# Ossipee Watershed

## 10-Year Water Quality Report

## 2002-2011

**March 2015**


**Prepared by:**

FB environmental


**Prepared for:**

GREEN MOUNTAIN CONSERVATION GROUP


**Funded in part by:**

Adelard & Valeda Lea Roy Foundation

Little Royal Family Foundation

Davis Conservation Foundation

# Green Mountain Conservation Group

# Ossipee Watershed 10-Year Water Quality Report

Prepared for the Green Mountain Conservation Group by FB Environmental Associates
in cooperation with the Green Mountain Conservation Group.

## March 2015


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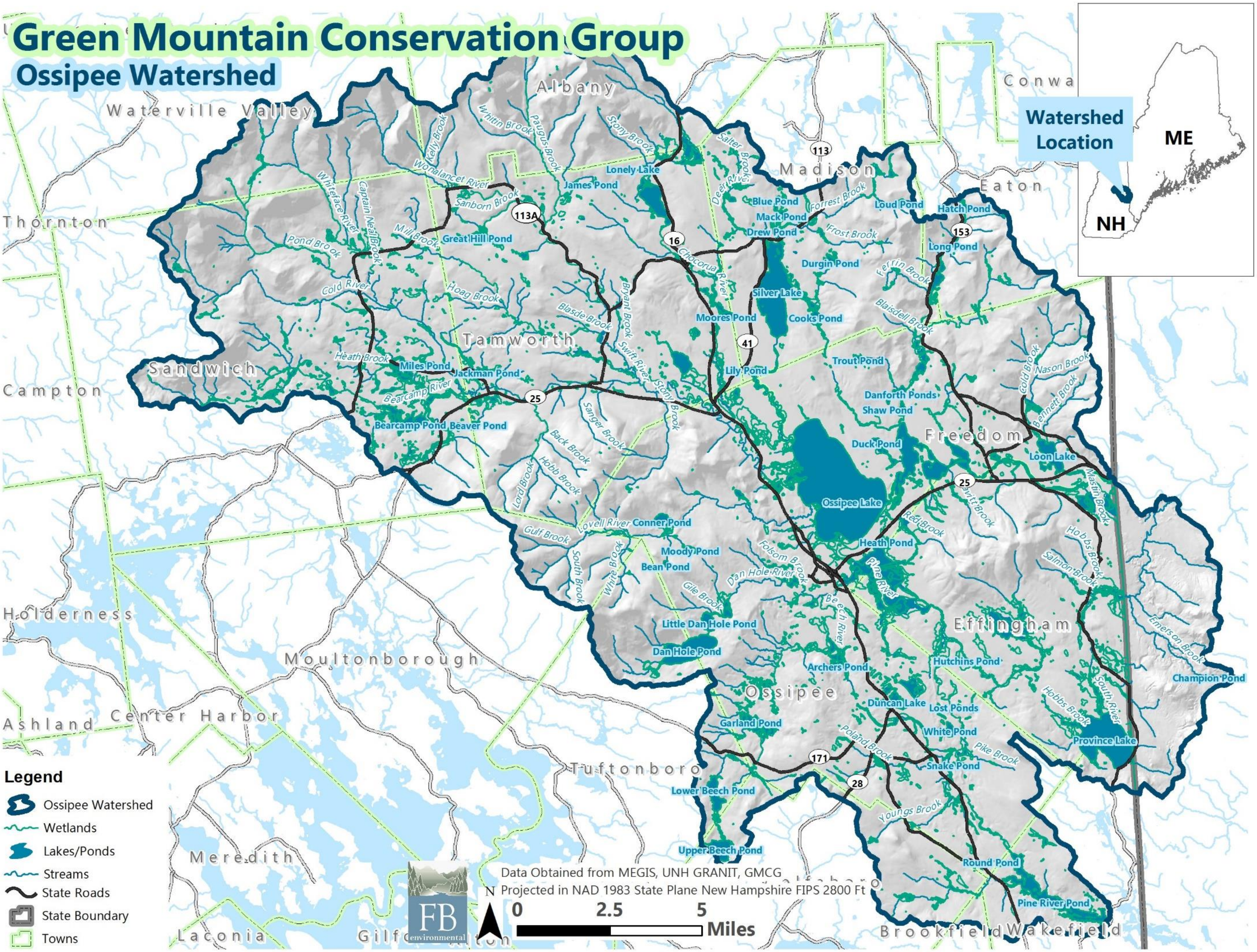
Cover photos: Green Mountain Conservation Group



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# ACKNOWLEDGEMENTS

Green Mountain Conservation Group (GMCG) would like to acknowledge the individuals and organizations that have been instrumental in the creation and continuation of the Ossipee Watershed Water Quality Monitoring Program. These volunteers and organizations contribute thousands of hours to the program each year, and it would not be possible without their support.

**Ossipee Watershed Towns:** GMCG is grateful to the Towns of Effingham, Freedom, Madison, Ossipee, Sandwich, Tamworth, and Eaton for their past and continued financial support to the water quality program. Without funding from these watershed towns, the data reported herein could not have been collected.

**Funding Organizations:** Rotary Club of Ossipee, Captain Planet Foundation, Little Royal Family Foundation, Adelard & Valeda Lea Roy Foundation, Davis Conservation Foundation, Jocelyn Gutchess Fund of the New Hampshire Charitable Foundation, Fred Van Cor Memorial Fund, New Hampshire Charitable Foundation, Quimby Foundation, Timberland, Inc., and Patagonia, Inc.

**NH Water Resources Research Center (WRRC):** The NH WRRC (directed by Dr. Bill McDowell and Associate Director, Michelle Daley) provided funding for analysis of monthly, year-round nutrient and chloride analysis of samples collected from seven long-term sites, as well as two sites of GMCG's choosing. Samples were analyzed at the NH Water Quality Analysis Laboratory (WQAL), formerly managed by Jeff Merriam and currently managed by Jody Potter.

**Volunteers 2001-2014:** Roger Thurrell, Lyn Slanetz, Rose de Mars, Claes Thelemarck, Jim & Jamie Shea, Beth Earle, Ned Hatfield, Dawn & Brad Marion, Jared Stepanauskas, Ralph Lutjen, Jennifer Hocking Wiley, Anne Filson, Chele Miller, Katie McCarthy, Ruth Timchak, Tim White, Mary Beth McAllister, Elizabeth Gillette, Donna & Michael Veilleux, Noreen & Dave Downs, Herb Cooper, Mike & Kate Cauble, Al Levesque, Lee Pollock, John Shipman, Sylvia Carney, Liz Ahearn, Kate Yarrison, Justin Chapman, Emelyn Albert, Theresa Swanick, Anne Garland, Maynard Thomson, Frank Lucas, Don & Wendy Miskelly, Jean Hansen, Susan Fine, Sherri, Sam & Hannah Therrien, Steve Gray, Melanie Lekousi, Jim Pittman, Fred Peabody, Marilyn Tillinghast, Jean Hansen, Kamalendu Nath, Arlene Allen, Laura Deming, Cindy Romano, Corey Lane, Mary Holmes, Maria LaGuardia, Debbie Piekut, Patty O'Day-Senior, Brianne Fowles, Mary & Sepp Meier, Harry Merrow, Caroline Snyder, Beverly & Ted Stanier, Julie Streeter, John Cooley, John Mersfelder, Lori Lenart, Deborah Frock, Stan Shimer, Paula Hammond, Mike Rossi, Rich Soltanis, Carolyn Buskirk, Tammy & Evan Brown, Kathy Johnson, Warren Miller, Joel Rhymer, Dana Crocker, Mark Martin, Moselle Spiller, Sarah Van Cor-Hosmer, Rich

Water quality monitoring volunteers from Camp Calumet assisted with collecting data from OL-2, Bearcamp River. (Photo: GMCG)

Dandeneau, David Smith, Susan Marks, Cindy Sawyer, Emily Camm, Ben Tripp, Joy Chase, and Eve and Bill Klotz, Rick Klausner, Kevin Connorton, Peter Klose, Norm Sizemore, Jesse Mixer, Dick Brisbois, Tim Otterbach Chris Young, Anne Packard, Brian and Carol Taylor, Frank Virnelli Larry Wogman, Laura Campbell, Jen and Sara Elsemore, Ed Green, Bob Houle, Howard Bouve, Jim Madgee, Nick Libby, Paul Tung, Eric Stokes, Walter Bailey, Jim Fitzpatrick, Jesse Walsh, Anne Cunningham, Scott Brooks, Jim McElroy, Jody Skelton, Barry Keith, Paul Wheeler, Jean Marshall, Pat Jones, John Wacker, Dianne Battles, Sheila Jones, Acton Wakefield Watershed Alliance, Ossipee Lake Alliance, Global Action Local Awareness, Ossipee Lake Marina, Totem Pole Park, and anyone else that has volunteered their time and efforts to the protection of the Ossipee Watershed.

**Volunteer Memorial:** GMCG would also like to recognize volunteers who are no longer with us: Jim Clemons, Fred Van Cor, Larry Leavitt, Steve Timchak, Warren Walker, Beverly Klitsch, and Charlie Smith.

**GMCG 2014 Board Members:** Jerry Knirk, Carol Stansell, Holly Larsen, Diana Levy, Susan Slack, Alice Custard, Nicole Maher Whiteside, Jay Buckley, Larry Wogman, Bob Butcher, Peter Klose, Peter Zack, and Blair Folts (Executive Director).

**GMCG 2014 Staff:** Blair Folts (Executive Director), Corey Lane (Water Quality Coordinator), Noreen Downs (Outreach Coordinator), Chris Young (Land Trust), and Maureen Brooks (Water Quality Intern).

**New Hampshire Department of Environmental Services (NHDES):** Eric Williams, Barbara McMillan, David Neils, Dawn Keppler, Greg Dlubac, Sarah Sumner, Andrew Cornwell, Jeff Marcoux, Jillian McCarthy, and Lisa Loosigian.

**Plymouth State University:** Lisa Doner, Marc Green, and Melanie Perello.

**Volunteers from Camps, Schools, & Organizations:**

- *Camp Calumet:* Paul Lindhal; *Camp Cody:* Nick Robbins; *Camp Huckins:* Jody Skelton; *Camp Marist:* Joe Bouchard; *Camp Robin Hood:* Chuck Illig; *Danforth Bay Campground:* Craig Niiler
- *Sandwich Central School:* Justin Chapman, parents, and students
- *Ossipee Central School:* Erin Dyer and students
- *Effingham Elementary School:* Kyra Dulmage and students
- *Tamworth Learning Circle School:* Jamie Riel, Richard Posner, and students
- *Freedom Elementary School*: Lori Palmer and students
- *Conway Elementary School:* Ms. Kane, Ms. Koroski, Ms. Coleman, and students
- *Madison Elementary School:* Tracey Holmes and students
- *Moultonborough Elementary:* Maud Anderson, students, and parents
- *The Community School:* Joslin Heyn and students
- *Home School Group:* Amy Carter, parents, and students
- Saco River Corridor Commission (Dennis Finn, Executive Director)
- UNH Cooperative Extension & Lakes Lay Monitoring: Bob Craycraft
- Conservation Commissions from the Towns of Effingham, Freedom, Madison, Ossipee, Sandwich, Tamworth, and Eaton
- New Hampshire Lakes: Andrea LaMoreaux

# EXECUTIVE SUMMARY

The 10-year water quality analysis provides valuable information to help protect the water resources in the Ossipee Lake Watershed. (Photo: GMCG)

Clean water is vital to New Hampshire's communities and economy, particularly in the Ossipee Watershed where pristine streams and clear lakes are abundant and feed into the State's largest stratified drift aquifer. The aquifer provides clean drinking water to local communities. These natural resources are being threatened as development pressures and environmental stressors increase. A 2007 report by the NH Lakes Association (NHLA) found that a perceived reduction in surface water clarity and purity could lead to lost sales of $25 million, lost income of $8.8 million, and 131 lost jobs in the Lakes Region alone. This makes long-term monitoring programs incredibly important for protecting these ecologically, economically, and socially valued natural resources.

The Saco/Ossipee Watershed Monitoring Program, created by Green Mountain Conservation Group (GMCG) in New Hampshire and Saco River Corridor Commission (SRCC) in Maine, is designed to be one water quality monitoring program under a single Quality Assurance Project Plan (QAPP) that encompasses ***one watershed, two states, and twenty-six towns.*** One of the goals of the program is to provide the public with volunteer-collected, baseline water quality data that give an overall picture of water quality in the watershed. GMCG volunteers have collected water quality information regularly (i.e. twenty-four biological, physical, and chemical parameters) from nineteen Ossipee Watershed river (RIVERS) sites, eleven Ossipee Lake tributary (OLT) sites, and five deep hole stations on Danforth Ponds, Ossipee Lake, and its lower bays. This report showcases a subset of parameters from select sites (sixteen RIVERS sites and six OLT sites; Table 2, Figure 1).

This report provides surface water quality information, analyses, and recommendations for towns within the Ossipee Watershed, including Effingham, Freedom, Madison, Ossipee, Sandwich, Tamworth, and Eaton. Results are based on data collected from 2002 to 2011 through the GMCG Regional Interstate Volunteers for the Ecosystems and Rivers of Saco (RIVERS) Watershed Monitoring Program and the GMCG Ossipee Lake and Tributaries (OLT) program. The data presented include four physical parameters (pH, water temperature, turbidity, and specific conductivity) and seven chemical parameters (dissolved oxygen, total phosphorus, phosphate, total dissolved nitrogen, nitrate, ammonium, and chloride) for twenty-two tributary sites within the Ossipee Watershed (Tables 1 and 2). Also included in this report is a summary of the total phosphorus analysis for five deep water spots on Danforth Ponds and Ossipee Lake and its lower bays (Broad, Leavitt, and Berry Bays) from the 2015 watershed management plan (FBE, 2015). Lake data were collected through the UNH Center for Freshwater Biology Lakes Lay Monitoring Program (LLMP) and the NHDES Volunteer Lakes Assessment Program (VLAP), with local support from camps, volunteers, and GMCG staff.

The physical and chemical parameters presented in this report are important indicators of aquatic habitat integrity and the extent and impact of human activities on aquatic life function. The remaining parameters not included in this report (i.e. dissolved organic nitrogen, dissolved organic carbon, silica, sulfate, sodium, potassium, magnesium, and calcium) are still important indicators of aquatic health and should be included in future analyses as resources permit.

Analysis of water quality data for select tributary sites in the Ossipee Watershed between 2002-2011 showed that ***water quality in the watershed is very good overall***. Many parameters across the select sites met established New Hampshire water quality standards or fell within levels indicative of natural conditions rather than direct human impact, with some notable exceptions. Table 1 lists the select eleven physical and chemical parameters measured along with descriptions of their importance and any established State standards or relative guidelines for data interpretation. Table 2 provides a summary of water quality results based on these standards or guidelines for the eleven parameters for each of the select twenty-two tributary sites.

While the water quality is generally good for the Ossipee Watershed, ***some tributary sites have emerging problems*** that need attention (refer to Table 2).

- Low **pH** (slightly acidic waters) is common at all sites, some of which is a result of natural conditions in New Hampshire streams from local geology and acid rain. Most sites experienced periods of dangerously low pH that can inhibit aquatic life function.
- **Water temperature** exceeded a recommended maximum of 24° C for coldwater fish species at Ossipee River (GE-3), Danforth Pond outlet (GF-1), West Branch River 1 (OL-1u), Banfield Brook (GM-1), and Bearcamp River 4 (OL-2).
- **Specific conductivity** exceeded 100 µS/cm one at least one occasion at thirteen of the twenty sites (out of 30 actives sites), suggesting that human disturbance contributes chemical ions (e.g. chloride, nutrients, etc.) to surface waters in the watershed above natural conditions.
- **Turbidity** has increased (worsened) over the past ten years at Cold Brook A2 (GF-3), Banfield Brook (GM-1), Forrest Brook 2 (GM-3), and Red Brook 3 (OL-7). This is likely a result of soil erosion following rain events, which can be fixed with riparian buffer plantings and road maintenance.
- **Dissolved oxygen** has decreased (worsened) over the past ten years at Pine River 1 (GE-1), and exceeded the State standard for concentration and percent saturation at five and seventeen sites, respectively.
- **Total phosphorus** and **phosphate** were elevated at Weetamoe Brook 1 (OL-5ua) and Red Brook 3 (OL-7).
- **Total dissolved nitrogen** has increased (worsened) over the past ten years at Danforth Pond outlet (GF-1) and Bearcamp River 4 (OL-2).

