13-01e Roseland Lake Nutrient Loads Modeling Project, Task 1e

2015

Review of Previous Studies of Roseland Lake, Woodstock, CT

Eastern Connecticut Conservation District
238 West Town Street
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13-01e Roseland Lake Nutrient Loads Modeling Project

Task 1e Acquire and Review Historic Water Quality Information

Introduction

Roseland Lake has been listed as eutrophic and impaired for recreational contact in the CT Department of Energy and Environmental Protection (DEEP) Water Quality Assessment Report to Congress for several cycles, most recently in 2014. DEEP defines eutrophic as “water highly enriched with plant nutrients and with high biological productivity characterized by occasional blooms of algae or extensive areas of dense macrophyte beds.” Roseland Lake is located in Woodstock, CT. The surface area of the lake is approximately 96 acres. The maximum depth of the lake is approximately 20 feet. The average depth of the lake is 10 feet deep (DEP)[1].

Approximately two miles downstream of the Roseland Lake outlet into Little River, the Town of Putnam withdraws water from Little River to serve as a public drinking water supply. The State of Connecticut does not allow for wastewater discharges into surface water upstream of a public drinking water supply intake. Therefore, the sources of nutrient enrichment in Roseland Lake are either from diffuse, non-point sources, or illicit discharges.

Roseland Lake is a natural lake. There is no dam restricting the outlet of the lake into Little River. After the last ice age, a large sand and gravel deposit formed under what is referred to as glacial “Lake Quinebaug”. What was left behind is where the Quinebaug River now flows. An arm of Lake Quinebaug followed what is now the Little River into Woodstock. During ice melt, deeper pockets formed here and there. Roseland Lake is located where one of those deeper pockets formed.

The watershed that drains into Roseland Lake has land that has been in agriculture production for centuries. The main tributary draining into Roseland Lake is named Muddy Brook. Mill Brook also drains into Roseland Lake on the southwestern side. Two intermittent streams also drain into the lake seasonally.

In 2009, Eastern Connecticut Conservation District (ECCD) prepared *Muddy Brook and Little River Water Quality Improvement Plan*. The Plan recommended follow up studies to ascertain the sources of nutrients impacting Roseland Lake to determine if they were internal to the lake, external to the lake or both.

In 2015, ECCD was awarded US Environmental Protection Agency (EPA) Clean Water Act § 319 Non-Point Source funds through the DEEP to develop a model of nutrient loads impacting the water quality in Roseland Lake. To better understand the trends in lake water quality, a review of previous studies is a required task of this current project. The following report contains summaries of those previous studies.

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[1] On July 1, 2011, the CT Department of Environmental Protection (DEP) was restructured into the Department of Energy and Environmental Protection (DEEP). The acronym used to describe the agency will reflect its name at the time of publication of any document referred to in this report.

Edward S. Deevey Jr. 1940. Limnological Studies in Connecticut: V, A contribution to regional limnology. American Journal of Science in the October 1, 1940.

Roseland Lake was included in a review of forty-nine lakes in Connecticut and nearby New York State to determine if there was a close relationship between regional geology and the quantity of phytoplankton. Roseland Lake is located in the Eastern Highlands region of Connecticut. The bedrock of the region is metamorphic Paleozoic crystalline rock of many sorts. Water quality data collected from Roseland Lake during this study included summer chlorophyll, total phosphorus, summer nitrate-nitrogen, summer alkalinity, transparency and color. The data summaries contained in this report presented the average of all results for each lake studied. Specific dates, including the year(s) the sampling took place, and the number of samples on which the average was determined were not included with the published report. Therefore, this data only represents a snapshot of conditions in Roseland Lake prior to 1940 from data collected between 1937 and 1939.

Lake	Area HA = M^2 x 10^4	Mean Depth M	Maximum Depth M	Summer Chlorophyll mean mg/M^3 (ppb)	Total Phosphorus mean mg/l	Nitrate Mean summer mg N/M^3 (ppb)	Alkalinity summer Mg HCO_3/l	Transparency Mean M	USGS color mean
Roseland	38.1	3.1	6.0	4.80	13.	29	29.6	2.5	30

Extracted from Table 1, Summary of hydrographic and limnologic data. Chemical analysis for surface water only[2].

Comparing the above data to the 2013 Connecticut Water Quality Standards, Parameters and Defining Ranges of Trophic State of Lakes in Connecticut, the data suggests that Roseland Lake would be categorized as Mesotrophic during the period of time the samples were collected for this study. This is the earliest known published data from Roseland Lake.

Connecticut. Department of Environmental Protection. The Causes of Algae Growth in Roseland Lake, Woodstock, CT. Hartford, CT: 1978. Print.

In 1978 the Connecticut DEP released a report to the Joint Standing Committee on the Environment that discusses the eutrophic conditions of Roseland Lake. DEP analysis supported the theory that due to the large upstream watershed area and relatively small lake volume, Roseland Lake would likely support high levels of primary productivity (algae and/or aquatic plants) even without anthropogenic (human) influences. The lake is described as an eutrophic warm water lake that becomes thermally stratified in the summer months. By June, the bottom layer becomes anaerobic (no oxygen) and remains so throughout the summer. In the anaerobic condition, the bottom sediments release phosphorus, but it was theorized that poor mixing potential would not make that phosphorus available to support plant growth until fall overturn.

During fall overturn, normal flows would flush the excess nutrients out of the basin. Limited tributary sampling indicated that even under low flow conditions, the tributaries contained sufficiently high nutrient loads to support nuisance algae growth.

[2] 1 g/m3 = 1 mg/L = 1 ppm. Likewise, one milligram per cubic meter (mg/m3) is the same concentration in water as one microgram per liter (ug/L), which is about 1 ppb.

Excess nutrient concentrations in the surface water of a lake support algae growth. Concentrations of the three forms of nutrients which are readily available for uptake by algae (soluble phosphorus, nitrate nitrogen and ammonia nitrogen) was reported to be "quite high" in comparison to other Connecticut lakes.

