Columbus Avenue Project

This Wetland is Working for You

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CES 301/302

July 2002

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Abstract

This is a report of a community-based project focused on analyzing the ability of a wetland to mitigate and attenuate nutrient runoff from a highway and developing a management plan for improving the functions of the wetland. The overall premise is to improve the quality of the water entering Lake Sunapee at Herrick Cove. The Columbus Avenue wetland provides a buffer against the runoff from Interstate 89 (I-89), as well as stream and tributary flow from a broader watershed. This project is in response to the construction of a water impoundment structure, by the New London Conservation Commission and the Lake Sunapee Protective Association in 2000.

Quantitative and qualitative research was done to help extrapolate information vital to the function of the dam and the wetland over a limited period of time. Water quality analysis through sampling and testing for specific factors, such as pH, turbidity, conductivity, dissolved oxygen, and phosphorous were all used in conjunction with a thorough watershed investigation. In order to help present the researched material and understand the general publics' perceptions and knowledge of wetlands, surveys and interviews were also conducted.

The results of this project show that there are several different management plans that can be used to improve the quality of the water entering Lake Sunapee by treating different factors, which may include phosphorous, nitrogen, metals, and sediments. The recommended management plan is that the both retention boards at the weir next to Columbus Avenue be removed twice a year, once after spring runoff and replaced in early fall, then removed again after hurricane season and replaced prior to spring runoff. This management plan will provide the best mitigation of phosphorus when it is most likely to flow into Herrick Cove during the spring and fall when there is heavy precipitation. This plan also gives the wetland time to dry out during the summer growing season when most of the phosphorus would be taken up by plants and allow for nitrogen aeration. Furthermore, leaving the boards down during the summer as well as during the winter months provides needed absorption room for hurricane season and spring runoff. This method would increase the wetlands ability to act as a sink during periods of high nutrient inflow.

Acknowledgements

We would like to thank the New London Conservation Commission, Lake Sunapee Protective Association, Merrimack County Cooperative Extension, Ausbon Sargent Land Preservation Trust, New London Town Archives, and the Town of New London. We would like to especially like to thank the following individuals: Bonnie Lewis, Terry Dancy, Robert "Woody" Wood, John Callewaert, Leon-C. Malan, Laura Alexander, Michael Simpson, Cotton Cleveland, Ann Page Stecker, Hilary Cleveland, Lynn Garrioch, our interviewees, Gerry Ridzon, Pierre Bedard, Diddy Menkart, and the Information Resources crew at Colby-Sawyer College.

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Introduction

Purpose of the Study

The purpose of this study was to determine the effectiveness of the water impoundment structure at Columbus Avenue in New London, New Hampshire near Herrick Cove of Lake Sunapee. The project partners were interested in gathering baseline data as to the effectiveness of the dam and to identify a management plan for the site. The goal of this study was also to support the integrity and functions of the wetland as much as possible based on the findings of this research.

Problem

"Runoff from I-89 has led to high conductivity (salt), turbidity (sediment), and phosphorus readings in the stream which flows into Herrick Cove," (Major Grant Funded Erosion Control Projects, 2000, 4). Herrick Cove is reported to be the only place where algae blooms occur. Additionally, concerns have been expressed about the leaching of materials from the nearby rock cut on I-89.

