New Hampshire Volunteer Lake Assessment Program

2014
Great North Woods
Regional Report

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

R-WD-16-07

New Hampshire
Volunteer Lake Assessment Program
2014 Great North Woods Regional Report

State of New Hampshire
Department of Environmental Services
Water Division
Watershed Management Bureau
P.O. Box 95
29 Hazen Drive
Concord, NH 03302-0095

Thomas S. Burack
Commissioner

Eugene Forbes
Water Division Director

Ted Diers
Watershed Management Bureau Administrator

Prepared By:

Sara Steiner
VLAP Coordinator

Kirsten Nelson
Biologist

December 2015

REGIONAL HIGHLIGHTS

- The Great North Woods Region (GNW) consists of those towns in New Hampshire's *Coos County*.

- Regional freshwater recreation, including boating, fishing and swimming, in the GNW Region generate approximately **$26 million dollars in sales, $9 million in household income, and 419 jobs annually** (Nordstrom, 2007).

- **A perceived decline in water quality** as measured by water clarity, aesthetic beauty, or overuse could result in approximately **$2 million dollars in lost revenue, $650,000 in lost household income and 30 lost jobs** (Nordstrom, 2007).

- Regional population is expected to grow by **3,000 people by 2030**, with the majority of growth anticipated for Berlin, Lancaster, and Colebrook.

- The region is home to approximately **20,000 acres of lakes, river, and wetlands**. Approximately **1,500 acres or 6.5 percent** of water occurs in the towns predicted to experience the heaviest population growth.

- Regional average summer air temperatures were 0.6° F above average regional climate conditions in 2013 but were 0.8° F below average in 2014. Regional surface water temperature samples were limited. Annual summer regional precipitation was 0.77 inches above regional average conditions in 2013 and equal to the regional average in 2014.

- The GNW region consists of **85 lakes** or great ponds. Regional lakes are classified into three categories that describe the overall productivity of the lake as oligotrophic, mesotrophic or eutrophic by the NHDES Lake Trophic Survey Program. Eighteen lakes are oligotrophic, 35 are mesotrophic, six are eutrophic and 26 are un-assessed for trophic classification.

- Regional water quality data is collected at **four lakes participating in VLAP** while the remaining **95 percent of lakes are sparsely monitored** through the Lake Trophic Survey Program.

- VLAP lakes are monitored at the deepest point in the lake and at streams entering or exiting the lake. Lakes are monitored monthly during the summer season to establish baseline water quality data and discern long term water quality trends that provide information on overall waterbody health.

- Regional trend analysis performed on historical water quality data found no significant trend for parameters chlorophyll-*a* and total phosphorus, while acid neutralizing capacity (ANC), conductivity, pH, and turbidity were all found to significantly increase over time, and transparency significantly decreased over time. No trend analysis was performed on chloride due to a lack of data.

GNW WATER QUALITY INDICATORS

The following describes the water quality indicator measured through VLAP, the regional trend that was detected and the current status of the indicator. Trends were determined with a non-parametric Mann-Kendall trend test of the annual medians for each parameter.

Exotic Species	Chlorophyll-a	Transparency	P Phosphorus	DO Dissolved Oxygen	pH	Conductivity	NaCl Chloride	Turbidity

Indicator	Trend	Description
	N/A	To date, no lakes in the GNW region are known to have exotic species. *Didymo*, a.k.a. Rock Snot, has been found in 54 river miles in the North Country.
	↔	No significant regional trend from 1985 - 2014. Regional median is 4.54 mg/m^3 and representative of mesotrophic conditions or average chlorophyll levels. Lake specific trend analysis indicates two lakes with stable chlorophyll-a trends.
	↓	Significantly decreasing (worsening) regional trend meaning that lake clarity has declined from 1985 - 2014. The regional median is 3.25 meters and representative of good conditions. Lake specific trend analysis indicates two lakes with stable transparency trends.
P	↔	No significant regional trend from 1985 - 2014. Regional median is 9 ug/L and representative of mesotrophic or average phosphorus conditions. Lake specific trend analysis indicates significantly decreasing (improving) epilimnetic phosphorus at one lake and a stable epilimnetic phosphorus trend at the other.
DO	N/A	Dissolved oxygen levels fluctuate temporally and spatially within a lake system. Ideal levels are between 6.0 and 8.0 mg/L. The average whole water column dissolved oxygen level from 1985 to 2014 is 5.41 mg/L, which is considered to be in the critical range for aquatic life.
	↑	Significantly increasing (improving) regional trend from 1985 - 2014. Regional median is 7.08 and within a desirable pH range. Lake specific trend analysis indicates two lakes with stable epilimnetic pH trends.
	↑	Significantly increasing (worsening) regional trend from 1985 – 2014. The regional median is 44.1 uMhos/cm which is within a desirable range, however, individual lake conductivity fluctuates widely from approximately 21 to 106 uMhos/cm due to differences in watershed development. Lake specific trend analysis indicates two lakes with stable epilimnetic conductivity trends.
NaCl	N/A	Trend analysis was not performed on the GNW region because fewer than ten years of data were available. Regional median is 4.9 mg/L and approximately equal to the state median of 4 ug/L, much less than acute and chronic chloride standards.
	↑	Significant increasing (worsening) regional trend from 1992 - 2014. Regional median is 0.81 NTU and is indicative of average water quality. Turbidity trend analysis is not conducted on individual lakes.

Table of Contents

List of Tables

List of Figures

Appendices

INTRODUCTION AND HISTORY

New Hampshire is home to approximately 1,200 lakes and ponds, and thousands of river miles. Protecting our lakes and rivers is critical to sustaining New Hampshire's drinking water resources, aquatic and natural environments, recreational and tourism industries.

The New Hampshire Department of Environmental Services (NHDES) recognizes the importance of these waterbodies in maintaining a healthy ecosystem for our current and future generations. Protecting high-quality waters, and restoring those that are impaired, requires coordination and partnership between federal, state and local governments, non-profits, regional commissions, lake associations and watershed residents.

To help citizens assess the health of New Hampshire's lakes and ponds, NHDES established the Volunteer Lake Assessment Program (VLAP) in 1985. The program is a volunteer-driven cooperative effort between the State and local governments, lake associations and lake residents. VLAP trains citizen volunteer monitors to collect water quality data at lakes and their associated tributaries on a monthly basis during the summer. VLAP compiles, interprets and reports the data back to state, federal and local governments, lake associations and lake residents.

VLAP volunteer monitors are invaluable stewards for New Hampshire's lakes. Volunteer monitoring allows NHDES to establish a strong set of baseline chemical and biological data, determine long-term water quality trends and identify emerging water quality issues. NHDES acts on these findings through its funding and regulatory programs. Volunteers use this information to educate lake and watershed residents, businesses and local governments on best management practices to keep New Hampshire's lakes and ponds clean. They have been, and will continue to be, a key element in protecting the integrity of New Hampshire's lakes.

PROGRAM OVERVIEW

VLAP is a cooperative program between NHDES and lake residents and associations. Approximately 500 volunteers monitor water quality at 170 lakes throughout New Hampshire through VLAP. Interest in the program has grown drastically in the past ten years as citizens have become more aware of the connections between land use activities and water quality. Volunteer monitors continually collect high-quality data on their local waterbodies and educate watershed residents.

Volunteer monitors are trained by NHDES to collect lake water quality data, survey the surrounding watershed, and sample the streams and rivers that are tributaries to the lake. Each of the participating lakes must be visited by a NHDES biologist on a biennial basis. This visit is a valuable event in which the volunteer monitors have an opportunity to discuss water quality and watershed concerns and receive recommendations on potential remediation activities. Also, the event allows NHDES biologists to perform a field sampling techniques audit to evaluate volunteer monitor's ability to collect quality data, and to collect information on additional water quality parameters as necessary. Volunteers then sample on their own for the remaining summer months.

To further encourage volunteer monitoring, NHDES, established partnerships with the Lake Sunapee Protective Association (LSPA), Colby Sawyer College (CSC) in New London, NH and Plymouth State University (PSU) in Plymouth, NH to operate VLAP satellite laboratories. These satellite laboratories serve as a convenient location for volunteers to borrow sampling equipment and deliver water samples for analysis. These strategic locations serve the Dartmouth Lake Sunapee, North Country and White Mountain regions.

The data gathered by the volunteers are reviewed by NHDES quality assurance officers and satellite laboratory managers and imported into NHDES' Environmental Monitoring Database (EMD). During the winter, NHDES biologists review and interpret the water quality data, perform trend analyses, and compile the results into annual reports. The high quality data gathered through VLAP also helps NHDES to conduct statewide surface water quality assessments. Assessment results are submitted to the Environmental Protection Agency (EPA) by NHDES every two years as a requirement of the Clean Water Act.

Once the volunteer monitors receive the data and the annual report for their lake, NHDES encourages the volunteers to relay that information to their respective associations, organizations, businesses and local governments. Volunteers are also kept informed of the latest in lake management and water quality issues through an annual newsletter, technical and educational materials, regional workshops and information on important legislation. In addition, NHDES biologists give presentations at lake association meetings and participate in youth education events. Educational initiatives, such as those mentioned above, allow volunteers to recognize potential water quality or shoreland violations around the lake and report their findings to NHDES.

MONITORING AND PARAMETER SUMMARY

VLAP encourages the collection of comprehensive data sets on key water quality parameters to determine overall health of the system. Lakes and tributaries are sampled several times each year over a period of years. This establishes baseline water quality data and allows for the discernment of long-term water quality trends. These trends depict lake health and provide invaluable information to NHDES' mission to protect New Hampshire's lakes. The sampling efforts of the volunteer monitors supplement the environmental monitoring efforts of NHDES. Only through the assistance of volunteer monitors can such a high volume of sampling be accomplished throughout the state.

NHDES recognizes the importance of collecting data sets that are representative of varying conditions. VLAP has an EPA-approved Quality Assurance Project Plan (QAPP). The QAPP identifies specific responsibilities of NHDES and volunteers, sampling rationale, training procedures, data management and quality control. NHDES and volunteers adhere to the QAPP regime to ensure high quality and representative data sets are collected.

Volunteers collect samples once per month in June, July and August, with some lakes monitored more or less frequently. Samples are collected at approximately the same location each month at each of the deep spot thermal layer, major tributaries (those flowing year round) and seasonal tributaries during spring run-off. The samples are analyzed for a variety of chemical and biological parameters including: pH, ANC, conductivity, chloride, turbidity, total phosphorus, and *E. coli* (optional). Additional in-lake data are also collected at the deep spot including lake transparency (with and without a viewscope), chlorophyll-a, phytoplankton, and dissolved oxygen and temperature profiles. Volunteer monitors are also trained to identify and collect samples of suspicious aquatic plants and cyanobacteria.

Environmental outcomes are measured by making comparisons to established New Hampshire averages, medians, ranges of lake water quality and state water quality standards. If analytical results for a particular sampling station frequently exceed state water quality standards, then additional sampling to identify potential pollution sources is necessary. Volunteers often conduct storm event sampling, tributary bracket sampling, and spring run-off sampling to better assess watershed health and provide additional data to guide lake management decisions.

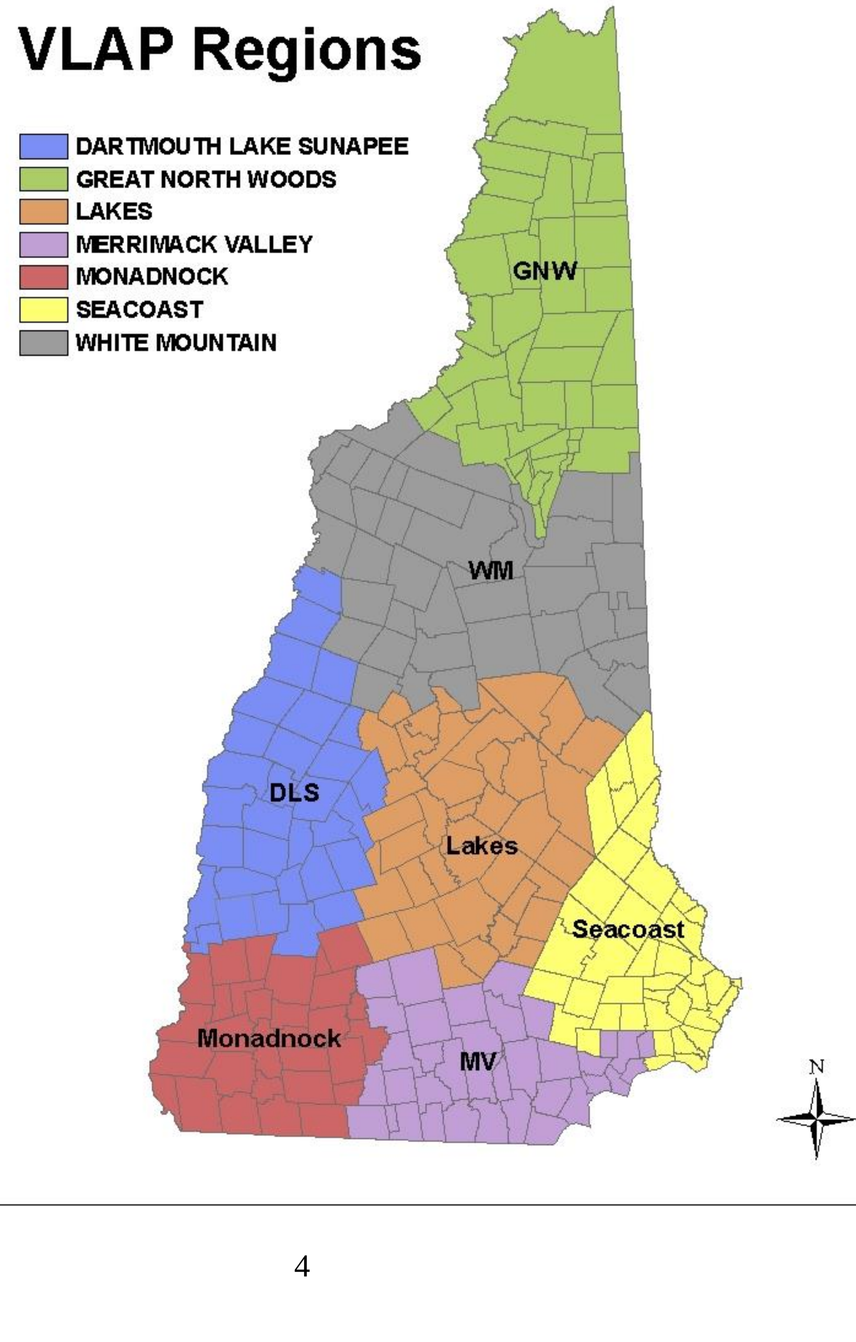
Appendix A includes a summary of each monitoring parameter and Appendix B includes recommended best management practices to remediate pollution sources.