Agency	Date	Depth meters	NO2 N Mg/L	NO3- N Mg/L	NH3-N Mg/L	TN Mg/L	Ortho P Mg/L	Total P Mg/L	N/P ratio
ERA[3]	6/7/71					2.28		0.24	9.5/1
	8/27/71					0.96		0.40	24/1
CAES[4]	10/23/73	.2		0.390	0.090	0.900	0.015	0.024	37.5/1
		3		0.330	0.080	0.880	0.014	0.031	28.4/1
		5		0.380	0.120	0.970	0.012	0.037	26.2/1
CAES	5/2/74	.2		0.500	0	0.950	0.009	0.030	31.7.1
		3		0.500	0.030	0.930	0.010	0.034	27.4/1
		5		0.500	0.030	0.980	0.010	0.038	25.8/1
	7/17/74	2-0.2		0.260	0.110	1.220	0.018	0.047	25.9/1
		3		0.029	0.180	1.114	0.021	0.048	23.8/1
		5		0.130	0.800	1.520	.0092	0.125	12.2/1
	8/27/74	0-3		0.030	0.040	0.650	0.012	0.029	22.4/1
		5		0.230	0.320	1.390		0.114	12.2/1
DEP[5]	8/30/77	0.2	<0.02	0.00	0.04	0.640		0.07	9.1/1
		0.2	<0.02	0.00	0.05	0.070		0.07	1.1/1
		3-4	<0.02	0.10	0.20	1.000		0.11	9.1/1

Summary of In-lake Nutrient Data from multiple sources

Organization	Sample date	Location	Suspended Solids	NO3 –N mg/L	NH3-N mg/L	Org-N Mg/L	Total N Mg/L	Ortho P mg/L	Total P mg/L	Total Coliform/ 100ml	Fecal coliform/100ml
ERA	6/7/71	Mill Brook inlet	4	0			0.96		0.32		
DEP	8/30/77	Mill Brook inlet		0.15	0.06	1.0	1.21		0.06	4100	70
DEP	8/30/77	Muddy Brook		0.60	0.08	0.30	0.98		0.08	>20,000	210

Summary of Roseland Lake Tributary Nutrient Data presented within the report

Other report findings:

- The importance of control of erosion and sedimentation was emphasized in the recommendations to reduce phosphorus loadings and seasonal algae blooms in Roseland Lake.

[3] From Environmental Research and Application, Inc., Roseland Lake Survey Reports, 1971.
[4] From Connecticut Agricultural Experiment Station, Water Chemistry and Fertility of 23 Connecticut Lakes, 1975.
[5] CT Department of Environmental Protection Water Compliance Unit, Roseland Lake Investigative Report (1978)

- Copper sulfate used as a temporary in-lake algae management practice should be coordinated with the DEP as the treatment may impact non-target species such as trout that is annually stocked in the lake by the DEP.
- The average yearly hydraulic residence time[6] for Roseland Lake is 8.1 days. The average summer hydraulic residence time for Roseland Lake is 24.9 days.

Eileen H. Jokinen. The Freshwater Snails of Connecticut, State Geological and Natural History Survey of Connecticut, DEP 1983. Bulletin 109.

In 1983, Eileen Jokinen of the University of Connecticut published a guide, *The Freshwater Snails of Connecticut*, as part of the State of Connecticut State Geological and Natural History Survey. Freshwater snails are an important part of the bottom dwelling fauna in lakes, ponds and rivers. The majority of them are primary consumers, grazing on various kinds of algae and decaying organic matter. In turn, snails are an important food resource for mammals, birds, turtles, crayfish, fish, aquatic insects and leeches. Some species can also serve as an intermediate host for parasites that infect wildlife, livestock and man.

Field sampling from 200 aquatic habitats took place from 1975-1979. Proportionally, more sampling sites were located in northeastern Connecticut than other regions of the state, likely due to the proximity to the University of Connecticut main campus. Lakes, ponds and streams with a variety of physical and chemical conditions were represented in the survey. Language within the text suggests that the author of the guide was using Roseland Lake in Woodstock for other studies and, therefore, provides useful baseline information. For example, at the time the guide was published, the author notes that Roseland Lake had more species of freshwater snails (17 in total) in it than any of the other waterbodies surveyed during the study period. She also suggested that the use of copper sulfate to treat algae in Connecticut lakes was a recent practice. Specific to Roseland Lake, she wrote, "Copper application in Roseland began several summers ago. Roseland is the site of an ongoing study by the author on the structure of the snail community because it has the highest diversity of snail species of any lake in the state. The first application of copper destroyed snails in the vicinity of the landing dock, where application was heaviest. Snails in other parts of the lake did not seem to be significantly affected. When the macrophytic vegetation began to die back in the fall, mats of filamentous blue-green alga, Lyngbya sp., which were attached to the macrophytes, broke loose and floated into shore. Snails were rafted back to the loading dock on the Lingbya. It is suspected that, whereas isolated and occasional copper applications would not greatly diminish snail diversity, repeated regular applications would" (page 10).

[6] The average time required to completely renew a lake's water volume (lake volume divided by outflow rate) is called the hydraulic residence time or flushing rate. Hydraulic residence time is a function of the volume of water entering or leaving the lake relative to the volume of the lake (i.e., the water budget). The larger the lake volume and the smaller the hydraulic inputs or outputs, the longer will be the residence time. Lake residence time may vary from a few hours or days to many years. Lake Superior, for example, has a residence time of 184 years. However, most lakes typically have residence times of days to months. http://www.nalms.org/home/lake-mgmt/the-basics-of-limnology/the-basics-of-limnology-home.cmsx

The following seventeen species of snails were verified to be present in Roseland Lake during the 1975-79 survey period. The species with an asterisk is currently listed as "Special Concern" species in Connecticut.

Campeloma decisum	*Amnicola limosa*	*Gyraulus deflectus*	*Gyraulus circumstriatus**
Helisoma anceps	*Helisoma campanulatum*	*Lyogyrus granum*	*Lyogyrus pupoidea*
Planorbula armigera	*Micromenetus dilatatus*	*Fossaria modicella*	*Pseudosuccinea columella*
Promenetus exacuous	*Laevapex fuscus*	*Ferrissia fragilis*	*Physella ancillaria*
Physa (new species)			

In total, The Freshwater Snails of Connecticut guide describes 35 species of freshwater snails.

Site name	pH	mgC/l	Conductivity µmhos/cm	Color	Ca++ mg/l	Mg++ mg/l	Na+ mg/l	K+ mg/l	Area ha
Roseland Lake	6.4	4.8	78	0.052	7.2	1.4	5.0	1.9	35.60

The above table references water quality conditions in Roseland Lake during the survey period. No date was provided for data collection.

C. R. Frink, and W. A. Norvell, *Chemical and Physical Properties of Connecticut Lakes* Connecticut Agricultural Experiment Station Bulletin 817, April 1984.