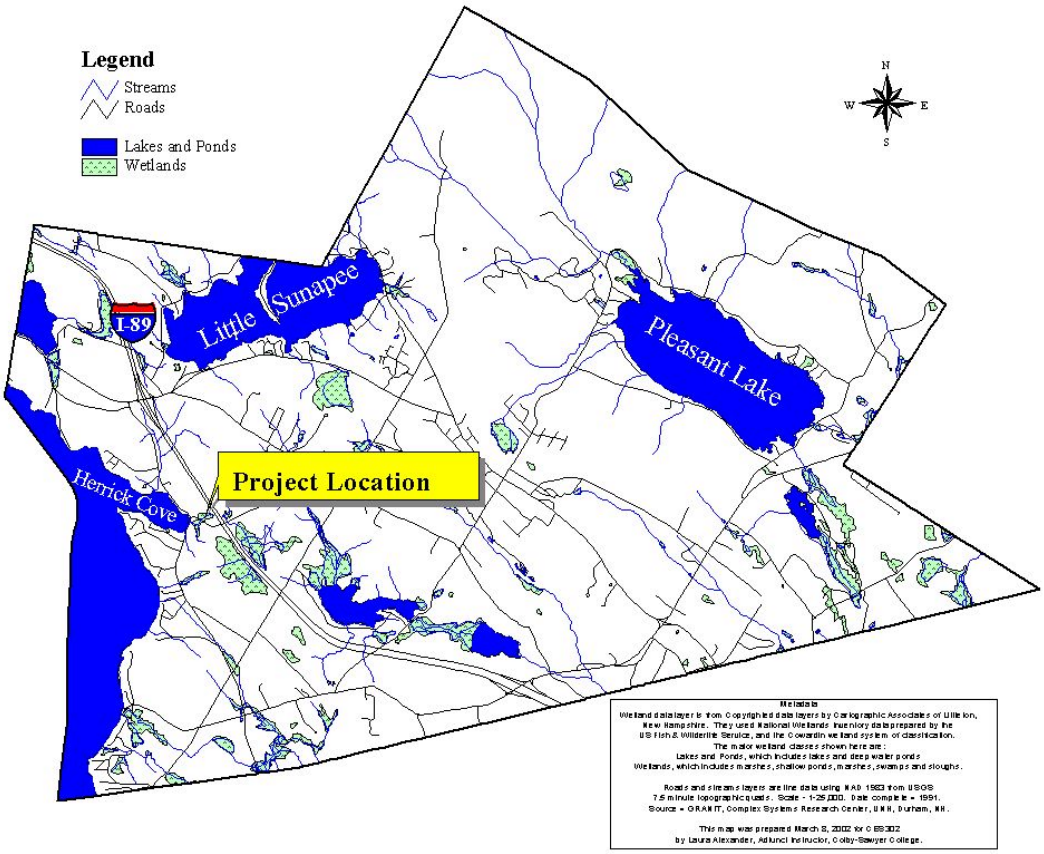


Figure 1: Project Site Map

Literature Review

To guide our project work, an extensive literature review was done to look for any other similar projects. We did not find any similar projects. However, we did take a few pieces of information that we could relate to our project. For example, since 1996, about sixty-four million dollars in federal funding has been spent to compensate for federal highway impacts on wetlands, with about 4000 acres of wetlands restored, created or preserved annually, according to the Federal Highway Administration (FHWA). Under the Clinton administration's Clean Water Action Plan, FHWA has established a goal of increasing the net wetlands acreage resulting from federally funded highway projects by 50% over 10 years (West Virginia Wetlands Ride the Highway, 1998).

There is also a growing awareness of the importance of wetlands for managing runoff. Snoonian (2001) notes that wetlands can be effective for managing storm water runoff and that certain characteristics of wetlands, such as a dense cover of plant growth, are essential for removing pollutants. Others have examined the effectiveness of constructed wetlands for the retention of nonpoint-soure pollution (Schulz and Peall, 2001). Much of the literature demonstrates that people care about the environment and are willing to use constructed wetlands as a means to an end. The literature also showed how important wetlands are to our current culture and society. They purify our drinking water, protect us from floods and help support fish, waterfowl, and other wildlife. Wetlands also provide a sense of wonder. Contrary to popular superstition, wetlands are not major breeders of pests or reservoirs of disease. In fact, wetlands are essential to our lives and to our economy (Williams, 1996, p. 43-44). However, wetlands have not always been valued. In the US, more than half of the original supply of wetlands have been destroyed. In the contiguous 48 states, 120 million of an original 215 million acres of wetlands are gone. The rate of destruction has recently slowed from about 290,000 acres per year to approximately 80,000, primarily due to the fluxuations of real estate values rather than environmental awareness, (Williams, 1996, p. 47).

Community Partners

The community partners for this project were The Town of New London Conservation Commission (NLCC) and The Lake Sunapee Protective Association (LSPA). The NLCC constructed the water impoundment structure in December of 2000, which is next to the Columbus Avenue culver. The structure provides the ability to control water depth. LSPA regularly monitors tributary and deep-water sites throughout the Lake Sunapee watershed. Water samples are tested for pH, conductivity, turbidity and phosphorus, which all help to indicate the

Figure 2: Water Impoundment Structure at Columbus Avenue, ***image courtesy of Terry Dancy***

quality of the water in Lake Sunapee and measure its quality against state standards. These tests act as an alarm to show if anything is being added or taken away from the water that could affect the health of the wetlands and nearby lakes. The tributary that flows through the Columbus Avenue wetland and into Herrick Cove has been the focus of LSPA efforts for several years, (Major Grant Funded Erosion Control Projects, 2000, 4). Table 1 provides funding and construction details for the project. The costs paid by the town of New London were approved at the annual town meeting in 2000 (Town of New London New Hampshire, 2000, 16).

