Acid Rain Status and Trends

New Hampshire Lakes, Ponds and Rainfall

Stinson Lake, Rumney, NH

June 2015

NEW HAMPSHIRE
DEPARTMENT OF
Environmental
Services

Acid Rain Status and Trends

New Hampshire Lakes, Ponds and Rainfall

2015

Prepared by
Kirsten Nelson, *Biologist*
David Neils, *Chief Water Pollution Biologist*
Water Division

In conjunction with
Dave Healy, *Environmentalist IV*, and Jeff Underhill, *Administrator IV*
Air Resources Division

Thomas Burack, *Commissioner*
Keith Dubois, *Acting Assistant Commissioner*
Gene Forbes, *Water Division Director*
Craig Wright, *Air Division Director*

New Hampshire Department of Environmental Services
29 Hazen Drive
Concord, NH 03301
des.nh.gov

TABLE OF CONTENTS

A1 INTRODUCTION 1
A1.1 Acid rain background information 1
A2 MONITORING PROGRAMS 3
A2.1 Rooftop Rain Program 3
A2.2 Remote Pond Program 4
A2.3 Acid Outlet Monitoring 4
A3 ANALYSES 5
A4 CHANGES IN METHODOLOGY 5
B1 ROOFTOP RAIN MONITORING AT NHDES 5
B1.1 Results and Trends in Rooftop Rain Monitoring 5
B1.2 Conclusions in Rooftop Rain Monitoring 8
B2 REMOTE POND PROGRAM 9
B2.1 Summary Statistics in Remote Pond Monitoring 9
B2.2 Results and Trends in Remote Pond Monitoring 11
B2.3 Remote Pond Conclusions 13
B3 ACID OUTLET PROGRAM 13
B3.1 Summary Statistics in Acid Outlet Monitoring 13
B3.2 Results and Trends in Acid Outlet Monitoring 15
B3.3 Acid Outlet Conclusions 18
C1 OVERALL CONCLUSIONS 18
C2 RECOMMENDATIONS 19
D REFERENCES 19

LIST OF TABLES

Table A1.1 Chronology of major Federal and State regulations that resulted in reduced sulfur dioxide and nitrogen oxide emissions, 1990-current 2

Table B1.1 Average, minimum, maximum, and median pH values of rooftop rain sampled at NHDES (Hazen Dr., Concord, NH) by year. 5

Table B1.2 Average and median values of sulfate, nitrate nitrogen, and total phosphorus concentrations of rooftop rain sampled by NHDES (Hazen Dr., Concord, NH) by year……..7

Table B2.1 Total number of waterbodies and acid deposition-related parameters sampled by year……8

Table B2.2 Individual name and location by town of waterbodies currently monitored under the Remote Pond Program……...10

Table B2.3 Trend direction of pH, ANC, specific conductance, sulfate, and nitrate nitrogen concentration parameters as determined by a Mann-Kendall test. Significance was declared at p≤0.05. Positive trends are indicated by "↑", negative trends are indicated by "↓", and non-significant trends are indicated by "0"……...10

Table B2.4 Acid Sensitivity Narrative Categories for 1995 pH and ANC data of remote ponds……...12

Table B2.5 Acid Sensitivity Narrative Categories for 2014 pH and ANC data of remote ponds……...12

Table B3.1 List of monitored waterbodies and their number of years of data for acid deposition-related parameters……...13

Table B3.2 Trend direction of pH, ANC, specific conductance, sulfate, and nitrate nitrogen concentration parameters as determined by a Mann-Kendall test. Significance was declared at p≤0.05……15

Table B3.3 Acid Sensitivity Narrative Categories for Fall 1995 / Spring 1995 pH and ANC data of acid outlet waterbodies……16

Table B3.4 Acid Sensitivity Narrative Categories for Fall 2013/ Spring 2014 pH and ANC data of acid outlet waterbodies……16

LIST OF FIGURES

Figure A1.1 Trend in US SO_2 Emissions, 1970 – 2013 (Thousands of Tons)……3

Figure B1.1 pH Trends in Rooftop Rain at NHDES (1972-2013)… See Appendix B for all Rooftop Rain graphs……7

Figure B2.1 Example of remote pond pH and ANC trend data of an individual waterbody. See Appendix C for all Remote Pond graphs……...11

Figure B3.1 Example of acid outlet pH trend data of an individual waterbody. See Appendix D for all Acid Outlet graphs……16

A1 INTRODUCTION

A1.1 Acid rain background information

Acid rain is caused primarily by the reaction of gaseous sulfur dioxide (SO_2) and nitrogen oxides (NO_x). Although these compounds occur naturally, elevated levels in the atmosphere are associated with anthropogenic activities. The majority of sulfur dioxide is released by point-source electric utilities and industrial activities, whereas nitrogen oxides are more difficult to monitor as they primarily come from the transportation sector. When these chemicals are released into the atmosphere, they react with water molecules to produce acids. During precipitation events, those acids and acidifying compounds are returned to Earth's surface, where they have been found to influence ecosystems by leaching base cations from the soil, decreasing pH and alkalinity in waterbodies, and harming vegetation and wildlife (Driscoll et al. 2001). In waterbodies specifically, acid precipitation has been found to reduce diversity and abundance of aquatic life, enhance mercury bioaccumulation in fishes, and increase inorganic aluminum concentration, which is toxic to fishes (Driscoll et al. 2001).

Consistent studying of the effects of acid rain began in the 1960s, and, in 1970, the U.S. Congress established the Clean Air Act (CAA), aimed at reducing emissions of sulfur dioxide and other pollutants using a wide range of air pollution control programs (Table A1.1). The CAA was amended in 1977 to establish permit review requirements that ensure attainment and maintenance of air quality standards. In 1980, the Acid Deposition Act established a research program intended to examine acid rain influences. As evidence for detrimental influences accumulated, the U.S. Congress passed additional amendments to the CAA in 1990. Some key aspects of the CAA are: 1.) Set standards for sulfur dioxide and other pollutants and require the Environmental Protection Agency (EPA) and States to develop implementation plans to ensure that air quality standards are met; 2.) Directs EPA and States to establish air quality programs which set enforceable emissions limits on large pollutant-emitting facilities; 3.) Authorizes EPA to set emission standards for motor vehicles and fuels; and 4.) Set forth provisions to reduce acidifying compounds. A chronology of legislation aimed at reducing sulfur dioxide and nitrogen oxide emissions is detailed in Table A1.1. Additional information regarding sulfur dioxide emissions data can be found in Appendix A.

New Hampshire waterbodies are especially vulnerable to the influences of acid rain. Natural buffers against sulfur dioxide and nitrogen oxides, such as calcium carbonate, tend to be present in very low amounts due to the composition of the state's natural geology. A lack of buffering capacity makes many lakes and ponds sensitive to the influences of acid rain, which can have detrimental influences on aquatic life (Driscoll et al. 2001, Strock et al. 2014). Emissions of acid rain-causing chemicals have been regulated, and thereby reduced, in New Hampshire via implementation of federal requirements as well as state regulations. In 1987, New Hampshire created the Air Toxics Control Program to reduce the emissions and ambient air impacts of a variety of pollutants. Additionally, in 2006, the New Hampshire General Court determined it was in the public interest to reduce mercury emissions at Eversource's (Public

Service of New Hampshire) Merrimack Station power plant (RSA 125-O:11; Table A1.1). The legislation required scrubbers to be installed that were directed at reducing mercury emissions. This equipment was also highly effective at controlling sulfur dioxide emissions. Therefore, sulfur dioxide emissions at Eversource Merrimack Station have decreased substantially since the equipment was installed in 2011. Table A1.1 below provides a chronology of the major SO_2-reducing efforts implemented through the CAA as well as Federal and New Hampshire-specific regulations since 1990. Figure A1.1 and Appendix A further documents sulfur dioxide emission trends at local, regional, and national spatial scales.

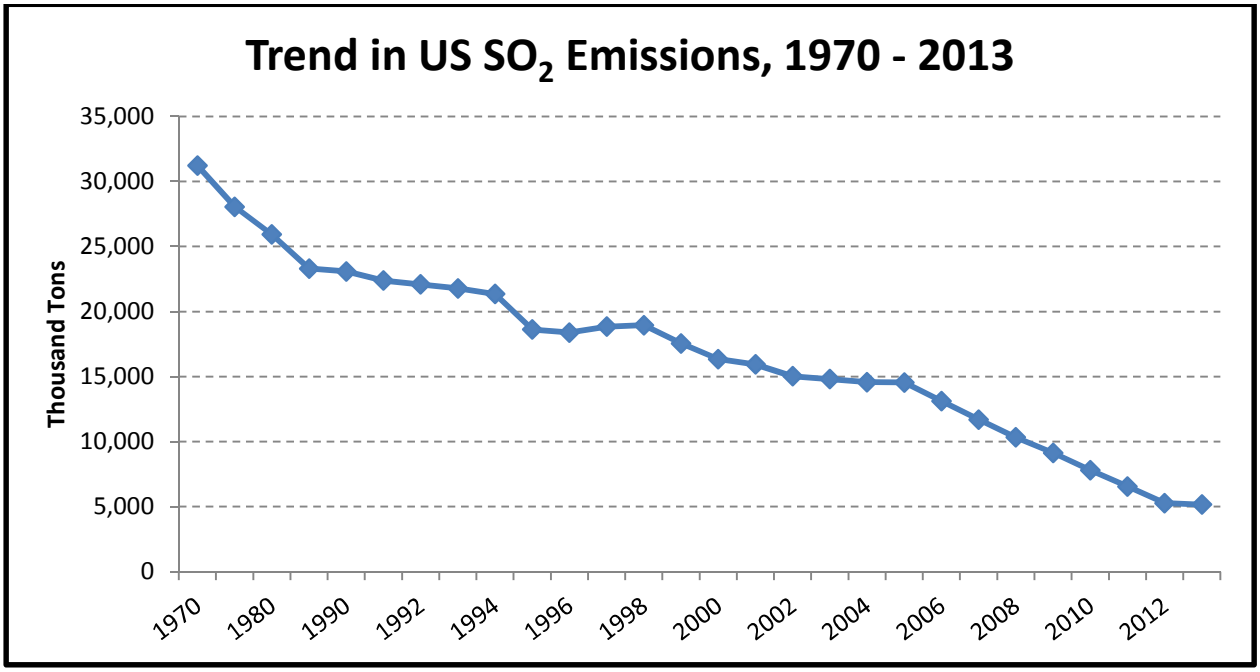
Table A1.1 Chronology of major federal and state regulations that resulted in reduced sulfur dioxide and nitrogen oxide emissions, 1990-current.

Regulation	Promulgation Date	Phase-in Date	Principal Requirements
Acid Rain Program	1990	1995	Phase I: SO_2 reductions at 445 affected facilities achieved via allowance trading and other compliance measures.
		2000	Phase II: More stringent emissions caps on Phase I facilities and new restrictions for other facilities, over 2,000 total affected facilities nationally.
Tier 2 Vehicle and Gasoline Sulfur Program	2000	2004	Gasoline refiners and importers required to meet a cap of 300 ppm[1] sulfur.
		2006	Gasoline refiners and importers required to meet a cap of 80 ppm sulfur.
Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements	2001	2006	Highway diesel fuel sulfur content no more than 15 ppm.
Clean Air Nonroad Diesel Rule	2004	2007	Sulfur in non-road diesel fuel limited to 500 ppm.
		2010	Sulfur in non-road diesel fuel reduced to 15 ppm.
Clean Air Interstate Rule/Cross State Air Pollution Rule (CAIR/CSAPR)	2005	2010	Cap and trade program to reduce power plant SO_2 and NO_x emissions in 28 states in the Midwestern US.
New Hampshire: RSA 125-O:11, Mercury Emissions	2006	2011	Installation of a scrubber at Eversource Merrimack Station to control mercury emissions, with the co-benefit of reducing SO_2 emissions.

[1] ppm = parts per million

Sulfur dioxide emissions are primarily dominated by point-sources, thus they are easier to regulate. Nationwide, sulfur dioxide emissions have declined with increased air quality regulation (Figure A1.1). On the contrary, nitrogen oxides are primarily released from transportation sources, are more difficult to regulate, and have received less attention. Supplemental air quality information can be found in Appendix A.

Figure A1.1 Trend in US SO_2 Emissions, 1970 – 2013 (Thousands of Tons)



To determine the long-term influences of acid-deposition parameters on New Hampshire waterbodies, NHDES initiated three monitoring programs, described below in Section A2. Information gathered from these long term monitoring programs has allowed NHDES to support efforts to implement acid rain controls, and later, as data accrued, demonstrate the effectiveness of federal and state legislative action at protecting New Hampshire's waterbodies. The following analyses provide an update of the status and trends of the most informative water quality parameters collected as part of these programs.

A2 MONITORING PROGRAMS

A2.1 Rooftop Rain Program

Since 1972, NHDES has monitored the pH and other analytes of precipitation by collecting water and snow samples on the roof of the NHDES building on Hazen Drive in Concord, NH. The purpose of this monitoring program is to describe acid rain trends via the monitoring of acid deposition-related parameters in precipitation. The majority of precipitation events are monitored, however, samples may be discarded if loss of sample integrity is suspected. The

volume of precipitation collected dictates the parameters analyzed. For example, only pH may be analyzed if precipitation volume was small, whereas additional analytes such as sulfate or nitrogen may be analyzed after a large precipitation event.

A2.2 Remote Pond Program

This long-term monitoring program was initiated in 1981 in cooperation with the New Hampshire Fish and Game Department (NH F&G). The purpose of this program is to describe acid rain trends in remote, mostly high elevation brook trout ponds. These ponds are most susceptible to the effects of acid rain precipitation due to small watershed size, shallow soils, and elevated precipitation rates. Once a year in May – June, NH F&G stocks brook trout (*Salvelinus fontinalis*) into remote, mostly high elevation ponds via helicopter. To determine long-term trends in acid deposition-related parameters, NH F&G collects a 0.5 m deep water sample from the approximate middle of the pond by Kemmerer bottle. NHDES biologists meet the helicopter at pre-determined sites to receive the samples which are later analyzed by NHDES. In 1999, ten of the ponds were selected to provide long-term trend data to the New England Governors/ Eastern Canadian Premiers acidity trend network (NEG-ECP) for acid rain trends. A total of 60 ponds were sampled at least once since the program's inception with a core of 23 ponds sampled almost every year through 2005. Due to increased costs and budgetary issues, only the ten NEG-ECP ponds have been sampled regularly since 2006. Since 2008, NHDES has provided $1000/year to NH F&G to partially reimburse the cost of the increased hover time required to collect the water samples.

A2.3 Acid Outlet Monitoring

NHDES established a long-term monitoring program of acid-deposition-related parameters for 20 relatively lower elevation lakes and ponds in 1983. The purpose of this monitoring program was to determine trends in acid deposition-related parameters in lower elevation, selected lakes and ponds. Water samples are collected biannually in the spring (April – May) and fall (October – November), times that are associated with turnover so that the outlet water is representative of whole-lake conditions. Waterbodies were selected based on the following criteria:

a. Outlet is easily accessible by car;
b. Pond is a headwater pond with a relatively small watershed (Two of the waterbodies are not truly headwaters);
c. Apparent color is less than or equal to 30;
d. Watershed contains no point sources or significant non-point sources of pollutants;
e. Pond is sensitive to acid deposition based on the calcite saturation index (CSI; an index used to determine the amount of calcite that will be precipitated or dissolved).

A3 ANALYSES

Data were plotted using Microsoft Excel 2010 while significance of trends was examined using non-parametric Mann-Kendall tests (MKT) with SYSTAT 13, a statistical software package. Data were examined with a two-way Mann-Kendall test to determine if a trend was present, with significance being determined at a p-value of 0.05. In some cases, if trend presence was approaching significance ($0.05 < p\text{-value} < 0.10$), the plotted data was examined visually and a one-way Mann-Kendall test was performed in the direction of the possible trend. Significance was declared at $p \leq 0.05$. A Loess smoothing curve is displayed in addition to raw data values for Acid Outlet and Remote Pond parameters to visually demonstrate trend direction.

A4 CHANGES IN METHODOLOGY

Sample collection methodology has remained consistent since the inception of the programs; however, some laboratory sample processing has changed as new technology became available or as laboratory standards changed. Samples are processed by the NHDES Jody Connor Limnology Center (JCLC) and the New Hampshire Department of Health and Human Services Public Health Laboratories-Water Analysis Lab (PHL WAL).

Acid neutralizing capacity (ANC) was originally determined by titrating to a fixed endpoint of pH 4.5 prior to 1984. After January 1984, the Gran plot method was incorporated into the sample processing methodology. Both methods were used until 1993, after which the fixed endpoint method was discontinued. The Gran plot procedure is more sensitive than the original procedure, and generally results in alkalinity values 1.5 mg/L lower than the fixed endpoint method. For this report, only ANC values determined by the Gran plot method were analyzed.

In 2005/2006, the PHL WAL implemented a new Laboratory Information Management System (LIMS). Prior to 2005, laboratory results that were numeric values under ten (<10) were reported as a whole number. Under the new LIMS, numeric laboratory results that were under ten were reported with one decimal point, allowing for greater precision (e.g. sulfate values in Appendices C& D).

All three programs focused on pH values; additionally, the Remote Pond and Acid Outlet programs also consistently monitored ANC and specific conductance. Additional parameters have been added or removed over the years. Sulfate and nitrate concentrations were added in the late 1980s and are still currently sampled. Other parameters, such as calcium and aluminum concentrations, were added around the same time but discontinued in 2011.

B1 ROOFTOP RAIN MONITORING AT NHDES

B1.1 Results and Trends in Rooftop Rain Monitoring

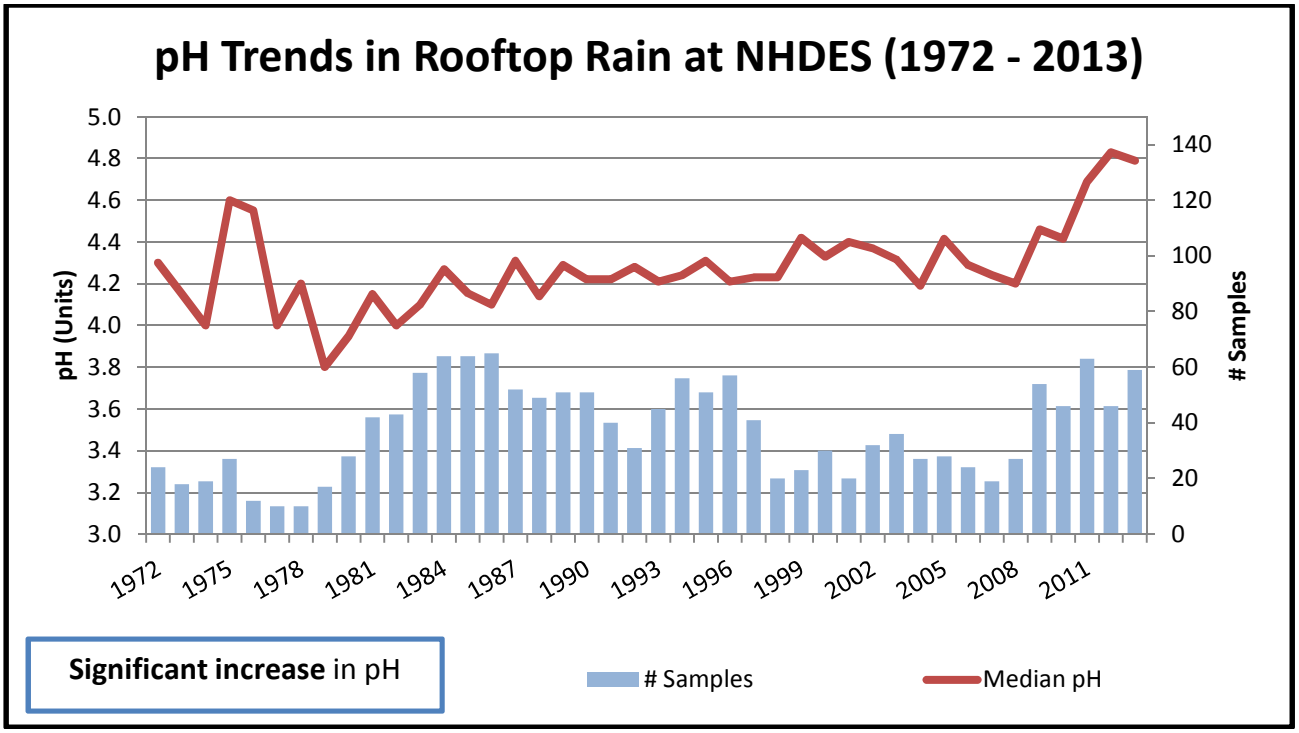
Since the program's inception in 1972 through the end of 2013, NHDES biologists monitored 1,579 precipitation events. Table B1.1 provides the average, median, minimum, and maximum pH values from 1972 – 2013. Median pH had a significant upward trend (MKT $p \leq 0.05$) over time (Figure B1.1, Appendix B).

Table B1.1 Average, minimum, maximum, and median pH values of rooftop rain sampled at NHDES (Hazen Dr., Concord, NH) by year.

Year	# of Samples	Average pH	Minimum pH	Maximum pH	Median pH
1972	24	4.45	3.6	6.6	4.3
1973	18	4.39	3.5	5.8	4.15
1974	19	4.32	3.5	7.5	4
1975	27	4.67	3.5	7.1	4.6
1976	12	4.77	3.6	6.5	4.55
1977	10	4.11	3.8	4.7	4
1978	10	4.90	3.8	7.8	4.2
1979	17	4.04	3.6	6.2	3.8
1980	28	3.95	2.9	5	3.95
1981	42	4.18	3.5	6.1	4.15
1982	43	4.02	3.4	5.1	4
1983	58	4.10	3.2	4.9	4.1
1984	64	4.26	3.5	5.2	4.27
1985	64	4.21	3.52	4.98	4.155
1986	65	4.18	3.45	5.29	4.1
1987	52	4.31	3.3	5.14	4.31
1988	49	4.18	3.52	5.06	4.14
1989	51	4.34	3.81	4.98	4.29
1990	51	4.28	3.66	5.22	4.22
1991	40	4.28	3.31	5.44	4.22
1992	31	4.24	3.51	5.13	4.28
1993	45	4.23	3.01	5.77	4.21
1994	56	4.32	3.29	5.71	4.24
1995	51	4.42	3.43	6.4	4.31
1996	57	4.30	3.64	5.28	4.21
1997	41	4.22	3.5	5.21	4.23
1998	20	4.17	3.4	4.65	4.23
1999	23	4.46	3.65	5.33	4.42
2000	30	4.37	3.19	5.02	4.33
2001	20	4.42	3.77	5.52	4.4
2002	32	4.37	3.54	5.05	4.37
2003	36	4.32	3.78	5.13	4.315
2004	27	4.17	3.29	5.13	4.19
2005	28	4.50	3.66	6.08	4.415
2006	24	4.24	3.64	5.02	4.29
2007	19	4.23	3.54	5	4.24

Year	# of Samples	Average pH	Minimum pH	Maximum pH	Median pH
2008	27	4.20	3.48	4.99	4.2
2009	54	4.47	3.65	6.24	4.46
2010	46	4.41	3.41	5.36	4.415
2011	63	4.67	3.73	5.94	4.69
2012	46	4.87	4.18	5.69	4.83
2013	59	4.74	3.54	6.08	4.79

Figure B1.1 pH Trends in Rooftop Rain at NHDES (1972-2013). See Appendix B for all Rooftop Rain graphs.



NHDES expanded its monitoring efforts in 1986, testing a subset of precipitation samples not only for pH, but also for sulfate concentration, nitrate concentration, and total phosphorus concentration (Appendix B). Table B1.2 details the average and median values of these parameters by year (Sulfate: 0-4 mg/L; Nitrogen: 0.11-0.43 mg/L; Total Phosphorus: 0-27 µm/L), as well as the total number of samples that were tested. Median sulfate, nitrate, and total phosphorus concentrations in rainfall have decreased significantly since testing began (MKT $p \leq 0.05$; Appendix B).

Table B1.2 Average and median values of sulfate, nitrate, and total phosphorus concentrations of rooftop rain sampled by NHDES (Hazen Dr., Concord, NH) by year.

Year	Sulfate (mg/L)			Nitrate (mg/L)			Total Phosphorus (µm/L)		
	# of Samples	Average	Median	# of Samples	Average	Median	# of Samples	Average	Median
1986	5	1.7	1.7	6	0.17	0.11	8	10	10
1987	11	2.8	2.3	12	0.69	0.25	11	10	10
1988	20	3.2	3.0	20	0.36	0.33	21	10	10
1989	30	3.3	3.5	30	0.47	0.43	28	20	20
1990	35	3.7	4.0	35	0.41	0.35	32	20	20
1991	32	6.4	3.5	32	0.58	0.42	30	40	20
1992	24	3.1	2.0	24	0.50	0.36	22	30	20
1993	32	2.8	2.0	32	0.44	0.33	31	30	10
1994	37	1.9	2.0	37	0.45	0.31	21	30	30
1995	39	2.5	2.0	39	0.54	0.36	35	20	10
1996	35	2.1	2.0	41	0.40	0.34	34	20	10
1997	28	2.4	2.0	28	0.49	0.34	28	20	10
1998	13	3.8	3.0	13	0.48	0.35	10	50	10
1999	19	2.0	2.0	19	0.30	0.31	20	20	10
2000	23	1.9	2.0	23	0.37	0.32	22	30	20
2001	17	2.5	2.0	17	0.46	0.38	13	10	10
2002	29	1.6	2.0	29	0.31	0.24	23	10	10
2003	29	1.8	2.0	30	0.26	0.21	26	10	10
2004	22	1.8	1.0	24	0.32	0.26	23	10	10
2005	23	0.8	1.0	21	0.18	0.18	23	10	10
2006	23	1.3	1.2	22	0.18	0.17	23	20	10
2007	19	1.7	1.2	15	0.27	0.26	17	10	0
2008	21	0.9	0.0	21	0.26	0.21	19	10	0
2009	45	1.1	0.0	45	0.22	0.17	44	20	10
2010	39	1.4	1.2	40	0.30	0.22	40	10	10
2011	54	1.0	0.0	54	0.26	0.18	46	20	10
2012	39	0.5	0.0	39	0.30	0.28	37	10	10
2013	41	0.3	0.0	41	0.28	0.19	40	10	10

B1.2 Conclusions in Rooftop Rain Monitoring

The pH of precipitation became significantly higher, while nitrate and sulfate concentrations significantly decreased. Since the program's inception in 1972, precipitation has become less acidic. The reduction of total phosphorus, while not related to acidifying pollutants, may be related to changes in land use practices.

B2 REMOTE POND PROGRAM

B2.1 Summary Statistics in Remote Pond Monitoring

Since the Remote Pond Program was initiated in 1981, 61 remote waterbodies have been sampled at least once, generating 785 pH samples, 719 ANC samples, 765 specific conductance samples, 587 sulfate samples, and 560 nitrate samples. Between 7 and 41 waterbodies were sampled each year for a variety of parameters (Table B2.1). Due to budgetary restraints, ten ponds were chosen for exclusive sampling as of 2006 (Table B2.2; Appendix C). While many aqueous parameters have been monitored under this program, pH, ANC, specific conductance, sulfate concentration, and nitrate concentration were focused on due to either the completeness of their dataset, the importance of the parameter relating to acid-related deposition, or both reasons. Data manipulation included samples from 2014 as they were collected in June 2014 and all lab analyses had been performed. A single sample was collected at each waterbody per year, therefore no within-year averages or medians were available.

Table B2.1 Total number of waterbodies and acid deposition-related parameters sampled by year.

Year	Ponds Sampled	pH	ANC	Specific Conductance	Sulfate	Nitrate
1981	7	7	7	0	0	0
1982	30	30	0	23	0	0
1983	36	36	0	36	0	0
1984	41	41	41	41	0	0
1985	27	27	27	27	0	0
1986	32	32	32	32	0	0
1987	29	29	29	29	10	10
1988	27	27	27	27	27	0
1989	26	26	26	25	25	25
1990	28	28	28	26	27	27
1991	25	25	25	25	24	24
1992	32	32	32	29	29	29
1993	32	32	32	32	32	32
1994	34	34	34	34	34	34
1995	29	29	29	29	29	29
1996	28	28	28	28	28	28
1997	29	29	29	29	29	29
1998	28	28	28	28	28	28

Year	Ponds Sampled	pH	ANC	Specific Conductance	Sulfate	Nitrate
1999	28	28	28	28	28	28
2000	27	27	27	27	27	27
2001	29	29	29	29	29	29
2002	21	21	21	21	21	21
2003	23	23	23	23	23	23
2004	23	23	23	23	23	23
2005	24	24	24	24	24	24
2006	10	10	10	10	10	10
2007	10	10	10	10	10	10
2008	10	10	10	10	10	10
2009	10	10	10	10	10	10
2010	10	10	10	10	10	10
2011	10	10	10	10	10	10
2012	10	10	10	10	10	10
2013	10	10	10	10	10	10
2014	10	10	10	10	10	10

Table B2.2 Individual name and location by town of waterbodies currently monitored under the Remote Pond Program.

Waterbody	Town
Black Pond	Lincoln
Black Mountain Pond	Sandwich
Cole Pond	Enfield
Flat Mountain Pond	Waterville Valley
Halfmile Pond	Enfield
One and Two Trio Ponds	Odell
Peaked Hill Pond	Thornton
Signal Pond	Errol
Lake Solitude	Newbury
Upper Greeley Pond	Livermore

B2.2 Results and Trends in Remote Pond Monitoring

Three out of the ten monitored waterbodies had significantly increasing pH values (MKT $p \leq 0.05$), while the remaining seven exhibited no significant trend (MKT $p > 0.05$; Table B2.3; Appendix C). ANC significantly decreased in one pond (MKT $p \leq 0.05$), while the remaining nine ponds did not vary significantly (MKT $p > 0.05$; Table B2.3; Figure B2.1; Appendix C). Specific conductance and sulfate concentration significantly decreased in all ten ponds over time (MKT $p \leq 0.05$; Table B2.3; Appendix C). A comparison of data from the last acid rain report (1995) to the most current data (2014) based on acid sensitivity narrative categories found that the majority of waterbodies did not change in acid sensitivity classification (Tables B2.4, B2.5).

Nitrate concentration has been tested for consistently since 1989. Since 2006, however, a majority of the monitored remote ponds had nitrate concentrations below the 0.05 mg/L detection limit used with current sampling methodology (Appendix C). Overall, 31% of the total nitrate samples were found to have non-detectable values. For the purposes of trend analyses, non-detectable samples were assigned a value of 0.025 mg/L, which is half of the detection limit. With the assumption that non-detectable nitrate concentrations have a value half of the detection limit, nine of the ten remote ponds exhibited a significant decrease in nitrate concentration (Table B2.3).

Table B2.3 Trend direction of pH, ANC, specific conductance, sulfate concentration, and nitrate concentration as determined by a Mann-Kendall test. Significance was declared at p≤ 0.05. Positive trends are indicated by "↑", negative trends are indicated by "↓", and non-significant trends are indicated by "0".

			pH (unit)		ANC (mg/L)		Specific Conductance (umho/cm)		Sulfate (mg/L)		Nitrate (mg/L)	
Waterbody	Town	First Sampled	Years of Data	Trend	Years of Data	Trend	Years of Data	Trend	Years of Data	Trend	Years of Data	Trend
Black Pond	Lincoln	1983	32	0	31	0	32	↓	27	↓	26	↓
Black Mountain Pond	Sandwich	1982	33	↑	31	0	33	↓	26	↓	25	↓
Cole Pond	Enfield	1981[1]	33	0	30	↓	30	↓	26	↓	25	↓
Flat Mountain Pond	Waterville Valley	1982	33	0	31	0	33	↓	27	↓	26	↓
Halfmile Pond	Enfield	1982	33	↑	32	0	31	↓	25	↓	27	↓
One and Two Trio Ponds	Odell	1982[2]	32	↑	30	0	32	↓	26	↓	25	↓
Peaked Hill Pond	Thornton	1981	34	0	31	0	33	↓	27	↓	26	↓
Signal Pond	Errol	1982	33	0	29	0	32	↓	26	↓	25	↓
Lake Solitude	Newbury	1981[3]	33	0	30	0	32	↓	27	↓	26	↓

Upper Greeley Pond	Livermore	1982[4]	32	0	30	0	31	↓	27	↓	26	0

[1]Not sampled in 2002
[2]Not sampled in 2005
[3]Not sampled in 2003
[4]Not sampled in 2006

	# of waterbodies	# of waterbodies	# of waterbodies	# of waterbodies	# of waterbodies
Increasing	3	0	0	0	0
No trend	7	9	0	0	1
Decreasing	0	1	10	10	9

Figure B2.1 Example of remote pond pH and ANC trend data of an individual waterbody. See Appendix C for all Remote Pond graphs.

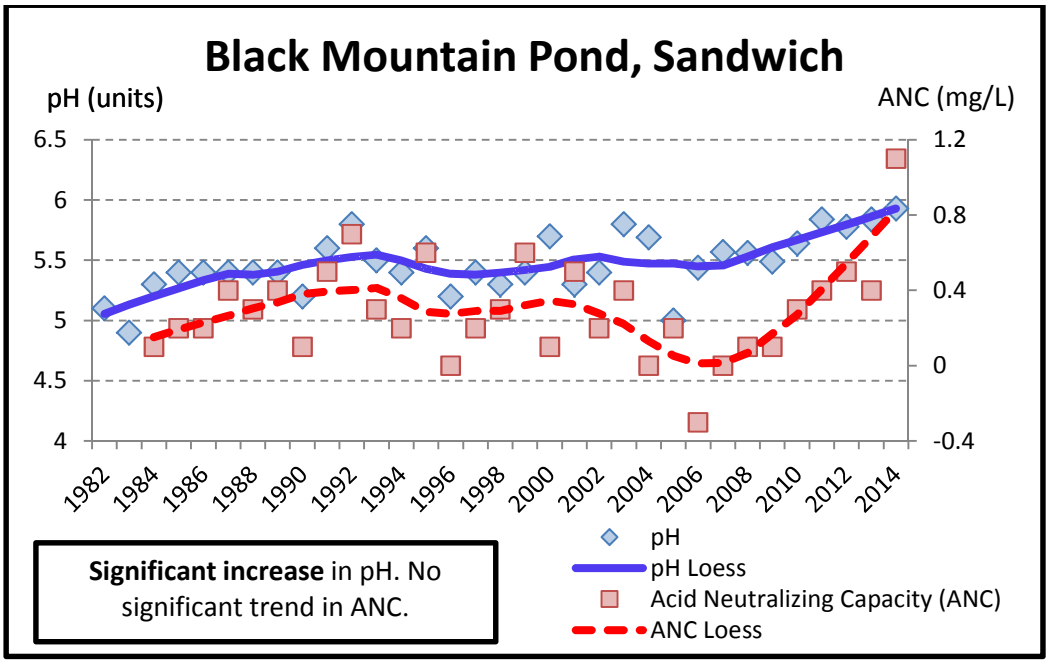


Table B2.4 Acid sensitivity narrative categories for 1995 pH and ANC data of remote ponds.

Sensitivity Category	pH			ANC		
	unit	#	%	mg/L	#	%
Acidified	< 5.0	0	0	≤0	0	0
Critical	5.0 - 5.4	2	20	>0 - 2	7	70
Endangered	5.5 - 6.0	6	60	>2 - 5	3	30
Satisfactory	> 6.0	2	20	n/a	0	0
		#	%		#	%
Total		10	100		10	100

Table B2.5 Acid sensitivity narrative categories for 2014 pH and ANC data of remote ponds.

Sensitivity Category	pH			ANC		
	unit	#	%	mg/L	#	%
Acidified	< 5.0	1	10	≤0	0	0
Critical	5.0 - 5.4	1	10	>0 - 2	8	80
Endangered	5.5 - 6.0	6	60	>2 - 5	2	20
Satisfactory	> 6.0	2	20	n/a	0	0
		#	%		#	%
Total		10	100		10	100

B2.3 Remote Pond Conclusions

Although atmospheric pollutant loads have been reduced in the Eastern United States due to more stringent air quality regulations, recovery of waterbodies from acid deposition-related parameters occurs slowly (Likens 1996). Relatively high elevation ponds, such as the ten monitored under the Remote Pond program (average elevation: 1980 feet), are more vulnerable to acid rain influences than lower elevation waterbodies due to rainfall constituting a greater portion of aqueous inputs, a result of minimal tributary inflows and small watershed size. While only three of the ten waterbodies showed a significant overall increase in pH, a more drastic positive effect was observed by the steady decline of sulfate concentration and specific conductance in all ten ponds. Additionally, nitrate also exhibited declines in 90% of the monitored waterbodies; however, the results were based on assigned a numeric value (0.025 mg/L) to sample results below the lab detection limit (0.05 mg/L). The declining trends of acidifying compounds suggest air quality regulations are successfully reducing acid-causing pollutants. With the exception of the one declining ANC trend, overall the remotes ponds appear stable with respect to acidity.

By comparing acid sensitivity categories reported in 1995 to the 2014, little has changed. One waterbody worsened by moving from the ‘critical’ to ‘acidified’ categories for pH, and one waterbody worsened from the ‘endangered’ to ‘critical’ categories for ANC. Yearly fluctuations in analytes are typical, so while comparing 1995 data to 2014 data gives a snapshot of how analytes have changed, trend analyses provide a more robust method of determining changes.

B3 ACID OUTLET PROGRAM

B3.1 Summary Statistics in Acid Outlet Monitoring

Twenty waterbodies have been consistently monitored biannually for acid deposition-related parameters since the program’s inception in 1983, which has generated 1,243 pH and ANC samples, 1,233 specific conductance samples, 1,122 sulfate samples, and 1,083 nitrate samples. Depending on the parameter, 26–32 years of data were available for trend analysis (Table

B3.1). Not all fall 2014 data for each pond was available at the time of analyses, therefore, only a subset of waterbodies had fall 2014 data. While many aqueous parameters have been monitored under this program, the focus in this report is on pH, ANC, specific conductance, sulfate concentration and nitrate concentration (Appendix D). These parameters were focused on due to either the completeness of their dataset, the importance of the parameter relating to acid-related deposition, or both reasons. Biannual samples were not combined for an average as investigating differences in seasonal trends was of interest.

Table B3.1 List of monitored waterbodies and their number of years of data for acid deposition-related parameters.

			pH		ANC		Specific Conductance		Sulfate		Nitrate	
			Years of Data		Years of Data		Years of Data		Years of Data		Years of Data	
Waterbody	Town	First Sampled	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring
Bow Lake	Strafford	1983	32	31	32	31	32	31	29	28	28	27
Center Pond	Nelson	1983	31	31	31	31	31	31	29	27	29	26
Cold Spring Pond	Stoddard	1983	31	31	31	31	31	31	29	27	28	26
Connor Pond	Ossipee	1983	32	31	32	31	32	31	29	28	28	27
Cooks Pond	Brookfield	1983	32	31	32	31	32	31	28	28	27	27
Dublin Pond	Dublin	1983	31	31	31	31	31	31	28	26	28	25
Echo Lake	Franconia	1983	31	31	31	31	28	28	29	28	26	26
Granite Lake	Nelson	1983	31	31	31	31	31	30	29	27	28	26
Long Pond	Lempster	1983	31	31	31	31	30	31	29	27	28	26
Loon Lake	Plymouth	1983	31	31	31	31	31	31	28	27	27	26
Loon Pond	Gilmanton	1983	32	31	32	31	32	31	29	28	28	27
Millen Pond	Washington	1983	31	30	31	30	31	29	29	26	28	25

			pH		ANC		Specific Conductance		Sulfate		Nitrate	
			Years of Data		Years of Data		Years of Data		Years of Data		Years of Data	
Waterbody	Town	First Sampled	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring
Nubanusit Lake	Nelson	1983	31	31	31	31	31	31	29	26	28	26
Pleasant Lake	Deerfield	1983	32	31	32	31	32	31	29	28	28	27
Russell Pond	Woodstock	1984	30	31	30	31	30	31	28	28	28	27
Silver Lake	Harrisville	1983	31	31	31	31	31	31	29	27	28	26
Spectacle Pond	Groton	1983	31	31	31	31	30	31	29	28	28	27
Stinson Lake	Rumney	1983	31	31	31	31	31	31	29	28	28	27
Stone Pond	Marlboroug h	1983	31	31	31	31	31	31	29	27	28	26
White Lake	Tamworth	1983	31	31	31	31	31	31	28	28	27	27

B3.2 Results and Trends in Acid Outlet Monitoring

Trend results differed slightly between spring and fall sampling (Table B3.2, Figure B3.1). Although waterbodies in both sampling periods are assumed to be under fully mixed conditions, spring sampling conditions are thought to be representative of the worst case scenario due the deposition of airborne pollutants in snowpack with each snow event throughout the winter. As the snow melts in the spring, the accumulated pollutants are rapidly introduced into waterbodies, causing temporary declines in pH and ANC (Strock et al. 2014). It appears our data reflects this tendency as more lakes demonstrated pH and ANC increases in the fall, with improvements of 30 and 50% respectively, than they did in the spring, with pH and ANC improvements of 15 and 20% respectively (Table B3.2; Appendix D). Additionally, the most recently available complete dataset from fall 2013 and spring 2014 was categorized by acid sensitivity narrative categories and compared to fall and spring 1995 data, which would have been the most recently available data for the previous 1996 acid rain report (Tables B3.3, B3.4). In general, waterbodies demonstrated improvement for both pH and ANC (Tables B3.3, B3.4). For pH, not only did the 'critical' category not contain any waterbodies in 2013/2014, the percentage of waterbodies with pH values in the 'satisfactory' category jumped from less than half in 1995 to 90% and 85% in fall 2013 and spring 2014 respectively (Tables B3.3, B3.4). The improvement was less drastic for ANC values, but the comparison of this snapshot data

revealed the 'acidified' category went from 5% of waterbodies in 1995 to 0% in 2013/2014, and for fall data, the majority of waterbodies improved from 'critical' to 'endangered' (Tables B3.3, B3.4).

The acid outlet waterbodies also showed a strong decrease in sulfate concentration, with 19 of 20 monitored waterbodies exhibiting a significant decrease in spring and fall (Table B3.2). Similar to the remote ponds, a majority of the monitored acid outlet waterbodies had nitrate concentrations below the 0.05 mg/L detection limit used with current sampling methodology since 2006 (Appendix D). Overall, 29% of the total nitrate samples were found to have non-detectable values. For the purposes of trend analyses, non-detectable samples were assigned a value of 0.025 mg/L, which is half of the detection limit. With that assumption, all but two waterbodies in the fall and one in the spring exhibited significant decreases in nitrate concentration (Table B3.2). Specific conductance, on the other hand, did not correspond to sulfate concentration as it appeared to with the remote ponds, and was divided roughly into thirds among increasing trends, decreasing trends, and no significant trends (Table B3.2).

Table B3.2 Trend direction of pH, ANC, specific conductance, sulfate concentration, and nitrate nitrogen concentration as determined by a Mann-Kendall test in acid outlet waterbodies. Significance was declared at p≤ 0.05.

	pH		**ANC**		**Specific Conductance**		**Sulfate**		**Nitrate**	
TREND	**Fall**	**Spring**	**Fall**	**Spring**	**Fall**	**Spring**	**Fall**	**Spring**	**Fall**	**Spring**
Increasing Trend	6	3	10	4	5	7	0	0	0	0
No significant change	11	16	10	14	8	4	1	1	2	1
Decreasing Trend	3	1	0	2	7	9	19	19	18	19
TOTAL	*20*	*20*	*20*	*20*	*20*	*20*	*20*	*20*	*20*	*20*
PERCENTAGE	%	%	%	%	%	%	%	%	%	%
Increasing Trend	30	15	50	20	25	35	0	0	0	0
No significant change	55	80	50	70	40	20	5	5	10	5
Decreasing Trend	15	5	0	10	35	45	95	95	90	95
TOTAL	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*

Figure B3.1 Example of acid outlet pH trend data of an individual waterbody. See Appendix D for all acid outlet graphs.

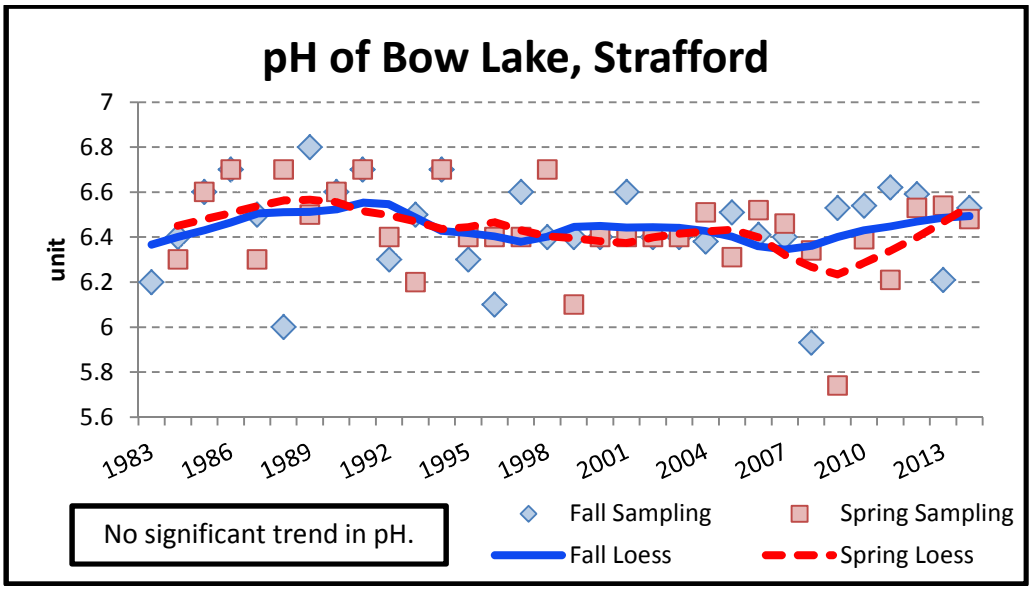


Table B3.3 Acid sensitivity narrative categories for fall 1995/spring 1995 pH and ANC data of acid outlet waterbodies.

Sensitivity Category	unit	pH				Sensitivity Category	mg/L	ANC			
		Fall 1995		Spring 1995				Fall 1995		Spring 1995	
		#	%	#	%			#	%	#	%
Acidified	< 5.0	0	0	0	0	Acidified	≤0	1	5	1	5
Critical	5.0 - 5.4	1	5	3	15	Critical	>0 - 2	11	55	13	65
Endangered	5.5 - 6.0	10	50	10	50	Endangered	>2 - 5	6	30	4	20
Satisfactory	> 6.0	9	45	7	35	Highly Sensitive	>5 - 10	2	10	2	10
Total		#	%	#	%	Total		#	%	#	%
		20	100	20	100			20	100	20	100

Table B3.4 Acid sensitivity narrative categories for fall 2013/ spring 2014 pH and ANC data of acid outlet waterbodies.

Sensitivity Category	unit	pH				Sensitivity Category	mg/L	ANC			
		Fall 2013		Spring 2014				Fall 2013		Spring 2014	
		#	%	#	%			#	%	#	%
Acidified	< 5.0	0	0	0	0	Acidified	≤0	0	0	0	0
Critical	5.0 - 5.4	0	0	0	0	Critical	>0 - 2	5	25	11	55
Endangered	5.5 - 6.0	2	10	3	15	Endangered	>2 - 5	10	50	7	35
Satisfactory	> 6.0	18	90	17	85	Highly Sensitive	>5 - 10	5	25	2	10
Total		#	%	#	%	Total		#	%	#	%
		20	100	20	100			20	100	20	100

B3.3 Acid Outlet Conclusions

Fall sampling revealed greater pH and ANC recovery among the 20 acid outlet waterbodies, while spring sampling, representative of the worst case scenario, had more non-significant trends. Few waterbodies exhibited declines in pH and ANC concentrations. As of the most recent complete rounds of sampling (Fall 2013 and Spring 2014) no waterbodies fell into the acidified category, defined as having pH <5.0 or ≤0 mg/L ANC (Tables B3.3, B3.4). No waterbodies fell into the pH critical category, and just over half were listed as critical for ANC (Table B3.4). This is a noticeable improvement in ANC from the last acid rain report in 1996, where 5% of waterbodies were considered acidified by ANC categories and 5–15% of waterbodies were considered critical by pH categories (Table B3.3). The majority of waterbodies improved from the 'critical' to 'endangered' categories in ANC in the fall, however, spring data showed the majority of waterbodies remained in the 'critical' category (Tables B3.3, B3.4).

Similar to the remote ponds, ≥90% of the acid outlet waterbodies exhibited significant declines in sulfate and nitrate concentrations, corresponding with reductions in pollutants via air quality regulations implemented in the last several decades. Unlike the remote ponds, however, the sulfate declines did not closely correspond with specific conductance trends. The acid outlet ponds are lower elevation ponds and exposed to greater human activity and presence, therefore changes in specific conductance may have been influenced by road salt, erosion, or septic systems.

C1 OVERALL CONCLUSIONS

Rooftop rain has demonstrated a statistically significant increase in pH over the sample collection history, while also revealing a statistically significant decrease in sulfate, nitrogen and

phosphorus concentrations. A majority of remote pond and acid outlet waterbodies demonstrated non-significant or significantly increasing trends in pH and ANC. Specific conductance has shown a statistically significant decrease at all of the remote pond locations and has remained stable or decreased at a majority of the acid outlet ponds. Sulfate concentrations have shown a statistically significant decrease at all of the remote pond locations and have remained stable or decreased at all of the acid outlet ponds. Nitrate, with the assumption that non-detectable samples were assigned a value of 0.025 mg/L, also demonstrated significant decreases at a majority of remote pond and acid outlet waterbodies. All of these trends have been accompanied by a large reduction in emissions of sulfur dioxide to the atmosphere over several decades (Appendix A). The improvements documented by these monitoring projects are encouraging and provide evidence of the success of national and state air quality policies in protecting our environment. The results also highlight that waterbody recovery from acid deposition parameters is a work in progress, as pH and ANC values at many of the waterbodies have remained stable despite the reduction in acid deposition-related variables. This lag in recovery time is especially severe in sensitive ecosystems like those found in New Hampshire and is attributed to the long-term accumulation of acids and loss of buffering capacity in soils (Driscoll et al. 2001, Strock et al. 2014). While pH and ANC concentrations are unlikely to return to pre-industrial levels, water quality improvements have been and will continue to be realized as long as regulations responsible for reductions in acid-causing pollutants are maintained or strengthened.

C2 RECOMMENDATIONS

Water quality data generated through these programs serve as the basis for understanding regional acid deposition impacts, as well as informing the development and support of water and air management policies. Consistent and ongoing monitoring of pH, ANC, specific conductance, sulfate concentration, and nitrate concentration is necessary to continue tracking the response and recovery of New Hampshire waterbodies. We highly recommend the continuation of the rooftop rain, remote pond, and acid outlet programs to monitor the ongoing recovery of New Hampshire waterbodies. Long-term data sets such as these are rare and valuable for trend monitoring. Additionally, we recommend investigating laboratory procedures that would increase sensitivity for detecting nitrate concentration, thereby lowering the detection limit (currently at 0.05 mg/L), to provide more informative data for analyses.

D REFERENCES

Driscoll, C.T., G.B. Lawrence, A.J. Bulger, T.J. Butler, C.S. Cronan, C. Eager, K.F. Lambert, G.E. Likens, J.L. Stoddard, and K.C. Weathers. 2001. Acid rain revisited: advances in scientific understanding since the passage of the 1970 and 1990 Clear Air Act amendments. Hubbard Brook Research Foundation. Science Links™ Publication, Vol. 1, no. 1.

Likens, G.E., C.T. Driscoll, and D.C. Buso. 1996. Long term effects of acid rain: response and recovery of a forest ecosystem. Science, New Series, Vol. 272, No. 5259: 244-246.

Strock, K. E., S. J. Nelson, J. S. Kahl, J. E. Saros, and W. H. McDowell. 2014. Decadal trends reveal recent acceleration in the rate of recovery from acidification in the Northeastern U.S. Environmental Science and Technology, Vol. 48: 4681 – 4689.

Appendix A
Sulfur Dioxide Emissions

The United States Environmental Protection Agency (EPA) compiles a national inventory of criteria and hazardous air pollutant emissions on a 3-year cycle. This inventory is largely comprised of data submitted to EPA by state, local and tribal air agencies. Every three years, it is compiled and released to the public as the National Emissions Inventory (NEI). Tables 1-3 with accompanying Figures 1-3 show sulfur dioxide (SO_2) emissions estimates from the NEI for the 3-year cycles from 1999 to 2011 at a local, regional, and national scale, which is the most recently available release (note: due to a major technical modification made to the NEI system, the 2005 NEI was a limited effort and is therefore not included in the tables). Additionally, EPA has compiled estimates of annual sulfur dioxide emissions from 1970 to 2013, which are presented in Figure 4. The emissions data are broken down into the following categories:

- Point Sources are discrete stationary sources of emissions such as large power plants and industrial facilities. These types of emissions sources generally perform their own emissions estimates, or measure their emissions directly with continuous monitoring equipment, and report the emissions as part of a state or federal air permitting program.
- Area Sources are stationary sources of emissions that are too numerous or widespread to be inventoried individually. There are hundreds of area source emissions categories; some examples include residential fuel combustion, consumer solvent use and evaporative emissions from gasoline dispensing.
- Non-Road Mobile Sources are off-highway vehicles and equipment such as aircraft, locomotives, ships, construction vehicles, lawn and garden equipment, and recreational vehicles.
- On-Road Mobile Sources are on-highway vehicles such as cars, SUVs, trucks, buses and motorcycles.

Table 1: SO_2 emissions in New Hampshire, 1999 – 2011 (Thousands of Tons)

Category	**1999**	**2002**	**2008**	**2011**
Point	60.8	46.6	38.9	25.7
Area	9.7	7.1	6.5	5.4
Non-Road Mobile	0.9	0.7	0.1	0.0
On-Road Mobile	1.5	0.9	0.1	0.1
Total	**72.9**	**55.2**	**45.7**	**31.3**

Figure 1: SO_2 emissions in New Hampshire, 1999-2011 (Thousands of Tons)

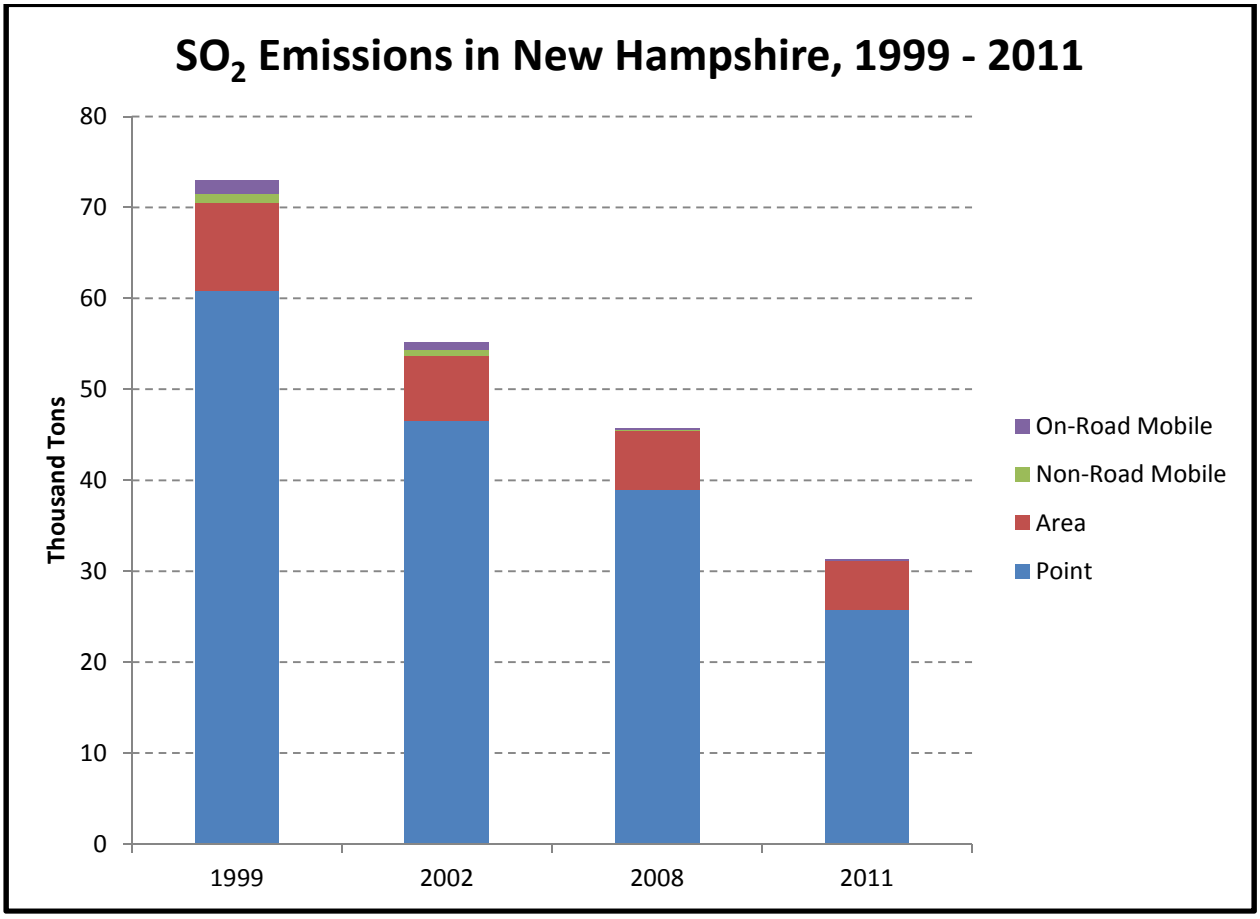


Table 2: SO_2 emissions in the Northeastern US, 1999 – 2011 (Thousands of Tons)

Category	1999	2002	2008	2011
Point	8,200.2	6,628.7	4,859.5	2,836.8
Area	719.3	295.3	326.8	203.9
Non-Road Mobile	154.7	153.9	12.9	1.6
On-Road Mobile	124.5	97.7	12.8	11.1
Total	**9,198.7**	**7,175.6**	**5,212.0**	**3,053.5**

Note: For the purposes of this table and subsequent figure, the northeastern US includes all states east of IL and WI (inclusive) and north of KY and VA (inclusive).

