# Water Resources Research Center
# Annual Technical Report
# FY 2004

## Introduction

The New Hampshire Water Resources Research Center, located on the campus of the University of New Hampshire, is an institute which serves as a focal point for research and information on water issues in the state. The NH WRRC actually predates the Federal program. In the late 1950s Professor Gordon Byers (now retired) began a Water Center at UNH. This Center was incorporated into the Federal program in 1965 as one of the original 14 state institutes established under the Water Resource Research Act of 1964. The NH WRRC is currently directed by Dr. William McDowell with administrative and technical assistance from Shanna Fredyma, Jeff Merriam and Jody Potter. The NH WRRC is a stand alone organization, in that it is not directly affiliated with any other administrative unit at UNH. The NH WRRC has no dedicated laboratory, administrative or research space on campus and no formal library holdings. To overcome these potential limitations, our website (www.wrrc.unh.edu) is used heavily, and serves as a focal point for information dissemination and includes all NH WRRC publications and results from past research, as well as links to other sites of interest to NH citizens and researchers.

## Research Program

Three research projects were funded over the report period. Two projects help fund longterm monitoring of lakes and streams in New Hampshire. The third project contributed to our understanding of biosolid application and treatment.

# Effects of Land Use on Water Quality in a Changing Landscape

## Basic Information

| | |
|---|---|
| **Title:** | Effects of Land Use on Water Quality in a Changing Landscape |
| **Project Number:** | 2002NH4B |
| **Start Date:** | 3/1/2004 |
| **End Date:** | 2/28/2005 |
| **Funding Source:** | 104B |
| **Congressional District:** | 01 |
| **Research Category:** | Water Quality |
| **Focus Category:** | Water Quality, Non Point Pollution, Nutrients |
| **Descriptors:** | |
| **Principal Investigators:** | Jeffrey Schloss |

## Publication


1. Schloss, Jeff and Ellie Ely. 2004. Measuring Clarity, Transparency, Turbidity, and TSS. 2004. Volunteer Monitor National Newsletter of Volunteer Water Quality Monitoring. Winter Edition.http://www.epa.gov/owow/monitoring/volunteer/newsletter/volmon16no1.pdf
2. Schloss, Jeffrey A. 2004. Participatory Watershed Monitoring: Linking Citizens to Scientists Through the NH Lakes Lay Monitoring Program. National Water Quality Monitorng Council Conference. May 2004. Chattanooga TN. Powerpoint: http://water.usgs.gov/wicp/acwi/monitoring/conference/2004/conference_agenda_links/power_points_etc/04_ConcurrentSessionB/36_Rm11_Schloss.pdf ExtendedAbstract: http://water.usgs.gov/wicp/acwi/monitoring/conference/2004/conference_agenda_links/title_pages/block_b/attach_36.pdf
3. R. Craycraft and J. Schloss. 2004. Lakes Lay Monitoring Program Annual Report for 2003. A series of more than 50 individual lake reports distributed to lake associations, towns, conservation and planning commissions, and state agencies.
4. J. Schloss and R. Craycraft and 2004. Lake Chocorua Watershed Road Drainage Best Management Practice Evaluation and Wetlands Study. Final Report for Phase 3 of the NH Department of Environmental Services Nonpoint Source Pollution Program. UNH Cooperative Extension, UNH Center for Freshwater Biology, Carrol County Consrvation District, Lake Chocorua Association.
5. J Schloss 2004 Squam Lakes Diagnostic Watershed Study. UNH Center for Freshwater Biology Project Report.

Jeff Schloss – USGS WRRC Status Report 2004
Problem and Research Objectives:

**State:** New Hampshire
**Project Number:** NH761
**Title:** Effects of Land Use on Water Quality in a Changing Landscape
**Project Type:** Research Project
**Focus Category:** Water Quality, Non Point Pollution, Nutrients
**Keywords:** lake, stream, water quality, nutrients, land use
**Start Date:** 03/01/2004
**End Date:** 02/28/2005
**Congressional District:** 1
**PI:** Jeffrey A. Schloss
Professional Staff, University of New Hampshire
phone:603-862-3848

Objectives:
1- The continued collection and analysis of long-term water quality data in selected watersheds.
2- The dissemination of the results of the analysis to cooperating agencies, water managers, educators and the public on a local, statewide and regional basis.
3- To offer undergraduate and graduate students the opportunity to gain hands-on experience in water quality sampling, laboratory analysis, data management and interpretation.
4- To further document the changing water quality in selected lake and river watersheds (Lake Winnipesaukee, the Squam Lakes, Ossippee Lake and the Saco River) in the face of land use changes and management efforts.
5- To continue to document the effectiveness of constructed BMPs in the Chocorua Lake Watershed and provide the final sproject summary results.
6- To determine the next steps for further analysis of long-term data sets.

Methodology
Lake and stream monitoring through the LLMP generally involved a minimum of monthly sampling from spring runoff through lake stratification, and weekly to bi-weekly sampling from stratification until fall overturn. Water clarity, chlorophyll a, acid neutralizing capacity, color, dissolved oxygen and nutrients (total N, total P and nitrate) was the default suite of parameters measured for lakes while nutrients, turbidity, color and flow were the parameters of choice for the lake tributary work. On occasion, student field teams traveled to join the volunteer monitors to perform quality assurance checks and do more in-depth analysis and lake profiling.
Land cover changes to study subwatersheds was documented on our established GIS data base and new management practices or conservation efforts were also documented. Particular emphasis was placed on the Squam Lakes Watershed this year.
This project was coordinated from the University of New Hampshire, which supplied the office and laboratory space (analytical and computer). The Center for Freshwater Biology Analytical Water Quality Laboratory has a Quality Assurance Project Plan for surface water analysis on file with the US Environmental Protection Agency Region 1 Office (EPA New England). Besides nutrient analysis (Total Phosphorus, Total Nitrogen, Nitrate), other water quality measurements included chlorophyll a, dissolved oxygen, dissolved Co2, acid neutralizing capacity, specific conductivity, pH, ORP, turbidity, water clarity, iron and E.coli. UNH Cooperative Extension and the Natural Resource Department provided vehicles for travel for PI's, students and interns at a cost (mileage) basis. A dedicated GIS PC NT workstation was provided for use including Arc/Info and ArcView Software, ArcView Extensions: Spatial Analyst, 3D Analyst, Image Analysis and ArcPress. This was used in addition to other data input PC stations, laser printers and a large format (36" wide) ink jet plotter that was made available for the project.

The project utilized an extensive GIS database for the study subwatersheds created through previous WRRC funding to the PI. Updated and additional GIS data including a new land cover dataset for 2000 was made available through the UNH Complex Systems Research Center which manages the NH GRANIT statewide GIS data depository. The extensive data directory contains statewide GIS data layers (usually at 1:24,000 scale) including hydrology, geology, soils, National Wetlands Inventory, land-use, land cover, and digital elevation models. Also available are Landsat Thematic Mapper, SPOT Panchromatic and digital orthophoto imagery.

Principal Findings and Significance

The final year of data analysis of the Lake Chocorua BMP Evaluation Study confirmed that a significant reduction in the phosphous loading was due to the road drainage mitigation techniques. In 2003 we documented from 2003 data that the combination of the use of plunge pools, diversions to settling areas and a large collecting infiltration swale reduced loadings during storm events by 82-94%. The P concentration range from the runoff was also reduced significantly (pre-range of 34 to 281ppb post range of 13 to 23 ppb). Additional monitoring was done in 2003 under a previous USGS WWRC grant to capture spring runoff and additional storm events. Those results were summarized in June of 2004. Some highlights:

- The total phosphorus concentrations documented in the Route 16 drainage culverts prior to BMP implementation (1997, range 25 to 245 parts per billion) were significantly higher than the post BMP total phosphorus concentrations (2003, 2 to 38 parts per billion).
- The spring total phosphorus loading was reduced in Culvert B (a treatment culvert), which constituted our primary comparison site due to the most complete set of water quality data. Even with the marked increase in spring 2003 precipitation, compared to 1997, the spring 2003 total phosphorus loading values were significantly lower than the 1997 data and maintained an average 92% reduction . In addition, the 2003 spring total phosphorus loadings represented a 60% reduction, even when compared to the initial post-BMP installation total phosphorus loading values measured in 2000.
- The greatest total phosphorus (226 ug/L), turbidity and TSS measurements were documented at the control site, MH-1 Rt16 (no BMPs), during the 2003 study period and reached levels considered more typical of an impaired system.
- Total suspended solids were low at the treatment culverts in 2003 and remained near or below detectible limits.
- Turbidity was generally low and generally measured less than 1 NTU during the spring and summer sampling period.
- The natural detention basin located in the McGregor Hill Culvert was highly effective at attenuating nutrients during the intense, September 23, 2003 storm event. The water quality data suggest BMPs should be implemented at this site to assure maximum nutrient attenuation in the future.
- Total phosphorus and total nitrogen were higher late in the season and reflected natural increases in organic matter and nutrient loading (total phosphorus and total nitrogen) during periods of high discharge.
- Significant amounts of organic debris (leaves and twigs) collected in the Route 16 drainage culverts in the spring and fall and thus a regimented culvert cleaning schedule should be implemented to maximize the efficiency of the implemented BMPs.
- A comparison among the total phosphorus data collected prior to BMP implementation (1997), during the early stages of BMP implementation (2000) and following completion of the BMPs (2003) indicates a significant reduction in the range of the annual total phosphorus concentrations collectively reported for the treatment culverts: Culverts A, B, C and the swale. The total phosphorus concentrations ranged from 25 to 245 parts per billion (ppb) prior to BMP implementation (1997), ranged from 2 to 26 ppb during the early stages of BMP implementation (2000), and ranged from 2 to 38 ppb following full BMP implementation (2003). The decrease in the phosphorus range is largely associated with a corresponding reduction in the suspended sediment load into Chocorua Lake. While total suspended solids

were not quantified prior to 2003, historical records indicate significant amounts of sediments were documented in the total phosphorus samples during the 1997 sampling season and corresponded to the high total phosphorus concentrations.

- Annual total phosphorus loading values were compared among the three sampling seasons (1997, 2000 and 2003) at the McGregor Hill (control) culvert to help assess the natural variation in the total phosphorus load among the three years. Since no BMPs were implemented in or adjacent to the McGregor Hill culvert, the annual variation documented at this site is assumed to reflect natural variations in phosphorus loading among years. The annual total phosphorus load decreased by 10% in the year 2000 and increased by 31% in 2003, relative to the 1997 loading value. Thus, when assessing the effectiveness of the implemented Route 16 BMPs, the annual data will be weighted against the annual precipitation data to account for the natural variations in phosphorus loading that are associated with climatic variables and, while beyond our control, had a profound influence on the annual phosphorus loading values.
- A comparison among the pre-BMP implementation (1997), BMP construction phase (2000) and the post-BMP (2003) data was conducted using phosphorus loading values weighted for precipitation. The 2003 spring total phosphorus loading values were significantly lower than either the 1997 (92% reduction) or the 2000 (60% reduction) "normalized" spring phosphorus loading values. During the pre-BMP sampling season (1997) a significant amount of sediment was observed (but not quantified) in the total phosphorus samples while the 2000 and the 2003 samples contained negligible amounts of sediments; the 2003 suspended sediment samples were near or below detectible limits in the treatment culverts. The low suspended sediment levels, documented during the 2003 study season, corroborated the lack of significant sediment load during the post-BMP implementation period.
- The spring runoff period is represented by minimal vegetative cover and high flow periods associated with snowmelt and a saturated water table. Thus, the spring runoff period is oftentimes characterized by a high potential for sediment washout and increased nutrient loading potential, particularly when erosion control measures are not in place in sensitive areas.
- A second comparison was undertaken between the 1997 and 2003 "normalized" spring and fall phosphorus loading data to further assess the effectiveness of the Route 16 BMPs. Note: limited rainfall during the fall of 2000 limited the late season runoff and thus the BMP construction phase (2000) data were excluded from this comparison. The composite of the spring and fall water quality data revealed a 30% reduction in the annual phosphorus load when comparing the pre-BMP (1997) and the post-BMP (2003) data. An intense, September 23, 2003, storm event accounted for a significant amount of the phosphorus load and reflected a storm event that exceeded the capacity of the Route 16 BMPs to attenuate the nutrient load. If the anomalous nutrient loading data from the September 23, 2003 storm event are removed from the pre and post-BMP comparison the data indicate a 58% reduction in the phosphorus loading values. The fall 2003 water quality data reflect a worse case scenario for sediment and nutrient loading due to the saturated soil conditions that coincided with atypically high rainfall, coupled with intense storm events that occurred in September and October, 2003. The result was an atypically high runoff period in 2003 during which, even with the implemented BMPs, the discharge volume exceeded the capacity of the BMPs to attenuate nutrients. On the other hand, the 30% reduction in the 2003 phosphorus load is testament to the effectiveness of the BMPs even through the discharge volumes at times exceeded the BMP capacities.
- The BMP nutrient attenuation efficiency was reduced when the fall water quality data were incorporated into the comparison. The fall data were collected when significant vegetative cover characterized the drainage basin and when deciduous leaf senescence was occurring. The 2003 fall water quality samples consistently contained organic debris (i.e. decomposing leaf debris) that appears to have contributed to the reduced efficiency of the BMPs at attenuating nutrients. The rip-rap, and plunge pools are very effective at removing inorganic debris such as sand and other relatively heavy inorganic particles. On the other hand, the organic debris is light and is more likely to remain suspended in the streamflow and enter Chocorua Lake. Thus, it appears the reduced efficiency of the BMPs in the fall are associated

with the natural shift in particulate debris from "heavy" sediment rich effluent, that is rapidly attenuated by the BMPs, to a mix of lighter organic and inorganic particles, much of which will reach the lake before being attenuated. While seasonal fluctuations in the BMP effectiveness do exist, the data that were collected in the Route 16 culverts indicate the erosion control measures have been quite effective at mitigating the historical sediment washout problems.

Ongoing collection of ambient water quality data across the state continues. We added new sites for our statewide lake study. We saw a 6% increase in monitoring samples collected statewide with over 30% of that increase in samples collected specifically in the Lakes region of NH: In all, we saw the addition of 2 new lakes, and the expansion of programs on 8 other lakes with the addition of new or reactivated sampling sites. We provided training for 18 new volunteer monitors!

Further analysis of the Squam Lake Watershed nutrient budget results and a more limited tributary sampling in 2004 disclosed that subwatersheds with construction activity, active agriculture and the more extensive road drainage networks were the largest contributors of phosphorous on an aerial basis. Further study will be done on analysis of the effect of riparian buffer extent and updated nutrient export coefficients will be calculated in the upcoming year as part of a Ph'D dissertation.

Students involved or funded (#, undergrad, Masters, and PhD)

| **Name** | **Major/Class** | **Degree** |
|---|---|---|
| Maggie Bartlett -- | Sociology / Fr | BA |
| Zach Bodah -- | Marine & Freshwater/ Jr | BS |
| Shane Brand | Zoology | PHD |
| Nicole Cappadona -- | Undeclared/ Fr | ? |
| Jonathan Gravel -- | WARM/ Sr | BS |
| Marissa Grier -- | WARM/ Jr | BS |
| Matt Hinderlitter | Zoology | MS |
| Kara Houghton -- | English/ Jr | BA |
| Caitlin Milone -- | Psychology/ Fr | BA |
| Cassandra Payne -- | Hospitality/ So | BA |
| Julie Shelly-- | Biology/ Fr | BS |
| Katie Sinnott -- | Undeclared/ So | ? |
| Michelle Williams | Extension (Colorado State) | MS |

This totals to 10 Undergraduate, 2 Masters and 1 PhD student

In addition: water quality and GIS data were used in:
WARM 604- Watershed Hydrology -9 students
Zoology/Botany 719/819- Field Limnology- 12 students
Biology/Zoology 896- Multidisciplinary Lake Management- 12 students

Any publications, reports, presentations, from this work.

Publications:
Newsletters:

Schloss, Jeff and Ellie Ely. 2004. Measuring Clarity, Transparency, Turbidity, and TSS. 2004. "Volunteer Monitor" National Newsletter of Volunteer Water Quality Monitoring. Winter Edition link: http://www.epa.gov/owow/monitoring/volunteer/newsletter/volmon16no1.pdf

Proceedings/ Abstracts:

Schloss, Jeffrey A. 2004. Participatory Watershed Monitoring: Linking Citizens to Scientists Through the NH Lakes Lay Monitoring Program. National Water Quality Monitorng Council Conference. May 2004. Chattanooga TN.
Powerpoint:
http://water.usgs.gov/wicp/acwi/monitoring/conference/2004/conference_agenda_links/power_points_etc/04_ConcurrentSessionB/36_Rm11_Schloss.pdf
ExtendedAbstract:
http://water.usgs.gov/wicp/acwi/monitoring/conference/2004/conference_agenda_links/title_pages/block_b/attach_36.pdf

Reports:
R. Craycraft and J. Schloss. 2004. Lakes Lay Monitoring Program Annual Report for 2003. A series of more than 50 individual lake reports distributed to lake associations, towns, conservation and planning commissions, and state agencies.

J. Schloss and R. Craycraft and 2004. Lake Chocorua Watershed Road Drainage Best Management Practice Evaluation and Wetlands Study. Final Report for Phase 3 of the NH Department of Environmental Services Nonpoint Source Pollution Program. UNH Cooperative Extension, UNH Center for Freshwater Biology, Carrol County Consrvation District, Lake Chocorua Association.

J Schloss 2004 Squam Lakes Diagnostic Watershed Study. UNH Center for Freshwater Biology Project Report.

Presentations by Jeff Schloss covering all or parts of research study:

| Name of Organization | Focus of Meeting | Date and Location | Topic |
|---|---|---|---|
| National Water Quality Monitoring Council | Water Quality Monitoring Conference | May 2004 Chattanooga, TN | Invited Presentation: “Participatory Watershed Monitoring: Linking Citizens to Scientists Through the NH Lakes Lay Monitoring Program, |
| | | | |
| New England Chapter-North American Lake Management Society/ | New England Lakes Management Conference | June 2004 Kingston, RI | Conducted Following the Flow NPS Assessment Workshop |
| | | | |
| New Hampshire Lakes Association | Annual Lakes Congress | June 2004 Concord, NH | Invited Presentation: “Lake Monitoring: Data to Action”. |
| | | | |
| New Hampshire Lake lay Monitoring Program | 25 Year Celebration and Workshop | July 2004 | “Over 25 Years of Participatory Monitoring: What we know now” |
| | | | |
| Plymouth State College and NH Department of Environmental Services | Annual Lakes Region Water Conference | December 2004 | Invited Speaker: “Over 25 of Monitoring the Squam lakes Watershed: What have |

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|---|---|---|---|
| | | | we learned?” |
| | | | |
| USDA CSREES 406 Water Quality Program | Annual Extension Water Quality Program Conference | February 2005 San Diego, CA | Invited Volunteer Monitoring Workshop Presenter: “Empowering Local Citizens for Watershed Protection” |
| | | | |

# Water Quality and the Landscape: Long-term monitoring of rapidly developing suburban watersheds

## Basic Information

| | |
|---|---|
| **Title:** | Water Quality and the Landscape: Long-term monitoring of rapidly developing suburban watersheds |
| **Project Number:** | 2003NH21B |
| **Start Date:** | 3/1/2004 |
| **End Date:** | 2/28/2005 |
| **Funding Source:** | 104B |
| **Congressional District:** | |
| **Research Category:** | Water Quality |
| **Focus Category:** | Non Point Pollution, Surface Water, Nutrients |
| **Descriptors:** | |
| **Principal Investigators:** | William H. McDowell |

## Publication

# Water Quality and the Landscape: Long-term monitoring of rapidly developing suburban watersheds

## Statement of Critical Regional or State Water Problem

New Hampshire's surface waters are a very valuable resource, contributing to the state's economic base through recreation (fishing, boating, and swimming), tourism and real estate values. Many rivers and lakes also serve as local water supplies. New Hampshire currently leads all New England states in the rate of development and redevelopment (2000 Census). The long-term impacts of population growth and the associated changes in land use to New Hampshire's surface waters are uncertain. Of particular concern are the impacts of non-point source pollution to the state's surface waters (e.g. septic, urban run off, road salt application, deforestation and wetland conversion). Long-term datasets that include year-to-year variability in precipitation, weather patterns and other factors will allow adequate documentation of the cumulative effects of land use change and quantification of the effectiveness of watershed management programs.

## Statement of Results or Benefits

The proposed project will provide detailed, high-quality, long-term datasets which will allow for a better understanding of the impacts of land use change and development on surface water quality. This could occur through the development, testing and refinement of predictive models, accurately assessing the impacts of watershed management practices, and potentially early warning of dramatic changes to surface water quality in the region resulting from rapid development.

## Objectives of the Project

This project allows for the continued collection of long-term water quality data in New Hampshire. It will use UNH staff, students and volunteers from local communities to collect samples from the College Brook watershed (Durham, NH), the Lamprey River Watershed, the Oyster River watershed, and the Ossipee Watershed.

The College Brook watershed, which is dominated by the University of New Hampshire, receives a variety of non-point pollution from several different land uses. Suspended sediments, pH, conductivity, biological oxygen demand (BOD) and nutrient concentrations ($Cl^-$, $SO_4^{-2}$, $Na^+$, $K^+$, $Mg^{+2}$, $Ca^{+2}$, $NO_3$, $NH_4$, $PO_4$, DOC, TDN) will be measured to assess water quality. Samples from 7 sites will be collected monthly throughout the year. Sampling of College Brook began in 1991. Sample collection will be done by UNH staff and/or students, with analyses done by UNH staff at the Water Quality Analysis Lab (WQAL) of the WRRC.

The Lamprey River will be sampled weekly throughout the year and during major storm events. Samples will be measured for suspended sediments, pH, conductivity, and nutrient concentrations ($Cl^-$, $SO_4^{-2}$, $Na^+$, $K^+$, $Mg^{+2}$, $Ca^{+2}$, $NO_3$, $NH_4$, $PO_4$, DOC, TDN). Sampling and analyses will be done by UNH staff. Weekly sampling of the Lamprey River began in 1999.

Several locations along the Oyster River (the drinking water supply for Durham) will be sampled by volunteers from the Oyster River Monitoring Group. Samples will be collected monthly from

June to October.  Sample analysis ($Cl^-$, $SO_4^{-2}$, $Na^+$, $K^+$, $Mg^{+2}$, $Ca^{+2}$, $NO_3$, $NO_2$, $NH_4$, $PO_4$) will be done at the Water Quality Analysis Lab (WQAL) at UNH on a cost per sample basis.  Additional analyses (DOC and TDN) will be done by the WQAL as part of the cost share for this project. Staff of the WRRC will also aid in data interpretation and analysis.

Samples will also be collected monthly (when surface streams are present) at Moore Fields, a 42 acre agricultural property near the Oyster River.  Moore Fields is owned by UNH and is used for soil science courses and research as well as growing feed for the university's livestock. Sampling began here when a land use change to soccer fields was proposed.  This proposal has since been withdrawn.  Samples will be collected and analyzed by UNH staff at the WQAL.

Streams within the Ossipee watershed of New Hampshire will be sampled by volunteers of the Green Mountain Conservation Group.  Samples will be collected every 2 weeks from May to November.  Water chemistry ($Cl^-$, $SO_4^{-2}$, $Na^+$, $K^+$, $Mg^{+2}$, $Ca^{+2}$, $NO_3$, $NH_4$, $PO_4$, DOC, TDN) will be measured by the WQAL at a per sample cost.  WRRC staff will assist in data interpretation.

**Principal Findings and Significance**

College Brook

Samples have been collected from College Brook as planned during 2003-2004.  However, data analysis was not complete at the time this report was due.  Previous work on College Brook in the early 1990's (McDowell unpublished) shows that the UNH campus had a severe impact on water quality and was negatively affecting stream biota and the integrity of downstream ecosystems. By any yardstick, campus operations could not be considered sustainable. There was clear evidence that the UNH incinerator was causing excessive organic matter loading, resulting in high biochemical oxygen demand (BOD) and low dissolved oxygen in stream water. Other practices, such as washing of waste art materials (slip, poster paint, etc.) into street drains near the Service Building, were also impacting College Brook.

Comparisons between data collected in 1991 and 2000-present have indicated that overall water quality has improved in College Brook with the closing of the UNH incinerator and greater ecological awareness on campus. Recent water quality analysis (2000-2003) indicates that the drought of 2001 has a significant effect on water quality. It was the third driest year for the state of New Hampshire for 1895-2003 and water chemistry indicated that the health of the stream was at its lowest for some parameters (TDN, nitrate, ammonium, BOD, etc…). Construction on campus has also likely had an impact on stream quality and in 2001 construction occurred in close proximity to the stream in the watershed. Construction accidents (i.e. - water main break) caused large runoff discharges into College Brook and likely had effects on the stream, which further complicates the picture. Further analysis of the data and continued monitoring of College Brook is scheduled to continue. The College Brook web site can be viewed at http://www.wrrc.unh.edu/current_research/collegebrook/collegebrookhome.htm.

Weekly Lamprey Sampling and the Lamprey River Hydrologic Observatory

We have continued to sample the Lamprey River at the USGS gaging station in Durham, NH (referred to as "Lamprey") on a weekly basis for DOC, DIC, DON, $NO_3$-N, $NH_4$-N, $PO_4$-P, major cations (Na, Ca, Mg, K), major anions (Cl, $SO_4$), $SiO_2$, TSS, Particulate C, Particulate N, pH, DO, temperature and conductivity. We have added two other stations in the watershed to our weekly sampling regime where we measure DOC, DON, $NO_3$-N, $NH_4$-N, $PO_4$-P, pH, DO, temperature and conductivity. One station is located on the North River at the USGS gaging station (L3) and one station is located on a small tributary to the Lamprey River in Lee, NH (L1). We have installed a distance meter at L1 to serve as a stream gage and are now developing a rating curve for this site. We continue to collect precipitation at Thompson Farm (UNH property located in Durham, NH) and work with NOAA in an attempt to link to precipitation chemistry to airmass chemistry. Results of stream chemistry to date show an increase in peak $NO_3$-N concentration over time in the Lamprey and a link between population density and $NO_3$-N concentration and export. Dissolved organic matter (DOM) in the Lamprey watershed is related to wetland cover, but there are no clear trends in DOM over time nor is there a consistent relationship between DOM and stream discharge. Results of precipitation monitoring show that DOC in precipitation is related to atmospheric alkyl-nitrates and DON in precipitation is related to atmospheric black carbon. Potassium in precipitation is related to several atmospheric volatile organic carbons (VOCs).

Other projects in the Lamprey watershed include linking groundwater chemistry to landscape characteristics and documenting changes in nitrogen concentrations in riparian zones. We sampled numerous homeowner wells in 15 sub-basins of the Lamprey to link average sub-basin water quality (DOC, DON, $NO_3$-N, $NH_4$-N, $PO_4$-N and As) to sub-basin landscape characteristics. Thus far we found a positive relationship between average sub-basin $NO_3$-N concentration and sub-basin population density and that average sub-basin groundwater $NO_3$-N is higher than $NO_3$-N in the stream water. Arsenic concentrations in individual wells vary in response to bedrock type. In riparian zones, there is a large reduction in $NO_3$-N (approximately 4.5 mg $NO_3$-N upslope to 0.2 mg/L $NO_3$-N near the stream) and an increase in $NH_4$-N (approximately 0.02 mg $NH_4$-N upslope to 0.2 mg/L $NH_4$-N near the stream) over a small distance (approximately 10 m).

Ossipee River watershed sampling

# Ossipee Watershed
# Water Quality Monitoring Program
# 2004 Season

*Prepared by:*

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**Green Mountain Conservation Group**

**Ossipee Watershed**
**2004 Water Quality Monitoring Program**
**Table of Contents**

**Acknowledgements**

Green Mountain Conservation Group would like to acknowledge a number of individuals and organizations who have been instrumental in the creation and continuation of the Ossipee Watershed Water Quality Monitoring Program. With the knowledge, advice and continual support of so many, this program has been enormously successful in its first three years. More importantly, it is through the commitments and efforts of so many that collectively we are able to ensure the protection of the Ossipee Watershed and its natural resources for future generations. GMCG would like to thank the following:

**New Hampshire Department of Environmental Services**: Eric Williams, Jillian Jones, Paul Currier, and Andrew Cornwell

**Saco River Corridor Commission**

**Effingham, Freedom, Madison, Ossipee, Sandwich and Tamworth Selectmen and Conservation Commissions**

**UNH Cooperative Extension**: Bob Craycraft

**UNH Water Resources Research Lab**: Bill McDowell, Michelle Daley, Jeff Merriam

**New Hampshire Charitable Foundation**

**New England Grassroots Environmental Fund**

**Volunteers**: Jim Clemons, Roger Thurrell, Lyn Slanetz, Rose de Mars, Claes Thelemarck, The Community School, Ned Hatfield, Fred Van Cor, Carolyn Buskirk, Joel Rhymer, Jennifer Hocking Wiley, Lyn Slanetz, Chele Miller, Katie Remmetter, Tim White, Warren Walker, Mary Beth McAllister, Cindy Sawyer, Susan Fine, Anne Filson, and Sam Therrien

**Camp Calumet:** Don Johnson, Paul Lindhal

**Camp Cody:** Alasdayr

**Camp Huckins:** Jody Skelton

**Camp Marist:** Dayna Rousseau

**Camp Robin Hood:** Chuck Illig

**Danforth Bay Campground:** Craig Niiler

**Agnes Drumm**

**GMCG Board members**

**Eve and Bill Klotz and Farm by the River**

## Water Quality Monitoring Program

### Executive Summary

In 2002, Green Mountain Conservation Group began testing the waters of the Ossipee Watershed by selecting ten sites in cooperation with the towns' conservation commissions. Impact of land use practices were heavily considered in selecting the site. All sections were further validated by natural resource experts from UNH. In 2002, fifteen volunteers were responsible for testing the ten sites.

2003 marked the second year of water quality monitoring for GMCG and a year of growth and expansion for the program. Five new sites were selected, and over twenty-five volunteers were recruited for testing. GMCG created and implemented an informal macroinvertebrate sampling event to further augment water quality testing in the Ossipee Watershed. In addition, GMCG and Ossipee Lake Alliance (OLA) launched the Ossipee Lake Protection Program (OLPP). As the first comprehensive program that encompassed all of Ossipee Lake, the OLPP served to examine three parts of the health of the lake and its surrounding area. The thirteen tributaries were tested four times throughout the summer. In partnership with NH Department of Environmental Services, the deepest spot of each of the lake's five water bodies (Ossipee Lake, Berry Bay, Broad Bay, Leavitt Bay, and Danforth Pond) were test once a month June through August. Finally, lake recreation was examined and quantified through the Lake Environmental Assessment Plan (LEAP).

This was the largest and most comprehensive program ever initiated on Ossipee Lake. The major successes of this project were:

- Collected a baseline of data for both the tributaries and deep water locations.
- United the six children's camps in the area and engaged them in water quality monitoring.
- Discovered a variable milfoil infestation in Philips Brook.
- Counted 337 boats at Ossipee Lake Natural Area on July 4.

2004 was the third year of sampling for the RIVERS program. In cooperation with the town conservation commissions and UNH experts, some sites were added or removed and a total of 15 sites remain throughout the six towns. Also in 2004, GMCG and OLA split the duties of the OLPP program. While GMCG took on the tributary testing as part of their Water Quality Monitoring Program, OLA continued to test the deep water spots on the lake, monitor milfoil on the lake, and monitor recreation on the lake. The tributary testing was renamed the Ossipee Lake Tributaries (OLT) program.

A comprehensive assessment of the health of the water can only be achieved by observing water quality trends over a period of many years. As this was only the second year for this water quality monitoring program, and there is sparse historical data for the area, firm conclusions cannot yet be drawn. However, an important set of baseline data have been established. Continuing water sampling in the Ossipee Watershed over the long term will allow for a more comprehensive understanding of water quality trends over time. Thus, GMCG is working toward the long term sustainability of this program into the future.

# 1. Introduction

## 1.1 Green Mountain Conservation Group

The Green Mountain Conservation Group (GMCG) is a community-based, charitable organization dedicated to the protection and conservation of natural resources in the Ossipee Watershed in central Carroll County including the towns of Effingham, Freedom, Madison, Ossipee, Sandwich and Tamworth.
Founded in 1997, GMCG's mission is to coordinate and carry out environmental education, research, natural resource advocacy and voluntary land protection. GMCG is a networking and referral resource for area residents concerned about land use issues in their communities. It encourages individual and small group activism based on common sense and non-confrontational approaches to resolving problems. The guiding principle in its public education and activism is to present objective information in a neutral format with the belief that informed citizens will make good judgments about their area's natural resources.

During the summer of 2000 GMCG responded to growing concerns about Ossipee Lake by hosting a forum that featured a panel discussion by state experts and representatives of the New Hampshire Audubon Society and The Nature Conservancy. One of the conclusions drawn from the forum was that resolution of lake issues was being hampered by the lack of an organization representing the interests of a majority of the lake's stakeholders.
In 2000, GMCG worked with the University of New Hampshire Cooperative Extension and the Society for the Protection of the New Hampshire Forests to produce a series of Natural Resource Inventory (NRI) maps of each town in the Ossipee Watershed. The NRI maps include information on hydrology, soils, town conservation land, unfragmented land, public water supplies, known and potential contamination sites as well as co-occurrences of important resources. Copies of these maps were provided to each town in the watershed and are displayed at the town halls for public use.