Roseland Lake was included in a survey of 70 lakes in Connecticut. In spring and summer 1974, the lake was sampled to determine Total P, Total N and Chlorophyll A concentrations. Other select physical and chemical properties were also determined. The results of those tests are included in the tables below.

Year sampled	Summer transparency M	Summer Color ppm	Alkalinity meq/L	Calcium meq/L	Magnesium meq/L	Sodium meq/L	Potassium meq/L	Chloride meq/L
1974	2.8	20	0.45	0.47	0.14	0.22	0.06	0.17

Date	Total N ppb	Total P ppb	Chl A ppb
May 2, 1974	950	30	nd
July 17, 1974	1220	47	31
August 27, 1974	650	29	9.9

The Roseland Lake watershed was estimated as 1.9% urban, 25.2% agricultural and 72.9% wooded in this report. Estimates of phosphorus export from various kinds of land uses were urban 1.52 lb/acre, agriculture 0.48 lb/acre and wooded 0.09 lb/acre. Predictions of phosphorus concentrations in the lakes studied in this survey agreed reasonably well with observed concentrations based on a model developed after an early survey of a subset of the same lakes.

Kenneth P. Kulp. *Suspended-Sediment Characteristics of Muddy Brook at Woodstock, CT.* US Geological Survey, CT DEP Connecticut Water Resources Bulletin No. 43. 1991.

Roseland Lake is located in Woodstock, CT. The Roseland Lake drainage area is approximately 31 square miles. The majority of upland drainage into Roseland Lake is carried by Muddy

Brook and Mill Brook. The Muddy Brook drainage area represents 23.6 square mi. The Mill Brook drainage area is 6.8 square miles. Roseland Lake and its drainage area are a public water-supply watershed for Putnam, CT. The lake is also a valuable recreational resource for fishing and boating. Prior to the study, accelerated water quality deterioration, or cultural eutrophication, was a concern for local residents, increasing the cost of water treatment for drinking water, and discouraging recreational usage due to seasonal algal blooms.

The watershed area upstream of Roseland Lake was estimated to be comprised of approximately 25% agricultural land in 1982. Non-point source runoff from agricultural activities was believed to be the main source of nutrients impacting water quality in the lake. Prior to the study, sediment and erosion control best management practices were implemented on 3200 acres of upland agricultural land and 10 animal waste control facilities were installed as part of a USDA agriculture management program.

A reconnaissance study of water quality in Roseland Lake took place from May 1980 through September 1983. Muddy Brook and Mill Brook are the main tributaries of Roseland Lake. Little River begins downstream of the Roseland Lake outlet. Stream sampling emphasized nutrient concentrations during storm related high flows. Lake sampling in Roseland Lake included depth profiling and sampling of the bottom materials.

In Muddy Brook, five sampling stations were located to bracket its major tributary streams that drain agricultural areas. Sampling in June 1980 did not demonstrate any spatial variability between the five Muddy Brook sites. Subsequent sampling from 1981 - 1983 focused on the most downstream monitoring station at Child Hill Road/Roseland Park Road. In addition, a single sampling station to assess the water quality of Mill Brook was set up near the inlet to Roseland Lake, and Little River was sampled downstream of the Roseland Lake outlet.

Roseland Lake was monitored at monthly intervals from April – September 1981. The sampling included a depth profile of the lake. Water clarity was determined using a secchi disk. Depth profiles for temperature, pH, specific conductivity and dissolved oxygen were conducted at multiple sites. It was determined that the sampling site over the deepest part of the lake was representative of the conditions in the entire lake.

Surficial samples were collected from the bottom of the lake on September 7, 1983 and analyzed by USGS. Samples were collected with a Ponar dredge. Sediment samples were analyzed for organic carbon, Total Nitrogen, Total Phosphorus, arsenic, copper, iron, lead, mercury and zinc.

Nitrogen nitrate+ nitrite total as nitrogen (mg/kg)	Nitrogen ammonia+ organic, total as nitrogen (mg/kg)	Phosphorus total as phosphorus (mg/kg)	Arsenic total (µg/g)	Copper, recoverable (µg/g)	Iron, recoverable (µg/g)	Lead, recoverable (µg/g)	Mercury, recoverable (µg/g)	Zinc, recoverable (µg/g)	Carbon, organic total (g/kg)	Caron inorganic + organic, total (g/kg)
<2.0	6000	1000	3	8	5100	20	0.05	40	95	95.1

Report summary:

The mean daily suspended sediment load during the period of the study was estimated at 1.8 tons. Higher sediment loads in Muddy Brook are transported during heavy rain events.

Suspended sediment discharges were highest during winter and spring when agricultural fields lacked vegetative cover and higher rainfall amounts were experienced.

The theoretical trap efficiency of Roseland Lake was estimated to be 65%. Based on that number, it was estimated that Muddy Brook deposited 427 tons of sediment annually into Roseland Lake.

Nutrient loads in the major tributaries to Roseland Lake were sufficient to support eutrophic conditions in the lake. Muddy Brook transported the highest nutrient load to the lake.

Roseland Lake becomes thermally stratified during the summer months, with anoxic conditions in the bottom layer. Bottom sediments were rich in organic material and contained low levels of copper, lead, mercury and zinc. Relatively high levels of nutrients, nitrogen and phosphorus, were present in the bottom sediments. The author hypothesized it was unlikely the nutrients were available to support phytoplankton in the upper layers of the lake due to the strong thermal stratification in the lake.

This project was a cooperative effort of the US Geological Survey, CT Department of Environmental Protection and the Northeast Connecticut Regional Planning Agency.

Connecticut Agricultural Experiment Station Submerged Aquatic Plant Survey

A submerged aquatic plant survey was completed by the Connecticut Agricultural Experiment Station on June 18-19, 2012. The survey found 12 aquatic species growing in the lake. None were invasive. The most dominant plant was a lily pad, *Nuphar variegata*. It grew in large patches along the northern shore as well as smaller patches along the western and southern shores. A shoreline species, *Pontederia cordata,* was found growing along much of the shoreline. The majority of the lake had a thin shallow area before the bottom of the lake dropped to deeper depths where light does not reach and plants cannot grow.

The most species-rich area was in the southern cove. This area was very shallow, allowing for light to reach the bottom, and enabling greater plant growth. Various native plant species such as *Nuphar variegata*, *Nymphaea odorata*, *Peltandra virginica*, *Pontederia cordata*, *Potamogeton epihydrus, Potamogeton robbinsii*, and *Sagittaria* were found there. *Potamogeton foliosus* was found only in the north near an inlet. *Vallisneria americana* was only found as a single plant along the eastern shore in one location.A review of transect data revealed that no vascular plants were reported in water deeper than 0.7 meters.