Figure 2: SO_2 emissions in the Northeastern US, 1999 – 2011 (Thousands of Tons)

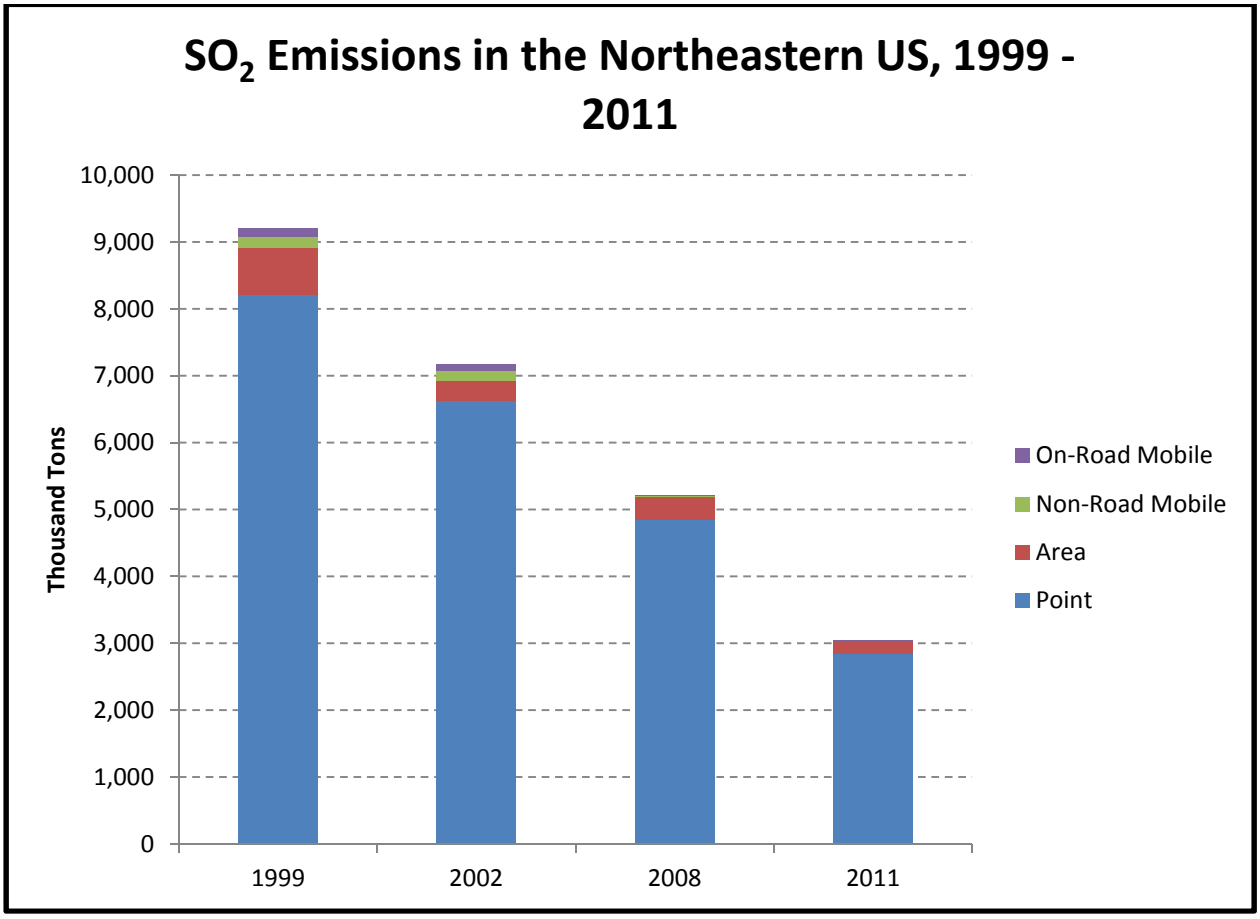


Table 3: SO_2 Emissions in the US, 1999 – 2011 (Thousands of Tons)

Category	1999	2002	2008	2011
Point	15,481.4	12,637.7	9,489.1	5,836.4
Area	1,288.3	958.3	1,101.9	807.0
Non-Road Mobile	469.6	608.7	33.9	4.1
On-Road Mobile	298.8	245.3	39.4	29.5
Total	**17,538.1**	**14,450.0**	**10,664.3**	**6,676.9**

Figure 3: SO_2 Emissions in the US, 1999 – 2011 (Thousands of Tons)

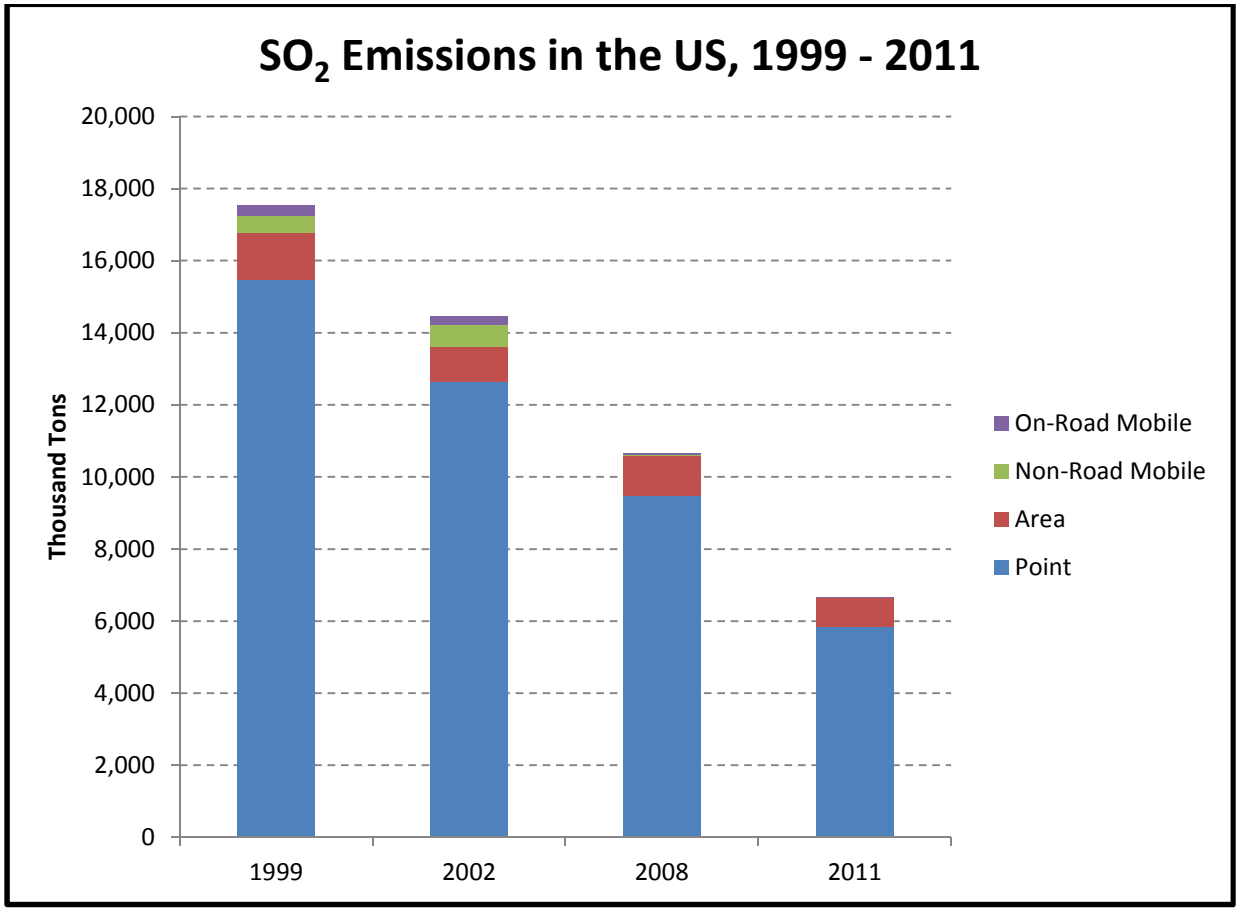
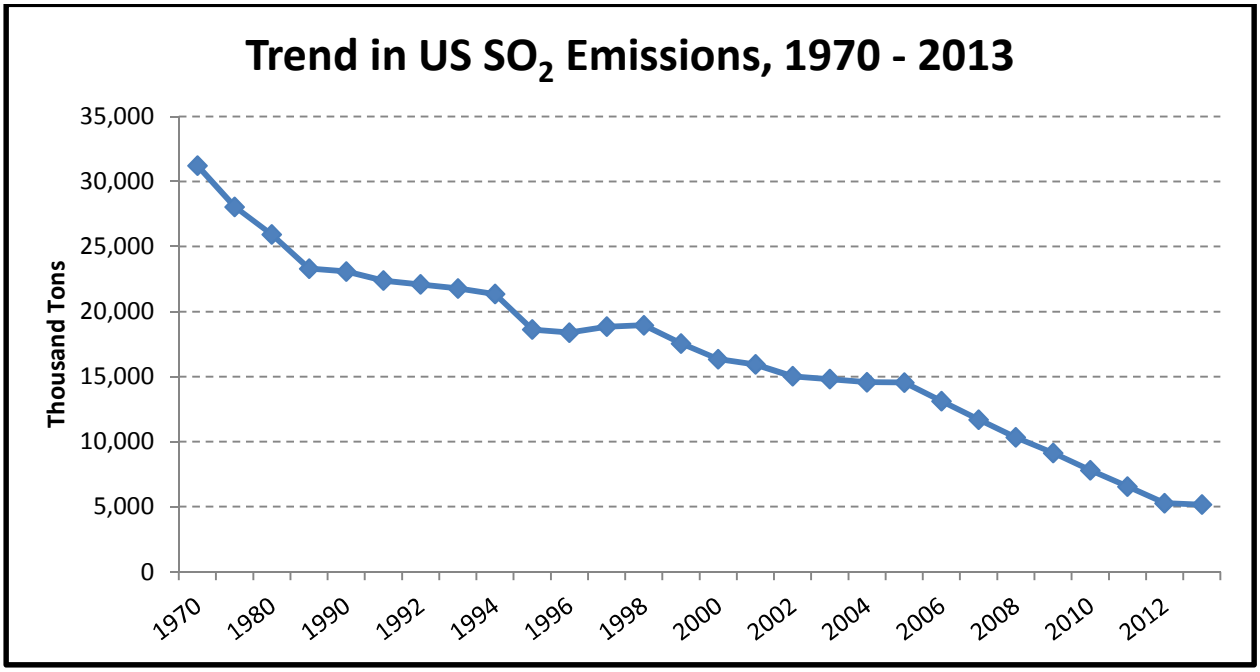


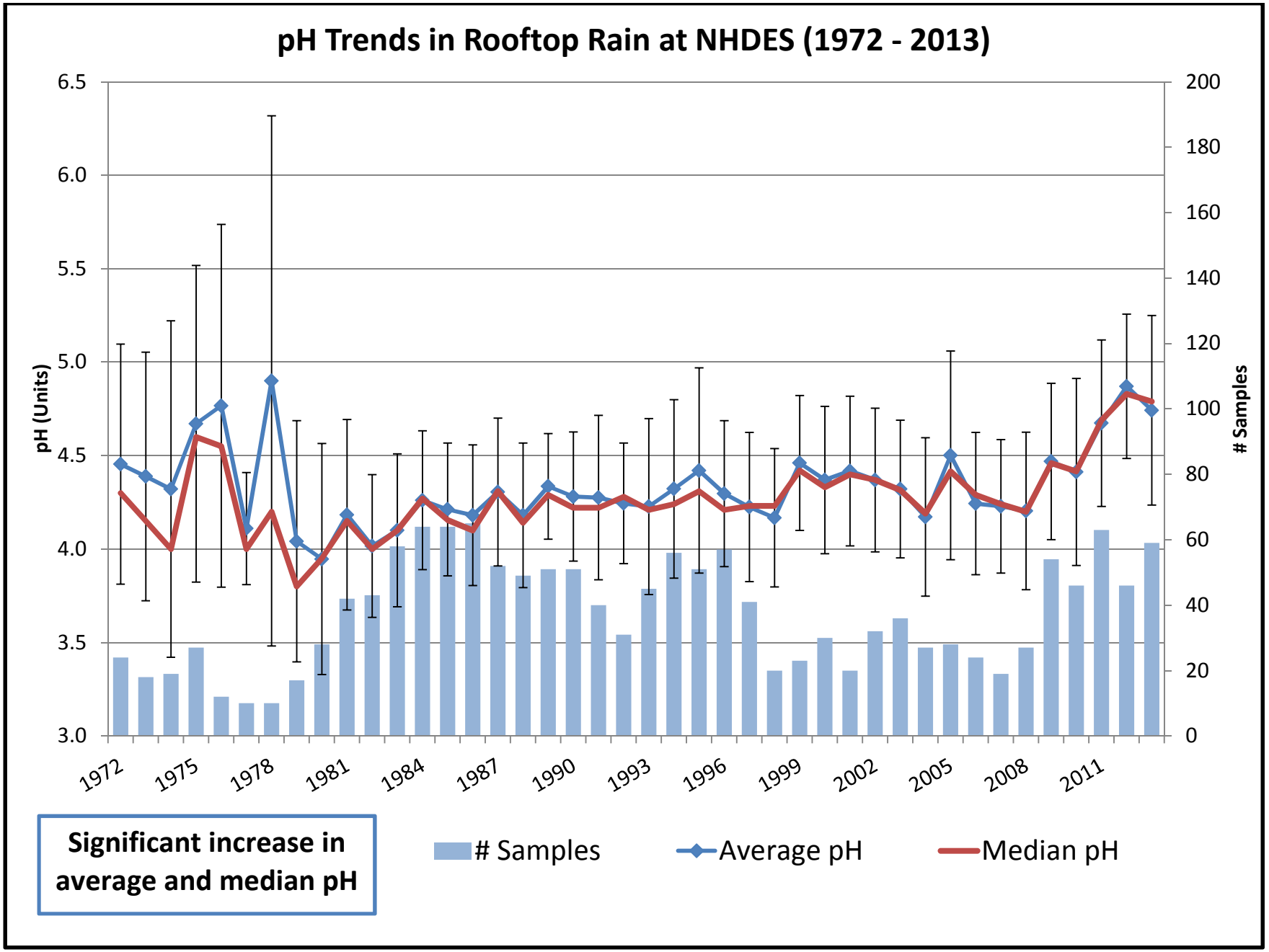
Figure 4: Trend in US SO_2 Emissions, 1970 – 2013 (Thousands of Tons)

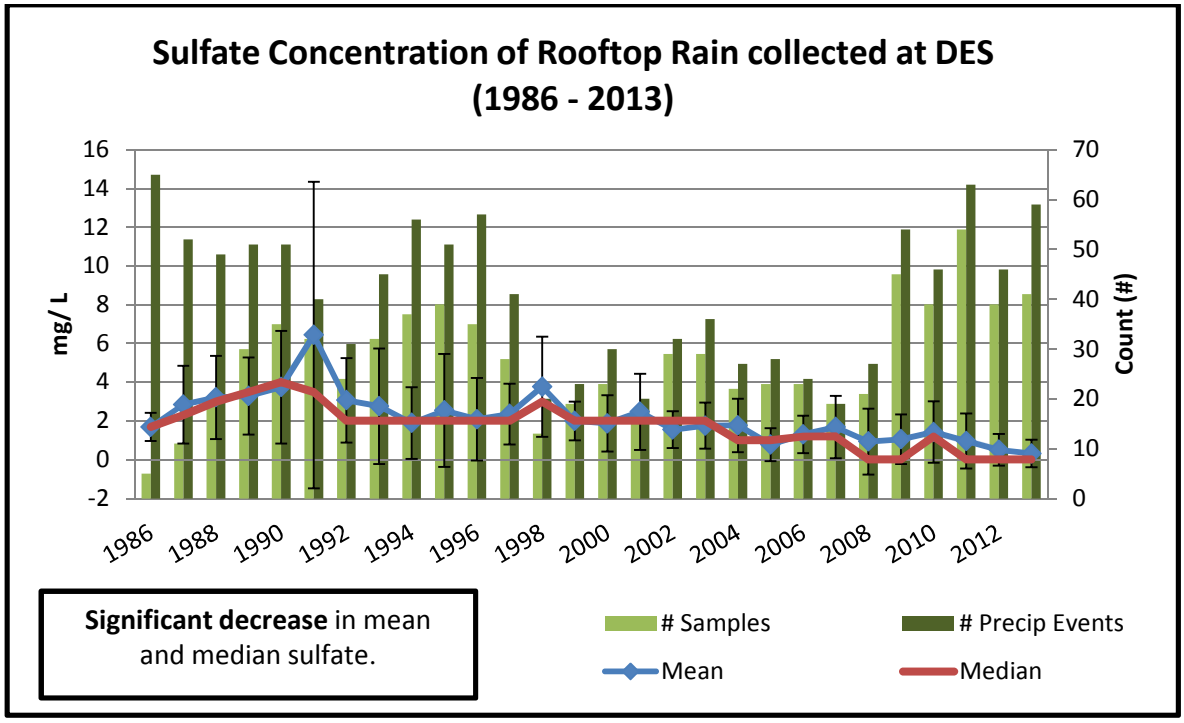


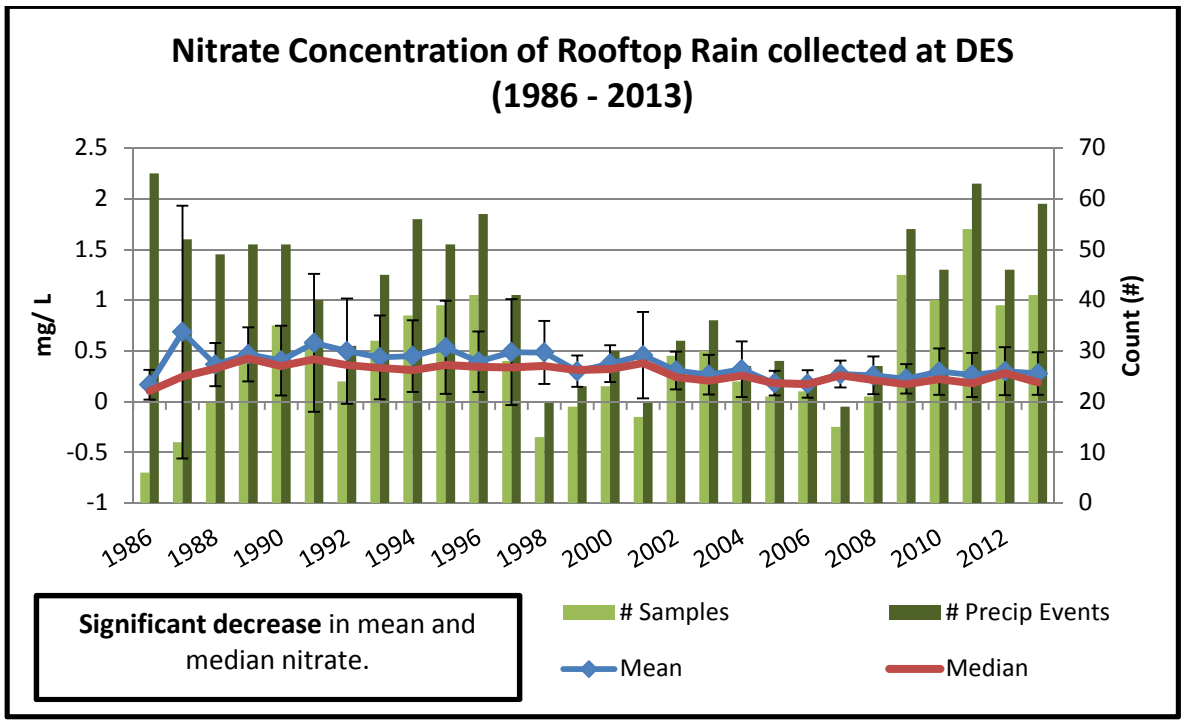
Tables 1-3 and Figures 1-4 indicate large reductions in sulfur dioxide emissions have occurred for point-source emissions. This is particularly evident in 2011 for the Northeast US and the US as a whole due to the sulfur dioxide reductions driven by the CAIR/CSAPR rules beginning in 2010 (Table A1.1, main text). For New Hampshire, in particular, a scrubber was installed at PSNH Merrimack Station halfway through 2011 for the primary purpose of reducing mercury emissions, with the additional benefit of removing sulfur dioxide. Further decreases in New Hampshire's sulfur dioxide emissions are expected in following years' data with the scrubber fully operational year-round.

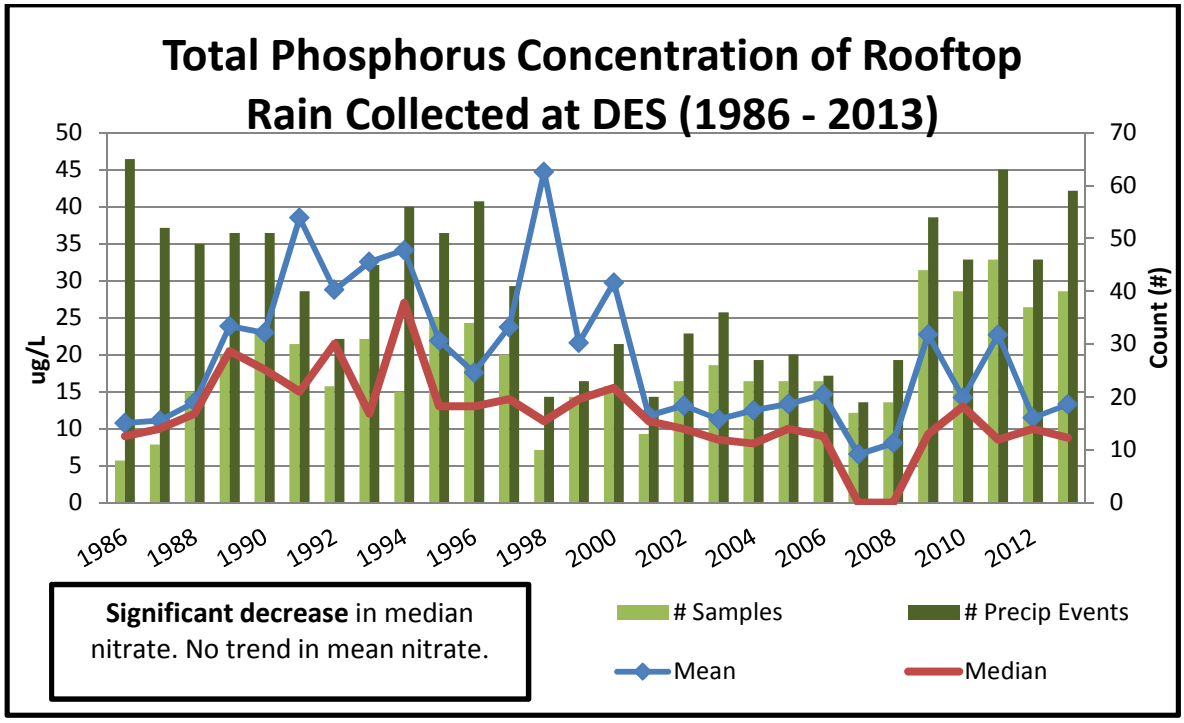
Although non-road and on-road mobile sources are lesser contributors to sulfur dioxide emissions than point sources, large reductions have occurred for these categories as well. This is primarily due to the on-road and non-road gasoline and diesel sulfur rules that phased in starting in 2004 as mandated by the Vehicle and Gasoline Sulfur Program (with larger cuts in non-road diesel sulfur starting in 2010, see Table A1.1, main text).

Appendix B
Rooftop Rain


pH Trends in Rooftop Rain at NHDES (1972 - 2013)
pH (Units)
Samples
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
200
180
160
140
120
100
80
60
40
20
0
1972
1975
1978
1981
1984
1987
1990
1993
1996
1999
2002
2005
2008
2011
Significant increase in average and median pH
Samples
Average pH
Median pH

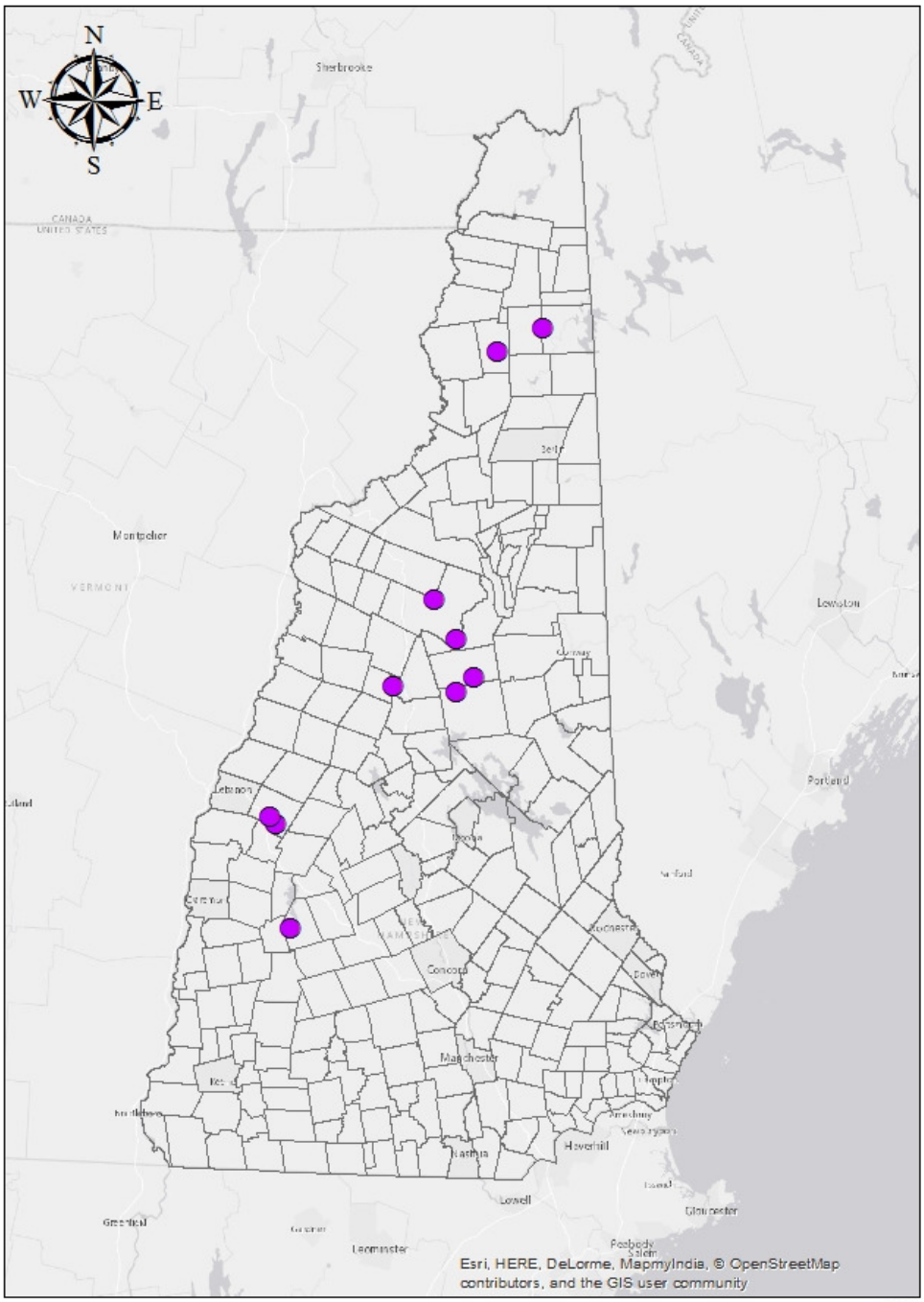

Sulfate Concentration of Rooftop Rain collected at DES
(1986 - 2013)
mg/ L
Count (#)
16
14
12
10
8
6
4
2
0
-2
70
60
50
40
30
20
10
0
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
Significant decrease in mean and median sulfate.
Samples
Precip Events
Mean
Median


Nitrate Concentration of Rooftop Rain collected at DES
(1986 - 2013)
mg/ L
Count (#)
2.5
2
1.5
1
0.5
0
-0.5
-1
70
60
50
40
30
20
10
0
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
Significant decrease in mean and median nitrate.
Samples
Precip Events
Mean
Median


Total Phosphorus Concentration of Rooftop Rain Collected at DES (1986 - 2013)
ug/L
Count (#)
50
45
40
35
30
25
20
15
10
5
0
70
60
50
40
30
20
10
0
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
Significant decrease in median nitrate. No trend in mean nitrate.
Samples
Precip Events
Mean
Median

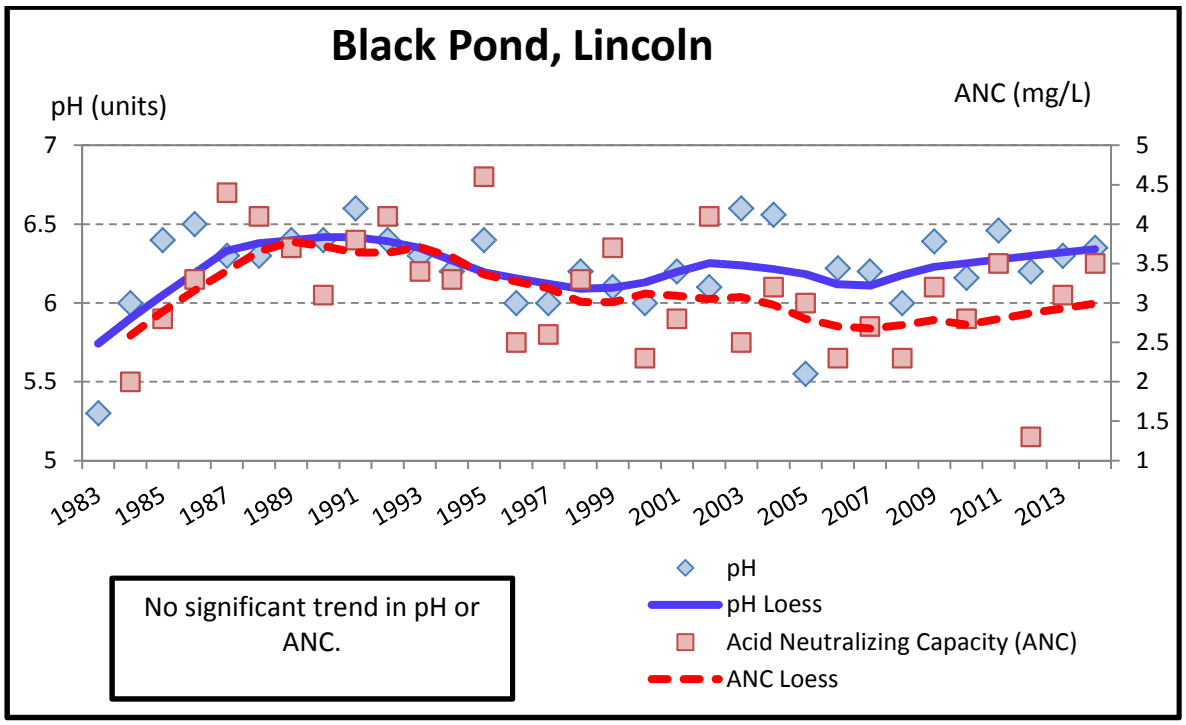
Appendix C
Remote Pond

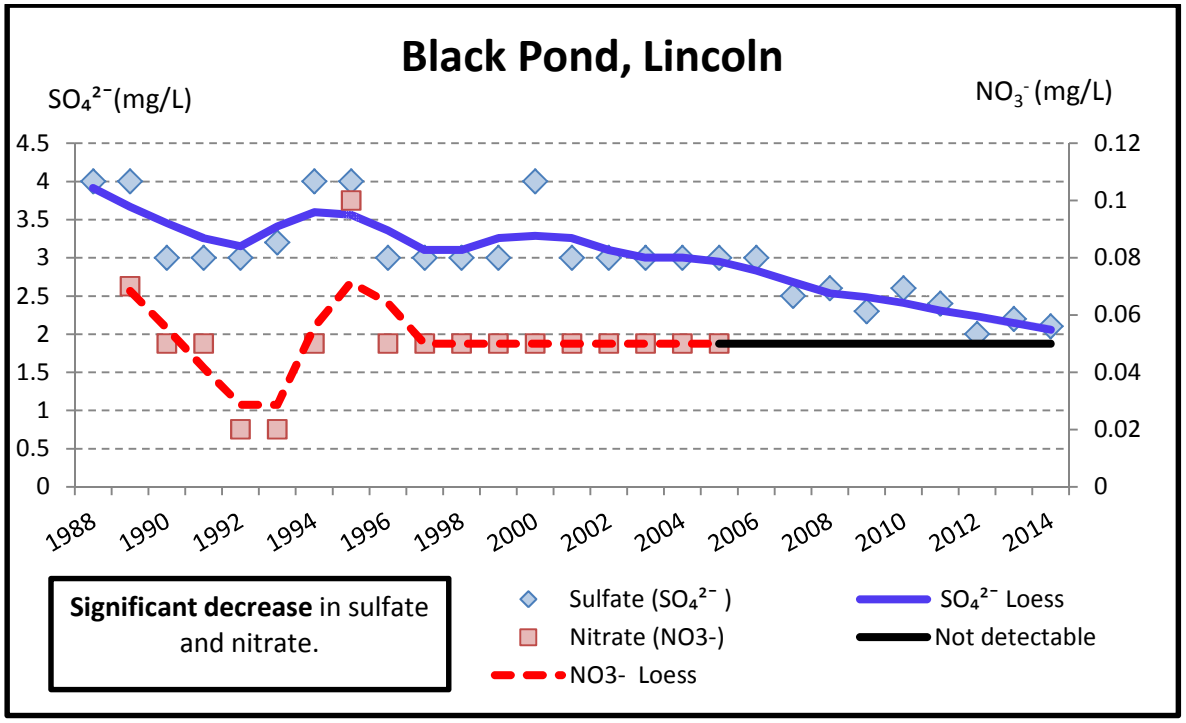
Remote Pond Locations

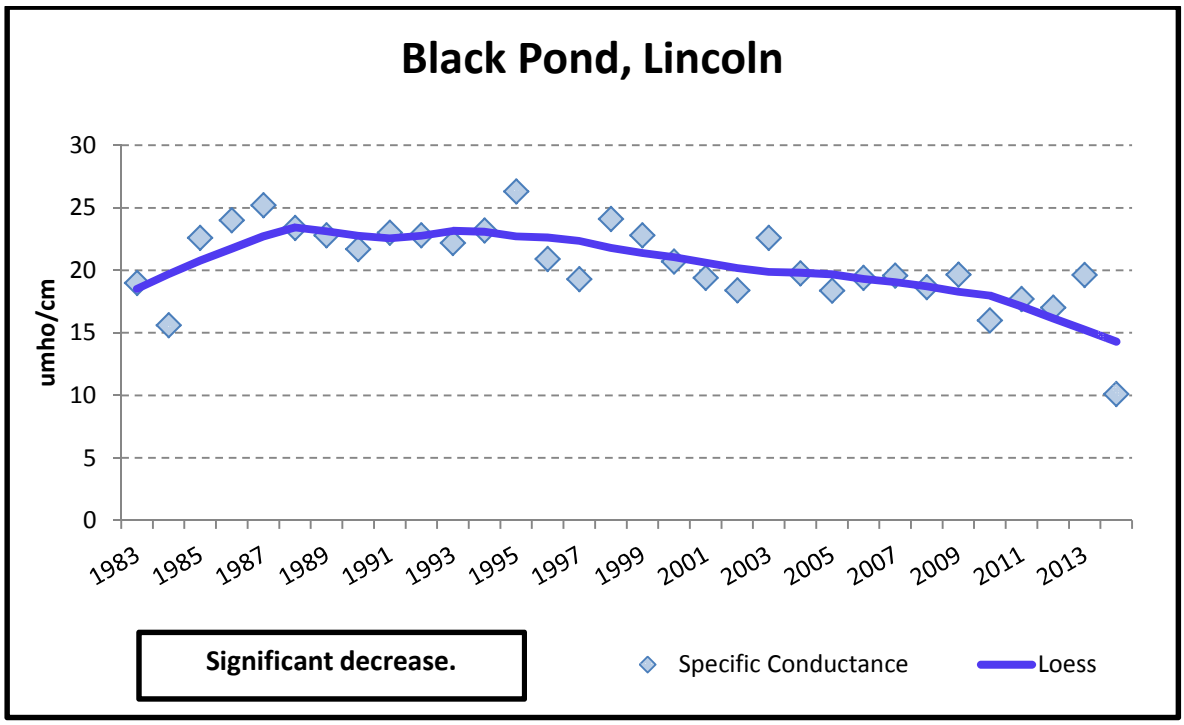


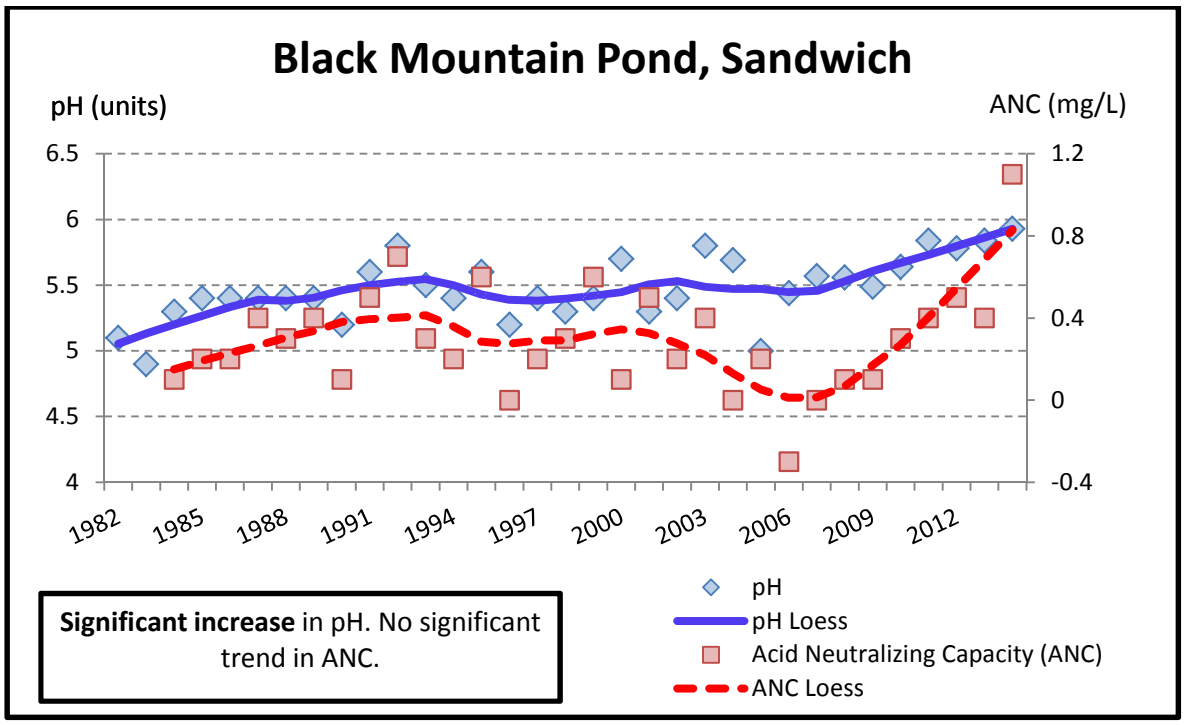
0 12.5 25 50 Miles

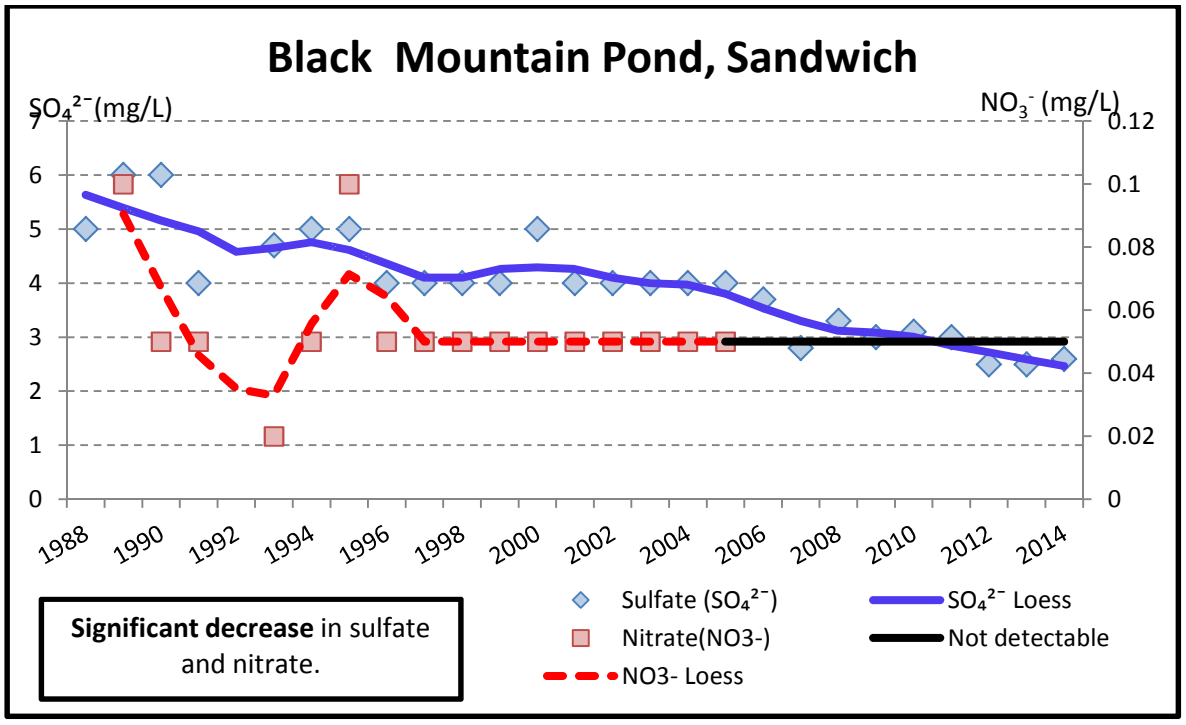
Environmental Services

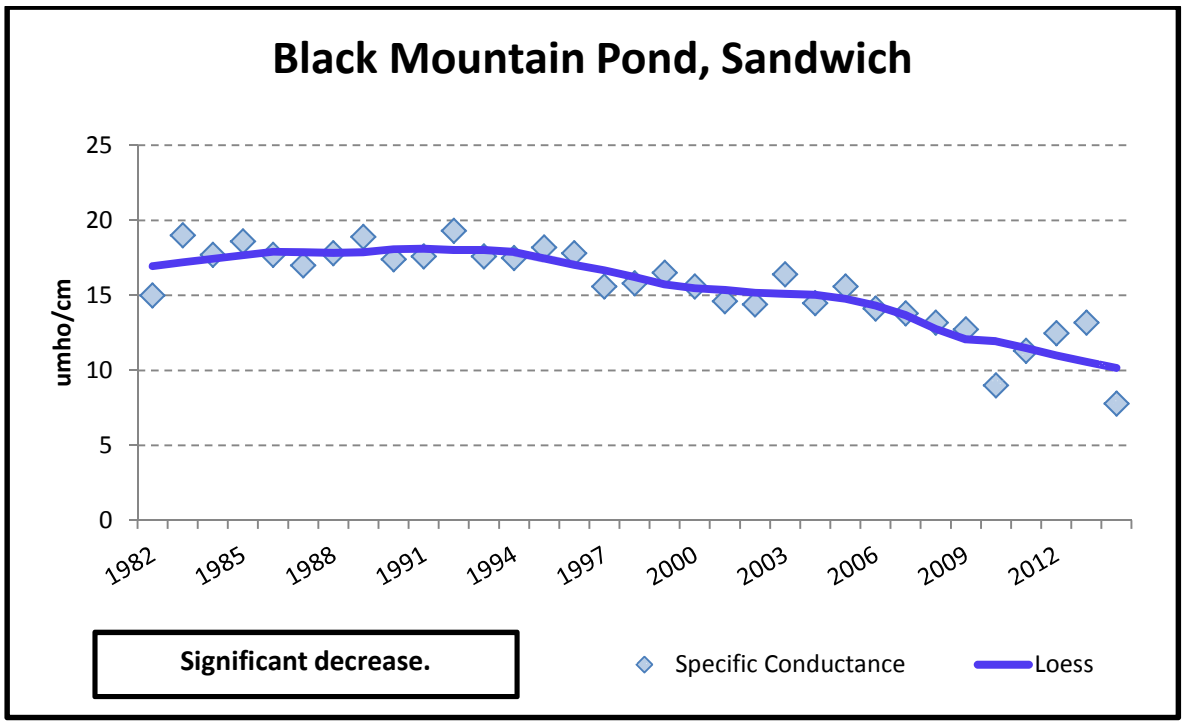

Black Pond, Lincoln
pH (units)
ANC (mg/L)
7
6.5
6
5.5
5
5
4.5
4
3.5
3
2.5
2
1.5
1
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
No significant trend in pH or ANC.
pH
pH Loess
Acid Neutralizing Capacity (ANC)
ANC Loess

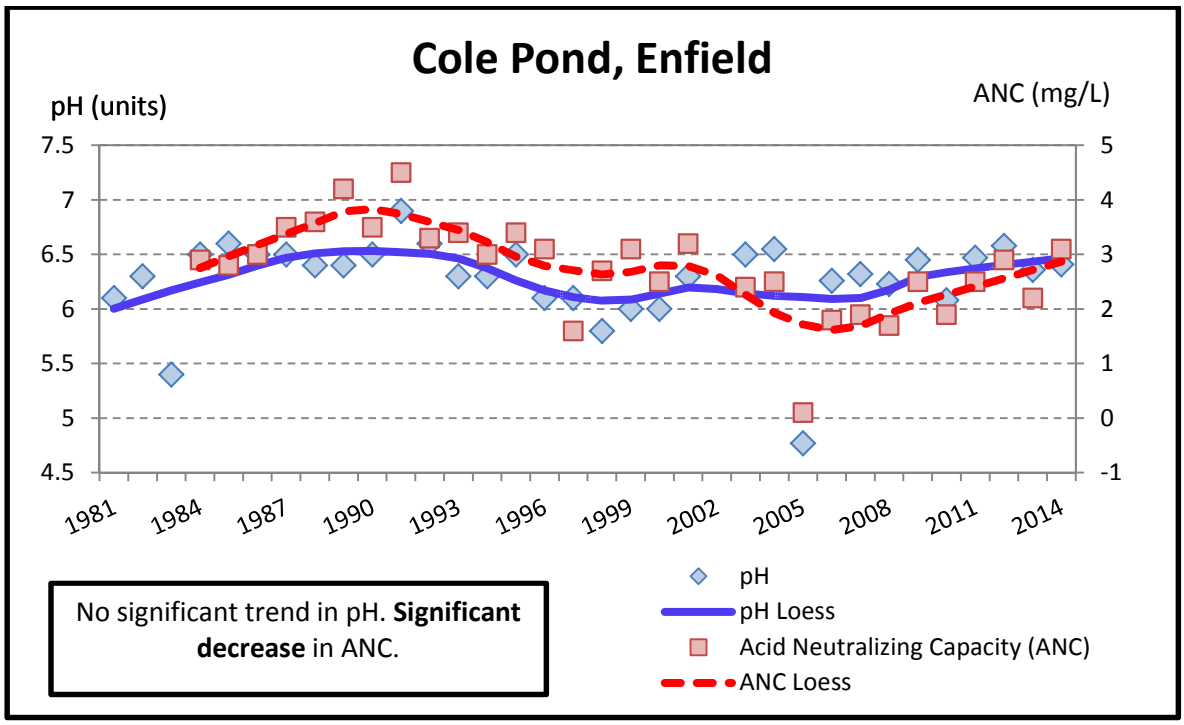

Black Pond, Lincoln
SO_4^{2-}(mg/L)
NO_3^- (mg/L)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0.12
0.1
0.08
0.06
0.04
0.02
0
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
Significant decrease in sulfate and nitrate.
Sulfate (SO_4^{2-})
Nitrate (NO3-)
NO3- Loess
SO_4^{2-} Loess
Not detectable

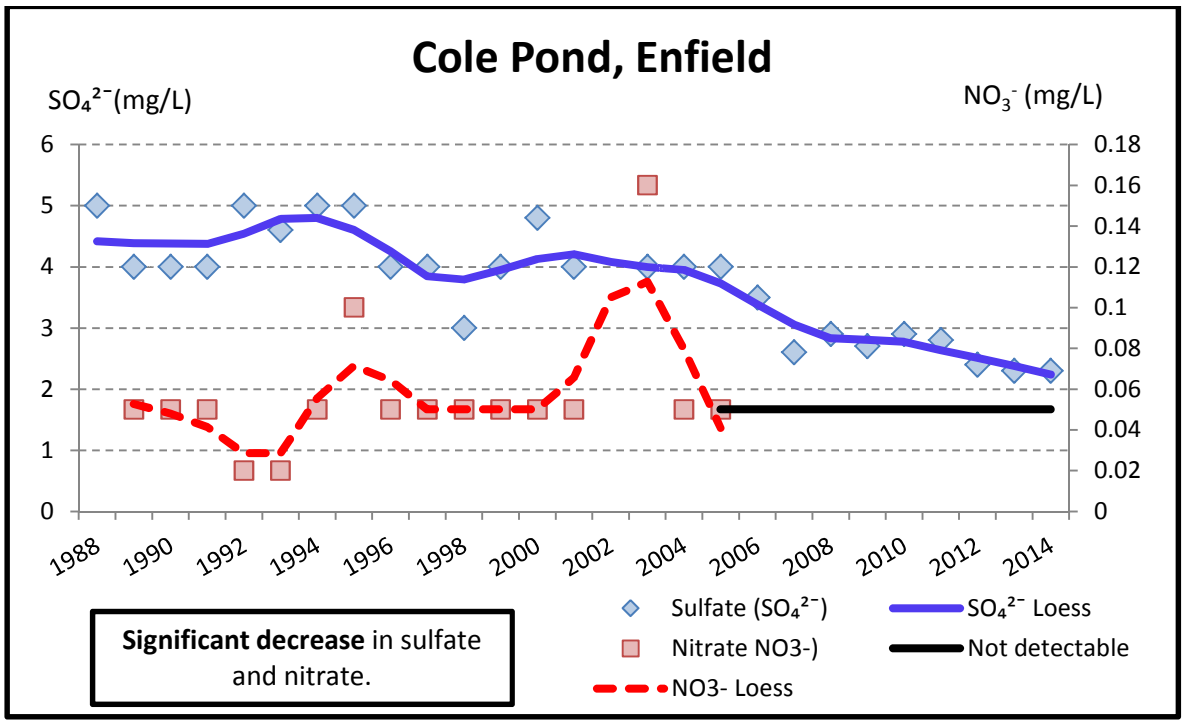

Black Pond, Lincoln
umho/cm
30
25
20
15
10
5
0
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
Significant decrease.
Specific Conductance
Loess

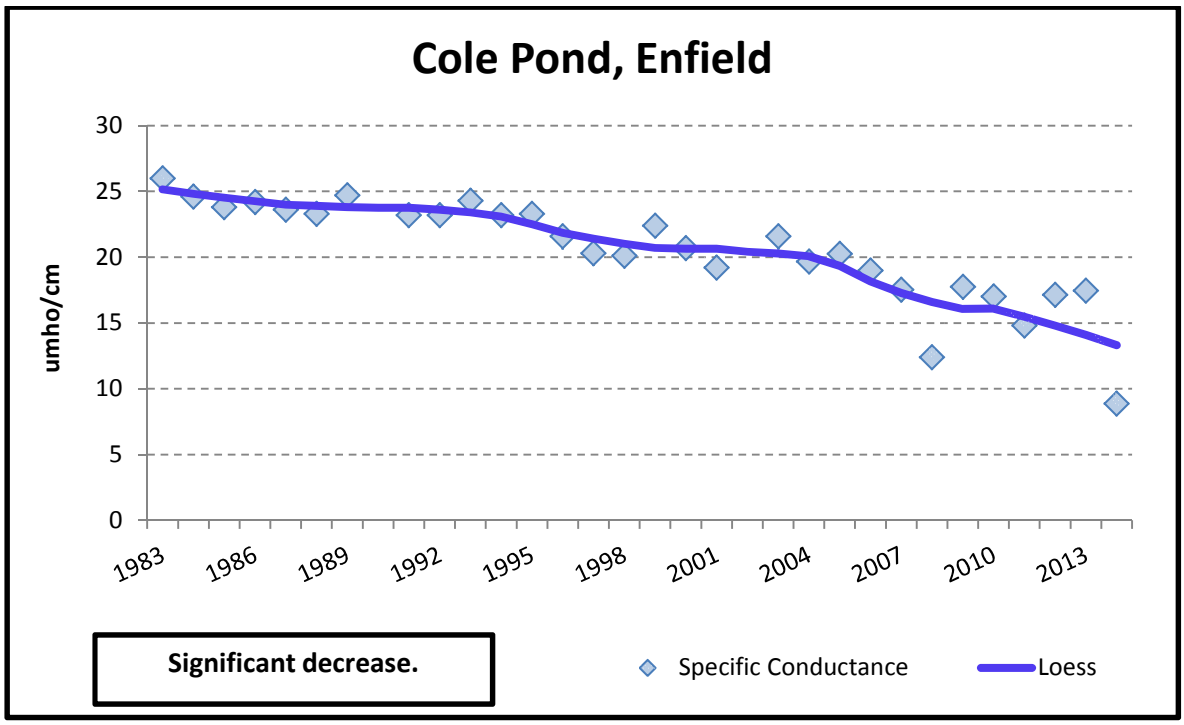

Black Mountain Pond, Sandwich
pH (units)
ANC (mg/L)
6.5
6
5.5
5
4.5
4
1.2
0.8
0.4
0
-0.4
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
pH
pH Loess
Acid Neutralizing Capacity (ANC)
ANC Loess
Significant increase in pH. No significant trend in ANC.

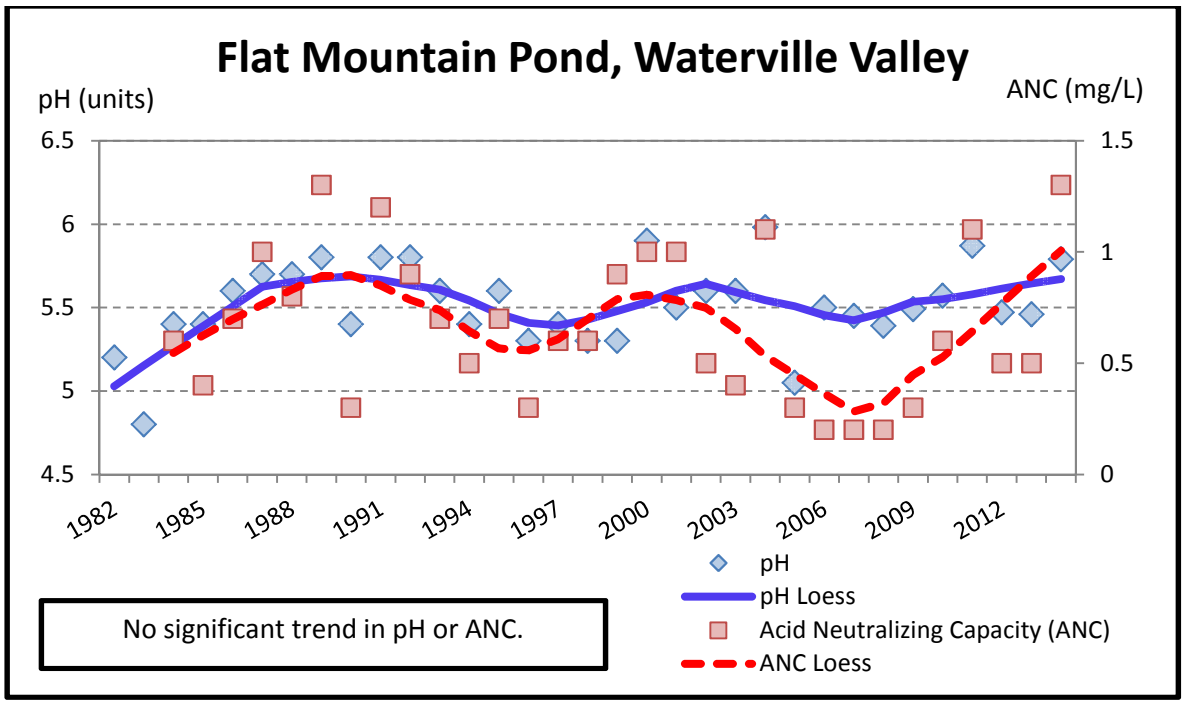

Black Mountain Pond, Sandwich
SO_4^{2-} (mg/L)
NO_3^- (mg/L)
7
6
5
4
3
2
1
0
0.12
0.1
0.08
0.06
0.04
0.02
0
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
Sulfate (SO_4^{2-})
Nitrate(NO3-)
NO3- Loess
SO_4^{2-} Loess
Not detectable
Significant decrease in sulfate and nitrate.

