APPENDIX A: LAKE STUDIES

UNDERSTANDING OSSIPEE'S LAKE SYSTEM OVER THE CENTURIES

By Dr. Lisa Doner, Plymouth State University

For over a decade now, citizen volunteers from the Ossipee region have diligently collected data on water quality from basins throughout the lake system. This data is now being analyzed to see if there are any trends towards lower water quality that might require mitigation. But how can we know what a trend over 10 years can mean if we don't know the baseline level that is natural to the system?

Sediment cores from the bottom of the lake provides information about what the conditions were in the lake over the past several centuries. (Photo: Lisa Doner)

Longer records of water quality can help with that particular problem. But these longer records cannot be obtained from the water itself. That record is long gone. Instead, Plymouth State University (PSU) faculty and students are working towards recreating that long-term record using lake sediments generated over the years by algae, fish and other lake life forms, and by sediments carried in by watershed erosion. Sediments from all those sources settle out of the water column continuously, accumulating into thicker and thicker deposits every year, with each year's deposits reflecting local watershed events and longer-term processes. The very deepest part of each lake generally has the thickest deposits because gravity pushes all materials downslope, to a point a maximum repose. In a lake, that's the "deep spot", and so that is where researchers of paleolimnology (paleo = ancient; limnology = study of fresh waters) go most often to seek answers. One such researcher is Dr. Lisa Doner, of PSU's Center for the Environment and Environmental Science and Policy Department.

Doner has been collaborating with the Green Mountain Conservation Group (GMCG) to help determine if the Ossipee lake system is being overly stressed by recent changes in land use and climate change. She has collected over ten sediment cores, with at least one from every basin in the Ossipee lakes, in 2012 and 2013. Additional cores are planned for 2014, from Lake Ossipee itself. From these cores it is possible to study changes across the lake system, and over centuries of time. The cores were collected using a hand-held "surface corer". Ideally, the corer collects an entire sequence of sediment without disturbing the sediment-water interface (top-most material in contact with the lake water), with the top of the core (Core Depth =0) being modern material and sequentially deeper sediments in the core being progressively older material.

When lake bottoms are very soft, surface corers can penetrate far into the mud, resulting in a relatively long core. When the bottom sediments are harder, these corers are unable to penetrate far and so the resulting cores tend to be short. Almost all of the cores from the chain of Ossipee lakes are relatively short, and have a remarkably consistent length about 20-23 cm (7-9") length. This consistency suggests that the lake system experienced some event that left behind a hard layer, and that layer has subsequently been buried under 20-

23 cm of softer muds. The hard layer might be sand (ie. from regional flooding), soil from a time when the lakes dried out (if ever), or clay left by the glaciers.

New information is coming in all the time, as more and more analyses on the cores are completed by students working on the project as part of their research training. Over eight PSU undergraduates have worked on the eight cores collected in 2012. They measured total phosphorus (TP) from the pore water, and total organic content, of each sample. Their findings indicate no system-wide trend towards eutrophication, but TP levels in the sediments are measurably high. Upper and Lower Danforth Pond and Ossipee Lake show recent increases in TP deposition (Figure A1). To examine these recent events in more detail, in 2013, Michael Garcia collected, sampled and analyzed two cores from Lower Danforth Pond, operating from the ice surface with a special push-style corer that allowed us to collect longer sediment sequences. Core 1 is 46 cm and Core 2 is 36 cm long. With the help of donated funds to the GMCG, Core 2 was analyzed for radioactive lead (^{210}Pb) to establish a chronology for the whole core such that every centimeter of core is associated with a calendar date. You can learn more about this method at the following two websites: http://gec.cr.usgs.gov/archive/lacs/lead.htm, and http://www.flettresearch.ca/Webdoc4.htm.

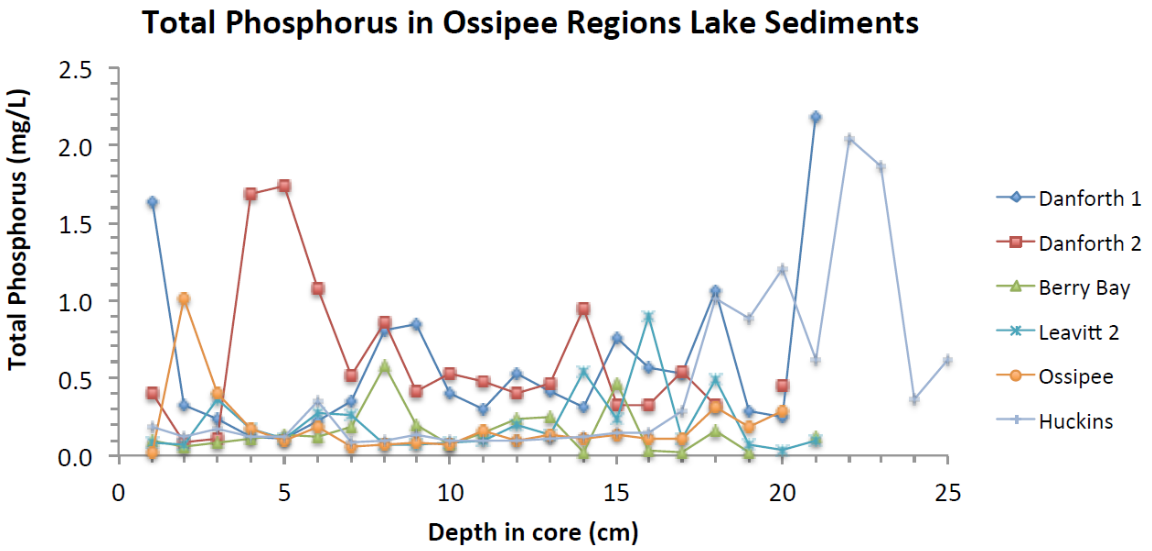


Figure A1. Phosphorus concentrations in sediment cores from lakes in the Ossipee region.

Garcia presented his results in November 2013, at the Freedom Town Library, with a time series of sedimentary TP levels plotted over the last 240 years (Figure A2). It seems that, until AD 1913 at least, the Lower Danforth pond sediments stored phosphorus at fairly high levels. After 1913, dramatic changes occurred in the TP storage such that either a) the sediments were no longer receiving much phosphorus from the overlying lake waters, or b) the sediments were no longer capable of holding onto phosphorus, instead releasing it all back to the lake and leaving the sediments depleted. The second scenario would almost certainly be caused by a lack of oxygen at the lake bottom, at some point in the year. Summer stratification of the water column could cause this, as could winter ice cover after a productive summer. In either case, algal decay would play a role in using up the oxygen.

A final and important result from Garcia's work is that salt influx, as indicated by sodium (Na^+) and chloride (Cl^-) concentrations in the sediment pore waters, began to increase significantly after AD 2000. Sources include road salt draining overland into the lake, coming in as near-surface ground water, or in river inflows. Water softener chemicals are also primarily sodium chloride. When applied to household water supplies, these chemicals may pass through septic systems and enter the lake system.

