.

Soil conservation is key to preventing contamination of lake water by soil, fertilizers and pesticide residues. Using soil conservation practices, we can maintain clean water in three ways, diversion of water around the farmland, filtering of water though the soil and groundcovers to provide a protective barrier to break the force of raindrops. While erosion continues to be a concern, efforts of soil conservation and controlling development on steeper slopes should prove to be fruitful practices.

Hydrography & Water Users

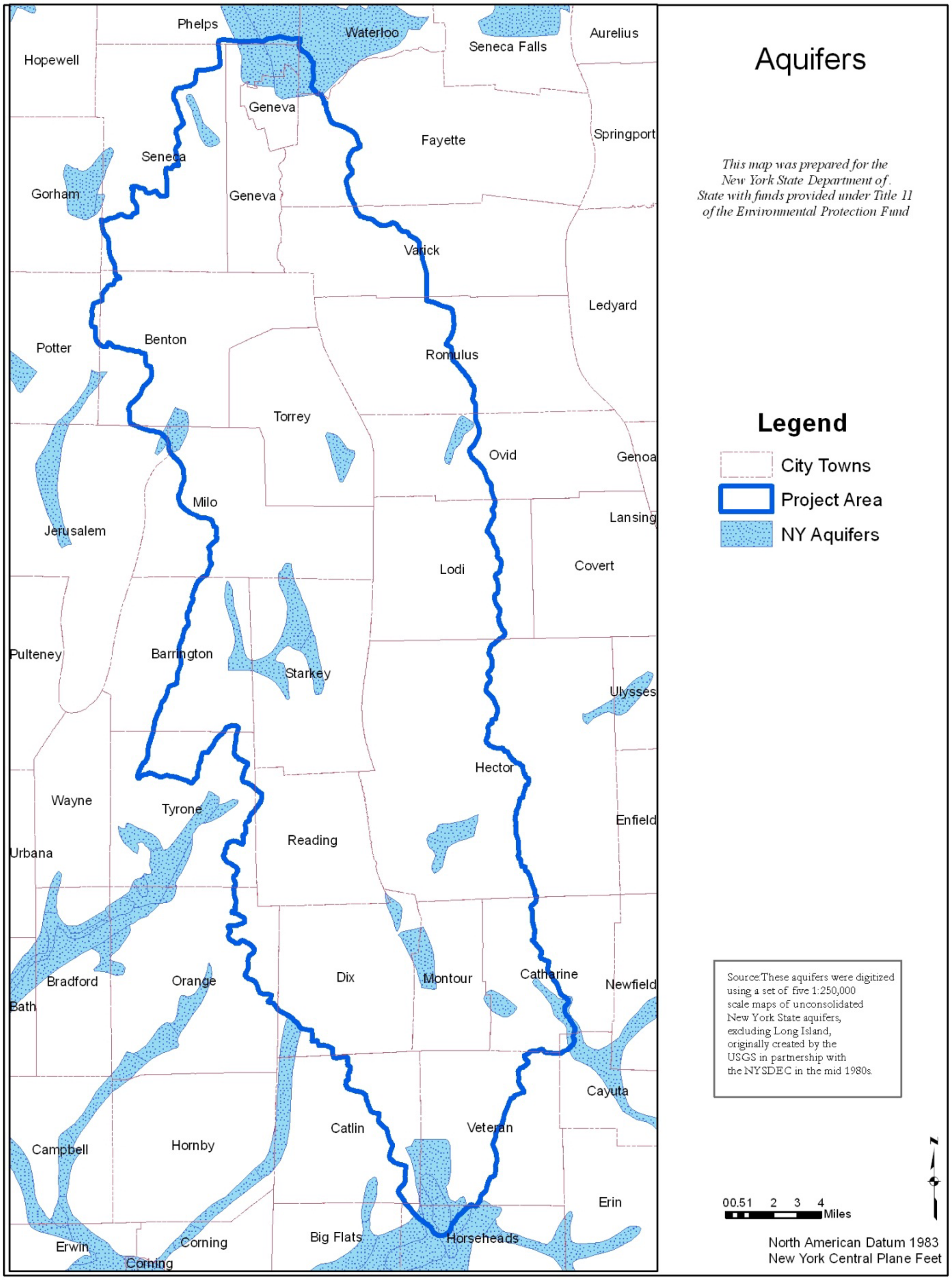
Surface water is the water that collects on the ground, in a stream, river lake or wetland. This water naturally increases with precipitation and is lost through evaporation, evapotranspiration, infiltration and runoff. Seneca Lake watershed is home to many different water body types. Seneca Lake itself is the largest of these water bodies and the largest and deepest of the glacial Finger Lakes in New York State. Seneca Lake is 38 miles long and has a volume of approximately 4.2 trillion gallons. The Lake's maximum depth is 618 feet. All of the surface water located in the Seneca Lake watershed naturally drains into Seneca Lake.

Seneca Lake watershed encompasses a total of 42 municipalities. Of these municipalities, 11 use surface water for their municipal public water systems. Keeping the surface water and groundwater clean is vital to the health and safety of Seneca Lake's watershed residents (Fig. 4).

Groundwater is the water located beneath the ground within the soil, or fractures of rock formations. Groundwater springs are also hypothesized to seep directly into the lake along the lake floor. This water eventually comes to surface via springs and can even form wetlands. Groundwater is stored in and moves through moderately to highly permeable rocks called aquifers. These aquifers can be sand and/or gravel, glacial tills, or layers of sandstone or cavernous limestone bedrock. New York State has mapped and identified aquifers throughout the Seneca Lake Watershed. The largest aquifers are located at the southern and northern tip of Seneca Lake, with a few smaller aquifers located in the middle of Yates and Seneca County (Fig. 12). These sources of groundwater are important as one fourth of New Yorkers rely on groundwater for their drinking water. Within the Seneca Lake watershed, 11 municipalities rely on groundwater for their public water systems ("My Water's Fluoride", 2012). If public water is not available, watershed residents utilize private surface, shallow lakeshore wells or deeper groundwater sources (Table 3).

Table 3: Public water sources for water users in the Seneca Lake watershed.

County	Public Water Supply
Chemung County	
Town of Big Flats	Ground
Town of Catlin	No Public Water
Town of Horseheads	No Public Water
Town of Veteran	No Public Water
Village of Horseheads	Ground
Village of Millport	No Public Water
Ontario County	
City of Geneva	Surface
Town of Geneva -9Districts	Surface, Ground
Town of Gorham	No Public Water
Town of Phelps	Ground
Town of Seneca	Ground
Schuyler County	
Town of Catharine	No Public Water
Town of Cayuta	No Public Water
Town of Dix	Surface
Town of Hector	Ground
Town of Montour	No Public Water
Town of Orange	No Public Water
Town of Reading	Surface
Town of Tyrone	No Public Water
Village of Burdett	Ground
Village of Montour Falls	No Public Water
Village of Odessa	Ground
Village of Watkins Glen	Surface
Seneca County	
Town of Covert	No Public Water
Town of Fayette	No Public Water
Town of Lodi	No Public Water
Town of Romulus	No Public Water
Town of Seneca Falls	Surface
Town of Varick	No Public Water
Town of Waterloo	Surface
Village of Lodi Point	No Public Water
Village of Ovid	Surface
Yates County	
Town of Barrington	No Public Water
Town of Benton- 3 Districts	Surface, Ground
Town of Milo	Surface
Town of Potter	No Public Water
Town of Torrey	No Public Water
Town of Starkey	No Public Water
Village of Dresden	Ground
Village of Dundee	Ground
Village of Penn Yan	Surface



This map was prepared for the New York State Department of State with funds provided under Title 11 of the Environmental Protection Fund

Source:These aquifers were digitized using a set of five 1:250,000 scale maps of unconsolidated New York State aquifers, excluding Long Island, originally created by the USGS in partnership with the NYSDEC in the mid 1980s.

Fig. 12. Aquifers in the Seneca Lake watershed.

Seneca Lake is underlain by salt-rich and carbonate bedrock. This bedrock can increase the salinity and hardness of the groundwater. In Watkins Glen, located at the southern tip of Seneca Lake, the salt beds are mined and processed into salt.

Floodplains

The level of Seneca Lake is dependent on the amount of rainfall received over any given period of time. If soils are fully saturated and rainfall is falling directly into the lake, for every inch of rainfall the lake level increases by one foot within 1 to 2 days. Seneca Lake then can take a week or more to fully drain into the Barge Canal because the lake level can be lowered by only a tenth of a foot per day. This is one of the many challenges of lake level control for the Finger Lakes. Seneca Lake and basin suffer from rapid flowing inputs and very slow draining outflow. Often lake level issues are looked at as only local issues. Yet one municipality's "fix" to a flooding issue in a stream may cause much more harm in the way of sediment loading into the lake from the downstream erosion of stream banks, culverts and ditches.

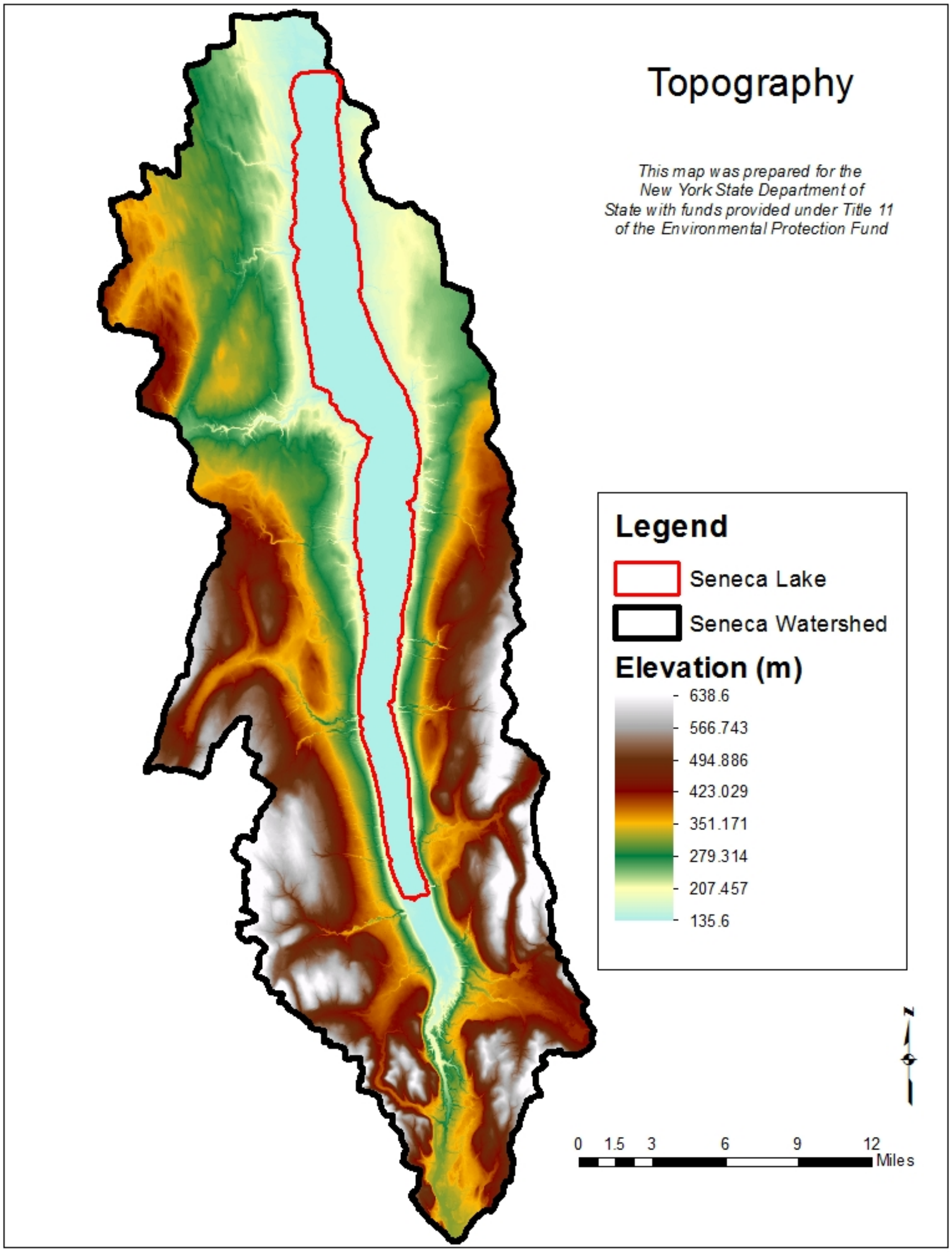
Issues of flooding are even further exacerbated by the limitations of weather forecasting. Accuracy of forecasts diminishes significantly past two days, and two days is not enough time to prepare the Oswego River Basin for a heavy rain.

Water Use and Lake Level Control

Besides utilizing Seneca Lake is as a municipal and private drinking water source with permitted withdrawals of approximately 9 million gallons per day from four different sites (Callinan, 2001), industries utilize lake water as well. The primary user was the AES Greenidge coal-fired power plant in Dresden, however it recently closed this past year (2011). Lake level is controlled by dams along the outlet. New York State Thruway Authority attempts to balance the control of lake levels within their winter and summer ranges with minimum flows along the outlet to operate the locks, move industrial and municipal effluents, and allow power generation at two hydroelectric power stations along the canal, and prevent flooding of the flat-lying Oswego River system farther downstream.

Topography and Steep Slopes

Seneca Lake has relatively flat topography at the north end of the watershed changing to rolling hills and then steep sided valleys, characteristically extending 900-1,000 feet below hill crests, to the south. The most conspicuous landform features are the Lake itself with an elevation of about 445 feet above sea level, and the carved rock channel gorges of east-west tributaries and their associated series of waterfalls. The lake has a smooth, regular shoreline. Irregularities that do occur are small and result from flat deltas built by tributary streams and wave action. From the surface edge of the lake to the bottom edge of the lake is a very steep slope, averaging nine percent (Fig. 13).



This map was prepared for the New York State Department of State with funds provided under Title 11 of the Environmental Protection Fund

Fig. 13. Topography in the Seneca Lake watershed.

Most of the steep slopes within the Seneca Lake watershed are located in Yates County to the west of Seneca Lake, and along the southern half of the lakeshore. As Figure 14 indicates, slopes above 15% are located within Yates county and Seneca county and farther south slopes are above 30% grade on the Lake's shoreline. Reducing development on slopes above 15% is vital to help control erosion. It is the stream bank erosion within the watershed that is the core sources of sediment loading into Seneca Lake. Protecting these stream banks is vital to controlling sediment loading and maintaining the rock structures and vegetation will help to prevent erosion.

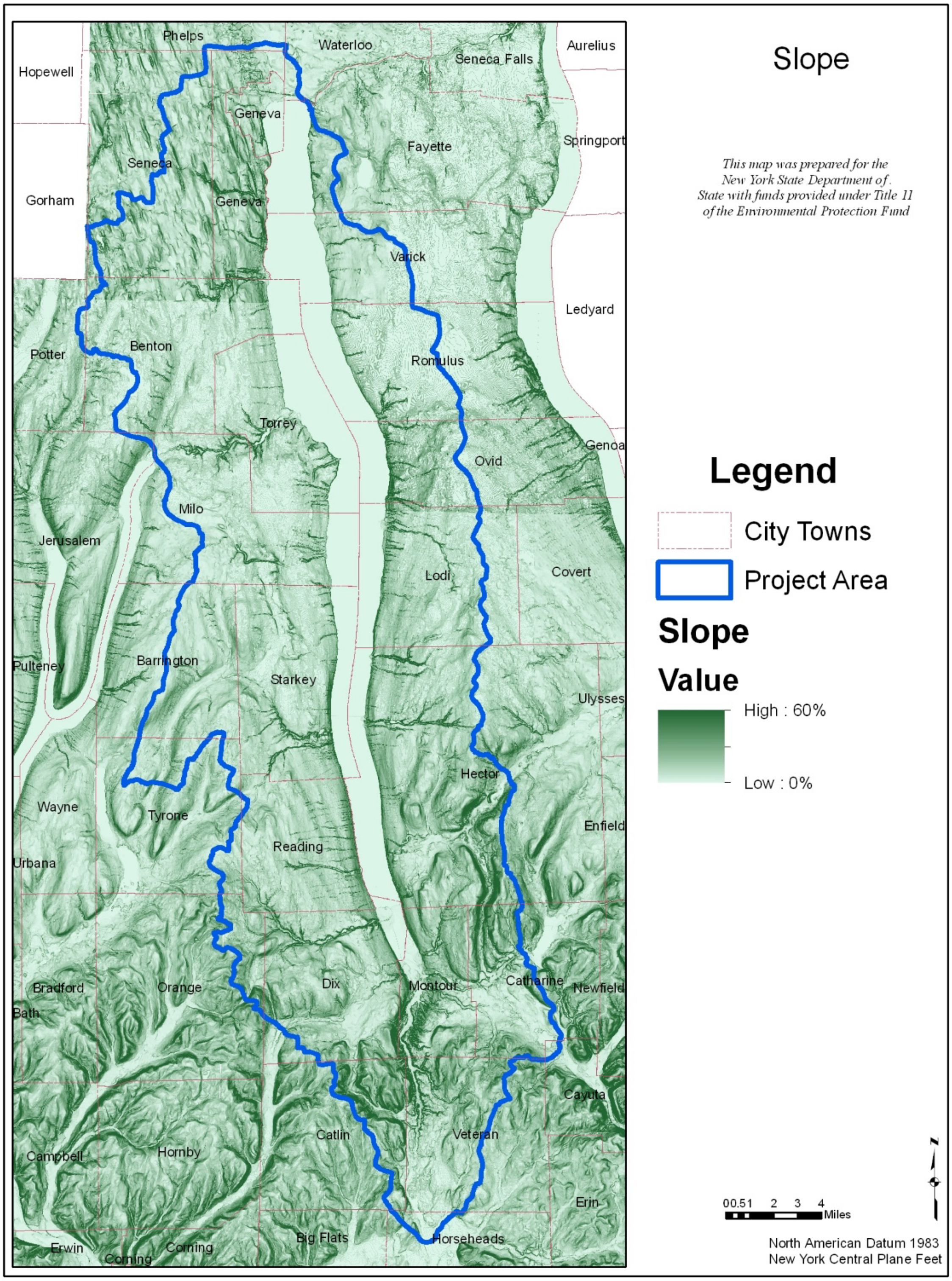


Fig.14. Slopes in the Seneca Lake watershed.

Areas of Erosion

One of the major sources of pollutants in Seneca Lake is sediment loading from eroding stream banks, road banks and the steep slopes surrounding the lake. As mentioned in the soils and steep slopes section, evaluating what soils exist and if they are at a high risk of erosion is important. After evaluating the most commonly occurring soils within the watershed, it was found that these soils were not at high risk of erosion. Yet, the steep slopes that exist throughout the watershed (Fig. 14) particularly on the banks of Seneca Lake are reason for concern. Controlling development and slowing down the water as it runs down these steep slopes is vital to preventing erosion. Controlling development may mean limiting development on slopes above 15%, which is already the local law in many municipalities surrounding the late. Educating the watershed residents and municipalities on how to prevent erosion is also essential to controlling erosion. Slowing down runoff that flows through roadside ditches and culverts and maintaining those ditch and culverts will assist in preventing erosion and thus sediment loading into the lake. Lastly, stream bank stabilization to assist in slowing the velocity of the water flowing in the streams and thus how fast this water empties into the lake will be helpful in the fight to prevent erosion.

Demographics

Population

Population figures and trends are largely based on information provided through the decennial census of population conducted by the US Census Bureau. The following section provides a brief overview of our understanding of current population statistics and trends in the Seneca Lake watershed.

Census Block Analysis

The smallest geographic unit of observation (or land area) that the US Census Bureau reports population figures for is called the *census block*. Census blocks generally conform to municipal or neighborhood boundaries, not natural boundaries, such as a watershed. Therefore, it is not possible to identify a specific population figure for a watershed boundary utilizing decennial data from the US Census. Furthermore, the geographic units of observation often change between decennial census years, making 10-year trend analysis at the block level a difficult endeavor.

The Seneca Lake Watershed consists of multiple census blocks; by identifying those blocks that are completely within the watershed boundary and those that overlap the watershed boundary, we are provided with a reliable population range. An analysis of census block figures within the Seneca Lake watershed from Census 2000 showed a population range between 52,888 and 57,887 persons, a difference of over 4,999 persons (US Census Bureau, 2001). Figures for Census 2010 show a population range between 54,114 and 58,897 persons, a difference of over 4,783 persons (US Census Bureau, 2010). This assumption is based on close observation of population density maps in combination with the census block boundaries themselves (Table 4).

Table 4. Population estimated for 2000 and 2010 census in the Seneca Lake watershed by county.

County	Watershed Population (Census 2000)	Watershed Population (Census 2000)
Chemung	<14,929	<15,228
Ontario	<5,547	<7,313
Seneca	<13,274	<12,550
Schuyler	<18,693	<18,337
Yates	<5,444	<5,469

Population Density Map Census 2000 and Census 2010

Population density maps provide insight to the locations with the highest concentrations of population in the watershed (Fig. 15, 16). In both the Census 2000 and Census 2010 the greatest population density appears to be in the City of Geneva and the Village of Penn Yan, in the northern and western portion of the Seneca Lake watershed. Other locations with high population density include all of the villages and hamlets in the watershed, especially areas in the Towns of Geneva, Montour, Hector, Dix, Veteran, Milo, Benton Fayette and Starkey.

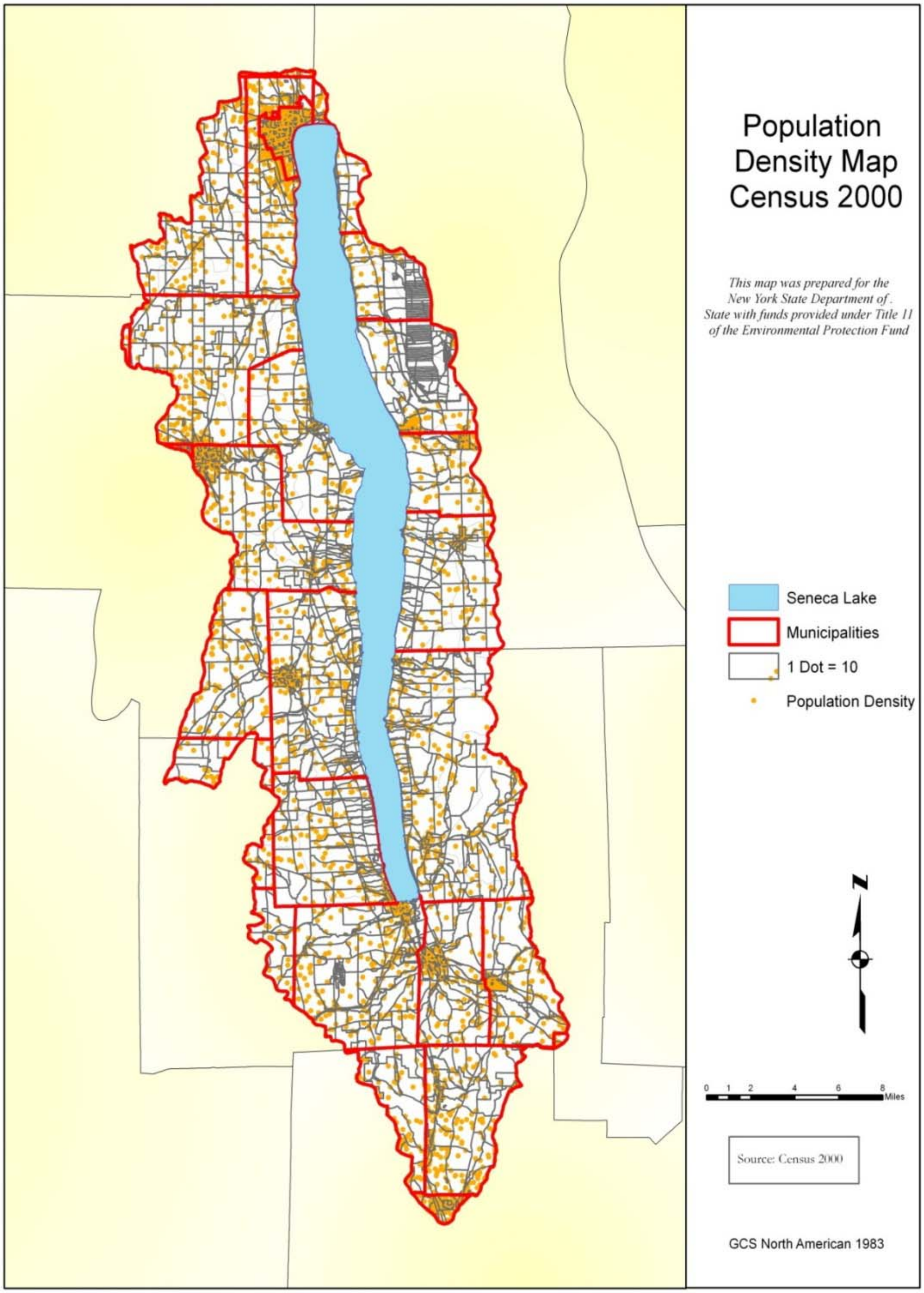


Fig. 15. Population density for 2000 in the Seneca Lake watershed.

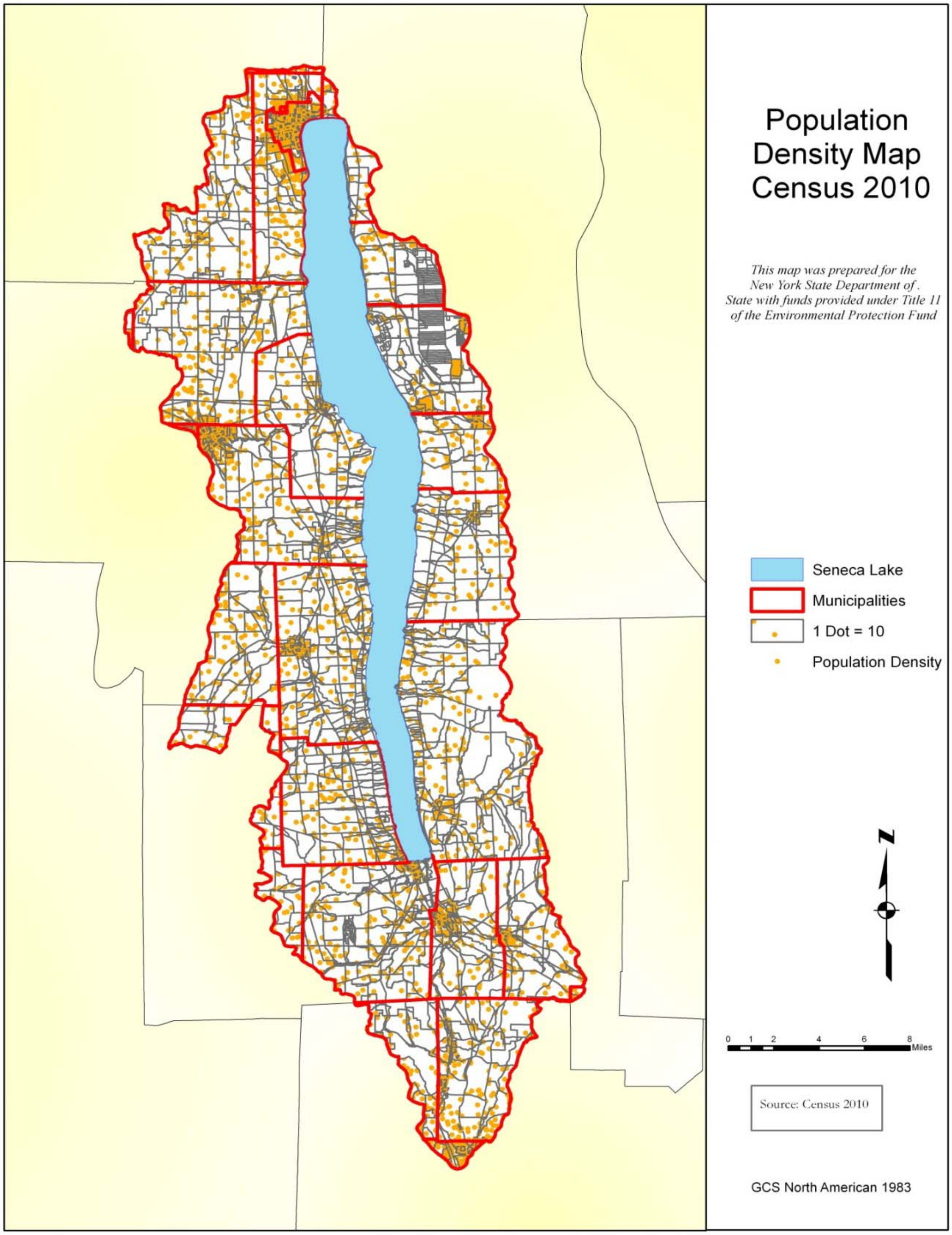


Fig. 16. Population density for 2010 in the Seneca Lake watershed.

Overall, population has been relatively stable in most municipalities in the Seneca Lake watershed since 1970; population trends are generally in line with those across Upstate New York and throughout the Great Lakes region of the United States during this period of time (Table 5). Of the 42 municipalities that have some portion of land area within the Seneca Lake watershed, seven have experienced continual increases in population since 1970– the towns of Milo, Hector, Fayette, Romulus Varick, Barrington, and Starkey and the village of Dundee. The most significant population increases are concentrated in the municipalities on the western and northeastern portions of the watershed, which happen to also be the most suburbanized towns in the watershed.

Population Projections

Population projections were calculated out to the year 2040 for the all counties (part), cities, towns, and villages in the Seneca Lake Watershed. The methodology was developed primarily by the Capital District Regional Planning Commission. The Population Projection Model involves two distinct stages: a quantitative first stage using a log-linear projection model set up in a MS Excel Workbook, and a qualitative second stage using non-quantitative judgments of the likelihood and extent of future population change within particular jurisdictions. The projected data provided in Table 6 and 7 represent the quantitative population projections.

Table 5. Population totals 1970-2010 for municipalities in the Seneca Lake watershed.

Municipality	Population													Total Change	
	1970	**1980**	**(+/-) '70 to '80**	**(%) '70 to '80**	**1990**	**(+/-) '80 to '90**	**(%) '80 to '90**	**2000**	**(+/) '90 to '00**	**(%) '90 to '00**	**2010**	**(+/-) '00 to '10**	**(%) '00 to '10**	**(+/-) '70 to '10**	**(%) '70 to '10**
Chemung County (part)	6,484	6,370	-114	-1.8%	6,436	66	1.0%	6,220	-216	-3.4%	6,243	23	0.4%	-241	-3.7%
Town of Catlin	2,461	2,719	258	10.5%	2,626	-93	-3.4%	2,649	23	0.9%	2,618	-31	-1.2%	157	6.4%
Town of Veteran	3,543	3,211	-332	-9.4%	3,468	257	8.0%	3,274	-194	-5.6%	3,313	39	1.2%	-230	-6.5%
Village of Millport	480	440	-40	-8.3%	342	-98	-22.3%	297	-45	-13.2%	312	15	5.1%	-168	-35.0%
Ontario County (part)	22,382	20,959	-1,423	-6.4%	19,857	-1,102	-5.3%	19,637	-220	-1.1%	19,273	-364	-1.9%	-3,109	-13.9%
City of Geneva	16,793	15,133	-1,660	-9.9%	14,143	-990	-6.5%	13,617	-526	-3.7%	13,261	-356	-2.6%	-3,532	-21.0%
Town of Geneva	2,781	3,077	296	10.6%	2,967	-110	-3.6%	3,289	322	10.9%	3,291	2	0.1%	510	18.3%
Town of Seneca	2,808	2,749	-59	-2.1%	2,747	-2	-0.1%	2,731	-16	-0.6%	2,721	-10	-0.4%	-87	-3.1%
Schuyler County (part)	21,472	22,374	902	4.2%	23,473	1,099	4.9%	23,599	126	0.5%	22,288	-1,311	-5.6%	816	3.8%
Town of Catharine	1,886	1,932	46	2.4%	1,991	59	3.1%	1,930	-61	-3.1%	1,762	-168	-8.7%	-124	-6.6%
Village of Odessa	568	613	45	7.9%	986	373	60.8%	617	-369	-37.4%	591	-26	-4.2%	23	4.0%
Town of Dix	4,201	4,138	-63	-1.5%	4,130	-8	-0.2%	4,197	67	1.6%	3,864	-333	-7.9%	-337	-8.0%
Town of Hector	3,671	3,793	122	3.3%	4,423	630	16.6%	4,854	431	9.7%	4,940	86	1.8%	1,269	34.6%
Village of Burdett	454	410	-44	-9.7%	372	-38	-9.3%	357	-15	-4.0%	340	-17	-4.8%	-114	-25.1%
Town of Montour	2,324	2,607	283	12.2%	2,528	-79	-3.0%	2,446	-82	-3.2%	2,308	-138	-5.6%	-16	-0.7%
Village of Montour Falls	1,534	1,791	257	16.8%	1,845	54	3.0%	1,797	-48	-2.6%	1,711	-86	-4.8%	177	11.5%
Town of Orange	1,076	1,358	282	26.2%	1,561	203	14.9%	1,752	191	12.2%	1,609	-143	-8.2%	533	49.5%
Town of Reading	1,768	1,813	45	2.5%	1,810	-3	-0.2%	1,786	-24	-1.3%	1,707	-79	-4.4%	-61	-3.5%
Village of Watkins Glen	2,736	2,440	-296	-10.8%	2,207	-233	-9.5%	2,149	-58	-2.6%	1,859	-290	-13.5%	-877	-32.1%
Town of Tyrone	1,254	1,479	225	17.9%	1,620	141	9.5%	1,714	94	5.8%	1,597	-117	-6.8%	343	27.4%
Seneca County (part)	14,507	12,583	-1,924	-13.3%	13,091	508	4.0%	12,591	-500	-3.8%	14,856	2,265	18.0%	349	2.4%
Town of Fayette	2,997	3,561	564	18.8%	3,636	75	2.1%	3,643	7	0.2%	3,929	286	7.9%	932	31.1%
Town of Lodi	1,287	1,184	-103	-8.0%	1,429	245	20.7%	1,476	47	3.3%	1,550	74	5.0%	263	20.4%
Village of Lodi	353	334	-19	-5.4%	364	30	9.0%	338	-26	-7.1%	291	-47	-13.9%	-62	-17.6%
Town of Ovid	3,107	2,530	-577	-18.6%	2,309	-221	-8.7%	2,757	448	19.4%	2,311	-446	-16.2%	-796	-25.6%
Village of Ovid	779	666	-113	-14.5%	660	-6	-0.9%	612	-48	-7.3%	602	-10	-1.6%	-177	-22.7%
Town of Romulus	4,284	2,440	-1,844	-43.0%	2,532	92	3.8%	2,036	-496	-19.6%	4,316	2,280	112.0%	32	0.7%
Town of Varick	1,700	1,868	168	9.9%	2,161	293	15.7%	1,729	-432	-20.0%	1,857	128	7.4%	157	9.2%
Yates County (part)	21,068	21,211	143	0.7%	22,215	1,004	4.7%	23,044	829	3.7%	24,440	1,396	6.1%	3,372	16.0%
Town of Barrington	929	1,091	162	17.4%	1,195	104	9.5%	1,396	201	16.8%	1,651	255	18.3%	722	77.7%
Town of Benton	2,159	1,981	-178	-8.2%	2,380	399	20.1%	2,640	260	10.9%	2,836	196	7.4%	677	31.4%
Town of Milo	6,854	6,732	-122	-1.8%	7,023	291	4.3%	7,020	-3	0.0%	7,906	886	12.6%	1,052	15.3%
Village of Penn Yan	5,168	5,242	74	1.4%	5,248	6	0.1%	5,219	-29	-0.6%	5,159	-60	-1.1%	-9	-0.2%
Town of Starkey	2,783	2,868	85	3.1%	3,173	305	10.6%	3,465	292	9.2%	3,573	108	3.1%	790	28.4%
Village of Dundee	1,539	1,556	17	1.1%	1,588	32	2.1%	1,690	102	6.4%	1,725	35	2.1%	186	12.1%
Town of Torrey	1,186	1,363	177	14.9%	1,269	-94	-6.9%	1,307	38	3.0%	1,282	-25	-1.9%	96	8.1%
Village of Dresden	450	378	-72	-16.0%	339	-39	-10.3%	307	-32	-9.4%	308	1	0.3%	-142	-31.6%
TOTAL	**85,913**	**83,497**	**-2,416**	**-2.8%**	**85,072**	**1,575**	**1.9%**	**85,091**	**19**	**0.0%**	**87,100**	**2,009**	**2.4%**	**1,187**	**1.4%**

Source: US Census Bureau 1970-2010

Table 6. Population historic and projections.

Municipality	Historical									Projected					
	1970	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040
Chemung County (part)	6,484	6,420	6,370	6,397	6,436	6,326	6,220	6,230	6,243	6,237	6,231	6,226	6,221	6,217	6,213
Town of Catlin	2,461	2,587	2,719	2,672	2,626	2,637	2,649	2,633	2,618	2,622	2,626	2,630	2,633	2,636	2,638
Town of Veteran	3,543	3,373	3,211	3,337	3,468	3,370	3,274	3,293	3,313	3,308	3,304	3,299	3,296	3,292	3,288
Village of Millport	480	460	440	388	342	319	297	304	312	307	302	298	294	290	287
Ontario County (part)	22,382	21,644	20,959	20,399	19,857	19,741	19,637	19,454	19,273	19,190	19,114	19,044	18,980	18,919	18,863
City of Geneva	16,793	15,941	15,133	14,630	14,143	13,878	13,617	13,438	13,261	13,167	13,082	13,003	12,930	12,862	12,798
Town of Geneva	2,781	2,925	3,077	3,021	2,967	3,124	3,289	3,290	3,291	3,304	3,315	3,326	3,336	3,345	3,354
Town of Seneca	2,808	2,778	2,749	2,748	2,747	2,739	2,731	2,726	2,721	2,719	2,717	2,715	2,714	2,712	2,711
Schuyler County (part)	21,472	21,895	22,374	22,880	23,473	23,504	23,599	22,927	22,288	22,332	22,373	22,413	22,447	22,481	22,510
Town of Catharine	1,886	1,909	1,932	1,961	1,991	1,960	1,930	1,844	1,762	1,761	1,760	1,760	1,759	1,759	1,758
Village of Odessa	568	590	613	777	986	780	617	604	591	594	597	600	602	605	607
Town of Dix	4,201	4,169	4,138	4,134	4,130	4,163	4,197	4,027	3,864	3,859	3,855	3,852	3,848	3,845	3,842
Town of Hector	3,671	3,732	3,793	4,096	4,423	4,633	4,854	4,897	4,940	4,976	5,008	5,038	5,066	5,092	5,116
Village of Burdett	454	431	410	391	372	364	357	348	340	337	334	332	329	327	325
Town of Montour	2,324	2,461	2,607	2,567	2,528	2,487	2,446	2,376	2,308	2,309	2,310	2,311	2,312	2,312	2,313
Village of Montour Falls	1,534	1,658	1,791	1,818	1,845	1,821	1,797	1,753	1,711	1,717	1,722	1,728	1,733	1,737	1,741
Town of Orange	1,076	1,209	1,358	1,456	1,561	1,654	1,752	1,679	1,609	1,626	1,642	1,656	1,669	1,682	1,693
Town of Reading	1,768	1,790	1,813	1,811	1,810	1,798	1,786	1,746	1,707	1,706	1,706	1,705	1,705	1,704	1,704
Village of Watkins Glen	2,736	2,584	2,440	2,321	2,207	2,178	2,149	1,999	1,859	1,839	1,820	1,803	1,787	1,772	1,758
Town of Tyrone	1,254	1,362	1,479	1,548	1,620	1,666	1,714	1,654	1,597	1,608	1,619	1,628	1,637	1,646	1,653
Seneca County (part)	14,507	13,383	12,583	12,823	13,091	12,804	12,591	13,497	14,856	14,838	14,820	14,803	14,789	14,774	14,762
Town of Fayette	2,997	3,267	3,561	3,598	3,636	3,639	3,643	3,783	3,929	3,950	3,969	3,987	4,004	4,019	4,034
Town of Lodi	1,287	1,234	1,184	1,301	1,429	1,452	1,476	1,513	1,550	1,557	1,564	1,570	1,576	1,581	1,586
Village of Lodi	353	343	334	349	364	351	338	314	291	291	290	289	289	288	287
Town of Ovid	3,107	2,804	2,530	2,417	2,309	2,523	2,757	2,524	2,311	2,295	2,280	2,266	2,253	2,241	2,230
Village of Ovid	779	720	666	663	660	636	612	607	602	598	594	590	586	583	580
Town of Romulus	4,284	3,233	2,440	2,486	2,532	2,270	2,036	2,964	4,316	4,286	4,258	4,233	4,209	4,187	4,167
Town of Varick	1,700	1,782	1,868	2,009	2,161	1,933	1,729	1,792	1,857	1,861	1,865	1,868	1,872	1,875	1,878
Yates County (part)	21,068	21,128	21,211	21,696	22,215	22,618	23,044	23,720	24,440	24,514	24,582	24,646	24,705	24,759	24,810
Town of Barrington	929	1,007	1,091	1,142	1,195	1,292	1,396	1,518	1,651	1,667	1,681	1,695	1,707	1,719	1,730
Town of Benton	2,159	2,068	1,981	2,171	2,380	2,507	2,640	2,736	2,836	2,853	2,869	2,884	2,897	2,910	2,921
Town of Milo	6,854	6,793	6,732	6,876	7,023	7,021	7,020	7,450	7,906	7,923	7,939	7,953	7,967	7,979	7,991
Village of Penn Yan	5,168	5,205	5,242	5,245	5,248	5,233	5,219	5,189	5,159	5,160	5,161	5,161	5,162	5,162	5,163
Town of Starkey	2,783	2,825	2,868	3,017	3,173	3,316	3,465	3,519	3,573	3,594	3,613	3,631	3,647	3,662	3,676
Village of Dundee	1,539	1,547	1,556	1,572	1,588	1,638	1,690	1,707	1,725	1,729	3,613	3,631	3,647	3,662	3,676
Town of Torrey	1,186	1,271	1,363	1,315	1,269	1,288	1,307	1,294	1,282	1,284	1,286	1,288	1,290	1,292	1,294
Village of Dresden	450	412	378	358	339	323	307	307	308	304	300	297	294	291	288

Table 7. Historic and projected decennial changes in the Seneca Lake watershed.