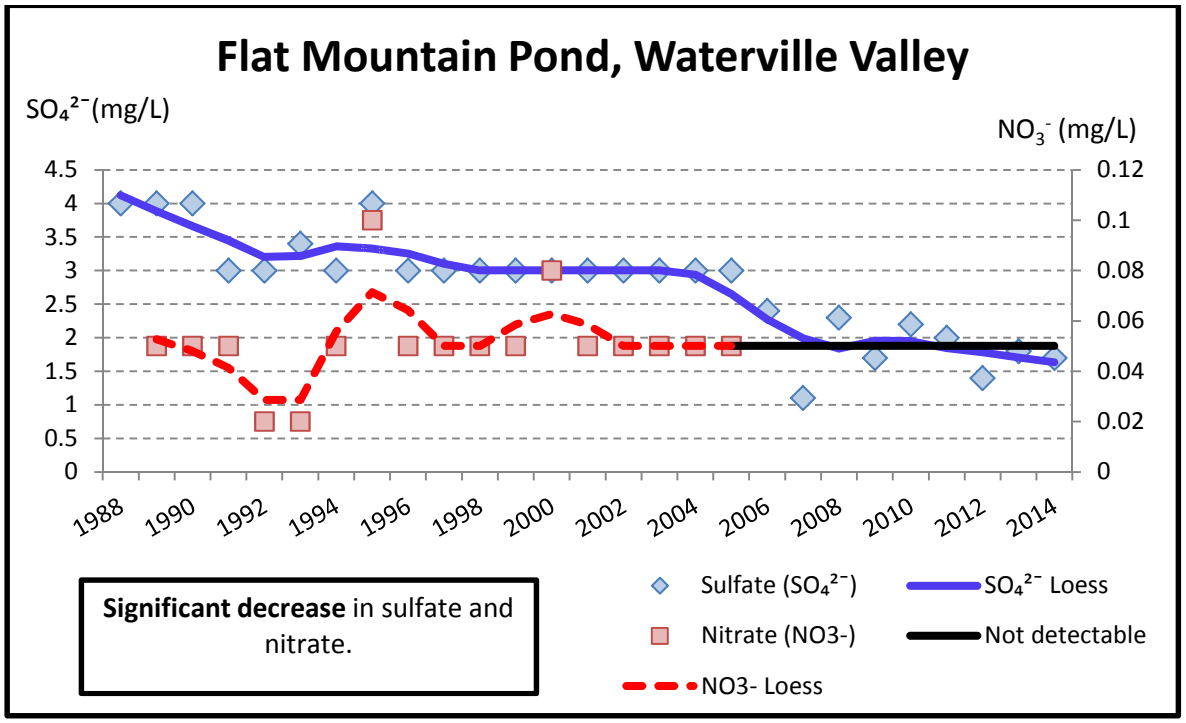

Black Mountain Pond, Sandwich
umho/cm
25
20
15
10
5
0
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
Significant decrease.
Specific Conductance
Loess

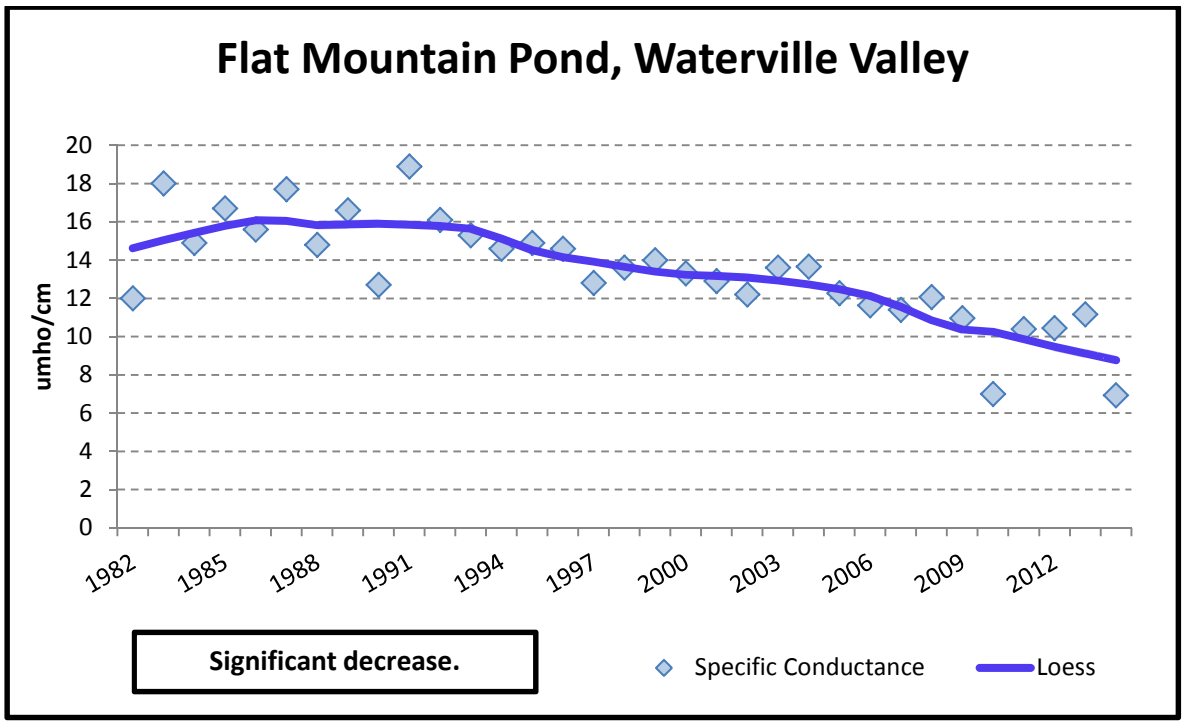

Cole Pond, Enfield
pH (units)
ANC (mg/L)
7.5
7
6.5
6
5.5
5
4.5
5
4
3
2
1
0
-1
1981
1984
1987
1990
1993
1996
1999
2002
2005
2008
2011
2014
pH
pH Loess
Acid Neutralizing Capacity (ANC)
ANC Loess
No significant trend in pH. **Significant decrease** in ANC.

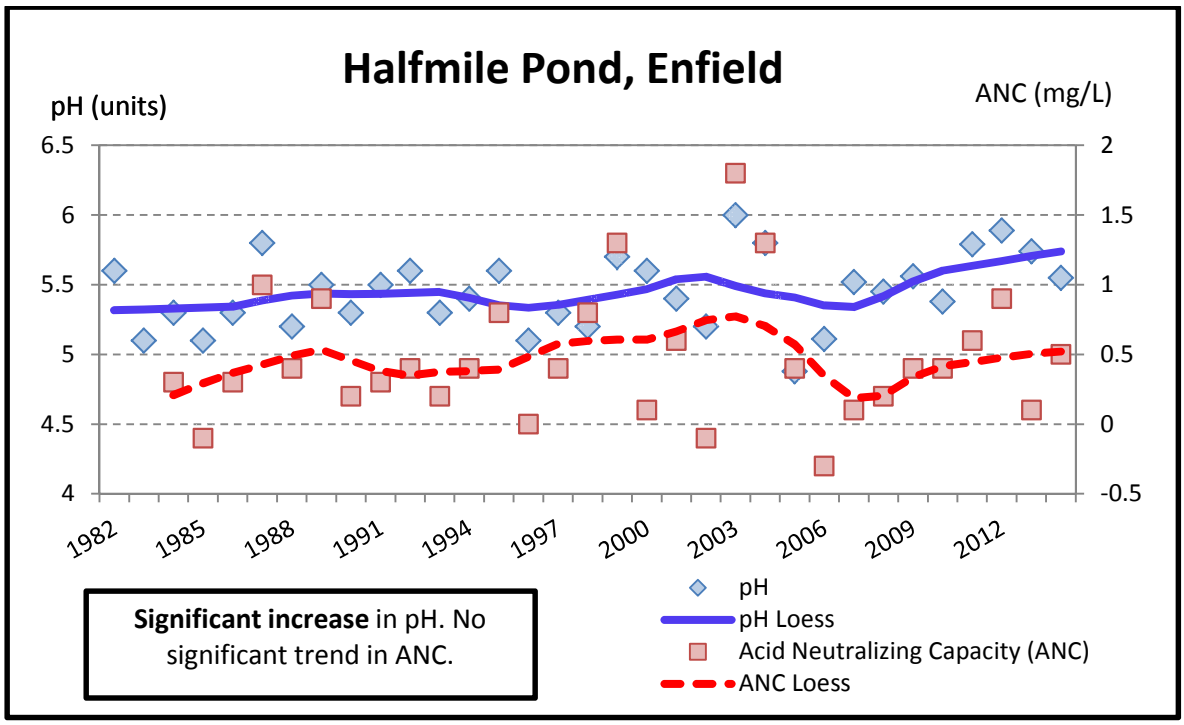

Cole Pond, Enfield
SO_4^{2-}(mg/L)
NO_3^- (mg/L)
6
5
4
3
2
1
0
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
Sulfate (SO_4^{2-})
SO_4^{2-} Loess
Nitrate NO3-)
Not detectable
NO3- Loess
Significant decrease in sulfate and nitrate.

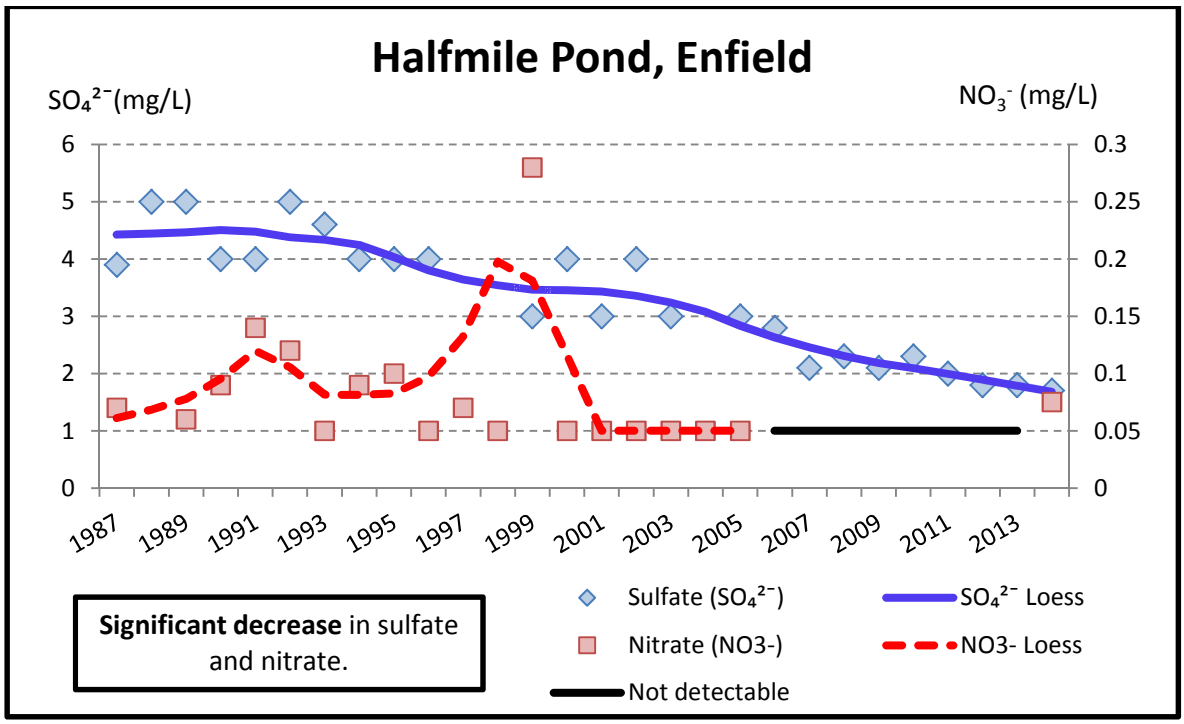

Cole Pond, Enfield
umho/cm
30
25
20
15
10
5
0
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Significant decrease.
Specific Conductance
Loess

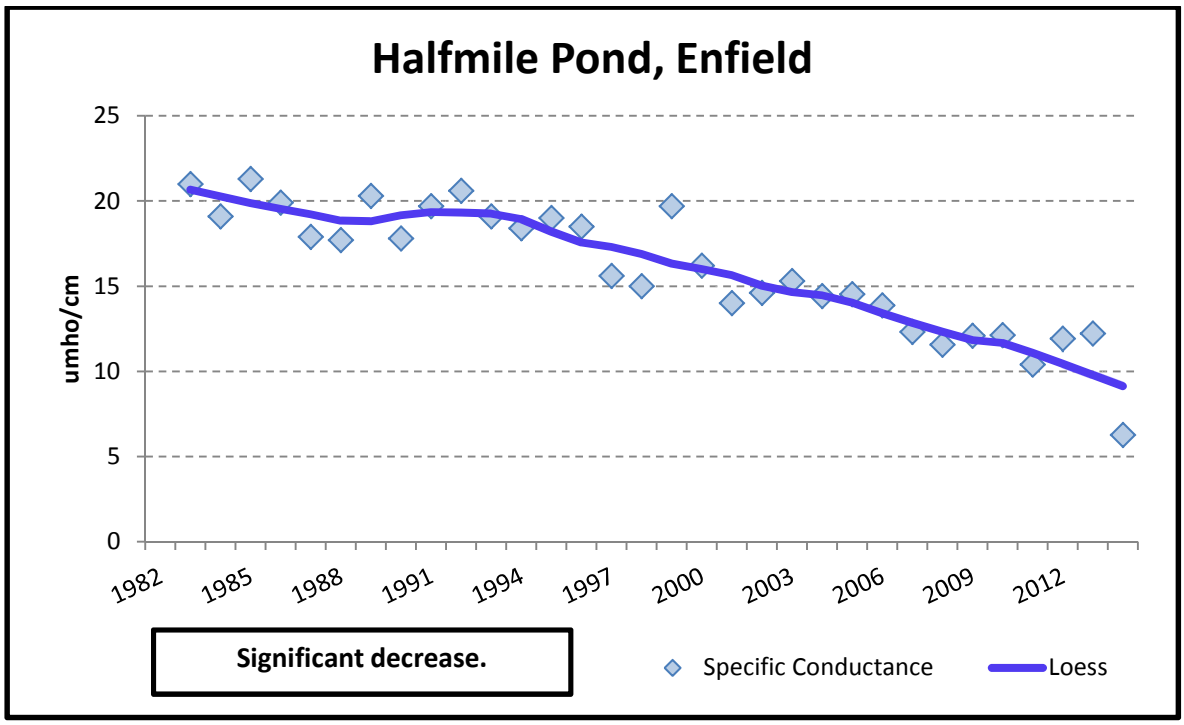

Flat Mountain Pond, Waterville Valley
pH (units)
ANC (mg/L)
6.5
6
5.5
5
4.5
1.5
1
0.5
0
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
pH
pH Loess
Acid Neutralizing Capacity (ANC)
ANC Loess
No significant trend in pH or ANC.

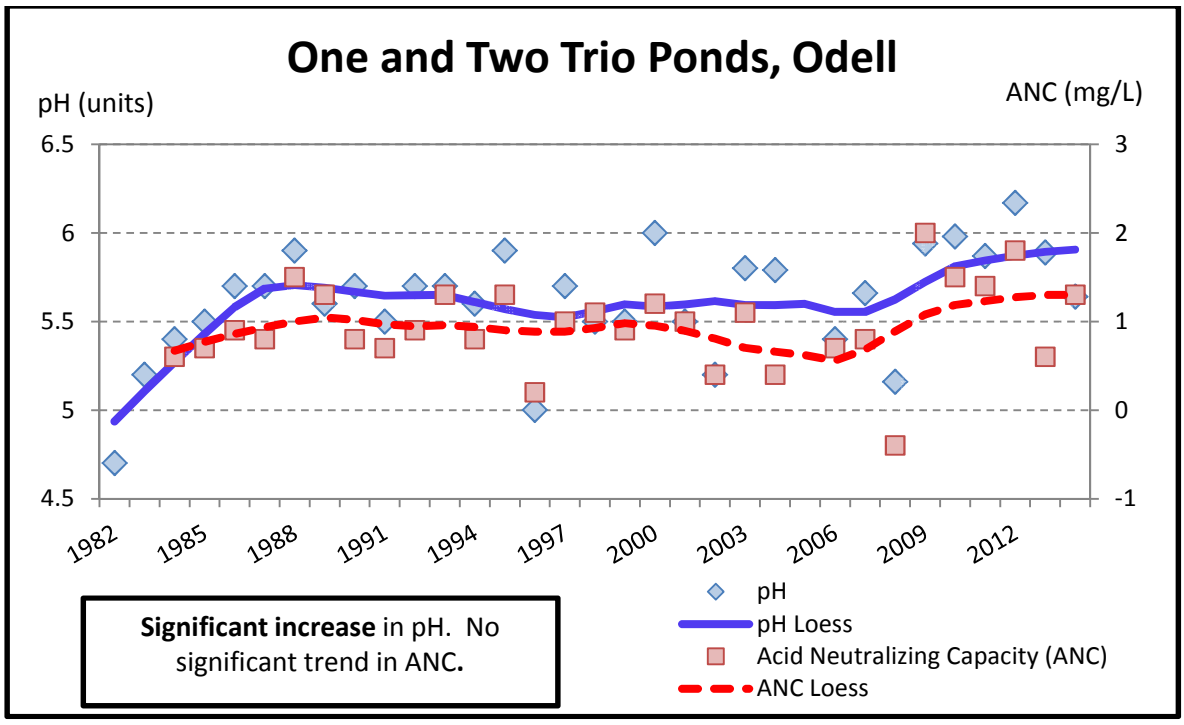

Flat Mountain Pond, Waterville Valley
SO_4^{2-}(mg/L)
NO_3^- (mg/L)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0.12
0.1
0.08
0.06
0.04
0.02
0
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
Sulfate (SO_4^{2-})
SO_4^{2-} Loess
Nitrate (NO3-)
Not detectable
NO3- Loess
Significant decrease in sulfate and nitrate.

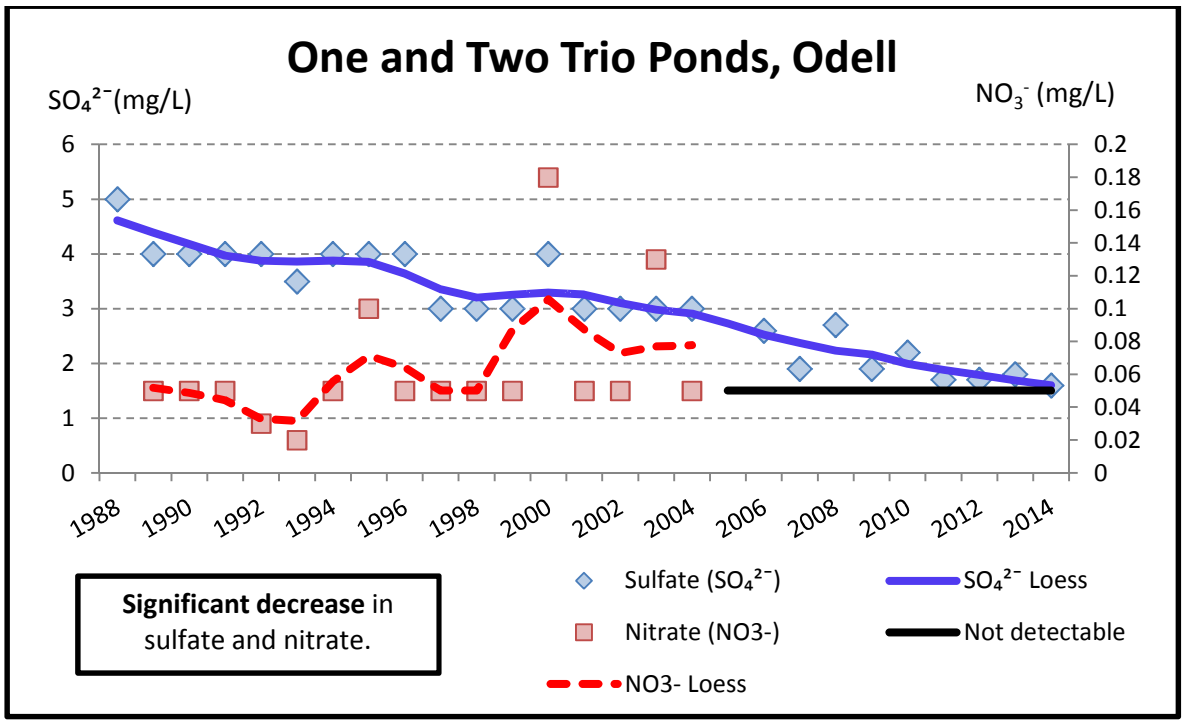

Flat Mountain Pond, Waterville Valley
umho/cm
20
18
16
14
12
10
8
6
4
2
0
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
Significant decrease.
Specific Conductance
Loess

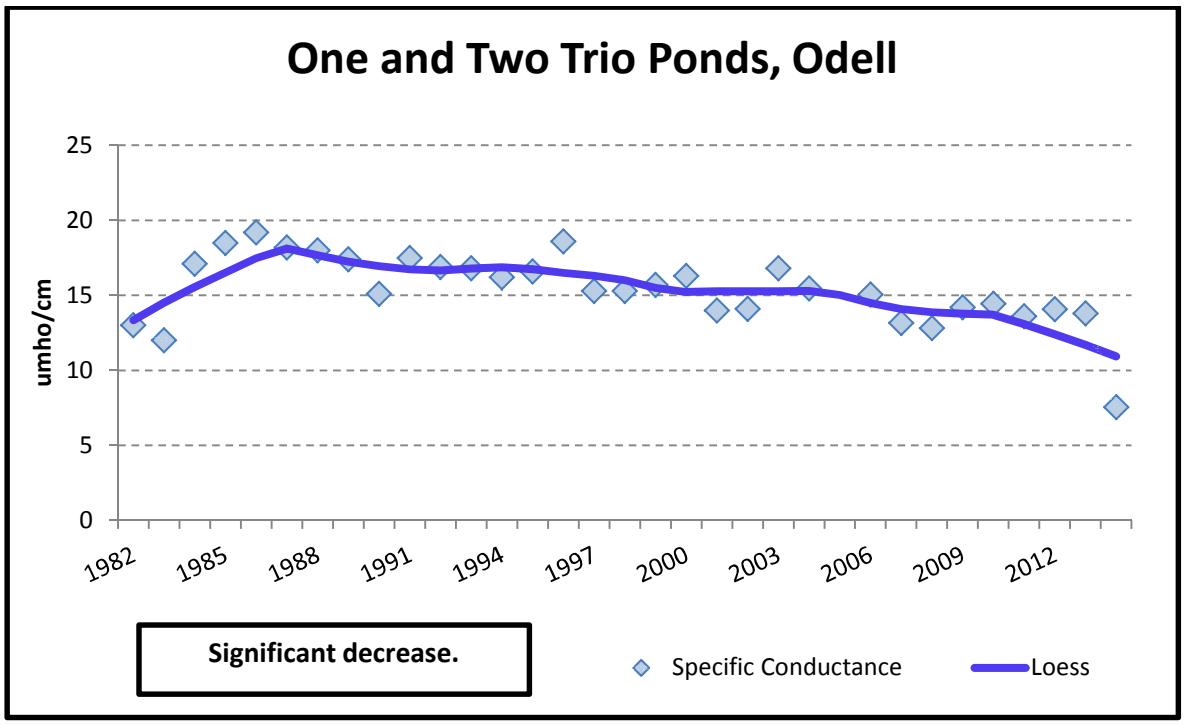

Halfmile Pond, Enfield
pH (units)
ANC (mg/L)
6.5
6
5.5
5
4.5
4
2
1.5
1
0.5
0
-0.5
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
pH
pH Loess
Acid Neutralizing Capacity (ANC)
ANC Loess
Significant increase in pH. No significant trend in ANC.

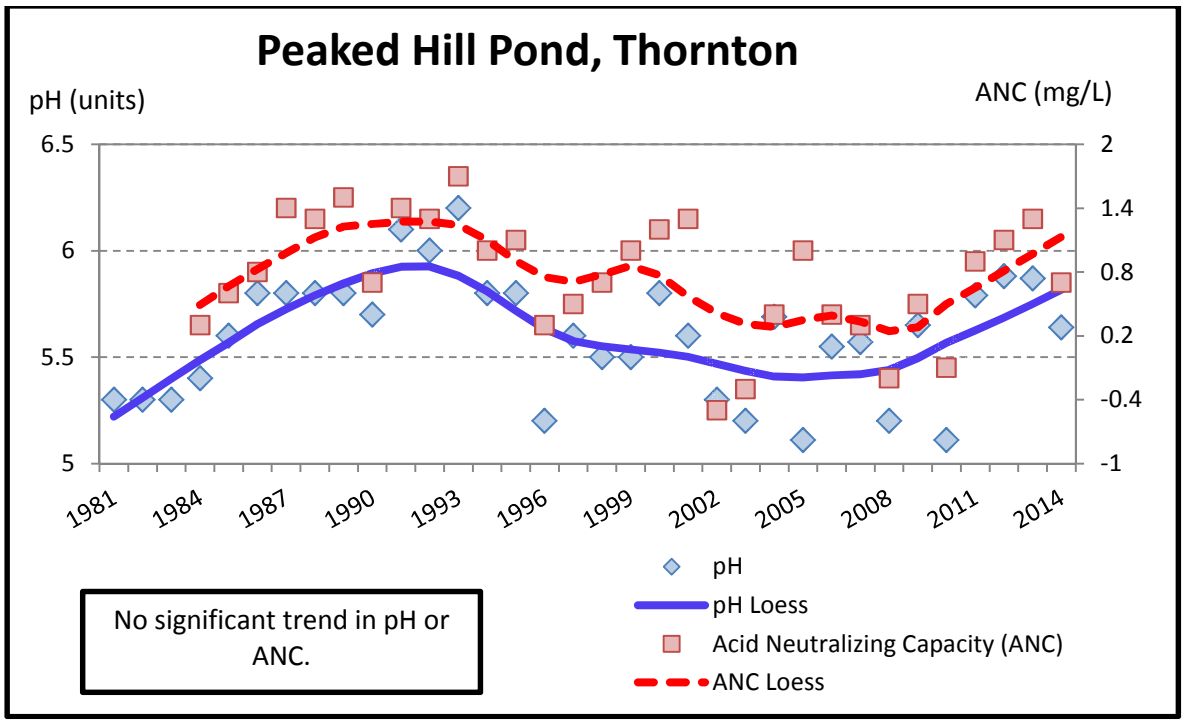

Halfmile Pond, Enfield
SO_4^{2-}(mg/L)
NO_3^- (mg/L)
6
5
4
3
2
1
0
0.3
0.25
0.2
0.15
0.1
0.05
0
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
Sulfate (SO_4^{2-})
SO_4^{2-} Loess
Nitrate (NO3-)
NO3- Loess
Not detectable
Significant decrease in sulfate and nitrate.

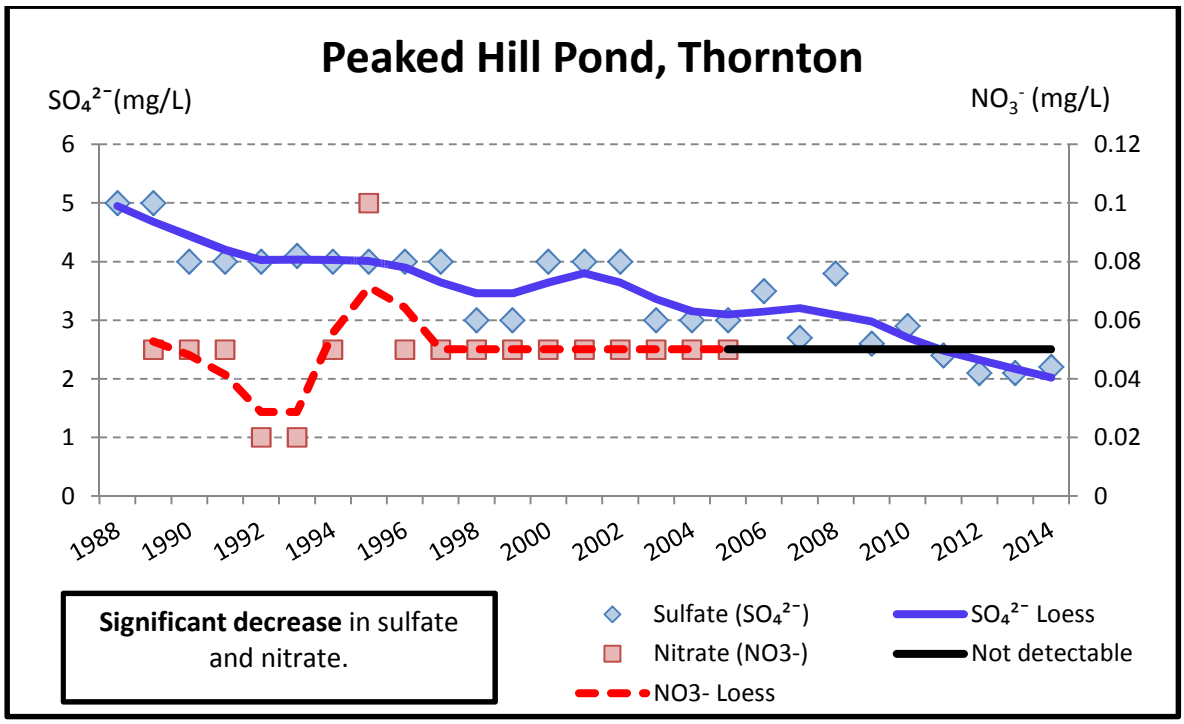

Halfmile Pond, Enfield
umho/cm
25
20
15
10
5
0
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
Significant decrease.
Specific Conductance
Loess

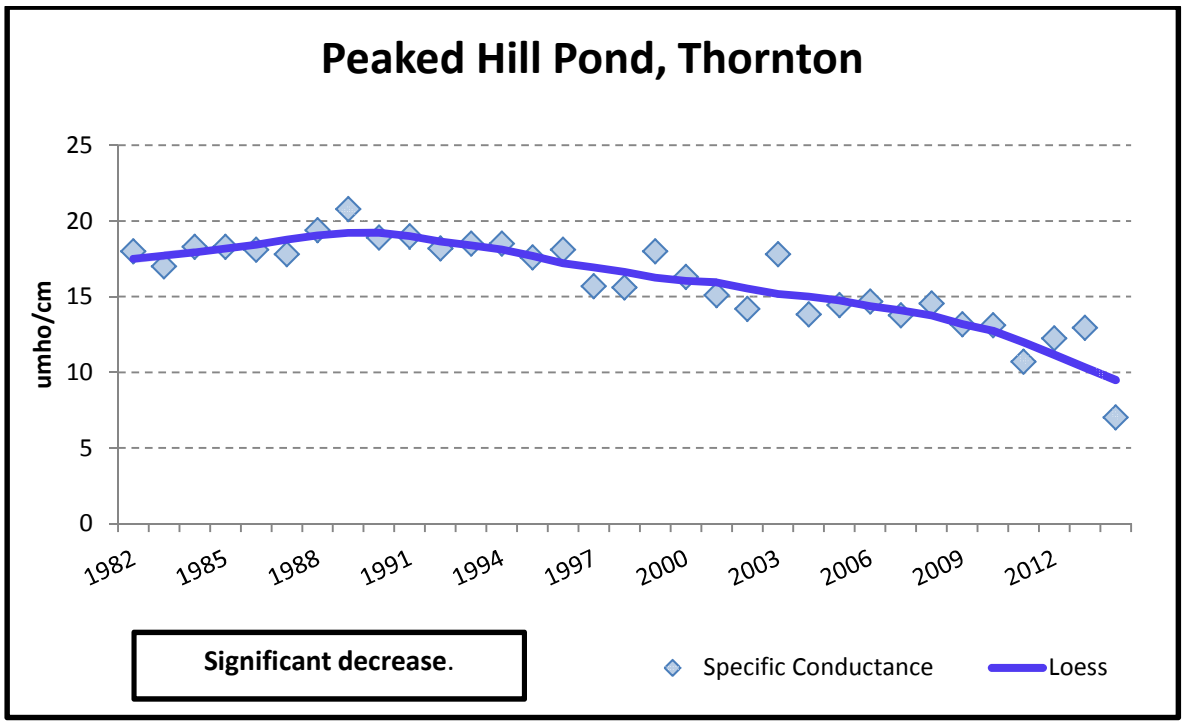

One and Two Trio Ponds, Odell
pH (units)
ANC (mg/L)
6.5
6
5.5
5
4.5
3
2
1
0
-1
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
Significant increase in pH. No significant trend in ANC.
pH
pH Loess
Acid Neutralizing Capacity (ANC)
ANC Loess

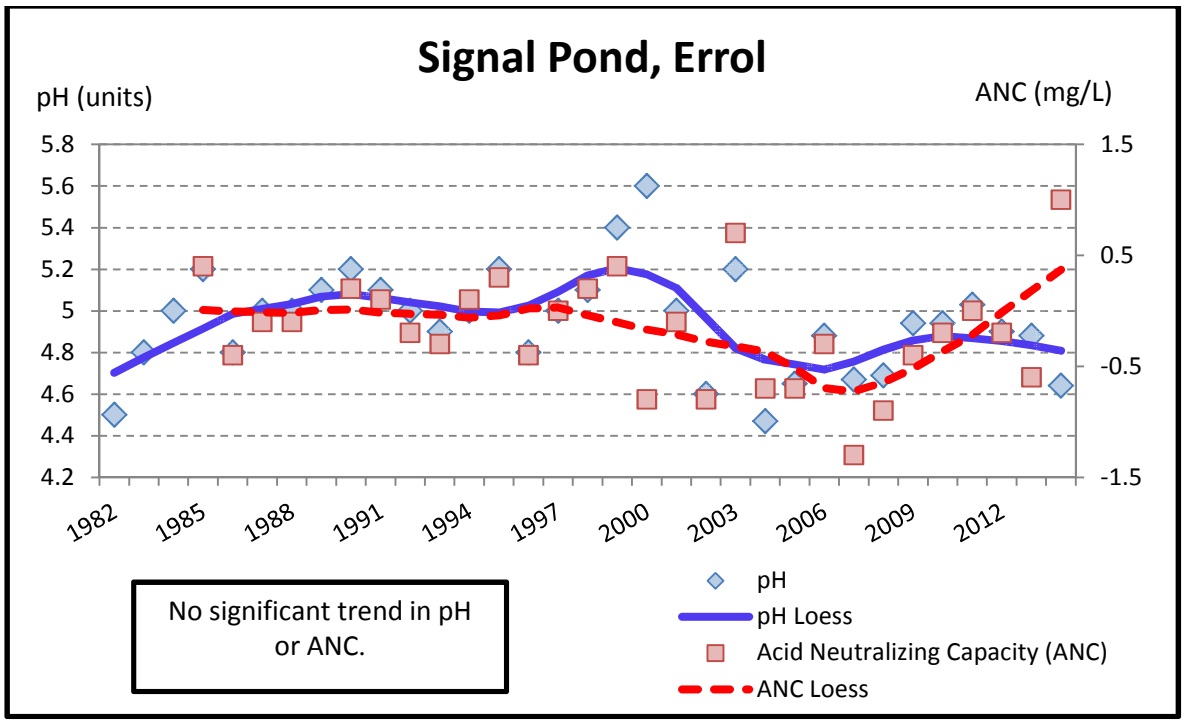

One and Two Trio Ponds, Odell
SO_4^{2-}(mg/L)
NO_3^- (mg/L)
6
5
4
3
2
1
0
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
Significant decrease in sulfate and nitrate.
Sulfate (SO_4^{2-})
SO_4^{2-} Loess
Nitrate (NO3-)
Not detectable
NO3- Loess

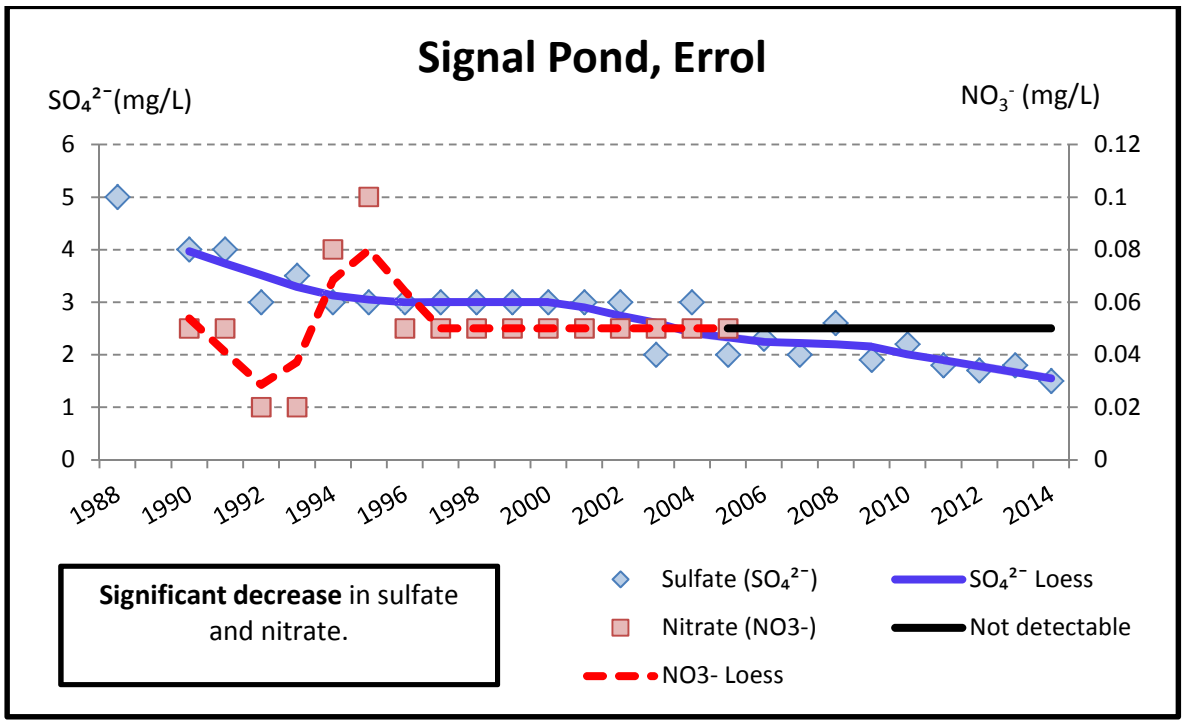

One and Two Trio Ponds, Odell
umho/cm
25
20
15
10
5
0
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
Significant decrease.
Specific Conductance
Loess

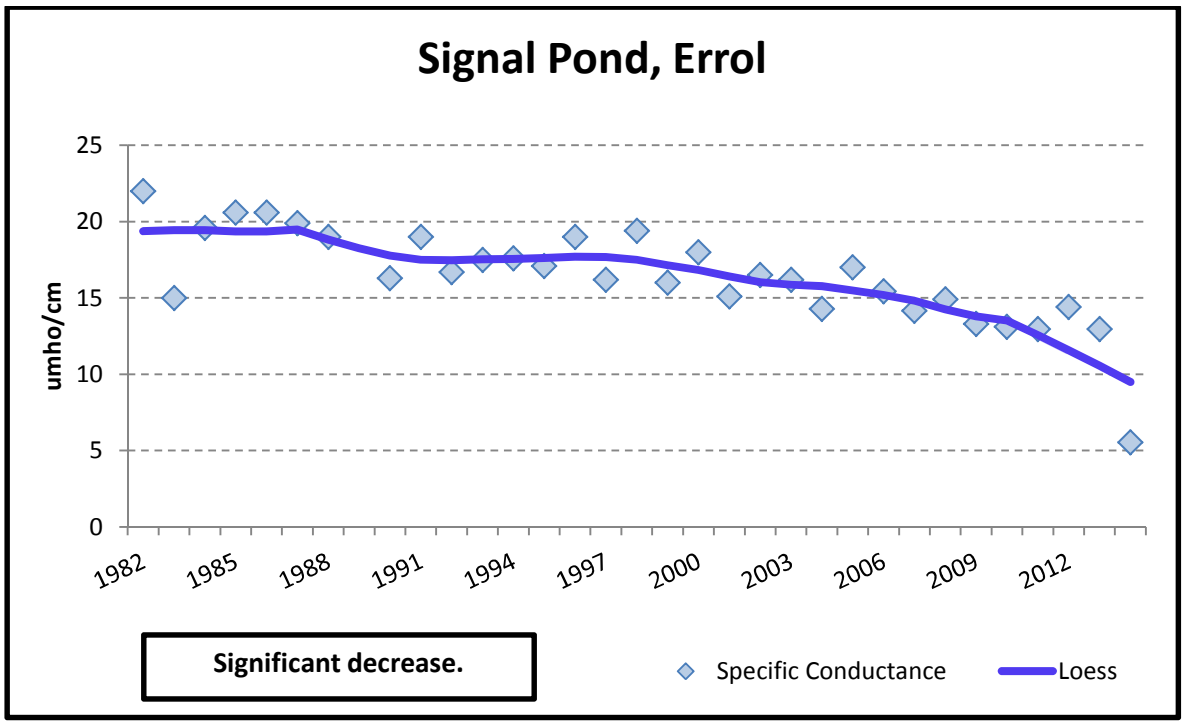

Peaked Hill Pond, Thornton
pH (units)
ANC (mg/L)
6.5
6
5.5
5
2
1.4
0.8
0.2
-0.4
-1
1981
1984
1987
1990
1993
1996
1999
2002
2005
2008
2011
2014
pH
pH Loess
Acid Neutralizing Capacity (ANC)
ANC Loess
No significant trend in pH or ANC.

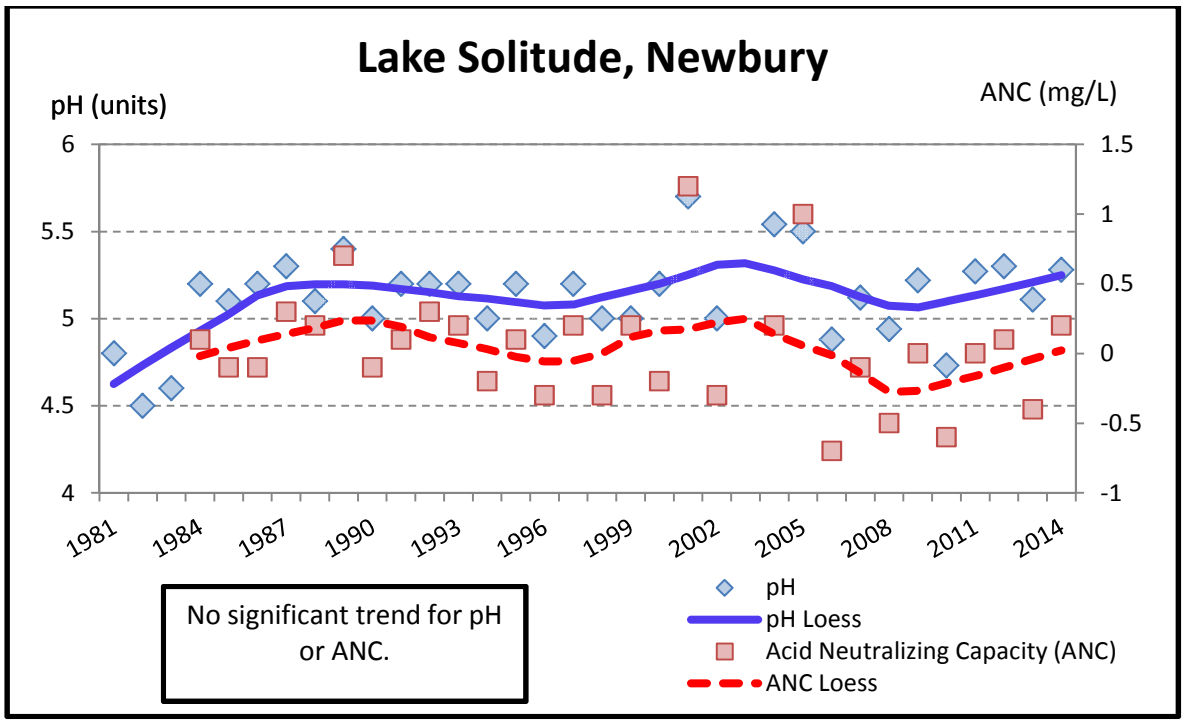

Peaked Hill Pond, Thornton
SO_4^{2-}(mg/L)
NO_3^- (mg/L)
6
5
4
3
2
1
0
0.12
0.1
0.08
0.06
0.04
0.02
0
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
Sulfate (SO_4^{2-})
Nitrate (NO3-)
NO3- Loess
SO_4^{2-} Loess
Not detectable
Significant decrease in sulfate and nitrate.

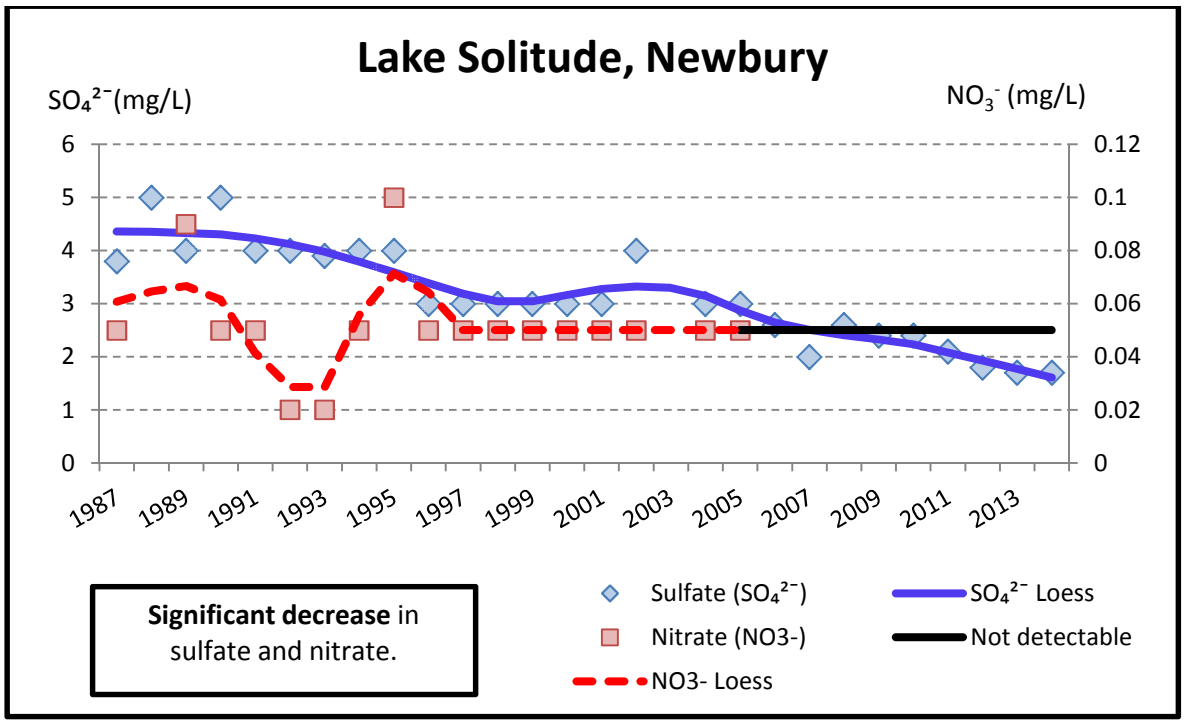

Peaked Hill Pond, Thornton
umho/cm
25
20
15
10
5
0
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
Significant decrease.
Specific Conductance
Loess

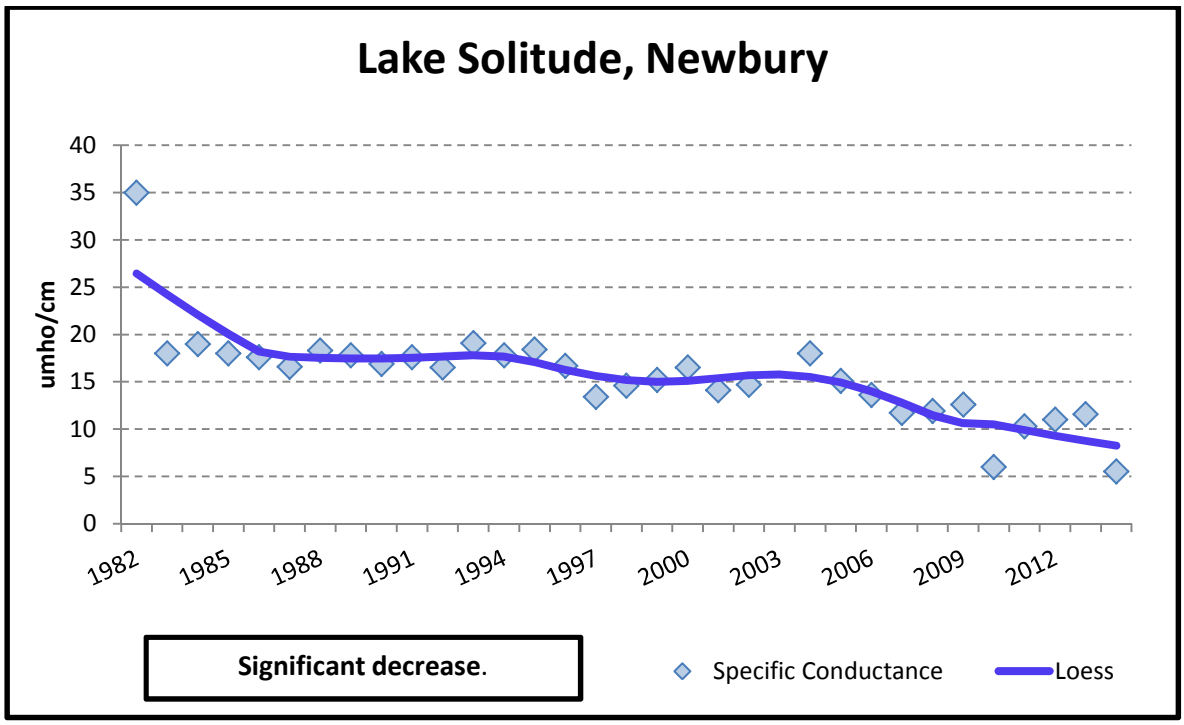

Signal Pond, Errol
pH (units)
ANC (mg/L)
5.8
5.6
5.4
5.2
5
4.8
4.6
4.4
4.2
1.5
0.5
-0.5
-1.5
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
No significant trend in pH or ANC.
pH
pH Loess
Acid Neutralizing Capacity (ANC)
ANC Loess

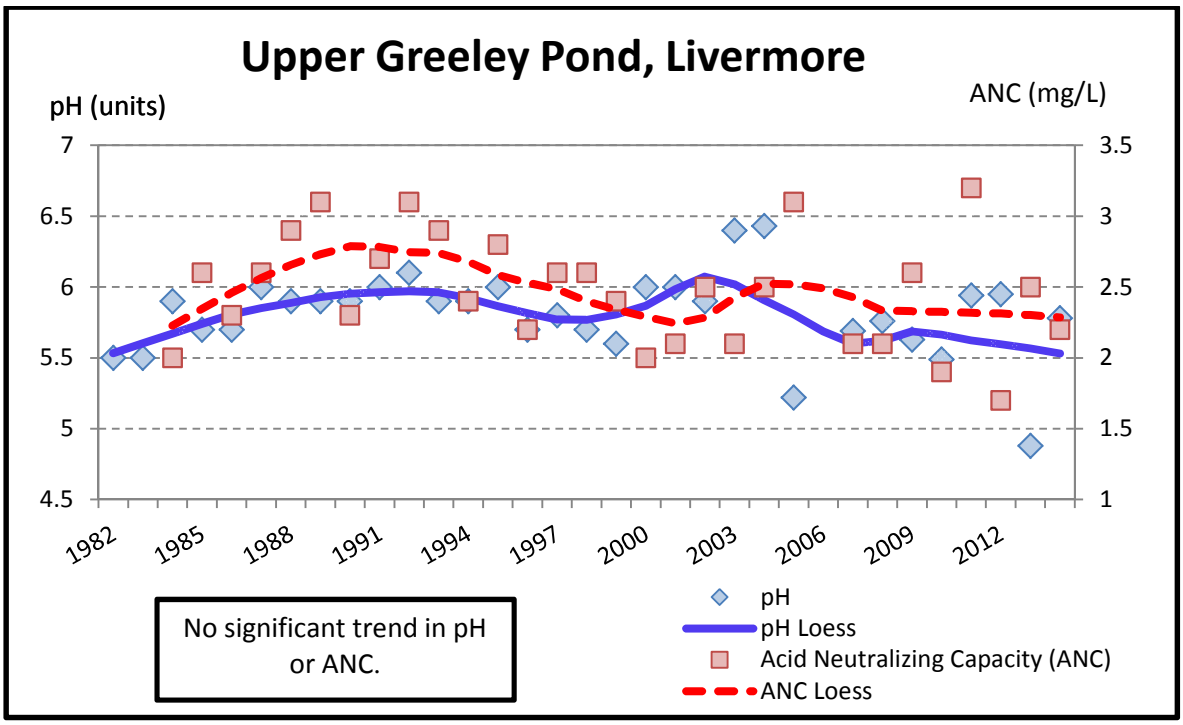

Signal Pond, Errol
SO_4^{2-}(mg/L)
NO_3^- (mg/L)
6
5
4
3
2
1
0
0.12
0.1
0.08
0.06
0.04
0.02
0
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
Significant decrease in sulfate and nitrate.
Sulfate (SO_4^{2-})
SO_4^{2-} Loess
Nitrate (NO3-)
Not detectable
NO3- Loess

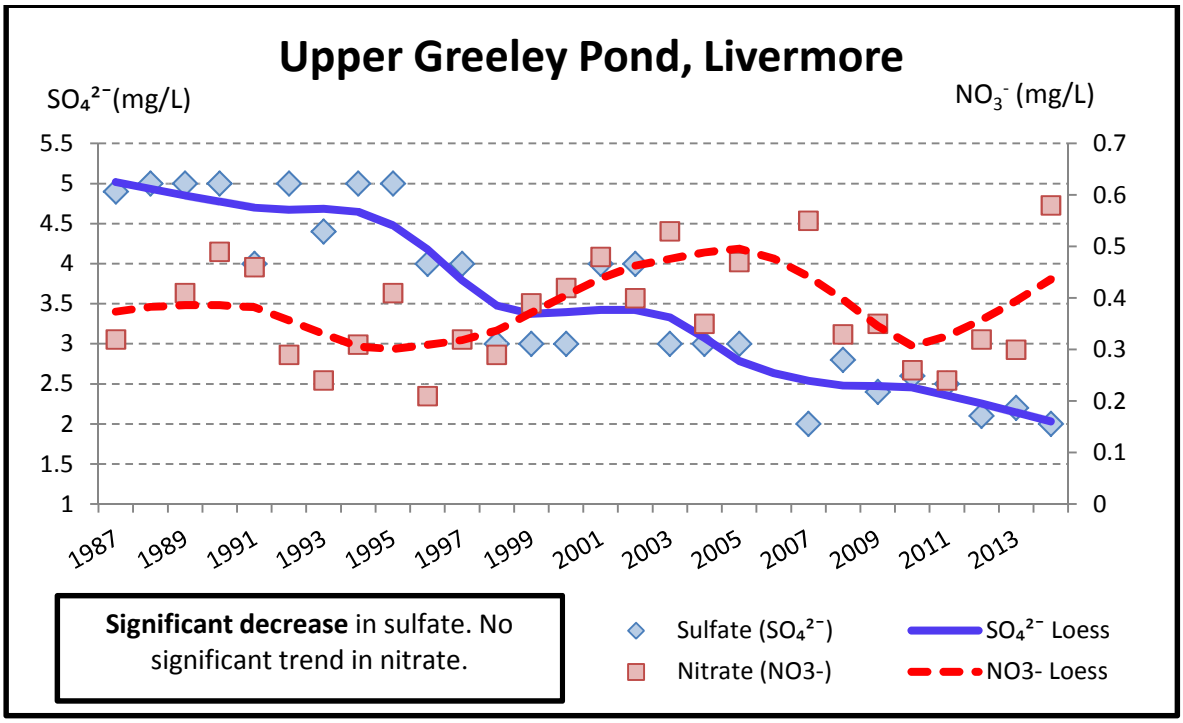

Signal Pond, Errol
umho/cm
25
20
15
10
5
0
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
Significant decrease.
Specific Conductance
Loess

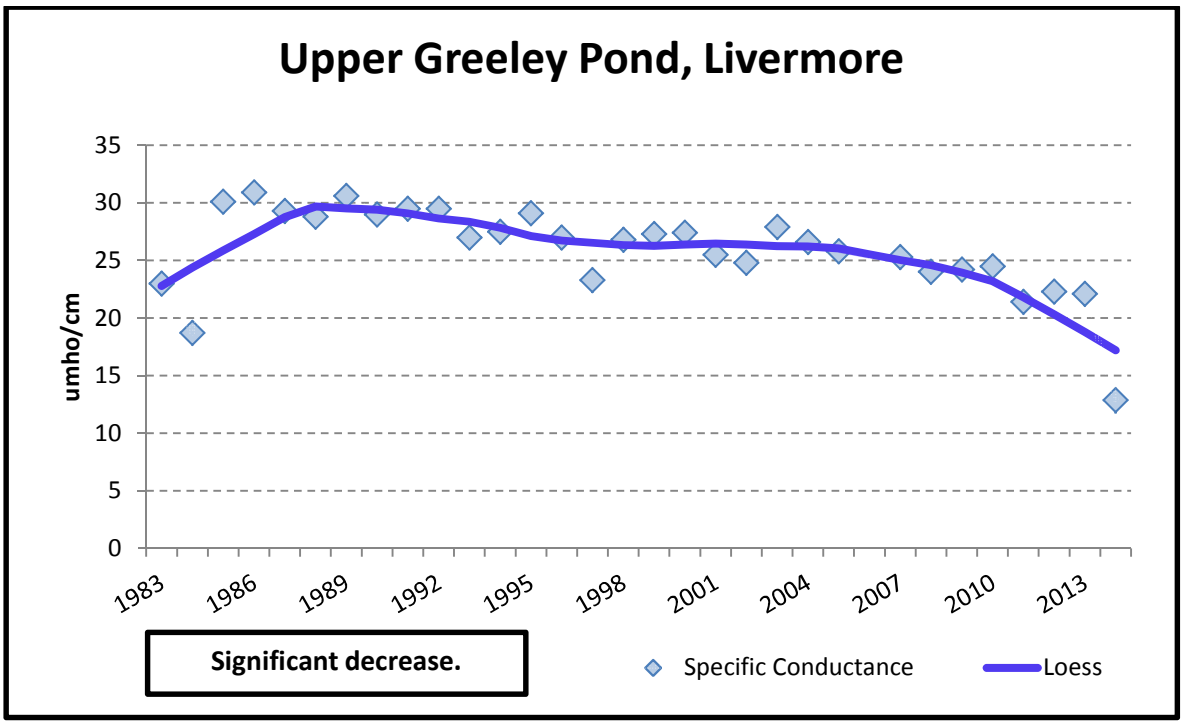

Lake Solitude, Newbury
pH (units)
ANC (mg/L)
6
5.5
5
4.5
4
1.5
1
0.5
0
-0.5
-1
1981
1984
1987
1990
1993
1996
1999
2002
2005
2008
2011
2014
No significant trend for pH or ANC.
pH
pH Loess
Acid Neutralizing Capacity (ANC)
ANC Loess