- **Ammonium** has increased (worsened) over the past ten years at Ossipee River (GE-3) and has exceeded natural levels at Weetamoe Brook 1 (OL-5ua) and Red Brook 3 (OL-7).
- Spring **chloride** has increased (worsened) over the last ten years at Cold River (GS-1), but spring and summer chloride have decreased (improved) at Frenchman Brook 4 (GO-2) and Forrest Brook 2 (GM-3), respectively. Although chloride concentrations were well below State standards for chronic exposure, several sites exceeded natural background levels of 30 mg/L on at least one occasion, including Cold Brook A2 (GF-3), Banfield Brook (GM-1), Beech River 1 (GO-1), Frenchman Brook 4 (GO-2), and Bearcamp River 1 (GT-1). These higher chloride concentrations are likely from road salt applications, which enter streams via culverts and ditches and infiltrate to groundwater via roadside soils (Daley et al. 2009).

These analyses revealed ***four tributary sites that have multiple water quality parameters exceeding State water quality standards, exceeding natural background levels, and/or showing deteriorating trends***: Pine River 1 (**GE-1**), Banfield Brook (**GM-1**), Weetamoe Brook 1 (**OL-5ua**), and Red Brook 3 (**OL-7**). These sites should be priority targets for future restoration efforts.

All five monitored deep water spots on Danforth Ponds and Ossipee Lake and its lower bays (Broad Bay, Leavitt Bay, and Berry Bay) within the Ossipee Watershed meet the State water quality standard for their respective trophic class (i.e. oligotrophic or mesotrophic), and analyses of total phosphorus in these bays show a stable trend from 2003-2014. Total phosphorus within Broad and Berry Bays fell within their "reserve" assimilative capacity, indicating that phosphorus management is needed within the watershed to protect these bays from exceeding State water quality standards in the near future. GMCG is currently developing watershed-based management plans that focus on phosphorus reduction initiatives in the Ossipee Watershed. It is also important to note that lake water quality changes naturally over hundreds or thousands of years, gradually transforming from less productive (oligotrophic) to more productive (eutrophic) systems; human disturbances within a watershed can accelerate this transformation on the scale of a few decades, which is why remedial steps should be sought to better manage this change.

In sum, several tributary sites analyzed in this report show deteriorating trends in some water quality parameters, but water quality at these sites still meet State water quality standards. This presents a ***unique opportunity for engaged stakeholders***, such as GMCG and watershed towns, to utilize restoration techniques that can reverse or stabilize these deteriorating trends in water quality. Results of the analyses can be used by the watershed towns and their partners (GMCG, OLA, NHDES, and others) to prioritize and direct future monitoring and water quality protection efforts throughout the Ossipee Watershed. Recommendations for future monitoring, watershed planning, and restoration actions to reduce nonpoint source (NPS) pollution in the Ossipee Watershed are discussed at the end of the report.

**Table 1.** Description and Class B standards or indicators for streams for interpreting the select eleven physical (blue) and chemical (green) parameters.

| Parameter | Definition | Importance | NH Water Quality Standard for Class B Waters | Natural Background/Minimal Disturbance Levels for NH |
|---|---|---|---|---|
| **pH** | Measure of acidity in terms of hydrogen ion concentration in water (ranges from 0 to 14 with 7 being neutral) | Affects chemical and biological processes; organisms function under optimal range | Must occur between 6.5 and 8.0 | As low as 6.0 due to acid rain and low buffering capacity of underlying geology |
| **Water Temperature** | Measure of the degree of heat in a waterbody | Regulates metabolic rates of organisms and growth of aquatic plants; influences amount of dissolved gases | No quantitative standard | Coldwater fish species thrive under maximum weekly and instantaneous temperatures of 19° and 24° C |
| **Turbidity** | Measure of the amount of suspended material in water, such as clay, silt, algae, sediment, and decaying plant material | Indicator of soil erosion, particularly during rain events; high turbidity clogs fish gills and covers stream bottom habitats | Shall not exceed 10 NTU above natural conditions | Median = 1.0 NTU |
| **Specific Conductivity** | Measure of the electrical current in water normalized to a water temperature of 25° C; surrogate measure for chemical ions in water | Indicator of pollution from road salting, septic systems, and stormwater runoff | No quantitative standard | Less than 100 µS/cm, above which is likely a result of human disturbance |
| **Dissolved Oxygen (DO)** | Measure of the concentration or percent saturation of dissolved oxygen in water | Facilitates critical chemical reactions within the channel and benthic sediments that support life processes and functions | Shall not fall below 5 mg/L or 75% saturation | Low dissolved oxygen can occur naturally in slow-moving waters or waterbodies located downstream of wetlands |
| **Total Phosphorus (TP)** | Measure of all dissolved phosphorus (i.e. organic and inorganic) as well as phosphorus contained in or adhered to suspended particles, such as sediment and plankton | Indicator of eutrophication likely as a result of human disturbance | No quantitative standard | Less than 20 µg/L |
| **Phosphate ($PO_4^{3-}$)** | Measure of the inorganic component of total phosphorus | Indicator of eutrophication likely as a result of human disturbance; serves as an essential nutrient for growth; most biologically-available form | No quantitative standard | Less than 20 µg/L |
| **Total Dissolved Nitrogen (TDN)** | Measure of dissolved organic and inorganic nitrogen concentration in water | Indicator of eutrophication likely as a result of human disturbance; serves as an essential nutrient for growth | No quantitative standard | Difficult to pinpoint due to variability in natural sources of organic nitrogen |
| **Ammonium ($NH_4^+$)** | Measure of a component of inorganic nitrogen in water; waste product of metabolic processes in organisms | Indicator of eutrophication likely as a result of human disturbance; serves as an essential nutrient for growth; most biologically-available form | No quantitative standard | Less than 0.2 mg/L |
| **Nitrate ($NO_3^-$)** | Measure of a component of inorganic nitrogen in water; product of ammonium nitrification under oxidizing conditions | Indicator of eutrophication likely as a result of human disturbance; serves as an essential nutrient for growth | No quantitative standard | Less than 0.5 mg/L |
| **Chloride ($Cl^-$)** | Measure of the element chloride in water derived from geology, atmospheric deposition, or human activities | Indicator of human disturbance (e.g. road salting) | Shall not exceed 860 mg/L for acute toxicity and 230 mg/L for chronic toxicity | Less than 30 mg/L |

**Table 2.** Summary of water quality results for the select eleven physical and chemical parameters for the select twenty-two tributary sites.

| Town | Site # | Site Name | Physical Parameters | | | | Chemical Parameters | | | | | | | | Sum | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | pH | Water Temp | Turbidity | Sp. Cond. | DO (mg/L) | DO (% sat) | TP | $PO_4^{3-}$ | TDN | $NH_4^+$ | $NO_3^-$ | $Cl^-$ | ✓ | ! | * | * | Total |
| Effingham | **GE-1** | **Pine River 1** | ✓ | | | ! | * | ✓ | ! | | | | | | 2 | 2 | 1 | | **5** |
| | GE-2 | South River | ✓ | | | | ✓ | ✓ | ! | | | | | | 3 | 1 | 0 | | 4 |
| | GE-3 | Ossipee River | ✓ | ! | | | | ✓ | | | | * | | | 2 | 1 | 1 | | 4 |
| Freedom | GF-1 | Danforth Pond Outlet | ✓ | ! | | | | ✓ | | | * | | | | 2 | 1 | 1 | | 4 |
| | GF-2 | Cold River | ✓ | | | ! | | ✓ | ! | | | | | | 2 | 2 | 0 | | 4 |
| | GF-3 | Cold Brook A2 | ✓ | | * | ! | | ✓ | | | | | | | 2 | 1 | 1 | | 4 |
| | OL-1u | West Branch River 1 | ✓ | ! | | | ✓ | ✓ | | | | | | | 3 | 1 | 0 | | 4 |
| | OL-9u | Cold Brook B1 | ✓ | | | | | | | | | | | | 1 | 0 | 0 | | 1 |
| Madison | **GM-1** | **Banfield Brook** | ✓ | ! | * | ! | | ✓ | | | | | | ! | 2 | 3 | 1 | | **6** |
| | GM-3 | Forrest Brook 2 | ✓ | | * | | | ✓ | | | | | | * | 2 | 0 | 1 | -1 | 2 |
| Ossipee | GO-1 | Beech River 1 | ✓ | | | | | ✓ | | | | | | | 2 | 0 | 0 | | 2 |
| | GO-2 | Frenchman Brook 4 | ✓ | | | ! | | | ! | | | | | *! | 1 | 3 | 0 | -1 | 3 |
| | GO-4 | Bearcamp River 3 | ✓ | | | | | ✓ | | | | | | | 2 | 0 | 0 | | 2 |
| | GO-5 | Bearcamp River 2 | ✓ | | | | | ✓ | | | | | | | 2 | 0 | 0 | | 2 |
| | OL-2 | Bearcamp River 4 | ✓ | ! | | | | | | | * | | | | 1 | 1 | 1 | | 3 |
| | OL-4u | Lovell River 1 | ✓ | | | | | ✓ | | | | | | | 2 | 0 | 0 | | 2 |
| | **OL-5ua** | **Weetamoe Brook 1** | ✓ | | | | ✓ | ✓ | ! | ! | | ! | | | 3 | 3 | 0 | | **6** |
| | **OL-7** | **Red Brook 3** | ✓ | | * | ! | ✓ | ✓ | ! | ! | | ! | | | 3 | 4 | 1 | | **8** |
| Sandwich | GS-1 | Cold River | ✓ | | | | | | | | | | | * | 1 | 0 | 1 | | 2 |
| Tamworth | GT-1 | Bearcamp River 1 | ✓ | | | | ✓ | ✓ | | | | | | | 3 | 0 | 0 | | 3 |
| | GT-4 | Chocorua River | ✓ | | | | | ✓ | | | | | | | 2 | 0 | 0 | | 2 |
| | GT-5 | Swift River | ✓ | | | | | | | | | | | | 1 | 0 | 0 | | 1 |

✓ *Exceeded State standards*
! *No State standards for parameter, but exceeded natural background levels likely as a result of human activities*
* *Degrading water quality trend (Mann-Kendall tests)*
* *Improving water quality trend (Mann-Kendall tests)*
***Sites in red text exhibited the most parameters exceeding State standards or natural background conditions and/or showing a deteriorating trend***

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# INTRODUCTION

As demand increases, clean water quickly becomes a more valuable resource, requiring long-term study and protection on a watershed and even global scale. In recent years, water has become one of the most important political issues in New Hampshire with issues spanning from water scarcity to water extraction to water contamination to wellhead protection. Since New Hampshire does not have a Statewide protection program or legislation to proactively protect surface or groundwater from development pressures and environmental stressors, it is incumbent upon communities to protect their own water resources from potential contamination or misuse.

The Ossipee Watershed is home to the largest stratified drift aquifer in New Hampshire, an important State resource for existing and future drinking water supplies. The majority of residents and businesses in this fourteen-town watershed derive their drinking water from this aquifer. In addition, water flowing through this region is also a source of drinking water for Maine communities located downstream. Because of this, the Ossipee Watershed's lakes, ponds, rivers, and streams have important ecological, economic, and social values for the region. With the population of Carroll County is expected to increase 50% by 2020, it is imperative to protect these resources for the future (SPNHF, 2005).

One of the best ways to protect surface waters that feed into underground drinking water supplies, like the Ossipee Aquifer, is to develop a long-term and consistent monitoring program for major streams, rivers, and lakes. Green Mountain Conservation Group (GMCG) has taken the lead in establishing a consistent water quality monitoring program for currently twenty-four parameters at thirty active tributary sites in the Ossipee Watershed since 2002. This effort is in direct collaboration with Saco River Corridor Commission (SRCC) through a shared Quality Assurance Project Plan (QAPP) that spans one watershed, two states, and twenty-six towns. With over ten years of monitoring data at many sites, GMCG is now able to assess long-term trends in water quality across the Ossipee Watershed and make educated watershed management decisions based on the assessments outlined in this report. The intended use of these analyses will be to establish a baseline from which to assess future changes in water quality as a result of human disturbance or climate change.

# PROGRAM BACKGROUND

## GREEN MOUNTAIN CONSERVATION GROUP

GMCG is a community-based, charitable organization dedicated to the protection of natural resources in the Ossipee Watershed towns of Effingham, Freedom, Madison, Ossipee, Sandwich, Tamworth, and Eaton. Founded in 1997, GMCG's mission is to coordinate and carry out environmental education, research, natural resource advocacy, and voluntary land protection with the goal to promote an awareness of and appreciation for clean water and the wise use of shared natural resources across the Ossipee Watershed. Its guiding principle is to present objective information in a non-confrontational manner to enable the public to make informed natural resource decisions.

## WATER QUALITY MONITORING PROGRAM HISTORY

Hundreds of summer campers and school children have participated in GMCG's lake and river sampling programs. (Photo: GMCG)

Since the source of waters flowing to the Saco River originates in New Hampshire, GMCG began working collaboratively in 2001 with its downstream neighbors, the Saco River Corridor Commission (SRCC) and Maine communities within the Saco River basin. This collaboration is best represented by a shared, bi-state Quality Assurance Project Plan (QAPP) for the Saco River basin that was approved in 2003 and updated in 2014 (GMCG & SRCC, 2014). Out of this QAPP came the establishment of the Regional Interstate Volunteers for the Ecosystems and Rivers of Saco (RIVERS) Water Quality Monitoring (WQM) program, though GMCG and SRCC began their surface water quality monitoring in 2002 and 2001, respectively. The goal of the RIVERS WQM program was to establish a ten-year baseline of water quality data as a reference for assessing future water quality and to help preserve the high quality surface and groundwater resources of the Saco River basin, which includes the Ossipee Watershed.

With its focus on the Ossipee Watershed within the Saco River basin, GMCG has developed strong partnerships with the watershed towns of Effingham, Freedom, Madison, Ossipee, Sandwich, Tamworth, and Eaton, as well as towns in Maine in partnership with SRCC. Volunteer support has increased from an initial fifteen residents to now over fifty individuals who regularly sample streams, rivers, and lakes in the Ossipee Watershed each year. Hundreds of summer campers and school children have also participated in lake and river sampling with the assistance of locally-hired interns. **GMCG is thankful for the continued support that local towns, citizens, and organizations have provided for this program.**

GMCG conducts physical and chemical surface water quality monitoring through three basic programs:

- **April – October Tributary Sampling**

  GMCG began monitoring rivers and streams in the Ossipee Watershed in 2002. The purpose was to collect baseline data and ultimately track water quality changes in the watershed over time. Initially there were two programs collecting water quality samples at nineteen river sites through the RIVERS WQM (Regional Interstate Volunteers for the Ecosystems and Rivers of Saco Water Quality Monitoring) program and eleven tributary sites through the OLT (Ossipee Lake and Tributaries) program (Figure 1). These programs have merged to become the full RIVERS WQM program. Eleven streams and rivers are also sampled through VBAP (Volunteer Biological Assessment Program), which is an educational youth program that partners with schools to sample for macroinvertebrates, teach about water literacy, and encourage youth to learn more about their watershed. The biological monitoring results from VBAP are not presented in this report (more information can be found at www.gmcg.org). The tributary sites were chosen based on size, accessibility, and surrounding land use. For example, sites are located downstream from gravel pits, designated drinking water zones, transfer stations, landfills, or next to major roads or developments. Other sites were chosen to track the quality of water entering and leaving Ossipee Lake, or because of concerns over septic systems, erosion, timber-cutting, mill sites, junkyards, old tanneries, or to bracket potential sources of contamination for further investigation. Refer to the QAPP for more detailed information about site selection and parameters measured (GMCG & SRCC, 2014).