Municipality	**Historical**				**Projected**			**Historical**				**Projected**		
	1970-80 Net	**1980-90 Net**	**1990-00 Net**	**2000-10 Net**	**2010-20 Net**	**2020-30 Net**	**2030-40 Net**	**1970-80 Percent**	**1980-90 Percent**	**1990-00 Percent**	**2000-10 Percent**	**2010-20 Percent**	**2020-30 Percent**	**2030-40 Percent**
Chemung County (part)	-114	-23	66	-71	-216	-96	23	-1.8%	-0.4%	1.1%	-1.1%	-3.5%	-1.5%	0.4%
Town of Catlin	258	85	-93	-35	23	-4	-31	9.5%	3.2%	-3.5%	-1.3%	0.9%	-0.2%	-1.2%
Town of Veteran	-332	-36	257	33	-194	-77	39	-10.3%	-1.0%	7.8%	1.0%	-5.9%	-2.3%	1.2%
Village of Millport	-40	-72	-98	-69	-45	-15	15	-9.1%	-21.1%	-33.0%	-22.1%	-14.9%	-5.1%	5.2%
Ontario County (part)	-1,423	-1,245	-1,102	-658	-220	-287	-364	-6.8%	-6.3%	-5.6%	-3.4%	-1.2%	-1.5%	-1.9%
City of Geneva	-1,660	-1,311	-990	-752	-526	-440	-356	-11.0%	-9.3%	-7.3%	-5.7%	-4.0%	-3.4%	-2.8%
Town of Geneva	296	96	-110	103	322	166	2	9.6%	3.2%	-3.3%	3.1%	9.7%	5.0%	0.1%
Town of Seneca	-59	-30	-2	-9	-16	-13	-10	-2.1%	-1.1%	-0.1%	-0.3%	-0.6%	-0.5%	-0.4%
Schuyler County (part)	902	985	1,099	624	126	-577	-1,311	4.0%	4.2%	4.7%	2.8%	0.6%	-2.6%	-5.8%
Town of Catharine	46	52	59	-1	-61	-116	-168	2.4%	2.6%	3.1%	-0.1%	-3.5%	-6.6%	-9.6%
Village of Odessa	45	187	373	3	-369	-176	-26	7.3%	19.0%	60.5%	0.5%	-61.8%	-29.2%	-4.3%
Town of Dix	-63	-35	-8	29	67	-136	-333	-1.5%	-0.8%	-0.2%	0.8%	1.7%	-3.5%	-8.7%
Town of Hector	122	364	630	537	431	264	86	3.2%	8.2%	13.0%	10.9%	8.6%	5.2%	1.7%
Village of Burdett	-44	-40	-38	-27	-15	-16	-17	-10.7%	-10.8%	-10.6%	-7.9%	-4.5%	-4.9%	-5.2%
Town of Montour	283	106	-79	-80	-82	-111	-138	10.9%	4.2%	-3.2%	-3.5%	-3.5%	-4.8%	-6.0%
Village of Montour Falls	257	160	54	3	-48	-68	-86	14.3%	8.7%	3.0%	0.2%	-2.8%	-3.9%	-4.9%
Town of Orange	282	247	203	198	191	25	-143	20.8%	15.8%	11.6%	12.3%	11.6%	1.5%	-8.4%
Town of Reading	45	21	-3	-13	-24	-52	-79	2.5%	1.2%	-0.2%	-0.8%	-1.4%	-3.0%	-4.6%
Village of Watkins Glen	-296	-263	-233	-143	-58	-179	-290	-12.1%	-11.9%	-10.8%	-7.7%	-3.2%	-10.0%	-16.5%
Town of Tyrone	225	186	141	118	94	-12	-117	15.2%	11.5%	8.2%	7.4%	5.8%	-0.7%	-7.1%
Seneca County (part)	-1,924	-560	508	-19	-500	693	2,265	-15.3%	-4.3%	4.0%	-0.1%	-3.4%	4.7%	15.3%
Town of Fayette	564	331	75	41	7	144	286	15.8%	9.1%	2.1%	1.0%	0.2%	3.6%	7.1%
Town of Lodi	-103	67	245	151	47	61	74	-8.7%	4.7%	16.6%	9.7%	3.0%	3.9%	4.7%
Village of Lodi	-19	6	30	2	-26	-37	-47	-5.7%	1.6%	8.9%	0.7%	-9.0%	-12.8%	-16.4%
Town of Ovid	-577	-387	-221	106	448	1	-446	-22.8%	-16.8%	-8.0%	4.6%	19.6%	0.0%	-20.0%
Village of Ovid	-113	-57	-6	-27	-48	-29	-10	-17.0%	-8.6%	-1.0%	-4.5%	-8.1%	-4.9%	-1.7%
Town of Romulus	-1,844	-747	92	-216	-496	694	2,280	-75.6%	-29.5%	4.5%	-5.0%	-11.6%	16.5%	54.7%
Town of Varick	168	227	293	-76	-432	-141	128	9.0%	10.5%	16.9%	-4.1%	-23.2%	-7.5%	6.8%
Yates County (part)	143	568	1,004	922	829	1,102	1,396	0.7%	2.6%	4.4%	3.8%	3.4%	4.5%	5.6%
Town of Barrington	162	135	104	150	201	226	255	14.8%	11.3%	7.4%	9.1%	12.0%	13.2%	14.7%
Town of Benton	-178	103	399	336	260	229	196	-9.0%	4.3%	15.1%	11.8%	9.1%	7.9%	6.7%
Town of Milo	-122	83	291	145	-3	429	886	-1.8%	1.2%	4.1%	1.8%	-0.0%	5.4%	11.1%
Village of Penn Yan	74	40	6	-12	-29	-44	-60	1.4%	0.8%	0.1%	-0.2%	-0.6%	-0.9%	-1.2%
Town of Starkey	85	192	305	299	292	203	108	3.0%	6.1%	8.8%	8.4%	8.1%	5.6%	2.9%
Village of Dundee	17	25	32	66	102	69	35	1.1%	1.6%	1.9%	3.8%	2.8%	1.9%	1.0%
Town of Torrey	177	44	-94	-27	38	6	-25	13.0%	3.5%	-7.2%	-2.1%	3.0%	0.5%	-1.9%
Village of Dresden	-72	-54	-39	-35	-32	-16	1	-19.0%	-15.9%	-12.7%	-11.4%	-10.7%	-5.4%	0.3%

Land Use and Land Cover

Land activities and water quality are inherently linked to one another. The type of activities that take place on the land will directly influence the quality and characteristics of the water that runs off of it. Understanding the characteristics of the land within a watershed area is therefore a central aspect of watershed planning. When combined with a Geographic Information System analysis, land use and land cover information can be compared and contrasted in a variety of ways, providing users with multiple applications for the management and restoration of land and water. Subjects such as the present and future uses of the land, agricultural productivity, habitat, and environmental sensitivity can be readily assessed for an entire watershed or any given area within it.

Land Use History

In general on a watershed-wide basis, agricultural land has been on a steady decline, forests and developed areas have increased, and the category of idle land has been on the increase.

Early discussions of land uses in the Seneca Lake watershed are descriptive and informative (New York State Water Pollution Control Board, 1956) there was no documentation of acreages of land uses until the Land Use and Natural Resources (LUNR) inventory. This inventory which was conducted in 1969 across the state used the resource of satellite imagery to interpret land use. This database was created at a USGS quad scale (1:24,000) and was the basis for extensive land use planning in the early 1970's. The next statewide land use survey was conducted by the USGS in 1981; however, because the scale was much larger (1:250,000) and because it used different land use categories, it was not directly comparable to LUNR, but was useful in regional planning applications. As a result, aerial photos taken in 1994 and in 1995 were digitized by the Genesee/Finger Lakes Regional Planning Council (GFL) as part of the *Setting A Course for Seneca Lake, The State of the Seneca Lake Watershed* report. The scale, 1:7920, was more accurate and provided excellent data for not only an analysis of the current land use mix, but also for comparison with earlier LUNR inventory datasets.

Land uses documented in 1971, 1981 and 1995 were compared to assess the changes over time. Because of the differences in scale and in land use categories, detailed comparisons could not be made; but generalizations could be drawn once the land use types were combined into broader classifications. Table 7 provides the qualitative breakdown of the generalized land use types.

Table 8. Generalized classifications of land use within the Seneca Lake watershed: 1971, 1980, 1995.

Land Use	1971	1980	1995
(1) Agricultural	42.50%	53.20%	39.10%
(2) Forest	40.40%	38.50%	41.30%
(3) Idle	14.00%	2.10%	11.30%
(4) Development	3.10%	6.20%	8.30%

Land Use

Land use refers to the human purposes ascribed to the land, such as “industrial” or “residential” use. Land use can be analyzed utilizing Geographic Information System data derived from county Real Property System (RPS) tax parcel records. As explained on the New York State Department of Taxation and Finance Office of Real Property Tax Services website:

> The Assessment Improvement Law (Laws of 1970, Chapter 957) required local governments to prepare and maintain tax maps in accordance with standards established by the State Board of Equalization and Assessment (currently Office of Real Property Services). For the most part, this requirement is a county responsibility…Perhaps the most essential of all assessment tools is an adequate tax map reflecting the size, shape and geographical characteristics of each parcel of land in the assessing unit. The tax map is a graphic display of each assessing unit's land inventory and as such is the major source to the real property assessment roll. The working copy of the tax map used by the assessor can be utilized to record and analyze property transfers, to record other features pertinent to the valuation of land and in the development of a Geographic Information System (GIS). [The GIS] allows us to analyze and map the wealth of parcel level assessment information to solve problems related to: property valuation, local government reassessments, land use, environmental assessment, facility siting and economic development, public health, emergency services and disaster planning (“Tax Mapping in New York State”, 2011).

Tax parcel information is available in GIS format from each county within the study area. Each GIS utilizes the same uniform classification system developed by the New York State Office of Real

Property Services that is used in assessment administration in New York State. The system of classification consists of numeric codes in nine categories.

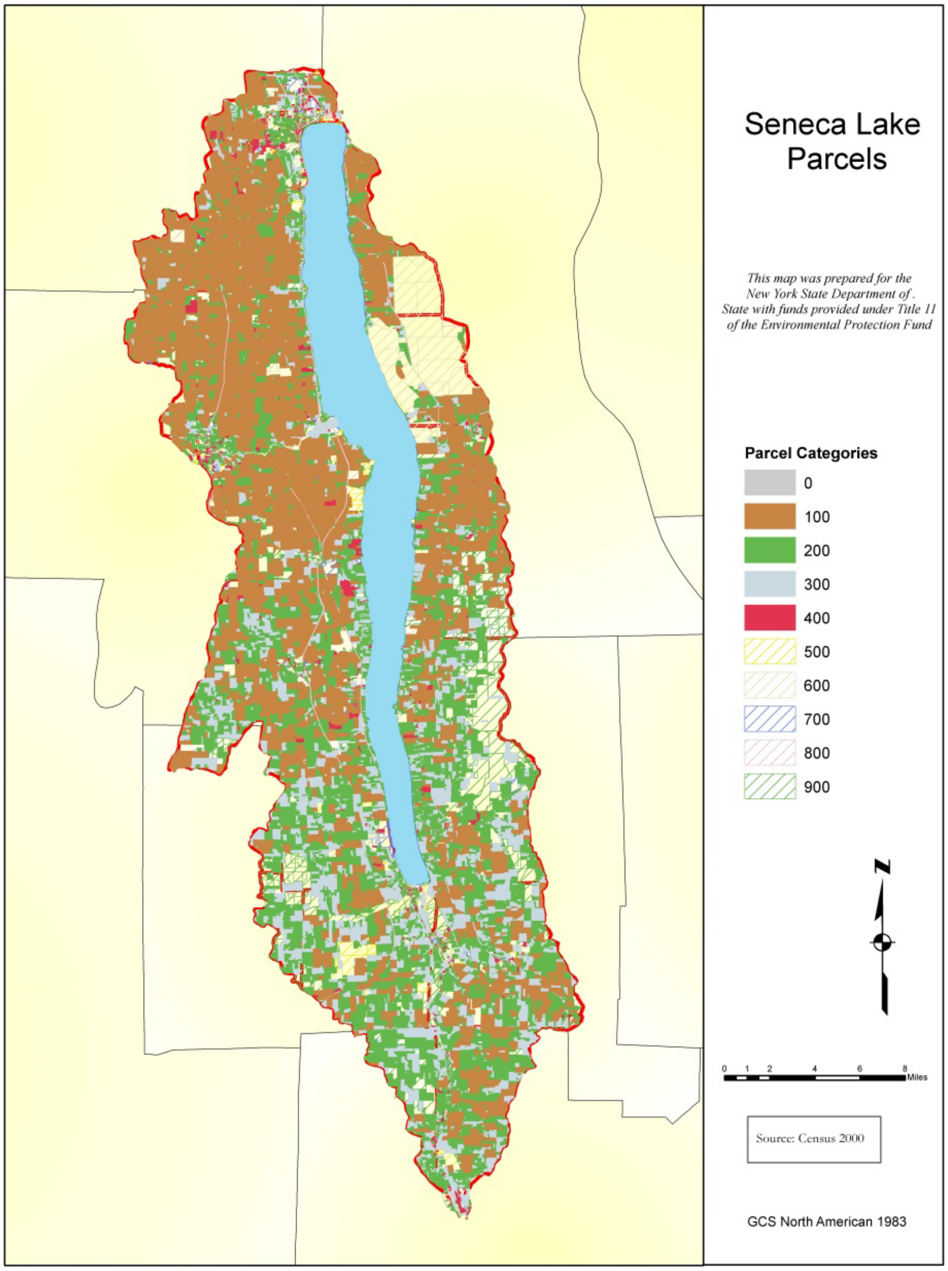
The results listed in Table 9 were tabulated based on an analysis of those properties within the Seneca Lake watershed.

Table 9. Land use within the Seneca Lake watershed.

Property Classification Category	**Acres**	**% of Seneca Lake Watershed Area**	**# of Parcels**	**Average Size (Acres)**
(1) Agricultural **Property used for the production of crops or livestock**	122,541.27	42.2%	1,837	72
(2) Residential **Property used for human habitation**	79,691.94	27.5%	18,105	5
(3) Vacant Land **Property that is not in use, is in temporary use, or lacks permanent improvement**	41,848.78	14.4%	4,817	9
(4) Commercial **Property used for the sale of goods and/or services**	3,549.75	1.2%	1,517	2
(5) Recreation and Entertainment **Property used by groups for recreation, amusement, or entertainment**	3,103.54	1.1%	109	29
(6) Community Services **Property used for the well-being of the community**	14,888.49	5.1%	552	29
(7) Industrial **Property used for the production and fabrication of durable and nondurable man-made goods**	1,482.05	0.5%	71	22
(8) Public Services **Property used to provide services to the general public**	2,316.90	0.8%	250	11
(9) Wild, Forested, Conservation Lands & Public Parks **Reforested lands, preserves, and private hunting and fishing clubs**	17,233.64	5.9%	259	86
Unclassified ***Property or land that has not been or is unable to be classified***	3,647.75	1.3%	380	11

Note: Waterbodies, road rights of way and other minor boundary irregularities account for a cumulative discrepancy between the actual total area of the watershed and the total property acreage that is ultimately classified through the real property system.

It is important to note that property classification and tax map maintenance is a responsibility of the county assessor's office (or local equivalent). While the classification system standards are intended to create uniform results, human error and subjectivity can sometimes lead to different interpretations of property types from place to place. Some level of inaccuracy with the results in Table 7 should therefore be assumed. Furthermore, properties are classified primarily for the purposes of taxation and public finance, not environmental analysis. While the information aides environmental assessment (lakefront vs. non-lakefront, wooded lot vs. pasture, etc.), the application of these results to watershed planning has its limitations. The information can nonetheless provide useful insight when combined and compared with land cover data and other land use analysis tools (Fig. 17).


Seneca Lake Parcels

This map was prepared for the New York State Department of . State with funds provided under Title 11 of the Environmental Protection Fund

Source: Census 2000

GCS North American 1983

Fig. 17. Seneca Lake watershed land use parcels.

<u>Parcel Categories (</u>"How to Locate the Proper Property Type Classification Code", 2012)
100 - Agricultural - Property used for the production of crops or livestock.
200 - Residential - Property used for human habitation. Living accommodations such as hotels, motels, and apartments are in the Commercial category - 400.
300 - Vacant Land - Property that is not in use, is in temporary use, or lacks permanent improvement.
400 - Commercial - Property used for the sale of goods and/or services.
500 - Recreation & Entertainment - Property used by groups for recreation, amusement, or entertainment.
600 - Community Services - Property used for the well-being of the community.
700 - Industrial - Property used for the production and fabrication of durable and nondurable man-made goods.
800 - Public Services - Property used to provide services to the general public.
900 - Wild, Forested, Conservation Lands & Public Parks - Reforested lands, preserves, and private hunting and fishing clubs

Land Cover

Land cover refers to the type of features present on the surface of the earth. For example, agricultural fields, water, pine forests, and parking lots are all land cover types. Land cover may refer to a biological categorization of the surface, such as grassland or forest, or to a physical or chemical categorization.

Land cover was assessed in the Seneca Lake watershed utilizing imagery associated with the National Land Cover Dataset (Table 10).

Table 10. 2006 NLCD Land Cover within the Seneca Lake watershed.

NLCD Category	Acres	% Cover
11 - Open Water	43,933	12.9
21 - Developed, Open Space	16,554	4.9
22 - Developed, Low Intensity	4,329	1.3
23 - Developed, Medium Intensity	1,316	.4
24 - Developed, High Intensity	382	.11
31 - Barren Land	191	.05
41 - Deciduous Forest	61,939	18.3
42 - Evergreen Forest	5,127	1.5
43 - Mixed Forest	23,123	6.7
52 - Shrub/Scrub	22,151	6.5
71 - Grassland/Herbaceous	2,190	.54
81 - Pasture Hay	83,620	24.5
82 - Cultivated Crops	61,281	18.0
90 - Woody Wetlands	13,228	3.8
95 - Emergent Herbaceous Wetlands	1,755	0.5
Total	341,119	100

This dataset was developed by the Multi-Resolution Land Characteristics (MRLC) Consortium, a group of federal agencies who first joined together in 1993 (Fry et. al., 2011) to purchase satellite imagery for the conterminous U.S. to develop the NLCD. The National Land Cover Dataset 2006 is a 15-class land cover classification scheme that has been applied consistently across the conterminous United States at a spatial resolution of 30 meters (Fry et. al., 2011).

An analysis of the 2006 NLCD land cover within the Seneca Lake Watershed estimates that there are 341,119 acres in the watershed. (Fig. 18) Nearly, 25% of land cover within the watershed fell under the category of ‘Pasture Hay’. About 18% of the land cover was under the category of ‘Deciduous Forest’. Approximately, 13% of the watershed was categorized as ‘Open Water’ with the majority of that land cover attributed to Seneca Lake.

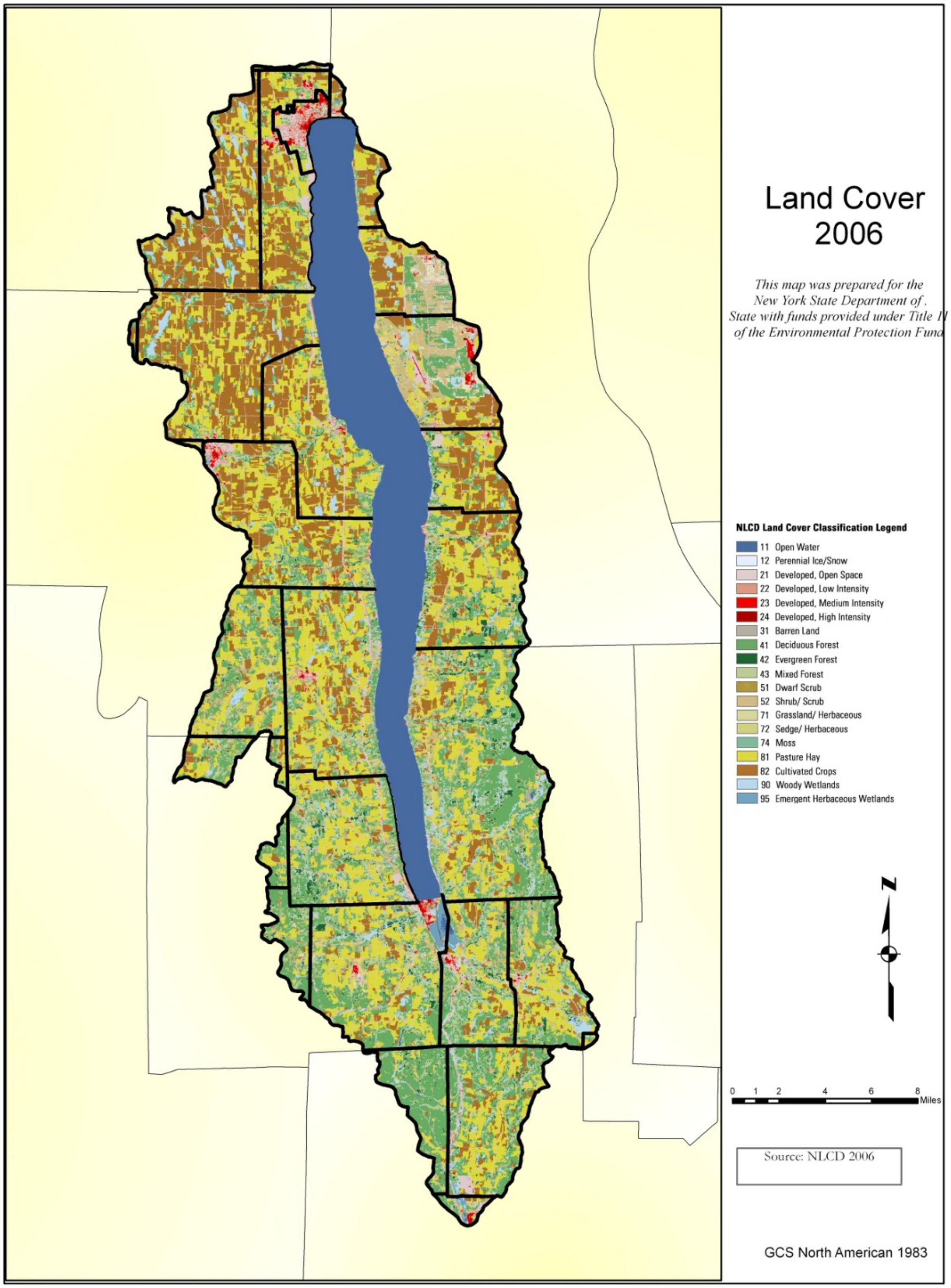


Fig. 18. Land cover in the Seneca Lake watershed.

A full explanation of 2006 NLCD categories (Fry et. al., 2011) and results by sub watershed is below:

11 – Open Water: All areas of open water, generally with less than 25% cover of vegetation or soil.

21 – Developed, Open Space: Includes areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes

22 – Developed, Low Intensity: Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20-49 percent of total cover. These areas most commonly include single-family housing units.

23 – Developed, Medium Intensity: Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50-79 percent of the total cover. These areas most commonly include single-family housing units.

24 – Developed, High Intensity: Includes highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80 to100 percent of the total cover.

31 – Barren Land (Rock/Sand/Clay): Barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.

41 – Deciduous Forest: Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75 percent of the tree species shed foliage simultaneously in response to seasonal change.

42 – Evergreen Forest: Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.

43 – Mixed Forest: Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75 percent of total tree cover.

52 – Shrub/Scrub: Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early succession stage or trees stunted from environmental conditions.

71 – Grassland/Herbaceous: Areas dominated by grammanoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.

81 – Pasture/Hay: Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20 percent of total vegetation.

82 – Cultivated Crops: Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled.

90 – Woody Wetlands: Areas where forest or shrub land vegetation accounts for greater than 20 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

95 – Emergent Herbaceous Wetlands: Areas where perennial herbaceous vegetation accounts for greater than 80 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water

Public Lands

Public lands can be classified into a number of different categories. The varieties of public lands that exist in the Seneca Lake watershed vary tremendously in terms of size, ownership, operation and maintenance, and designated and permitted uses. Public land uses include local municipal ball fields and cemeteries, multi-use county parks, and significant holdings of conservation lands by not-for-profit conservation organizations and land trusts, such as The Nature Conservancy, or other local and regional land trusts, such as The Finger Lakes Land Trust.

Federal Lands

Approximately 7,484 acres of the 16,212 acre Finger Lakes National Forest lies within the Seneca Lake watershed, located in Seneca and Schuyler Counties on the eastern side of Seneca Lake watershed. Lands continue to be acquired in the vicinity of the forest making an accurate measure of land area difficult to calculate. It is New York State's only National Forest and has over 30 miles of interconnecting trails that traverse gorges, ravines, pastures and woodlands.

NYS DEC Lands

The largest contiguous holding of NYSDEC land within the watershed is Sugar Hill State Forest ("Sugar Hill State Forest", 2012). Sugar Hill State Forest is located on the southwestern side of the watershed in Schuyler County and consists of over 9,000 acres of land, 2,440 of which is within the Seneca Lake Watershed. Texas Hollow State Forest consists of 931 acres, all of which lie on the southeastern side of the Seneca Lake watershed in the Towns of Hector and Catherine (Table 11).

Table 11. NYS DEC Lands within the Seneca Lake watershed.

Land Unit Name	Land Unit Category	Location	Acreage within Seneca Lake Watershed	Total Acreage
Sugar Hill	State Forest	Schuyler County	2,440	9,099
Texas Hollow	State Forest	Schuyler County	931	931
Catharine Creek	Wildlife Management Area	Schuyler County	705	705
Coon Hollow	State Forest	Schuyler County	395	2,433
Willard	Wildlife Management Area	Seneca County	154	154
Seneca Lake	Boat Launch	Yates County	13	13
Catharine Creek	Fishing Access	Chemung County	3	3

The Catherine Creek State Wildlife Management Area lies at the southern end of Seneca Lake, between Watkins Glen and Montour Falls. Sedimentation and manipulation of the lake level has led to the formation of a 1,000 acre marsh complex. The area, named for the local Seneca Indian Queen, Catharine Montour, provides a haven for innumerable wildlife. Once navigable into what is now Montour Falls, the waters of Catharine Creek still feed a remnant section of the Chemung Barge Canal, which runs through the center of the marsh. This canal, critical to local industrial development, connected this portion of southern New York to the entire east coast. The Pennsylvania Railroad, bordering the canal through the marsh, served the area after the canal was closed in 1878. The area is rich with history from the time of the Senecas through the years, when much of the marsh was used for truck crop farming, muskrat farming and eventually reed harvesting ("Catherine Creek State Wildlife Management Area", 2012). The complex also provides ample public fishing access.

In addition, the Willard Wildlife Management Area is located in the Town of Ovid in Seneca County and consists of 135 acres of cropland and 23 acres of woodland which borders on Seneca Lake. Because of its past agricultural history, the crop land is rented to local farmers and income from rentals has been used to develop roads, trails, and parking areas. Other improvements to make this area more productive for fish and wildlife resources are planned for the future ("Willard Wildlife State Wildlife Management Area", 2012).

Office of Parks, Recreation and Historic Preservation Lands

The New York State Office of Parks, Recreation and Historic Preservation has a number of land holdings that lie within the Seneca Lake watershed. These are listed in Table 12.

Table 12. NYS OPRHP lands within the Seneca Lake watershed.

Land Unit Name	Land Unit Category	County	Acreage within Seneca Lake Watershed	Total Acreage
Sampson	State Park	Seneca County	2,038	2,038
Watkins Glen	State Park	Schuyler County	804	804
Mark Twain	State Park	Chemung County	467	467
Bonavista	State Park	Seneca County	250	250
Seneca Lake	State Park	Ontario/Seneca Counties	103	145
Lodi Point	Marine Facility	Seneca County	12	12
Parrot Hall	State Historic Site	Ontario County	1	1

Other Local Public Lands

An analysis of locally and privately-owned public lands produced an interesting array of lands throughout the watershed (Fig. 19). Most notable among them include the Keuka Outlet Trail. Owned and maintained by Friends of the Outlet, a local non-profit organization working with the community to preserve, protect and develop the properties along the Outlet. GIS analysis indicated that the Friends of the Outlet presently owns and maintains 277 acres of land in the Towns of Milo and Torrey and Village of Penn Yan.

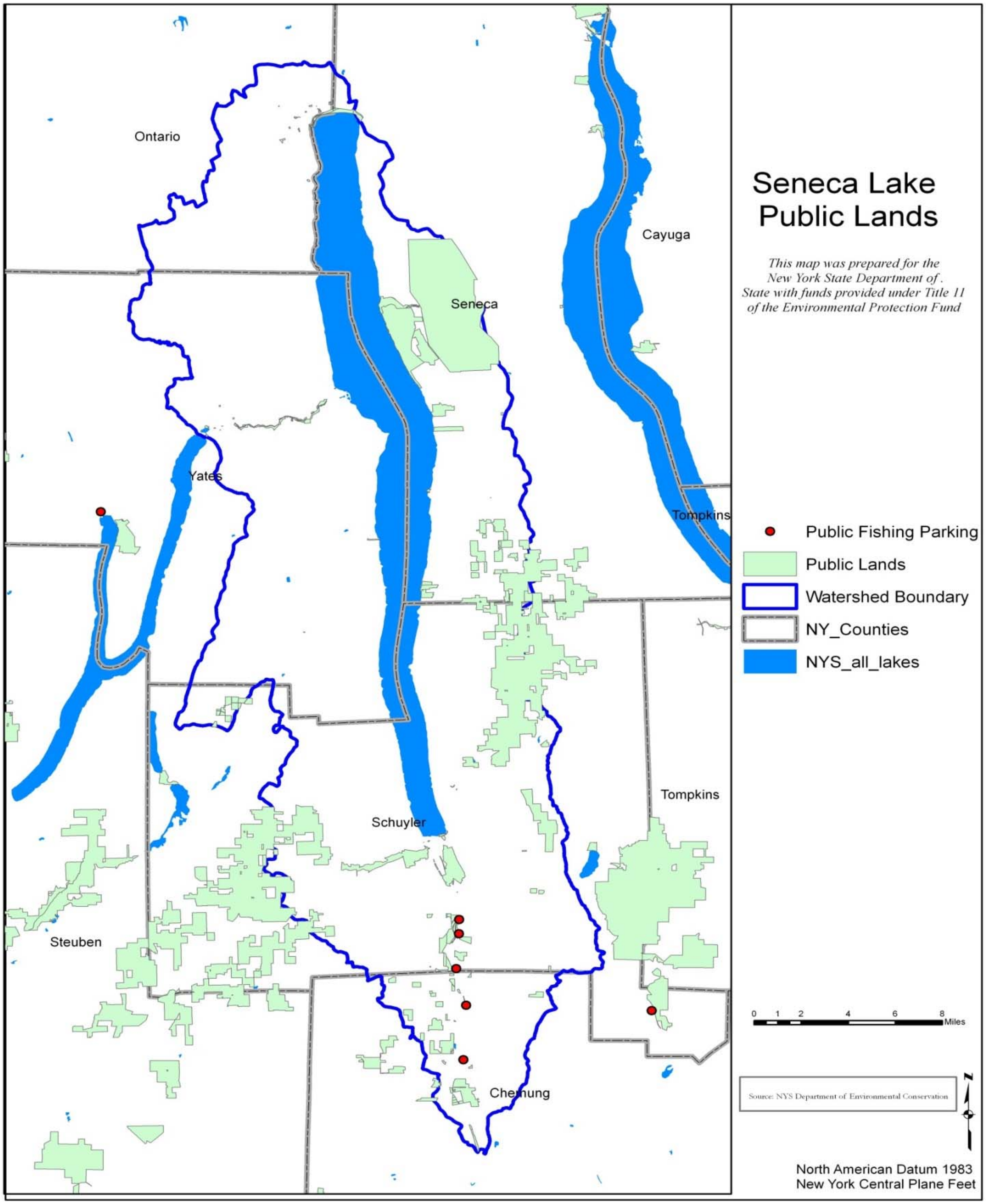


Fig. 19. Public lands [cemeteries excluded] in the Seneca Lake watershed.

The City of Geneva owns and maintains over 50 acres of parkland on the northern edge of Seneca Lake, which is contiguous with lands owned by the State of New York.

In addition to these lands, several small parcels of public land can be found scattered throughout the watershed which are located directly adjacent to Seneca Lake itself. While relatively small in size, these areas are extremely important public assets and can serve as important nodal linkages for public access across the lake.

New York State Open Space Conservation Plan

The *2009 New York State Open Space Conservation Plan* includes lists of regional priority conservation projects that have been identified by Regional Advisory Committees and through public comments received through the Plan's review process. Priority projects included on this list are eligible for funding from the State's Environmental Protection Fund, and other State, federal and local funding sources. The Plan states that, "For most of the project areas identified, a combination of State and local acquisition, land use regulation, smart development decisions, land owner incentives and other conservation tools used in various combinations, will be needed to succeed in conserving these open space resources for the long term" ("Open Space Conservation Plan", 2009). In addition to the Priority Projects listed in the body of the report, the Region 8 Advisory Committee also identified "Additional Priority Projects" warranting attention and focus for preservation and enhancement if resources allow.

Priority Projects

Finger Lakes Shorelines - While the Finger Lakes Region is identified in the 2002 Plan as a Major Resource Area and strategies such as acquisition of additional public access and consolidation of existing State projects are mentioned, the shorelines of these unique lakes are tied up in private ownership to a degree seldom seen in other states, so that most citizens have little direct experience of these beautiful lakes, even though their length provides hundreds of miles of shoreline. Public access for swimming, photography, shoreline fishing, and canoeing is minimal. Natural, forested shoreline is itself a scarce resource, incrementally lost over time to home site development.

Projects to preserve portions of the shoreline of these lakes for public access or wildlife could utilize acquisitions, easements, or additions to existing public segments. Parties including New York State, local governments, and non-profit organizations need to be prepared to capitalize on opportunities which will become increasingly critical as shoreline development and prices continue to climb. While it is not possible to predict future opportunities, several potential lakeshore protection projects can be listed now:

- Finger Lakes Water Trails - a network of strategically spaced open shoreline parcels to support low intensity and passive recreational uses, including: kayaking, boating, bird watching, angling, hunting, and simply seeking solitude by the water. Extending the eastern terminus of the Outlet Trail to the Seneca Lake shoreline at Dresden (Region 8).
- Additional analysis is needed in order to identify other priority sites, especially on Seneca Lake where some of the greatest opportunities for currently undeveloped shoreline may exist.

Catharine Valley Complex - This unique Southern Tier complex extends from the southern end of Seneca Lake in Schuyler County, south to the Village of Horseheads in Chemung County. The complex is composed of three major environmental areas with varying habitats and recreational opportunities. Just south of Seneca Lake are towering shale cliffs bordered by Rock Cabin Road. This site harbors a rare plant community and an uncommon plant that is the exclusive food source for three butterflies considered rare in this region. The Wild Nodding onion, a rare species and listed on the NYS list of protected plants, grows in profusion on the cliffside. In addition more than 120 wildflower species have been identified on this site. Adjacent to Rock Cabin Road is the Queen Catharine wetland, identified as an Important Bird Area by the National Audubon Society. The second environmental area in this complex is the Horseheads Marsh, a Class 1 wetland and the largest freshwater wetland in Chemung County. The marsh is the headwaters for Catharine Creek, a world class trout stream and provides the stream with water quality and flood control functions. In addition, the marsh provides habitat for many species of birds (some on the endangered species list), wildlife and reptiles. The third focus in this complex is the abandoned Chemung Canal property, which passes through Horseheads Marsh. Purchase of this property will allow the Catharine Valley Trail connection to the Village of Horseheads by developing a trail along the historic Chemung Canal towpath. This complex offers opportunities to treasure and protect the biodiverisity present in the area and to expand recreational and educational opportunities in the valuable open space lands of the Southern Tier.

Seneca Army Deport Conservation Area - Located in the Towns of Varick and Romulus, Seneca County, this project is necessary to protect a unique population of white deer. The lands comprised part of a U.S. Army installation developed in the early 1940s and closed in the 1990's. The land is traversed by tributaries of four streams, and contains a 60-acre pond and nearly 500 acres of wetlands. The fenced perimeter allowed for the protection and management of the white deer herd, which is believed to be the largest, single herd of white deer in the world with approximately 200 individuals. The area also provides habitat for many species of birds and small game. As plans are devised for the development of the Depot, this project offers a unique open space opportunity (“Open Space Conservation Plan”, 2009).

Unabridged versions of the reports containing the regional priority project narratives and information on the identification process can be found in the Plan's Appendix A: Notes/Resources.

Wetlands

Wetlands are lands where saturation with water is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the soil and on its surface (Cowardin et. al., 1992). Wetlands serve a number of important functions within a watershed, including sediment trapping, chemical detoxification, nutrient removal, flood protection, shoreline stabilization, ground water recharge, stream flow maintenance, and wildlife and fisheries habitat. Numerous federal and state laws affect the use and protection of wetlands. Because no single one of these laws was specifically designed as a comprehensive policy for wetlands management, understanding how and when the various laws and levels of regulation apply can be somewhat confusing.

The principal federal laws that regulate activities in wetlands are Sections 404 and 401 of the Clean Water Act, and Section 10 of the Rivers and Harbors Act. Wetlands, as defined under the Federal Clean Water Act, are: "…those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions" ("Clean Water Act", n.d.).

In 1986, the Emergency Wetlands Resources Act mandated that the US Fish and Wildlife Service complete the mapping and digitizing of the Nation's wetlands. The result is the Wetlands Geospatial Data Layer of the National Spatial Data Infrastructure. This digital data provides highly-detailed information on freshwater wetlands and ponds with numerous classifications and sub-classifications. Federal wetlands (referred to as the National Wetlands Inventory, NWI) in the Seneca Lake watershed are illustrated on Figure 20 below. An analysis of the NWI geospatial information by county is provided in Table 13.

Table 13. US Fish and Wildlife Service National Wetlands Inventory for the Seneca Lake watershed.

County	Total Acreage	*Freshwater Emergent Wetland*	*Freshwater Forested/Shrub Wetland*	*Freshwater Pond*	*Lake*	*Other*	*Riverine*
Chemung County	804.5	458.5	212.1	133.9			
Ontario County	2,042.9	298.0	1,690.5	48.6	5.7	0.2	
Schuyler County	10,234.6	1,174.2	1,900.4	317.7	6,746.2	4.1	92.0
Seneca County	22,504.2	102.8	1,127.8	60.3	21,213.4		
Yates County	18,227.2	435.0	2,078.3	178.4	15,504.3	0.6	30.8
Watershed	**53,813.5**	**2,468.5**	**7,009.0**	**738.9**	**43,469.5**	**4.8**	**122.8**

The principal New York State regulation affecting development activities in and near wetlands in the Seneca Lake watershed is the Freshwater Wetlands Act, Article 24 and Title 23 of Article 71 of the NYS Environmental Conservation Law. The NYSDEC has mapped the approximate boundaries of all freshwater wetlands of 12.4 acres or more in New York. In some cases, these maps include smaller wetlands of unusual local importance. An adjacent area of 100 feet is also protected to provide a buffer zone to the wetland (Fig. 20).

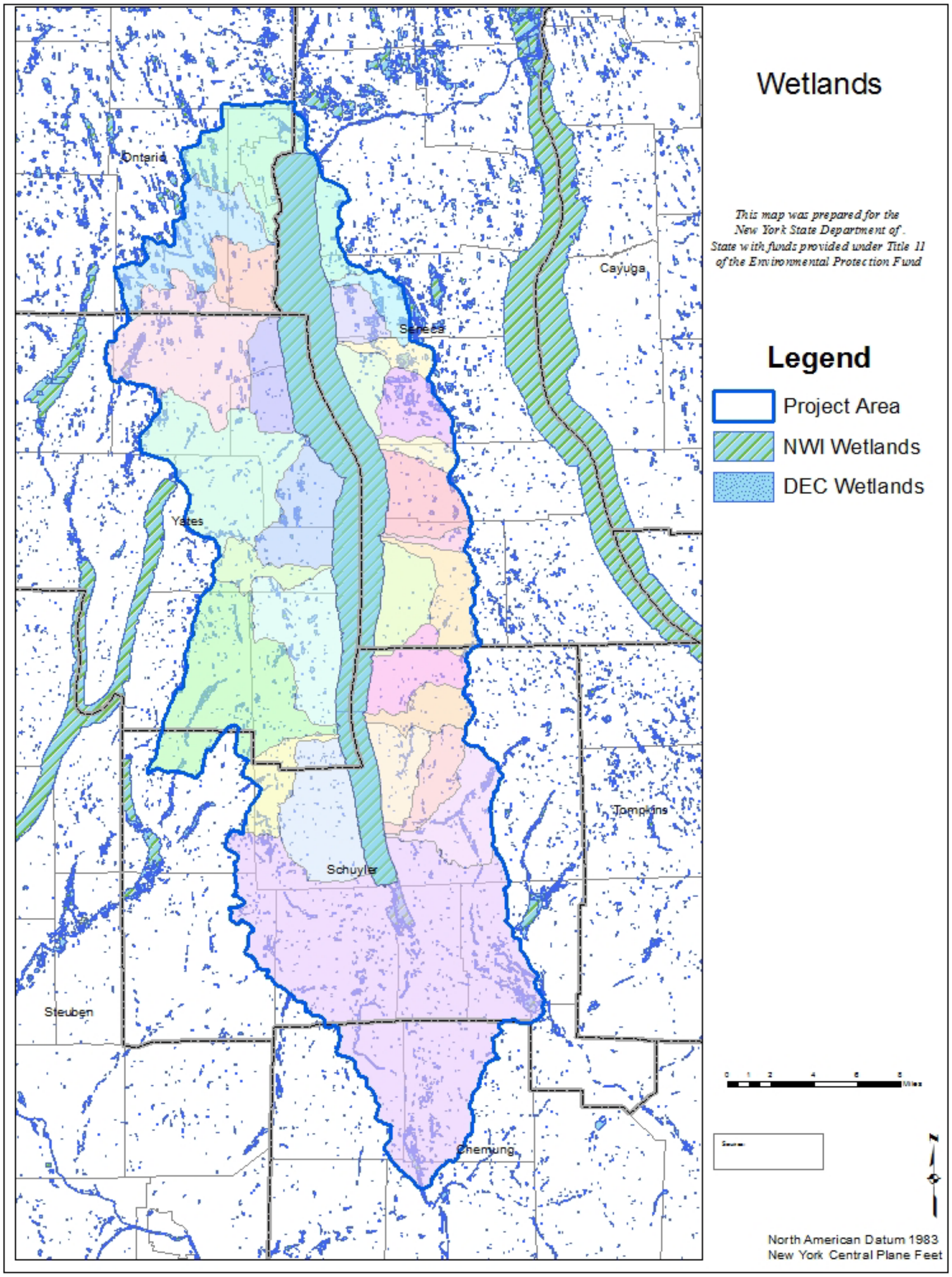


Fig. 20. Wetlands located within the Seneca Lake watershed.

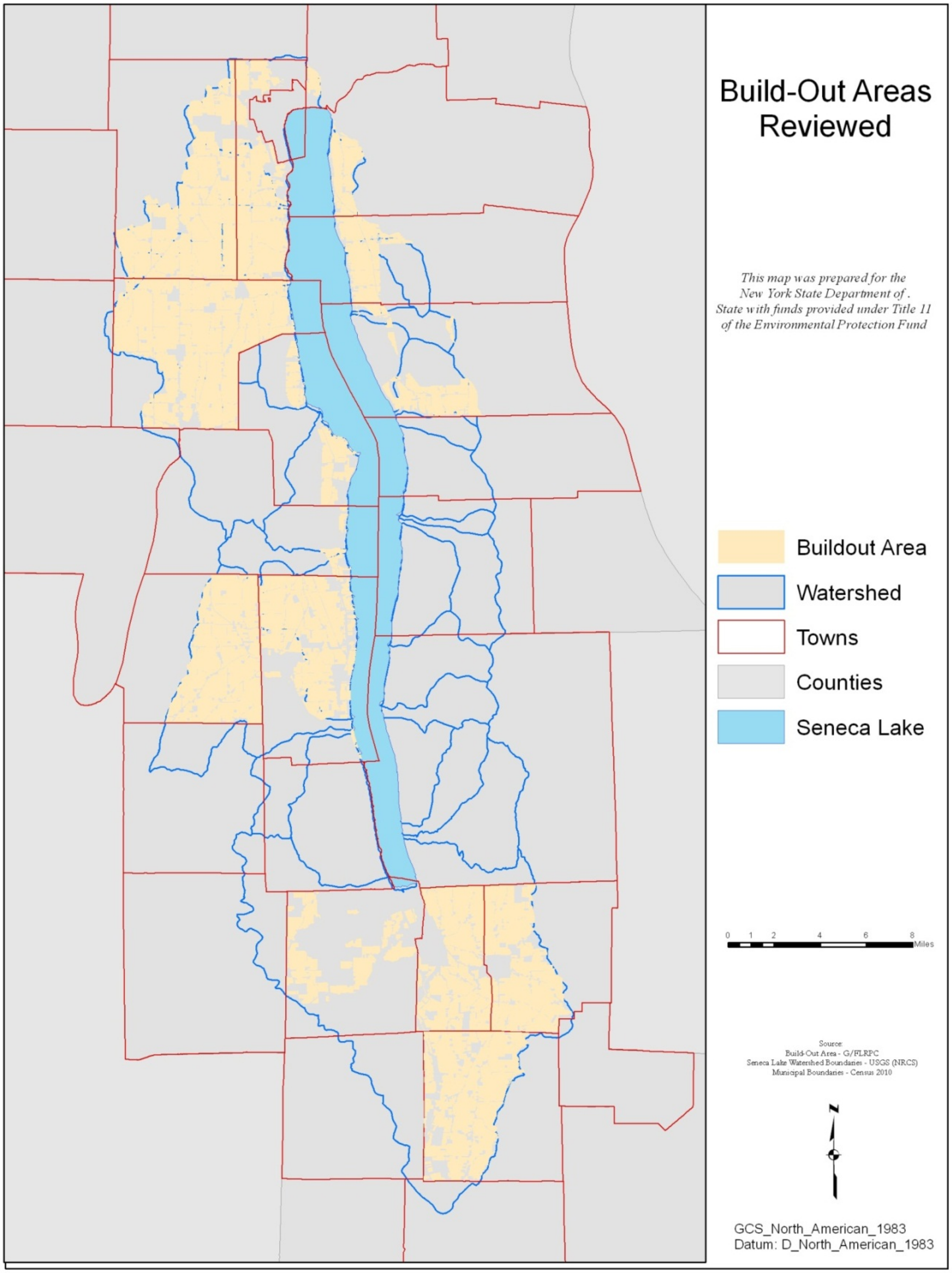
Build-out Analysis

"Build-out" refers to a hypothetical point in time when a municipality (or, more specifically, a zoning district within a municipality) cannot accommodate any more development due to the lack of additional space as dictated by local land-use regulations. Build-out scenarios are typically mathematical exercises that attempt to calculate the point in time when build-out is likely to occur given a projected rate of growth and development.