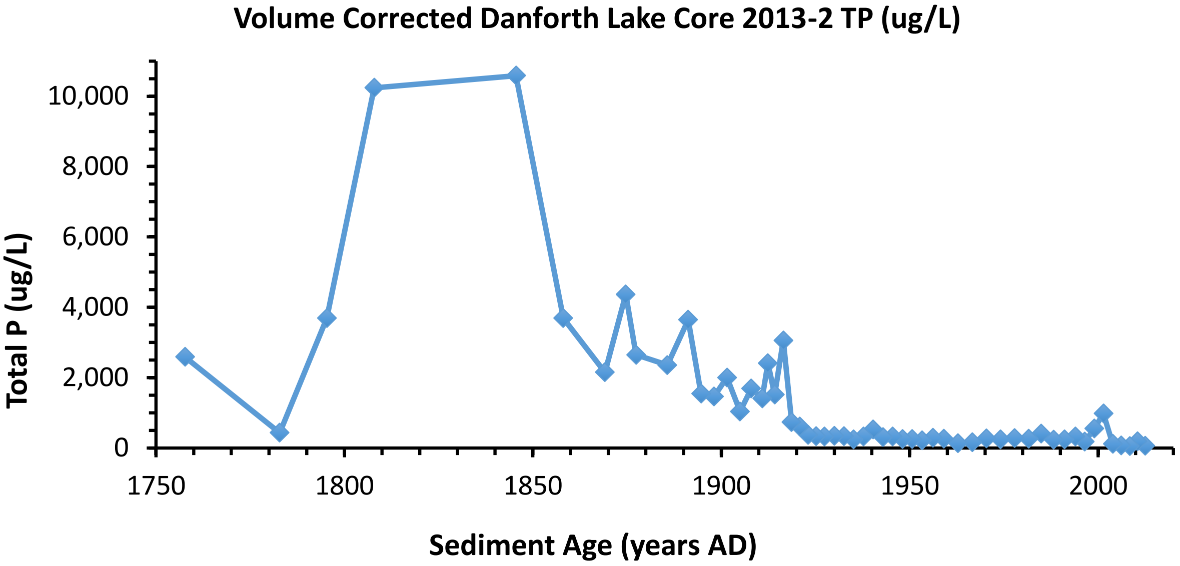


Figure A2. Phosphorus concentrations in sediment, plotted with calendar dates obtained from ^{210}Pb radioactive dating, taken from Lower Danforth Pond in 2013.

At the moment, we cannot distinguish between several competing hypotheses about the cause for the post-AD 1913 changes in Lower Danforth Pond. The coincident, or nearly coincident changes in total phosphorus and sand levels do point to a significant change in the lake state, however, that continues today. To answer the questions that remain, Doner and PSU graduate student Melanie Perello are now working on Lake Ossipee, collecting a new sediment core in 2014, and monitoring the character of the sediments being deposited, the lake's thermal stratification all year-round, and annual water quality variations. The Lake Ossipee Core will also be dated using funds from grants written specifically to support this work.

OSSIPEE TEMPERATURE MONITORING AND FUTURE CORING RESEARCH

By Melanie Perello, Plymouth State University

Assessing the effects of climate change on lake ecosystems mainly revolves around the study of past climate conditions using paleolimnological assessments of sediment cores and their properties (Saros et al. 2012, Williamson et al. 2009). The relationship between climate change and water quality issues has been previously studied using paleoecological techniques, which focus on assessment of biological indicators in the sediments to estimate climate and nutrient conditions (Saros et al. 2012). Sedimentary records can provide important information regarding the functioning, climate, and biological history of a lake (Carey and Rydin, 2011, Saros et al. 2012).

The ongoing study on Ossipee Lake aims to assess both current and past relationships between climate and water quality by combining monitoring and paleolimnological methods. Monitoring current water quality and climate will allow us to relate water-column temperature trends with water conditions.

Paleolimnological studies of sediment cores will provide information on past climate and water quality conditions. We expect to find that water quality issues in the lake can be linked to climate and that there are strong correlations between changes in climate and changes in water quality. Trends found in Ossipee Lake will be compared with our study in Squam Lake, with the expectation that similar water quality trends between the two watersheds will be related to climate rather than local influences. Our goal is to better connect climate issues with water quality, because changing climate will have significant impacts on our aquatic resources.

Our temperature monitoring involves the establishment of a mooring in the deep part of the lake in February. The rope mooring, set 3 m below the surface, has temperature probes at 1 meter intervals that will collect water temperature data every 15 minutes. The mooring also contains two sediment traps, one at the bottom of the lake and one closer to the surface, that will collect debris and sediments, which can be used to determine the sedimentation rate of the lake. The mooring will remain in the lake year-round allowing us to determine the temperature profile of the lake in all four seasons.

Broad Bay in winter. (Photo: GMCG)

To assess current water-quality in the lake, we will take water samples at the deep spot of the lake to relate it to our temperature profile. Water samples will be taken at three depths, near the surface, the middle, and bottom of the water-column, to provide an overall profile of water quality. Samples collected will be analyzed for basic parameters including pH, chlorophyll-a, total phosphorus, and ions at the Center for the Environment Water Quality Lab. Water samples will be taken on a monthly basis from February-April and a weekly basis from May-October. Dissolved oxygen (DO) and water temperature will be determined every meter using a probe during sampling.

Sediment cores will be collected near the mooring. Each core will be separated at 1 cm intervals and then freeze-dried to determine water content (%). The dried samples will then be divided (riffled) and subsamples using to assess Loss-on-Ignition or organic carbon content (%) and magnetic susceptibility (High Frequency and Low Frequency). Lead-210 and 14Carbon dating will be conducted, dependent on funding, providing a date profile for the sediments to relate sediment depth with time. Sediment geochemistry will also be analyzed for samples, dependent on funding. Remaining sediment samples will be analyzed for diatom aggregates, which can be used to predict certain climate and water quality conditions.

With the monitoring and sediment analyses we expect to establish relationships between climate and water quality for both past climate and current climate conditions. Temperature monitoring of Ossipee Lake will be ongoing with the goal of observing any changes in the temperature profile of the lake and relating those changes to climate patterns. Future coring projects will continue the goal of understanding past regional climate trends using lake sediments.

APPENDIX B: SITE DESCRIPTIONS

GMCG Test Sites:

The selection of the water monitoring sites was a collaborative effort between GMCG and the town officials of Eaton, Effingham, Freedom, Madison, Ossipee, Sandwich and Tamworth. The primary consideration for sites beginning with "G" was how current land uses were affecting nearby surface waters. All test site selections were validated by natural resource experts from UNH and UNH Cooperative Extension. Since the program began, some of the original sites have been dropped and new ones added to meet the requests of town officials or because better, more representative sites were found.