- **Winter Tributary Sampling**

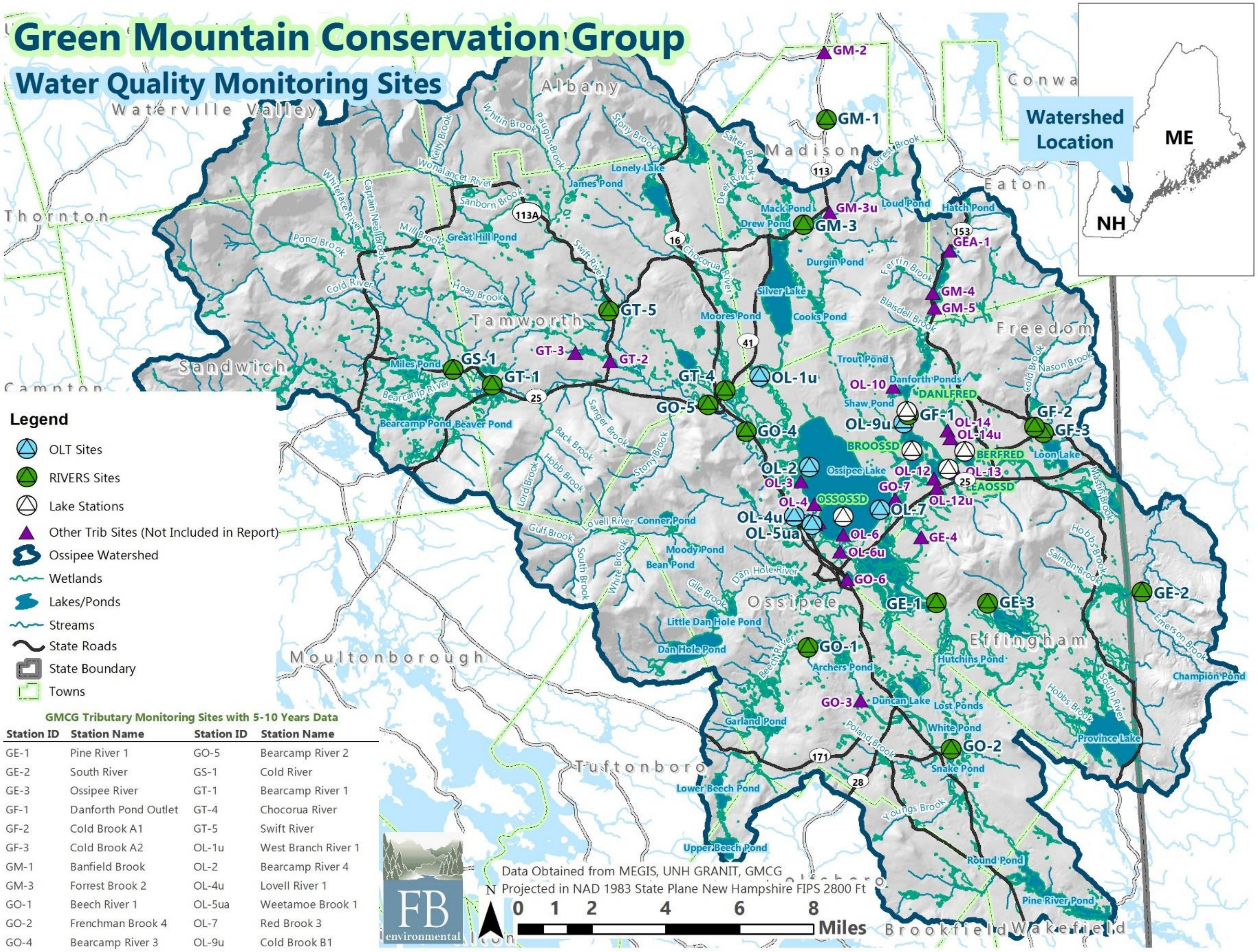
  Tributary sampling was extended for seven RIVERS (8-10 years of April to October data, year-round since 2004) and two OLT (7 years of summer data, year-round since 2009) sites to include winter sampling as a means to better understand year-round conditions. Refer to the QAPP for more detailed information about site selection and parameters measured (GMCG & SRCC, 2014).

- **Summer Lake Sampling**

  Every summer since 2003, monthly water quality data has been collected at the deep spots of five major waterbodies in the Ossipee Watershed: Ossipee Lake, Broad Bay, Leavitt Bay, Berry Bay, and Lower Danforth Pond through the NHDES Volunteer Lake Assessment Program (VLAP) and the UNH Lakes Lay Monitoring Program (LLMP). Broad and Leavitt Bays have been monitored since 1990. Refer to the GMCG website for detailed lake condition reports (http://www.gmcg.org/water-quality-data.php). For information about other major lakes and ponds, including those with lake associations and monitoring programs, see the Ossipee Watershed Natural Resource Guide: http://www.gmcg.org/administration/pdf/07%20Water%20Resources%20Chapter%20Lakes%20&%20Ponds.pdf. Analyses of lake sediment cores and lake/river temperatures were also conducted by Plymouth State University. Refer to Appendix A for a summary of these studies.

While this report only showcases select physical and chemical parameters collected from river, stream, and lake sites, GMCG also supports strong biological monitoring (e.g. macroinvertebrate sampling through VBAP and invasive species boat inspections) and water literacy (e.g. Trout in the Classroom, Groundwater Education Through Evaluation and Testing (GET WET), storm drain stenciling, and nonpoint source pollution education) programs. Refer to www.gmcg.org for more information about these programs.

Volunteers help ensure the success of long-term monitoring in the Ossipee Watershed. (Photo: GMCG)




GMCG Tributary Monitoring Sites with 5-10 Years Data

| Station ID | Station Name | Station ID | Station Name |
|---|---|---|---|
| GE-1 | Pine River 1 | GO-5 | Bearcamp River 2 |
| GE-2 | South River | GS-1 | Cold River |
| GE-3 | Ossipee River | GT-1 | Bearcamp River 1 |
| GF-1 | Danforth Pond Outlet | GT-4 | Chocorua River |
| GF-2 | Cold Brook A1 | GT-5 | Swift River |
| GF-3 | Cold Brook A2 | OL-1u | West Branch River 1 |
| GM-1 | Banfield Brook | OL-2 | Bearcamp River 4 |
| GM-3 | Forrest Brook 2 | OL-4u | Lovell River 1 |
| GO-1 | Beech River 1 | OL-5ua | Weetamoe Brook 1 |
| GO-2 | Frenchman Brook 4 | OL-7 | Red Brook 3 |
| GO-4 | Bearcamp River 3 | OL-9u | Cold Brook B1 |

**Figure 1.** GMCG tributary water quality monitoring sites in the Ossipee Watershed of New Hampshire. RIVERS tributary site location codes are first letter G=GMCG and second letter M=Madison, E=Effingham, S=Sandwich, T=Tamworth, F=Freedom, O=Ossipee, and EA=Eaton. OLT tributary site locations are tributaries in close proximity to Ossipee Lake and the lower bays. Both programs were combined under the RIVERS WQM program.

# STUDY AREA

## The Saco River Basin

The Ossipee Watershed is part of the Saco River Basin, a 1,700 square mile area that includes 63 municipalities in New Hampshire and Maine (Figure 2). The Saco River originates in the White Mountains of New Hampshire at Saco Lake, and converges with the Ossipee River in Cornish, Maine before emptying into the Atlantic Ocean via Saco Bay in Maine. Elevations in the basin range from 6,288 feet at the summit of Mount Washington in Sargent's Purchase, New Hampshire to sea level at the mouth of the Saco River in Saco and Biddeford, Maine (SMRPC, 1983). The Saco River serves as a water supply for the citizens and businesses of Saco, Biddeford, Old Orchard Beach, and part of Scarborough, Maine. The river is also used to supplement local water supplies in the Kennebunk-Kennebunkport-Wells Water District. The river itself has seen a dramatic increase in recreation and shoreline development in recent years, and much of the land bordering its surface waters is privately-owned.

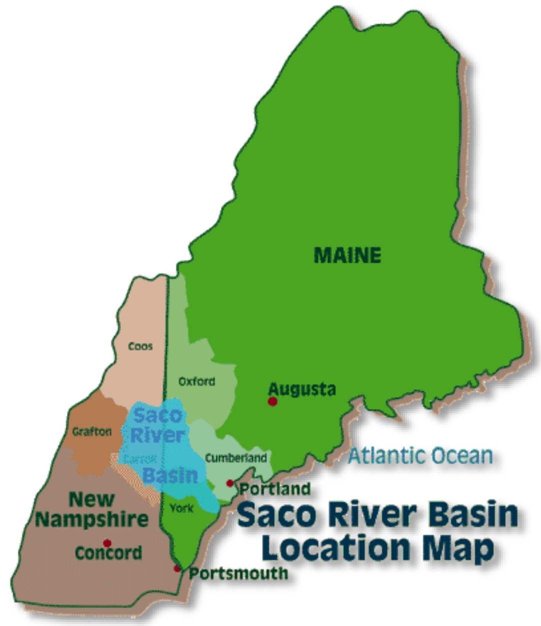



**Figure 2.** The Saco River Basin Watershed begins in the White Mountains in New Hampshire and empties into the Atlantic Ocean in Maine.

## The Ossipee Watershed

The Ossipee Watershed is a subwatershed of the Saco River Basin and covers about 379 square miles in fourteen towns in Carroll and Grafton Counties, New Hampshire. It contains 82 lakes and ponds that cover about 9,400 acres with Ossipee Lake, the seventh largest lake in New Hampshire, at the center of the watershed (Figure 3). Ossipee Lake is connected to five other major waterbodies in the watershed (Broad Bay, Leavitt Bay, Berry Bay, Danforth Ponds, and Huckins Pond), all of which are fed by fourteen major tributaries. At its widest point, the watershed extends 29 miles east and west and 23 miles north and south. The watershed is bound by the mountains of the Sandwich Range to the northwest, the Ossipee Mountains to the south, and the sandy pine barren lands of the Ossipee-Freedom-Effingham plains to the east. Elevations range from 375 feet at the Maine-New Hampshire border in Effingham to 4,060 feet on Mount Passaconway in Waterville Valley.


**Figure 3.** The Ossipee Watershed and overlapping towns in New Hampshire.

The watershed contains New Hampshire's largest and deepest **stratified-drift aquifer** (Figure 4). This type of aquifer recharges more rapidly than any other aquifer due to its porous and gravel soils deposited by water from melting glaciers, but it also allows pollution and contamination to be carried more rapidly into groundwater supply. In many areas of the Ossipee Aquifer, water can travel more than 2,000 $ft^2$ per day, depending on the permeability of soils above the aquifer. Because of this, conservation of recharge lands and their surface waters are vital to protecting drinking water supplies. Fortunately, roughly 20% (5,557 acres) of the 27,000 acres of high yield aquifer are already currently protected beneath conservation land in the Ossipee Watershed.

**Stratified drift aquifers** consist primarily of sand and gravel deposits that were deposited in layers by meltwater streams flowing from retreating glacial ice around 14,000 years ago. It is estimated that 71% of all drinking water in New Hampshire is derived from these aquifers (USGS, 1995).

The Ossipee Watershed also contains two globally rare pondshore communities along Ossipee Lake, pine barrens, and a federally-protected kettlehole quaking bog. These are unique and precious ecological assets that are being threatened by developmental pressure and environmental stress.

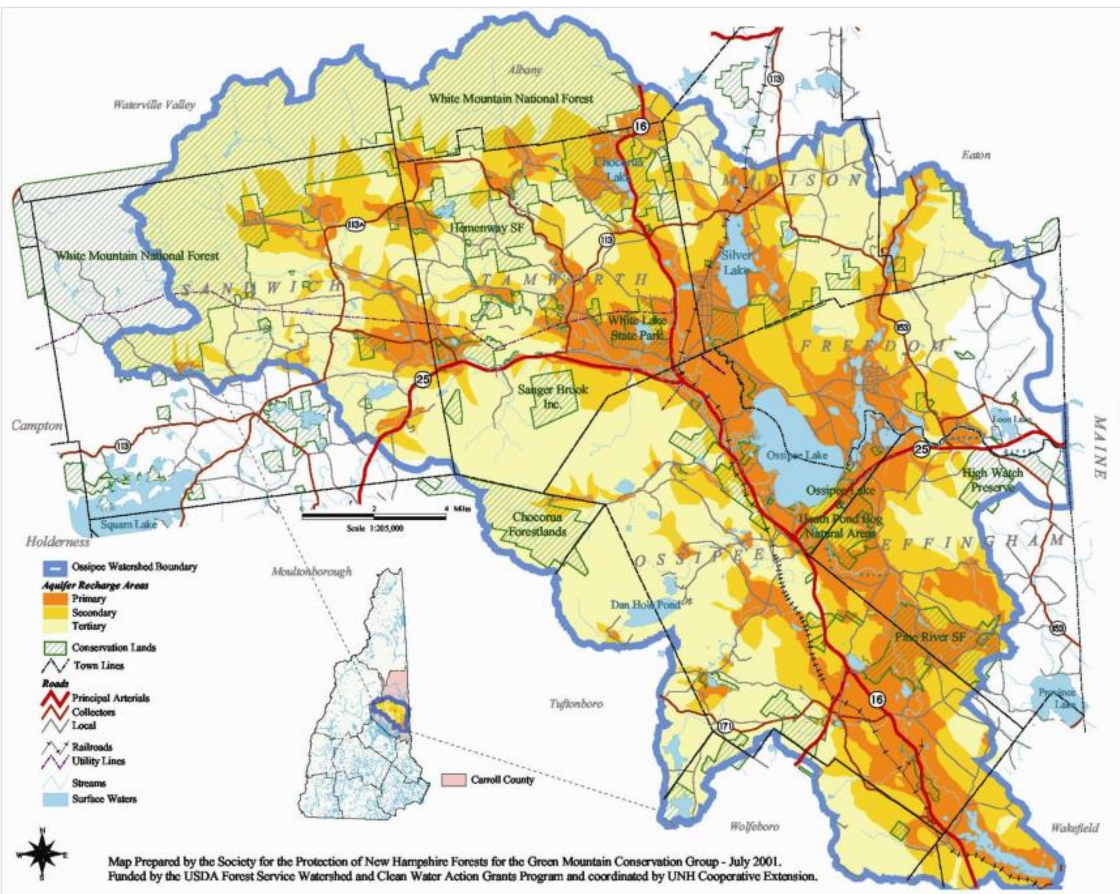



**Figure 4.** Aquifer recharge areas in the Ossipee Watershed. The Ossipee Watershed is home to the largest stratified-drift aquifer in New Hampshire, a critical resource for existing and future drinking water supplies in New Hampshire. Darker shades of orange represent primary recharge areas where water moves quickly from the land surface to groundwater, sometimes up to 2,000 $ft^3$ per day. These areas are particularly vulnerable to contamination. Map courtesy of the Society for the Protection of New Hampshire Forests.

# WATER QUALITY ASSESSMENT

## WHAT IS WATER QUALITY?

Before moving directly into a discussion of water quality results, it is important to understand how we interpret "good" and "poor" water quality in the context of today's economic, social, and environmental conditions. The essence of **water quality** is easy to illustrate when comparing a murky-green, warm lake to a clear, cool lake with abundant wildlife. The green lake has no fish, is not ideal for recreation, and property values around the lake are low. The clear lake has ample fish and other wildlife, is more suitable for recreation, and property values around the lake are high. The difference between the two lakes is *water quality*. A widely agreed upon definition of water quality is more difficult to find since it is a complex topic, with differing definitions depending on the intended use, criteria, and state and federal standards guiding what is acceptable from one place to the next. One definition that has been used is the following: **water quality is the ability of a waterbody to support all appropriate beneficial uses.**

**Water quality** is the ability of a waterbody to support all appropriate beneficial uses.

**Beneficial Uses** include recreation, the support of aquatic life, and in some cases, drinking water supplies.

Surveying the shoreline on Berry Bay in Freedom, NH. (Photo: FBE)

**Beneficial uses** refer to the ways water is used by humans and wildlife, such as for drinking water and fish habitat. If water supports a beneficial use, water quality is said to be "good" or "unimpaired." If water does not support a beneficial use, water quality is said to be "poor" or "impaired." Good water quality implies that harmful substances (pollutants) are absent from the water, and needed substances (oxygen and nutrients at low to moderate levels) are present.

New Hampshire surface waters are classified according to their designated beneficial uses. Most streams, rivers, ponds, and lakes in New Hampshire are designated as Class B. Class B waters are considered acceptable for fishing, swimming, and other recreational purposes, and as water supplies after adequate treatment. New Hampshire sets water quality standards for different biological, physical, and chemical attributes based on class, which all waters must meet to support their designated beneficial uses.

Water quality of streams and rivers in the Ossipee Watershed is measured against standards set for Class B waters, pursuant to New Hampshire Statutes in RSA Section 485-A:8. Water quality standards are the "yardstick" for identifying water quality exceedances and for determining the effectiveness of state regulatory pollution control and prevention programs designed to protect beneficial uses. To determine if a waterbody is meeting its designated beneficial uses, water quality standards for various water quality parameters (such as total phosphorus, dissolved oxygen, pH, and turbidity) are applied to water quality data. If a waterbody meets or is better than the water quality standard, the designated use is supported. If a waterbody does not meet the water quality standard, it is considered impaired for the designated use. It is helpful to point out that the standards are based on upper limits for all water quality parameters except dissolved oxygen, which has lower limits. In other words, decreasing values in dissolved oxygen indicates a deteriorating trend compared with all other parameters where increasing values indicate water quality deterioration. Refer to Table 1 for a list and description of select parameters and their applicable water quality standard that GMCG uses to monitor water quality of rivers and streams in the Ossipee Watershed.