GREAT NORTH WOODS REGIONAL SUMMARY

The Great North Woods Region (GNW) consists of those towns in New Hampshire's Coos County. Bordering portions of the Connecticut River, Vermont, Maine and Canada, the area is home to the pristine Lake Umbagog National Wildlife Refuge, portions of the White Mountain National Forest, and the Connecticut Lake System.

Freshwater resources in the GNW region provide valuable drinking water and recreational opportunities and play an important role in the regional economy.
Freshwater recreation, including boating, fishing and swimming, in the GNW Region generate approximately $26 million dollars in sales, $9 million in household income, and 419 jobs annually (Nordstrom, 2007).
A perceived decline in water quality, as measured by water clarity, aesthetic beauty or overuse, could result in approximately $2 million dollars in lost revenue, $650,000 in lost household income and 30 lost jobs (Nordstrom, 2007).

Figure 1. VLAP Regions

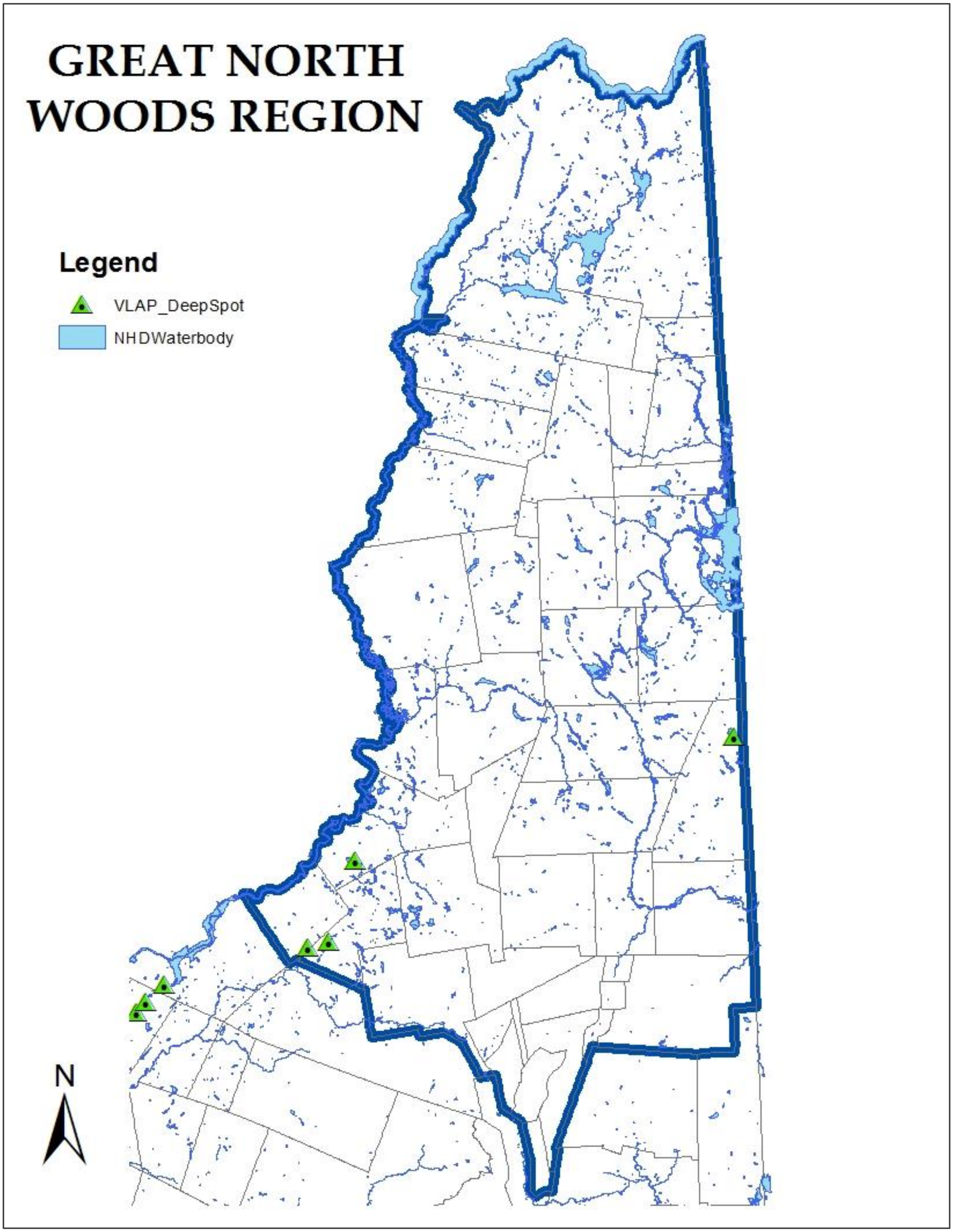


Similarly, a decline in water clarity alone can result in a decrease in New Hampshire lakefront property values. A one meter decrease in water clarity can lead to an average decrease in property values of between 0.9% and 6.0% in New Hampshire (Gibbs, Halstead, Boyle& Huang, 2002). This may negatively impact property tax revenues, especially in a state where there are approximately 64,000 vacation homes concentrated around the Lakes Region (lakes), Seacoast (ocean) and North Country (skiing) (Loder, 2011). According to a 1999 publication of the Society for the Protection of New Hampshire Forests, "The Economic Impact of Open Space in New Hampshire," vacation homes contribute approximately $286 million to state and local tax revenues (note: open space includes lakes). For a town with a large number of lakefront homes (vacation or residential), a decline in water clarity can cause decreased property values and local tax revenue.

The GNW region encompasses the Level 8 Hydrologic Unit Code (HUC) Watersheds of the Upper Connecticut River, Upper Androscoggin River and Lower Androscoggin River. The HUC boundary defines a specific drainage basin of a major river or series of smaller rivers. There are 18 HUC 8 watersheds in New Hampshire. There are seven VLAP regions (Figure 1). The GNW Region consists of four VLAP lakes as follows. Individual reports for Clarksville Pond and Martin Meadow Pond can be found in Appendix E.

Lake Name	**Town**
Success Pond	Success
Martin Meadow Pond	Lancaster
Burns Pond	Whitefield
Forest Lake	Whitefield/Dalton

Figure 2. Great North Woods Region Lakes



LAND USE AND POPULATION GROWTH

According to the 2010 update of the Society for the Protection of New Hampshire Forests' publication "New Hampshire's Changing Landscape 2010," New Hampshire's population is expected to increase by 180,000 through 2030 (Figure 3). Almost 70% of that growth will occur in the Southeastern part of the state, particularly in Merrimack, Hillsborough and Rockingham counties.

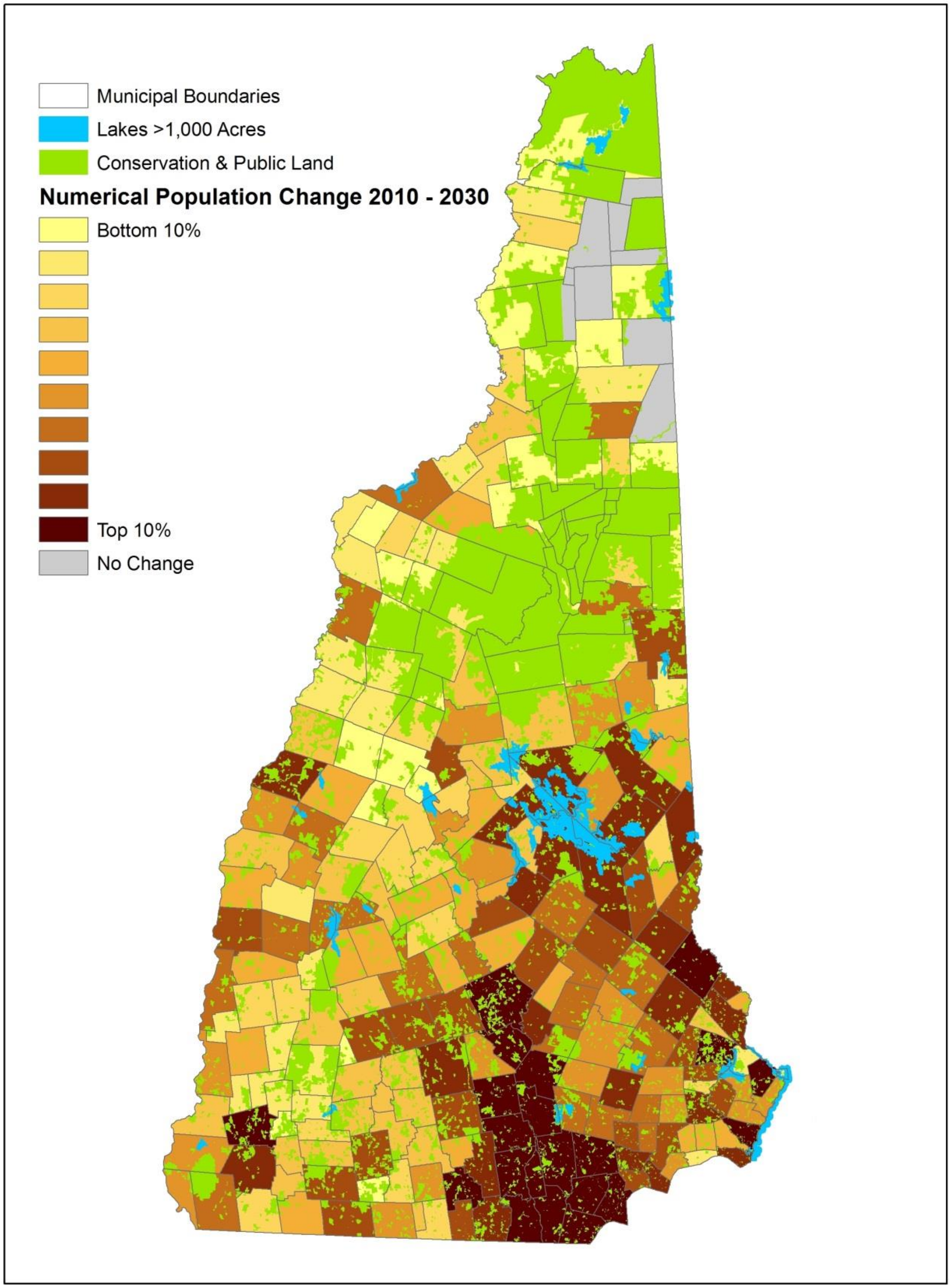
The population is anticipated to grow by approximately 3,000 people in Coos County by 2030. The majority of growth is estimated to follow main road corridors and urbanizing areas and is anticipated to be greatest in the towns of Berlin, Lancaster and Colebrook.

The GNW Region consists of over one million acres of land and surface water. Approximately 20,000 acres are surface waters (lakes, river, and wetlands) representing 2% of the total acreage of the GNW Region. Approximately 1,500 acres of surface water occurs in the towns predicted to experience the heaviest population growth, which represents approximately 6.5% of the total waterbody acreage in the GNW region. Approximately 60% of surface waters in the GNW Region lie solely in the towns of Pittsburg and Errol.

Major land use categories in the GNW Region are forest, developed and agriculture. Population growth and land use change go hand-in-hand. Growing populations necessitate land clearing to accommodate new homes, housing complexes, roadways and commercial businesses. Developed land corresponds to more impervious surfaces such as roadways, driveways and rooftops. It also corresponds to the loss of tree canopy coverage, unstable sediments, wildlife habitat loss and vegetative buffer loss. Consequences of development can negatively affect our waterbodies through increases in stormwater runoff, water temperatures, erosion, turbidity and nutrients, as well as shifts in aquatic life, aquatic plant, algae and cyanobacteria growth.

Population growth in the GNW region is a small percentage of the projected statewide growth. However, the GNW region contains a large percentage of total surface water area in New Hampshire. Efforts should be made to evaluate current land use activities, infrastructure, and regional water quality. This information should facilitate a plan to accommodate projected population growth while conserving and protecting valuable land and water resources.