Sites beginning with "OL" were part of the Ossipee Lake and Tributary program that began in 2003. A monitoring station was created for each tributary draining directly to Ossipee Lake. These sites were not selected with consideration of land use, but as part of the lake assessment program. Many of these sites have continued to be monitored by GMCG since 2004.

Twenty-seven test site locations are currently being tested with 1 out of 1 site in Eaton, 3 out of 4 sites in Effingham, 2 out of 3 sites in Freedom, 4 out of 7 sites in Ossipee, 3 out of 6 sites in Madison, 3 out of 5 sites in Tamworth, and 1 out of 1 site in Sandwich. As the program expands in coming years, GMCG will continue to adjust the number of tests sites to meet the needs of the towns. The following summarizes the test site locations and reasons why each test site was chosen. Site locations are described as if the viewer were looking downstream.

OL-1u Ossipee Brook River (West Branch River), Ossipee Lake Road, Ossipee/Freedom Town Line (monitored 2005-present)

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. This station is located on the upstream side of Ossipee Lake Road where access is easiest.

OL-2 Bearcamp River (monitored 2003-present)

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. This station is located upstream of the mouth of the river, just beyond a rope swing, and is access by boat from the lake. This site was chosen in 2003 as part of project to collect samples from the inputs of every tributary into Ossipee Lake.

OL-3 Patch Pond Point River (monitored 2003-2004)

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, which itself is south of the Bearcamp River "delta." This site was discontinued in 2005 & 2006 for lack of an upstream access point. This site could be sampled in the future from a small watercraft.

OL-4 Lovell River, outlet to lake (monitored 2003-2004)

This river originates above 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 a large housing development called The Bluffs. This site was moved upstream in 2005 to OL-4u to eliminate the influence of lake water.

OL-4u Lovell River, Route 16, Ossipee (monitored 2005-present)

This station is accessed just downstream of Route 16 adjacent to the Indian Mound Golf Club.

OL-5 Weetamoe Brook, outlet to lake (monitored 2003-2004)

At the recommendation of UNH water quality experts, in 2005 this site was moved upstream to OL-5u to ensure lake water would not influence samples and data.

OL-5u Weetamoe Brook, Weetamoe Road, Ossipee (monitored 2005)

The site was discontinued in 2005 in an effort to find more reliable flow upstream at site OL-5ua.

OL-5ua Weetamoe Brook, Weetamoe Road, Ossipee (monitored 2006-2012)

This brook flows into the main lake at the former location of Camp Weetamoe, a Girl Scout summer camp that is 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, two high impact land uses. This site was discontinued in 2012 due to very low flow.

OL-6 Pine River (monitored 2003-2006)

Pine River is one of the lake's major tributaries and has heavy daily recreational use that includes powerboats. 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, adjacent to the ecologically fragile Ossipee Lake Natural Area. This station was accessed by boat and discontinued in 2006 due to lack of reliable access.

OL-6u Pine River (pilot site 2013)

This site is located on Hodson Road in Ossipee. Significant transportation and recreational land uses are just upstream, as is a very large wetland. This site would help to characterize the entire flow of the Pine River watershed into Ossipee Lake

OL-7 Red Brook (monitored 2003-present)

This brook enters the southeast end of the main body of Ossipee Lake between Long Sands and the Ossipee Lake Natural Area. It flows from the Heath Bog, passing the commercial operations of South African Pulp and Paper Industries. The station is at the outlet of a culvert that carries the brook under Long Sands Road.

OL-9 Cold Brook, outlet to lake (monitored 2003-2004)

This site was moved upstream in 2005 to OL-9u to eliminate the influence of lake water.

OL-9u Cold Brook, Alvino Road, Freedom (monitored 2005-present)

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. This station is located at the end of Alvino Road, which is off of Marina Road. The brook flows under a foot path through a culvert.

OL-10 Huckins Pond Outflow (monitored 2003-2007)

This brook flows into Danforth Pond from Huckins Pond. Access is across private property at the Danforth Bay Camping Resort. A gravel camp road leads to a boat trailer parking area from which the western bank of this stream is accessed.

OL-11 Danforth Brook, outlet of Lower Danforth Pond (monitored 2003-2004; same site as GF-1)

This site was discontinued as a tributary site since it was already being monitored as RIVERS site GF-1.

OL-12 Phillips Brook, outlet to Leavitt Bay (monitored 2003-2004)

This site was moved permanently upstream from the mouth of the brook in 2005 to OL-12u to avoid contamination from lake water.

OL-12u Phillips Brook, Remle Road, Effingham (monitored 2005-present)

Phillips Brook runs under Route 25 just east of Leavitt Road in Effingham. The brook passes through a concrete box culvert under a utility right of way also known as Abel Boulevard. The station is on the downstream side of the culvert. Flow is low but consistent. The culvert is often partially obstructed by beaver dams.

OL-13 Leavitt Brook, Camp Marist property, Effingham (monitored 2003-present)

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. The site is located just west of Marist Road, where Abel Boulevard crosses the brook.

OL-14 Square Brook, outlet at Broad Bay, Freedom (monitored 2003-2004)

This site was moved permanently upstream from its mouth in 2005 to site OL-14u to avoid contamination from lake water.

OL-14u Square Brook, Ossipee Lake Road, Freedom (monitored 2005-present)

Square Brook runs under Ossipee Lake Road through a corrugated steel culvert east of West Bay Road. This perched culvert has created a pool below it. The sampling station is at the downstream end of the pool, most easily accessed from the right side of the brook.

GE-1 Pine River, Elm Street, Effingham (monitored 2002-present)

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 downstream of a modern bridge with substantial concrete abutments. A dry hydrant access lane leads to the site, which is obviously used regularly by recreational fishermen and beer drinkers. 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, ME (monitored 2002-present)

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 (monitored 2003-present)

The Ossipee River drains Ossipee Lake. GE-3 is located at the point of land 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 20-30 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. Because this is such a popular fishing site there is also unfortunately a lot of trash here. The site is accessed via Ironworks road where the tester parks at the Ossipee Lake Dam, then crosses over the 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.

GE-4 Red Brook, Green Mountain Road, Effingham (pilot site 2005-2006)

This site was discontinued in 2006. Red Brook is now monitored near its mouth at the south end of the main body of Ossipee Lake at OL-7.

GEA-1 Long Pond outlet, Route 153, Eaton (pilot site in 2013)

This site is located in the outlet stream south of Long Pond in Eaton. An unnamed private association road approximately 150 feet northeast of Youngs Road along Route 153 crosses the flow. This site was added to help get a better picture of phosphorus concentrations in the Danforth Pond watershed.

GF-1 Danforth Brook, Ossipee Lake Road, Freedom (monitored 2002-present)

GF-1 is located where Danforth Brook flows under Ossipee Lake Road at the southern end of Danforth Pond. It is a slow moving stream from Danforth Pond to Broad Bay. It is about 15 feet wide by 3-4 feet deep during summer months. The testing site is about 100 feet downstream from the outlet of the pond. 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. 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 Brook, Maple Street, Freedom (monitored 2002-2008)

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 under 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. Large number of storm drains carry water from nearby roads into the brook. 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. This site was discontinued in 2008.