One of the 30 rivers and tributaries sites in the Ossipee Watershed (Photo: GMCG)

Water quality standards for lakes are based on trophic state, which is the degree of biological productivity of a lake. This is determined by water clarity, chlorophyll-a concentration, phosphorus concentration, aquatic plant biomass, and dissolved oxygen concentration at the deep spot of a lake. Trophic state is divided into three categories ranging from low productivity (good water quality) to high productivity (poor water quality); these are named oligotrophic, mesotrophic, and eutrophic. Each of these trophic states have thresholds for total phosphorus (input parameter) and chlorophyll-a (response to input parameter; Table 3). Phosphorus is considered one of the limiting nutrients to productivity in lake systems; even small increases in phosphorus can stimulate algal and plant growth.

**Table 3.** Lake trophic class nutrient threshold ranges in New Hampshire.

| Trophic State | TP (ppb) | Chl-a (ppb) |
|---|---|---|
| **Oligotrophic** | < 8.0 | < 3.3 |
| **Mesotrophic** | > 8.0 - 12.0 | > 3.3 - 5.0 |
| **Eutrophic** | > 12.0 - 28.0 | > 5.0 - 11.0 |

## PRECIPITATION AND FLOW DATA

Precipitation totals ranged from 43.15 inches in 2004 to 67.51 inches in 2008, as measured by the USGS monitoring station located on the Bearcamp River in Tamworth (Table 4). Month-to-month variation was considerable in some cases, as in October 2005 when record rainfall amounts and flows were documented in many areas of the northeast (Figure 5). These heavy rains and flooding contributed to turbulent waters at Effingham Falls on the Ossipee River, and caused uprooted trees and scoured shorelines as floodwaters overflowed river banks. In May of 2006, New Hampshire received record amounts of rainfall once again, also known as the “Mother’s Day Storm,” which resulted “in excessive soil erosion and increased nutrient loading to surface waters throughout the State” (NHDES, 2006). In general, rainfall can play a large role in surface water quality by affecting its physical and chemical composition as runoff from the landscape can influence temperature, pH, and nutrient and sediment loading. Keep in mind that what flows into Ossipee Lake comes from what runs off the 379 square miles of land in the watershed surrounding the lake. For example, during dry periods, pollutants accumulate in the uplands and are ultimately flushed to receiving waters during storm events. Rivers and streams in the Ossipee Watershed were often flooded over the course of the ten years from 2002-2011, causing significant damage and erosion to roads. Heavy rainfall in 2007 and 2008 contributed to dirt road erosion and sedimentation in nearby waterways.

Since most measured parameters are presented as concentrations, flow (i.e. the volume of water per time) is an important consideration when comparing changes in concentration over time. For example, if chloride shows a decreasing trend over time while flow is increasing, chloride is likely being diluted by higher flows. Both precipitation and discharge may have been increasing from 2002-2011, but the increase is very small and highly variable (Figure 5). However, it does seem that increasing precipitation was experienced across all seasons for the ten year record, resulting in more frequent, but smaller, peaks in discharge in the latter half of the record. The reader should be aware that water quality data were not normalized (adjusted for) levels of precipitation or river flows, nor were correlations between water quality measurements and flows calculated for this report.

**Table 4.** Summary of yearly precipitation data from Tamworth 4, NH station.

| Year | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Total Precip (in)** | 45.54 | 55.44 | 43.15 | 65.95 | 65.74 | 52.13 | 67.51 | 61.94 | 51.41 | 66.04 |

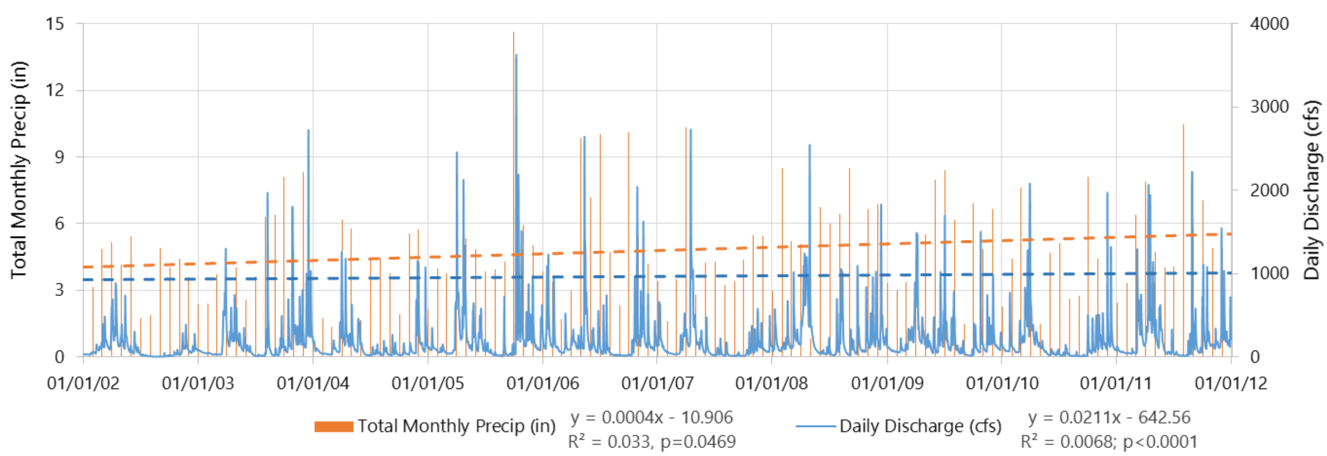



**Figure 5.** Total monthly precipitation and daily discharge from 2002 to 2011. Precipitation data was obtained from NOAA NCDC GHCND:USC00278614 Bearcamp River in Tamworth, NH; discharge data was obtained from USGS 01064801 Bearcamp River in South Tamworth, NH. Orange solid line indicates total monthly precipitation levels with corresponding orange dotted regression line. Blue solid line indicates daily discharge with corresponding blue dotted regression line.

## TRIBUTARY RESULTS

For this report, water quality data from sixteen of the nineteen RIVERS sites and six of the eleven OLT sites were used in the water quality analysis; these sites had five or more years of data for most parameters (Figure 1; refer to Appendix B for detailed site location descriptions). The data for each site were displayed in **boxplots** and compared to State water quality standards, where available. Statistical trend analyses were also conducted by FB Environmental Associates (Mann-Kendall trend tests; USGS, 2002; USEPA, 2009) for eleven physical and chemical water quality parameters for each site, including:

- pH
- Water Temperature
- Turbidity
- Specific Conductivity
- Dissolved Oxygen
- Total Phosphorus/Phosphate
- Total Dissolved Nitrogen/Ammonium/Nitrate
- Chloride

All data, including parameters not included in this analysis, are readily available on GMCG's website at www.gmcg.org. Descriptions of the monitoring testing schedule and parameters can be found in the 2002-2008 Water Quality Report or the RIVERS WQM Program QAPP (GMCG, 2009; GMCG & SRCC, 2014). More information about trend analysis methods and full results used can be found in Appendix C.

Trend analyses revealed that eleven parameters at ten sites had water quality measurements significantly change over time, nine of which showed deteriorating trends, but observed values were still within State water quality standards (Table 5). The other two sites showed improving trends, one of which had observed values exceed the State water quality standard for chloride. Results for sites with statistically significant trends are presented in Table 5 and Figure 6.

**Table 5.** Statistically significant trends in tributary site data, as identified by Mann-Kendall trend tests, and the implication of water quality condition. If not listed here, no significant trend was found for the site or not enough data was available for adequate assessment.

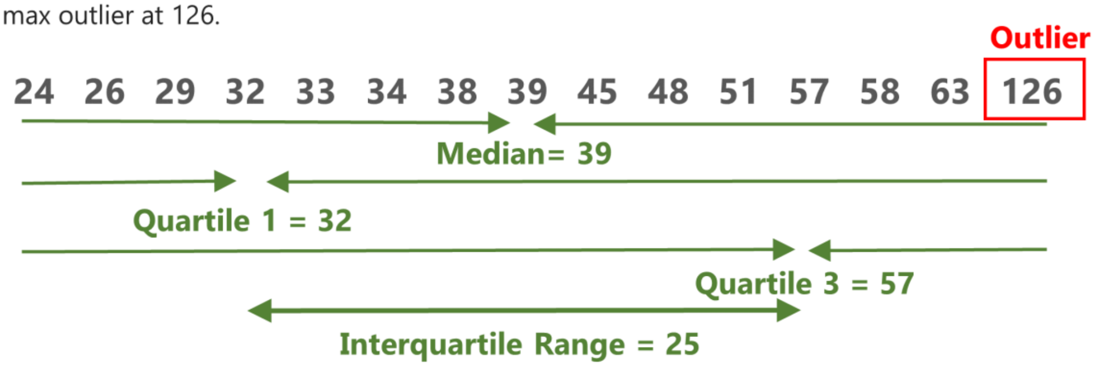
| Town | Site | | Parameter | Trend | Water Quality Implication |
|---|---|---|---|---|---|
| **Effingham** | GE-1 | Pine River 1 | Dissolved Oxygen | Decreasing | **Degrading** |
| | GE-3 | Ossipee River | Ammonium | Increasing | **Degrading** |
| **Freedom** | GF-1 | Danforth Pond Outlet | Total Dissolved Nitrogen | Increasing | **Degrading** |
| | GF-3 | Cold Brook A2 | Turbidity | Increasing | **Degrading** |
| **Madison** | GM-1 | Banfield Brook | Turbidity | Increasing | **Degrading** |
| | GM-3 | Forrest Brook 2 | Turbidity | Increasing | **Degrading** |
| | | | Summer Chloride | Decreasing | **Improving** |
| **Ossipee** | GO-2 | Frenchman Brook 4 | Spring Chloride | Decreasing | **Improving** |
| | OL-2 | Bearcamp River 4 | Total Dissolved Nitrogen | Increasing | **Degrading** |
| | OL-7 | Red Brook 3 | Turbidity | Increasing | **Degrading** |
| **Sandwich** | GS-1 | Cold River | Spring Chloride | Increasing | **Degrading** |

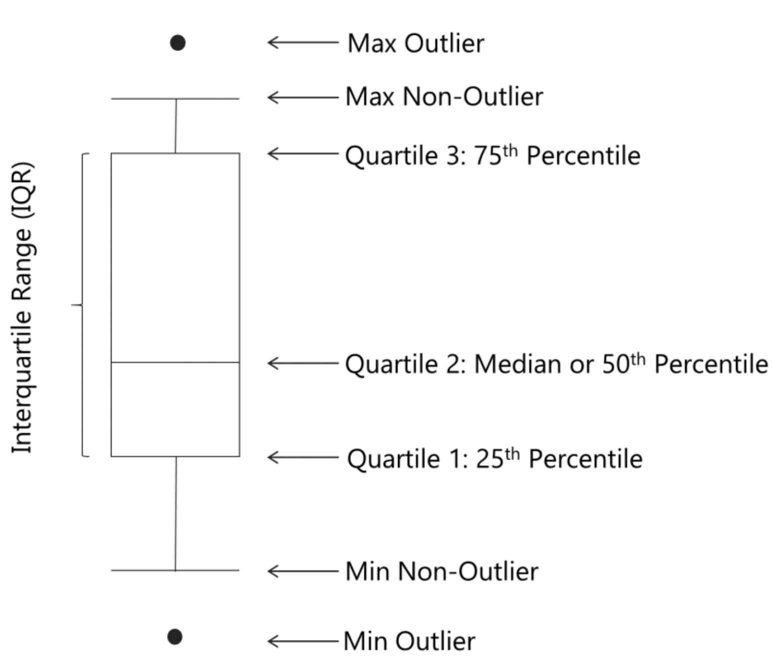
The following section provides a summary of significant results and results by parameter for the select twenty-two out of thirty active tributary monitoring sites in the watershed. Review "How to Read Boxplots" for a refresher on boxplot interpretation before moving on to the data summaries.

## HOW TO READ BOXPLOTS

Boxplots are a type of visual graphic that display the distribution or 'spread' of data. First, the data are ordered from the smallest to largest value (see below).

- The **median** represents the 50th percentile of the data or the value at which half the data points fall below and above. The median is the preferred metric when determining the center of a data set because the median is resistant to outliers that may skew the mean. For these data, the mean is 47 because the outlier of 126 pulls the mean higher than the median (hence: right or positive skewed).
- **Quartile 1** is the 25th percentile or the value at which 25% of the data points fall below (15 data points * 0.25 = 4 (rounded to the nearest whole number). Counting 4 points over from the smallest value gives you 32. **Quartile 3** is the 75th percentile or the value at which 75% of the data points fall below (15 data points * 0.75 = 12 (rounded to the nearest whole number). Counting 12 points over from the smallest value gives you 57. The range between Quartile 1 and 3 is the **Interquartile Range (IQR)** or the "box" representing 50% of the data around the median.
- The **min** and **max non-outliers** represent the "whiskers," which are calculated as Quartile 1 minus 1.5 times the IQR and Quartile 3 plus 1.5 times the IQR; the nearest data points are used. In this case, the IQR is 25 and the min and max non-outliers are 24 and 63, respectively. Any values below or above the min and max non-outliers are considered outliers, which are values that are non-typical to the data set. In this case, there is one max outlier at 126.




There are several basic pieces of information that can be obtained from a boxplot:

**RANGE:** The total spread of data ranges from the min to max outliers, if any, otherwise from the min to max non-outliers. The latter gives a better understanding of the typical data distribution without the influence of non-typical outliers.

**INTERQUARTILE RANGE** is the width of the "box" from Quartile 1 to Quartile 3. The distribution of this box helps to understand the **SKEWNESS** of the data around the median or whether most observations are concentrated on the lower or higher end of the distribution. Water quality data are typically positively skewed, meaning the mean is greater than the median due to max outliers.

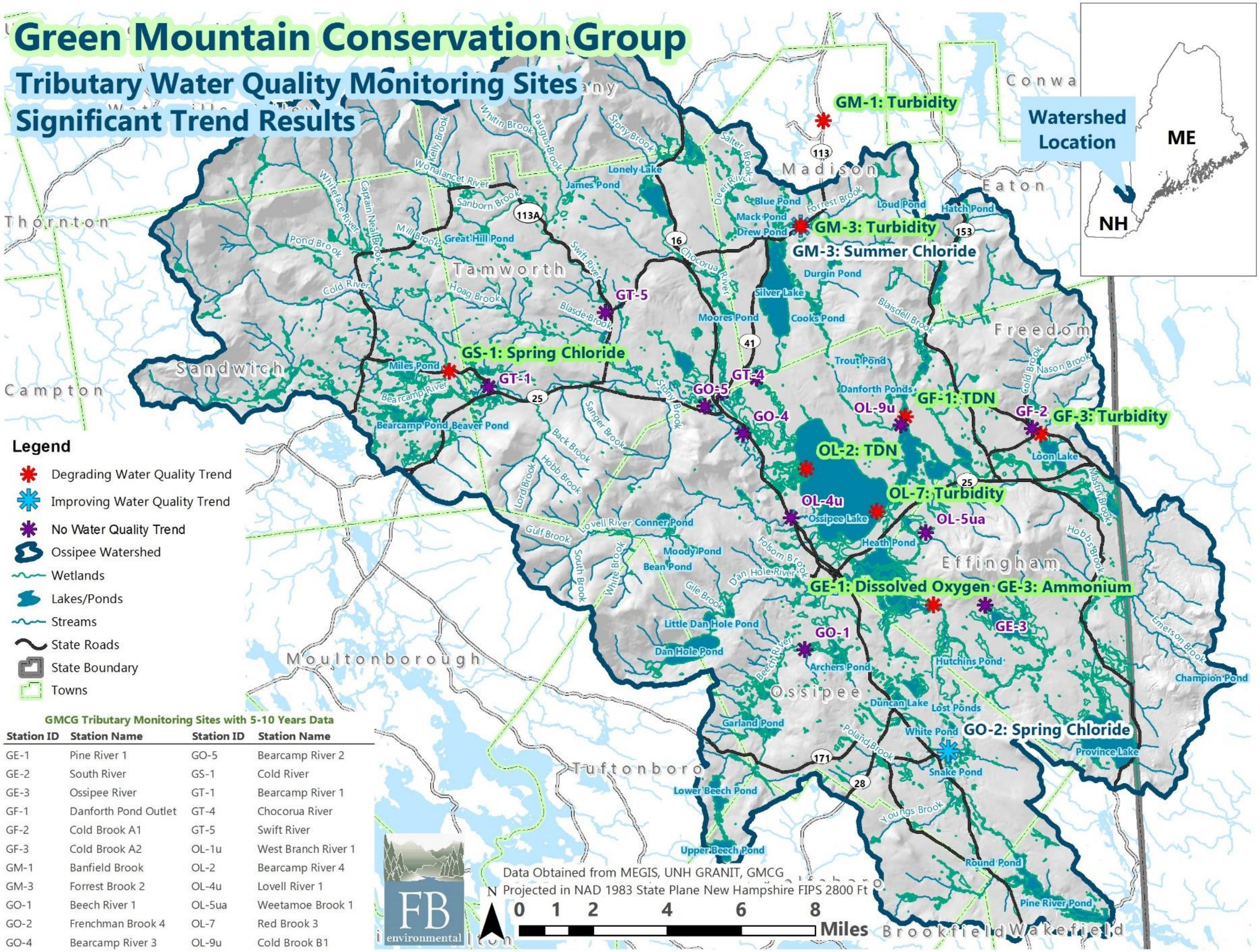



**Figure 6.** Map of study area showing results of the water quality trend tests for select twenty-two tributary monitoring sites with 5-10 years of data.