A Water Quality Monitoring (WQM) program grew out of the NRI mapping project as a way to further study our natural resources and as a way to work with the broader community to plan for growth while protecting the environment. Since water does not recognize political boundaries, GMCG began working collaboratively on the WQM program with Saco River Corridor Commission (SRCC), an organization located in Maine.

Saco River Corridor Commission began its WQM program in 2001 and monitors 27 sites in twenty towns along the Saco River. GMCG modeled its Water Quality Program after SRCC. Beginning in 2002, GMCG monitored ten sites across the six towns in the Ossipee Watershed, a subwatershed of the Saco Watershed. In 2003, GMCG increased the number of sites it tests from ten to fifteen. Together GMCG and SRCC monitor the quality of the water across two states, 26 towns and one watershed in the RIVERS (Regional Interstate Volunteers for the Ecosystems and Rivers of Saco) Program. These WQM programs enable the study of the health of the entire watershed and track changes over time and educate the public.

Also in 2003, GMCG expanded the WQM program to include a biological monitoring component. With help from local "Bug Experts," GMCG created and initiated a macroinvertebrate sampling event. Macroinvertebrates are tiny aquatic animals that lack a back bone but are visible to the naked eye. Often they can serve as unique water quality indicators. As funding becomes more readily available, GMCG would like to create a more comprehensive macroinvertebrate program.

### 1.2 Ossipee Watershed

The Ossipee Watershed (Figure 1) is part of the Saco River Basin, which is an area of about 379 square miles located in Carroll and Grafton Counties, New Hampshire. It contains 82 lakes and ponds that cover about 9,400 acres in thirteen towns. At its widest point the watershed extends approximately 29 miles east and west and twenty-three miles north and south. Water from the Ossipee Watershed flows into the Saco River and through Maine to the Atlantic Ocean. The watershed's drainage area 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.

The Ossipee Watershed contains New Hampshire's largest stratified-drift aquifer. This type of aquifer is unique because it recharges more rapidly than any other. As a result of this quick recharge, stratified drift aquifers allow pollution and contamination to be carried more rapidly into the underground water supply. Therefore, conservation of the recharge lands is vital to the protection of drinking water supplies in New Hampshire and Maine.

The Ossipee Watershed is one of New Hampshire's most rural areas but is under developmental pressure. A study by the Office of State Planning, co-authored by The Society for the Protection of New Hampshire Forests and The Nature Conservancy, predicts that the population of Carroll County will increase 50% by 2020.

### 1.3 Ossipee Lake

Ossipee Lake is the center of the Ossipee Watershed. Comprised of over 4000 acres of water, the lake consists of a main body of water known as Ossipee Lake (or the Main Lake) and five large connecting bodies of water: Berry Bay, Broad Bay, Leavitt Bay, Danforth Pond and Huckins Pond (Figure 2).

As one of New Hampshire's largest lakes, it is a major economic contributor to the towns of Freedom and Ossipee. A primary destination for vacationers, boaters and wildlife enthusiasts, its appeal has placed it under developmental pressure and environmental stress. Particularly vulnerable are its unique ecological assets, including two globally rare pondshore communities, a pine barrens, a kettlehole quaking bog and the largest stratified drift aquifer in NH.

In 1995 the Environmental Protection Agency listed Ossipee Lake as one of the top five areas in New Hampshire to protect. However, there still has been no public education program on the importance of the lake and its environmental assets and the lake does not have a management or stewardship plan.

### 1.4 Water Quality Monitoring

Increased population, rapid residential and commercial development and expanded recreational use have put pressure and stress on Ossipee Lake and its rivers, making it advisable to implement a comprehensive Water Quality Monitoring (WQM) program. Routine water sampling and testing are essential for early detection of changes in water quality so that problems can be traced to their source before the lake becomes aversely affected.

Water quality data provides an understanding of how land use and underlying geological controls affect the water in our lakes, rives and streams. Because we do not have sufficient historical data or long term background information to review, it is difficult to determine if current land use practices are negatively affecting water quality.  Compiling water quality data will allow us to determine the effectiveness or harmfulness of specific land use practices in maintaining good water quality.  These determinations can further guide us in making informed decisions to protect the watershed's natural resources.  Minimally impaired reference sites might serve as a standard by which data from other sites are compared to determine the level of impairment.

Water quality data commonly reflect land-use variations but can also be associated with short-term climatic variations, such as temperature and precipitation. For example, during dry periods pollutants accumulate in the uplands and are ultimately flushed into the receiving waters during storm events. However, some short-term data (immediately after a storm event) can be quite revealing.

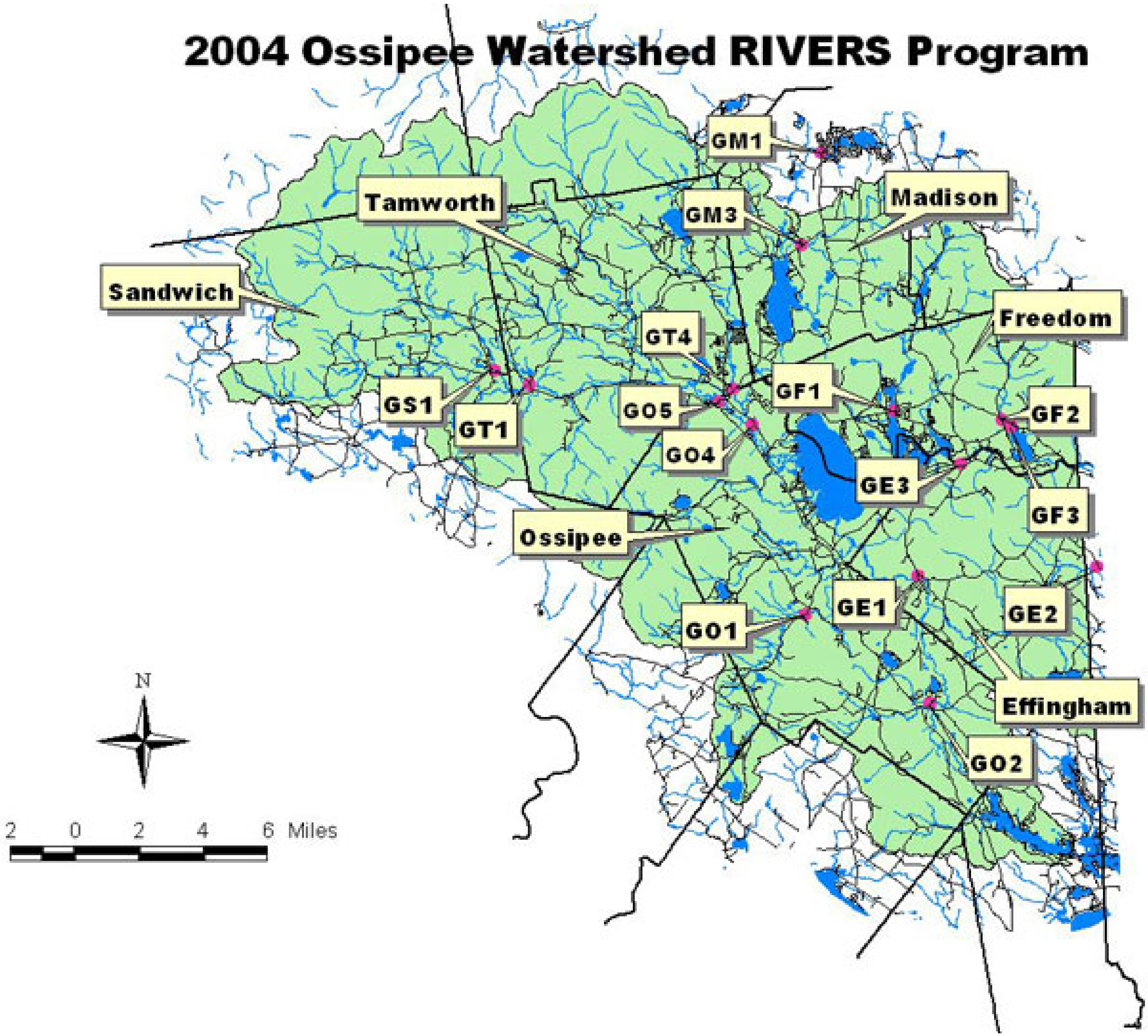


**Figure 1. 2004 Ossipee Watershed Regional Interstate Volunteers for the Ecosystems and River of the Saco (RIVERS) Program test sites**

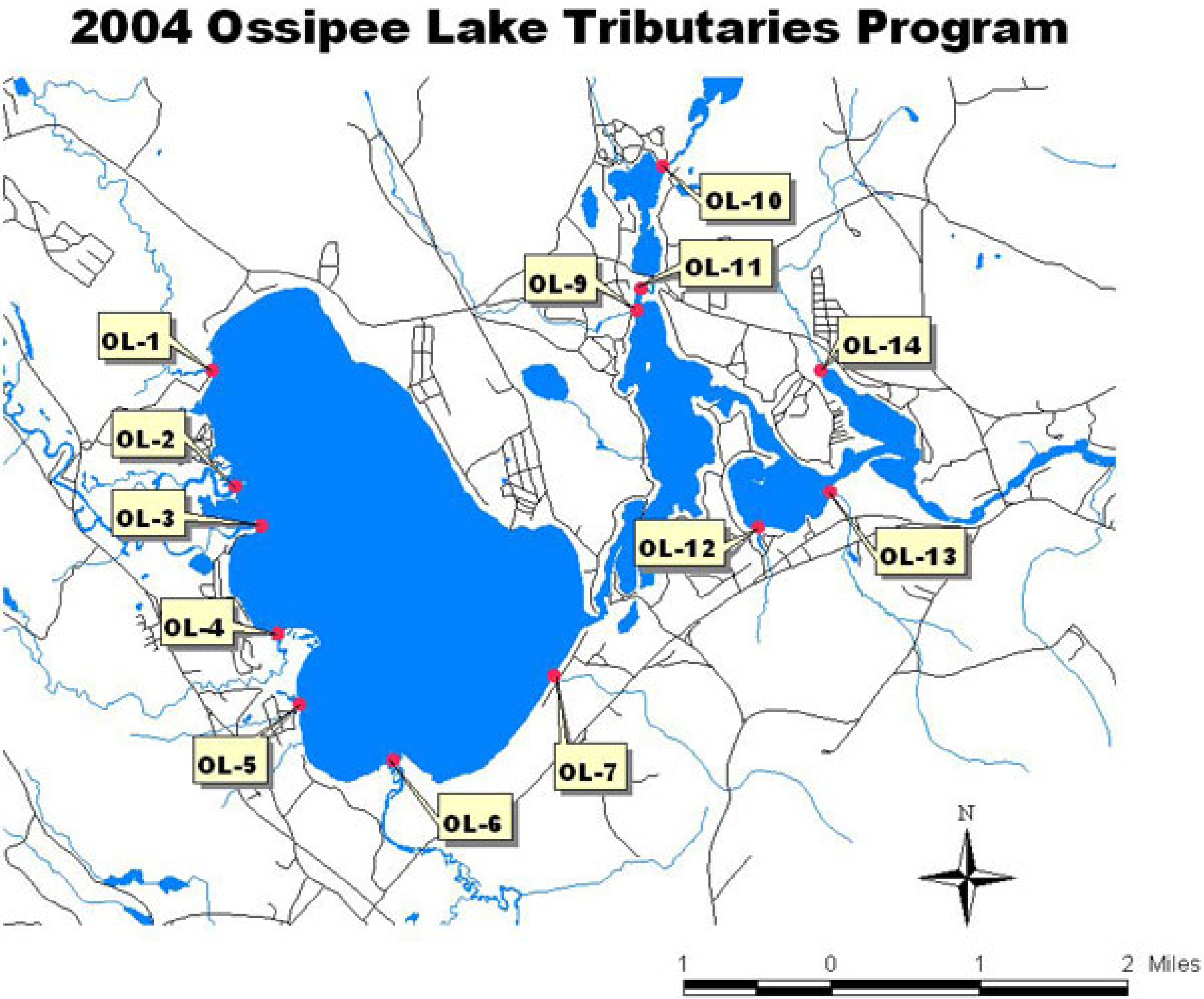


**Figure 2. 2004 Ossipee Lake Tributaries (OLT) program test sites**

## 2.0 Methods

### 2.1.1 RIVERS Site descriptions

Testing occurred at each of the fifteen sites through out the Ossipee Watershed (Figure 1). The following sites were sampled during the 2003 season (note: GMCG is grateful for the volunteers who helped write many of these descriptions).

**GE-1 Pine River, Elm Street, Effingham**

Pine River is a meandering river passing through glacial deposits. Bottom varies from sand to gravel to silt. At the test site the bottom appears to be mostly fine sand to silty mud. The water tends to be the color of strong tea most of the time, due to decaying vegetable matter. Long, streaming underwater grasses grow in the vicinity of the bridge, as well as water plants with small, oval leaves. Surrounding forest is mixed pine and hardwood, predominantly pine, with a lot of pitch pine and red pine as well as white. The terrain is quite flat along the river itself, though one end of the range that contains Green Mountain rises within an eighth of a mile of the river at the bridge. Fresh trash does not appear very frequently, but one can see old tires, a decaying television set, cans, bottles and scraps of packaging. The Pine River flows from the southern boundary of the Ossipee Watershed, through the Pine River State Forest, through several wetlands including Heath Pond Bog and into Ossipee Lake near Ossipee Lake Natural Area. GE-1 is located where the Pine River flows under Elm Street. The site is in the downstream shadow of a modern bridge with substantial concrete abutments. The river is about twenty feet wide. The current is steady enough to bend the subsurface weeds, but there are no surface ripples. Both up and downstream from the site, the river is open to the sky and mostly pines set back from both banks. This site was chosen because it is located downstream of two gravel pits as well as a designated drinking water zone. This site was also easily accessible.

**GE-2 South River, Plantation Road, Parsonsfield, Maine**

The South River flows from Province Lake and Lords Lake, through several wetlands and into Maine where it joins the Ossipee River. GE-2 is located just below the outlet of Lords Lake on Plantation Road. The testing site is immediately upstream from an aging concrete and steel bridge; the abutments are decaying and have clearly dropped cement into the river but some twenty feet below the actual test site. At the site, the river is about twenty feet wide, perhaps four to five feet deep toward the middle of the stream. The current is strong; there are several small rapids above and below the site. Much of the site gets direct sunlight, but the surrounding trees, mostly deciduous, overhang the river somewhat. There is some evidence of fishing activity. This site was chosen because it is located downstream of the town's transfer station and capped landfill. Potential road run-off is a concern as well. The site was also easily accessible.

**GE-3 Ossipee River, Effingham Falls - New site in 2003**

The Ossipee River drains Ossipee Lake. GE-3 is located just below the Ossipee Lake dam. The flow is rapid, and the water level is largely variable due to dam height and precipitation. Downstream the river turns to a slower moving meandering stream as the channel widens. The bottom is mostly gravel with sparse boulders and cobble. The stream is approximately 15-20 feet wide. Red maple, white pine, and bushes dominate the landscape around the site with a sandy top soil and a fine sand soil underneath. There are often fishermen here as this is a popular fishing site. People fish for rainbow trout just below the dam and rainbow trout at the site.

Because this is such a popular fishing site there is also unfortunately a lot of trash here. The site is accessed via trail where the tester parks at the Ossipee Lake Dam. The site is located at the end of the path downstream of the dam on the northern side of the stream. This site was chosen to determine the quality of water as it leaves Ossipee Lake.

**GF-1 Danforth Brook, Ossipee Lake Road, Freedom**
GF-1 is located where Danforth Brook flows under Ossipee Lake Road. It is a slow moving stream from Danforth Bay to Broad Bay. It is about 20 feet wide by 3-4 feet deep. Testing site is on the exit of Danforth about 150 feet. There is some outboard boat traffic entering Danforth from Broad Bay (1/day), but mostly canoe and kayak (2-3/day). Agitation exists in Danforth due to boat motors and water skiing. Site is surrounded by dense riparian vegetation. Some of this vegetation was cut early during the sampling season in 2003 and left exposed gravel. This test site was chosen to determine the impact of road run-off. Additional considerations were its accessibility and the fact that a previous study had been conducted.

**GF-2 Cold River, Maple Street Bridge, Freedom**
GF-2 is located in downtown Freedom Village where the Cold Brook flows under Maple Street. The sampling site is about 30 feet upstream from the dam that holds the Mill Pond. The pond is about 150 ft long, 20-25 feet across, with an average depth less than 6 feet. The actual sample site is located within 10 feet of a bridge that carries much of the auto and foot traffic within the village of Freedom. The pond is quite still during most of the summer as water does not flow over the top of the dam, just through a particular spillway. There is little human interaction with the water in the pond except when it is stocked for the kids fishing derby and the plastic duck race. This test site was chosen to determine the impact of road run-off and because the Brook runs through the village of Freedom and is easily accessible. An additional consideration was that the Freedom Conservation Commission has data on this site that had been gathered over a 20 year period.

**GF-3 Cold River, Inlet to Loon Lake, Freedom - New Site in 2003**
Cold Brook flows through Freedom Village and over a dam, just below GF-2, and into Loon Lake. GF-3 is several hundred yards upstream of the Cold Brook inlet to Loon Lake. The sampling site substrate consists mostly of gravel with minimal aquatic vegetation. A swiftly moving riffle is directly upstream, but the flow is slower at the site. The stream is approximately 5-6 feet wide. The site is surrounded by a mixed hardwood forest of ash, basswood, red maple, white oak, hemlock, and beech with a large amount of large white pines on the eastern side of the river. The herbaceous layer consists mostly of asters, golden rod, and ferns. There is a think top soil with plenty on leaf litter. The gravelly beach where sampling occurs is lined by grass. There are few obvious human influences at the site. There is a farm house upstream and a cemetery directly next to the site. Various wildlife inhabits the area including beaver and otter. The site is accessed via Maple Road where the tester parks at the cemetery. The site is just over the bank behind the cemetery. There is a path down the bank that goes to the right and the site is a little further to the right from this path at a gravelly beach on the stream situated between two white pines just off shore. This site was chosen because of concern over potential malfunctioning septic systems in Freedom Village.

**GM-1 Banfield Brook, Route 113, Madison**
While not in the Ossipee Watershed, this site is in the greater Saco Watershed. The brook comes down from Pea Porridge Pond in Madison and runs under Route 113. There are some houses

along the brook's upper reaches in the Eidelweiss development. Banfield is rocky, with generally clear water. It stumbles down over a low concrete ledge ten feet before our testing site. In the summer there are water striders on the surface of the brook. This test site was chosen to determine the impact of road run-off, erosion and timber cutting to Pea Porridge Ponds. The stream also flows through the Eidelweiss development, located upstream of test site.

**GM-2 Pequawket Brook, Route 113, Madison - New site in 2003**
While not in the Ossipee Watershed, this site is in the greater Saco Watershed. GM-2 is off 113. It flows from a wetland at the edge of the watershed. There is a steep incline down to stream. The area surrounding the site is moderately wooded with deciduous trees. A large gravel operation near the stream is buffered only by twenty feet of forest. An abandon road leads up to stream embankment. Various wildlife such as beaver and river otter has been noted at the site occasionally. There is some erosion along banks and some dead fall of trees. Depth of stream varies with amount of rainfall. Stream has some aquatic growth and rocky/sandy in areas. This site was chosen because it's down stream of a large gravel operation. *This site was discontinued in 2004 because it did not appear that the gravel operation had any impact on the water and the site was outside of the Ossipee Watershed.*

**GM-3 Forrest Brook, Silver Lake Hardware, Rt. 113, Madison - New Site in 2004**
Forrest Brook, at the test site, has a smooth, slow-moving surface. The stream is about 12 feet wide, and the clear water carries very little amounts of floating matter: some bubbles/foam, leaves, bits of tree bark, and water striders. At the test site, the water has varied during the summer from 12 inches to less than 6 inches deep, depending on area rainfall. Both upstream and downstream are areas of shallower water where the stream burbles actively over rocks. The stream bottom consists of sand, gravel and cobble. Additionally, on the stream bottom lie pieces of tree detritus from overhanging trees and some leaves hinting of the nearness of autumn's arrival. The site is on the west side of the stream about twenty-five meters downstream from the culvert that carries Route 113 over the stream, and some eight feet down the road. (The culvert is the usual half-circle of corrugated, somewhat rusted, metal that highway departments install.) The site is reached by an undistinguished path from the parking lot of the Silver Lake Home Center down to the stream some ten meters downstream from the test site, and then along the stream, the detour necessitated by poison ivy just upslope from the test site. At the sample site, the stream flows south to north. To the west, the land rises about five feet up a gentle slope to its floodplain (on which Silver Lake Home Center is built); to the east, there is a steep bank some ten feet high up to rolling land where private residences are built (on lots of perhaps an acre each) along Forest Pines Road. The stream at this point gives no sign that it has descended on one branch down a mountainside through a scenic cascades area, and on another branch from a bog and past a cemetery. On the steep east shore, roots from two large pines and several smaller red maples grow over stream edge boulders and extend into the water which actively undercuts the stream bank trees. The mostly deciduous canopy of red maple, beech, and pines of several varieties shade the stream quite thoroughly at the test site. The understory trees include spruce, fir, hemlock, ash, witch hazel, and scrub oak. On the sandy banks grow mosses, ferns, asters and other wildflowers, poison ivy, Canada mayflowers, and other herbaceous plants. Only two pieces of litter were anywhere in sight at the time of writing this description. Eight meters downstream from the site, on the east side, a large water/sewer concrete construction rears up ten feet above the stream. Finally, in the late 1950s or early 1960s, when a late spring snowstorm melted rapidly, this section of Forrest Brook rose six feet above the road in this low, floodplain

area. This site was chosen as it is located in the center of Madison within the Ossipee Watershed and is located near two drinking water protection zones.

**GO-1 Beech River, Tuftonboro Road, Ossipee**

The Beech River flows from Melvin Pond and Garland Pond in the southern Ossipee Mountains, along the Tuftonboro Road, and into the Pine River. The sampling location is where the river flows underneath the Tuftonboro Road. The stream is approximately 15 feet wide and 1-2 feet deep with a rocky substrate. The stream has a medium flow at the site and is clear with some foam/bubbles on top. There is a large beaver dam upstream of the bridge. Deciduous trees surround the site, including maple, oak, and ash with some hemlock and pine. Towards the end of the summer and into fall there is a thick shrub layer of golden rod, Queen Anne's lace, and aster. This site was chosen because of accessibility and because it is located upstream of a mill, dump and old tannery.

**GO-2 Frenchman Brook, White Pond Road, Ossipee**

This site is located about a ½ mile down White Pond Road just off Granite Road in the section of Ossipee known as Granite. White Pond Rd is a dirt road, maintained by the town. The site is approximately 40 feet upstream of where the stream crosses under White Pond Rd. There is a small pull-off below the brook and across the road is a barely discernible path that leads to a very small clearing on the bank where we do our testing. It is a quiet, apparently rarely visited site, except perhaps by deer and raccoon. At the site, the brook is narrow, about 5 feet across and curves both above and below the test area. The brook runs moderately fast with ripples in the center, and generally calm on the sides. The center of the brook is approximately 1 foot deep. There is a smaller brook that joins Frenchman's brook directly across from the test site. The bottom is silty with a deposit of dark colored pebbles in mid-stream. There are a couple of large dead branches in the brook downstream from the testing site. There is a moderate amount of organic debris (pine needles, leaves, ect.) near the edges of the brook; however, there are no aquatic plants. In general, the land from which we test is stable, although one week when we tested during a heavy rain event we noted a lot of disturbance when we stepped close to the edge of the brook. There is a large hemlock sheltering the test site. Other plants in the area include several types of fern (Royal, Sensitive, and Wood fern among them). The surrounding woods are mostly alder, mixed hardwood with a lot of maple samplings and pine. The topography surrounding the brook is mostly flat. Frenchman's Brook flows from Polly's Crossing, through a gravel pit, and into White Pond. This site also seems to be a common dumping station as a few bags of trash accumulated at the site and even a television and tool box in the middle of the stream. This site was chosen because Frenchman Brook runs under Route 16 just upstream of the test site, and there is the potential for road run-off impact. In addition, dumping has previously occurred upstream and at this site.

**GO-3 Frenchman Brook, Polly's Crossing, Ossipee - New site in 2003**

GO-3 is located in Polly's Crossing immediately downstream of a wetland. Sampling occurred where the stream flowed out of a culvert under a Class VI road. An upland forest surrounds the site. The stream is narrow and experiences intermittent flow during the drier months of the summer. This site was chosen because of concern over high nutrient levels seen at GO-2 in 2002 that suggest a disturbance is occurring upstream. This site will help pinpoint the source of the disturbance. *This site was discontinued because intermittent low flow of the site prevents regular sampling.*

**GO-4 Bearcamp River, UNH property, Newman Drew Rd, West Ossipee – New site in 2004**
GO-4 is located on UNH property off of Newman Drew Rd. The site is accessed, however, from the Whit's End Campground land. Upstream from the site, the river makes a sharp right bend. The site is located on a small beach after this bend. There are often deer tracks along this beech, along with occasional moose and beaver tracks. The bottom is mostly sand with some gravel at the site with some large fallen trees in the water. The water is moderately fast moving, moving more swiftly than other Bearcamp River sites, and is about 0.5 – 2 feet deep, depending on rain fall and positioning in river due to an uneven and often changing bottom. Pine is the dominant tree here, along with some silver maples. This site was chosen to bracket development in the Ossipee area and because it was located on UNH property.

**GO-5 Bearcamp River, Whittier Bridge, West Ossipee – New Site in 2004**
GO-5 is located on the Bearcamp River in West Ossipee. The Bearcamp River flows from the Sandwich Range into Bearcamp Pond. Then it drains Bearcamp Pond and flows through along Rt. 25 in Tamworth until it flows into Ossipee Lake in Ossipee. The site is just below the Whittier Covered Bridge on Whittier Bridge Rd. GO-5 is approximately 2.5—3 river miles upstream from GO-4. Just downstream the river makes a horseshoe bend pointing north. The river is moderately fast moving here, but slow enough so that this is a popular swimming hole in the summer. The bottom is sandy and there is about a 100 foot wide beach on the north side of the stream where we test, another reason why this is such a popular swimming place. The river is about 30-35 feet wide and towards the middle the river is about 3-4 feet deep, depending on rainfall. There are no aquatic plants due to the sandy nature of the bottom. The surrounding forest is a mixed deciduous forest with some pine. This site was chosen to bracket development in the Ossipee area and because it is easily accessed.

**GS-1 Cold River, Route 113, Sandwich.**
GS-1 is located where the Cold River passes under Route 113 in Sandwich near the Tamworth/Sandwich town line. Cold River drains several streams that flow out of the White Mountain National Forest and the Sandwich Range Wilderness including Flat Mountain Pond. The river is about ten meters wide. GS-1 is downstream from a riffle and has a rocky substrate. The river stands up for its name as this site is usually the coldest in the WQM program. There is dense riparian vegetation on one side of the river and an upland deciduous forest on the other. This test site was chosen because of concerns about the gravel pit located upstream of the test site and because the river is situated upstream of Tamworth's drinking water wellhead protection zone.

**GT-1 Bearcamp River, Route 113, Tamworth**
The site is located under the bridge where Rout 113 crosses the Bearcamp in South Tamworth near the Community School. The Bearcamp drains several streams that flow from Mount Israel in Sandwich. At the sampling site, the Bearcamp is a straight stretch of slow moving tea stained water. The river is 50-60 feet wide with a sandy bottom with scattered cobble and boulder sized rocks. It is about four feet deep at its deepest spot during summer median water level. There is no forest canopy directly at the sampling site and it receives full sunlight with the exception of the portion under the bridge. There are red maples growing about 100 feet on either side of the bridge offering partial shade for much of the river. This site was chosen because of accessibility and because it provided a way for the students at The Community School to get involved with water testing. This site is located downstream of Tamworth's drinking water protection zone.

**GT-2 Mill Brook, Earle Remick Natural Area, Tamworth**
This sampling site is located within the Earle Remick Natural Area. The Mill Brook flows from the White Mountain National Forest and the Sandwich Range Wilderness and past the recently-capped Tamworth landfill. The site is set amongst a hemlock forest. The stream is about five meters wide and is swift moving with a rocky substrate. This test site was chosen because Tamworth's recently closed dump is located upstream and because established and well-maintained trails provide accessibility. *This site is no longer being sampled because the state has monitoring wells to document water quality near the capped landfill.*

**GT-3 Mill Brook, Durrell Road, Tamworth - New site in 2003**
The site is located about one mile down Durrell Road on the North side of the road. The sampling site is on a straight stretch of stream with a steep slope leading down from the road and a relatively flat area on the opposite bank. Forest cover is dominated by eastern hemlock providing ample shade at the sampling site. The stream is straight, about 25-30 feet wide at the site and rather shallow: about 1-1.5 feet at its deepest point. It is about three to six inches deep where I sample. The bottom is dominated by sand and gravel with lost of cobble and bolder sized rocks scattered about. This site was chosen because of high nutrient levels seen at the downstream site (GT-2) in 2002 that suggests a disturbance has occurred up stream. Testing here will help pinpoint the source of this disturbance. *This site is no longer being sampled because the state has monitoring wells to monitor the capped landfill.*

**GT-4 Chocorua River, RT. 41, Tamworth - New site in 2004**
From its source high on Mt. Chocorua, the Chocorua River drains the southeast side of the mountain. Just north of Lake Chocorua, the river's waters commingle with those of Stony Brook, Meadow Brook and their network of tributaries which drain the southern flanks of the mountain. Together, they enter the northern end of Lake Chocorua and eventually exit to the south under the landmark bridge and into adjacent Little Lake. From there they trace a long, slow, inverted "S" to Chocorua Village and pool before spilling over the dam, passing under Routes 113 and 16 and flowing south, contributing to the large marsh which runs along the east side of Route 16 from Chocorua to Moores Pond. From Moores Pond the river flows 2-1/2 miles through large stretches of marsh and finally emerges and passes under Route 41 at the Tamworth/West Ossipee line and just west of the Madison line. Monitoring Site GT#4 is at that bridge. A short distance from the site, the Chocorua River joins the Bearcamp River and flows into Ossipee Lake. The Chocorua River's course from source waters on the mountain to the Bearcamp River and Ossipee Lake points to the importance of this sampling site. It serves to monitor occurrences along a seven mile stretch of the busiest and most diversely utilized highway in our area, including locally cherished, pristine Lake Chocorua; and it feeds Ossipee Lake. The river is 8 to 12 feet wide in the area of the sampling site with a consistent, gentle flow with more ripples and surface effect at the site itself due to its location on the far side of the bend. About 3 to 5 feet deep in the center, the river appears to fluctuate 12 to 18 inches as indicated by the water lines on the walls. The water is clear and free from any odor. The bottom at the site is sand interspersed with stones and rocks and some scattered woody debris, with a tinge of rust presumably from the steel walls. About 6 feet downstream, beyond the bend and the current, there are patches of green algae on more stable sand covered with a thin layer of brown sediment. Due to the flow pattern, the east side differs significantly with green and brown algae and more grasses and accumulated woody debris in general on that side. About 40 feet upstream from the site, intermittent tree falls interrupt the flow and capture small amounts of debris, in one

area creating a small waterfall. The site is bordered on the east by Route 41 and on the west by mixed young forest dominated by 3" to 10" diameter maples, some white oak and some small white pines. The dominant tree is a healthy, 24" diameter white oak. The lower story is dense with mixed grasses and ferns, mostly royal fern. In the immediate area of the sampling site where the substrate is coarse and uneven, obviously affected by the bridge construction, sweet fern, coarse grasses, a few birch saplings and goldenrod have taken hold.

### 2.1.2 OLT Site Descriptions

**Table 1. Descriptions of tributary testing sites**

| Site # | Tributary Name | Description |
|---|---|---|
| OL-1 | West Branch River | This river starts at the south end of Silver Lake and flows into Lily Pond adjacent to the International Paper mill on Route 41. From there it flows south and crosses Ossipee Lake Road, forming the boundary between Freedom and Ossipee. It enters Ossipee Lake between Babcock Road in Freedom and Nichols Road in Ossipee. |
| OL-2 | Bearcamp River | This river originates in the town of Sandwich and follows Route 113 through the town of Tamworth, crossing under Route 16 south of West Ossipee. It passes the Gitchie Gumie Campground before entering the main body of Ossipee Lake north of Deer Cove. |
| OL-3 | Patch Pond River | The tributary at Patch Pond Point begins as a pond behind the housing development at Deer Cove. The point at which the water flows into Ossipee Lake is on the north side of Deer Cove, south of Meadow Cove. |
| OL-4 | Lovell River | This river originates at Connor Pond in the Ossipee Mountain Range and flows under Route 16 at the Indian Mound Golf Club. It enters the main body of Ossipee Lake south of Deer Cove at the site of the Bluffs, a housing development. |
| OL-5 | Weetamoe Inlet | This brook flows into the Main Lake at the former location of Camp Weetamoe, now used for private rental cottages. The brook flows under Route 16, a major state highway, and through the Indian Mound Shopping Center and the Indian Mound Golf Course. |
| OL-6 | Pine River | Pine River is one of the lake's major tributaries. It is the location of the only state boat ramp providing access to Ossipee Lake. From that location it flows under Route 25 and passes several clusters of homes before entering the main lake at its southern end where it crosses through the Ossipee Lake Natural Area. |
| OL-7 | Red Brook | This brook enters the southeast end of the main body of Ossipee Lake between Long Sands and Ossipee Lake Natural Area. It flows past the Heath Pond Bog Natural Area, passing the commercial operations of South African Pulp and Paper Industries. |
| OL-9 | Cold Brook | The headwaters of this brook are west of Trout Pond. It runs between Trout Pond and the Jackman Ridge along the Pequawket Trail and passes under the Ossipee Lake Road east of the Pequawket Trail. It subsequently enters the north side of Broad Bay between Camp Huckins and Ossipee Lake Marina. |
| OL-10 | Danforth Pond Outlet | This brook flows into Danforth Pond from Huckins Pond, which is undeveloped. Although there is some use of this tributary by fishing boats with small engines and by personal watercraft. |
| OL-11 | Danforth Brook | Danforth Brook flows from Danforth Pond, past Ossipee Lake Marina and into Broad Bay. |
| OL-12 | Phillips Brook | This brook starts at Hanson Top and Davis Top. It crosses under Route 25 at Leavitt Road and enters Leavitt Bay, passing a housing development and campground near the point where it enters Leavitt Bay. |
| OL-13 | Leavitt Brook | This brook starts at Hanson Top and Davis Top in the Green Mountain range. It crosses under Route 25 close to Camp Marist and enters the south end of Leavitt Bay between Leavitt Bay and the channel to Berry Bay on Camp Marist property. |
| OL-14 | Square Brook | This brook passes through the Square Brook housing development on the northeast side of Ossipee Lake Road, passes under that road before entering the northwest end of Berry Bay. |

### 2.1.3 RIVERS Testing Schedule

Sampling began on June 14 and ended on October 21. Sampling occurred ten times (every other week) throughout this period. Sampling occurred between 6:00 and 9:00 am because of two factors that influence dissolved oxygen in streams. First, dissolved oxygen levels can be affected as water temperatures rise throughout the day. Second, after a night of carbon dioxide-producing respiration, aquatic plants and algae begin producing oxygen through photosynthesis, thereby altering oxygen levels in the water. In order to maintain consistent dissolved oxygen measurements, it is important to test at the same time of day during each sampling period.