The intent of the build-out is not to generalize development as positive or negative but rather to illustrate when and where development may occur in order to consider the possible effects and plan ahead to manage these. Developments have the potential to affect water quality as well as the availability of open space and farmland among other things. The result of this analysis may indicate the need for local law review/revision to better guide development and protect local resources that are considered important.

Build-out scenarios are most accurate when they are focused on a very small area. Even when land-use, zoning and development forecasts are readily available and accurate, build-out scenarios have limited application when generalized across a large land area or multiple zoning districts.

In light of these challenges, a concentrated approach was conducted in the Seneca Lake watershed in order to focus the analysis on areas that allow, and have potential for, single family residential development in the future (Fig. 21).



Build-Out Areas Reviewed

This map was prepared for the New York State Department of . State with funds provided under Title 11 of the Environmental Protection Fund

Source:
Build-Out Area - G/FLRPC
Seneca Lake Watershed Boundaries - USGS (NRCS)
Municipal Boundaries - Census 2010

Fig. 21. Build-out areas in the Seneca Lake watershed.

In order to calculate build-out, a number of basic assumptions needed to be made. First, this model assumes that zoning laws regarding allowable uses and lot densities will remain the same over time. Next, the model requires a projected rate of growth to be assumed over time; this analysis used Census 2000-2010 municipal housing unit growth numbers as its basis for projected growth. Finally, the model should attempt to calculate or predict standardized constraints to development within a given area that would not be open to new home construction due to environmental restrictions or other physical constraints. This analysis included constraints such as areas of standing water, regulated/protected wetlands, and land that could be required for roads, parks, and other public services (see Appendix A-Notes/Resources).

Build-out Criteria

The areas considered for the build-out analysis were based on the following criteria:

- Villages were excluded - Most villages are often at or near buildable capacity, have limits to growth governed by their municipal boundaries or have significantly less developable land than towns.
- Only those zoning districts presently zoned 'residential' or 'agricultural' were analyzed.
    - While many agricultural areas in the watershed are deliberately zoned as such in order to protect and maintain agricultural uses, the model assumes that those protections may be waived by the land owner or municipality in lieu of residential development.
    - Mixed-use zoning districts were excluded as it would be nearly impossible to determine what the amount of land that would be developed in the future for each type of use.
- Towns without zoning were excluded – Towns with no zoning seldom have significant development pressure and this build-out method requires land-use regulations for its calculations.
- Only zoning districts that had access or potential access to public water or lake water were analyzed.
    - Water that is available either through public distribution or through extraction from Seneca Lake has the potential to induce faster residential growth and development.
- Only vacant residential, large lot residential or agricultural parcels equal to or larger than the minimum lot size for the zoning district were included in the analysis.

Limitations

Some limitations are apparent with this model based on the complexity of potential build-out, availability of data and the size of the watershed.

One limitation is that density of development is set based on minimum lot sizes which in turn shows the maximum number of single family homes that could fit within a zoning district. It is very difficult to predict if future development would occur at or near the minimum size. Often times lots are built much larger than minimum requirements.

One assumption regarding the availability of water can be considered a limitation. A zoning district that had a small amount of access to public water, including bulk lines, was considered to be developable throughout the entire zoning district. The assumption was made that future development could potentially tie into these lines but this may not be realistic as the decision to expand water infrastructure would have to be made along with available funding to do so. This may be most important to consider in some of the large agricultural zoning districts with little access to public water currently as it is unlikely that the whole zoning district would be connected to public water, but these areas were included in the study in order to illustrate the potential for this happening.

Build-Out Calculation

Results of the analysis are provided in Table 14. A full methodology of the build-out can be found in Appendix A- Notes/Resources.

Table 14. Estimated build-out for selected zones in the Seneca Lake watershed.

County	Municipality	Zone	Net Developable Land (acres)	Adjusted Developable Land (acres)*	Minimum Lot Size (sq. ft.)	Potential new units per zone	Potential new units per town (select zones)	Estimated unit growth per year**	Potential years until build-out occurs by zone	Potential years until build-out occurs by town (select zones)
Chemung	Veteran	RA	11,645.1	4,741.6	130,680	1,475	1,475	4.59	>100	>100
Ontario	Geneva (T)	A	6,906.3	4,017.6	45,000	3,852	6,592	9.2	>100	>100
Ontario	Geneva (T)	R1	1,451.1	917.0	15,000	2,658			>100	
Ontario	Geneva (T)	R2	48.7	28.5	15,000	82			9	
Ontario	Seneca	AG	13,926.8	***13,926.8	43,560	***444	788	2.84	>100	>100
Ontario	Seneca	R1	231.6	126.5	25,000	217			76	
Ontario	Seneca	R2	89.8	58.4	20,000	127			45	
Schuyler	Catharine	A1	8,768.6	2,723.1	87,120	1,296	1,296	-1.91	>100	>100
Schuyler	Dix	OSD	4,516.9	1,758.7	217,800	304	499	-1.68	>100	>100
Schuyler	Dix	RR-C	290.0	161.6	45,000	151			>100	
Schuyler	Dix	RR-S	138.4	88.7	80,000	44			>100	
Schuyler	Montour	RD	8,552.3	2,723.8	40,000	2,899	2,899	7.2	>100	>100
Seneca	Fayette	AR	2,108.3	1,352.3	40,000	1,467	1,467	3.4	>100	>100
Seneca	Fayette	L	26.2	8.8	40,000	9			3	
Seneca	Romulus	AG	3,250.1	1,970.4	43,560	1,950	2,213	14.99	>100	>100
Seneca	Romulus	HR	270.3	130.4	21,780	259			17	
Seneca	Romulus	LR	13.5	4.4	43,560	4			1	
Seneca	Varick	AGRR	3,232.7	2,027.3	30,492	2,889	3,001	1.9	>100	>100
Seneca	Varick	LR	123.0	78.5	30,492	112			59	
Seneca	Waterloo (T)	AG	393.6	228.7	30,000	331	331	0.52	>100	>100
Yates	Barrington	AR	11,575.4	6,083.7	43,560	5,981	5,981	10.37	>100	>100
Yates	Benton	AR1	18,368.0	11,114.0	40,000	12,048	12,986	10.77	>100	>100
Yates	Benton	ARB	1,433.1	852.5	40,000	917			85	
Yates	Benton	LR	31.7	19.7	40,000	21			2	
Yates	Milo	AMR	335.8	136.6	40,000	142	485	18.21	8	27
Yates	Milo	RR	270.8	158.6	20,000	343			19	
Yates	Starkey	A1	9,397.0	5,857.6	44,000	5,749	6,085	13.5	>100	>100
Yates	Starkey	R2	61.1	39.3	10,000	170			13	
Yates	Starkey	RR	814.4	187.7	44,000	166			12	
Yates	Torrey	AR	2,695.2	1,519.6	43,560	1,510	1,510	6.6	>100	>100

*Residential Land within watershed adjusted based on all constraints.

**Yearly average based on U.S. Census 10 year total unit growth by municipality. Estimate adjusted based on percentage of land within the watershed.

***Subdivision laws regulate in a way that would probably prevent any constraints from limiting developable land. Minimum lot sizes are 1 acre minimum but subdivision is limited to: 5-100acres - 2 lots, 100-150acres - 3 lots, 150-200acres - 4 lots, >200a

Results

As the table illustrates, most zoning districts could take over 100 years to be built-out based on current rates of growth and land-use regulations, while a few could be built-out much sooner. All five zoning districts with a potential build-out of less than 10 years and two of the four zoning districts with a build-out between 10 and 20 years were adjacent to the shoreline of Seneca Lake. Most of the nine zoning districts that could be built-out in less than 20 years had small amounts of developable land in comparison to other zoning districts, also affecting the years until built-out.

Due to the very slow residential growth in the recent past and the vast amounts of undeveloped land available in targeted municipalities, a maximum build-out scenario is unlikely to occur in the next 100 years in all towns but Milo (projected to be built-out in 27 years).

While limitations may hinder this build-out's predictions, the model is still valuable and provides several useful insights.

The result of the calculation of net acres available for residential development (see Appendix A-Notes/Resources) is very useful. These are reliable figures that can provide local officials with a very rapid assessment of a zoning district's potential for further residential development.

Much of the land considered developable is productive farmland. Many build-out models operate under the assumption that residential uses are the highest market value and could eventually consume most farmland, but this is probably not the case here. The Seneca Lake watershed's specific location and quality soil types (which cannot simply be replicated elsewhere) have an influence on the value of the land being used for agriculture. This is especially true regarding the local wine and grape industry which has seen much success and is tied heavily to the soils and micro-climate surrounding Seneca Lake.

Although it is unlikely that all or most of the farmland in the watershed focus areas will be developed, the inclusion of farmland in the build-out should not be considered a limitation. There is still the potential for agricultural land to be converted to residential, and it is important to bring attention to the possibility. The demand for productive farmland vs. residential can quickly change at the local, regional, or statewide level. Unfortunately, while the demand and value can easily change, once agricultural land is developed, the possibility of ever changing it back to productive farmland is unlikely. If communities believe that preserving farmland is a priority than this build-out can be used as a gauge to determine whether land-use regulations and practices are adequate or if they need to be expanded or revised.

Establishing better site planning and design standards and creating incentives for developers to conserve open space, farmland and natural areas could be a few ways to meet a community's demand for future growth without sacrificing environmental quality. These types of land often add value to the community and environment, but could be lost if a different use could be more profitable to the land owner. Decreasing minimum lot sizes and increasing density, mandating cluster subdivisions, conserving sensitive lands, and buffering water resources are among the tools and practices that can be incorporated directly into local law. By doing so, communities can make strides toward creating economically viable, yet environmentally sensitive development decisions. Such principles are already present in select municipalities and will be investigated in further depth in the Assessment of Local Laws, Programs and Practices Affecting Water Quality portion of the watershed management plan.

Municipalities should use the data within this analysis and seriously consider the type and amount of future growth and development that could occur and adjust land-use policies and regulations to guide the future of their communities.

Related Infrastructure

Dams

The first dam on Seneca Lake was built at Waterloo in 1828. That dam, which included four sluice gates, was replaced with the present dam and navigation lock in 1916. Before the 1916 damn was built, the lake level in Seneca Lake fluctuated more and farmers were able to raise truck crops in the wetland area on the south end of the lake, now known as Queen Catharine Marsh. Flooding in the late 1800's lead to the creation of the NYS Water Storage Committee in 1902, whose purpose was to regulate river flow and to develop hydroelectric power sources. According to historical records, the farmers at the south end of the lake were opposed to this regulation since it would raise the lake so that farming would no longer be possible. They did not prevail. The Barge Canal, successor to the Erie Canal, was completed in 1917 and opened to boat traffic in 1918.

Outflow from Seneca Lake now passes though control structures at Waterloo and Seneca Falls (Fig. 22). There is a hydroelectric plant at Waterloo and a second one along the Cayuga-Seneca Canal. The level of the lake can be regulated by controls at the outlet or a control further downstream. During the winter the lake is drawn down to prevent ice and wind damage to docks and shore structures and to provide storage for spring runoff. In the summer the lake is stabilized to take into account priority uses of the lake such as boating (so convenient dock heights are considered.) Planned winter lake levels range between 445 plus or minus 0.3 feet. Summer levels are planned 446.0 plus or minus 0.3 feet. In the 1972 flood, lake levels rose to 450 feet. Flood stage is 448 feet.

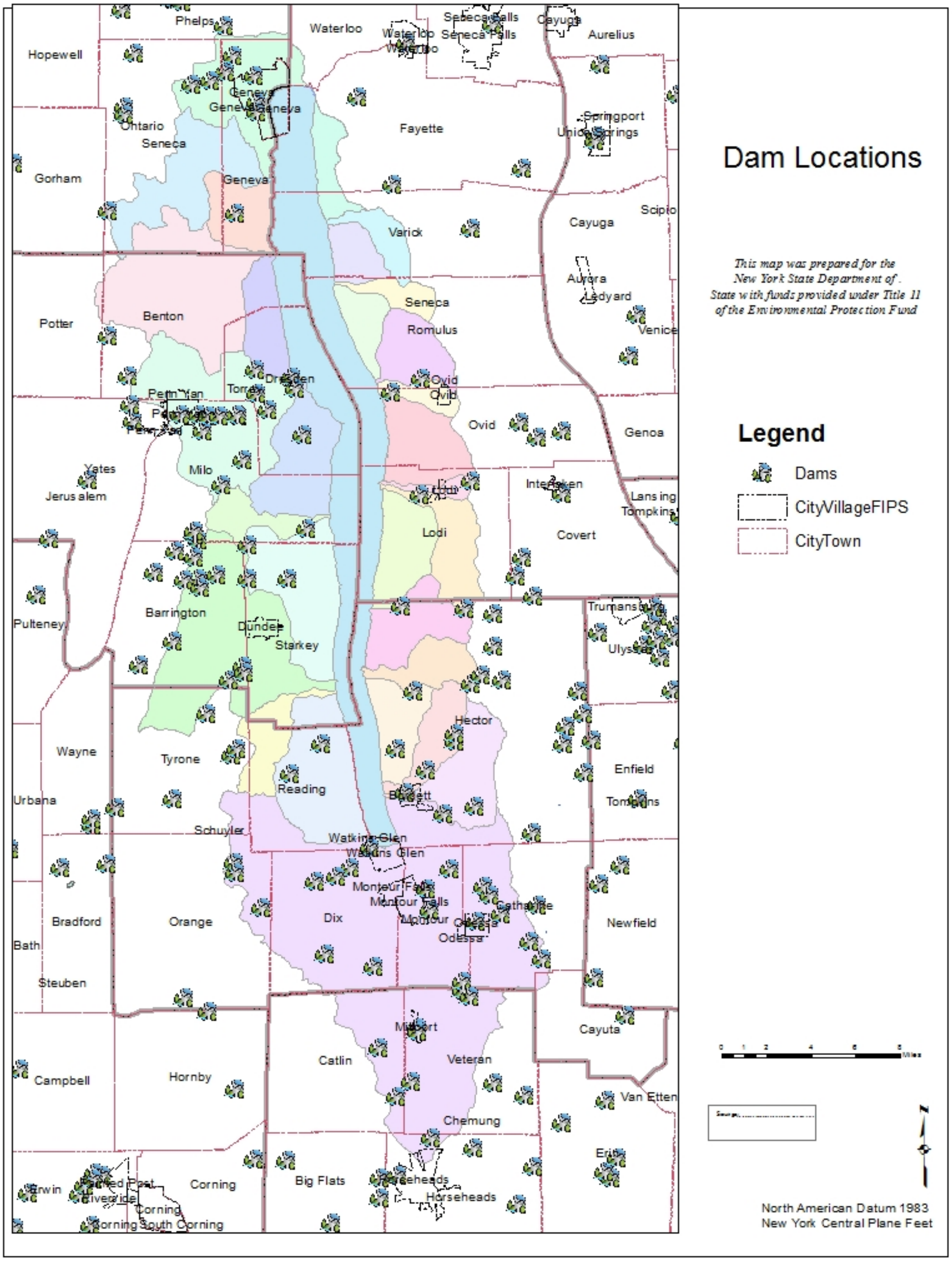


Fig. 22. Dam locations in the Seneca Lake watershed.

SPDES Permits

The State Pollutant Discharge Elimination System (SPDES) permit is a United States Environmental Protection Agency program for the control of wastewater and storm water discharge in accordance with the Clean Water Act. This program helps to control point source discharges to groundwater as well as surface water. A SPDES permit is needed for any construction activities that are using an outlet or discharge pipe that discharges wastewater into the surface or ground waters of the New York State, or for construction or operation of a disposal system such as a sewage treatment plant. According to New York State DEC, a total of 15 SPDES permits currently exist in the Seneca Lake watershed (Fig. 23).

Ontario County	2 Permits
Seneca County	3 Permits
Yates County	5 Permits
Schuyler County	4 Permits
Chemung County	1 Permit

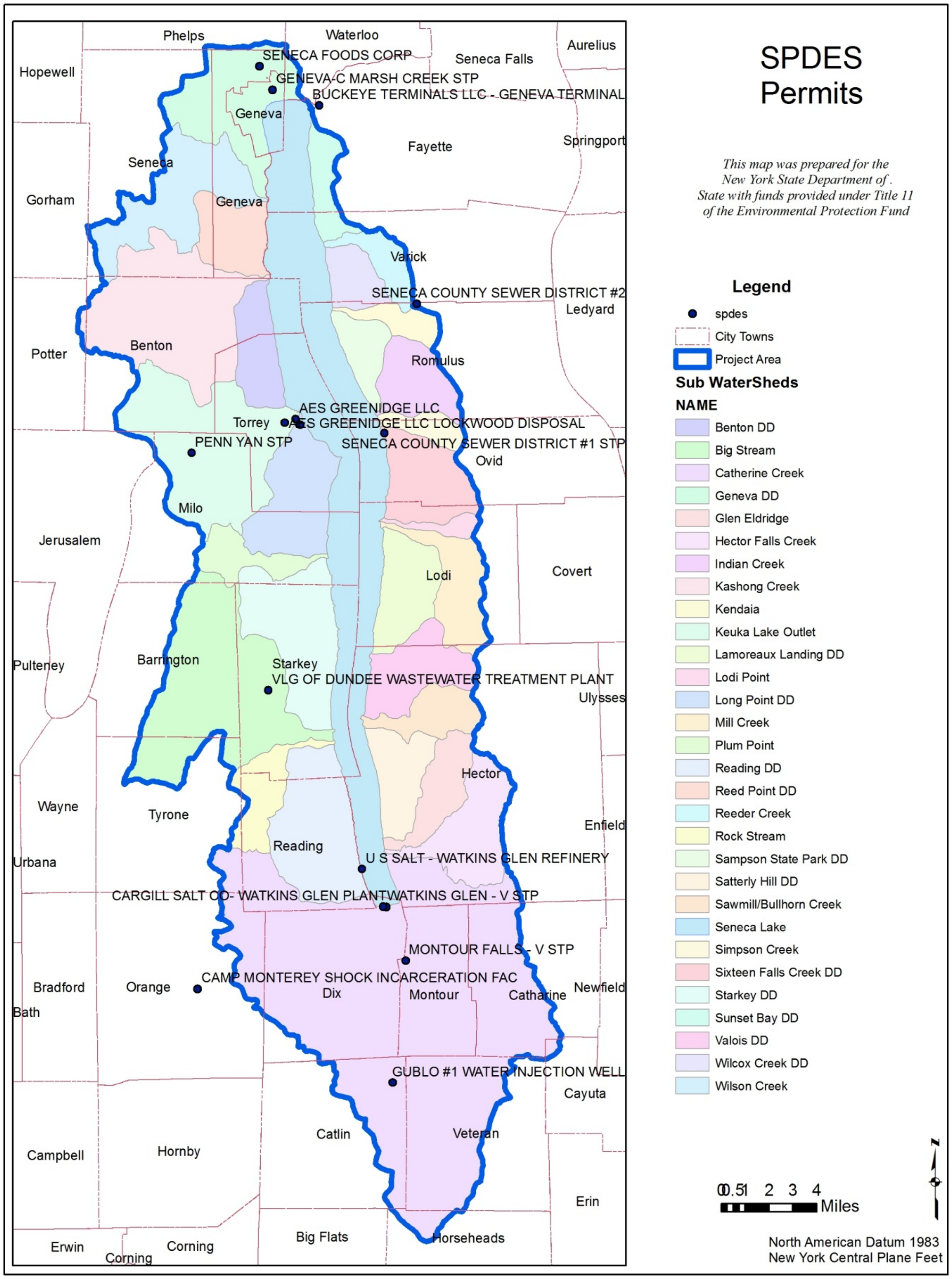


Fig. 23. SPDES permit in the Seneca Lake watershed.

Natural Gas and Marcellus Shale

Natural gas has been commercially drilled in New York State since 1821. It has been piped to towns for light, heat, and energy since the 1870s. The first storage facilities were developed in 1916. Hydraulic fracturing of vertical wells was first used in New York to develop low permeability reservoirs in the Medina Group around the 1970s-80s. Six new Trenton-Black River plays (underground reservoir rocks with fossil fuels) were discovered in 2005. There are dozens of plays across the country. Soon New York State may witness its first Marcellus Shale 'play'.

Recent advances in horizontal drilling and hydraulic fracturing have allowed extraction of natural gas from deep gas shale reserves, such as the Marcellus shale, to be economically feasible. The Utica Shale is a deeper and more expansive formation that may also have economic viability for the state. Both formations underlie the watershed. The Marcellus formation is exposed at the ground surface along the northern edge of the watershed (Fig. 9) and is found at progressive deeper depths southward towards Pennsylvania. The shale must be below approximately 3,000 ft. of overlying rock before it is a successfully play. The Marcellus is at or deeper than this depth near the southern edge of the watershed and into the southern tier.

The increased demand for cleaner energy and the proximity of these reserves to the Northeast's population hubs makes these particular 'plays' significant. There are certain financial benefits landowners may receive for leasing their land and certain economic gains a community could reap, but there will be challenges and costs that are associated to these benefits.

New York State Department of Environmental Conservation is developing the generic environmental impact statement to permit high volume hydraulic fracturing natural gas by horizontal well extraction. Many wells that are not considered high volume hydraulic fracturing wells have already been permitted. Figure 24 shows the current NYS Department of Environmental Conservation permitted natural gas wells. The developing horizontal well regulations are designed to ensure that all natural gas extraction is safe, does not significantly disrupt the natural flow of surface (or ground) water to make the hydrofracking fluids, and hydrofracking fluids will be disposed of safely as to not pollute our local water sources. This is vital in the Seneca Lake watershed as the surface and ground water is the source for Class AA drinking water for residents in the watershed. Furthermore, Seneca Lake is key to the tourism industry, and this primary economic driver would be damaged if the Lake was polluted.

The associated storage and transmission of natural gas are also under development. Petroleum industries are seeking a permit to storage liquid petroleum in the Seneca Lake natural gas storage facility located in Schuyler County, New York, and have developed two related pipelines for approximately $65 million from New York State Electric & Gas Corporation ("Salt Cavern Storage", 2012). The Watkins Glen facility has abandoned salt caverns filled with salt brine that could be used to store liquid petroleum and natural gas. This proposed use provides some concerns as the liquid petroleum or salt brine could contaminate the Lake and its watershed.

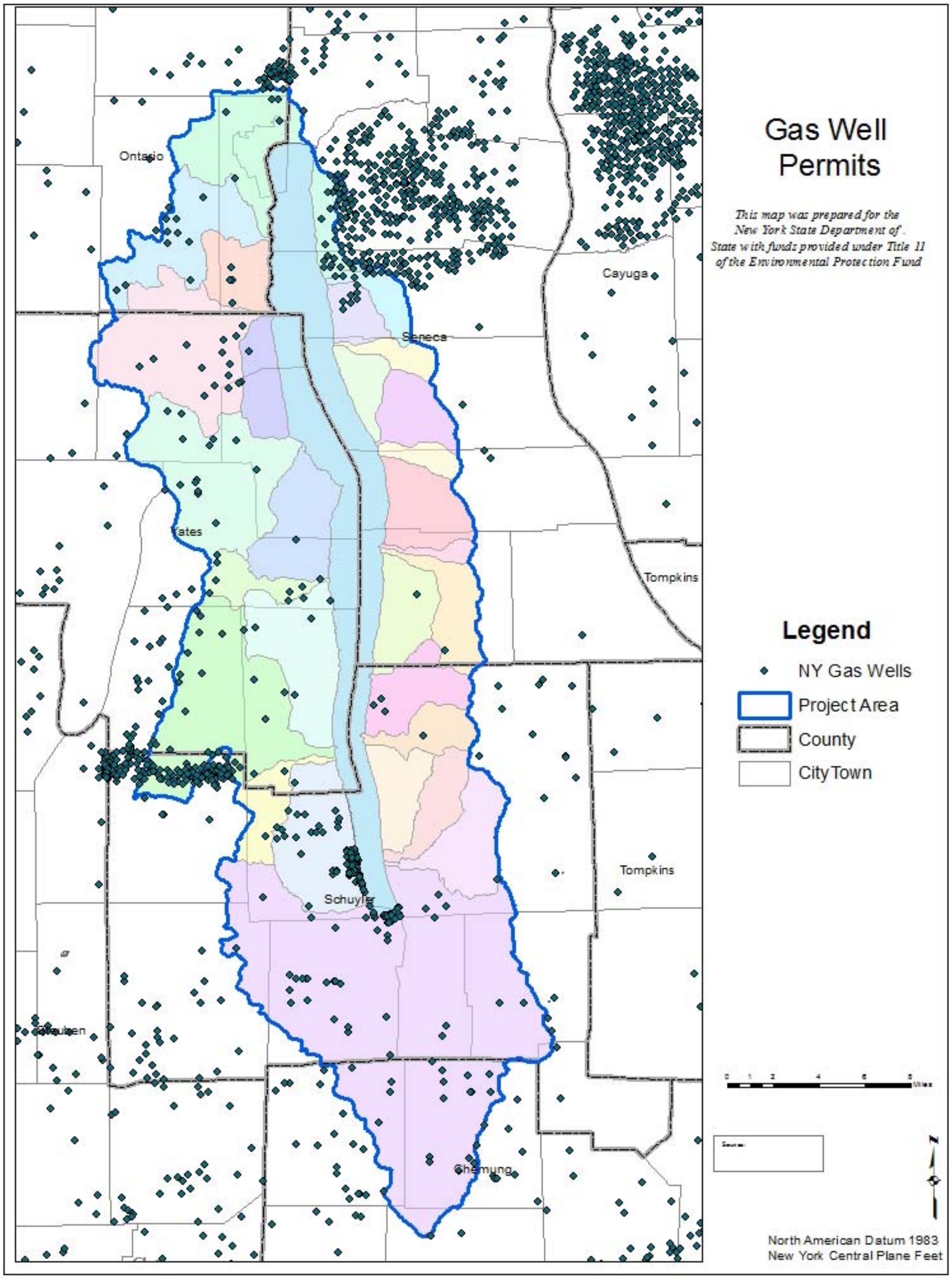


Fig. 24. Gas well permits in the Seneca Lake watershed.

Mining

The Seneca Lake watershed has 40 permitted, primarily open-pit, mine operations (Fig. 25). The most common mines are Sand and Gravel, Topsoil, Limestone and Shale primarily used in the construction industries. The southern end of Seneca Lake watershed has the most mines, with 25 mines in Schuyler County. There are a total of 40 mines permitted within the watershed boundaries. These mines are permitted though New York State Department of Environmental Conservation (NYS DEC). NYS DEC currently permits approximately 2,100 active mines throughout New York State. Due to mining reclamation laws, most mines are bonded, which preserves funds to reclaim the mine after operations cease.

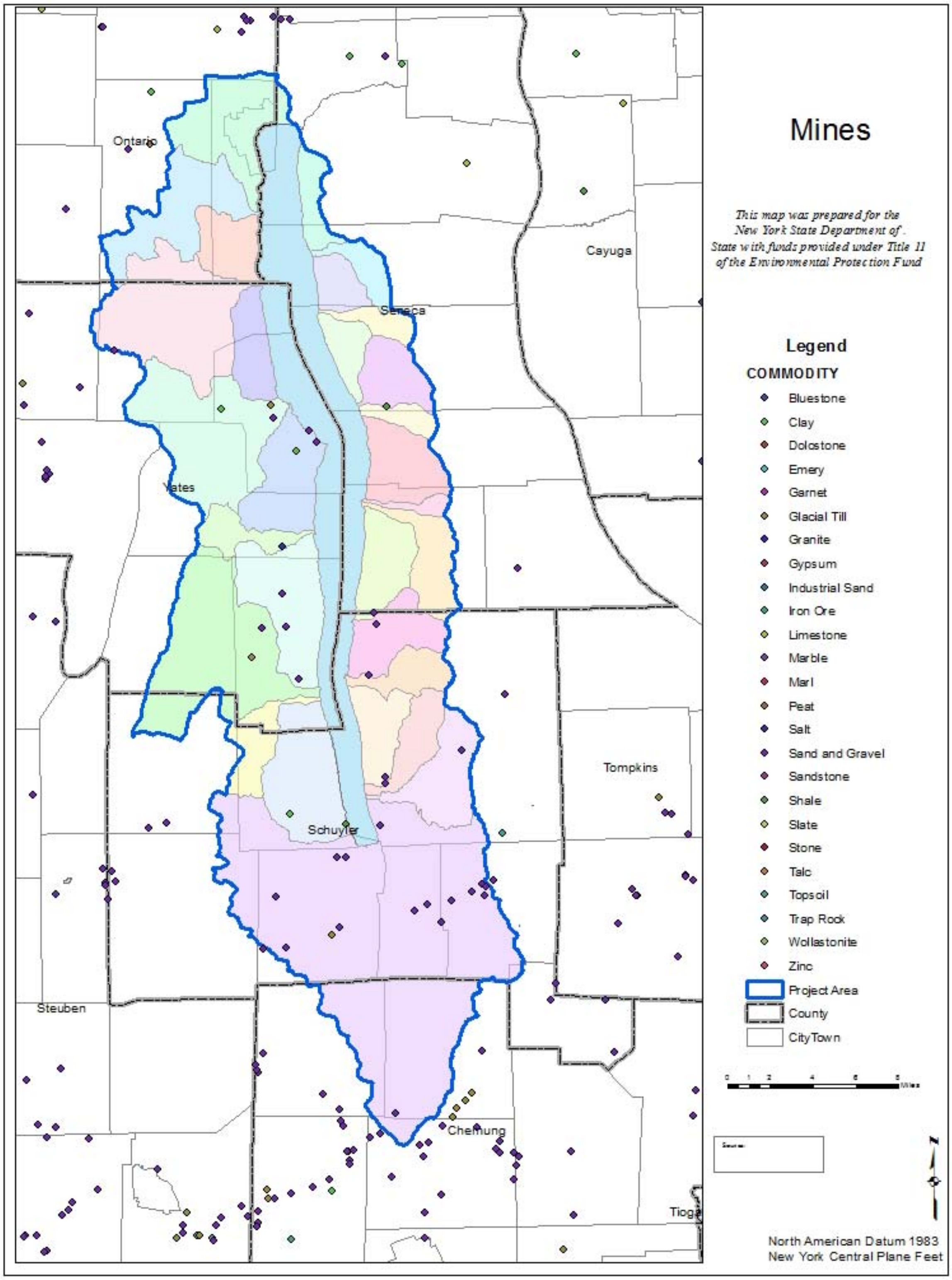


Fig. 25. Surface and subsurface mines in the Seneca Lake watershed.

Mined lands are of particular concern, as they can be a source of pollution within the Seneca Lake watershed. To mine lands, often large amounts of land are disturbed and this can increase the amount of erosion and sedimentation that can run off into nearby streams, rivers and the lake. New York State Environmental Conservation Law requires that runoff from the distributed lands be stored or detained to reduce potential for flooding, erosion, siltation and pollution. With the potential increase in natural gas extraction developments, more sand and gravel will be needed to run the natural gas pipes throughout the region. There is an expectation that sand and gravel mining will grow throughout the Seneca Lake watershed.

Surface mining provides the raw materials for consumer goods. It is the basis for many construction projects. The availability of "hydraulic" cement was as important in the success of the Erie Canal as it is to the maintenance of the New York State Thruway. Mines provided materials to improve the standard of living and the quality of life.

However, during the last five to ten years, there has been a steady decrease in the number of mines and mining applications in New York. This is because most mines produce materials used for construction aggregates, that is, crushed stone and sand and gravel. These are products that are high in volume but low in value. They must be produced close to market lest the value of transporting the material to the site of use exceeds the valued of the product itself. Depending on variables such as the cost of fuel and traffic congestion, the cost of hauling distances of thirty miles or less can be greater than the value of the material being delivered (Kelly, 2010).

DEC's Waterbody Inventory and Priority Waterbodies List (WI PWL)

The Oswego River / Finger Lakes Waterbody Inventory (WI) and Priority Waterbodies List (WI PWL) published by the New York State Department of Environmental Conservation (NYS-DEC) in 2008 divides Seneca Lake (Ont 66-12-P369) into three sections, the extreme Northern, Middle and extreme Southern, portions of the lake. The drinking water suppliers drawing directly from this waterbody include the City and Town of Geneva, the Village of Waterloo, and Village of Ovid, and all three draw from the Middle section ("Oswego River/Finger Lakes WI PWL", 2012). The NYS DEC has rates segments of the watershed that reveal the degree of severity of the water quality problem or diminished use. Minimal changes were noted from those published in the 1999 State of the Seneca Lake Watershed report (Appendix C).

Water Quality Classifications

The main lake, northern section (0705-0026), reveals no known use impairment. This segment includes the portion of the lake north of an east-west line extending from Pastime Park on the east shore to a point 0.2 miles south of the City of Geneva on the west shore. This portion of the lake is Class B(T). These results are based on NYS-DEC samples and Finger Lakes Water Quality Report (Callinan, 2001) from approximately a decade ago, thus a bit outdated. It characterizes this section of the lake as oligomesotrophic, between poorly to moderately productive. Hypolimnetic waters remain well oxygenated throughout the growing season. Recent sampling also reveals a significant decline in chloride and sodium levels (Callinan, 2001). The report further states that the lake supports a productive fishery of lake, brown and rainbow trout, landlocked salmon, perch, pike and smallmouth bass. Lake trout, brown trout and landlocked salmon have been stocked in the lake; the lake supports wild populations of the other species. Impacts to the fishery from invasive species are a threat and a concern. The sea lamprey eel first appeared in the lake in the 1960s. Control of the lamprey by chemical treatment of spawning streams has been conducted over the past 25 years and has been largely successful. Zebra and quagga mussels have arrived in the lake more recently. These filter feeding species have significantly reduced algae in the lake, especially in the late 1990s. Similarly, the fishhook water flea is a carnivorous zooplankton whose feeding on herbaceous zooplankton reduces the supply of algae to the rest of the aquatic ecosystem.

The main lake, middle section (0705-0021), reveals possible threats to water quality as it related to its use as a water supply. This segment includes the portion of the lake south of an east-west line extending from Pastime Park on the east shore to a point 0.2 miles south of the City of Geneva. The southern boundary is defined by an east-west line from the mouth of an unnamed tributary (-58) on the eastern shore to the mouth of Quarter Mile Creek (-61) on the western shore (near Salt Point, Watkins Glen). This portion of the lake is primarily Class AA(TS); the portion of the lake within an one mile radius of the mouth of Keuka lake Outlet is Class B(T). The resolution potential is high, i.e., worthy of the expenditure of available resources (time and dollars) because the level of public interest is high, and unnamed management strategies are being implemented. The water supply use of this portion of the lake may experience minor threats due to various activities in the watershed. A recent NYS Department of Health Source Water Assessment Program (SWAP), which estimates the potential for untreated drinking water sources to be impacted by contamination ad not the safety of quality of treated finished portable water, found an elevated susceptibility of contamination for this source of drinking water. Specifically, the amount of agricultural lands in the assessment area results in elevated potential for phosphorus, DBP precursors, and pesticides contamination. While there are some facilities and industries present, permitted discharges do not likely represent an important threat to source water quality based on their density in the region. However, it appears that the total amount of wastewater discharged to surface water in this area is high enough to raise the potential for contamination. Some susceptibility associated with other sources, such as landfills, was also noted (NYS-DOH, Source Water Assessment Program, 2004). The inclusion of this waterbody on the DEC/DOW Priority Waterbodies List as a threatened water is a reflection of the particular resource value reflected in this designation and the need to provide additional protection, rather than any specifically identifiable threats.

The main lake, south section (0705-0014), reveals no known use impairment. This segment includes the portion of the lake south of an east-west line extending the mouth of an unnamed tributary (-58) on the eastern shore to the mouth of Quarter Mile Creek (-61) on the western shore. This portion of the lake is Class B(T). No additional comments were reported for this section not already mentioned doe the other two sections.

The following creeks and tributaries were designated as no known use impairment: Mill Creek, Saw Mill Creek, Hector Falls Creek, Catharine Creek, Rock Stream, Big Stream Keuka Lake Outlet, and Sugar Creek. The following creeks and tributaries have not been assessed by DEC: Reeder Creek, Indian Creek, Mitchell Hollow Creek, Glen Creek, Old Barge Canal, Shequaga Creek, Upper reaches of Big Stream, Plum Point Creek, upper reaches of Sugar Creek, Wilson/Burrel Creek, and various minor creeks along Seneca and Keuka Lakes. Almost all of these assessed creeks and tributaries were classified as Class C. A few were classified as A, C(T), C(TS) or D. Class A was Johns Creek. C(T) was Cranberry Creek, and Keuka Lake Outlet. C(TS) was Sawmill Creek, Bullhorn Creek, Hector Falls Creek, Catharine Creek, Catlin Mill Creek, Glen Creek, and upper portion of Big Stream. Class D was found in the lower portion of Big Stream, and various tributaries to Keuka Lake.

The following criteria are used in order of high to low impairment:

- **Precluded (P)**: frequent and/or persistent impairment prevents all aspects of waterbody use including drinking, bathing/swimming, fish consumption, and fish propagation.
- **Impaired (I):** Occasional water quality or quantity, conditions and/or habitat characteristics periodically prevent the use of the waterbody, e.g., high coliform levels due to stormwater runoff, fish consumption advisories. Drinking water requires additional/advanced measures for treatment.
- **Stresses (S):** Waterbody uses are not significantly limited or restricted, but occasional water quality, or quantity conditions and/or associated habitat degradation periodically discourage the use of the waterbody.
- **Threatened (T):** Water quality currently supports waterbody uses and the ecosystem exhibits no obvious signs of stress, however existing or changing land use patterns may result in restricted use of ecosystem disruption (e.g., residential development). The classifications are defined below:
- **Class AA:** The best usages of Class AA waters are: a source of water supply for drinking, culinary or food processing purposes, primary and secondary contact recreations, and fishing. The waters shall be suitable for fish, shellfish, and wildlife propagation and survival. This classification of waters, if subjected to approved disinfection treatment, meet or will meet NYS Department of Health drinking water standards.
- **Class A:** The best usages of Class A waters are: a source of water supply for drinking, culinary or food processing purposes, primary and secondary contact recreations, and fishing. The waters shall be suitable for fish, shellfish, and wildlife propagation and survival. This classification of waters, if subjected to approved coagulate sedimentation, filtration and disinfection treatments, meet or will meet NYS Department of Health drinking water standards.
- **Class B:** The best use of Class B waters are primary and secondary contract recreation and fishing. The waters shall be suitable for fish, shellfish, and wildlife propagation and survival.
- **Class C:** The best use of Class C waters is fishing. The waters shall be suitable for fish, shellfish, and wildlife propagation and survival. The water quality is suitable for primary and secondary contact recreation, although other factors may limit the use for these purposes.
- **Class D:** The best use of class D waters is fishing. Due to natural conditions as intermittent flow, water conditions not conductive to propagation of game fishery, or stream bed conditions, the waters do not support fish propagation. The waters shall be suitable for fish, shellfish, and wildlife survival. The water quality is suitable for primary and secondary contact recreation, although other factors may limit the use for these purposes.
- **Class SA SB or SC:** Waters too saline for drinking, but suitable for A, shell fishing, B, primary and secondary recreation and fishing, and C, fishing.

The symbol (**T**) in the standards column in the classification means that the classified waters are trout waters. Any water quality standard, guidance value, or thermal criterion that specifically refers to trout or trout waters applies. The symbol (**TS**) distinguishes the waterbody as a trout spawning waters. Any water quality standard, guidance value, or thermal criterion that specifically refers to trout spawning or trout spawning waters applies.

Chapter 3: Watershed and Subwatershed Habitats

Habitat of Fisheries

Seneca Lake supports an important fishery for primarily lake trout *Salvelinus namaycush*, although brown trout *Salmo trutta*, Atlantic salmon *Salmo salar* and rainbow trout *Oncorhynchus mykiss*) provide added diversity to the salmonine catch. Connelly and Brown (2009) estimated that a total of 340,000 angler days occurred on Seneca Lake in 2007, making it the 8th most heavily fished waterbody in New York and the most heavily fished Finger Lake. Anglers spent an estimated $8.5 million dollars related to fishing in Seneca Lake (Connelly and Brown, 2009). Salmonine fishing accounted for about 33% of targeted effort. Seneca Lake is also known for its high quality yellow perch *Perca flavescens* fishery fishing. Smallmouth bass *Micropterus dolomieui* and northern pike *Esox lucius* fishing has historically been excellent although based on angler reports, populations appear to have recently declined.

Historically, alewives and smelt, although not native to these lakes, have provided excellent forage for predators in Seneca Lake. Recently, the smelt population has significantly declined. Potential reasons for this decline include the invasion of zebra mussels *Dreissena polymorpha* in the mid 1990's and more recently quagga mussels *D. burgensis*, and resultant impacts on the base of the food chain (Hammers et al. 2007). Additionally an increase in lake trout abundance may also have negatively impacted these forage populations (Hammers and Kosowski, 2011). Chiotti (1980) provides pre-*Dreissenid* descriptions of the ecology and biology as well as a fisheries management plan for Seneca Lake.

The native lake trout are the dominant salmonine in Seneca Lake, and the City of Geneva, located at the north end of Seneca Lake is dubbed the "Lake Trout Capital of the World". Although native to Seneca Lake, records indicate that lake trout were stocked in 1894 (Chiotti, 1980), and more consistent stocking began in the 1930's (NYS DEC stocking records, Avon). Seneca strain lake trout have been the primary source of stocked lake trout throughout the New York state as well as numerous other states. They have been highly valued throughout New York and the Great Lakes as they have been thought to be more tolerant of sea lamprey *Petromyzon marinus* attacks than other strains of lake trout. Therefore measures to ensure their continued success are warranted.