# pH

## What is pH?

pH is a measure of the acidity of water in terms of hydrogen ion concentration. pH below 7.0 is acidic and above 7.0 is alkaline. Everything that water comes in contact with affects pH, including soils, organic acids (decaying leaves or other organic matter), and human-induced acids in acid rain.

## Why is pH important?

pH affects many chemical and biological processes in water, and various organisms flourish under different pH ranges, the most preferred being between 6.5 and 8.0. The ability of aquatic organisms to complete a life cycle greatly diminishes as pH falls below 5.0 or exceeds 9.0. Levels below 5.5 can severely limit growth and reproduction in fish, as is the case with brook trout in New England streams. Low pH can also allow toxic elements and compounds such as heavy metals to become mobile and "available" for uptake by aquatic plants and animals. This can cause deformities in fish and produce conditions that are toxic to aquatic life. These low pH levels can be due to naturally-occurring conditions, such as the influence of tannic and humic acids from decaying plants in wetlands. Low pH can also be influenced by humans as a result of wastewater discharge and atmospheric deposition of nitric and sulfuric acids in acid rain. Surface waters in New Hampshire are particularly vulnerable to acid rain because their contact with granite offers little buffering capacity (as opposed to limestone-based waterbodies). Since the Ossipee Watershed is downwind of industrial and urban areas with automobile and coal power plant emissions (west of the New England states), air quality and its effects on the pH of waterways is a major concern.

**Class B NH Surface Water Quality Standard:** pH must be between 6.5 and 8.0, unless naturally-occurring. Reducing the minimum pH criteria to 6.0 may be considered by the State since lower pH values (between 6.0 and 8.0) are often observed in New Hampshire streams given the acidified rain (average pH of rain in New England is 4.3) and low buffering capacity of the water as a result of underlying geology. Until the statute and regulations are changed, however, compliance for pH must be based on this range. Roughly 70% of aquatic life impairments in New Hampshire's lakes and ponds are a result of low pH; 3,419 miles of stream length are listed as impaired for pH out of a total 16,896 miles of stream length in New Hampshire (USEPA, 2010).

**10-Year Results:** All 22 tributary sites had pH levels below the State standard and are considered impaired for pH, with the average for all sites at 5.6 (Figure 7). pH varied from as acidic as 3.6 at Bearcamp River 3 (GO-4) in 2005 to as basic as 8.9 at Red Brook 3 (OL-7) in 2011. pH decreased (became more acidic) at most sites in 2005 and 2006, likely due to higher rainfall experienced in those years (typical rainwater in New England has a pH of 4.3). Mean pH fell below 5.5 (the level that is critical for growth and reproduction in fish) at Red Brook (OL-7; 5.0), Bearcamp River 3 (GO-4; 5.3), and Weetamoe Brook 1 (OL-5ua; 5.3) in Ossipee, at Cold River (GS-1; 5.0) in Sandwich, and at Swift River (GT-5; 5.3) in Tamworth. The presence of humic acids from upstream wetlands could account for the lower pH observed at Red Brook 3 (OL-7). Lower pH levels could also be due to organic matter, restrictions to water flow, stagnation, or other inputs. Mann-Kendall tests revealed no significant (α=0.05) change in pH from 2002-2011 at any of the 22 tributary sites.

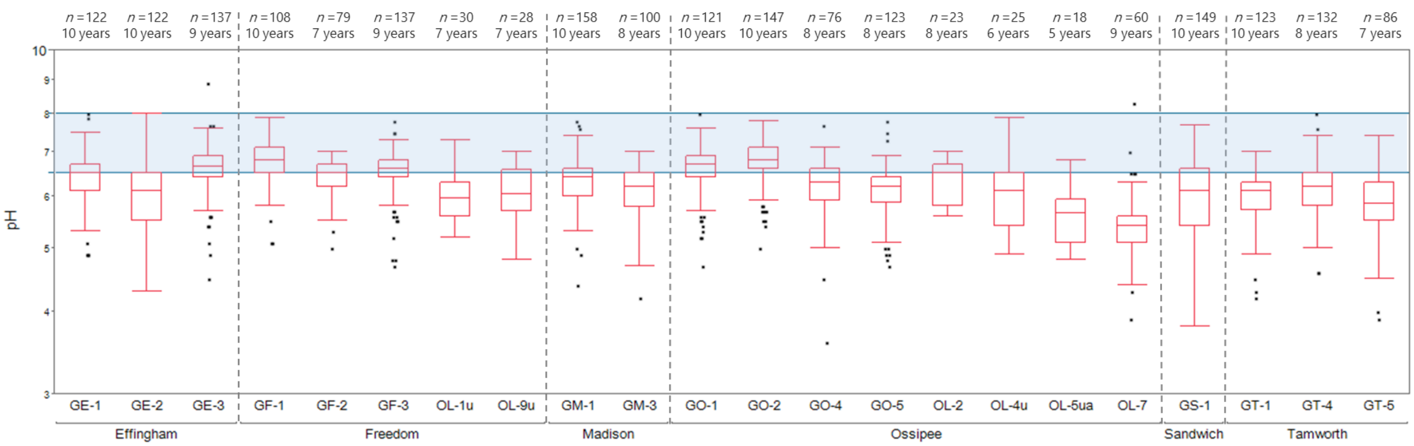
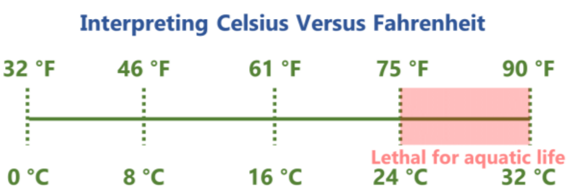



**Figure 7.** pH levels recorded for tributary sites from 2002 to 2011. Data are organized by site and town. Optimal pH range is 6.5 to 8.0 (shaded area); any readings above or below this range may inhibit aquatic life function. Note that the pH scale (left side) is in logarithmic scale not a linear scale. Red boxplots show sites with exceedances of the optimal pH range for aquatic life. "n" is the number of samples. Refer to Figure 1 for site locations.

# Water Temperature

## Why is water temperature important?

Water temperature is influenced by a number of variables, including air temperature, sunlight, shading, water source, and the width, depth, and circulation of the waterbody. Human activities that can affect water temperature include: stormwater, industrial discharge of water used as coolant (thermal pollution), removal of shade-providing trees in the riparian zone, erection of dams or other impoundments, and erosion of soil (e.g. turbid water absorbs more heat from the sun). The metabolic rates of organisms and the growth of aquatic plants increase with increasing water temperature, which in turn increases the need for oxygen as organisms require oxygen for metabolic processes and bacteria use up oxygen to decompose dead plant material. Since gases dissolve more easily in cooler water, water temperature also plays a large role in the amount of dissolved oxygen found in waterbodies. Organisms, such as trout and mayfly nymphs, thrive in cooler, more oxygen-rich waters (13 ºC and below), while other organisms, such as bass and most plant life, prefer warmer waters (20 ºC and above). The mid-range of these temperatures support salmon, trout, water beetles, and limited plant life.




**Class B NH Surface Water Quality Standard:** Temperature in Class B waters (i.e. waters that are clean enough to safely swim and fish) shall be in accordance with RSA 485-A:8, II which states in part "any stream temperature increase associated with the discharge of treated sewage, waste or cooling water, water diversions, or releases shall not be such as to appreciably interfere with the uses assigned to this class." Many fish species thrive under optimal water temperatures, which trigger reproductive functions and regulate growth of juvenile fish. Maximum weekly and instantaneous temperature means of 19° and 24° C were found to be the limit for juvenile brook trout survival (Brungs and Jones 1977).

**10-Year Results:** Temperatures varied across the tributary sites. The highest surface water temperatures (greater than the recommended maximum of 24 °C for coldwater fish species survival) were observed at Ossipee River (GE-3; n=21), Danforth Pond outlet (GF-1; n=18), West Branch River 1 (OL-1u; n=2), Banfield Brook (GM-1; n=1), and Bearcamp River 4 (OL-2; n=1; Figure 8). Warmer surface water temperatures at Bearcamp River 4 (OL-2) and West Branch River 1 (OL-1u) were likely a result of warmer lake water mixing at these sites. Because of this, most tributary sampling stations were moved slightly upstream away from the lake in 2005 to eliminate the influence of warmer lake water. Most of the new upstream sites exhibited cooler water temperatures than downstream sites in previous years. Mann-Kendall tests revealed no significant (α=0.05) change in mean annual water temperature from 2002-2011 at any of the 22 tributary sites.

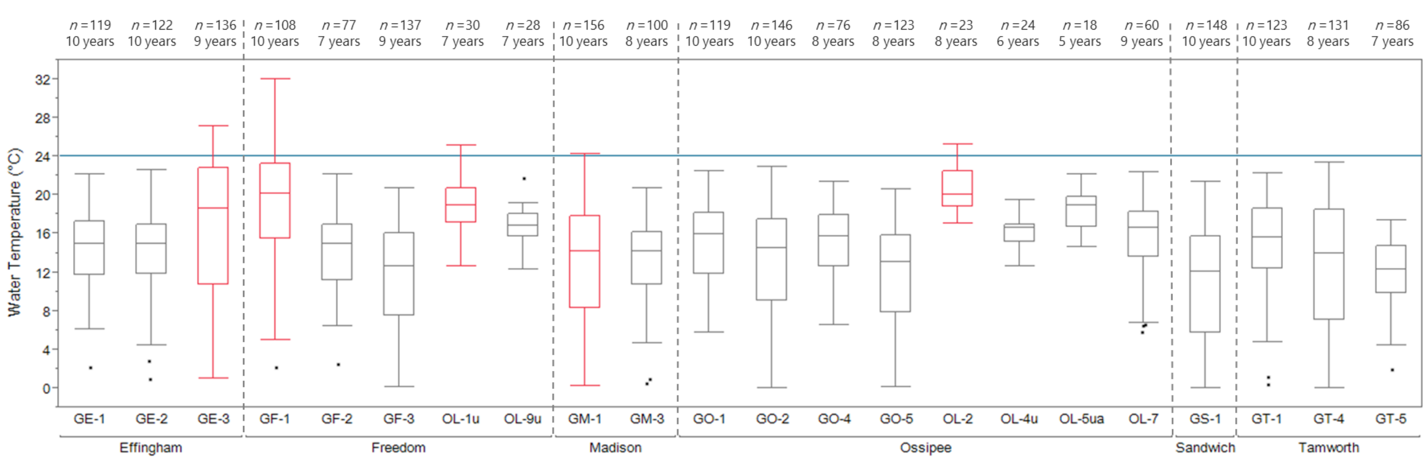



**Figure 8.** Water temperature recorded for tributary sites from 2002 to 2011. Data are organized by site and town. Any readings above 24 °C may inhibit aquatic life function for coldwater fish species. Note: this data represent year-round water temperatures for seven sites and seasonal (April through October) water temperatures for the other sites. Red boxplots show sites exceeding the recommended maximum water temperature of 24 °C. "n" is the number of samples. Refer to Figure 1 for site locations.

# Turbidity

## What is turbidity?

Turbidity is a measurement of the amount of suspended material in water, such as clay, silt, algae, sediment, and decaying plant material. Turbidity is measured in nephelometric turbidity units (NTU), which measure light refraction through a vial of water. The more suspended material in water, the more light is refracted and the higher the turbidity reading. In general, the murkier the water, the higher the turbidity.

## Why is turbidity important?

Sources of increased turbidity include soil erosion, waste discharge, stormwater runoff, and excessive algal growth. Rain events often contribute to surface water turbidity by flushing sediment, organic matter, and other materials from the surrounding landscape. These suspended materials can clog fish gills, which reduces disease resistance in fish, lowers growth rates, and affects egg and larval development. As particles settle, they can blanket the stream bottom, especially in slower moving waters, and smother fish eggs and benthic macroinvertebrates. High turbidity can increase water temperature as suspended particles absorb more heat. This reduces the concentration of dissolved oxygen because warm water holds less oxygen than cold water. High turbidity can also reduce the amount of light that penetrates water, which reduces photosynthesis and the production of life-supporting dissolved oxygen.

**Class B NH Surface Water Quality Standard:** Turbidity shall not exceed naturally-occurring conditions by more than 10 NTUs. In New Hampshire streams, turbidity ranges from 0 to 22 NTU with a median of 1.0 NTU.

**10-Year Results:** All 22 tributary sites in the Ossipee Lake watershed exhibited low turbidity levels well within State standards (<10 NTU) and showed a healthy range of 0.1 to 6.7 NTU and an average for all sites at 1.1 NTU (Figure 9). Mean turbidity levels fell below 2 NTU for all sites with the exception of Weetamoe Brook 1 (OL-5ua) at 2.1 NTU. Four sites exhibited maximum turbidity levels above 6 NTU: Danforth Pond outlet (GF-1 at 6.2 NTU), Banfield Brook (GM-1 at 6.7 NTU), Forrest Brook 2 (GM-3 at 6.7 NTU), and Frenchman Brook 4 (GO-2 at 6.5 NTU). A nearby sand parking lot may be contributing to the high turbidity readings at Frenchman Brook 4 (GO-2). These turbidity readings were likely collected during dry weather conditions and do not reflect storm conditions that may cause exceedances in turbidity at many sites. Mann-Kendall tests revealed declining trends in turbidity from 2002-2011 at Red Brook 3 (OL-7), Cold Brook A2 (GF-3), Banfield Brook (GM-1), and Forrest Brook 2 (GM-3).

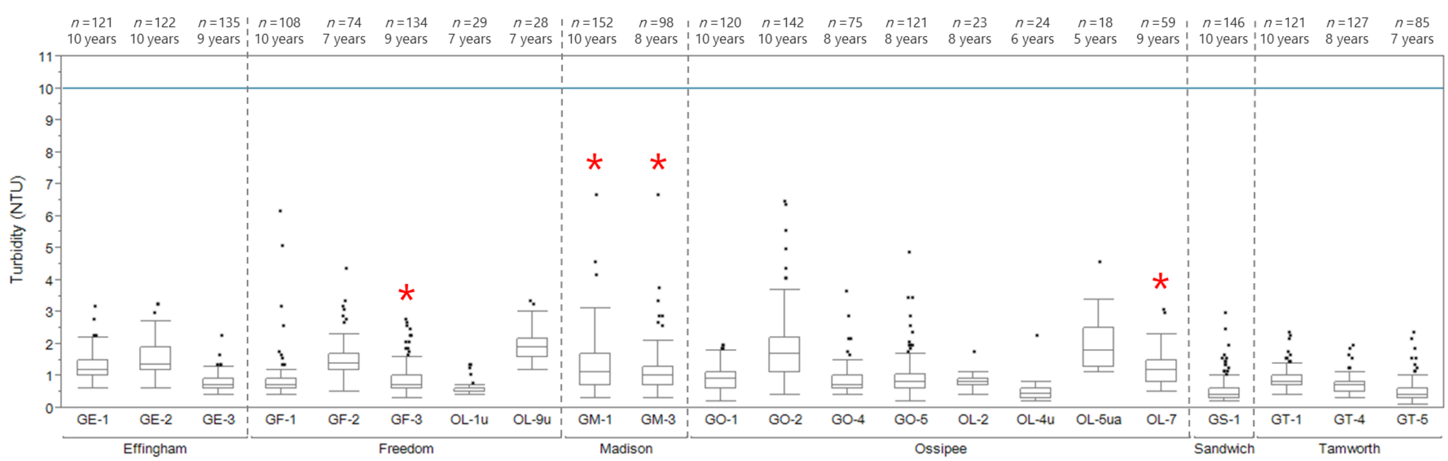



**Figure 9.** Turbidity recorded for tributary sites from 2002 to 2011. Data are organized by site and town. Any readings above 10 NTU may inhibit aquatic life function. Red asterisks indicate sites with degrading trends in turbidity from 2002-2011 using Mann-Kendall tests. "n" is the number of samples. Refer to Figure 1 for site locations.

