Pleasant Lake

Community Watershed Analysis

Final Report 2024

Colby-Sawyer College

Community-Based Research Class of 2023-2024

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Abstract

Over the 2023-2024 academic year, the Colby-Sawyer College ENV301 Community-Based Project class, in collaboration with the Pleasant Lake Protective Association (PLPA), and the Town of New London, worked to enhance the caliber of the existing water quality data of Pleasant Lake. The focus of work this year was to better understand water quality impacts within the Pleasant Lake watershed, while examining loading of various nutrients and minerals. For the past two summers, Pleasant Lake experienced cyanobacteria blooms, which are often fueled by excess phosphorus inputs into the system. To better understand contributions of excess nutrients and minerals in the watershed, the class completed extended sampling and sub-watershed delineation to pin-point areas of concern. The spring semester was spent continuing water sampling as well as a thorough analysis of septic system data, road salt application practices, areas of development and impervious surfaces within the watershed. Community outreach through monthly newsletters kept the PLPA and Pleasant Lake Community members aware of project progression. The team generated newsletters that provided best practice recommendations in relation to fall landscaping and septic system maintenance for the community. This report shares the team's progress for the Fall and Spring semesters regarding its communication with the community, sampling efforts in the Pleasant Lake tributaries, data analysis, and final project findings.

Objective

The aim of this quantitative study on Pleasant Lake was to analyze dynamics within the Pleasant Lake watershed regarding tributaries, discharge, water chemistry, land cover, and human activities. An early focus of this work was to calculate the average daily load of nutrients and pollutants from the tributaries, to determine areas of concern of the lake's water quality. The main water characteristics analyzed in the project included total phosphorus, chloride, pH, turbidity, apparent color, and conductivity. Changes to these parameters as a result of storm-related precipitation, seasonal snow thaw, and seasonality was investigated. Additionally, a major goal was to determine the influence of septic tanks and human development on water quality, namely phosphorus, in each sub-watershed leading to the Lake. Furthermore, project data will be compared to historical data to determine if there have been significant changes in the condition of the lake over time. The data collected in this watershed analysis will be submitted to NHDES's VLAP program and added to their statewide dataset and project findings will be archived and communicated with the entire New London and Pleasant Lake community.

Project Members

Our team consists of ten Environmental Science and Studies students in their third or fourth year at Colby-Sawyer College, alongside three faculty advisors. Members of the class include Quinn Aldrich, Grace Carpenter, Samantha Carus, Dryden Eliason, Hannah Haughey, Aidan Jensen, Ashley Keleher, Baley Tremblay, Serena Van Wicklin, and Steven Williamson. We were advised and supported by three faculty members: Nick Baer, David Lutz, and Teriko MacConnell. The Community-Based Research courses, ENV301/302, provide students with a yearlong applied experience opportunity to partner with a community stakeholder to address an environmental concern in the area. In this year's partnership with the Pleasant Lake Protective Association and the Town of New London, students gained skills in field sampling, laboratory techniques, data analysis, public communication, and working as a team.

Picture 1: The 2023-24 Colby-Sawyer College Community-Based Research Class with two faculty advisors. Left to right: Professor Nick Baer, Steven Williamson, Baley Tremblay, Serena Van Wicklin, Hannah Haughey, Quinn Aldrich, Ashley Keleher, Sam Carus, Grace Carpenter, Aidan Jensen, Dryden Eliason, and Professor David Lutz.

The Study System: Pleasant Lake

Lakes are sentinels of past land use history. To better understand the current conditions of and stressors to Pleasant Lake, it is critical to have a firm grasp of the history of the lake and the watershed. This section briefly reviews the team's historical research this semester and how past land use and population increase within the Pleasant Lake watershed could be affecting the lakes water quality today.

The Pleasant Lake watershed, situated in a bowl below the New London town center, has supported flourishing communities for centuries. Pre-colonization, indigenous peoples, the Penacook, summered on the region's lakes to fish, then retreated into the forest for winter. Eight indigenous fireplaces have been found on the shores of Pleasant Lake. On the Pingree farm, the earliest settler came upon a fireplace with ashes still smoldering (Lord, 1972). That was the only sign of recent indigenous life in New London.

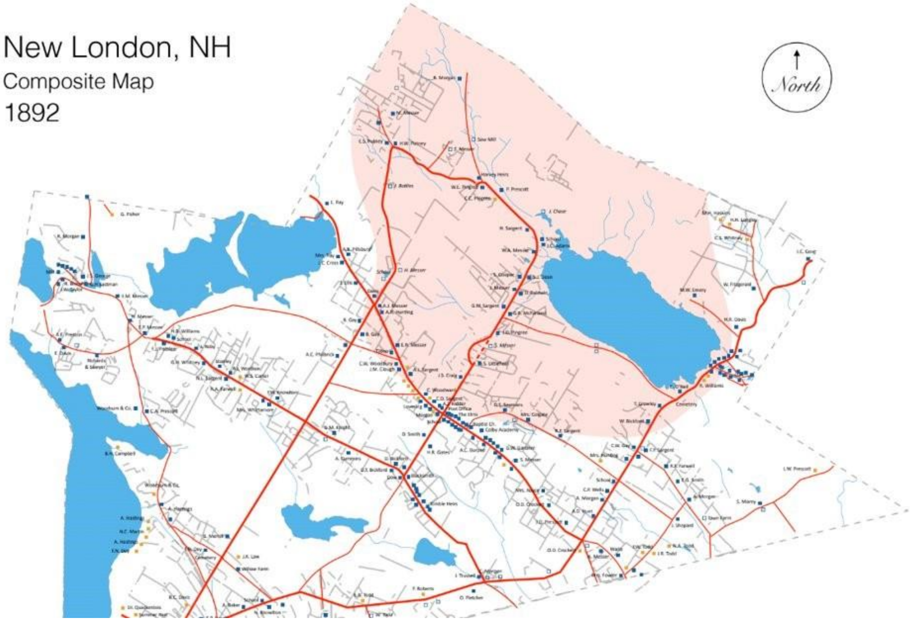


Figure 1: This is a map of New London in 1892 (Perkins, 2023). The pink area is the Pleasant Lake watershed. The grey lines are stonewalling separating farmland, and the blue dots are family residences. You can see the descendants of the Pleasant Street pioneers on the North of Pleasant Lake and the population density of Scythe Ville.

In the late 18th century, colonial settlers desiring new lands entered the area, followed by generations of farmers and craftsmen utilizing nearby lumber, water, and fertile soil. As seen in **Figure 1**, a society of families established themselves in the northern part of the watershed along

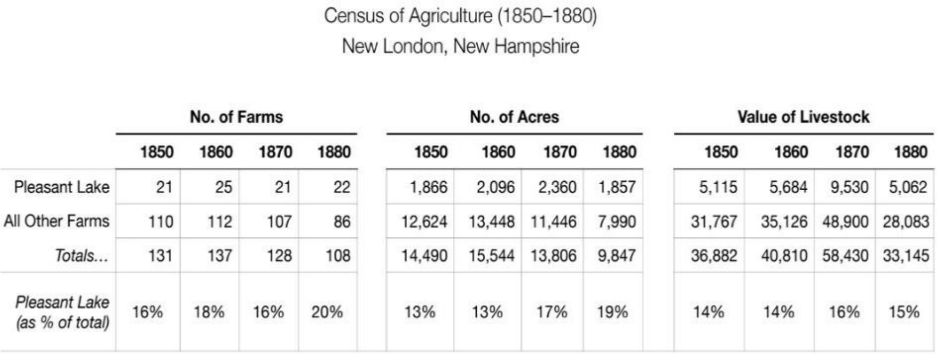
Great Brook, and at the foot of Morgan Hill. They lived in the wooded lands, farming and working near each other with no town center. This community was known as the Pleasant Street Pioneers (SEVC, 1984). At the time, Great Brook supported two sawmills and a cider mill, and the outflow of Pleasant Lake supported a prosperous village for industry. On the other side of the lake, a growing industrial community was flourishing. Scytheville, known today as the town of Elkins, was established in 1835 and named in reference to the New London Scythe Company (SESC, 1984). The company manufactured scythes and sold them across the country for the harvesting of grains and hay. (SESC, 1984). This company thrived from 1837 to 1888 as evidenced by their reported annual revenue of $100,000 (Lord, 1972), equivalent to a little over $3 million in today's economy. This local industry supported a workforce of seventy. The first dam on Pleasant Lake was constructed in 1836 and the dam that exists today was built in 1850 (SESC, 1984). **Figure 2** captures a historic view of Pleasant Lake's outlet, which supported the scythe company and a network of mills. This led to Scytheville being the most densely populated part of New London from 1835 to 1896 (SESC, 1984). The largest tributary, Great Brook, and the only outflow supported the two communities on the lake during the 19th century.

Figure 2: The New London Scythe Company anchored their production at the eastern dam on Pleasant Lake in the mid 1800's. Image is from 'Reflections in a Millpond' (SESC, 1984).

Although indigenous communities utilized the area for millennia, the landscape was modified in a significant manner from the late 18th through the 19th century when the rolling hills surrounding Pleasant Lake were cleared as pastureland for sheep and cattle, as seen in **Figure 3**. Sheep were the leading livestock in the town from the 1830's to 1850's, but when the need for wool diminished after the Civil War, the focus switched to cattle in the 1860's (Ausbon Sargent, n.d.). Roughly every home in New London had a farm during the 19th century (Perkins, 2023). Subsequently, the land surrounding Pleasant Lake was a mixture of fields, pastures, and early successional forests with considerable quantities of pine.

Figure 3: Pastureland on the north end of Pleasant around the year 1900 (Perkins, 2023).

The full picture of how significantly the landscape surrounding Pleasant Lake differs from today is evidenced in **Table** 1, which illustrates the number of farms, total acres of agriculture, and the value of livestock within New London from 1850 to 1880. This table shows all the farms located within the Pleasant Lake watershed, as well as those throughout the rest of New London. Notably, after 1860, the number of farms outside of the watershed dropped from 112 to 86, and only 21 remained around Pleasant Lake. Those within the watershed went from representing 16% of the farms in town, to representing 20%. The percentage of agricultural acreage also increased within the watershed. This shows that pastureland and agriculture held on a little longer within the watershed compared to the rest of the town. In any event, for many decades, agricultural lands were robust within the lake's watershed.



Census of Agriculture (1850–1880)
New London, New Hampshire

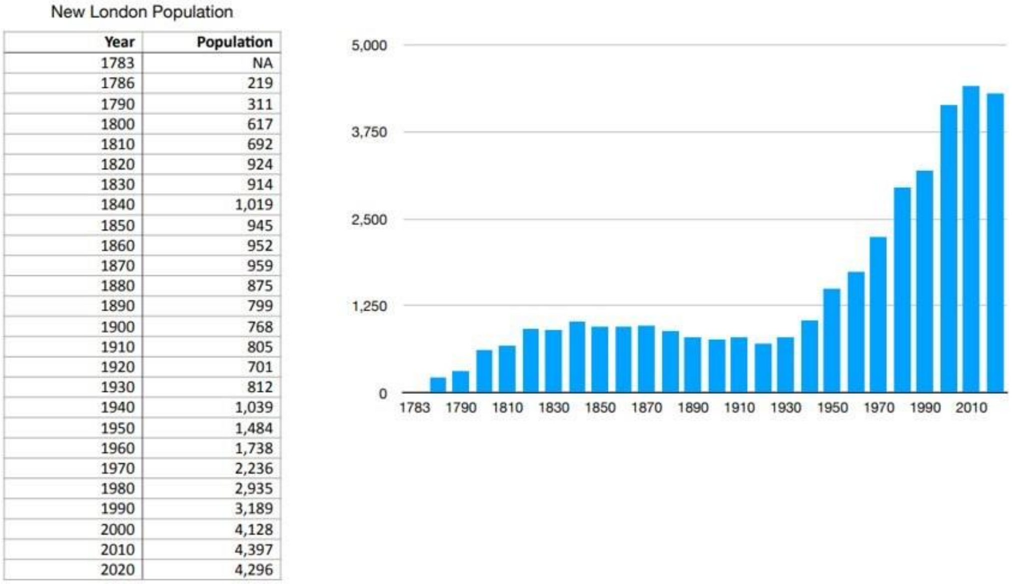
	No. of Farms				No. of Acres				Value of Livestock			
	1850	1860	1870	1880	1850	1860	1870	1880	1850	1860	1870	1880
Pleasant Lake	21	25	21	22	1,866	2,096	2,360	1,857	5,115	5,684	9,530	5,062
All Other Farms	110	112	107	86	12,624	13,448	11,446	7,990	31,767	35,126	48,900	28,083
Totals…	131	137	128	108	14,490	15,544	13,806	9,847	36,882	40,810	58,430	33,145
Pleasant Lake (as % of total)	16%	18%	16%	20%	13%	13%	17%	19%	14%	14%	16%	15%

Table 1: Agricultural Census of the town of New London and the Pleasant Lake watershed (Perkins, 2023). This table shows the beginning of the decline of total farmland and grazing land in the Civil and post-War period.

One example of agricultural production in the Lake's watershed was the Jacob Messer farm situated on Little Lake Sunapee Road. This was one of the most successful farms in New London during the 19th and early 20th century, and one of the last thriving dairy farms in the local region throughout the 1940's and 1950's. The Messer farm is now owned by the Ausbon Sargent Land Preservation and leased by Spring Ledge Farm. One indication of how agriculture can influence the lake comes from a 1979 report on soil erosion and agricultural waste in Merrimack County; the report was provided to the project team by Jim Perkins and the town archives. In the report, there were three agricultural waste sites listed within the watershed. On site 1, Messer Farm, the report states that there were 641 tons of dairy cattle manure produced each year, generated by 86 dairy cows. According to the report, this waste would be spread over the farm's surrounding cropland every day. This quantity is the equivalent of two truckloads of manure being spread every day. Two other sites in the report were site 3, located near the junction of Seamans Road and route 11, which produced nine tons of sheep manure. Site 4, also near the junction of Seaman's Road and Route 11, produced 442 tons per year of swine and horse manure. Each of these sites would spread this waste to fertilize their crops and let it sit over winter. This quantity of manure being dispersed within the watershed likely contributed large quantities of nitrogen and phosphorus to the Lake via transportation in tributaries and soil erosion. The phosphorous could have also been bound to the soil, made insoluble, and been retained in lake sediments over the years.

Studies have shown that past agricultural practices that contributed excess phosphorus to ecosystems can be stored in soils (Jarvie 2013). This type of phosphorus is known as legacy phosphorus. Legacy phosphorus is a component of lake sediments that originate from previously applied manures and fertilizers that have been bound to soil particles and sediment. This stored phosphorus can then be washed into tributaries, or directly into the lake during storm events, which can carry a higher load of sediments. It appears that the long history of agriculture and pastoralism in Pleasant Lake's watershed could serve as a source of legacy phosphorus Pleasant Lake is an oligotrophic lake which has naturally large magnitudes of dissolved oxygen. However, anoxic conditions could spark a major release of sediment-bound reactive phosphorus (Wang et al. 2008), and thus it may be possible for this legacy phosphorus to enter Pleasant Lake.

Presently, many farms in the region make efforts to reduce phosphorus runoff from the topsoil. However, research efforts indicate that even with these current practices, there is still a "chronic release of P from "legacy P" stores, which have accumulated in watersheds and water bodies" (Jarvie, 2013). For this reason, it is a complex challenge to maintain water quality in water bodies with deep agricultural histories such as Pleasant Lake. The effects of legacy P on runoff have been known to continue for decades unless steps are taken to reduce soil P concentrations (Wironen, et. al, 2018). Vermont and New Hampshire have very similar agricultural histories, so the project's investigation of Pleasant Lake water quality may mirror issues that other communities in the region are also facing.



New London Population

Year	Population
1783	NA
1786	219
1790	311
1800	617
1810	692
1820	924
1830	914
1840	1,019
1850	945
1860	952
1870	959
1880	875
1890	799
1900	768
1910	805
1920	701
1930	812
1940	1,039
1950	1,484
1960	1,738
1970	2,236
1980	2,935
1990	3,189
2000	4,128
2010	4,397
2020	4,296

Figure 4: The population of New London increased dramatically following World War II (Perkins, 2023)

Aside from agricultural impacts, the presence of homes and development in the town of New London has had an impact on Pleasant Lake. **Figure 4** shows the fluctuation of population in New London from the first settlements in the 1780's to present day. During the height of agriculture and the New London Scythe Company, there was a rise in population. However, the population dropped after the Civil War and World War I. Following World War II, the population began to climb dramatically, and New London became a place of prosperity and new ideas. With an ever-changing society and growing population, more and more people wanted to live in tranquil rural towns like New London. The lakes in the area were a highlight of this wish. In the 1960's, citizens and stakeholders of the town became increasingly conscious of land use changes (Stecker, 2000). This allowed conservation and recreation to start overlapping with, and in many cases, replacing agriculture in the region. What was once pastureland and crop fields for almost two centuries was left to be reforested.

Beginning in the 1960's, Pleasant Lake and New London quickly became prominent vacation destinations. The construction of I-89 provided easier access to this quaint town and connected people from Boston to Burlington (Stecker, 2000). The improved access to this rural destination led to more development, such as the Slope and Shore community, as well as permanent residences and summer homes on Lamson Lane, Bunker Road, and Lakeshore Drive. At the same time, hard surfaced roads became more abundant. Any form of hard surface roads, whether it is hard packed gravel or asphalt, can increase runoff in a watershed and influence water quality in nearby lakes. The influence of more developed landscapes, septic systems, and impervious surfaces may likely have an impact on water quality in the Lake, yet a formal analysis of water quality has not investigated historical data or its relationship to spatial distributions of development. This project attempts to address that paucity of findings.

Residents of the Pleasant Lake watershed value the lake as a source of recreation, scenic beauty, and as part of the community's identity. Throughout the fall and this spring semester the project team communicated with past and present community members willing to share their historical perspectives of living around Pleasant Lake. Learning about what Pleasant Lakes water means to the community gave our team a better understanding of what has happened within the watershed and what measures are needed to protect Pleasant Lake for the future.

Scientific Background of Freshwater Lake Systems

Issues in Freshwater Watersheds

A watershed, otherwise known as a drainage basin or catchment area, is an area of land where all surface water flows downhill along the land's contours, converging into a body of water's rivers and streams. The water flowing directly into the larger body of water, such as a lake, is known as a tributary. As all the water in a watershed eventually converges into a lake's tributaries, the watershed's condition impacts the health of the receiving water body. Tributaries also carry sediment and nutrients into the water body, further influencing the health of its ecosystem. Understanding and monitoring a lake's tributaries is a crucial effort to assessing the quality of a lake and its watershed (USGS 2019). In this project, we analyzed water coming from many tributaries within the Pleasant Lake watershed to provide a holistic view of water quality entering the Lake.

One perpetual issue related to freshwater systems that abut human-dominated landscapes regards eutrophication and its consequences for ecosystem health. Excessive plant and algal growth seen during eutrophication often leads to the occurrence of potentially toxic cyanobacteria blooms (Smil, 2000). Lakes with a history of significant external nutrient loading can, even when this loading is reduced, internally cycle these nutrients for long periods of time. This slow process from external to internal loading allows cyanobacteria to bloom even when external nutrient inputs have been mitigated (Mantzouki et al., 2016). Cyanobacteria, informally referred to erroneously as blue-green algae, are photosynthetic microorganisms that naturally occur in aquatic environments. Phytoplankton hold many forms such as dinoflagellates, green algae, golden-brown algae, and diatoms and are an integral component of a healthy lake system; however, disparities in phytoplankton profiles, such as when a single species dominates the water column, can be an indication of poor water quality (Kruk et al., 2010).