Natural recruitment of lake trout has fluctuated throughout the years. Naturally spawned lake trout were estimated to be as high as 70% of the population in the 1950's (Webster 1959) to only 5% in 1980 (Kosowski, 1980). Factors including increased predation by sea lampreys (Chiotti, 1980), degradation of spawning habitat (Sly and Widmer, 1984), possible predation by smelt (Sly and Widmer, 1984), and Early Mortality Syndrome, a result of thiamin deficiency from alewife consumption were suggested to account for this reduction. More recently, natural recruitment of lake trout has been estimated to be at least 60% of the lake population (Hammers and Kosowski, 2011), and has resulted in recent reductions in lake trout stocking. Potential reasons for this increase relate to reduced predation as the smelt population disappeared, increased spawning habitat and interstitial spaces created by *dreissenid* populations, and a reduction in EMS as alewife populations decreased (Hammers and Kosowski 2011). However, more research is needed, especially to see if *dreissenid* beds have created additional spawning habitat or have further degraded it.

Currently, rainbow trout populations in Seneca Lake are self-sustaining, relying primarily on quality tributaries such as Catharine Creek and its tributaries for both spawning and nursery habitat. However, there is growing concern from NYS DEC staff and anglers about a decrease in the rainbow trout abundance primarily during the spring spawning run in Catharine Creek (Hammers, 2011; Hammers and Kosowski, 2011). Although numerous tributaries along the lake provide spawning habitat for rainbow trout, production is limited in these tributaries because of the relatively short stream reaches due to impassible falls related to steep topography surrounding the lake. Catharine Creek and its tributaries have no such barriers and result in the production of the majority of rainbow trout in Seneca Lake. Rainbow trout were introduced in 1910 (Chiotti, 1980). Recent population declines have been linked to abundant lake predators, primarily lake trout, reduced lake forage, which provide a buffer between young rainbow trout and lake predators, and to changes in stream habitat.

Historically, Catharine Creek has been subjected to extensive manipulation by flooding, extreme fluctuations in water levels, and man induced activities, both detrimental (i.e. bulldozer activities-stream channelization, flood control improvements) and beneficial (i.e. pool diggers, log cribbing, bank stabilization) (Heacox, 1943; Hartman, 1958). Stream conditions were generally favorable for trout spawning, but warming water and lack of pools and other cover resulted in poor nursery habitat, thus rainbow trout migrated to Seneca Lake in summer months during their first year (Hartman, 1958). Extensive habitat improvement in 1950's and 60's along with increased protection of water quality and habitat through regulatory processes improved Catharine Creek as a trout nursery stream (Kosowski, 1988) as evidenced by results from the 1970's production surveys showing decent numbers of age 1+ and older trout in the late summer.

In 1996, extensive flooding followed by extreme flood control measures utilizing heavy equipment by NYS DEC emergency personnel resulted in significant damage to both spawning and nursery habitat, both manmade and natural, in Catharine Creek. This likely resulted in stream conditions similar to those described by Hartman (1958) resulting in earlier rainbow trout migrations to the lake, potentially accounting for the lower abundance of YOY and age 1+ and older trout found in recent production studies. As part of the 1996 Clean Water, Clean Air Bond Act grant program, extensive stream and bank restoration and improvements occurred in the early 2000's (Sanderson, 2000). This work included extensive bank stabilization using rip-rap, numerous pool diggers both on Catharine Creek and Sleepers Creek, and willow plantings to provide shading. These stream improvements should provide additional cover and habitat for both YOY and age 1+ and older trout hopefully delaying their return to the Seneca Lake until at least age 1+.

Negative impacts of sea lamprey on salmonine populations have been well documented in Seneca Lake (Jolliff et al., 1980, Engstrom-Heg and Kosowski, 1991). Sea lamprey control measures have been used successfully in Seneca Lake since 1982. Treatment guidelines were established by Kosowski and Hulbert (1993) based on the evaluation of a five-year experimental program using lampricides to treat Seneca Lake (Engstrom-Heg and Kosowski, 1991). Since 1982, Catharine Creek and Keuka Lake Outlet, have been treated with the lampricide TFM (3-trifluoromethyl-4'-nitrophenol) a total of nine and six times, respectively, with the most recent treatment of Catharine Creek occurring in 2011. To maintain adequate control of sea lamprey populations, stream treatments are recommended every three years (Kosowski and Hulbert 1993). The delta areas off Catharine Creek in Watkins Glen and Keuka Lake Outlet in Dresden were treated with Bayer 73 (niclosamide) in 1982 and 1986. In 2008, a 41 acre portion of the Dresden Delta in the immediate vicinity of the mouth of Keuka Outlet was treated with Bayluscide (niclosamide). Additionally, a 10 acre portion of the Catharine Creek Canal, a slow moving section immediately downstream of Catharine Creek was treated with Bayluscide in 2008. NYS DEC fishery personnel visually inspected 49 tributaries to Seneca Lake in 2006 to determine likelihood of sea lamprey spawning or nursery habitat. Only three streams had suitable habitat, however sampling yielded no ammocoetes (NYS DEC, unpublished data).

Experience gained from sea lamprey control efforts since 1982 and new methods employed in the Great Lakes and Lake Champlain sea lamprey programs provide guidance for developing specific control strategies for streams and delta areas in Seneca Lake. Increased knowledge of sea lamprey distributions and abundance, recolonization of treated areas, efficacy and longevity of control processes, assessment techniques and applicability of control techniques have contributed to the development and refinement of sea lamprey control methodologies. Sea lamprey control techniques currently under development (sterile male releases, pheromone attractants) are recognized and will be scrutinized for application to Seneca Lake if and when they become feasible for use as part of the Finger Lakes sea lamprey control program. Flexibility will be an important component of an effective sea lamprey control program because sea lamprey distribution and production are not static.

Other Habitats

Besides habitats for lake trout and other fisheries, other habitats are important for the overall ecology of the Seneca Lake watershed, and include the profundal lake floor, nearshore macrophyte beds, streams and stream corridors, wetlands and buffering lands, as well as forested shorelines in the watershed. These habitats and the native species are stressed by exotics, including the zebra and quagga mussels, Eurasian watermilfoil, *Cercopagis pengoi* and other plankton. Native populations are also on the decline. For example, benthic *Diporeia* populations are declining, and the decline is a concern because they form an important link in the food chain for lake trout and other fish species. The nearshore macrophytes form an important habitat for the growth and development of many plankton and fish species, yet can be a nuisance for lakeshore property owners. *C. pengoi*, a carnivorous zooplankton, presents a “top-down” ecologic stressor. These details are described more fully in the Lake Limnology and Stream Hydrogeochemistry chapter. Unfortunately, much less is known about streams, stream corridors and upland habitats, and wetlands and buffering lands in the watershed and should be the focus of additional research.

Chapter 4: Seneca Lake Limnology and Stream Hydrochemistry

Introduction

Since the pioneering limnological investigations by Birge and Juday (1914), and summaries by Schaffner and Olgesby (1978), only a few groups have monitored Seneca Lake and/or its watershed until 1990. The DEC included Seneca Lake in its regional survey of lakes and streams (Callinan, 2001), and has not issued a report since. Other federal, state, regional, county or local groups have investigated one or more water quality aspects but never in a systematic and extended way. For example, Dr. Dawn Dittman, USGS Cortland, systematically collected and analyzes sediment samples to assess the benthic invertebrate community. Dr. Bin Zhu, U Hartford, CT collected zebra and quagga mussels and macrophyte surveys at various locations and depths around the lake. Dr. Hank Mullins, Syracuse U., collected and analyzed sediment cores for records of environmental change preserved in the sediments. Debra Smith, Finger Lakes National Forest, has preliminary data on the benthic ecology of streams in the southeastern part of the watershed. Locally, the various municipal water providers monitor the water dispersed to their customers. Their information was included in this report when possible, but much of it is unpublished.

The most extensive collection of Seneca Lake watershed data over the past decade and since the 1999 publication of *Setting a Course for Seneca Lake – State of the Seneca Lake Watershed Report* in 1999 (Halfman, et al., 1999a, 1999b) was by researchers at Hobart and William Smith Colleges. Dr. John Halfman routinely monitors the basic limnology and hydrogeochemistry of the lake and selected tributaries. Dr. Meghan Brown investigated the biological limnology with a focus on zooplankton dynamics. Dr. Susan Cushman has preliminary information on stream macroinvertebrate and fish populations. Dr. Lisa Cleckner has preliminary heavy metal analyses on stream and lakes samples. Finally, Dr. Tara Curtin has a few sediment cores with historical organic carbon and mercury flux data. Much of the following report summarizes information compiled in a Seneca Lake volume (Halfman, 2012; Brown, 2012; Abbott and Curtin, 2012; and Cushman, 2012), and the primary source for this report. The objective of this report is to summarize new limnological and stream hydrogeochemical findings since the 1999 publication.

Seneca Lake Limnology

Physical Limnology

Hobart and William Smith Colleges has been investigating the physical limnology of the lake for the past few decades. The primary data set for these interpretations are water column profiles by CTDs and a buoyed platform. Current meter and current Doppler profiles were also collected. The thermal structure, its seasonal changes and associated lake dynamics are critical to understand in the lake because they influence the internal dynamics, which impacts, for example, distributions of algal and other organisms, concentrations of nutrients and dissolved oxygen, and other aspects of the lake.

CTD profiles have been collected from four northern sites and occasionally from nine sites distributed along the entire lake since the early 1990s and more frequently since 1996 (Fig. 26).

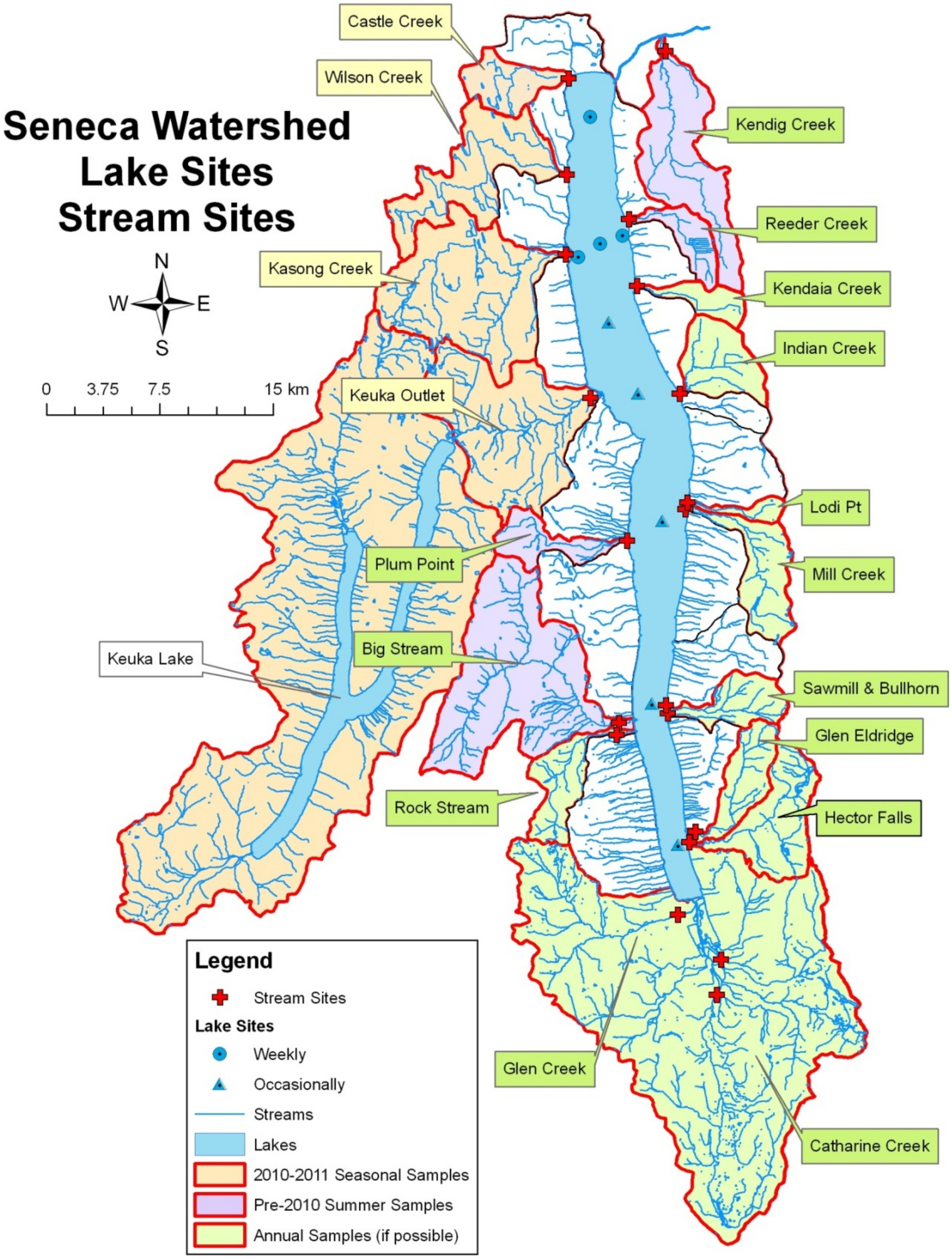


Fig. 26. Lake and stream sites for the limnological and hydrogeochemical investigations (Halfman, 2012).

Profiles were typically collected weekly during the ice free, April to November, field season but the actual frequency depended on classroom and research use. Before 2007, a SeaBird SBE-19 CTD electronically collected water column profiles of temperature, conductivity (reported as specific conductance), dissolved oxygen, pH, and light transmission (water clarity, inversely proportional to turbidity) every 0.5 m through the entire water column. In 2007, the CTD was upgraded to a SeaBird SBE-25 with additional sensors for photosynthetically active radiation (PAR), turbidity by light scattering and chlorophyll-a by fluorescence. In addition, a water quality (WQ) monitoring buoy, a YSI 6952 platform with a YSI 6600-D logger, collected two water quality profiles each day of temperature, conductivity, turbidity and fluorescence (chlorophyll) data. The WQ buoy also collected hourly averaged meteorological data including air temperature, barometric pressure, light intensity, relative humidity, wind speed and direction.

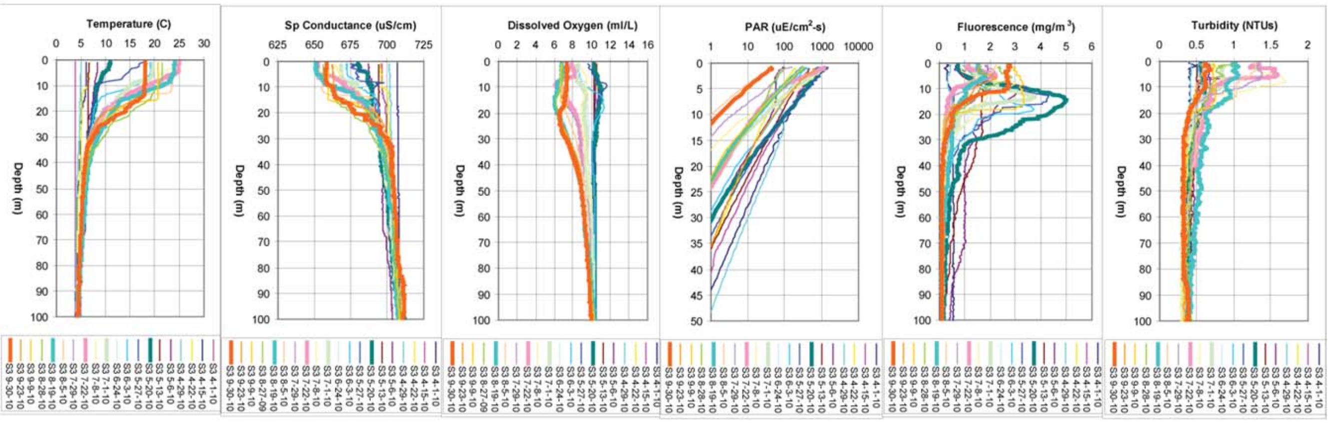
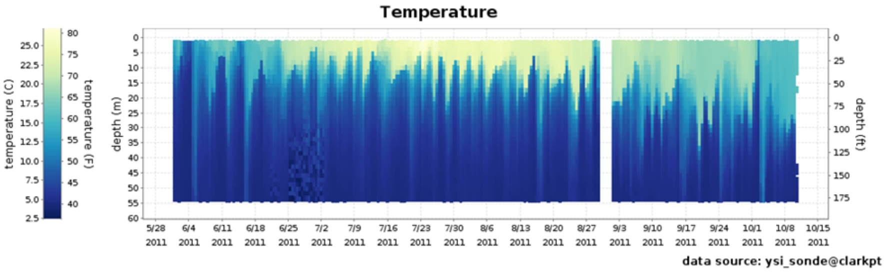


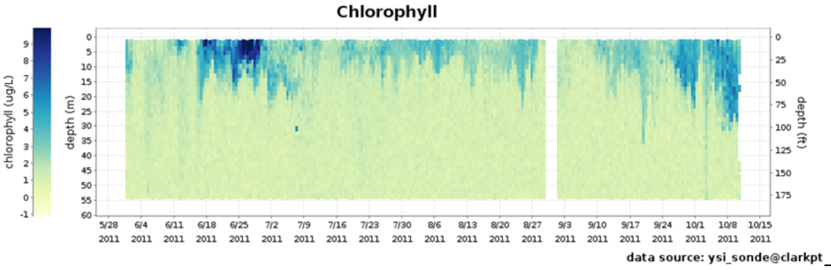
Fig. 27. Seneca Lake 2010, Site 3. Temperature, photosynthetic active radiation (PAR, light), specific conductance (salinity), dissolved oxygen, fluorescence (chlorophyll-a) and turbidity CTD profiles from 2010. This year was representative for earlier data.

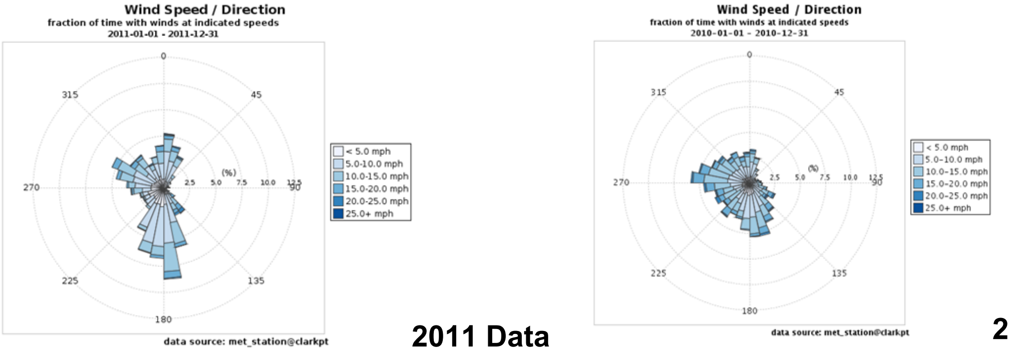
CTD temperature profiles were typical for a relatively deep lake in central New York (Fig. 27). A thermocline typically developed in early May as the epilimnion (surface waters) warmed above 4ºC in the early spring to 25ºC (or more) by mid to late summer. The thermal stratification persisted throughout the remainder of each field season as the surface waters never cooled to isothermal conditions (4ºC) by the last cruise of the year. Data was unavailable to determine if the lake is dimictic (spring and fall overturn each year) or warm monomictic (one overturn throughout the winter), however the lake has never completely frozen since 1912 and strongly suggests a monomictic lake. Surveys of the entire lake revealed consistent temperature profiles from one site to the next on any given cruise, and similar seasonal progressions through the year, except for the occasional change in the depth of the thermocline due to seiche activity.

When present, the thermocline was typically at a depth of 20 m. However, its depth oscillated vertically in response to internal seiche activity, epilimnetic mixing by storm waves, and season warming and cooling of the epilimnion. Its seasonal presence and depth are fundamental to biological, chemical and geological processes because it forms the boundary between the warmer (4 to 25°C), less-dense and sunlit epilimnion and the colder (4°C), more-dense and dark hypolimnion. The more frequent WQ buoy profiles revealed that the thermocline depth moved vertically by 10 to 15 meters on a weekly time frame (Fig. 28).



2011 Data





2011 Data **2010 Data**

Fig. 28. Seneca Lake WQ buoy contoured temperature and specific conductance data for 2011, and wind rose diagrams from 2010 and 2011. The other years revealed similar patterns (Halfman, 2012).

It suggests that wind stress sets up the thermocline for subsequent internal seiche activity. Mean thermocline depths typically result from epilimnetic mixing by wind and waves. The largest theoretical wind-generated wave height and length based on the maximum length (maximum fetch) is 2.5 m high and up to 40 m long with a mixing depth of approximately 20 meters. This depth was slightly larger than the observed deepest depth of the summertime thermocline.

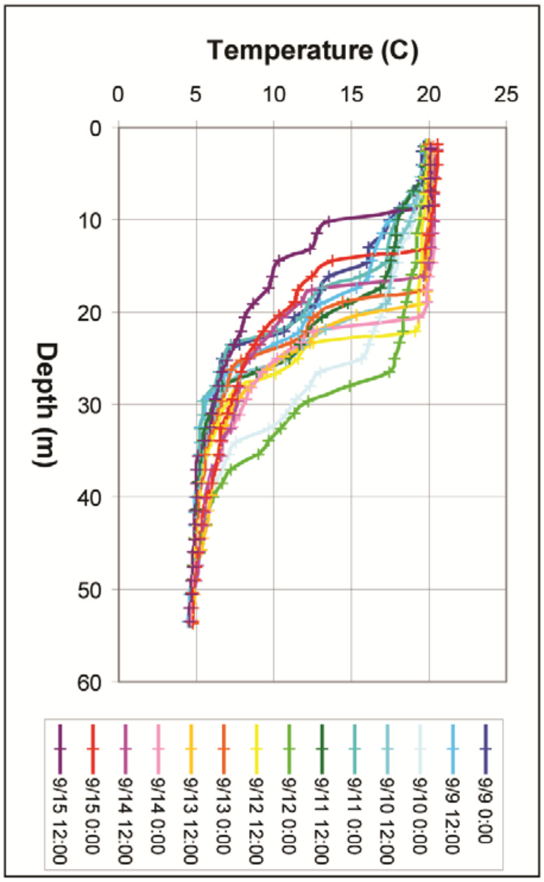


Fig. 29. WQ buoy temperature profiles form 9/9/2011 to 9/15/2011 exhibiting a ~2-day 20-m vertical oscillation of the thermocline due to internal seiche activity.

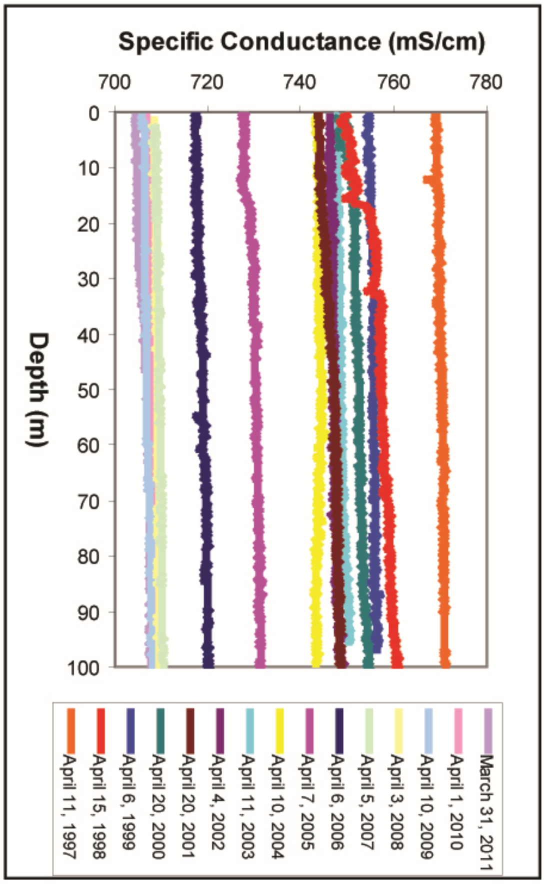


Fig. 30. 1997 to 2011 early spring, isothermal, specific conductance profiles.

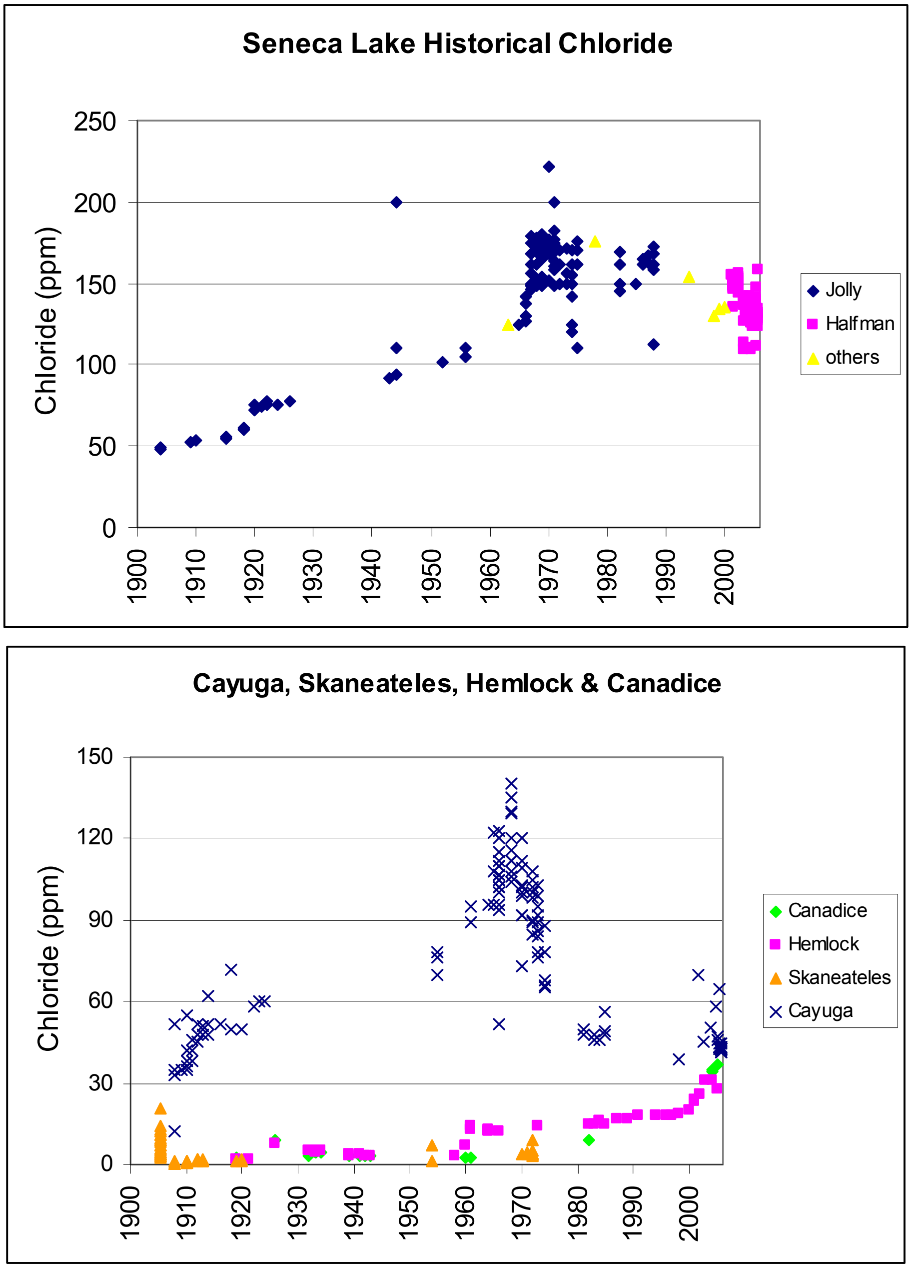
The theoretical period of the surface and internal seiche activity are 1 hour and 1.7 days, respectively, based on mean depth, maximum length and estimated thermocline depth of 20 meters, and summer temperatures for the epilimnion and hypolimnion (25 and 4°C). Lake water-level data recorded by Dr. Ahrnsbrak in the 1970s indicated a surface seiche amplitude of ~2-3 cm and period of 50-55 minutes, similar to the theoretical period. A 9/9/2011 to 9/15/2011 snapshot of the WQ buoy data revealed a thermocline that vertically oscillated with a periodicity of ~2 days (Fig. 29). Differences between theory and real-life were due to non-ideal basin geometry, friction and other factors. Currents exceeding 40 cm/s have been detected at 1 m above the lake floor in association with internal seiche activity (Ahrnsbrak, 1974; Ahrnsbrak *et al*., 1996; Laird, unpublished data). The weather instruments on the Seneca Lake buoy revealed variability from one year to the next (Fig. 28). For example, annual wind rose diagrams revealed more intense southerly winds in 2011 than 2010, thus a larger wind stress along the long axis of the lake in 2011 may precipitate more internal seiche activity. More work is required to better understand the linkages between the meteorology, heat fluxes of the dynamics in the lake.

Light is fundamental to physical and biological processes, as its availability drives the seasonal thermal structure of the lake and phytoplankton growth. CTD photosynthetic active radiation (PAR) intensities in the CTD data decreased exponentially from a few 100 to a few 1,000 μE/cm^2-s at the surface to ~1%

surface intensities at 10 to 30m depth, near the base of the epilimnion. The surface variability reflected the season and cloud cover. The 1% surface light depth typically represents the minimum amount of solar energy for algal survival, i.e., a net production of zero. The observed exponential decrease reflected the expected absorption and conversion of longer wavelengths of light (infrared, red, orange, yellow) to heat, and scattering of shorter wavelengths of light (ultraviolet, violet, blue) back to the atmosphere. Seasonal changes were observed, and light penetration was deeper in the early spring, and shallower in the summer months. The change was inversely proportional to the density of algae in the water column.

Chemical Limnology

CTD specific conductance (salinity) profiles revealed an isopycnal lake in early spring, just over 700 µS/cm (or ~0.33 ppt) in 2011 (Fig. 30; Halfman, 2012). This concentration was approximately a thousand times smaller than the maximum concentrations for safe drinking water. Specific conductance decreased in the epilimnion throughout the stratified season by ~50 µS/cm presumably until overturn in the fall of each year. The decrease was most likely influenced by the input of more dilute precipitation and associated runoff. The hypolimnion salinity remained relatively constant when stratified but decreased from one year to the next. The lake wide specific conductance decreased by ~10 µS/cm each year over the past decade (Fig. 31). The QW buoy and full-lake CTD surveys revealed similar trends (Fig. 28).


Seneca Lake Historical Chloride

Cayuga, Skaneateles, Hemlock & Canadice

Fig. 31. Historical chloride data in Seneca and Cayuga Lakes (Jolly, 2005, 2006), and in Canadice, Hemlock and Skaneateles Lakes (Sukeforth and Halfman, 2006).

The salinity of Seneca Lake was dominated by chloride (140 mg/L, Cl^-), bicarbonate (105 mg/L HCO_3^-, measured as total alkalinity), sodium (80 mg/L Na^+) and calcium (42 mg/L Ca^{2+}) with lesser amounts of sulfate (38 mg/L SO_4^{2-}), magnesium (11 mg/L Mg^{2+}) and potassium (3 mg/L K^+) (Halfman et al., 2006). The composition reflected the weathering of carbonate-rich bedrock, tills and soils. The lake was more saline than the other Finger Lake due to elevated chloride and sodium concentrations. For example, chloride and sodium concentrations are ~140 and ~80 mg/L in Seneca Lake and only ~40 and ~20 mg/L in the other Finger Lakes, respectively.

The fluvial flux of chloride and sodium to the lake was insufficient to provide the concentrations measured in Seneca, and to a lesser extent Cayuga, but was sufficient to support the chloride and sodium concentrations in neighboring Finger Lakes. Thus, a groundwater source for chloride and sodium was hypothesized to compliment fluvial sources (Wing et al., 1995, Halfman et al., 2006). The bedrock floor of Seneca, and to a lesser extent Cayuga, is deep enough to intersect the Silurian beds of commercial-grade rock salt located ~450-600 m below the surface (Mullins et al., 1996). Historical chloride data revealed two distinct century-scale patterns in the Finger Lakes (Jolly, 2005; Jolly, 2006; Sukeforth and Halfman, 2006) (Fig. 31). In Seneca, chloride concentrations were low ~40 mg/L in 1900, rose to ~170 mg/L by the 1960's, and subsequently decreased since 1980 to the present day concentration of ~120 mg/L with parallel changes in Cayuga Lake (Jolly, 2005; 2006). The decrease over the past two decades was substantiated by major ion analyses and CTD profiles (Fig. 30; Halfman, 2012). Historical chloride concentrations from Canadice, Hemlock and Skaneateles were much smaller than Seneca, and increased from below 10 mg/L to above 30 mg/L from 1920 to the present day. They were interpreted to reflect increased use of road salt on our major roadways (Sukeforth and Halfman, 2006). A groundwater source for chloride and sodium was still necessary in Seneca and Cayuga, however the flux of salt from the ground must have varied during the past century. Perhaps the historical change was dictated by an increase and subsequent decrease in solution salt mining activity at the southern end of the watershed, and would provide an interesting avenue of future research.

Mass-balance arguments indicated that sulfate also has an additional groundwater source to complement fluvial inputs, perhaps originating from the underlying gypsum-rich ($CaSO_4 \cdot H_20$), Bertie Formation. The calcium and magnesium data indicated moderately hard water in Seneca Lake. Calcium, magnesium and alkalinity concentrations were smaller in the lake than predicted by stream inputs, and were removed from the water column by the precipitation of fine-grained, calcium carbonate ($CaCO_3$) during algal bloom induced whiting events and formation of carbonate shells for *Dreissena spps.* (zebra & quagga mussels), clams, snails and other shelled animals.

The pH of Seneca Lake was consistently between 8 to 9 (Halfman, 2012). Thus, acid rain has had a minimal impact on the acidity of the lake due to the buffering capacity (i.e., the ability to neutralize acid rain acids) in this watershed. Limestone is abundant in the glacial tills and bedrock under the northern portion of the watershed, and the lake is alkaline, i.e., the water is rich in bicarbonate and other acid buffering compounds.

The epilimnetic dissolved oxygen (DO) concentrations revealed by CTD profiles decreased from the spring to summer and increased again in the fall. The seasonal progression reflected the seasonal warming and cooling of the epilimnion as DO concentrations remained saturated or nearly saturated throughout the field season. Sources of oxygen to the epilimnion include diffusion from the atmosphere and photosynthesis. Both kept the epilimnion saturated. In the hypolimnion, DO concentrations steadily decreased to from 12 to 13 mg/L (100% saturation) just after spring overturn to 6 mg/L (~40% of saturation) just below the thermocline by the end of the stratified season. Decreases in DO were only down to 10 or 11 mg/L in deeper water. Similar profiles were observed in the deeper portions of the lake on the full-lake cruises. Sinks for DO in the hypolimnion were primarily bacterial respiration, and it lacked sources like diffusion from the atmosphere and/or inputs from photosynthesis. The hypolimnetic temperature was a constant 4°C, thus had no influence on the summer season decline in DO. Seneca Lake was apparently large enough and respiratory needs small enough to restrict the bulk of the oxygen depletion to the upper hypolimnion. Over the past two decade, the maximum DO deficit in the upper hypolimnion has fluctuated between 5 and 7 mg/L (Halfman, 2012).

Biological Limnology

A basic limnological primer for temperate, deep lakes is required to understand the implications of this section, and starts with the thermal control on basic biological processes. Isothermal conditions during spring overturn mix essential nutrients, phosphates and nitrates, uniformly throughout the water column. Add sunlight, and phytoplankton (algae) bloom, i.e., initiate sustained growth just as the lake becomes stratified, as it helps keep algae in the sunlit epilimnion. Summer stratification however isolates photosynthesis to the epilimnion and nutrients become scarce due to algal uptake. Nutrients are instead replenished in the hypolimnion (dark, colder, more dense, bottom waters) by bacterial decomposition (respiration) over time. The nutrient scarcity in the epilimnion reduces algal populations. Predation by herbaceous zooplankton also keeps algal populations in check. Algal populations typically remain small through the summer until another bloom during the thermal decay of the epilimnion during the fall and mixing of hypolimnetic nutrients into the sunlight. Nutrient loading by tributaries, internal seiche activity, waves and currents, upwelling and other events can also introduce nutrients to the epilimnion and stimulate algal blooms. Reduced light limits algal growth in the winter.

Manipulating nutrients and light is not the only means to induce algal blooms. Zooplanktivorous fish like alewife and/or carnivorous zooplankton like *Cercopagis pengoi* the fishhook water flea can induce algal blooms as well (Brown, 2012). Their predation on herbaceous zooplankton reduces zooplankton predation on algae. Thus, both “bottom up” nutrient loading and “top down” predation on herbaceous zooplankton can stimulate algal blooms and decrease water quality.

The following is a compilation of open water limnological data, including CTD fluorometer profiles, secchi disk depths, and surface and bottom water concentrations of chlorophyll-a, nutrients, including total phosphate (TP), dissolved phosphate (SRP) and nitrate, and total suspended solids (TSS). Water samples were analyzed by standard limnological techniques (Wetzel and Likens, 2000). Additional information on the plant and animal communities in the lake comes from plankton tows (e.g., Brown, 2012), nearshore benthic sampling for macrophytes (Zhu, 2009) and deep water dredging for benthic invertebrates (Shelley et al., 2003; Zhu, unpublished data; Dittman, unpublished data).

Open-Water Limnology: Phytoplankton biomass, as detected by the CTD fluorescence profiles, were found throughout the epilimnion and occasionally extended into the metalimnion of the lake. Algal peak concentrations were up to 7 or 8 μg/L during algal blooms, and peaks were typically located 5 to 20 m below the water’s surface. The peak depth typically rose and fell with light availability (i.e., algal density), and depth or absence of the thermocline. The hypolimnion rarely had any algae (< 0.5 μg/L), as expected because it was too dark for photosynthesis.

The fluorometer data collected by the WQ buoy revealed spring and fall phytoplankton blooms and associated with the onset and decay of the summer stratification season (Fig. 27). Additional blooms were detected mid-summer during the stratified season. Some of these mid-summer blooms may be related to the “bottom up” inputs of nutrients, especially growth limiting phosphates, by major runoff events, and/or mixing of hypolimnetic waters into the epilimnion by the internal seiche activity (e.g., Baldwin, 2002). The blooms may also be related to the reduction of herbaceous zooplankton by “top down” ecological stressors like *C. pengoi*, and/or zooplanktivorous fish.

The open-lake limnological data are not life threatening as nitrate concentrations were below the 10 mg/L MCL and phosphate concentrations below NYS DEC's 20 µg/L threshold for impaired water bodies (Table 15, Fig. 32). An epilimnion to hypolimnion increase in nutrient concentrations and decrease in chlorophyll-a concentrations over the stratified season reflected a normal seasonal progression of the algal uptake and removal of nutrients in the epilimnion, and algal decomposition and nutrient release by bacteria in the hypolimnion. P:N ratios in the water column averaged 1:160 over the past decade. The P:N ratio required by phytoplankton is 1:7 (Redfield Ratio), so the significantly larger Seneca Lake ratio dictated that phosphate, not nitrate, was the limiting nutrient in a lake, like most of the other Finger Lakes. It also implies that additional inputs of phosphate from the watershed or atmosphere should stimulate algal growth and move the lake to a more productivity system with declining water quality.

Table 15. Annual Mean Chlorophyll and Nutrient Data (2000-2011 Average).

	Secchi Depth	**Chlorophyll**	**Total Phosphate**	**Phosphate, SRP**	**Nitrate**	**TSS**
	(m)	(µg/L)	(µg/L, P)	(µg/L, P)	(mg/L, N)	(mg/L)
Surface	6.3	2.3	9.7	1.4	0.4	1.1
Bottom	N/A	0.7	9.7	2.6	0.4	0.7

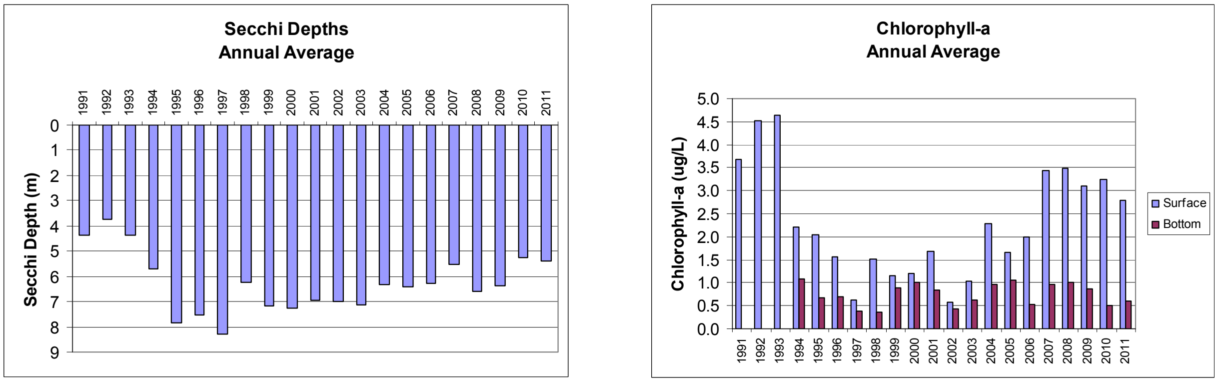


Fig. 32. Annual mean secchi disk depths and surface and bottom water chlorophyll-a data (Halfman, 2012).

Significant decade-scale changes were observed in secchi disk depths and chlorophyll concentrations of Seneca Lake (Halfman and Franklin, 2007; Halfman, 2012, Fig. 32). The data divided into two primary, decade-scale trends: from 1992 to 1997, and 1998 to 2011. Annual average secchi disc depths became progressively deeper from 3 to 4 m in the early 1990's to 7 to 8 m by the end of 1997, and since then decreased to nearly 5 m by 2011. Chlorophyll-a concentrations decreased from an annual average of ~4.5 µg/L in the early 1990's to 0.6 µg/L by 1997, and then steadily increased to 2.5 to 3.5 µg/L by 2010 and 2011 with a deviation to larger concentrations, up to 3 to 4 µg/L, in 2007.

The 1992 through 1997 trends were consistent with increased grazing by the growing population of filter-feeding zebra mussels in the early 1990's (Halfman et al., 2001; Halfman and Franklin, 2007) and consistent with findings elsewhere (e.g., Strayer, 2010). Zebra mussels were first detected in 1992, and successfully colonized Seneca Lake within a few years. The introduction and establishment had implications on the limnology of the lake by decreasing algal concentrations and sequestering nutrients in their live biomass. Fewer nutrients reinforced declining algal biomass. Unfortunately, zebra mussel densities were not consistently measured over this time frame to confirm this hypothesis.

The trend reversed after the initial major die off of zebra mussels in 1998. The die off and associated bacterial decomposition of the mussel biomass released the previously sequestered nutrients back into the water column during 1998 and 1999, as reflected in increasing TP, N, SRP and algal concentrations and decreasing secchi disk depths. The lake became progressively more impaired since, as shown by shallower secchi dish depths and larger chlorophyll concentrations (Hoering and Halfman, 2010; Halfman and Franklin, 2008; Halfman et al., 2010).