Lake Solitude, Newbury
SO_4^{2-}(mg/L)
NO_3^- (mg/L)
6
5
4
3
2
1
0
0.12
0.1
0.08
0.06
0.04
0.02
0
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
Significant decrease in sulfate and nitrate.
Sulfate (SO_4^{2-})
Nitrate (NO3-)
NO3- Loess
SO_4^{2-} Loess
Not detectable


Lake Solitude, Newbury
umho/cm
40
35
30
25
20
15
10
5
0
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
Significant decrease.
Specific Conductance
Loess

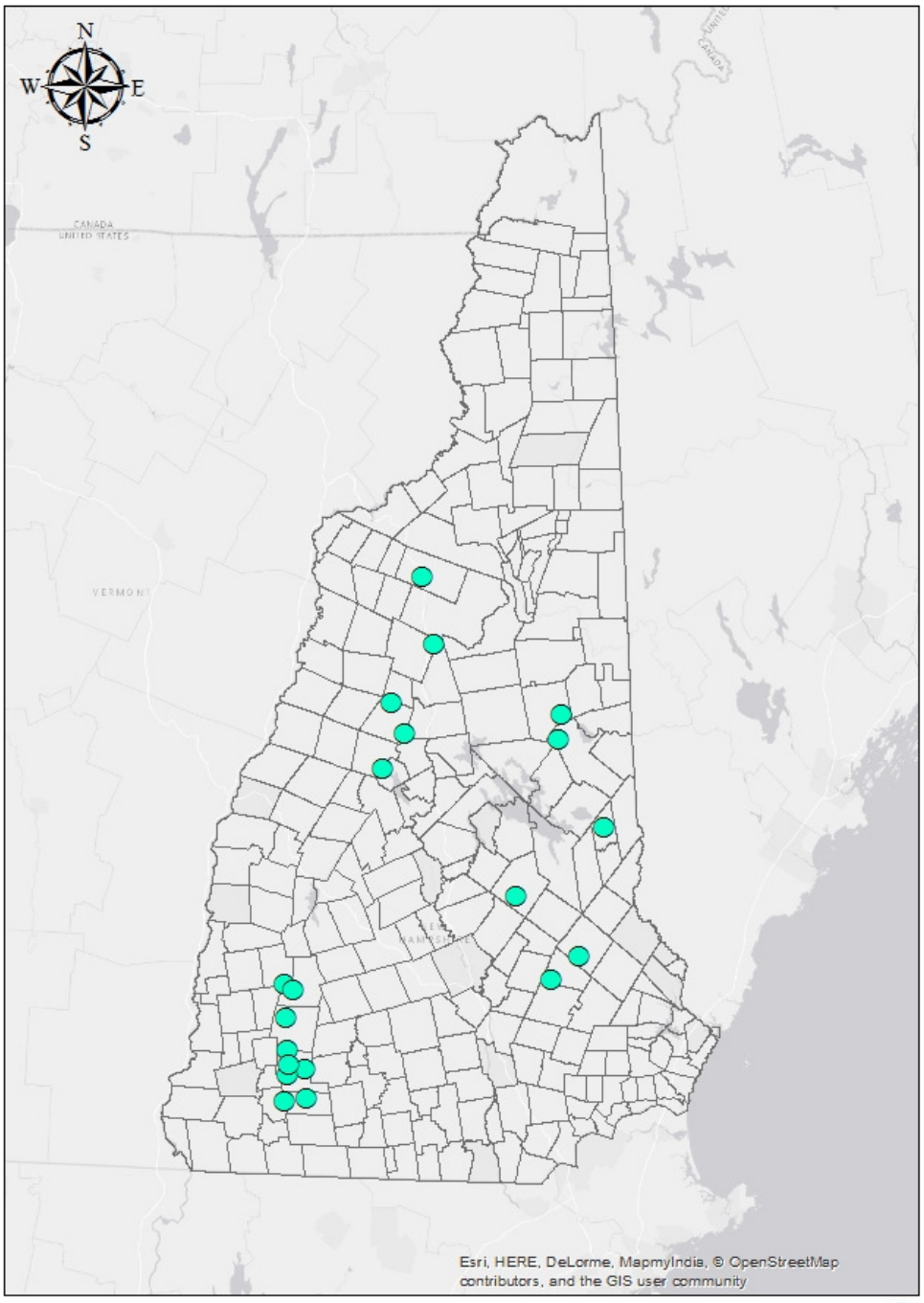

Upper Greeley Pond, Livermore
pH (units)
ANC (mg/L)
7
6.5
6
5.5
5
4.5
3.5
3
2.5
2
1.5
1
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
No significant trend in pH or ANC.
pH
pH Loess
Acid Neutralizing Capacity (ANC)
ANC Loess


Upper Greeley Pond, Livermore
SO_4^{2-}(mg/L)
NO_3^- (mg/L)
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
Significant decrease in sulfate. No significant trend in nitrate.
Sulfate (SO_4^{2-})
Nitrate (NO3-)
SO_4^{2-} Loess
NO3- Loess


Upper Greeley Pond, Livermore
umho/cm
35
30
25
20
15
10
5
0
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Significant decrease.
Specific Conductance
Loess

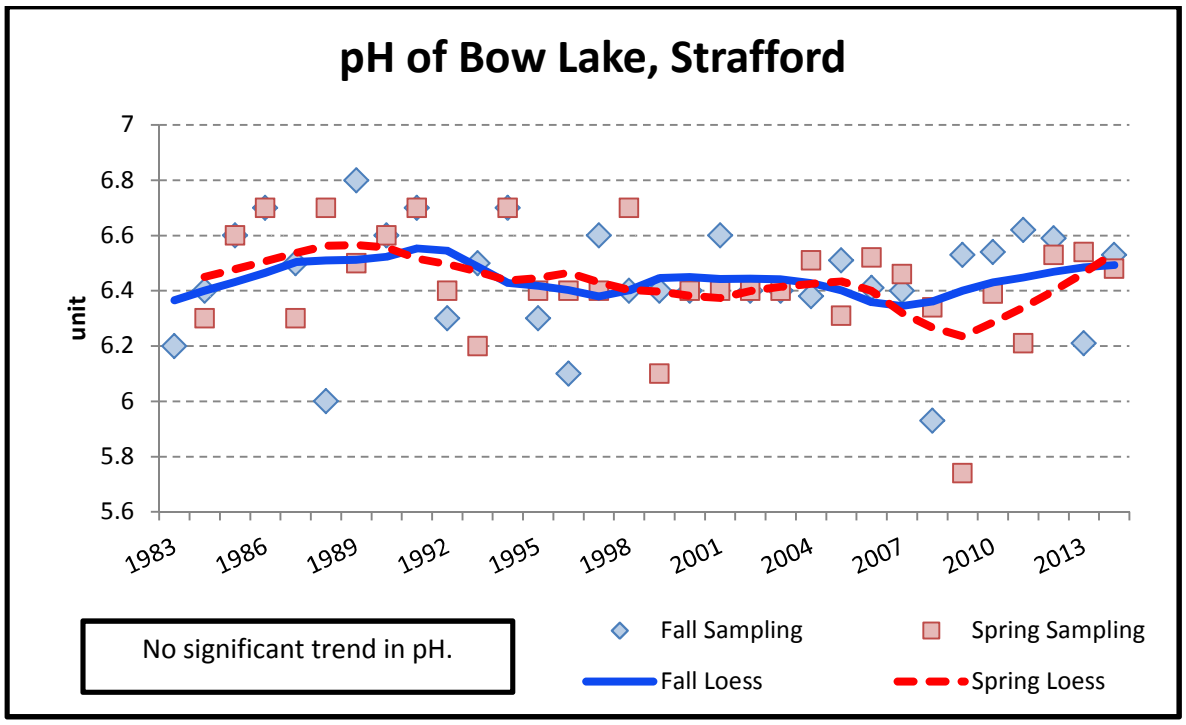
Appendix D
Acid Outlet

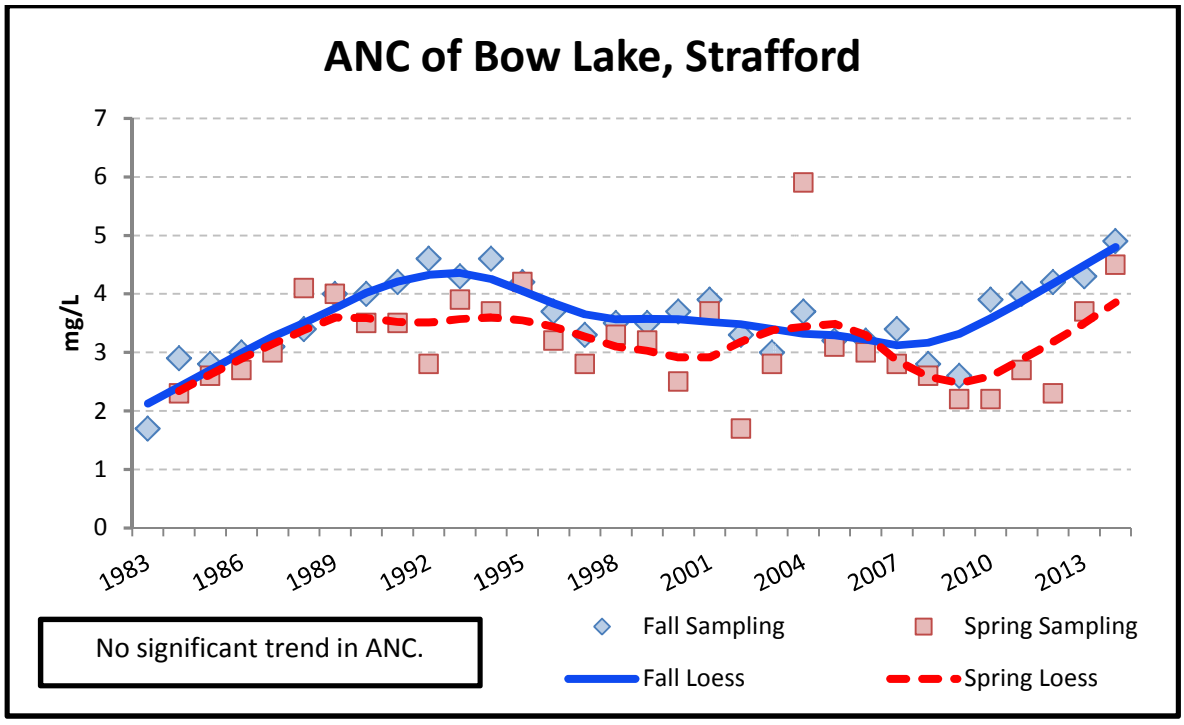
Acid Outlet Pond Locations

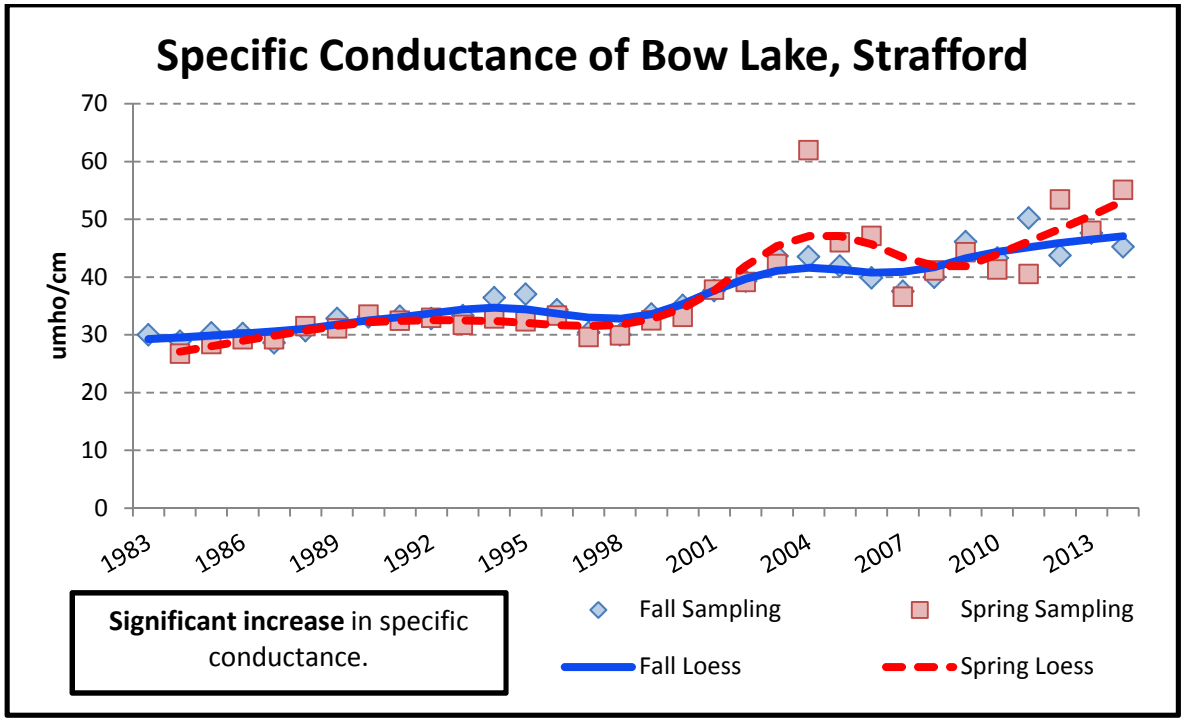


0 12.5 25 50 Miles

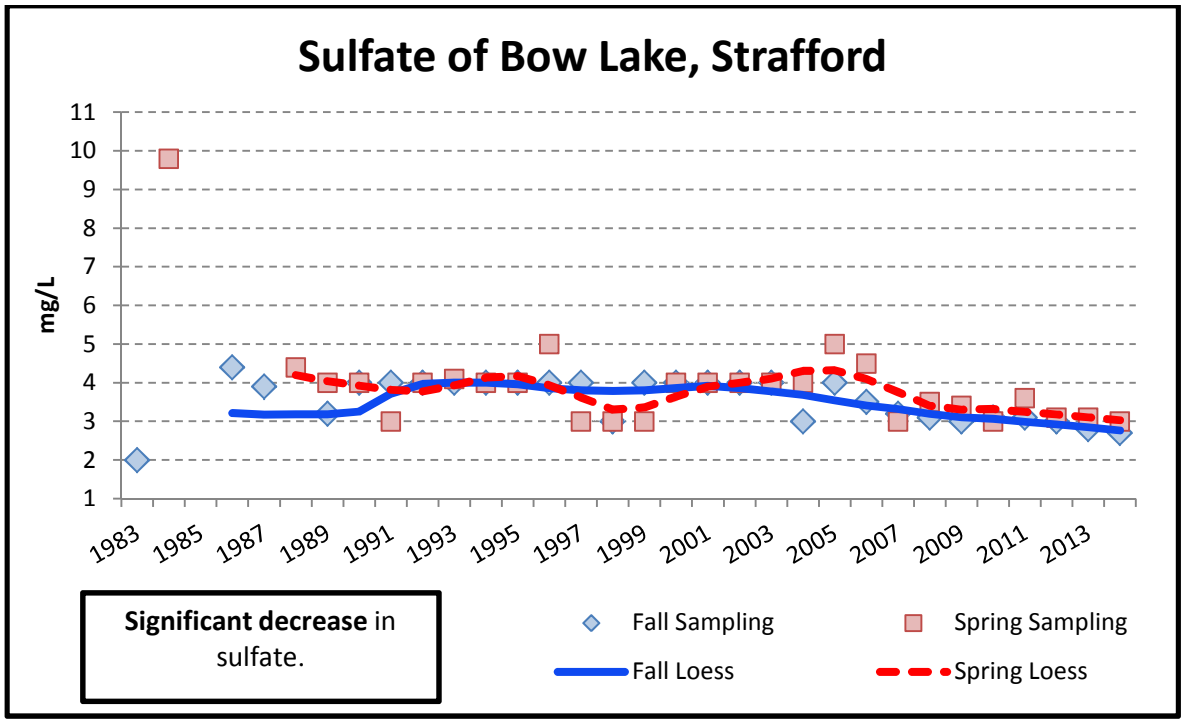
NH Department of Environmental Services


pH of Bow Lake, Strafford
unit
7
6.8
6.6
6.4
6.2
6
5.8
5.6
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
No significant trend in pH.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

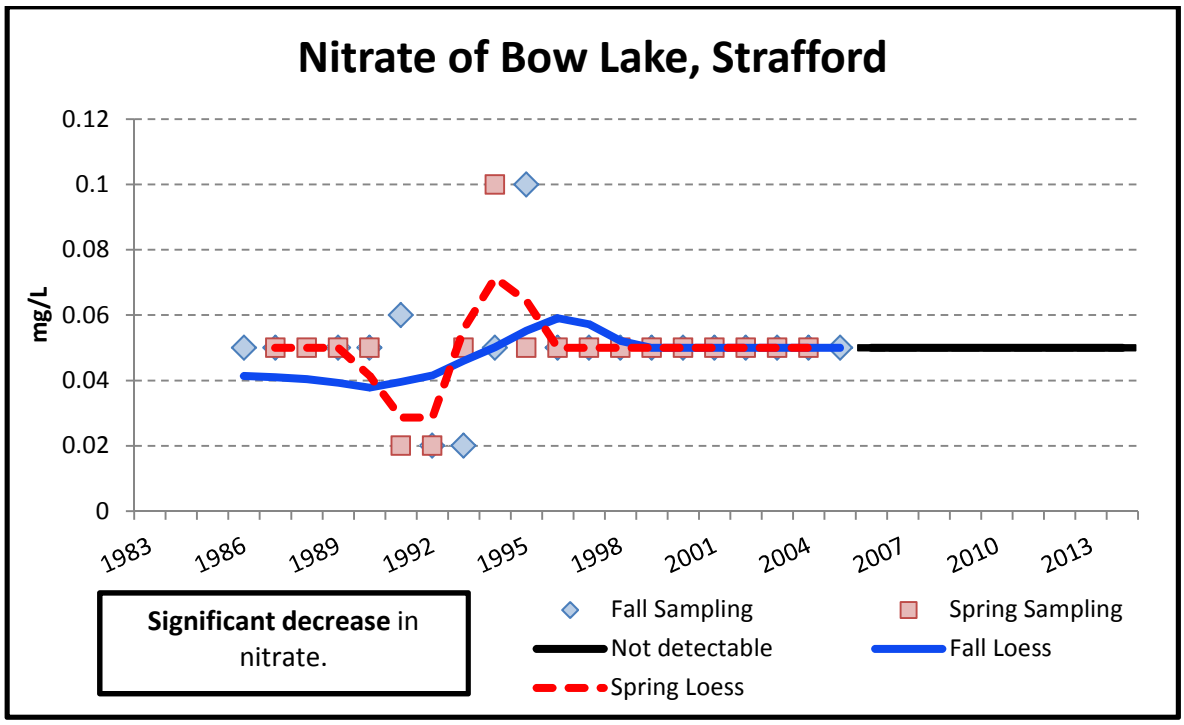

ANC of Bow Lake, Strafford
mg/L
7
6
5
4
3
2
1
0
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
No significant trend in ANC.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

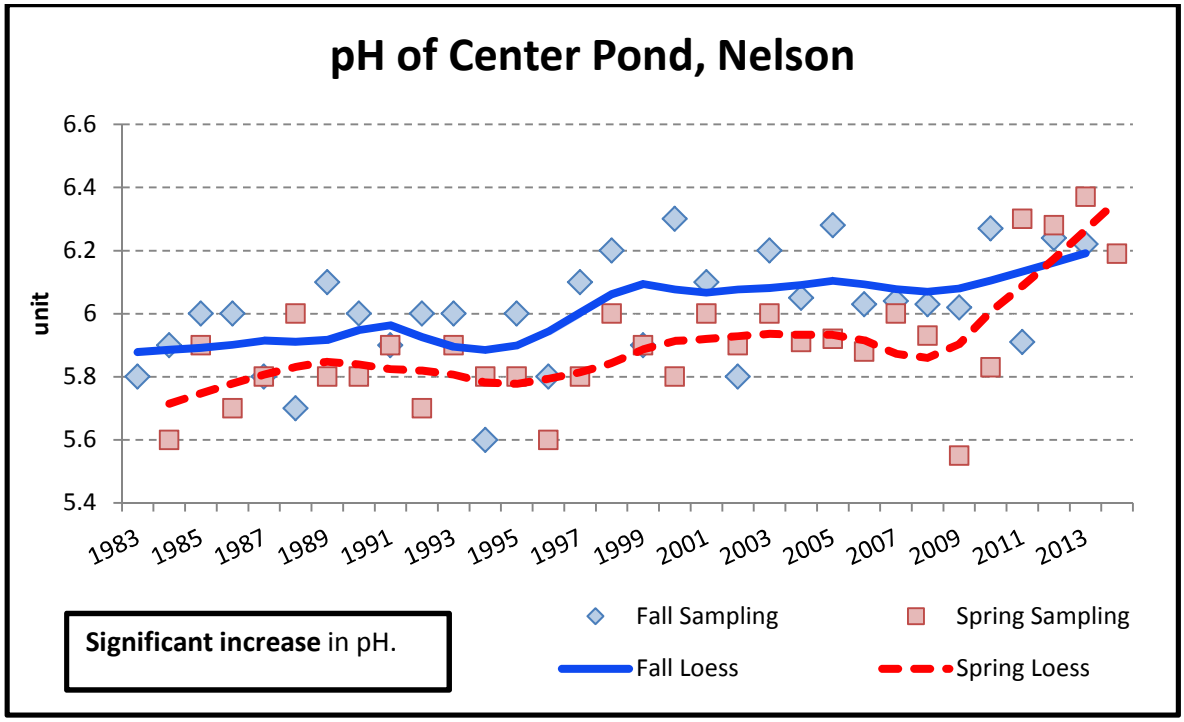


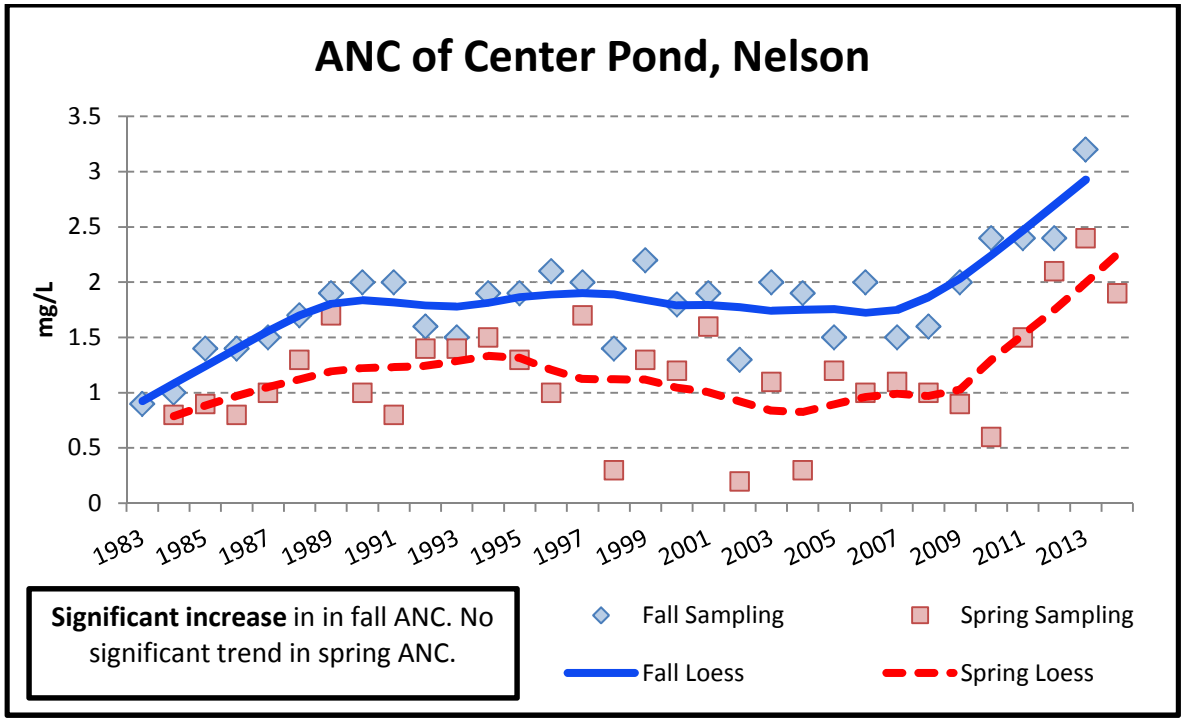
Significant increase in specific conductance.

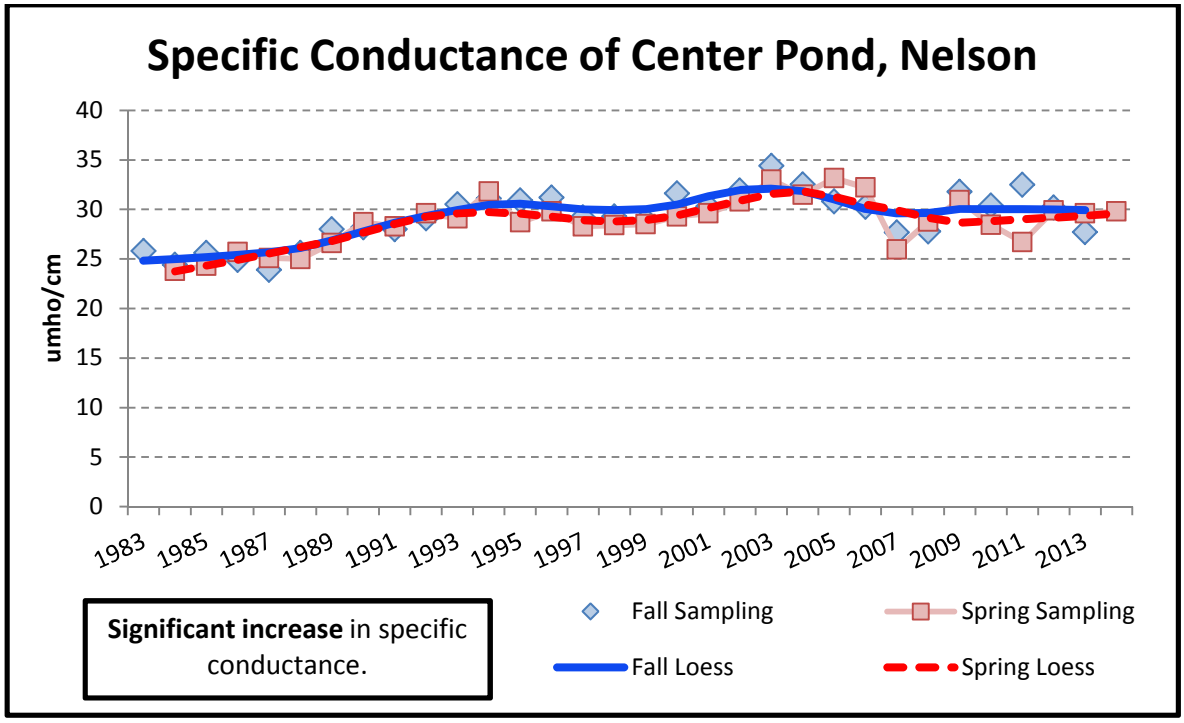


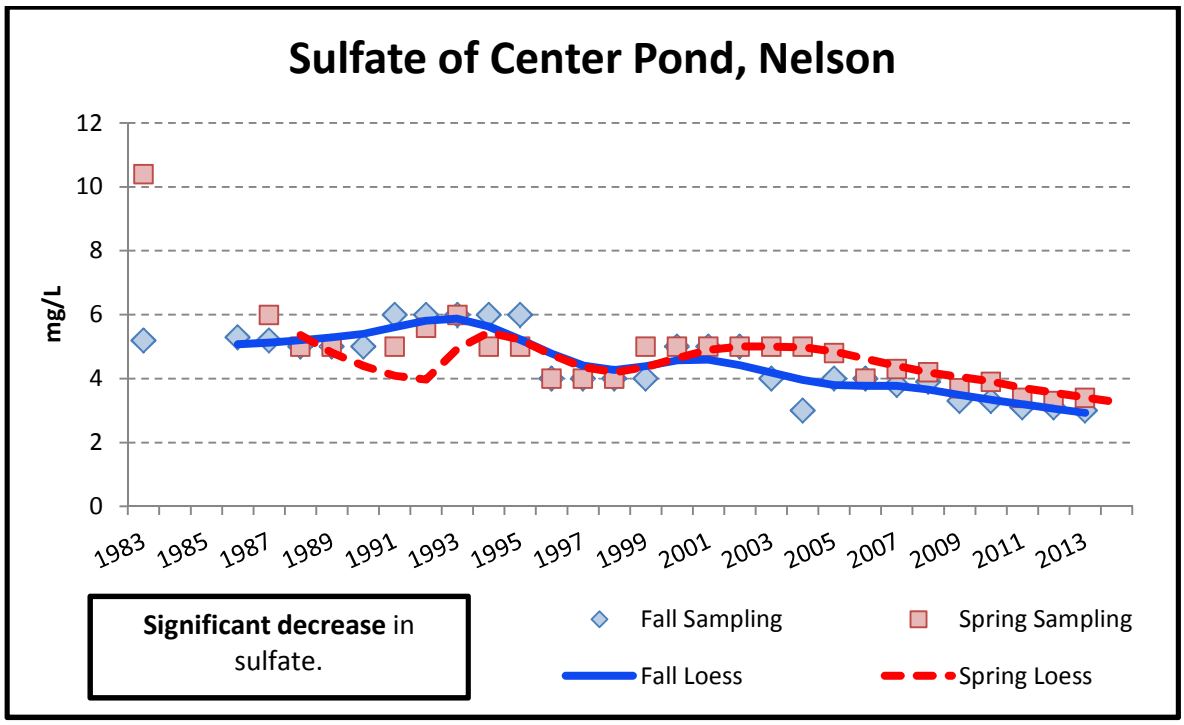
Significant decrease in sulfate.

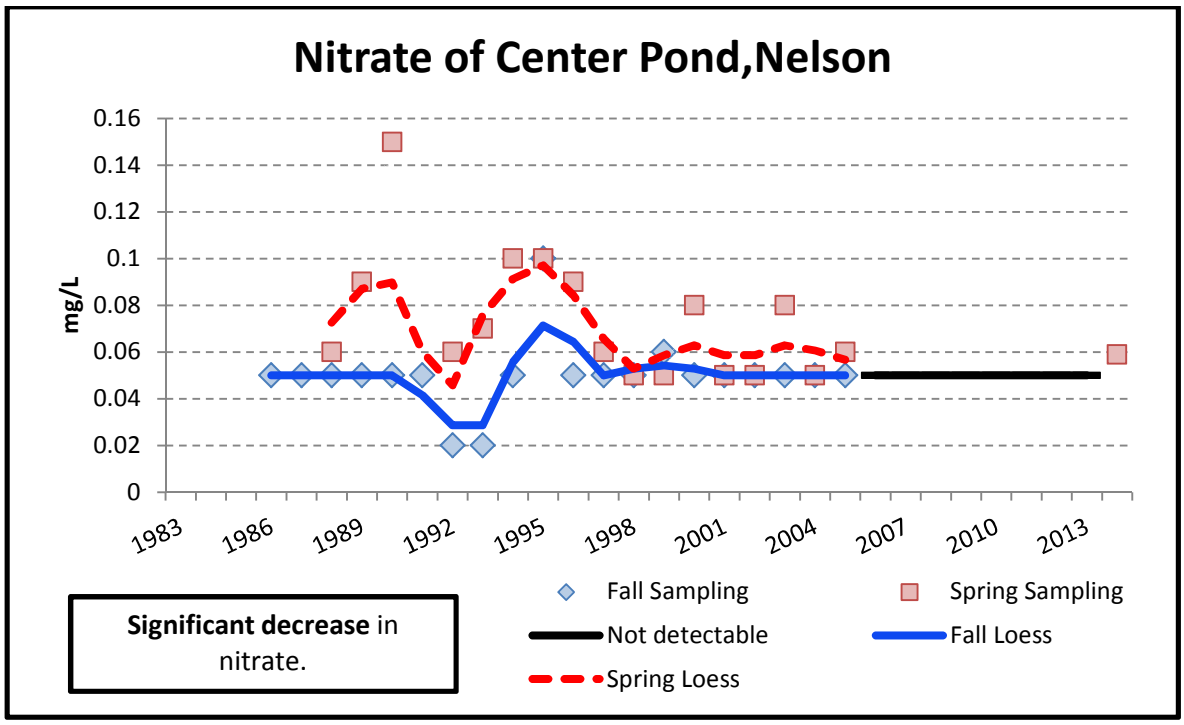

Nitrate of Bow Lake, Strafford
mg/L
0.12
0.1
0.08
0.06
0.04
0.02
0
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Significant decrease in nitrate.
Fall Sampling
Spring Sampling
Not detectable
Fall Loess
Spring Loess

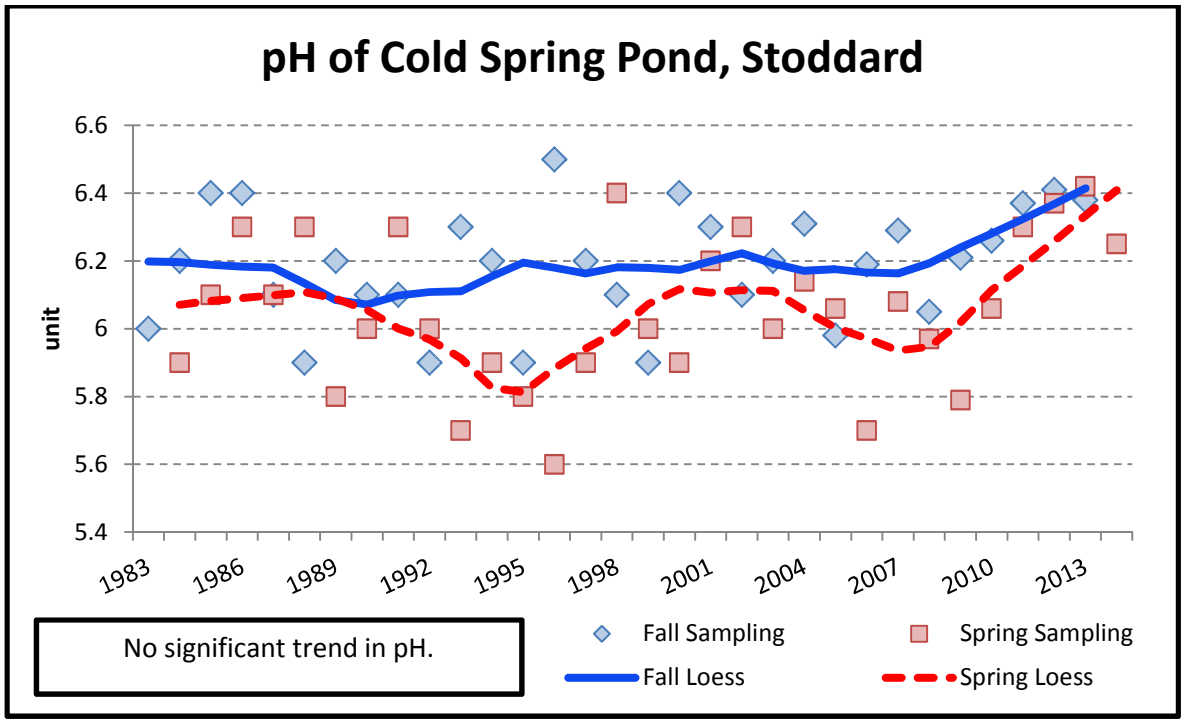

pH of Center Pond, Nelson
unit
6.6
6.4
6.2
6
5.8
5.6
5.4
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess
Significant increase in pH.

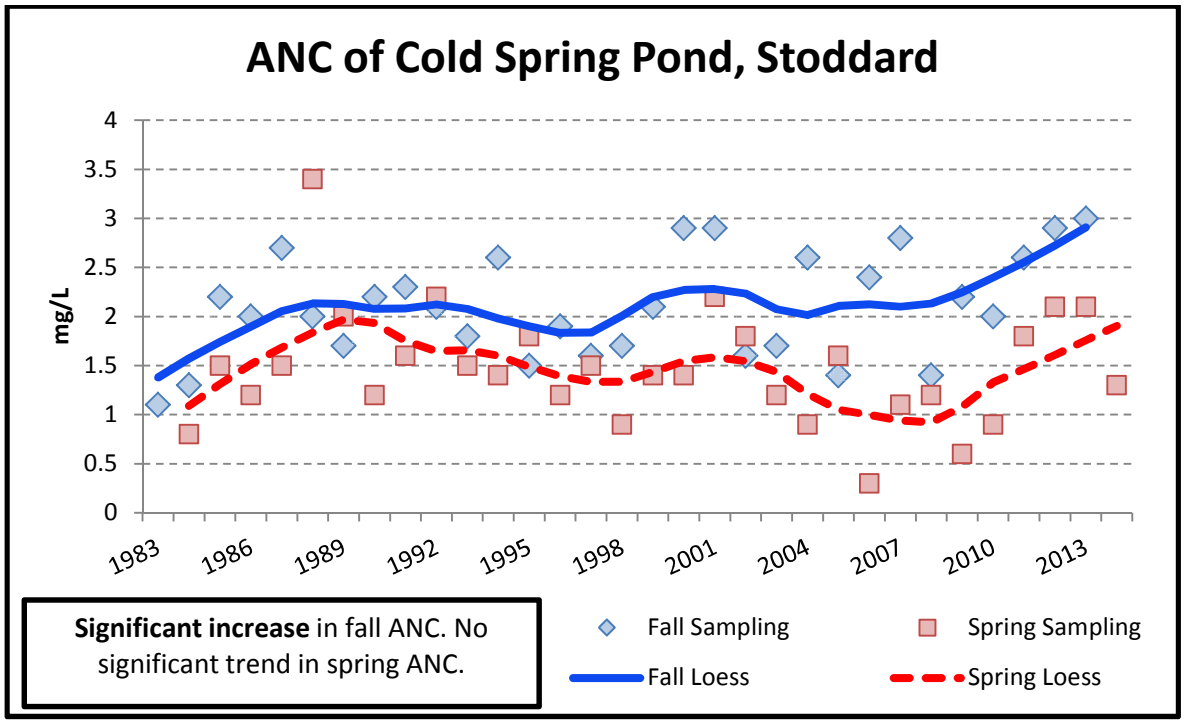

ANC of Center Pond, Nelson
mg/L
3.5
3
2.5
2
1.5
1
0.5
0
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess
Significant increase in in fall ANC. No significant trend in spring ANC.

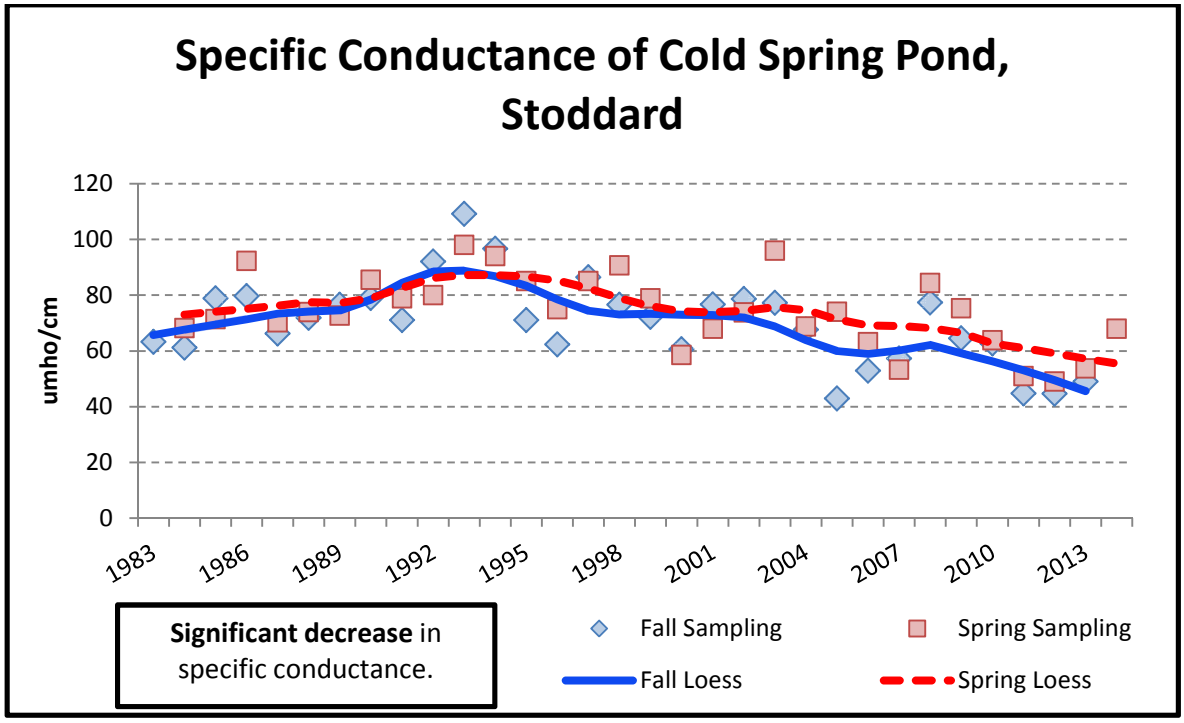

Specific Conductance of Center Pond, Nelson
umho/cm
40
35
30
25
20
15
10
5
0
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess
Significant increase in specific conductance.

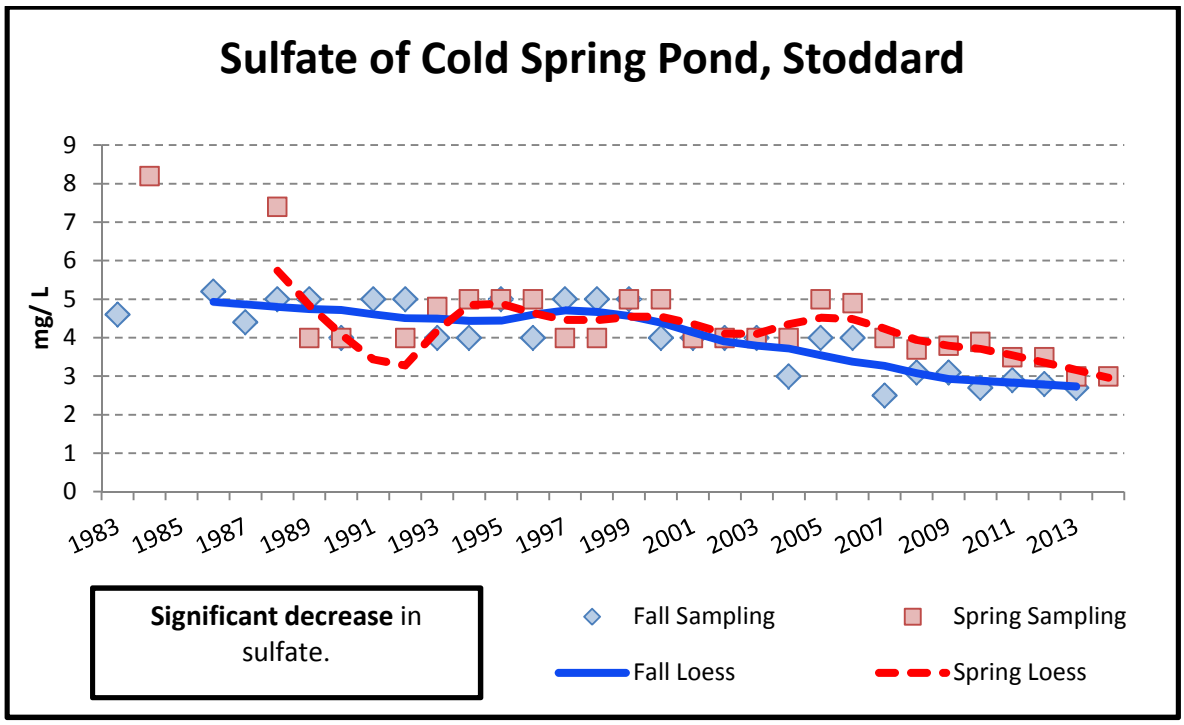

Sulfate of Center Pond, Nelson
mg/L
12
10
8
6
4
2
0
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess
Significant decrease in sulfate.

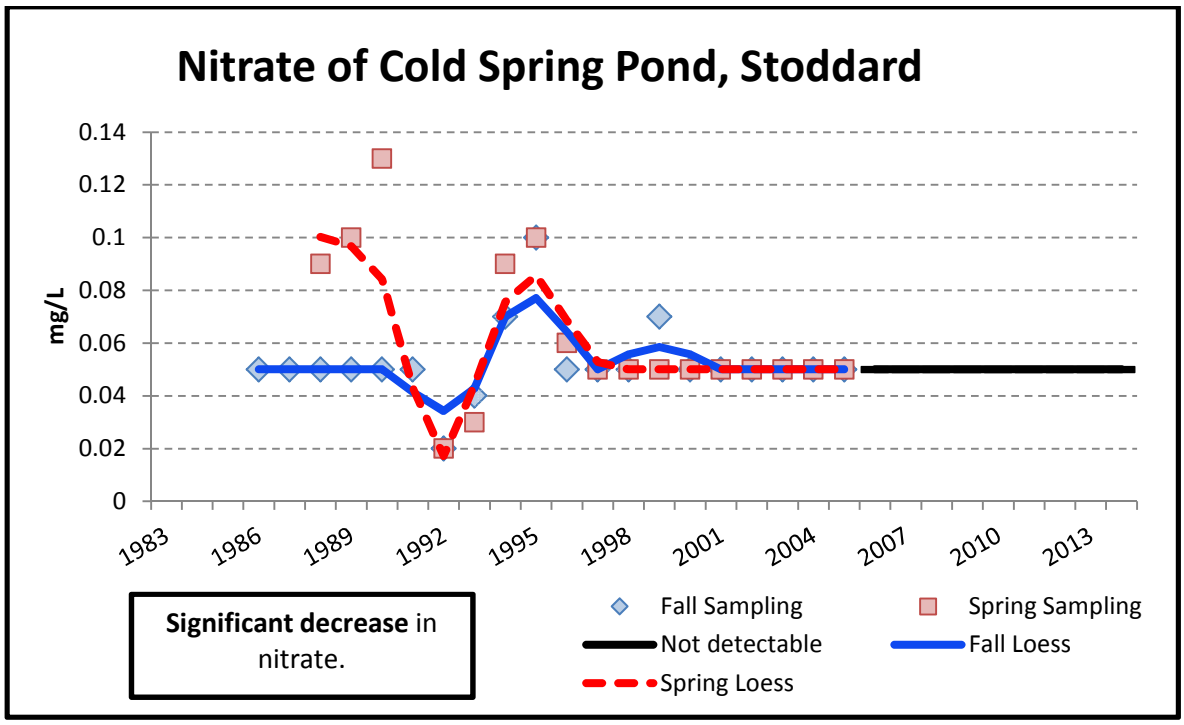

Nitrate of Center Pond,Nelson
mg/L
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Fall Sampling
Spring Sampling
Not detectable
Fall Loess
Spring Loess
Significant decrease in nitrate.

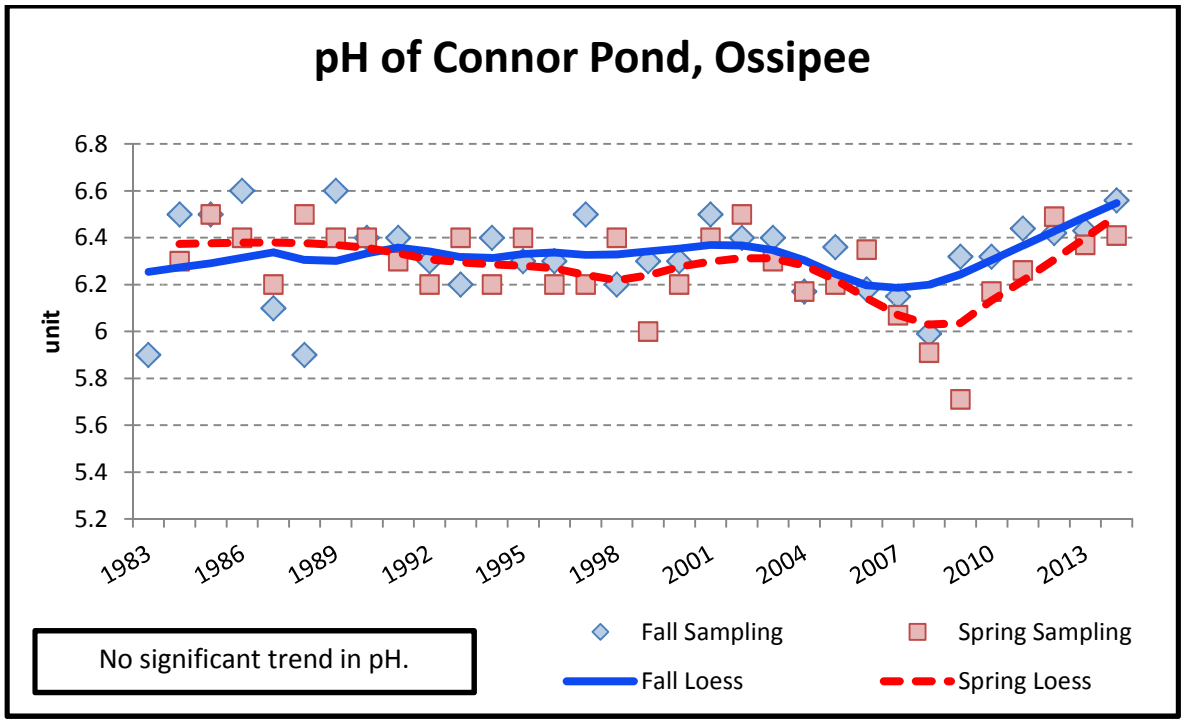

pH of Cold Spring Pond, Stoddard
unit
6.6
6.4
6.2
6
5.8
5.6
5.4
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
No significant trend in pH.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

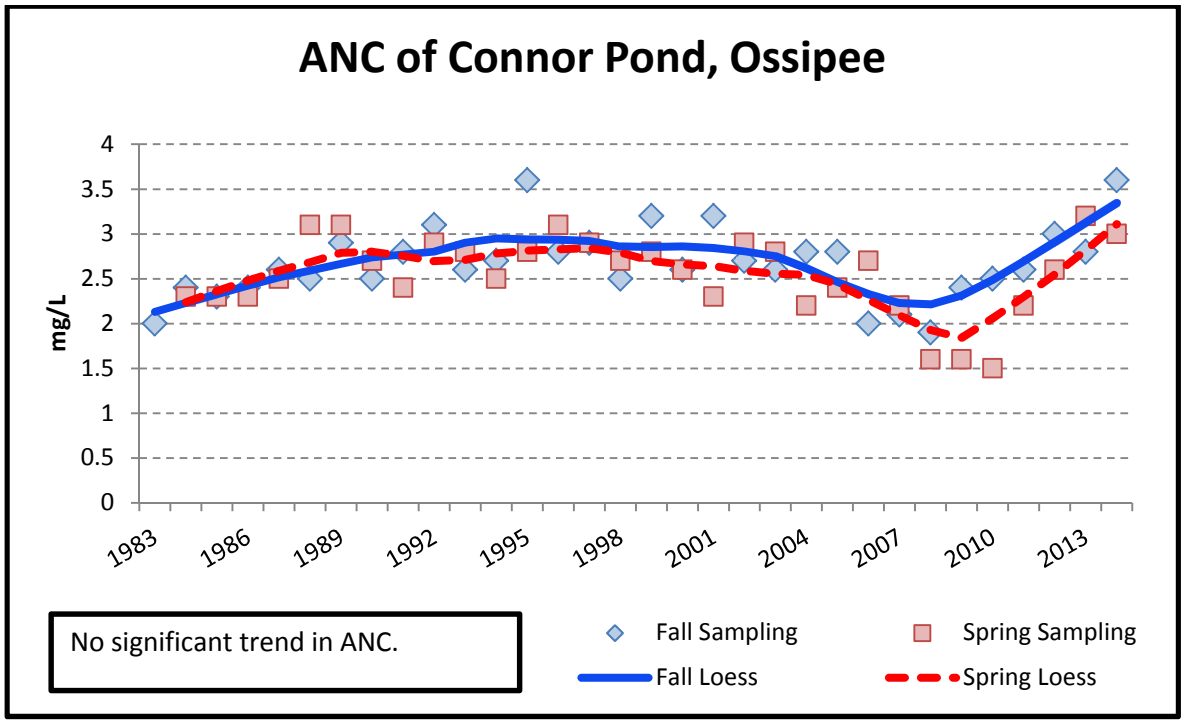

ANC of Cold Spring Pond, Stoddard
mg/L
4
3.5
3
2.5
2
1.5
1
0.5
0
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Significant increase in fall ANC. No significant trend in spring ANC.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

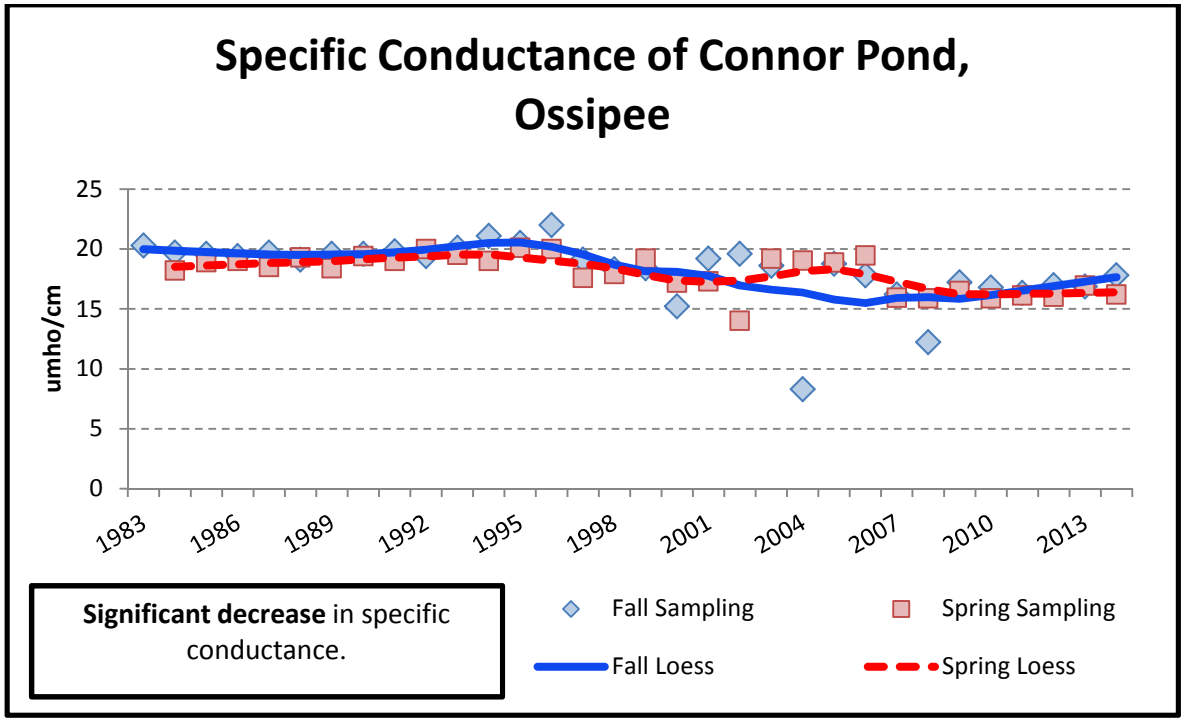

Specific Conductance of Cold Spring Pond, Stoddard
umho/cm
120
100
80
60
40
20
0
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Significant decrease in specific conductance.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

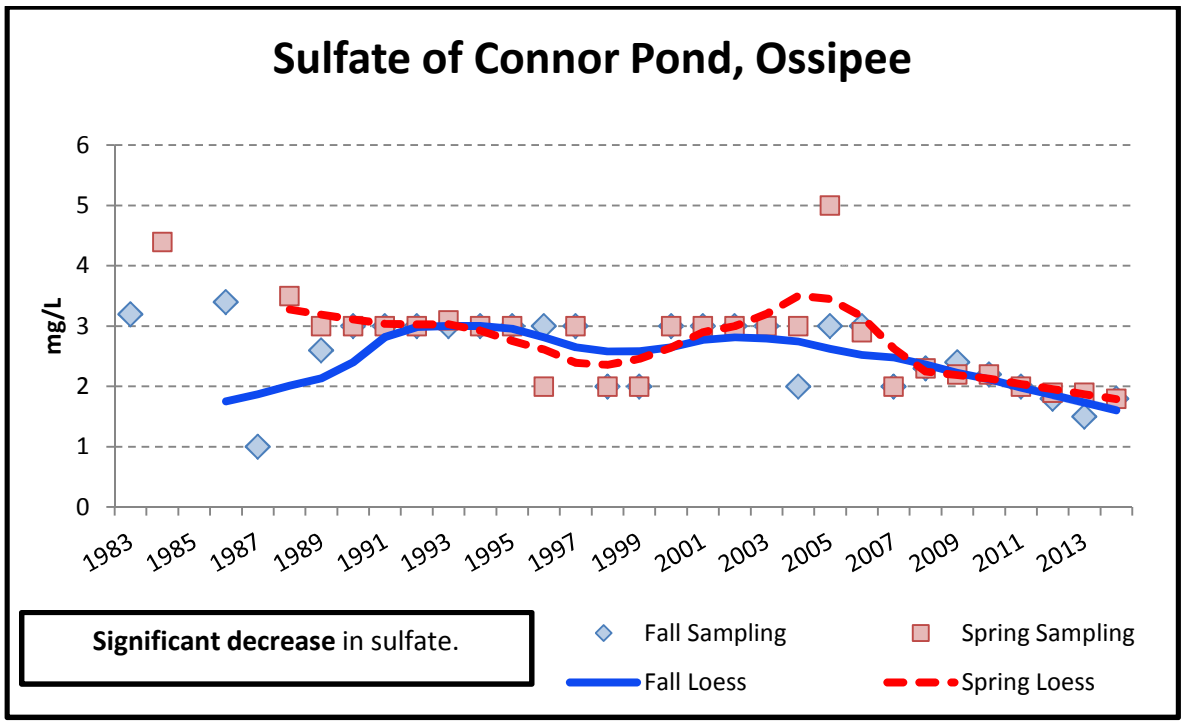

Sulfate of Cold Spring Pond, Stoddard
mg/ L
9
8
7
6
5
4
3
2
1
0
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
Significant decrease in sulfate.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