### 2.1.4 OLT Testing Schedule

Similar to the RIVERS program, sampling occurred between 6:00 and 9:00 am because of factors that influence dissolved oxygen in streams. OLT sites were sampled four times (biweekly) between July 5 and August 19.

**Table 2.** 2004 sampling schedule for Ossipee Lake Tributaries test sites

| Dates | WQM Staff | Sites | Volunteers | Access |
|---|---|---|---|---|
| Monday, July 5 & 19, August 2 & 16 | Jennifer | OL13 | | Road |
| Tuesday, July 6 & 20, August 3 & 17 | Jennifer | OL12 | Robin Hood | Boat |
| | Claes | OL9<br>OL11 | Camp Huckins | Boat |
| | | OL1<br>OL2 | Carolyn Buskirk & Cindy Sawyer | Boat |
| Wednesday, July 7 & 21, August 4 & 18 | Jennifer | OL5<br>OL6 | Camp Cody | Boat |
| | Claes | OL3<br>OL4 | Camp Calumet | Boat |
| Thursday, July 8 & 22, August 5 & 19 | Jennifer | OL7<br>OL10 | | Boat<br>Road |
| | | OL14 | Susan Fine | Road |

### 2.1.5 Parameters

Seventeen parameters were tested in the monitoring program. Four parameters were tested in the field by volunteers and GMCG staff (Table 1). These parameters were recorded on a data sheet (Appendix A) and replicated. For instructions on how to use field parameter equipment, refer to Appendix B.

**Table 3.** Field parameters tested

| Parameter | Units | Instrument Used | Range | Accuracy |
|---|---|---|---|---|
| **pH** | pH units | YSI 60 | 0 to 14 | ±0.1 unit within 10°C of calibration ±0.2 unit within 20°C |
| **Dissolved Oxygen** | mg/l, % | YSI 550A | 0-50 mg/L 0-500% air saturation | 0-200 % : ±2% air sat. or ±2% of reading, whichever is greater 200-500% : ±6% of reading 0-20 mg/L : ±0.3 mg/L or ±2% of reading, whichever is greater 20-50 mg/L : ±6% of reading |
| **Turbidity** | NTU | HACH Model 2100P Portable Turbidimeter | 0-1000 NTU | +\- 2% of reading |
| **Temperature** | ˚C | HACH Non-mercury thermometer | -5 to 45˚C | +\- 0.3˚C |

Fourteen additional chemical parameters were tested (Table 2). Two water samples were collected in 250 ml bottles at each site. One sample was acidified with one milliliter of concentrated sulfuric acid then frozen. The other sample was filtered using a 47 mm diameter 0.45 micron mesh Whatman filter, stored in a 60 ml bottle and frozen.

**Table 4.** Lab parameters tested

| Parameter | Units | Instrument Used | Description | Sample Preservative |
|---|---|---|---|---|
| Total Phosphorus (TP) | ppb | Milton-Roy 1001$^{+}$ Spectrophotometer | Std Methods Ascorbic Acid method. 10cm pathlength cuvette | 1 ml concentrated sulfuric acid and frozen |
| Dissolved Organic Carbon (DOC) | mg C/L | Shimadzu TOC 5000 with autosampler | High Temperature Catalytic Oxidation (HTCO) | Filtered and Frozen |
| Total Dissolved Nitrogen (TDN) | mg N/L | Shimadzu TOC 5000 coupled with an Antekk 720 N detector | HTCO with chemiluminescent N detection | |
| Nitrate ($NO_3^-$) | mg N/L | Lachat QuikChem AE | Automated Cd-Cu reduction | |
| Ammonium ($NH_4^-$) | mg N/L | | Automated Phenate | |
| Dissolved Organic Nitrogen (DON) | mg N/L | | DON= TDN-( $NO_3^-$+ $NH_4^{-)}$ | |
| Phosphate ($PO_4^{3-}$) | mg P/L | Lachat QuikChem AE | Automated Ascorbic Acid | |
| Silica ($SiO_2$) | mg $SiO_2$/L | | Automated Molybdate Reactive Method | |
| Anions ($Cl^-$, $SO_4^{2-}$) | mg/L | Ion Chromatograph | Anions via ion chromatography with suppressed conductivity | |
| Cations ($Na^+$, $K^+$, $Ca^{2+}$, $Mg^{2+}$) | mg/L | | Cations via ion chromatography and conductivity | |

## 3. Summary and Discussion

*(Please see 2003 WQM report for parameter descriptions)*

### 3.1 Precipitation

Precipitation during the first three months of 2004 was below the rainfall amounts for the previous three years of 2001-2003 (Figure 3). However, precipitation in April and May of 2004 was higher than the previous three years, while June of 2004 was relatively dry. The months of July-September 2004 harbored similar rainfall amounts that were similar to the four year average. October precipitation fell below the four year average, while November was slightly above.

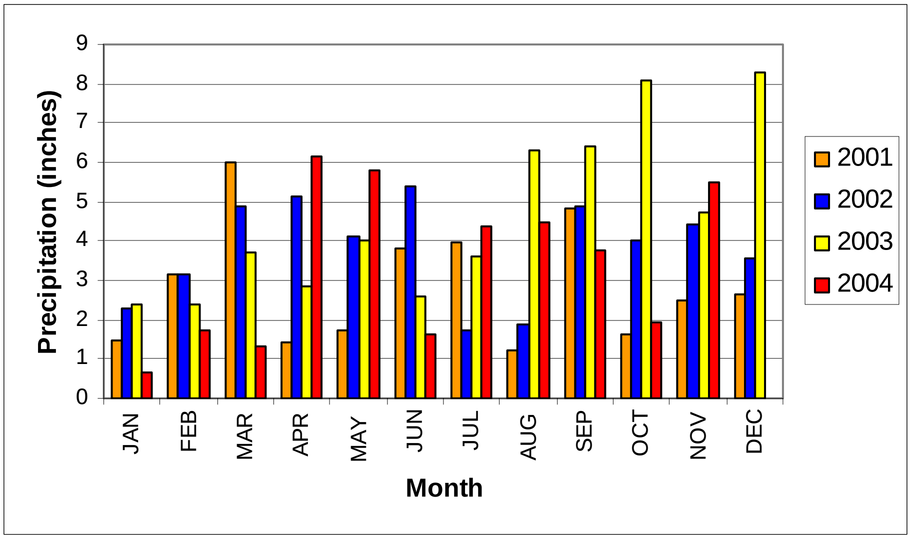


**Figure 3:** Tamworth precipitation, 2001-2004

### 3.2 Temperature

Temperatures were variable across the RIVERS sites in 2004 (Figure 4). The highest average temperatures were observed at GF-1 (19.7 ˚C) and GE-3 (20.5 ˚C), both outlets to bodies of Ossipee Lake. The lowest mean temperature was seen at site GM-3 (13.0 ˚C) with GS-1 not much higher at 13.2 ˚C.

Mean temperatures at each RIVERS site in 2004 were similar to 2003 and lower than 2002 (Figure 5). In 2004, the Ossipee Watershed experienced less rainfall than 2003; however the average air temperatures were lower than 2003, which could attribute to similar temperature values for 2003 and 2004.

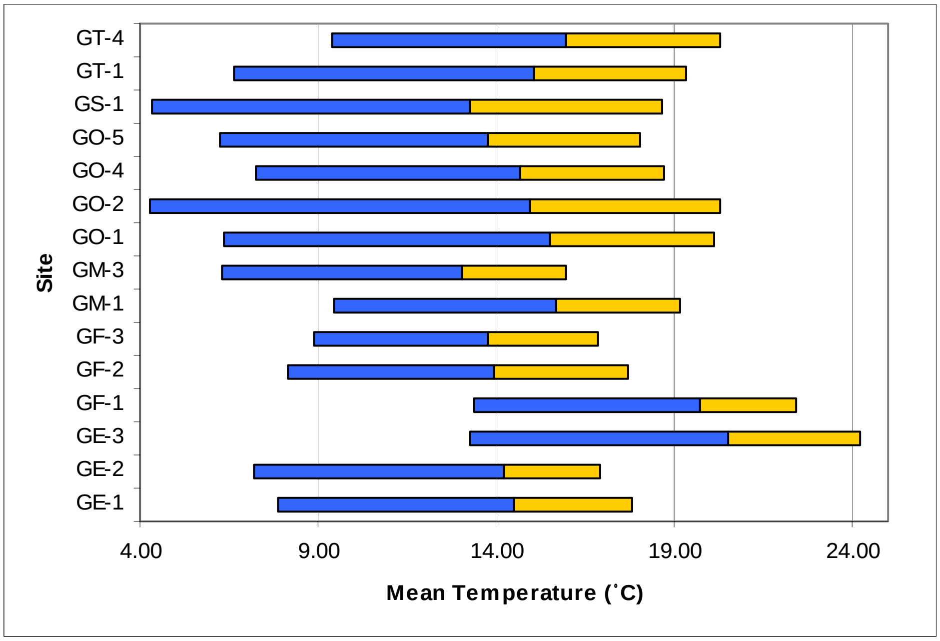


**Figure 4:** RIVERS inter site temperature comparison for 2004. Bars show range of temperatures. Darker bars show range less than the mean. Lighter bars show range greater than the mean. Mean value is at point where dark and light bars meet.

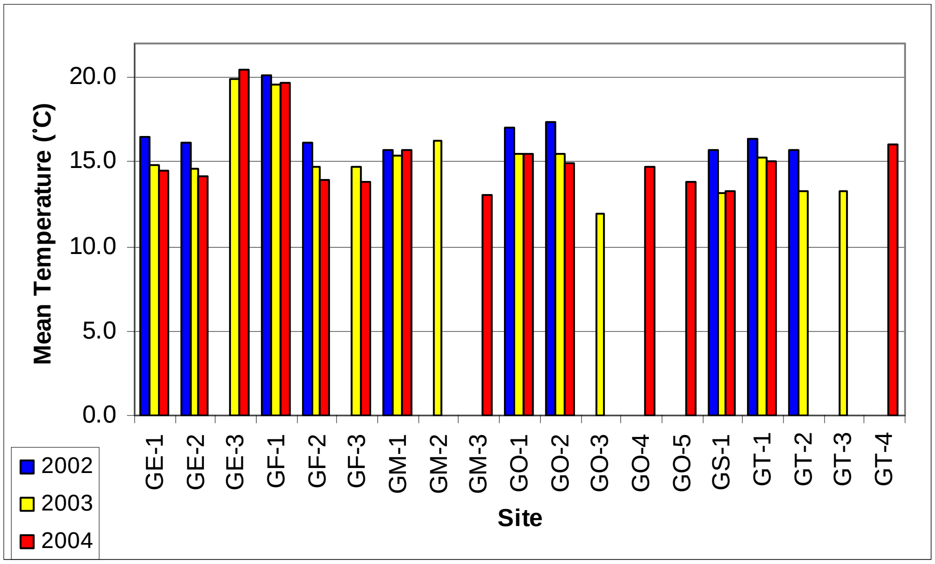


**Figure 5:** RIVERS site mean temperature comparison for 2002, 2003, and 2004.

Temperatures were variable across the tributaries of Ossipee Lake (Figure 6). Water temperatures ranged from 15.8˚C at site OL-9 to 25.2˚C at site OL-2. This variation could be due a number of factors. Some of the Ossipee Lake tributary sites were sampled where river flow is minimal and there is an influx of lake water. Sampling of lake water will alter results. Sites with more riparian vegetative cover may be cooler. Tributaries with a lot of humic acids are warmer. There is also seasonal variation associated with ambient air temperatures. If tributaries are groundwater fed, as could be the case for OL-7 with the lowest mean temperature, they are likely cooler than streams that receive surface water recharge. Finally, temperatures found in Ossipee Lake tributaries could vary due to differences in stream length, wide and depth.

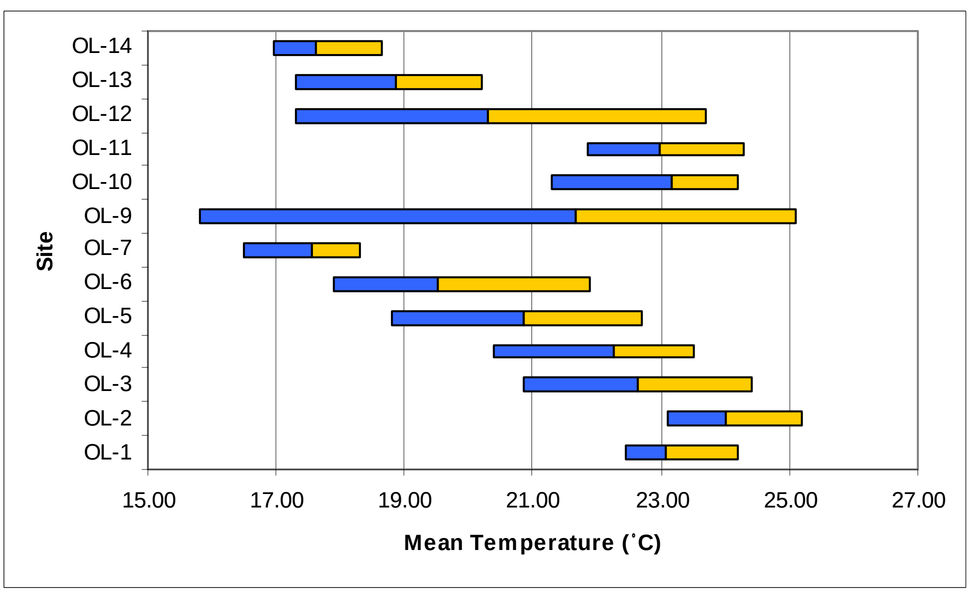


**Figure 6:** OLT inter site temperature comparison for 2004. Bars show range of temperatures. Darker bars show range less than the mean. Lighter bars show range greater than the mean. Mean value is at point where dark and light bars meet.

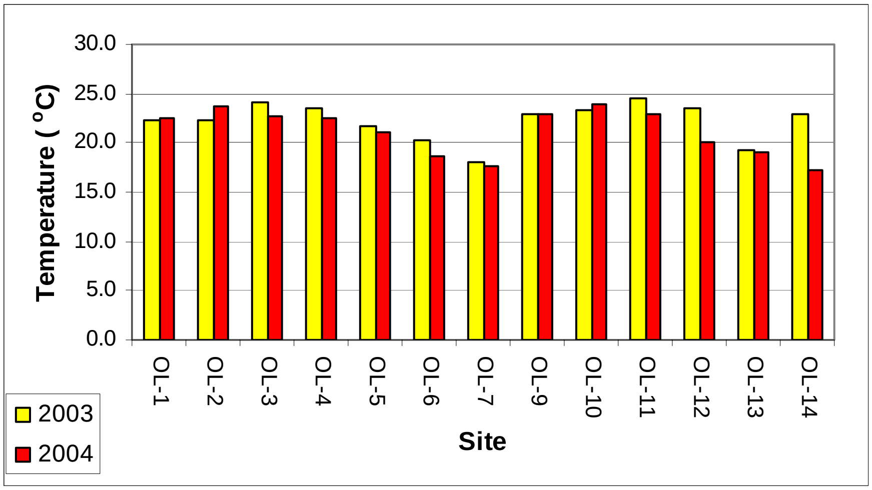


**Figure 7:** OLT site mean temperature comparison for 2003 and 2004.

As seen in Figure 7, 2004 OLT site water temperatures were similar to 2003 temperatures. However 2004 water temperatures at sites OL-12 and OL-14 appear to be significantly lower than 2003 temperatures. This could be due to sampling further upstream this year to obtain riparian data rather than lake data. In fact, many of the sites temperatures were slightly lower this year, despite lower precipitation amounts, which can be most likely attributed to sites being higher upstream from the lake.

### 3.3 Dissolved Oxygen

The dissolved oxygen concentrations in the RIVERS sites in 2004 ranged from 7.10 mg/L at GF-1 and 7.13 mg/L at GO-1 to 13.96 mg/L at GO-2 and 12.60 mg/L at GS-1 (Figure 8). GS-1 was found to be the site with that provides the best example of good water quality in the Ossipee Watershed during the 2002 and 2003 RIVERS program. Percent saturations in the RIVERS sites ranged from 73.5% at GE-2 to 107.3% at GO-2 (Figure 9). As seen in Figure 10, most sites have a similar dissolved oxygen concentration in 2004 as in 2002 and 2003.

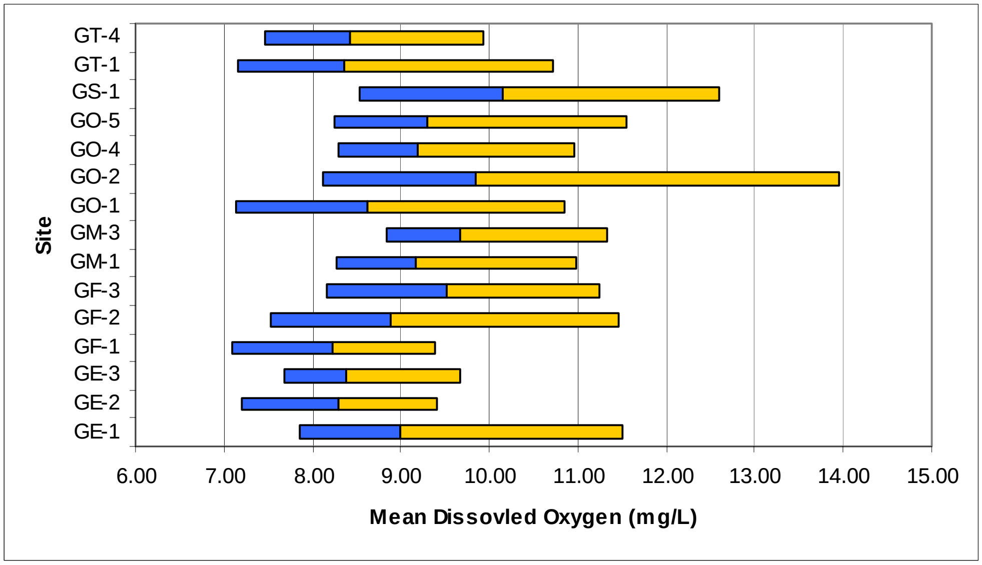


**Figure 8:** RIVERS dissolved oxygen concentration site comparison for 2004. Bars show range of dissolved oxygen concentrations. Darker bars show range less than the mean. Lighter bars show range greater than the mean. Mean value is at point where dark and light bars meet.

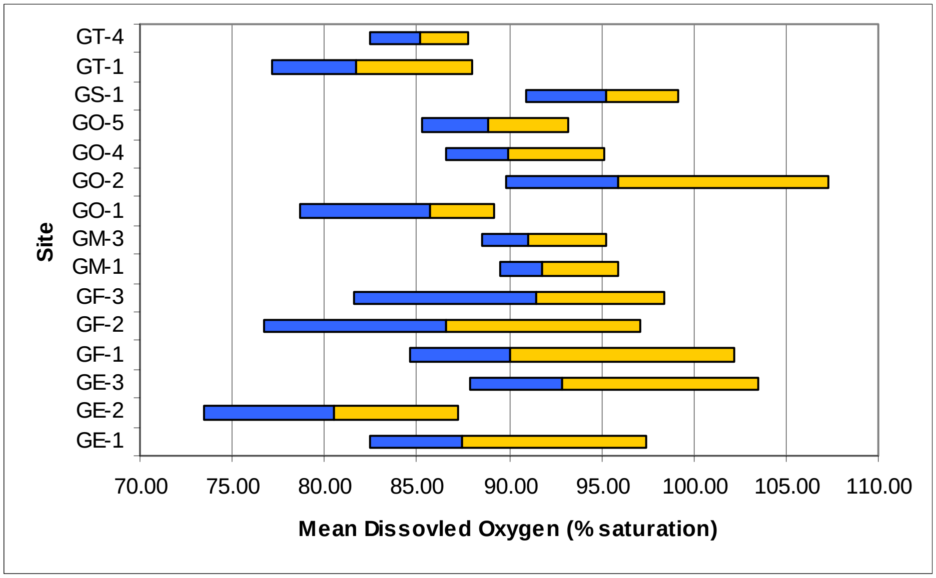


**Figure 9:** RIVERS dissolved oxygen percent saturation site comparison for 2004. Bars show range of dissolved oxygen concentrations. Darker bars show range less than the mean. Lighter bars show range greater than the mean. Mean value is at point where dark and light bars meet.

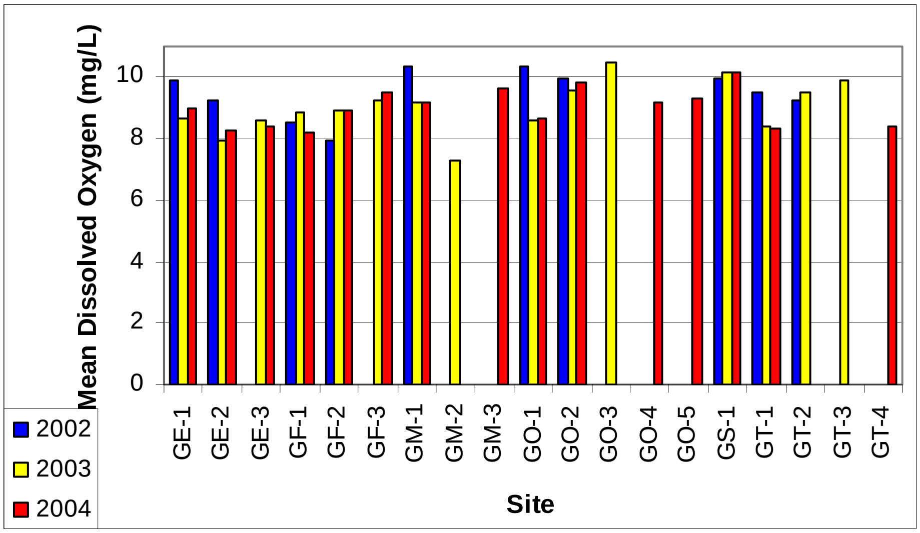


**Figure 10:** RIVERS site mean dissolved oxygen comparison for 2002, 2003, 2004.

The dissolved oxygen concentrations measured in Ossipee Lake during the summer of 2004 ranged from 0.88 mg/L at OL-7 to 9.47 mg/L at OL-9 (Figure 11). Very low oxygen concentrations should be expected at OL-7, despite its low temperatures. This site exhibits low flow and drains a large wetland. Indeed, this site had by far the lowest range of dissolved oxygen concentrations.

Percent saturation ranged from 60.2% (OL-6) to 102.7% (OL-2; Figure 12) at all sites except for OL-7 where the percent saturation was less than 15%. If this area is stagnant enough, natural decomposition might also result in significant consumption of oxygen. OL-7 also displayed a high percentage of organic nitrogen (Section 3.1.9), indicating there is a lot of material to be decomposed at this site. According to the EPA, dissolved oxygen levels are considered critical when they fall below 5 mg/L. In 2004, none of the sites, except for OL-7, fell below 5 mg/L of dissolved oxygen.

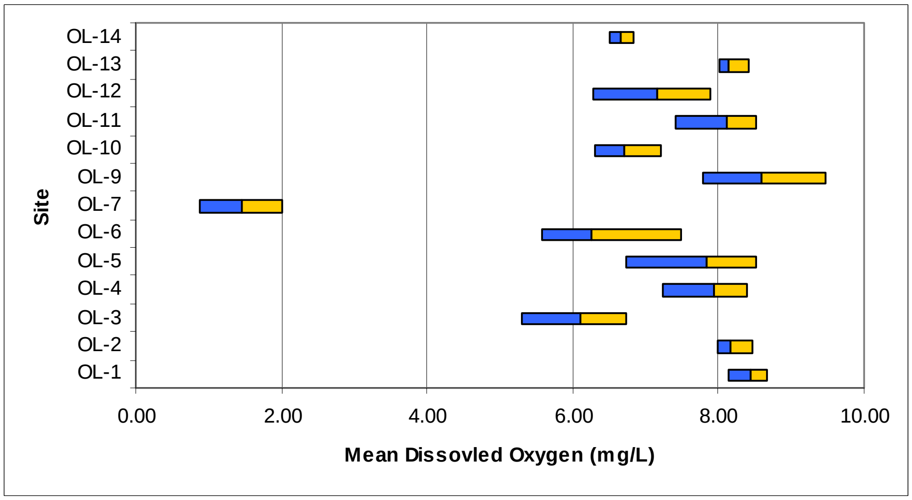


**Figure 11:** OLT dissolved oxygen concentration site comparison for 2004. Bars show range of dissolved oxygen concentrations. Darker bars show range less than the mean. Lighter bars show range greater than the mean. Mean value is at point where dark and light bars meet.

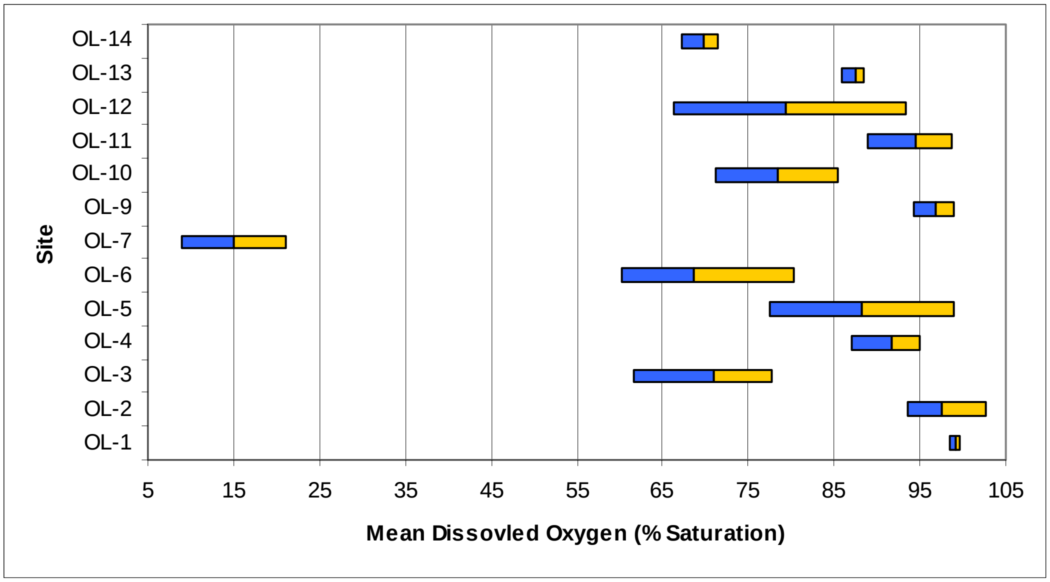


**Figure 12:** OLT dissolved oxygen percent saturation site comparison for 2004. Bars show range of dissolved oxygen concentrations. Darker bars show range less than the mean. Lighter bars show range greater than the mean. Mean value is at point where dark and light bars meet.

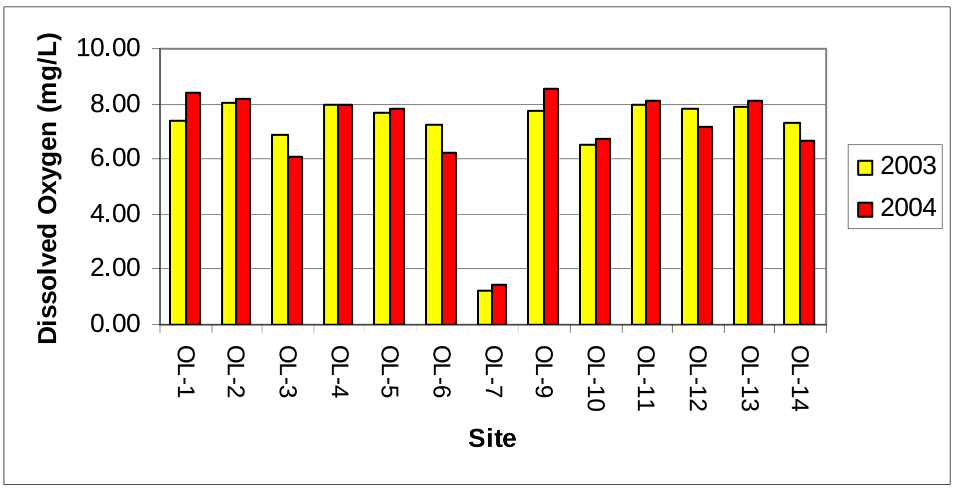


**Figure 13:** OLT site mean dissolved oxygen comparison for 2003 and 2004.

2004 mean dissolved oxygen levels varied some from 2003 levels. This could be due to changes in site locations, lower air temperatures in 2004, and less precipitation in 2004.

### 3.4 pH

2004 pH in the Ossipee Watershed ranged from 5.92 at GE-2 to 7.63 at GE-3 (Figure 14). Mean pH in 2004 was slightly higher at all sites and dates than in 2003, but lower than 2002 data (except for GF-1) (Figure 15). GMCG began using new pH equipment in 2003. Volunteers frequently had trouble with the new pH meter and one was sent back twice for service. It is unknown if the meters are the reason behind the pH discrepancy from 2002 to 2003 and 2004. In addition, the higher volume of rain in 2003 could be reason for lower pH. However, sites along the Saco River, as measured by the volunteers of the Saco River Corridor Commission, did not exhibit a similar trend.

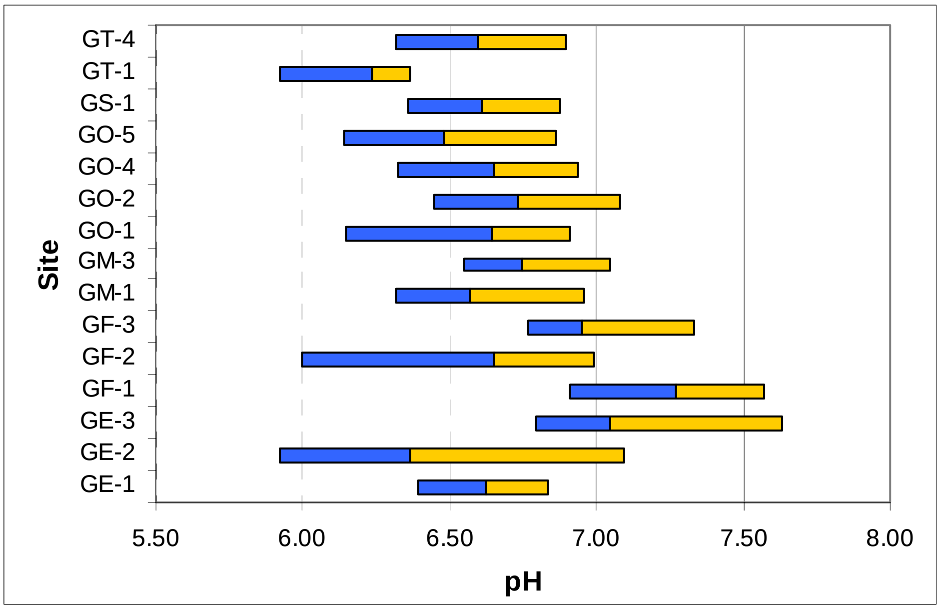


**Figure 14:** RIVERS site pH comparison for 2004. Bars show range of pH. Darker bars show range less than the mean. Lighter bars show the range greater than the mean. Mean value is at point where dark and light bars meet.