Figure 3. New Hampshire Population Growth per Town 2010-2030



EXOTIC SPECIES

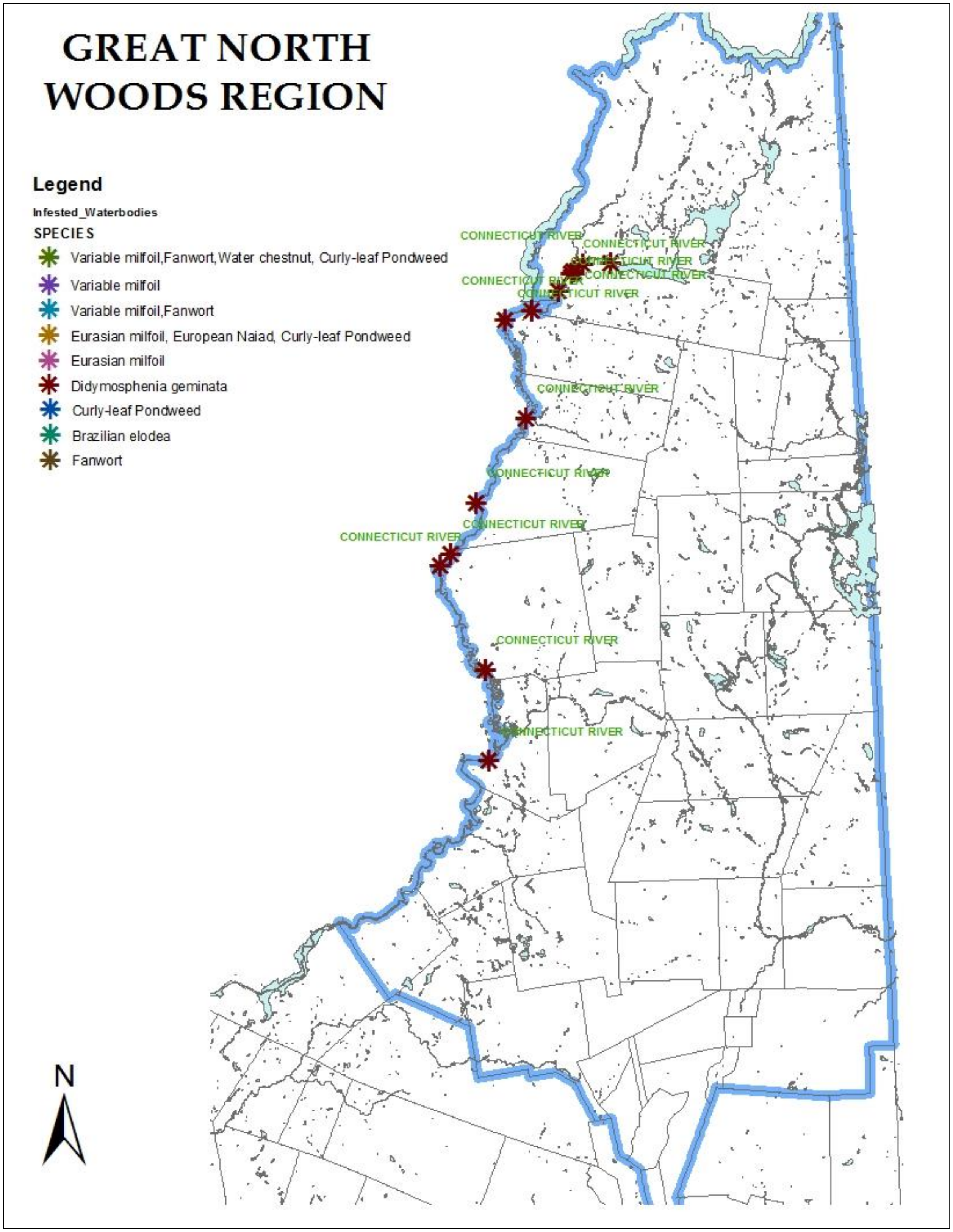
Exotic aquatic nuisance species are those plants and animals not native to New Hampshire's waterbodies, spread quickly through the aquatic environment, negatively affect economic and recreational activities, and can have a detrimental influence on natural habitats, the ecology of the system, and native species. They are a serious threat to the health of New Hampshire's aquatic ecosystems, recreation and tourism industries.

New Hampshire has 106 exotic plant infestations in 85 waterbodies. Those include Variable milfoil, Eurasian milfoil, Brazilian Elodea, Water chestnut, Curly-leaf Pondweed, Fanwort, European Naiad and *Didymo* (Rock Snot). Variable milfoil inhabits the majority of infested waterbodies, and *Didymo*, an alga, has now infested 54 river miles in the North Country. Currently, the GNW Region has remained exotic species free, that NHDES is aware of, except for the *Didymo* infestations in portions of the Connecticut River and smaller rivers/streams (Figure 4). Managing and monitoring the spread of *Didymo* is important to the recreational fishing industry. As *Didymo* grows, it chokes out habitat for macroinvertebrates (aquatic insects) and small fish and causes oxygen depletion as it decomposes. It is also aesthetically unpleasing, drastically changing the stream or river's appearance. Interestingly, in 2014 and 2015, researchers have begun to believe that *Didymo* is actually a native algal species, which forms bloom type growths (mats) when phosphorus levels in streams become very low. Fossil records in lake sediments show that *Didymo* has been present in the region for thousands of years, at low levels. NHDES is continuing to track this evolving topic, and will provide updates as they become available from researchers.

The unique nature and invasive tendencies of these exotic species heighten the need to prevent new infestations, manage current infestations and engage watershed residents. The newest infestation of Eurasian milfoil occurred in 2010, and Variable milfoil in 2012. Public education is integral in preventing further infestations. One program that educates the public and engages watershed residents is the NHDES Weed Watchers Program. The Weed Watchers program has approximately 750 volunteers dedicated to monitoring lakes and ponds for the presence of exotic aquatic plants. Volunteers are trained to survey their lake or pond once a month from May through September. To survey, volunteers slowly boat, or sometimes snorkel, around the perimeter of the waterbody and its islands looking for suspicious aquatic plant species. If a suspicious plant is found, the volunteers send a specimen to NHDES for identification, either in the form of a live specimen, or as a photograph emailed to the Exotic Species Program Coordinator. Upon positive identification, a biologist visits the site to determine the extent of infestation, initiates a rapid response management technique where possible, and formulates a long-term management plan to control the nuisance infestation.

Another program dedicated to public education and engaging watershed residents regarding exotic plant species is the Lake Host™ program, which was developed in 2002 by the non-profit organization New Hampshire Lake Association (NHLA, a.k.a. NH LAKES) and NHDES. The Lake Host™ Program is funded through NHDES and federal grants and provides courtesy boat inspections at boat ramps to prevent invasive species introduction and spread. Since the program was implemented, the number of participating waterbodies, volunteers, and number of "saves" (exotic plants discovered) has consistently increased. The program is invaluable in educating boaters, preventing recreational hazards, avoiding property value and aquatic ecosystem decline, addressing aesthetic issues and saving costly remediation efforts.

Figure 4. NH Exotic Aquatic Plant Infestations



GEOMORPHOLOGY AND CLIMATE

Chemical, physical and biological properties of lakes often reflect how they were formed. Lake formation can occur in a variety of ways. In New Hampshire, most lakes were formed during the last ice age as glaciers retreated approximately 12,000 years ago. Lakes are also formed from rivers (oxbow) and are man-and animal-made (e.g., impoundments, dams and beavers). These formations create distinct lake morphology. Included in a lake's morphology are length, width, area, volume and shape. Lake morphology affects the lake's overall ability to adapt to shifts in climate and land use.

Along with the morphological characteristics of lakes, the bedrock and sediment geology is also important in understanding lake properties. Underlying geological properties can affect the pH and ANC of our surface and groundwater. New Hampshire is typically referred to as the "Granite State" because the bedrock geology consists of variations of igneous rock high in granite content that contributes to a lower capacity to buffer acidic inputs such as acid rain. Metamorphic rocks make up the remainder of bedrock geology and consist of slate, schist, quartzite and carbonate rocks, which tend to contribute to a more neutral pH and better buffering capacity.

Climate also drives multiple processes in lake systems. Lakes respond to shifting weather conditions such as sunlight, rainfall, air temperature, and wind and wave action in various ways. This variability is reflected in the types and number of biological communities present, and chemical and physical properties of the lake system. It is essential that we understand how these factors influence water quality data collected at individual lake systems. Therefore, volunteers record pertinent weather data, rain and storm event totals, on field data sheets while sampling.

The GNW Regional climate conditions in 2013 were warm and wet based on the weather conditions recorded in Berlin, NH and surface water temperatures recorded by VLAP (Table 1). Air temperatures were above average in May, July and only slightly below average in June, August and September. Overall, the 2013 average regional summer air temperature was 0.6° warmer than the historical regional average. Regional surface water temperatures were slightly below average in June and above average in July, however this is based on only two lake sampling events, and likely is not representative of the regional average. The 2013 monthly summer rainfall levels were above average in May, July and September, whereas the months of June and August were below average. Overall, average regional precipitation was 0.77 inches above average.

In contrast, the 2014 sampling season was slightly cooler and drier. Average air temperatures were below normal from June through September, resulting in the 2014 seasonal average being 0.8 degrees cooler than the historical average. Surface water temperatures were slightly cool in July and average in August; however, this is based on a limited number of lakes and not representative of a regional average. The 2014 monthly summer rainfall was well above average in May and July and well below average in June, August and September. This resulted in the 2014 average summer precipitation being approximately equal to the historical average.

Table 1. Current Year and Historical Average Temperature and Precipitation Data for GNW Region

	May	June	July	August	September	Summer
2013 Average Air Temperature (°F)	56.5	62.6	69.3	63.5	56.1	61.6
2014 Average Air Temperature (°F)	53.8	61.7	66.4	63.0	55.9	60.2
Annual Average Air Temperature (°F)	53.0	63.0	67.0	65.0	57.0	61.0
2013 Average Surface Water Temperature (°F)	-------	-------	78.1	75.4	--------	76.8
2014 Average Surface Water Temperature (°F)	-------	-------	69.6	73.6	--------	71.6
Regional Average Surface Water Temperature (˚F)		67.3	73.9	73.5		71.6
2013 Precipitation (in.)	5.31	3.88	5.47	3.07	5.06	4.56
2014 Precipitation (in.)	5.43	2.37	6.74	3.25	1.08	3.77
Annual Average (in.)	3.49	4.12	3.81	4.06	3.51	3.79

MONITORING AND ASSESSMENT

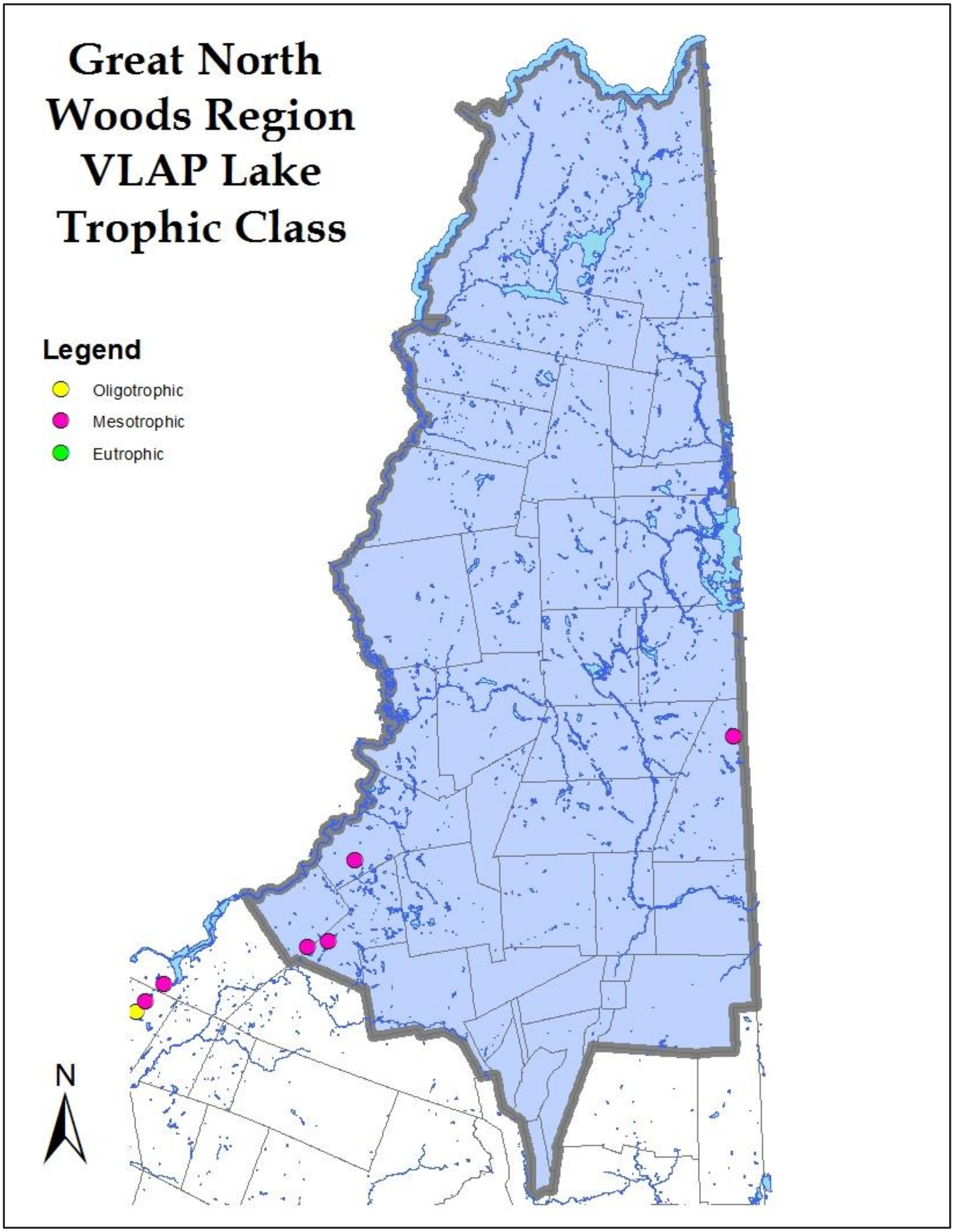
New Hampshire considers a public water to be great ponds or artificial impoundments greater than 10 acres in size, public rivers, streams and tidal waters. The GNW region consists of 85 lakes, or great ponds, four of which participate in VLAP. These data are critical for informing the local public of lake conditions, but also in making formal national water quality assessments reported to EPA. Data on the remaining 95% of lakes are sparse, being only occasionally sampled through the NHDES Lake Trophic Survey Program, or not sampled at all.