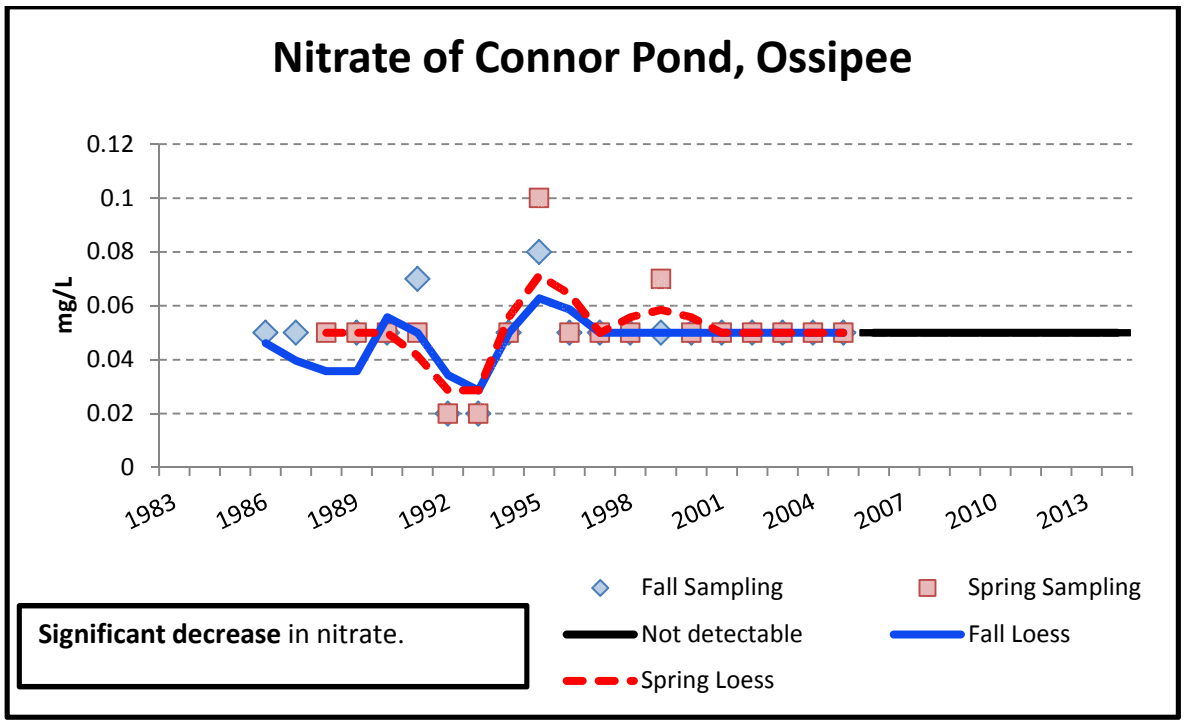

Nitrate of Cold Spring Pond, Stoddard
mg/L
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Significant decrease in nitrate.
Fall Sampling
Spring Sampling
Not detectable
Fall Loess
Spring Loess

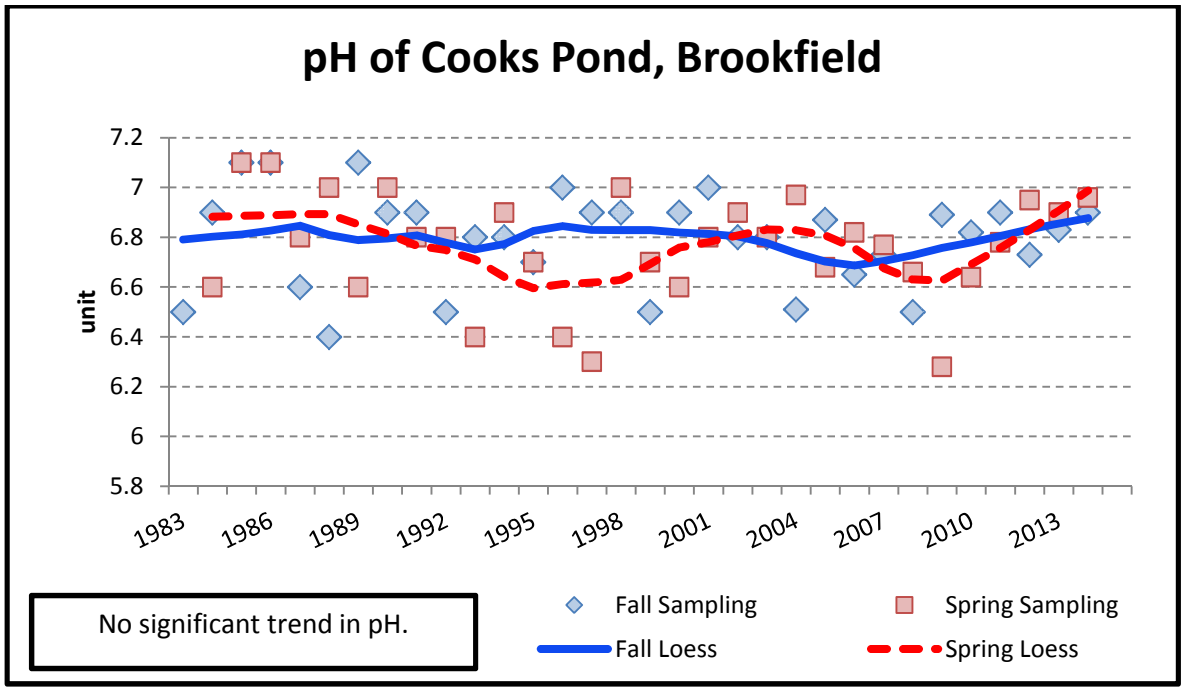

pH of Connor Pond, Ossipee
unit
6.8
6.6
6.4
6.2
6
5.8
5.6
5.4
5.2
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
No significant trend in pH.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

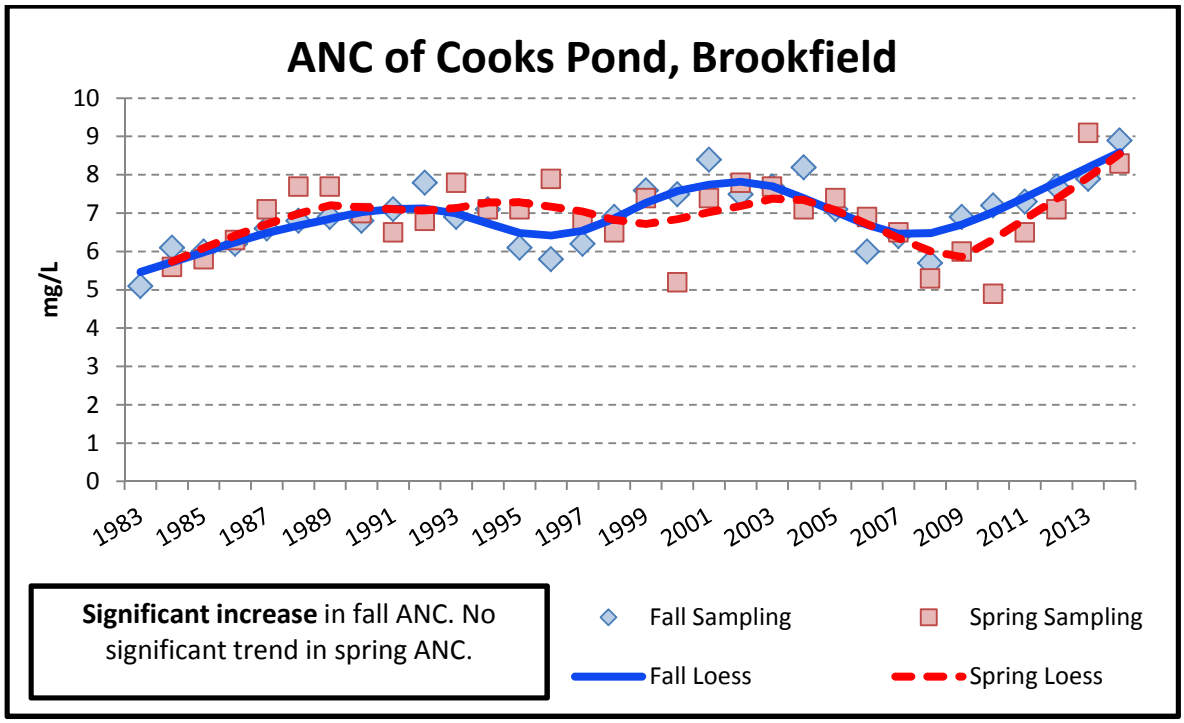

ANC of Connor Pond, Ossipee
mg/L
4
3.5
3
2.5
2
1.5
1
0.5
0
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
No significant trend in ANC.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

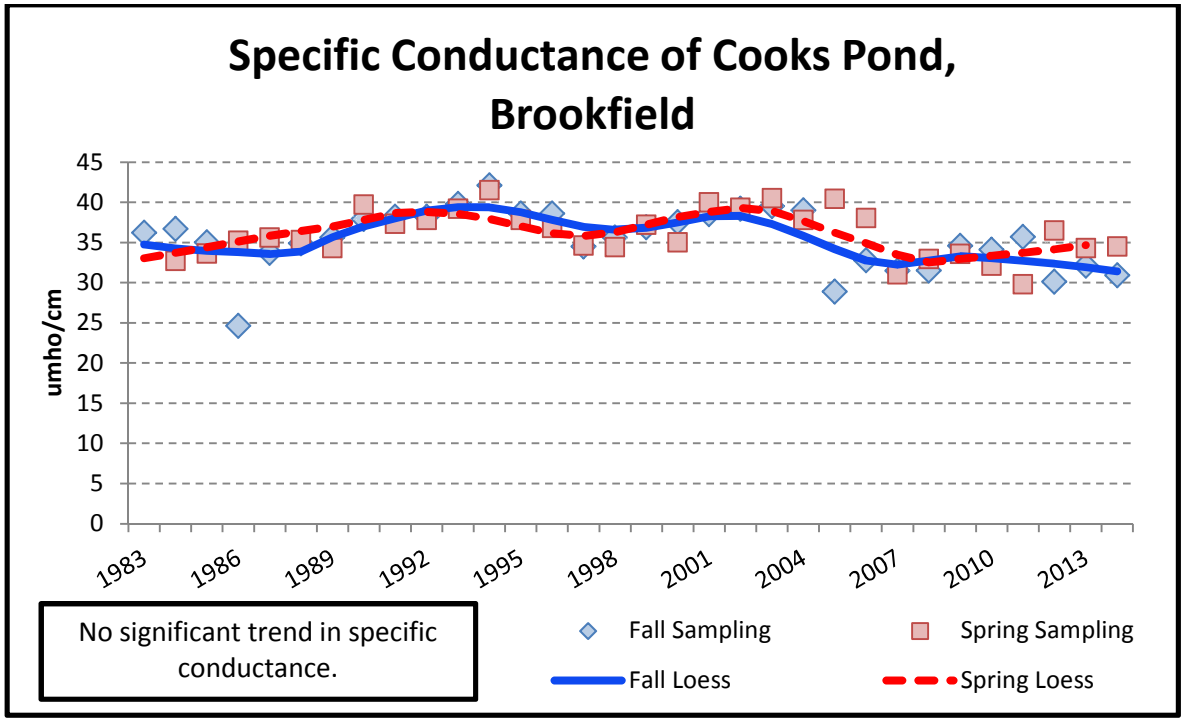

Specific Conductance of Connor Pond, Ossipee
umho/cm
25
20
15
10
5
0
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Significant decrease in specific conductance.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

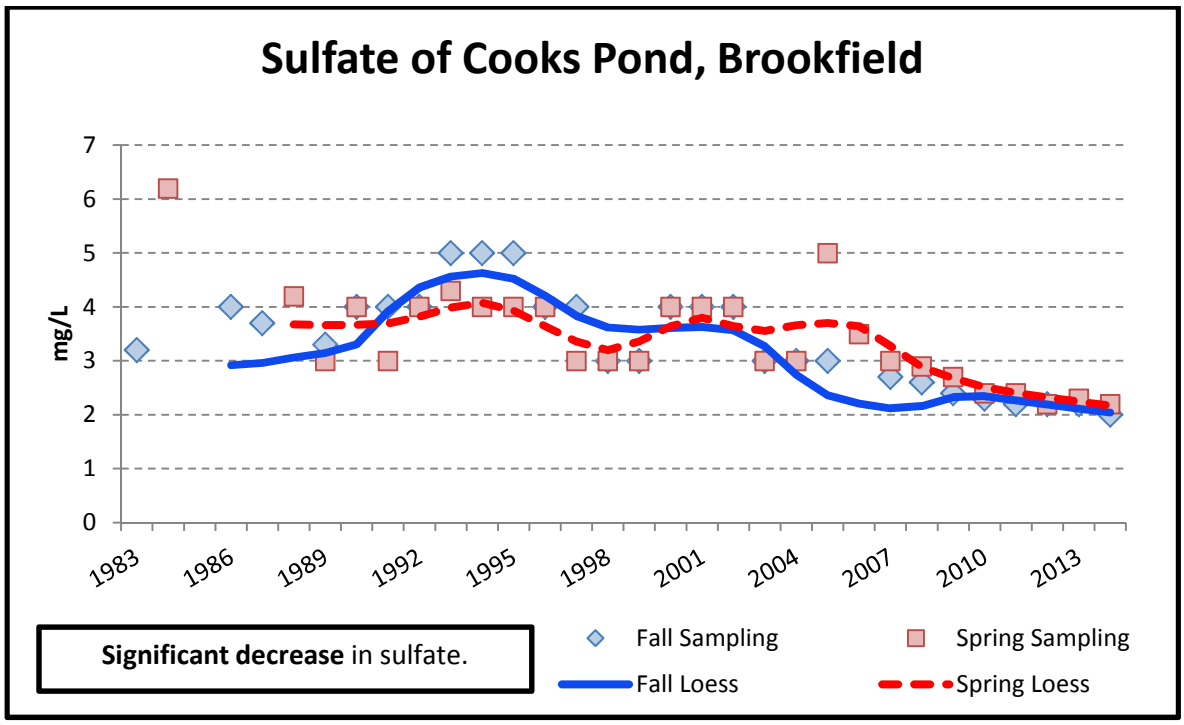

Sulfate of Connor Pond, Ossipee
mg/L
6
5
4
3
2
1
0
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
Significant decrease in sulfate.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

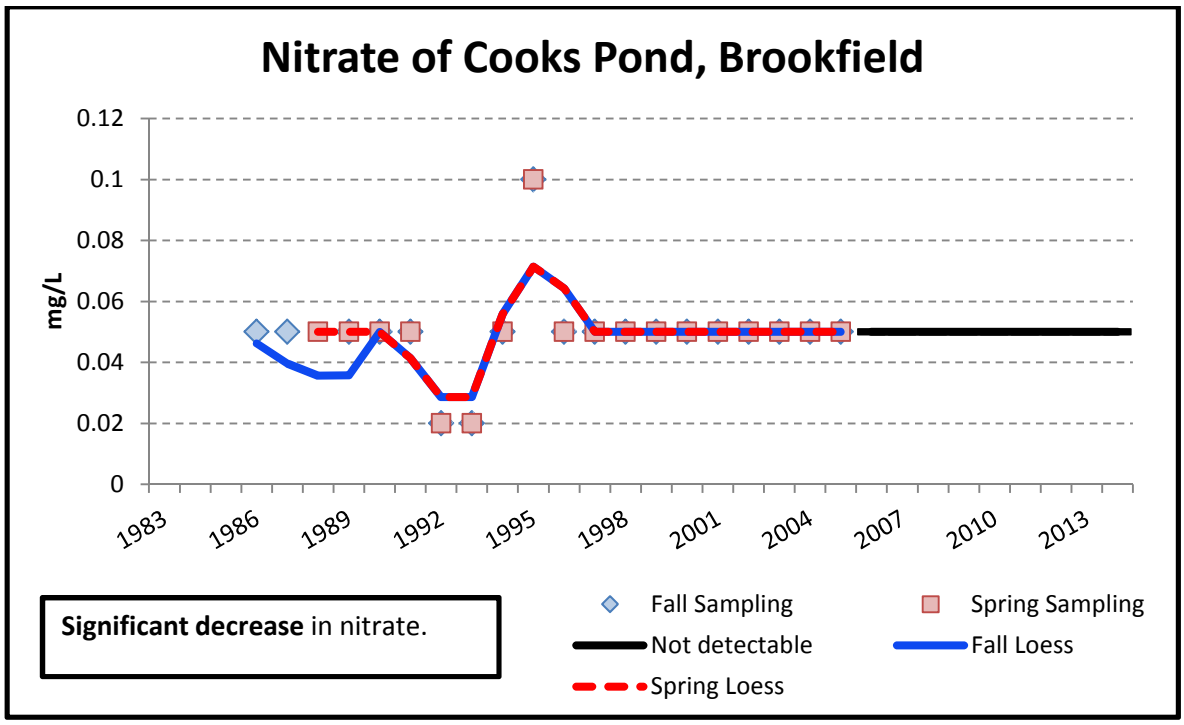

Nitrate of Connor Pond, Ossipee
0.12
0.1
0.08
0.06
0.04
0.02
0
mg/L
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Fall Sampling
Spring Sampling
Not detectable
Fall Loess
Spring Loess
Significant decrease in nitrate.

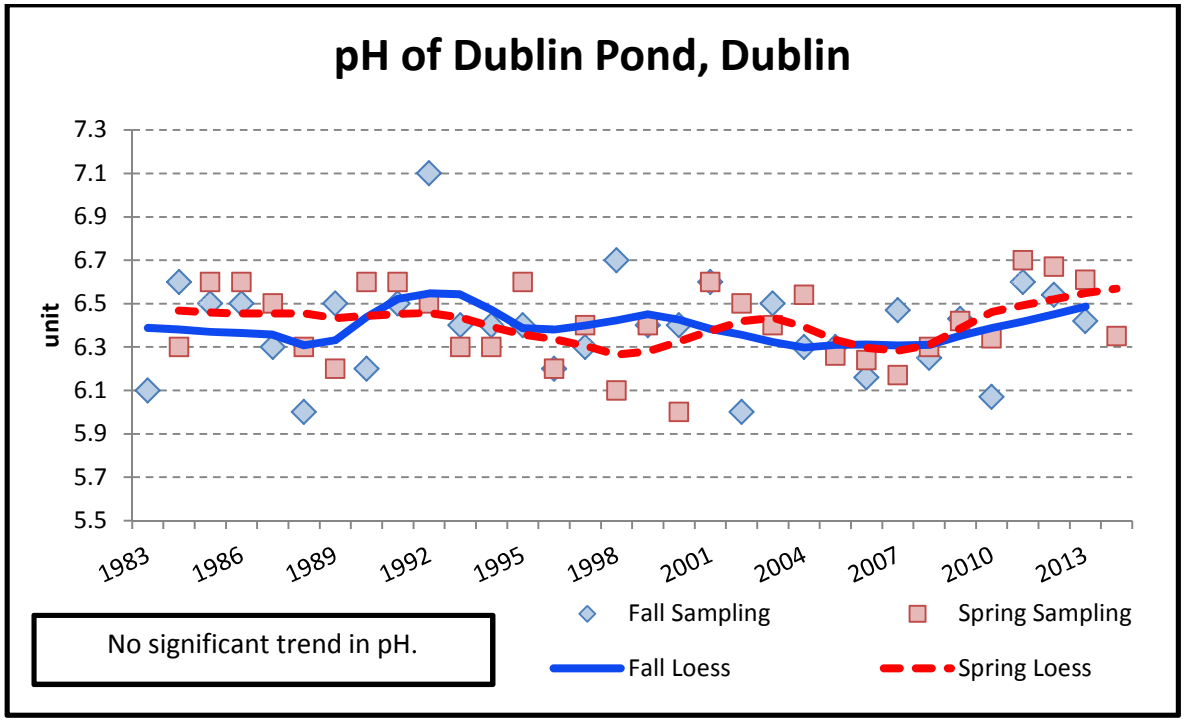

pH of Cooks Pond, Brookfield
unit
7.2
7
6.8
6.6
6.4
6.2
6
5.8
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
No significant trend in pH.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

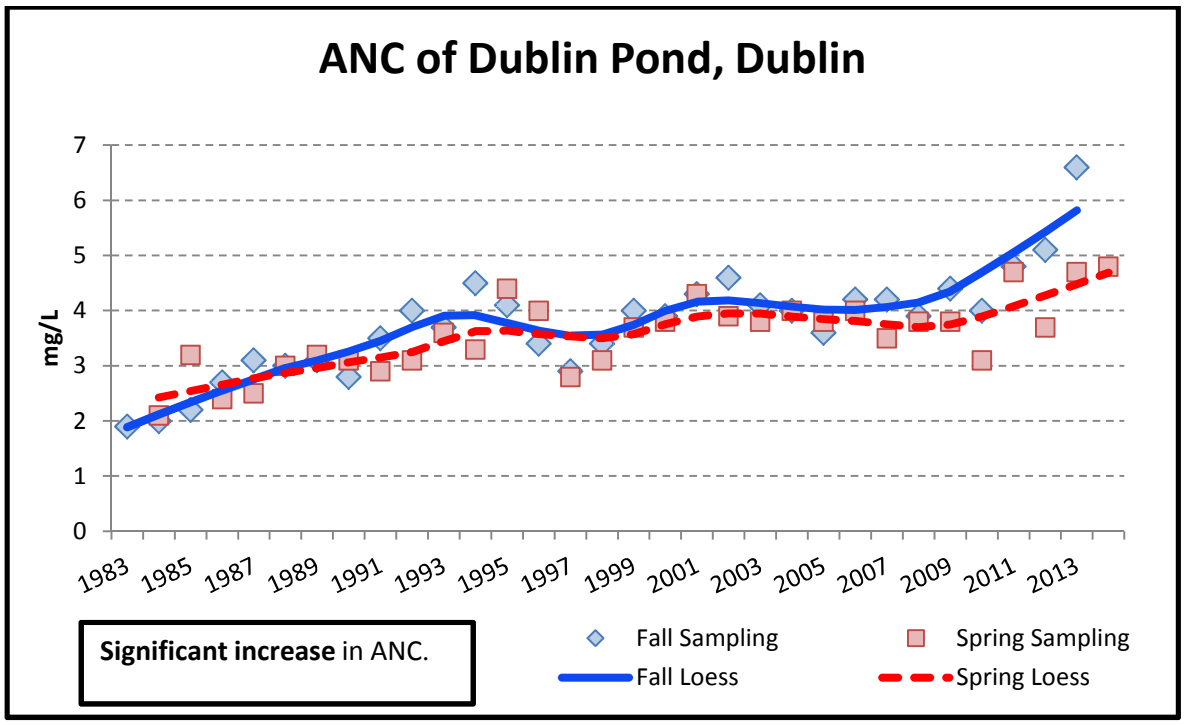

ANC of Cooks Pond, Brookfield
mg/L
10
9
8
7
6
5
4
3
2
1
0
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
Significant increase in fall ANC. No significant trend in spring ANC.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

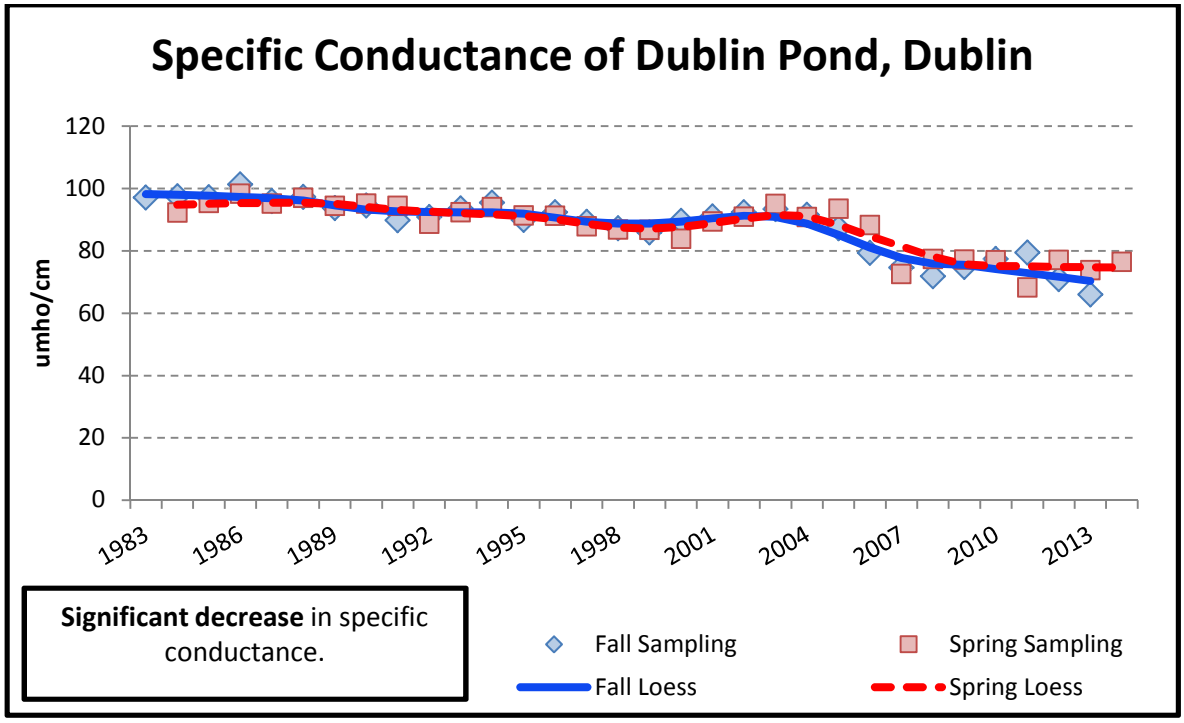

Specific Conductance of Cooks Pond, Brookfield
umho/cm
45
40
35
30
25
20
15
10
5
0
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
No significant trend in specific conductance.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

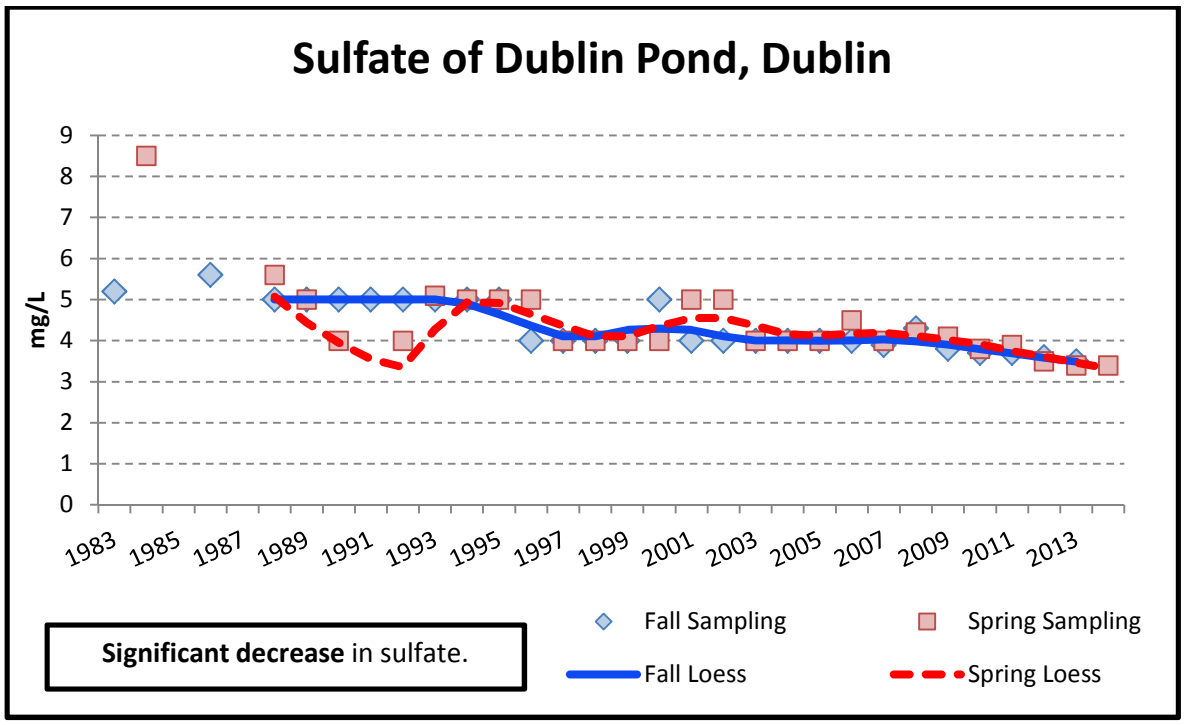

Sulfate of Cooks Pond, Brookfield
mg/L
7
6
5
4
3
2
1
0
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Significant decrease in sulfate.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

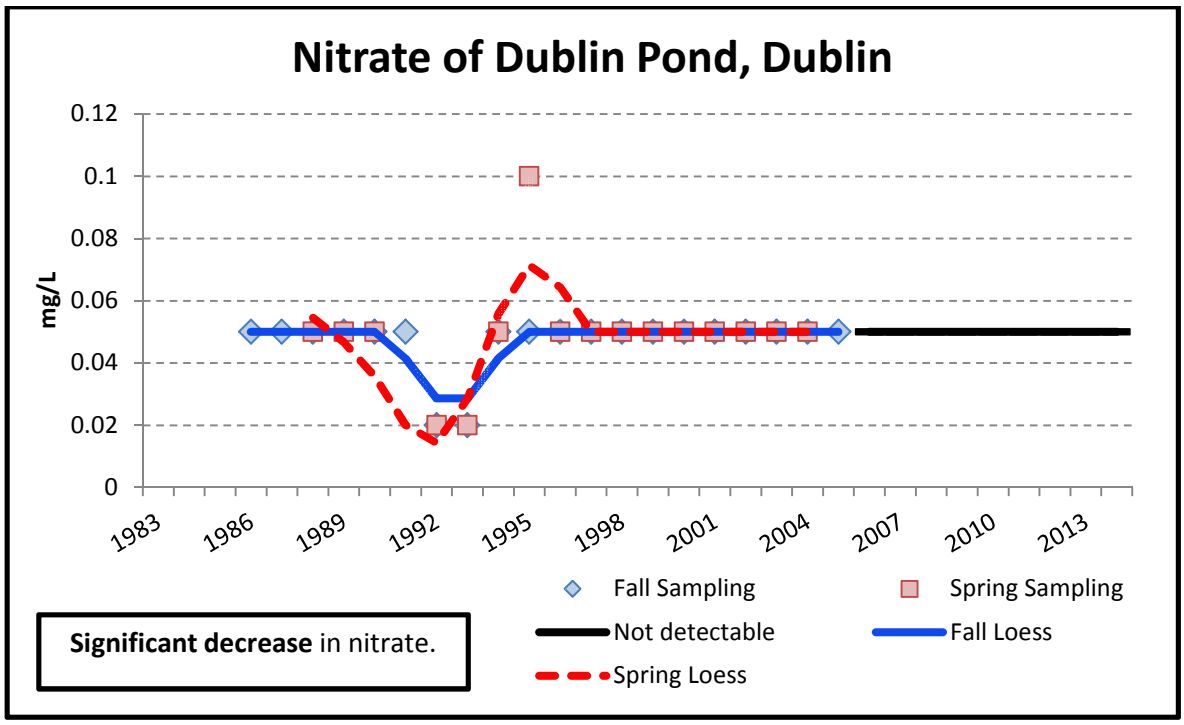

Nitrate of Cooks Pond, Brookfield
0.12
0.1
0.08
0.06
0.04
0.02
0
mg/L
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Significant decrease in nitrate.
Fall Sampling
Spring Sampling
Not detectable
Fall Loess
Spring Loess

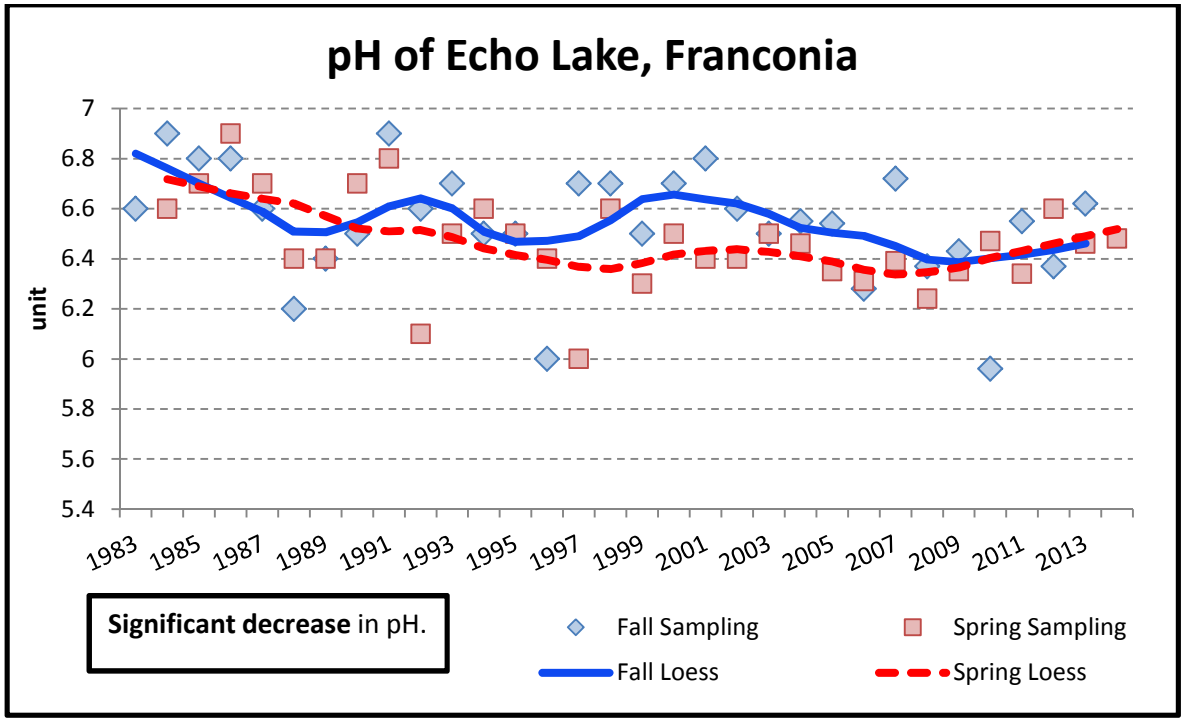

pH of Dublin Pond, Dublin
unit
7.3
7.1
6.9
6.7
6.5
6.3
6.1
5.9
5.7
5.5
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess
No significant trend in pH.

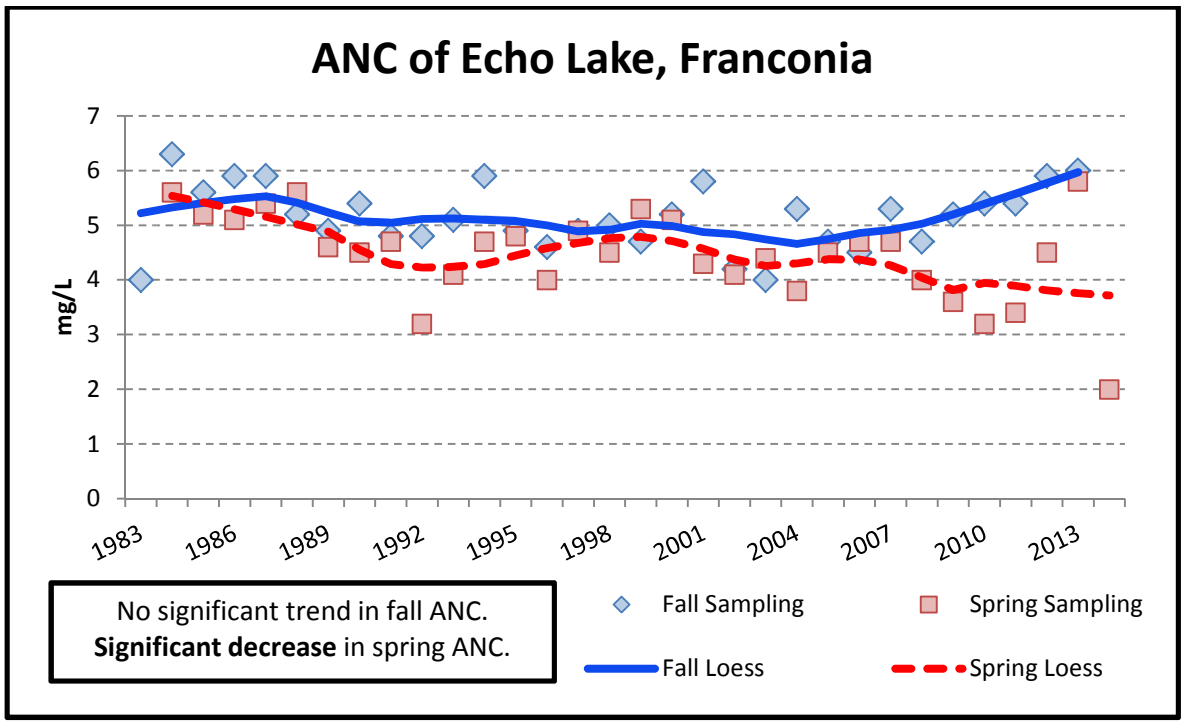

ANC of Dublin Pond, Dublin
mg/L
7
6
5
4
3
2
1
0
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess
Significant increase in ANC.

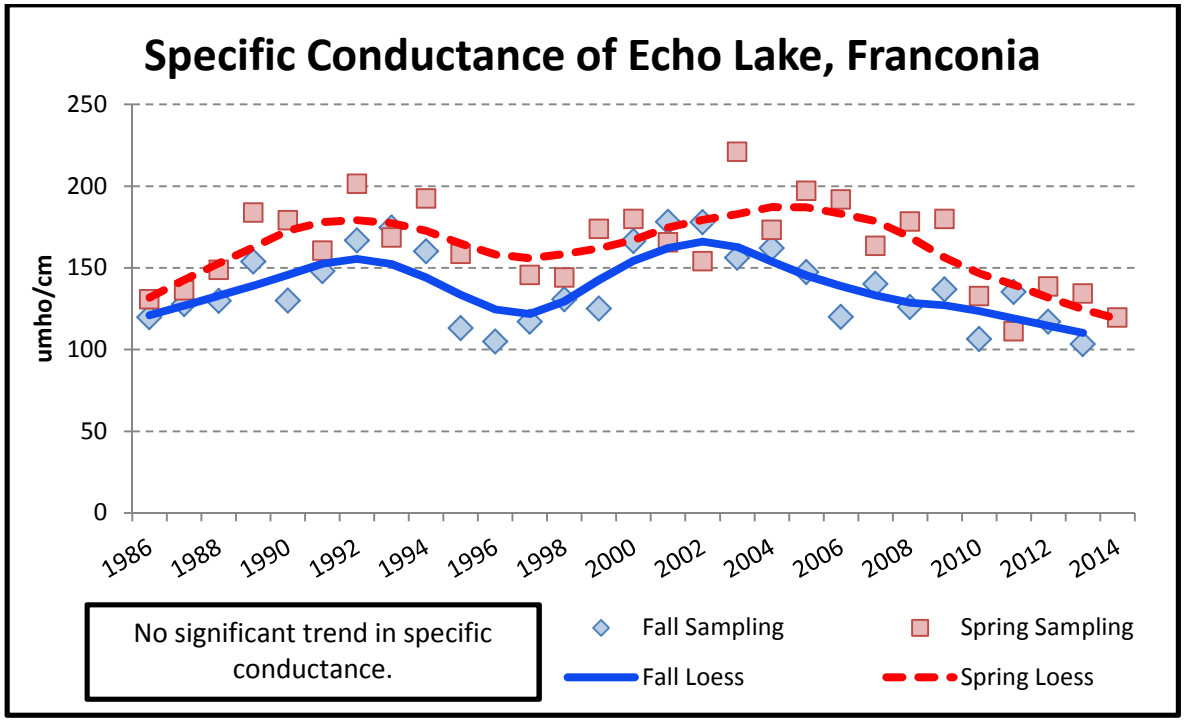

Specific Conductance of Dublin Pond, Dublin
umho/cm
120
100
80
60
40
20
0
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Significant decrease in specific conductance.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

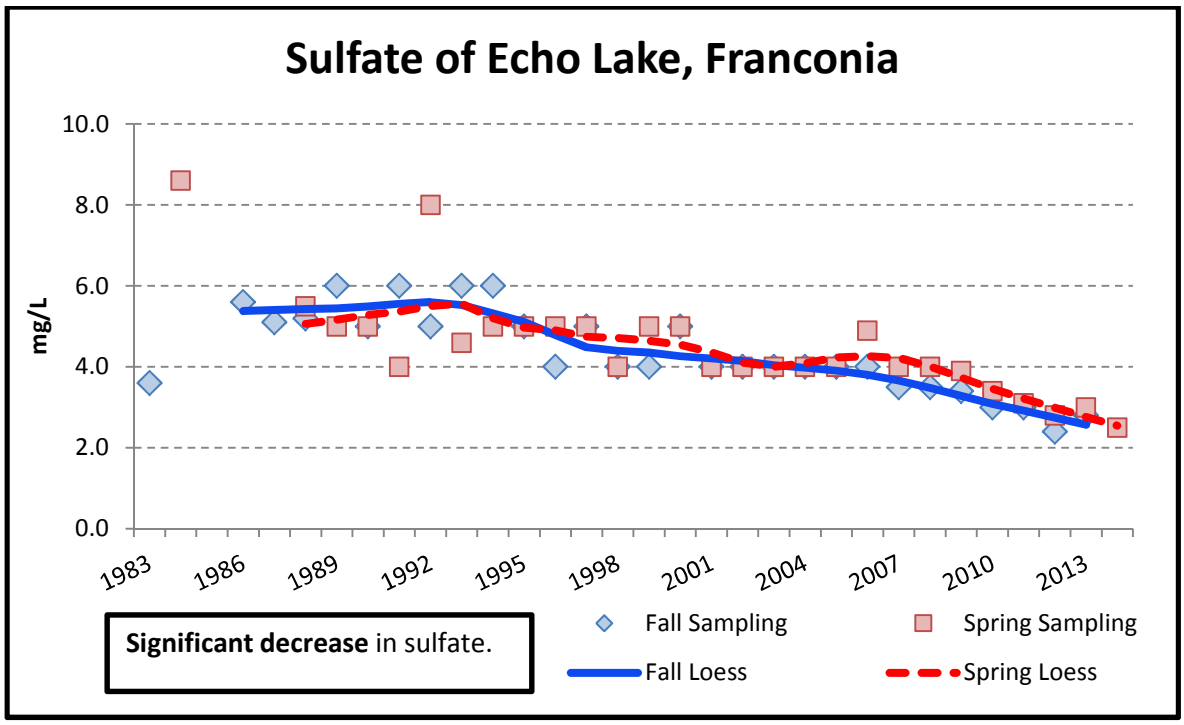

Sulfate of Dublin Pond, Dublin
mg/L
9
8
7
6
5
4
3
2
1
0
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
Significant decrease in sulfate.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

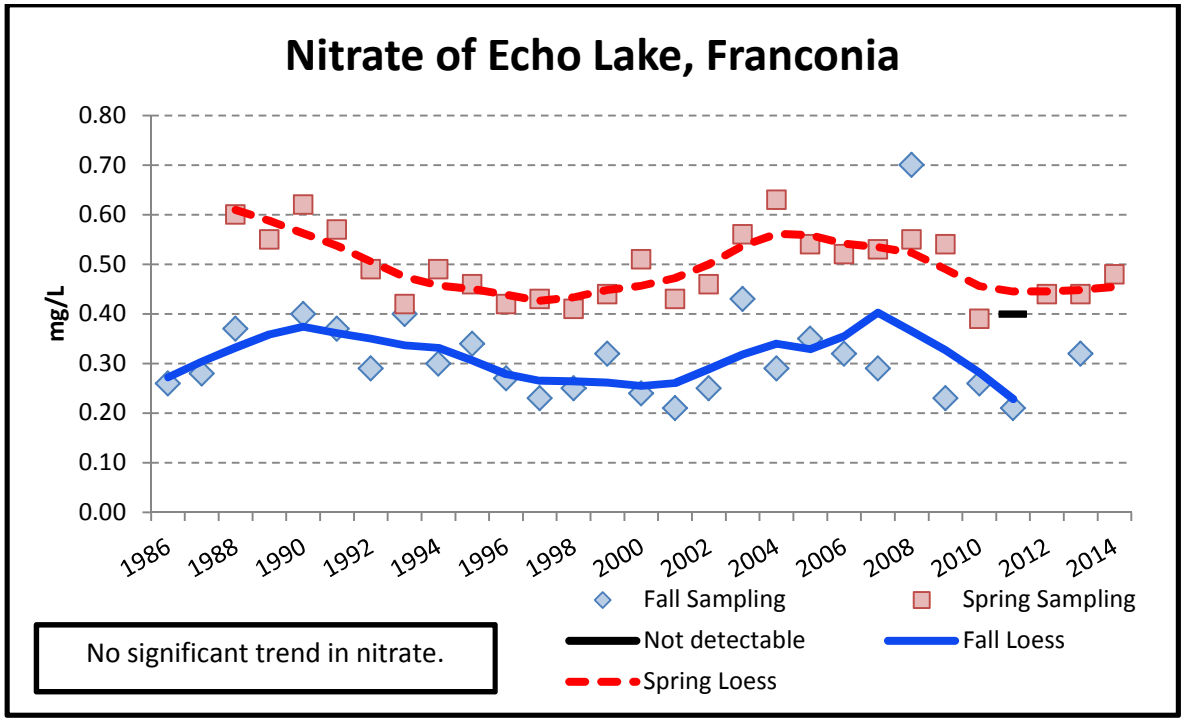

Nitrate of Dublin Pond, Dublin
0.12
0.1
0.08
0.06
0.04
0.02
0
mg/L
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Fall Sampling
Spring Sampling
Not detectable
Fall Loess
Spring Loess
Significant decrease in nitrate.

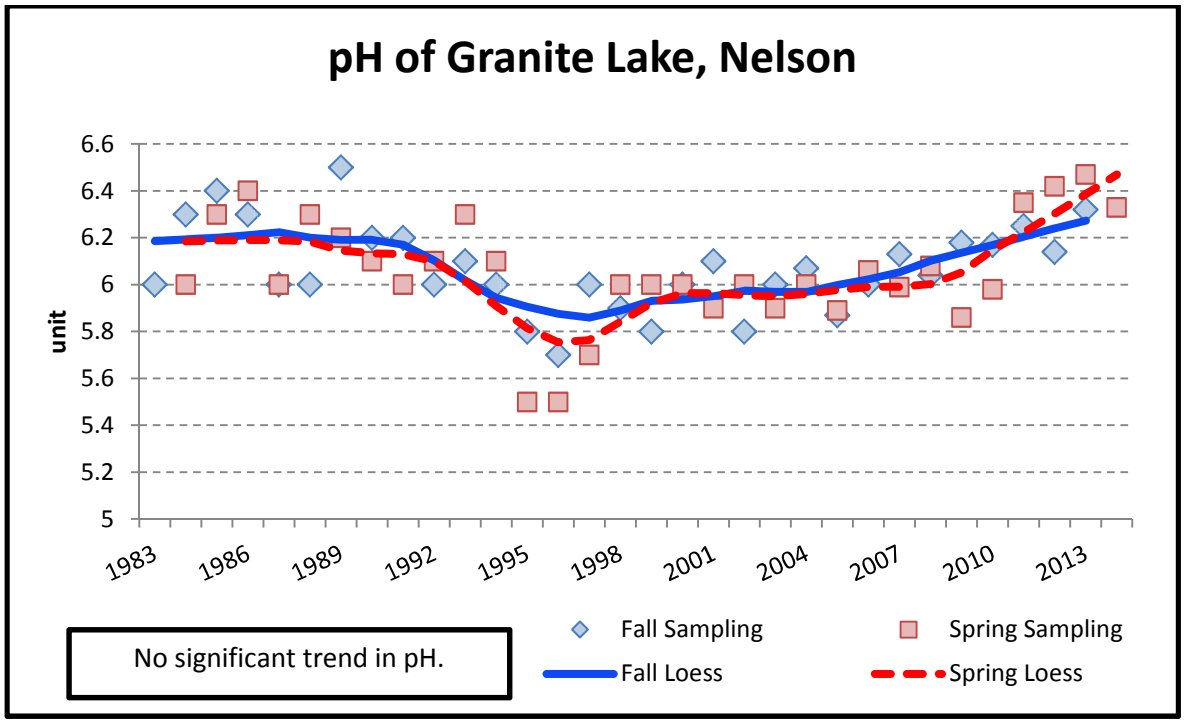

pH of Echo Lake, Franconia
unit
7
6.8
6.6
6.4
6.2
6
5.8
5.6
5.4
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
Significant decrease in pH.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

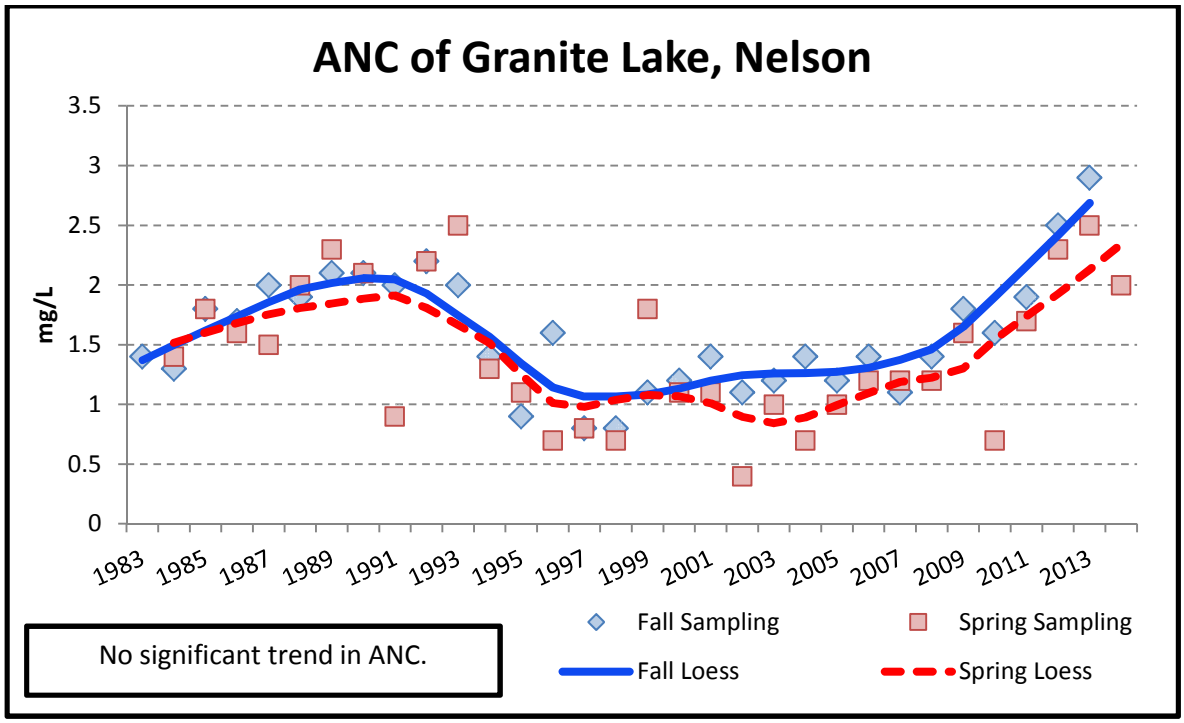

ANC of Echo Lake, Franconia
mg/L
7
6
5
4
3
2
1
0
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
No significant trend in fall ANC.
Significant decrease in spring ANC.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

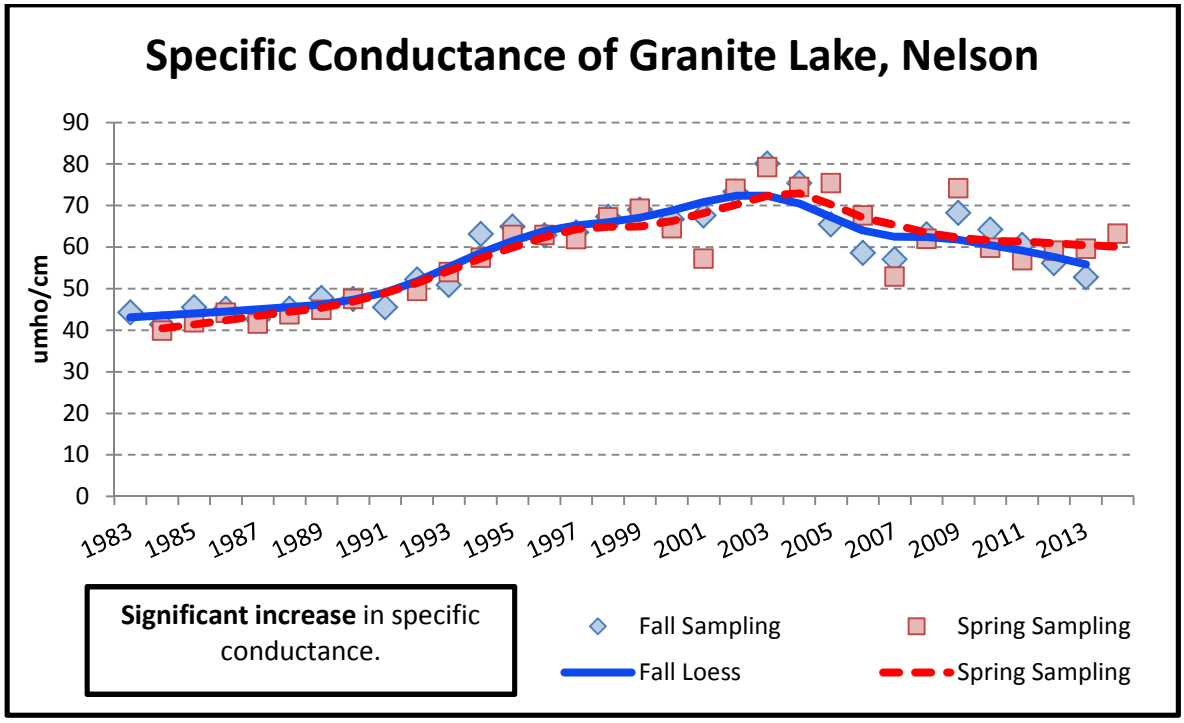

Specific Conductance of Echo Lake, Franconia
umho/cm
250
200
150
100
50
0
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
No significant trend in specific conductance.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

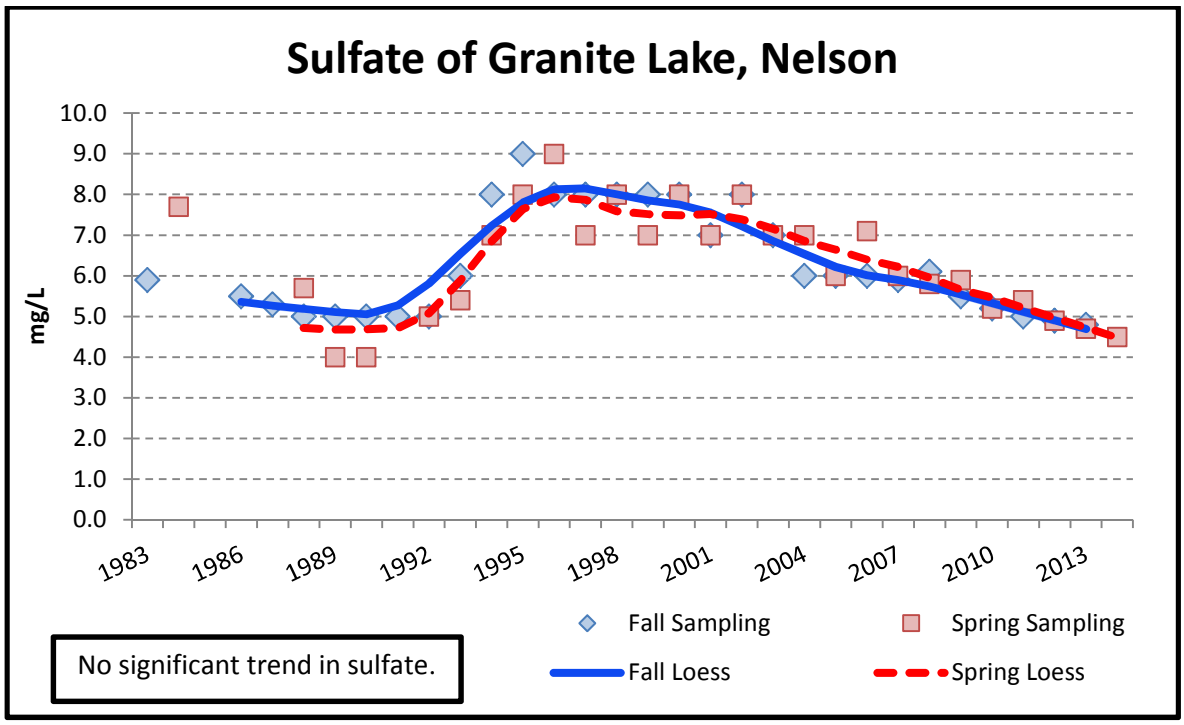

Sulfate of Echo Lake, Franconia
mg/L
10.0
8.0
6.0
4.0
2.0
0.0
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Significant decrease in sulfate.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

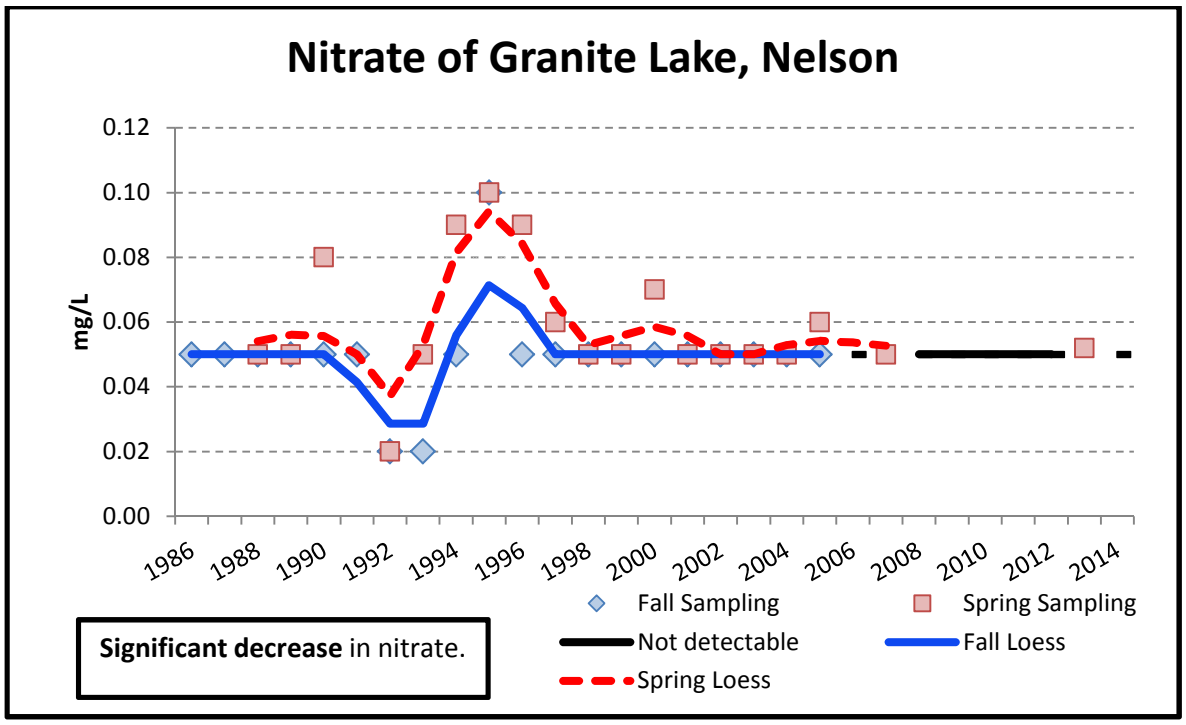

Nitrate of Echo Lake, Franconia
mg/L
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
Fall Sampling
Spring Sampling
Not detectable
Fall Loess
Spring Loess
No significant trend in nitrate.