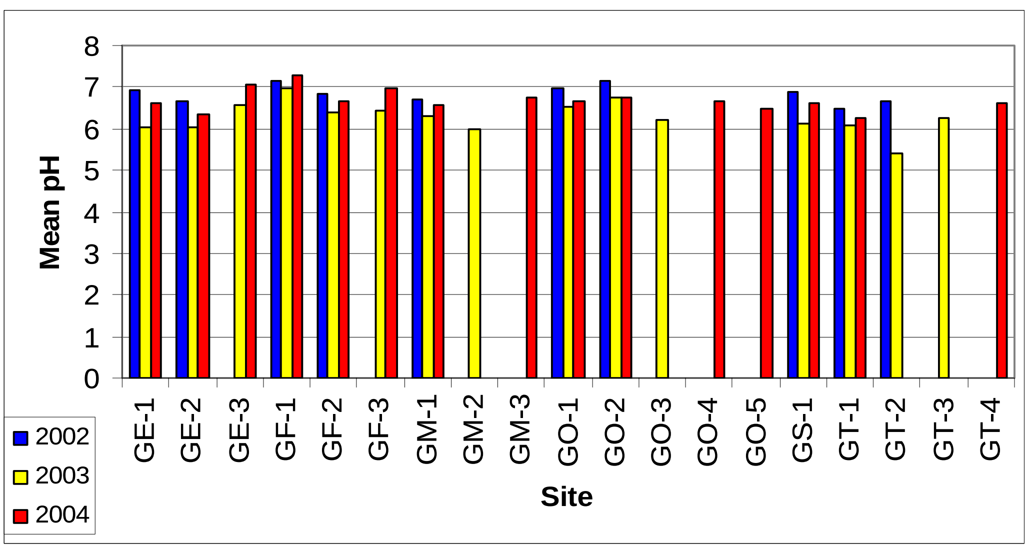


**Figure 15:** RIVERS site mean pH comparison for 2002, 2003, and 2004.

pH in the OLT sites in 2004 ranged from 5.10 at OL-7 to 7.11 at OL-4 (Figure 16) . All sites except for OL-7 had a pH of greater than or equal to 5.50. Site OL-7 drains a wetland. Therefore, presence of humic acids in wetlands would be cause for the low pH observed.

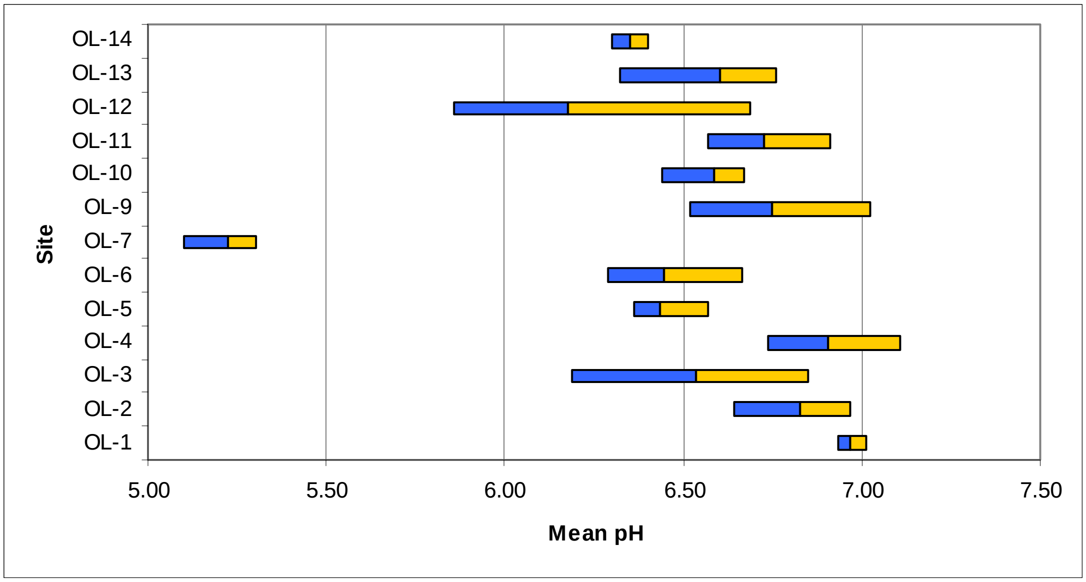


**Figure 16:** OLT site pH comparison for 2004. Bars show range of pH. Darker bars show range less than the mean. Lighter bars show the range greater than the mean. Mean value is at point where dark and light bars meet.

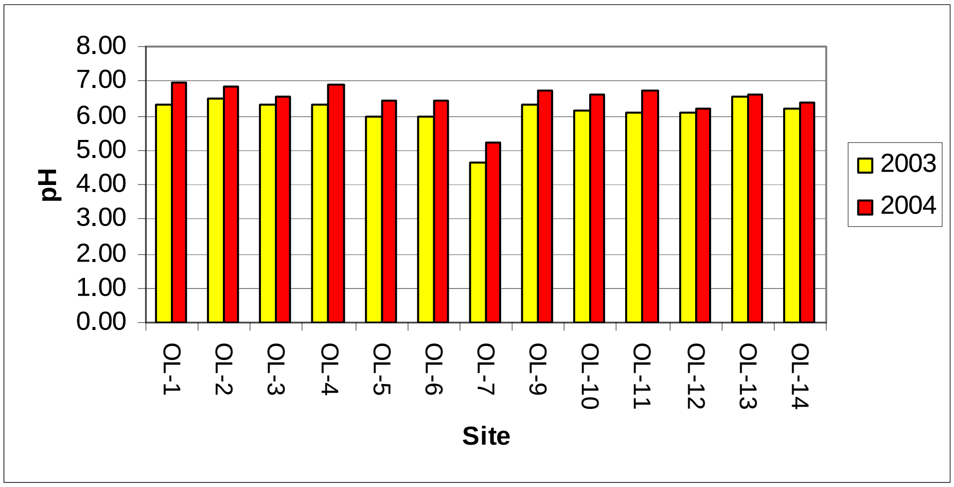


**Figure 17:** OLT site mean pH comparison for 2003 and 2004.

Similarly to the 2003 and 2004 RIVERS data, 2004 pH levels were slightly higher than 2003 levels at all OLT sites (Figure 17). This, again, could be due to equipment problems in 2003.

### 3.5 Turbidity

Many chemical pollutants and nutrients are commonly attached to silt particles and in some instances the turbidity might be used as a surrogate for other more expensive and involved analyses such as total phosphorus measurements (Figure 10). In previous years, it did not appear than total phosphorus in Ossipee Watershed sites was related to turbidity. However, in 2004 there was a closer relationship ($R^2$=0.6105).

The mean turbidity in the RIVERS sites ranged from 0.19 NTU at GS-1 to 6.50 NTU at GO-2 (Figure 19). The high reading at GO-2 could also be attributed to a soft bank that was disturbed during sampling. With considerably more rainfall in 2003 than 2002 and 2004, it is expected that some sites will exhibit higher turbidity (Figure 20). However, in 2004 GM-1, GO-1, and GO-2 experienced raised levels of turbidity in comparison to previous year's data.

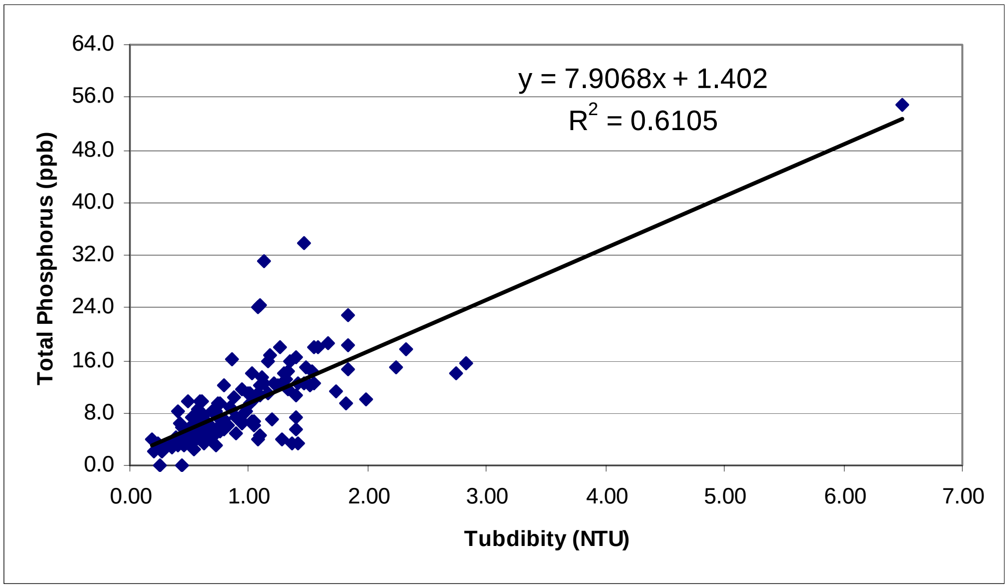


**Figure 18:** Total phosphorus vs. turbidity for RIVERS, 2004.

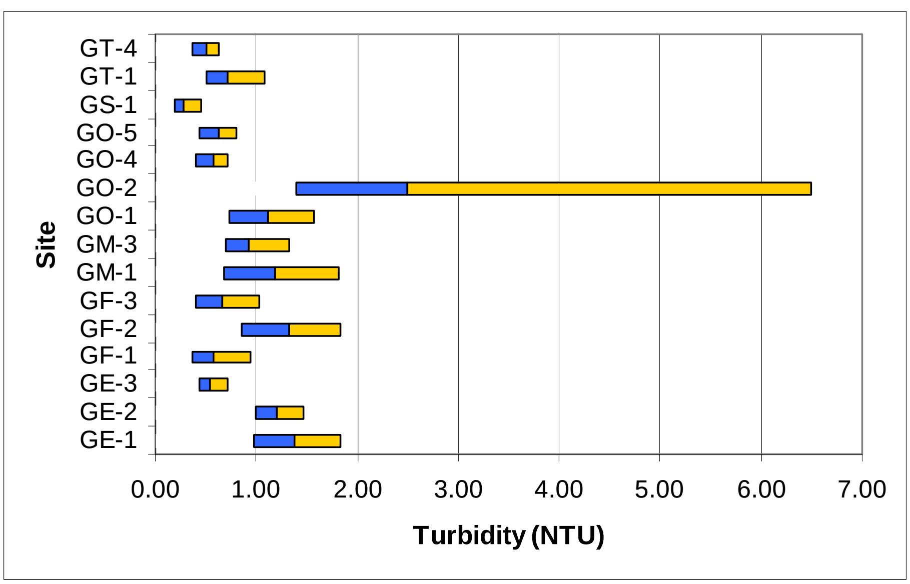

**Figure 19:** 2004 RIVERS inter site turbidity comparison. Bars show range of turbidity. Darker bars show range less than the mean. Lighter bars show range greater than the mean. Mean value is at point where dark and light bars meet.

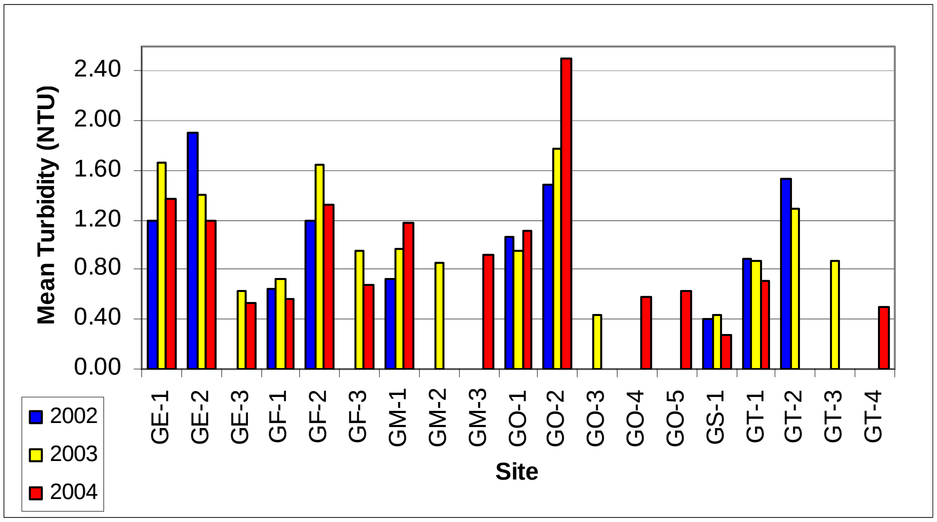


**Figure 20:** RIVERS site turbidity comparison for 2002, 2003, and 2004.

Aside from a couple of outliers, it appears that in 2004 there was a relationship between turbidity and total phosphorus in the OLT sites (Figure 21). Eliminating the two outliers gave a stronger regression relationship ($R^2$=0.5466).
Turbidity in Ossipee Lake tributaries in 2004 ranged from 0.43 NTU at site OL-1 to 2.03 NTU at OL-14 (Figure 22). All sites are within a healthy range. The turbidity in 2004 was lower at most sites than 2004, which can be attributed to less precipitation in 2004. However, sites OL-2, OL-13, and OL-14 showed higher levels. OL-14 showed a significantly higher turbidity which is likely due to the site being moved significantly upstream. The changes in OL-2 and OL-13 are also mostly likely due to site location changes.

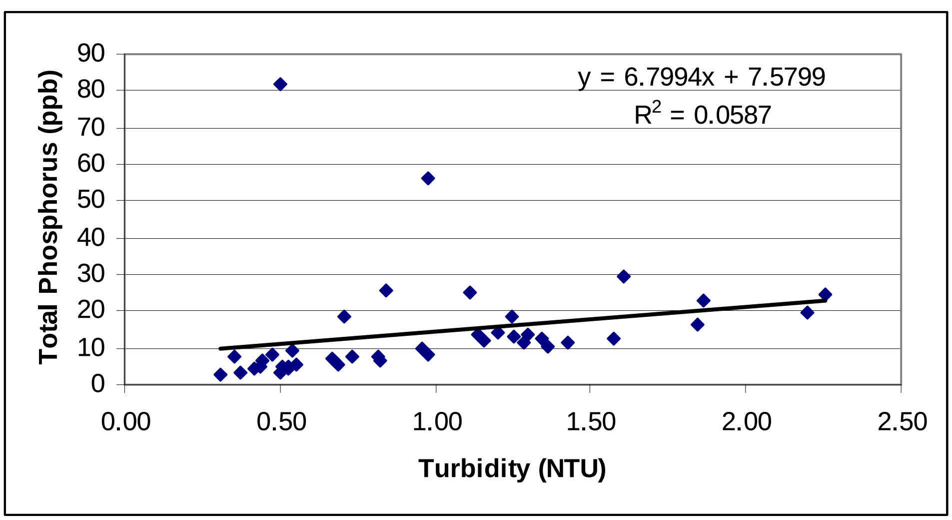


**Figure 21:** Total phosphorus vs. turbidity for OLT, 2004.

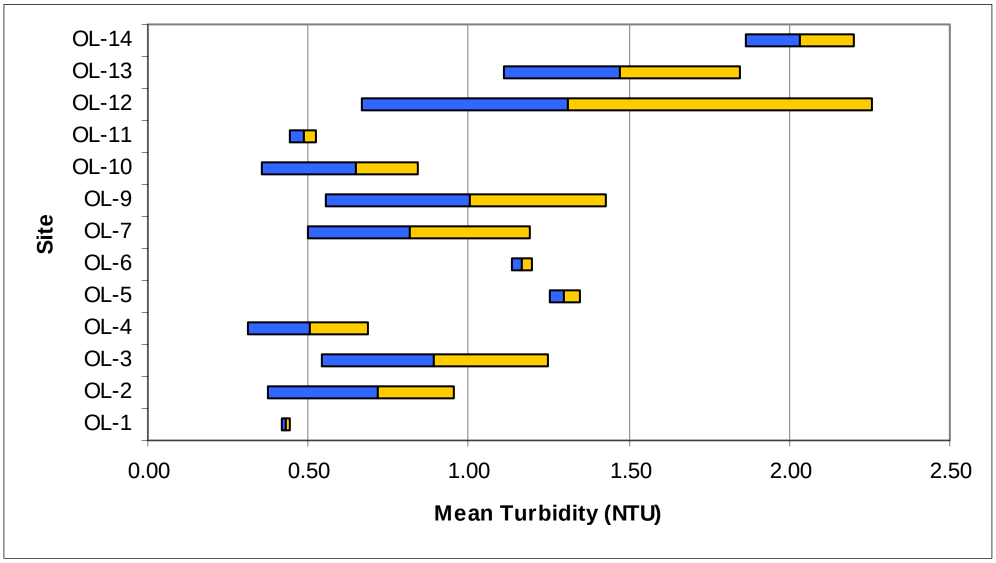


**Figure 22:** OLT inter site turbidity comparison. Bars show range of turbidity. Darker bars show range less than the mean. Lighter bars show range greater than the mean. Mean value is at point where dark and light bars meet.

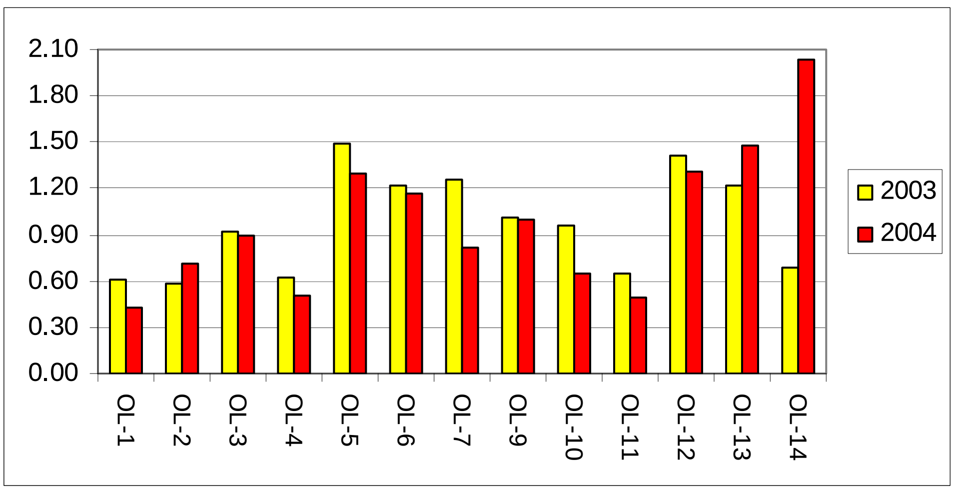


**Figure 23:** OLT site turbidity comparison for 2003, and 2004.

### 3.6 Total Phosphorus

Total phosphorus in the RIVERS sites in 2004 ranged from 0.00 ppb at GS-1 to 54.90 ppb at GO-2 (Figure 24). The low total phosphorus level at GS-1 is comparable to the low levels observed in 2002 and 2003 (Figure 25).

Mean total phosphorus at most sites was lower in 2004 than 2003 and was similar to 2002 levels, except at GE-2, GF-2, and GO-2 which experienced higher levels (Figure 14). This could be due to the lower rainfall than 2003 and similar amount of rainfall to 2002. However, it should be expected that high total phosphorus due to rain is coupled with high turbidity. GO-2 did experience a raise in turbidity with the raise in total phosphorus; however, GE-2 and GF-2 did not. Other sites did experience a decrease in turbidity with a decrease in total phosphorus.

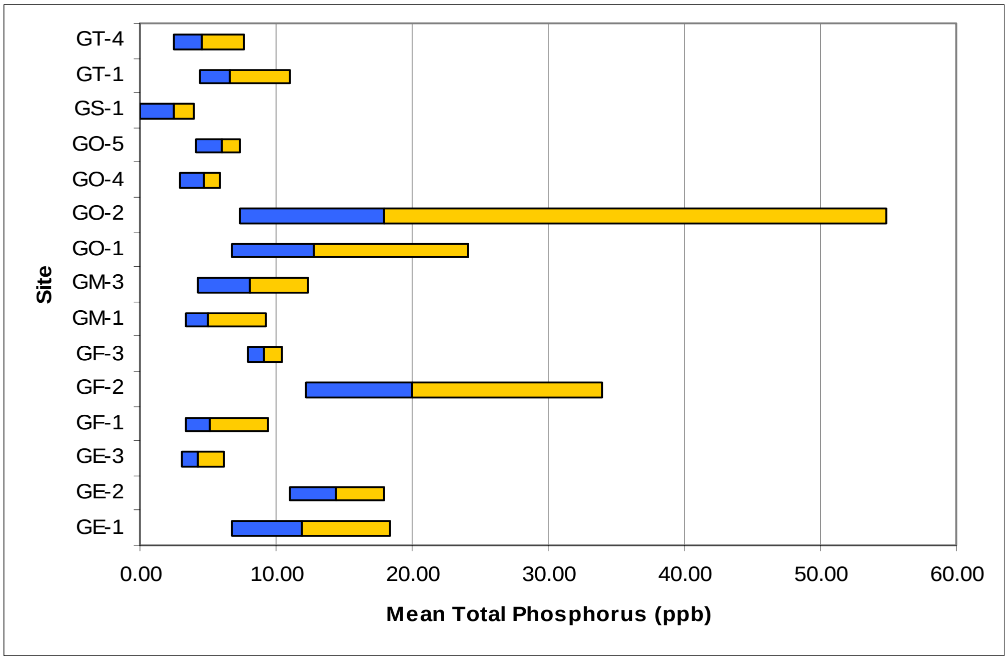


**Figure 24:** 2004 RIVERS total phosphorus site comparison. Darker bars show range less than the mean. Lighter bars show the range greater than the mean. Mean value is at point where dark and light bars meet.

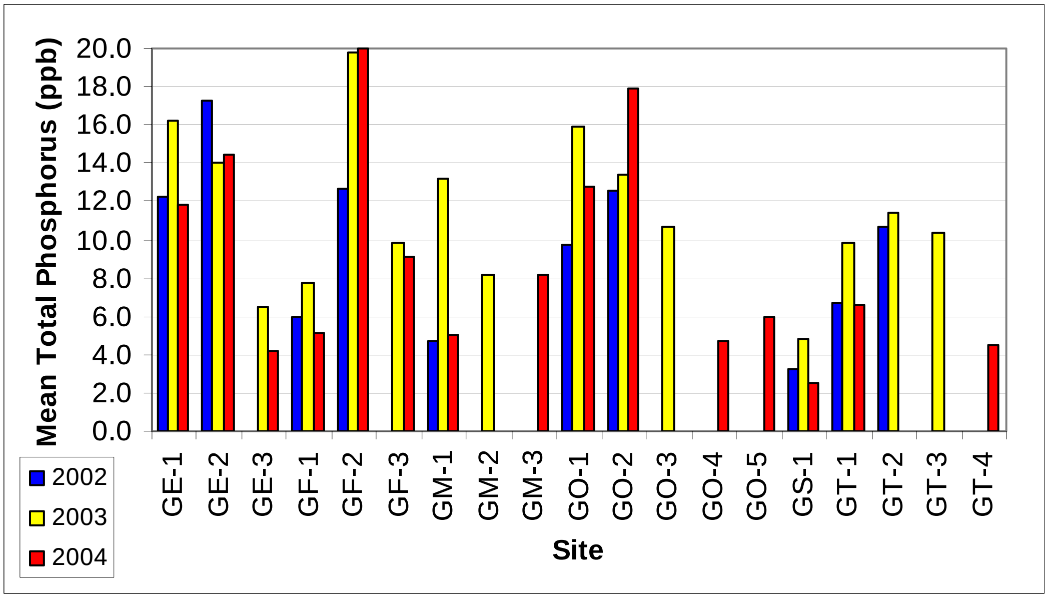


**Figure 25:** RIVERS site total phosphorus comparison for 2002, 2003, and 2004.

Total phosphorus on Ossipee Lake (2004) varied from 4.8 ppb (OL-4) to 81.6 ppb at OL-7 (Figure 26). Again, OL-7 is part of a large wetland complex. It is possible that the higher total phosphorus levels may be attributed to this wetland.

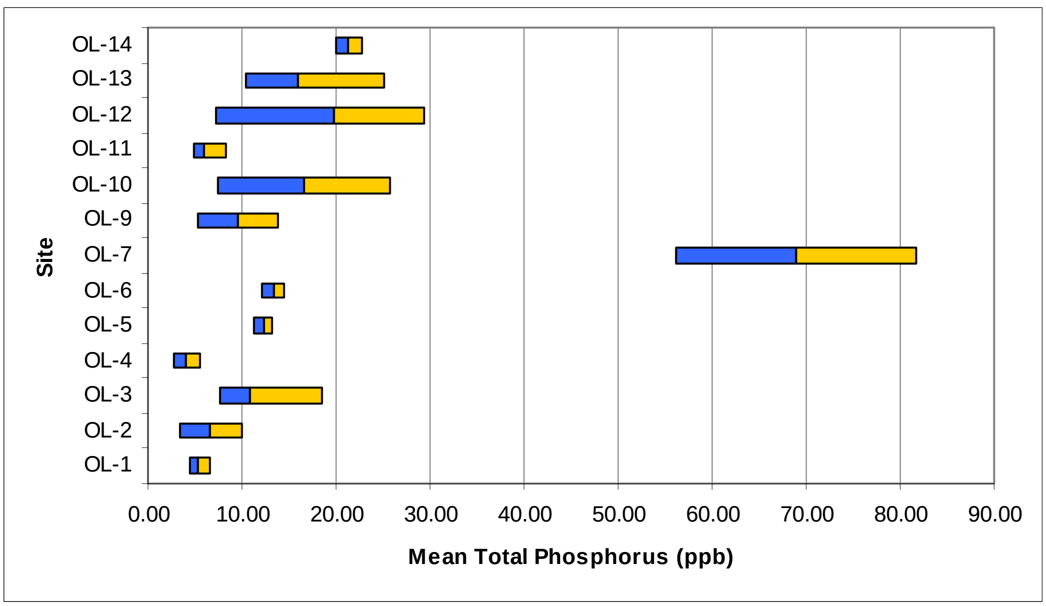


**Figure 26:** 2004 OLT total phosphorus site comparison. Darker bars show range less than the mean. Lighter bars show the range greater than the mean. Mean value is at point where dark and light bars meet.

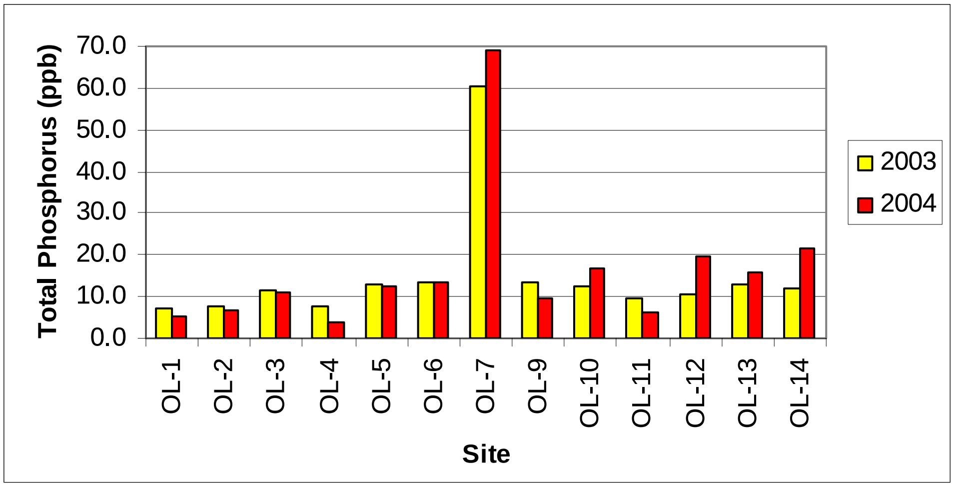


**Figure 27:** OLT site total phosphorus comparison for 2003 and 2004.

Total phosphorus levels in 2004 were similar to those found in 2003 (Figure 27).

### 3.7 Phosphate

Total phosphorus and phosphate are related. However, it is impossible for phosphate to exceed total phosphorus. By examining the total phosphorus and phosphate data, it is clear that there have been no lab errors, and total phosphorus exceeds phosphate levels (Figure 28).

Phosphate in the RIVERS sites in 2004 ranged from zero at all sites to 17.72 µg P/L at GE-1 (Figure 29). Phosphate levels in 2003 were varied from 2002 (Figure 30). For some sites, this variation could be a result of higher precipitation amounts. Phosphate levels in 2004 were mostly lower than 2003, except for at GE-3, GO-2, and GT-1, most likely due to decrease rainfall.

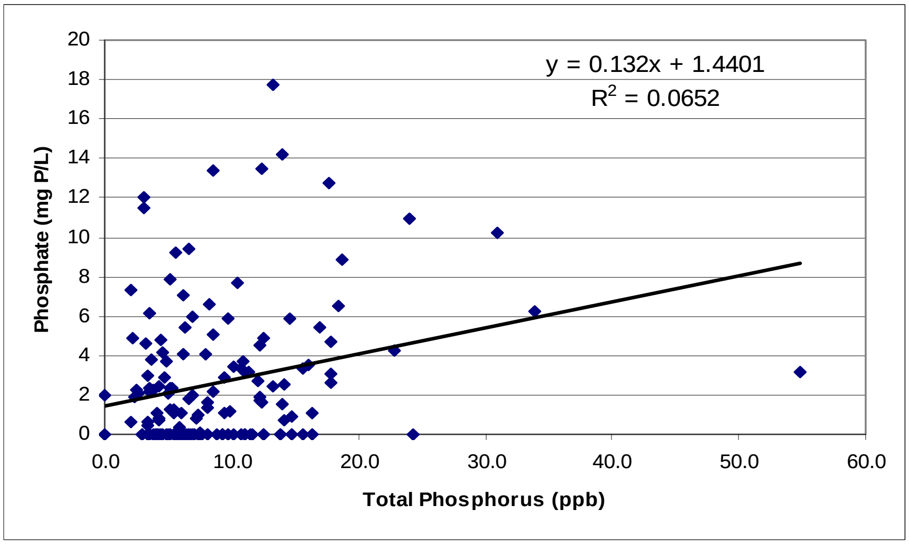


**Figure 28**: Comparison of phosphate and total phosphorus measurements for RIVERS test sites, 2004

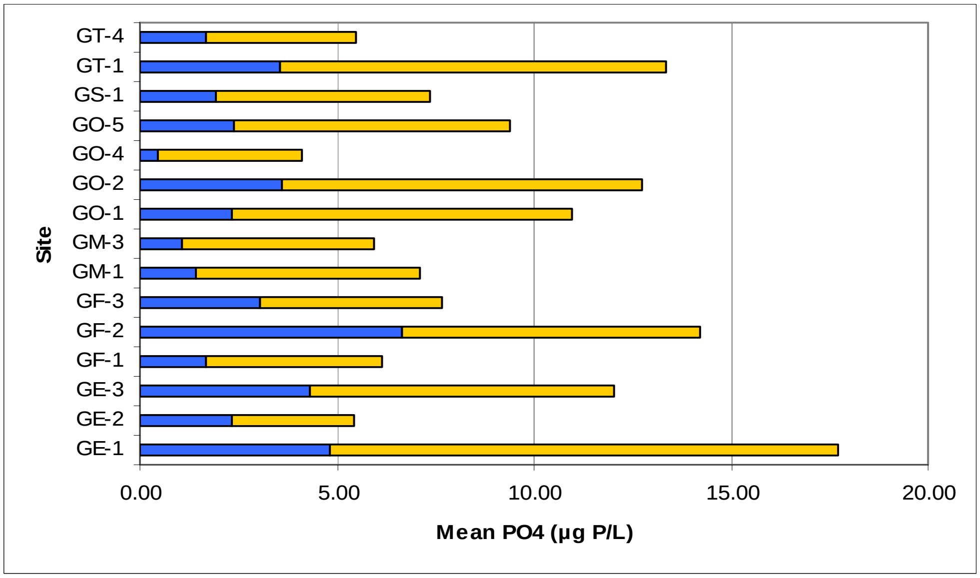


**Figure 29:** 2004 RIVERS site phosphate comparison. Bars show range of phosphate concentrations. Darker bars show range less than the mean. Lighter bars shows range greater than the mean. Mean value is at point where dark and light bars meet.

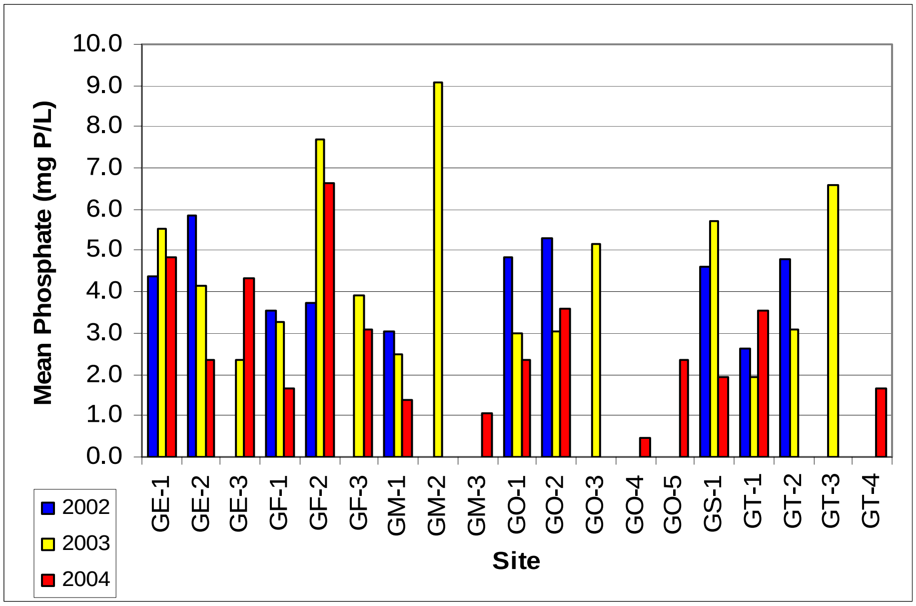


**Figure 30:** RIVERS site phosphate comparison for 2002, 2003, and 2004.

In 2004, there was a strong relationship between phosphate and total phosphorus levels (Figure 31). In Ossipee Lake tributary sites in 2004, phosphate concentrations ranged from 0.0 at several sites to 54.7 µg P/L at OL-7 (Figure 32). All sites except for OL-7 had phosphate levels below 8.0 µg P/L. A phosphate rich environment could be explained by the wetland that OL-7 drains. Mean phosphate levels in the OLT sites in 2004 were similar to 2003 levels (Figure 33).