GF-3 Cold Brook, Loon Lake inlet, Freedom (monitored 2003-present)

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 thick 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 (monitored 2002-present)

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. The testing site is on the downstream side of Route 113. 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, Rt. 113, Madison (monitored 2003, 2006-present)

While not in the Ossipee Watershed, this site is in the greater Saco Watershed. GM-2 is located on the west side of Route 113, about 4 tenths of a mile south of the junction with Route 16. This is the most difficult site to access. It flows from a wetland at the edge of the watershed. There is a steep incline down to the 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 abandoned road leads up to the stream embankment. Various wildlife such as beaver and river otter have been noted at the site occasionally. There is some erosion along the 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 is downstream of a large gravel operation.

GM-3 Forrest Brook, Rt. 113, Madison (monitored 2004-present)

Forrest Brook, at the test site, has a smooth, slow-moving surface. The stream is about twelve 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. There is a brown film, which may be mineralization/decay of the rocks, or decomposed organic matter, or some kind of algae. Whatever the cause, the film is rough rather than slimy. 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. It appears to be just an ordinary and rather lazy stream. 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. 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.

GM-3u Forrest Brook upstream site, East Madison Road, Madison (monitored 2007-2008)

This site was discontinued in 2008.

GM-4 Ferrin Brook, Route 153, Madison (pilot site in 2013)

This site is located just downstream of NH153. Significant amounts of stormwater are shed off of the wide sandy shoulder of NH153 directly into Ferrin Brook, which flows into the south end of Purity Lake. This stream is lower volume than the others, but may transport more NPS pollution.

GM-5 Mill Brook, Route 153, Madison (pilot site in 2013)

This site is located about 600 feet south of where Route 153 passes over the outflow of Purity Lake. This site was added to better understand phosphorus concentrations within the Danforth Pond Watershed.

GO-1 Beech River, Tuftonboro Road, Ossipee (monitored 2002-present)

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 (monitored 2002-present)

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 our 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 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.

GO-3 Frenchman Brook, Polly's Crossing, Ossipee. (monitored 2003)

This site was discontinued due to intermittent flow and dry conditions during the summer months.

GO-4 Bearcamp River, UNH property, Newman Drew Rd., Ossipee (monitored 2004-present)

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.

GO-5 Bearcamp River, Whittier Bridge, Ossipee (monitored 2004-present)

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.

GO-6 Beech River, Route 16, Ossipee (pilot site 2005-2006)

Three random testing events at this pilot site through 2006 were conducted based on a request from town officials who thought potential impairing inputs from an old mill and tannery could be affecting the stream. It has not been tested since.

GO-7 Ossipee Lake outflow, Ossipee (pilot site begun November 2012)

This site was added in the Fall of 2012 in order to quantify the upstream inputs into the lower bays of Ossipee Lake. Physical parameter testing and total phosphorus samples will be collected on a year-round monthly basis. This site is located on the sandy southern shore of the main body of Ossipee Lake, where the lake flows out a channel before entering Broad Bay. The site is accessed one of two ways. On foot, one can walk along the Conservation Boardwalk that is accessed on Long Sands Road. The site can be reached by car by turning right at the end of Long Sands Road and driving to the end. The sandy shore is a town owned property. Sampling takes place as far down stream as possible.

GS-1 Cold River, Route 113, Sandwich (monitored 2002-present)

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 wellhead zone.

GT-1 Bearcamp River, Route 113, Tamworth (monitored 2002-present)

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 supply zone.

GT-2 Mill Brook, Earle Remick Natural Area, Tamworth (monitored 2002-2003)

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. The site was discontinued in 2003.

GT-3 Mill Brook, Durrell Road, Tamworth (monitored 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. This site was discontinued because NH DES has monitoring wells nearby to monitor the capped landfill for nutrients and other chemicals.

GT-4 Chocorua River, RT. 41, Tamworth (monitored 2004-present)

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 relatively new sampling site; GT-4. It serves to monitor occurrences along a seven miles stretch of the busiest and most diversely utilized highway in our area, including locally cherished, pristine Lake Chocorua; and it feeds Ossipee Lake.

Site GT-4 itself is a bit precarious. The sampler must affect a straddle with one foot on a log butt and the other on a projection at the base of a 21 foot long steel retaining wall which is part of the bridge. The actual steel-based bridge is preceded by 20 to 30 feet of 8-foot steel walls on either side. To stabilize the embankment along the east side, large granite slabs are laid lengthwise along the final 15 feet up to the steel wall. The slabs and steel walls channel the river around a 45 degree bend to its passage through the 18 foot bridge opening and under the roadway. The river exits around an opposite 45 degree bend on the other side.

The site is bordered on the east by Route 41 and on the west by mixed young forest dominated by 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.

The active truck and morning travel on Route 41 notwithstanding, site GT-4 is a pleasant place to be early on a summer morning.

GT-5 Swift River, Tamworth Village, Tamworth (monitored 2005-present)

This site was added in 2005 to the monitoring program at the suggestion of town officials at a Selectmen meeting in the spring of 2005. The site is in the center of the village, downstream from new development and is easily accessible. The site is behind "The Other Store", located on Cleveland Hill Road.

Appendix C. Water Quality Analysis Technical Summary

A trend analysis of the ten-year GMCG water quality monitoring dataset, which includes monitoring data for twenty-two tributary sites and five lakes (Figure 1), shows that the watershed is in very good condition and that water quality is generally stable. Mann-Kendall trend tests (USGS 2002, USEPA 2009) were done for eleven parameters to determine if these water quality measurements were showing significant declines or improvements over the ten-year monitoring period. Of the 235 separate statistical tests, only eleven parameters at ten sites showed significant trends (Table C1). This shows that most of the sites and water quality parameters are stable across the watershed. There are nine sites that have long-term trends indicative of declining water quality, but the measurement values are still well within the water quality standards for the State of New Hampshire, while two sites show improving trends.

Analysis

The Mann-Kendall Trend Test is a non-parametric statistical test that determines if the central value (median) of a dataset has changed over time. A non-parametric test is appropriate here because it does not make assumptions about the normality or variability of the dataset; variation seen year-to-year or within seasons will not influence the results of non-parametric analysis the way that parametric tests can be.

Summer (June – September) median annual tributary data was used in the trend analysis. It was screened for the following criteria: for inclusion in the analysis, the dataset for a site must a) have data spanning the ten-year time period, and b) have more than five years of data collected (some sites had years with no data). For lakes, annual median summer epilimnion total phosphorus data were used for the trend test.