Cyanobacteria have several physical and chemical advantages that allow them to out-compete other phytoplankton in certain situations. For instance, cyanobacteria utilize phycocyanin, a unique color pigment that is able to capture a wider spectrum of light than chlorophyll, which increases the efficiency of photosynthesis under low light conditions (Morançais et al., 2018). Cyanobacteria also possess specialized cells called heterocysts, with allow these organisms the ability to fix atmospheric nitrogen (Garcia-Pichel, 2009). Cyanobacteria also possess another set of specialized cells called akinetes that overwinter in the bottom sediment of lakes and later rise in the water column when conditions become favorable for growth in the spring (Sukenik et al, 2018). These specific adaptations give cyanobacteria the ability to flourish in phosphorus-rich environments when waters are warm and turbid.

In recent years there have been growing concerns regarding cyanobacteria blooms due to increased awareness of their toxicity and more frequent bloom events. Cyanobacteria can produce a variety of hepatotoxins and neurotoxins including, but not limited to, Microcystins, Cylindrospermopsins, and Anatoxin-a. Different cyanobacteria taxa, such as Dolichospermum, Microcystis, and Woronichinia produce various arrays of toxins across a bloom’s duration (Sivonen, 2009). These cyanotoxins can cause negative health effects in aquatic and terrestrial organisms including humans. Some of the human health impacts include respiratory distress/reaction, muscle weakness, bodily irritation, organ damage, and increased uptake of carcinogens (Zhang, et al., 2022).

Cyanobacteria blooms have been on the rise in New Hampshire, with more advisories issued for lakes in 2023 than any previous year (NHDES, 2023). NHDES issued 69 advisories in 2023 for potentially toxic cyanobacteria blooms in New Hampshire waters. **Figure 5** displays the prevalence of cyanobacteria advisories and alerts since 2003, disregarding this current year. The number of advisories dropped in 2020 due to the COVID-19 pandemic that limited intern staffing to collect samples. However, cyanobacteria alerts were implemented in 2020 allowing the NHDES to alert the public of blooms based on photos, rather than an official cell count. Alerts remained in integral part of the cyanobacteria program over the next two years. A steady increase of advisories is observed from 2020-22, with 2023 continuing the trend. This increase may be the result of worsening conditions but may also be attributed to increased public awareness of cyanobacteria, as well as the NHDES’s Cyanobacteria Program’s improved resources for reporting blooms. The Cyanobacteria Bloom Report Form makes reporting a bloom, along with pictures and necessary information, easy and efficient. To check the current cyanobacteria advisories and alerts, the NHDES Healthy Swimming Mapper is kept updated with cell counts, recent sampling, and photos.

With regards to Pleasant Lake, cyanobacteria blooms have been observed in June of both 2022 and 2023, resulting in alerts for the waterbody (NHDES, 2023). The NHDES has no formal cell counts in their records for Pleasant Lake since the 2022 bloom was sampled after the material had begun to degrade and the 2023 bloom was never sampled. However, NHDES issues waterbody-wide warnings (advisories) when the cell count exceeds 70,000 cells/mL, indicating that such cell counts were quite high. Alerts are a step-down from an official advisory, with the purpose of keeping the community informed of a cyanobacteria situation that may develop into an advisory. The Pleasant Lake 2022 sample had a toxicity of 0.99 PPB of microcystin. To protect public health, the United States Environmental Protection Agency (US EPA) has recommended recreational standards for microcystin concentrations of < 8 PPB (US EPA, 2019). However, it is important to note that a bloom's toxicity level and toxins produced vary over its duration due to environmental factors (Sivonen, 2009). As a result, these recent incidents suggest that cyanobacteria blooms may become a more common event within Pleasant Lake.

Figure 5: The total number of cyanobacteria advisories and alerts in New Hampshire waterbodies from 2003-2022 indicate a rising trend. (NHDES New Hampshire Cyanobacteria Plan)

The presence of harmful toxins found in cyanobacteria impacts biodiversity, native plants, and native fish species (Bennett, et al., 2001). A study by Schindler et al (2016) reviewed the evidence of numerous long-term studies of lake ecosystems in North America and revealed that controlling algal blooms and other eutrophication symptoms depends solely on the reduction of phosphorus. Consequences of eutrophication also extend to economic losses and damages. A study by Dodds et al (2009) estimated an annual cost of $2.2 billion (about $7 per person in the US) from the consequences of eutrophication to freshwater ecosystems in the United States, with the greatest losses attributed to lakefront property values and recreational uses. A more recent study by Wurtsbaugh et al (2019) revised the estimate, calculating an annual cost of $2.4 billion (about $7 per person in the US) to freshwater ecosystem services. Since it is clear that nutrient loading resulting in eutrophication and cyanobacteria blooms can cause great harm to lotic ecosystems, it is critical that routine sampling and monitoring of key nutrients and conditions be completed to ensure ecosystem health. The following nutrients were areas of focus for our monitoring efforts on Pleasant Lake for this project.

Phosphorus:

Phosphorus (P) is a major limiting macronutrient in aquatic systems and serves as a control on the growth of aquatic plants and algae, particularly in lakes. Phosphorus is essential for biological development and reproduction, but too much exacerbates unwanted growth, often presenting itself in the form of cyanobacteria blooms (US EPA, 2023_a). While a main consequence of phosphorus loading to lakes is the increased presence of cyanobacteria blooms, there are other consequences. Excess phosphorus can lead to the depletion of dissolved oxygen levels and cause harm to aquatic species. The adverse effects of eutrophication are not often seen immediately following a major phosphorus loading event. Instead, phosphorus can linger and negatively impact the environment for an extended period.

Terrestrial sources of anthropogenic phosphorus entering aquatic systems include fertilizers, improperly managed sewage-related discharge, and lake-bottom sediments containing legacy phosphorus (Smil, 2000). The accumulation of phosphorus from fertilizer begins with phosphate particles in soil and is influenced by the nutrient’s ability to bind quickly and easily. Phosphorus is found as a natural component of soil and is especially prevalent in areas like New Hampshire with abundant apatite-containing metamorphic rock. Soil, and its associated phosphorus, then enters waterways in large quantities through runoff or erosion, which can pull sediment, surface water, and any other excess nutrients into streams to be deposited into surrounding waters (Bennett, et al., 2001). In heavy precipitation, such deposition can be exacerbated, and elevated intensity or occurrence of storm events can become a major contributor to waterbody degradation.

Heavy nutrient loading from precipitation events pose a threat to the New England region, as storms are more frequent, and temperatures rise. A study by Biagi et al. evaluated this phenomenon using five years' worth of data from eleven watersheds in the Great Lakes Basin and found that, while the proportion of phosphorous transported may be highly variable during any one event (47-94%), three events over the course of an entire year were responsible for almost half of the phosphorous observed (2022). In New England, climate change has been predicted to affect rain events, increasing the frequency of intense precipitation storm events (Huang et al. 2018). Climate change has also most notably increased New Hampshire’s air temperature by 3°F (~1.67° C) in the past century. With every 1° Celsius warming of the atmosphere, the air’s water-holding capacity increases by 7%. A study aimed at measuring the influence of storm events on total phosphorus (TP) concentrations in runoff revealed that TP loading was highest when the maximum rainfall intensity or duration of the storm was also highest (Luo, et al., 2009).

Another contributor of phosphorus entering waterways is improperly managed sewage effluent. Human waste is rich in phosphorus and septic tanks, which are common in the Pleasant Lake watershed, contain large amounts of this nutrient. When correctly maintained, septic systems release treated water that is safe to enter the environment. However, several factors impact the maintenance of a septic system such as household size, the amount of wastewater produced, the quantity of solids in wastewater, and septic tank size. The United States Environmental Protection Agency recommends that household septic systems be inspected at least every three years by a septic professional. Household septic tanks are typically pumped every three to five years (US EPA, 2023$_b$). Proper maintenance of septic systems protects from leaching. Leaching of phosphorus into the groundwater from septic tanks occurs throughout the system’s drain field, particularly within the infiltration pipes. Besides regular pumping, the soil around a septic system can impact phosphorus entering the groundwater. A soil’s buffering capacity can impact phosphorus leaching into groundwater from the drain fields. Furthermore, draining fields in non-calcareous soil (87% sand, 13% silt) resulted in lower pH, thus less phosphorus leaching. In contrast, septic systems in calcareous soil (97% sand, 2.8% silt, and clay) result in more phosphorus leaching into groundwater (Wilhem *et al*, 2017). Most of the soil near Pleasant Lake is a mixture of clay-like soil with high run-off potential and soil that allows slow infiltration. Therefore, the clay in the soil near Pleasant Lake may be leading to increased leaching of phosphorus from septic tanks which then runoff into the lake during rain events.

Internal phosphorus loading from lake sediments is another contributor to cyanobacteria in clear-water oligotrophic lakes (Bormans et al, 2016). Historical phosphorus inputs sequestered in the bottom sediment and made labile in the water during anoxic conditions that can occur in the late summertime. A case study by NHDES (2023) looked at Nippo Lake in Barrington, New Hampshire, which experienced frequent cyanobacteria blooms due to one-third of its total phosphorus coming from the bottom sediment. Anoxic conditions occur when a lake is stratified by temperature. Anoxic leads to organic material at the bottom being consumed by bacteria that then consume the remaining oxygen. Typically, the depths of a waterbody are too deep for sunlight to reach, allowing no aquatic vegetation growth that would replenish dissolved oxygen. Stratification occurs as these layers do not mix, and dissolved oxygen from upper layers is unable to replenish the bottom (Bormans et al, 2016). Past agricultural practices and land use within the Pleasant Lake watershed may have led to legacy phosphorus bound to bottom sediment. Future studies in Pleasant Lake may include sediment cores to quantify legacy phosphorus levels within the lake and determine risks of internal loading.

Chloride:

Chloride enters the environment in the form of sodium, calcium, and magnesium chloride, or salts (Hong, 2023). Low chloride concentrations are found naturally in freshwater bodies, from sources such as weathering rocks and minerals, and atmospheric deposition (Hong, 2023). However, due to road and de-icing salt application during the winter months, chloride concentrations in lakes and ponds have been rising. According to New Hampshire Lakes, chloride levels in New Hampshire freshwater bodies are around 100 times higher today than compared to 50 years ago, or prior to road salt application being implemented. Chloride is not effectively removed from the environment by vegetation or natural processes, so nearly all chloride applied as road salt will eventually end up in nearby surface waters (NHDES, n.d). **Figure 6** shows historic data for rock salt usage as de-icing salt in the United States from 1940 to 2008 (Salt Institute, 2008). Usage begins to increase significantly around 1960, reaching peak levels in the 90s into the 2000s. The New Hampshire Department of Environmental Services has calculated that on average, a reduction of salt use by 25 – 40 % is needed to meet water quality standards.

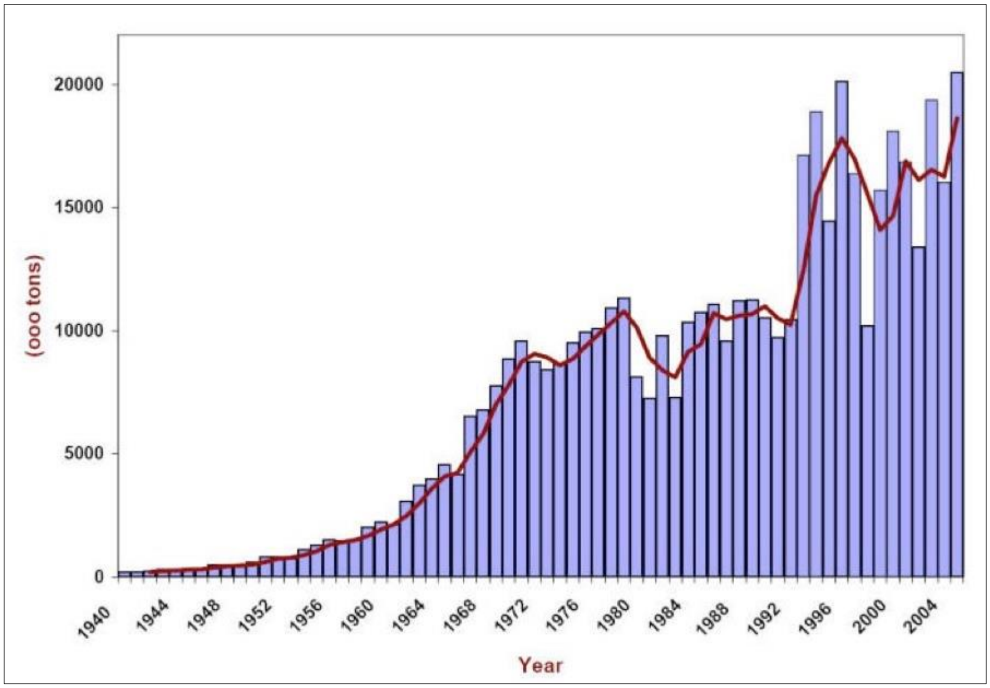


Figure 6: Over the past 70 years, the usage of rock salt for deicing in the U.S. in thousands of tons has been increasing significantly (Salt Institute).

Chloride is a pollutant of concern in terms of water quality, as rising concentrations can greatly impact freshwater ecosystems. The EPA has designated the concentration of chloride that is considered toxic to aquatic organisms at 230 mg/L (US EPA, 1988). However, sensitive species experience health implications at lower levels. A study conducted by McClymont et al in Canada (2022) investigated the impacts of increasing chloride concentrations on freshwater plankton communities, which are integral to a healthy lake system. Their data showed that increasing chloride concentrations increased cyanobacteria abundance, while reducing zooplankton diversity and richness. Other studies have found implications including a decrease in reproductive rates, inhibition of plant growth, and increased mortality rates of sensitive species (Arnott, 2020). Therefore, one focus of our study was to identify sites with consistently elevated chloride levels and examine the potential causes and sources

Historical Data on Pleasant Lake Water Quality:

It is important to note that this project is not the first assessment of water quality at Pleasant Lake. In fact, the Lake has been monitored by the New Hampshire Department of Environmental Science (NHDES) through their Volunteer Lake Assessment Program (VLAP) since 1985. This volunteer monitoring group is trained by the NHDES to gather water quality data, which is then reviewed for quality assurance. To encourage ongoing sampling, the NHDES has established partnerships with the Lake Sunapee Protective Association, Colby Sawyer College, and Plymouth State University, to operate VLAP satellite laboratories. NHDES monitors Pleasant Lake's conditions following the Water Monitoring Strategy, published in 2016 (NHDES).

For this project, our group worked closely with the Pleasant Lake Protective Association (PLPA) to build upon their ongoing conservation and monitoring efforts of the lake. The PLPA was formed in 1969 to monitor development, boating, invasive species, wildlife conservation, water quality, and the dam at the outlet of the lake. The water testing of Pleasant Lake was first performed in 1987 by Dr. Terry and Dr. Edna Dancy. Pleasant Lake is currently tested every month in the summer at the deepest middle portion of the lake, as well as at the intersection of several tributaries leading into the lake, and the lake itself. Historically, these tributary sites include Chandler Brook, White Brook, Great Book, Red Brook, Dancy's Brook, and the Dam Outlet. Our current project expanded this dataset by sampling 66 individual tributaries surrounding Pleasant Lake throughout the fall, winter, and spring seasons during both the academic fall and spring semesters. The data collected by the PLPA for VLAP provided us with an extensive dataset and a unique look into the historic water quality of the like. This gave us a baseline understanding that we could then compare our findings.

Methodological Approach of this Project:

To interpret and understand scientific findings, it is important to document the process of collecting data, both in the lab and in the field. In the controlled environment of the lab, we followed state standardized procedures adapted from the NHDES VLAP program to ensure accuracy and reliability. This included precise measurements, controlled variables, and experimentation quality checks and assurances. In the field our team gathered water samples and measured the area and velocity from the tributaries surrounding the lake. The water samples were analyzed for total phosphorus, color, turbidity, pH, chloride, and conductivity for each tributary. In addition to these samples, we estimated discharge at each tributary. Discharge is the volumetric flow rate of water, including any sediments, chemicals, or solids that are dissolved or mixed within a defined channel cross section during a specific period (Buchanan, Somers 1969) and is most often measured in cubic meters per second. discharge calculations provide inference regarding the size of a tributary and its flow rate, factors that can affect water quality when paired with nutrient concentrations. Larger, faster-flowing streams with discharges containing harmful contaminants have a greater effect on the main body of water, when directly compared to tributaries with a smaller volume of flow containing similar level of contaminants. Collecting discharge data thus helps understand the estimations of sediment or chemical pollutants entering a body of water.

With the combination of water samples and discharge data, we were able to calculate the total phosphorus load entering the lake and pinpoint specific sources of high phosphorus concentrations. This comprehensive approach allowed us to evaluate the impact of each tributary on the lake's phosphorus and chloride levels. By identifying these specific tributaries, we were able to discuss develop targeted mitigation strategies to reduce nutrient inputs and improve water quality. Additionally, by understanding the spatial distribution of phosphorus sources, we could help evaluate the impact of land cover, land use, and conservation efforts aimed at minimizing pollution and preserving the ecological integrity of the watershed.

The following sections provide a detailed overview of each methodological step that our team took during field sampling, lab work, and data analysis.

Field Sampling

I. Water Collection

For every field sampling date, a water sample for water quality parameters, a water sample for phosphorus analysis, and discharge measurements were collected at every flowing site. The water collection process was adapted from the State of New Hampshire's protocols. At every site, two water samples were taken to analyze the total phosphorus, color, turbidity, pH, chloride, and conductivity. Both bottles were labeled with the date and time as well as site number. This was to avoid confusion when analyzing multiple samples and multiple days of samples. It was also important to document the time at each site upon the sample bottles in maker as well as in the discharge book. When collecting phosphorus samples, we filled a clear 500-milliliter bottle with the water flowing in the tributary then proceeded to dump it out. This is known as “seasoning” the bottle, a process that when done correctly, ensures only the tributary’s contents are being sampled. We made sure to avoid any contact with the bottom of the tributary as this could have disturbed the sediments and caused a spike of phosphorus in the sample. If we stirred up the sediments, we moved slightly above the disturbed area, rinsed out the bottle, and tried again. After properly seasoning a bottle, we emptied its contents into a brown 250-milliliter container containing sulfuric acid. This sample was used for total phosphorus analysis. Lastly, we fill the original bottle with water from the tributary. This sample was used to assess all other parameters. Bottles containing samples were stored in a cooler throughout sampling, until the sampling team returned to the lab.

II. Discharge

Discharge measurements can be completed in several ways, depending on the quantity of water flowing at a sampling site. The first method is through the use of a bucket and stopwatch, and the second is through the use of a flow meter and meter stick. We used both of these methods during our field sampling and recorded value in a notebook in an orderly way. We wrote the date, time, and site number next to each measurement to avoid confusion later when entering data alongside water samples.

For the bucket method of calculating discharge, we utilized a small bucked and a stopwatch to measure time. Overall, we needed to convert our measurements into the appropriate unit for discharge which is generally cubic meters per second. This method only worked at sites where the totality of the tributary’s flow could be captured in a bucket. Most often this was done at the exit of a culvert when a tributary crossed a roadway. This provided us with the space needed to place a bucket beneath the flow to capture accurate discharge. This method limited the size of tributary we could sample and therefore was insufficient by itself. For both larger tributaries and tributaries that may not leave the ground as to be collected by a bucket we also used the flow meter and meterstick method.