## What is specific conductivity?

Specific conductivity is the numerical expression of water's ability to carry an electrical current normalized to a water temperature of 25 °C. Specific conductivity measures cations (calcium, sodium, potassium, and magnesium) and anions (chloride, nitrate/nitrite, and sulfate) in water. Many of these ions are weathering products and reflect differences in parent geology and human activities within the surrounding landscape.

## Why is specific conductivity important?

High specific conductivity can be a sign of pollution from road salting, septic systems, wastewater treatment plants, and urban or agricultural runoff. Since chloride in streams contaminated by excess road salts often dominates total ionic particles within a waterbody, specific conductivity can be used as a surrogate measure for chloride levels; high chloride levels can be toxic to aquatic life.

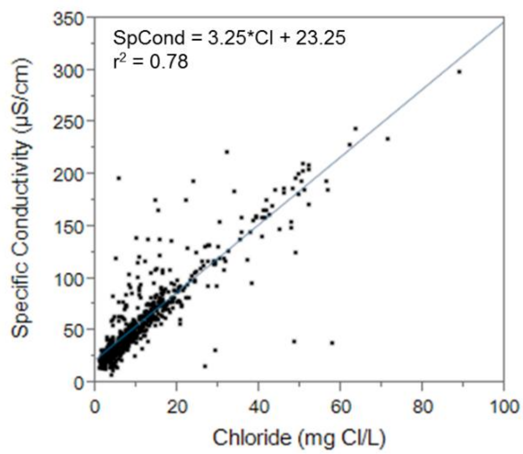



**Figure 11.** Variation in chloride accounts for 78% of variation in specific conductivity at all 22 tributary sites, likely from road salt in stormwater runoff from impervious surfaces. This suggests that specific conductivity can be used as a surrogate for chloride if funding is unavailable for all sites.

**Class B NH Surface Water Quality Standard:** While there is no numeric standard for surface waters in the State because levels vary naturally according to local geology, values exceeding 100 µS/cm generally indicate human disturbance. According to the NH DES, New Hampshire's surface waters traditionally have low conductivity values, but levels are increasing at a statistically significant rate largely due to the influence of road salting.

**10-Year Results:** For the 22 tributary sites in the Ossipee Lake watershed, specific conductivity shows a close relationship with chloride levels, which account for 78% of the variation in specific conductivity (Figure 10). This relationship suggests that specific conductivity measurements can be used as a surrogate for chloride in future monitoring efforts if funding is unavailable for laboratory analysis of chloride. This should be used with the understanding the 22% of the variability in specific conductivity is due to ions other than chloride. All sites showed mean specific conductivity levels below 100 µS/cm with the exceptions of Banfield Brook (GM-1 at 116 µS/cm) and Frenchman Brook 4 (GO-2 at 137 µS/cm), both of which also hold the highest maximum values of all the sites at 300 and 335 µS/cm for GM-1 and GO-2, respectively. These sites are located downstream from major roads and have elevated sodium and chloride levels compared to the other sites (components of road salt). Thirteen of the 22 tributary sites exceeded 100 µS/cm on at least one occasion, which indicates human disturbance likely from road salts in stormwater runoff from impervious surfaces (Figure 11). Mann-Kendall tests revealed no significant (α=0.05) change in specific conductivity from 2002-2011 at any of the 22 tributary sites.

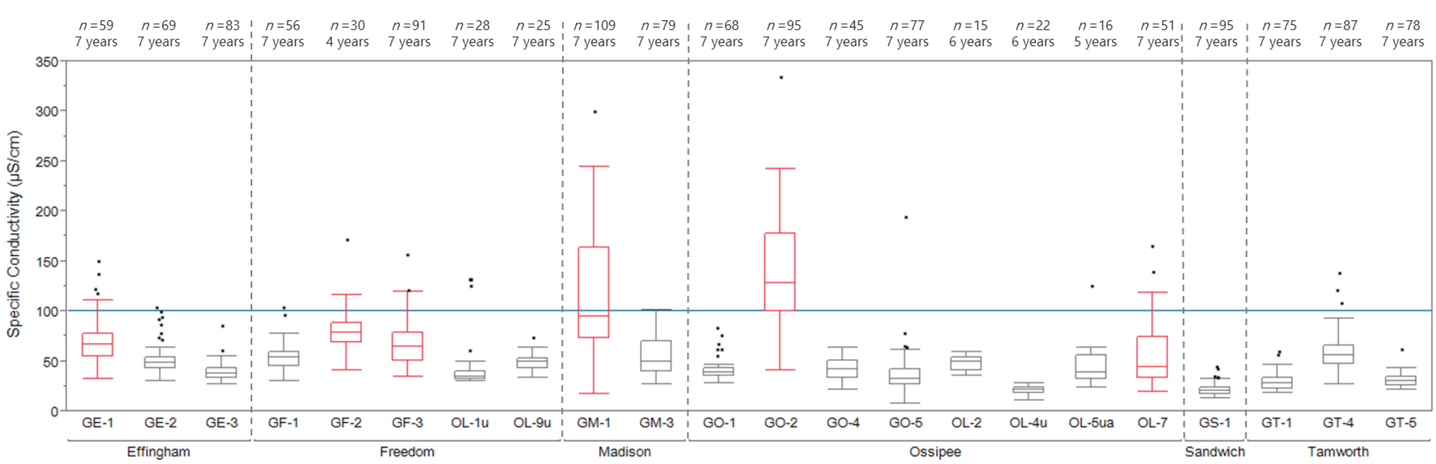



**Figure 10.** Specific conductivity recorded for tributary sites from 2002 to 2011. Data are organized by site and town. Red boxplots show sites with specific conductivity readings greater than 100 µS/cm, suggesting influence by human activities. "n" is the number of samples. Refer to Figure 1 for site locations.

# Dissolved Oxygen

## What is dissolved oxygen?

Dissolved oxygen (DO) is commonly expressed as a concentration in terms of milligrams per liter (mg/L) or as a percent saturation. Percent saturation is the amount of oxygen dissolved in water divided by the maximum amount of oxygen that water can hold at a given temperature; this depends on temperature and atmospheric pressure as gases dissolve more easily in cooler water under higher pressure. Water flow, depth, and the amount of organic matter can also influence DO in water.

## Why is dissolved oxygen important?

DO facilitates critical chemical reactions within water and benthic sediments that support life processes and functions. Depletion of available oxygen (known as hypoxia or anoxia) inhibits physiological functioning of aquatic life and its persistence can reduce the diversity and abundance of biota. DO fluctuates naturally on a diurnal basis depending on a suite of interactions and resource availability (e.g. light, nutrients, organic matter, temperature, etc.). DO is often highest during the day when sunlight drives photosynthesis (produces oxygen), while DO is often lowest at night when autotrophic respiration and decomposition of organic matter dominates (consumes oxygen). In some instances, water can become saturated with more than 100% DO when turbulent water enhances gas exchange with the atmosphere and/or when photosynthesis by aquatic plants (i.e. production of oxygen) exceeds respiration (i.e. consumption of oxygen).

**Class B NH Surface Water Quality Standard:** Dissolved oxygen shall not fall below 5 mg/L at any place or time or 75% saturation minimum daily average, unless naturally occurring. When dissolved oxygen falls below 5 mg/L or a 75% minimum daily average, inputs of nutrients, wastes, or other organic material may be occurring. Levels are also considered critical for aquatic organisms when they fall below 5 mg/L.

**10-Year Results:** The majority of tributary sites demonstrated DO concentrations above 5 mg/L and 75% saturation (Figure 12). DO for all sites ranged from 0.1 to 16.9 mg/L and 5% to 132% saturation, with an average of 9.4 mg/L and 89% saturation. Two sites had mean DO concentrations and percent saturation fall below State standards: Weetamoe Brook (OL-5) at 4.5 mg/L and 46% saturation and Red Brook (OL-7) at 3.6 mg/L and 35% saturation. One additional site had mean percent saturation fall below the State standard: West Branch River (OL-1u) at 73%. Of the 22 RIVERS and OLT sites, 5 sites and 17 sites showed some readings below the State standard for DO concentration and percent saturation, respectively. Natural conditions may be depleting DO at South River (GE-2) and Red Brook (OL-7), since both sites are located downstream of wetlands. Lower flow rates and associated build-up of organic matter, whether natural or human-induced, could also be depleting DO at Cold Brook (GF-2) and Weetamoe Brook (OL-5ua). Dams and culverts causing restrictions to water flow and resulting in stagnation and organic matter build-up could be the cause of low DO in a few cases as well. Mann-Kendall tests revealed a declining trend in DO concentration from 2002-2011 at Pine River (GE-1).

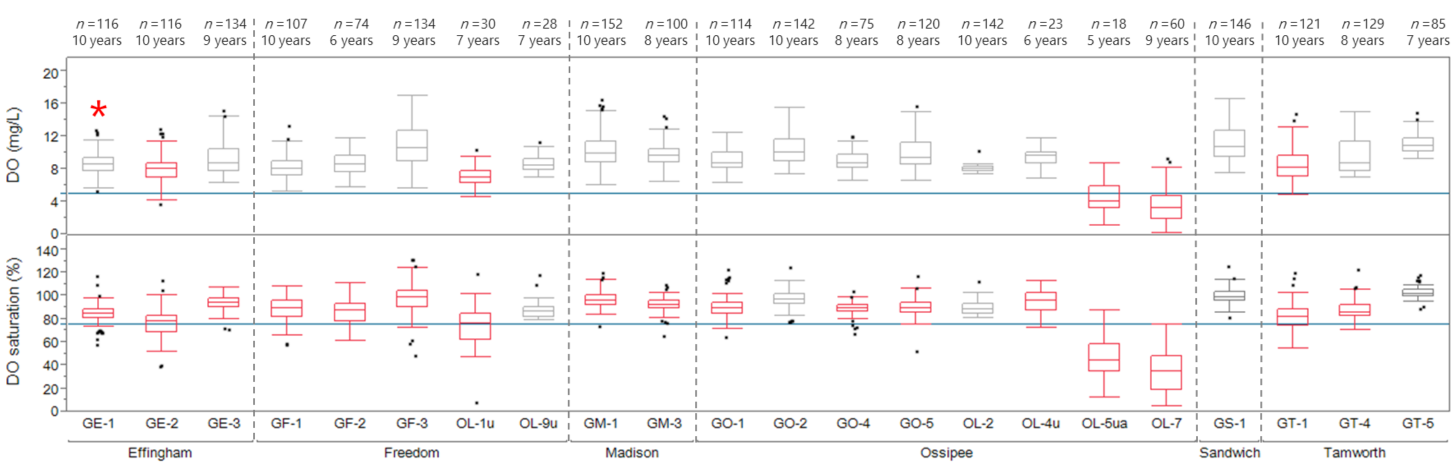



**Figure 12.** Dissolved oxygen (DO) as concentration (top) and percent saturation (bottom) recorded for tributary sites from 2002 to 2011. Data are organized by site and town. Any readings below 5 mg/L or 75% saturation may inhibit aquatic life function. Red boxplots show sites where some DO readings fell below State standards. Red asterisks indicate sites with degrading trends in DO from 2002-2011 using Mann-Kendall tests. "n" is the number of samples. Refer to Figure 1 for site locations.

# Phosphorus

## What is phosphorus?

Total phosphorus includes all dissolved phosphorus (i.e. organic and inorganic phosphorus) as well as the phosphorus contained in or adhered to suspended particles, such as sediment and plankton (i.e. particulate phosphorus). Phosphate is the inorganic component of total phosphorus and is the most biologically available form of phosphorus.

## Why is phosphorus important?

Phosphorus is an essential nutrient for growth, and is one of the limiting nutrients to plant growth in freshwater systems. Phosphorus is typically very low in natural systems; therefore, even a small increase can have a large impact, triggering problematic algal blooms and plant growth that can lead to cultural eutrophication. Eutrophication (nutrient enrichment that increases productivity) can cause anoxia, or deficiency of oxygen, for aquatic organisms and cause other water quality problems. Higher concentrations of phosphorus are primarily associated with human activities within a watershed and are therefore important to monitor and control. Sources of phosphorus include: human waste, animal waste, industrial waste, soil erosion, fertilizers, disturbance of land and vegetation (e.g. draining or filling wetlands), agricultural runoff, and stormwater runoff. Synthetic phosphates are also often used in laundry detergents as a water softener. Phosphorus tends to "stick" to sediment, and in instances of shoreline disturbance or heavy rain events causing erosion, phosphorus attached to soil particles can be washed into waterways. Total phosphorus will also accumulate in slow moving stream reaches and in impoundments (i.e. upstream of a dam, and in lakes and wetlands) where particulate phosphorus settles out of the water column

**Class B NH Surface Water Quality Standard:** "Class B waters shall contain no phosphorus or nitrogen in such concentrations that would impair any existing or designated uses, unless naturally occurring." Due to the high degree of natural variability in phosphorous and difficulty in pinpointing an exact source, there is no numeric standard. However, NH DES does pay attention to readings above 50 µg/L (parts per billion), while the USEPA recommends < 20 µg/L. Typical total phosphorus levels in New Hampshire streams range from 0 to 20 µg P/L; any concentrations greater than 20 µg P/L is considered high for New Hampshire streams under natural conditions.

**10-Year Results:** All 22 sites ranged from 0 to 171.3 µg/L with an average of 11.1 µg/L for total phosphorus and from 0 to 105.3 µg/L with an average of 4.0 µg/L for phosphate (Figure 13). The majority of sites had mean total phosphorus concentrations below 20 µg/L with the exceptions of Cold Brook A1 (GF-2) at 20.8 µg/L, Weetamoe Brook 1 (OL-5ua) at 65.1 µg/L and Red Brook 3 (OL-7) at 66.6 µg/L. Mean phosphate exceeded 20 µg/L at Weetamoe Brook 1 (OL-5ua) at 28.7 µg/L and Red Brook 3 (OL-7) at 37.3 µg/L. Red Brook (OL-7) had the highest maximum value for both total phosphorus and phosphate. Ossipee River (GE-3) exceeded 20 µg/L on only one occasion on 7/6/2009 at 87.4 µg/L phosphate; this measurement is a distinct outlier and does not correlate to a significant rain event. The sample may have been contaminated by some other unknown and non-typical disturbance upstream, particularly since median phosphate for this site is below detection limits (<5 µg/L). Mann-Kendall tests revealed no significant (α=0.05) change in phosphorus from 2002-2011 at any of the 22 tributary sites.

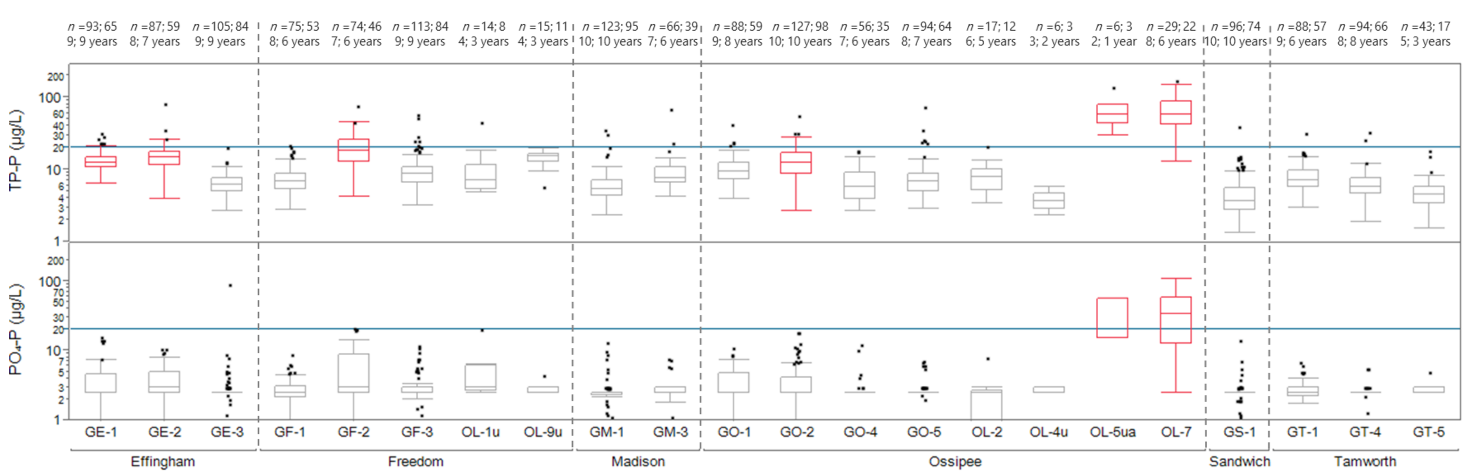



**Figure 13.** Total phosphorus (TP; top) and phosphate ($PO_4$; bottom) recorded for tributary sites from 2002 to 2011. Data are organized by site and town. Note that the pH scale (left side) is in logarithmic scale not a linear scale. Red boxplots show sites where phosphorus fell above natural levels of 20 µg/L. "n" is the number of samples. Refer to Figure 1 for site locations.