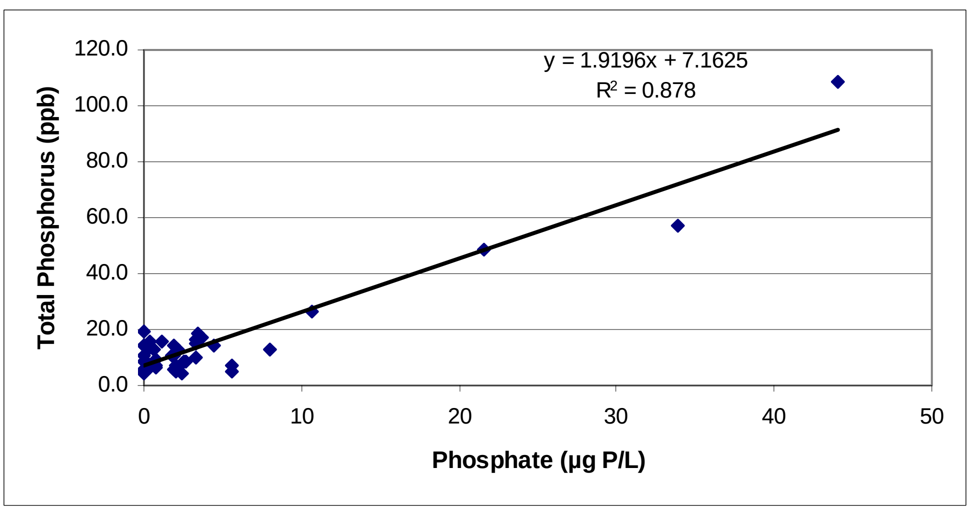


**Figure 31**: Comparison of phosphate and total phosphorus measurements for OLT test sites, 2004

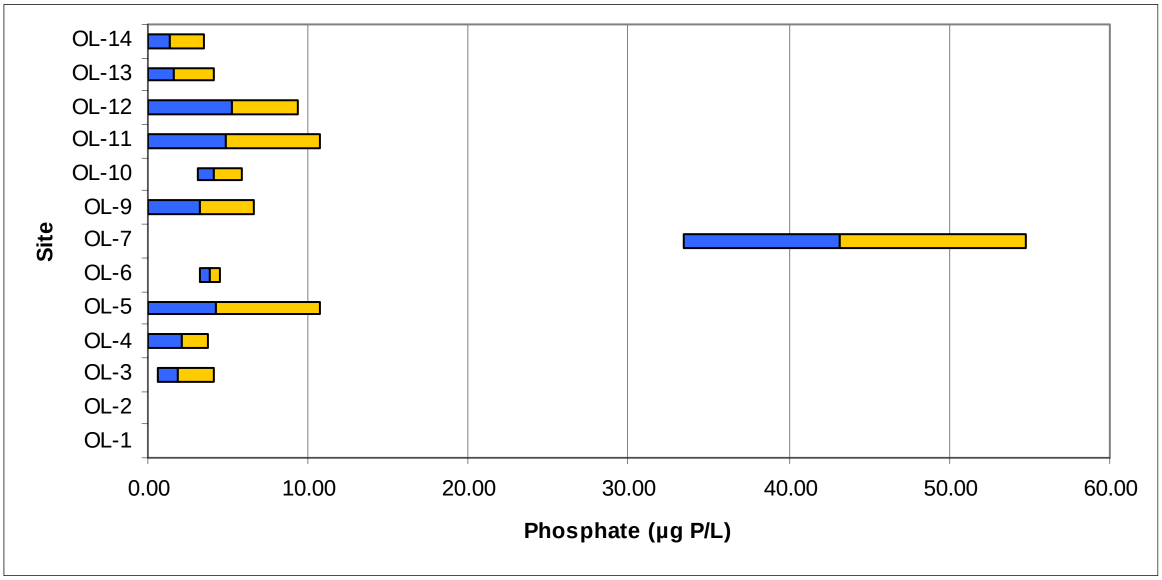


**Figure 32:** 2004 OLT site phosphate comparison. Bars show range of phosphate concentrations. Darker bars show range less than the mean. Lighter bars shows range greater than the mean. Mean value is at point where dark and light bars meet.

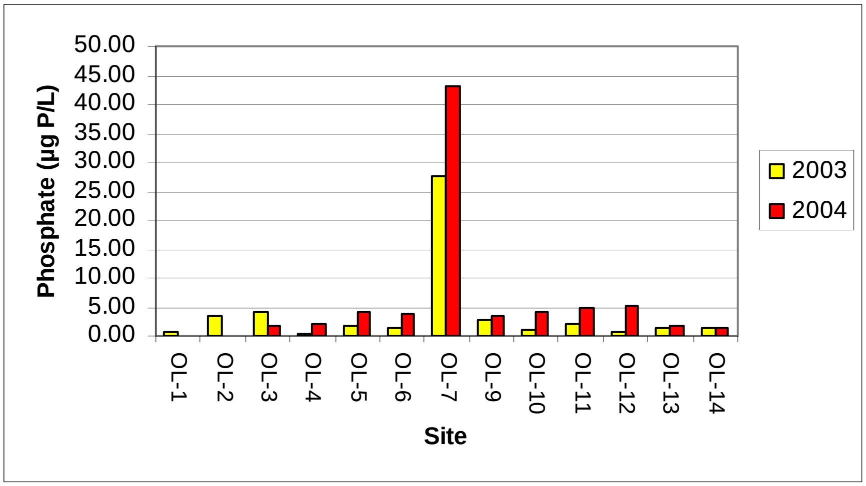


**Figure 33:** OLT site phosphate comparison for 2003 and 2004.

### 3. 8 Dissolved Organic Carbon (DOC)

Mean DOC concentrations in the RIVERS sites in 2004 ranged from 1.14 mg C/L at GM-1 to 12.03 mg C/L at site GE-2 (Figure 34). The high concentrations at both GE-1 and GE-2 are most likely due to wetlands upstream of the sampling sites. Mean DOC concentrations in 2004 were mostly lower at each site than in 2003 and higher than in 2002 (Figure 35). These fluctuations could be due to changes in precipitation.

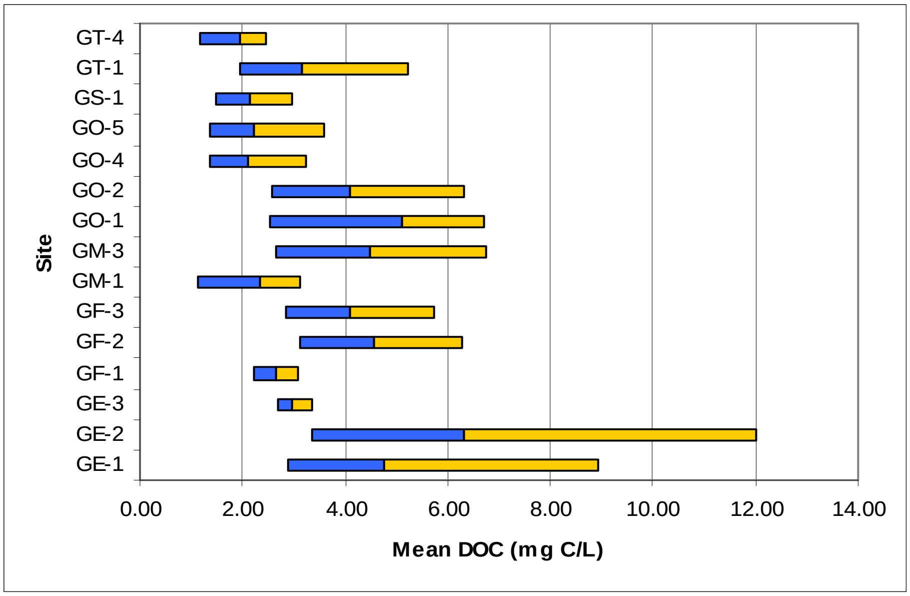


**Figure 34:** 2004 RIVERS site DOC comparison. Bars show range of DOC concentrations. Darker bars show range less than the mean. Lighter bars shows range greater than the mean. Mean value is at point where dark and light bars meet.

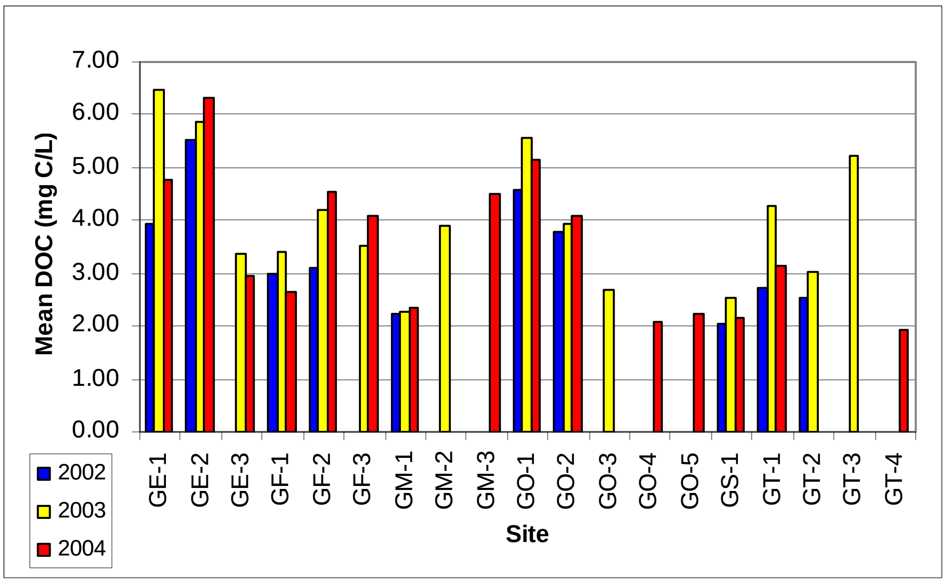


**Figure 35:** RIVERS site DOC comparison for 2002, 2003, and 2004.

Dissolved organic carbon levels varied in the OLT sites in 2004 from 2.01 mg C/L at OL-5 to 20.46 mg C/L at OL-7 (Figure 36). High DOC values are to be expected at OL-7 because of the wetland system that it drains. 2004 DOC levels in the OLT sites were similar to 2003 readings. However, 2004 DOC readings at OL-12 were slightly higher, which could be attributed to a change in site location.

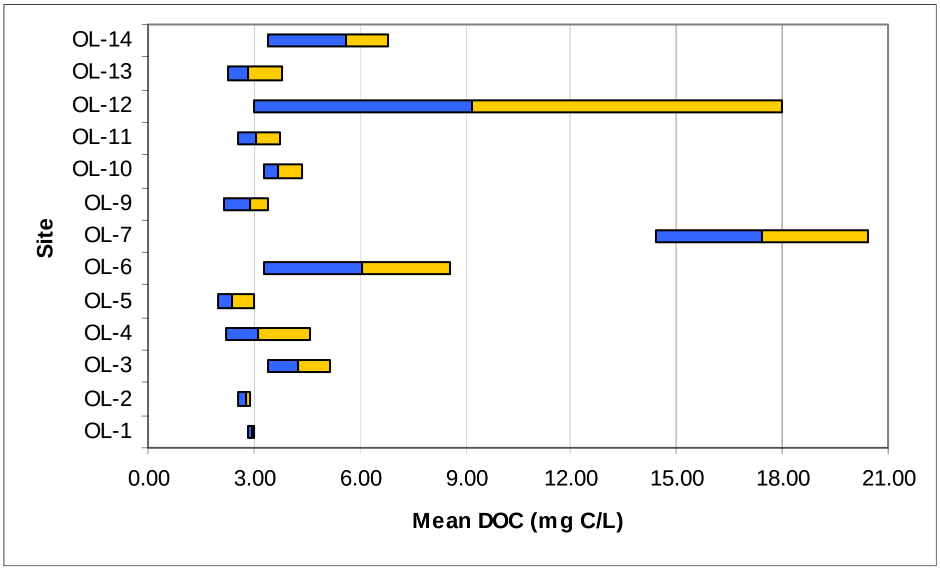


**Figure 36:** 2004 OLT site DOC comparison. Bars show range of DOC concentrations. Darker bars show range less than the mean. Lighter bars shows range greater than the mean. Mean value is at point where dark and light bars meet.

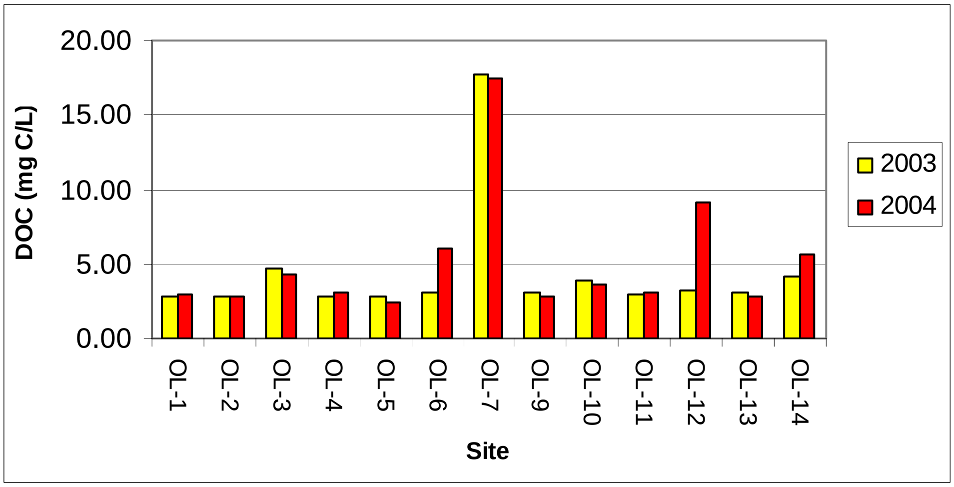


**Figure 37:** OLT site DOC comparison for 2003 and 2004.

### 3. 9 Nitrogen

Mean TDN concentrations among the RIVERS sites in 2004 were relatively low (Table 5 and Figure 38) and ranged from 0.09 mg N/L at site GO-3 and GS-1 to 0.24 mg N/L at GO-2 and GT-2. Dissolved organic nitrogen ranged from 0.06 mg N/L at several sites including GO-3, GS-1 and GT-2 to 0.17 at GO-1. At all RIVERS sites, mean nitrate concentrations were less than 0.09 mg N/L. Mean ammonium concentrations were less than 0.040 mg N/L at all sites except for GT-2, where the mean concentration was 0.095 mg N/L.

Mean DON comprised of more than 53% of the mean TDN at all sites in 2004, except for GM-3, GO-4, GO-5, and GT-4 (all new sites this year), where DIN dominated TDN (Table 6, Figure 38). At site GM-3 and GO-5, mean DON was 47% of the mean TDN, while the mean DON at GO-4 was 49% of the mean TDN. As organic nitrogen typically dominates in unimpaired systems, the low percentage of DON at site GT-4 (38%) could be indicative of an impairing input. Future testing at these sites will determine if there may be a constant source impairing these systems.

**Table 5:** Nitrogen concentrations for RIVERS test sites in 2002, 2003 and 2004. All concentrations are in mg/L.

| site | 2002 | | | | 2003 | | | | 2004 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | DON | Nitrate | $NH_4$ | TDN | DON | Nitrate | $NH_4$ | TDN | DON | Nitrate | $NH_4$ | TDN |
| GE-1 | 0.13 | 0.05 | 0.02 | 0.20 | 0.16 | 0.05 | 0.012 | 0.23 | 0.15 | 0.08 | 0.012 | 0.24 |
| GE-2 | 0.18 | 0.02 | 0.03 | 0.22 | 0.14 | 0.02 | 0.015 | 0.17 | 0.14 | 0.03 | 0.013 | 0.19 |
| GE-3 | | | | | 0.09 | 0.02 | 0.01 | 0.12 | 0.10 | 0.02 | 0.011 | 0.15 |
| GF-1 | 0.11 | 0.01 | 0.017 | 0.14 | 0.09 | 0.01 | 0.012 | 0.12 | 0.08 | 0.02 | 0.013 | 0.15 |
| GF-2 | 0.11 | 0.04 | 0.021 | 0.17 | 0.19 | 0.02 | 0.019 | 0.23 | 0.22 | 0.04 | 0.020 | 0.27 |
| GF-3 | | | | | 0.12 | 0.06 | 0.008 | 0.18 | 0.13 | 0.06 | 0.011 | 0.20 |
| GM-1 | 0.10 | 0.04 | 0.027 | 0.17 | 0.08 | 0.03 | 0.016 | 0.12 | 0.08 | 0.03 | 0.020 | 0.14 |
| GM-2 | | | | | 0.09 | 0.02 | 0.013 | 0.13 | | | | |
| GM-3 | | | | | | | | | 0.15 | 0.16 | 0.011 | 0.33 |
| GO-1 | 0.13 | 0.03 | 0.015 | 0.17 | 0.17 | 0.02 | 0.015 | 0.20 | 0.13 | 0.03 | 0.017 | 0.18 |
| GO-2 | 0.17 | 0.08 | 0.024 | 0.27 | 0.13 | 0.09 | 0.016 | 0.24 | 0.13 | 0.07 | 0.022 | 0.23 |
| GO-3 | | | | | 0.06 | 0.02 | 0.01 | 0.09 | | | | |
| GO-4 | | | | | | | | | 0.08 | 0.08 | 0.008 | 0.17 |
| GO-5 | | | | | | | | | 0.08 | 0.08 | 0.009 | 0.17 |
| GS-1 | 0.05 | 0.05 | 0.014 | 0.14 | 0.06 | 0.03 | 0.006 | 0.09 | 0.08 | 0.03 | 0.008 | 0.12 |
| GT-1 | 0.09 | 0.03 | 0.018 | 0.15 | 0.11 | 0.02 | 0.008 | 0.14 | 0.12 | 0.02 | 0.010 | 0.16 |
| GT-2 | 0.05 | 0.09 | 0.097 | 0.23 | 0.08 | 0.09 | 0.0095 | 0.27 | | | | |
| GT-3 | | | | | 0.17 | 0.05 | 0.039 | 0.26 | | | | |
| GT-4 | | | | | | | | | 0.08 | 0.12 | 0.014 | 0.22 |

**Table 6:** Percentages of Nitrogen Concentrations of Total Dissolved Nitrogen in RIVERS test sites in 2002, 2003 and 2004.

| site | 2002 | | | | 2003 | | | | 2004 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | DON | Nitrate | $NH_4$ | TDN | DON | Nitrate | $NH_4$ | TDN | DON | Nitrate | $NH_4$ | TDN |
| GE-1 | 64% | 25% | 10% | 99% | 70% | 22% | 5% | 97% | 63% | 32% | 5% | 100% |
| GE-2 | 81% | 9% | 14% | 104% | 82% | 12% | 9% | 103% | 74% | 19% | 7% | 100% |
| GE-3 | | | | | 75% | 17% | 8% | 100% | 69% | 12% | 8% | 89% |
| GF-1 | 80% | 7% | 12% | 99% | 75% | 8% | 10% | 93% | 53% | 15% | 8% | 76% |
| GF-2 | 64% | 24% | 12% | 100% | 83% | 9% | 8% | 100% | 82% | 16% | 8% | 106% |
| GF-3 | | | | | 67% | 33% | 4% | 104% | 66% | 29% | 6% | 100% |
| GM-1 | 60% | 24% | 16% | 99% | 67% | 25% | 13% | 105% | 60% | 26% | 15% | 100% |
| GM-2 | | | | | 69% | 15% | 10% | 95% | | | | |
| GM-3 | | | | | | | | | 47% | 49% | 3% | 100% |
| GO-1 | 74% | 18% | 9% | 100% | 85% | 10% | 8% | 103% | 72% | 18% | 10% | 100% |
| GO-2 | 63% | 30% | 9% | 101% | 54% | 38% | 7% | 98% | 59% | 31% | 10% | 100% |
| GO-3 | | | | | 67% | 22% | 11% | 100% | | | | |
| GO-4 | | | | | | | | | 49% | 46% | 5% | 100% |
| GO-5 | | | | | | | | | 47% | 47% | 5% | 100% |
| GS-1 | 38% | 36% | 10% | 84% | 67% | 33% | 7% | 107% | 65% | 28% | 7% | 100% |
| GT-1 | 57% | 20% | 12% | 89% | 79% | 14% | 6% | 99% | 78% | 16% | 6% | 100% |
| GT-2 | 21% | 39% | 42% | 103% | 30% | 33% | 4% | 66% | | | | |
| GT-3 | | | | | 65% | 19% | 15% | 100% | | | | |
| GT-4 | | | | | | | | | 38% | 56% | 6% | 100% |

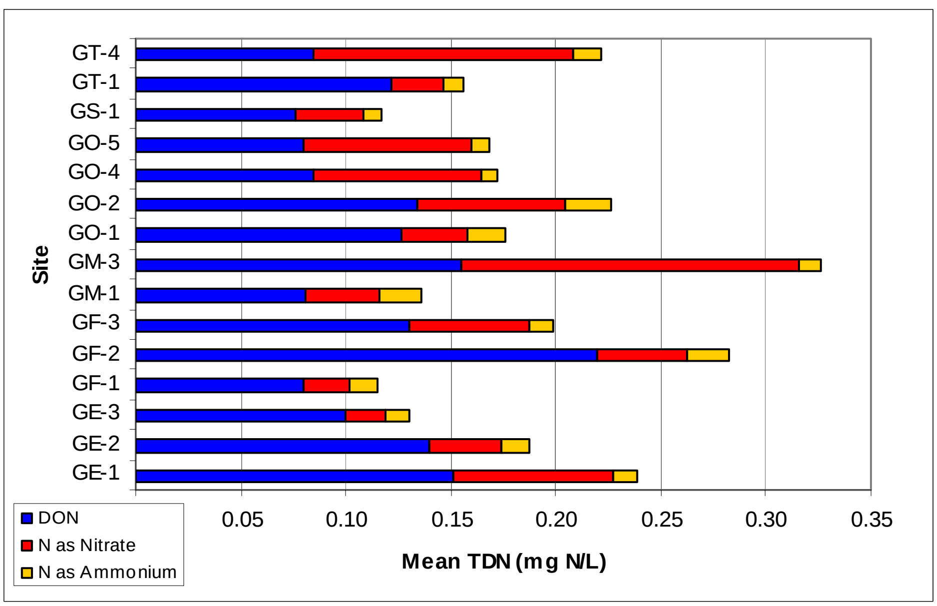


**Figure 38:** Mean TDM concentrations among the RIVERS test sites in 2004 with fractions of DON, nitrate and ammonium shown.

Mean TDN concentrations among the Ossipee Lake tributary sites in 2004, with the exception of Red Brook (OL-7), were relatively low (Table 7 and Figure 39) and ranged from 0.11 mg/L at OL-11 and 2.04 mg/L at OL-3. Highest mean DON concentrations were found at OL-3 (0.69 mg N/L) and OL-7 (0.61 mg N/L) mostly likely due to the wetland input. At all sites in 2004, mean nitrate concentration was less than 0.12 mg N/L. Mean ammonium concentration was less than 0.091 mg N/L at all sites in 2004.

**Table 7:** Nitrogen concentrations for OLT test sites in 2003 and 2004. All concentrations are in mg/L.

| site | 2003 | | | | 2004 | | | |
|---|---|---|---|---|---|---|---|---|
| | DON | Nitrate | $NH_4$ | TDN | DON | Nitrate | $NH_4$ | TDN |
| OL-1 | 0.10 | 0.01 | 0.008 | 0.12 | 0.18 | 0.02 | 0.012 | 0.21 |
| OL-2 | 0.11 | 0.03 | 0.083 | 0.14 | 0.13 | 0.02 | 0.013 | 0.16 |
| OL-3 | 0.21 | 0.03 | 0.017 | 0.25 | 0.65 | 0.02 | 0.016 | 0.69 |
| OL-4 | 0.10 | 0.01 | 0.010 | 0.12 | 0.22 | 0.03 | 0.014 | 0.26 |
| OL-5 | 0.12 | 0.02 | 0.011 | 0.15 | 0.12 | 0.07 | 0.014 | 0.21 |
| OL-6 | 0.11 | 0.04 | 0.020 | 0.17 | 0.28 | 0.05 | 0.008 | 0.34 |
| OL-7 | 0.44 | 0.00 | 0.066 | 0.51 | 0.50 | 0.02 | 0.091 | 0.61 |
| OL-9 | 0.09 | 0.01 | 0.013 | 0.11 | 0.14 | 0.01 | 0.022 | 0.21 |
| OL-10 | 0.12 | 0.00 | 0.023 | 0.15 | 0.14 | 0.01 | 0.013 | 0.16 |
| OL-11 | 0.11 | 0.01 | 0.007 | 0.13 | 0.14 | 0.02 | 0.008 | 0.17 |
| OL-12 | 0.12 | 0.00 | 0.005 | 0.13 | 0.25 | 0.03 | 0.033 | 0.32 |
| OL-13 | 0.07 | 0.01 | 0.026 | 0.10 | 0.44 | 0.03 | 0.029 | 0.50 |
| OL-14 | 0.14 | 0.00 | 0.009 | 0.15 | 0.22 | 0.12 | 0.029 | 0.37 |

**Table 8:** Percentages of Nitrogen Concentrations of Total Dissolved Nitrogen in OLT test sites in 2003 and 2004.

| site | 2003 | | | | 2004 | | | |
|---|---|---|---|---|---|---|---|---|
| | DON | Nitrate | $NH_4$ | TDN | DON | Nitrate | $NH_4$ | TDN |
| OL-1 | 84% | 9% | 7% | 100% | 84% | 11% | 5% | 100% |
| OL-2 | 77% | 18% | 60% | 155% | 80% | 12% | 8% | 100% |
| OL-3 | 82% | 11% | 7% | 100% | 94% | 3% | 2% | 100% |
| OL-4 | 82% | 10% | 8% | 100% | 83% | 11% | 6% | 100% |
| OL-5 | 79% | 13% | 7% | 100% | 58% | 35% | 7% | 100% |
| OL-6 | 66% | 22% | 12% | 100% | 83% | 15% | 2% | 100% |
| OL-7 | 87% | 0% | 13% | 100% | 82% | 3% | 15% | 100% |
| OL-9 | 81% | 8% | 11% | 100% | 67% | 6% | 10% | 83% |
| OL-10 | 82% | 2% | 16% | 100% | 89% | 3% | 8% | 100% |
| OL-11 | 90% | 5% | 5% | 100% | 84% | 12% | 5% | 100% |
| OL-12 | 93% | 3% | 4% | 100% | 80% | 10% | 10% | 100% |
| OL-13 | 67% | 12% | 25% | 104% | 89% | 5% | 6% | 100% |
| OL-14 | 92% | 2% | 6% | 100% | 59% | 33% | 8% | 100% |

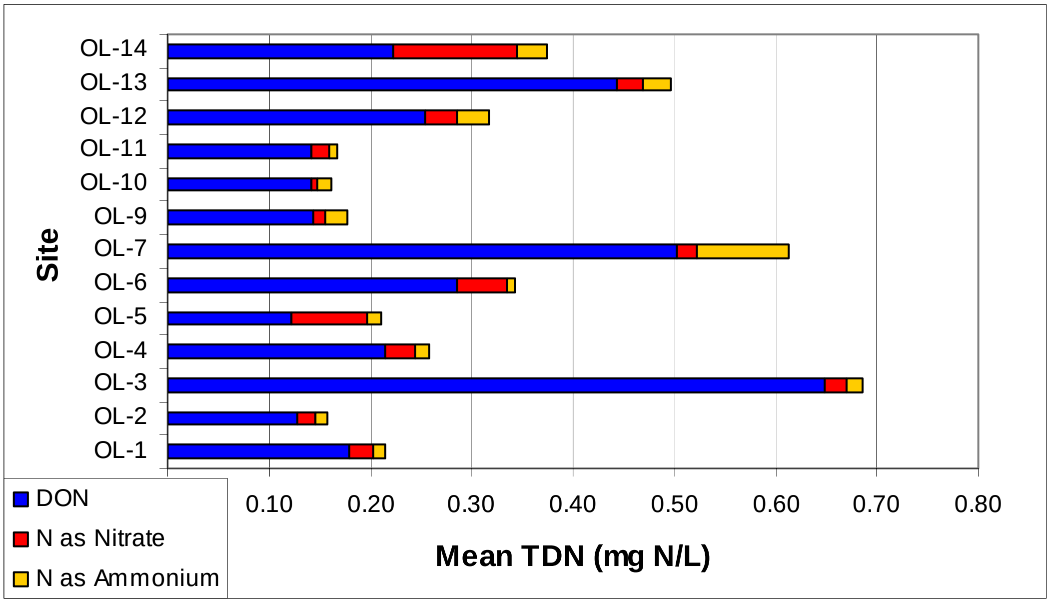


**Figure 39:** Mean TDN concentrations among the OLT test sites in 2004 with fractions of DON, nitrate and ammonium shown.

Mean DON comprised more than 58% of the mean TDN at all sites (Table 8, Figure 39). Mean nitrate accounted for less than 35% of the mean TDN at all sites and mean ammonium concentration was less than 15% at all sites in 2004. In 2003, OL-2 appeared to be impaired due to a large percentage of ammonium; however these percentages added up to over 100 %, which could indicate a lab error. Ammonium only counted for 8% of the total dissolved oxygen in 2004, which also confirms either one time impairment or an error.

### 3. 10 Dissolved Organic Matter

The regression line in Figure 40 does not seem to represent a strong linear relationship between DOC and DON in the 2004 RIVERS sites. There is scatter around the line indicating that it may not be possible to accurately infer one from the other. By examining the linear regression in Figure 41, it also does not appear that there is a strong linear relationship among the Ossipee Lake tributary sites in 2004.

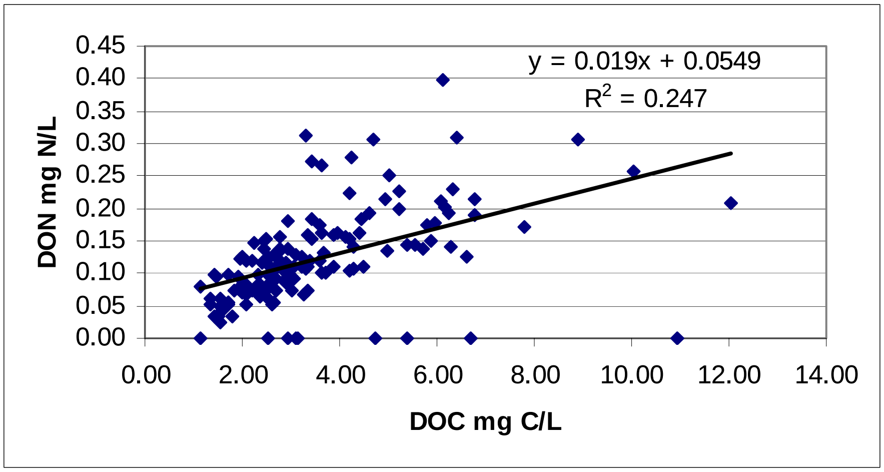


**Figure 40:** The relationship between dissolved organic nitrogen and dissolved organic carbon for RIVERS test sites during the 2004 sampling season.

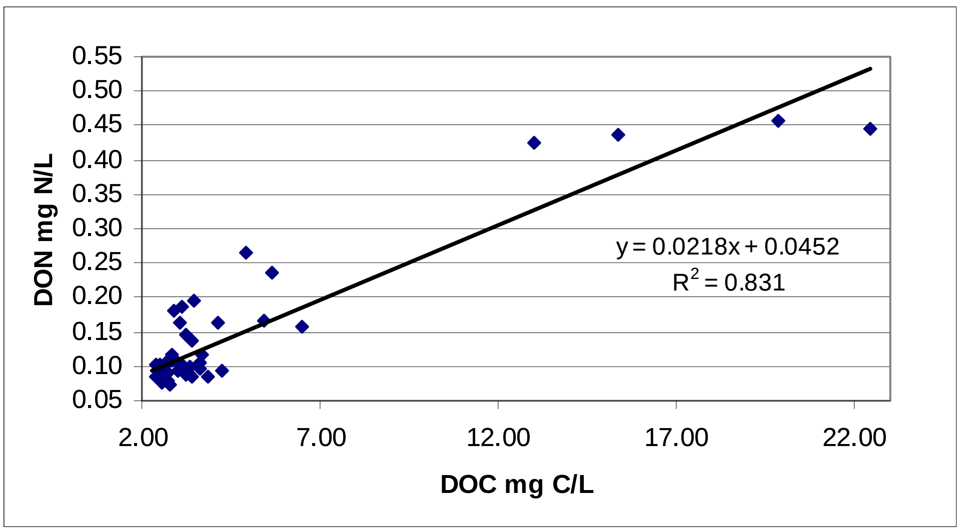


**Figure 41:** The relationship between dissolved organic nitrogen and dissolved organic carbon for OLT test sites during the 2004 sampling season.

### 3.11 Sodium and Chloride

Sodium and chloride are typically related to each other. The linear regression line in Figure 42 appears to represent a strong linear relationship between sodium and chloride in the 2004 RIVERS sites ($R^2$=0.9569).