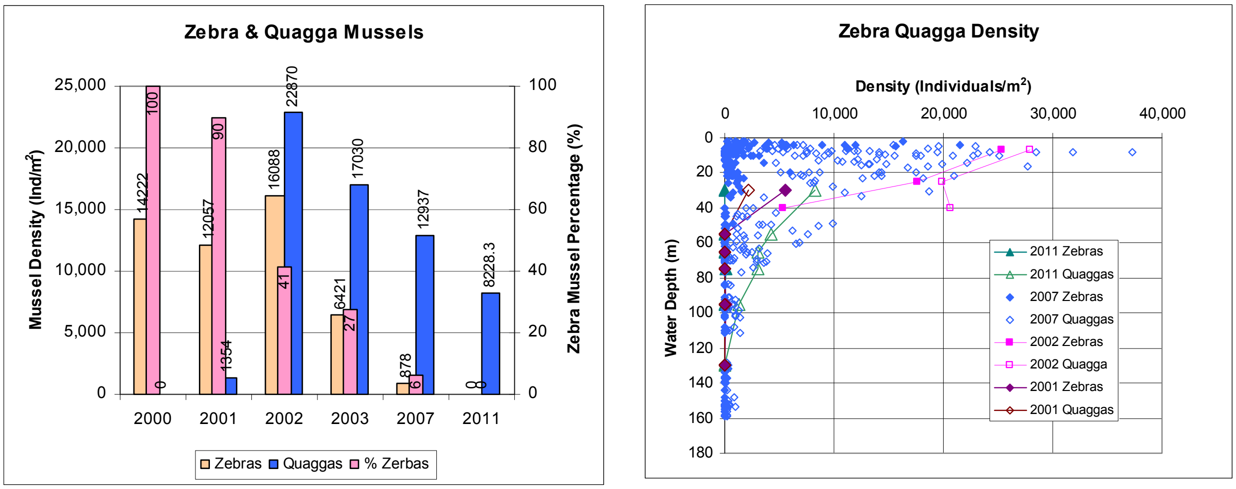


Fig. 33. Zebra and quagga mussel populations from 10 to 40 meters (left) and depth distributions (right) over the past decade (B Zhu ‘07, B Shelley ‘02, D Dittman ‘01 & ‘11, Geo-330 class data ‘00, ‘01, ‘03, unpublished data, Shelley et al., 2003). The 2001 to 2011 data exhibited a significant increase in quagga mussel densities at depths below 40 m (D Dittman, unpublished data).

Various factors contributed to the decline in water quality over the past decade. First, the available data suggest that both zebra and quagga mussel populations declined since 2002 (B Zhu, unpublished data; D. Dittman, unpublished data; Shelley et al., 2003, Fig. 33). Zebra mussels posted the largest decline, from 100% to 0% of the total mussel population between 10 and 40 meters of water from 2000 to 2011. Thus, the mussel impact on and reduction of the algal populations probably decreased as well. Unfortunately, these conclusions are speculative at this time because the data were collected from a variety of water depths and site locations, and mussel densities are depth and site sensitive (Fig. 33). Second, nutrient loading could have stimulated algal growth and decreased secchi disk depths. The stream hydrogeochemistry and the phosphorus budget sections below highlight the nutrient loading issue (Halfman, 2012). Finally, “top down” predation pressures on herbaceous zooplankton would promote summertime blooms and a decline in water quality. For more details on “top down” pressures, see the zooplankton section below and more details in Brown (2012).

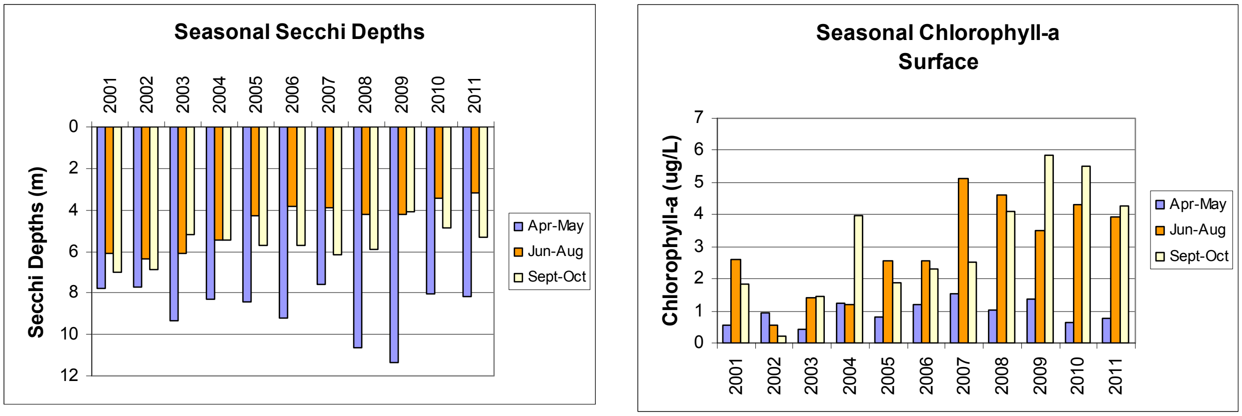


Fig. 34. Seasonal variability in secchi disk and chlorophyll data from 2001 through 2011 (from Halfman, 2012).

Seasonal patterns in the limnology of the lake were also observed (Fig. 34). Secchi disk depths became progressively deeper from 2001 to 2011 in the early spring but were progressively shallower in the summer and fall. Parallel trends were also detected in the chlorophyll, TSS and SRP data, e.g., smaller algal concentrations in the spring but progressive larger algal concentrations in the summer and the fall. The exact reasons for the increased water clarity in the spring were unclear but were perhaps related to mussels grazing and light limitations as both limit algal growth and their impact on nutrient concentrations in the near isothermal spring. Finally, shallow secchi depths and larger chlorophyll concentrations in the summer and fall were critical to the overall change in the annual concentrations over the past decade.

Trophic Status: Nutrient concentrations, algal concentrations, secchi disk depths and dissolved oxygen concentrations document the trophic status of a lake, i.e., the degree of productivity. Lakes are divided into oligotrophic (poorly productive), mesotrophic (intermediate) to eutrophic (highly productive) systems which parallels water quality using secchi disk depths, and concentrations of chlorophyll-a, total nitrogen, total phosphate, and hypolimnetic dissolved oxygen (Table 16).

Table 16. Oligotrophic, Mesotrophic and Eutrophic Indicator Concentrations (EPA).

Trophic Status	Secchi Depth (m)	Total Nitrogen (N, mg/L, ppm)	Total Phosphate (P, µg/L, ppb)	Chlorophyll a (µg/L, ppb)	Oxygen (% saturation)
Oligotrophic	> 4	< 2	< 10	< 4	> 80
Mesotrophic	2 to 4	2 to 5	10 to 20	4 to 10	10 to 80
Eutrophic	< 2	> 5	> 20 (> 30)	> 10	< 10

In Seneca Lake, 2011 annual mean total phosphate concentrations and hypolimnetic oxygen saturation data were within the mesotrophic range however, secchi disk depths, chlorophyll and nitrate concentrations were oligotrophic (Table 15) even after adding estimated nitrogen from the particulate organic matter to the nitrate concentrations. In 2007 and earlier, all of the parameters were in the oligotrophic range, although some were near the oligotrophic-mesotrophic cutoff. Thus, Seneca Lake has migrated from an oligotrophic to borderline oligotrophic-mesotrophic lake, and water quality has declined over the past decade.

Finger Lake Water Quality Comparison: Since 2005, the Finger Lakes Institute, under the direction of Dr. Halfman, has maintained a water quality monitoring program for the eight eastern Finger Lakes: Honeoye, Canandaigua, Keuka, Seneca, Cayuga, Owasco, Skaneateles, and Otisco (added in 2008). The survey collected and compared CTD profiles, secchi disk depths, plankton tows, and the analysis of surface water samples from at least two open water sites in each lake. The water samples were analyzed for chlorophyll-a, total phosphate, soluble reactive phosphate, nitrate and total suspended solids following standard limnological techniques. Annual ranks were calculated from the annual average water quality data. For each parameter and subsequently for the overall annual rank, the worst lake is set at 8, the best at 1, and the remaining six proportionally in between these end members. Seneca Lake water quality was still one of the worst, and only slightly better than the ranks calculated for Honeoye, Cayuga, Owasco and Otisco (Fig. 35). The other three lakes, Canandaigua, Keuka and Skaneateles, consistently exhibited the best water quality of the group. Lake to lake and year to year differences in water quality were due to the degree of water quality protection, the percentage of agricultural land, the amount of precipitation and other factors in each watershed (e.g., Bush, 2006; Halfman and Bush, 2006; Halfman et al., 2011). Other stressors like human population density, watershed size and watershed size to volume ratio, exhibited minimal correlations (Halfman and O'Neill, 2009).

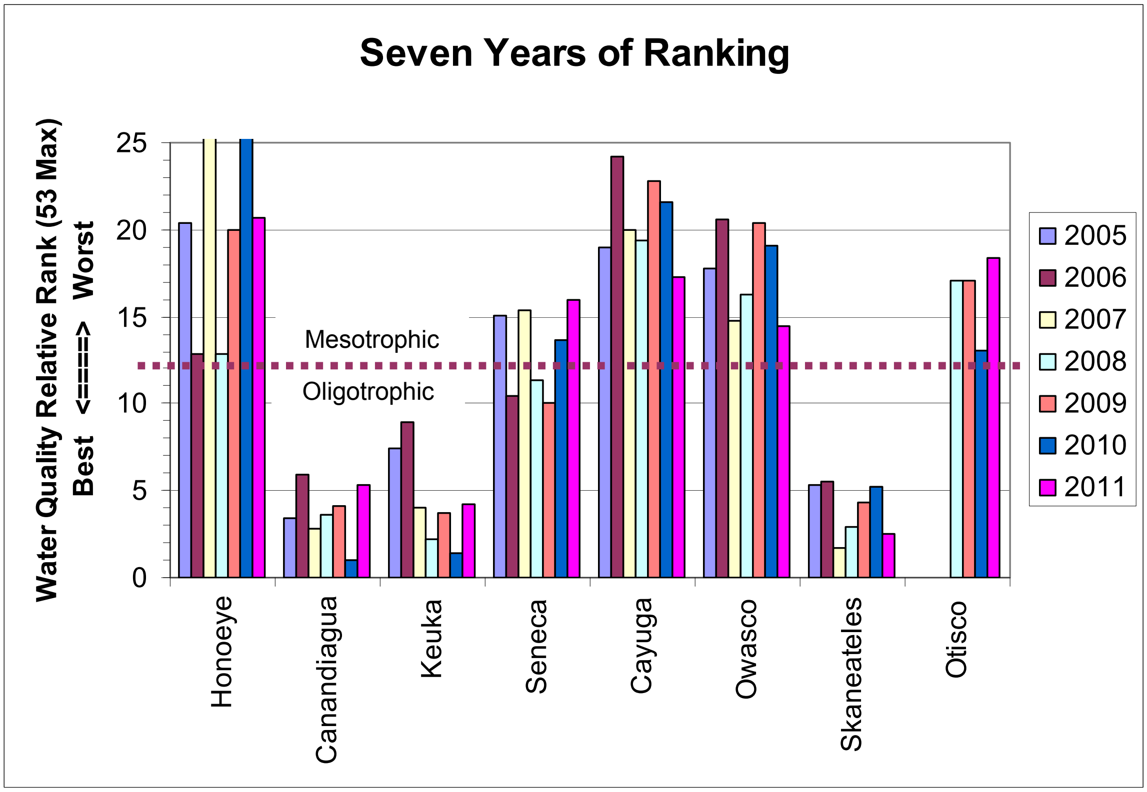


Fig. 35. Annual water quality ranks for the eight easternmost Finger Lakes. The dashed purple line is the boundary between oligotrophic and mesotrophic lakes converted to the Finger Lake "ranking" systems (Halfman et al., 2012).

Phytoplankton: Phytoplankton are the base of the aquatic food web, and the driver for water clarity, transparency, and quality issues. They were collected at each site through an 85 μm mesh, 0.2 m diameter opening net, horizontally along the surface and vertically integrating the upper 20 m, preserved in a formalin/Ethanol mixture, and the first 100 to 200 identified to genus, or species level when possible. Over the past decade, annual average abundances were dominated by the diatoms *Asterionella* (25%), *Tabellaria* (5%), *Diatoma* (13%), and *Flagillaria* (13%), and during the early part of the decade by dinoflagellates *Dinobryon* (2%) and *Ceratium* (2%). The seasonal succession typically moved from *Asterionella* (>50%) to *Tabellaria* & *Diatoma* (>50%) to *Flagillaria*, *Diatoma*, *Dinobryon* & *Ceratium* (>50%) to *Flagillaria* (>50%). Over the past decade, fewer dinoflagellates were detected in the tows (annual averages decreased from 10% to less than 1%). *Tabellaria* was less prevalent than *Diatoma* starting in 2006 through 2010 but returned in 2011. Quagga mussel larvae were first detected in 2004 (Table 17).

Table 17. Mean annual plankton abundance from near surface tows in Seneca Lake.

Diatoms	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**Average**
Fragilaria	13.7	14.5	12.5	15.1	13.9	10.8	5.3	19.0	13.2	9.7	11.0	12.6
Tabellaria	1.9	5.1	20.2	7.5	11.7	0.0	0.1	0.3	0.2	0.2	6.5	4.9
Diatoma	0.0	0.0	0.0	0.0	0.0	29.4	34.5	11.3	21.7	26.2	21.5	13.1
Asterionella	43.8	15.4	35.2	25.8	29.0	29.1	21.8	15.1	26.0	21.0	17.9	25.5
Synedra	2.4	8.3	2.7	1.9	0.8	2.7	2.7	14.7	0.7	1.1	2.6	3.7
Cymbella	2.0	0.4	0.3	0.1	0.0	0.0	0.1	0.1	0.1	0.3	0.2	0.3
Stephanodiscus	0.3	0.4	0.2	0.7	0.2	0.1	0.9	0.3	0.0	0.3	0.4	0.4
Cocconeis	0.0	0.0	0.5	1.1	0.5	0.7	0.6	1.5	0.2	0.7	0.7	0.6
Melosira	0.0	0.0	0.0	0.0	0.0	0.9	0.1	0.3	0.0	0.1	0.8	0.2
Rhoicosphenia	0.0	0.0	0.0	0.0	0.0	1.7	0.4	2.4	5.8	0.8	0.5	1.1
Other Diatom	2.0	3.2	0.1	0.6	4.7	0.5	1.3	0.9	0.0	0.4	0.3	1.3
Dinoflagellates												
Chrysosphaerella	0.0	0.3	0.1	5.7	0.1	0.0	0.0	0.8	0.0	0.1	0.0	0.6
Dinobryon	1.7	8.9	4.0	2.6	2.0	1.7	0.9	1.2	0.8	1.0	0.0	2.3
Ceratium	11.2	5.2	1.7	0.1	0.5	0.2	0.2	0.6	0.1	0.1	0.1	1.8
Colacium	0.3	1.8	0.0	2.8	2.3	0.7	5.4	0.2	1.9	5.3	0.5	1.9
Copepods												
Copepods	0.9	1.3	1.2	3.6	7.5	0.6	0.5	4.0	2.4	1.2	4.7	2.5
Naupilus	1.2	3.4	1.3	3.1	3.7	0.9	0.4	3.9	1.4	1.1	1.6	2.0
Rotifers												
Keratella	5.0	0.6	5.5	3.1	2.9	5.7	2.3	0.8	4.9	5.2	5.3	3.7
Kellicottia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Polyarthra	0.8	1.0	0.8	1.2	2.5	1.5	1.2	5.1	0.6	0.7	1.2	1.5
Monostyla	0.9	6.8	2.1	1.4	1.7	2.7	2.2	0.3	5.1	2.5	1.5	2.5
Asplanchna	0.0	0.0	0.0	0.0	0.0	0.3	1.1	0.4	0.0	0.9	0.5	0.3
Cladocerans												
Cladocerans	1.1	3.8	1.9	0.0	1.4	1.7	6.3	1.6	1.9	4.1	4.1	2.5
Cercopagis	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.4	0.4	0.7	0.5	0.2
Other Things												
Staurastrum	0.2	0.2	0.0	0.7	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.1
Pediastrum	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.1	0.1	0.3	0.1
Anabaena	0.7	0.7	0.1	0.1	0.0	0.3	0.6	0.1	1.2	0.7	0.3	0.4
Stichosiphon	0.3	1.8	0.1	0.0	0.4	0.1	0.5	2.0	0.4	0.1	0.7	0.6
Trichodesmium	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.1
Microcystis	0.0	0.0	0.0	0.0	0.0	0.2	0.5	0.3	0.3	0.9	0.2	0.2
Chroococcus	2.9	0.4	0.2	1.7	0.2	0.3	0.3	0.0	0.1	0.2	0.9	0.7
Wolffiella	0.0	0.9	1.1	0.5	0.2	0.0	0.4	0.7	0.8	0.6	0.8	0.6
Zebra Larvae	0.2	1.0	0.2	0.2	0.2	0.4	0.1	0.3	0.2	0.2	0.1	0.3
Quagga Larvae	0.0	0.0	0.0	0.3	0.3	0.6	0.4	0.4	0.2	0.3	0.3	0.3

Zooplankton: Invertebrate animals are important members of the Seneca Lake food web. In Seneca Lake herbivorous zooplankton included members of the Cladocera (e.g., *Daphnia*, *Bosmina*), Copepoda, and Rotifera. Some invertebrates, such as the common cladoceran *Daphnia*, are considered keystone taxa because their grazing can control phytoplankton growth and nutrient cycling, and their own biomass provides an immense food source for fish (e.g., Carpenter, 1987; Kitchell, 1992).

There is a subset of invertebrate animals that are predacious and primarily prey on herbivorous zooplankton (Thorp and Covich, 2001). In Seneca Lake, predatory species of cladocerans occupy the water column and their populations can grow exponentially when lake temperatures warm in the spring and summer due to rapid asexual reproduction. These cladocerans are typically absent for the water column during the winter and are maintained in a sediment egg bank (Pennak, 1989). In contrast, the native mysid in Seneca Lake, *Mysis diluviana,* is a cold-water stenotherm that is confined to the cold-water regions of the lake and reproduces sexually (Pennak, 1989). The following examines the dominant predatory crustacean zooplankton and mysids present in offshore areas of Seneca Lake with the objectives to 1) generally characterize the species assemblage in Seneca Lake, 2) measure seasonal changing in density of dominant species from May until November and 3) measure daily changes in vertical position. Details are in Brown (2012).

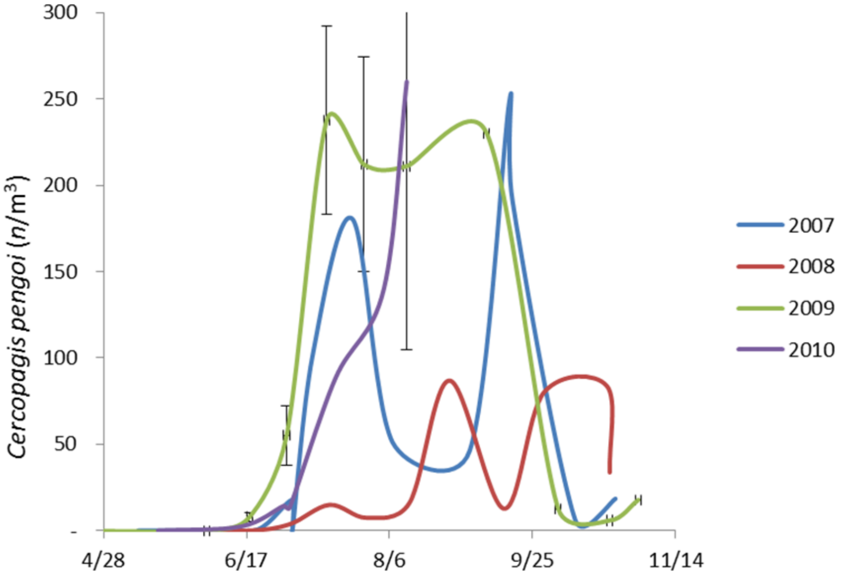


Fig. 36: Abundance of Cercopagis pengoi at the reference station (see methods) from 2007-2010 during the ice-free season. Error bars (+ 1SD) are shown only for 2009 for clarification. In 2010, samples after August were not collected.

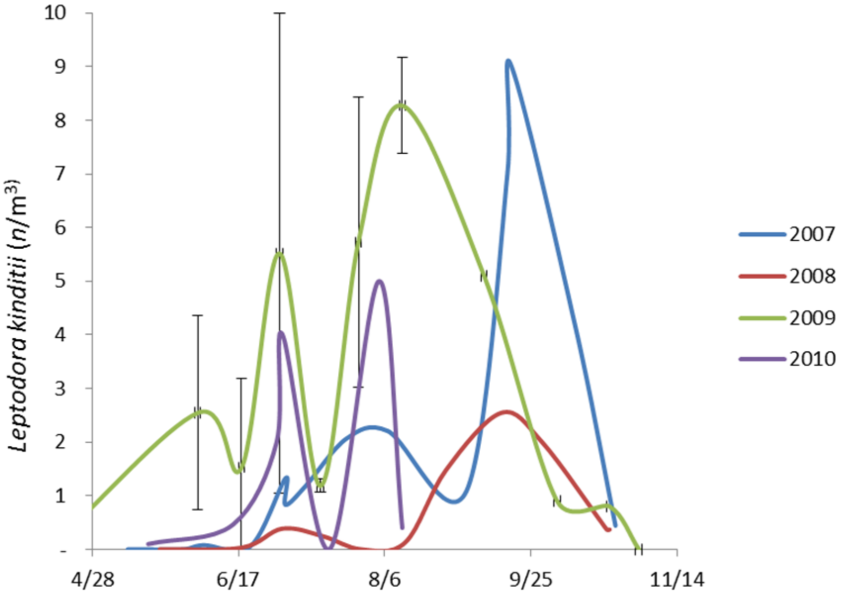


Fig. 37: As per Figure 36, but for *Leptodora kindtii*.

Table 18. Recorded Maximum Density of *M. diluviana* at Site 3 from 2007-2010.

Year	**2007**	**2008**	**2009**	**2010**
Max Density (n/m3)	1.5	2	1.1	1.7

In the open-lake from 2007 to 2010, the abundance of *Cercopagis pengoi* was higher, at times more than 100 fold, than that of *L. kindtii* and *M. diluviana* at the reference sampling station (Figs. 36 & 37, Table 18). Maximum densities of *C. pengoi* often exceeded 100 n/m^3 at the 100m-deep reference station (Fig. 36) and were much higher at other sampled stations (data not shown). The seasonal phenology (i.e., life cycle patterns) and abundance for *C. pengoi* and *L. kindtii* displayed a consistent pattern among years for the first appearance and autumn decline of each species (Figs. 36 & 37). *C. pengoi* typically exhibited two peaks in summer density (Fig. 36), whereas *L. kindtii* densities were less patterned and overall numerically much lower (Fig. 37).

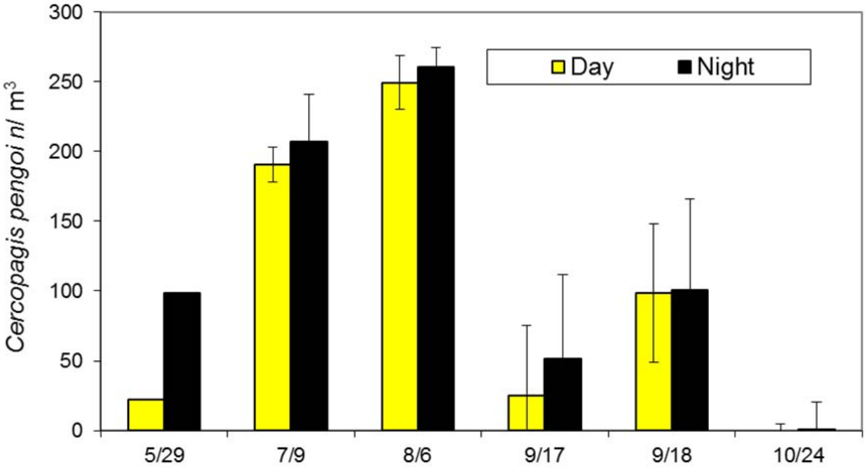


Fig. 38: Day and Night mean abundances (± 1SD) of *Cercopagis pengoi* at the reference station in 2008. Note that no error bars are displayed for May 29th because replicates were not enumerated separately. Mean abundance for October 24th was less than 10 n/m^3.

Since *C. pengoi* are a non-native species to the Finger Lakes and their day-to-night behavior was unknown, this study investigated diel behavior. *C. pengoi* were observed at substantial densities during both the day and night (Fig. 38), indicating the water-column position of this zooplankter does not change with changing light intensity. This was also true of *L. kindtii* (data not shown). The patterns in 2008 (Fig. 38) were similar to observations in other years of the study. A non-native mysid, *Hemimysis anomala* (bloody red shrimp) recently established in the nearshore of Seneca Lake and its abundance and season demography are reported in Brown et al. 2011. Both *C. pengoi* and *H. anomala* are native to Eurasia and were most likely introduced to the North American Great Lakes through ballast water discharged by transatlantic ships. A secondary invasion of the Finger Lakes is likely a result of human and/or natural vectors moving propagules from regional invaded lakes (e.g., Brown et al., 2011).

In Seneca Lake, *C. pengoi* abundance was higher throughout the summer than either of the native species, which indicated that *C. pengoi* avoided fish predation pressure and has the propensity to consume a greater share of zooplankton prey resources. The presence and numerical dominance of *C. pengoi* may pose an ecological shift for Seneca Lake, as this species consumes zooplankton prey at a rate of up to 16 individuals per day. *C. pengoi* feeds by ripping open its prey and then consuming the contents (Laxson et al., 2003). *C. pengoi* commonly exhibits this predacious behavior on *Daphnia* *retrocurva* and *Bosmina longirostris*, and field studies have illustrated a steady decrease in both of these native, zooplankton species when *C. pengoi* population increases in abundance, which may result in competition with native fish for zooplankton prey (Laxson et al., 2003; Brown and Balk, 2008).

Ecological shifts after an invasion of *C. pengoi* were also supported by investigating the sediment record. Microfossils and eggs of *C. pengoi* and their prey accumulate at the bottom of Seneca Lake and cores were extracted to study the historical record. In fact, the abundance of herbivorous zooplankton prey declined dramatically and their size increased coincident with the introduction of *C. pengoi* to Seneca Lake (Brown et al., in revision). Although *C. pengoi* may compete with native invertebrate predators for prey, the seasonal abundances of native species, *L. kindtii* and *M. diluviana*, showed the three species co-exist. Future laboratory studies should investigate the interaction of these three predatory invertebrates, and although challenging, would provide an interesting avenue of research.

How these three invertebrate predators interact with fish predators in the lake is another area for future research. In Seneca lake, *C. pengoi* and *L. kindtii* abundance was similar from day to night, unlike *M. diluviana*, which was observed solely during night sampling due to its extensive vertical migration to avoid fish predation. The long caudal appendage of *C. pengoi* may reduce its vulnerability to fish predators (Laxson et al., 2003) and allow the species to maintain a position high in the water column to consume prey. The similar phenology in stage 1 and 2 during 2008 could reflect a vulnerability of these smaller stages to predation, but is also likely tied to recruitment and reproduction of *C. pengoi* and should be further investigated (Fig. 39).

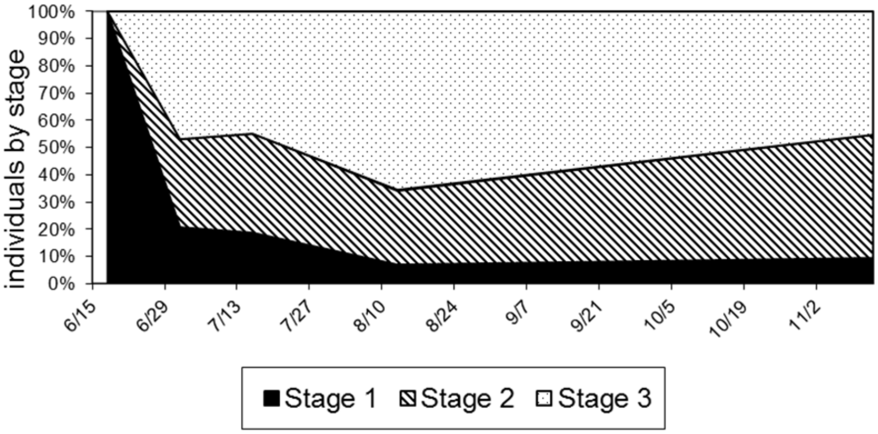


Fig. 39: Stage class distribution of *Cercopagis pengoi* at the reference station (see methods) in 2008. *C. pengoi* are born into stage 1 and possess a single pair of lateral barbs. They molt into stage 2 individuals that have two pairs of lateral barbs, and then molt a second time to stage 3, and possess three pairs of lateral barbs.

Benthic Ecology: The pelagic (deep water) benthic ecology was populated by *Dreissena polymorpha* and *D. rotriformis* (zebra and quagga mussels). Zebra mussels were first detected in Seneca Lake by 1992 and soon afterwards became firmly established in the lake. Quagga mussels were first detected in 2001. Three studies investigated the density of zebra and quagga mussels. Lake wide investigations in 2002, in 2007, and a third duplicated a N-S, mid-lake transect in 2001 and 2011 (Shelley et al., 2003; Zhu, unpublished data; Dittman, unpublished data). In each study, lake-floor densities (individuals/m^2) were determined for live zebra and quagga mussels. These data were augmented with less robust data collected in 2000, 2001 and 2003 from the Fall Geolimnology Class at HWS. The data revealed that zebra mussel populations preferred shallow water, as live zebra mussels were rarely found deeper than 40 meters, whereas quaggas lived in deeper water and some live quagga mussels were recovered from

160 m (Fig. 33). Both mussel populations declined in water depths shallower than 5 m. Annual mean zebra mussel densities between 10 and 40 meters fluctuated from 2000 to 2002 but then declined since 2002 (Fig. 33). None were recovered in 2011. Similar multi-decade records of initial invasion, dominance, and subsequent decline, change in zebra to quagga dominance, and their impact of these changes on the rest of the ecosystem were detected elsewhere, e.g., the Hudson River, NY and the Great Lakes (Nalepa, et al., 2007; Nalepa et al., 2009; Strayer et al., 2011). The number of quagga mussels increased from 2001 to 2002 and then declined afterwards in the 10 to 40 meter interval. However their total population increased from 2001 to 2011, from 1,300 to 3,300 ind/m^2, respectively, if deeper depths were included in the tally (D Dittman, unpublished data). Speculating, the 10 to 40 m decline may be due to mussel reproductive problems, competition, predation of the planktonic veligers and/or the migration of the zebra to quagga depth distributions, and should be further investigated.

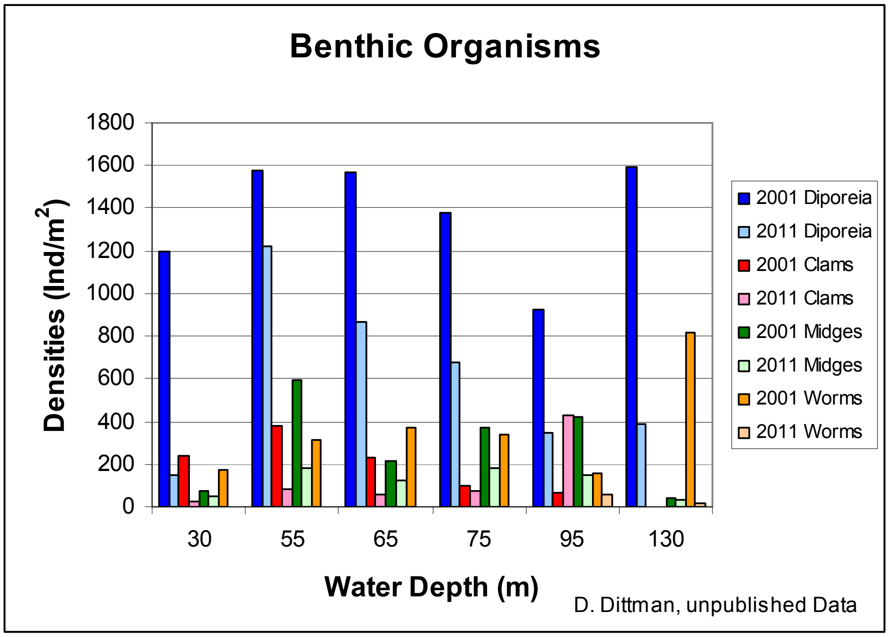


Fig. 40. Other benthic organisms in Seneca Lake (D Dittman, unpublished data).

Other benthic organisms were detected by D Dittman, USGS (unpublished data). *Diporeia spps*, a deep water amphipod and critical to the Lake Trout food chain, has decreased from 2001 to 2011 from ~1,400 to 600 individuals/m^2, but have not disappeared completely from Seneca Lake like they have in neighboring Great Lakes (Fig. 40, Dittman, unpublished data). Small clams, worms and various midges comprise the remainder of the benthic community at densities of ~10 to 300 individuals/m^2. Their populations have declined from 2001 to 2011 as well, but reasons for the decline are unclear at this time. Perhaps the deepwater benthic organisms were influenced by the multi-decade impact of zebra mussels and their supposed pelagic to littoral zone transfer of aquatic ecosystem resources. These declines should be further investigated.

Macrophyte Ecology: Scientific knowledge is scarce on the macrophyte communities in Seneca Lake despite a public outcry on their nuisance qualities and their importance for littoral zone (shallow water) food webs and nursery habitats for zooplankton, invertebrates and fish (especially juveniles) (Zhu, 2009). Macrophytes, the macroscopic plants in aquatic systems, include both large algae such as *Chara spps* and flowering plants such as the invasive Eurasian water milfoil. They are what comprise the "weed beds" in shallow-water environments, many of them rooted into the substrate. A preliminary study at 26 sites split between the northern and southern ends of the lake indentified eleven different taxa (Zhu, 2009). Eurasian water milfoil (*Myriophyllum spicatum*) and Sago pondweed (*Potamogeton pectinatus*) comprised an average of 130 and 25, respectively of the total macrophyte dried biomass of 170 g/m^2, and collectively over 90% of the macrophytes in the lake. Other taxa included: contail, (*Ceratophyllum demersum)*, stonewart, (*Chara spps)*, Elodea, (*Elodea canadensis)*, slender naiad, (*Najas flexilis)*, large-leaf pondweed, (*Potamogeton amplifolius)*, curly-leaf pondweed, (*Potamogeton crispus)*, leafy pondweed, (*Potamogeton foliosus)*, Richardson's pondweed, (*Potamogeton pectinatus)*, eelgrass, (*Vallisneria americana)*. Similar species were detected along the Seneca County shoreline (B. Johnson, personal communication).

Milfoil's dominance was not surprising because it dominates most lakes throughout the northeastern US. Macrophyte species richness was larger in neighboring Owasco (18) and Honeoye (20) but the difference may be due to the less detailed sampling in Seneca (26 vs. ~100 sites). Seneca species richness was also lower than its sediment total phosphate concentrations would predict (Zhu, 2009). Laboratory studies confirmed that Eurasian water milfoil was light limited in most aquatic ecosystems, more so than phosphate limited (Zhu et al., 2008). Thus, the lakeshore property owners outcry was not surprising when perceived macrophyte densities increased as zebra mussels increased water transparency in the late 1990s. Luckily, no sightings of the European frogbit (*Hydricharis morsis-vanae L.*), hydrilla (*Hydrilla verticillata*), or water chestnut (*Trapa natans L.*) have been reported in the lake but they are expected to arrive in the near future (Zhu et al., 2008). All three can completely dominate the littoral zone community, completely choke waterways, and have been detected in nearby waterways and lakes. These limited findings and scary future provide numerous avenues for future research.

Historical Water Quality Changes

Limnological data for Seneca Lake are sparse before 1990 (Brown et al., in revision). Secchi disk and chlorophyll-a data reveal some changes over the past 100 years (Fig. 41a; Birge and Juday, 1914, Muenscher, 1928; Mills, 1975). The available data suggest that Seneca Lake was more oligotrophic during the early 1900s. The data gaps however preclude comment on additional pre-1990 water quality trends. To overcome these data gaps, researchers investigated records of environmental change, namely organic matter, carbonate content and/or total mercury content, that were preserved in short, ~50-cm long, sediment box cores (Lajewski et al. 2003; Abbott and Curtin, 2010; Brown et al., in revision). These short cores span the past 100 to 200 years, thus provide a record of the historical water quality changes for Seneca Lake.

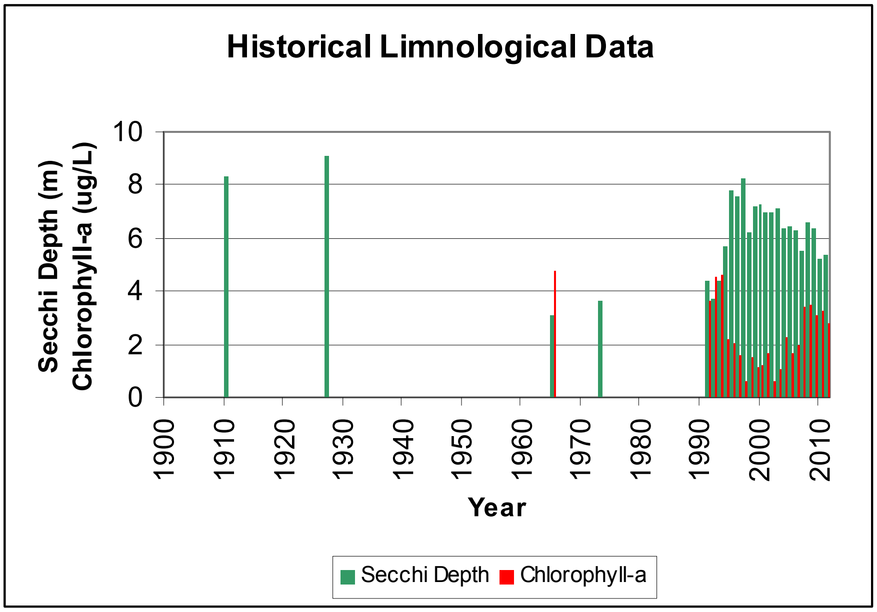


Fig. 41. Historical records of secchi disk depths and chlrorophyll-a concentrations (Birge and Judy, 1914, Muenscher, 1928, Mills, 1975).

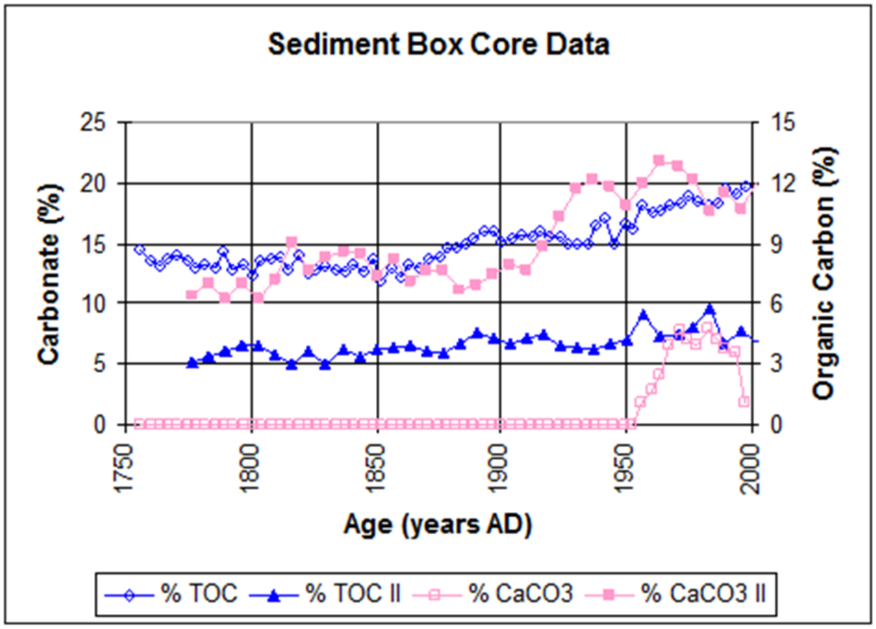


Fig. 42. Box core records of total organic carbon and carbonate content (Lajewski et al., 2003, Brown et al., in revision).

Historical Productivity: Box cores revealed increasing organic matter and carbonate contents from ca. 1770 to today (Fig. 42). Total organic matter concentrations in sediments (TOC) reflect the amount of algal production in the lake, and increasing TOC trends are typically sometimes interpreted as increasing productivity in the lake (Dean, 1974; Brown et al., in revision). The change was interpreted to reflect increased nutrient loading from the increase in human population densities and agricultural activities in the watershed. Carbonate precipitation is controlled by temperature, algal productivity and the watershed supply of calcium and bicarbonate/carbonate (alkalinity) to the lake. Warmer temperatures can induce calcite precipitation due to a reduction of carbon dioxide saturation concentrations (and acidity) in the water. Algal photosynthesis also removes carbon dioxide from the water. On a warm summer day, blooms can induce whiting events, the precipitation of calcium carbonate, and turn the surface waters into a milky (calcite) green (algae) color. Increasing up-core carbonate concentrations, suggest that algal productivity increased from ca. 1770 to today as well. Alternatively, increasing the supply of calcium and alkalinity to the lake increases the likelihood for the precipitation of calcite. The supply of calcium and bicarbonate/carbonate has increased due to the increase in acid rain since the late 1850's. Thus, these records could also reflect the onset of acid rain, and its impact on chemical weathering rates in the watershed. Lajewski et al. (2003) favored the latter interpretation because many neighboring Finger Lakes do not reveal a parallel change in total organic matter, and only carbonate increased up-core. Interestingly, the limited historical data are more consistent with the increasing productivity interpretation (Brown et al., in revision).

Mercury Levels: Lake sediment records across the Northern Hemisphere preserve evidence for increases in atmospheric deposition of mercury (Hg) over the last ~150 years (Bookman et al., 2008). Mercury contamination is pervasive in aquatic ecosystems across North America. Its bioaccumulation can lead to severe health concerns for both wildlife and humans, and in 2001, sixty three lakes in New York were added to the Department of Health's fish consumption advisory list due to elevated levels of Hg (Fitzgerald and Clarkson, 1991; US EPA, 1997; Callinan, 2001). There are many potential natural (e.g., forest fire, volcanic eruptions) and anthropogenic (e.g., fossil fuel combustion, medical and municipal waste incineration, metal smelting) sources of Hg in the environment (Bookman et al, 2008; Pirrone et al, 1998; Lorey & Driscoll, 1999; Perry et al., 2004). Previous studies in the Seneca Lake watershed show that the highest surficial sediment Hg concentrations in the lake occurred near the mouth of the Keuka Outlet (Blackburn et al., 1979, Abbott and Halfman, 2009). Abbott and Curtin (2010) analyzed a ~50-cm long sediment box core to assess the timing and magnitude of change in Hg deposition in Seneca Lake and potential sources of contamination (Fig. 43).

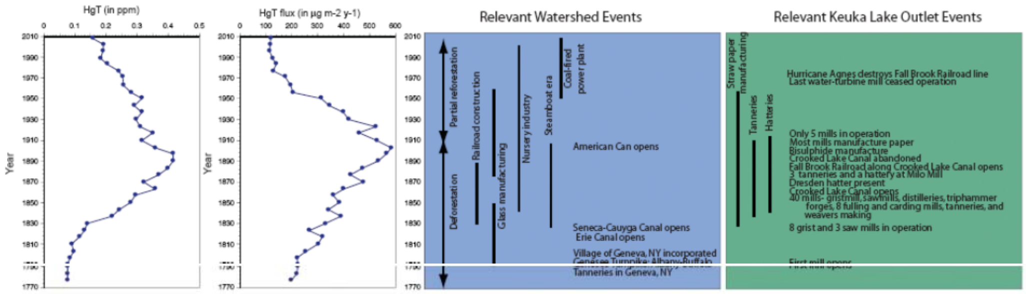


Fig. 43. HgT concentrations and HgT fluxes with age in the core. The timing of changes in Hg are compared with events in the Seneca Lake watershed and Keuka Lake Outlet (Abbott and Curtin, 2012).

Analysis of a ^{137}Cs and ^{210}Pb-dated sediment box core indicates total Hg (HgT) concentrations ranged from 0.075 ppm in 1790 to a maximum of 0.414 ppm between 1890 and 1897 with an average of 0.24 ppm (Appleby and Oldfield, 1978). No correlations appeared to exist between the HgT to wt% organic matter, carbonate, or terrigenous grain size. The onset of Hg contamination in Seneca Lake was at ~1810, whereas in nearby lakes the onset was clearly much later, between 1910 and 1930. In Seneca Lake, HgT fluxes were low (197 µgm-2y-1) in 1770 and peaked between 1890 and 1910 (583 µg/m^2/yr) and gradually returned to regional background levels (127 µg/m^2/yr) by 1977. This peak in HgT flux predates those observed in other local and regional lakes (Fig. 44), the maximum flux is greater than in most local lakes except Lakes Ontario and Erie. Other lakes in the northeastern United

States reached their maximum HgT flux post World-War II. Because of the mismatch in timing of peak Hg accumulation in these lakes, a more localized point source rather than widespread atmospheric deposition appears to be the reason for increased HgT flux to the sediment in Seneca.