Water chemistry data was collected on June 19, 2012. The transparency (Secchi) was reported to be 1.5 m.

. Water Chemistry

Depth (m)	**Conductivity (ms/cm)**	**pH**	**Alkalinity expressed as Calcium Carbonate (mg/L)**	**Phosphorus (parts per billion)**
0.5	94	8.0	22.5	82.1
5	96	6.5	34.5	334.9

Depth Profile

Latitude*	**Longitude**	**Depth (m)**	**Dissolved Oxygen (mg/L)**	**Temperature (°C)**
41.95089	-71.95093	0.5	9.6	21.5
		1	9.4	21.2
		2	8.6	18.5
		3	0.1	15.2
		4	0	13.0
		5	0	12.4

A Study of the Chemical and Physical Properties of Fifty-six Connecticut Lakes (Canavan and Siver)

Roseland Lake is classified as a hypereutrophic lake in this comparison of Connecticut Lakes. Roseland Lake is reported to have higher calcium and alkalinity than most lakes in the Eastern Highlands Region. The nutrient and chlorophyll a levels in the lake greatly exceeded other lakes in the eastern uplands region of Connecticut. The hypereutrophic condition of the lake was attributed to the high degree of agriculture in the watershed and internal loading of nutrients. The watershed area to surface area ratio was reported at 211:1 and the retention time of water in the lake was reported at 8 days. The flushing rate of a lake will determine how it responds to many inputs from the atmosphere and its watershed.

Many salts and chemical substances become more soluble in anoxic water. It is common for the salts to leach out from the bottom sediments during summer when a lake becomes thermally stratified. As more salts are dissolved in the bottom water, it is common to see an increase in conductivity.

Date	Transparency	Sample depth (M)	Chlorophyll a µg/L	Total P	Total N	pH	Alkalinity	Specific Conductance	Base Cations (meq/L)			
									K	Na	Mg	Ca
1937-9	2.5	Surface	4.8	13			0.49					
10/23/73		0.2 3 5		24 31 37	900 880 970		0.48					
5/2/74	2.0	0.2 3 5		30 34 38	950 930 980		0.30					
7/17/74	2.5	0-2 3 5	31	47 48 125	1220 1140 1520		0.48	73	0.06	0.22	0.14	0.47
8/27/74	3.0	0-3 5	9.9	29 114	650 1390		0.53					
6/11/92	1.2	1	37.5	120 61		9.4	0.42	96		0.04	0.25	
11/30/92		Surface	5.0									
3/29/93		Surface				6.4		73	0.06	0.18	0.08	0.01
6/20/93		Surface							0.07	0.30	0.16	0.53
6/28/93	0.6	1	100.8	71		10.0	0.56	142	0.06	0.18	0.18	0.59

A compilation of historic data from multiple sources was used to show Roseland Lake conditions over time.

Historical Changes in Connecticut Lakes Over a 55-year Period (Siver, Canavan and Field).

Forty-two Connecticut Lakes were compared for physical and chemical changes. Data collected over 3 time periods (1930s, 1970s and 1990s) were used for the comparison. On average, Connecticut Lakes have shown a decrease in secchi transparency and an increase in total phosphorus. There was also an overall trend towards an increase in sodium and chloride ions. Lakes in watersheds with increased residential areas also showed an increase in alkalinity.

	Secchi depth, m		Total Phosphorus, µg/L		Alkalinity, meg/L	
	90-70	90-30	90-70	90-30	90-70	90-30
Roseland	-1.9	-1.6	58	83	0.070	0.035
CT Average	-0.8	-1.2	9	13	0.090	0.080
Range	-3.2 – 1.2	-6.1 – 2.2	-4 – 58	-5 – 83	-0.160 – 0.990	-0.186 – 0.710

Differences between Secchi disk depth, total Phosphorus and alkalinity between the 1990s and 1970s (90 – 70) and the 1990s and 1930s (90 – 30). A positive number reflects an increase and a negative number reflects a decrease in that variable relative to the more recent time period. The CT average values and value range are listed to provide context to this abbreviated table from the Siver et al report.

From the above table, the overall trend statewide was for a decrease in water clarity as measured by a Secchi disk, an increase in total phosphorus and an increase in alkalinity during the period of time represented by the study. By comparison, Roseland Lake water transparency decreased by a higher amount than the state average. The total phosphorus in the water had the highest increase in the lakes monitored as part of this project. The alkalinity in the lake also increased.

	Total		Na+		Cl-		$Ca^{2+} + Mg^{2+}$	
Lake	Absolute difference	% change	Absolute difference	% change	Absolute difference	% change	Absolute difference	% change
Roseland	-0.07	-8	0.01	4	0.013	76	-0.08	-13
CT Average	0.07	9	0.06	15	0.10	47	0.01	-6
Range	-0.33 – 0.80	-53 - 100	-0.01 - 0.73	-59 - 251	-0.05 – 0.77	-25 - 285	-0.24 – 0.19	-67 - 66

Differences between base cations (total), sodium, calcium +magnesium and chloride between the 1990s and 1970s (90 – 70) and the 1990s and 1930s (90 – 30). A positive number reflects an increase and a negative number reflects a decrease in that variable relative to the more recent time period. The CT average values and value range are listed to provide context to this abbreviated table from the Siver et al report.

The report authors concluded that in general the changes in lake chemistry are generally related to increased urbanization and decreased forest cover in the watersheds around the lakes. The use of NaCl for road deicing was suspected as a factor in increases in those ions.

EPA National Lakes Assessment including Roseland Lake in 2007 and 2012

Roseland Lake was randomly selected to be monitored as part of a national lakes assessment (NLA) program in 2007 and 2012. It was one of over 1000 lakes across the nation that was sampled using specific EPA protocols. The purpose of this project was to estimate the condition of natural and man-made freshwater lakes, ponds, and reservoirs greater than ten acres and at least one meter deep in the continental United States. Field crews collected samples using the same methods at all lakes to ensure that results could be compared across the country. CT DEEP staff were trained in the sampling techniques and EPA researchers processed and analyzed 680,000 measurements, including indicators of water quality such as nutrients, dissolved oxygen and algal density; biological indicators such as phytoplankton and zooplankton (algae and microscopic animals); recreational indicators such as algal toxins and pathogens; and physical habitat indicators such as lakeshore and shallow water habitat cover.