The NHDES Lake Trophic Survey Program monitors New Hampshire's lakes on a rotating basis, with the goal of conducting a comprehensive lake survey every 10 to 15 years. The surveys compile chemical, biological and morphological data. The data are used to assign a lake trophic class to each waterbody. The trophic class provides an assessment on lake productivity and can provide information on how population growth and human activities may be accelerating the lake-aging process, also known as lake eutrophication.

Three trophic classes are used to assess a lake's overall health: oligotrophic, mesotrophic, and eutrophic. Oligotrophic lakes have high dissolved oxygen levels (> 5 mg/L), high transparency (> 12 ft. or 3.65 m), low chlorophyll-a concentrations (< 4 mg/L), low phosphorus concentrations (< 10 ug/L), and sparse aquatic plant growth. Eutrophic lakes have low levels of dissolved oxygen (< 2 mg/L), low transparency (< 6 ft. or 1.8 m), high chlorophyll-a concentrations (> 15 mg/L), high phosphorus concentrations (> 20 ug/L), and abundant aquatic plant growth. Mesotrophic lakes have characteristics that fall in between those of oligotrophic and eutrophic lakes for the parameters listed.

The trophic class breakdown of GNW region lakes is as follows: 18 lakes are oligotrophic, 35 mesotrophic, 6 eutrophic and 26 un-assessed for trophic classification due to lack of data. Four mesotrophic lakes participate in VLAP (Figure 5). Approximately 60% of the GNW lakes are classified as oligotrophic and mesotrophic, however, approximately 90% of those lakes do not participate in VLAP or a similar monitoring program. As human activities in watersheds accelerate lake aging, it is imperative to keep a close eye on the health of those lakes. Efforts should also be made to gather data on the un-assessed waterbodies. Protecting a lake and preventing lake aging is much more cost-effective than restoring a damaged lake.

Figure 5. GNW Region VLAP Lake Trophic Status



VLAP WATER QUALITY DATA INTERPRETATION

The GNW Region is home to four lakes and ponds that participate in VLAP; however, one lake did not sample and is not included. Volunteer monitors at each lake collect comprehensive data sets at the deepest spot of the lake and from streams entering or exiting the lake. Deep spot sample collection is representative of overall lake quality, and data are used to establish long-term water quality trends and to provide information into the overall health of the waterbody. Stream sample collection is representative of what flows into the lake from the surrounding watershed. Stream data are used to identify potential watershed pollution problems, such as stormwater inputs, so that remediation actions occur before they negatively impact the overall health of the waterbody.

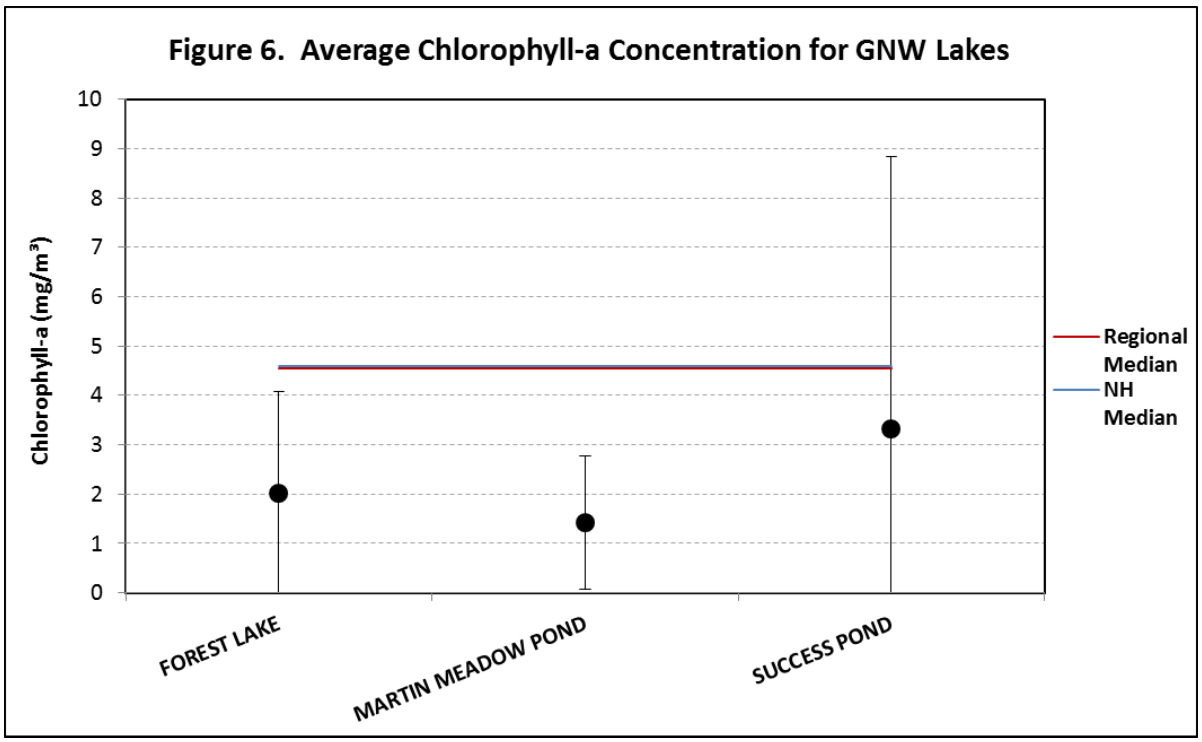
The following section provides a summary of the VLAP monitoring parameters, long-term water quality trends, and an analysis of the current year and historical data for the VLAP lakes and ponds in the GNW region compared with regional and state medians. The deep spot data for the epilimnion, or surface water layer, is compared to the New Hampshire median to provide an understanding of how the quality of a lake deep spot compares to other New Hampshire lake deep spots. Similarly, the epilimnion data are compared to the regional median to provide an understanding of how the quality of your lake deep spot compares with other local lakes. Median values were utilized to represent typical conditions while minimizing the effects of extreme (i.e. outlier) values. Average annual lake and regional values are then compared to the historical medians.

A complete list of monitoring parameters and how to interpret data are included in Appendix A.

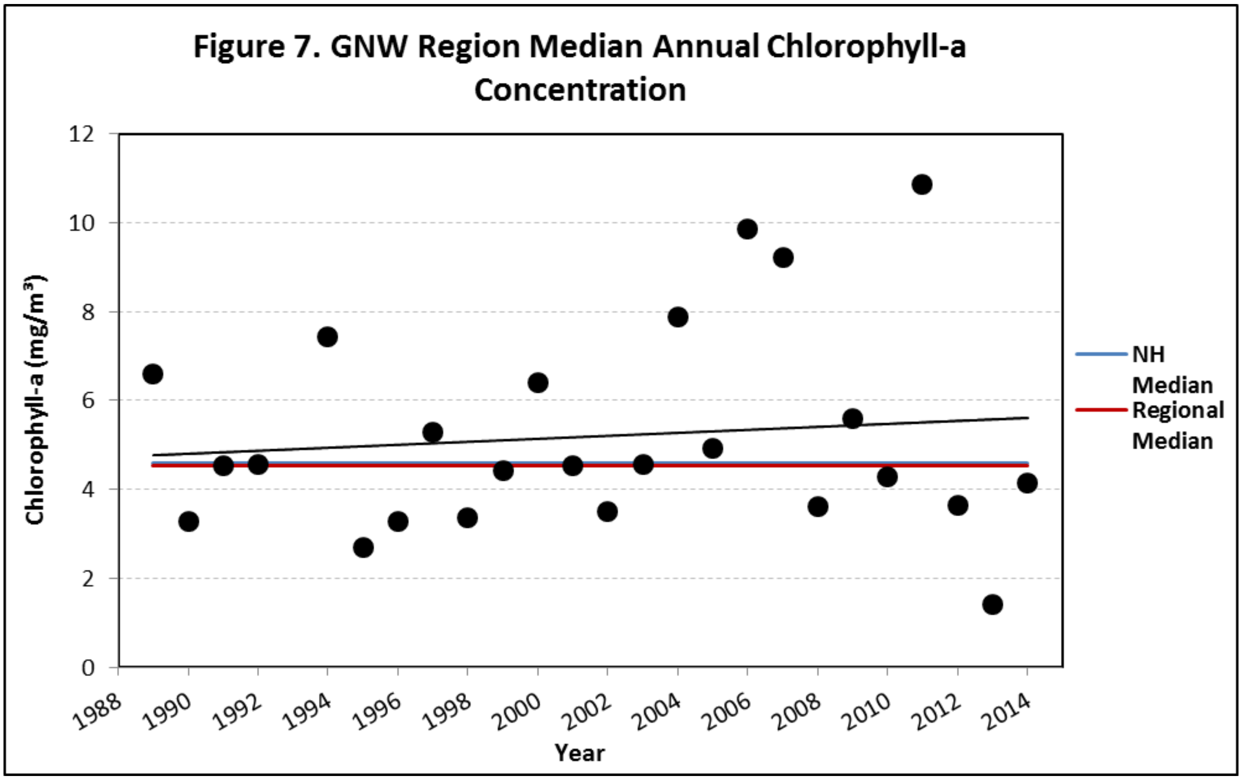
Annual and Historical Chlorophyll-*a* Data Analysis

Algae are microscopic plants that are naturally found in the lake ecosystem. Algae, including cyanobacteria, contain chlorophyll-*a*, a pigment used for photosynthesis. The measurement of chlorophyll-*a* in the water gives biologists an estimation of the algal abundance or lake productivity. **The median summer chlorophyll-*a* concentration for New Hampshire's lakes and ponds is 4.58 mg/m^3. The median chlorophyll-*a* concentration for the GNW region is 4.54 mg/m^3.**

Figure 6 represents the combined 2013 and 2014 average chlorophyll-*a* concentrations for each lake in the GNW Region compared with state and regional medians. The average chlorophyll-*a* concentration at three GNW lake deep spot stations were well below the state and regional medians and are typically representative of good water quality in the oligotrophic and mesotrophic classifications. Typically, chlorophyll-*a* concentrations that exceed 5.0 mg/m^3 are considered higher than desirable.



The annual median chlorophyll-*a* concentrations for the GNW region are represented in Figure 7. Prior to 2005, chlorophyll-*a* concentrations represent one lake, Forest Lake in Whitefield, whose average chlorophyll-*a* concentrations remained between 3.0 and 6.0 mg/m^3. Additional GNW lakes began sampling in 2005. The 2013 median was the lowest regional median measured since monitoring began. The 2014 median increased to a normal level for the region. However, the limited number of lakes sampling indicates additional lakes and data sets are needed to establish representative regional chlorophyll-*a* trends.



Chlorophyll-*a* Trend Analysis

The regional median chlorophyll-*a* level was subject to Mann-Kendall non-parametric statistical analyses to determine if a significant regional trend existed using a 95% confidence limit. No significant trend was detected for the region (Appendix D: Table D-1) consistent with the majority of state regional trends.

In addition to the regional trend analysis, GNW region lakes with 10 or more consecutive years of data were subject to linear regression analyses to determine whether water quality trends were significantly increasing, decreasing, or stable over time. Chlorophyll-*a* trends were assessed for 2 lake deep spots in the region.

No significant chlorophyll-*a* trends were found for individual GNW region lakes. Chlorophyll-*a* and has remained relatively stable at each lake deep spot (Appendix D: Table D-3). Chlorophyll-*a* concentrations are typically related to phosphorus concentrations. Phosphorus is a nutrient that promotes plant and algal growth in New Hampshire lakes. As phosphorus levels increase in lakes, it will normally cause an increase in algal growth. Stable chlorophyll-*a* trends are a positive sign for the lakes.

Annual and Historical Transparency Data Analysis

Volunteer monitors use the Secchi disk, a 20 cm disk with alternating black and white quadrants, to measure how far a person can see into the water. Transparency, a measure of water clarity, can be affected by algae and sediment in the water, as well as the natural color of the water. Transparency may also be measured using a viewscope, a cylindrical tube, designed to decrease surface water properties that may cause difficulty in viewing the Secchi disk. A comparison of transparency readings collected with and without the use of a viewscope shows that the viewscope typically increases the depth to which the Secchi disk can be seen into the lake, particularly on sunny and windy days. **The median summer transparency for New Hampshire's lakes and ponds is 3.20 meters. The median transparency for the GNW region is 3.25 meters.**

Figure 8 represents the combined 2013 and 2014 average transparency for each lake in the GNW Region compared with state and regional medians. The average transparencies at two GNW lake deep spots are greater than the state and regional medians and typically representative of average water quality conditions, while transparency at one lake is below the state and regional medians. Overall lake depth plays an important role when interpreting transparency data. Shallow lakes will typically report lower transparencies than deeper lakes, yet these waterbodies may be quite clear and have good water quality. A better representation would be to look at how transparency changes over time.