The Mann-Kendall test focuses on the "S" value, which is calculated by sequential random pairing of data points along a time series (here, the measured values are the variables and sampling year is the time series). If the second point in the time series (the later measurement) is higher, "1" is added to the S score. If the second point is lower, 1 is subtracted from the S score. This is done for all possible pairs of points. The higher the S score, the greater the increase in the parameter over time; conversely, a negative S score indicates a declining trend over time. A value of S near zero indicates there is no trend. The magnitude of the S value is then compared to the variance of S, and a *p* value is determined from a statistical probability table (much like a t-test). The trend analysis output is shown below in Table C2, and parameters at sites showing improving and deteriorating trends are shown below in Figure C1 and Figure C2, respectively.

Results - Tributaries

Mann-Kendall trend analysis was completed for all sites with parameter measurements for five or more years. This resulted in analyses for eleven parameters at twenty-two tributary locations, and 235 total tests (Table C1). Of these, eleven parameters at ten sites were found to be significant at $\alpha=0.05$ (Figure 2). Nine of these eleven significant trends were indicative of declining water quality, but the observed values of these parameters are still within the water quality standards for New Hampshire. The most recent values are still indicative of good water quality, but suggest that water quality is changing over time in the watershed. **It is important to note that West Branch River (OL-1u) had four parameters with significant trends, but the results were deemed inconclusive since the trends were a function of the site being relocated**

multiple times upstream to eliminate lake effect. For example, water temperature was one of the parameters with a significant decreasing trend, which is logical because the sampling site was moved away from warmer lake water.

Table C1. List of parameters measured, their relevance to water quality, and the number of sites that were analyzed for each parameter.

Parameter	Reason for Measurement	Response to Watershed Disturbance	# Sites Evaluated for 10-Year Trend
Temperature	Habtiat and Chemistry	Increases	22
Turbidity	Habitat - indicates cloudier water and increased erosion in watershed	Increases	22
pH	Chemistry - can be influenced by acidic deposition (acidic rain and snow)	Varies	22
DO (mg/L)	Habitat and Chemistry - necessary for aquatic life; many species like brook trout and sensitive macroinvertebrates need high levels of dissolved oxygen	Decreases	22
Specific Conductivity	Chemistry - a measurement of ions in the water; usually a measurement of urban or resdiential development in watershed	Increases	22
Total Phosphorus	Nutrients- usually the limiting nutrient in freshwater systems	Increases	19
PO_4	Nutrients - biologically reactive form of Phosphorus	Increases	19
Total Nitrogen	Nutrients - Like phosphorus, nitrogen is necessary for plant growth but is cannot be used by plants in this form; High nitrogen is an indication of nutrient enrichment in the watershed; sources include agricultural runoff and sewage	Increases	19
NH_4	Nutrients - Nitrogen in the form of Ammonium, which may be used by plants; the most reduced form of nitrogen, found in waters with low dissolved oxygen	Increases	19
NO_3	Nutrients - Nitrogen in the form of Nitrate, which may be used by plants; excess nitrate can contribute to eutrophican of lakes; may originate from agricultural or wastewater sources	Increases	19
Summer Chloride	Chemistry - measure of salt in the surface waters; may originate from watershed geology or winter road salt	Increases	19
Spring Chloride	Chemistry - measure of salt in the surface waters; may originate from watershed geology or winter road salt	Increases	11
Total number of analyses			**235**

Notably, no sites showed a significant trend for phosphorus, which indicates that phosphorus concentrations in the sampled tributaries and lakes have remained stable over the past ten years. This is important since phosphorus is usually the limiting nutrient in freshwater systems, and excess phosphorus is the primary cause of unwanted algae blooms and nuisance plant growth in lakes.

Of the eleven trends that were found to be significant for the sites evaluated, turbidity most commonly showed a significant trend. Significant turbidity trends were observed at Red Brook in Freedom (OL-7), Cold Brook in Freedom (GF-3), Banfield Brook in Madison (GM-1), and Forrest Brook in Madison (GM-3; Figure C2). Turbidity appears to be increasing in all of these sites, suggesting declining water quality. Turbidity is a measure of particles in the water that make water less clear. In the Ossipee Watershed, high turbidity is most often linked to sediment that has entered the water from areas of erosion. Areas of erosion can be failing stream banks, poorly maintained roads, or any other area where sediment is released into the stream. These trends could be directly addressed by finding erosion issues in these watersheds and using Best Management Practices (BMPs) to manage stormwater and reduce land erosion. It is notable that, despite the increasing trends, turbidity in these sites is still quite low. The New Hampshire water quality standard for Turbidity is 10 NTU above natural conditions, which all of these sites are well below. However, detecting a trend now and fixing the cause will be much easier and cheaper than waiting for these streams to violate the State water quality standard.

Dissolved Oxygen (DO) is showing a significant decline in the Pine River at Site GE-1 in Effingham (Figure C2). The median DO concentration has gone from 8.6 in 2003 to 7.8 mg/L in 2011. 7.8 mg/L is still an adequate value to support aquatic life, but this downward trend indicates that something in the watershed is adversely impacting this critical component of stream habitat. DO may be depleted in streams in many ways, but this is commonly seen in slower waters when streams are not mixed well and bacterial decomposition of organic matter (decaying plants, algae, leaves, etc.) uses up available oxygen in the water column.

Total dissolved nitrogen was found to be increasing in both Bearcamp River in Ossipee (OL-2) and Danforth Pond Outlet in Freedom (GF-1; Figure C2). These results may be linked to nutrient runoff in the watershed, but require further investigation. The Ossipee River in Effingham (GE-3) was found to be increasing in ammonium-nitrogen (NH_4; Figure C2). This result is indicative of a larger issue than results seen at smaller tributaries, since the Ossipee River and its watershed are so large at this location (this site has a roughly 330 mi^2 drainage area). As such, water quality issues such as increasing nutrients can take a long time to be detected and may be indicative of substantial water quality problems upstream. This issue should be investigated further, as the trend could be indicative of watershed runoff issues (e.g., from agricultural practices or septic effluent) or nutrient processing in the lakes and bays.

Chloride trend analyses were separated into spring and summer concentrations to investigate the contribution of road salt to the chloride concentration in streams across seasons and the contribution of road salt in groundwater at baseflow in summer. Two sites appear to have decreasing chloride concentrations – Frenchman Brook in Ossipee (GO-2; spring) and Forrest Brook in Eaton (GM-3; summer) – suggesting a trend towards better water quality (Figure C1). Spring chloride was found to be significantly increasing at one location – the Cold River in Sandwich (GS-1). However, chloride concentrations across the watershed are generally low, especially in the spring. In fact, all sites with data from both spring and summer baseflow show low chloride values in the spring. Note that all median chloride values are well below the State water quality standards of 230 mg/L (for a continuous average) and 860 mg/L (for an acute, one-time reading).