Roseland Lake was monitored on July 31, 2007 and July 11, 2012 as part of this initiative. The Roseland Lake (NLA06608-0498) data results for 2007 were downloaded from the EPA website. Results from the 2012 NLA of Roseland Lake are still pending.

Biological Health

The biological health of a lake is determined by multiple factors. This rating is based on an index of phytoplankton and zooplankton taxa loss – the percentage of taxa observed compared to those that are expected, based on conditions at least-disturbed lakes.

The survey measured a set of key stressors to lake condition to determine their extent across the nation. Analysts also examined the relationship between these stressors and lake biological health. Poor habitat conditions along the lakeshore and high levels of the nutrients nitrogen and phosphorus are the most significant stressors of those assessed in the survey. Poor biological health is three times more likely in lakes with poor lakeshore habitat relative to lakes with good habitat. Poor biological health is 2.5 times more likely in lakes with high nutrient levels.

Physical habitat estimate based on 55 different metrics from 2007 NLA for Roseland Lake

Parameter	Rank	Physical Habitat Index OE
Riparian Disturbance	Intermediate disturbance	
Riparian Vegetation Disturbance class	Least disturbed	1.392623137
Littoral vegetation cover condition class	Least disturbed	0.742076937
Littoral riparian cover condition class	Least disturbed	1.125789387

2007 Water quality assessment data

As part of the NLA protocols, each lake was assessed over the deepest part of the lake. Secchi disk readings were taken. A depth profile of temperature, dissolved oxygen, pH and conductivity were determined at 1 M intervals.

The Roseland Lake average secchi disk depth on July 31, 2007 was 1.05 M. The average dissolved oxygen concentration at the surface was 11.67 mg/L.

Depth profile for Roseland Lake July 31, 2007

DEPTH (M)	METALIMNION (thermocline range)	Temperature ˚C	Dissolved O^2 mg/L	pH	Conductivity µS/cm
0		27.4	11.8	9.6	141
1		27	11.7	9.6	140
2	Top	24.5	11.5	8.8	139
3		21.5	1.5	7	135
4		16.2	0.2	6.6	157
5	Bottom	13.5	0.2	6.7	194
5.5		13.5	0.2	6.7	194

The depth profile demonstrates that Roseland Lake becomes thermally stratified during the summer. Oxygen is depleted below the thermocline. The increase in the conductivity is related to the release of ions from the bottom sediments under anoxic conditions.

Chemical Assessment Roseland Lake July 31. 2007

Parameter	Result	Rank
Total P	44 µg/L	Intermediately disturbed
Total N	820 µg/L	Intermediately disturbed
Turbidity	5.56 NTU	Least disturbed
ANC	624,4 µeg/L	Least disturbed
DOC	3.66 mg/L	Not ranked
Conductivity	128 µS/cm	Least disturbed
Chlorophyll A	26.24 µg/L	Least disturbed

Recreational Water Quality

Recreational quality assessment data was collected to determine the suitability or safety for recreational use including swimming, waterskiing, windsurfing, fishing, boating, and many other activities.

The data collected as part of the 2007 NLA were compared to standards developed by the World Health Organization.

World Health Organization Thresholds of Risk Associated with Potential Exposure to Cyanotoxins

Indicator (units)	Low Risk of Exposure	Moderate Risk of Exposure	High Risk of Exposure
Chlorophyll-*a* (µg/L)	<10	10 - <50	>50
Cyanobacteria cell counts (#/L)	< 20,000	20,000 - <100,000	≥ 100,000
Microcystin (µg/L)	<10	10 - ≤20	>20

Water samples for this analysis were collected over the deepest part of the lake. It was acknowledged in the documentation that accompanied the results that algae blooms may be more concentrated in nearshore areas where people and animals are more likely to be exposed to them.

Roseland Lake Risk of Exposure to Cyanotoxins July 2007

Indicator (units)	Result	Risk of Exposure
Chlorophyll-a (µg/L)	26.24	Moderate Risk of Exposure
Cyanobacteria[7] cell counts (#/L)	15184	Low Risk of Exposure
Microcystin[8] (µg/L)	0.05	Low Risk of Exposure

In the report, Roseland Lake is listed as "unswimmable". This is a reference to the Connecticut Public Health Code that restricts public swimming beaches within two miles upstream of a

[7] Although there are relatively few documented cases of severe human health effects, exposure to cyanobacteria or their toxins may produce allergic reactions such as skin rashes, eye irritations, respiratory symptoms, and in some cases gastroenteritis, liver and kidney failure, or death. The most likely exposure route for humans is through accidental ingestion or inhalation during recreational activities, though cyanotoxins are also cause for concern in drinking water. Cyanotoxins can also kill livestock and pets that drink affected water. While many varieties of cyanotoxins exist, microcystin is currently believed to be the most common in lakes. Microcystin is a potent liver toxin, a known tumor promoter, and a possible human carcinogen.

[8] During the 2007 survey, microcystin samples were collected at mid-lake, in open water. However, large windblown accumulations of cyanobacteria often occur at nearshore areas in lakes and it is the concentrations along the lake's edge that are typically of most concern to health officials.

public drinking water supply surface intake. A water sample was analyzed for *Escherichia coli* bacteria, which is the indicator species utilized for fecal contamination. The result was 10 cfu/100 ml. In Connecticut, recreational standards for a single sample exceedance in a non-bathing area is <576 cfu/100 ml. For a bathing beach, the threshold is <235 cfu/100 ml.

Diatom Inference Model Data

Diatoms are a type of photosynthetic algae that produce distinctive cell walls made of silicon dioxide. These cell walls remain after the living matter decomposes. The diatom shells will sink to the bottom of a lake and become part of the bottom substrate. Scientists developed a way to use the taxonomic composition and relative abundance of different types of diatoms in the lake bottom sediments to develop a diatom Index of Biological Integrity (IBI) or a Lake Diatom Condition Index (LDCI). Indicator species analysis was used to determine diatom taxa that were characteristically found in reference or impaired lakes, and to determine diatom taxa characteristically found in either high TN and/or TP, or low TN and/or TP. In most cases, three variants of each candidate metric were calculated: one based on taxa richness, one based on the proportion of individuals, and one based on the proportion of taxa.