For this second method, we used a meter stick or tap measure to break the cross section of the tributary up into different sub-sections. The depths of each sub-section were then determined with a meter stick. The number of subsections were determined depending on size of the tributary. For a smaller tributary, fewer sections were established and measured than larger tributaries. For instance, we used twenty-five centimeters for a 1-meter wide tributary or ten centimeters sections for a fifty centimeter-wide tributary. We never exceeded 50-centimeter subsections so as not to miss defining changes in the rivers structure. Once the depths were measured, and sub-sections were established, the flow meter was used to collect velocity data and flow rates in each sub-section. We repeated the process for all sub-sections to determine total discharge. The first step of this process was to turn the flow meter on and attach the node to the end of the rod, making sure the tip of the node was not touched or scratched. Scratches or oils from hands can interfere with electric currents. We then placed the rod directly on the bottom of the tributary, facing upstream in a designated sub-section. The individual taking the measurement would be standing downstream of the instrument so as not to affect the flow rate. Before anything was measured, we adjusted the height of the node so it was exactly two-thirds of the way down within the water column, which would give the most accurate representation of flow velocity, combining the fast-flowing water at the surface of the water and the slower currents at the bottom. For smaller tributaries it was important that the node was completely covered by water. If it was not, flow rates may have been skewed or unreadable. After finding the correct height, press the on button again to calibrate the instrument. We repeated this process for all the designated sub-sections and recorded all data points in a notebook (**Figure 7**). The notebook’s measurements were kept in an orderly way as to then later be entered into an excel spreadsheet and the calculate discharge.

III. Fall Sampling Design

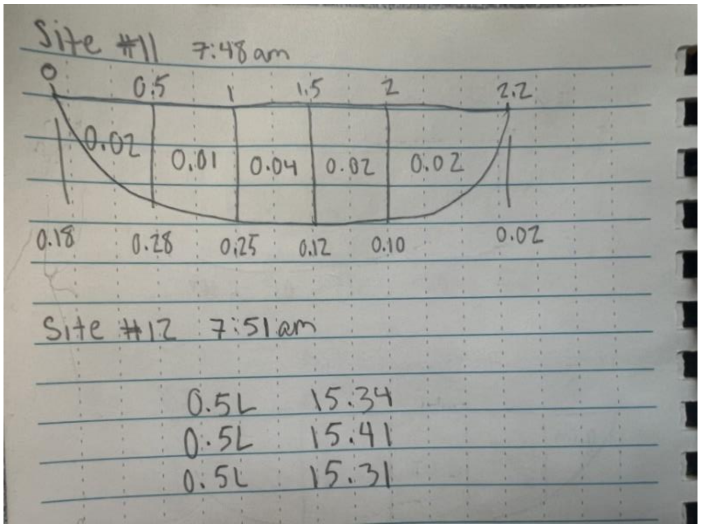


Figure 7: An example of a discharge schematic showing sub-sections of a tributary, their length, and total quantities of water flowing. These data were used to estimate discharge concurrent to each water sample.

In our project, we aimed to monitor phosphorus loading in the Pleasant Lake watershed to better understand its dynamics and potential impacts on water quality. We were initially focused on sampling fourteen sites that had been provided by the PLPA (Pleasant Lake Protection Association). However, we quickly realized the need to expand our sampling efforts due to the presence of numerous tributaries that had not been monitored prior.

Sampling commenced during the fall semester on a bi-weekly schedule, allowing for phosphorus sampling on alternate Fridays and laboratory analysis of phosphorus between weeks. Storm events were captured on an irregular basis whenever necessary. However, the discovery of additional tributaries necessitated a reassessment of our sampling strategy. Following the identification of 13 new sites after a small storm event, we increased the total number of our sampling sites to a total of 27. The notable additional sites included seven locations sites along Lamson Lane and a culvert at the end of Bunker Road in Elkins. By expanding the number of our sampling sites, we were able to construct a more comprehensive assessment of phosphorus loading in the lake. Despite starting with 14 sites, by the time we constructed our mid-term report, our data reflected consistent sampling at 27 sites. As rainfall increased and our familiarity with the lake improved, we continued to add tributaries, ultimately increasing our sampling sites to 30 by the end of the fall semester.

On December 11th, our sampling strategy was reevaluated following a significant storm event. During this field effort, which lasted 10 hours, we were able to identify and sample a total of sixty-three sites. This event highlighted the dynamic nature of environmental monitoring and the need for flexibility in our methodologies. As we transitioned into the spring semester, we recognized the need to adapt our sampling strategy to accommodate the increasing demand on our sampling plan with the ever-changing conditions of the environment. The inclusion of additional tributaries in our sampling regime allowed for a more accurate representation of phosphorus loading dynamics, particularly during storm events. By expanding our focus beyond the initial fourteen sites, we were able to capture a more comprehensive picture of nutrient inputs into the lake.

IV. Spring Sampling Design

In anticipation of increased storm events during the Spring semester, we refined our strategy to efficiently handle large-scale storm events while considering constraints such as reduced lab time availability. This revised approach involved a comprehensive analysis of storm discharge data, phosphorus daily loading data, and overall phosphorus measurements. Utilizing data collected from September to mid-November, we assessed the fluctuation in storm events and the contribution of individual sites to the lake's phosphorus load. Additionally, we examined phosphorus levels specifically on December 11th to identify areas of concern that were not captured in previous samples. Our analysis revealed a correlation between sites with high discharge and those contributing most to phosphorus daily loading. However, elevated phosphorus levels on December 11th were predominantly observed in sites that were not among the top discharge contributors. These sites, sampled exclusively on December 11th, likely accumulate phosphorus due to stagnant water conditions, which exacerbates phosphorus levels during flash storm events. Based on our findings, we opted to retain sixteen existing sites and introduce one additional site, designated as site 7.5, below Spring Ledge Farms. This new site targeted potential farm runoff based on satellite imagery and flow accumulation analysis. Our decision to maintain a total of seventeen sites for standard bi-weekly sampling was driven by practical considerations to avoid data surplus and excessive lab time. While occasional storm event samplings were planned for deeper insight into mass storm events, full sixty site sampling runs were not the primary focus of our sampling efforts.

During the spring semester, our sampling efforts encountered several challenges necessitating adjustments to our plan. Sites 7, 7.5, and 9 presented significant difficulties, primarily related to adverse weather conditions, snowpack, and ice formation. Site 9, a small tributary, became completely obscured by snow, rendering it inaccessible for sampling without risk of contamination. Similarly, site 7.5 proved challenging due to thin, slushy ice cover, leading to significant sediment contamination when attempting to break through the ice. At site 7, ice formation redirected the flow of the river away from the sampling point, resulting in a substantial decrease in water levels and the presence of silt and mud instead of suitable sampling water. However, during two large-scale storm events, water levels at sites 7 and 7.5 temporarily rose, allowing for clean sample collection. Additionally, site 9 became accessible due to heavy rainfall and elevated temperatures. However, subsequent freezing weather conditions rendered these sites unsuitable for sampling once again. Other sites, including site 3 and site 5.75, faced intermittent sampling challenges due to snow and ice accumulation in the tributaries. Some smaller sites froze entirely before being covered by snow, further complicating sample collection efforts. Consequently, our sampling efforts during the spring semester were limited to an average of thirteen to fourteen sites, falling short of the planned seventeen sites, primarily due to adverse weather conditions.

Despite facing weather-related obstacles, our sampling team remained adaptable and persevered in collecting valuable data. By adapting to the dynamic nature of the lake environment and incorporating additional sampling sites, we were able to enhance the robustness of our phosphorus loading analysis. Our experience in the field also underscores the importance of regularly reassessing sampling strategies in environmental monitoring endeavors and the importance of continuous adaptation and expansion in environmental monitoring efforts to ensure comprehensive data collection and accurate assessments of ecosystem health.

Lab Procedures:

I. General Procedures

The samples collected were analyzed through various meters that read the pH, conductivity, color, chloride, turbidity, and total phosphorous levels. To ensure the accuracy of the readings, there were quality checks and assurance procedures put in place. Each instrument had differing calibration techniques and continuous quality checks, although there were general procedures for all samples. Once the samples were brought to the laboratory, they were refrigerated unless they were immediately being tested. The samples in clear 500 mL bottles were run within 24 hours of collection to limit changes in the water chemistry. Meanwhile, total-phosphorus sample containers could be held in the fridge for up to 28 days (about 4 weeks) due to the sulfuric acid presence that lowers the pH to 2, preserving the sample.

Before testing samples contained in the clear 500 mL bottle, the water must be warmed to at least 20°C but no greater than 25°C. If the samples were too cold, we filled a plastic tub with warm water and placed the closed sample bottles in the water bath. We continuously checked the temperatures of the samples with a thermometer until it reached the wanted temperature. While the samples were warming, we ensured that each machine had been calibrated the same day. To prevent contamination, we took steps in between the runs such as rinsing the probe thoroughly with deionized water (DI) between each sample. Furthermore, we ensured that each probe was "seasoned" with the sample being tested. Seasoning is the process of using a small amount of the sample to dip into the probe or swirl in the cuvette before running, to ensure only the sample is being measured and not excess deionized water.

Throughout lab analysis, there were quality checks set in place to ensure the calibration of each instrument was maintained. After every nine samples, the standard for each parameter was recorded. Standards are premade solutions with a known value that are used to calibrate the machine. Depending on the parameter, the machine must read within +/- units of the known standard (refer to table 2). Furthermore, after every nine samples a replication process occurred, which involved reassessing the previous sample. These two runs of the same sample must read with +/- units of each other depending on the parameter in question (**Table 2**). All parameters' accepted ranges are shown in the chart below. If the standards or replicates read beyond the required range, the machine needed to be recalibrated and the samples after the last successful check of the standard needed to be rerun.

Continuing Calibration Verification (CCV)			
Parameter	Frequency	CCV Standard	Accepted Limit
pH	Every ten samples and after the last sample of the day	6.0 pH	+/- 0.1 pH unit
Conductivity		100 uS	+/- 10%
Turbidity		10 NTU	+/- 10%
Chloride		100 mg/ml	+/- 10%
Apparent Color		50 PCU	+/- 10%
Total Phosphorous	Once Per run	50 PPB	+/- 10%

Table 2: Accepted range limits of standard for the variety of parameters

Replicate Acceptance Limits	
Parameter	Acceptance Limit
pH	+/- 0.5 units
Chloride	<10%
Conductivity	<10%
Turbidity	0-20 NTU: +/- 1 >20-100 NTU: +/- 3 > 100 NTU +/- 10
Total Phosphorous	+/- 0.004 mg/L
Apparent Color	+/- 10 PCU

Table 3: Accepted range limit of replicated samples for the variety of standards

II. pH

The pH in the environment is the concentration of hydrogen ions in a liquid. When there are more H+ monatomic ions than OH- diatomic ions, the liquid will be acidic. Meanwhile, when there are more OH- diatomic ions than H+ ions, the liquid will be basic. These ratios waver in different amounts from an equal proportion of OH- and H+ ions. The pH scale ranges from 0 – 14 with 7 being neutral, such as water with a 1 to 1 hydroxyl and hydrogen ion ratio. Once the number is below seven, an increase in hydrogen ions is present, meaning that the liquid is acidic. Once the number goes above seven, there is a decrease in hydrogen ions meaning the liquid is more basic (US EPA, 2015).

The pH level is crucial in understanding the health of water quality due to the power it has to alter chemical processes. The Environmental Protective Association suggests that freshwater bodies should have a pH level between 6.5 - 9 for optimal biological/chemical activity. The NHDES suggests a tighter pH range of 6.5 -8.00 with a slightly acidic medium pH level of 6.82 (Steiner, 2015). The levels being below or above the optimal pH range can be a sign of contaminants, pollutions, or a low buffering capacity.

For pH, there are three standards; pH 4, pH 6, and pH 7, which were changed every week to ensure their reliability. The meter used throughout the project was the Beckman pH Meter, Model Phi 510. The probe was stored in a cover filled with deionized water to ensure its health and was removed before the calibration process. Once calibrated, the machine will return to the screen to measure the pH of samples. For a quality check, we placed the probe into the pH 6 standard. If it read between 5.9 and 6.1 pH, we could guarantee that the calibration worked. We repeat the calibration process if the reading was out of the range and recorded the calibration findings in the logbook. The standard was checked after nine samples if the pH was 6 which must read within +/- 0.1 pH. When the replication process occurred, the samples must have read between +/- 0.5 of each other. Before analyzing all the samples, we placed the probe into the pH 6 standard to ensure that it was still within the previously stated range of +/- 0.1 pH. We pour the sample into a sampling cup and recorded the results in a logbook along with the time and date. We emptied the sample cup contents into a waste bucket and rinsed both the cup and probe with deionized water. Next, we seasoned the sampling cup and probe with the next sample before repeating the reading process. After our last sample, we checked the standard once more before turning off the machine.

III. Conductivity

Conductivity determines the ability of water to pass an electrical current. This is caused by dissolved inorganic substances such as salt. These ions can be measured through a conductivity probe that has two electrodes with a voltage sent through them. This probe is submersed in a water sample and when ions pass through the electrodes it will lead to a partial block in the electrical current (US EPA, 2024). Therefore, the conductivity is measured by this drop in voltage in micro siemens per centimeter (µs/cm). The average conductivity of lakes in NH is between 15 – 198 µs/cm. Fluctuations may occur depending on the watershed and geological conditions. Elevated conductivity can indicate unnatural contaminants in the flow (US EPA, 2024). High conductivity levels put unnatural stress on aquatic plants and animals, making it a crucial water characteristic to monitor routinely.

To ensure the electrodes were working properly within the probe, we followed a calibration process for quality assurance. We began the procedure by filling a sample cup with fresh deionized water and submerged the probe. We made sure that the final reading was less than or equal to 2.0 µs/cm showing that the water system has properly been deionized. If it did not read below 2.0 µs/cm, we let the deionized water run longer before refilling the cup to repeat the process. After we received an acceptable value, we entered the machine in calibration mode by pressing the upper left “COND/CAL” button. We placed the probe into the standard which has been made to have a conductivity of 100 µs/cm. We made sure that the reading was within +/- 10% of the 100 µs/cm or between 90-110 and recorded the reading in the calibration log.

Beyond calibration, there were protocols throughout sampling that we completed to ensure the calibration was maintained, known as a quality check. For every ten samples, we read the 100 µs/cm standard and ensured that it measured within +/- 10% of the standard. If not, the machine was recalibrated, and samples run after the last successful quality check were reanalyzed. Furthermore, after every ten samples, the previous sample was rerun, a process known as replication. The identical samples must have read between +/- 10 µs/cm of each other. If the replication was not within the parameters, the same recalibration process during a failed quality check took place.

IV. Color

The importance of testing water color is because it provides important information related to biological and mineralogical composition. Water color often is indicative of the quality of nearby ground water that could be used as drinking water. Suspended and dissolved particles influence water color and can be affected by the aquatic environment of the stream. These factors include, rusted pipes, iron, algal blooms, and/or decomposing suspended material (California State Water Resources Control Board, n.d). The color of water may also be affected by weather, particularly precipitation that may wash sediment into running water, and agricultural practices that use fertilizers, irrigation, and farm animal waste (USGS, 2018). This is important to note as storm events and their impact, which can exacerbate sediment concentrations and modify water temperature, are within the scope of this project.

Color is measured by how much light of varying wavelengths can pass through the water sample. The color of the water was tested using the Hanna 96727 Color Meter. The first step in our procedure was to calibrate the meter The meter was calibrated using pre-made standards of 50 and 0 PCU. Before running a sample, we rinsed a cuvette with deionized water, then "seasoned" the cuvette by pouring a small amount of the sample in, to ensure there was no excess deionized water. After seasoning, we poured the sample into the cuvette until it reached the black line. Next, we replaced the cover and wiped the cuvette with a Kim-Wipe to ensure no smudges would skew the reading. We placed the cuvette in the machine, lining up the arrow on the cover with that on the machine, and pressed the red "read" button. We then recorded the values in the logbook along with the date, time, site, and temperature. Finally, we replace the sample cuvette with the 0 standard and pressed zero.

Quality checks were performed to ensure the Hanna 96727 Color Meter was reading accurately and ensured that the individual running the samples was accountable as well. If a sample read a value much higher than the rest, we would rerun and record the new value. Once all the samples were tested, the 50 PCU standard was read once more before the machine was turned off.

V. Chloride

The importance of testing chloride concentration in a stream sample is to measure the concentration of chloride ions in the water since they impact the biology and biogeochemistry of freshwater. Chloride is naturally occurring in lakes and streams, but can be affected by geology, soil, and other natural materials (USGS, 2019). Chloride is one measure of salinity, and varying concentrations can affect the ecosystem, wildlife, and plants in the waterbody in a number of different ways (Missouri Department of Natural Resources 2023). Many aquatic organisms need chloride to live, but too much can be harmful.

Chloride was tested using the Orion Versa Star Pro. Quality checks were performed to ensure the machine read accurately and that the individual running it was accountable as well. Before use, the machine was calibrated using premade standards. The standards used for chloride were 10 mg/L and 1000 mg/L. In between each measurement, the probe was rinsed off with DI water. The chloride machine often did not read the correct measurement of the standards when the read button was pushed, so we often had to reanalyze the standard several times until the machine was calibrated correctly. After the machine finished calibrating, the 100 mg/L standard was read again to ensure it was within the range. In addition to calibration, replicates were run to ensure accuracy throughout sample analysis. A replicate's measurement should have fallen within +/- 10% to ensure accuracy. Between every 5-10 samples, the 100 mg/L standard was read, and it had to fall within the accepted range of +/- 10%. However, the Orion Versa Star Pro meter could be finicky, so even if it fell within a value close to either end of the range, there still might have needed a recalibration. The tighter accepted range of the 100 mg/L standard was tested more often because of its accuracy. If a sample measured a value much greater than the rest, the sample was rerun and recorded to ensure the reading was accurate.

The first step when running the sample was to rinse out the sampling cup with deionized water. A small amount of the sample was poured into the sampling cup to "season" the cup and probe to eliminate any excess DI water. Next, the water sample was poured into the cup so that the level was above the sensor on the probe. The probe was lowered into the sample and the "measure" button was pushed. The machine was then allowed to stabilize with a value on the screen. This value was written down in the data book along with the date, time, site, temperature, and the initials of the person doing the measurement. Once all the samples had been tested, the 100 mg/L was read once more before the machine was turned off.

VI. Turbidity

Turbidity is the measure of clarity caused by suspended material in the water column. Suspended material may include silt, clay, sand, algae, plankton, microbes, and other substances (US EPA 2021). When a tributary appears cloudy or opaque, it is likely to be high in turbidity (USGS 2018). The New Hampshire average turbidity for lakes is 50 NTU (Nephelometric Turbidity Unit).

The Turbidity HF Scientific Micro 100 was used to measure turbidity by the amount of light that passed through a water sample. Before running any samples, the machine was calibrated using pre-made standards to ensure accurate readings. The standard concentrations tested were 1000, 10, and 0.02 NTU, and these solutions were changed every week to avoid contamination. Beyond calibration, a replicate sample and the 10 NTU standard were read to ensure the machine continued to run properly. The replicate sample was read prior to the standard and had to read a value +/- 10% of the previous reading. The standard was read next and should have fallen within +/- 10% away from 10 NTU. If the replicate or standard read out of the range, the machine was recalibrated. In between every sample, a tube with nothing in it was used to protect the machine. If a sample read significantly higher than others, the sample was rerun and recorded for accuracy. The individual running the sample after each time wrote their initials down in the book so if any questions were asked, it could be ensured all the samples were run.

After proper calibration, the samples were ready to be tested. The process began by rinsing the cuvette with deionized water to remove any contaminants. The cuvette was "seasoned" by pouring a small amount of the sample in to ensure all excess deionized water was removed. The cuvette was dumped into waste and refilled with the sample. The cover was tightened, and the cuvette was inverted to resuspend the floating particles. The cuvette was placed into the machine where the arrows lined up. Values on the screen immediately changed, going up then down. The highest number of the first peak was recorded in the logbook along with the date, time, site, temperature, and the analyzer's initials. The sample was dumped into waste, the cuvette was rinsed with deionized water, and the process was repeated for the remaining samples. Once all the samples had been tested, the standard of 10 NTU was read once more before the machine was turned off.