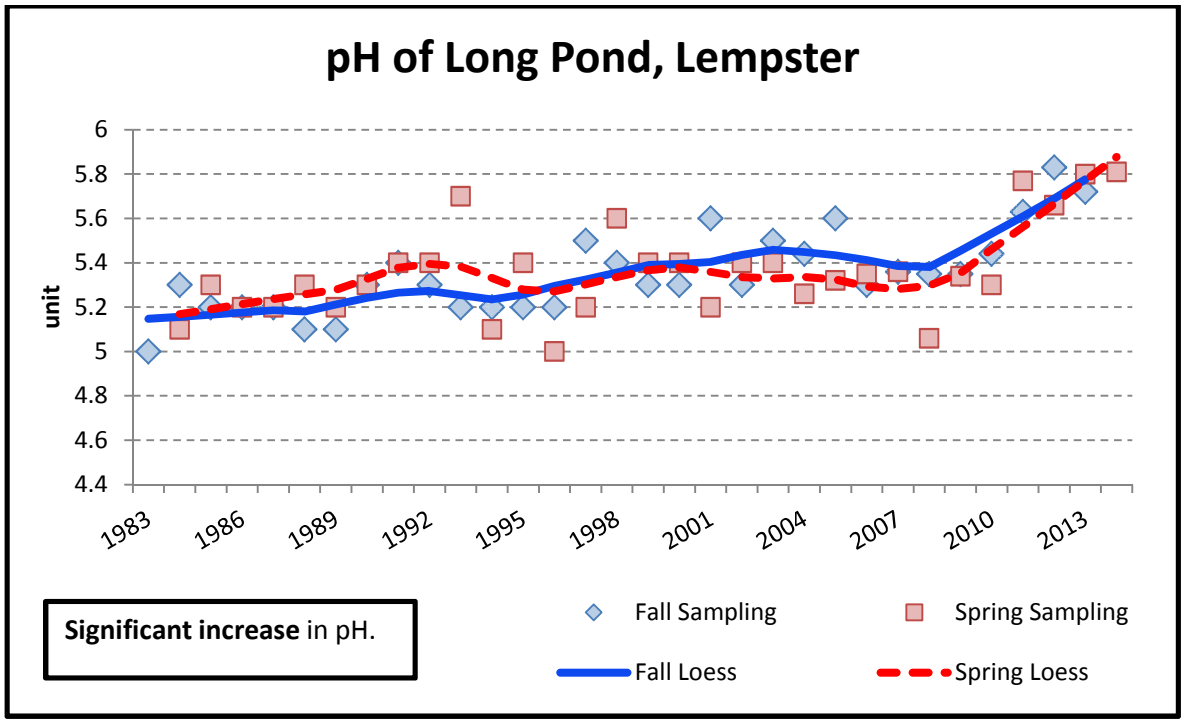

pH of Granite Lake, Nelson
unit
6.6
6.4
6.2
6
5.8
5.6
5.4
5.2
5
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
No significant trend in pH.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess


ANC of Granite Lake, Nelson
mg/L
3.5
3
2.5
2
1.5
1
0.5
0
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
No significant trend in ANC.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

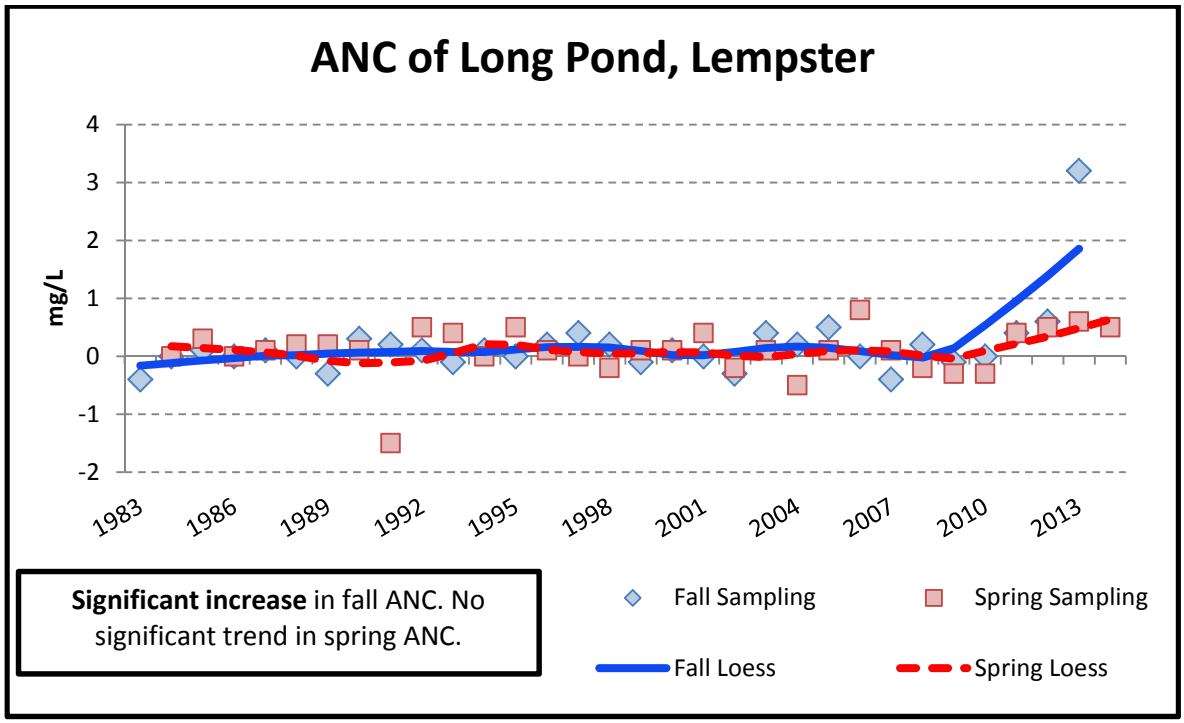

Specific Conductance of Granite Lake, Nelson
umho/cm
90
80
70
60
50
40
30
20
10
0
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
Significant increase in specific conductance.
Fall Sampling
Spring Sampling
Fall Loess
Spring Sampling


Sulfate of Granite Lake, Nelson
mg/L
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
No significant trend in sulfate.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

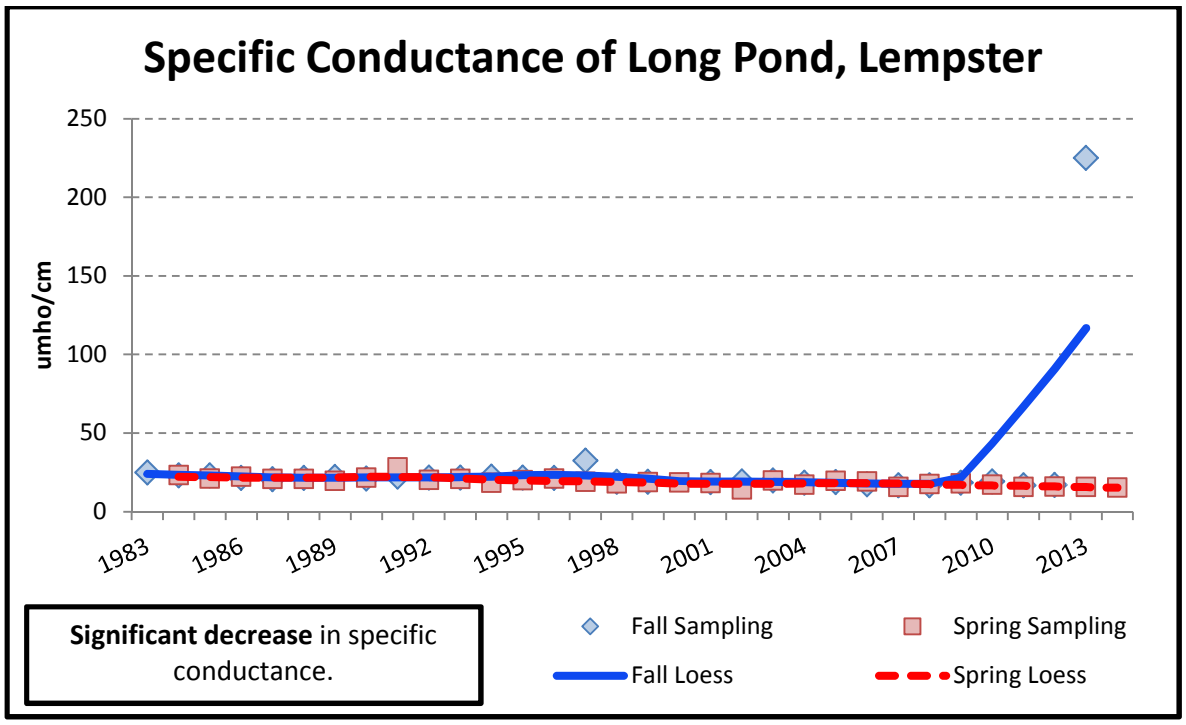

Nitrate of Granite Lake, Nelson
mg/L
0.12
0.10
0.08
0.06
0.04
0.02
0.00
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
Fall Sampling
Spring Sampling
Not detectable
Fall Loess
Spring Loess
Significant decrease in nitrate.

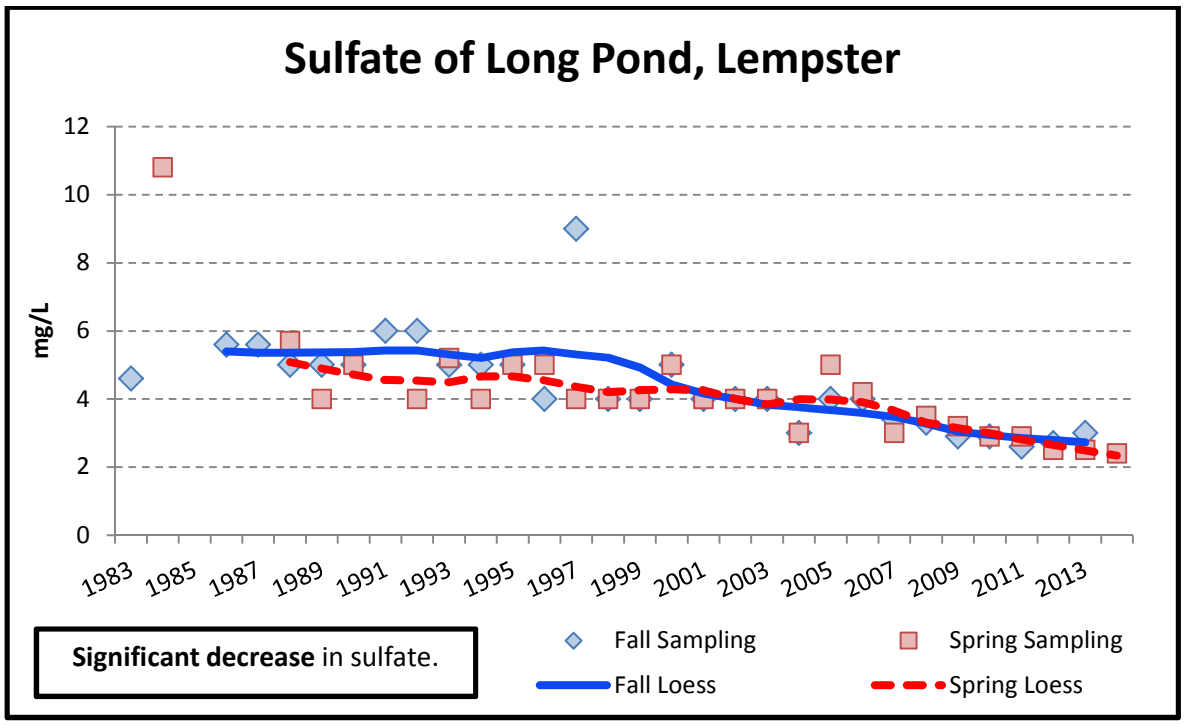


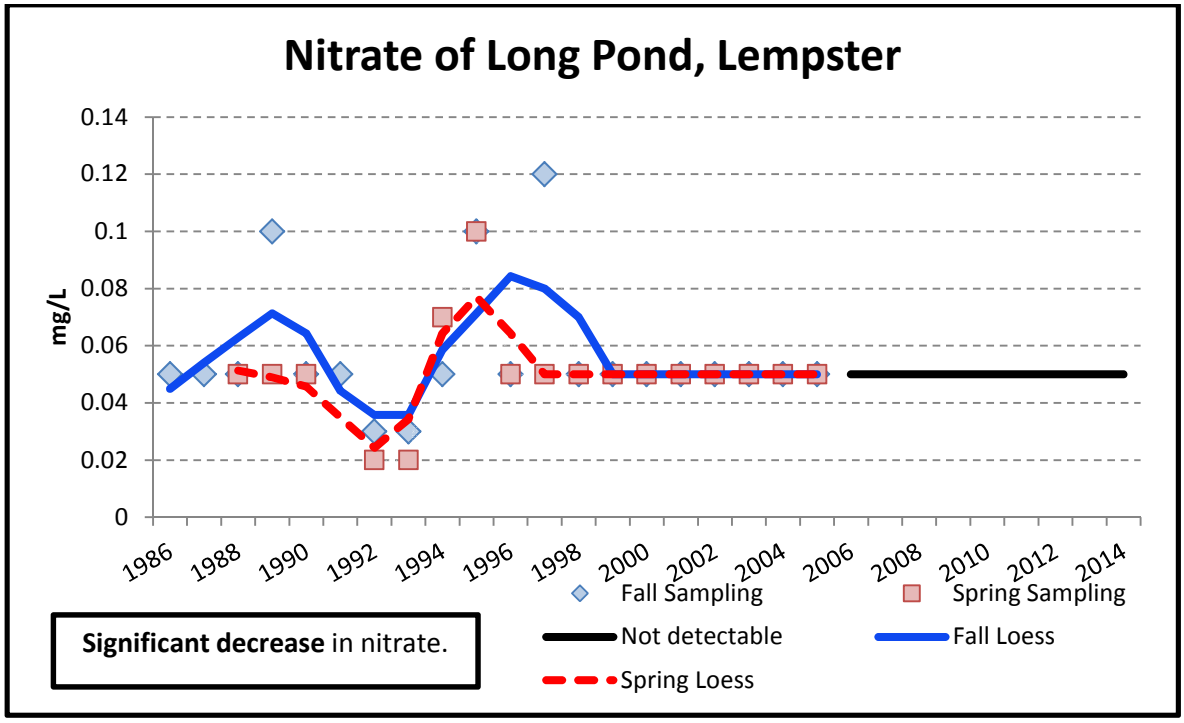
Significant increase in pH.

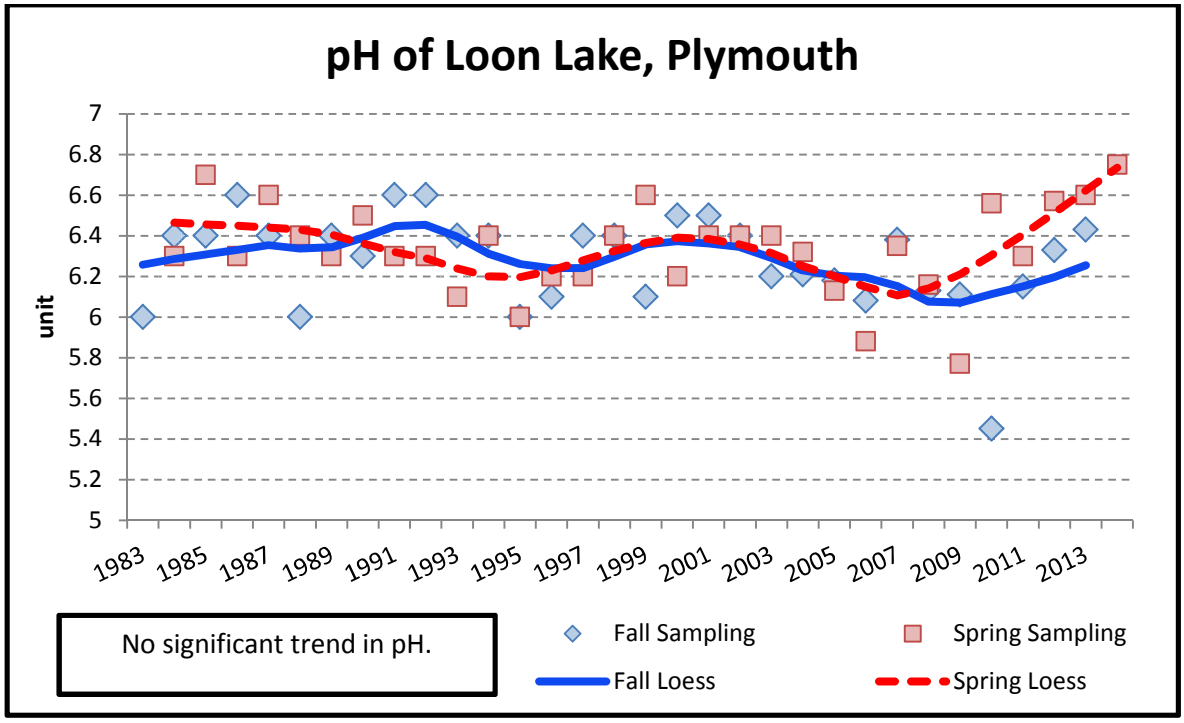


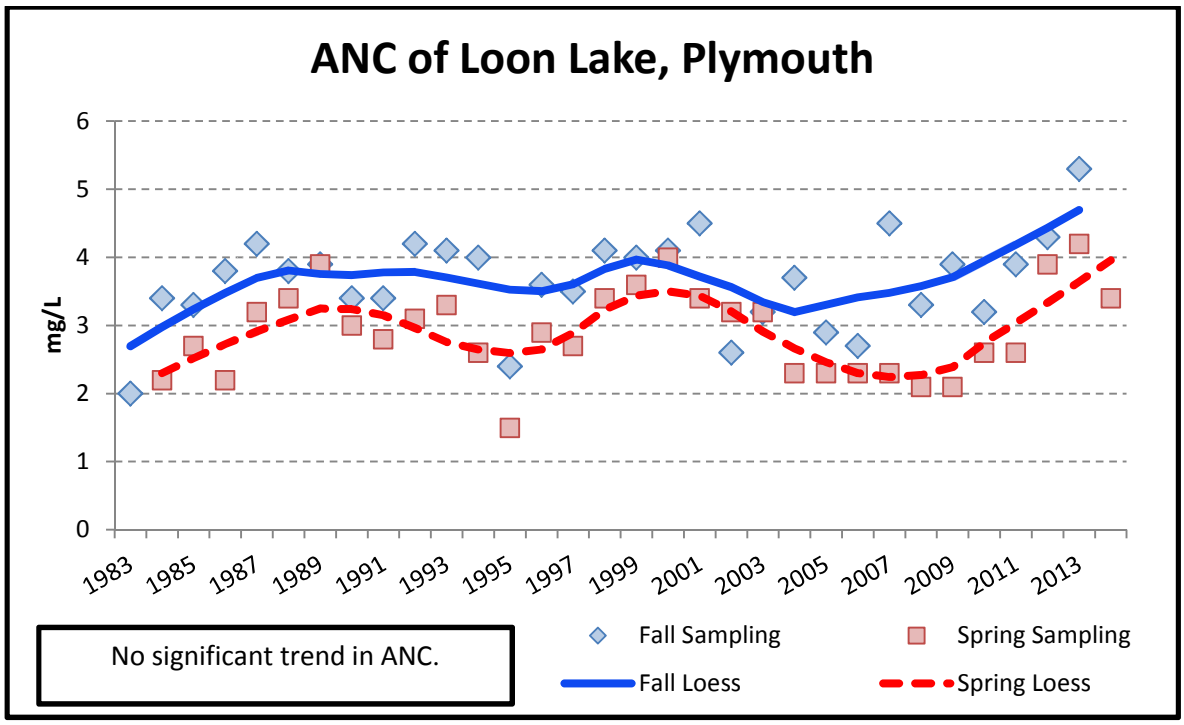
Significant increase in fall ANC. No significant trend in spring ANC.

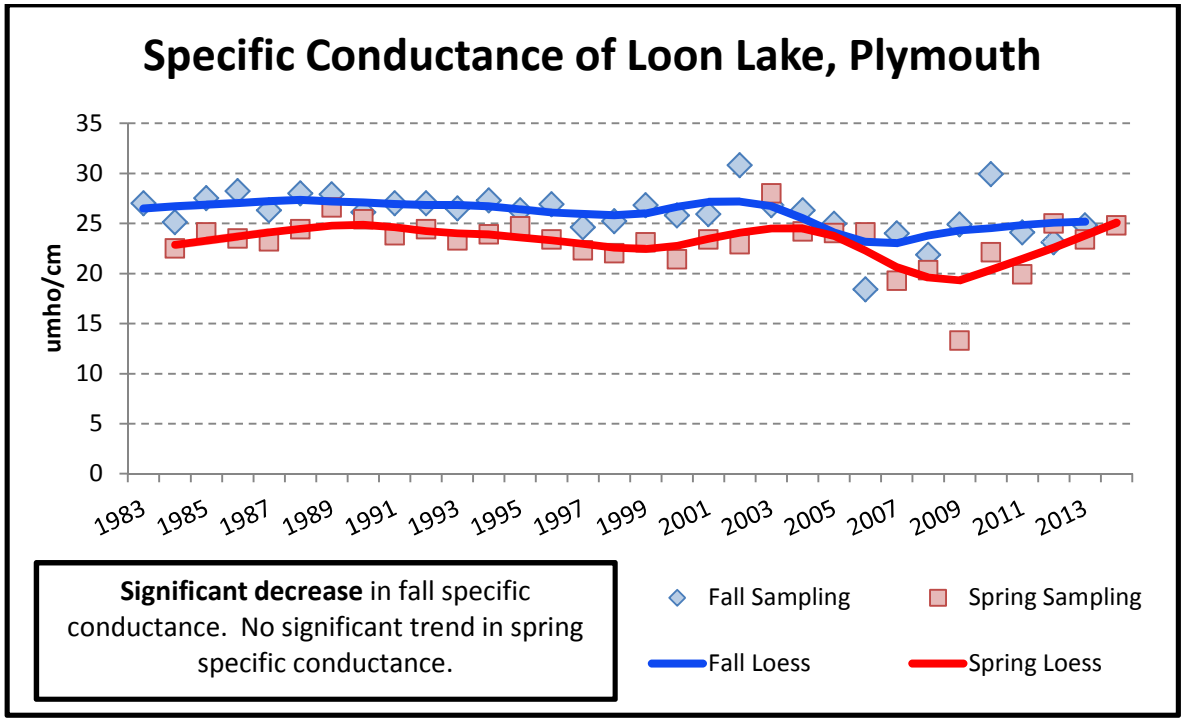

Specific Conductance of Long Pond, Lempster
umho/cm
250
200
150
100
50
0
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Significant decrease in specific conductance.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

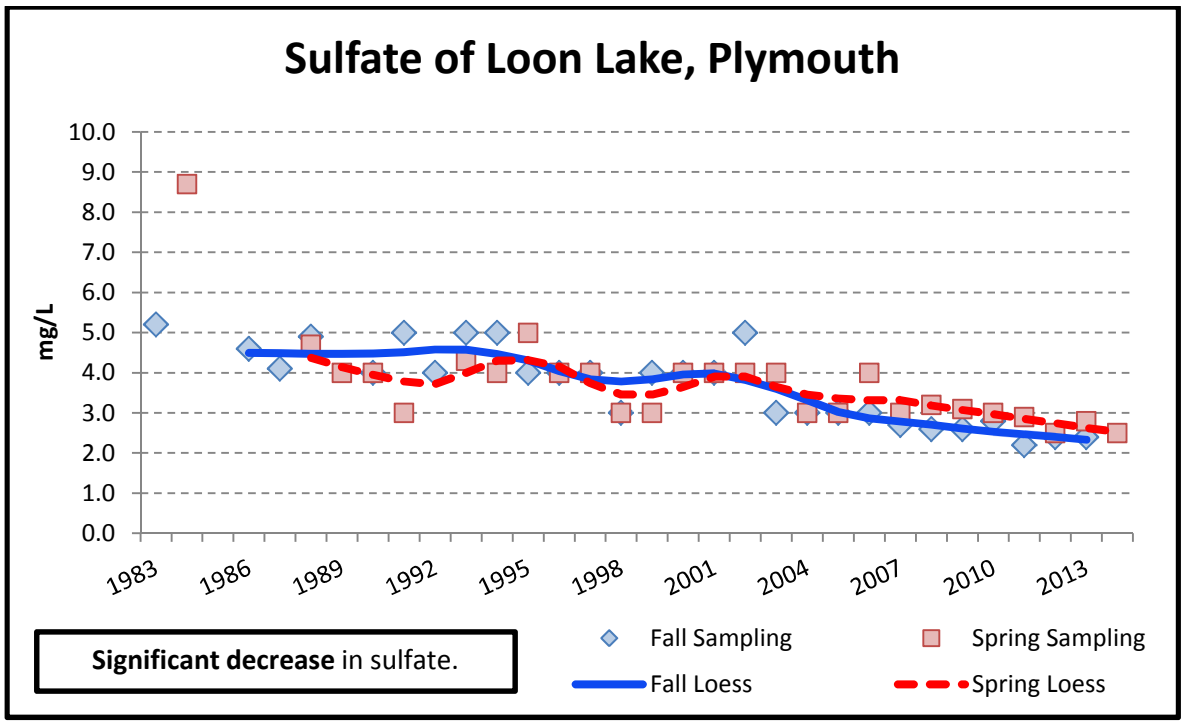

Sulfate of Long Pond, Lempster
mg/L
12
10
8
6
4
2
0
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
Significant decrease in sulfate.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

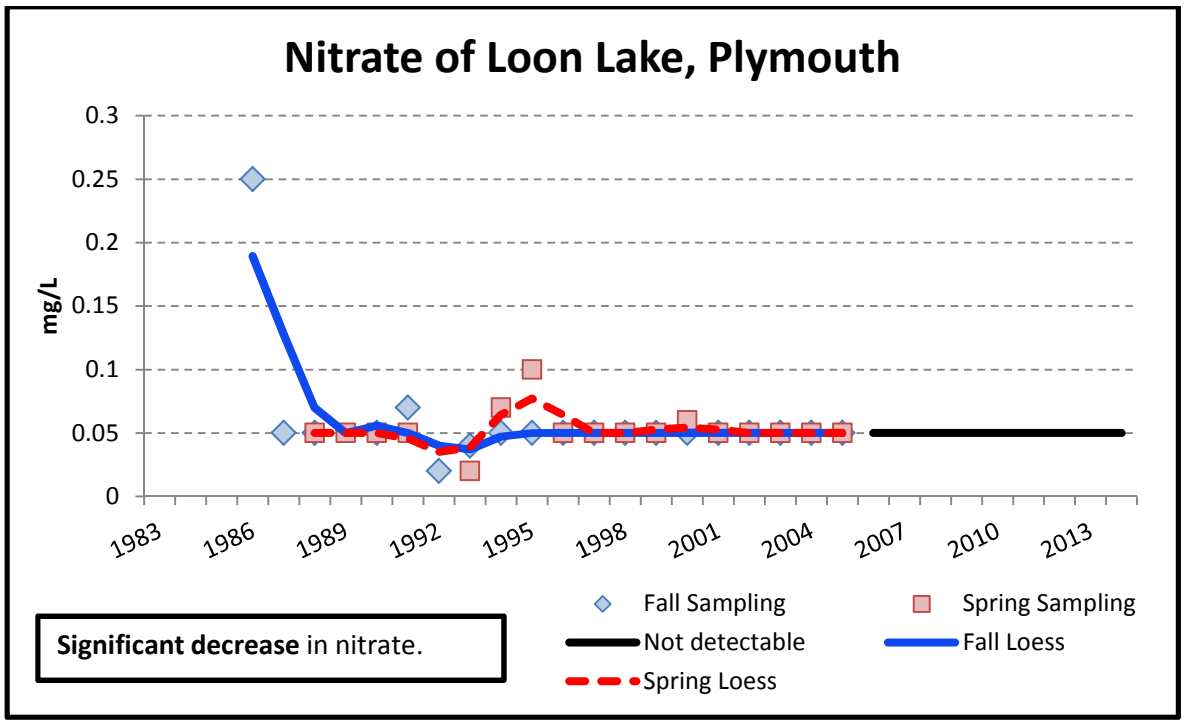

Nitrate of Long Pond, Lempster
mg/L
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
Fall Sampling
Spring Sampling
Not detectable
Fall Loess
Spring Loess
Significant decrease in nitrate.

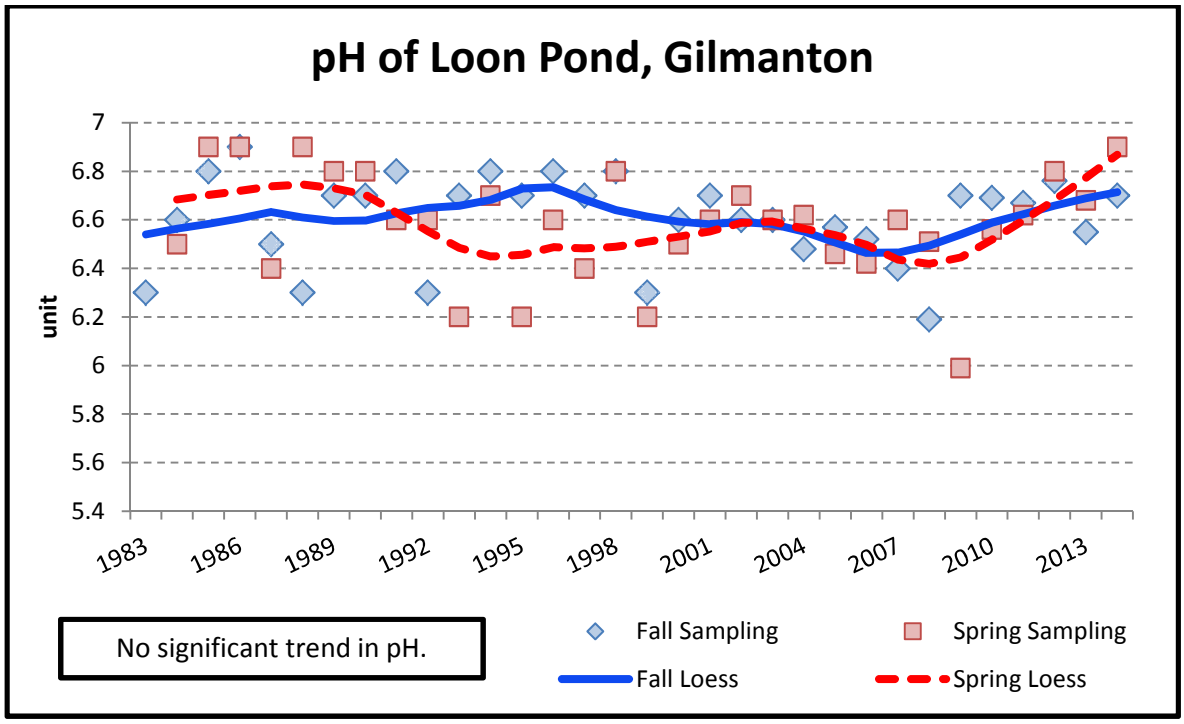

pH of Loon Lake, Plymouth
unit
7
6.8
6.6
6.4
6.2
6
5.8
5.6
5.4
5.2
5
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
No significant trend in pH.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

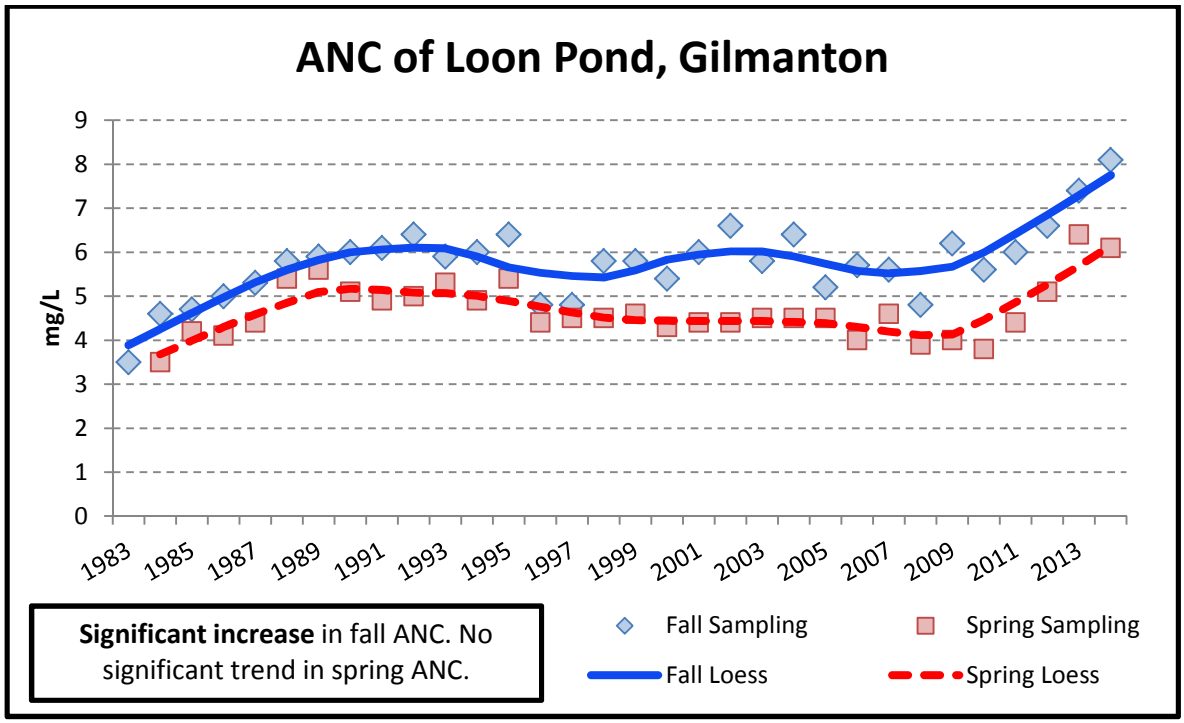

ANC of Loon Lake, Plymouth
mg/L
6
5
4
3
2
1
0
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
No significant trend in ANC.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

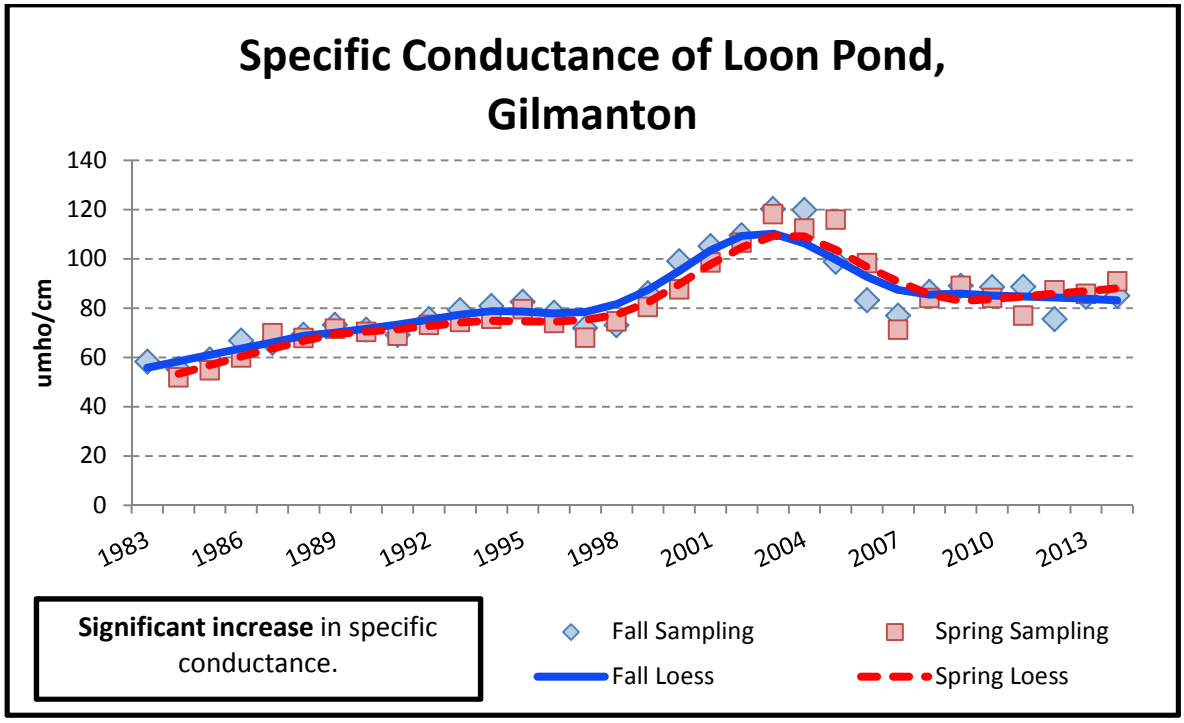

Specific Conductance of Loon Lake, Plymouth
umho/cm
35
30
25
20
15
10
5
0
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
Significant decrease in fall specific conductance. No significant trend in spring specific conductance.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

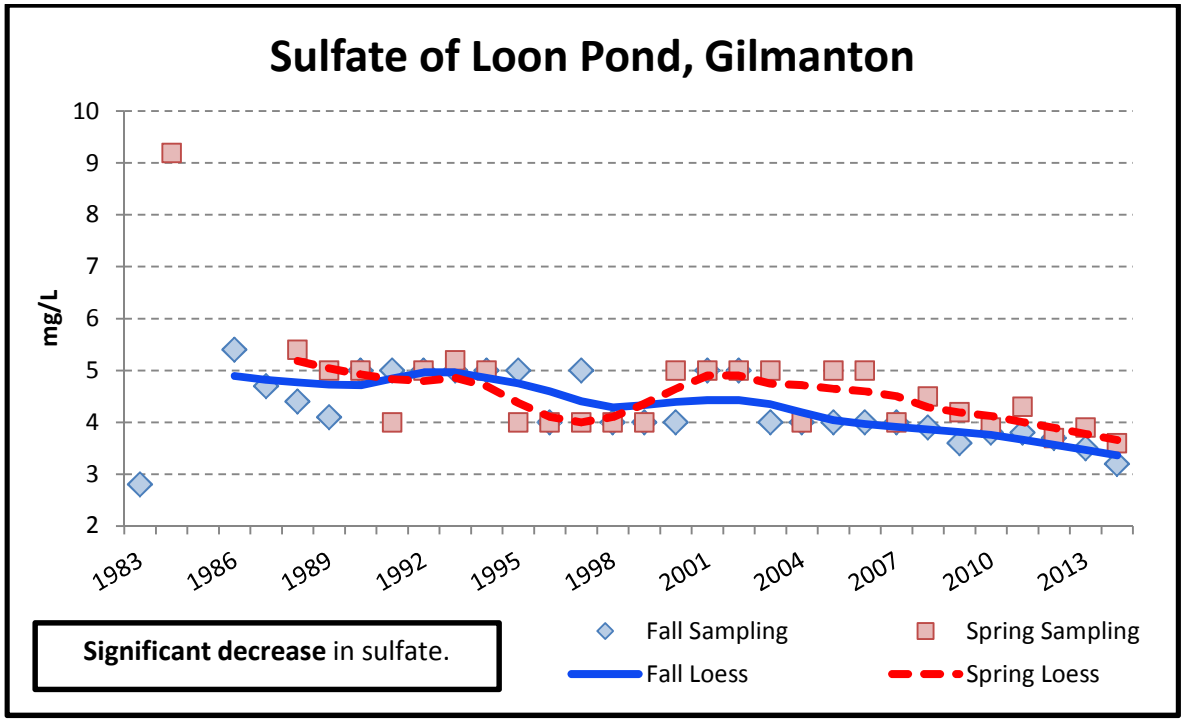

Sulfate of Loon Lake, Plymouth
mg/L
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Significant decrease in sulfate.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

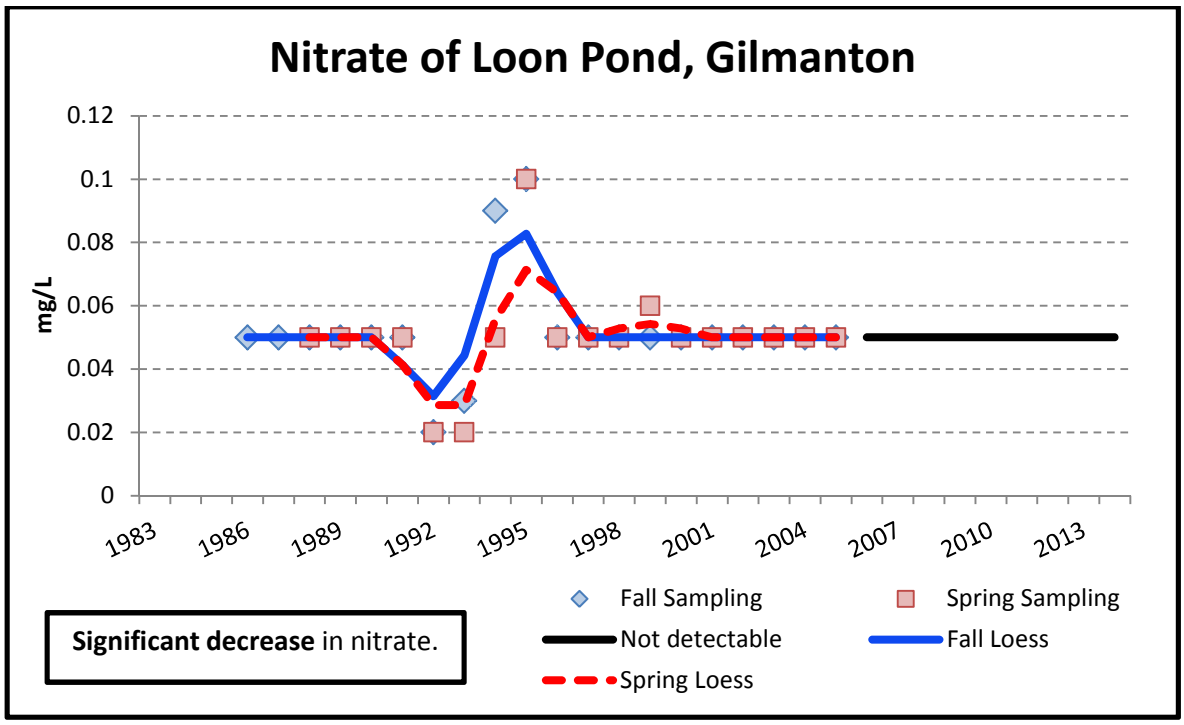

Nitrate of Loon Lake, Plymouth
mg/L
0.3
0.25
0.2
0.15
0.1
0.05
0
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Fall Sampling
Spring Sampling
Not detectable
Fall Loess
Spring Loess
Significant decrease in nitrate.

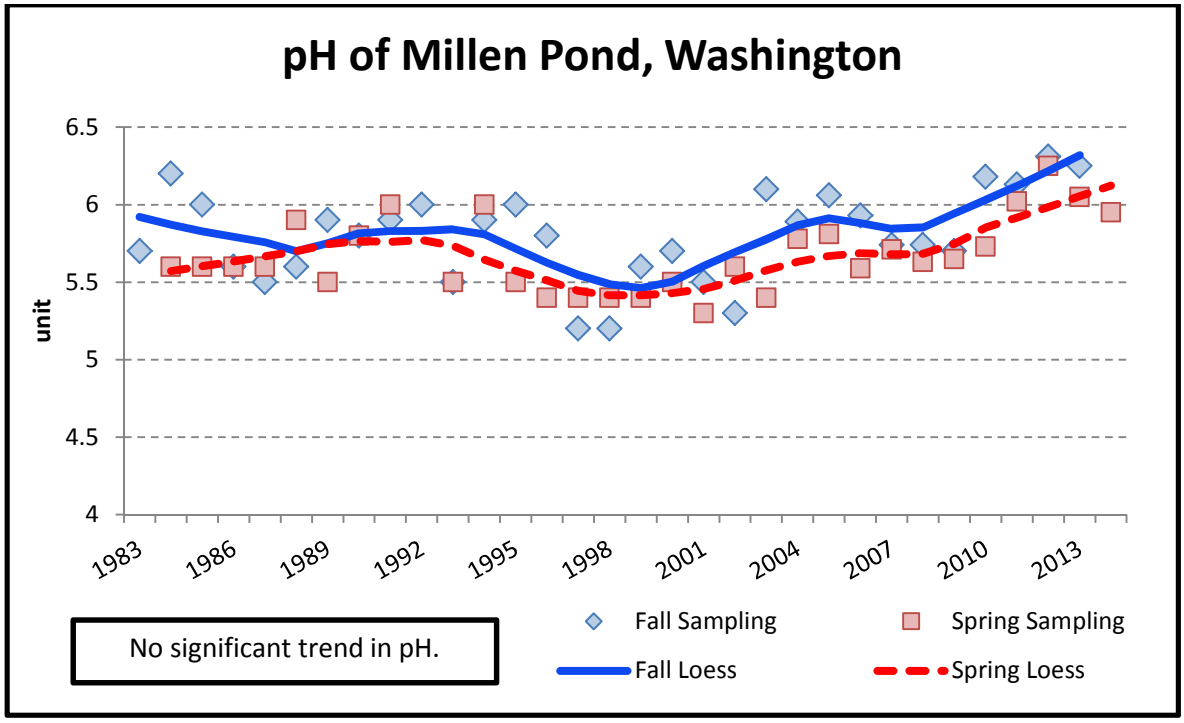

pH of Loon Pond, Gilmanton
unit
7
6.8
6.6
6.4
6.2
6
5.8
5.6
5.4
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
No significant trend in pH.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

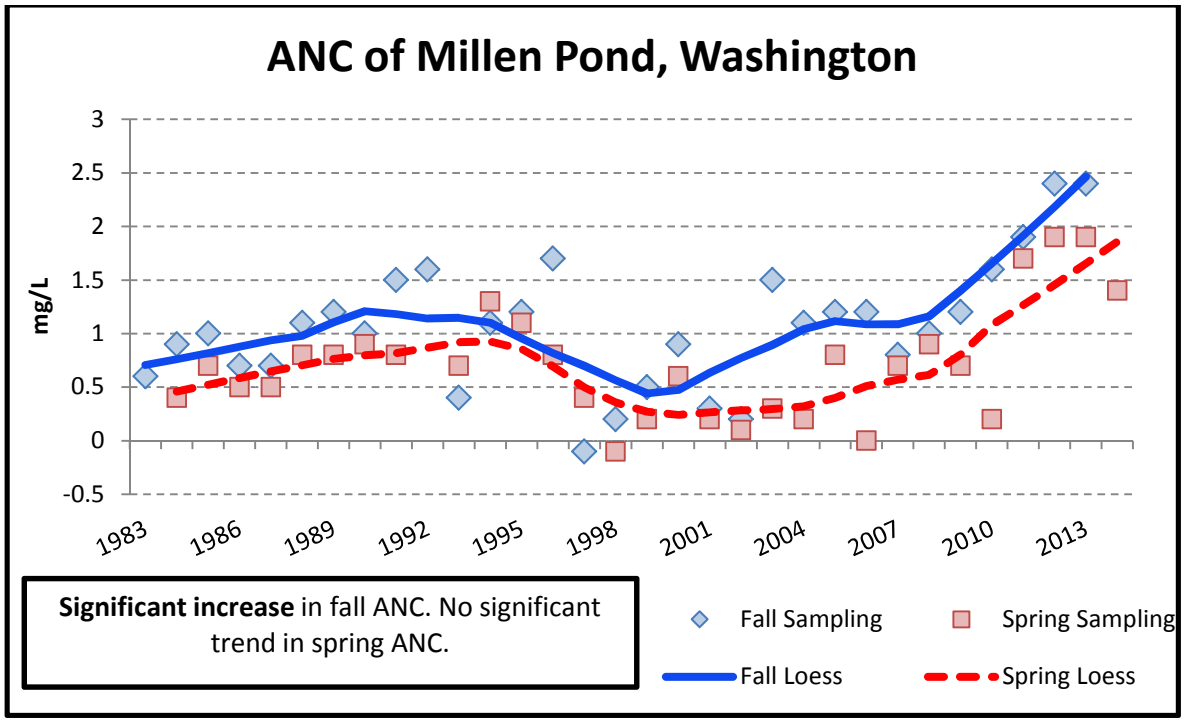

ANC of Loon Pond, Gilmanton
mg/L
9
8
7
6
5
4
3
2
1
0
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
Significant increase in fall ANC. No significant trend in spring ANC.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

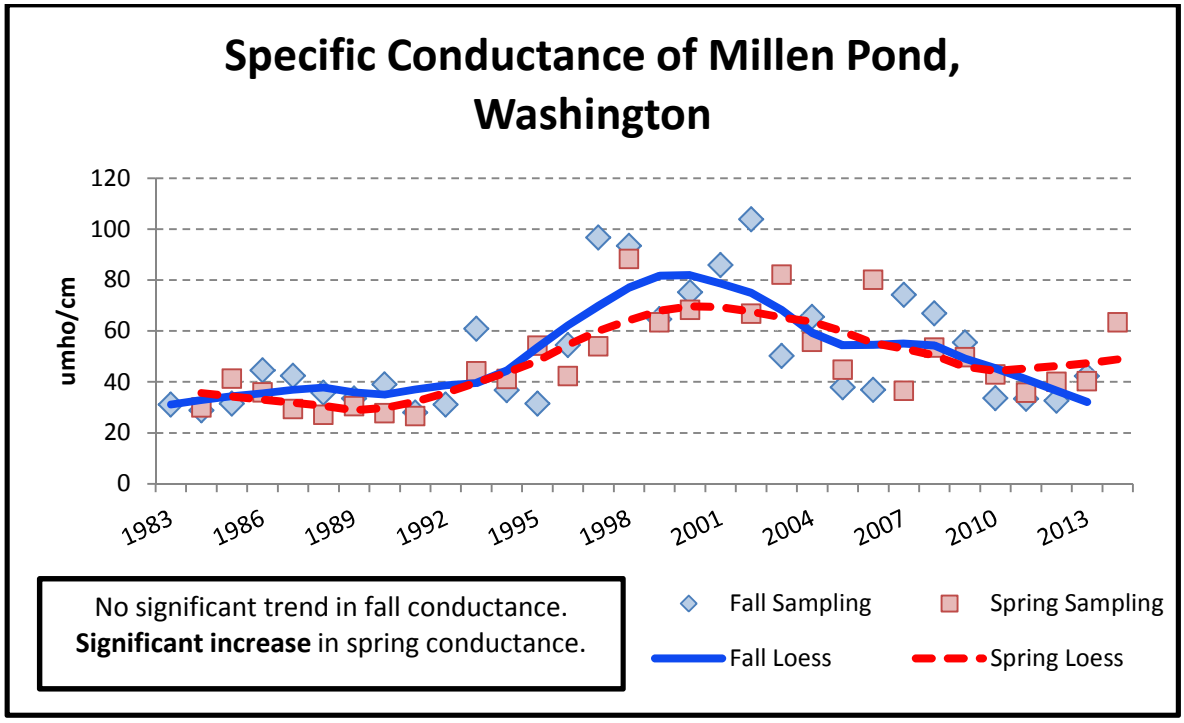

Specific Conductance of Loon Pond, Gilmanton
umho/cm
140
120
100
80
60
40
20
0
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Significant increase in specific conductance.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

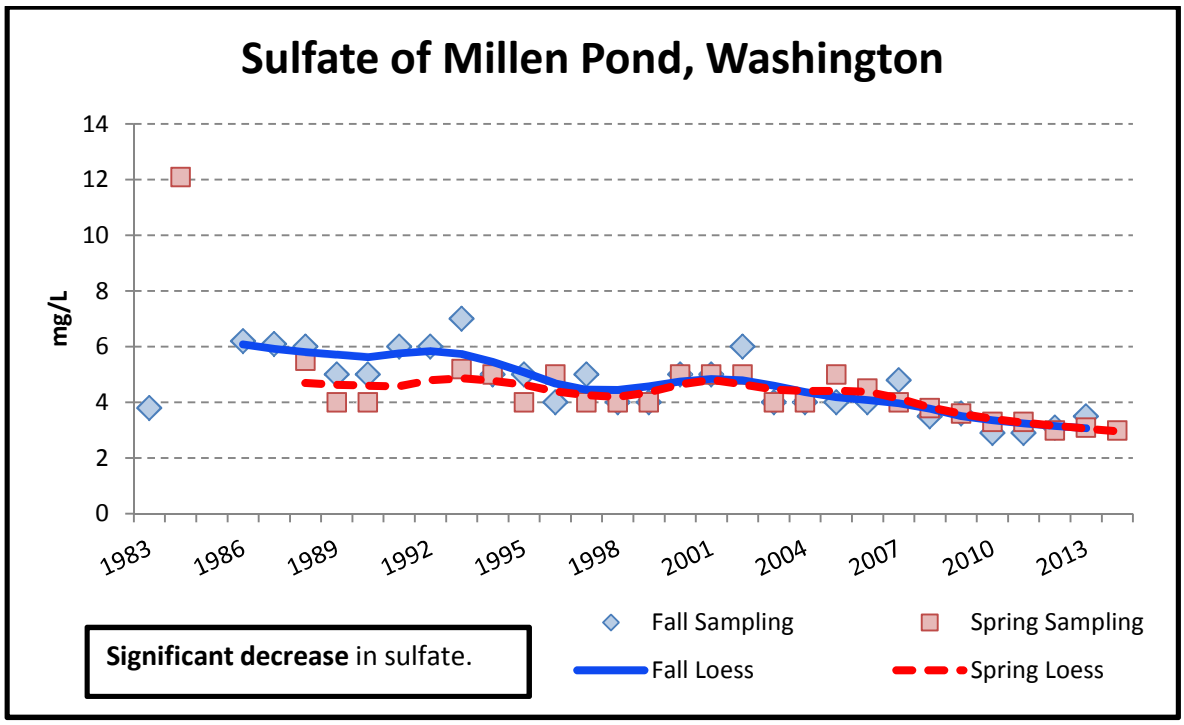

Sulfate of Loon Pond, Gilmanton
mg/L
10
9
8
7
6
5
4
3
2
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Significant decrease in sulfate.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

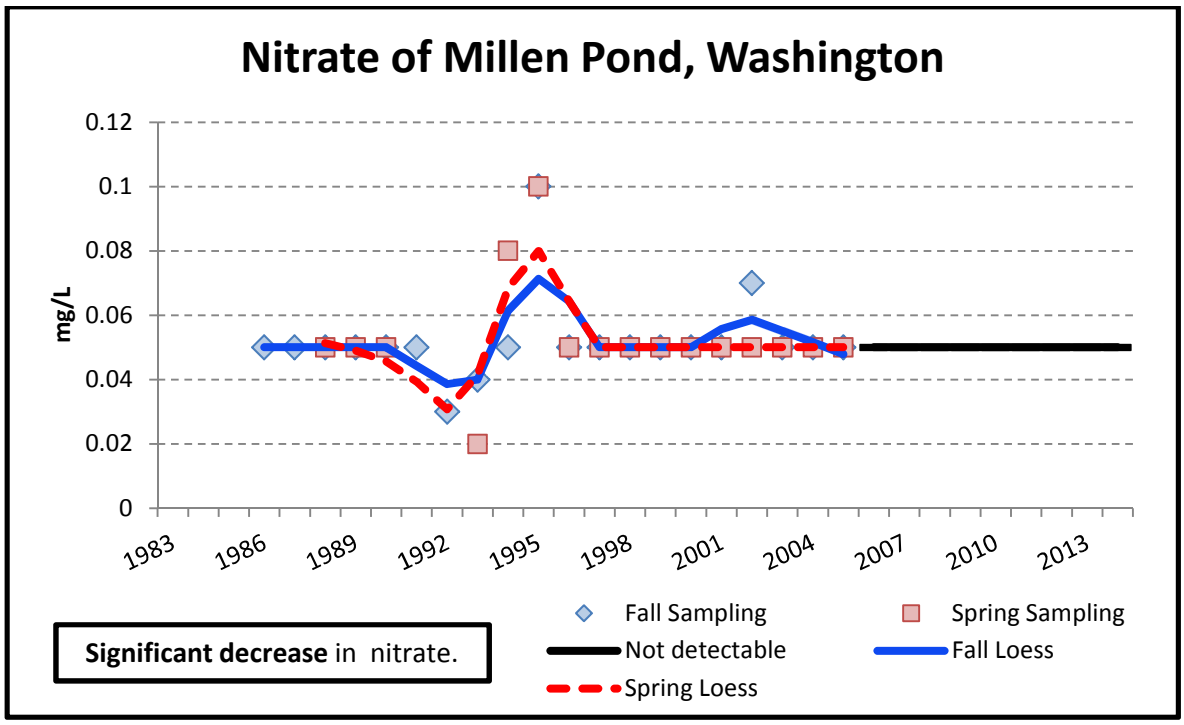

Nitrate of Loon Pond, Gilmanton
0.12
0.1
0.08
0.06
0.04
0.02
0
mg/L
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Fall Sampling
Spring Sampling
Not detectable
Fall Loess
Spring Loess
Significant decrease in nitrate.