As part of the 2007 assessment of Roseland Lake, CT DEEP staff collected bottom core samples using a special 43 cm long core sampler. The top 1 cm of core sampled was carefully sliced off the core and collected in a prepared sample jar. This sample represents the most recently deposited sediment layer. The core was pushed up to the 40 cm level. This portion of the core was sliced off and discarded. The next 1 cm from the 40 – 41 cm of the core sampled was pushed up and carefully sliced off and collected in another prepared sample jar. This core sample represents sediments that were deposited during an unspecified period of time. Both samples were analyzed for diatom skeletons. Diatom diversity is an indicator of water quality, and the number and type of diatoms isolated in the bottom sediments can be used to infer water quality conditions in the lake at the time they were deposited.

Inferred chemical properties of Roseland Lake based on a diatom inference model

Metric	0 - 1 cm of core	40-41 cm of core	Difference
Inferred Total Phosphorus (µg/L)	16.69	30.06	-13.37
Inferred Total Nitrogen (µg/L)	417.69	432.2	-14.51
Inferred Conductivity (µS/cm)	126.5525883	91.60587278	34.94671548
Inferred pH	8.263806213	7.753473828	0.510332385

Using diatom shells deposited in the lake sediments at the bottom of Roseland Lake, the data suggests that the nutrient levels in the lake at the time represented by the core layers were significantly different and demonstrate a significant reduction in total phosphorus and total nitrogen at the surface of the lake during the time period represented by the core samples. An increase in conductivity is also inferred using this method. The pH increase was listed as not significantly different.

Lake Depth Profile

DEPTH	METALIMNION	TEMP_FIELD	DO_FIELD	PH_FIELD	COND_FIELD
0		27.4	11.8	9.6	141
1		27	11.7	9.6	140
2	Top	24.5	11.5	8.8	139
3		21.5	1.5	7	135
4		16.2	0.2	6.6	157
5	Bottom	13.5	0.2	6.7	194
5.5		13.5	0.2	6.7	194

Lake depth profile July 31, 2007

Sampling data from July 2007 demonstrates a well-defined thermocline, anoxic conditions in the bottom layer of the lake and an increase in conductivity under anoxic conditions.

Measurement of Lake Trophic Status

Parameter	Result	Rank
Total P	44 µg/L	Eutrophic
Total N	820 µg/L	Eutrophic
Chlorophyll a	26.24	Eutrophic
Secchi Depth	1.05 M	Eutrophic

Other Water Quality Data

pH (field)	9.6		TOC	4.25 mg/L		TP	44 µg/L		Na	0.54 ppm
Depth	1 M		DOC	3.66 mg/L		Cl	12.452 ppm		K	2.476 ppm
pH (lab)	8.01		NH_4-N	0.013 ppm		NO3-N	0.055 ppm		color	25 PCU
conductivity	127.6 µS/cm		NO3 – NO2	0.042 ppm?		SO4	8.357 ppm		SiO_2	0.661mg/L
Turbidity	5.56 NTU		TN	820 µg/L		Mg	2.091 ppm			

2012 Water Quality Assessment Data

Sampling to support a second lake assessment of Roseland Lake was completed by CT DEEP staff trained in the EPA sampling protocol in July 2012. Data were collected for the following indicators: Algal Toxins, Benthic Macroinvertebrates, Chlorophyll A, Nutrients, Phytoplankton, Sediment Dating, Sediment Diatoms, Sediment Mercury, Water Chemistry, and Zooplankton. The samples were sent to EPA for sample processing, data cleanup, and data analysis. Results of the 2012 assessment of Roseland Lake are still pending completion.

MARY A. ROGALSKI - Tainted resurrection: metal pollution is linked with reduced hatching and high juvenile mortality in Daphnia egg banks. Ecology, 96(5), 2015, pp. 1166–1173, 2015 by the Ecological Society of America.

This study by Yale University doctoral candidate Mary Rogalski compared the hatching rate and developmental success of Daphnia species hatched from dormant, or diapausing eggs, at different depths and ages of lake sediments in four Connecticut lakes. Daphnia is a genus of filter feeding zooplankton that play a key role in a lake food web. The four lakes in her study were Alexander Lake in Dayville, Black Pond and Roseland Lake in Woodstock, and Cedar Pond in Branford.

Lake sediment core samples were collected by divers. Each core sample was partitioned into 1.5 cm intervals. The age of each slice of core sample was determined using the Pb-210 method.

The Pb-210 method is used to determine the accumulation rate of sediments in lakes, oceans and other water bodies. In a typical application, the average accumulation rate over a period of 100 - 200 years is obtained. From the accumulation rate, the age of sediment from a particular depth in the sediment column can be estimated based on the decay of Pb-210 radio-isotope.

Ms. Rogalski's study indicated that the sedimentation rate for Roseland Lake was significantly higher during the last 20 year period compared to sediment deposits that were 20 – 100 years old but the decline in Pb-210 with core depth indicated the core was undisturbed and the use of the method was valid.

Metals measured during this study included cadmium, chromium, copper, lead and zinc. Roseland Lake core samples indicated an 11-fold increase in copper concentrations during the period from 1960 – 1990. This was attributed to the consistent use of CuSO4 to treat algal blooms by the Putnam Water Department [begun circa 1980].

Dormant eggs deposited in lake sediments can be hatched more than a century or longer after being buried in lake sediments. Rogalski observed that Daphnia hatched from Roseland Lake from more recent sediment deposits where metal contamination was at its peak suffered from higher juvenile mortality after hatching.

Assorted Roseland Lake Tributary Studies

Muddy Brook (CT3708-01_02) (from Route 197 crossing, US to confluence with Moss Brook just DS of Route 169 crossing, Sherman corner area) had been listed in the Connecticut Water Quality Assessment Report to Congress as not meeting aquatic life use support conditions. This classification has been reported for several cycles of the report, most recently in 2012 based on data collected in 1999. The 2014 Connecticut Water Quality Assessment Report to Congress lists this stream segment as fully supporting aquatic life use support conditions.

In 2006, the Northeast District Department of Health (NDDH) performed a series of water quality tests in support of the Little River Sourcewater Protection Plan development team. Fifteen sampling locations were selected both upstream and downstream of Roseland Lake. Each sampling location was sampled in February, May, August and October. Each sample was assessed for *E. coli*, Turbidity, Total Suspended Solids, pH, Alkalinity, Hardness, Chloride, Color, Organic Nitrogen, Ammonia nitrogen, Total Kjeldahl nitrogen, Nitrate (mdl = 0.1 mg/l) Nitrate (mdl = 0.05 mg/l), Total Phosphorous and Orthophosphorus. The data was reviewed and summarized by Richard Canavan IV of CME Associates on request of ECCD during the process of preparing the Muddy Brook and Little River Water Quality Improvement Plan (2009). Dr. Canavan's conclusions after reviewing the data include:

- The results did not indicate trends of poor water quality by location, season or individual parameter.
- Any future testing should include Taylor Brook and Mill Brook where results were poor relative to other locations.
- Based on previous studies, it is probable that phosphorus-rich sediments at the bottom of Roseland Lake may be a major source of nutrients for algae growth in Roseland Lake.