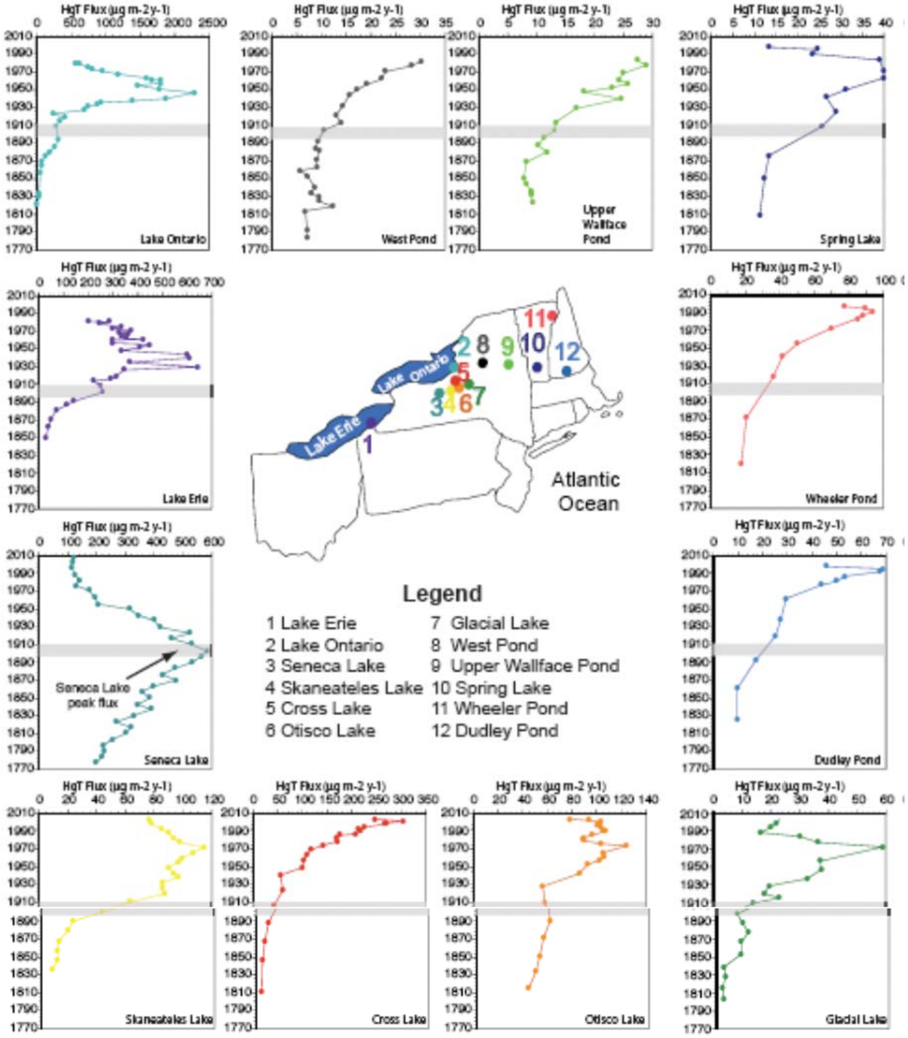


Fig. 44. Regional comparison of HgT fluxes (Abbott and Curtin, 2012, Bookman et al., 2008, Pirrone et al., 1998).

Natural sources such as active volcanoes do not exist locally, and evidence for local forest fires was not detected in the sediment. The timing of the HgT peak in Seneca Lake is also incongruent with the 19th century peak of the gold and silver mining in North America (locally in Ontario, Canada). Any of these regional sources, forest fires or mining activities would also have shown up in the neighboring lake records. The records of Hg contaminant in neighboring lakes instead typically match the atmospheric deposition from burning fossil fuels, smelters, and waste incineration, or local sources.

Agriculture has played a significant role in the western NY economy for centuries (Cunningham and Wessels, 1939). Since the 1800’s, orchards and nurseries were abundant at the northern end of Seneca Lake, and among the largest in the country. Mercury was used as an effective pesticide for agriculture, typically in the form of mercuric chloride. However, typical application rates fall far below the amounts accumulating in the sediment record. Mercury was also used for a common cure-all solution. It was commonly used as rat poison, and a cure for constipation and other forms of gastrointestinal agony (Willich and Mease, 1803). These uses also cannot account for the high concentrations found in the lake. Other industries existed in the region. For example, the Ontario Glass Manufacturing Company and Geneva Glass Works, now defunct, operated small plants at Glass Factory Bay along the northwestern shore of the lake in the 1800s to mid-1990s (Miscellaneous Register, 1823; Foley, 1963).

The Keuka Outlet was a magnet for mills, and chemical processing plants, because the many waterfalls and an elevation drop of 82 m make the course an ideal location for hydropower. Early industry, including tanneries, battery factories, paper mills, and a flourishing nursery market, as well as a growing population during the late 19th century are possible sources for the high Hg concentrations found at Seneca Lake (Clayton, 1926; Collier, 1893; Dumas, 1989; Watras and Hucklebee, 1992; Merwin et al., 1994; Grebinger and Grebinger, 1993). Numerous gist mils, sawmills, tanneries, paper mills, battery and other chemical factories were built along the outlet. The largest Hg producers could be the tanneries, paper mills, and battery and other chemical factories. The timing of the greatest number of mills coincides with the HgT flux peak in the sediment record.

Another possible reason for the rapid increase in HgT flux is the result of land use change. Deforestation in the watershed initiated during the early 1800s as land was cleared for agriculture (Galpin, 1941; DeLaubenfels, 1966; Siles, 1978). Deforestation destabilizes soils and results in a major increase in the contribution of terrestrial material to the lake. The increased HgT flux to Seneca Lake is coincident with an increase in the land are used for agriculture. Although paper production and other mill activity ceased in the watershed by 1910, and deforestation slowed and reforestation began, Hg still entered the lake as erosion continued to mobilize remnant Hg in the soils.

Mercury in Fish: The New York State Department of Environmental Conservation has published mercury data for lake trout, an organism found at the top of the aquatic foodweb for Seneca Lake (Skinner et al. 2010.) The reported concentrations of mercury in four to six year old lake trout are about 300 ng/g mercury wet weight. For older fish (> six years old), the Mercury concentrations are higher, on average, with levels around 400 ng/g mercury with a maximum concentration of 578 ng/g (Skinner et al., 2010.). This analysis was done on approximately 76 lake trout collected in 2008 from Seneca Lake in Seneca, Yates, and Schuyler counties (NYSDEC Bureau of Habitat, 2010).

The action level for mercury in fish issued by the US Food and Drug Administration (FDA) is 1,000 ng/g of methyl mercury. The action level “represents limits at or above which FDA will take legal action to remove products from the market (“Guidance for Industry”, 2000). Since virtually all of the mercury present in fish at the top of the foodweb is methyl mercury, total mercury measurements are often used as a surrogate for methyl mercury (Bloom, 1992). The US EPA has issued a screening value of 300 ng/g for methyl mercury in fish. This concentration “in fish tissue should not be exceeded to protect the health of consumers of noncommercial freshwater/estuarine fish” (“Human Health Criteria”, 2001).

An earlier investigation of mercury concentrations in fish across NY was conducted between 2003 and 2005 (NYSDEC, 2008). Yellow perch and smallmouth bass were collected from Seneca Lake in Seneca County and analyzed for total mercury concentrations. Results of this analysis are summarized in Table 16. These mercury concentrations overlap those from the lake trout collected in 2008. Since different species of fish were sampled during different years, it is not known whether mercury levels in fish are decreasing in Seneca Lake or if the data reflect interspecies differences between lake trout, smallmouth bass, and yellow perch. In general, of the fish analyzed for mercury, one would expect yellow perch to have the lowest concentrations of mercury since they are at the lowest trophic level.

However, the data were inconclusive and revealed too much variability within individuals of the same species from the 2003 to 2005 sampling since the coefficient of variation for the yellow perch samples is 60% and 36% for the smallmouth bass. (Table 17)

Table 19. Fish mercury data from Seneca Lake from NYSDEC's "*Strategic Monitoring of Mercury in New York State Fish*," (NYSDEC, 2008).

Fish	n	Mean Length (mm) (Range)	Mean Weight (g) (Range)	Mean Fish Mercury (ng /g) (Range)
Smallmouth bass	6	291 ± 52 (226 – 365)	456 ± 265 (158 – 890)	421 ± 151 (222 – 668)
Yellow perch	10	262 ± 28 (225 – 322)	294 ± 111 (201 – 574)	295 ± 177 (129 – 678)

In order to understand more about the fish total mercury levels in Seneca Lake tributaries, analysis of small fish collected by Dr. Cushman in summer 2011 was performed at the Finger Lakes Institute. Determining fish mercury levels is important since tributaries and watersheds are known locations of methyl mercury production and mercury bioaccumulation (Hurley et al. 1995; Cleckner et al. 2003). Streams are also ecologically important for macroinvertebrates and fish, and are popular locations for sport anglers. Figure 45 show mercury concentrations for a small number (n=2 to 5 composited fish per site) of blacknose dace in selected Seneca Lake tributaries. Blacknose dace are a small ubiquitous omnivorous fish, found throughout the Finger Lakes and NY (Kraft et al., 2006).

Large differences in blacknose dace mercury concentrations were observed among the sampled Seneca Lake watershed tributaries. In general, higher fish total mercury concentrations were found in tributaries at the northern and southern ends of the watershed (Figure 44). However, the levels of mercury in the tributary blacknose dace are on average below those reported for the yellow perch, smallmouth bass, and lake trout sampled in Seneca Lake. This is expected since the blacknose dace are at the bottom of the foodweb. From this preliminary analysis, it appears that blacknose dace is an excellent indicator species to investigate spatial and temporal variability in mercury, since they are found at every site, show differences in mercury concentrations among sites, typically live about three years, have a range of about 26 m (Cushman, 2006), and are eaten by larger fish such as trout (Kraft et al., 2006). Further analyses should determine methyl mercury levels in these small fish to determine the percentage of total mercury present as methyl.

Based on the mercury data in fish for Seneca Lake, the consumption advice for eating Seneca Lake fish is the same as for the State of New York – "Eat no more than one meal per week" (NYSDEC, 2008.)

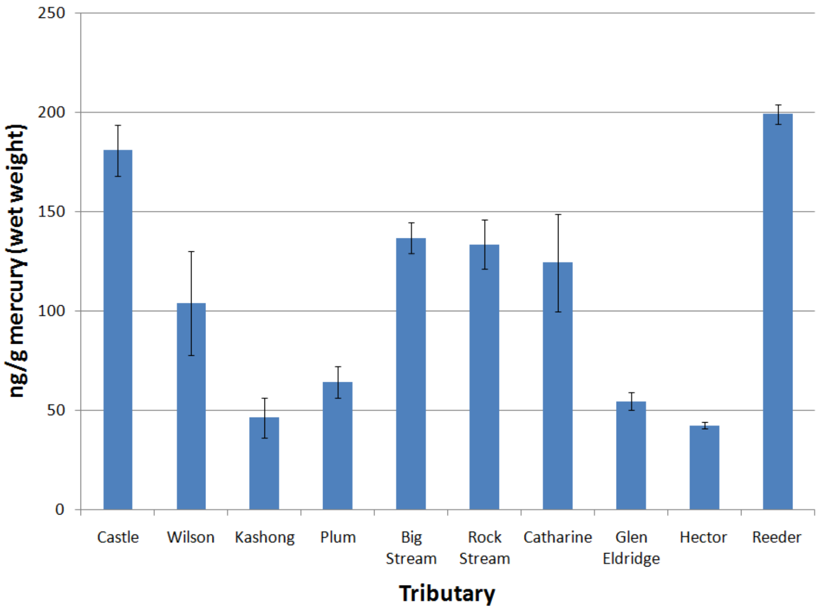


Fig. 45. Blacknose dace mercury levels (ng mercury per g of wet weight fish tissue) in tested Seneca Lake Watershed tributaries. Error bars represent two standard deviations for fish tissue sub-samples from each site. The average coefficient of variation for all analyses is 8.6%.

Seneca Lake Subwatersheds and Stream Hydrogeochemistry

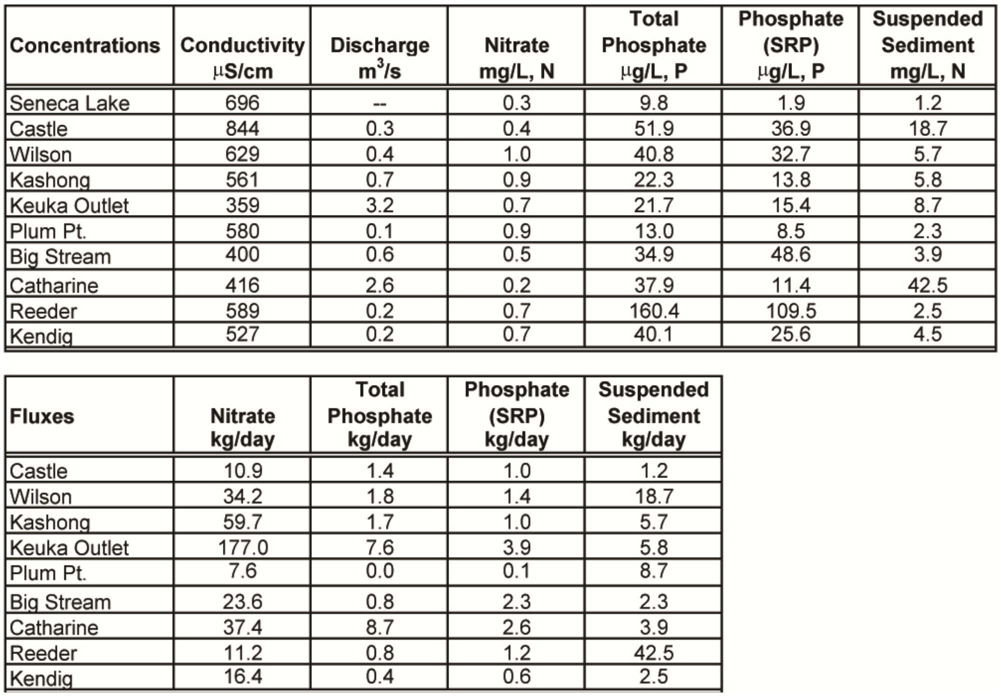
Stream Hydrology & Hydrogeochemistry

HWS has been monitoring selected streams in the Seneca watershed since 1998. The data were typically collected near the terminus of Wilson, Kashong, Keuka Outlet, Plum Pt, Big Stream, Reeder and Kendig Creek during the late spring and early summer, and less frequently from the other major tributaries in the watershed. Since 2010, year round, weekly to bi-monthly, sampling focused on Castle, Wilson, Kashong, and Keuka Outlet to assess seasonal differences in stream hydrogeochemistry, nutrient loading and other issues. Catharine Creek was also sampled in 2011, but the other tributaries were sampled less frequently, if at all, in 2010 and 2011. On each visit, stream discharge, temperature, pH, conductivity, dissolved oxygen and alkalinity were measured onsite, and additional water was collected and analyzed back in the laboratory for total phosphate (TP), dissolved phosphate (SRP), nitrate, total suspended sediment (TSS), and major ion concentrations following identical procedures to the lake samples. Details can be found in (Halfman , 2012).

Stream Discharge: The 1999-2011 average stream discharge for each primary site ranged from less than 0.1 to 7.9 m^3/s in the watershed (Table 20, Fig. 46). The smallest discharge was detected in the smallest watersheds, e.g., Plum Pt and Castle Creek, and largest was detected in the largest watersheds, e.g., Keuka Outlet and Catharine Creek. Basin size was the primary determinant for stream discharge ($r^2 = 0.99$). All of the tributaries exhibited a flashy, precipitation-event influenced, hydrology. Almost every tributary, except for the largest tributaries, was dry for a portion of the summer.

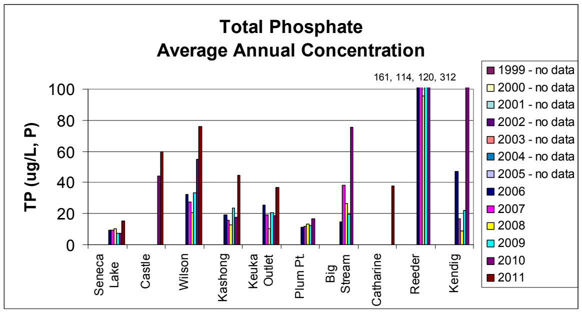
Two United States Geological Survey (USGS) gauge sites are located in the Seneca Lake watershed. One monitors flow down the Keuka Outlet, the largest tributary to the lake (USGS Site: 04232482). The Keuka Outlet is the outflow for Keuka Lake to the west. The other monitors flow out the outlet, the Seneca River, near Seneca Falls, NY (USGS Site: 04232734).

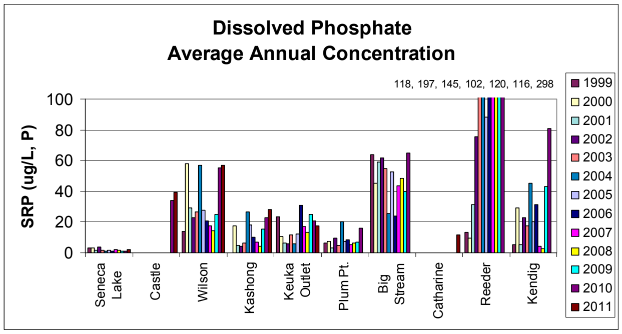
Table 20. Average stream concentration and flux data 1999-2011 (Halfman, 2012).

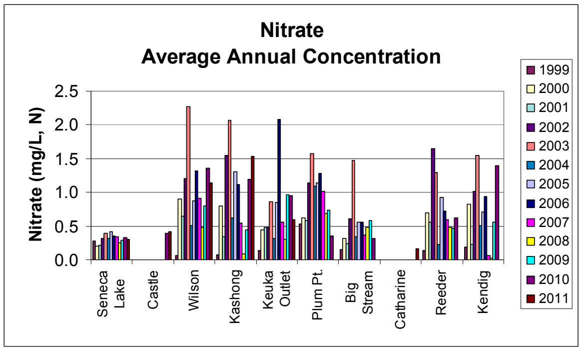


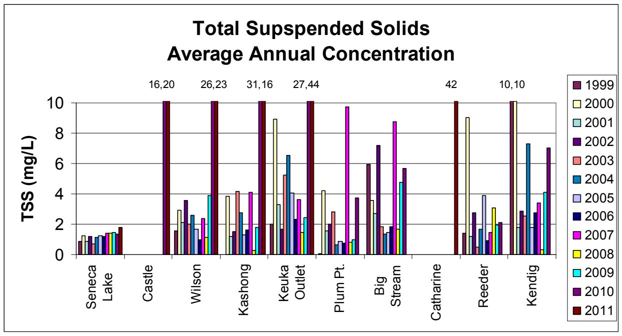
Concentrations	Conductivity µS/cm	Discharge m³/s	Nitrate mg/L, N	Total Phosphate µg/L, P	Phosphate (SRP) µg/L, P	Suspended Sediment mg/L, N
Seneca Lake	696	--	0.3	9.8	1.9	1.2
Castle	844	0.3	0.4	51.9	36.9	18.7
Wilson	629	0.4	1.0	40.8	32.7	5.7
Kashong	561	0.7	0.9	22.3	13.8	5.8
Keuka Outlet	359	3.2	0.7	21.7	15.4	8.7
Plum Pt.	580	0.1	0.9	13.0	8.5	2.3
Big Stream	400	0.6	0.5	34.9	48.6	3.9
Catharine	416	2.6	0.2	37.9	11.4	42.5
Reeder	589	0.2	0.7	160.4	109.5	2.5
Kendig	527	0.2	0.7	40.1	25.6	4.5

Fluxes	Nitrate kg/day	Total Phosphate kg/day	Phosphate (SRP) kg/day	Suspended Sediment kg/day
Castle	10.9	1.4	1.0	1.2
Wilson	34.2	1.8	1.4	18.7
Kashong	59.7	1.7	1.0	5.7
Keuka Outlet	177.0	7.6	3.9	5.8
Plum Pt.	7.6	0.0	0.1	8.7
Big Stream	23.6	0.8	2.3	2.3
Catharine	37.4	8.7	2.6	3.9
Reeder	11.2	0.8	1.2	42.5
Kendig	16.4	0.4	0.6	2.5









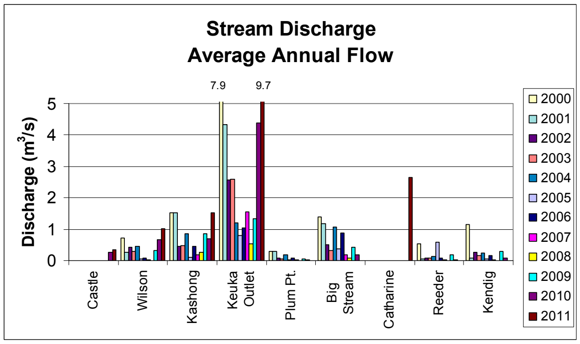


Fig. 46. Annual, site-averaged, stream discharge and water quality data. Castle Creek was added to the survey in 2010 which also focused on Wilson, Kashong and Keuka Outlet. Catharine Creek was only sampled in 2011. Annual Seneca Lake concentrations are shown for comparison.

The annual average, mean daily inflow at Keuka Outlet from 2001 to 2010 was 5.5 m^3/s, and individual annual-average, mean-daily flows ranged from 3.4 (2001) to 9.1 m^3/s (2004) (Fig. 46). Annual hydrographs exhibited larger discharges in the winter and/or spring (13.5 and 15.7 m^3/s) than the summer and fall (5.0 and 10.7 m^3/s). The fall flows were larger than expected due to the release of upstream Keuka Lake water through its outlet dam to maintain lower winter levels in the lake. The annual inflow of water averaged 173 million m^3/yr and ranged between 107 (2001) and 287 (2004) million m^3/yr during the past decade. This basin encompasses ~30% of the watershed.

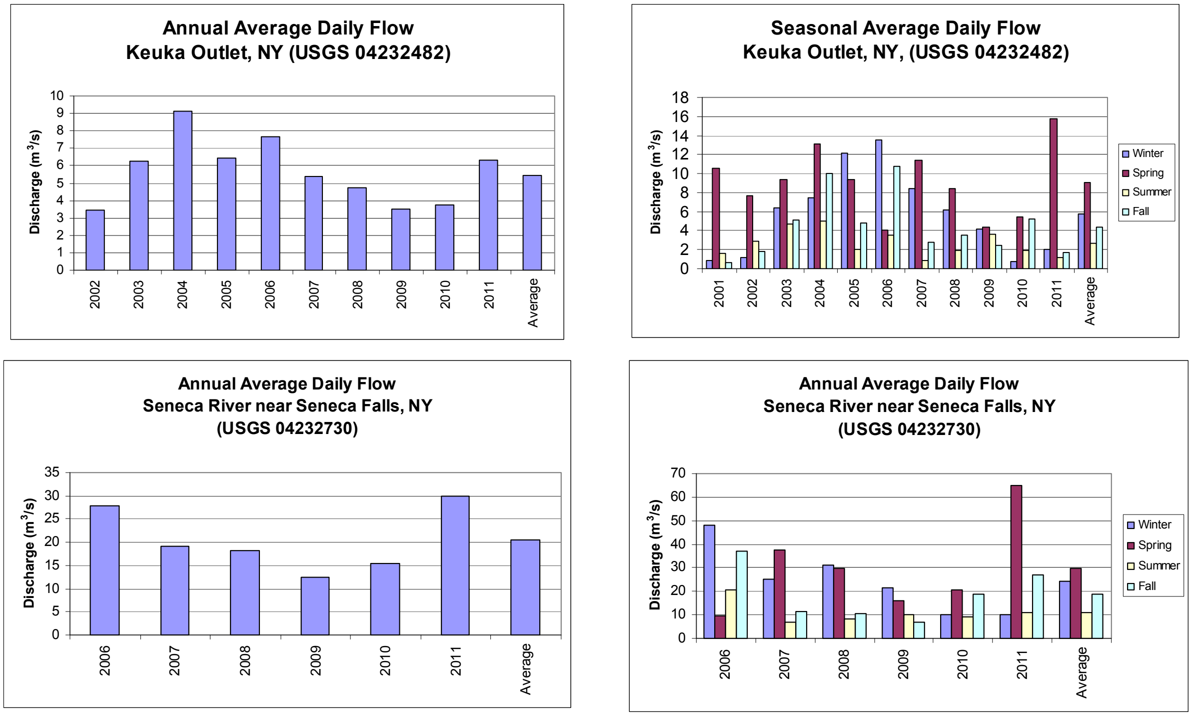


Fig. 47. Annual average, daily discharges at the USGS gauge stations on Keuka Outlet (top-left) at Dresden, and on the Seneca River (bottom-left), near Seneca Falls, NY, for the past six and ten years respectively. Seasonal average, daily discharges, are also shown for both sites (top & bottom right). (http://waterdata.usgs.gov/nwis)

The annual average, mean daily flow out the Seneca River near Seneca Falls, NY from 2006 to 2010 was 20.5 m^3/s, and individual annual-average, mean-daily flows ranged from 12.6 (2009) to 29.9 m^3/s (2011) (Fig. 46). Larger discharges were typically detected in the winter and/or spring (34.4 and 39.7 m^3/s) than the summer and fall (11.0 and 18.7 m^3/s). The flow was regulated by a dam. The NYS Thruway Authority attempts to balance disparate needs including Seneca Lake levels "rule curve", Erie Canal levels, minimum flows for boat traffic and downstream flooding, flow though a hydroelectric facility, and minimum flows for industrial discharges like the Waterloo wastewater treatment facility (Kappel and Landre, 2000). The Seneca Lake level "rule curve" is targeted at 446 ± 0.3 ft relative to the Barge Canal Datum in the summer (March 15 to November 1), and 445 ± 0.3 ft in the winter (December 15 to March 1) (http://www.canals.ny.gov/faq/oswego/netdata/seneca-levels.pdf). Flood stage is at 448 ft, and major flood stage at 449 ft (National Weather Service, http://water.weather.gov/ahps/). The annual discharge out the outlet averaged 645 million m^3/yr and ranged between 390 and 942 million m^3/yr over the past six years. The available hydrologic data paint an incomplete picture of the watershed hydrology and should be investigated further.

Seneca Lake's water residence time estimated using tritium, stable isotope and USGS Runoff data were estimated at: 12, 18, 19 and 23 years and average ~18 years (Michel and Kraemer, 1995).

Nutrient Concentrations in Streams: Nutrient loading impacted the watershed (Halfman & Franklin, 2007; Halfman, 2012). All of the nutrient and TSS concentrations were larger in the streams than the lake (Table 19, Fig. 46). For example, fluvial total phosphate concentrations averaged 47 μg/L but were below 10 μg/L in the lake, fluvial nitrate concentrations averaged 0.7 mg/L but averaged 0.3 mg/L in the lake over the past decade. Thus, Seneca has a nutrient loading problem, as do most agriculturally-rich watersheds in the Finger Lakes.

Annual mean nutrient concentrations varied from stream to stream. Wilson Creek, Kendig Creek, Castle Creek, Big Stream, and especially Reeder Creek revealed larger phosphate concentrations than the other tributaries. Unfortunately, no one reason accounts for these differences (Spitzer, 1999; Halfman and Franklin, 2007; Halfman, 2012). Wilson and Kendig Creeks have large nutrient concentrations because they drain larger portions of agricultural land (e.g., Makarewicz, 2009). The loading characteristically increased during an intense runoff event at Wilson Creek (Kostick and Halfman, 2003). In contrast, Big Stream drained much less agricultural land but had larger phosphate concentrations than Wilson and Kendig. Stream segment analysis in 2001 indicated that the Dundee wastewater treatment (WWT) facility was an important point source of nutrients to the stream but stream concentrations never increased above MCLs (Bowser, 2002). A similar segment analysis along the Keuka Outlet indicated that the Penn Yan WWT facility was not a significant point source of nutrients to Keuka Outlet (Hintz, 2004).

Catharine Creek revealed larger total suspended solid concentrations, but smaller phosphates (both TP and SRP), nitrates and specific conductance data than the other streams. It drains more forested land than the other surveyed watersheds (~60% compared to 15 to 18% forested land), and forested watersheds typically yield fewer nutrients and suspended sediments than agricultural watersheds, especially during runoff events. The larger suspended solid concentrations in Catharine were inconsistent with forested watersheds, and perhaps reflected upstream logging, construction and/or gravel pit practices in the watershed. Forested watersheds in neighboring lakes revealed minimal nutrient and TSS loads compared to their neighboring agricultural-rich streams (Halfman et al., 2011).

The largest concentrations of SRP and TP were consistently detected in Reeder Creek. This “honor” started in 2002 when SRP concentrations rose from typical tributary values of ~20 µg/L to 100 µg/L or more. Concentrated Animal Feeding Operations (CAFOs), in this case pig farms, entered the region, and the former Seneca Army Depot was systematically disposing of and exploding old, unstable, phosphate-bearing, munitions at this time. Both could contribute to the initial increase in 2002 but only pig farms persisted through 2011.

Finally, annual mean discharges, TP and TSS concentrations were larger in 2010 and 2011 than previous years in Castle, Wilson, Kashong, and Keuka Outlet, and larger than most of the other tributaries. These four streams were sampled year round since 2010, whereas every stream was only sampled in the late spring and early summer during pre-2010 fieldwork. The seasonal analysis (see below) revealed larger discharges, concentrations and fluxes during the winter and/or spring compared to the summer months, which dictated this difference.

Nutrient Fluxes:

The largest fluxes were from streams with the largest basin areas (Table 19, Fig. 48). For example, Keuka Outlet and Catharine Creek, the largest streams sampled, revealed annual average fluxes of 7.6 and 8.7 kg/day for total phosphates compared to loads below 2 kg/day in the other streams, and 4,800 and 9,700 kg/day for total suspended solids vs. 500 kg/day in the other streams. The smallest fluxes were from the smallest watersheds, like Plum Pt. and Reeder Creek, adding only 0.04 and 0.8 kg/day for TP, and 20 and 65 kg/day for TSS over the past decade. These trends were interesting because Keuka Outlet revealed one of the smaller concentrations and Redder Creek one of the largest concentrations for TP but Keuka Outlet had the largest fluxes and Reeder the smallest. Castle Creek, another small watershed, discharged as much TP (1.4 kg/day), SRP (1.0 kg/day), and TSS (500 kg/day) as its larger and more agricultural neighbors, Wilson and Kashong Creeks. Perhaps Castle Creek’s elevated flux reflected drainage of an urban area, and/or annual averages from year round samples;

whereas the other stream averages included years with summer only data. Mean TP, SRP, TSS and nitrate fluxes correlated to basin size (r^2 from 0.63 and 0.85, Halfman, 2012).

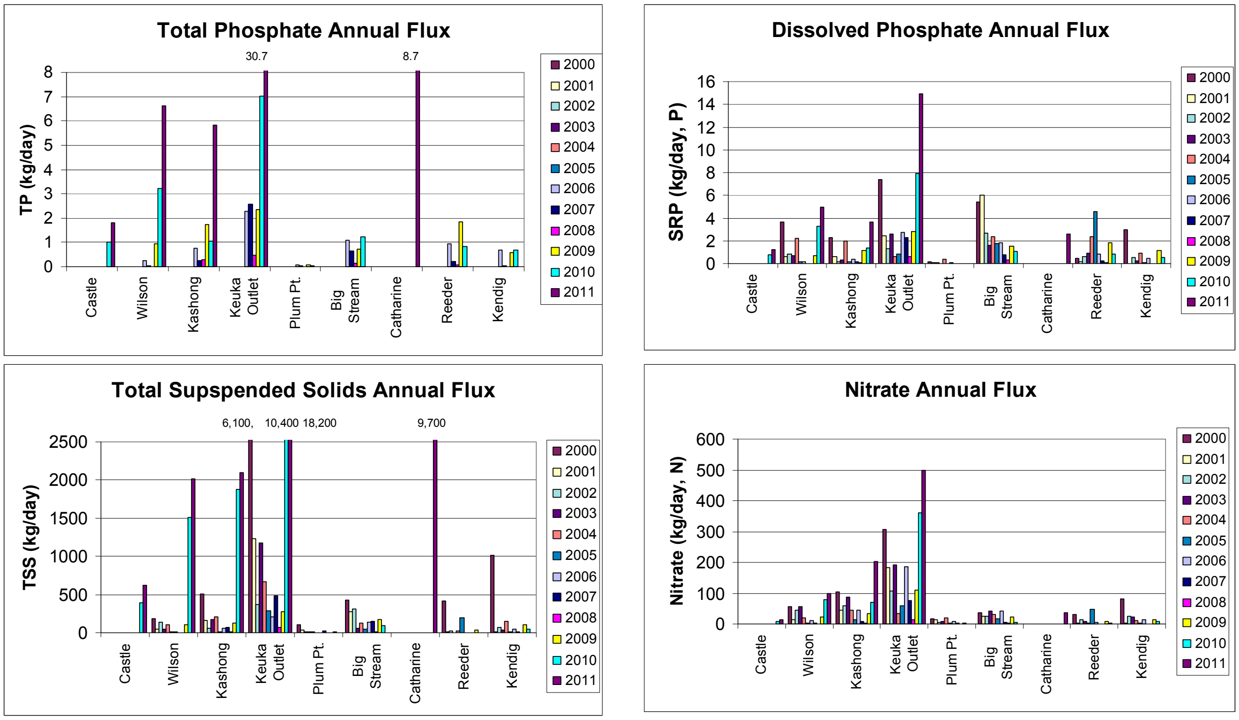


Fig. 48. Annual average flux of nutrients and suspended sediments to Seneca Lake (Halfman, 2012).

Seasonal Changes in Stream Data: Stream discharge, concentrations and fluxes of nutrients and suspended sediments changed seasonally (Fig. 35). These changes were critical for long term comparisons because the pre-2010 samples were typically restricted to the late spring and early summer, whereas the post-2010 samples were collected year round. Stream discharge was largest in the winter and/or spring and smallest in the summer and fall. Whether the season was winter or spring was dependent on the timing of snow melt and “spring” rains. Spring rains sometime happened in late winter. The anomalous large fall discharge at Keuka Outlet reflects the dam on Keuka Lake and fall releases to lower Keuka Lake to winter levels. TSS concentrations were larger in the winter or spring and related to the timing of the early spring rains and snow melt. Seasonality for the other parameters was most apparent in their fluxes, with more material entering the lake in the late winter or early spring.

Phosphate Budget for Seneca Lake

Phosphorus is critical to the health and water quality of Seneca Lake because it limits algal growth. The stream concentrations and fluxes suggest that a nutrient loading problem exists. However, stream inputs are only one part of the equation. A phosphorus budget must also include additional inputs like atmospheric loading, lakeshore lawn care fertilizers, lakeshore septic systems and municipal wastewater treatment facilities, and outputs like the outflow of phosphorus-bearing, dissolved and particulate materials through the Seneca River and organic matter burial into the sediments (Fig. 49).

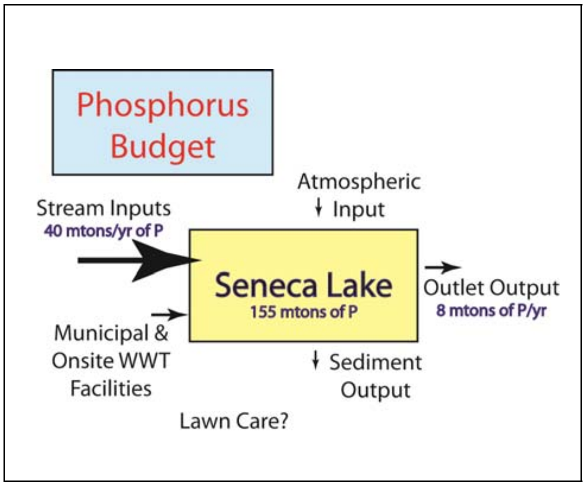


Fig. 49. Estimated phosphorus fluxes into and out of Seneca Lake. The arrow size is proportional its flux.

Inputs: The total fluvial flux of phosphorus to the lake is, on average, 40 metric tons/year, assuming a mean stream total phosphate concentration of 47 µg/L, and an estimated annual stream discharge of 863 x 10^6 m^3 (Wing et al., 1995). This stream influx is almost three times larger than the 17 metric tons/year estimated earlier using the same annual discharge (Halfman and Franklin, 2007). The difference reflected the inclusion of year round samples in the more recent calculation.

Other notable inputs include lakeshore septic systems, lakeshore lawn care, atmospheric deposition and municipal wastewater treatment facilities that do not discharge into a sampled stream (Halfman, 2012). Extrapolating a septic input per km of shoreline estimated for Owasco Lake (Halfman et al., 2011), the lakeshore septic influx is approximately 5 metric tons/yr. The atmospheric loading of 0.8 metric tons/year directly onto the lake's surface was estimated from National Atmospheric Deposition Program data collected at Ithaca, NY (Site NY67, e.g., Koelliker et al., 2004). Finally, the Geneva (Marsh Creek) wastewater treatment facility discharged approximately 2.4 metric tons of phosphorus per year (http://www.epa-echo.gov/echo/). Unfortunately, phosphate data was not publically available for the Waterloo and other facilities, and estimating a lawn care/fertilizer flux is too tenuous at this time.

Combining all the known inputs, the influx of phosphorus to the lake was approximately 55 metric tons/year. This estimate was probably low due to the lack of some, albeit minor, contributions and simplifying assumptions.

Losses: Phosphorus was lost from Seneca Lake through the outlet and into the sediments. The efflux through the outlet was estimated at ~8 metric tons per year, assuming a mean lake TP concentration of 10 µg/L, and an outflow discharge of 760 x 10^6 m^3/year (Wing et al., 1995). Unfortunately, very few sediment cores have both total phosphate and sedimentation rate data. Extrapolation from the limited number of cores estimated a flux of 1.5 metric tons/year to the sediments. The sediment burial estimate is tentative at this time.

Combining all the outputs, the efflux of phosphorus from the lake was approximately 10 metric tons/year. This total efflux is less certain than the inputs.

Budget: The total inputs estimated at 55 mtons/yr were much larger than the total outputs estimated at 10 mtons/yr, thus Seneca Lake experienced a significant nutrient loading problem over the past two decades. The total amount of phosphorus in the lake was 155 metric tons estimated from the 2011 mean lake total phosphate concentration of 10 mg/L and a lake volume of 15.5 km^3. Thus the annual net gain was approximately 1/3^{rd} of the phosphorus in the lake. Assuming a net positive flux of 45 metric tons/year, the lake is destined to become eutrophic. Predicting when eutrophication will happen is difficult to estimate. For example, larger algal productivity from nutrient loading induces larger effluxes out the outlet and to the sediments. Changes in rainfall, thus runoff and discharge, proportionally influence the fluvial flux. However, the budget highlights the tenuous nature of the lake, and the need to proactively decrease nutrient loading, and especially loading from streams. The budget should be more thoroughly investigated in the future.

In conclusion, the Seneca Lake watershed has a number point and nonpoint sources of nutrients. They included municipal wastewater treatment facilities and onsite wastewater treatment (septic systems), atmospheric loading, runoff from agricultural land both crop farming and animal husbandry, and runoff of nutrients and other products from well-manicured lawns. The preliminary analysis indicated that runoff from streams dominated all inputs to the lake. Clearly, the phosphorus budget indicates that inputs overshadow outputs. This net flux was consistent with the observed degradation in water quality degradation over the past decade. Resolving these "bottom up" stressors with various "top down" forces makes Seneca Lake an excellent, but complicated, natural laboratory and numerous projects over the next decade (Fig. 50).

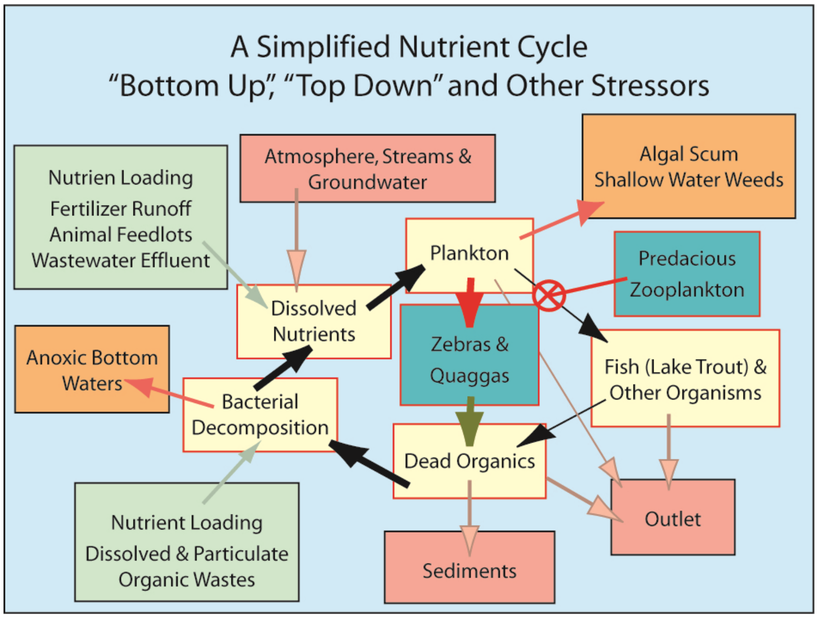


Fig. 50. A simplified nutrient cycle with "bottom up", i.e., nutrient loading, "top down", i.e., carnivorous zooplankton, and other stressors like zebra and quagga mussels.

Other Hydrogeochemical Water Quality Indicators

Herbicides: The source of atrazine, a common herbicide to control board-left weeds in corn in the Seneca Lake watershed was investigated in 1999 and 2000 (McSweeney, 1999; Baldwin and Halfman, 2000; Baldwin et al., 2001; Baldwin, 2002; Halfman and Franklin, 2007). Atrazine concentrations were typically below 1.0 μg/L throughout 1999. In 2000, concentrations were similar to 1999 values up to the end of May. After May, stream concentrations rose to or very close to 3 μg/L, the EPA's MCL, with the largest detected concentration of 8 μg/L at Kendig Creek (August, 2000). The study concluded with following spatial and temporal changes. First, streams draining more agricultural land had larger atrazine concentrations. Second, atrazine concentrations peaked during June, July and August, a timing that corresponds with the application of atrazine in the fields. Third, the amount of rainfall co-varied with the concentration of atrazine in the runoff. The largest concentrations were detected during a large rainfall event. The smaller concentrations in 1999 compared to 2000 corresponded to lower rainfall in 1999. Finally, none of the lake concentrations exceeded 1 μg/L, consistently below the EPA's MCL.

Coliform & E. coli Bacteria: Total coliform and *E. coli* bacteria concentrations in 2003, 2004 and 2005 were typically below the EPA's MCL (Bush and Halfman, 2006; Bush, 2006). These bacteria are used to monitor for the presence of human organic wastes and associated disease causing organisms in natural waters. However, these bacteria themselves pose minimal health threats, except for a few toxic strains of *E. coli*. Coliform sources also include geese, dogs, deer and other warm blooded, wild and domesticated, animals. Lake samples were typically ten times less concentrated than stream water, and lacked any temporal or spatial trends. Bacteria concentrations were largest in the streams during runoff events, and a runoff event influenced the large mean counts in 2005. Wilson and Hector Falls regularly had larger bacteria concentrations than the other streams, especially during runoff events. It suggests that agricultural and rural landscapes with aging septic systems input more bacterial than the other drainage systems, and pose potential but currently not detrimental threats to the Seneca Lake watershed.