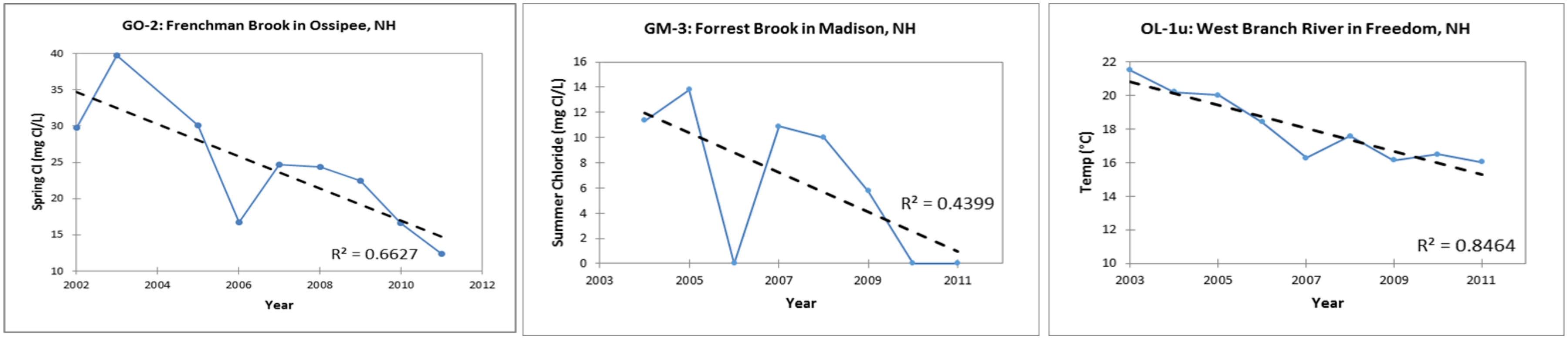
Table C2. Summary of Mann-Kendall trend test statistics for select twenty-two tributary sites in the Ossipee Watershed. Note that West Branch River (OL-1u) had four parameters with significant trends, but the results were deemed inconclusive since the trends were a function of the site being relocated multiple times upstream to eliminate lake effect.

Site	*Stats*	Temp	Turbidity	pH	DO (mg/L)	Sp. Cond.	TP	NH_4	PO_4	TDN	NO_3	Summer Chloride	Spring Chloride
GE-1	Kendall's tau	0.500	0.141	0.167	-0.556	-0.238	0.500	0.429	-0.265	0.524	0.098	-0.143	-0.429
	S	18.000	5.000	6.000	-20.000	-5.000	14.000	9.000	-7.000	11.000	2.000	-3.000	-9.000
	Var(S)	0.000	91.000	91.000	91.000	91.000	91.000	91.000	61.667	61.667	43.333	91.000	0.000
	p-value	0.075	0.675	0.612	***0.045***	0.562	0.109	0.239	0.445	0.136	0.879	0.773	0.239
	n	9	9	9	9	7	8	7	8	7	7	7	7
GE-2	Kendall's tau	0.111	0.244	-0.156	-0.067	0.067	0.000	-0.143	-0.488	0.524	-0.250	-0.333	-0.200
	S	5.000	11.000	-7.000	-3.000	1.000	0.000	-3.000	-10.000	11.000	-5.000	-7.000	-2.000
	Var(S)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	43.333	43.333	42.333	0.000	0.000
	p-value	0.727	0.381	0.601	0.862	1.000	0.905	0.773	0.172	0.136	0.539	0.381	0.817
	n	10	10	10	10	6	8	7	7	7	7	7	5
GE-3	Kendall's tau	0.222	0.535	0.222	-0.389	0.354	0.333	0.611	0.061	0.514	-0.183	-0.278	-0.429
	S	8.000	19.000	8.000	-14.000	12.000	12.000	22.000	2.000	18.000	-6.000	-10.000	-12.000
	Var(S)	0.000	91.000	91.000	91.000	87.333	87.333	87.333	83.333	90.000	83.333	87.333	0.000
	p-value	0.477	0.059	0.477	0.180	0.239	0.260	***0.025***	0.913	0.073	0.584	0.358	0.179
	n	9	9	9	9	9	9	9	9	9	9	9	8
GF-1	Kendall's tau	-0.111	0.360	-0.244	-0.289	0.195	0.143	0.200	0.276	0.828	0.072	-0.467	*n too low to evaluate significance*
	S	-5.000	16.000	-11.000	-13.000	4.000	3.000	3.000	4.000	12.000	1.000	-7.000	
	Var(S)	0.000	124.000	124.000	124.000	43.333	43.333	43.333	27.333	27.333	26.333	43.333	
	p-value	0.727	0.178	0.381	0.291	0.649	0.773	0.719	0.566	***0.035***	1.000	0.272	
	n	10	10	10	10	7	7	6	6	6	6	6	
GF-2	Kendall's tau	-0.143	-0.143	0.143	-0.600	0.000	-0.143	0.200	-0.067	0.276	0.389	-0.690	*n too low to evaluate significance*
	S	-3.000	-3.000	3.000	-9.000	0.000	-3.000	3.000	-1.000	4.000	5.000	-10.000	
	Var(S)	0.000	0.000	0.000	0.000	0.000	0.000	27.333	27.333	27.333	23.667	27.333	
	p-value	0.773	0.773	0.773	0.136	0.750	0.773	0.719	1.000	0.566	0.411	0.085	
	n	7	7	7	6	4	7	6	6	6	6	6	
GF-3	Kendall's tau	0.141	0.556	0.028	0.197	0.310	0.222	0.056	0.036	0.000	-0.150	-0.444	-0.429
	S	5.000	20.000	1.000	7.000	11.000	8.000	2.000	1.000	0.000	-5.000	-16.000	-12.000
	Var(S)	91.000	91.000	91.000	91.000	91.000	91.000	91.000	63.667	87.333	86.333	91.000	0.000
	p-value	0.675	***0.045***	1.000	0.529	0.295	0.477	0.919	1.000	1.000	0.667	0.119	0.179
	n	9	9	9	9	9	9	9	9	9	0	9	9