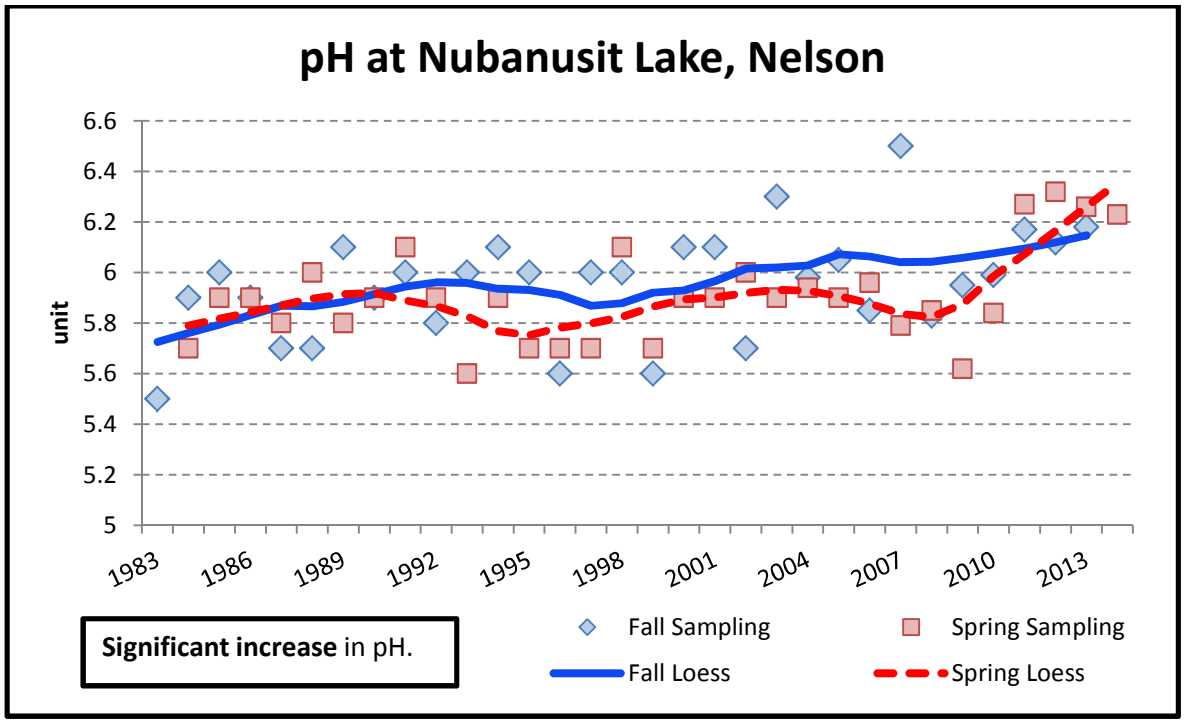

pH of Millen Pond, Washington
6.5
6
5.5
5
4.5
4
unit
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
No significant trend in pH.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

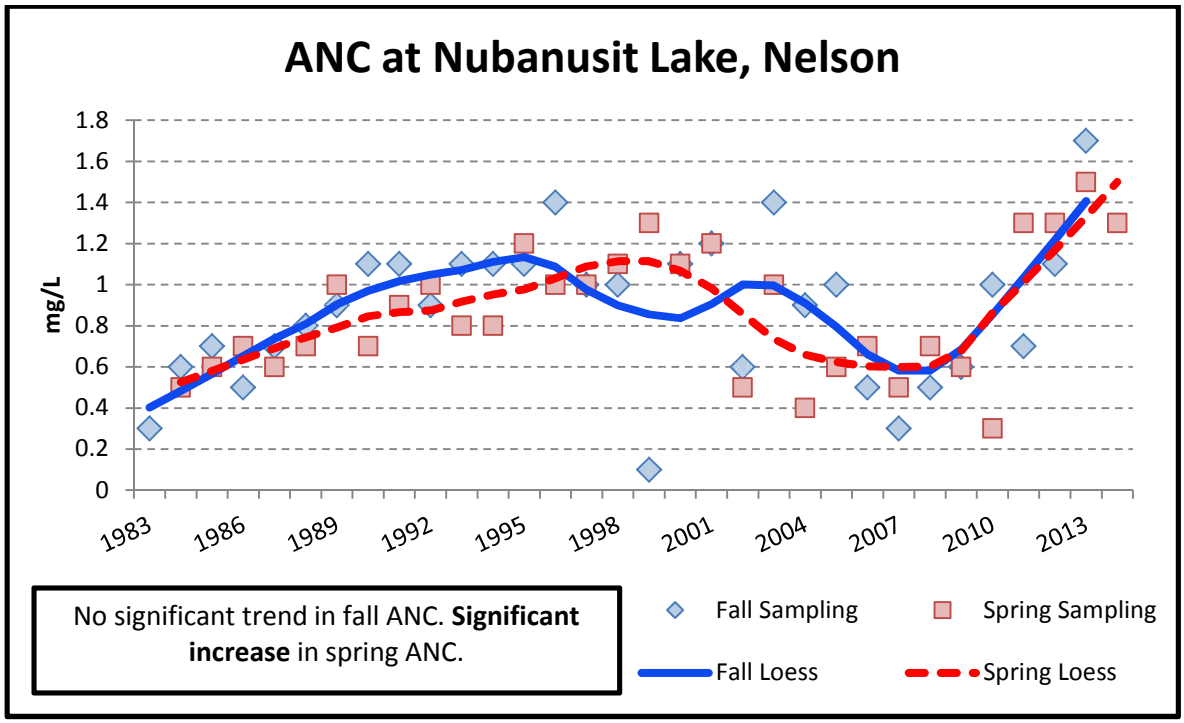

ANC of Millen Pond, Washington
3
2.5
2
1.5
1
0.5
0
-0.5
mg/L
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Significant increase in fall ANC. No significant trend in spring ANC.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

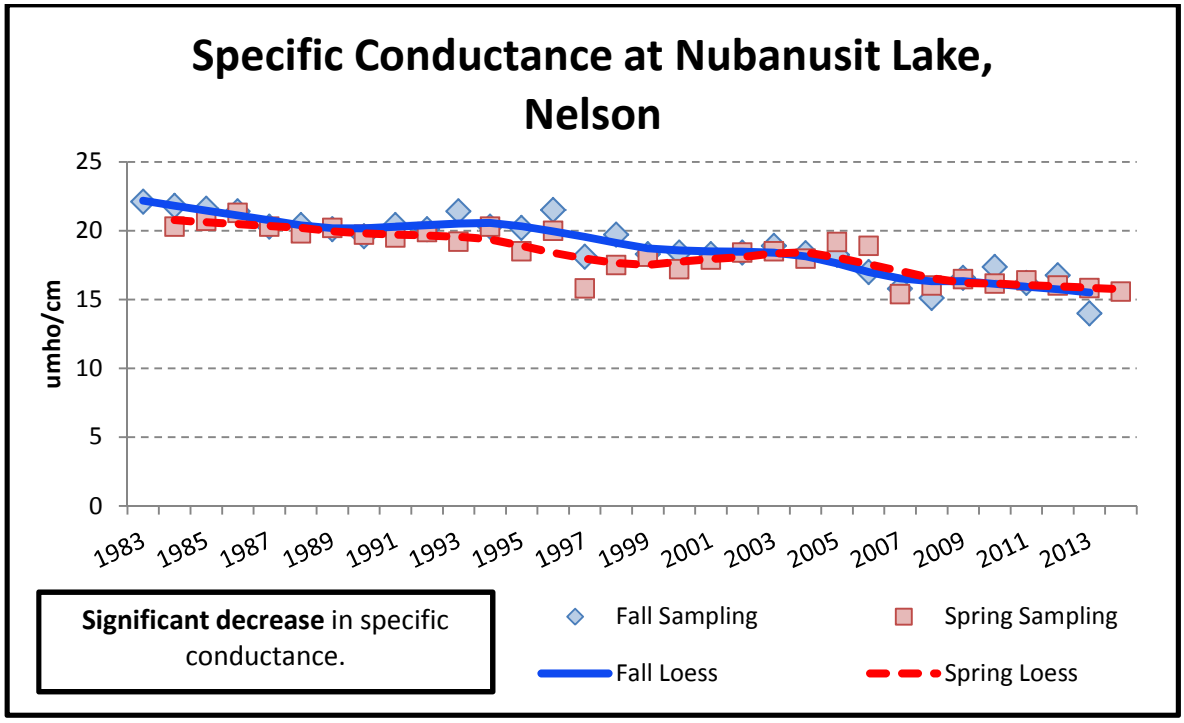

Specific Conductance of Millen Pond, Washington
umho/cm
120
100
80
60
40
20
0
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
No significant trend in fall conductance.
Significant increase in spring conductance.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

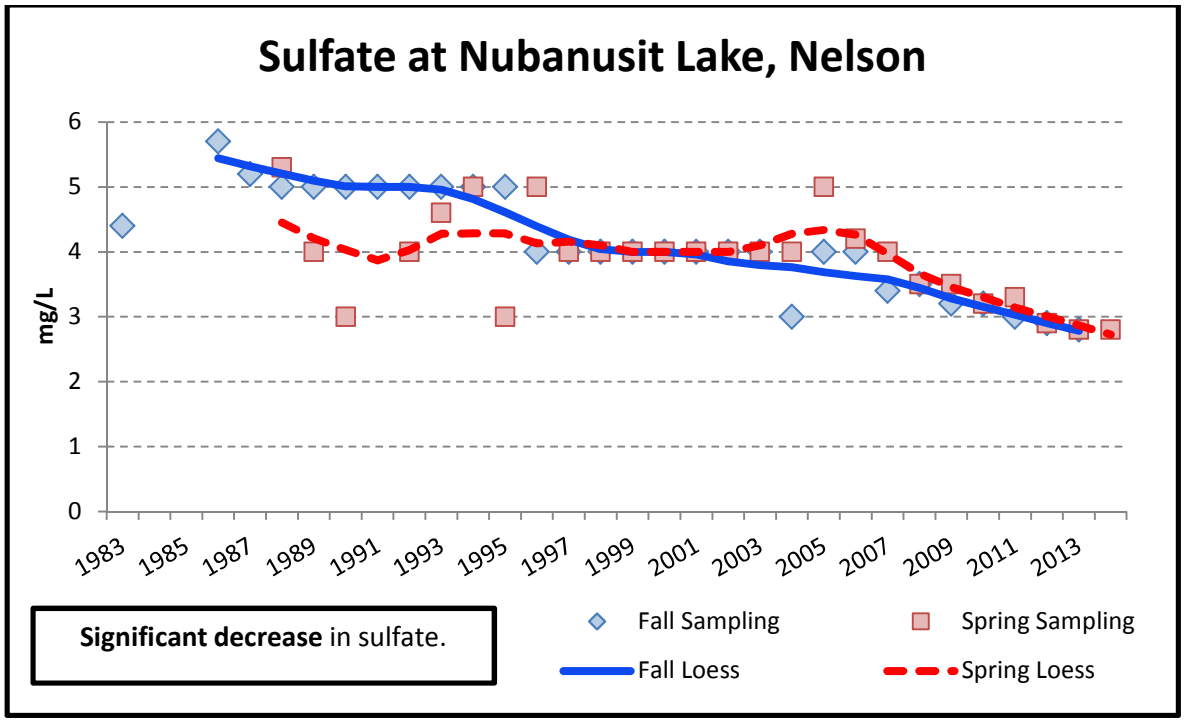

Sulfate of Millen Pond, Washington
mg/L
14
12
10
8
6
4
2
0
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Significant decrease in sulfate.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

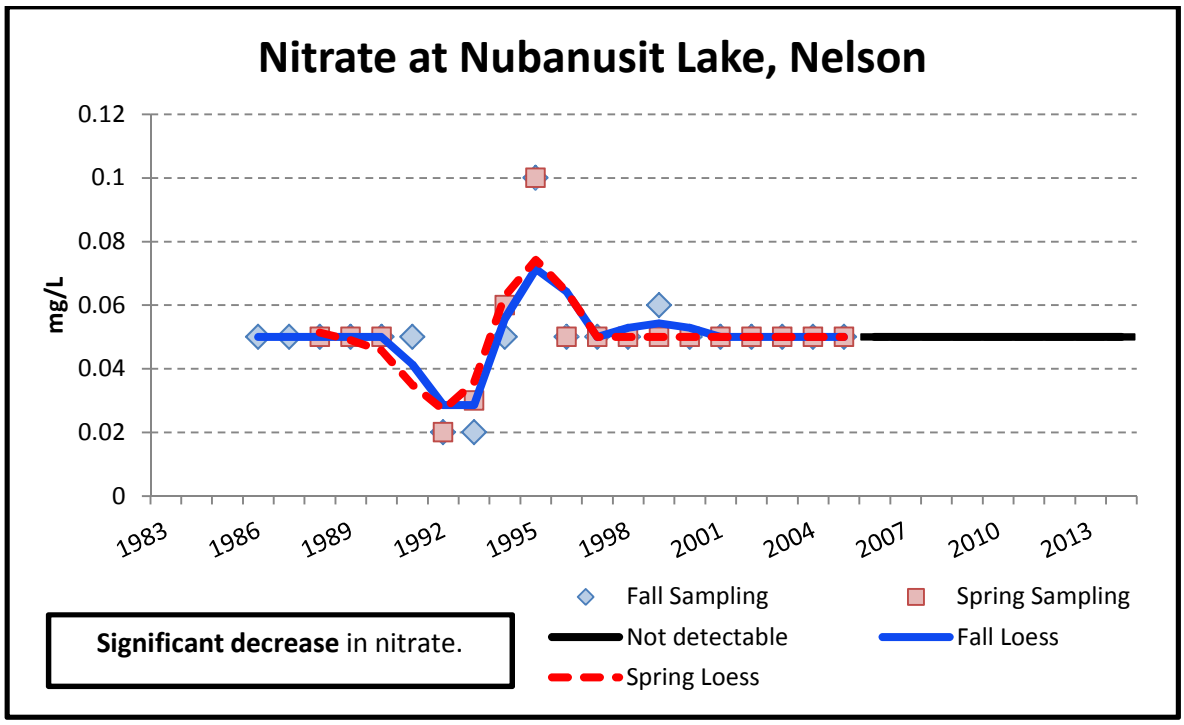

Nitrate of Millen Pond, Washington
0.12
0.1
0.08
0.06
0.04
0.02
0
mg/L
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Fall Sampling
Spring Sampling
Not detectable
Fall Loess
Spring Loess
Significant decrease in nitrate.

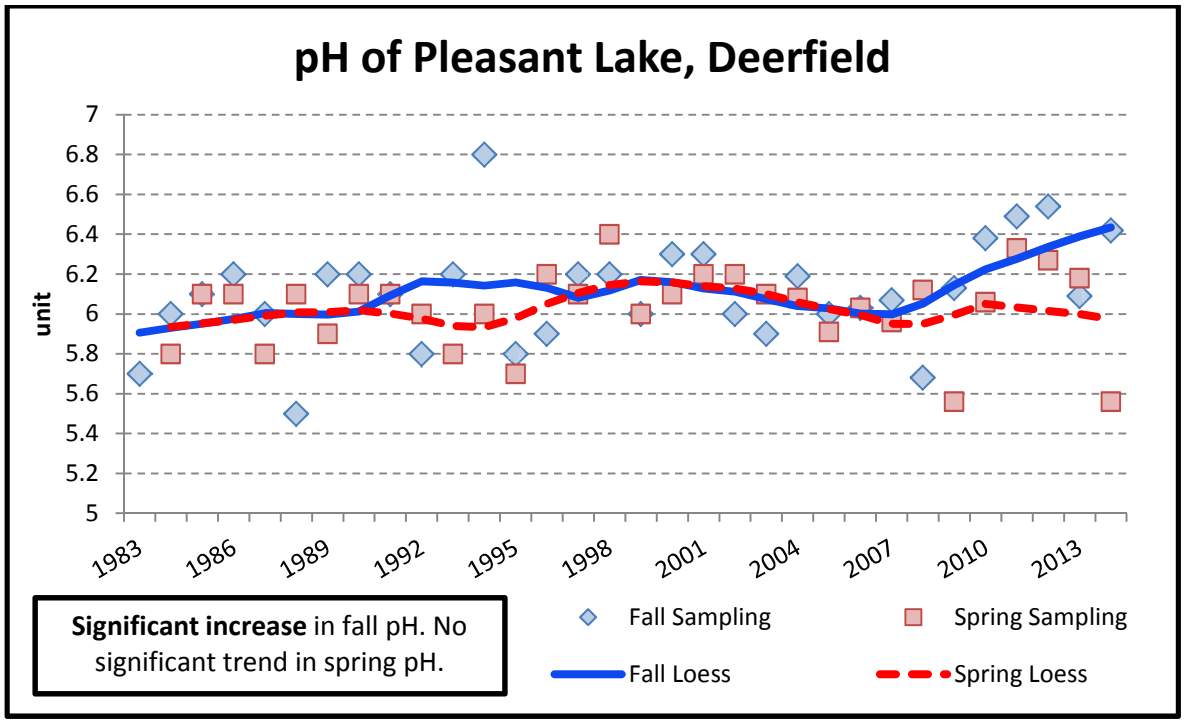

pH at Nubanusit Lake, Nelson
unit
6.6
6.4
6.2
6
5.8
5.6
5.4
5.2
5
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Significant increase in pH.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

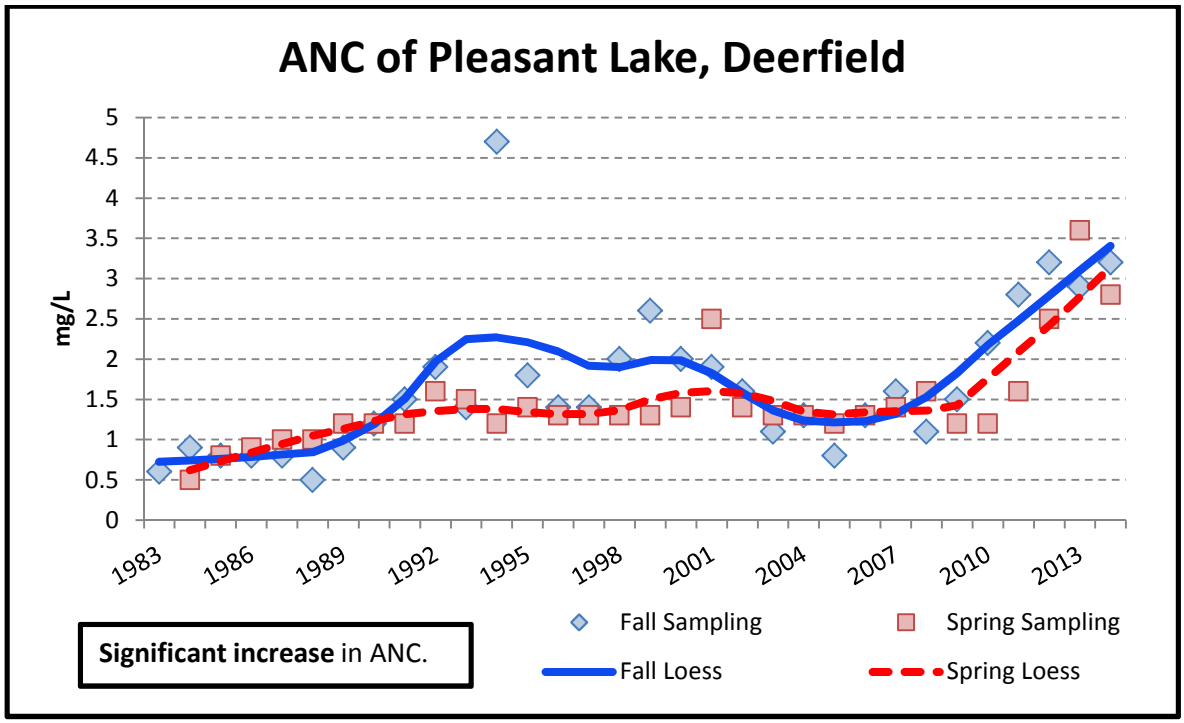

ANC at Nubanusit Lake, Nelson
mg/L
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
No significant trend in fall ANC. Significant increase in spring ANC.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

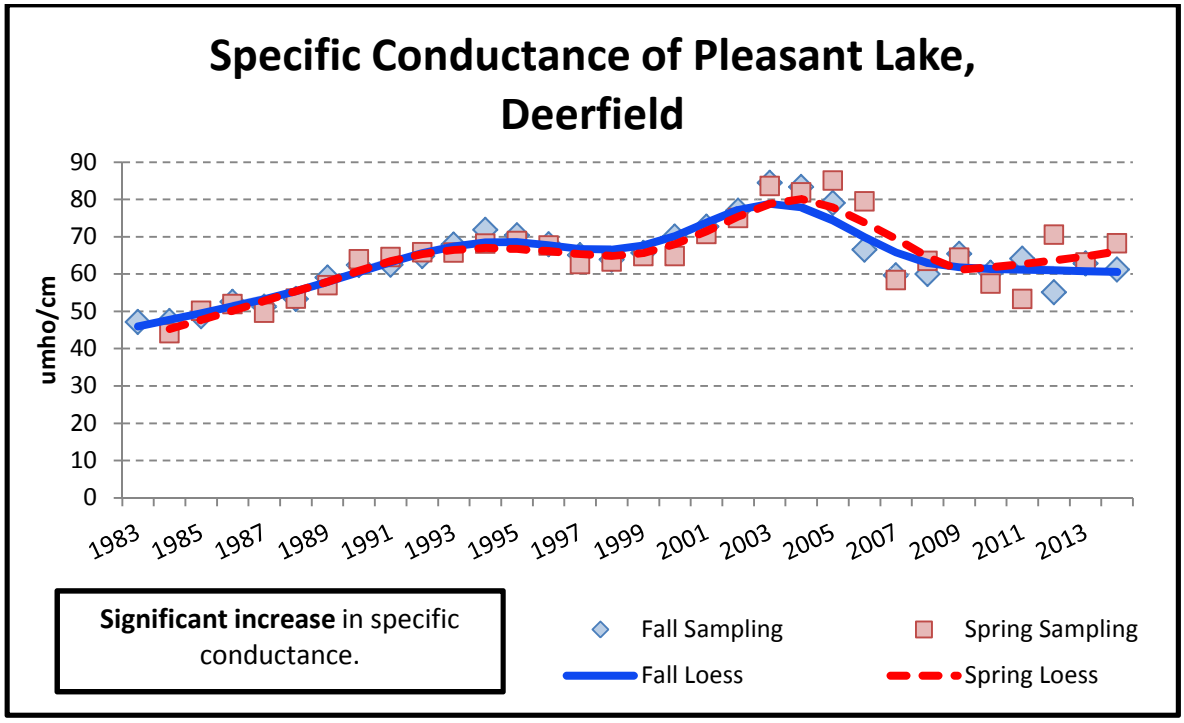

Specific Conductance at Nubanusit Lake, Nelson
umho/cm
25
20
15
10
5
0
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
Significant decrease in specific conductance.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

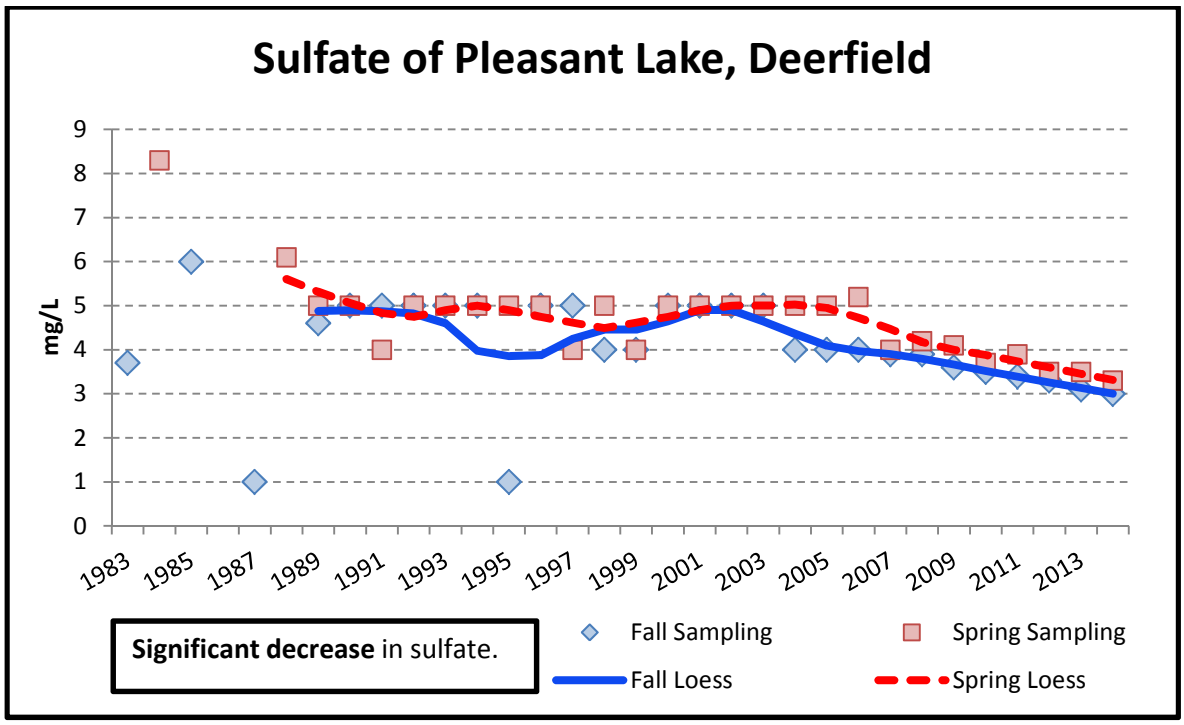

Sulfate at Nubanusit Lake, Nelson
mg/L
6
5
4
3
2
1
0
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
Significant decrease in sulfate.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

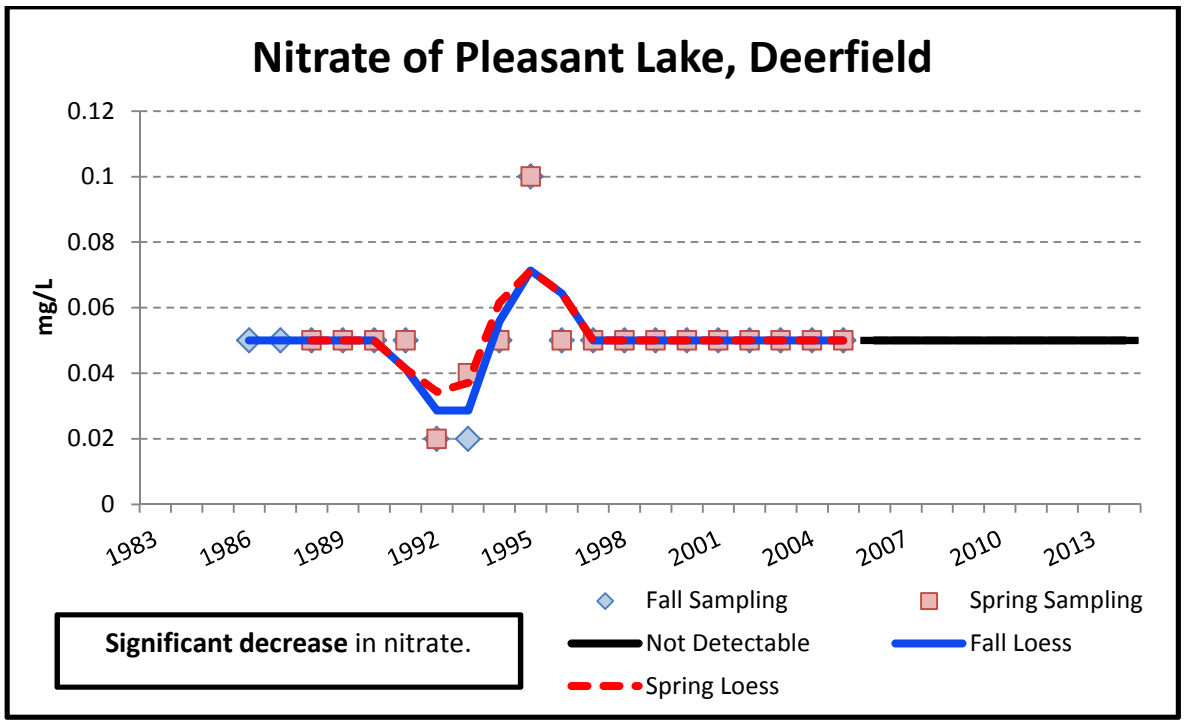

Nitrate at Nubanusit Lake, Nelson
0.12
0.1
0.08
0.06
0.04
0.02
0
mg/L
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Fall Sampling
Spring Sampling
Not detectable
Fall Loess
Spring Loess
Significant decrease in nitrate.

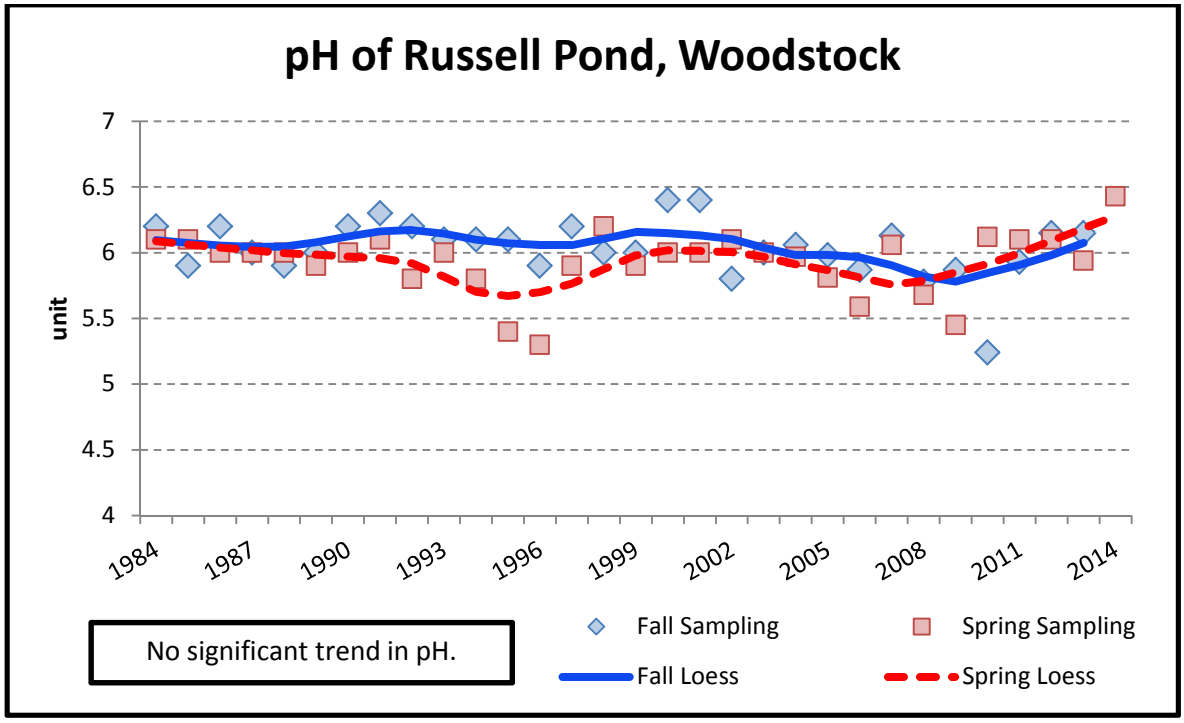

pH of Pleasant Lake, Deerfield
unit
7
6.8
6.6
6.4
6.2
6
5.8
5.6
5.4
5.2
5
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Significant increase in fall pH. No significant trend in spring pH.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

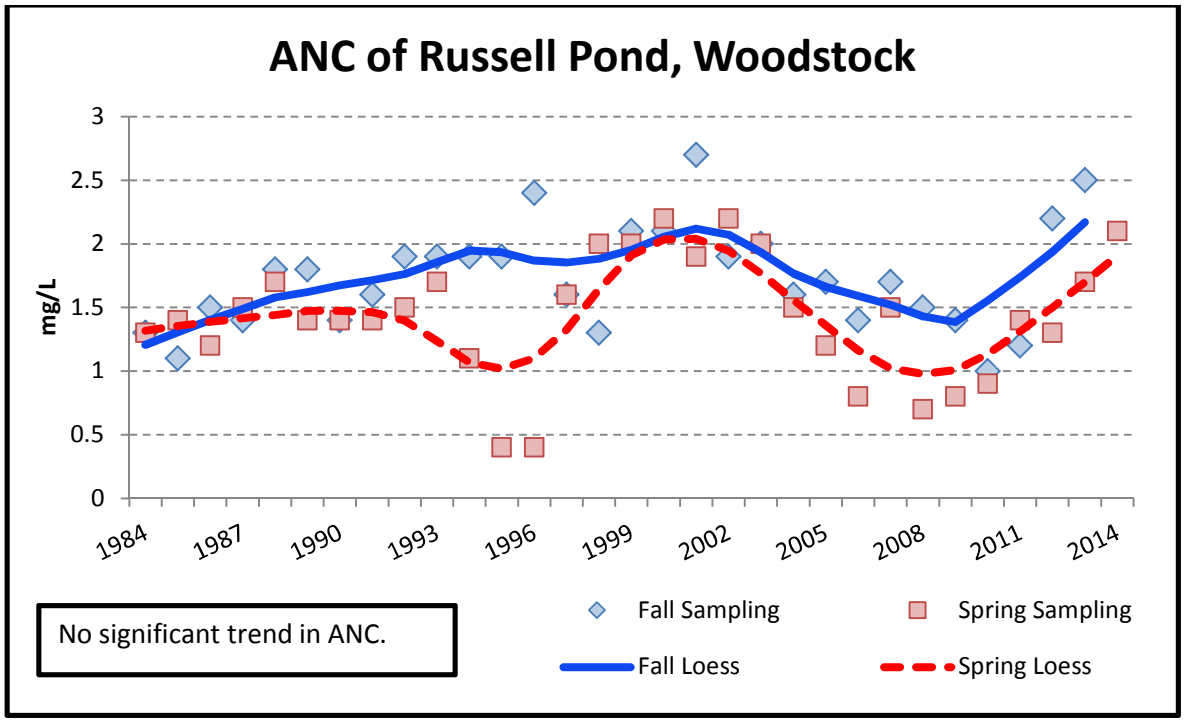

ANC of Pleasant Lake, Deerfield
mg/L
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Significant increase in ANC.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

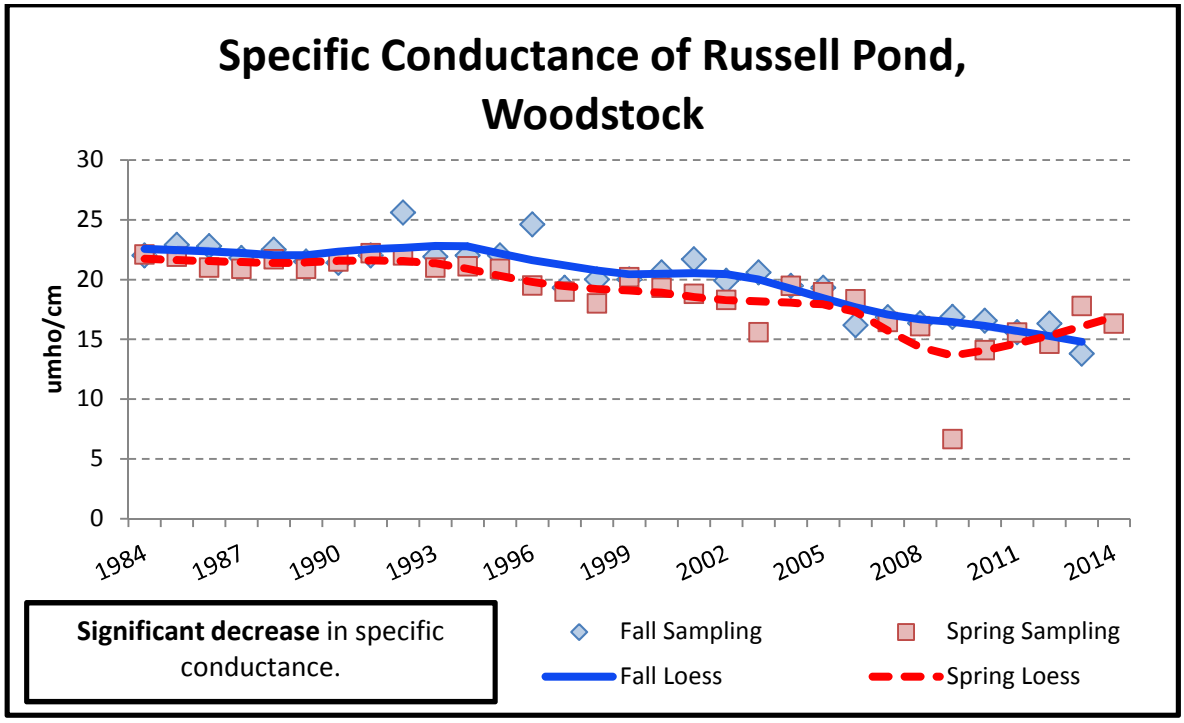

Specific Conductance of Pleasant Lake, Deerfield
umho/cm
90
80
70
60
50
40
30
20
10
0
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
Significant increase in specific conductance.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

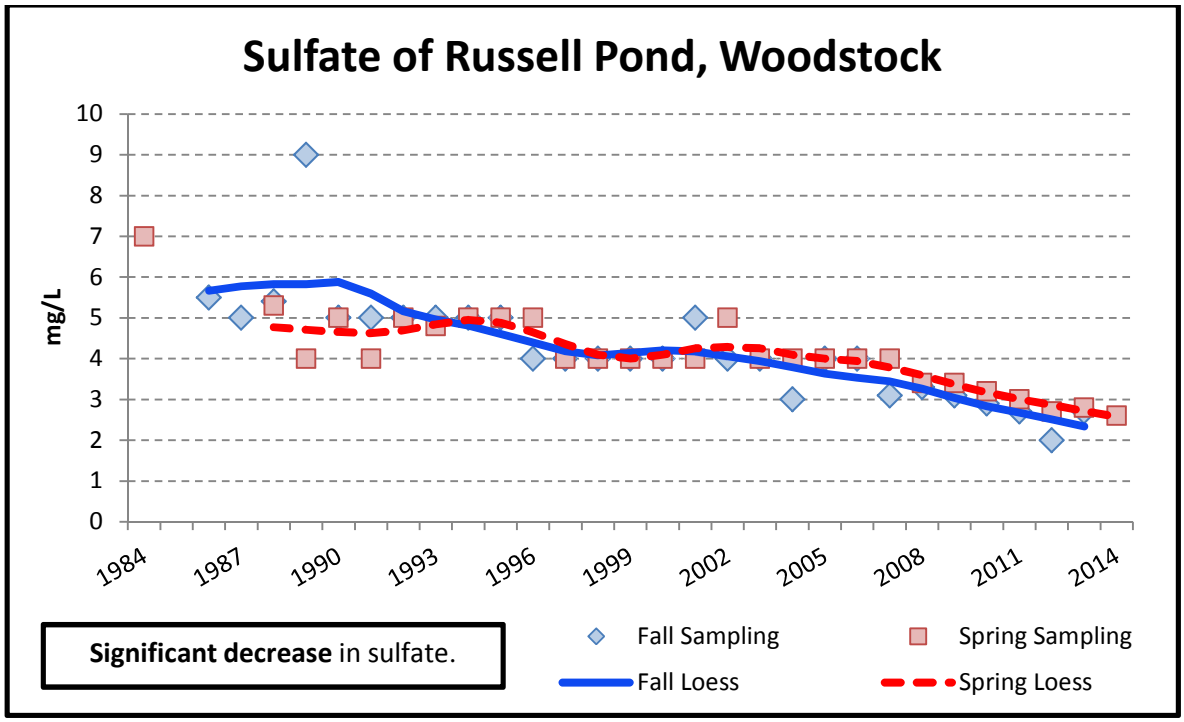

Sulfate of Pleasant Lake, Deerfield
mg/L
9
8
7
6
5
4
3
2
1
0
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
Significant decrease in sulfate.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

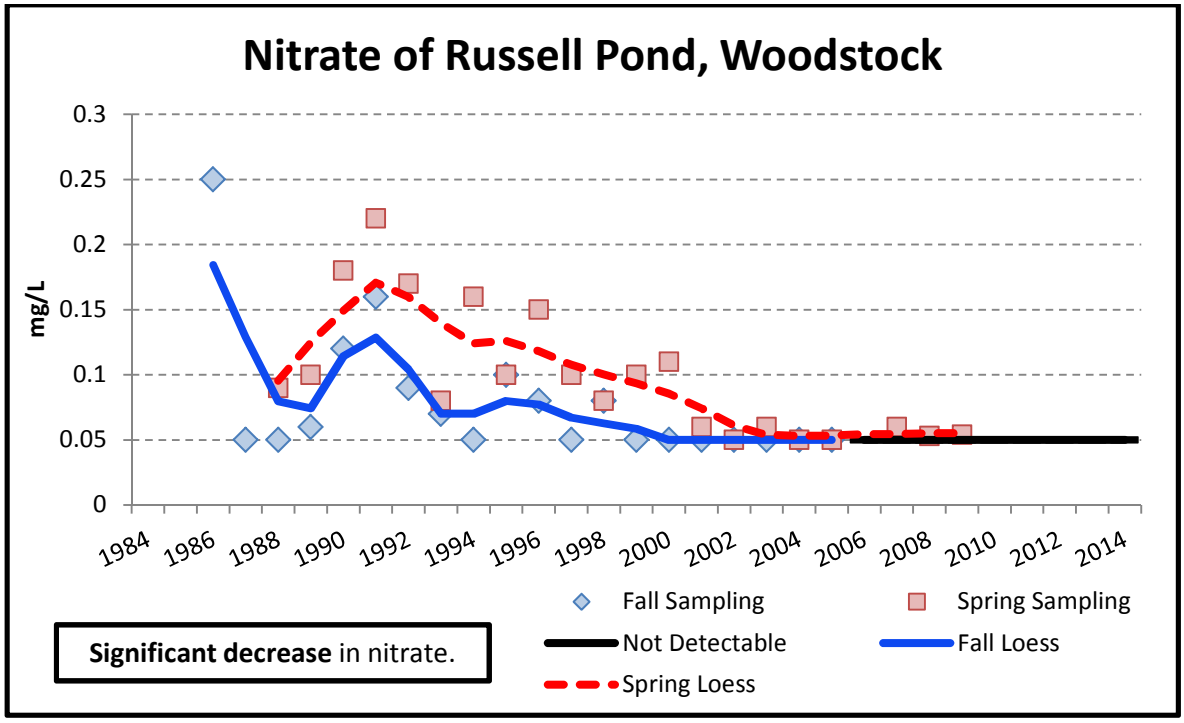

Nitrate of Pleasant Lake, Deerfield
mg/L
0.12
0.1
0.08
0.06
0.04
0.02
0
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Fall Sampling
Spring Sampling
Not Detectable
Fall Loess
Spring Loess
Significant decrease in nitrate.

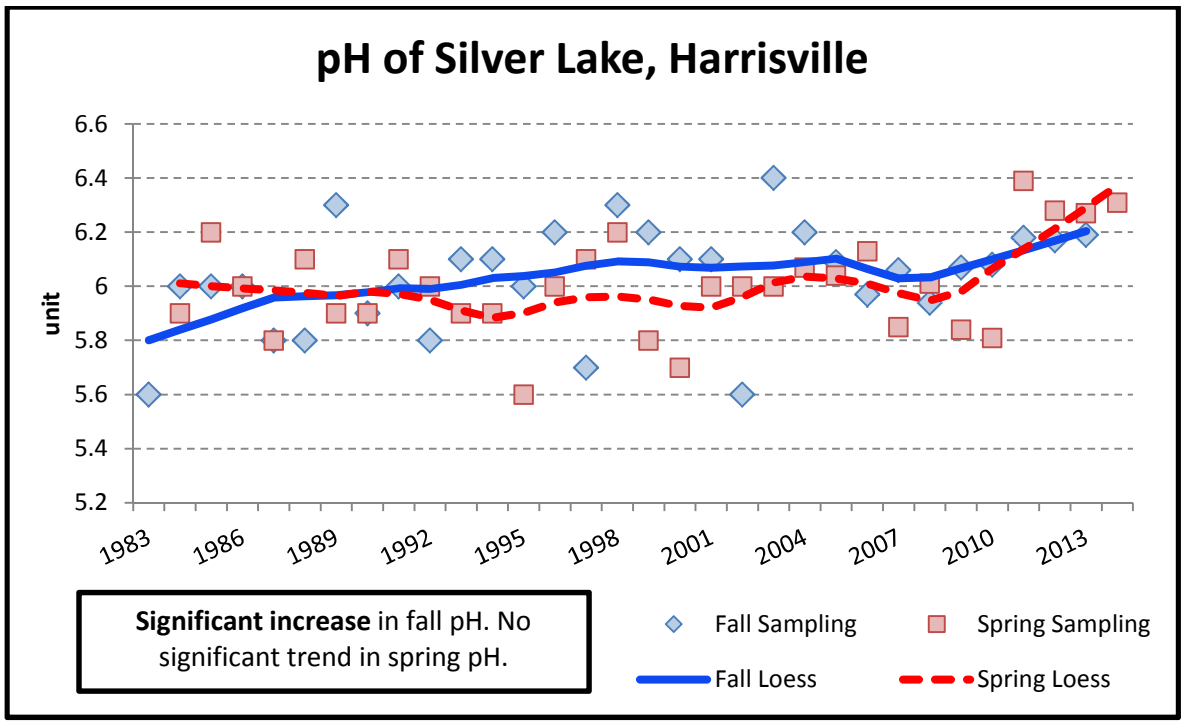

pH of Russell Pond, Woodstock
unit
7
6.5
6
5.5
5
4.5
4
1984
1987
1990
1993
1996
1999
2002
2005
2008
2011
2014
No significant trend in pH.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

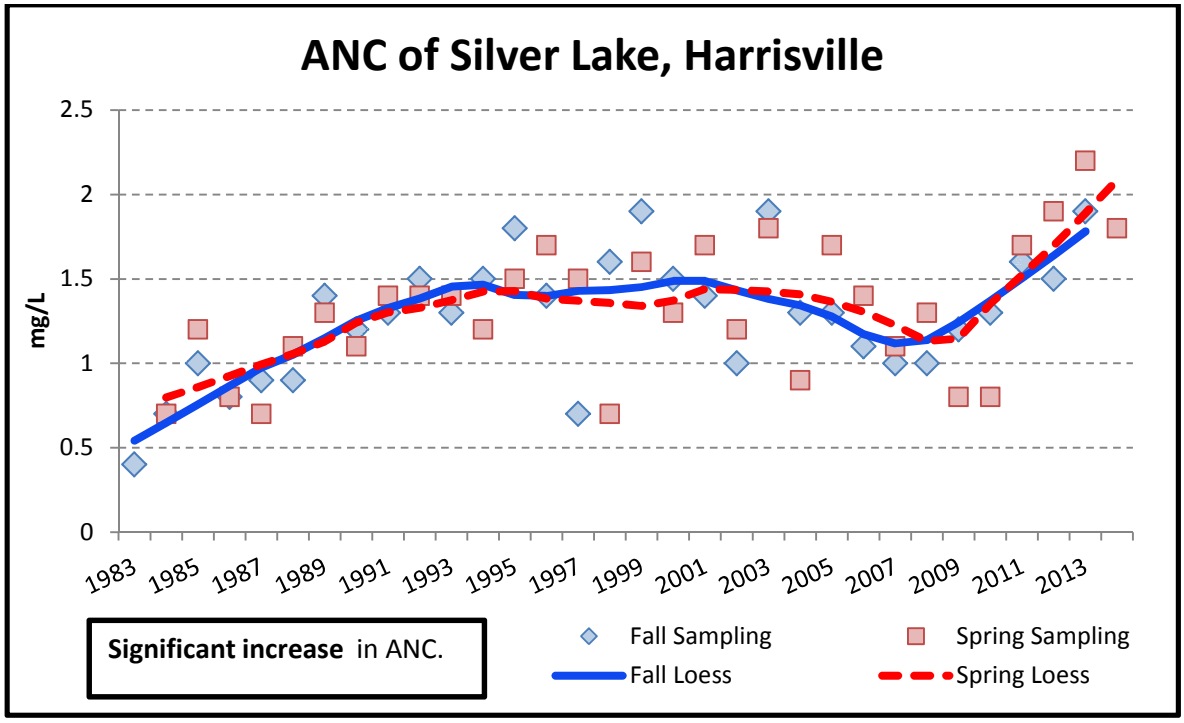

ANC of Russell Pond, Woodstock
mg/L
3
2.5
2
1.5
1
0.5
0
1984
1987
1990
1993
1996
1999
2002
2005
2008
2011
2014
No significant trend in ANC.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

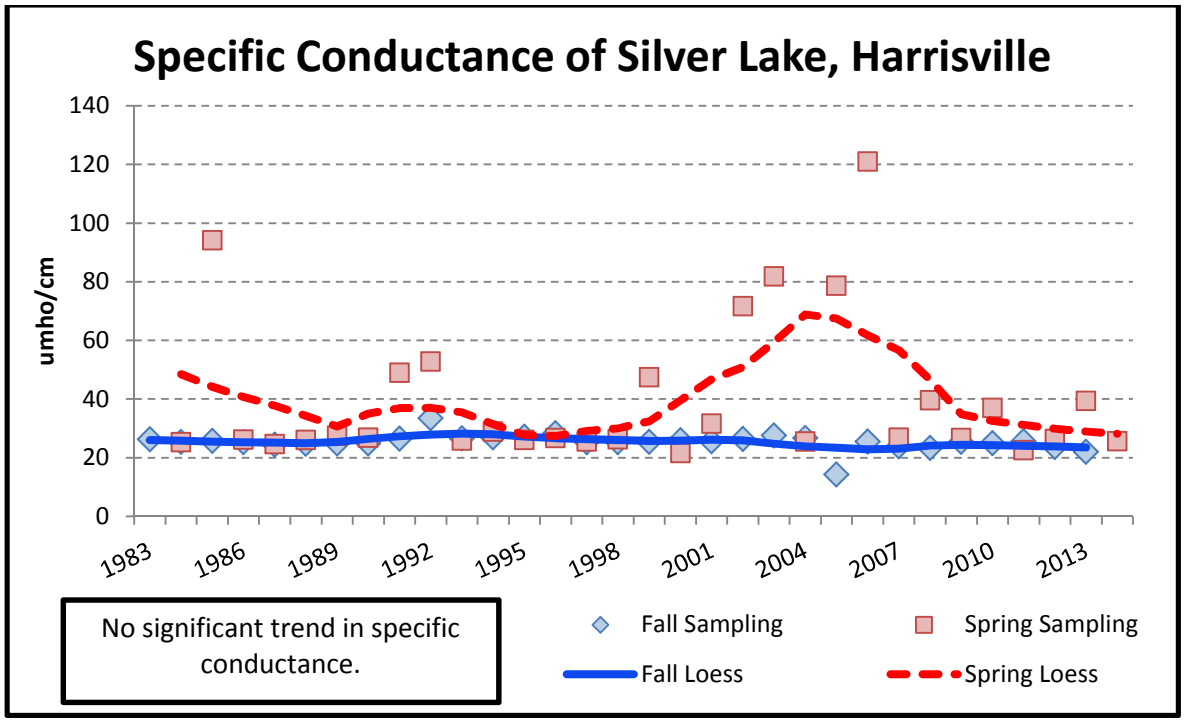

Specific Conductance of Russell Pond, Woodstock
umho/cm
30
25
20
15
10
5
0
1984
1987
1990
1993
1996
1999
2002
2005
2008
2011
2014
Significant decrease in specific conductance.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

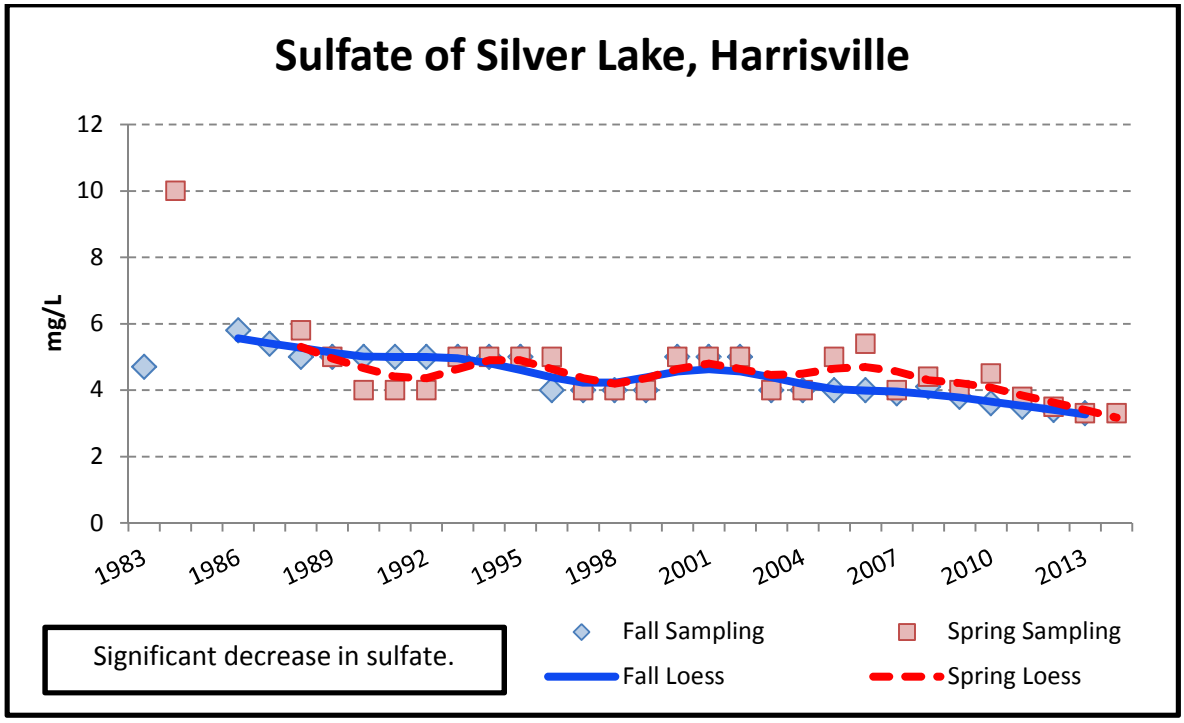

Sulfate of Russell Pond, Woodstock
mg/L
10
9
8
7
6
5
4
3
2
1
0
1984
1987
1990
1993
1996
1999
2002
2005
2008
2011
2014
Significant decrease in sulfate.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

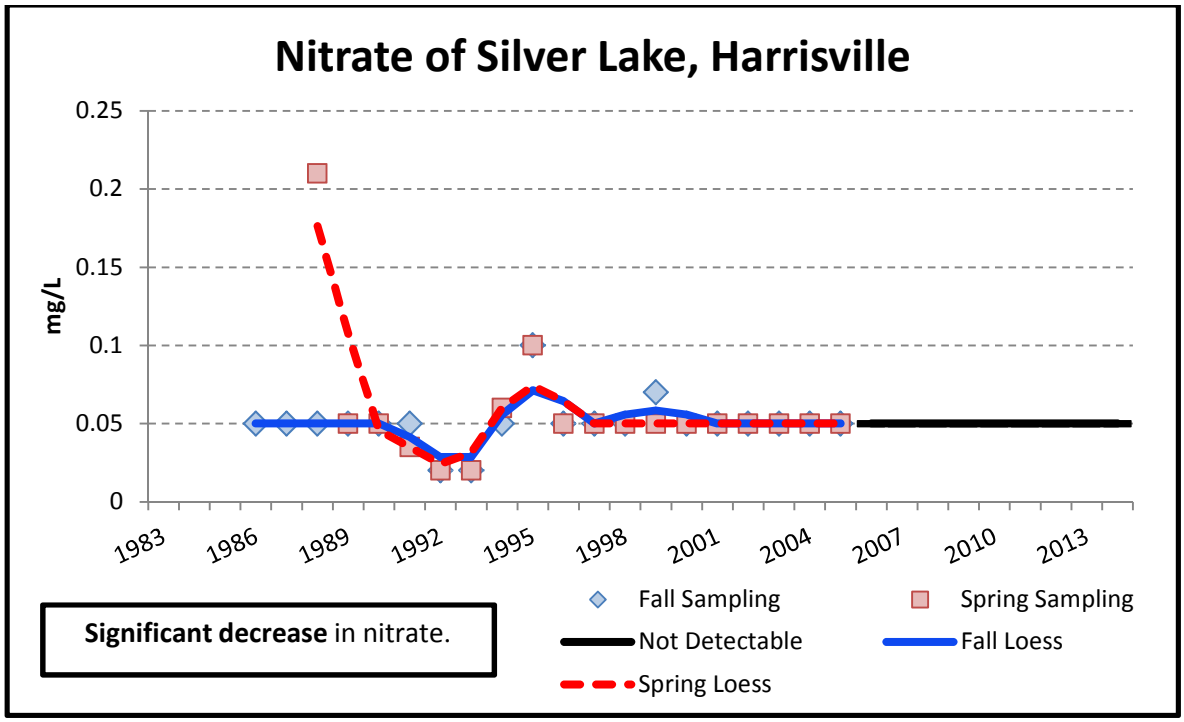

Nitrate of Russell Pond, Woodstock
mg/L
0.3
0.25
0.2
0.15
0.1
0.05
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
Fall Sampling
Spring Sampling
Not Detectable
Fall Loess
Spring Loess
Significant decrease in nitrate.