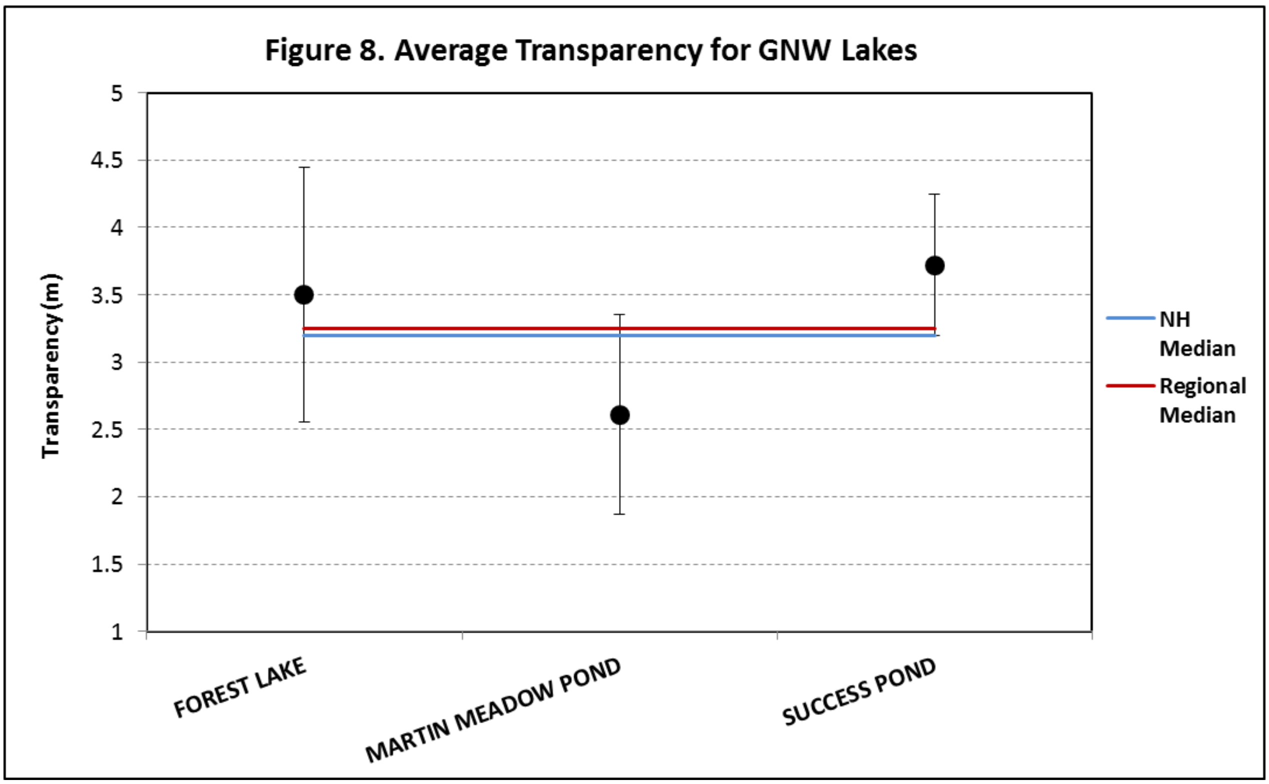
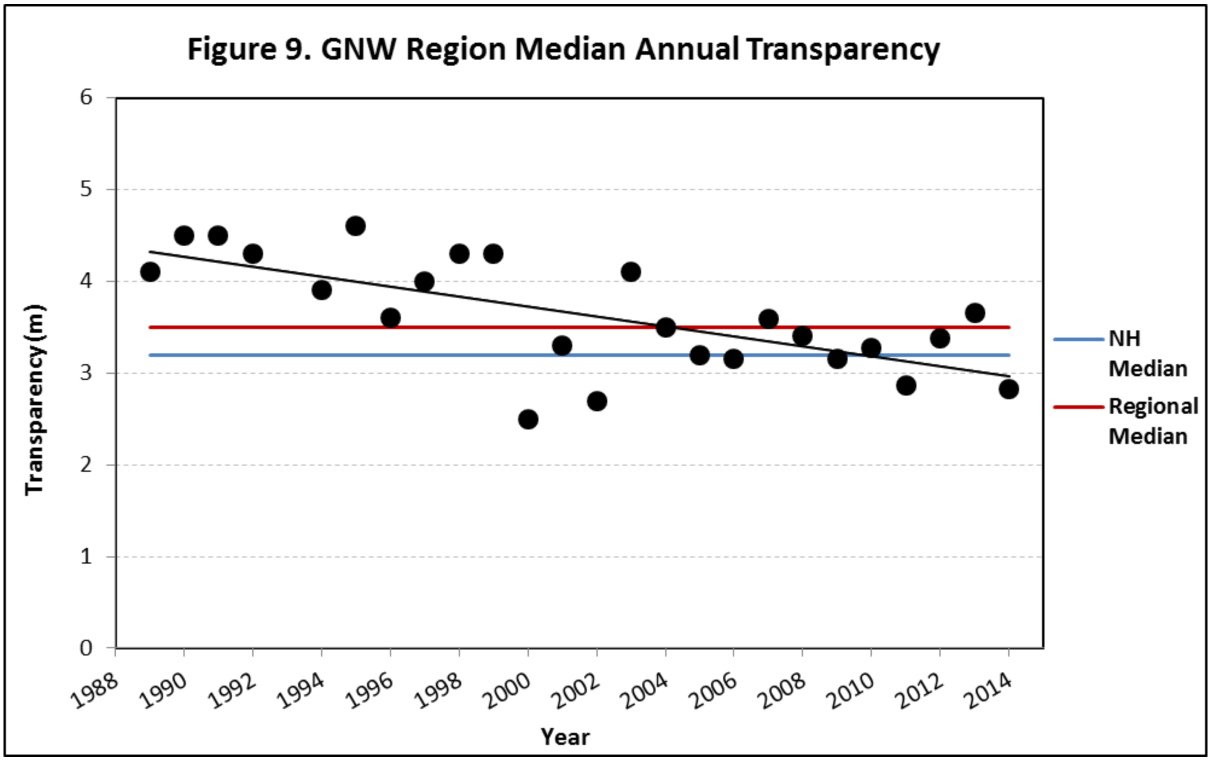


Figure 9 represents the annual median transparency for the GNW region. Median transparencies for the period 1989 to 2004 represent one lake, Forest Lake in Whitefield where transparency has remained relatively stable. Additional GNW lakes began sampling in 2005, and since then transparency has remained stable between three and four meters. Overall, additional lake data are needed to accurately assess transparency trends in the GNW region.



Transparency Trend Analyses

The regional median transparency was subject to Mann-Kendall non-parametric statistical analyses to determine if a significant regional trend existed using a 95% confidence limit. A significant decreasing (worsening) trend was detected for the region (Appendix D: Table D-1) consistent with all other state regional trends except the Lakes Region. However, this trend utilizes data from just one lake prior to 2004, and since then transparency has remained stable in the region.

In addition to the regional trend analysis, GNW region lakes with 10 or more consecutive years of data were subject to linear regression analyses to determine whether water quality trends were significantly increasing, decreasing, or stable over time. Transparency trends were assessed for two GNW lake deep spots and have remained stable over time (Appendix D: Table D-3).

Transparency, or water clarity, is typically affected by the amount of algae, color, and particulate matter within the water column. The increased frequency and intensity of storm events has resulted in an increase in stormwater runoff as well as increased flushing of wetland systems. Stormwater runoff can transport exposed and unstable sediments and other debris to lake systems, thus resulting in decreased transparency. Wetland systems are rich in organic acids that add color to the water making it appear dark. Lake watersheds with extensive wetland systems may also experience decreased transparency due to the influx of dark water during storm events. Transparency impacts due to wetland flushing is a natural occurrence, however erosion due to stormwater runoff can be mitigated to reduce sediments and particulate entering lake systems.

Refer to Appendix B for more information on how to manage stormwater runoff.

Annual and Historical Total Phosphorus Data Analysis

Phosphorus is typically the limiting nutrient for vascular plant and algal growth in New Hampshire's lakes and ponds. Excessive phosphorus in a pond can lead to increased plant and algal growth over time. **The median summer epilimnetic (upper layer) total phosphorus concentration of New Hampshire's lakes and ponds is 12 ug/L. The median epilimnetic total phosphorus concentration of the GNW region is 9 ug/L.**

Figure 10 represents the combined 2013 and 2014 average epilimnetic total phosphorus concentration for GNW region lakes compared with state and regional medians. Phosphorus concentrations at Forest Lake and Martin Meadow Pond were less than the state and regional medians while phosphorus concentrations at Success Pond were approximately equal to the regional median and all are representative of oligotrophic-mesotrophic conditions.

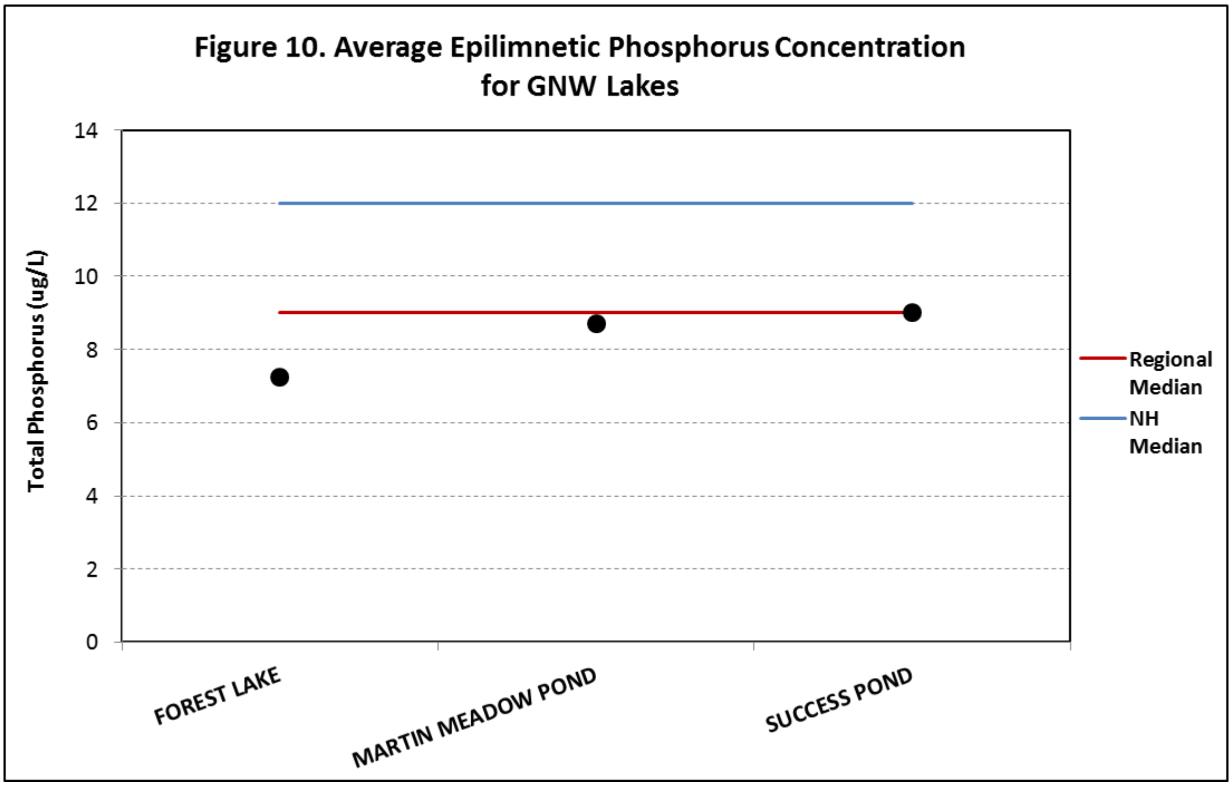
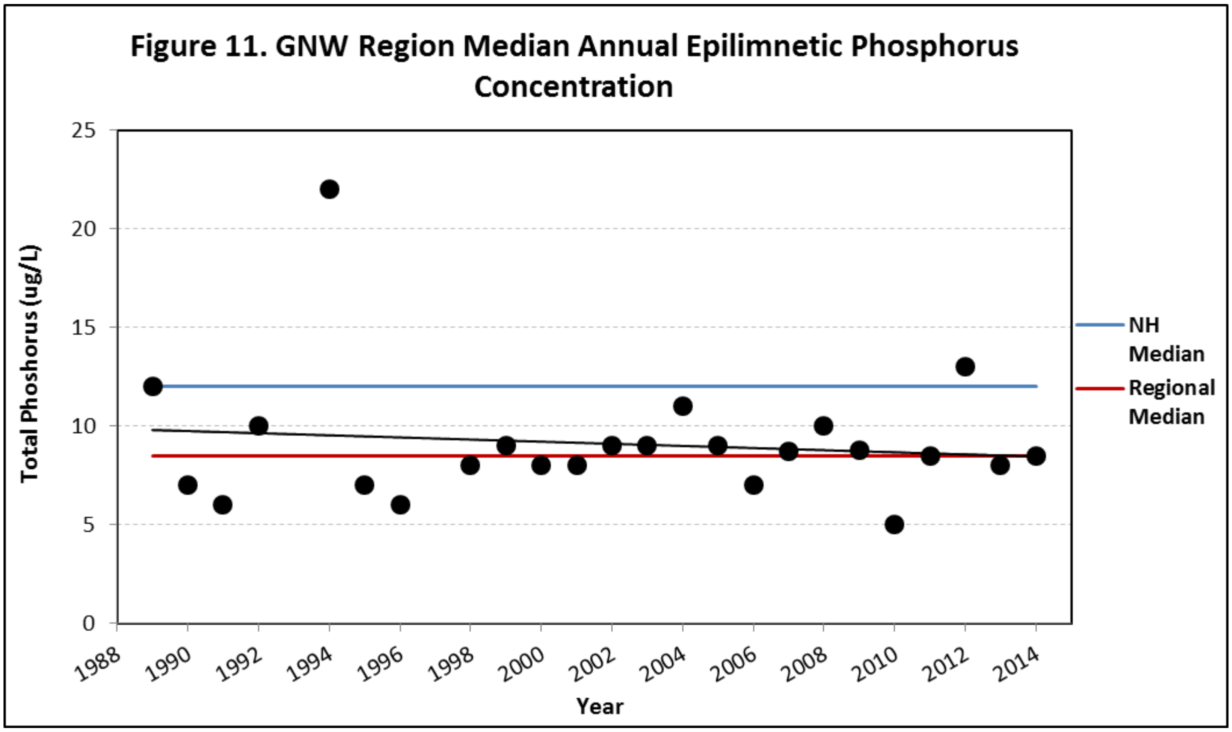


Figure 11 represents the median annual epilimnetic phosphorus concentration for the GNW region. The median regional epilimnetic phosphorus concentrations have generally hovered around the regional median of 9 ug/L since 1989. Data from 1989 through 2004 represent one lake, Forest Lake in Whitefield. Additional GNW lakes began sampling in 2005, and since then, median epilimnetic phosphorus concentrations have decreased slightly, but have generally remained stable over time. Overall, additional lake data are needed to accurately assess epilimnetic phosphorus trends in the GNW region.