VI. Total Phosphorus

Phosphorus is a necessary nutrient for organisms to function and for aquatic vegetation to grow. It is often referred to as a limiting nutrient due to the significant contribution it has to the rate at which algae and other plants grow. However, an excess of the nutrient phosphorus leads to a dense growth of aquatic vegetation that can lead to eutrophication. This can lead to a decrease in available oxygen levels and cyanobacteria blooms that may produce toxins (US EPA, 2024). This project tested the levels of phosphorus in each water sample through a total phosphorus reading; this procedure tests all forms of phosphorus present in water samples. In short, this involved digesting the water samples through acidifying and heating them, which converted all forms of phosphorus to orthophosphate. From here, the procedure required the addition of another acid which changes the hue of the sample to different intensities of blue depending on the amount of phosphorous in the sample. This allows for the color to be read through passing light in a spectrophotometer which measures the absorbency. By generating a standard curve relating absorbency to known phosphorus concentrations in standard solutions, we could estimate the amount of total phosphorus in our samples.

The nutrient levels in lake water determine the trophic category assigned to the water body. These categories are oligotrophic, mesotrophic, and eutrophic. In ascending order, starting from oligotrophic, each trophic level indicates a higher level of nutrient concentrations in the water and phosphorous is a key determinant in this categorization. The New Hampshire Department of Environmental Services uses these trophic levels to describe how productive a lake may be. For instance, Pleasant Lake is categorized as an Oligotrophic Lake which represents a total phosphorous threshold of < 8.0 µg/L. On average, Pleasant Lakes total phosphorus levels are between 3 – 6 µg/L (NHDES 2021).

To ensure the reliability of the phosphorus readings, the lab procedures followed the New Hampshire State's standard procedure. Before the total phosphorus samples were read, there was a standard procedure which estimates a correlation, or R-value, between measures of absorbency and known standards to ensure the calibration of the spectrophotometer. The following list of premade phosphorus standards were used to create our standard curves:

0.300 mg Phosphorus/Liter

0.100 mg Phosphorus/Liter

0.050 mg Phosphorus/Liter

0.025 mg Phosphorus/Liter

0.010 mg Phosphorus/Liter

0.005 mg Phosphorus/Liter

The six 50 mL Erlenmeyer flasks, which were pre-labeled with each standard concentration in descending order, were aligned. Before pouring the individual standards into the corresponding flasks, the flasks were triple rinsed and seasoned, or coated, with a small amount of the sample. A 25 mL graduated cylinder, triple rinsed with deionized water and seasoned with the corresponding standard, was obtained. In the graduated cylinder, precisely 25 mL of the standard was measured out, paying attention to the meniscus. This was then poured into the corresponding Erlenmeyer flask. This process was continued with the rest of the standards.

Beyond the standards, there were also premade solutions that were used for quality checks (QC) rather than creating the standard curve. The concentrations of the QC solutions were:

0.300 mg Phosphorus/Liter

0.050 mg Phosphorus/Liter

0.025 mg Phosphorus/Liter

0.005 mg Phosphorus/Liter

Similarly, there were prelabeled Erlenmeyer flasks labeled with varying QC solution concentrations. The same procedure was followed when pouring the QC solutions as when pouring the standards. The 0.050 mg P/L was read every ten samples to ensure the continued calibration of the machine. Lastly, there was a flask labeled “blank spike,” which was simply 25 mL of deionized water with 0.5 mL of the spike solution. The spike was a premade concentrated solution of 5 mg P/L used to test the accuracy of higher readings. A micropipette adjusted to 0.5 mL was used to add the spike.

Before the samples were poured, a potassium persulfate solution needed to be prepared. This solution was required to digest all forms of phosphate in the sample to orthophosphate. The solution was made based on the chart below, **Table 4**, which shows the ratio of potassium persulfate powder to deionized water needed for a certain number of flasks.

	For Digestion of Total Phosphorous (4 mL per Flask)					
Distilled Water	95 mL	142.5 mL	190 mL	237.5 mL	285 mL	332.5 mL
Potassium Persulfate	5 g	7.5 g	10 g	12.5 g	15 g	17.5 g
mL of Complete Solution	100 mL	150 mL	200 mL	250 mL	300 mL	350 mL
# of Flasks Filled	23	35	47	59	71	83

Table 4: Total Phosphorous Digestion table

Once the persulfate solution was prepared, it had to sit for 45 minutes. During this time, the samples could be poured into the corresponding flasks. The flasks were labeled with numbers that were assigned to samples. The sample bottles were labeled with the corresponding flask number as a quality assurance practice. Once this was complete, the samples were poured into their corresponding flasks. The samples were shaken to resuspend any settled phosphorus before pouring. From there, the procedure was the same as pouring the standards. The flask and graduated cylinder were seasoned, 25 mL of the sample was measured, and it was poured into the flask. Once this was done, a micropipette was adjusted to 4 mL for adding the potassium persulfate solution previously made to each standard, QC, blank, and sample. Next, the sample labeled number 12 had a replicate spike sample which needed the 0.5 mL concentrate previously used in the spike blank. While a person was preparing the autoclave, which was required to digest the phosphorus, the flasks needed to be covered with tinfoil to assure the preservation of the samples. Autoclave tape was spread throughout roughly five flasks to ensure the proper heating of the autoclave. The autoclave heat was adjusted to 121 degrees Celsius, set to liquid, and the timer set for 45 minutes.

Once the autoclave temperature had lowered to below 100 degrees Celsius, to ensure the pressure change did not cause the samples to boil over, the flasks could be taken out. Before the phosphorus could be read, a color reagent needed to be made. The color reagent changed the color of the flasks to different hues of blue depending on the concentration of orthophosphate present. The more intense the blue color, the more orthophosphate was present. There was a chart that showed the amount of each solution needed to make the color reagent, depending on the number of flasks. The solutions were mixed in order from top to bottom as listed on the chart below, **Table 5**.

	Color Reagent Solution (2.5 mL per flask)					
Sulfuric Acid	25 mL	50 mL	62.5 mL	75 mL	87.5 mL	100 mL
Ammonium Molybdate	10 mL	20 mL	25 mL	30 mL	35 mL	40 mL
Ascorbic Acid	10 mL	20 mL	25 mL	30 mL	35 mL	40 mL
Antimony Potassium Tartrate	5 mL	10 mL	12.5 mL	15 mL	17.5 mL	20 mL
mL of Complete Solution	50 mL	100 mL	125 mL	150 mL	175 mL	200 mL
# of Flasks Filled	20	40	50	60	70	80

Table 5: Total Phosphorous Color Reagent Solution

Once the ascorbic acid was added, the solution should turn yellow, which ensured that the reagent was made properly. Once the solution was mixed, it needed to sit for ten minutes. Using a micropipette adjusted to 2.5 mL, the color reagent was put into each flask and then left to sit for 45 minutes. During this waiting period, the Genesys 30 spectrometer was set up. Fixed display was selected, and wavelength (λ) was set to 880 nm. When pouring each sample into the cuvette, care was taken to rinse with deionized water, season, pour carefully, and wipe the outside of the cuvette with a wipe. It was noted that the cuvette had a grooved side, which should not face toward the passing light but was used as a holding place to transfer the cuvette. The spectrometer indicated to zero it, which involved pouring deionized water into the cuvette. From there, the standards could be read following the previously mentioned protocol. The absorbency level popped up on the screen, which had to be recorded on the data sheet. In Excel, the standard curve was checked to ensure the R-value was above 0.995. If it was below this value, it indicated that a step went wrong throughout the process, meaning that the total phosphorus run needed to be scrapped due to the lack of reliability. From there, the quality checks and samples were read following the same procedure, ensuring results were recorded. The data recorded was not the result; the absorbency was used to calculate the total phosphorus concentration. This required using the slope calculation previously made during the standard curve graph:

$$Absorbance = (Slope \times Concentration) + Intercept$$

The last step was checking that the replicates fell within 0.004 mg/L of each other. If the sample and replicate did not fall within 0.004 mg/L of each other, the data was considered unreliable, and the entire sampling procedure needed to be redone.

Spatial Analysis Procedures:

Septic Tanks

In hopes of pinpointing possible phosphorus hotspots, our class developed a dataset containing every house in the Pleasant Lake watershed with crucial septic information. The attributes investigated include the age of the house, number of bedrooms, renovations, acreage, parcel values, house size, and whether the house is a seasonal home. This information can be found on the Town of New London, NH website under the On-Line Assessing & GIS Mapping tab. Once on the parcel map, we clicked on the Search option and enter the proper address. The map highlighted the address on the map. From there, the house's property card was available for public access. This was where the information for the house age, number of bedrooms, renovations, acreage, parcel values, house size, and if it is seasonal or not was found. Class members also made multiple visits to the New London town offices where paper copies of the property cards were stored. Additional information regarding renovations and septic installment were also located in the offices that were useful for our data collection.

For septic-specific attributes, the septic design years, operation approval year, and septic installment were the most important to our project. Some of this information could be found on the Town of New London's On-Line Assessing & GIS Mapping website, as well as the town offices, but most of the data was collected from the New Hampshire Department of Environmental Services' Subsurface Applications Status Query website. On the website, we selected the Subsurface Application Status Query. There were multiple ways to search for a specific house. We entered in the specific address, general street name, or a person's last name, and found the address. We made sure New London is the selected town before executing the query. A list then appeared with the addresses. We clicked on the Select option on the far left once the address was found. Under the Application Documents section, there were documents containing septic information. This was where data for design years, operation approval year, and installment was located.

Many of these attributes were not consistently available in the State databases, or the town records. Operational approval year of septic systems was the most consistent piece of data that was found in the search. Therefore, septic age and installment years in relation to phosphorus were the main focuses for the end result.

Sub-watershed Delineation

We knew from the beginning of our project that we would like to delineate the individual sub-watersheds for each sampling site as it would enable us to precisely identify the land area contributing water to each sampling point. This approach provided context for our analysis on both phosphorus loading and chloride. By integrating this watershed data with data detailing land use status and impervious surfaces, we could then gain a comprehensive understanding of the environmental dynamics at play across the sampling area. The number of sites and therefore sub watersheds allowed a more detailed understanding of pollution sources, and the impact of land use practices on water quality and quantity around the lake.

To delineate our sub watersheds, we used GIS (Geographic Information System), or more specifically in our case Esri's ArcGIS Pro. GIS is a technology that uses spatial data to analyze, interpret, and visualize geographical information. To use GIS to generate the boundaries of each sub-watershed, we had to utilize a digital elevation model of our area. Creating watersheds in a GIS involves delineating the boundaries of drainage areas based on digital elevation models (DEMs) and selecting points on the surface, which in our case, corresponded to our sampling sites. We gathered the exact location of our sampling sites using a GPS, creating a unique point for each site that we could then import into ArcProGIS later. The DEM was gathered from the United States Geological Service (USGS) in partnership with the University of New Hampshire's (UNH) free use GIS data library (GRANIT). The selected data had a spatial resolution of (.76meters) and ensured the study area was captured in full detail.

In our GIS program the initial steps included uploading both the DEM dataset and site locations. Using a base layer containing the entire Cascade watershed, acquired from GRANIT, the DEM could be clipped our study area. From there any imperfections were masked using the Fill function under the spatial analyst Hydrology toolbox. The other tools used for the sub watershed delineation also fell under the spatial analyst Hydrology toolbox as well.

The first Tool in the process was Flow Direction. As its name implies, this tool calculates the flow direction from the filled DEM by assigning each cell in the DEM a value representing the direction of steepest descent from that cell. This information is used by the secondary tool Flow Accumulation, which estimates the number of cells that contribute flow to each individual cell in the DEM and assigns each cell the sum of contributing cells. When paired with the correct symbology shows accumulating flow along the flow paths determined by the flow direction raster. This was used to define the "outlets" of each watershed or in our case the point of accumulation at or nearest to our sampling location. To do this we created a new point feature and individually select the cell closest to our sample site that displays a clear high accumulation of flow. This new point layer was assigned like values to our sample sites to match our site numbers and avoid confusion in the process. The newly created point layer was then converted to a raster using the Create Snap Pour Points tool. This converted the feature class to a raster and matches the cell sizes of the Pour points (our sites) with the base DEM.

To finalize the watersheds, we needed to combine the created pour points as well as the slope direction layers. This was done in the Watershed tool, again under the Hydrology toolbox. The watershed tool took the rasterized pour points layer (our sites) and placed them on the slope direction layer. The tool calculated the accumulative flow paths of water to each point, in a similar manner to Flow Accumulation, and outlined the area that accumulates at each point. These outlines show the delineation of each sub watershed and the land encompassed by each. The sub watershed raster was then converted to polygons. This allowed us to join the sub watersheds layer to layers including impervious surfaces, houses, land use, and forest type for our analysis.

During the delineation process we ran into a few issues regarding the sub watersheds. Namely these issues centered upon unnatural land barriers in the DEM that were created by roads. The DEM data did not account for culverts in certain areas such as Route 11, Seamans

Road, and Hall Farm Road. This generated sub watersheds with inaccurate delineations. To fix the issue, pour points were created at locations where water crossed the roads on opposite sides, and the outputs were merged, to show the correct sub-watershed. Other areas of concern could be manually changed in post using split and merge functions between sub watershed polygons.

Land Cover Type Map:

2024 ESRI world satellite imagery of the watershed was used within ArcGIS to create new feature classes based on land cover type. Impervious surfaces included paved/gravel and roofed structures. Other impervious surfaces such as tracks and tennis courts were included as “other impervious surfaces”. Based on the use of satellite imagery, gravel and paved roads were not separated, which is a limitation of this procedure. Non-impervious surfaces were defined as fields, lawns, farmed areas, forests, wetlands, and water bodies. The sub-watershed map was merged with this digitized land cover layer. After a pairwise intersection was performed, the attribute table of each sub-watershed was used to determine the area (meters squared) of each land cover type in each sub-watershed. Using R, replicates were excluded from the analysis. Samples from site 1, the lake outflow, were excluded prior to performing the linear regression. The percent impervious surface of each watershed was calculated by adding the area of the defined impervious surface classification and dividing it by the total area of the sub-watershed.

Salt Application Map

Understanding winter road salt application in the Pleasant Lake Watershed required a multi-step process that encompassed interviews with the town, research into existing literature, mapping, and statistical analysis. First, a team member met with the town’s department of transportation to determine the salt and sand application rates for New London. We learned that the town has an estimated salt application rate of 1 ton/mile/year, as well as a composition of ½ yard of salt to 16 yards of sand when applying. The town is mindful when treating the roads around Pleasant Lake and only salt the sharp turns of the roads and the steep hill on Pleasant Street a little heavier. This mindful salting practice was apparent to the group as we conducted our winter sampling. The town informed the group of the NHDOT’s (New Hampshire Department of Transportation) salt application rate, of 17.2/tons/mile/year, which is much higher than the town’s rate. Two state roads fall within the Pleasant Lake Watershed: a section of State Route 11 and State Route 114. We expected these roads to greatly impact the concentration of chloride going into the lake through the tributaries near them.

In addition to roadways, parking lot and driveway application rates were estimated through a literature review of similar studies in the New Hampshire or New England Region. A study by Trowbridge et al (2010) examined the salt application rates in six New Hampshire watersheds to determine the impacts on water quality. This study included estimates for parking lot loading in mg/ha/year of chloride into the waterbodies. This value was adapted using discharge calculations determined for Pleasant Lake to calculate an application rate for the town’s parking lots. Lastly, an estimate for driveway application was estimated by determining which method would be most accurate for the area. One study in New York applied the same state road salt application rate to private driveways, which we determined would be far too high an estimate. The driveway application rate was estimated to be 0.5 tons/mile/year, which is half the town application rate, as many residents in the Pleasant Lake Watershed do not salt their driveways. However, in future analyses, it may be more accurate to exclude private roads and driveways from the calculation or survey the community to determine a more real value. It is important to remember that these values are estimates, and do not precisely depict the application rate for each individual driveway in the watershed.

A Road Type Map was created in ArcGIS Pro utilizing the digitizing feature to create different feature classes for each category of road and parking lot. These different classes were then associated with a specific application rate, such as 17.2 tons/mile/year from state roads. The digitized feature classes were then clipped to the watershed delineation layer's boundaries, to ensure that only the roads within the watershed were considered for the analysis. Many of the driveways located close to the shoreline of Pleasant Lake were clipped out, as they do not fall within a specific sub watershed of a tributary but have a direct impact to the lake. Each feature class has a designated attribute table of values with a column for total length of each road in meters, and which sub-watershed the roads fall into. The attribute tables for each road, driveway, and parking lot type were then compiled into a single CSV (comma separated value) file and imported into R. This comprehensive dataset allowed analyses of road salt application and chloride levels to be completed.

Results

Chloride:

I. Historical Chloride

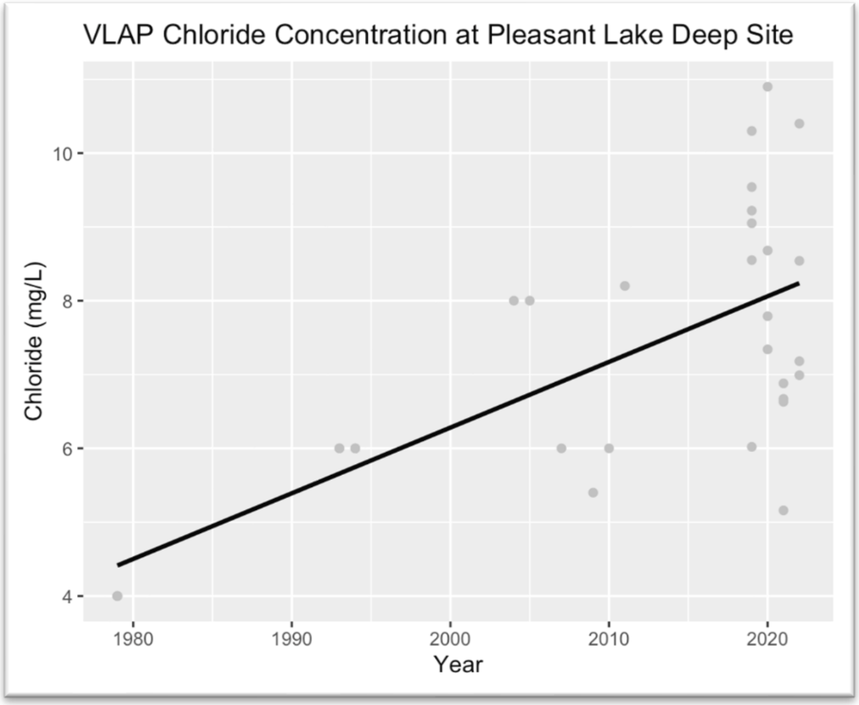


Figure 8: Historical VLAP data collected by the NHDES from 1979 to 2022 shows significantly increasing chloride concentrations at the deep spot in Pleasant Lake. With a p-value of .00003, the data supports an increase of chloride concentrations within the lake. Linear Regression Equation: y = 0.089x – 171.6, df: 29, r-squared: 0.4371

To begin to understand chloride dynamics within Pleasant Lake, we had to analyze the historical VLAP data for any trends. VLAP data collected from 1979-2022 shows an increasing trend of chloride concentration at the Pleasant Lake deep spot (**Figure 8**). Though data points before 1995 are limited, there is still a significant relationship, seeing values rise from around 4 mg/L in 1979, to over 10 mg/L in 2022. While in-lake samples are effective in documenting trends over time, measuring inputs from the watershed and its tributaries better signifies direct sources of contaminants. Winter road and de-icing salt application rates, changing in development and landcover within the watershed, and impact of storm events may impact the amount of chloride entering the lake either directly, or through its tributaries. Investigating these different variables is important in determining the greatest sources, hotspots, and causational factors of increasing chloride. Further regulation road salt application rates may be a necessary strategy to implement to better protect Pleasant Lake and prevent cyanobacteria blooms. An investigation into state, public, and private winter de-icing salt application was conducted to better understand the impacts on the watershed. Analyzing differences in chloride concentration between tributary sites was the first step in beginning to pinpoint areas of concern for consistently high values.