# Nitrogen

## What is nitrogen?

Total dissolved nitrogen (TDN) is the sum of dissolved organic and inorganic nitrogen (i.e. DON, DIN). DIN consists of two forms of inorganic nitrogen, ammonium ($NH_4^+$), nitrate ($NO_3^-$), and nitrite ($NO_2^-$). Ammonium is a waste product of metabolic processes in animals, and can be toxic in high amounts; nitrate occurs naturally by nitrification of ammonium in oxidizing environments where microbes convert ammonium to nitrite to nitrate. This conversion is so rapid that nitrite is usually undetectable. Particulate nitrogen is not abundant in nature since it is highly soluble.

## Why is nitrogen important?

Nitrogen makes up about 80% of the earth's atmosphere, is found in all plant and animal tissues, and is considered one of the main limiting nutrients to primary productivity. Excess nitrogen loading in streams can act as a fertilizer to algae and other aquatic plants, resulting in unwanted algal blooms and excessive plant growth; this eventually leads to anoxia that can degrade aquatic life function. DIN enters waterbodies from stormwater runoff, septic systems, animal waste, agricultural runoff, excess fertilizer from lawns, and discharge from car exhausts, while DON is typically generated by natural processes that occur in wetlands and forest soils. Ammonium is easier for plant and microbial to uptake since it is more energy efficient to use than nitrate. However, ammonium is typically low in undisturbed streams as a result of direct uptake or nitrification to nitrate. High levels of ammonium usually indicate some type of pollution. Nitrate contamination of drinking water can cause Methemoglobenemia, a serious illness in infants that inhibits respiration and increases the risk of gastric cancer at levels above 4 mg $NO_3$-N/L.

**Class B NH Surface Water Quality Standard:** No quantitative standard exists for nitrogen; however, nitrogen should not occur in any concentration that would impair designated uses, unless naturally-occurring. The USEPA limit for nitrate in drinking water is 10 mg $NO_3$-N/L; however, some studies have suggested that concentrations above 4 mg $NO_3$-N/L can cause neurological damages to humans. Typical nitrate levels in undisturbed streams are usually 0 to 0.5 mg $NO_3$-N/L; anywhere from 0.5 to 2 mg $NO_3$-N/L suggests some level of disturbance; nitrate greater than 2 mg $NO_3$-N/L clearly indicates disturbance. In the Lamprey River Watershed (southeastern NH), streams range from 0 to 1 mg $NO_3$-N/L, depending on development. Ammonium is also usually low, typically less than 0.2 mg $NH_4$-N/L, and ranges from 0 to 0.1 mg $NH_4$-N /L. in the Lamprey River Watershed.

**10-Year Results:** All 22 tributary sites ranged from 0 to 1.81 mg/L with an average of 0.2 mg/L for total dissolved nitrogen, 0 to 0.44 mg/L with an average of 0.18 mg/L for ammonium, and 0 to 0.40 mg/L with an average of 0.06 mg/L for nitrate (Figure 14). The majority of sites had mean total dissolved nitrogen less than 0.3 mg/L with the exceptions of Red Brook 3 (OL-7) at 0.49 mg/L and Weetamoe Brook 1 (OL-5ua) at 0.67 mg/L. Chocorua River (GT-4) had the highest maximum total dissolved nitrogen at 1.81 mg/L, but this was an outlier (all other points for this site fell below 0.5 mg/L) comprised mostly of dissolved organic nitrogen (1.58 mg/L). All sites had mean ammonium below 0.2 mg/L, but 5 sites (GO-5, OL-5ua, OL-7, GS-1, and GT-1) exceeded 0.2 mg/L on one or more occasion with Red Brook 3 (OL-7) exhibiting the highest maximum concentration at 0.44 mg/L. All sites had mean and single sample nitrate below 0.5 mg/L with Lower Bearcamp River 2 (GO-5) exhibiting the highest maximum concentration at 0.40 mg/L. Mann-Kendall tests revealed degrading trends from 2002-2011 at Ossipee River (GE-3), Danforth Pond outlet (GF-1), and Bearcamp River 4 (OL-2).

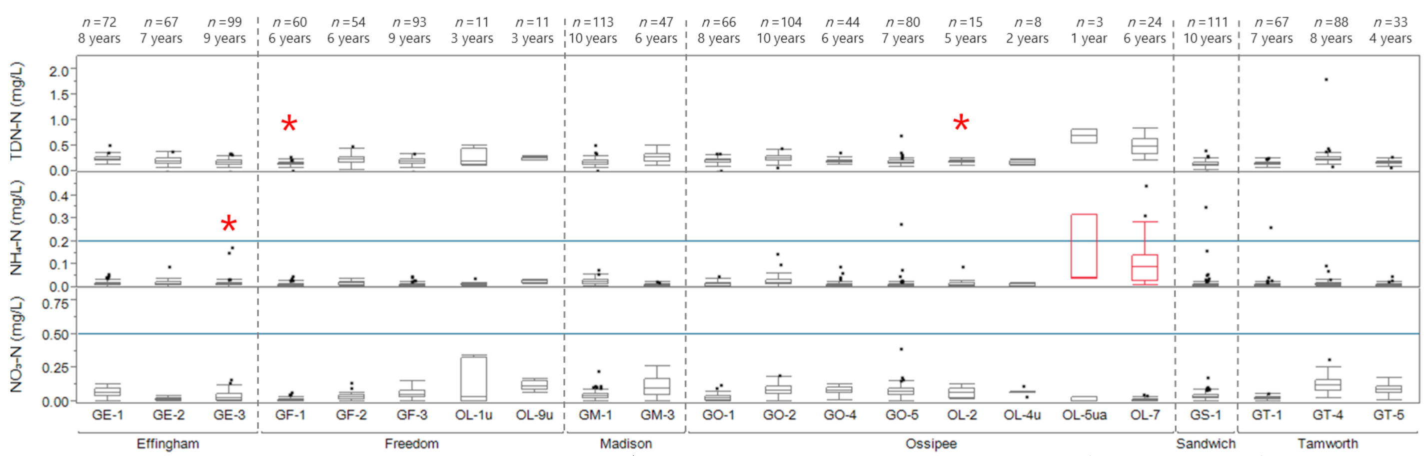



**Figure 14.** Total dissolved nitrogen (TDN; top), ammonium ($NH_4^+$; middle), and nitrate ($NO_3^-$; bottom) recorded for tributary sites from 2002 to 2011. Data are organized by site and town. Red boxplots show sites where nitrogen falls above natural levels of 0.2 mg $NH_4$-N/L and 0.5 mg $NO_3$-N/L. Red asterisks indicate sites with degrading trends in nitrogen from 2002-2011 using Mann-Kendall tests. "n" is the number of samples. Refer to Figure 1 for site locations.

# Chloride

## What is chloride?

Chloride ($Cl^-$) is an element present in most waterbodies, but concentrations are typically low and vary depending on geology, atmospheric deposition, and human activities.

## Why is chloride important?

Chloride is of primary interest to management because it represents a large anthropogenic source of pollutants from road salt, water softeners, septic systems, wastewater treatment plants, and stormwater runoff. Because of this, the concentration of chloride is directly linked to population density and percent impervious cover (e.g. roads) where greater runoff from developed areas impacted by road salt application leads to high inputs of chloride. High chloride concentrations in streams and groundwater can be toxic to aquatic life and human health.

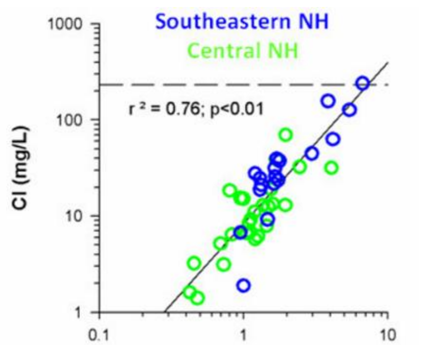



**Figure 15.** Average chloride concentrations among streams in southeastern and central NH increase with increasing watershed road density (GMCG, 2009).

**Class B NH Surface Water Quality Standard:** The acute toxicity limit for chloride (i.e. level which sudden and severe impacts occur) is 860 mg Cl/L and the chronic toxicity limit for chloride (i.e. level which negatively impacts aquatic health) is 230 mg Cl/L for NH surface waters. The drinking water limit for chloride is 250 mg Cl/L. Typical background levels in NH surface waters are less than 30 mg Cl/L.

**10-Year Results:** All 22 tributary sites had chloride concentrations below the acute and chronic toxicity limit for chloride, ranging from 0.6 to 90.6 mg/L with an average of 12.5 mg/L. The majority of sites showed mean chloride less than 30 mg/L except for Frenchman Brook 4 (GO-2) at 36.3 mg/L, and 5 sites (GF-3, GM-1, GO-1, GO-2, and GT-1) had chloride levels above 30 mg/L on at least one occasion (Figure 16). Frenchman Brook 4 (GO-2) also had the highest maximum chloride concentration at 90.6 mg/L. Mann-Kendall tests revealed a declining trend in spring chloride from 2002-2011 at Cold River (GS-1), but improving trends in summer and spring chloride from 2002-2011 at Forrest Brook 2 (GM-3) and Frenchman Brook 4 (GO-2), respectively. Higher levels of chloride at Frenchman Brook 4 (GO-2) and Banfield Brook (GM-1) may be attributed to their proximity to major routes, such as Route 113 and 25 where road salt application is prominent. Average chloride concentrations among streams in southeastern and central NH were closely related to their respective road density (Figure 15). This suggests that road salting practices on these impervious surfaces are elevating stream chloride levels and the chronic toxicity limit (horizontal dashed line in Figure 15) may be reached in central NH streams in the near future.

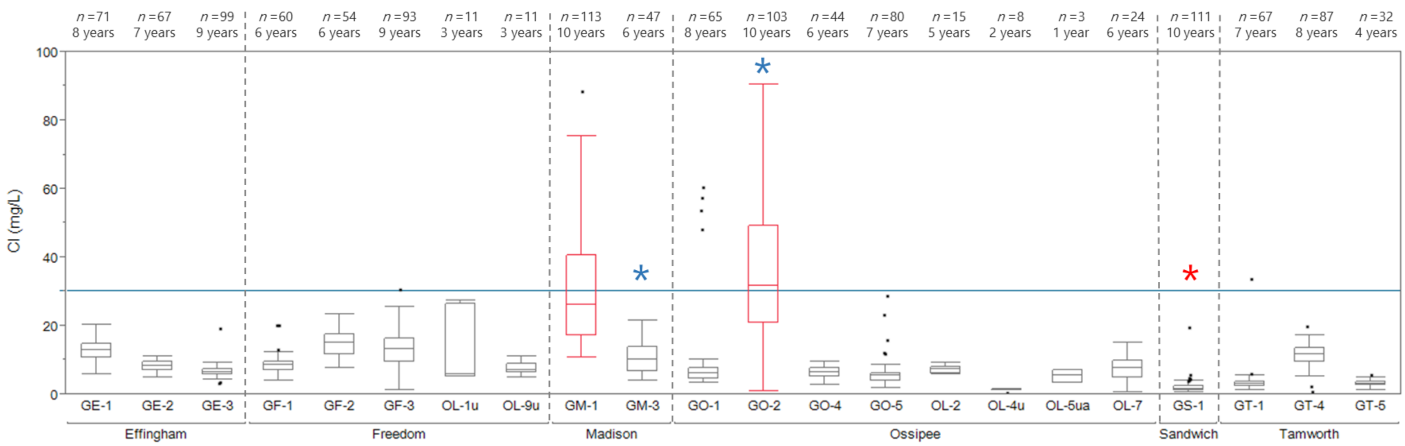



**Figure 16.** Chloride levels recorded for tributary sites from 2002 to 2011. Data are organized by site and town. All sites fell below the State standard for chronic toxicity limit for chloride at 230 mg/L by more than half the limit. Red boxplots show sites with readings above 30 mg/L, which suggests possible human impact above natural background levels for New Hampshire. Red asterisks indicate sites with degrading trends, while blue asterisks indicate sites with improving trends for chloride from 2002-2011 using Mann-Kendall tests. GM-3 is improving in summer chloride levels (i.e. road salt in groundwater); GO-2 is improving in spring chloride levels (i.e. road salt from spring snowmelt flushing); and GS-1 is degrading in spring chloride levels (i.e. road salt from spring snowmelt flushing). "n" is the number of samples. Refer to Figure 1 for site locations.

## LAKE RESULTS

Five deep spots in the Ossipee Watershed have been monitored for total phosphorus, among other parameters, by the NH Lakes Lay Monitoring Program (LLMP) and the NHDES Volunteer Lakes Assessment Program (VLAP), with assistance from local camps, volunteers, and GMCG staff (refer to Figure 1 on page 4). Two bays (Broad Bay and Leavitt Bay) have been tested since 1990; and three others (Ossipee Lake, Berry Bay, and Lower Danforth Pond) have been tested since 2003. Sampling was limited to mid-summer, so sample size is smaller than the tributaries program (1-3 samples per year until 2013-14 when sampling increased to 4-5). These monitoring efforts have generated a historical database that will help to determine year-to-year variability in lake condition and identify any short or long-term changes in water quality.

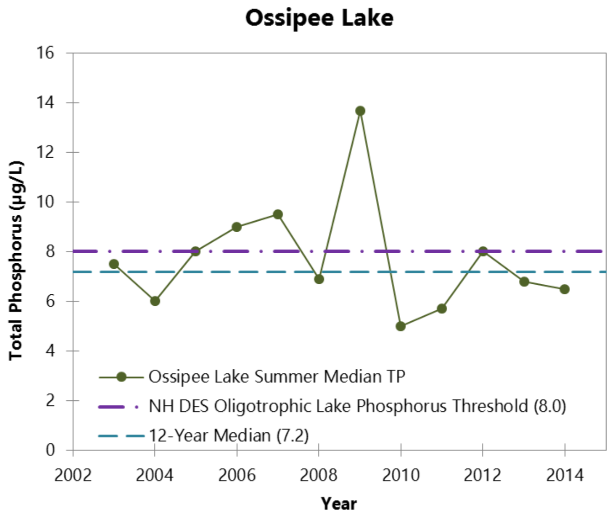
A volunteer lowers a Secchi disk into the lake to measure water clarity. (Photo: GMCG)

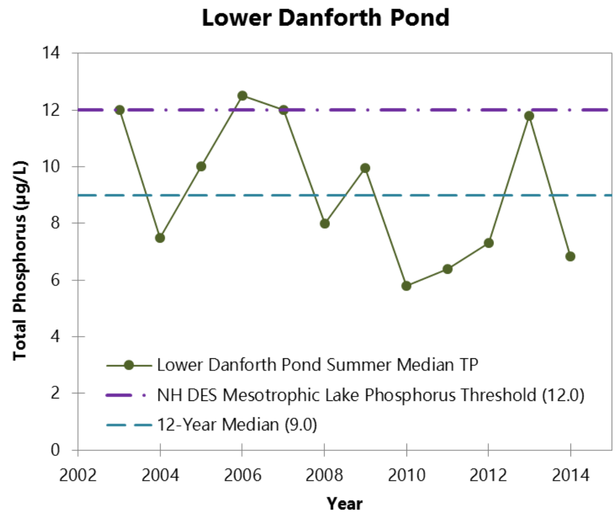
Trend analyses for data collected between 2003 and 2014 were completed by FB Environmental Associates for total phosphorus in Ossipee Lake, Broad Bay, Leavitt Bay, Berry Bay, and Lower Danforth Pond. Full results and discussion can be found in the watershed management plans for these waterbodies (FBE, 2015). Data and trend analyses for other important lake parameters can be found on the NHDES VLAP website for individual lake reports at http://des.nh.gov/organization/divisions/water/wmb/vlap/annual_reports/2013/lake-reports.htm.