Epilimnetic Phosphorus Trend Analyses

The regional median epilimnetic phosphorus was subject to Mann-Kendall non-parametric statistical analyses to determine if a significant regional trend existed using a 95% confidence limit. No significant trend was detected for the region (Appendix D: Table D-1) consistent with all other state regional trends except the Lakes and Seacoast Regions.

In addition to the regional trend analysis, GNW region lakes with 10 or more consecutive years of data were subject to linear regression analyses to determine whether water quality trends were significantly increasing, decreasing or stable over time. Epilimnetic phosphorus trends were assessed for two GNW lake deep spots. Trend analysis revealed a significantly decreasing (improving) phosphorus trend at Forest Lake (Table 2). For a full list of GNW trend results by individual lake, see Appendix D: Table D-3.

Increasing epilimnetic phosphorus trends are often a result of phosphorus-enriched stormwater runoff related to increased watershed development. An increase in watershed development often results in an increase in impervious surfaces and unstable sediments. This contributes to an increase in stormwater runoff and sedimentation to rivers and lakes. Efforts should be made to adopt watershed ordinances to limit stormwater runoff and other phosphorus contributions. Watershed residents should be educated on utilizing and installing stormwater management controls on their properties. For more information and resources to control stormwater and phosphorus loading refer to Appendix B.

Table 2. Significant Epilimnetic Total Phosphorus Trends at GNW Region Lakes

Lake Name	Total Phosphorus
	Decreasing Trend
	p
Forest Lake	0.04

Dissolved Oxygen Data Analysis

The presence of dissolved oxygen is vital to bottom-dwelling organisms as well as fish and amphibians. If the concentration of dissolved oxygen is low, typically less than 5 mg/L, species intolerant, meaning sensitive, to this situation, such as trout, will be forced to migrate closer to the surface where there is more dissolved oxygen but the water is generally warmer, and the species may not survive. Temperature and time of day also play a role in the amount of dissolved oxygen in the water column. Water can hold more oxygen at colder temperatures than at warmer temperatures. Therefore, a lake will typically have a higher concentration of dissolved oxygen during the winter, spring and fall than during the summer. Oxygen concentrations are typically lower overnight than during the day. Plants and algae respire (use oxygen) at night and photosynthesize (produce oxygen) during the day. Dissolved oxygen levels may shift depending on the abundance of aquatic plants and algae in the littoral (near shore) and pelagic (deep water) zones.

Dissolved oxygen and temperature profiles are collected at VLAP lakes on an annual or biennial basis. The average whole column dissolved oxygen level for the GNW region is 5.41 mg/L, which is in a critical range to support a wide variety of aquatic life. For additional information regarding dissolved oxygen, please refer to Appendix A.

Annual and Historical Deep Spot pH Data Analysis

pH is measured on a logarithmic scale of 0 (acidic) to 14 (basic). pH is important to the survival and reproduction of fish and other aquatic life. A pH below 6.0 typically limits the growth and reproduction of fish. A waterbody is considered impaired for aquatic life when the pH falls below 6.5 or above 8.0. **The median epilimnetic pH value for New Hampshire's lakes is 6.6, which indicates that the state surface waters are slightly acidic. The median epilimnetic pH for the GNW region is 7.08.**

Figure 12 represents the combined 2013 and 2014 average epilimnetic pH for individual GNW region lakes compared with state and regional medians. Forest Lake and Success Pond pH was between the state and regional medians, while Martin Meadow Pond pH was greater than the state and regional medians, and all were within the desirable range 6.5 - 8.0 units for New Hampshire lakes.

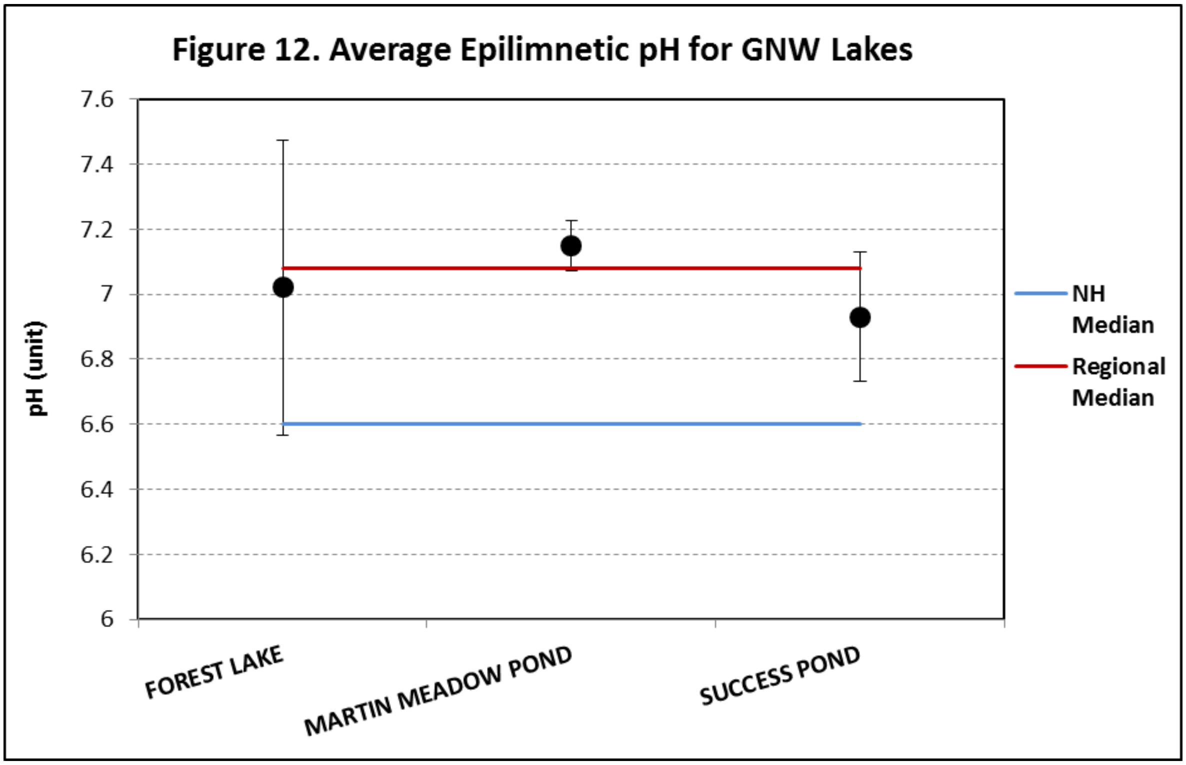
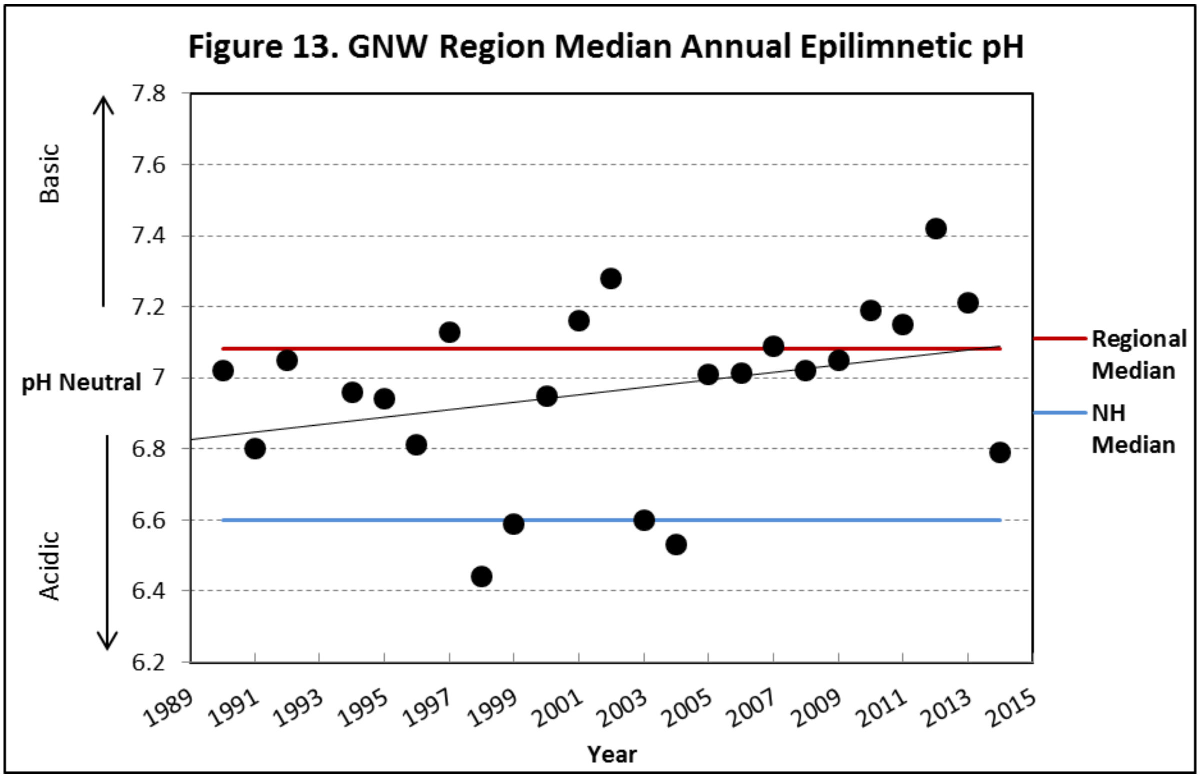


Figure 13 represents the median annual pH value for GNW lakes. The 2014 median epilimnetic pH value at GNW lakes was 6.79 and within the desirable range 6.5 - 8.0 units for New Hampshire lakes. Regional pH tends to fluctuate between 6.8 and 7.2 and is considered approximately neutral and better than the New Hampshire Median. Overall, additional lake data are needed to accurately assess pH trends in the GNW region.



Variations in pH values between lakes and between different geographical regions may depend on the composition and weathering of underlying bedrock and the lake water chemistry. Another contributing factor to pH is acid deposition received as a result of emissions from power plants and vehicles. This increases levels of atmospheric carbon, nitrogen and sulfur which fall back to the earth in the form of acidic precipitation.

pH Trend Analysis

The regional median epilimnetic pH was subject to Mann-Kendall non-parametric statistical analyses to determine if a significant regional trend existed using a 95% confidence limit. A significantly increasing (improving) trend was detected for the region (Appendix D: Table D-1). This trend was also detected in the Monadnock region; however, most other regions of the state experienced stable trends (Appendix D: Table D-1).

In addition to the regional trend analysis, DLS region lakes with 10 or more consecutive years of data were subject to linear regression analyses to determine whether water quality trends were significantly increasing, decreasing or stable over time. Epilimnetic pH trends were assessed for two GNW lake deep spots and have remained stable over time (Appendix D: Table D-3).

Variations in pH values between lakes and between different geographical regions may depend on the composition and weathering of underlying bedrock and the lake water chemistry. Another contributing factor to pH is acid deposition received as a result of emissions from power plants and vehicles. This increases levels of atmospheric carbon, nitrogen and sulfur, which fall back to the earth in the form of acidic precipitation.

A recent report published by NHDES “Acid Rain Status and Trends New Hampshire Lakes, Ponds and Rainfall” analyzed trends in historical pH, ANC, conductivity, sulfate and nitrate concentrations from three state-wide monitoring programs to determine if the state’s lakes and ponds are recovering from the effects of acid rain. The Acid Outlet, Remote Pond, and Rooftop Rain programs have been collecting data since the early 1970s and 1980s. Analysis of sulfate, nitrate and pH concentrations of precipitation indicate that pH levels have significantly increased (become less acidic), and sulfate and nitrate concentrations have significantly decreased (improved) since 1972. Analysis of sulfate, nitrate, pH and ANC concentrations of lake water indicate that the majority of lakes sampled have experienced a stable trend or increase (improvement) in pH and ANC as well as a 90% reduction in sulfate and nitrate concentration. This supports significant improvements in local and national air quality as regulations have improved acid rain; however, our surface waters reflect a slower rate of recovery.

Annual and Historical ANC Data Analysis

ANC measures the buffering capacity of a water body, or its ability to resist changes in pH by neutralizing acidic inputs. These "buffers" are typically bases such as bicarbonate and carbonate. Geology can play an important part in a water body's buffering capacity. Lakes located in areas with predominantly limestone (calcium carbonate), sedimentary rocks and carbonate-rich soils often have a higher ANC, while lakes located in areas with predominantly granite and carbon-poor soils often have a lower ANC. The higher the ANC, the more readily a waterbody can resist change in pH. **The median ANC value for New Hampshire's lakes and ponds is 4.8 mg/L, and the median ANC value for the GNW region is 7.85 mg/L, which indicates that many lakes and ponds in the region are "moderately vulnerability" to acidic inputs.**

Figure 14 represents the combined 2013 and 2014 average epilimnetic ANC for GNW regional lakes compared to the state and regional medians. Forest Lake and Martin Meadow Pond have ANC values greater than the state and regional medians, while Success Pond has ANC values between the state and regional medians and all are within a "moderately vulnerable" range.

For more information on ANC values for New Hampshire lakes see Appendix A.