II. Chloride: Loading and Concentration for Storm and Sites

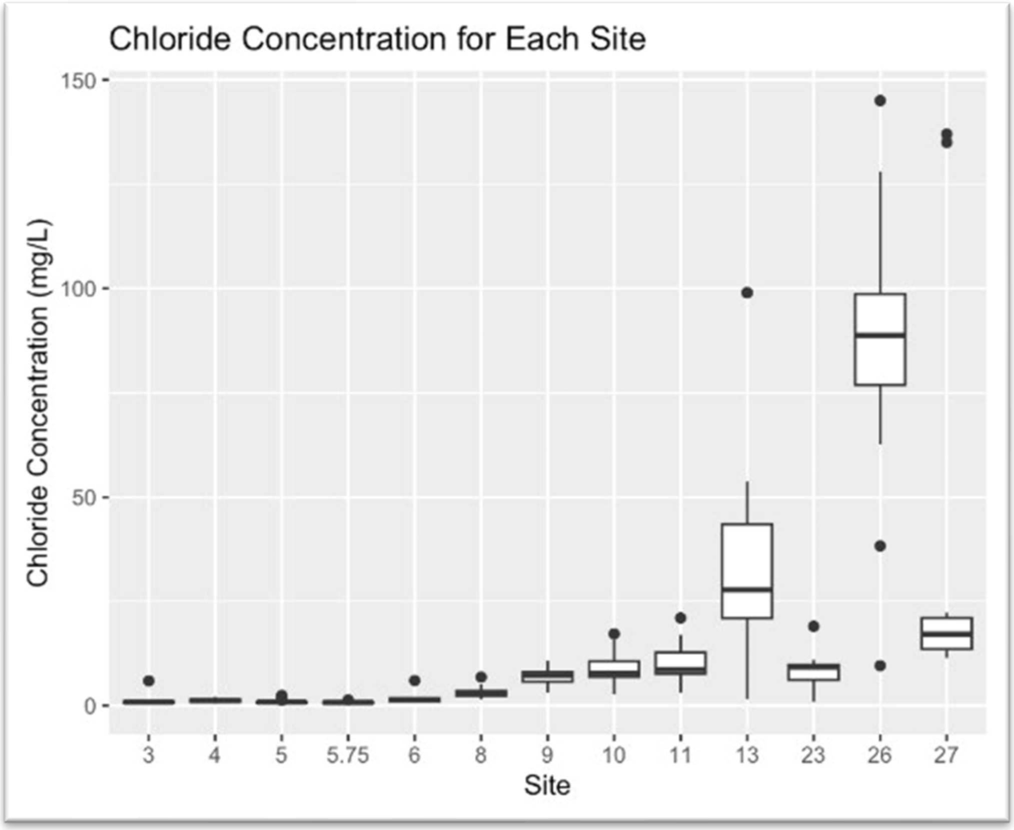


Figure9: Differences in chloride concentration for routine sampling sites are displayed in the box and whisker plot. A one-way ANOVA and Post-hoc Tukey Test were conducted to determine significance between sites. One-way ANOVA $p<0.001$. Post-hoc Tukey 13-27 $p<0.001$.

Visual differences in chloride concentration between routine tributary sample sites are seen in **Figure 9**. Sites 13 and 27, Red Brook and Bunker/Elkins respectively, have significantly higher chloride concentrations than the rest of the sites. Bunker/Elkins has an average of 79 mg/L chloride across fall and spring collections. Red Brook has an average of 27 mg/L chloride across fall and spring collections. Sites 27 and 11, the Fire Pond and White Brook respectively, are approaching consistently elevated levels as well, compared to the rest of the sites. A trend was seen in elevated chloride levels in tributaries located on certain ends of the watershed. Tributaries located on the south end, such as White Brook, Red Brook, Bunker/Elkins and the Fire Pond had significantly higher chloride concentration than tributaries on the north end, such as Great Brook, and unnamed streams 3-5.75. Seeing how chloride levels varied between sites, the group began looking into potential chloride sources in the watershed, and reasons to explain the differences observed.

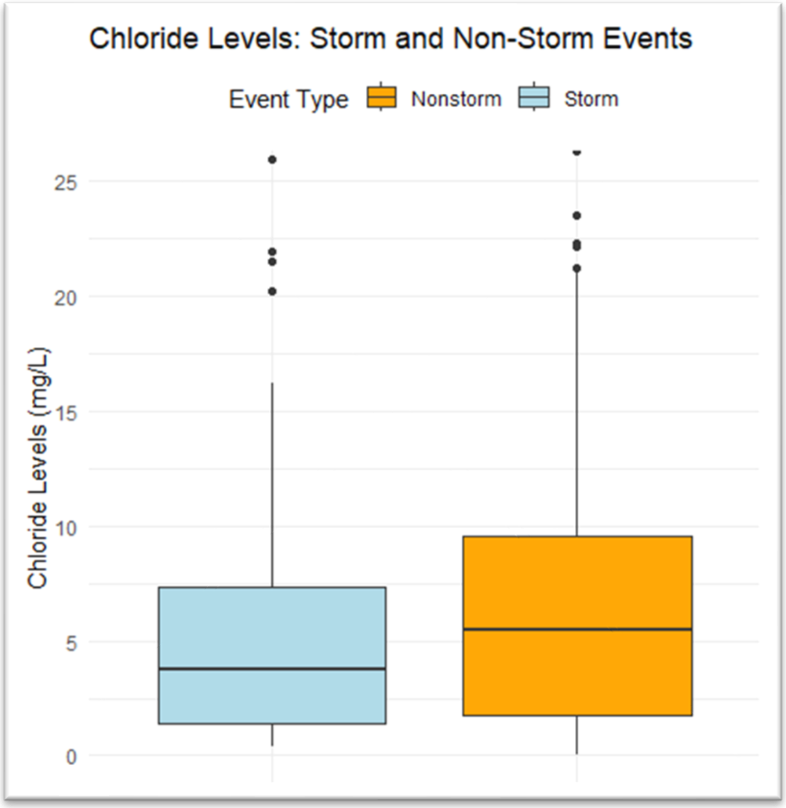


Figure 10: Box and whisker plot showing average chloride concentrations between storm and non-storm events. Through a Wilcoxon Signed Rank Test, due to non-normal distribution, a $p<0.001$ was revealed showing a significant difference in the concentrations.

Understanding the impact of storm events on water quality was a key focus in analyzing the Pleasant Lake Watershed. As seen earlier in the Phosphorus section, storm events significantly impacted, and elevated, phosphorus concentrations in Pleasant Lake's tributaries. It was important to determine whether storms impacted every parameter in this way, and to what degree. When looking at **Figure 10**of non-storm vs storm event chloride levels, a different story can be noticed. Storm events exhibited a notable 1.5 mg/L decrease in average chloride levels compared to non-storm samples, with the distribution during storm events notably narrower. Interestingly, outliers in the 20-27 mg/L range were similarly present in both types of sampling. The outliers between the chloride levels during storm and baseflow events are from the same sites, 13 and 26. It is clear that rather than elevate, storm events dilute chloride concentrations. However, it is important to analyze chloride loading in addition to concentration, to quantify the impact of storms on the lake as a whole.

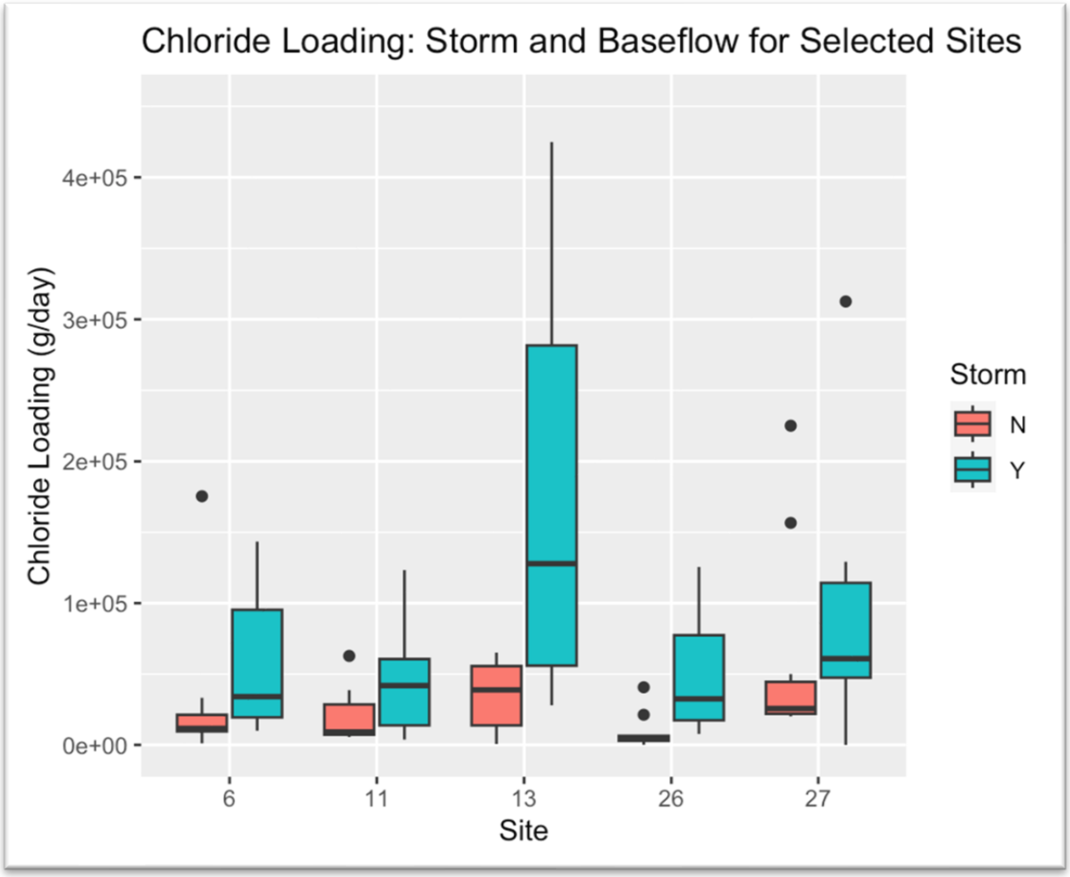


Figure 11: The box and whisker plot above display the chloride loading values for select sites for storm vs baseflow days. A two-way ANOVA was conducted on normalized data, with a p value = 0.00156 for Storm vs Baseflow, and a p value < 0.001 between sites.

Measuring chloride loading is important in understanding the impact of storm events in the watershed. Differences in chloride loading during storm and baseflow days reveals a different pattern than chloride concentrations, as seen in **Figure 11**. Chloride loading is significantly higher on storm event days than baseflow, and the same trend is seen across all sites. This emphasizes the value of loading analysis, as a look at chloride concentration supports dilution of chloride levels during storms. Site 13, Red Brook, has the highest average daily loading for chloride during storms and baseflow. Since Great Brook contributes almost half of the water entering the lake through its tributaries, it signifies there is little human influence within the sub-watershed impacting the chloride. However, it also signifies significant human impact in the Red Brook sub-watershed, that is contributing to high chloride concentration and loading. Red Brook's chloride loading during storm events is over three times as high of that of Great Brook. While it may look like storms dilute chloride when analyzing only concentration, a loading analysis reveals the bigger picture, and the significant impact of stormwater runoff.

III. Salt Application Analyses

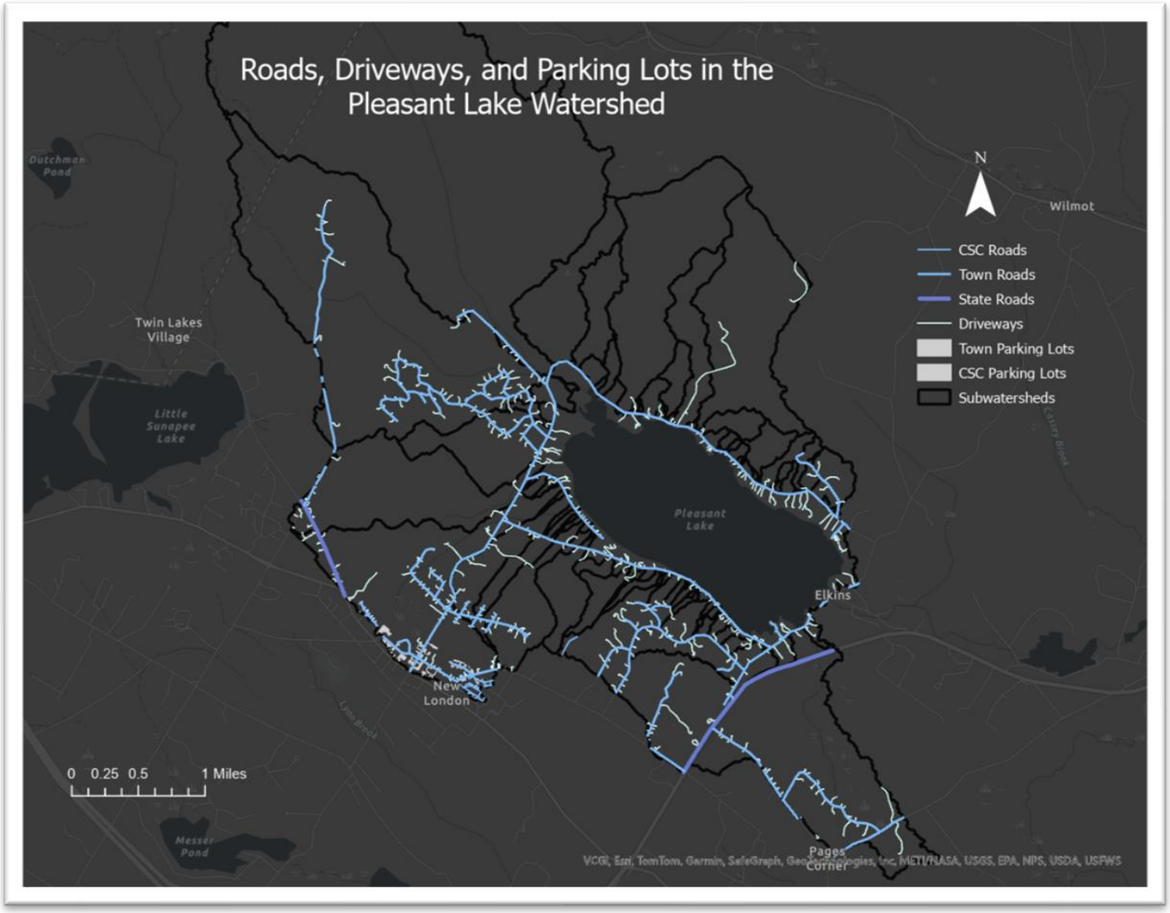


Figure 12: Every town road, state road, private driveway, town parking lot, Colby-Sawyer College road, and parking lot within the Pleasant Lake Watershed are displayed in the image above, along with the delineated subwatersheds.

Figure 12 displays all driveways, roads, and parking lots that fall within the Pleasant Lake Watershed, as well as the delineated sub-watersheds for each tributary. This map was created in ArcGIS Pro utilizing the digitizing feature to create different feature classes for each category of road and parking lot. These different classes were then associated with a specific application rate, such as 17.2 tons/mile/year from state roads. The digitized feature classes were then clipped to the boundaries of the watershed delineation layer, to ensure that only the roads within the watershed were taken into consideration for the analysis. Many of the driveways located close to the shoreline of Pleasant Lake were clipped out, as they do not fall within a specific sub watershed of a tributary but have a direct impact to the lake. Each feature class has a designated attribute table of values with a column for total length of each road in meters, and which sub-watershed the roads fall into. The attribute tables for each road, driveway, and parking lot type were then compiled into a single CSV (comma separated value) file and imported into R.

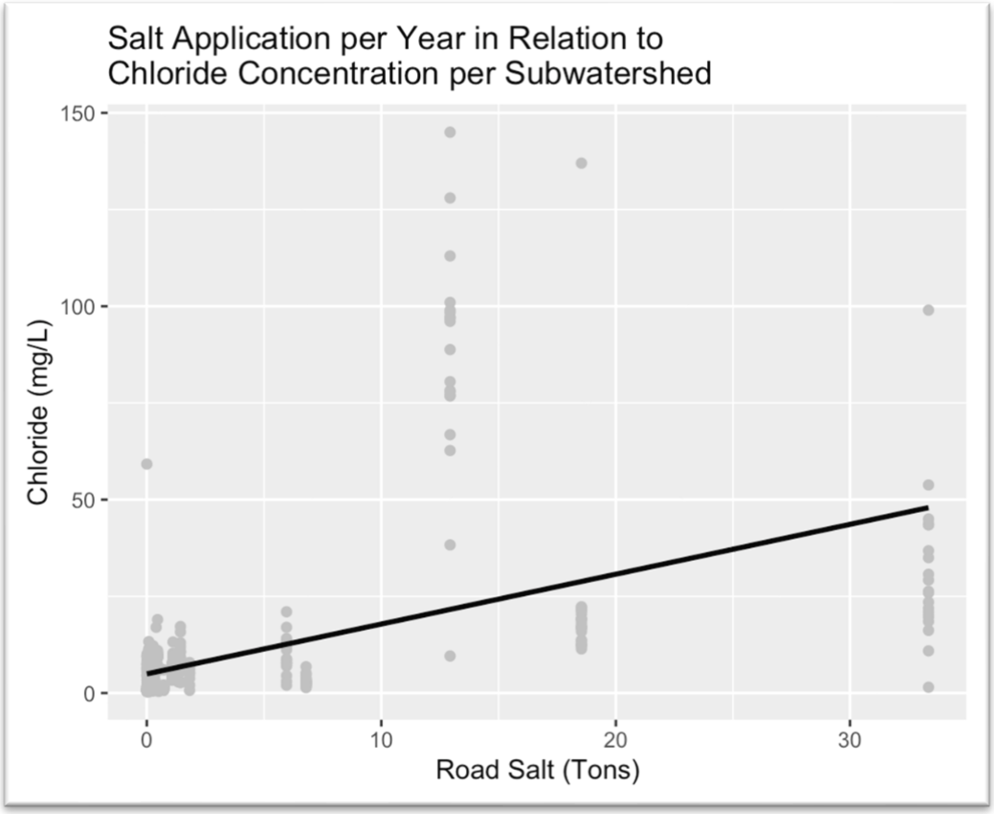


Figure 2: The winter road salt application total in tons per sub-watershed in relation to chloride concentrations per site is depicted. p-value: <0.001, Regression Equation: y = 1.289x + 4.947, df: 500, r-squared: 0.2663

The total amount of winter road salt applied to all driveways, town roads, state roads, parking lots, and college roads and parking lots within each sub-watershed was calculated in tons per year. These values per sub-watershed were then merged with the master dataset for chloride values per site, and then regressed with chloride concentration as the dependent variable and salt application in tons as the independent variable, as seen in **Figure 1**3. Site 13, Red Brook, is an outlier in terms of amount of road salt in tons, with an estimate of 33 tons applied per year. This is likely an overestimate, as this site is comprised of every town parking lot, part of State Route 114, and a large part of Colby-Sawyer College campus that flows into the lake. These paved areas are also located relatively far away from the lake itself, so chloride ions are more likely to infiltrate into the soils before being caught in the brook and deposited into the lake. However, a significant relation between salt application and chloride concentration is seen in **Figure 1**3, with sub-watersheds receiving more salt seeing higher levels of chloride in their tributaries. Sites 13, 26, and 27 have the highest calculated salt application totals, as well as have state roads within their watersheds. With the state’s application rate being 17 times that of the town, it is likely a contributor to these sites consistently elevated chloride concentrations. Understanding the cause behind rising chloride concentration in Pleasant Lake requires investigating chloride loading to determine the greatest sources of chloride.