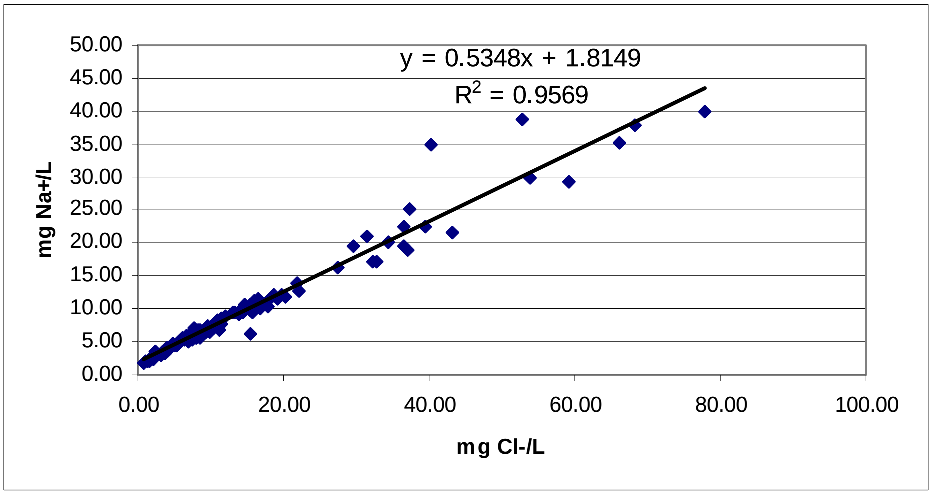


**Figure 42:** The relationship between sodium and chloride concentrations for RIVERS test sites, 2004.

Mean sodium concentration among the 2004 RIVERS sites were below 12 mg/L except for GM-1 (18.80 mg/L) and GO-2 (29.25 mg/L) (Figure 43). Mean chloride concentrations among the 2004 RIVERS sites were less than 20 mg/L at all sites except for GM-1 (34.16 mg/L) and GO-2 (47.90 mg/L) (Figure 44). Elevated sodium and chloride concentrations could indicate contamination from road salt application. Trends observed in 2002 and 2003 were similar (Figure 25 and 26).

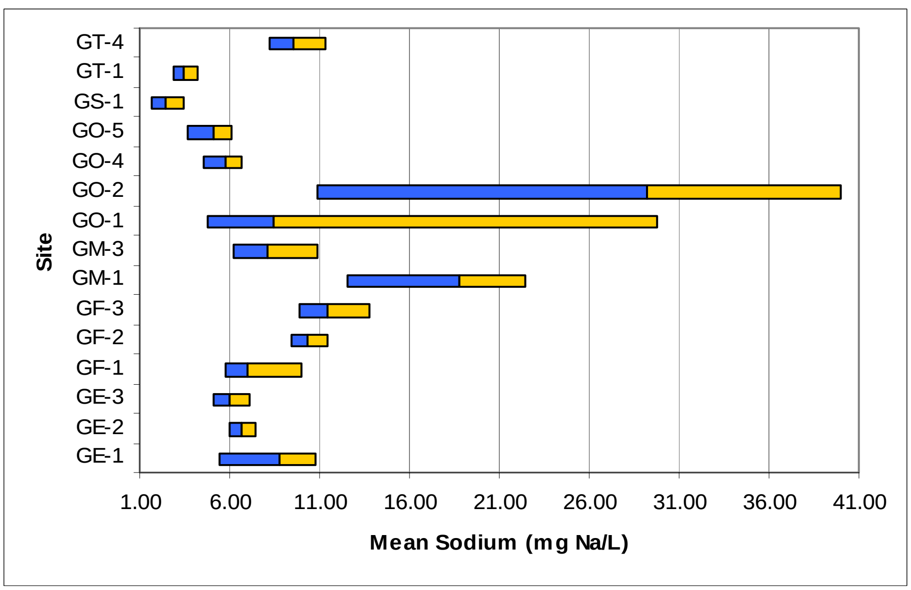


**Figure 43:** 2004 RIVERS site sodium comparison. Bars show range of sodium concentrations. Darker bars show range less than the mean. Lighter bars show range greater than the mean. Mean value is at point where dark and light bars meet.

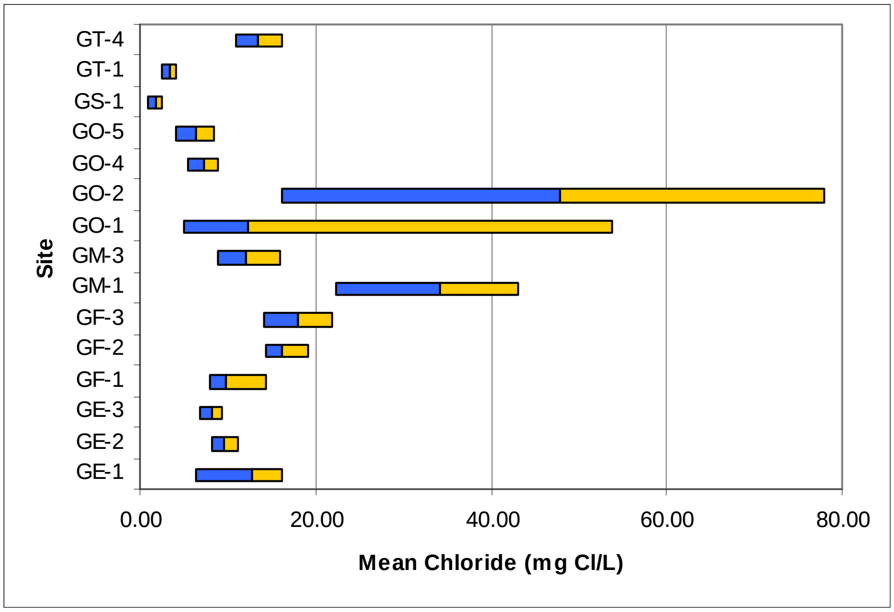


**Figure 44:** 2004 RIVERS site chloride comparison. Bars show range of chloride concentrations. Darker bars show range less than the mean. Lighter bars show range greater than the mean. Mean value is at point where dark and light bars meet.

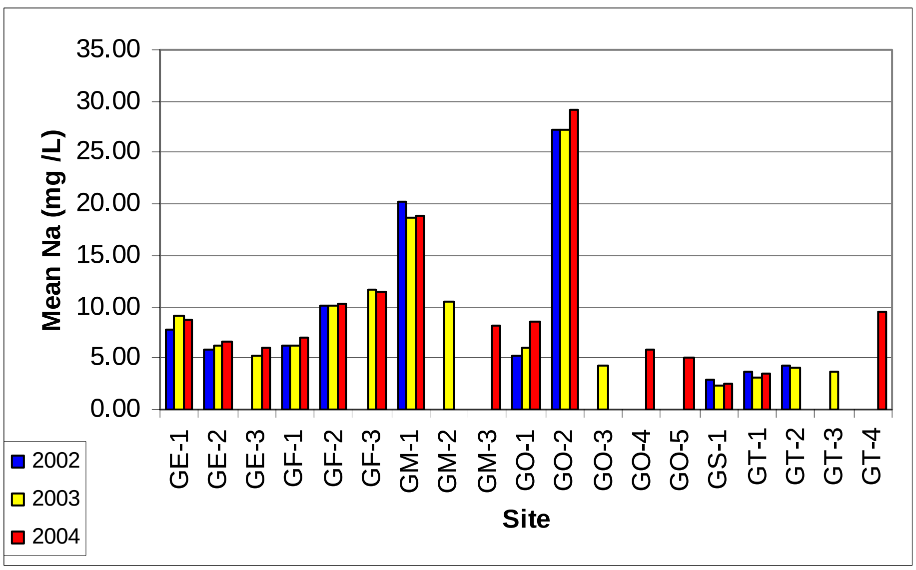


**Figure 45:** RIVERS site sodium comparison for 2002, 2003, and 2004. Bars show yearly mean chloride concentrations.

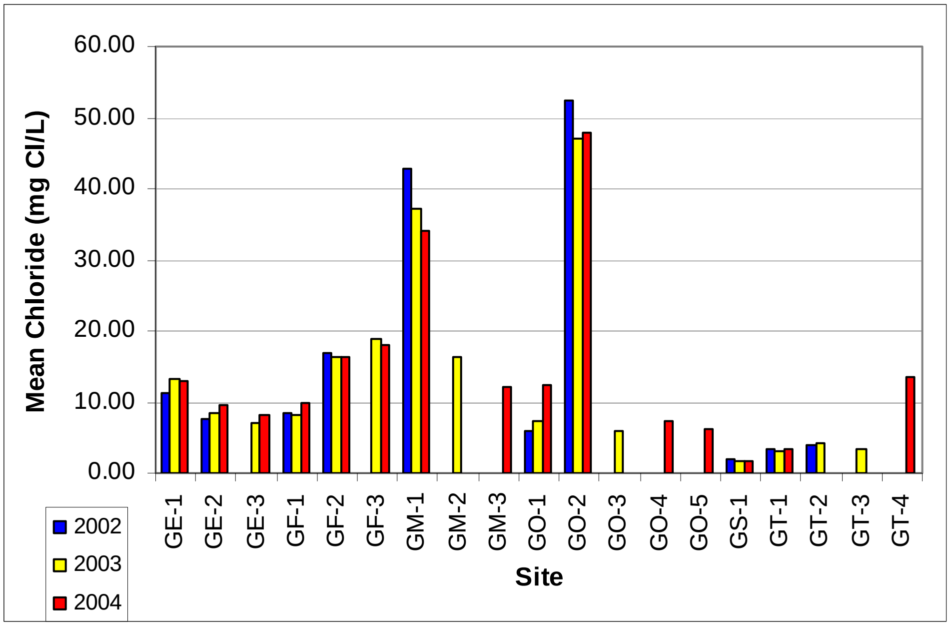


**Figure 46:** RIVERS site chloride comparison for 2002, 2003, and 2004. Bars show yearly mean chloride concentrations.

Sodium and chloride were strongly related to each other in the Ossipee Lake tributary sites in 2004 ($R^2$= 0.9786) (Figure 47). Sodium concentration among the 2004 OLT sites ranged from 2.30 mg Na/L at site OL-7 to 19.92 mg Na/L at OL-14 (Figure 48). Chloride concentration ranged from 0.58 mg Cl/L at OL-7 and 42.09 mg Cl/L at OL-14 (Figure 49).

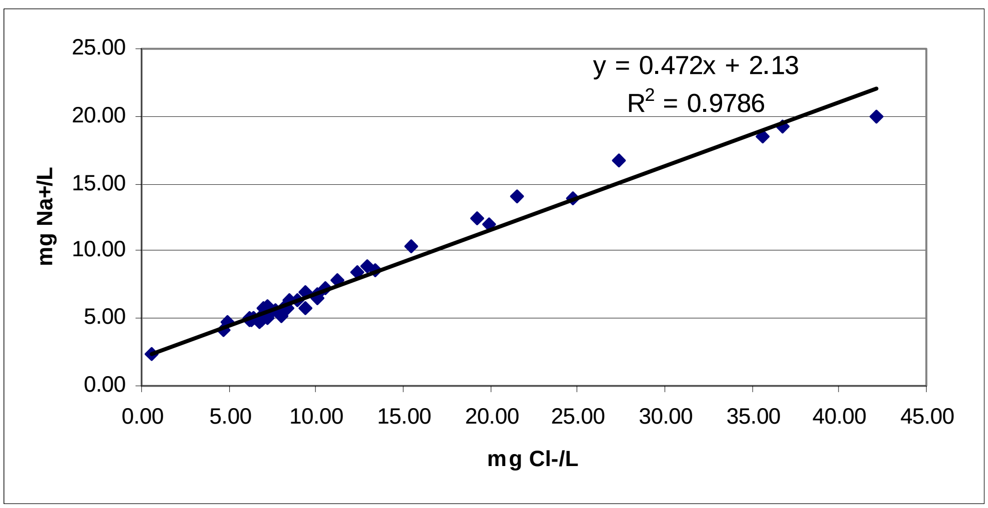


**Figure 47:** The relationship between sodium and chloride concentrations for OLT test sites, 2004.

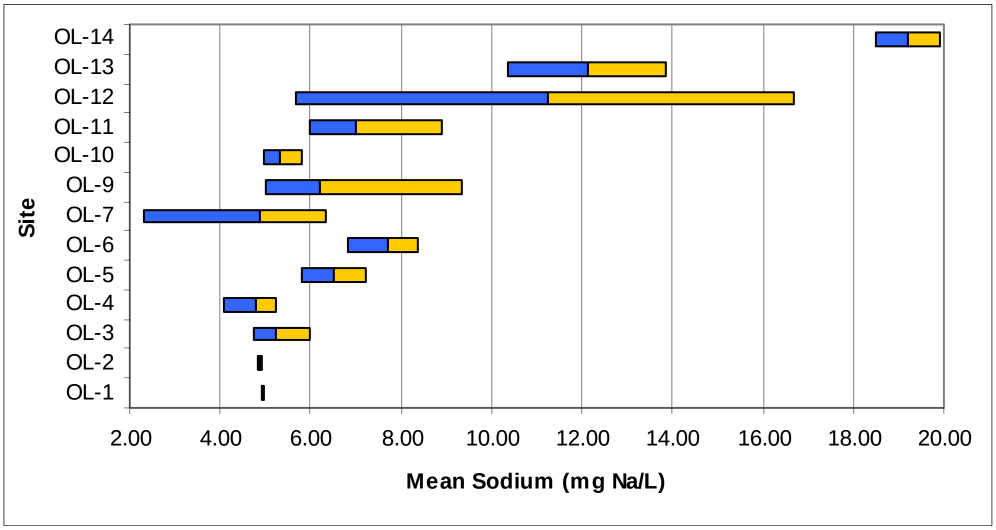


**Figure 48:** 2004 OLT site sodium comparison. Bars show range of sodium concentrations. Darker bars show range less than the mean. Lighter bars show range greater than the mean. Mean value is at point where dark and light bars meet.

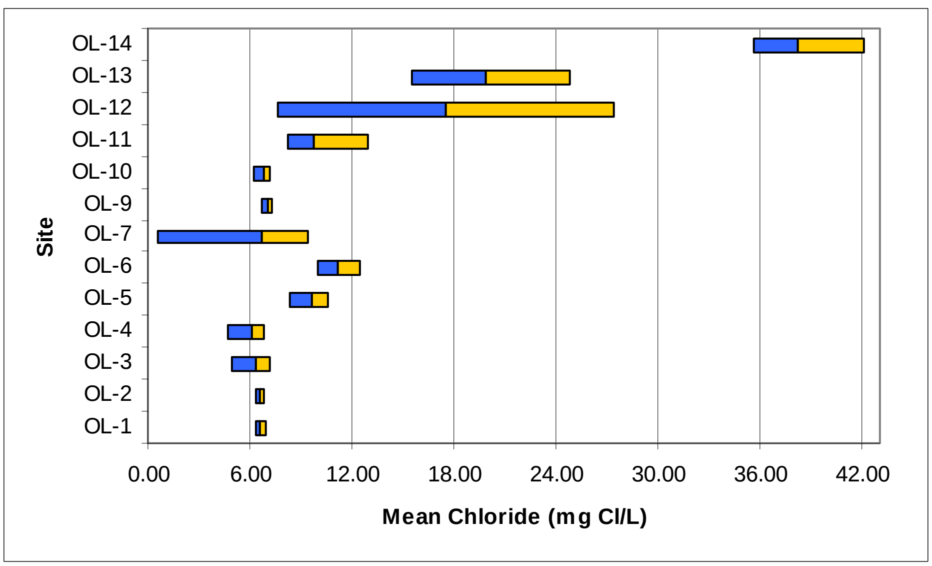


**Figure 49:** 2004 OLT site chloride comparison. Bars show range of chloride concentrations. Darker bars show range less than the mean. Lighter bars show range greater than the mean. Mean value is at point where dark and light bars meet.

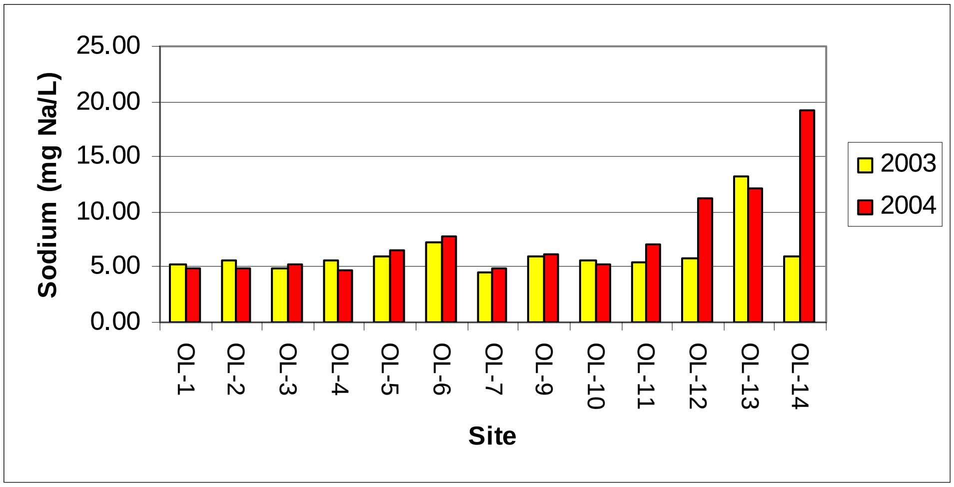


**Figure 50:** OLT site sodium comparison for 2003 and 2004. Bars show yearly mean chloride concentrations.

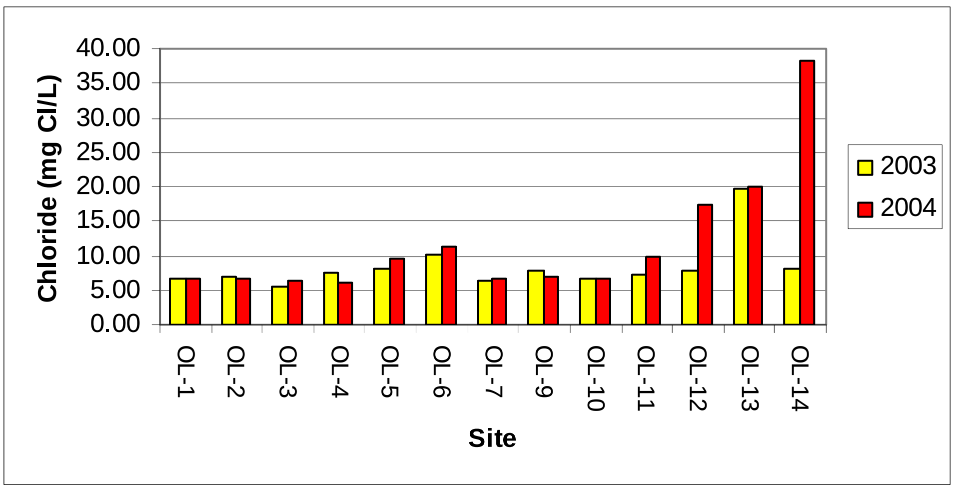


**Figure 51:** OLT site chloride comparison for 2003 and 2004. Bars show yearly mean chloride concentrations.

2004 OLT sodium and chloride levels were similar to 2003 levels at all sites except for OL-12 and OL-14 (Figure 50 and 51). This could be due to site locations being located further upstream in 2004 than in 2003.

### 3.12 Sulfate

Sulfate concentrations among the 2004 RIVERS sites ranged from 0.41 mg S/L at GO-1 to 3.56 mg S/L at GO-5 (Figure 52). Sulfate concentrations were mostly higher in 2004 than in 2003 and lower than 2002 (Figure 53). The peak in sulfate levels in 2003 at GF-3 was not found in 2004 suggesting that this was a one time event.

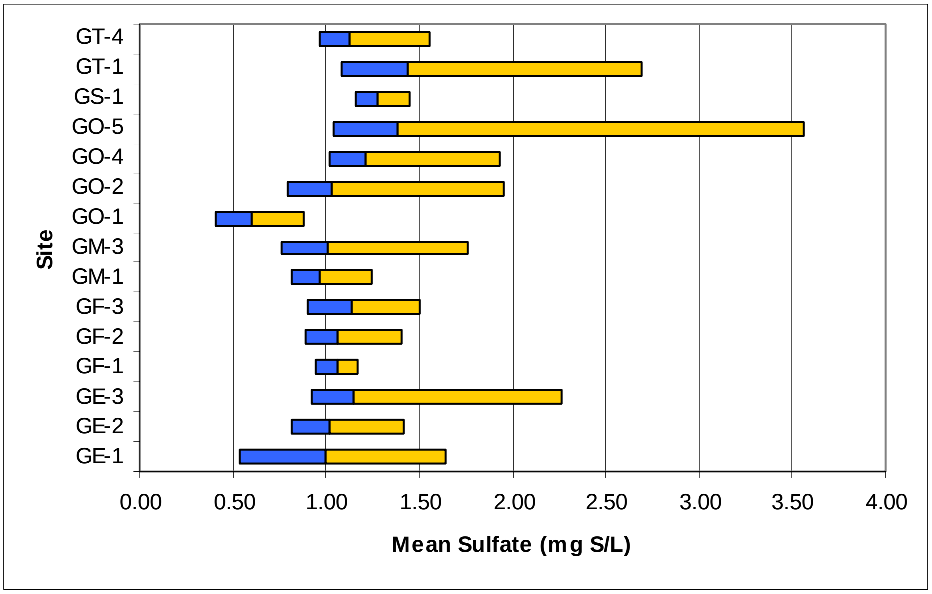


**Figure 52:** 2004 RIVERS site sulfate comparison. Bars show range of sulfate concentrations. Darker bars show range less than the mean. Lighter bars show range greater than the mean. Mean value is at point where dark and light bars meet.

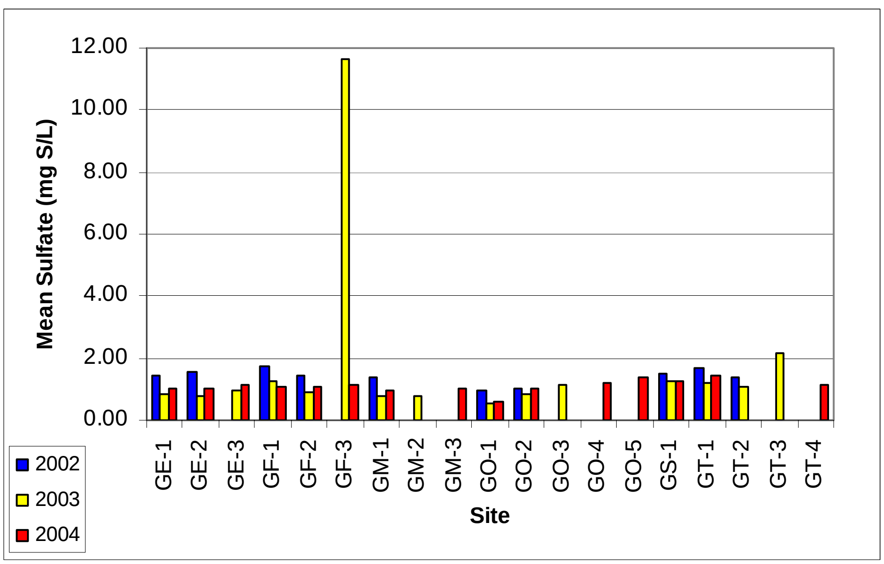


**Figure 53:** RIVERS site sulfate comparison for 2002, 2003, and 2004.

Sulfate concentrations among the 2004 OLT sites ranged from 0.05 mg S/L at OL-7 and 2.12 mg S/L at OL-9 (Figure 54). Similar to 2004 RIVERS sites, 2004 OLT sulfate levels were mostly higher than 2003 levels (Figure 55).

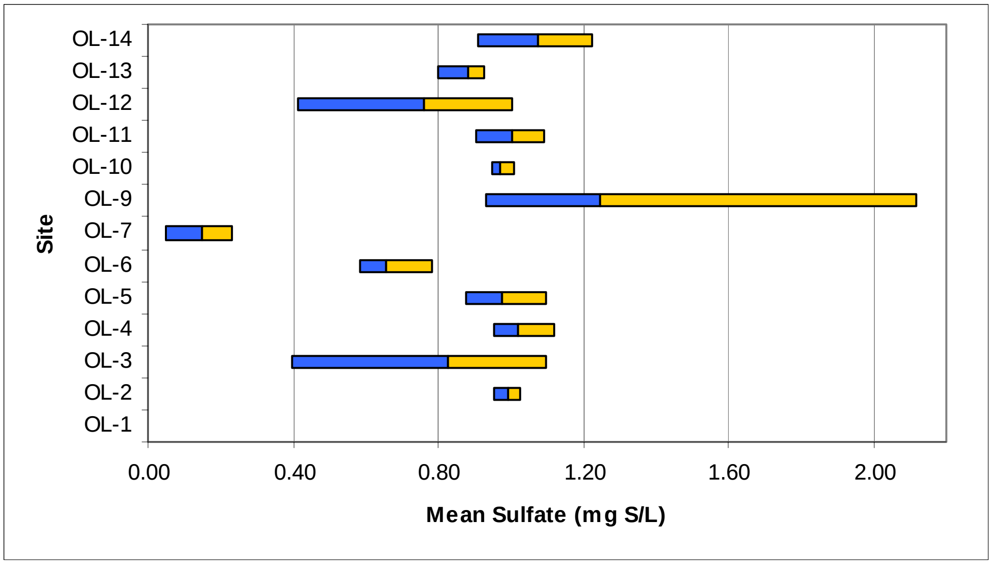


**Figure 54:** 2004 OLT site sulfate comparison. Bars show range of sulfate concentrations. Darker bars show range less than the mean. Lighter bars show range greater than the mean. Mean value is at point where dark and light bars meet.

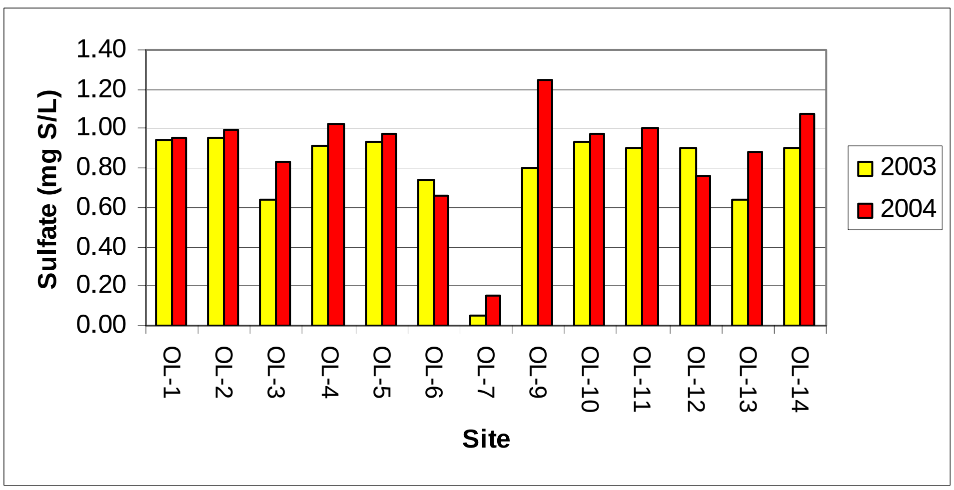


**Figure 55:** OLT site sulfate comparison for 2003 and 2004.

### 3.13 Silica

In the 2004 RIVERS sites, silica concentrations ranged from 0.00 mg $SiO_2$/L at GE-1 to 11.57 mg $SiO_2$/L at GF-3 (Figure 56). Mean silica concentrations in 2004 were doubled at all sites in comparison to 2003 and were higher than 2002 levels (Figure 57). These sites most likely received more of their flow from groundwater during 2004 due to the decrease in precipitation.

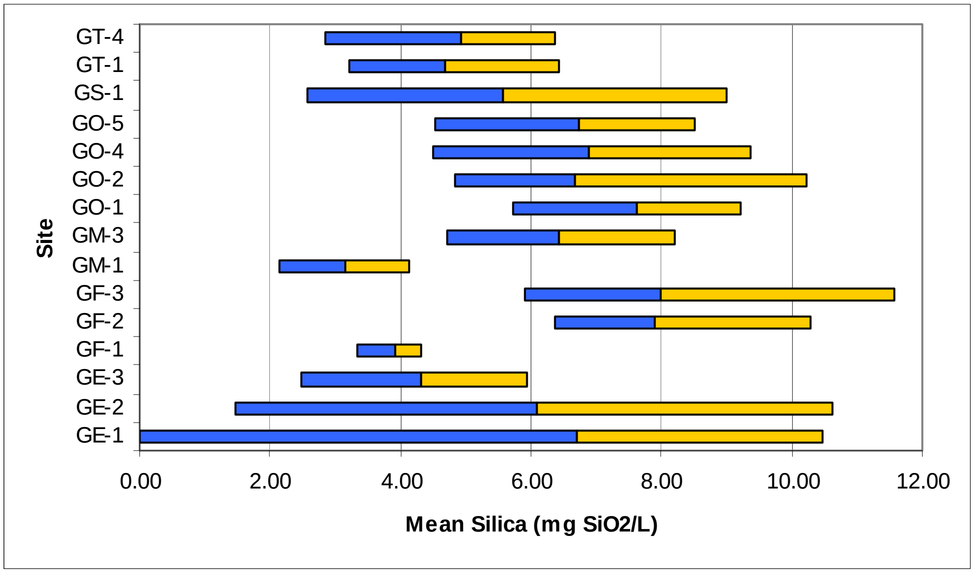


**Figure 56:** 2004 RIVERS site silica comparison. Bars show range of silica concentrations. Darker bars show range less than the mean. Lighter bars show range greater than the mean. Mean value is at point where dark and light bars meet.

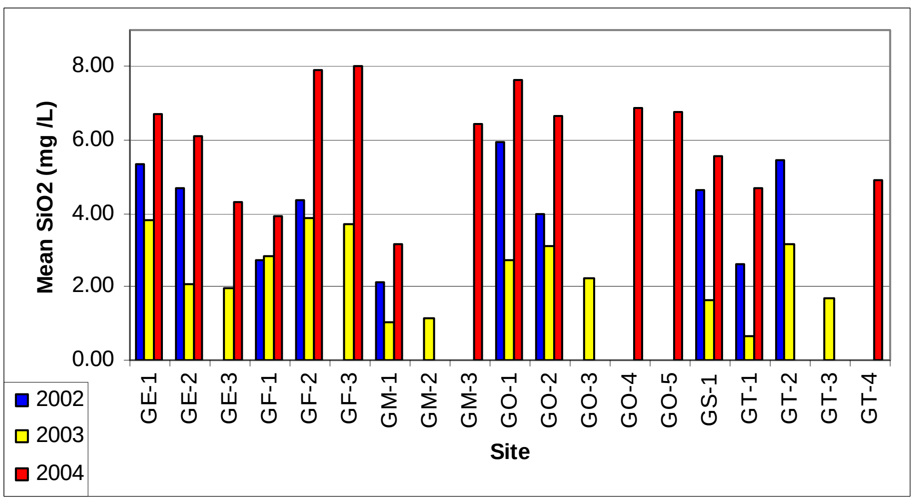


**Figure 57:** RIVERS site silica comparison for 2002, 2003, and 2004.

In the 2004 Ossipee Lake tributary sites, silica concentrations ranged from zero at most sites to 8.62 mg $SiO_2$/L at OL-13 (Figure 58). All sites, except for OL-7, had mean silica concentrations of greater than 2.58 mg $SiO_2$/L. The highest mean silica levels were found at OL-13 (6.08 mg $SiO_2$/L) and OL-14 (6.18 mg $SiO_2$/L). These sites may get more of their flow from groundwater sources. Most OLT sites in 2004 experienced higher levels of silica than 2003 (Figure 59). This could be attributed to higher amounts of groundwater input due to lower precipitation in 2004.

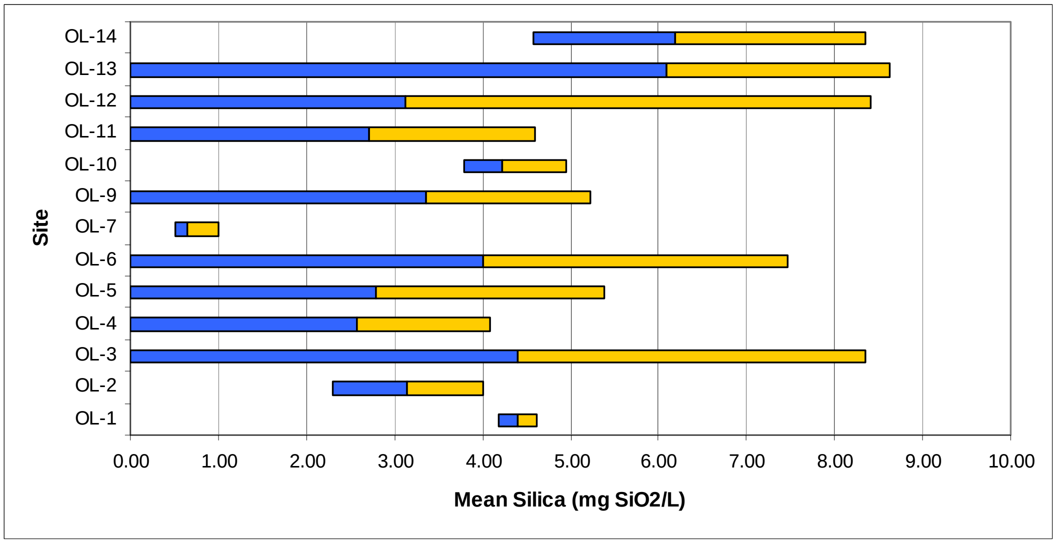


**Figure 58:** 2004 OLT site silica comparison. Bars show range of silica concentrations. Darker bars show range less than the mean. Lighter bars show range greater than the mean. Mean value is at point where dark and light bars meet.