Trihalomethanes: Trihalomethanes (THMs) concentrations were not above analytical detection limits for all the analyzed stream and lake water samples during the 2010 spring field season. Trihalomethanes (e.g., chloroform, bromoform, bromodichloromethane) are disinfection byproducts predominantly formed when chlorine is used to disinfect water.

Stream Macroinvertebrates & Fish

Biological indicators are an important analytical tool to determine water quality in flowing waters (Simon, 2002). Stream benthic macroinvertebrates (bottom-dwelling aquatic organisms without a backbone and not visible without magnification) are found in and around the stream channel and primarily include insects, gastropods, mollusks, and worms. Most insects spend their larval stage underwater and hatch into terrestrial adults, while other invertebrates spend their entire life in the stream. Macroinvertebrates are an important part of the stream food web, differ in their sensitivities to pollution, represent stream conditions over long time periods, are relatively easy to collect, and therefore serve as an important biological indicator of stream health (IWLA, 2000). Stream fish are dependent on insects and other invertebrates for food sources, but are generally more mobile on short time scales, and occupy and use different habitats than macroinvertebrates. Fish assemblage composition is also indicative of water quality and/or if stream habitat conditions are favorable or degraded (Karr, 1981).

Castle, Wilson, Kashong, Keuka Plum Pt, Big Stream, Rock Stream, Catharine (at two locations), Hector Falls, Glen Eldridge and Reeder Creek were sampled for macroinvertebrates and fish between May and June of 2011 (see Cushman, 2012 for details). The macroinvertebrates were collected by 500 μm benthic D-Net, sieved over a no. 60 sieve, preserved in 95% Ethanol, and 100 macroinvertebrates sorted and indentified to family level in each sample following standard DEC protocols (Bode et al., 2002).

The Percent Model Affinity (PMA) and Biotic Indices were utilized to assess the degree of impairment. PMA is a biological indicator developed for NY streams that provides a “model” community to which sample communities are compared (Novak and Bode, 1992). The model community is comprised of 40% ephemeroptera, 5% plecoptera, 10% trichoptera, 20% chironomidae, 10% coleopteran, 5% oligochaeta, and 10% other organisms. Those sample PMA scores that are greater than 65% are not impacted, while 50-64% are slightly impacted, 35-49% are moderately impacted, and lower than 35% are severely impacted (Novak and Bode, 1992). The Biotic Index (BI) indicator has higher specificity of taxonomic groupings and therefore impact level. Twenty-three groupings (by order and family groups) assigned biotic index scores are used to estimate the magnitude of water quality impact. Scores less than 4.5 represent non-impacted communities, but 4.51-5.50 are slightly impacted, 5.51-7.00 are moderately impacted, and 7.01-10.00 are severely impacted.

Fish were sampled by installing two 10 m block seine nets, at upstream and downstream boundaries, to isolate a 75 m sampling reach at each site. Starting at the downstream net, fish were stunned using a backpack electrofisher (Smith-Root LR 20B) and long-handled nets were used to retrieve fish. This was done twice. Fish were identified to species and two common species, *Rhinichthys atratulus* (blacknose dace) and *Semotilus atromaculatus* (creek chub), were measured for total length. The nets were then removed and all fish were returned to the stream channel. Dissolved oxygen, pH, temperature, and conductivity were measured using a YSI 556 multiprobe handheld meter to determine environmental conditions and proper settings for the electrofisher.

Results: The average PMA score for the entire Seneca Lake watershed was 61%, which represents slight water quality impact. Castle Creek, Keuka Outlet, Plum Creek, Rock Stream, the upper tributary of Catherine Creek and Glen Eldridge Creek all had PMA scores over 65% (no impact), while Reeder Creek, Wilson Creek, and Kashong Creek had scores ≤ 50%, representing moderate water quality impact (Fig. 51). None of the streams in the watershed were severely impacted. The best water quality among all subwatersheds was found in Plum Creek (PMA = 88%). The biotic index (BI), another biological indicator of water quality which incorporates a finer level taxonomic analysis, demonstrated similar findings.

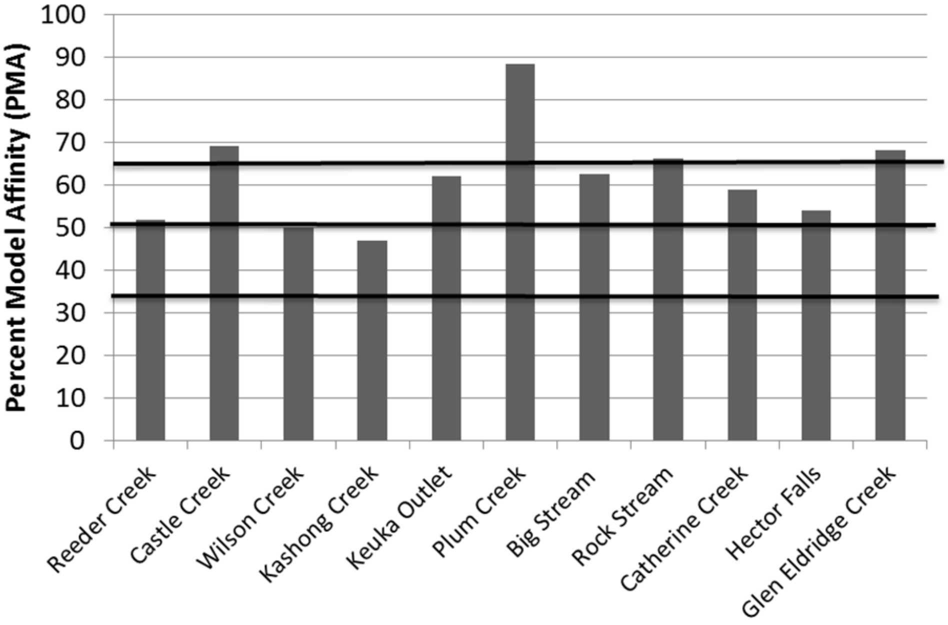


Fig. 51. Water quality in Seneca Lake subwatersheds indicated by the Percent Model Affinity (PMA) analysis. Scores represent the departure from a "model" benthic macroinvertebrate community using major group analysis in excellent stream water quality. Values greater than 65% indicated no water quality impact on the community (top bar), while those between 50 and 64% represent slight impact, 35-49% represent moderate impact and those below 35% are considered severely impacted (bottom bar).

On average, there are 4.5 species of fish in streams flowing into Seneca Lake. The typical fish assemblage, by order of average abundance, included *Rhinichthys atratulus* (blacknose dace), *Semotilus atromaculatus* (creek chub), *Campostoma anomalum* (central stoneroller), and *Catostomus commersoni* (white sucker). The first three are species in the minnow family, and the last is in the sucker family of fish. The only game fish and non-native salmonid species, *Salmo trutta* brown trout, was collected in Hector Falls Creek. In addition, one other non-native species, the swallowtail shiner *Notropis procne* was collected in Wilson Creek, Glen Eldridge Creek and Hector Falls Creek.

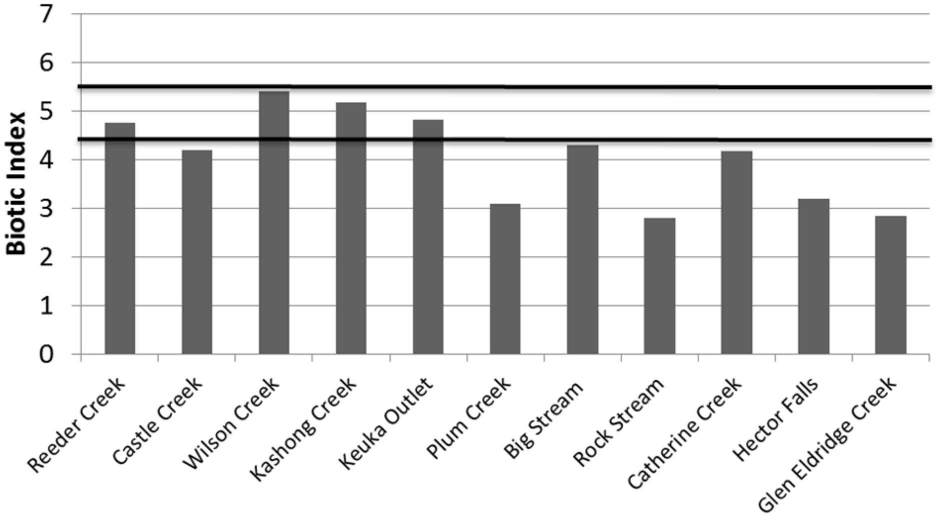


Fig. 52. Water quality in Seneca Lake subwatersheds indicated by the biotic index (BI). Scores represent a measure of diversity and sensitivity to water quality at both the family and order level of benthic macroinvertebrate identification. Values less than 4.50 indicated no water quality impact on the community (bottom bar), while those between 4.51 and 5.50 represent slight impact (top bar), 5.51-7.00 represent moderate impact and those above 7.01 are considered severely impacted.

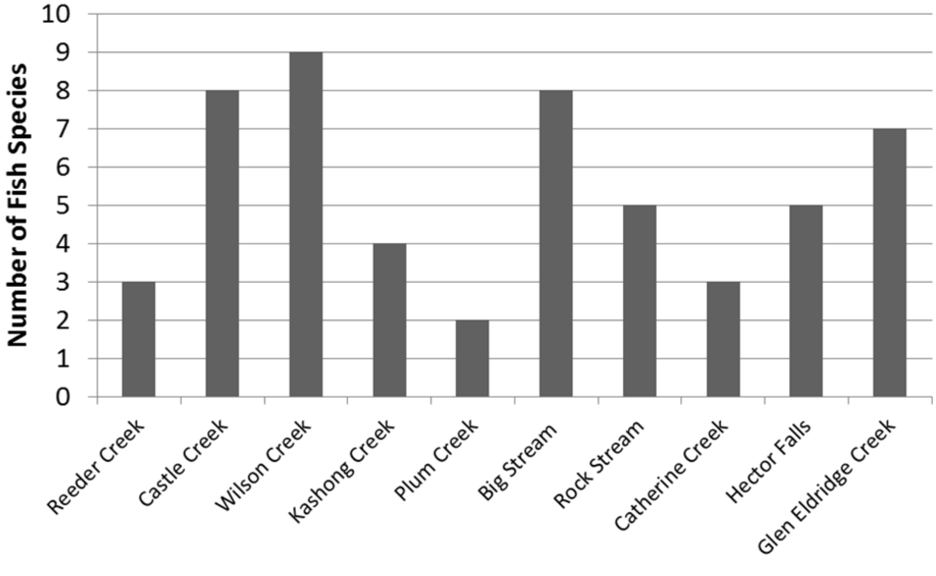


Fig. 53. Fish species richness in streams flowing into Seneca Lake. Fish were collected in a 75 m reach in each stream by double pass electrofishing.

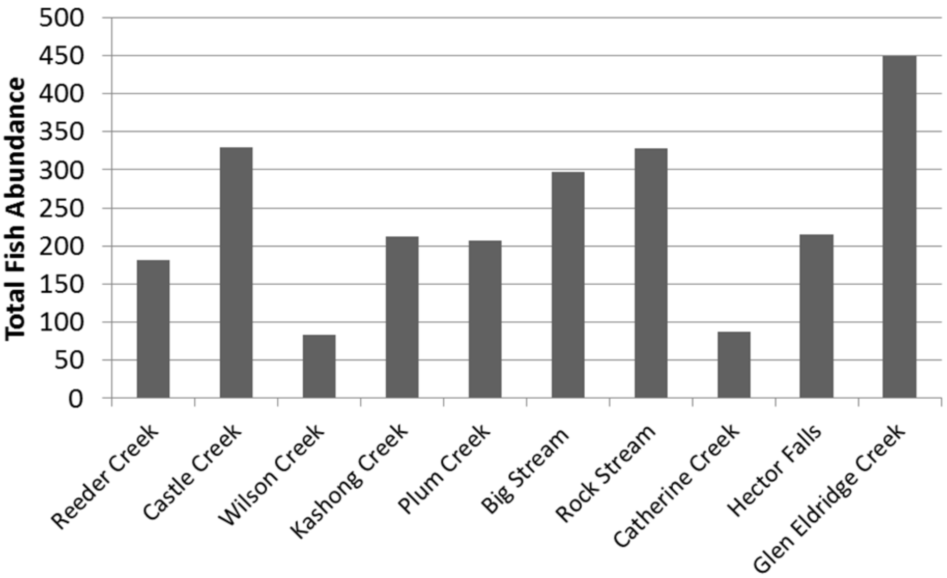


Fig. 54. Representative fish abundance (#fish/75 m) in streams flowing into Seneca Lake. Values represent all fish collected in a 75 m stream reach by double pass electrofishing.

Fish species richness varied across streams in the Seneca Lake watershed with the highest richness found in Wilson Creek (9 species) and the lowest in Plum Creek (2 species; Fig. 52). The smaller streams generally exhibited fewer species (Fig. 53). Fish abundance followed different trends, however. The highest total fish abundance (# fish per 75 m) was found in Glen Eldridge Creek (449 individuals), while the lowest fish abundance was in Wilson Creek (84 individuals; Fig. 54). Castle Creek, Big Stream, and Glen Eldridge Creek all both showed relatively high species richness and total fish abundance. Alternatively, Wilson Creek showed high species richness, but low total abundance, only 84 individuals. In 9 of the 10 streams where fish sampling was conducted, over 80% of the fish community was blacknose dace and creek chub.

Discussion: The macroinvertebrate analysis revealed that Reeder Creek, Wilson Creek and Kashong Creek have the worst water quality (slightly impacted). Wilson and Kashong Creeks have the most agriculture within each watershed impacting the macroinvertebrate assemblages. However, they both had excellent fish habitats including deep pools, excellent fish refuge/cover, i.e., instream woody debris, rootwads, and undercut banks (Cushman, data not shown). Reeder Creek exhibited poor macroinvertebrate habitat and low fish species richness and abundance due to scouring to bedrock layers, high silt covering bottom substrate, high conductivity, little woody debris and warm water (Cushman, data not shown). Castle Creek showed both good insect and fish habitat due to high frequency of woody debris, undercut banks, deep pools and overhead canopy cover by riparian buffer (Cushman, data not shown).

Big Stream exhibited good insect habitat with deep riffles, low conductivity and siltation, which are also good characteristics for fish habitat, except fish had little habitat to seek refuge. The fish community had a high prevalence of blackspot disease caused by a trematode parasite (*Neascus*). It also supported a small *Umbra limi* (central mudminnow) population that is a fish known for its tolerance to low dissolved oxygen. Rock Stream presented both poor insect and fish habitat, primarily due to bedrock as the primary bottom substrate resulting in a lack of riffles (insects) and deep pools

(Cushman, data not shown). The stream bottom showed evidence of heavy erosion upstream and resulting downstream siltation, as well as warmer stream water. The *Pimephales promelas* (fathead minnow) was also abundant in this community.

Plum Creek stood out as the best habitat for both insects and fish, with cool stream water, low siltation, thick overhead riparian canopy and equal distribution of riffle and pools. Plum Creek was comprised of 99% blacknose dace and 1% creek chub, two of the most common small stream fish species in the northeast and mid-Atlantic region of the US, but lacked deep pools for a greater fish diversity. Catherine Creek, Hector Falls, and Glen Eldridge all showed good insect and fish habitat i.e., excellent pool-riffle distribution, consistent with the water quality bioindicators. As a result, the tributary to Catherine Creek supported a unique fish species, *Etheostoma flabellare* (fantail darter), which are very intolerant of poor water quality including sedimentation. Hector Falls Creek also had excellent fish habitat, including good woody debris, debris jams, and cool temperatures (Cushman, unpublished data), which supported not only the common fish assemblage (above), but also *Salmo trutta* (brown trout). However, the eroded clay banks were consistent with silted riffles which lowered the quality of macroinvertebrate habitat. Finally, Glen Eldridge Creek represented good insect and great fish habitat, primarily due to good water quality, deep pools, some woody debris and rootwads, however upstream erosion was evident. The *Notropis procne* (swallowtail shiner), a non-native to this area was present (3) in this stream, along with the high fish abundance (449) of all sites sampled. Blacknose dace and creek chub were a high percentage of this community.

This preliminary survey adds to the limited knowledge about stream community composition in small streams in the Finger Lakes region. Considering the Finger Lakes are an important resource as both sources of water for surrounding communities as well as natural environment areas, it is important to study how the land across which water drains impacts the water quality. More importantly, since Seneca Lake is the deepest and holds the most water volume, knowing which subwatersheds influence water quality the most can play a large role in watershed planning and remediation (“Seneca Lake Watershed Management Plan”, 2010).

Chapter 5: Potential Sources of Pollution due to Human Activities

A number of potential sources of pollution due to human activities exist in the Seneca Lake watershed. They range from agricultural activities, forestry, urban landscapes, chemical and petroleum storage, spills, landfills and solid waste disposal, mining activities, road salt, road-bank erosion, boating activities, onsite and municipal liquid waste disposal, storm water runoff, construction activities, energy development, and air quality. Excellent details on these issues are found in the *Setting the Course for Seneca Lake, The State of the Seneca Lake Watershed* ("Seneca Lake Watershed Management Plan", 2010), and the information in this report is summarized below. These details were not updated for this report, and should be investigated and updated in the near future (see information gaps section, chapter 6).

A: Agriculture: The report attempted to quantify the non-point source impacts by agricultural activities using a comprehensive farm survey in conjunction with a nonpoint source computer model, generalized watershed loading functions model developed by Dr Haith, Cornell University. The survey identified the need for implementing agricultural best management practices in the Seneca Lake watershed. It also ranked each subwatershed in terms of its potential concern. Catharine Creek, Keuka Lake Outlet and Kashong Creek were ranked high, Reading drainage, Rock Stream, Big Stream, Starkey Drainage and Long Point Drainage as medium, and the remaining watersheds and drainages as low.

B: Chemical Bulk Storage: The report identified sixteen chemical bulk storage facility permits in the watershed. These facilities, and the sale, storage and handling of hazardous substances, fall under jurisdiction of Article 40 of the Environmental Conservation Law, the Hazardous Substance Bulk Storage Act of 1986, enforceable by NYS Department of Environmental Conservation (DEC). No facilities were in the Chemung County portion of the watershed, and only one facility ion the Seneca County portion. Schuyler had five, Ontario six, and Yates County four facilities. The chemicals included: aluminum sulfate, sodium hypochlorite, ferric chloride, sodium hydroxide, methanol, cupric chloride, phosphoric acid, nitric acid, ammonia, sulfuric acid, and 2- propanone.

C: Forestry & Forestry Practices: Forests are the best types of lands for protecting water quality. However timber harvesting is occurring throughout the watershed exposing highly erodible land. Best Management Practices are available for timber harvesting and apply to publically owned lands, e.g., USDA Forest Lands and NYS DEC properties. The private landowner, who controls the bulk of forested lands in the watershed, however may or may not employ these BMPs to stop erosion and sedimentation from reaching Seneca Lake.

D: Landfills, Dumps and Inactive Hazardous Waste Sites: Landfills are regulated by NYS DEC. Based on information from NYS DEC and conversations with local residents, twenty landfills and/or dumps were located in the watershed. At that time only two landfills were active, both located in Yates County. Twelve inactive hazardous waste sites were all considered closed with complete or some sort of remediation taking place. Five landfills were ranked with a high potential to threaten surface and/or groundwater (and located in Lodi, Montour, Hector, Torrey). Six others had a medium potential and eight with a low potential to threaten water quality. Nine of the twelve were identified as having a high potential to impact water quality (located in Romulus, Dix, Horseheads, Waterloo, Torrey, and Milo).

E: Mined Lands: Erosion from mined lands, especially surface mines, has the potential to impact sedimentation and water quality of nearby streams and the lake. NYS DEC law regulates onsite storage and/or runoff detention at each mine site. Thirty-six NYS DEC mined land and reclamation permits were listed in the watershed. Schuyler County had the most with 21, then Yates with 13 and Seneca with 2 mined land permits. These mines mostly extracted sand and gravel with some clay, glacial till, and shale. Mines worked prior to 1975 that are abandoned are not subject to reclamation laws, and may be potential water quality risks.

F: Petroleum Bulk Storage Faculties: NYS passed the Petroleum Bulk Storage Law in 1985. It requires NYS DEC to develop and enforce state code for the storage and handling of petroleum products to protect public health, welfare and the lands and waters of the state. These fuels include petroleum-based oils refined for use as a fuel to produce heat or energy or suitable as a lubricant (gasoline, heating oil, kerosene, lubricant oils, etc). A facility with a capacity of 1,100 to 400,000 gallons must be registered with NYS DEC. The watershed had 166 active, regulated and smaller unregulated petroleum bulk storage permits listed with NYS DEC. Geneva (38), Catharine (38) and Keuka Lake Outlet (24) subwatersheds had the greatest number of sites. Other subwatershed had eleven or less. Forty-three sites were not active.

G: Roadbank Erosion: A survey of all public roadways delineated roadbank conditions in the watershed, and categorized erosion in road ditches as moderate, severe or very severe. The very serve category implied cut, bare, and collapsing banks, exposed roots, and blow-out holes in ditch bottoms and gully erosion with estimated soil erosion rates of 100 to 200 tons per bankside mile. The very severe sections typically correlated to topographic slopes of 8% or more. Subwatersheds with the highest potential for roadbank erosion included Big Stream, Catharine Creek, Hector Falls Creek, Kashong Creek, and Mill Creek, Benton, Reading, Starkey and Sunset Bay subwatersheds. Those subwatersheds with the lowest rank included Kendaia, Lodi Point, Reeder, Wilson, Lamoreaux Landing, Reed Point, Sampson State Park and Valois subwatersheds.

H: Salt Storage & Deicing Materials: A survey of the county, municipal, and NYS Department of Transportation, Seneca Army Depot, and other private organizations that use salt revealed nineteen storage piles in the watershed. Two of them are exposed. In the 1997-1998 winter season, almost 7,000 tons of salt were applied to 1,270 road miles in the watershed, or 5.5 tons per mile. The largest amounts of salt were applied to the roads in the Big Stream, Catharine Creek, Geneva, Kashong Creek, Indian Creek, Reading, and Reed Point sunwatersheds. Benton, Glen Eldridge, Hector Fall Creek, Lamoreaux Landing, Long Point, Mill Creek, Plum Point Creek, Reeder Creek, Sampson State Park, Satterly Hill, Sawmill/Bullhorn Creek, Sixteen Falls Creek, and Valois subwatersheds were low contributors of deicing materials.

Shore Residences Environmental Health Risks: A survey of over 1000 lakeshore residents assessed the impact of lakeshore residents. The process also distributed Home*A*Syst books to each resident. The results indicated that 57% of the responses were from seasonal properties. Most people were not concerned about water quality as 65% did not treat the water, and 54% never had their water tested. However, 37% used bottle water for drinking. The average age of the septic system was 17 years. Almost one quarter used septic system additives. 95% of the residences were located within 500 ft of the lakeshore, and 42% within 50 ft of the shoreline. Over 80% of the residences had low erosion impact lawns (no bare spots), and 69% were not fertilized. Compost happened at 30% of the residences. Most participants recycled household wastes (90%) rather than burn it. A ranking system designated Catharine, Sixteen Falls, and Indian Creek subwatersheds to have the most risk from all these factors. Geneva drainage had the lowest risk and may reflect the use of public water and sewer systems.

J. State Pollution Discharge Elimination System (SPDES) Permits: A SPDES permit is a contract between NYS DEC and any facility discharging wastewater directly into surface or groundwater. The data gathered from NYS DEC revealed eighty significant SPDES permits in the watershed, i.e., those facilities with large amounts of wastewater discharge or wastewater with toxic substances, with fifty-one discharged to surface waters. Twenty-one discharged directly into Seneca Lake. Catharine Creek, Geneva, Keuka Lake Outlet, and Big Stream subwatersheds had the largest number of permitted facilities. Rock Stream, Reeder Creek, Kendaia Creek, Mill Creek, Lamoreauz Landing, Valois, Sawmill/Bullhorn Creek, and Glen Eldridge subwatersheds had none.

K: Spills: NYS DEC Spill Prevention and Response Data section maintains a record of all known reported spills and follow-up investigations. From 1974 to 1998 there were 990 hazardous material spills within the Seneca Lake watershed. The Geneva subwatershed had the most spills with 24% of the total number. Catharine Creek (20%), Keuka Lake Outlet (15%) and the Seneca Army Depot (10%) subwatersheds had the next largest number. Approximately 237% of the spills were petroleum products, primarily gasoline and #2 fuel oil.

L. Streambank Erosion: The erosion and sediment inventory conducted in 1974 by the USDA Soil Conservation Service (now the Natural Resources Conservation Service) estimated a sediment yield of 143 tons of sediment/bank mile/year or a total load of 43,657 tons per year. This study listed Kashong Creek, Big Stream and Catharine Creek subwatersheds as major contributors. The State of the Lake report also estimated that streambank erosion based on an Erosion Potential Index Number was largest in Catharine Creek, Big Stream, Keuka Lake Outlet, Reading, Starkey, Long Point, and Satterly Hill subwatersheds. It was lowest in Plum Point Creek, Wilson Creek, Reeder Creek, Kendaia Creek, Indian Creek, Simson Creek, Lodi Point, Mill Creek, Benton, Reed Point, Geneva, Sunset Bay, Wilcox, Sampson State Park, and Sixteen Falls Creek subwatersheds.

Chapter 6: Watershed and Subwatershed Information Gaps

The data and related information reported in this characterization is not exhaustive. A number of gaps exist in our knowledge of Seneca Lake and its watershed. These include issues alluded to in the previous chapters, and information not yet investigated. For example, the 1999 characterization, *Setting the Course for Seneca lake, the State of the Seneca Lake Watershed*, investigate a number of potential sources of pollution, including agricultural activities, forestry, urban landscapes, chemical and petroleum storage, spills, landfills and solid waste disposal, mining activities, road salt, road-bank erosion, boating activities, onsite and municipal liquid waste disposal, storm water runoff, construction activities, energy development, and air quality. The state of these issues and problems should be re-evaluated to see if water quality and/or conditions improved, declined or remained the same over the past decade. New industries and activities should be investigated to assess their impact on the watershed. For example, the proposed storage of energy products (propane and natural gas) in the abandoned salt caverns near Watkins Glen and drilling for shale gas loom close on the horizon. The Shale drilling has impacts on both water use and water quality. Pre- and post-drilling and storage monitoring should occur in nearby waterways to accurately assess potential future impacts. Finally, the terrestrial and wetland ecosystems in the watershed can be better understood.

Surface and groundwater sources are not very well understood. As mentioned in an earlier chapter, surface water resources are dependent on limited information and critical for numerous users in the watershed, and impact those downstream of the lake. For example, only the Keuka Outlet out of the numerous inflows is routinely monitored for flow. The volume of the lake is based on old “lead-line” depth data from the turn of the 20th century. The available residence time estimates vary considerably.

The availability and water quality of groundwater resources are even less understood. Aquifers are not abundant in the watershed, however many people still depend on groundwater for drinking water and other uses. Groundwater resources and its quality are also subjected to a variety of pollutant sources, see a partial list above. Preliminary studies indicate elevated levels of TCE and PAHs, arsenic, copper, lead and other metals, radioactivity, and beryllium in the water of both Kendaia and Reeder Creeks or in the sediments just offshore of these two creeks (Gonzales and Campbell, 2000). The source is probably from groundwater contamination and runoff over the former Seneca Army Depot site. Any investigation should initiate flow directions, recharge areas, and perhaps designate aquifer recharge protection zones in the watershed to protect its quality. For example, the well fields and groundwater systems for any of the groundwater dependent municipalities should be mapped and water quality assessments investigated.

Another large unknown in the Seneca Lake watershed is the new chemical and biological threats just becoming a concern across the nation in the past decade. These include items like human and veterinary drugs (including antibiotics), natural and synthetic hormones, detergent metabolites, plasticizers, herbicides, insecticides, caffeine, fire retardants, organic wastewater contaminants and other compounds (Koplin, et al., 2002, Barnes et al., 2012). All are at concentrations near, or above MCLs, when MCLs are known, in a variety of surface and groundwater systems across the nation. A number of these compounds are too new to have MCLs.

Various contributors to this characterization presented preliminary data that requires additional study for more complete understanding. This list, besides issues raised in the previous paragraphs, should include the following to arrive at a better understanding of the water supply and waste disposal coverage and associated infrastructure within the watershed, a better delineation and characterization of wetlands and stream corridors, monitoring the physical, biological, chemical and other aspects of the lake's limnology and the biology and hydrogeochemistry of its major tributaries. Each chapter typically mentioned where additional information is required. More work is required to better understand:

- The linkages between the meteorology, heat fluxes of the dynamics (physical limnology) in the lake.
- The linkages between salt mining activities and the salinity of the lake.
- The detection, distribution, impact and potential control of exotic species with the lake and its watershed.
- The observed decline of the benthic communities in the lake and its impact on the lake's ecology.
- Follow up on the initial fish and macroinvertebrate distributions, heavy metal concentrations, and other associations in the watershed's tributaries.
- The linkages between stream corridors, sediment transport, and habitat availability and quality.
- Maintain the active water quality monitoring program in the lake to document future changes in the lake's trophic status, and maintain efforts to determine its relationship to nutrient and sediment loading from the watershed and internal pressures by various exotic species.
- The historical record of heavy metals, organic and other potentially toxic compounds for the watershed.

Appendix A: Notes/Resources

Project Advisory Committee as of February 2012

Last Name	First Name	Title	Affiliation
Ahola	Richard	Board Member	Seneca Lake Pure Waters Association
Amidon	Patricia	Supervisor	Town of Tyre
Angelo	Ralph	Supervisor	Town of Richmond
Bagley	David	Supervisor	Town of Lodi
Baker	David	Supervisor - Ward 1 & 4	City of Canandaigua
Balyszak	Jim	District Manager	Yates County SWCD
Bartholomew	Kathryn	Chair	Schuyler County EMC
Bauter	Paul	Watershed Manager	Keuka Watershed Improvement Cooperative
Bellis	Mark	Mayor	Village of Dundee
Bertino	Rudy	Mayor	Village of Waterloo
Bishop	Lisa	Supervisor	Town of Tyrone
Bonshak	Shawna	Planner	Yates County Planning Department
Boudreau	Edward	Supervisor	Town of Waterloo
Burcaw	Richard	Supervisor	Town of Starkey
Calabrese	Richard	Supervisor	Town of Gorham
Casella	Sam	Supervisor	Town of Canandaigua
Champlin	John T.	Supervisor	Town of West Bloomfield
Church	Robert	Mayor	Village of Penn Yan
Clark	Robert	Supervisor	Town of Benton
Collier	William	Supervisor	Town of Catlin
Davey	Edith	Conservation Educator	Ontario County SWCD
Davidson	Lee	Supervisor	Town of Lodi
Dickens	Benjamin	Supervisor	Town of Hector
Duserick	Frank	Supervisor	Town of Naples
Edwards	Michael	Supervisor	Town of Horseheads
Einstein	Robert (Stu)	Mayor	City of Geneva
Emerick	P. J.	District Director	Ontario County SWCD
Evangelista	Charles	Supervisor - Ward 3 & 4	City of Geneva
Fafinski	Theodore	Supervisor	Town of Farmington
Flynn	Patrick	Supervisor	Town of Torrey
Gallahan	Jeffery	Supervisor	Town of Manchester
Green	Mary	Supervisor	Town of Hopewell
Griswold	Phillip	District Manager	Seneca County Water Quality Comm.
Hautaniemi	Danielle	Director of Planning and Development	Cornell Cooperative Ext. Schuyler Co.
Hayssen	Bob	Supervisor	Town of Varick
Hicks	Jenna	Enviro. Science Educator/EMC	Cornell Cooperative Extension
Hicks	Tim	Watershed Inspector	Schuyler County Watershed Protection Agency
Huber	Dorothy	Supervisor	Town of East Bloomfield
Hughes	Kristen Mark	Director	Ontario County Planning Dept.
Johns	Loujane	Mayor	Village of Dresden
Jones	Daryl	Supervisor	Town of Jerusalem
Kaiser	David	Supervisor	Town of Romulus
Kelley	Donna Jennings	Mayor	Village of Montour Falls
Kelly	Leon	Mayor	Village of Ovid
King	John	Supervisor	Town of Waterloo
LaRocca	Robert	Supervisor	City of Geneva
Larsen	Bill	Mayor	Village of Interlaken
Lorenzetti	Cindy	Supervisor	Town of Fayette
Luckern	Mary	Supervisor	Town of Geneva

Marshall	Daniel	Supervisor	Town of South Bristol
Meyer	Sarah	Community Outreach Coordinator	Finger Lakes Institute
Mooney	James	Supervisor	Town of Waterloo
Mullaney	William	Supervisor	Town of Orange
Multer	James	Supervisor	Town of Barrington
Ninestine	Donald	Supervisor - Ward 5 & 6	City of Geneva
O'Malley	Tracey	Coastal Resources Specialist	NYSDOS
Olthof	Randy J.	Commissioner	Chemung County Planning Department
Orlando	Carmen	Supervisor	Town of Phelps
Pfeiff	Janette	Supervisor	Town of Seneca Falls
Phillips	Judy	Mayor	Village of Watkins Glen
Polimeni	Ellen	Mayor	City of Canandiagua
Poormon	Howard	Supervisor	Town of Fayette
Prouty	Walter	Supervisor	Town of Ovid
Raps	Ed	Supervisor	Town of Starkey
Reed	David M.	Supervisor	Town of Cayuta
Reynolds	Michael	Supervisor	Town of Covert
Rollins	Dixon	Regional Water Engineer	NYSDEC Region 8
Rowe	Mitch	Director	Seneca County Planning Department
Russell	Harold	Supervisor	Town of Dix
Russell	Richard	Supervisor - Ward 2 & 3	City of Canandiagua
Same	Peter W.	Supervisor	Town of Seneca Falls
Scott	David	Supervisor	Town of Montour
Serven	Ronald	Supervisor	Town of Janius
Sheppard	John T.	Supervisor	Town of Seneca
Singer	Kristine	Supervisor	Town of Canadice
Slack	Brian	Associate Planner	Genesse/Finger Lakes RPC
Smith	Diana	Mayor	Village of Seneca Falls
Sowards	Connie	Administrator	Village of Waterloo
Stow	Gene		PRAC Member
Switzer	Marvin	Supervisor	Town of Reading
Verrigni	Jerry	District Manager	Schuyler County SWCD
Verrigni	Jessica	Stormwater Management Specialist	Chemung County SWCD
Walter	Dale	Mayor	Village of Burdett
Williams	Rodman	Supervisor	Town of Benton
Winkky	William	Supervisor	Town of Veteran
Wisor	Joanne	City of Geneva Mayor	City of Geneva
Wright	Frederick	Supervisor	Town of Barrington
Yearick	Chris	Community Educator	Upper Susquehanna Coaltion
Young	Theodore	Mayor	Village of Waterloo
Zajac	Ray	Supervisor	Town of Romulus
Zorn	Dave	Executive Director	Genesee/Finger Lakes RPC

Active Seneca Lake Watershed Organizations

Abbreviation	Organization
ACE	Army Corps of Engineers
AEM	Agricultural Environmental Management
AFT	American Farmland Trust
CCE	Citizens Campaign for the Environment
CCE	Cornell Cooperative Extension
CEC	Citizens Environmental Coalition
CEDC	Community Environmental Defense Council, Inc.
CEI	Center for Environmental Information
CNYRPDB	Central New York Regional Planning and Development Board
CPFL	Committee to Preserve The Finger Lakes
CPNY	Coalition to Protect New York
CSLAP	Citizens Statewide Lake Assessment Program
DOI	Department of Interior
DOT	Department of Transportation
EFC	Environmental Facilities Corporation
EMC	Environmental Management Council
EPA	Environmental Protection Agency
ESF	SUNY Environmental Science & Forestry
FDA	Food and Drug Administration
FEMA	Federal Emergency Management Agency
FF	Freshwater Future
FLA	Finger Lakes Association
FLCC	Finger Lakes Community College
FLCWI	Finger Lakes CleanWaters Initiative
FLEN	Finger Lakes Environmental Network, Inc.
FLI	Finger Lakes Institute
FLLOWPA	Finger Lakes-Lake Ontario Watershed Protection Alliance
FLLT	Finger Lakes Land Trust
FL-PRISM	Finger Lakes Partnership for Regional Invasive Species Management
FLRU	Finger Lakes ReUse
FLVC	Finger Lakes Visitors Connection
FLZWC	Finger Lakes Zero Waste Coalition
FOLA	Federation of Lake Associations
FSA	Farm Service Agency
GFLRPC	Genesee-Finger Lakes Regional Planning Council
GFS	Gas Free Seneca
GGC	Geneva Green Committee
GLBAC	Great Lakes Basin Advisory Council
GLRC	Great Lakes Research Consortium
GNRC	Geneva Neighborhood Resource Center
HWS	Hobart and William Smith Colleges
IAGT	Institute for the Application of Geospatial Technology, Inc.
ILEC	International Lake Environment Committee
IPCNYS	Invasive Plant Council of New York State
ISTF	New York State Invasive Species Task Force
KLA	Keuka Lake Association
KWIC	Keuka Watershed Improvement Cooperative
NALMS	North American Lake Management Society
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
NWF	National Wildlife Foundation

NWR	National Wildlife Refuge
NYFB	New York Farm Bureau
NYPIRG	New York Public Interest Research Group
NYS DAM	New York State Department of Agriculture and Markets
NYS DOH	New York State Department of Health
NYS DOS	New York State Department of State
NYS DOT	New York State Department of Transportation
NYS OPRHP	New York State Office of Parks, Recreation, and Historical Preservation
NYS ORPS	New York State Office of Real Property Services
NYSAES	New York State Agricultural Experiment Station
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health
NYSDOS	New York State Department of State
NYSDOT	New York State Department of Transportation
NYSERDA	New York State Energy Research and Development Agency
NYSFOLA	New York State Federation of Lake Associations
NYSG	New York Sea Grant
NYSTA	New York State Thruway Authority
OPRHP	Office of Parks, Recreation & Historic Preservation
ORPS	Office of Real Property Services (see also NYSORPS)
R-CAUSE	Rochesterians Concerned About Unsafe Shale-gas Extraction
SC-FL	Sierra Club Finger Lakes Group
SCOPED	Schuyler County Partnership for Economic Development
SCS	Soil Conservation Service
	Shaleshock
SHPO	State Historic Preservation Office
SLAP-5	Seneca Lake Area Partners in 5 Counties
SLPWA	Seneca Lake Pure Waters Association
STCRPDB	Southern Tier Central Regional Planning and Development Board
SUNY ESF	State University of New York Environmental Science and Forestry (ESF)
SWCD	Soil and Water Conservation District
TNC	The Nature Conservancy
TPA	Tourism Promotion Agency
TU	Trout Unlimited
USACE	United States Army Corp. of Engineers
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WAC	Watershed Advisory Council
WEC	Water Education Collaborative
WQCC	Water Quality Coordinating Committee
WQIP	Water Quality Improvement Program
WQMA	Water Quality Management Agency
WRC	Water Resource Council

Glossary of Acronyms

AEM	Agricultural Environmental Management
BMP	Best Management Practice
CAFO	Concentrated Animal Feeding Operation
CEO	Code Enforcement Officer
CPESC	Certified Professional in Erosion and Sediment Control
CREP	Conservation Reserve Enrollment Program
CRP	Conservation Reserve Program
CRS	Community Rating System (see NFIP)
CSLAP	Citizens Statewide Lake Assessment Program
CSO	Combined Sewage Overflow
CWA	Clean Water Act
CWS	Community Water System
CWSRF	Clean Water Act State Revolving Fund
DWSRF	Drinking Water State Revolving Fund
EIS	Environmental Impact Statement
EMC	Environmental Management Council
EPF	Environmental Protection Fund
EQIP	Environmental Quality Improvement Program
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FL-PRISM	Finger Lakes Partnership for Regional Invasive Species Management
FOIL	Freedom of Information Law
FSA	Farm Service Agency
GIS	Geographic Information System
GLRI	Great Lakes Restoration Initiative
GPS	Global Positioning System
HAZMAT	Hazardous Materials
IA	Inter-municipal Agreement
IDA	Industrial Development Agency
IJC	International Joint Commission
ILEC	International Lake Environment Committee
IO	Inter-municipal Organization
LEED	Leadership in Energy and Environmental Design
LOCI	Lake Ontario Coastal Initiative
LWRP	Local Waterfront Revitalization Plan
MOU	Memorandum of Understanding
MS4	Municipal Separate Storm Sewer Systems
NAAQS	National Ambient Air Quality Standards
NEPA	National Environmental Policy Act
NFIP	National Flood Insurance Program
NHS	National Historic Site
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
NPS	Non-point Source
NWF	National Wildlife Foundation
NWR	National Wildlife Refuge
OWWT	On-site wastewater treatment
PB	Planning Board
PUD	Planned Unit Development
WI PWL	Priority Waterbodies List

PWS	Public Water System
QA/QC	Quality assurance/quality control
RCRA	Resource Conservation and Recovery Act
RIBS	Rotating Intensive Basin Study
ROW	Right of way
SCS	Soil Conservation Service
SDWA	Safe Drinking Water Act
SEMO	State Emergency Management Office
SEQRA	State Environmental Quality Review Act
SHPO	State Historic Preservation Office
SPDES	State Pollution Discharge Elimination System
STP	Sewage Treatment Plant
SWCD	Soil and Water Conservation District
SWP	Source Water Protection
SWPPP	Stormwater Pollution Prevention Plan
SWTR	Surface Water Treatment Rule
TMDL	Total Maximum Daily Load
TPA	Tourism Promotion Agency
TRI	Toxic Release Inventory
TU	Trout Unlimited
USACE	United States Army Corp. of Engineers
VOC	Volatile Organic Compound
WAC	Watershed Advisory Council
WEC	Water Education Collaborative
WHPA	Wellhead Protection Area
WQCC	Water Quality Coordinating Committee
WQIP	Water Quality Improvement Program
WQMA	Water Quality Management Agency
WRC	Water Resource Council
WRI	Water Resource Institute
ZBA	Zoning Board of Appeals
ZEO	Zoning Enforcement Officer

Lake Facts

Carved out of bedrock over 10,000 years ago by glaciers, Seneca Lake is the deepest freshwater lake east of the Mississippi River outside the Great Lakes. Due to its depth, the lake does not freeze in the winter.
Location: New York, USA 42.39 N, 76.89 W; 135.6 m above sea level Lake
Type: Ground Moraine
Primary Inflows: Catharine Creek, Keuka Lake Outlet, underwater sources
Primary Outflows: Cayuga-Seneca Canal
Mean Length: 56.6 km (35.2 miles)
Max Length: 61 km (38 mi)
Mean Width: 3.10 km (1.9 miles)
Mean Depth: 88.6 m (290.7 ft)
Max Depth: 198.4 m (650.9 ft)
Surface Elevation: ~440 ft (130 m)
Surface Area: 42,800 acres, 66.9 sq mi, (173 km2)
Volume: 15.539 km3 (3.8 cu mi)
(approx Retention time is the longest (18.1 yr) of the Finger Lakes
1” of lake level on Seneca Lake = 1.2 billion gallons of water

Seneca Falls Power Corp normal operation = 1,500 cubic feet per second
Maximum operation = 3,200 CFS
Average usage: 1,500 cu ft sec = 11,221 gal/ sec = 40.4 million gal/hr = 323 million gal/8 hours

Canal locks 45’ x 328’, varying depths; 25’ (worst case) = 2.8 million gallons per operation
Summer hours: 7 AM to 10 PM; Winter hours: 7 AM to 5 PM
Average cycle time = 45 minutes
8 hours of operation = ~ 11 cycles = 31 million gal/8 hours

Water Level Data
Condition 6 of the Federal Energy Regulatory Commission requires that the daily fluctuation of Seneca Lake should not exceed 0.1 foot and the daily fluctuation of Van Cleef Lake should not exceed 0.25 feet from the daily target elevation for each lake, respectively, set by the New York State Thruway Authority (NYSTA). Seasonal fluctuations should be in accord with the rule curve developed by the New York State Department of Transportation and NYSEG in the late 1970s in response to concerns of the Seneca Lake Waterways Association.
*Fact sheet produced and published by Seneca Lake Pure Waters Association, www.senecalake.org

Data Sources and Notes

Public Lands and Recreation Trails

Public lands data compiled from multiple sources under the Genesee/Finger Lakes Regional Planning Council Finger Lakes Open Lands Conservation Project (2010). Project overview available online from http://gflrpc.org/Publications/FLOLCP/index.htm.