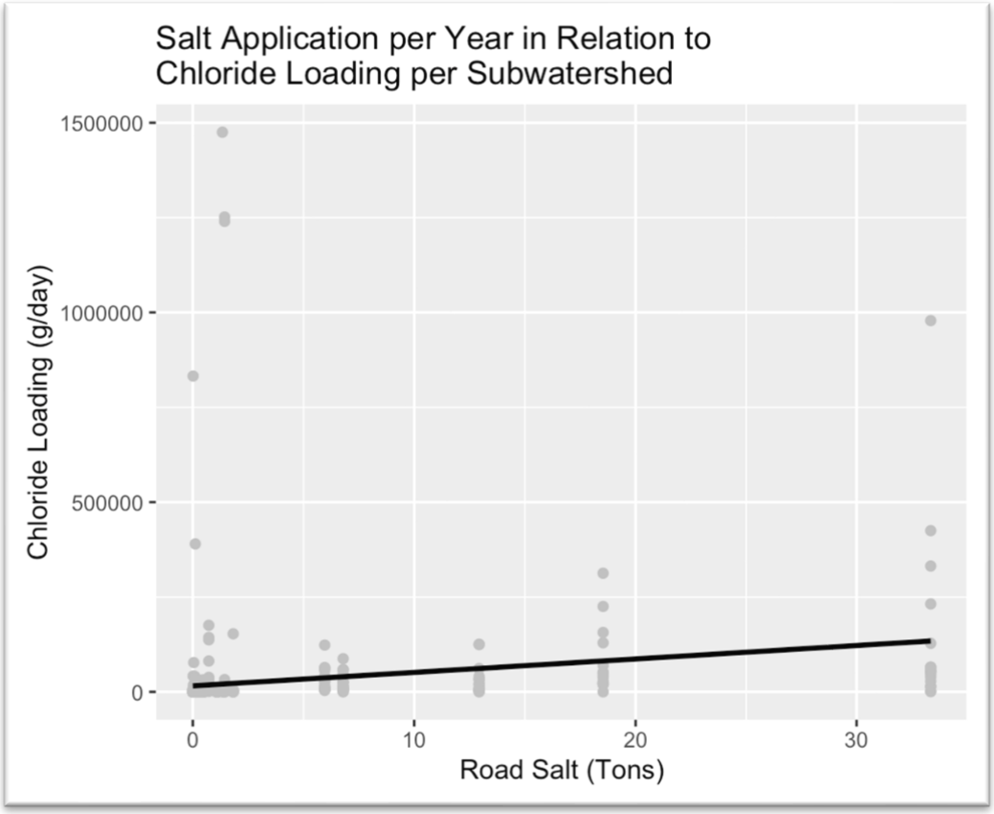


Figure 14: Tons of road salt applied per year to each sub-watershed is graphed in relation to chloride loading per sub-watershed. p-value: <0.001, Regression Equation: y = 1.330x + 4.931, df: 489, r-squared: 0.2727

Chloride loading in relation to salt application totals displayed the same trend as chloride concentration. A significant positive increase is observed between salt application and chloride loading, which is seen in **Figure 1**4. However, there are a few outliers to note in this analysis. Sites 6 and 8, Great Brook and Little Brook respectively, have high chloride loading due to their high discharge of water into the lake. However, these two watersheds have low salt application totals, as they are comprised of conserved land and mindfully salted town roads. Overall, road salt application has a strong correlation with both chloride concentration and loading. This analysis emphasizes the impact that different practices have on water quality and highlights the benefits of mindful practices that are already in place. Future action that can be taken by the town and lake association, as well as management practices that can be implemented will be discussed further in the conclusion.

Phosphorous

VLAP Phosphorus Data

As the primary limiting nutrient in freshwater systems, it is important to understand the potential sources of phosphorus in Pleasant Lake and different factors that may increase phosphorus loading. According to historic VLAP data for Pleasant Lake, the total Phosphorus concentration at the deep site has remained stable at an average of 6 micrograms/liter since 1993. However, samples taken in the watershed's major tributaries by the VLAP revealed more variability in phosphorus levels than samples taken in-lake. The Great Brook tributary sample remained below the oligotrophic lake threshold with an average phosphorus concentration of 4.9 micrograms/liter. In contrast, the Red Brook tributary samples had an average historical Phosphorus concentration of 15.38 micrograms/liter. Great Brook's average phosphorus concentration was greater than 8 micrograms per liter, which is the threshold for an oligotrophic lake. Investigating differences in phosphorus concentration and loading between sub watershed is critical in pinpointing areas of concern, as well as test influential factors.

Phosphorus Concentration

With regards to instantaneous phosphorous concentrations in tributary water samples, we learned that tributaries with elevated concentrations were the Fire Pond located across from Elkins Beach, the skating pond nearby the Slope and Shore community, Site 9 (standing water on Pleasant Street), and the stream leading into the Lake coming from Spring Ledge's Strawberry Field. Many of these sites' elevated phosphorus concentrations revealed the impact that standing water, enriched with organic material, can have on Phosphorus concentrations. Meanwhile, the other tributaries with large phosphorus concentrations were likely due to being near major road intersections or had more development. Following our analysis of concentrations, we wanted to fully understand the degree to which land use and development influenced our results. So, to explain the difference between sites and the impact of human development, we digitized land cover for the entire watershed of Pleasant Lake through Geographic Information Systems and recent aerial imagery. Additionally, we mapped and documented the impact of homeowner septic systems via public records from the Town of New London which helped explain variability between sites.

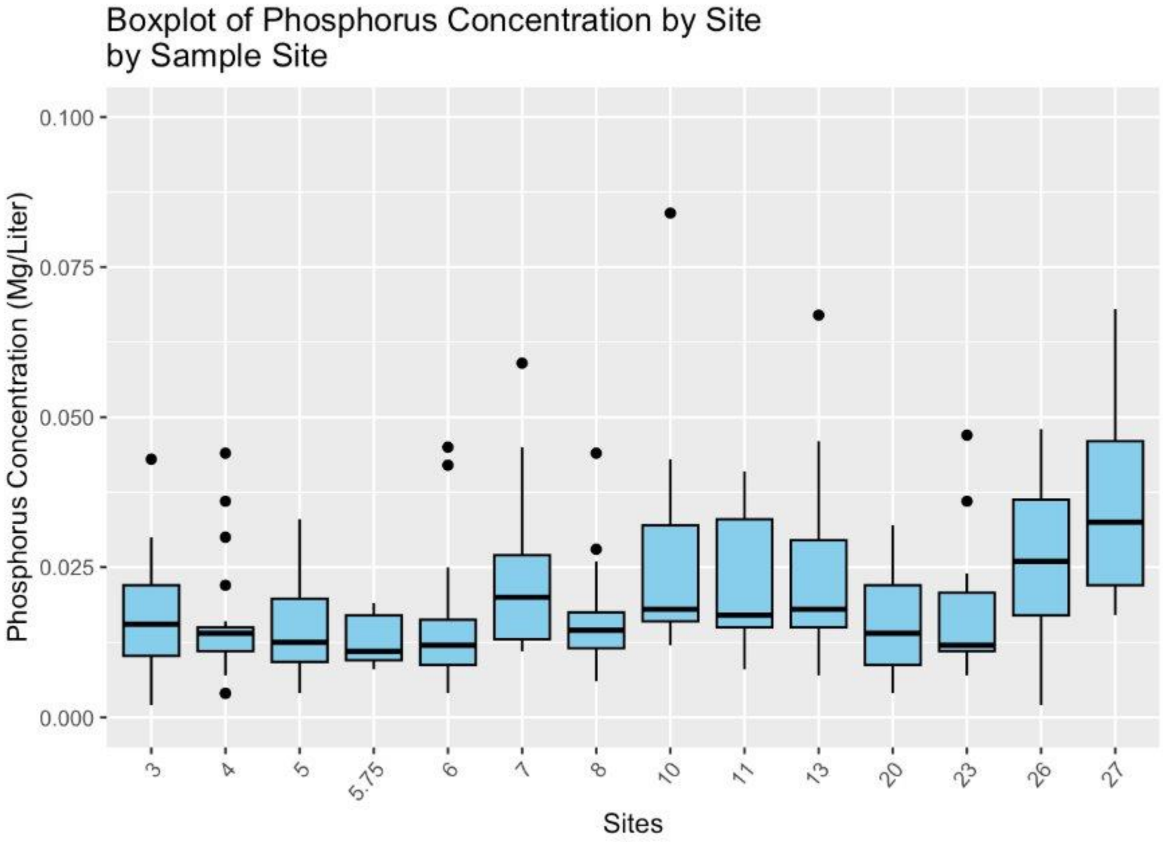


Figure 5: Box and Whisker plot showing Phosphorus Concentration in standard baseflow sites

Phosphorus Loading

With regards to phosphorous concentrations in tributary water samples, tributaries with elevated concentrations were the Fire Pond located across from Elkins Beach, the skating pond near Slope and Shore, Site 9 (standing water on Pleasant Street), and the stream leading into the Lake coming from Spring Ledge's Strawberry Field (**Figure 15**). Many of these sites' elevated phosphorus concentrations revealed the impact that standing water, enriched with organic material, can have on Phosphorus concentrations. Meanwhile, the other tributaries with large phosphorus concentrations were likely due to being near major road intersections or had more development.

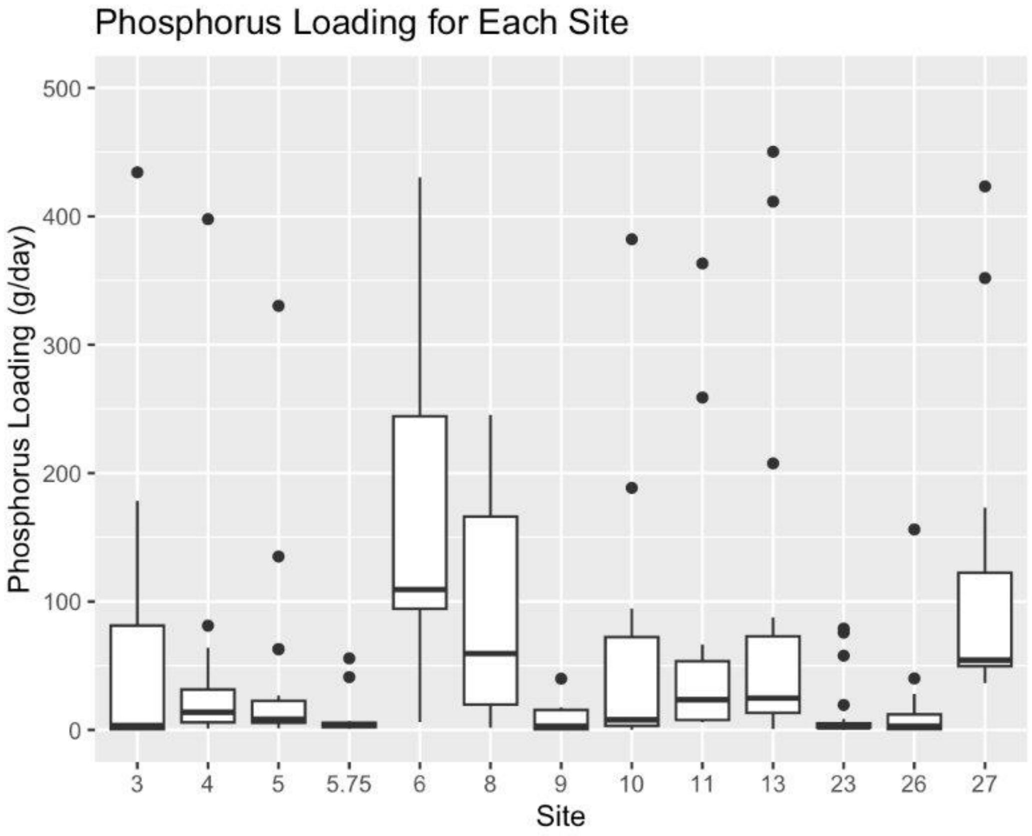


Figure 36 shows Phosphorus loading across standard baseflow sites a one-way ANOVA across all sites had a p<0.001 with a n=749

Great Brook (Site 6) is the highest contributor of phosphorus among all baseflow sites. Great Brook contributes approximately 40% of the water entering the lake and brings in the most phosphorus of 110 grams/day (**Figure 16**). Great Brook did not have a significantly higher phosphorus concentration than other sites, showing the significance of discharge in phosphorus loading. Great Brook falls within conserved forest showing that a large portion of phosphorus entering Pleasant Lake is from natural processes and organic matter instead of human development. Similarly, water flowing into the Fire Pond across from Elkins Beach (Site 27) flows from Cascade Marsh where it sits and collects organic matter. Little Brook (Site 8) has high discharge and human development within its watershed. Little Brook brings in water from Slope and Shore and is the second-highest phosphorus loading site. Overall, several watersheds with high phosphorus concentrations fall within areas with more human development, while sites with high phosphorus loading come from areas with high discharge and natural phosphorus sources. The main phosphorus contributors are Great Brook, Little Brook, and the Fire Pond located across from Elkins Beach. The outlet of each of these three inlets could likely be areas of future cyanobacteria blooms, thus we believe that these locations should be monitored the most closely year-round.

Storm Events

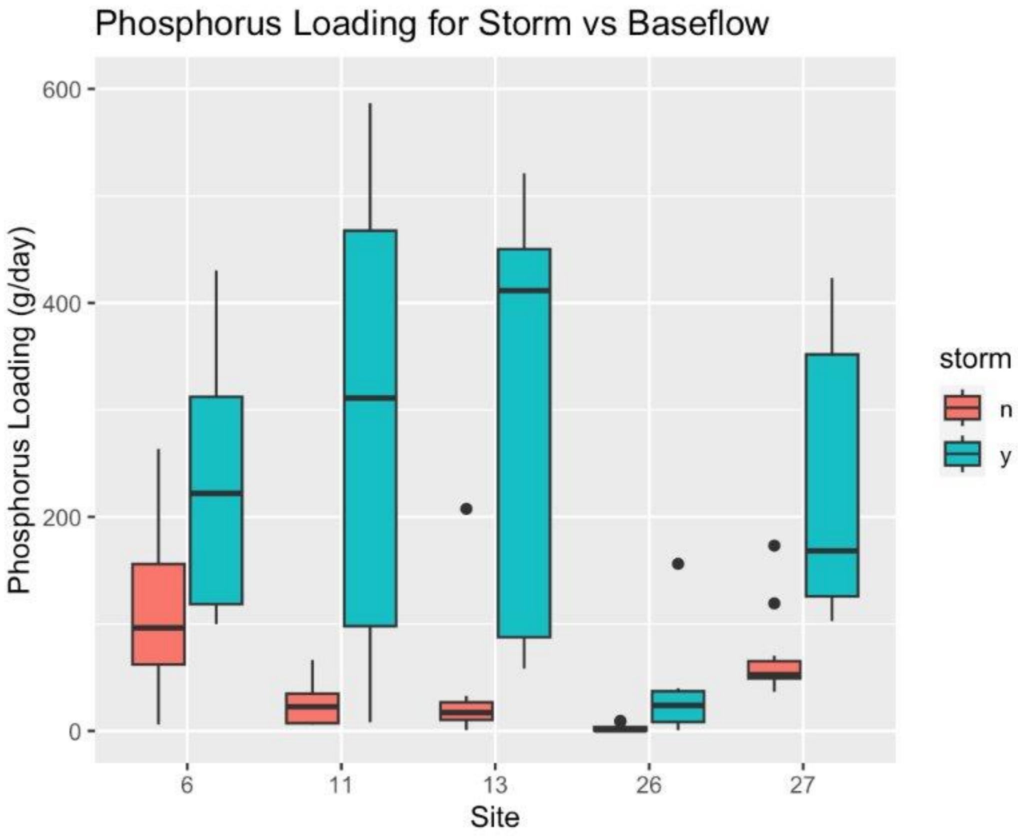
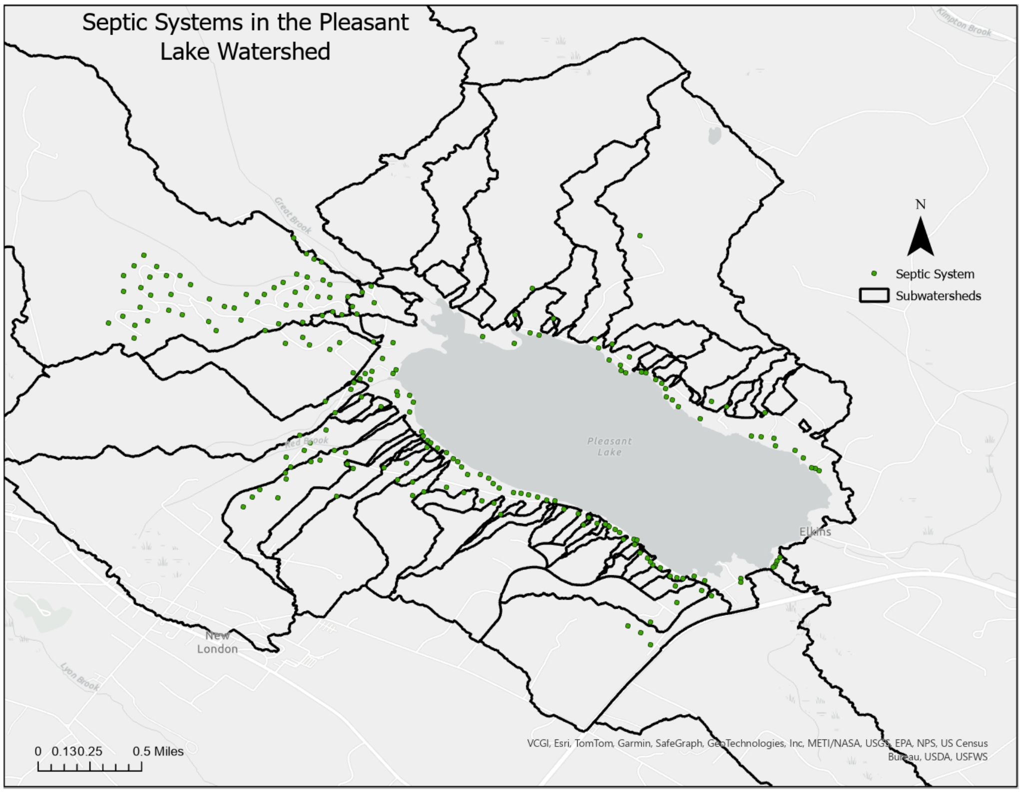


Figure 17: Bar plot shows the difference between storm and non-storm phosphorus loading. A two-way ANOVA found a p<0.001 and n=749.

While we were able to identify differences between tributaries with respect to overall phosphorous loading, we also were able to construct an analysis that examined the influence of storm events on loading to the Lake. This analysis showed phosphorus loading was significantly higher during storm events (**Figure 17**). This can be explained by increased discharge entering Pleasant Lake through its tributaries during precipitation and snow melt. With more water entering tributaries there is a greater potential of phosphorus entering the lake. Further, rain events and snowmelt stir up and pulses sediments, nutrients, and organic matter into tributaries, increasing phosphorus loading. Other sources support this trend of storm events significantly increasing phosphorus loading. Ross et al., found the frequency and intensity of precipitation impact discharge that contributes sediments, nutrients, organic matter, and other contaminates that impact phosphorus loading (2022). As climate change is predicted to increase the frequency and intensity of summer storms in our region, it will be important to monitor several of these inlets in the warm days following storm events if these generate conditions for a cyanobacteria bloom.