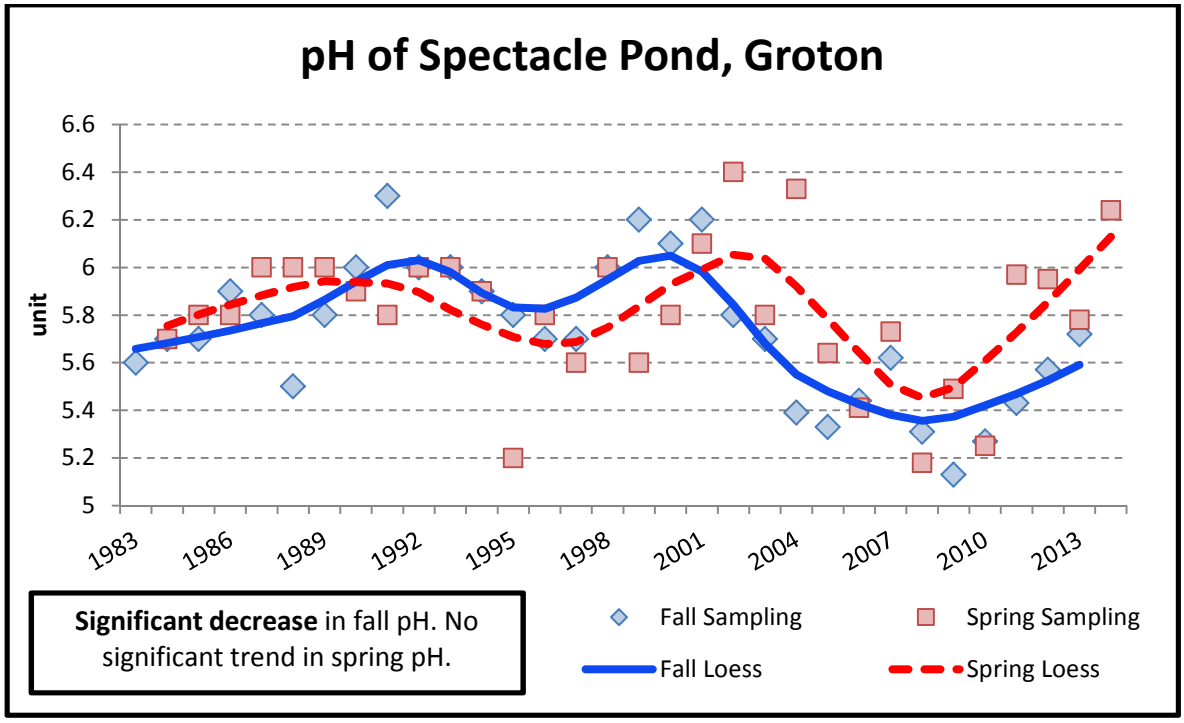

pH of Silver Lake, Harrisville
unit
6.6
6.4
6.2
6
5.8
5.6
5.4
5.2
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess
Significant increase in fall pH. No significant trend in spring pH.

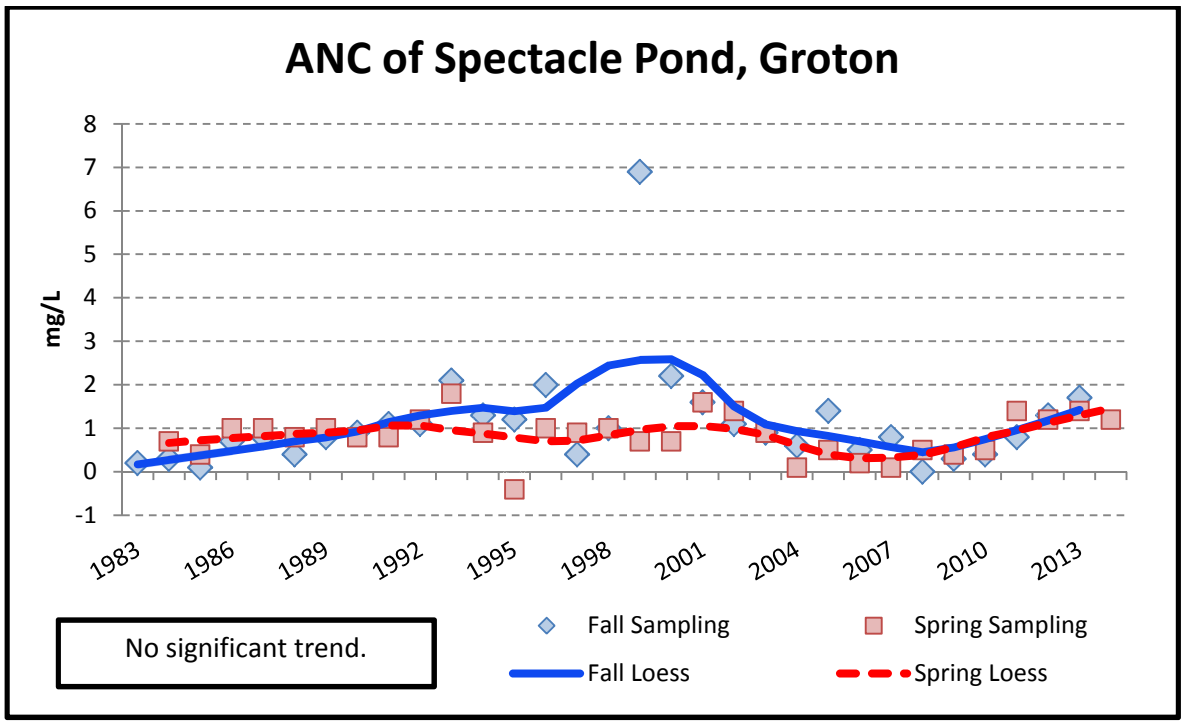

ANC of Silver Lake, Harrisville
mg/L
2.5
2
1.5
1
0.5
0
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
Significant increase in ANC.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

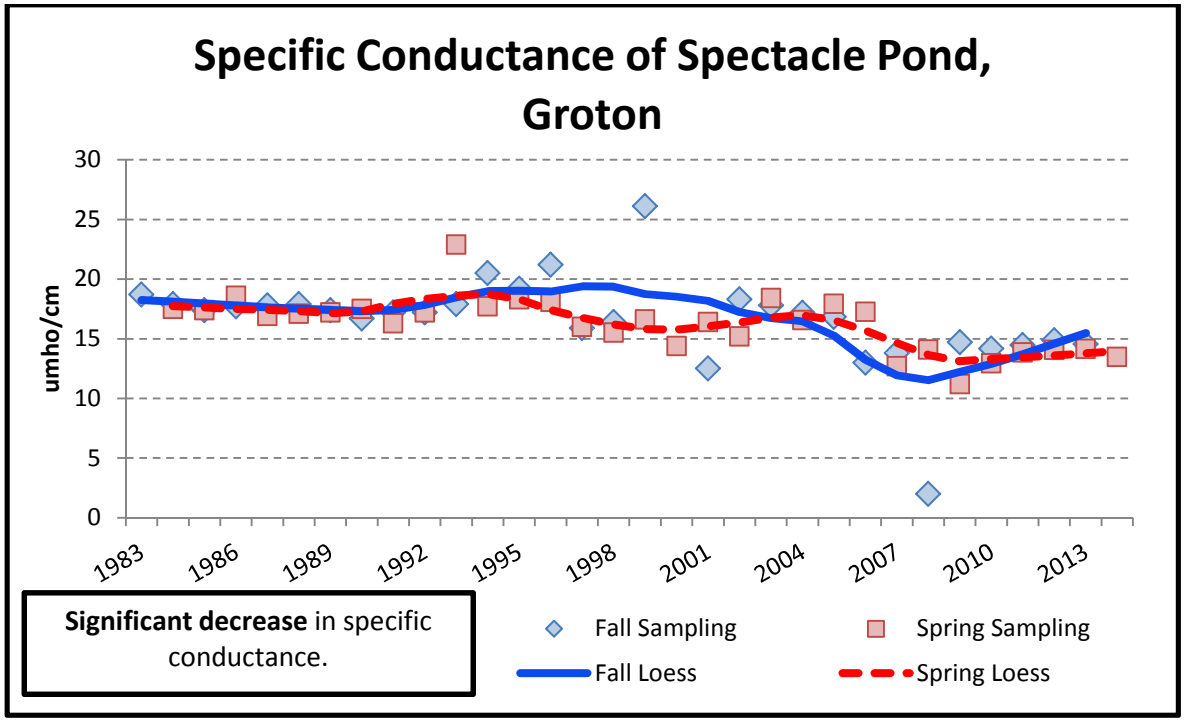

Specific Conductance of Silver Lake, Harrisville
umho/cm
140
120
100
80
60
40
20
0
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
No significant trend in specific conductance.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

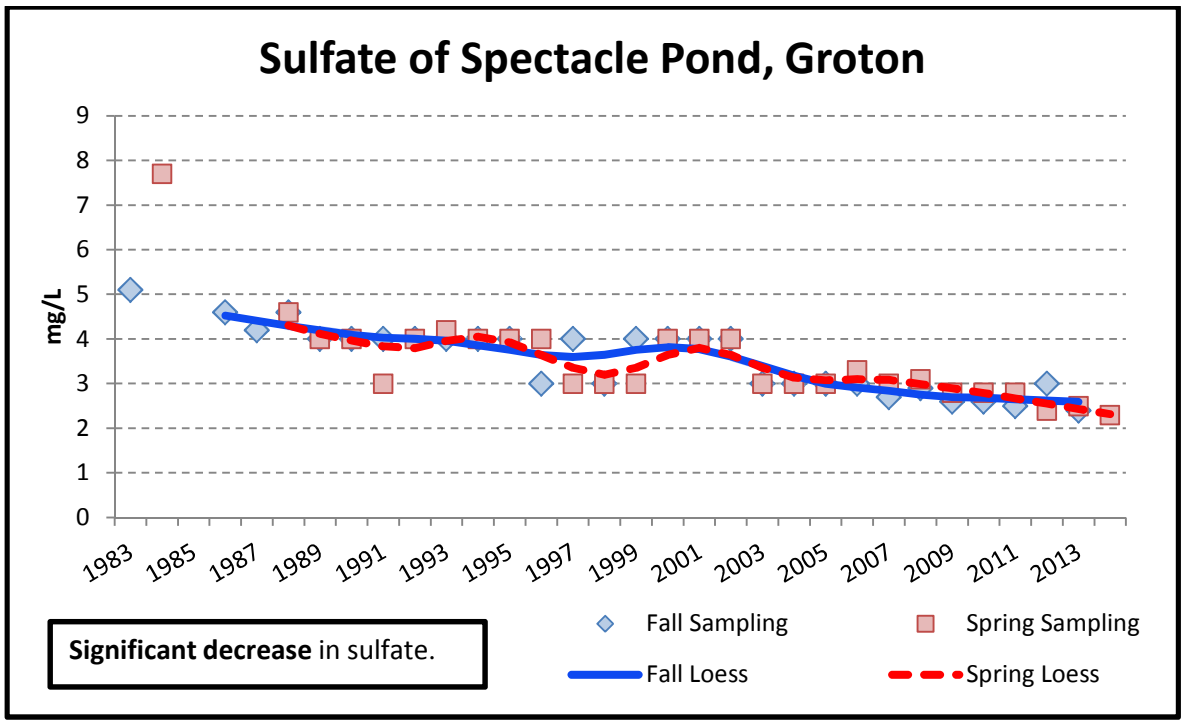

Sulfate of Silver Lake, Harrisville
mg/L
12
10
8
6
4
2
0
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess
Significant decrease in sulfate.

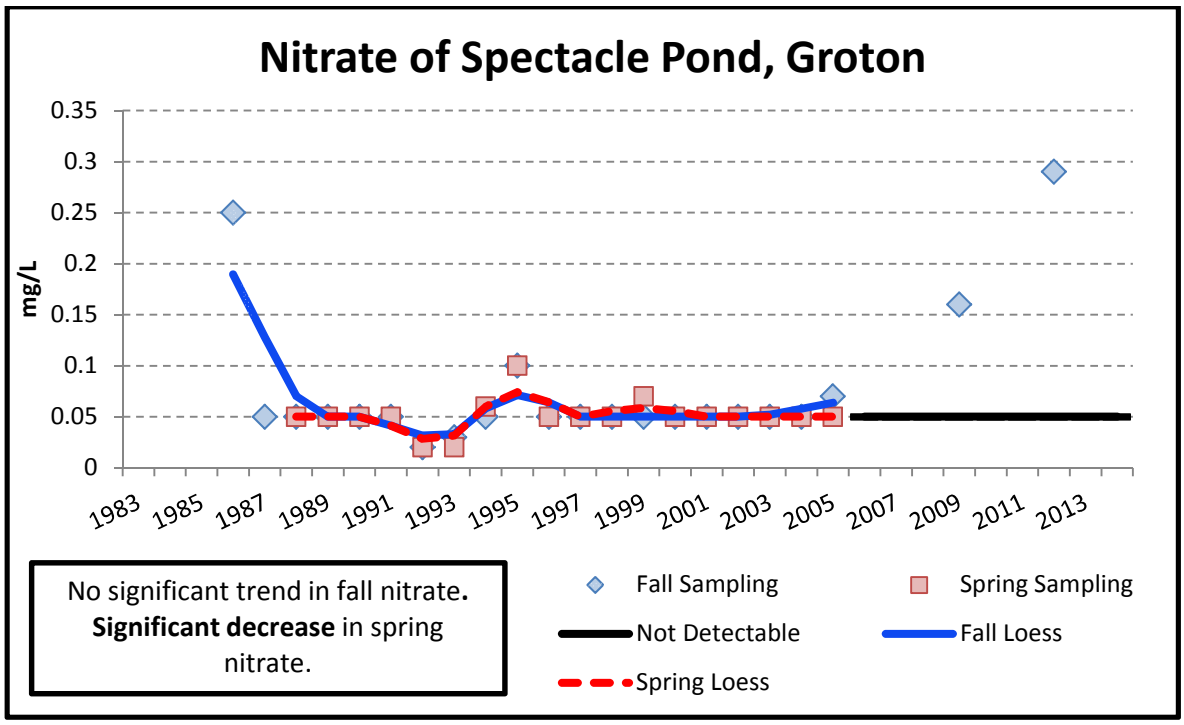

Nitrate of Silver Lake, Harrisville
mg/L
0.25
0.2
0.15
0.1
0.05
0
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Fall Sampling
Spring Sampling
Not Detectable
Fall Loess
Spring Loess
Significant decrease in nitrate.

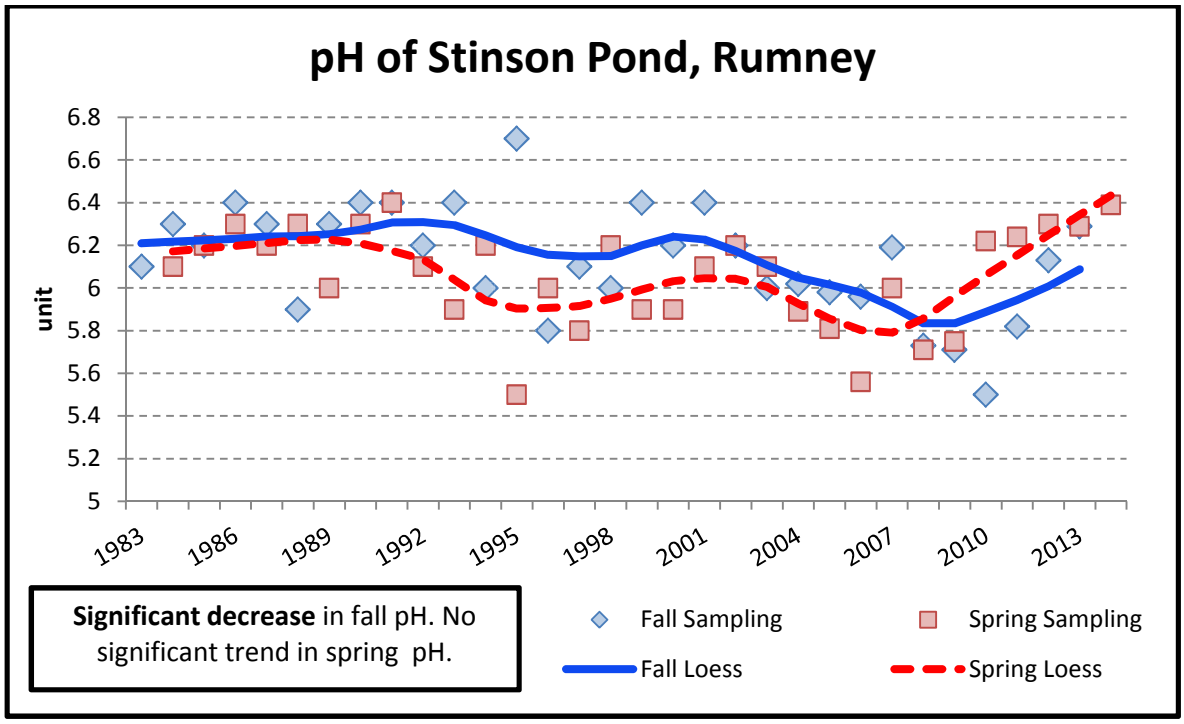

pH of Spectacle Pond, Groton
unit
6.6
6.4
6.2
6
5.8
5.6
5.4
5.2
5
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Significant decrease in fall pH. No significant trend in spring pH.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

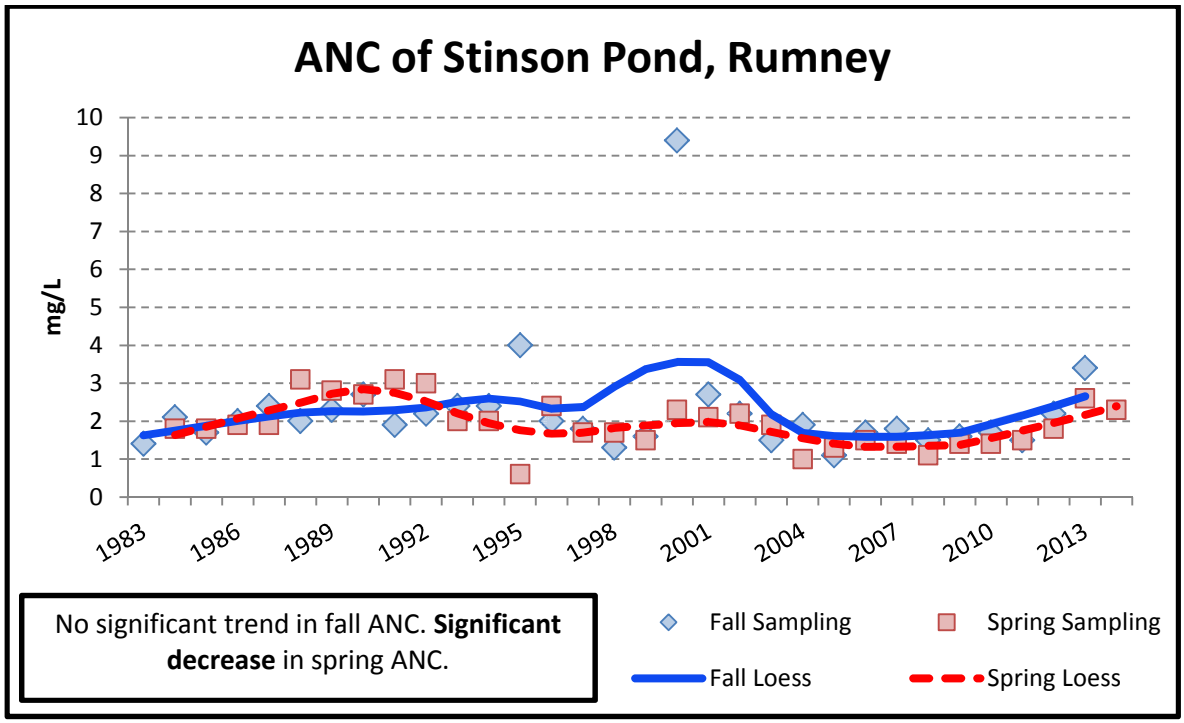

ANC of Spectacle Pond, Groton
mg/L
8
7
6
5
4
3
2
1
0
-1
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
No significant trend.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

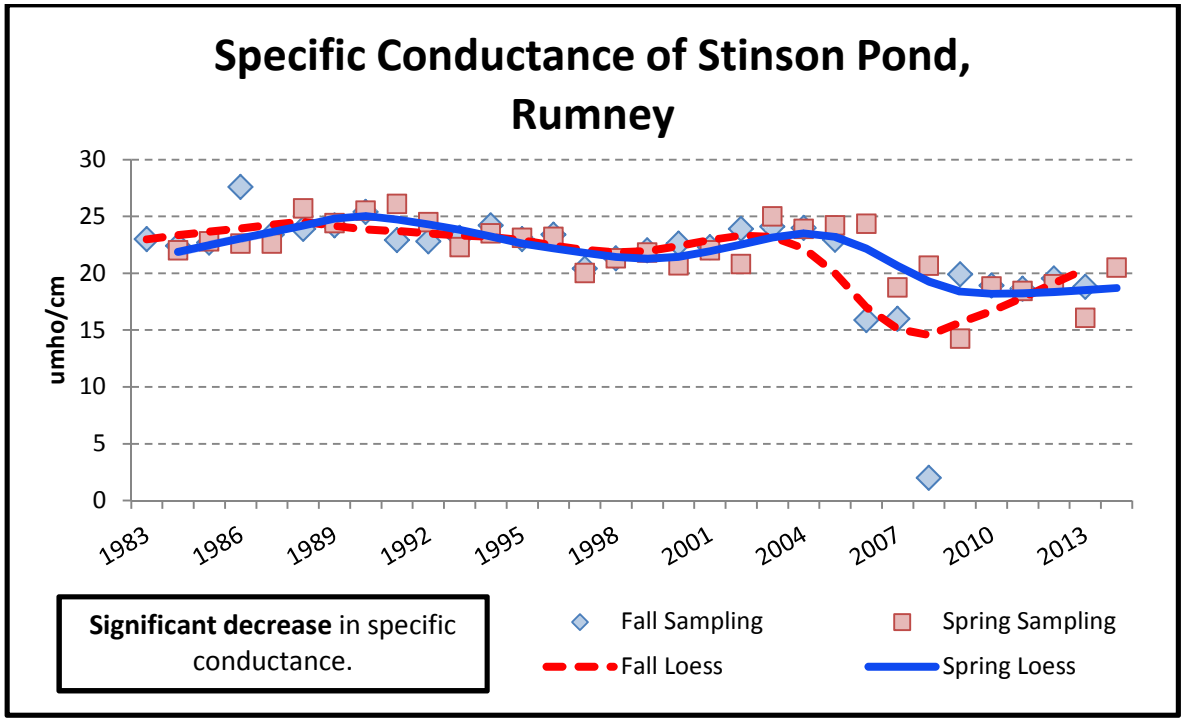

Specific Conductance of Spectacle Pond, Groton
umho/cm
30
25
20
15
10
5
0
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Significant decrease in specific conductance.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

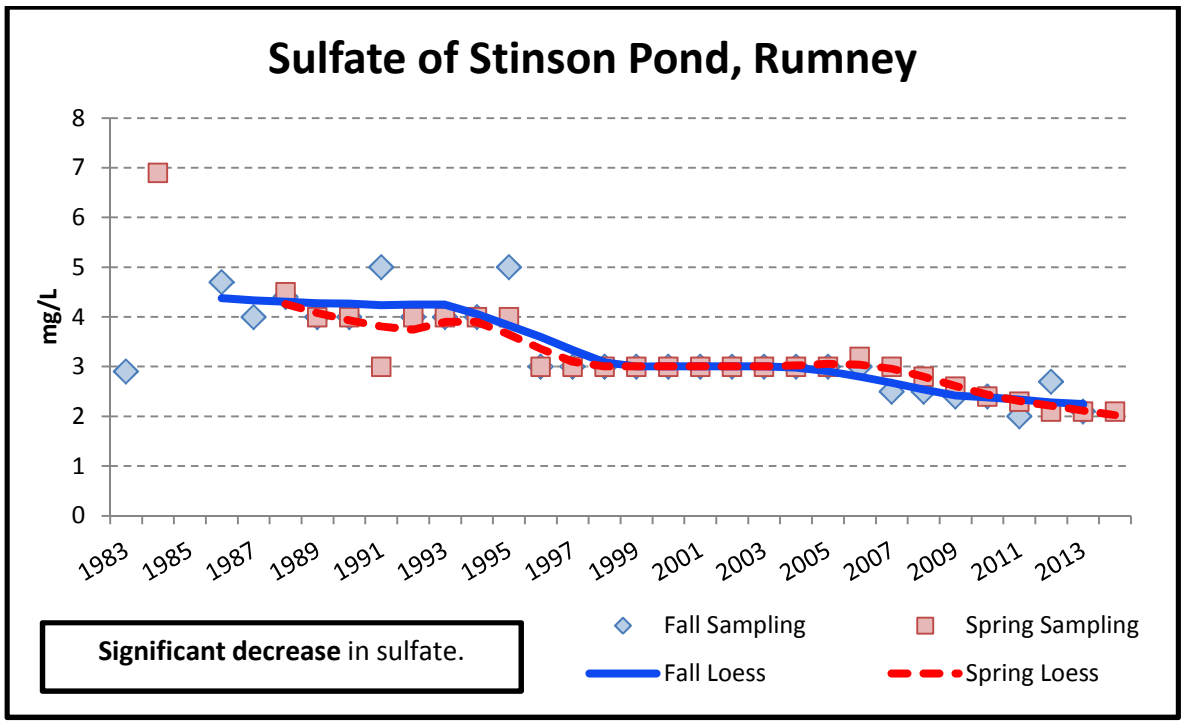

Sulfate of Spectacle Pond, Groton
mg/L
9
8
7
6
5
4
3
2
1
0
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
Significant decrease in sulfate.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

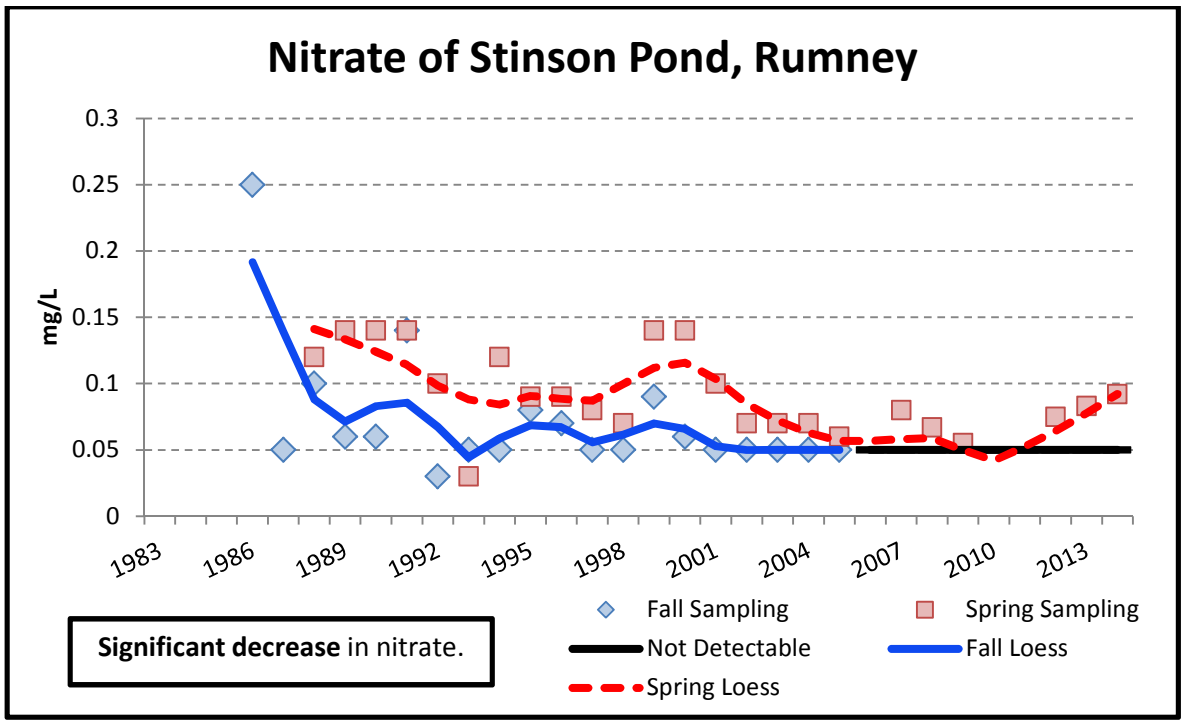

Nitrate of Spectacle Pond, Groton
mg/L
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
No significant trend in fall nitrate.
Significant decrease in spring nitrate.
Fall Sampling
Spring Sampling
Not Detectable
Fall Loess
Spring Loess

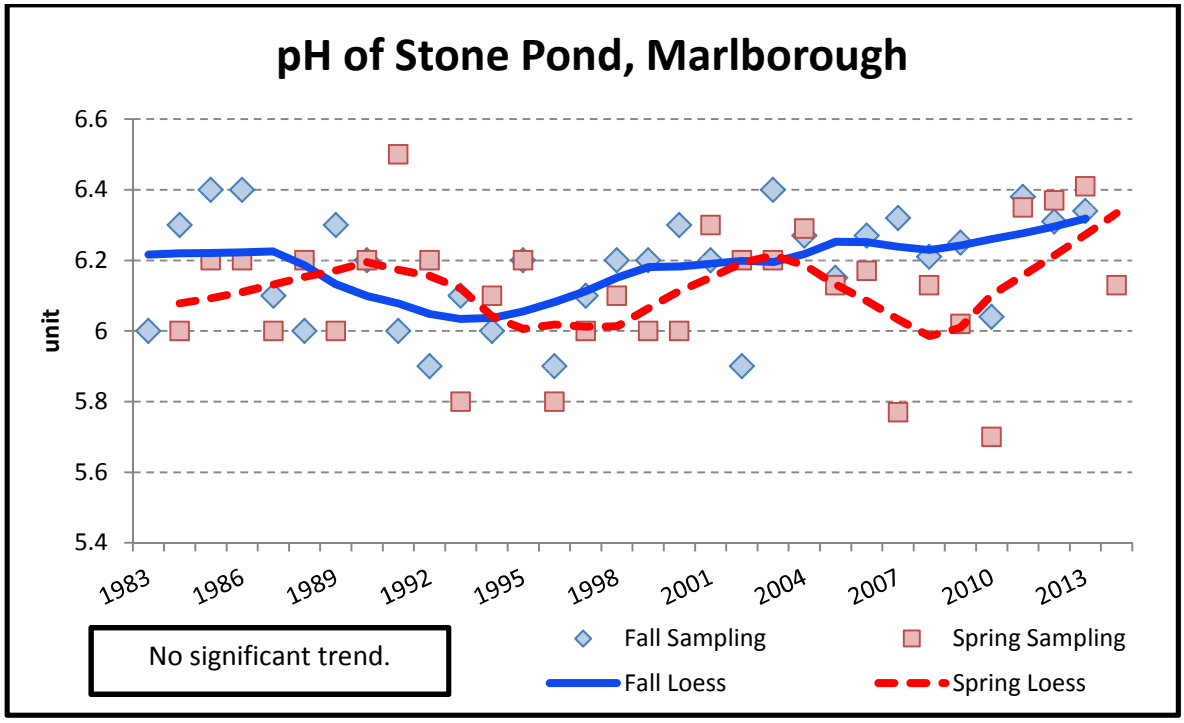

pH of Stinson Pond, Rumney
unit
6.8
6.6
6.4
6.2
6
5.8
5.6
5.4
5.2
5
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Significant decrease in fall pH. No significant trend in spring pH.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

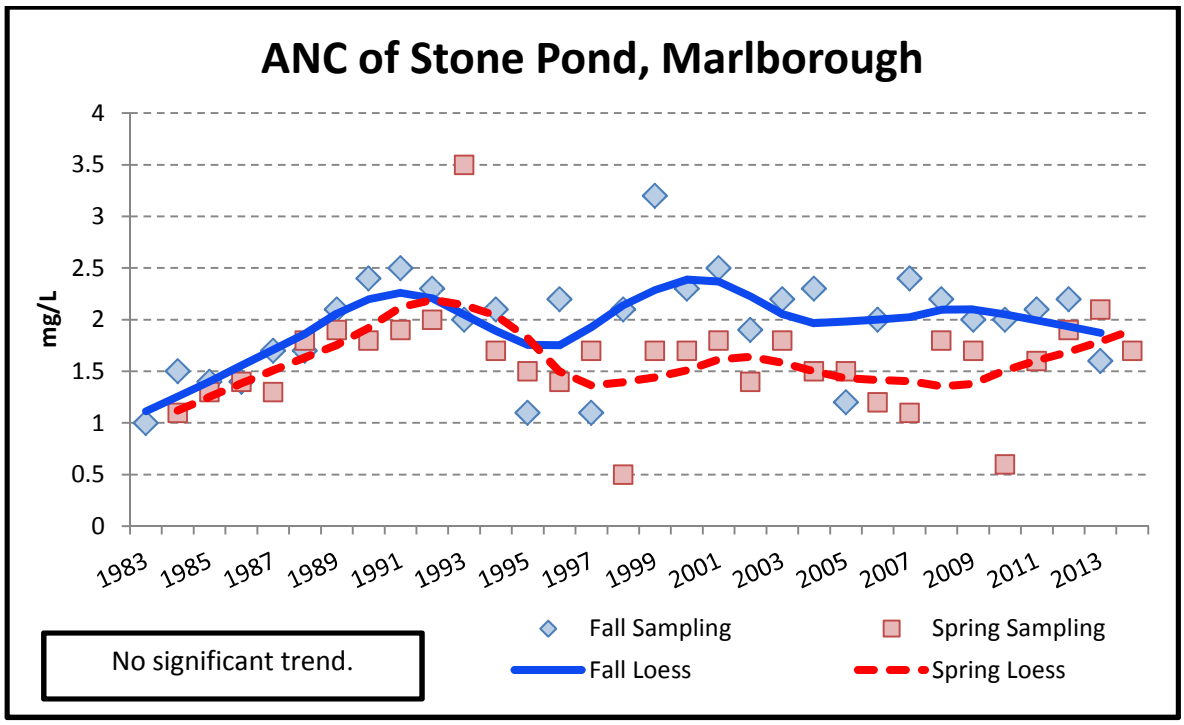

ANC of Stinson Pond, Rumney
mg/L
10
9
8
7
6
5
4
3
2
1
0
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
No significant trend in fall ANC. Significant decrease in spring ANC.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

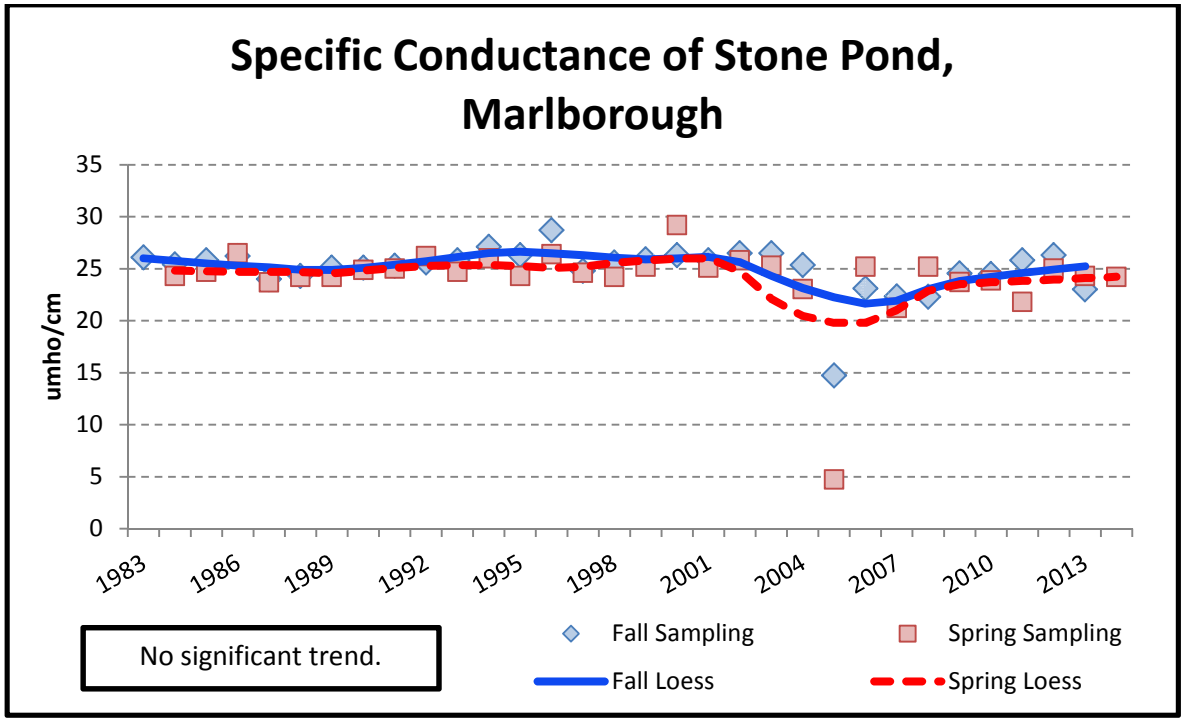

Specific Conductance of Stinson Pond, Rumney
umho/cm
30
25
20
15
10
5
0
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Significant decrease in specific conductance.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

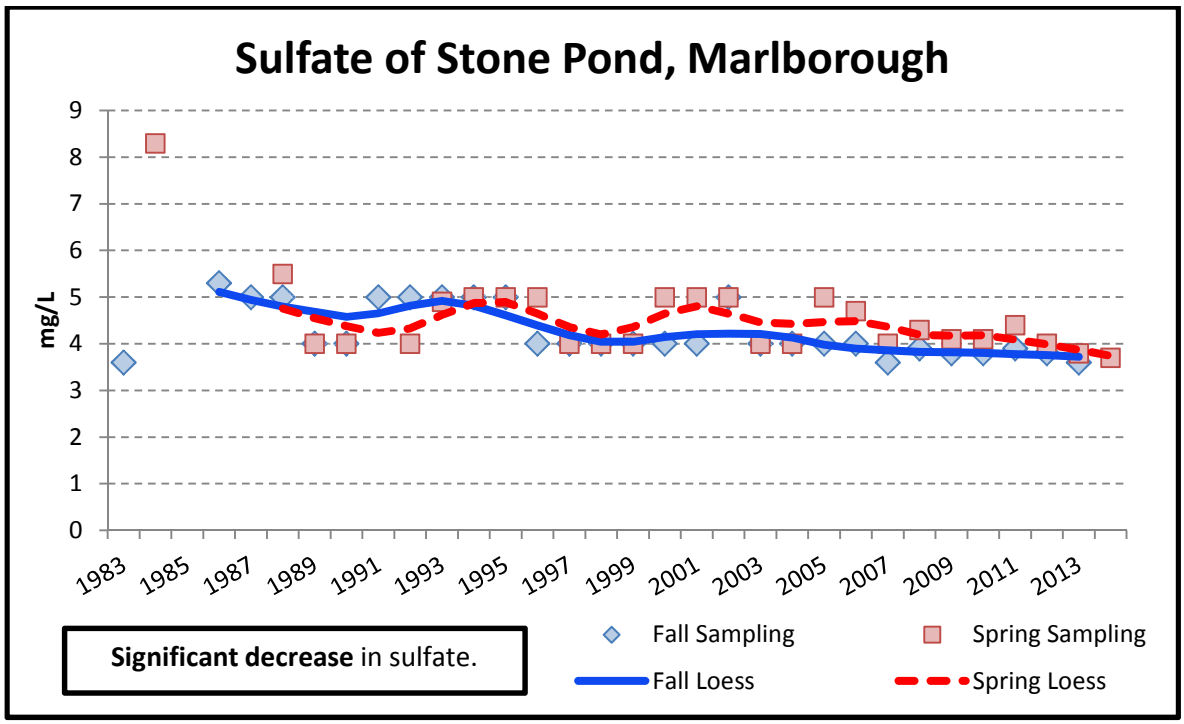

Sulfate of Stinson Pond, Rumney
mg/L
8
7
6
5
4
3
2
1
0
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
Significant decrease in sulfate.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

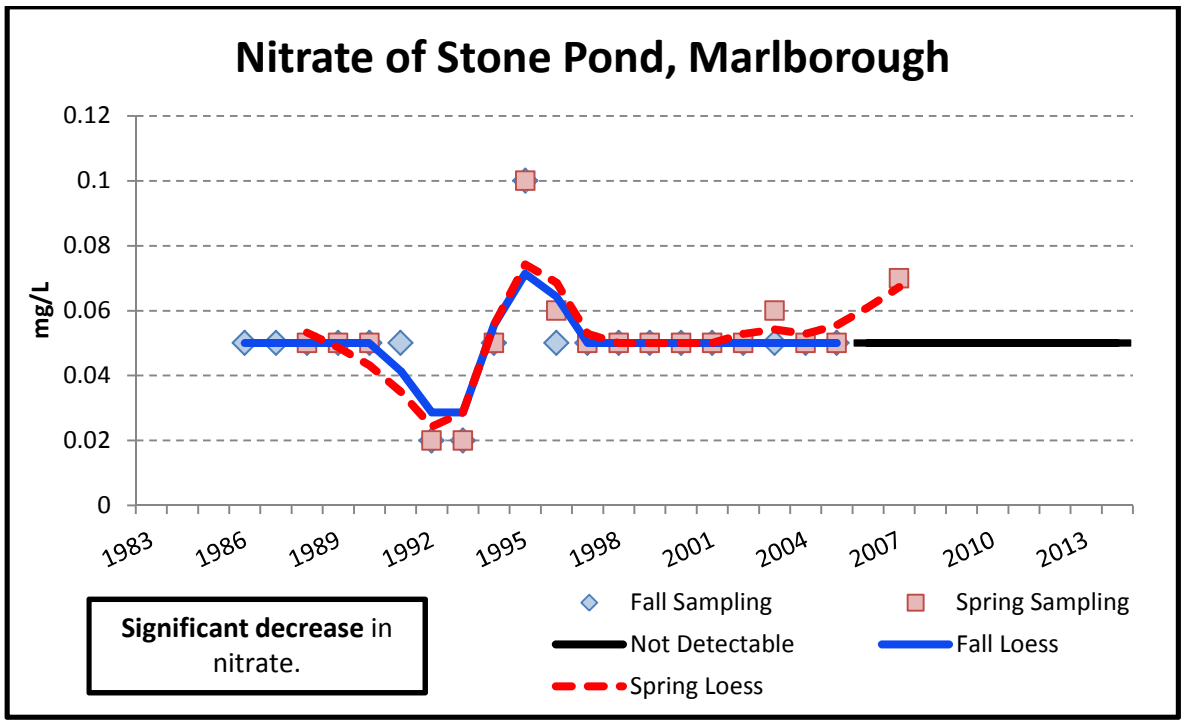

Nitrate of Stinson Pond, Rumney
mg/L
0.3
0.25
0.2
0.15
0.1
0.05
0
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Fall Sampling
Spring Sampling
Not Detectable
Fall Loess
Spring Loess
Significant decrease in nitrate.

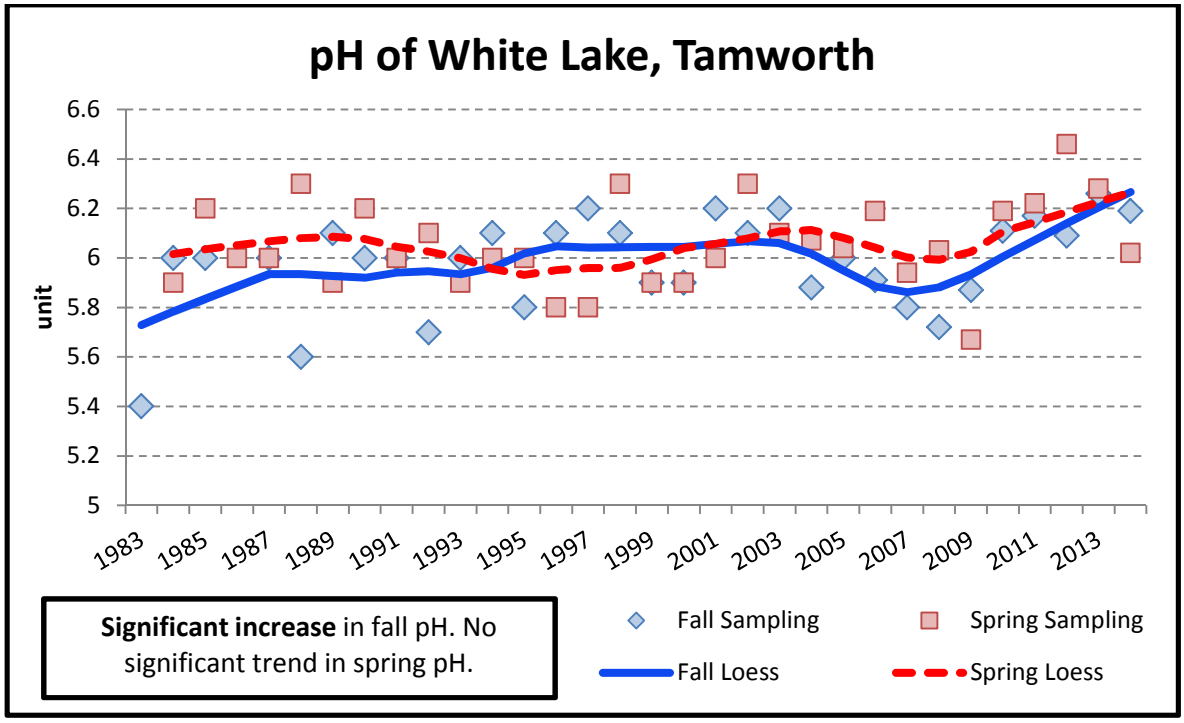

pH of Stone Pond, Marlborough
unit
6.6
6.4
6.2
6
5.8
5.6
5.4
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
No significant trend.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

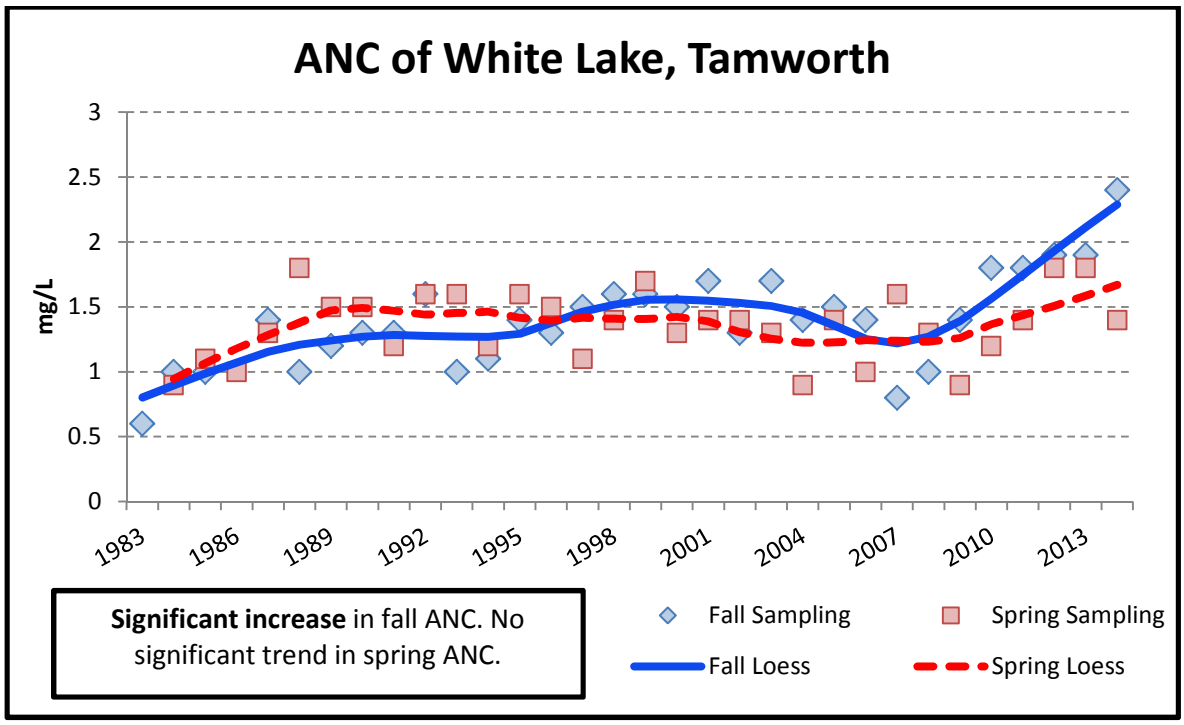

ANC of Stone Pond, Marlborough
mg/L
4
3.5
3
2.5
2
1.5
1
0.5
0
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
No significant trend.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

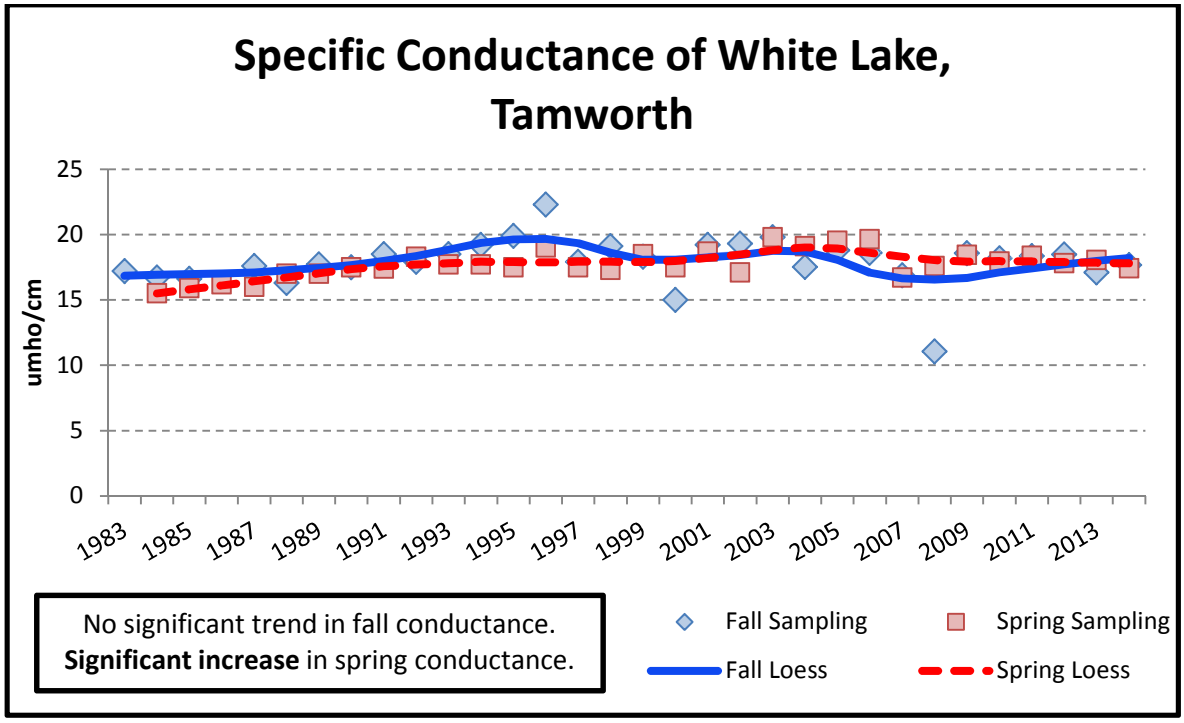

Specific Conductance of Stone Pond, Marlborough
umho/cm
35
30
25
20
15
10
5
0
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
No significant trend.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

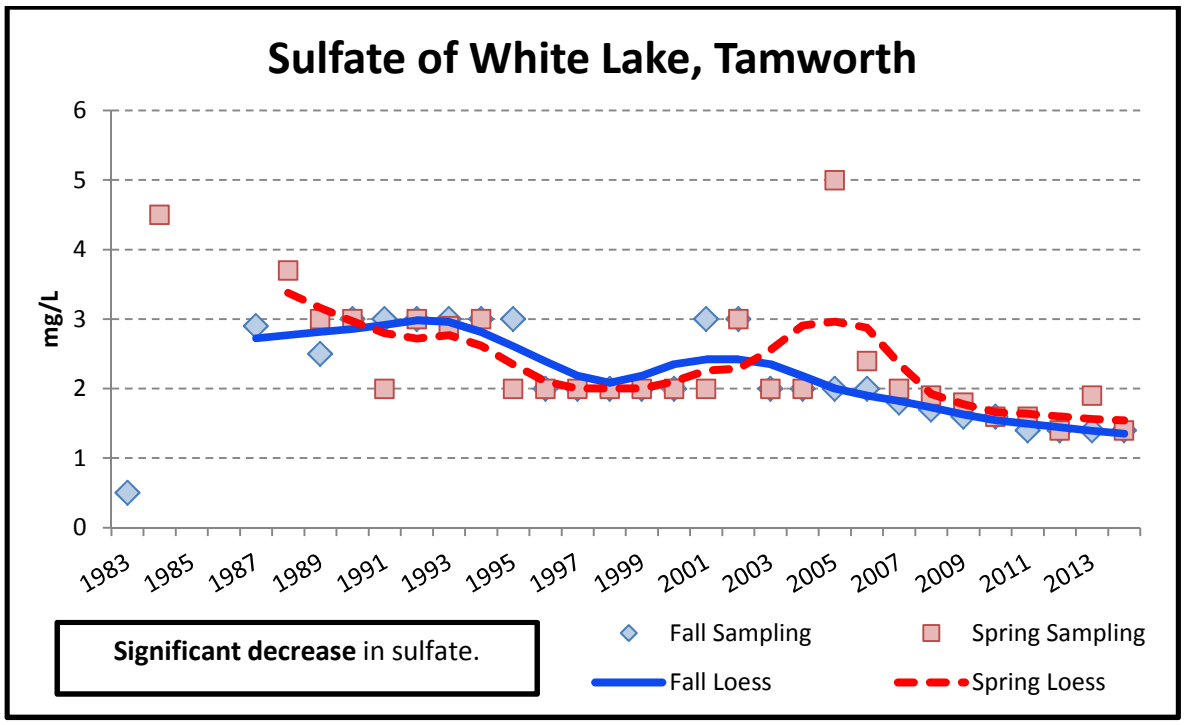

Sulfate of Stone Pond, Marlborough
mg/L
9
8
7
6
5
4
3
2
1
0
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
Significant decrease in sulfate.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess

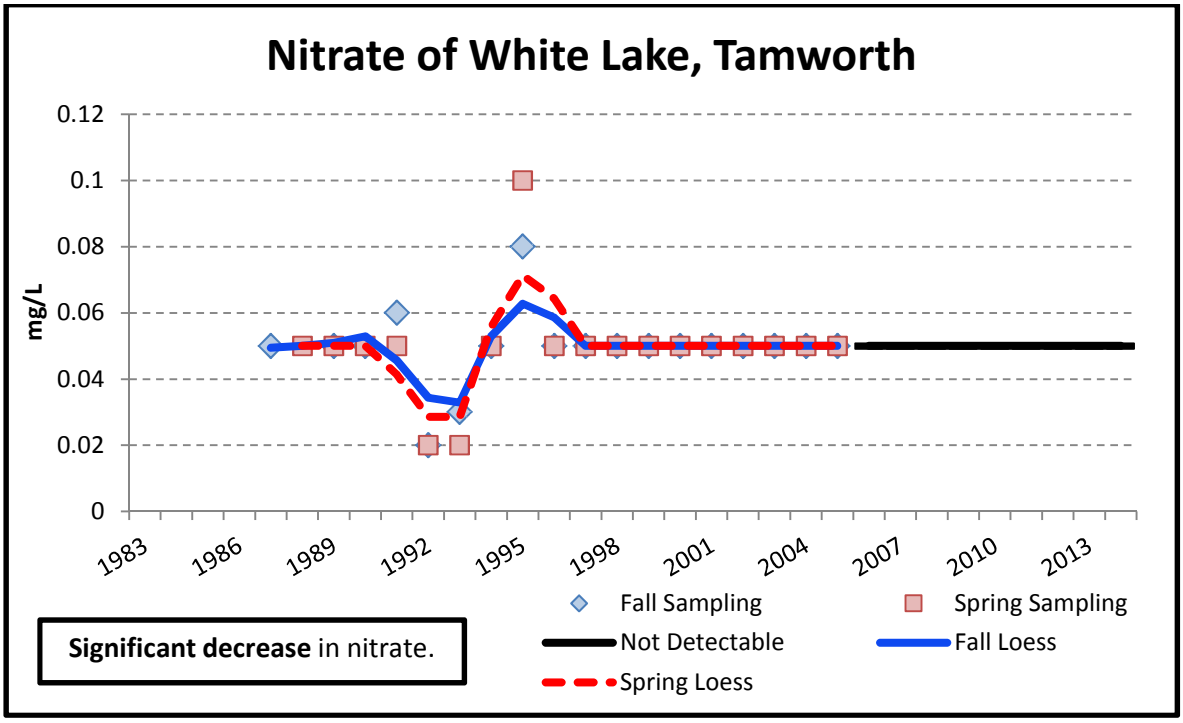

Nitrate of Stone Pond, Marlborough
0.12
0.1
0.08
0.06
0.04
0.02
0
mg/L
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Fall Sampling
Spring Sampling
Not Detectable
Fall Loess
Spring Loess
Significant decrease in nitrate.


pH of White Lake, Tamworth
unit
6.6
6.4
6.2
6
5.8
5.6
5.4
5.2
5
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
Significant increase in fall pH. No significant trend in spring pH.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess


ANC of White Lake, Tamworth
mg/L
3
2.5
2
1.5
1
0.5
0
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Significant increase in fall ANC. No significant trend in spring ANC.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess


Specific Conductance of White Lake, Tamworth
umho/cm
25
20
15
10
5
0
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
No significant trend in fall conductance.
Significant increase in spring conductance.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess


Sulfate of White Lake, Tamworth
mg/L
6
5
4
3
2
1
0
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
Significant decrease in sulfate.
Fall Sampling
Spring Sampling
Fall Loess
Spring Loess


Nitrate of White Lake, Tamworth
0.12
0.1
0.08
0.06
0.04
0.02
0
mg/L
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
Fall Sampling
Spring Sampling
Not Detectable
Fall Loess
Spring Loess
Significant decrease in nitrate.