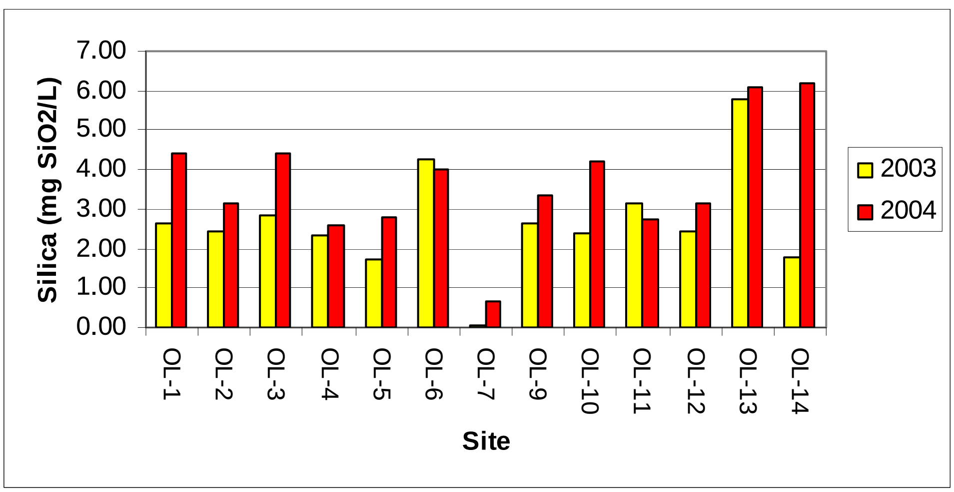


**Figure 59:** OLT site silica comparison for 2003 and 2004.

### 3.14 Potassium

Potassium concentrations among the 2004 RIVERS sites ranged from 0.35 mg K/L at GS-1 to 2.55 mg K/L at GO-2 (Figure 60). Mean potassium concentrations in 2004 were similar to those in 2003 and 2002 among the RIVERS sites (Figure 61).

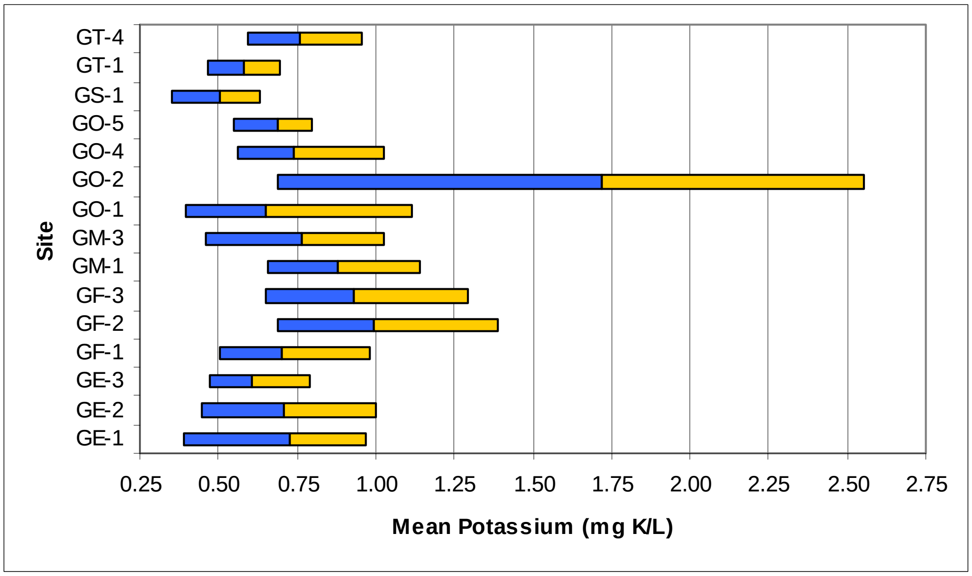


**Figure 60:** 2004 RIVERS site potassium comparison. Bars show range of potassium concentrations. Darker bars show range less than the mean. Lighter bars show range greater than the mean. Mean value is at point where dark and light bars meet.

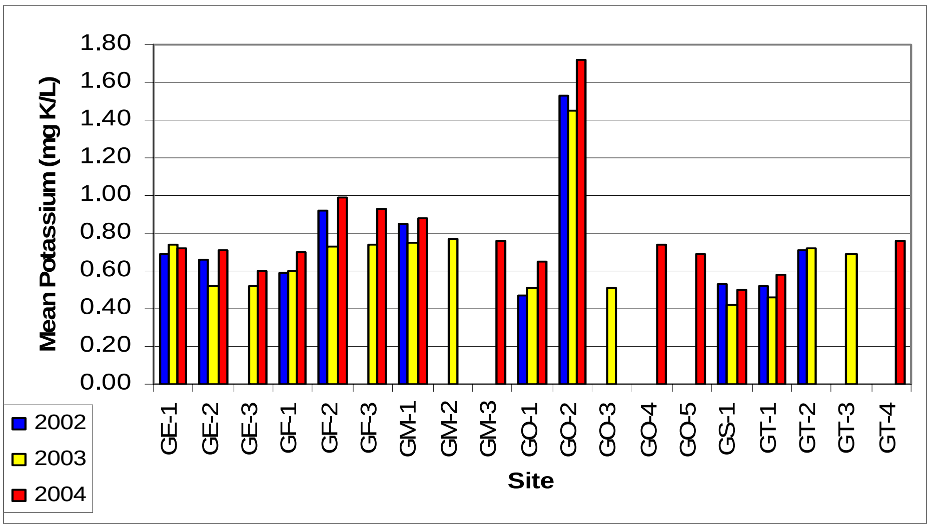


**Figure 61:** RIVERS site potassium comparison for 2002, 2003, and 2004.

Potassium concentrations among the 2004 OLT sites ranged from 0.21 mg K/L at OL-7 to 1.21 mg K/L at OL-14 (Figure 62). 2004 OLT average potassium concentrations were similar to 2003 levels, except at OL-14, which had a slightly higher concentration (Figure 63). This could be attributed to a change in site location between the two years.

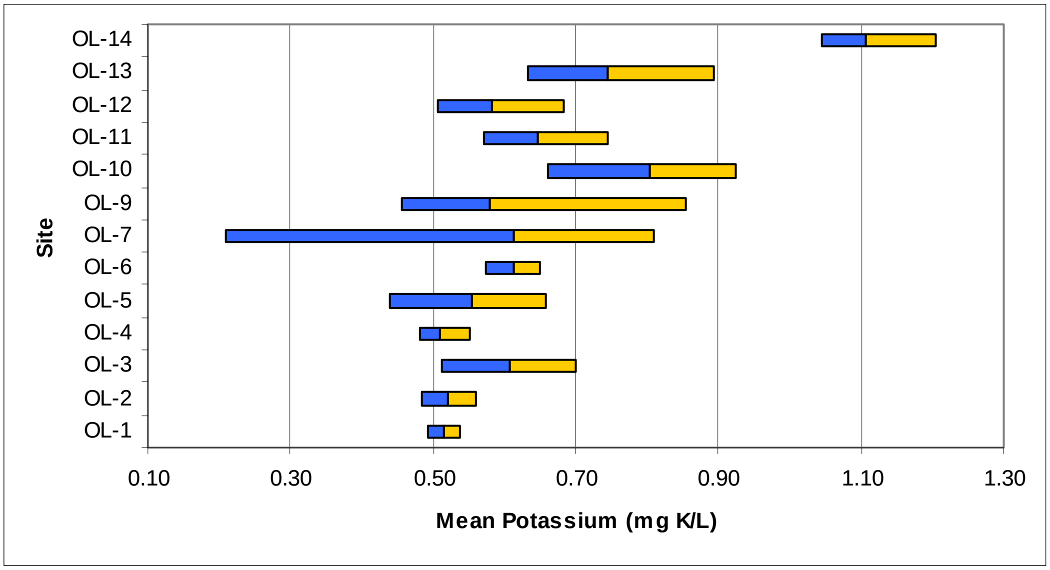


**Figure 62:** 2004 OLT site potassium comparison. Bars show range of potassium concentrations. Darker bars show range less than the mean. Lighter bars show range greater than the mean. Mean value is at point where dark and light bars meet.

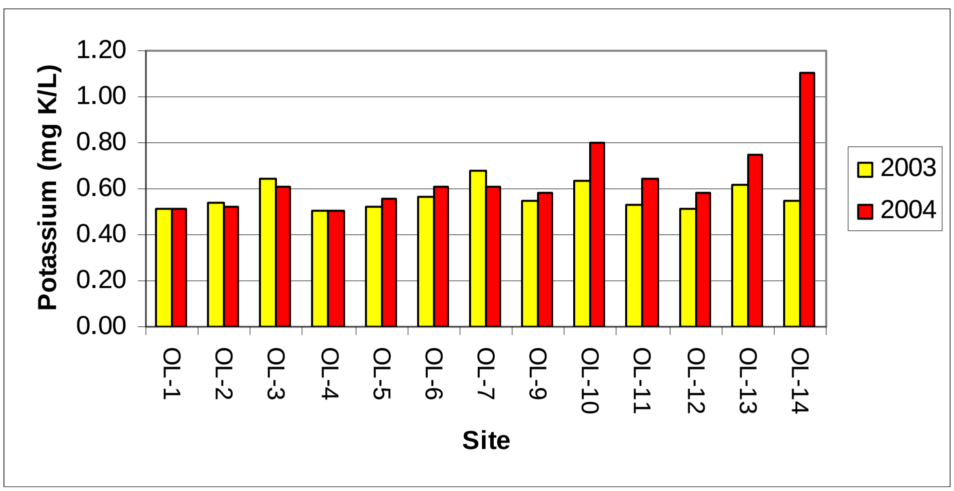


**Figure 63:** OLT site potassium comparison for 2003 and 2004.

## 3.15 Calcium and Magnesium

In the 2004 RIVERS sites, calcium concentration ranged from 1.89 mg/L at GS-1 to 7.16 mg/L at GO-2 (Figure 64) and magnesium concentrations ranged from 0.35 mg/L at GT-4 to 1.31 mg/L at GF-3 (Figure 65). Both calcium and magnesium 2004 mean concentrations were similar to 2003 and 2002 concentrations (Figures 66 and 67).

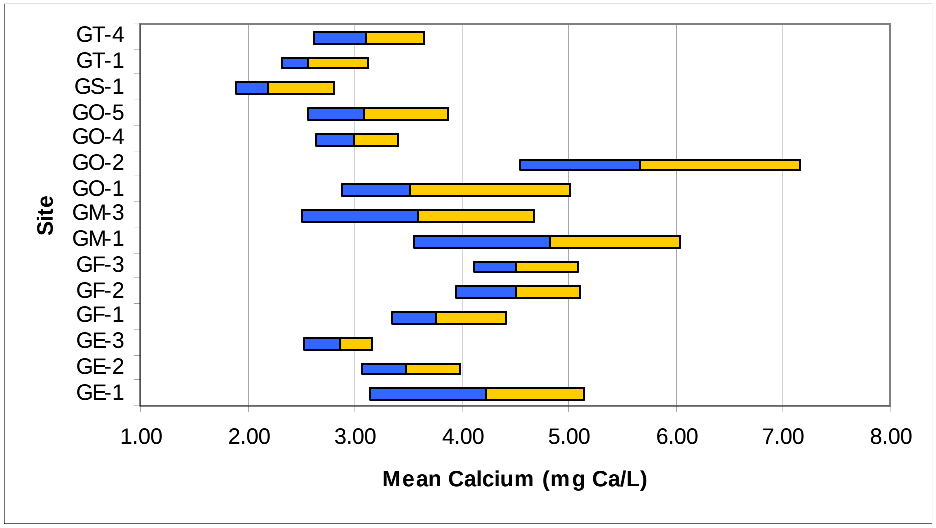


**Figure 64:** 2004 RIVERS site calcium comparison. Bars show range of calcium concentrations. Darker bars show range less than the mean. Lighter bars show range greater than the mean. Mean value is at point where dark and light bars meet.

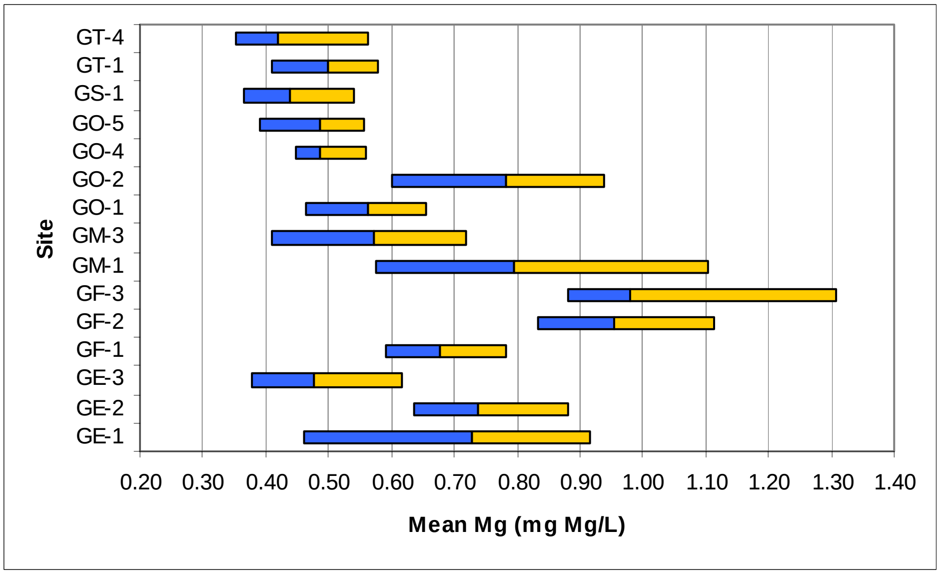


**Figure 65:** 2004 RIVERS site magnesium comparison. Bars show range of magnesium concentrations. Darker bars show range less than the mean. Lighter bars show range greater than the mean. Mean value is at point where dark and light bars meet.

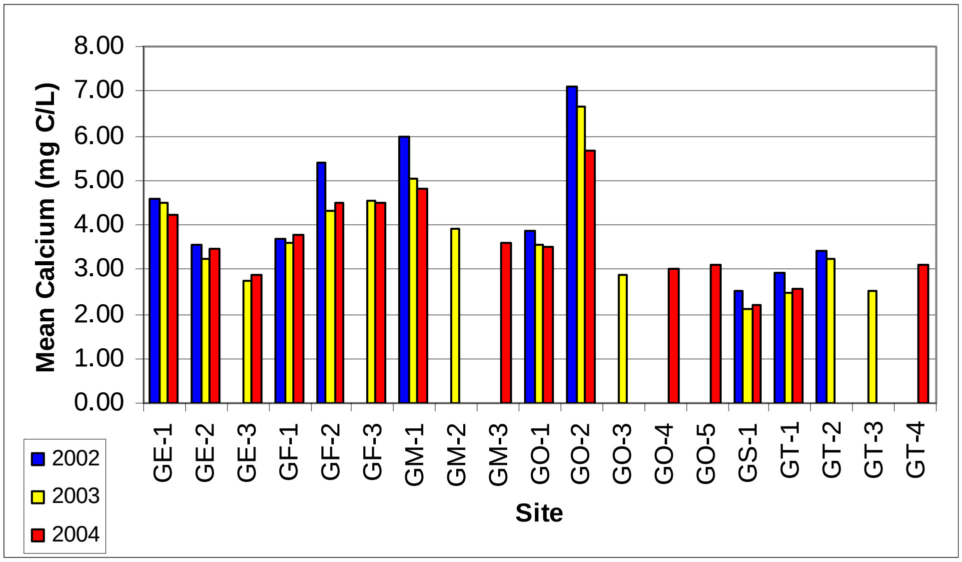


**Figure 66:** RIVERS site calcium comparison for 2002, 2003, and 2004.

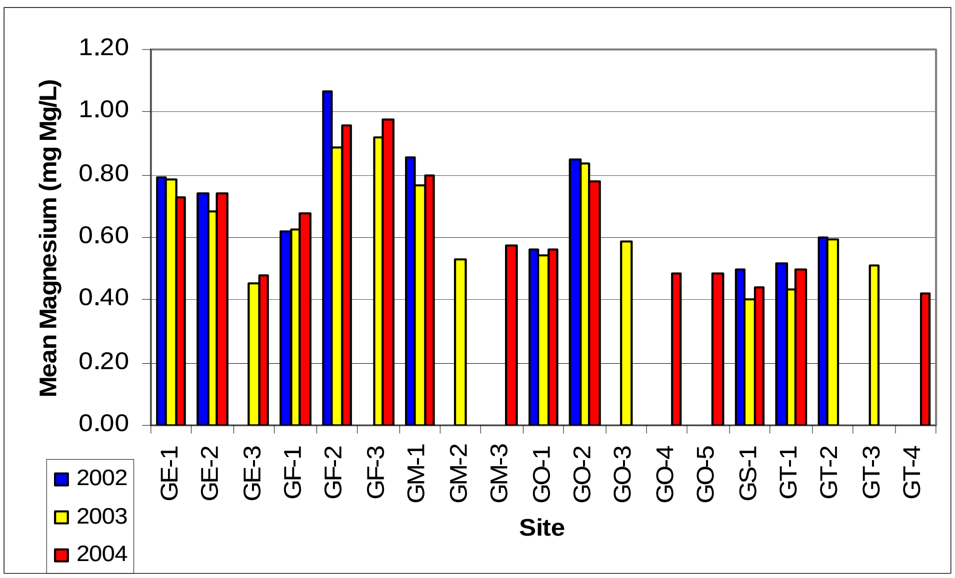


**Figure 67:** RIVERS site magnesium comparison for 2002, 2003, and 2004.

In the 2004 Ossipee Lake tributary sites, calcium concentration ranges from 2.42 mg/L at OL-1 to 7.80 mg/L at OL-14 (Figure 68) and magnesium concentrations ranged from 0.37 mg/L at OL-4 and OL-9 to 1.39 mg/L at OL-14 (Figure 69). 2004 OLT calcium and magnesium levels were similar to those in 2003, except at OL-14, which could be attributed to a change in site location (Figures 70 and 71).

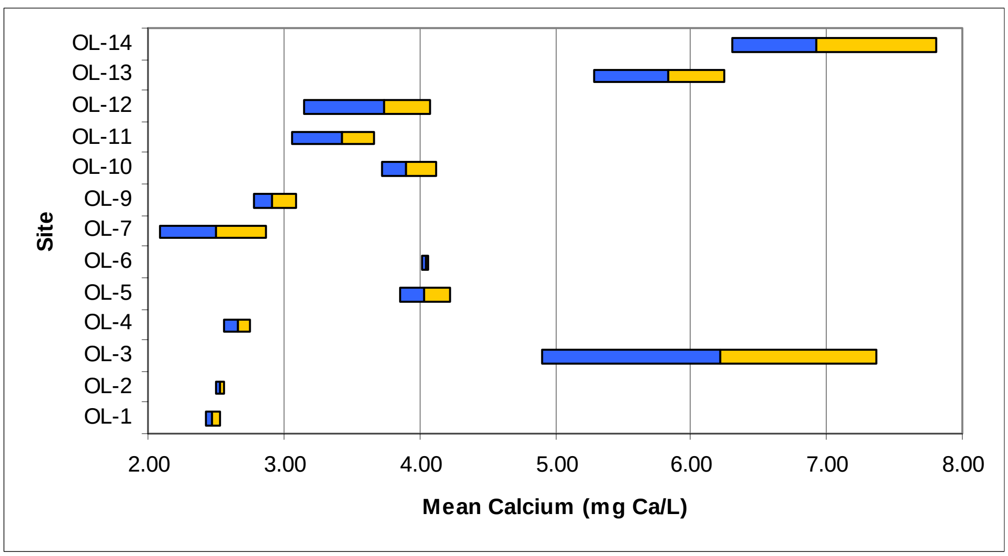


**Figure 68:** 2004 OLT site calcium comparison. Bars show range of calcium concentrations. Darker bars show range less than the mean. Lighter bars show range greater than the mean. Mean value is at point where dark and light bars meet.

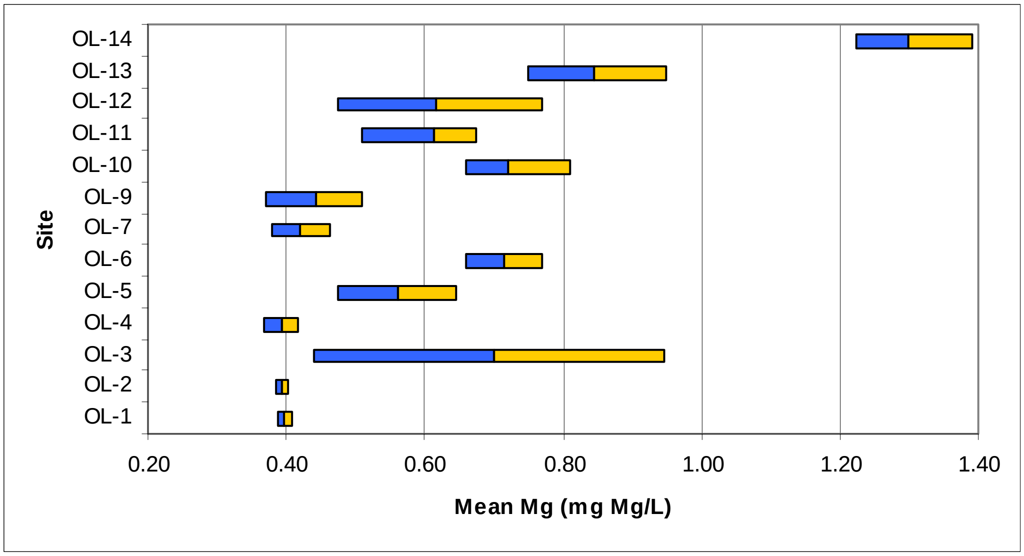


**Figure 69:** 2004 OLT site magnesium comparison. Bars show range of magnesium concentrations. Darker bars show range less than the mean. Lighter bars show range greater than the mean. Mean value is at point where dark and light bars meet.

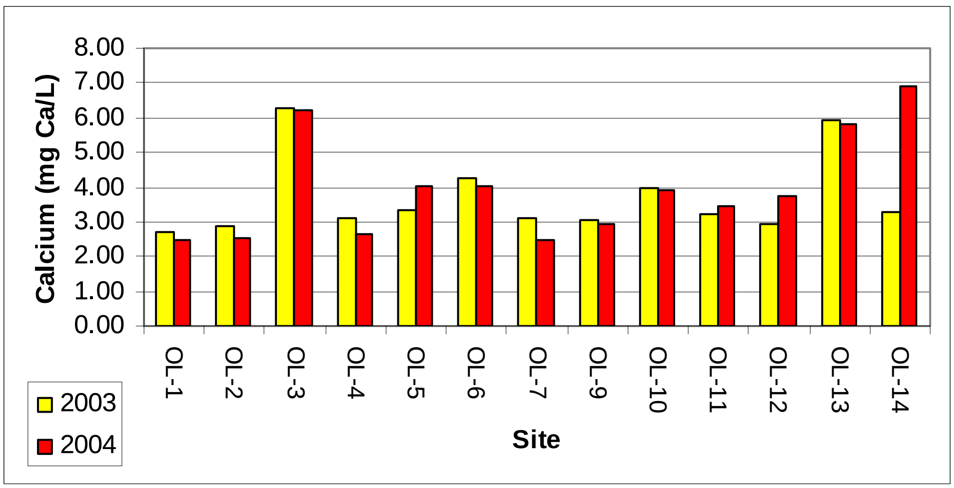


**Figure 70:** OLT site calcium comparison for 2003 and 2004.

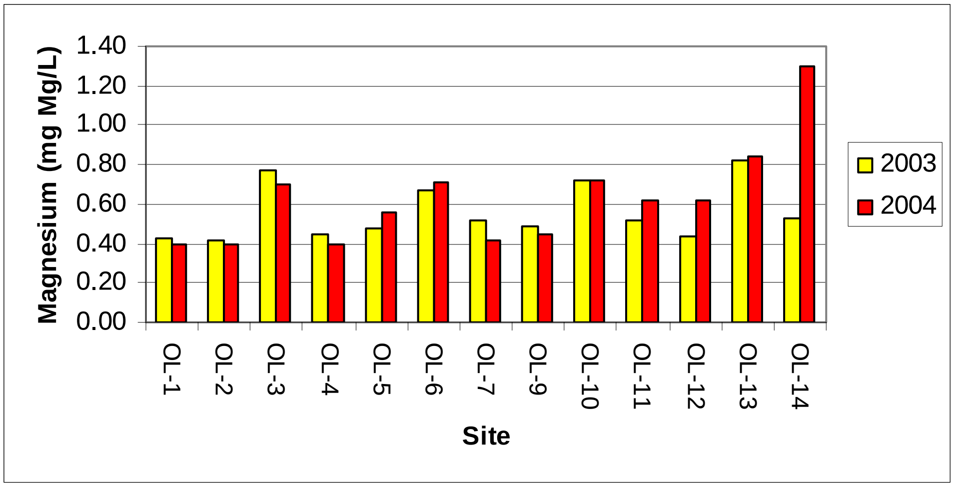


**Figure 71:** OLT site magnesium comparison for 2003 and 2004.

### 3.16 Relative RIVERS Site Summaries

**GE-1 Pine River, Elm Street, Effingham**

GE-1 exhibited high levels of silica. In 2004, silica levels were higher than 2002 and 2003 across the watershed due to less precipitation than both years which increased ground water input. 2004 silica levels at GE-1 were one of the highest of all the test sites. This may indicate that the Pine River receives a lot of input from groundwater flow. Indeed, the aquifer is at its closest point to the surface near this site. In addition, dissolved organic carbon levels were again relatively high at GE-1 indicating there is more decomposition at this site and possibly wetland input. However, dissolved organic nitrogen levels were not high in the 2004 season as was noted in 2003.

**GE-2 South River, Plantation Road, Parsonsfield, ME**

GE-2 also exhibited elevated levels of silica indicating more groundwater input with reduced precipitation in 2004. Dissolved organic carbon concentrations remained elevated as well.

**GE-3 Ossipee River, Effingham Falls**

Similar results were found in 2004 as in 2003 at GE-3. Just below the Ossipee Lake impoundment the Ossipee River has low turbidity and higher temperatures. These are most likely due to the lake water that flows through this site. The top layer of the lake is predominantly the layer that flows over the dam and into the Ossipee River. This layer typically has warmer temperature and lower turbidity.

**GF-1 Danforth Brook, Ossipee Lake Road, Freedom**

Similarly to 2003, Danforth Brook in 2004 was characterized by some of the highest temperatures in the watershed. This could be explained by the high temperatures in Danforth Pond. Danforth Pond had the highest temperatures of all the Ossipee Lake water bodies sampled in the Ossipee Lake Protection Program. Danforth Brook also showed high pH which was consistent with the high pH found in Danforth Pond.

**GF-2 Cold Brook, Maple Street, Freedom**

GF-2 exhibited the highest silica levels in the watershed in 2004 indicating groundwater input. Upstream of the sampling site, large, minimally moving wetland flows into Mill Pond that could have a large groundwater input. This could also explain the high dissolved organic nitrogen levels found in 2004 as well. In addition, total phosphorus levels were elevated in 2004.

**GF-3 Cold Brook, Loon Lake inlet, Freedom**

In 2003, GF-3 exhibited some of the highest sulfate levels in the watershed. However, this was not the case in 2004. This site also experienced a large increase in silica levels with the reduced precipitation in 2004.

**GM-1 Banfield Brook, Route 113, Madison**

As was seen in 2003, sodium and chloride levels were high at this site, potentially indicating road salt influence. Total phosphorus surges were not seen in 2004 as in 2003.

**GM-3 Forrest Brook, Rt. 113, Madison**
This site is very well shaded by the upper canopy and had the lowest mean temperature of all of the RIVERS sites. It also had high levels of silica indicating groundwater input. However, as with all of the new sites in 2004, the dissolved inorganic nitrogen dominated the total dissolved nitrogen, indicating impairment.

**GO-1 Beech River, Tuftonboro Road, Ossipee**
GO-1 silica levels were tripled in 2004 in comparison to 2003 levels most likely due to increased groundwater inflow due to a decrease in precipitation. Mean silica levels at GO-1 in 2003 were less than half of the values in 2002. It could be assumed that GO-1 was receiving a higher amount of groundwater inflow in 2002 than 2003. This could be due to increased precipitation levels in 2003.

**GO-2 Frenchman Brook, White Pond Road, Ossipee**
In 2002 and 2003, this site was identified as impaired due to several factors. First, dissolved inorganic nitrogen was high relative to the total dissolved nitrogen. Calcium, magnesium, sodium and chloride levels were also high. In 2004, calcium, magnesium, sodium, and chloride were again found to be elevated. In addition, the dissolved inorganic nitrogen was high relative to total dissolved nitrogen. This may indicate that this apparent impairment was not just single year event. In year past dumping has been recorded upstream. This year dumping occurred on numerous occasions at the site throughout the summer and volunteers helped clean up the site (Figure 72 and 73) Site GO-3 was added upstream in Frenchman Brook in an attempt to pinpoint the disturbance; however this site was discontinued due to its intermittent flow. More work should be done to locate a better upstream site.

**Figure 72. GO-1 trash**

**Figure 73. GO-1 trash in volunteers truck**

**GO-4 Bearcamp River, UNH property, Newman Drew Rd., Ossipee**
High silica levels at this site indicated a significant amount of groundwater input. There is some indication of impairment at this site as dissolved inorganic nitrogen dominated

the total dissolved nitrogen. This was a new site in 2004. Future testing will help determine if this is a common theme for this site.

**GO-5 Bearcamp River, Whittier Bridge, Ossipee**
Similarly to GO-4, this site as experience high levels of silica and the dissolved inorganic nitrogen dominated the total dissolved nitrogen. This also was a new site in 2004 and continued testing will help develop a baseline for this site.

**GS-1 Cold River, Route 113, Sandwich**
With its low nutrient concentration, temperature, and turbidity and high dissolved oxygen concentration, all of which were seen in 2002 and 2003, GS-1 can still serve as a minimally impacted reference site for the rest of the Ossipee Watershed.

**GT-1 Bearcamp River, Route 113, Tamworth**
Similar to 2002 and 2003, though the water is quite tea-stained at this site, GT-1 had a relatively low DOC level. However dissolved oxygen levels were also low. This could be a factor of the several wetlands that the Bearcamp winds through before passing by GT-1.

**GT-4 Chocorua River, RT. 41, Tamworth**
This new site's dissolved inorganic nitrogen also dominated the total dissolved nitrogen indicating impairment. Continued testing will determine if this is a common occurrence.

### 3.17 Relative OLT Site Summaries

**OL-1 West Branch River**
Similar to 2003, with low turbidity and nutrients and high dissolved oxygen and pH, this site exhibits good water quality.

**OL-2 Bearcamp River**
In 2003 it was suggested that dissolved inorganic nitrogen (DIN) dominated the total dissolved nitrogen (TDN), indicating that this site may be impaired. However the percentages added up to more than 100 % TDN. In addition, this site did not experience elevated levels of DIN in 2004, indicating that this was a single event or a lab error.

**OL-3 Patch Pond Point River**
In 2004, similarly to 2003, OL-3 experienced elevated levels of calcium relative to the other OLT sites.

**OL-4 Lovell River**
Similar to 2003, with low turbidity and nutrients and high dissolved oxygen and pH, this site exhibits good water quality.

**OL-5 Weetamoe Brook**
Similar to 2003, with low turbidity and nutrients and high dissolved oxygen and pH, this site exhibits good water quality.

**OL-6 Pine River**
In 2003 relative to other OLT sites sodium and chloride were high, indicating a potential disturbance. This, along with the higher levels of Ca and Mg were not seen at the RIVERS program site GE-1, upstream on the Pine River. In 2004, relative to the other OLT sites, sodium, chloride, magnesium and calcium were all at low levels. Silica levels did not seem as high either relative to the other OLT sites in 2004.

**OL-7 Red Brook**
Similar to 2003, OL-7 exhibits many traits of a wetland system: low dissolved oxygen and pH and high nitrogen, phosphate, total phosphorus, and dissolved organic carbon. Indeed, this site drains a large shrub-dominated wetland. The low temperatures in Red Brook could suggest ground water inflow.

**OL-9 Cold Brook**
In 2004, this site exhibited high levels of both total phosphorus and phosphate. However, in 2004, total phosphorus and phosphate were low relative to other OLT sites. In

addition, this site showed good water quality with low turbidity and nutrients and high dissolved oxygen.

**OL-10 Huckins Pond Outflow**
In 2004 OL-10 experienced elevated levels of phosphorus, dissolved organic carbon, phosphorus, calcium and magnesium. This however was not found in 2004. In 2004, temperatures were elevated in comparison to other OLT sites, but overall OL-10 showed good water quality.

**OL-11 Danforth Brook**
Similar to 2003, with low turbidity and nutrients and high dissolved oxygen and pH, this site exhibits good water quality.

**OL-12 Phillips Brook**
In 2003 this site exhibited higher temperatures in comparison to other OLT sites. A new infestation of variable milfoil was found also found at this site in 2003. In 2004, this site showed elevated levels of dissolved organic carbon and sodium and chloride relative to other OLT sites. This site was moved upstream to be sampled by the road when the campers could not sample. This could explain the difference in sodium and chloride as the water is more influence by roads.

**OL-13 Leavitt Brook**
In 2003, OL-13 exhibited high levels of magnesium, calcium, potassium, and silica. A high pH was also observed. In 2004, elevated levels of silica, calcium, sodium, and chloride were found. The high levels of silica could indicate that this site is groundwater fed.