Septic

Septic systems can impact phosphorus loading in freshwater systems by contributing excess nutrients that can contribute to eutrophication. The majority of homes in the watershed rely on private septic systems, and we hypothesized outdated systems could contribute excess nutrients to the watershed. The process for collecting septic system age utilized online and hardcopy resources to create an extensive dataset for homes in the watershed. We used the NHDES's One Stop database that contains permitting information and approvals for residential septic systems. However, this database was limited and only provided data for about 1/10 of the house's watershed. To collect the rest of the data, the group took multiple trips, totaling approximately 10 hours, to the New London Town Office to look through the file folders of each parcel (**Figure 18**). Many folders contained copies of the state's operational approval paperwork for the system, however, there were some with no septic information at all. There were stretches of homes in the close vicinity of Main Street that were on town septic, so those were excluded from the dataset. Many homes with available septic information were on the direct shoreline of Pleasant Lake and did not fall within any sub-watershed. These properties have a direct impact to the lake, and their effect is not able to be measured by our stream sampling.



VCGI, Esri, TomTom, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, NPS, US Census Bureau, USDA, USFWS

Figure 48: This map shows all residential septic systems our team found operational approval dates for within the Pleasant Lake Watershed.

Once all septic data was collected, phosphorus values per sub-watershed were then regressed with phosphorus concentration as the dependent variable and average septic age as the independent variable. There was no significance in either of these relationships. This indicates that the septic age does not significantly impact phosphorus concentration or loading in the watershed. This relationship could indicate more data is needed to understand the impact of septic systems on phosphorus concentrations and loading. The average age of the septic systems was the most consistent data point, this variable did not account for septic density and gave us limited information of the condition of septic systems in the watershed. It could also indicate that proper maintenance of septic systems in the watershed has prevented excess phosphorus from entering the watershed. Overall, it shows that septic systems alone are not the reason for higher phosphorus concentrations between sub watersheds.

Land Cover of Pleasant Lake

Human activities can exacerbate eutrophication when nutrients are added to freshwater systems. Fertilizers, soil from agriculture, housing density, and roads and driveways can alter how phosphorus enters freshwater systems. Having wetlands in a watershed impacts phosphorus concentrations due to their role as natural buffers, reducing the amount of phosphorus reaching downstream water bodies. Using a digitized map of the watershed, we found that 96.25% of the watershed is undeveloped, and only 3.75% is designated as covered by permanent structures (**Figure 19**). Just 99.53% of the watershed were permeable surfaces (including forests, fields, lawns, farms and wetlands) while only 0.47% were impervious surfaces (houses, roads).

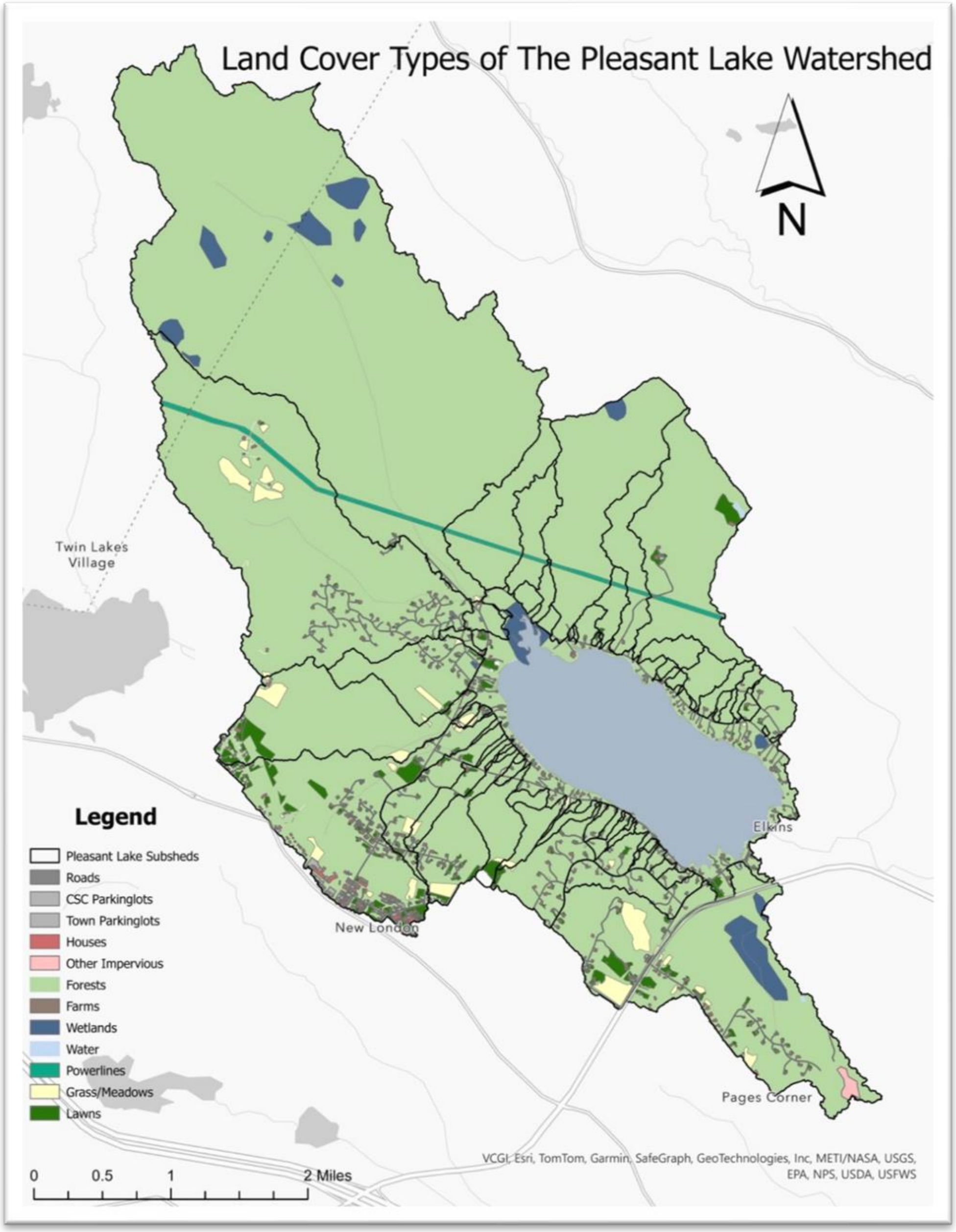


Figure 9: This map shows land use types within Pleasant Lake watershed. Land cover type was assigned based on the interpretation of high-resolution satellite imagery and Google Earth.

To understand how land use impacts phosphorus entering the watershed, a linear regression was performed of the percent land cover of each land use type in each sub-watershed and phosphorus concentrations. This analysis showed that farms, lawns, and wetlands did not significantly impact phosphorus concentrations and loading independently. However, there was a significant relationship between the percent cover of homes and phosphorus concentrations. This suggests that the amount of human development in the watershed, represented through impervious surfaces increases phosphorus entering Pleasant Lake through its tributaries. Anthropogenetic phosphorus sources include the use of fertilizers and overloaded/faulty septic systems. Increasing human development will increase the presence of these factors. Furthermore, stream alteration, erosion and loss of vegetation buffers will impact the flow of excess phosphorus entering a waterbody which is exacerbated by rain and snowmelt (NHDES 2019). This analysis shows the significant relationship between percent impervious surface and phosphorus concentration, as well as the significant relationship between percent house cover and phosphorus concentration. These two findings suggest that human development is a significant factor in phosphorus loading in Pleasant Lake.

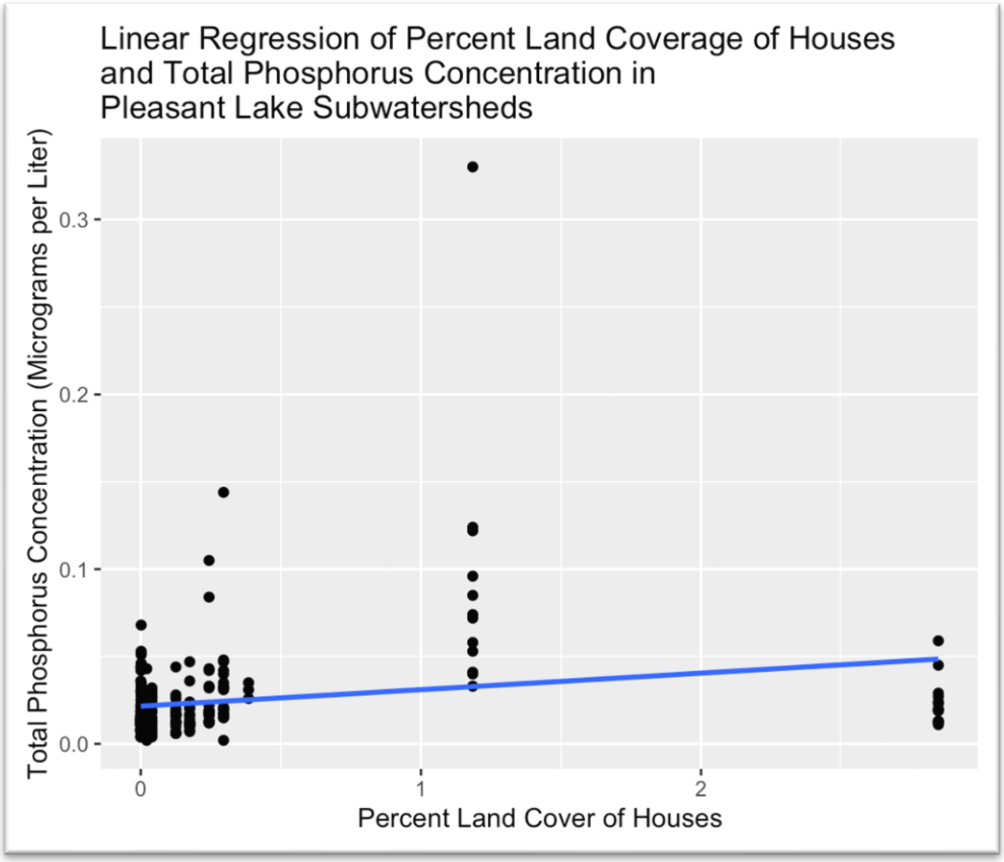


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Figure 20: a linear regression of percent impervious and total phosphorus concentrations in Pleasant Lake Sub-watersheds indicates a positive association between these two variables. The relationship had a P value of .0006481, the linear regression equation was y = 5.2723x – 1.714. with 228 degrees of freedom and an r^2 of 0.04568

To determine the percentage cover of houses in each sub watershed, the total area of houses in each watershed was divided by the total area of each sub-watershed. These values for the percent cover of houses were merged with the master dataset for phosphorus values per site, and then regressed with phosphorus concentration as the dependent variable and house land coverage percent in tons as the independent variable. The regression had a p-value of 0.0006481 showing a significant relationship between the two variables, and an adjusted r^2 of 0.04568. This low r^2 value shows that the percent land cover is not the only cause of elevated phosphorus values. Many factors impact phosphorus concentrations, and in freshwater systems, one factor will not be the only reason for elevated phosphorus concentrations.

Impervious Surfaces

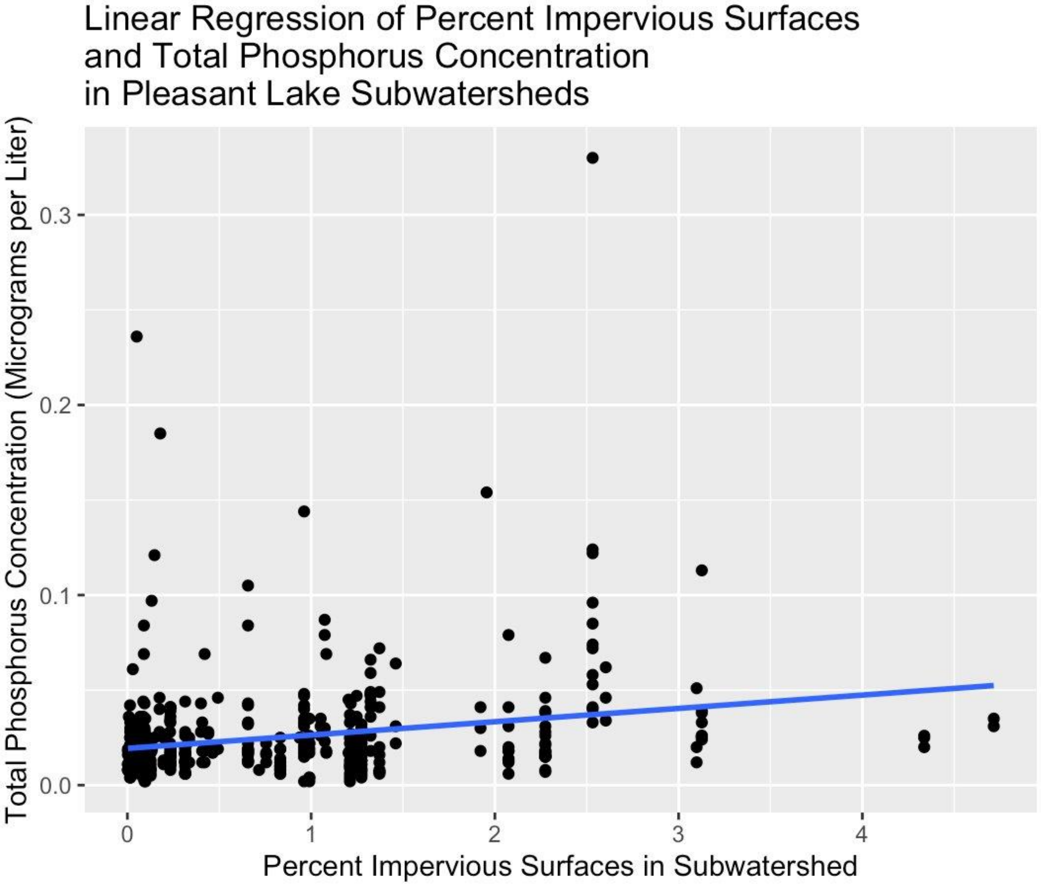

Figure 21: This figure shows a linear regression of percent impervious by total phosphorus concentrations in Pleasant Lake Sub-watersheds. The relationship had a P value of 0.000003122. The linear regression equation was $y = 0.6938x - 7.0283$, with 431 degrees of freedom and an r^2 of 0.04704.

As seen in **Figure 21** using a linear regression, there was a significant relationship between the percent impervious surfaces and phosphorus concentrations. This relationship can be explained by how permeable surfaces allow runoff and precipitation to infiltrate into the ground, filtering out sediments and pollutants surfaces contribute to increased surface runoff, carrying sediments from construction sites, roads, and urban areas into tributaries or directly into the lake. Despite only 0.47% of the watershed is impervious surfaces, it still has a relationship with phosphorus concentrations. For context, according to the EPA (2018), once a watershed is 10–20% impervious, surface runoff doubles and continues to increase (. 15% impervious surface cover is considered a threshold and beyond this there's a notable increase in phosphorus loading. Many sites are below .25% impervious surfaces within their sub watershed and have some of the lowest phosphorus concentrations. Site 13, with the highest percent impervious surfaces, includes main street and the Colby-Sawyer campus, and had the third highest phosphorus concertation. All of Pleasant Lake's sub-watersheds are below the EPA "threshold" of 15% impervious, however. All Pleasant Lake's sub-watersheds this "threshold" of 15% impervious, however it still impacts phosphorus concentrations. As the watershed continues to develop, education of phosphorus mitigation best practices is essential as well. Furthermore, continued tributary monitoring is essential to understand how phosphorus enters the watershed.

Color

Tannins are chemical substances derived from phenolic acids. They are classified as phenolic compounds, which are found in many species of plants, from all climates and all parts of the globe. They are large molecules that bind readily with proteins, cellulose, starches, and minerals. These resulting substances are insoluble and resistant to decomposition. Tannins occur in many species of coniferous trees and several flowering plant families. They are found commonly in the bark of trees, wood, leaves, buds, stems, fruits, seeds, and roots (U.S. Forest Service, 2024).

In the fall, there was a lot more variety in color of our water samples compared to spring. Tannins, which leach out of leaves, are the cause of the higher color results in the fall. As leaves senesce in the fall, the water in the soil becomes rich with tannins from the decomposing leaves and seeps into the ground water, rivers, streams, or drains that lead into lakes. The tannins create a brown appearance in the water, resulting in darker water and higher color results, as the maximum PCU was 360 and average PCU of 77.22. In the spring, the melting of the snow does not allow those tannins to be as prominent as they would be in the fall because there is so much more water flowing in streams and rivers. This resulted in the maximum PCU to only reach 200 and an average PCU of 53.16 for the spring (**Figure 22**). In both the fall and spring, Site 20 had the lowest average color and Site 27 had the highest. Site 27 is surrounded by a marsh that flows right into Pleasant Lake. Low-lying, marshy, coastal areas, or areas that contain a lot of decaying vegetation are more susceptible to water tannin contamination, which is why Site 27 tends to have higher average color compared to the other sites.

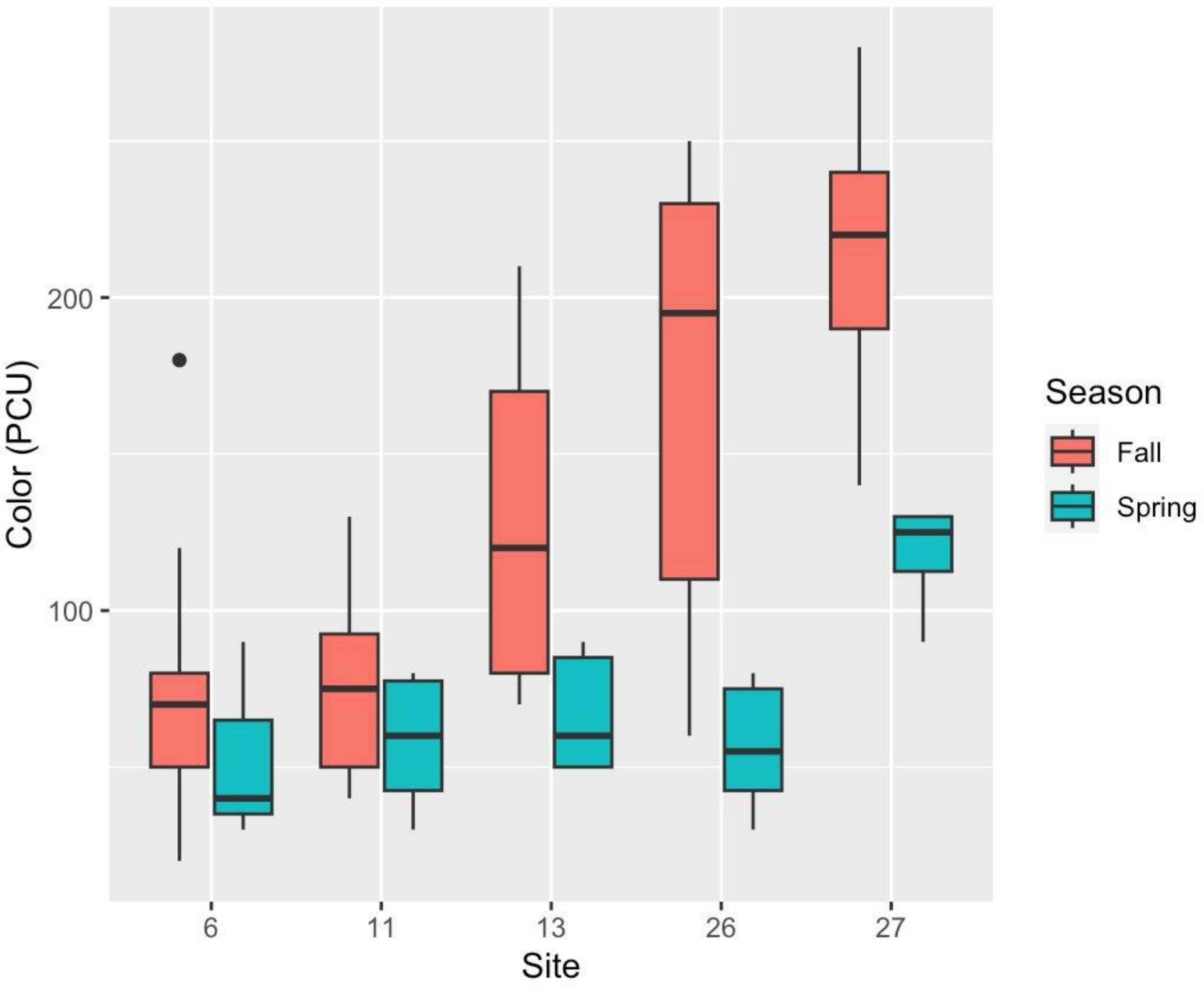

Figure 22: Apparent color at our main sampling sites was considerably greater in PCU in the fall season compared to the spring season. The presence of tannins likely contributed to the deeper colors found in autumn.