Site	***Stats***	Temp	Turbidity	pH	DO (mg/L)	Sp. Cond.	TP	NH_4	PO_4	TDN	NO_3	Summer Chloride	Spring Chloride
GM-1	Kendall's tau	-0.067	0.822	-0.045	-0.244	-0.429	0.378	0.467	0.490	0.349	0.386	-0.022	-0.278
	S	-3.000	37.000	-2.000	-11.000	-9.000	17.000	21.000	18.000	15.000	17.000	-1.000	-10.000
	Var(S)	0.000	0.000	124.000	124.000	124.000	124.000	124.000	96.667	121.000	123.000	124.000	0.000
	p-value	0.862	***0.000***	0.928	0.381	0.239	0.156	0.073	0.084	0.203	0.149	1.000	0.358
	n	10	10	10	10	7	10	10	10	10	10	10	9
GM-3	Kendall's tau	0.214	0.786	0.036	-0.286	0.036	-0.182	-0.189	-0.161	-0.540	-0.567	-0.643	*n too low to evaluate significance*
	S	6.000	22.000	1.000	-8.000	1.000	-5.000	-5.000	-4.000	-14.000	-15.000	-17.000	
	Var(S)	0.000	0.000	64.333	64.333	64.333	64.333	61.667	58.000	60.667	61.667	61.667	
	p-value	0.548	***0.006***	1.000	0.399	1.000	0.618	0.610	0.694	0.095	0.075	***0.042***	
	n	8	8	8	8	8	8	8	8	8	8	8	
GO-1	Kendall's tau	-0.200	-0.067	-0.022	0.156	-0.333	-0.167	0.143	0.103	0.293	-0.103	-0.429	-0.600
	S	-9.000	-3.000	-1.000	7.000	-7.000	-6.000	3.000	2.000	6.000	-2.000	-9.000	-9.000
	Var(S)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	40.667	43.333	40.667	0.000	0.000
	p-value	0.484	0.862	1.000	0.601	0.381	0.612	0.773	0.875	0.448	0.875	0.239	0.136
	n	10	10	10	10	7	9	7	7	7	7	7	6
GO-2	Kendall's tau	0.067	-0.022	0.289	0.135	-0.333	-0.244	-0.333	-0.544	0.135	0.368	-0.111	-0.722
	S	3.000	-1.000	13.000	6.000	-7.000	-11.000	-15.000	-20.000	6.000	16.000	-5.000	-26.000
	Var(S)	0.000	0.000	0.000	124.000	124.000	124.000	124.000	96.667	124.000	121.333	124.000	0.000
	p-value	0.862	1.000	0.291	0.653	0.381	0.381	0.216	0.053	0.653	0.173	0.727	***0.006***
	n	10	10	10	10	7	10	10	10	10	10	10	9
GO-4	Kendall's tau	0.357	0.429	0.214	-0.143	-0.067	-0.143	0.067	0.602	-0.149	0.138	-0.067	*n too low to evaluate significance*
	S	10.000	12.000	6.000	-4.000	-1.000	-3.000	1.000	7.000	-2.000	2.000	-1.000	
	Var(S)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	19.667	24.667	27.333	0.000	
	p-value	0.275	0.179	0.548	0.720	1.000	0.773	1.000	0.176	0.840	0.848	1.000	
	n	8	8	8	8	6	7	6	6	6	6	6	
GO-5	Kendall's tau	0.214	0.400	0.071	-0.143	-0.067	0.429	-0.238	0.329	-0.250	-0.524	-0.048	0.333
	S	6.000	11.000	2.000	-4.000	-1.000	12.000	-5.000	5.000	-5.000	-11.000	-1.000	5.000
	Var(S)	0.000	64.333	64.333	64.333	64.333	64.333	64.333	27.667	42.333	42.333	64.333	0.000
	p-value	0.548	0.212	0.905	0.720	1.000	0.179	0.562	0.447	0.539	0.136	1.000	0.469
	n	8	8	8	8	6	8	7	7	7	7	7	6
GS-1	Kendall's tau	-0.045	0.225	-0.022	0.200	-0.488	0.289	-0.111	-0.218	0.236	-0.163	0.333	0.667
	S	-2.000	10.000	-1.000	9.000	-10.000	13.000	-5.000	-8.000	10.000	-7.000	15.000	24.000
	Var(S)	124.000	124.000	124.000	124.000	43.333	43.333	43.333	96.667	119.333	120.333	43.333	0.000
	p-value	0.928	0.419	1.000	0.484	0.172	0.291	0.727	0.476	0.410	0.584	0.216	***0.013***
	n	10	10	10	10	7	10	10	10	10	10	10	9
GT-1	Kendall's tau	0.090	0.341	0.090	-0.422	-0.524	0.222	0.238	0.276	0.390	0.546	0.143	-0.600
	S	4.000	15.000	4.000	-19.000	-11.000	8.000	5.000	4.000	8.000	10.000	3.000	-6.000
	Var(S)	124.000	123.000	124.000	124.000	124.000	124.000	124.000	27.333	43.333	38.667	124.000	0.000
	p-value	0.788	0.207	0.788	0.108	0.136	0.477	0.562	0.566	0.288	0.148	0.773	0.233
	n	10	10	10	10	7	9	7	6	7	7	7	5

Site	***Stats***	Temp	Turbidity	pH	DO (mg/L)	Sp. Cond.	TP	NH_4	PO_4	TDN	NO_3	Summer Chloride	Spring Chloride
GT-4	Kendall's tau	-0.255	0.357	0.071	-0.571	0.048	0.357	-0.071	0.367	0.077	0.109	-0.429	-0.048
	S	-7.000	10.000	2.000	-16.000	1.000	10.000	-2.000	7.000	2.000	3.000	-12.000	-1.000
	Var(S)	64.333	64.333	64.333	64.333	64.333	64.333	64.333	37.000	60.667	64.333	64.333	0.000
	p-value	0.454	0.275	0.905	0.061	1.000	0.275	0.905	0.324	0.898	0.803	0.179	1.000
	n	8	8	8	8	7	8	8	8	8	8	8	7
GT-5	Kendall's tau	0.109	0.109	0.327	-0.109	-0.400	0.000	0.333	0.913	0.183	-0.667	0.000	*n too low to evaluate significance*
	S	3.000	3.000	9.000	-3.000	-11.000	0.000	2.000	5.000	1.000	-4.000	0.000	
	Var(S)	64.333	64.333	64.333	64.333	64.333	64.333	64.333	7.667	7.667	7.667	64.333	
	p-value	0.803	0.803	0.319	0.803	0.212	0.817	0.750	0.149	1.000	0.333	0.750	
	n	8	8	8	8	8	5	4	4	4	4	4	
OL-1u	Kendall's tau	-0.833	0.479	-0.278	0.111	0.524	0.500	0.714	0.340	0.571	0.786	0.857	*n too low to evaluate significance*
	S	-30.000	17.000	-10.000	4.000	11.000	18.000	20.000	9.000	16.000	22.000	24.000	
	Var(S)	0.000	91.000	91.000	91.000	91.000	91.000	91.000	61.667	61.667	61.667	91.000	
	p-value	***0.001***	0.093	0.358	0.761	0.136	0.075	***0.014***	0.308	0.061	***0.006***	***0.002***	
	n	8	8	8	8	6	8	7	7	7	7	7	
OL-2	Kendall's tau	-0.143	0.500	0.000	-0.429	0.200	0.333	0.600	0.316	1.000	0.738	0.200	*n too low to evaluate significance*
	S	-4.000	14.000	0.000	-12.000	3.000	5.000	6.000	3.000	10.000	7.000	2.000	
	Var(S)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	15.667	15.667	15.667	0.000	
	p-value	0.720	0.109	0.905	0.179	0.719	0.469	0.233	0.613	***0.017***	0.130	0.817	
	n	8	8	8	8	6	6	5	5	5	5	5	
OL-4u	Kendall's tau	0.200	0.467	0.067	-0.200	-0.333	*n too low to evaluate significance*	*n too low to evaluate significance*	*n too low to evaluate significance*	*n too low to evaluate significance*	*n too low to evaluate significance*	*n too low to evaluate significance*	*n too low to evaluate significance*
	S	3.000	7.000	1.000	-3.000	-5.000							
	Var(S)	0.000	0.000	0.000	0.000	0.000							
	p-value	0.719	0.272	1.000	0.719	0.469							
	n	6	6	6	6	6							
OL-5ua	Kendall's tau	0.000	0.800	0.400	-0.200	-0.600	*n too low to evaluate significance*	*n too low to evaluate significance*	*n too low to evaluate significance*	*n too low to evaluate significance*	*n too low to evaluate significance*	*n too low to evaluate significance*	*n too low to evaluate significance*
	S	0.000	8.000	4.000	-2.000	-6.000							
	Var(S)	0.000	0.000	0.000	0.000	0.000							
	p-value	0.817	0.083	0.483	0.817	0.233							
	n	5	5	5	5	5							
OL-7	Kendall's tau	-0.222	0.761	0.444	0.389	-0.048	0.000	-0.200	-0.200	-0.276	0.467	-0.200	*n too low to evaluate significance*
	S	-8.000	27.000	16.000	14.000	-1.000	0.000	-3.000	-3.000	-4.000	7.000	-3.000	
	Var(S)	0.000	91.000	91.000	91.000	91.000	91.000	91.000	91.000	27.333	27.333	91.000	
	p-value	0.477	***0.006***	0.119	0.180	1.000	0.905	0.719	0.719	0.566	0.272	0.719	
	n	9	9	9	9	7	8	6	6	6	6	6	