- A Roseland Lake study to determine the extent to which internal loading of nutrients from the sediment to the overlying water was recommended. The study should focus on the development of anoxic bottom waters, sediment phosphorus concentrations and sediment depth.
- Additional feasibility studies of how to best limit the impact of sediment nutrients should follow.

Statewide Bacteria Total Maximum Daily Load, Little River Watershed Summary, Muddy Brook and Peckham Brook (CT DEEP)

Muddy Brook – DEEP probabilistic monitoring for E. coli bacteria from 2006 to 2008 demonstrated that Muddy Brook at Roseland Park Road/Child Hill Road failed to meet CT recreational water quality standards. ECCD, with assistance from The Last Green Valley (TLGV) Volunteer Water Quality Monitoring Program, sampled Muddy Brook at the same location in 2011 and 2012 and achieved similar results. A 74% reduction in the geometric mean was recommended to restore the brook to meeting Connecticut water quality standards.

Peckham Brook – ECCD, with assistance from TLGV Volunteers, sampled Peckham Brook in 2011 and 2012. Peckham Brook failed to meet recreational water quality standards and was added to the list of impaired waters in 2014. A 50% reduction in the geometric mean was recommended to restore the brook to meeting Connecticut water quality standards.

EPA Non-Point Source Project Success Story – North Running Brook

North Running Brook is a tributary to Muddy Brook. The brook drains into Muddy Brook upstream of Roseland Park Road. Leachate from corn silage from a dairy farm was draining into North Running Brook. The stream bottom became coated with a fungal mat and the stream was listed as impaired for aquatic life use support functions in 2004. The USDA Natural Resources Conservation Service contracted with the farm to improve their manure storage. At the same time, the Eastern Connecticut Conservation District, with Clean Water Act § 319 Non-point Source funding through the CT DEEP, also worked with the farm to improve the corn silage bunker and redirect the leachate to the new manure storage facility. Installation of these and other agricultural Best Management Practices employed by Valleyside Farm improved water quality in North Running Brook. The stream was removed from the Connecticut list of impaired waters in 2012.

Discussion

The Connecticut Department of Energy and Environmental Protection, in collaboration with the US Environmental Protection Agency, is responsible for determining water quality standards for the State of Connecticut. The Connecticut Water Quality Standards and Classifications were last updated in October 2013. Within this document are parameters and defining ranges for the trophic state of lakes in Connecticut. The trophic state of a lake is determined by both water column data and the percentage of the surface area covered by aquatic plants large enough to be seen without magnification (macrophytes). Macrophyte distribution and abundance data shall be reviewed in conjunction with the water column data to determine the trophic states of lakes and ponds.

- If macrophyte growth is very extensive (75 - 100% of water body area) and dense, the trophic state of a lake or pond shall be considered "highly eutrophic" regardless of the water column data.
- If macrophyte growth is extensive (30 - 75% of water body area) and dense, the trophic state shall be considered "mesotrophic" when the water column indication is oligotrophic, and the trophic state shall be considered "eutrophic" when the water column indication is mesotrophic or eutrophic.

Parameters and Defining Ranges for Trophic State of Lakes in Connecticut		
Trophic State Based on Water Column Data	Parameter	Defining Range
Oligotrophic	Total Phosphorus	0-10 µg/L spring/summer
	Total Nitrogen	0-200 µg/L spring/summer
	Chlorophyll a	0-2 µg/L mid-summer
	Secchi Disk Transparency	6+ M mid-summer
Mesotrophic	Total Phosphorus	10 - 30 µg/L spring/summer
	Total Nitrogen	200 – 600 µg/L spring/summer
	Chlorophyll a	2 - 15 µg/L mid-summer
	Secchi Disk Transparency	2 – 6 M mid-summer
Eutrophic	Total Phosphorus	30 - 50 µg/L spring/summer
	Total Nitrogen	600 - 1000 µg/L spring/summer
	Chlorophyll a	15 - 30 µg/L mid-summer
	Secchi Disk Transparency	1 – 2 M mid-summer
Highly Eutrophic	Total Phosphorus	50+ µg/L spring/summer
	Total Nitrogen	1000+ µg/L spring/summer
	Chlorophyll a	30+ µg/L mid-summer
	Secchi Disk Transparency	0 – 1 mid-summer

From the Connecticut Water Quality Standards and Classifications, revised October 2013

There were a few studies of Roseland Lake that referenced macrophytes:

- A 1959 Fishery Survey of Lakes and Ponds in Connecticut by the State Board of Fisheries and Game reported submerged and emergent vegetation to be scarce in most areas.
- A reference to a 1971 study indicated extensive beds of emergent weeds and patches of submerged weeds were observed in unidentified locations and a considerable amount of weeds were present at the Roseland Park beach area.
- DEP surveyed the lake in August 1977 and reported a low density of weeds with several species including white pond lily, yellow pond lily, *Phragmites* and pickerel weed as

codominants. DEP concluded in their 1978 report, "The Causes of Algae Growth in Roseland Lake, Woodstock, CT," that aquatic macrophytes were only an occasional, localized problem at Roseland Lake. A hand drawn map of the lake demonstrates that the macrophyte growth areas represented <30% of the lake area. Phragmites was noted to be established along parts of the eastern shore at both the north and south end of the lake.

- The Connecticut Agricultural Experiment Station conducted an aquatic invasive species survey in 2012. As part of that survey, they mapped the aquatic macrophytes of Roseland Lake. Their review also indicated that <30% of the lake contained macrophyte growth.

By the early 2000s, *Phragmites australis* had become well established along the fringes of the lake, including most of the western shoreline along the frontage of Roseland Park (personal observation by Jean Pillo). In 2004, a multiyear herbicide treatment was initiated and presently, *Phragmites* is isolated to two areas: a small area on the northeastern shore and intermixed with other wetland plants at the lake outlet into Little River. However, the root masses from the treated *Phragmites* are still present along the shoreline. Native wetland plants have become established in the sediments associated with those root masses.

Below is a compilation of water quality data from previous studies cited in this report. The results are color coded to represent the trophic state indicated in the Connecticut Water Quality and Classification Standards.