Figure 14. Average ANC for GNW Lakes

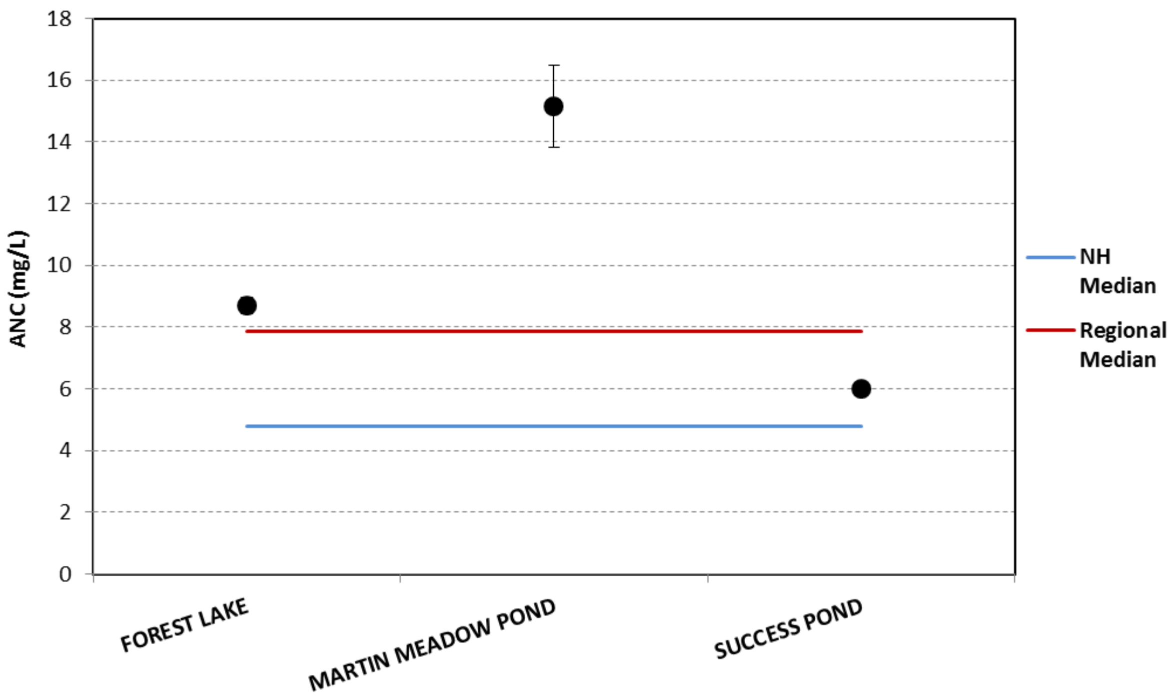
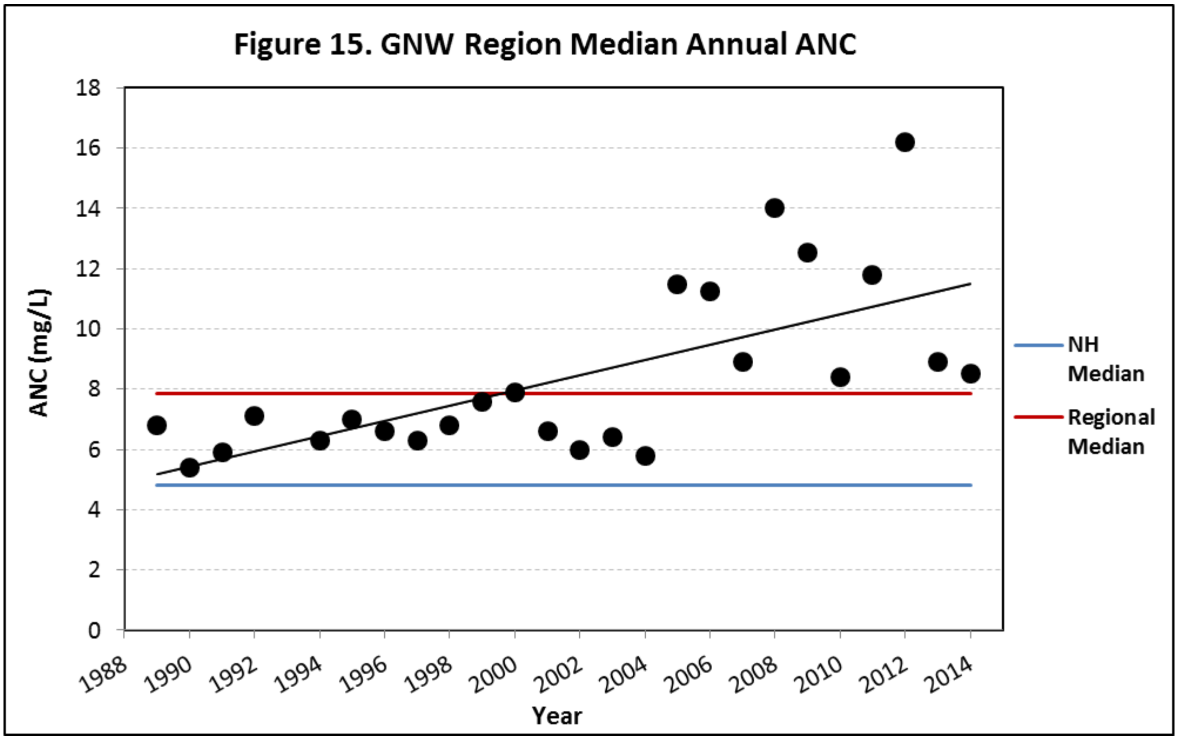


Figure 15 represents the median annual ANC for the GNW region. The median annual ANC remained between 5.0 and 8.0 mg/L from 1989 through 2004 and represented Forest Lake in Whitefield. Since then, additional lakes have joined the program and the median ANC has increased to between 8.0 and 16.0 mg/L. Overall, additional lake data are needed to accurately assess ANC trends in the GNW region.



Acid Neutralizing Capacity Trend Analysis

The regional median ANC was subject to Mann-Kendall non-parametric statistical analyses to determine if a significant regional trend existed using a 95% confidence limit. A significantly increasing (improving) trend was found for the GNW region, which was similar to the majority of other regions around the state (Appendix D: Table D-1). However, this is based on data from one lake through 2004 and does not accurately represent a true regional trend.

Annual and Historical Conductivity Data Analysis

Conductivity is the numerical expression of the ability of water to carry an electric current, which is determined by the number of negatively charged ions from metals, salts and minerals in the water column. The soft waters of New Hampshire have traditionally low conductivity values, generally less than 50 uMhos/cm. However, specific categories of good and bad levels cannot be constructed for conductivity because variations in watershed geology can result in natural fluctuations. **The median conductivity value for New Hampshire's lakes and ponds is 40.0 uMhos/cm. The median epilimnetic conductivity for the GNW region is 44.1 uMhos/cm.**

Figure 16 represents the 2013 and 2014 combined average epilimnetic conductivity for GNW lakes compared with state and regional medians. A wide range of epilimnetic conductivity values exist for the lakes. Forest Lake conductivity is generally between the state and regional medians, Martin Meadow Pond conductivity is much greater than the state and regional medians, while Success Pond conductivity is less than the state and regional medians.

Figure 16. Average Epilimnetic Conductivity for GNW Lakes

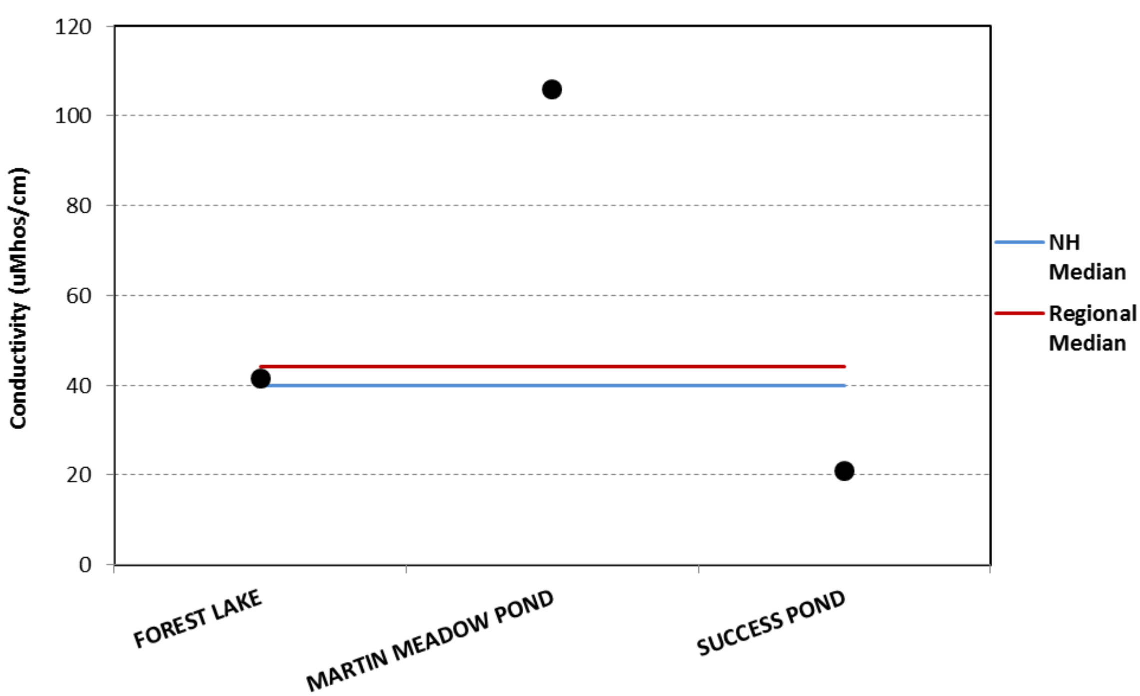
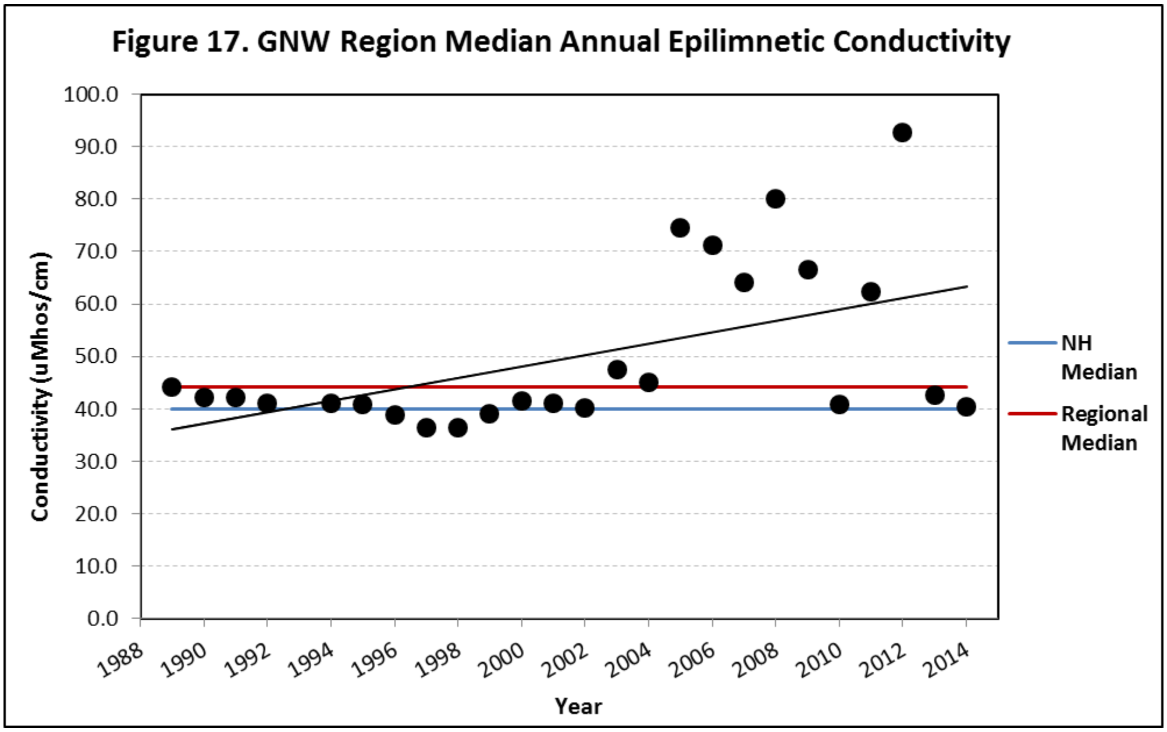


Figure 17 represents the median annual epilimnetic conductivity for the GNW region compared with the regional and state medians. The 2013 and 2014 median epilimnetic conductivity values at GNW Lakes were approximately equal to the New Hampshire median and decreased greatly from that measured in 2011 and 2012 indicating that conductivity values fluctuate widely among the region's lakes. Data from 1989 through 2004 represent Forest Lake in Whitefield and are stable and low. Additional lakes began sampling in 2005 causing the median conductivity to increase to between 60.0 and 100.0 uMhos/cm. Overall, additional lake data are needed to accurately assess epilimnetic conductivity in the GNW region.



Generally, conductivity values in New Hampshire lakes exceeding **100 uMhos/cm** indicate cultural, meaning human, disturbances. An elevated conductivity trend typically indicates point sources and/or non-point sources of pollution are occurring within the watershed. These sources include failed or marginally functioning septic systems, agricultural runoff, road runoff and groundwater inputs. New development in the watershed can alter runoff patterns and expose new soil and bedrock areas, which could also contribute to increasing conductivity. In addition, natural sources, such as mineral deposits in bedrock, can influence conductivity.