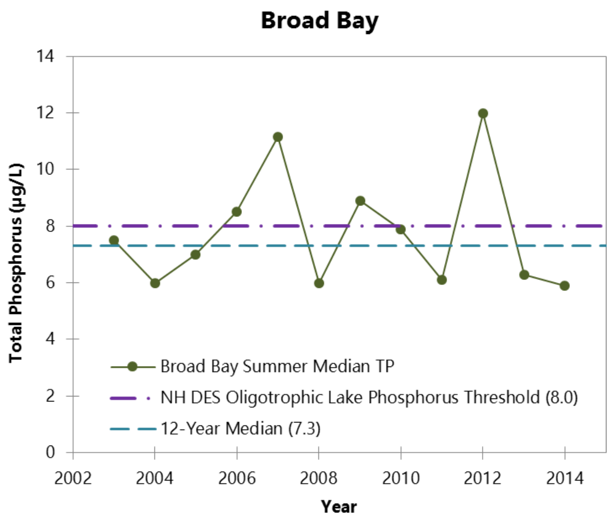
No statistically significant trend in total phosphorus was found for any of these waterbodies during the specified time period (Figure 17). This indicates that phosphorus has been relatively stable in Danforth Ponds, Ossipee Lake, and its lower bays over the past twelve years, with moderate variability. Year-to-year variability is expected in data from waterbodies with low sample sizes per year ($n$ = 1 to 5). These 2003-2014 trend analyses mirror those presented in the NH VLAP individual lake reports with the exception of Broad Bay, which shows degrading (increasing) phosphorus from 1990-2013.

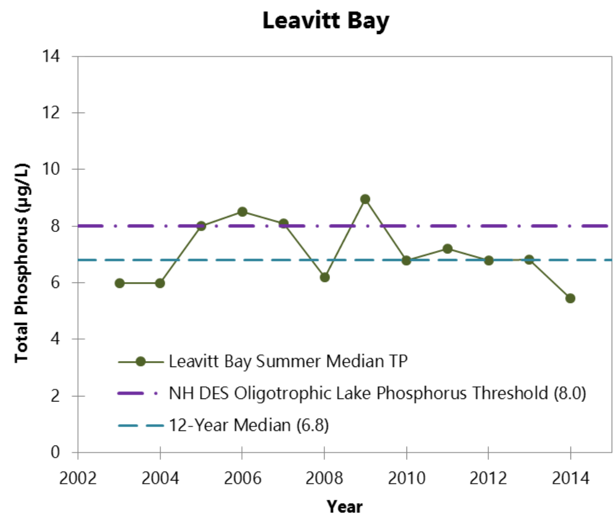
Monitoring results also show that Lower Danforth Pond has higher total phosphorus levels than the other bays of Ossipee Lake and Ossipee Lake itself, and has total phosphorus levels that are typically greater than the State mean. NHDES suggests that internal phosphorus loading (phosphorus that is re-released from bottom sediments into the water column as food for algae and plants; usually caused by low oxygen) in the hypolimnion of Lower Danforth Pond is likely contributing to this higher phosphorus concentration.

Finally, total phosphorus within Broad and Berry Bays fell within their "reserve" assimilative capacity (i.e. median concentrations within 10% of the State standard). This indicates that phosphorus management is needed within the watershed to reduce median phosphorus levels and protect these bays from exceeding State water quality standards in the near future. Refer to the Danforth Ponds and Lower Bays of Ossipee Lake Watershed Management Plan (FBE, 2015) for more detailed information.



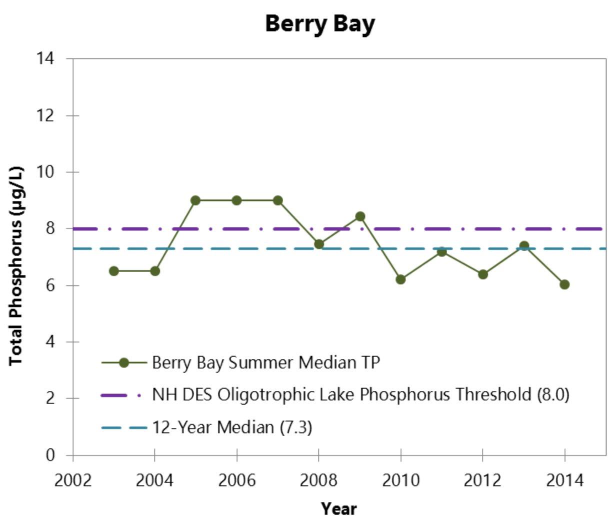




**Figure 17.** Trends for total phosphorus values (in parts per billion "ppb" or µg/L) in the study waterbodies from 2003-2014. Also shown is the 12-year median for each waterbody (blue dashed line), NH State phosphorus thresholds (purple dashed line) for oligotrophic (Ossipee Lake and Broad, Leavitt, and Berry Bays) and mesotrophic (Danforth Ponds). Mann-Kendall tests revealed no statistically significant trends in phosphorus concentrations over the time period.

# SUMMARY

Analysis of water quality data for select tributaries of the Ossipee Watershed between 2002-2011 showed that ***water quality in the watershed is very good overall***. Many parameters across the select sites met established New Hampshire water quality standards or fell within levels indicative of natural conditions and not human impact, with some notable exceptions. Refer to Tables 1 and 2 in the Executive Summary for a summation of water quality parameters analyzed for the select twenty-two tributary sites.

While the water quality is generally good for the Ossipee Watershed, ***some sites have emerging problems*** that need attention (refer to Table 2).

- Low **pH** (slightly acidic waters) is common at all sites, some of which is a result of natural conditions in New Hampshire streams from local geology and acid rain. Most sites experienced periods of dangerously low pH that can inhibit aquatic life function.
- **Water temperature** exceeded a recommended maximum of 24° C for coldwater fish species at Ossipee River (GE-3), Danforth Pond outlet (GF-1), West Branch River 1 (OL-1u), Banfield Brook (GM-1), and Bearcamp River 4 (OL-2).
- **Specific conductivity** exceeded 100 µS/cm on at least one occasion at thirteen of the twenty-two tributary sites (out of thirty active sites), suggesting that human disturbance is contributing chemical ions (e.g. chloride, nutrients, etc.) to surface waters in the watershed above natural conditions.
- **Turbidity** has increased (worsened) over the past ten years at Cold Brook A2 (GF-3), Banfield Brook (GM-1), Forrest Brook 2 (GM-3), and Red Brook 3 (OL-7). This is likely a result of soil erosion following rain events, which can be fixed with riparian buffer plantings and road maintenance.
- **Dissolved oxygen** has decreased (worsened) over the past ten years at Pine River 1 (GE-1), and exceeded the State standard for concentration and percent saturation at five and seventeen tributary sites, respectively.
- **Total phosphorus** and **phosphate** were elevated at Weetamoe Brook 1 (OL-5ua) and Red Brook 3 (OL-7).
- **Total dissolved nitrogen** has increased (worsened) over the past ten years at Danforth Pond outlet (GF-1) and Bearcamp River 4 (OL-2).
- **Ammonium** has increased (worsened) over the past ten years at Ossipee River (GE-3) and has exceeded natural levels at Weetamoe Brook 1 (OL-5ua) and Red Brook 3 (OL-7).
- Spring **chloride** has increased (worsened) over the last ten years at Cold River (GS-1), but spring and summer chloride have decreased (improved) at Frenchman Brook 4 (GO-2) and Forrest Brook 2 (GM-3), respectively. Although chloride concentrations were well below State standards for chronic exposure, several sites exceeded natural background levels of 30 mg/L on at least one occasion, including Cold Brook A2 (GF-3), Banfield Brook (GM-1), Beech River 1 (GO-1), Frenchman Brook 4 (GO-2), and Bearcamp River 1 (GT-1). These higher chloride concentrations are likely from road salt applications, which enter streams via culverts and ditches and infiltrate to groundwater via roadside soils (Daley et al. 2009).

These analyses revealed four sites that have multiple water quality parameters exceeding State water quality standards, exceeding natural background levels, and/or showing deteriorating trends: Pine River 1 (**GE-1**), Banfield Brook (**GM-1**), Weetamoe Brook 1 (**OL-5ua**), and Red Brook 3 (**OL-7**). These sites should be priority targets for future restoration efforts.

All five monitored deep spots (Ossipee Lake, Broad Bay, Leavitt Bay, Berry Bay, and Lower Danforth Pond) within the Ossipee Watershed meet the State water quality standard for their respective trophic class (i.e. oligotrophic or mesotrophic), and analyses of total phosphorus in these waterbodies show a stable trend from 2003-2014. However, these analyses were based on a limited dataset of one to five readings per year, which may not be a large enough annual sample size to make strong conclusions about trends in lake condition. Total phosphorus within Broad and Berry Bays fell within their "reserve" assimilative capacity. This indicates that phosphorus management is needed within the watershed to reduce median phosphorus levels and protect these bays from exceeding State water quality standards in the near future. GMCG is currently developing watershed-based management plans that focus on phosphorus in the Ossipee Watershed, with the goal of developing strategies to lessen the nutrient load to these waterbodies. It is also important to note that lake water quality changes naturally over hundreds or thousands of years, gradually transforming from less productive (oligotrophic) to more productive (eutrophic) systems; human disturbances within a watershed can accelerate this transformation within only a few years or decades, which is why remedial steps should be sought to mitigate and manage this change.

More than 1,000 streams, rivers, and lakes in the greater Saco River Watershed (which includes the Ossipee Watershed) in New Hampshire and Maine are listed as impaired, most of which are due to nonpoint source (NPS) pollution that enters surface and groundwater. Many New Hampshire streams, including several tributary sites analyzed in this report, show deteriorating trends in some water quality parameters, but water quality at these sites still meet State water quality standards. This presents a unique opportunity for engaged stakeholders, such as GMCG and watershed towns, to utilize restoration techniques that can reverse or stabilize these deteriorating trends in water quality.

Water quality information empowers communities to make informed planning and resource-protection decisions. Results of the analyses completed for this report can be used by the watershed towns and their partners (GMCG, OLA, NHDES, and others) to prioritize and direct future monitoring and water quality protection efforts throughout the Ossipee Watershed. Communities can address water quality issues by adopting NHDES, NHLA, and UNH recommended Best Management Practices (BMPs) and Low Impact Development (LID) techniques as parts of their local land-use planning and development regulations. Towns can also incorporate shoreland and aquifer protection priorities into their local planning and regulatory structures. Specific recommendations for future monitoring, watershed planning, and restoration actions to reduce NPS pollution in the Ossipee Watershed are discussed in the next section and in the Ossipee watershed management plans (FBE, 2015).

# RECOMMENDATIONS

Making recommendations is an important part of the watershed management planning process. The following recommendations should be viewed as a starting point for local discussion, planning, and implementation that may be modified based on new information or stakeholder priorities. A more specific plan will be outlined in the watershed management plans for the Ossipee Watershed, and those recommendations will be based on local review that will target appropriate actions for the watershed.

**Continue Long-Term Monitoring Program.** The most important step for future protection of the surface and groundwater resources in the Ossipee Watershed is to continue the existing monitoring program. Only through consistent, long-term data can we understand our ecosystems and recognize how and why they change. This is essential for making informed decisions about their future use and protection, and is relatively inexpensive insurance for maintaining good water quality in the future.

Recommendations for improving and/or expanding the current monitoring program include:

- Address areas around sites exhibiting deteriorating trends in water quality. Best Management Practice (BMP) examples for water quality parameters that showed deteriorating trends at certain sites include:
    - Turbidity- Prevent erosion at the source by maintaining roads, installing BMPs, or re-establishing the shoreline buffer.
    - Nutrients- Establish or maintain good shoreline buffers of native vegetation, and ensure adequate sewage treatment across watershed (e.g. properly functioning and maintained septic tanks). Reduce fertilizer application.
    - Chloride- Improve catchbasins and decrease road salt application as much as possible within safety limits, and investigate the connection with groundwater as a source of chloride to surface waters. Consider editing winter road guidelines to help lower use of road salt.
    - Dissolved Oxygen- Determine if areas with low dissolved oxygen are a result of natural or human-made conditions, such as slow flow, minimal water mixing, or point-source discharges that may cause oxygen depletion in streams.
    - Conduct bracket sampling upstream of sites with State water quality exceedances and/or deteriorating trends. This may help target specific “hotspots” of sediment or nutrient input to the streams.
- Protect areas in the watershed that contain sites with good water quality and stable trends.
- Establish annual groundwater monitoring to understand drinking water issues.
- Capture water samples during storm events to examine sediment and nutrient inputs during peak discharges. These samples may be collected either by manual or automatic grab samples during storm events at stream or lake sites. Sampling earlier and later in the year at lake sites would also be helpful in understanding lake condition during turnover periods.
- Deploy data loggers to capture continuous water quality information. Data loggers may be deployed at strategic locations in rivers, streams, and lakes to capture continuous (e.g., every 30

minutes) data for a number of parameters, including flow, water temperature, dissolved oxygen, specific conductivity, turbidity, chlorophyll-a, and algae abundance. These data would provide better understanding of local processes in the Ossipee Watershed, particularly at sites with deteriorating water quality trends. Of particular importance is measuring flow since measured concentrations are a function of water volume, which changes over the course of a single year and across multiple years.

- Review historical concentration data as influenced by precipitation and flow.

## Emphasize Coordinated Local Planning.

- Complete and follow the action items presented in the watershed management plans for the Ossipee Watershed. The measures presented in the plan will help guide local efforts in controlling sources of pollutants from entering waterbodies and improve water quality over time.
- Prevent pollution at the local level (e.g. watershed associations, local government, etc.) by utilizing LID techniques and BMPs in the watershed and developing local watershed initiatives.
- Encourage town officials to promote sustainable development and to develop watershed or aquifer overlay districts.
- Encourage town officials to coordinate planning and policy making with the other watershed towns.

## Minimize Nonpoint Source Pollution.

- Minimize NPS inputs from the landscape by developing erosion and sediment control initiatives, maintaining septic systems, limiting fertilizer and road salt usage, and implementing BMPs.

## Identify and Monitor Potential Contamination Sources.

- Identify and evaluate specific potential sources of contamination to surface waters and the aquifer and ensure BMPs are being followed and spill containment and emergency procedures are in place.

## Protect Shorelines.

- Protect riparian corridors, shorelines, and wetlands from development that could degrade water quality.
- Stabilize stream banks, shorelines, and disturbed soils, especially roads located next to rivers, tributaries, and lakes.
- Incorporate Comprehensive Shoreland Protection Act (CSPA) standards into municipal regulatory structures. Visit http://www.des.state.nh.us/CSPA/ for more details.

## Promote Best Management Practices.

- Promote the use of BMPs to prevent NPS pollution. BMPs include limiting or using alternatives to road salt/road salting strategies, the use of vegetative buffers, covering salt/sand piles, preventing snow dumping directly in surface waters, and proper treatment of runoff.
- Encourage and work with State and town DPWs to control salt application on roads by identifying sensitive sites for more control and making sure truck equipment is properly calibrated.

- Ensure that BMP guidance are built into local site plan initiatives where appropriate.
- Visit the following for more information:
  - BMPs for Groundwater Protection at http://www.des.state.nh.us/factsheets/ws/ws-224.htm
  - BMPs for Surface Water Protection: http://www.des.state.nh.us/wmb/was/manual/
  - UNH Stormwater Research Center: http://www.unh.edu/erg/cstev/
  - LRPC Aquifer Protection BMPs & Guide for Developers: http://www.lakesrpc.org/services_resources_aquifer.asp

### Promote Low Impact Development Techniques.

- Encourage the use of LID techniques in the Ossipee Watershed. For example, install permeable pavement to reduce the need for salting in the winter and increase infiltration and groundwater recharge.
- Support initiatives that limit development on steep slopes and protect water resources.

Water resources in the Ossipee Watershed have significant environmental, economic, and social values. (Photo: GMCG)

### Educate the Public.

- Continue to educate and engage watershed residents about the quality and value of the watershed's resources, the sources of pollutants in the watershed, and the positive and negative ecological, recreational, and economic impacts their utilization can have on the lakes, ponds, rivers, and streams of the Ossipee Watershed.
- Educate the public on the benefits of septic system upgrades and pumping, maintaining shoreline habitat, and utilizing homeowner BMPs.

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