Turbidity

In our sampling, we found a main difference in turbidity values between storm and non-storm event samples. **Figure 23** shows turbidity levels by weather event. It can be seen that storm events have a significantly higher mean value of turbidity than non-storm events. Using a Welch two-sample T test, we found that there was a significant difference between samples taken for a site and a sample taken at the same site during a recent storm-event. This can be explained by the increased erosion and runoff caused by precipitation. As phosphorus binds to sediments, higher turbidity values can serve as an explanation for increased loading during and after storms.

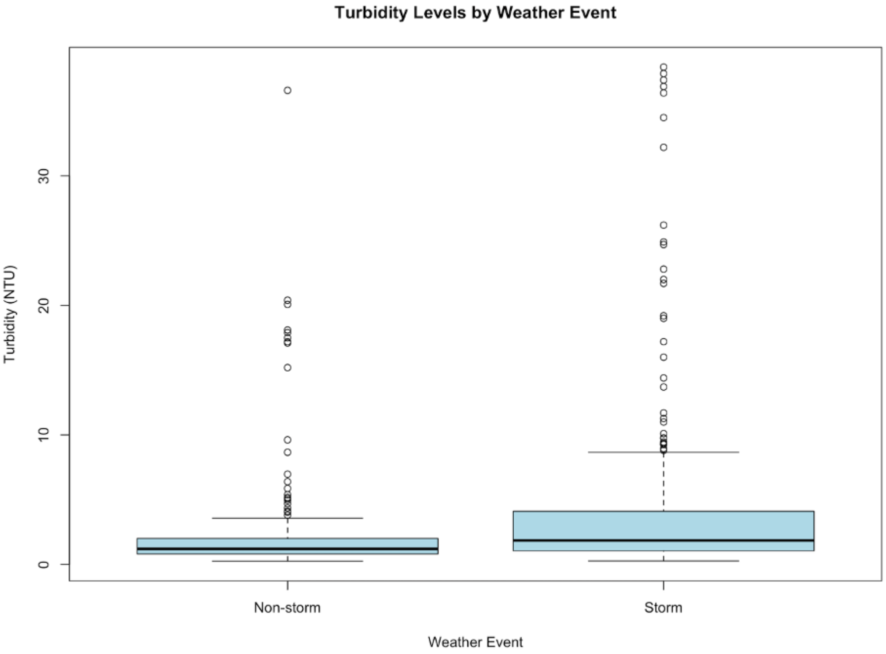

Figure 23: The box and whisker plot display average turbidity levels (NTU) between non-storm and storm events. A Welch Two Sample t-test gave a p-value of 0.01391, showing a significant difference in turbidity levels across these two weather conditions for each of the sites.

Water Quality and Community

Understanding values within a community is essential for making positive change. Since the fall, our project team held various conversations with past and present residents of New London and the Pleasant Lake watershed. Through historical perspectives, local data, and literature, we got an understanding of how past land use and development within the watershed have contributed to cyanobacteria blooms in pleasant today. Hearing historical perspectives helped us get a better understanding of the ecological and cultural importance of Pleasant Lake and the land it encompasses. The theme that kept resurfacing was this community's relationship to the water.

The Pleasant Lake watershed community is not bound by the watershed itself, nor state and political lines. People have lived their whole lives here, grew up here, moved here, and even visit in the summer to find relaxation on a deep glacial New Hampshire Lake. Generations of families call this watershed home. Pleasant Lake and its tributaries provide a sense of place as well as significant importance to the ecological, historical, and cultural identity of the people of this community.

There is one story that proved this to be true. A few weeks ago, project member Dryden Eliason went on a hike up the Great Brook Interpretive Trail with Mark Vernon, an avid conservationist and watershed native. As they hiked, Mark told Dryden about the agricultural community that lived along Great Brook using it for sawmills, cider mills and washing their sheep. He showed Dryden the Bunker-Woodward sawmill and the stone wall corals that the settlers used to wash their sheep in the brook. As they hiked up the old road that leads up to the old Morgan pastures, they came along a plaque in memory of the old Hayes family settlement. On the plaque is a picture of a woman, a little boy, and a man standing in front of the old farmhouse in the mid 1800's. The little boy was his great-great-grandfather. This new friend of Dryden's described how his family's ancestral history contributes to the lens that he sees through today. His ancestors utilized Great Brook as a resource to support their families and their livelihoods. Preserving this history and Great Brooks water quality was made possible through conservation.

In the 1960's, New London as well as the rest of the country were becoming increasingly conservation minded. The New London Conservation Commission (NLCC) was founded in 1965 by Esther Mead Currier, a biology teacher at Colby Sawyer. The commission maintains over 26 miles of trails within New London. The first conservation easement ever granted in NH was given by Dick Webb to the NLCC on the north end of Pleasant Lake in 1967 (ASLPT). Since then, Dick and his family have donated over 1,000 acres within the Great Brook watershed and other sub watersheds of Pleasant Lake now known as the Webb Forest Preserve. The New London Conservation Commission, New London Town Archives, and UNH Extension Service worked together to make the Great Brook Interpretive trail which visits cultural and historical heritage sites preserving important history to families that have called this watershed home for generations. This allows water to flow through forested land which was once cleared for pasture practicing positive management in the conservation of land to protect water quality.

The roads around Pleasant Lake were changed from gravel to paved in the 1950's which caused the management of these roads to change. Increasing the percentage of impervious surfaces usually leads to increasing amounts of road salt usage, which leads further to increasing amount of sodium and chloride dissolved in water and contaminating wells and watersheds. The number of NH Chloride-impaired waterbodies has been increasing. In 2008, New Hampshire had 19 chloride-impaired waterbodies listed under the Clean Water Act; that had increased to 50 by 2020. Sodium chloride can pollute water, even getting into drinking water, as shown in an analysis of wells in Merrimack, New Hampshire. In addition to roads, the salt comes from parking lots, driveways, and residential septic systems. Luckily, our findings show that the town is doing quite a bit to minimize road salt applications by applying less road salt on Bunker Road and Lakeshore Drive. If people want to have a positive impact to reduce road salt applications, people could investigate deicer alternatives northern states are using to reduce chloride levels. Alternatives being tested use carbohydrates, a form of sugar that reduces freezing point (Tenneti, 2022). These include brine solutions made from beet juice, cheese and pickle brine, molasses, corn, and soybean oil (Tenneti, 2022). Another alternative is sand mixed with salt and grit, but this leads to elevated sediment loading within the watershed. But there is a solution to this. The "Sunapee Swirler" stormwater treatment basin sits at the mouth of culverts to collect sediment before it makes its way into the lake. Pleasant Lake could use this same technique, or a road run off alternative.

Our findings show that some tributaries have elevated phosphorus levels, but this was not necessarily related to age of septic or percentage of lawns within the watershed. Septic nutrients do not appear to be contributing to the phosphorus concentrations of tributaries entering the lake which either means our analysis is inconclusive or perhaps that people are being conscious with their septic tank maintenance. It could still be a good thing for New London to establish septic ordinances like Sunapee which involve the best septic management practices for the health of the watershed. We are not aware of the lawn fertilizer applications on every lawn, but the percentage of lawn area was found to be insignificant for phosphorus loading.

While we did not detect a strong signal between phosphorus and septic systems, what we did find was that the percentage of houses within the watershed is significant in its relationship to phosphorus concentrations in our samples. The exact land management practice contributing to phosphorus loading was not pinpointed, though. This gives even more of an incentive to be conscious of nutrients coming from your property within the watershed. This could be limiting the use of phosphate rich detergents or soaps, not fertilizing lawns, and planting native plant species that take up phosphorus. Rubin et al. note that mitigation and remediation of phosphorus accumulation in landscapes may potentially be possible using phytoremediation, plants and fungi used for phosphorous uptake (2021). This study was based in Vermont, the authors may have further suggestions for native New England plants that might be planted near Pleasant Lake.

Nobody wants to see the environmental health of the place they cherish degraded, especially if it is close to their homes. Water quality impairments negatively affect the health of ecosystems and the health of humans that interact with them, but they also pose social and economic challenges to communities. Hamilton et al how property costs were affected by cyanobacteria blooms on 2,000 large inland lakes across the United States from 2008 to 2011. This study also looked at how home sales were affected by the distance they were to the lake. The authors found that a 10-percentage point increase in cyanobacteria bloom occurrence decreases near-shore home values 3.5 percent in the Upper Midwest, 4.3 percent in the Northeast, 3.8 percent in the South, and 3.3 percent in the Southeast (Hamilton et al. 2013). The analysis also found that the homes closest to the lake experienced the highest home sale decrease. Families have been living here for generations, passing down stories and perspectives. Other families have moved here in the more recent past contributing to innovative ideas, making their own connection to this tight-knit community and its natural treasures.

For the past two and a half centuries, this picturesque bowl surrounded by rolling hills has drawn people from all walks of life. Among all the people interviewed, there are deep connections to the lake and a commonality to preserve this special place. Deep connection to water and water quality. This naturally puts Pleasant Lake and its tributaries at risk of excess nutrients into the system if conscious property management practices are not upheld. The stewardship of Pleasant Lake’s water quality through proper land management within the watershed is essential to minimize human influenced nutrients into the system. Partnerships and mutual respect for appropriate land management for this watershed is necessary to preserve this community's cultural and historical identity. Finding the source and limiting inputs of excess nutrients and other water impurities into Pleasant will help preserve this special place for future generations.

Conclusions and Recommendations

The results of our watershed analysis of Pleasant Lake yielded significant findings that may serve as the foundation for future management plans or grant opportunities with the state. Overall, analysis of our data indicated that storm events are a significant contributor to water quality changes in Pleasant Lake. A significant difference between phosphorus concentrations, chloride loading, and turbidity values were found between storm and non-storm samples. These findings emphasize the importance of continued monitoring to capture the impact of storm events to prevent cyanobacteria blooms in Pleasant Lake. Additionally, we found correlations between land use and practices within the watershed and loading of phosphorus and chloride. Continued monitoring during the summer will be important in understanding the role in nutrient and mineral loading throughout the year and inform mitigation for cyanobacteria blooms in the watershed.

Tributary sites with consistently elevated phosphorus concentrations were identified, and the sources of phosphorus concentration variability were examined. Areas of concern in terms of high concentrations include Sites 26 and 27, Elkins/Bunker and the Fire Pond respectively, which may be impacted by human activity. These sites had average phosphorus concentrations over 25 ug/L, which is significantly higher than the threshold for an oligotrophic lake of 8 ug/L. The septic analysis of operational approval dates revealed that there was no significant relationship between outdated septic systems and phosphorus concentration or loading. This result suggests that effective maintenance of these systems has prevented excess nutrient input into the watershed. Continuing regular septic inspections, maintenance, and pumping will continue to prevent effluent from adding excess nutrients to the watershed. In 2023, the nearby town of Sunapee adopted an ordinance that requires all residential septic systems within the Shoreland Overlay District to be pumped a minimum of every three years. The Shoreland Overlay District is defined as developed properties within 250 feet of lakes & ponds over 10 acres in size and fourth order streams. A similar ordinance could be adopted by the town of New London, with the support of local lake associations such as Pleasant Lake and Little Lake Sunapee, to help ensure the continuation of proper maintenance of septic systems within watersheds.

In terms of phosphorus loading within the Pleasant Lake watershed, Sites 6 and 27, Great Brook and the Fire Pond respectively, deliver the most grams of phosphorus per day to the Lake. However, after an analysis of their sub-watersheds, these tributaries have little to no human development in their boundaries. It is important to remember that this is not a bad finding. Great Brook's watershed is placed in some form of conservation, meaning any phosphorus in its waters would likely be from natural sources such as leaves and other organic matter. Water entering the Fire Pond comes from the Cascade Marsh, which is in the Esther Currier protected land as well. Together, these two sites contribute over half of the phosphorus entering the lake in grams per day. This means that the greatest sources of phosphorus into Pleasant Lake are natural and not due to human influences. Nonetheless, there are still mitigation strategies that can be implemented to reduce phosphorus loading, especially during storm events. As mentioned, the Sunapee Swirler was installed along the shores of nearby Lake Sunapee, to reduce sediment entry and increase phosphorus into the lake (Figure 24). The Sunapee Swirler has a simple design that is affordable for small town budgets and requires no special maintenance (LSPA, 2005). These devices could be utilized by the PLPA in areas before water enters the lake through culverts, to help reduce sediment-bound phosphorus. Targeting sites with greater phosphorus loading that are not coming from natural sources may be locations worth investigating should values increasing with storm events in the future.

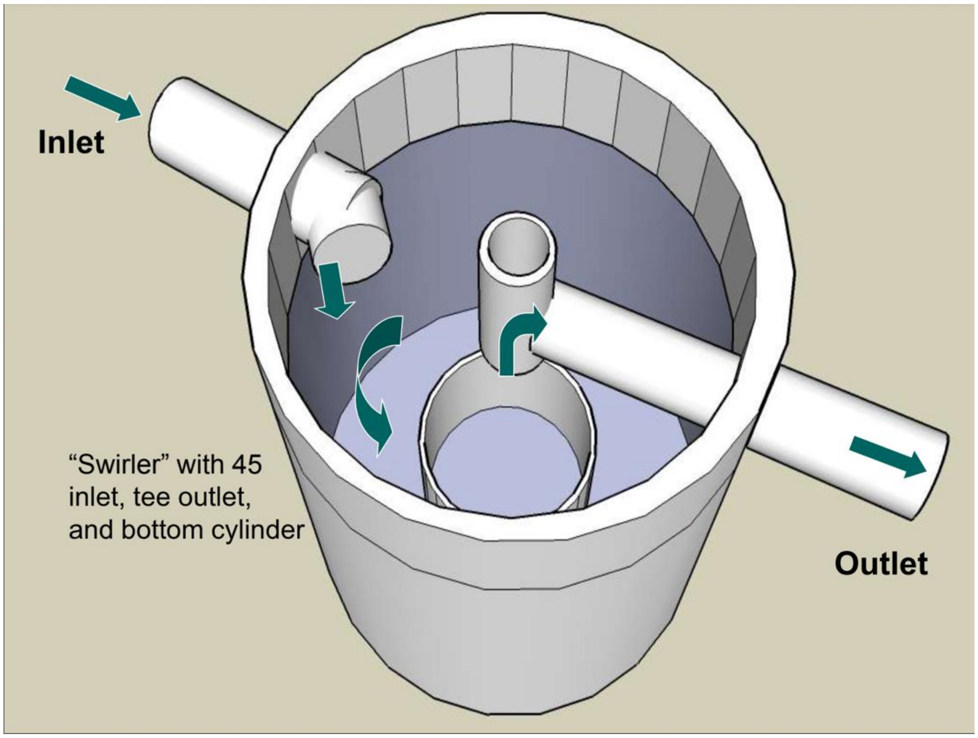

Figure 24: Diagram of the Sunapee Swirler and its components for sediment catchment (LSPA, 2005).

Our findings also highlight a significant correlation between the percent land cover of houses and impervious surfaces with phosphorus concentration. Despite Pleasant Lake's watershed having relatively low development, with ~3% developed, housing density and impervious surfaces still impacted phosphorus concentrations. These relationships show that human development does have an impact on phosphorus concentrations within the watershed, emphasizing the importance of management practices in the future. Should development within the watershed continue to increase, the effects could worsen. Educating landowners in the community of best land management practices for their properties to reduce the effects of stormwater runoff is of utmost importance. The NH Lakes organization runs a free and voluntary program called LakeSmart, where homeowners can have their property evaluated and certified that it is being properly managed to protect water quality and habitats. Property owners can fill out an online survey describing their property and receive tips and recommendations to implement in order to make their property lake friendly. The NHDES also offers a free program to residential and small commercial properties called ‘Soak Up the Rain’ that provides ways to manage stormwater runoff. Exploring either of these programs would be a positive way for residents and businesses within the Pleasant Lake Watershed to reduce their individual impact on the lake.

Results of analyses conducted on salt application practices and chloride concentrations revealed that New Hampshire state-maintained roads are likely the greatest contributors of chloride into the Pleasant Lake Watershed. Sites 26, 13, and 27, Bunker/Elkins, Red Brook, and the Fire Pond respectively, had the highest chloride concentrations, as well has had State Routes 11 and 114 within their watershed boundaries. The salt application rate of the state was found to be 17 times that of the town, at 17.2 tons/mile/year compared to 1 ton/mile/year. Action can be taken by the Town of New London and PLPA to lower the salt application rate on state roads within the watershed boundaries. Other lakes and ponds in New Hampshire, and even rivers, have implemented salt minimization plans to reduce increasing chloride levels due to excessive road salt application. The NHDES provides information for the creation and implementation of Salt Minimization Plans, and once implemented the New Hampshire Department of Transportation (NHDOT) will be required to follow the plan. More information on this process is located on the NHDES website and is linked in the references of this paper (NHDES, 2020). A successful pilot road salt reduction program exists on the Interstate 89 bridge between New Hampshire and Vermont, crossing the Connecticut River (PVPC, 2023). The program utilizes monitoring software that automatically detects conditions and applies appropriate salt treatment. The Town of New London and PLPA could work toward a Salt Minimization or Reduction plan with the NHDES or EPA as a way to effectively reduce chloride inputs into Pleasant Lake. A balance between ecological concerns and road safety would have to be met but implementing more mindful practices throughout the entire watershed would help to address rising chloride levels.

Lastly, with the generous support of the PLPA, several members of our team will be continuing sampling efforts throughout the summer from May until August. For many lakes in New Hampshire, water quality monitoring occurs in the summer months between May and September through the NHDES VLAP Program. These collections are mainly located within the lake, rather than on tributaries. However, our work revealed the importance of tributary sampling to help identify sources of nutrient and chemical loading to a lake. To build a comprehensive year-long data set for Pleasant Lake, we will need to collect samples in the summertime. This complete annual snapshot of tributary conditions can serve as the foundation for future potential watershed management plans and initiatives to help protect the Lake’s character, ecology, and biogeochemistry. This summer, our procedures will continue to follow the design we constructed during our course project. Methods for sample collection and lab analysis will continue to follow state protocols adapted from the NHDES VLAP. Three students will be routinely collecting water samples and discharge measurements multiple times a week, and data analysis will occur at the end of the summer season. Continuing to monitor conditions in the Pleasant Lake Watershed will help inform future management initiatives, potential grant opportunities, and preserve the quality of the lake for years to come.

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