Sources include:

NYS Department of Environmental Conservation:

- DEC Lands (2010)
- Public Fishing Rights (2010)
- Public Fishing Stream Parking Areas

NYS Office of Parks, Recreation & Historic Preservation

- New York State Historic Sites and Park Boundary
- State-funded Snowmobile Trails

Genesee Transportation Council

- Regional Trails Inventory

NYS Regulated Freshwater Wetlands

Freshwater Wetlands (DEC; NAD83) Coverages (wetlands boundary datasets) are published by county, and are updated as amendments occur, or as errors in the data are discovered and corrected. For the most recent updates to coverages by county, visit the Cornell University Geospatial Information Repository at http://cugir.mannlib.cornell.edu/ .

US Fish and Wildlife Service National Wetlands Inventory

The U.S. Fish and Wildlife Service is the principal Federal agency that provides information to the public on the extent and status of the Nation's wetlands. The agency has developed a series of topical maps to show wetlands and deepwater habitats. This geospatial information is used by Federal, State, and local agencies, academic institutions, and private industry for management, research, policy development, education and planning activities. Digital GIS data can be viewed and downloaded at http://www.fws.gov/wetlands/

Build-out Analysis Methodology

1. This analysis reviewed the potential for future residential growth only in locations that were pre-determined to have this potential.

2. Determined areas with higher potential growth for analysis by reviewing the following data sources:

- A) Zoning districts with the availability of public or lake water were considered to have higher potential for growth. Zoning districts that had any public water in them (even bulk lines) or were adjacent to the Lake were included.
- B) Villages were excluded from this analysis. Across the board, towns were considered as having both more potential and space for development, and were also the areas that this study was focused on as developments could potentially have more effects on the non-developed areas in towns.
- C) Towns with no zoning were excluded from this analysis as they usually have very little development pressure, and the build-out method is heavily based on land-use regulations.

3. Within selected towns, determined the zoning districts for further analysis

- A) Identified Residential, Agricultural, and Agricultural/Residential zoning districts in selected municipalities that are at least partially within the watershed and have access to public/lake water. Zoning districts that have water lines intersecting them at any point or are adjacent to Seneca Lake are considered to have access to public/lake water.
- B) Excluded Mobile Home Park zoning districts.
- C) Excluded Mixed Use/PUD zoning districts; it is extremely difficult to determine how these zoning districts will ultimately be developed.

4. Determined bulk regulations for identified zoning districts

- A) Bulk regulations refer to the minimum and maximum standards for lot sizes and address geometric and structural issues such as building setbacks and building height.
- B) The bulk regulations were reviewed in an effort to establish the minimum single family residential lot size in each selected zoning district.
  - a. This study excluded the potential for multi-family buildings/lots given the vast multitude of potential scenarios that these options would create for each zoning district.

5. Determined total land area open to potential development

- A) Only the portions of zoning districts that were within the watershed were considered for analysis.
  - a. This study only analyzed the area of zoning districts that fell within the boundary of the Seneca Lake watershed.
- B) Among zoning districts remaining for future consideration, the study considered bulk regulations and Office of Real Property Services parcel data to determine if those zoning districts had adequate vacant property to accommodate new development. "Developable" parcels are those that meet the following criteria:
  - a. Parcels identified as "vacant" residential property in RPS records and large enough for residential development.
  - b. Large residential lots 10 acres in size or larger were reviewed because it is assumed that these would be large enough to be subdivided without affecting existing structures or residences.
  - c. All agricultural properties large enough for residential development were considered.
    - i. While agricultural use is in many cases protected or specifically zoned "agricultural" in order to preserve such use, the property could feasibly be sold or re-zoned in the future for the purposes of residential development and are therefore considered for further analysis. This is for the purpose of portraying land that could be developed, not suggesting that these areas are always appropriate for development.
- C) Determined the total "developable" land area for each identified zoning district.

    a. Properties determined to qualify for future development as stated above were summed to arrive at a raw figure of total area in square feet for each zoning district.

6. Determined potential constraints to development within each zoning district

- A) Constraints to development were examined only on parcels considered developable, and subtracted from the amount of total developable land. This analysis did not conduct a parcel by parcel analysis of how constraints affected each property's buildable area but rather focused on the sum within each zoning district.
- B) Environmental constraints included:
    - a. NYS Regulated Freshwater Wetlands (+100ft buffer)
    - b. Surface water (lakes, ponds, streams, creeks, rivers, + a standard 50ft buffer area)
    - c. Land area that had a slope of 15% or greater based on 30 meter Digital Elevation Model data
- C) The remaining land area open for development was reduced by 35%
    - a. A 25% reduction was based on the space that could be needed to accommodate anticipated infrastructure (such as roads, sidewalks, power lines, stormwater facilities, etc.), natural features (including poor soils), and irregularly-shaped parcels (this is in accordance with the Monroe County Department of Transportation study "Ballantyne Corridor Study") (Erdman, 2005).
    - b. A 10% reduction was based on space reserved for parkland and open space. Some municipalities require or "may" require residential developments to set aside a certain percentage of land or a space per unit for open space or parkland. Others do not require this in code. The 10% was applied across the board to all zoning districts. Even developments in municipalities without this requirement would often have some open space even if it were simply due to lots built larger than the minimum size regulation.
- D) Land area within the identified 100-year flood zone was not considered to be a constraint. In most towns, 100-year flood zones were open to new development with proper precautions and approval. In some instances, towns have identified locations of high flood risk and zoned accordingly; these zoning districts were therefore removed from analysis early on in the build-out study.

7. Final calculation of potential land available for development.

- A) Each zoning district had a customized series of calculations performed in order to determine the estimated land area open to potential residential development. This is generally determined by conducting the following steps:
    - a. Environmental constraints (see 6.B above) are subtracted from the total gross land open to development
    - b. 35% standard reduction is applied to this figure (see 6.C above)
    - c. The result was a figure estimating the land area available for development within each zoning district.

8. Assuming a specific rate of growth and development, determine when the developable land with each zoning district will become "built-out"

- A) The minimum lot size for each zoning district is established under bulk regulations; this figure was divided into the land area available for development to determine a total lot number which was then adjusted based on units already present (any occupied units on residential lots over 10 acres that were included as developable) in order to determine the total number of new residential lots that the zoning district could accommodate.
- B) The average unit increase between the years 2000 and 2010 was determined by municipality using U.S. Census data and was adjusted based on the percentage of the municipal area within the watershed in order to estimate a yearly rate of development. The growth rate is specific to ten year total unit increase in the entire municipalities, rather than being specific to the zoning district or single family units.
- C) The estimated potential number of years until build-out could occur by zoning district was determined by dividing the estimated number of lots that the zoning district could accommodate by the average

yearly unit increase. This was determined for each zoning district assuming development were to be concentrated in each, as well as for the total of all selected zoning districts in each municipality**.**

Appendix B: Works Cited

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Appendix C: NYSDEC Water Quality Classifications

Copied from http://www.dec.ny.gov/regs/4536.html; New York State Department of Environmental Conservation web site: Part 898: Finger Lakes Drainage Basin.

This table pertains to Seneca Lake and its watershed (including Keuka Lake watershed). Item numbers include 397 through 474.

Water Index Number	Name	Description	Map Ref. No.	Class	Standards
Ont. 66-12-P 369 portion as described	Seneca Lake	That portion of Seneca Lake from most northerly point on north shore line of lake south 2.4 miles to an imaginary eastwest line across lake passing through Pastime Park with west end 0.2 miles south of south City of Geneva line.	J-12sw	B	B(T)
Ont. 66-12-P 369 portion as described	Seneca Lake	That portion of Seneca Lake within a 1-mile radius of mouth of Keuka Lake Outlet coming into Seneca Lake from west in Village of Dresden, 0.7 mile northwest of Perry Point.	K-12nw	B	B(T)
Ont. 66-12-P 369 portion as described	Seneca Lake	That portion of Seneca Lake beginning at imaginary east-west line passing through Pastime Park and extending southerly for approximately 32 miles to an imaginary line passing through mouth of Quarter Mile Creek (trib. 61) on west side of lake 0.2 mile south of north line of Village of Watkins Glen and through mouth of trib. 58 on east side of lake 0.2 mile north of north line of Village of Watkins Glen. The portion within a 1-mile radius of Keuka Lake Outlet is excluded.	J-12sw K-12nw K-12ne K-12se K-12sw L-12nw L-12ne	AA	AA(T)
Ont. 66-12-P 369 portion as described	Seneca Lake	That portion of Seneca Lake southerly of imaginary line across lake passing through mouth of Quarter Mile Creek and mouth of trib. 58 to south shore of lake.	L-12ne L-12nw	B	B(T)
Ont. 66-12-P 369-a, 2, 2a, 2b and tribs., 3, 4, 5 and trib.	Tribs. of Seneca Lake	Enter Seneca Lake along east shore from a point 0.1 mile south of where Seneca River enters lake and N.Y. Route 96A crosses Seneca River to a point 0.3 mile north of Yale Farm Road and 0.7 mile south of Sunset Bay.	J-12sw	C	C
Ont. 66-12-P 369-6 portion as described	Reeder Creek	Enters Seneca Lake from east at a point 0.3 mile southeast of intersection of East Lake Road and Yale Farm Road and extending 2.0 miles upstream to a point which is located 0.4 mile east of intersection of Route 96A and Yale Farm Road.	J-12sw	C	C(T)
Ont. 66-12-P 369-6 portion as described including all tribs.	Reeder Creek	From a point 2.0 miles upstream from mouth to source.	J-12sw J-12se K-12ne	C	C
Ont. 66-12-P 369-6a, 7, 7a, 8, 9 and trib., 10, 11, 12, 14 portion and tribs., 15 portion including P 371 and tribs., 16, 18, 19, 20 portion, 21 portion, 22 and trib., 23 portion and tribs., 25, 26, 26a, 27, 28 portion and tribs., 28a, 29 and trib., 30, 30a, 31, 32, 32a, 33, 34, 35 and trib., 36, 36a, 36b, 37, 37a, 37b, 37c, 37d, 38 portion and tribs.,	Tribs. of Seneca Lake	Enter Seneca Lake along east shore from a point 0.9 mile south of Yale Farm Road, 3.2 miles southwest of MacDougall, to a point 2.4 miles south of Seneca- Schuyler county line, 0.4 mile north of Peach Orchard Point. Trib. 9 portion upstream from	J-12sw K-12nw K-12ne K-12se K-12sw	C	C

39, 40 portion and trib., 40a, 41, 41a and trib., 42, 42a, 42b, 42c, 43		above Rt. 96A to source. Trib. 14 upstream from above trib. 2 to source. Trib. 15 upstream from above 1st road crossing within N.Y.S. Willard Psychiatric Center property, including tribs. and P 371, to source. Trib. 20 from above falls upstream to source. Trib. 21 from above falls upstream to source, also known as "16 Falls Creek". Trib. 23 upstream from above falls to source. Trib. 28 upstream from above falls, including tribs., to source. Trib. 38 upstream from above falls, including tribs., to source. Trib. 40 upstream from above falls to source.			
Ont. 66-12-P 369-44 portion as described	Sawmill Creek	Enters Seneca Lake from east at Peach Orchard Point 0.6 mile south of trib. 43. Mouth to falls 0.3 mile upstream.	L-12nw	C	C(TS)
Ont. 66-12-P 369-44 portion as described	Sawmill Creek	From falls 0.3 miles upstream from mouth to source.	L-12nw L-12ne K-12se	C	C
Ont. 66-12-P 369-44-a and trib., 1 and tribs., 2, 3, 4	Tribs. of Sawmill Creek	Enter Sawmill Creek from a point 1.7 miles upstream from mouth and 0.1 mile north of Hector Road to a point 3.9 miles upstream from mouth and 0.8 mile northeast of Logan.	L-12ne K-12se	C	C
Ont. 66-12-P 369-45 and trib., 46, 47, 48, 49, 51, 51a, 51b, 51c, 51d, 51e, 52 and tribs., 53 and trib., 54, 54a, 54b, 54c, 54d, 54e, 54f, 54g, 54h, 54j, and 54k	Tribs. of Seneca Lake	Enter Seneca Lake along east shore from McGrath Point 0.4 mile south of Peach Orchard Point southerly to 0.4 mile north of Glen Eldridge Point 1.1 miles northwest of Village of Burdett. Trib. 45 portion from above falls to source.	L-12nw L-12ne	C	C
Ont. 66-12-P 369-45 portion	Bull Horn Creek	From mouth upstream 650 ft. to falls.	L-12ne	C	C(TS)
Ont. 66-12-P 369-55 portion as described	Trib. of Seneca Lake	Enters Seneca Lake from east at Glen Eldridge Point 0.9 mile northwest of northwest corner of Village of Burdett. From mouth to first impassable falls located 0.1 mile upstream of mouth.	L-12ne	C	C(TS)
Ont. 66-12-P 369-55 portion as described	Trib. of Seneca Lake	From first impassable falls to N.Y. Route 414 bridge located 0.2 mile upstream of mouth.	L-12ne	C	C
Ont. 66-12-P 369-55 portion as described including P 371a and all tribs.	Tribs. of Seneca Lake	From N.Y. Route 414 bridge to source.	L-12ne	C	C
Ont. 66-12-P 369-56 portion as described	Hector Falls Creek	Enters Seneca Lake from east at Hector Falls Point 0.5 mile south of Glenn Eldridge Point and 0.7 mile west of Village of Burdett. From mouth to first falls impassable by fish, approx. 300 feet upstream of mouth.	L-12ne	C	C
Ont. 66-12-P 369-56 portion as described	Hector Falls Creek	From first falls impassable by fish to N.Y. Route 227 bridge in center of Village of Burdett.	L-12ne	C	C(TS)
Ont. 66-12-P 369-56-P 371b	Trib. of Hector Falls Creek	Unnamed pond.	L-12ne	C	C
Ont. 66-12-P 369-56 portion as described	Hector Falls	From N.Y. Route 227 bridge in Village of Burdett to trib. 6a.	L-12ne	C	C(TS)

	Creek				
Ont. 66-12-P 369-56 portion	Hector Falls Creek	From above trib. 6a upstream to source.	L-12ne	C	C(T)
Ont. 66-12-P 360-56-2 and trib., 3a	Tribs. of Hector Falls Creek	Enter Hector Falls Creek from a point 1.8 miles upstream from Route 227 bridge at Village of Burdett and 0.4 mile northwest of Bennettsburg to trib. 3a,1.0 mile upstream and 0.6 mile northwest of Bennettsburg.	L-12ne	C	C
Ont. 66-12-P 369-56-4	Trib. of Hector Falls Creek	Enters Hector Falls Creek from south 0.1 mile upstream from trib. 3a, 0.6 mile northeast of Bennetsburg. From mouth to source.	L-12ne	C	C(TS)
Ont. 66-12-P 369-56-4-1, 2, 4, 5, P 372a and P 372b	Tribs. of trib. 4 of Hector Falls Creek	Enter stream from a point 1.2 miles upstream from mouth and 1.0 mile southeast of Bennettsburg to a point 1.1 miles upstream and 0.7 mile west of Newtown Road.	L-12ne	C	C
Ont. 66-12-P 369-56-5, 6, 6a	Tribs. of Hector Falls Creek	Enter Hector Falls Creek from a point 1.1 miles west of Newtown Road and 0.3 mile north of N.Y. Route 227 to a point 0.8 mile west of Newtown Road and just north of N.Y. Route 227.	L-12ne	C	C
Ont. 66-12-P 369-56-8	Trib. of Hector Falls Creek	Enters Hector Falls Creek from west 0.5 mile south of Reynoldsville and 0.2 mile east of N.Y. Route 227.	L-12ne	C	C(T)
Ont. 66-12-P 369-56-8-1	Trib. of trib. 8 of Hector Falls Creek	Enters trib. 8 of Hector Falls Creek from south 0.3 mile upstream from mouth, 0.1 mile west of N.Y. Route 227.	L-12ne	C	C
Ont. 66-12-P 369-56-9 and trib., 10	Tribs. of Hector Falls Creek	Enter Hector Falls Creek from north and west 0.3 mile south and 0.5 mile southwest of Reynoldsville and 0.2 mile east and 0.1 mile west of N.Y. Route 227, respectively.	L-12ne	C	C
Ont. 66-12-P 369-57, 58 and trib., 58a	Tribs. of Seneca Lake	Enter Seneca Lake from east at a point 0.7 mile southeast of Hector Falls Point and 0.1 mile west of N.Y. Route 414 to a point just south at north line and just west of east line of Village of Watkins Glen.	L-12ne	C	C
Ont. 66-12-P 369-59 portion as described	Seneca Lake Inlet (name changes to Catherine Creek at trib. 6)	Enters Seneca Lake from south 0.2 mile south of north line and 0.1 mile west of east line of Village of Watkins Glen. From mouth to confluence with Barge Canal.	L-12ne L-12se	C	C(T)
Ont. 66-12-P 369-59 portion	Seneca Lake Inlet	From confluence with Barge Canal to trib. 6, 1.9 miles upstream.	L-12se	C	C(TS)
Ont. 66-12-P 369-59 portion as described	Catherine Creek	From trib. 6 to a point 1.0 mile upstream from trib. 28, 0.6 mile	L-12se M-12ne	C	C(TS)

	(upstream end of Seneca Lake Inlet)	south of Veteran-Horseheads town line and 0.8 mile east of N.Y. Route 14.			
Ont. 66-12-P 369-59 portion as described	Catherine Creek	From a point 1.0 mile upstream from trib. 28 to source.	M-12ne L-12se	C	C
Ont. 66-12-P 369-59-1	Trib. of Seneca Lake Inlet	Enters Seneca Lake Inlet from east at a point 1.1 miles upstream from mouth, 0.3 mile west of east line of Village of Watkins Glen.	L-12ne L-12se	C	C
Ont. 66-12-P 369-59-2	Diversion channel	From above trib. 3b to Barge Canal (previously unclassified).	L-12se	C	C(T)
Ont. 66-12-P 369-59-3a portion as described	Johns Creek	Enters Seneca Lake Inlet from east 1.3 miles upstream from trib. 1, 0.6 mile east of N.Y. Route 14 in Village of Montour Falls. From mouth 1.2 miles upstream to outlet of P 373a which is Village of Montour Falls water supply reservoir 1.7 miles south of Hector-Montour town line and 0.5 mile east of Skyline Drive.	L-13se	C	C
Ont. 66-12-P 369-59-3a portion as described including P 373a	Johns Creek	From and including P 373a to source.	L-12se L-12ne	A	A
Ont. 66-12-P 369-59-3a-1a	Trib. of Johns Creek	Enters Johns Creek from east 0.8 mile upstream from mouth and 0.5 mile north of N.Y. Route 224.	L-12se	C	C
Ont. 66-12-P 369-59-3a-6, 6a, 7, 9, 9a	Tribs. of Johns Creek	Enter Johns Creek from east and north from a point 0.5 mile south and 1.1 miles west of north and east Montour Town lines to a point 0.1 mile south and 0.9 mile west of said town lines.	L-12ne	A	A
Ont. 66-12-P 369-59-3b, 3c and trib.	Tribs. of Seneca Lake Inlet	Enter Seneca Lake Inlet from east in Village of Montour Falls, 0.1 mile north and just south of N.Y. Route 224 and 0.2 mile west of Skyline Drive. Trib. 3c portion from above falls to source.	L-12se	C	C
Ont. 66-12-P 369-59-3c	Trib. of Seneca Lake Inlet	From mouth upstream to falls.	L-12se	C	C(TS)
Ont. 66-12-P 369-59-5a	Catlin Mill Creek	Enters Seneca Lake Inlet from east in Village of Montour Falls 0.3 mile south of N.Y. Route 224 and 0.3 mile east of N.Y. Route 14. From mouth to source.	L-12se L-12ne	C	C(TS)
Ont. 66-12-P 369-59-5a-2	Cranberry Creek	Enters Catlin Mill Creek from north in Village of Odessa, 0.2 mile south and 0.2 mile west of north and east village lines, respectively. From mouth upstream to below trib. c.	L-12se L-12ne	C	C(T)
Ont. 66-12-P 369-59-5a-2 portion	Cranberry Creek	From trib. c upstream to source.	L-12se L-12ne	C	C(TS)
Ont. 66-12-P 369-59-5a-2-a, b, c	Tribs. of Cranberry Creek	Enter Cranberry Creek from a point 0.7 mile upstream from its mouth and 0.7 mile east of Upper Foots Hill Road to a point 1.9 miles upstream from its mouth and 0.6 mile east of Upper Foots	L-12se	C	C

		Hill Road.			
Ont. 66-12-P 369-59-5a-2a, 3, 3a, 3b	Tribs. of Catlin Mill Creek	Enter Catlin Mill Creek from a point 0.2 mile south and 0.1 mile west of north and east lines of Village of Odessa to a point 0.6 mile south of Victor-Catherine town line and 0.2 mile west of Steam Mill Road.	L-12se L-12ne	C	C
Ont. 66-12-P 369-59-5a-7	Trib. of Catlin Mill Creek	Entire trib. 7.	L-12ne	C	C(TS)
Ont. 66-12-P 369-59-5b	Trib. of Seneca Lake Inlet	Enters Seneca Lake Inlet from east 0.5 mile north of south line and 0.4 mile west of east line of Village of Montour Falls.	L-12se	C	C
Ont. 66-12-P 369-59-6 portion as described	Trib. of Seneca Lake Inlet	Enters Seneca Lake Inlet from east 0.1 mile north of south and 0.5 mile west of east lines of Village of Montour Falls. From mouth 1.0 mile upstream to a point 0.5 mile southeast of southeast corner of Village of Montour Falls.	L-12se	C	C(T)
Ont. 66-12-P 369-59-6 portion as described including all tribs.	Tribs. of Seneca Lake Inlet	From a point 1.0 mile upstream from mouth to source.	L-12se	C	C
Ont. 66-12-P 369-59-7 portion and tribs.	Trib. of Catherine Creek (name changed from Seneca Lake Inlet)	Enters Catherine Creek from east on south line of Village of Montour Falls 0.5 mile east of southeast corner of village. From above trib. 1 upstream to source.	L-12se	C	C
Ont. 66-12-P 369-59-7 portion	Tribs. of Catherine Creek	From mouth upstream to trib. 1.	L-12se	C	C(TS)
Ont. 66-12-P 369-59-9 portion as described	Trib. of Catherine Creek	Enters Catherine Creek from east at a point 0.3 mile south of south line of Village of Montour Falls and 0.1 mile west of N.Y. Route 14. Mouth to a point 0.8 mile upstream at Wigwam Road bridge.	L-12se	C	C(TS)
Ont. 66-12-P 369-59-9 portion as described	Trib. of Catherine Creek	From Wigwam Road bridge to source.	L-12se	C	C
Ont 66-12-P 369-59-1 and trib., 2, 3 and tribs.	Tribs. of trib. 9 of Catherine Creek	Enter trib. 9 from a point 0.1 mile upstream from mouth and 0.4 mile south of south line of Village of Montour Falls to a point 1.8 miles north of Schuyler- Chemung county line and 1.2 miles west of Montour-Catherine town line.	L-12se	C	C
Ont. 66-12-P 369-59-9a, 18, 18b, 19 portion and trib., 20a and tribs., 25 including P 377, 27 and trib., 27a, 28 and trib. including P 377a, 29, 33, 34	Tribs. of Catherine Creek	Enter Catherine Creek from a point 1.0 mile south of the south line of Montour Falls Village and 0.4 mile west of the Dix-Montour town line to a point 0.6 mile south of Merka Road and 0.4 mile west of Veteran Hill Road.	L-12se L-12sw M-12ne	C	C
Ont. 66-12-P 369-59-10a portion, 12 portion, 15 portion, 15-1 portion, 18a portion, 24 portion, 26 portion	Tribs. of	Trib. 10a, from mouth to 1.0 mile upstream; Trib. 12, from	L-12se L-12sw M-	C	C(TS)

	Catherine Creek	mouth to first falls impassable by fish (0.1 mile); trib. 15, mouth to first falls impassable by fish (1.0 mile); trib. 15-1, mouth to first falls impassable by fish (0.2 mile); trib. 18a, mouth to first falls impassable by fish (0.1 mile); trib. 24, from mouth upstream 0.5 mile; trib. 26, from mouth to 0.4 mile upstream of trib. 2.	12ne		
Ont. 66-12-P 369-59-10a portion and tribs., 12 portion and tribs., 15 portion and tribs. including trib. 1 portion, 18a portion and trib., 24 portion and trib., 26 portion and tribs.	Tribs of Catherine Creek	Trib. 10a, from 1.0 mile upstream of mouth to source; trib. 12, from first falls impassable by fish to source; trib. 15, from first falls impassable by fish to source; trib. 15-1, from first falls impassable by fish to source; trib. 18a, from first falls impassable by fish to source; trib. 24, from 0.5 mile upstream of mouth to source; trib. 26, from 0.4 mile upstream of trib. 2 to source.	L-12se L-12sw M-12ne	C	C
Ont. 66-12-P 369-59-22 and tribs.	Johnson Hollow Creek and tribs.	Enters Catherine Creek immediately and south of Burch Hill Road.	L-12se L-12sw	B	B
Ont. 66-12-P 369-59-19 portion	Trib. of Catherine Creek	From mouth upstream to below trib. 1.	L-12se	C	C(TS)
Ont. 66-12-P 369-60 portion as described	Glen Creek (trib. of Seneca Lake)	Enters Seneca Lake from south at a point 0.3 mile south of north line and 0.5 mile west of east line of Village of Watkins Glen. From mouth to trib. 1.	L-12ne	C	C
Ont. 66-12-P 369-60 portion as described	Glen Creek	From trib. to 1 N.Y. Route 14 bridge in Village of Watkins Glen.	L-12ne	C	C(TS)
Ont. 66-12-P 369-60 portion as described	Glen Creek	From N.Y. Route 14 bridge at Village of Watkins Glen to first falls impassable by fish (0.15 mile).	L-12ne L-12se	B	B(TS)
Ont. 66-12-P 369-60 portion as described including P 378a, P 378b and trib. 3	Glen Creek and VanZandt Hollow	From first falls impassable by fish to source, including P 378a, P 378b and trib. 3.	L-12se L-12nw L-12sw L-11ne	B	B
Ont. 66-12-P 369-60-1	Old Barge Canal Channel	Enters Glen Creek from south 0.3 mile upstream from mouth and 0.4 mile west of east line of Village of Watkins Glen to confluence of Seneca Lake Inlet and Catherine Creek 0.1 mile north of south line and 0.5 mile west of east line at Village of Montour Falls.	L-12ne L-12se	C	C(T)
Ont. 66-12-P 369-60-1-1 portion as described	Trib. of Old Barge Canal Channel	Enters Old Barge Canal Channel from west in Village of Montour Falls, 2.0miles upstream from mouth and 0.2 mile east of N.Y. Route 14. From mouth to first falls impassable by fish (0.15 mile).	L-12se	C	C(TS)
Ont. 66-12-P 369-60-1-1 portion as described and trib.	Trib. of Old Barge Canal Channel	From first falls impassable by fish to source.	L-12se L-12sw	C	C

Ont. 66-12-P 369-60-1-2 portion as described	Shequaga Creek	Enters Old Barge Canal Channel from south in Village of Montour Falls 2.2 miles upstream from mouth just south of N.Y. Route 14 crossing. Mouth to 0.7 mile upstream at Village of Montour Falls west line.	L-12se	C	C(T)
Ont. 66-12-P 369-60-1-2 portion as described	Shequaga Creek	From Village of Montour Falls west line to trib. 5.	L-12se L-12sw	C	C(TS)
Ont. 66-12-P 369-60-1-2 portion as described	Shequaga Creek	From trib. 5 to source (unnamed). Trib. 5 also named Shequaga Creek.	L-12sw	C	C
Ont. 66-12-P 369-60-1-2-a, 2, 3a, 4 and trib., 6, 8, 9	Tribs. of Shequaga Creek	Enter Shequaga Creek from a point 0.5 mile upstream from mouth in Village of Montour Falls and 0.2 mile east of Dix-Montour town line to a point 0.7 mile north of Schuyler-Chemung county line and 0.5 mile southwest of Moreland.	L-12se L-12sw	C	C
Ont. 66-12-P 369-60-1-2-5 portion as described	Trib. of Shequaga Creek	From mouth to 4.2 miles upstream of mouth.	L-12sw	C	C(TS)
Ont. 66-12-P 369-60-1-2-5 portion as described and tribs.	Trib. of Shequaga Creek	From 4.2 miles upstream of mouth to source.	L-12sw	C	C
Ont. 66-12-P 369-60-1-3 and trib.	Trib. of Old Barge Canal Channel	Enters Old Barge Canal Channel in Village of Montour Falls 0.6 mile north of its south line and 0.2 mile west of N.Y. Route 14.	L-12se	C	C
Ont. 66-12-P 369-60-6 and trib., 7 and tribs., 8 and trib., 11 and tribs., 13, 14, 15 and tribs., 16 and tribs., 19 and trib., 20, 21, 22 and trib., 23	Trib. of Glen Creek and VanZandt Hollow	Enter Glen Creek and VanZandt Hollow from a point on Glen Creek in Watkins Glen State Park 2.3 miles upstream from west line of Village of Watkins Glen and 0.1 mile north of N.Y. Route 329 to a point on VanZandt Hollow 0.9 mile west of Reading-Tyrone town line and 0.6 mile north of Mud Lake Road.	L-12sw L-12nw L-11ne	C	C
Ont. 66-12-P 369-61 and trib., 62, 63, 65, 66, 67, 68, 69, 70 and tribs., 70a, 71 and trib., 71a, 72 and trib., 73, 74, 74a, 75 and P 378c, 75a, 75b, 76, 78 and trib., 79 and trib., 81, 85, 85a, 86, 88, 88a, 89, 89a, 89b, 90 and trib., 93a, 94, 94a, 95, 95a, 96 and trib., 97 and trib., 98, 99, 101, 102 and tribs., 102a, 104a and trib., 104b and trib., 105, 105a, 105b, 106 and tribs., 106a, 106b, 106c, 106d, 107, 107a, 107b, 108, 108a, 109 and trib., 110, 112, 113 and tribs.	Tribs. of Seneca Lake	Enter Seneca Lake from west from a point in Village of Watkins Glen 0.2 mile south of north village line to Perry Point 0.3 mile south of Romulus-Ovid town line. Pond P 378c is unnamed.	L-12nw K-12sw K-12nw K-11se L-11ne	C	C
Ont. 66-12-P 369-93 portions as described, 104 and trib. 1a portions as described, 91 portion, 103 portion	Tribs. of Seneca Lake	Trib. 93, from mouth to first falls impassable by fish (0.15 mile). Trib. 104, from mouth to first falls impassable by fish (1.0 mile), trib. 104-1a from mouth to first falls impassable by fish (200 feet). Trib. 91 from mouth upstream to falls. Trib. 103 from mouth upstream to falls.	L-12nw K-12sw K-11se L-11ne	C	C(TS)
Ont. 66-12-P 369-104 and trib. 1a portions as described, and tribs., 91 portion and tribs. and P 378d, 103 portion and tribs.	Tribs. of Seneca Lake	Trib. 104 and trib. 1a, from first falls impassable by fish to source. Trib. 91 from above falls upstream to source, including all tribs. Trib. 103 from above falls upstream to source, including	L-12nw K-12sw K-11se L-11ne	C	C

		all tribs. Pond P 378d is unnamed, and stocked with brown, brook trout.			
Ont. 66-12-P 369-93 portion	Big Stream	Trib. 93 from falls (0.15 mile) to Rt. 14A.	L-12nw K-12sw	D	D
Ont. 66-12-P 369-93 portion	Big Stream	From Route 14A at Dundee upstream for about 1.0 mile to Pre-emption Road.	K-12sw	B	B
Ont. 66-12-P 369-93 portion	Big Stream	From Pre-emption Road to 1.0 mile above trib. 11.	K-12sw K-11se	C	C
Ont. 66-12-P 369-93 portion	Big Stream	From 1.0 mile above trib. 11 to trib. 16.	K-11se L-11ne	C	C(TS)
Ont. 66-12-P 369-93 portion and tribs.	Big Stream	From above trib. 16 to source. Includes all tribs.	L-11ne K-11se K-12sw L-12nw	C	C
Ont. 66-12-P 369-115 portion as described	Keuka Lake Outlet	Enters Seneca Lake from west in Village of Dresden on Seneca-Yates county line 0.8 mile northwest of Perry Point. From mouth 0.6 mile upstream to N.Y.C. Railroad bridge within Village of Dresden.	K-12nw	C	C(T)
Ont. 66-12-P 369-115 portion as described	Keuka Lake Outlet	From a point 0.6 mile upstream from mouth in Village of Dresden to trib. 10.	K-12nw K-11ne	C	C(T)
Ont. 66-12- P 369-115 portion as described	Keuka Lake Outlet	From trib. 10 to source at Keuka Lake south of Village of Penn Yan 0.2 mile west of East Lake Road and 0.5 mile south of West Lake Road.	K-11ne	C	C
Ont. 66-12-P 369-115-a, 1 and trib., 2, 2a, 2b, 3 and tribs., 3a, 3b, 3c, 4 and trib., 5, 6 and tribs., 7a, 8 and trib., 9, 10, 11, and tribs., 11a, 12 and tribs., 13, 14 and tribs.	Tribs. of Keuka Lake Outlet	Enter Keuka Lake Outlet from a point 0.1 mile upstream from mouth in Village of Dresden to a point 0.3 mile downstream from Keuka Lake just east of the westline of Village of Penn Yan.	K-12nw K-11ne K-12sw K-11se	D	D
Ont. 66-12-P 369-115-P 388	Keuka Lake	Begins at source of Keuka Lake Outlet south of Village of Penn Yan and extends southerly 18 miles to Village of Hammondsport.	K-11ne K-11se L-11ne L-11nw K-11sw	AA	AA(TS)
Ont. 66-12-P 369-115-P 388-a, 2, 3, 4 and tribs., 6, 7, 8 and trib., 8a, 8b, 9, 10, 11, 12 and trib., 12a, 13, 14 and trib., 15, 16 and tribs., 17, 18, 18a, 19, 19a, 20, 20a, 20b, 20c, 21 and tribs., 23 and trib., 24, 25, 25a and trib., 25b, 25c	Tribs of Keuka Lake	Enter Keuka Lake from east beginning at a point 0.6 mile south of Keuka Lake Outlet 0.1 mile west of East Lake Road to a point 11 miles south on Keuka Lake 1.0 mile northwest of junction of Yates, Schuyler and Steuben county lines and 0.5 mile west of Steuben-Yates county line where trib. 25c enters Lake.	K-11ne K-11se L-11ne	D	D
Ont. 66-12-P 369-115-P 388-26 portion as described and trib.	Power Flume	Enters Keuka Lake from east 0.1 mile southwest of trib. 25c,0.9 mile northwest of junction of Yates, Schuyler and Steuben county lines. This flume carries water diverted from Waneta and Lomoco Lake to Hydro-electric Station at Keuka on Keuka	L-11ne	D	D

		Lake. Mouth upstream to a point 0.3 mile downstream from Waneta Lake at Wayne.			
Ont. 66-12-P 369-115-P 388-26a, 27, 27a, 27b, 27c, 27d, 27e, 28 and trib., 30, 32, 32a, 33, 33a, 34, 35	Tribs. of Keuka Lake	Enter Keuka Lake from east from a point 0.1 mile southwest of trib. 26 (Power Flume) southwesterly 6.0 miles to Willow Point 1.0 mile east of Village of Hammondsport.	L-11ne L-11nw	C	C
Ont. 66-12-P 369-115-P 388-36	Keuka Inlet and Cold Brook	Enters Keuka Lake from south immediately south of southeast corner of Village of Hammondsport, 0.4 mile north of N.Y. Route 54. Mouth to a point 3.9 miles upstream to trib. 7 and Cold Brook from trib. 7 to source.	L-11nw L-10ne L-10se	C	C(TS)
Ont. 66-12-P 369-115-P 388-36-1 and tribs.	Tribs. of Keuka Inlet	Enter Keuka Inlet from south at a point 0.5 mile upstream from mouth and 0.2 mile north of N.Y. Route 54.	L-11nw	C	C
Ont. 66-12-P 369-115-P 388-36-2 portion as described	Trib. of Keuka Inlet	Enters Keuka Inlet from south at a point 0.1 mile upstream from trib. 1 and 0.2 mile north of N.Y. Route 54. Mouth to a point 1.2 miles upstream to N.Y. Route 54 bridge which is located 1.0 mile southwest of Village of Hammondsport.	L-11nw	C	C(T)
Ont. 66-12-P 369-115-P 388-36-2 portion as described, including trib.	Tribs. of Keuka Inlet	From N.Y. Route 54 bridge to source.	L-11nw L-10ne L-10se	C	C
Ont. 66-12-P 369-115-P 388-36-2a, 3 and tribs., 5 and trib., 6 and tribs., 6a and tribs., 7 and trib., 7a, 8, 9	Tribs. of Keuka Inlet and Cold Brook	Enter Keuka Inlet and Cold Brook from a point 0.3 mile north of N.Y. Route 54 and 0.3 mile west of N.Y. Route 54A to a point on Cold Brook in Town of Bath 0.3 mile south and 0.4 mile west of southwest Bath-Urbana town line.	L-11nw L-10ne L-10se	C	C
Ont. 66-12-P 369-115-P 388-37 and tribs., 37a, 37b, 37c, 38 and tribs., 40, 40a, 40b, 40c, 41, 42, 42a, 43, 44, 45, 46, 47 and tribs., 48 and tribs., 49, 50, 51, 51a, 52, 53, 54 and trib., 54a, 55, 56 and trib., 57 and tribs., 58, 58a,59, 60, 61 and tribs.	Tribs. of Keuka Lake	Enter Keuka Lake along entire west shore of lake beginning at a point in Village of Hammondsport 0.1 mile west of its east line and 0.1 mile south of N.Y. Route 54A to a point 0.8 mile north of Yates-Steuben County line and 0.2 mile east of N.Y. Route 54A.	L-11nw L-10ne K-11sw	C	C
Ont. 66-12-P 369-115-P 388-48-P 388a	Subtrib. of Keuka Lake	Unnamed pond.	K-11sw	C	C
Ont. 66-12-P 369-115-P 388-62	Sugar Creek	Enters Keuka Lake from north at Branchport hamlet 0.3 mile east and 0.2 mile south of N.Y. Route 54A. From mouth to trib. 4, and from trib. 20 to source.	K-11sw K-11nw K-11ne	C	C(T)
Ont. 66-12-P 369-115-P 388-62 portion	Sugar Creek	From trib. 4 upstream to trib. 20.	K-11sw K-11nw	C	C(TS)
Ont. 66-12-P 369-115-P 388-62-a, b, c, d and trib., 1, 1a, 3 and trib., 4 and trib. 4a, 5 and tribs., 5a, 5b and trib., 6, 8, 9, and tribs., 9a, 9b, 10, 12, 13, 13a, 13b, 13c, 14 and trib., 16, 17, 18, 18a,19 and trib., 19a, 20 and tribs., 21, 22 and trib., 22a, 23 and trib., 23a, 24 and tribs., 25 and tribs.	Tribs. of Sugar Creek	Enter Sugar Creek from east and west beginning at a point 0.1 mile upstream from mouth in Branchport hamlet to a point just west of Potter-Benton town line and 0.4 mile north of Tears Road. Trib. 9 from above falls to source, including all tribs.	K-11sw K-11nw K-11ne	D	D
Ont. 66-12-P 369-115-P 388-62-7, portion as described	Trib. of Sugar	From mouth upstream 0.8 mile.	K-11sw K-	C	C(TS)

	Creek		11nw		
Ont. 66-12-P 369-115-P 388-62-7 portion as described and tribs.	Trib. of Sugar Creek	From 0.8 mile upstream of mouth to source.	K-11nw K-11sw	C	C
Ont. 66-12-P 369-115-P 388-62-9 portion	Unnamed trib. of Sugar Creek	From mouth to falls, 4,000 ft. upstream.	K-11nw	C	C(TS)
Ont. 66-12-P 369-115-P 388-62a, 63 and trib., 63a, 63b, 63c and trib., 63d, 63e, 63f, 63g, 63h, 63I, 63j, 63k, 63l, 63m, 63n, 63o, 63p, 63q, 63r, 63s, 63t, 63u, 63v, 63w, 63x, 63y, 63z, 63aa, 63bb, 63cc, 63dd, 63ee, 63ff, 63gg, 64 and tribs.,64a, 65, 65a, 66 and trib., 66a, 67, 68, 69	Tribs. of Keuka Lake	Enter Keuka Lake from north, east and west from a point0.5 mile east of Branchport hamlet and continuing around periphery of lake to a point 0.6 mile west of Keuka Lake Outlet at Penn Yan, 1.2 miles south of Benton-Jerusalem town line.	K-11sw K-11se K-11ne	C	C
Ont. 66-12-P 369-115-P 388-67-P 388b, 68-P 388c	Subtribs. of Keuka Lake	Unnamed ponds.	K-11ne	C	C
Ont. 66-12-P 369-115a, 116,117, 118a, 121, 124, 127, 127a, 128 and tribs., 129, 130, 131, 132, 132a, 132b, 133 and tribs.	Tribs. of Seneca Lake	Enter Seneca Lake from west from a point on Seneca-Yates county line 0.1 mile north of Village of Dresden north line to a point 8.5 miles northerly to Clark Point which is located 0.2 mile northeast of intersection of N.Y Route 14 and Billsboro Road.	K-12nw J-12sw J-11se K-11ne	C	C
Ont. 66-12-P 369-134	White Springs Brook	Enters Seneca Lake from west at a point on Seneca-Ontario County line 0.3 mile southeast of intersection of N.Y. Route 14 and Turk Road.	J-12sw J-11se	C	C
Ont. 66-12-P 369-134-P 392, P 393, P 394	Ponds trib. to White Springs Brook	Three isolated ponds located 0.3, 0.2 and 0.2 mile east of Pre-Emption Road and 0.45, 0.5 and 0.3 mile south of N.Y. Route 5, respectively.	J-11se	C	C
Ont. 66-12-P 369-134-P 395	Pond trib. to White Springs Brook	Located 0.25 mile east of Pre-Emption Road and 0.28 mile south of N.Y. Route 5.	J-11se	B	B
Ont. 66-12-P 369-134-P 395a	Pond trib. to White Springs Brook	Located 0.2 mile east of Pre-Emption Road and 0.2 mile south of N.Y. Route 5.	J-11se	C	C
Ont. 66-12-P 369-136, 137, 138 and tribs., 138a, 139 and tribs.	Tribs. of Seneca Lake	Enter Seneca Lake from west and north from a point on Seneca-Ontario County line 0.6 mile south of south line of City of Geneva to a point just south of N.Y. Route 5 and 0.4 mile east of N.Y. Route 14.	J-12sw J-11se J-11ne J-12nw	C	C
None	Barge Canal	Beginning at confluence of State Bridge Canal and Canandaigua Outlet in Village of Lyons, westerly to drainage basin limits at Wayne Port 3.0 miles west of Village of Macedon.	H-12sw H-11se H-11sw H-10se	C	C