**OL-14 Square Brook**
In 2003, with low turbidity and nutrients and high dissolved oxygen and pH, this site exhibited good water quality. However, in 2004, this site exhibited high turbidity, dissolved inorganic nitrogen, sodium, chloride, potassium, calcium, and magnesium, indicating impairment. This site as exhibited high levels of silica suggesting that it is groundwater fed. The difference between the two years may be explained by a change in location further upstream from the lake.

## 4. Recommendations

In 2004, Green Mountain Conservation Group held its second Water Quality Monitoring Program Steering Committee meeting with stakeholders including: New Hampshire Department of Environmental Services, Maine Department of Environmental Protection, Saco River Corridor Commission, US Environmental Protection Agency Region 1, Chocorua Lakes Association, Maine Chapter of The Nature Conservancy, University of New Hampshire Water Resources Department, University of New Hampshire Cooperative Extension, The Community School, the Eaton Conservation Commission, and the Water Quality Monitoring volunteers in both Maine and New Hampshire. Recommendations from this meeting included:

- Continue monitoring in the Ossipee Watershed to expand upon three years of data to create a long term database
- Select 6 RIVERS sites to test throughout the winter on a monthly bases (weather permitting)
- Place staff and rain gages at each site to better monitor precipitation and water level
- Conduct more storm event sampling
- Purchase conductivity meter as a multi-parameter meter with a 66 foot cable to add a parameter to the RIVERS program and also to use in deep water sampling in Ossipee Lake
- Add deep water sampling to the WQM program with Camps on the lake with GMCG's own multi-parameter meter, Kemmerer bottle, and sechi disk.
- Sample all OLT sites from the road closest to the lake, except for Bearcamp and Pine River, to get more river data rather than lake data
- Work with towns to secure another year of funding and access if towns are committed to long range funding
- Work with other lake associations in the watershed to add their data to the GMCG website database
- Work with The Community School and Rose de Mars (WQM volunteer and hydrogeologist) to create GIS maps of several of the sites and their smaller watersheds
- Start the regular WQM season earlier (April)
- Work with Maine Department of Environmental Protection, New Hampshire Department of Environmental Services, Saco River Corridor Commission, and Ned Hatfield (WQM volunteer) to consider guiding volunteers in streamside assessment to gather qualitative data
- In the future consider adding macroinvertebrate and ground water sampling to the program
- Work with towns to create watershed wide water/aquifer protection program from the White Mountains to the Atlantic Ocean

## 5. Work Cited

Green Mountain Conservation Group and Saco River Corridor Commission. 2003 *Saco Watershed Water Quality Monitoring Program QAPP*.

New Hampshire Office of State Planning, Society for the Protection of New Hampshire Forests and The Nature Conservancy. *New Hampshire's Changing Landscape.*

# USE OF MALE SPECIFIC BACTERIOPHAGE AS AN INDICATOR FOR THE PRESENCE OF HEPATITIS A VIRUS IN ALKALINE STABILIZED BIOSOLIDS INTENDED FOR LAND APPLICATION

## Basic Information

| | |
|---|---|
| **Title:** | USE OF MALE SPECIFIC BACTERIOPHAGE AS AN INDICATOR FOR THE PRESENCE OF HEPATITIS A VIRUS IN ALKALINE STABILIZED BIOSOLIDS INTENDED FOR LAND APPLICATION |
| **Project Number:** | 2004NH31B |
| **Start Date:** | 3/1/2004 |
| **End Date:** | 2/28/2005 |
| **Funding Source:** | 104B |
| **Congressional District:** | 1 |
| **Research Category:** | Not Applicable |
| **Focus Category:** | Treatment, Methods, Toxic Substances |
| **Descriptors:** | |
| **Principal Investigators:** | Aaron B. Margolin |

## Publication


1. Katz, B.D. and A.B. Margolin. Submitted. Inactivation of Hepatitis A virus HM-175/18f, Reovirus type 1 Lang and Bacteriophage MS2 during alkaline stabilization of biosolids. Applied Environmental Microbiology.

**Title:** Inactivation of Hepatitis A virus HM-175/18f, Reovirus type 1 Lang and Bacteriophage MS2 during alkaline stabilization of biosolids.

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## ABSTRACT

A bench scale model was used to evaluate the inactivation of male-specific bacteriophage-2, hepatitis A HM-175/18f and reovirus type 1 Lang during alkaline stabilization of raw biosolids at both 28˚C and 4˚C. Male-specific bacteriophage-2 was inactivated at a similar rate compared to reovirus type 1 Lang at each time point evaluated (t = 0.1, 2, 12 and 24 hours) during 28˚C and 4˚C trials, and at a similar rate to hepatitis A HM-175/18f at 28˚C. At 4˚C male specific bacteriophage-2 was not inactivated similarly to hepatitis A HM-175/18f at the first two sampling time points (t = 0.1 and 2 hours) but was inactivated similarly following those time points. These data suggest male-specific bacteriophage-2 could serve as an indicator organism for the inactivation of reovirus type 1 Lang and hepatitis A HM-175/18f during alkaline stabilization at 28˚C and 4˚C.

## INTRODUCTION

Under the Code of Federal Regulations part 503 (CFR Part 503), which governs the use and testing requirements of biosolids, enteroviruses are used to represent enteric virus persistence during and following treatment. Enteroviruses, a sub-population of enteric viruses, were chosen as the representative indicator organism of enteric viruses due to similar resistances to treatment processes (8). The standard method for the detection and enumeration of enteroviruses in sludge and treated biosolids is organic flocculation (11) followed by plaque assay (8). Detection and enumeration of enteroviruses in sludge by this method is lengthy and complicated by the presence of inorganic and organic substances that may be toxic to tissue culture during plaque assay (10).

Studies have shown that if sewage is sampled monthly and sewage isolates compared to clinical cases, qualitatively a similar picture of enterovirus activity is evident in the clinical setting (16). Therefore, clinical cases of enteric virus disease should also correlate with presence in sludge and biosolids. Enteric viruses such as hepatitis A virus (HAV) infect approximately 140,000 people a year in the U.S. (2) and are known to be more resistant to both disinfection process and environmental pressures than enteroviruses (13). Relying on enteroviruses as the indictor of enteric viruses such as HAV may pose a health risk, allowing them to persist in land applied biosolids after enteroviruses are no longer detectable.

Phages, somatic and male-specific, have received significant evaluation as indicators of enteric virus presence and persistence following treatment in source water (5), drinking water (17) and waste water (9). Male-specific bacteriophages (MSB) have been suggested as useful indicator organisms for determining the fate of human viruses in sludge (12, 14). The number of MSB, such as male-specific phage-2 (MS2), found in wastewater and human feces are sufficient for detection and can be enumerated by inexpensive and rapid plaque assay methods (4).

Therefore MSB, such as MS2, should be evaluated for their potential to serve as indicator organisms for the inactivation of enteric viruses during biosolid treatment processes.

## MATERIALS AND METHODS

**Viral propagation**. MS2 (ATCC 15597-B1) was propagated using an *Escherichia coli* HS(pFamp)R host (ATCC 700891) harboring a conjugative plasmid and displaying streptomycin and ampicillin resistance (7). REO T1L (ATCC VR-230) was propagated using Buffalo Green Monkey Kidney Cells (BGM) grown to confluency in a closed system at 37˚C. BGM Growth media consisted of Eagles Minimal Essential Media (MEM) and Leibowitz media (L-15) supplemented with 5% fetal bovine serum (FBS) and 1% antibiotic/antimycotic (10,000 units/mL of penicillin, 10,000 µg/mL of streptomycin, and 25 µg/mL of amphotericin B). Tissue culture flasks were seeded at a multiplicity of infection (MOI) of approximately 0.96 and incubated for 6 days at 37˚C. Once CPE was evident, flasks were freeze-thawed three times, lysates aliquoted into 1.5 mL cryovials and stored at - 80˚C. HAV HM-175/18f (ATCC VR-1402) was propagated using Fetal Rhesus Monkey Kidney Cells (FRhK-4) grown to confluency in a closed system at 37˚C. FRhK-4 growth media consisted of MEM and L-15 supplemented with 12% FBS, and 1% antibiotic/antimycotic. Tissue culture flasks were seeded with virus at a MOI of approximately 0.01 and incubated at 37˚C for 12 days. Once CPE was evident, flasks were freeze-thawed three times as previously described and lysates chloroform extracted by placing 20 µL of chloroform per 1 mL of sample in a conical centrifuge tube and centrifuging at 10,000 x g, 4˚C, for 10 minutes. Extracted supernatants were then aliquoted into 1.5 mL cryovials and stored at -80˚C.

**Viral enumeration**. MS2 was enumerated by double agar overly plaque assay (1). REO T1L enumeration was performed using a method to enumerate rotaviruses (18). $25^2$ cm cell culture flasks containing a confluent monolayer of BGM cells were rinsed twice with serum-free MEM, inoculated with 100 µL of serially diluted sample and incubated at 37°C for 90 minutes. Following incubation, flasks were filled with 10 mL of a 2X MEM agarose overlay supplemented with 0.01 mg/mL trypsin (Gibco) and incubated inverted for 4 days at 37°C. On the $4^{th}$ day cells were fixed by adding 2 mL of 10% formaldehyde in normal saline and incubating at 37°C for 24 hours. The following day each culture flask was rinsed gently with warm water, shaken lightly to remove the overlay and stained with 1 mL of 0.1% crystal violet. Enumeration of HAV HM-175/18f was performed using a plaque assay adapted from a previously described method (6). $25^2$ cm cell culture flasks containing a confluent monolayer of FRhK-4 cells were rinsed twice with serum-free MEM, inoculated with 100 µL of serially diluted sample and incubated at 37°C for 90 minutes. Following incubation, flasks were filled with 5 mL of an agarose overlay and incubated for 7 days at 37°C. On the $7^{th}$ day a second 5 mL overlay containing 50 µl of neutral red (Sigma) was added to the culture flasks, allowed to set, and incubated for 3 days at 37°C.

**Alkaline stabilization**. A bench scale model for alkaline stabilization was constructed according to methodology established in prior studies (3, 15). The system was challenged three times for each of the two viral combinations at 4˚C and 28˚C. 100 mL of a 4% total solid (TS) sludge was placed into a series of 10 beakers containing a magnetic stir bar. The beakers represented four test time points 0.1, 2, 12, and 24 hours, and six controls. One control beaker was used to determine any background phage or enteric virus in the sludge, and 5 others (0, 0.1, 2, 12, and 24) represented each time point. An 11th beaker of 100 mL 1x PBS was also included as a temperature control. All beakers were brought to the indicated temperatures for the experiment and adjusted to pH 7 under continuous mixing by magnetic stir bar. Test beakers were elevated to pH 12 by addition of 8% $Ca(OH)_2$. Once pH 12 was reached and maintained virus was added as such: 1 mL $10^6$ PFU/mL of HAV HM-175/18f and 1 mL $10^6$ PFU/mL MS2, or 1 mL $10^6$ PFU/mL REO T1L and 1 mL $10^6$ PFU/mL MS2. All control beakers (temperature control, 0, 0.1, 2, 12 and 24 hour control) were spiked with approximately the same concentration and combination of viruses. The beakers used to detect endogenous virus and seeded viral concentration at time point 0, were immediately concentrated for enteric virus and bacteriophage. A pH 12 was maintained for 2 hours in the test beakers, then reduced to 11.5 by addition of 1M HCL for the remaining two time points. The pH of the control beakers was maintained at 7 with the addition of either 2M NaOH or 1M HCL throughout the experiment. At the indicated time, both test and control beakers were brought to a pH of 7 and the entire sample concentrated. Concentrations of both enteric virus and bacteriophage were determined by plaque assays performed in triplicate.

**Viral recovery from sludge.** MS2 was recovered from seeded sludge by mixing 5 mL of sludge from the stabilization experiment with 10 mL of a 3% beef extract in a 50 mL conical centrifuge tube. The pH of the sample was elevated to 9.5 with 2M NaOH then centrifuged at 2,500 x g for 10 minutes at 22˚C to pellet solids. The supernatant was transferred to a new 50 mL conical centrifuge tube, adjusted to a pH of 7 with 1M HCL and refrigerated at 4˚C until use. HAV HM-175/18f and REO T1L were recovered from seeded sludge using a modified version of the

USEPA method EPA/600/4-84/013. Modification to the procedure included eliminating sludge conditioning prior to concentration and further decontamination of eluents by adding 1 mL of chloroform per 10 mL of eluent and centrifuging at 10,000 x g for 10 minutes at 4˚C. Decontaminated eluents were then stored at - 80˚C until use.

**Statistical analyses.** Data from the alkaline stabilization experiments were square root transformed to insure a normal distribution then analyzed using a two way ANOVA in the statistical software program SYSTAT 11.0. A general linear model was constructed to evaluate the following null hypothesis: 1) alkaline stabilization data significantly varies from trial to trial in the same matrix, 2) alkaline stabilization does not have a significant effect on the inactivation of MS2, REO T1L and HAV HM-175/18f, 3) the effect of alkaline stabilization is not significantly affected by the amount of time that elapses during experimentation. A Tukey's Honestly Significantly Different test (Tukey HSD) was performed in order to determine if there was a significant difference in the inactivation of phage and enteric virus at specific time points during alkaline stabilization.

## RESULTS

Viral loss as a result of the recovery method and virucidal components (microbial and chemical) of the sludge was evaluated prior to alkaline stabilization. An average loss of 0.5 logs (79%), 1.5 logs (97%) and 0.5 logs (57%) was demonstrated for MS2, REO T1L and HAV HM-175/18f respectively. These data were used to normalize the total viral reduction detected and determine how much viral inactivation was occurring as a result of alkaline stabilization alone (B. D. Katz and A. B. Margolin, unpublished data).

**REO T1L and MS2 at 28˚C.** MS2 seeded into a 4% TS sludge at 28˚C was below detectable limits following 0.1 hours of alkaline stabilization in all three trials corresponding to a total reduction of ≥ 5 logs (0.5 logs due to recovery loss). REO T1L seeded into the same sludge sample was below detectable limits following 12 hours of alkaline stabilization in the first two trials and 2 hours in the third trial corresponding to a total reduction of ≥ 6 log (0.5 logs due to recovery loss) (Figure 1). Statistical analyses revealed no statistically significant difference between each trial ($p = 0.707$), that stabilization alone causes a significant inactivation of virus in each trial ($p = 0.000$) and time combined with alkaline stabilization has a significant effect on viral concentration ($p = 0.000$). Tukey HSD demonstrated no statistically significant difference in viral concentration ($p > 0.05$) at all time points evaluated (0.1, 2, 12 and 24 hrs).

**REOT1L and MS2 at 4˚C.** MS2 seeded into a 4% TS sludge at 4˚C was below detectable limits following 2 hours of alkaline stabilization during the first two trials and 12 hours in the third trial corresponding to a total reduction of ≥ 5 logs (0.5 logs due to recovery loss). REO T1L seeded into the same sludge sample was below detectable limits following 12 hours of alkaline stabilization in the first two trials and 24 hours in the third trial corresponding to a total reduction of ≥ 5 logs in all trials (0.5 logs due to recovery loss) (Figure 2). Statistical analyses revealed no statistically significant difference between each trial ($p= 0.335$), that alkaline stabilization alone causes a significant inactivation of virus in each trial ($p= 0.000$) and time combined with alkaline stabilization has a significant effect on viral concentration ($p= 0.001$). Tukey HSD demonstrated no statistically significant difference in viral concentration ($p > 0.05$) at all time points evaluated.

**HAV HM-175/18f and MS2 at 28˚C.** MS2 seeded into a 4% TS sludge at 28˚C was below detectable limits following 0.1 hours of alkaline stabilization during the first trial and 2 hours in the second and third trial corresponding to a total reduction of ≥ 5 logs (0.5 logs due to recovery loss). HAV HM-175/18f was below detectable limits following 2 hours of alkaline stabilization in the first and third trial and 12 hours in the second trial corresponding to a total reduction of ≥ 6 logs (1.5 logs due to recovery loss) (Figure 3). Statistical analyses revealed a statistically significant difference between each alkaline stabilization trial ($p = 0.001$), that alkaline stabilization alone causes a significant inactivation of virus in each trial ($p = 0.000$) and time combined with alkaline stabilization has a significant effect on viral concentration ($p = 0.000$). Tukey HSD demonstrated no statistically significant difference in viral concentration ($p > 0.05$) at all time points evaluated.

**HAV HM-175/18f and MS2 at 4˚C.** MS2 seeded into a 4% TS sludge and alkaline stabilized for 24 hours at 4˚C was below detectable limits following 24 hours of alkaline stabilization during all three trials corresponding to a total reduction of ≥ 5 logs (0.5 logs due to recovery loss). HAV HM-175/18f was below detectable limits following 24 hours of alkaline stabilization in the second and third trial corresponding to a total reduction of ≥ 6 logs (1.5 logs due to recovery loss). During the first trial HAV HM-175/18f was only reduced by 3 total logs (1.5 logs due to recovery loss) following 24 hours of alkaline stabilization (Figure 4). Statistical analyses revealed a statistically significant difference between each alkaline stabilization trial ($p = 0.000$), alkaline stabilization alone causes a significant inactivation of virus in each trial ($p = 0.000$) and time combined with alkaline stabilization has a significant effect on viral concentration ($p = 0.000$). Tukey HSD demonstrated a statistically significant difference in viral concentration ($p < 0.05$) at the 0.1 and 2 hour time points.

## DISCUSSION

When the CFR Part 503 regulations were established and enteroviruses were chosen as the indicator organism for the presence of enteric virus, data regarding the survival of HAV HM-175/18f, REO T1L, adenovirus 5 and rotavirus Wa during alkaline stabilization was unavailable. The research presented here, upon comparison to that presented in the literature, demonstrates that HAV HM-175/18f and REO T1L has the ability to persist longer than poliovirus, which was one of the original viruses evaluated during the formation of the CFR 503, following alkaline stabilization in a 4% biosolid matrix (3). Additional research also suggests that Adenovirus 5 and Rotavirus Wa persist longer in alkaline stabilized biosolids that are intended for land application than poliovirus (J. J. Brabants and A. B. Margolin, submitted for publication). Data from both of these studies may indicate that the original risks associated with the land application of alkaline stabilized biosolids might have been underestimated. Additional studies evaluating these viruses in biosolids produced by other mechanisms, such as anerobic digestion or composting, should also be performed to determine if they persist longer in these matricies. Ultimately, if it is determined that these viruses and others which could not previously be evaluated, demonstrate greater persistence then those viruses originally used for the development of the CFR 503, further risk analysis should be undertaken to determine if there is a greater risk from virus exposure associated with the practice of land application then was originally determined.

In addition, the research described here and by Brabants and Margolin demonstrates preliminary data that under prescribed conditions, MS2 or other male specific phages, may serve as an indicator organism for the inactivation of HM-175/18f, REO T1L, adenovirus 5 and rotavirus Wa during alkaline stabilization. Monitoring for these viruses in biosolids that are produced by alkaline stabilization is costly, labor intensive and slow, making monitoring an impractical approach. However, the preliminary data described here and by Brabants and Margolin does demonstrate the possibility of using bacteriophage as a means to evaluate the presence of these viruses. MS2 or other phages, such as somatic phages, need to be evaluated further to determine if they can be used as an indicator organism to accurately predict the inactivation of different enteric viruses that are present and inactivated during different biosolids processes, such as alkaline stabilization, composting and anerobic digestion. Assays that detect phage are rapid, relatively easy to perform and are much less expensive then those used for the detection of the anthropogenic virus themselves. If additional studies demonstrate, as this study did, that there is a good correlation between the inactivation of the human pathogen and the phage, eventually utilization of phage as an indicator organism can be evaluated for routine monitoring of processed biosolids.

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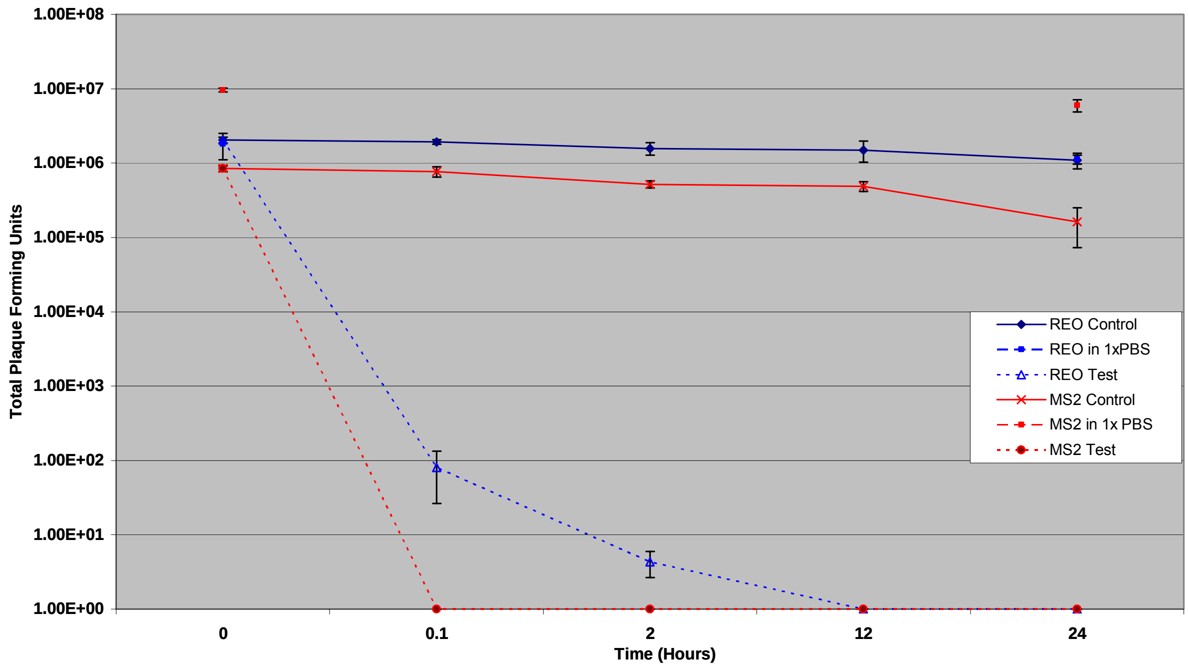


**Figure 1: Average Total Reduction of MS2 and REO T1L Following Three Trials of Alkaline Stabilization Performed for 24 Hours in a 4% TS Sludge at 28˚C-** REO T1L seeded to a concentration of 2.04 x $10^6$ PFU was below detectable limits following 12 hours of alkaline stabilization (REO test). MS2 seeded into the same sludge sample to a concentration of 8.48 x $10^5$ PFU was below detectable limits following 0.1 hours of alkaline stabilization (MS2 test). Error bars represent standard error

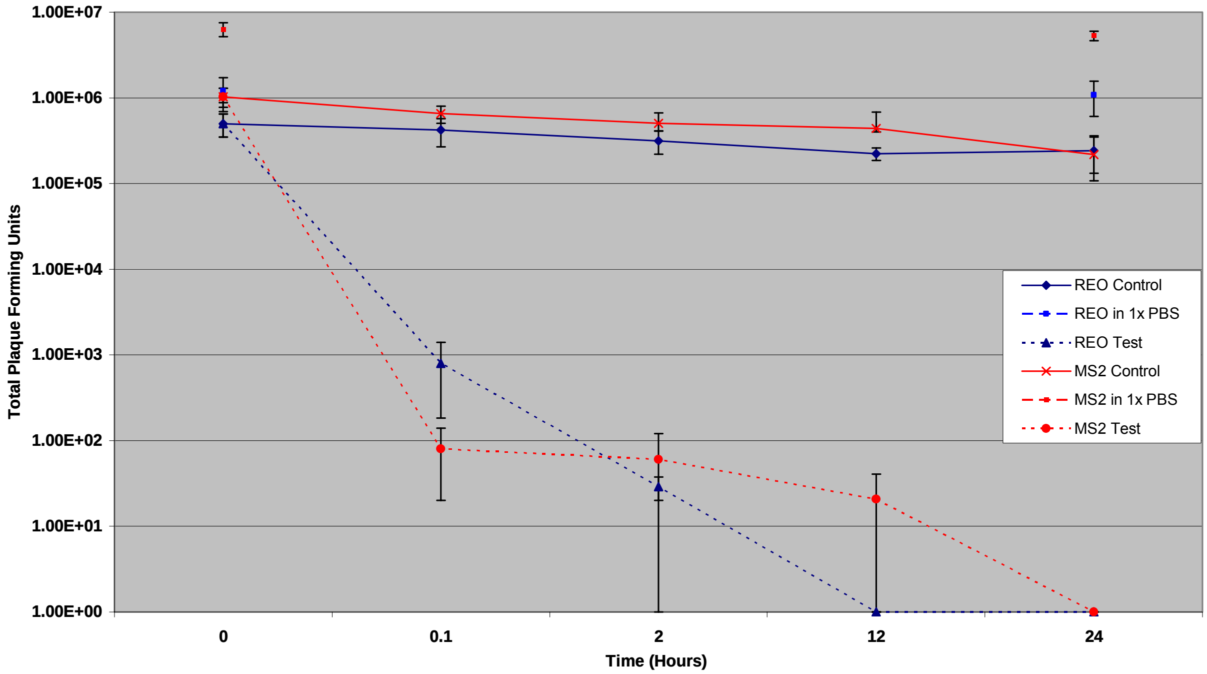


**Figure 2: Average Total Reduction of MS2 and REO T1L Following Three Trials of Alkaline Stabilization Performed for 24 Hours in a 4% TS Sludge at 4˚C-** REO T1L seeded to a concentration of 5.0x $10^5$ PFU was below detectable limits following 2 hours of alkaline stabilization (REO test). MS2 seeded to a concentration of 1.03x $10^6$ PFU in the same sludge sample was below detectable limits following 12 hours of alkaline stabilization (MS2 test). Error bars represent standard error.

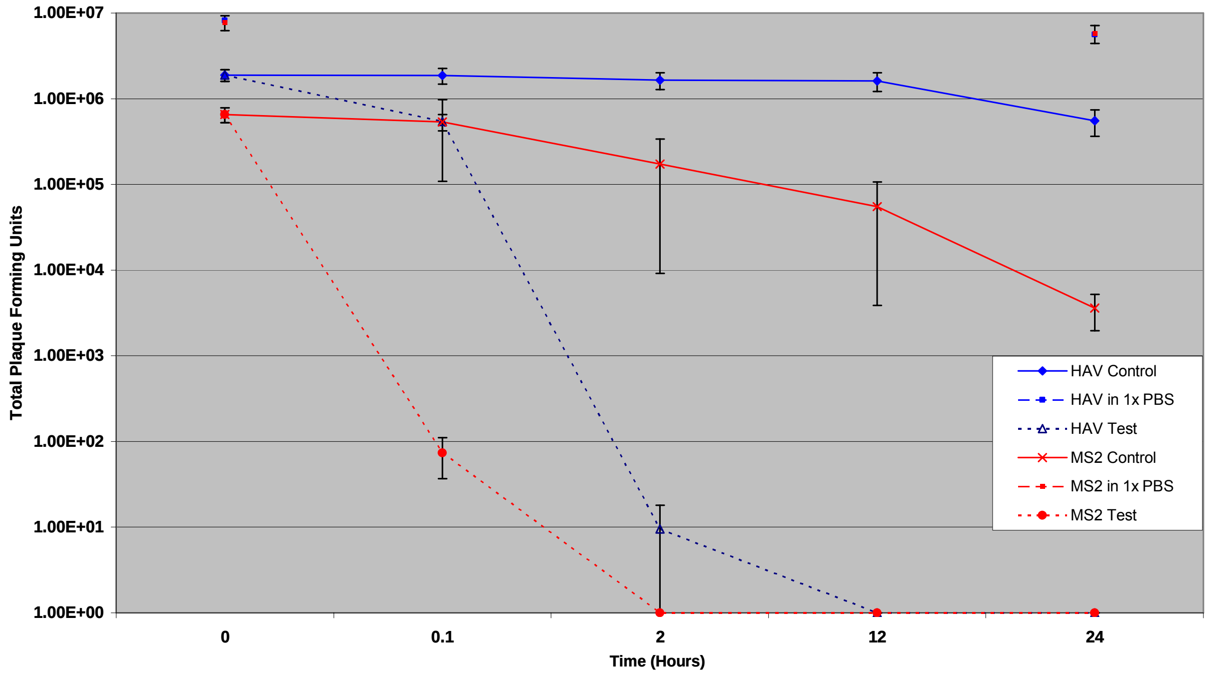


**Figure 3: Average Total Reduction of MS2 and HAV HM-175/18f Following Three Trials of Alkaline Stabilization Performed for 24 Hours in a 4% TS Sludge at 28˚C**- HAV HM-175/18f seeded to a concentration of 1.9 x $10^6$ PFU was below detectable limits following 12 hours of alkaline stabilization (HAV test). MS2 seeded into the same sludge to a concentration of 6.5 x $10^5$ PFU was below detectable limits following 2 hours of alkaline stabilization (MS2 test). Error bars represent standard error.

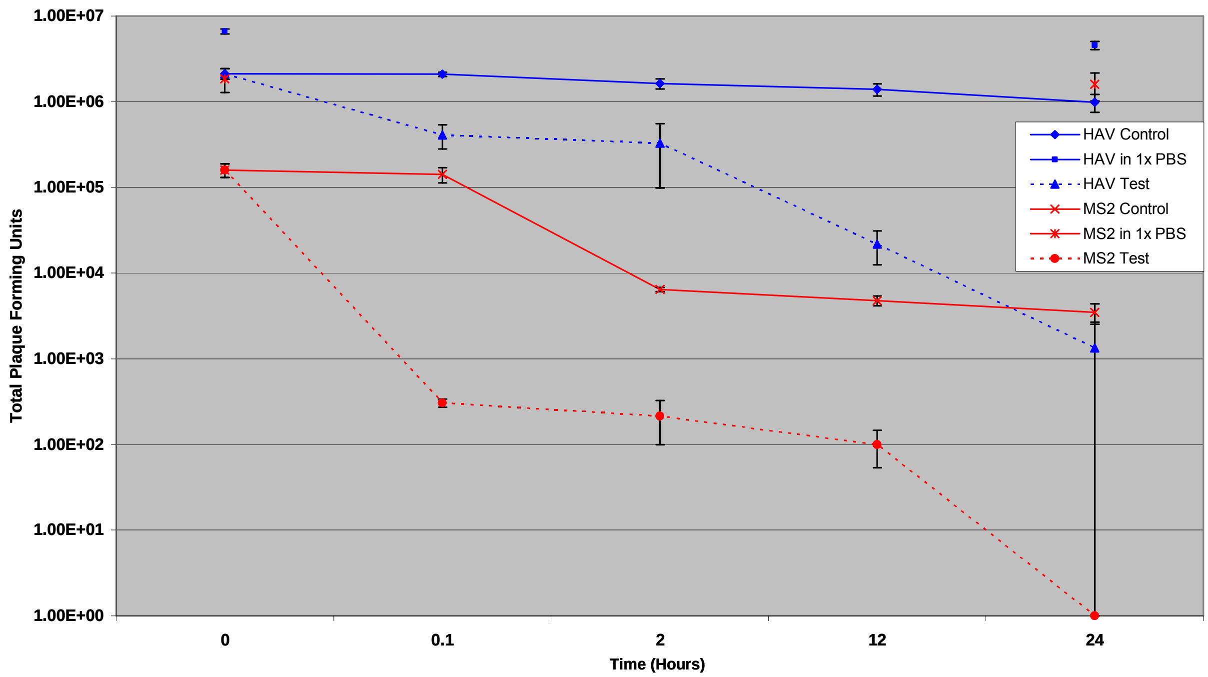


**Figure 4: Average Total Reduction of MS2 and HAV HM-175/18f Following Three Trials of Alkaline Stabilization Performed for 24 Hours in a 4% TS Sludge at 4˚C-** HAV HM-175/18f seeded to a concentration of 2.1 x $10^6$ PFU was was still at detectable limits (1.3x $10^3$ PFU) following 24 hours of alkaline stabilization (HAV test). MS2 seeded into the same sludge at a concentration of 1.59 x $10^5$ PFU was below detectable limits following 24 hours of alkaline stabilization (MS2 test). Error bars represent standard error.

# Information Transfer Program

# Student Support

| Student Support | | | | | |
|---|---|---|---|---|---|
| **Category** | **Section 104 Base Grant** | **Section 104 RCGP Award** | **NIWR-USGS Internship** | **Supplemental Awards** | **Total** |
| **Undergraduate** | 10 | 0 | 0 | 0 | 10 |
| **Masters** | 04 | 0 | 0 | 0 | 4 |
| **Ph.D.** | 1 | 0 | 0 | 0 | 1 |
| **Post-Doc.** | 0 | 0 | 0 | 0 | 0 |
| **Total** | 15 | 0 | 0 | 0 | 15 |

# Notable Awards and Achievements

# Publications from Prior Projects


1. 2002NH1B ("Linking Lakes with the Landscape: The Fate of Terrestrial Organic Matter in Planktonic Food Webs") - Articles in Refereed Scientific Journals - Lennon JT, Pfaff LE. (2005) The source and supply of terrestrial carbon affects aquatic microbial metabolism. Aquatic Microbial Ecology. 39:107-119.
2. 2002NH1B ("Linking Lakes with the Landscape: The Fate of Terrestrial Organic Matter in Planktonic Food Webs") - Articles in Refereed Scientific Journals - Lennon JT (2004) Experimental evidence that terrestrial carbon subsidies increase $CO_2$ flux from lake ecosystems. Oecologia 138: 584-591