Historical Conductivity Trend Analysis

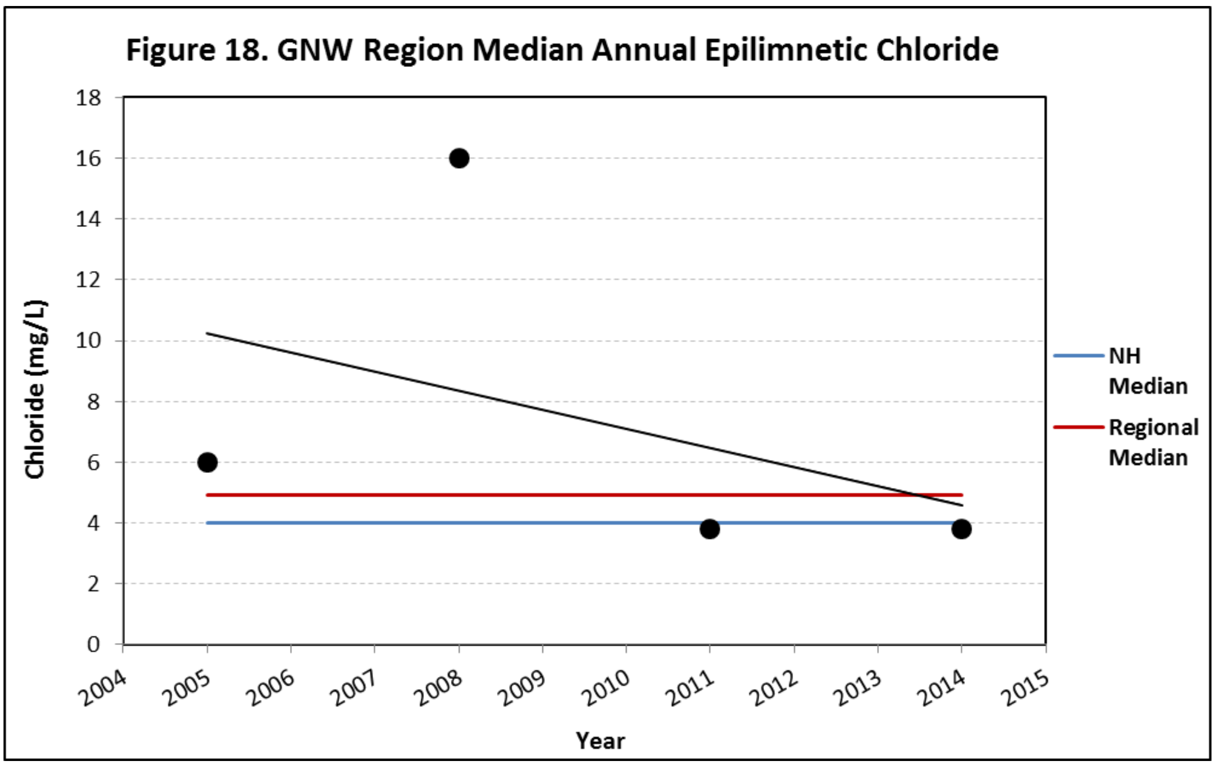
The regional median epilimnetic conductivity was subject to Mann-Kendall non-parametric statistical analyses to determine if a significant regional trend existed using a 95% confidence limit. The GNW region was found to have a significantly increasing (worsening) trend in epilimnetic conductivity. However, this is based on data from one lake through 2004 and does not accurately represent a true regional trend. All other state regions, with the exception of Dartmouth Lake Sunapee region, were found to have increasing epilimnetic conductivity trends (Appendix D: Table D-1).

In addition to the regional trend analysis, GNW region lakes with 10 or more consecutive years of data were subject to linear regression analyses to determine whether water quality trends were significantly increasing, decreasing or stable over time. Epilimnetic conductivity trends were assessed for two GNW lake deep spots and have remained stable over time (Appendix D: Table D-3).

Annual and Historical Chloride Data Analysis

High conductivity values are often due to elevated chloride levels, which are generally associated with road salt and/or septic inputs. The chloride ion (Cl^-) is found naturally in some surface and ground waters and in high concentrations in seawater. The chloride content in New Hampshire lakes is naturally low in surface waters located in remote areas away from habitation. Research has shown that elevated chloride levels can be toxic to freshwater aquatic life. In order to protect freshwater aquatic life in New Hampshire, the state has adopted acute and chronic chloride criteria of 860 and 230 mg/L respectively. **The median chloride value for New Hampshire's lakes is 4 mg/L. The median epilimnetic chloride value for the GNW region is 4.9 mg/L.**

Figure 18 depicts median annual epilimnetic chloride levels for select regional lakes compared with state and regional medians. The chloride measurement is relatively new for VLAP and is an optional analyte for participating lakes. Lakes that serve as water supplies or where conductivity levels may be influenced by chloride are analyzed annually. Chloride data were not collected at GNW lakes in 2012 and 2013. Regional chloride levels are generally very low and approximately equal to the state median. The 2008 chloride level was representative of one lake, Martin Meadow Pond in Lancaster. Overall, additional lake data are needed to accurately assess chloride trends in the GNW region.



Watershed management efforts to control un-natural sources of conductivity and chloride in waterbodies should employ a combination of best management practices in regards to winter salting practices. State and local governments and private homeowners should evaluate the use of road salt and alternatives to reduce the amount of material applied while maintaining public safety.

For additional information on the relationship between conductivity and chloride, please refer to Appendix A. For additional information on best management practices, please refer to Appendix B.

Historical Chloride Trend Analysis

Chloride monitoring is a relatively new analyte and optional for VLAP lakes. At this time, there is not enough data to conduct trend analysis for the GNW region.

Annual and Historical Turbidity Data Analysis

Turbidity in the water is caused by suspended matter (such as clay, silt and algae) that causes light to be scattered and absorbed, not transmitted in straight lines through water. Water clarity is strongly influenced by turbidity. **The Class B surface water quality standard for turbidity is no greater than 10 NTUs over the lake background level. The median epilimnetic turbidity for the GNW region is 0.81 NTU.**

Figure 19 depicts the 2013 and 2014 combined average epilimnetic turbidity compared to the regional median. Forest Lake, Martin Meadow Pond and Success Pond epilimnetic turbidities were greater than the regional median, however were much less than the Class B surface water quality standard.

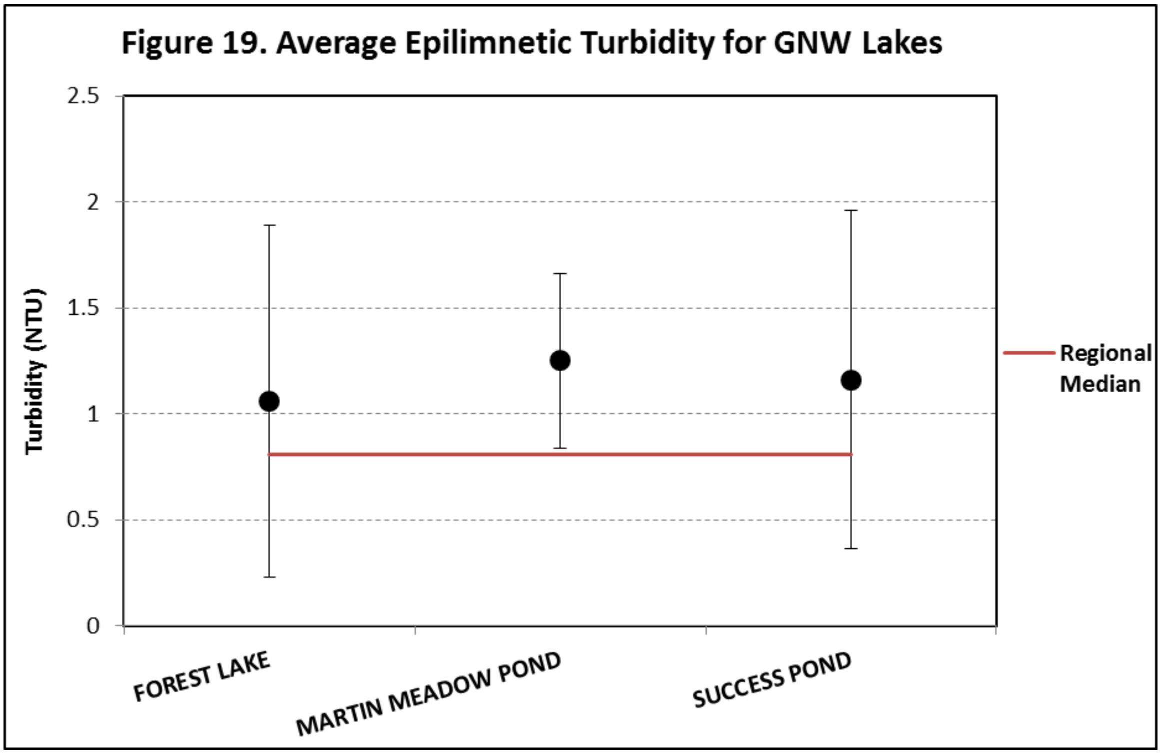
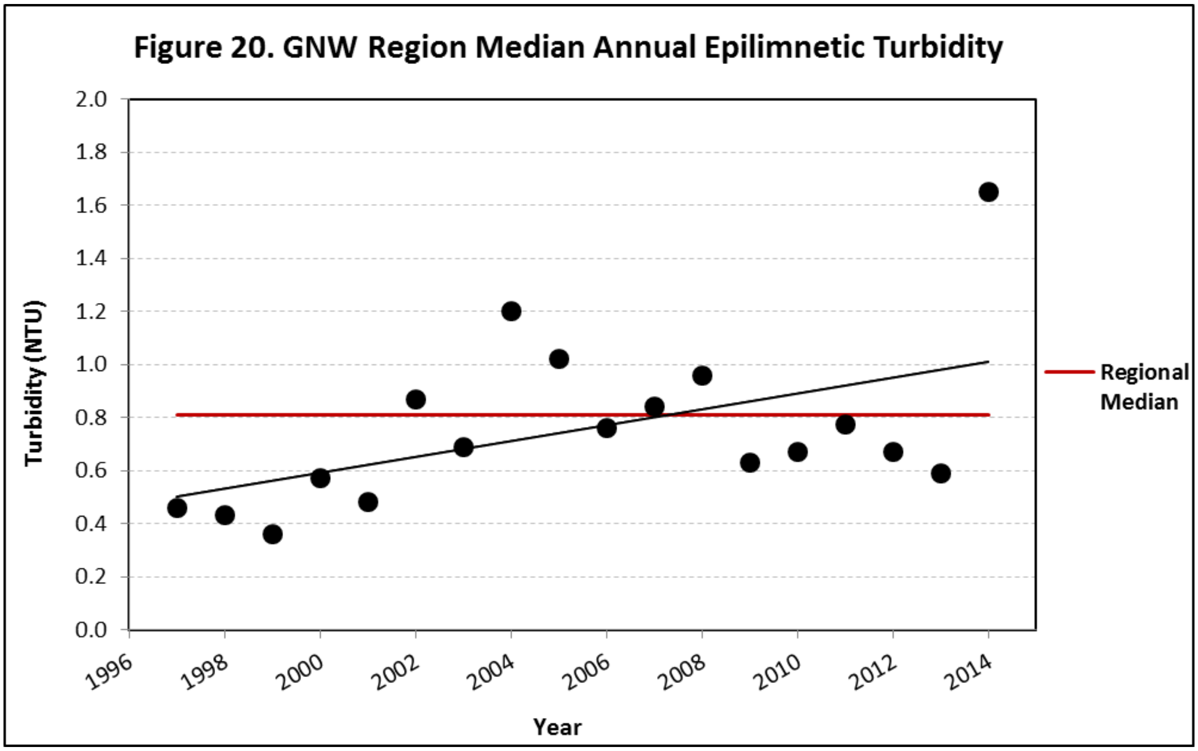


Figure 20 represents the median annual epilimnetic turbidity for the GNW region. The 2014 median epilimnetic turbidity at GNW lakes was 1.65 NTU, which is much greater than the regional median and was likely caused by stormwater runoff at Forest Lake and elevated algal growth at Success Pond. Regional epilimnetic turbidity is typically below 1.0 NTU and is average for most New Hampshire lakes. Data from 1997 through 2004 represent Forest Lake in Whitefield. Additional lakes joined the program in 2005, and since then median annual epilimnetic turbidity has remained slightly higher. Additional lake data are needed to accurately assess epilimnetic turbidity in the GNW region.



Historical Turbidity Trend Analysis

The regional median epilimnetic turbidity was subject to Mann-Kendall non-parametric statistical analyses to determine if a significant regional trend existed using a 95% confidence limit. The GNW region was found to have a significantly increasing (worsening) trend in turbidity, which is consistent with the rest of the state (Appendix D: Table D-1). However, this is based on data from one lake through 2004 and does not accurately represent a true regional trend.

New Hampshire has experienced more significant rainfall events in recent years which may be contributing to an increase in stormwater runoff and turbidity in the region's lakes. Elevated deep spot turbidity levels are typically the result of stormwater runoff, algal or cyanobacteria blooms, and/or disturbance of lake bottom sediments. Stormwater BMPs should be implemented when possible to reduce the amount of suspended sediments and debris transported to surface water. Boating activity in shallow areas should adhere to rules specified by the New Hampshire Marine Patrol in regards to speed and no wake zones. If an algal or cyanobacteria bloom is observed, please contact NHDES immediately. *For additional information on turbidity, stormwater BMPs, algae and cyanobacteria, please refer to Appendices A and B.*

Reference:

Gibbs, J. P., Halstead, J. M., Boyle, K. J., & Huang, J. (2002). An hedonic analysis of the effects of lake water clarity on New Hampshire lakefront properties. *Agricultural and Resource Economics Review*, *31*(1), 39-46.

Loder, A. (2011, September 08). *Vacation communities and the rest of New Hampshire: How their tax rates compare*. Retrieved from http://stateimpact.npr.org/new-hampshire 2/27/2012

Nordstrom, A. The New Hampshire Lakes, Rivers, Streams and Ponds Partnership, (2007). *The economic impact of potential decline in new hampshire water quality: The link between visitor perceptions, usage and spending*

Sundquist, D. Society for the Protection of New Hampshire Forests, (2010). *New Hampshire's changing landscape 2010*

The Society for the Protection of New Hampshire Forests, (1999). *The economic impact of open space in New Hampshire*