Site	***Stats***	Temp	Turbidity	pH	DO (mg/L)	Sp. Cond.	TP	NH_4	PO_4	TDN	NO_3	Summer Chloride	Spring Chloride
OL-9u	Kendall's tau	-0.238	-0.048	-0.488	0.333	-0.238	*n too low to evaluate significance*	*n too low to evaluate significance*	*n too low to evaluate significance*	*n too low to evaluate significance*	*n too low to evaluate significance*	*n too low to evaluate significance*	*n too low to evaluate significance*
	S	-5.000	-1.000	-10.000	7.000	-5.000							
	Var(S)	0.000	0.000	43.333	43.333	43.333							
	p-value	0.562	1.000	0.172	0.381	0.562							
	n	7	7	7	7	7							


GO-2: Frenchman Brook in Ossipee, NH

GM-3: Forrest Brook in Madison, NH

OL-1u: West Branch River in Freedom, NH

Figure C1. Sites/parameters showing significant improving water quality trends.

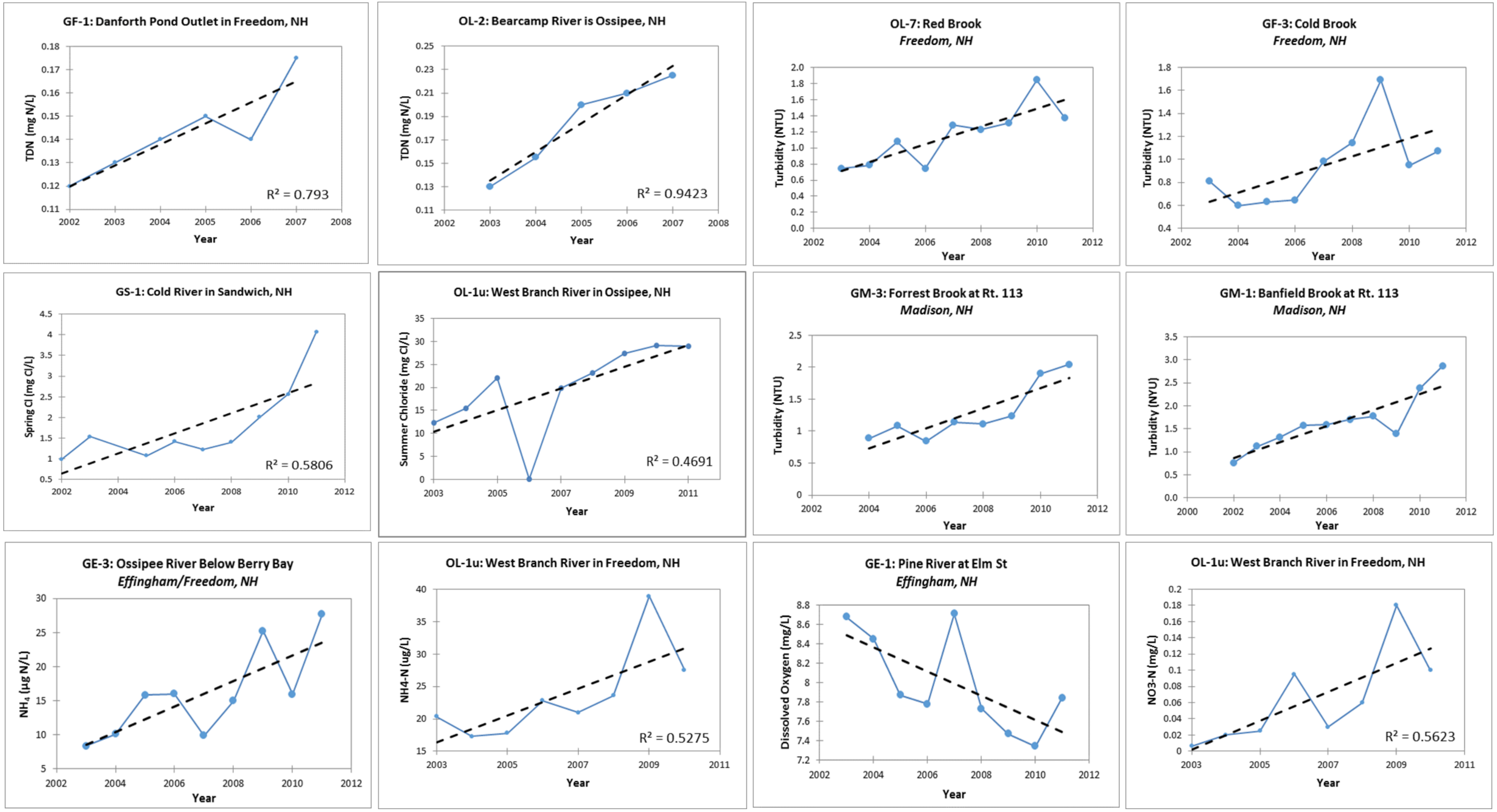


Figure C2. Sites/parameters showing significant deteriorating water quality trends.

Results – Lakes

Mann-Kendall trend tests were done for phosphorus concentrations in Ossipee Lake, Broad Bay, Leavitt Bay, Berry Bay, and Danforth Pond. No significant trend for phosphorus was found in any of the five lakes. Results indicate a stable water quality trend over the past ten years. Year to year variability is expected in lakes, and is evident in the data for these lakes.