Compilation of all data used to determine lake trophic status

Date	Total N ppb	Total P ppb	Chlorophyll a ppb	Secchi depth (m)	N:P Ratio
Summer 37-39 average	--	13	4.8	2.5	
June 1971	2280	240	--	--	9.5
August 1971	960	400	--	--	2.4
May 1974	950	30	--	2.0	31.6
July 1974	1220	47	31	2.5	26.0
August 1974	650	29	9.9	3.0	22.4
August 1977	640	7	--	2.25	91.4
June 1992	--	120	37.5	--	
June 1993	--	71	100.8	0.6	
July 2007	820	44	26.24	1.05	18.6
June 2012	--	82.1	--	--	

The data presented in the above table supports the classification of Roseland Lake as eutrophic/highly eutrophic. Compared to the data collected in the late 1930s, the water quality data from Roseland Lake demonstrates a decline in its trophic classification.

The EPA Diatom Inference Model compiled from the results of sediment samples from Roseland Lake in 2007 suggests a significant decrease in phosphorus and nitrogen concentrations in the lake and an increase in conductivity. The model results appear to conflict with the snapshot of spring and summer nutrient sample results collected over time in Roseland Lake. The model accurately reflects the increase in conductivity in the lake water.

The total nitrogen to total phosphorus ratio (TN:TP) has been observed to be an indicator of which nutrient is the limiting factor for algal growth in a lake. Low ratios of TN to TP can be indicators of conditions that favor N_2-fixing species of potentially harmful blue-green algae (cyanobacteria).

With the exception of 1971, the data indicates the N:P ratio to be >15. This suggests that nitrogen was not a limiting factor for algae growth at the time most of the water samples were collected and analyzed and phosphorus was abundant enough to support algae growth. However, blue-green algae have been visibly observed in the lake. ECCD will be collecting water samples that will be used to identify and enumerate the types of phytoplankton in Roseland Lake as part of this project. Concurrently, Peter Siver of Connecticut College is conducting a study of phytoplankton response to copper sulfate treatments in many lakes in the region. Roseland Lake is included in this project. Data from the two research projects will be shared.

There is conflicting information regarding toxic metal accumulations in the lake sediments. The data collected by Mary Rogalski shows a dramatic increase of copper in the bottom sediments which was interpreted to have begun around 1950 with an eleven-fold increase since then. A previous study conducted by USGS showed a lower copper amount in a sample collected and analyzed in 1983, which conflicts with Rogalski's analysis. Eileen Jokinen indicated that copper sulfate treatments in Roseland Lake began around 1980. Long term records for copper sulfate treatments of Roseland Lake by the Putnam Water Pollution Control Authority were requested but unavailable.

Heavy rain and subsequent flooding may have impacted land erosion and sedimentation rates in Roseland Lake, especially on farmland where no-till strategies were not employed. Upstream dam breaches may have also contributed to short-term high sediment loads. Several historic flood events occurred during the period of studies covered in this report:

- October 2005 - Rainfall totals during a 10-day period ranged from 10 to 15 inches within the Connecticut and Thames River basins, which slightly exceeds 100-year frequency 10-day totals of 12 to 13 inches.
- June 1982 - Up to 16 inches of rainfall resulted in major flooding throughout Connecticut
- August 1955 - Hurricanes Connie and Diane came a week apart to batter most of New England with the most significant flooding recorded at many locations.
- September 1938 - Widespread 10 inch rainfall caused by a hurricane resulted in major flooding throughout the Connecticut River valley.

There have been significant increases in potential anthropogenic sources of nitrogen and phosphorus since the Roseland Lake water quality data collection began.

- After World War II, chemical fertilizers and herbicides were introduced into agriculture. Chemical fertilizers are more water soluble and over-application would result in nutrient-enriched runoff from farm fields. Herbicide use reduces ground cover and exposes more soil to erosion.

- Dairy farming changed from pasture-raised cows to corn-fed cows in concentrated feed lots. More land was converted from grass to corn fields fertilized with chemical fertilizers.
- Also, after World War II, there was a migration of families from cities to more rural areas as the highway system was developed. More people owned cars and were able to commute to work. In rural areas such as Woodstock, residential housing relies predominantly on on-site waste water disposal systems. Guidelines to regulate these systems were inadequate and were not updated until after the Clean Water Act was passed in 1972. Many systems that pre-date the current regulations are still in use.
- Lye-based soap was replaced by detergents containing phosphates after World War II. After it was realized that phosphate-containing detergents were linked to eutrophication, phosphates were phased out of laundry detergents first, followed by elimination from other products more recently including dish detergents and dishwasher detergents.
- With an increase in residential housing came an increase in turf grass in the form of lawns. With this came an increase in lawn care products containing nutrients and pesticides. Connecticut recently implemented a ban on the sale of lawn fertilizers containing phosphorus unless a soil test indicates its application is necessary.

Conclusion

The trend towards nutrient enrichment and eutrophication is not unique to Roseland Lake. The comparison of historical data collected from Fifty-five Connecticut lakes compiled in 1984 demonstrates the trend is statewide and the main issue is the availability of phosphate to fuel the increase in productivity in the lakes (C. R. Frink). The need to understand ongoing nutrient loading to the lake and how the nutrients are cycling within the lake are the next steps to formulate a lake watershed management plan focusing on the means to decrease the rate of cultural (human influenced) eutrophication. Equally important is the need to develop practical strategies for in-lake algae management. Blue-green algae blooms are a potential public health threat. There are immediate health risks associated with exposure to potential toxic byproducts of blue-green algae when using the lake for recreation or a source of drinking water. The quality of the water drawn from Little River downstream for drinking water impacts the cost to treat it.

The photos on the following page help to demonstrate the impacts of the decline in water quality in Roseland Lake.

This 1942 photo was provided courtesy of the Woodstock Historical Society. It shows a diving board at the end of the boat dock as an indicator of water depth.

This photo was taken in 2009. It shows the former beach area supporting wetland plants and an accumulation of sediment. The depth of the water where the former diving board was located is reduced to about 1 m.

As recently as the early 1970s, the area under the deck by the boat dock was used to house rental row boats. The above photo was taken in August 2015 illustrating the amount of sediment that has filled in this part of the lake.

Blooms of blue-green algae are occasionally visible along the shoreline when the prevailing winds direct the algae to a concentrated area. This photo was taken in 2013. Photo courtesy of Patrick M. L. Smith.

Cover photo courtesy of Patrick M.L. Smith.

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