Table 1

Columbus Avenue Water Impoundment Project		
Date Paid	**Service**	**Amount**
05/21/99	Engineering services	1608.50
08/05/99	Wetland permit fee	50.00
08/05/99	Postage to DES	4.52
08/20/99	Survey work	1051.06
08/20/99	Engineering work	2239.00
06/23/00	Engineering work	1577.50
12/25/00	Concrete dam work	19530.00
12/25/00	Baseline field info	600.00
Total Expense of Project		26660.58
Minus donations by Lake Sunapee Protective Assoc.		-10000.00
Total cost to Town		**$ 16,660.58**

Description of the Project

As the literature review has shown, this project is very unique in that no other wetland project like this has been done. The main objective of this project is to give the NLCC and LSPA some considerations as to what should be done in order to manage the water impoundment structure at Columbus Avenue or if alternative methods need to be employed to improve the functions of the wetland. To achieve the goals of the project, our Community and Environmental Studies 301-302 class has focused its attention on the following; Columbus Avenue site analysis including mapping of the wetland stream and ponded area, digital images of the site, flora identification and wetland functional analyses. We also conducted water quality testing, storm events analysis, water flow measurements, and collected historical information as well as aerial maps of the site.

This report will explore the site and its history, which includes an overview of the land history and site maps. Then we will discuss the presence of exotic plant species that may be harmful to the wetland in the future. Next we will explain the methods, procedures and results of our work Finally, we conclude with a discussion section that includes the

limitations of the project, suggestions for a management plan, future research ideas and recommendations and a summary and conclusion section.

Review of the Site and its History

Overview of the Land History

The area of the cove near Columbus Avenue has undergone many significant changes. These have included physical changes in the land, both human made changes and natural changes over the past forty years. One interesting fact is that the Masonian Curve, a boundary line established in 1629 by John Mason as a 60-mile boundary centered on Portsmouth, transects the wetlands at Columbus Avenue.

Figure 3: Historic Postcard of 103-A near Herrick Cove, image courtesy of New London Town Archives

Lake Sunapee has been home to steam ships, grand hotels, and summer retreats since the nineteenth century. The steam ships would deliver guests and residents from the Newbury train station to different landings all around the lake. One such landing was Lakeside Landing, which is still located near the foundations of the old Lakeside Inn (Stecker, 2000, 109). This is also the closest Lake Sunapee landing to the center of New London and acted as the town closest access to the lake. Columbus Avenue is the nearest road to the Lakeside Landing that heads on one of the routes directly to the center of town.

The controversy in the 1960s surrounding the construction of Interstate Route 89 (I-89) is central to the work of this project. There were many different options for the positioning of the interstate, some plans had the highway going right through the center of New London. Most residents in New London did not want the interstate to come anywhere near the town, but the surrounding towns definitely wanted to be apart of the new highway that was coming, whether New London wanted it to come or not (Stecker, 2000, 64-93). In reviewing the hearing transcripts that were recorded when I-89 was in the process of being built, it is important to note that there was no mention of any

Figure 4: Historic Postcard of Lakeside Landing, image courtesy of New London Town Archives

environmental impact on the surrounding land including Lake Sunapee. In 1965, there seemed to be little concern for the environment. People were more concerned with the potential disruption the interstate would cause to their homes and property, (Report of the Special Committee, 1965).

Site Maps

Examining the site of Herrick Cove and the Columbus Avenue wetland is important in distinguishing how the land has changed physically over the years and how human have impacted the area surrounding the wetlands. Other aspects of the site that can be analyzed through aerial images are the amount of water present at a given time and any changes in the number of nearby developments. It is also important to analyze how the site has changed since after the installation of I-89 in 1965.

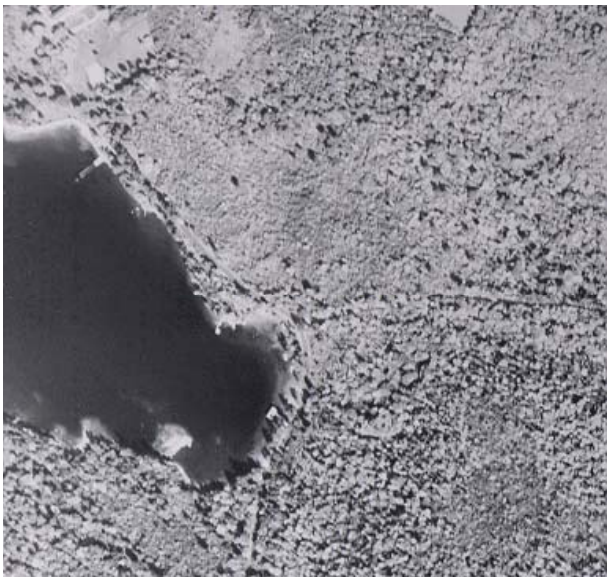


Figure 5: Columbus Avenue, 1953

Figure 5 offers an aerial image of the site from 1953[1]. Clearly, the area around Columbus Avenue is completely forested. There are a few boathouses on the lake, as well as the Lakeside landing. The only other road in the area is 103A, which runs between the landing and Columbus Avenue.

Figure 6: Columbus Avenue, 1974

The aerial image from 1974 (Figure 6) shows how the highway redirected Columbus Avenue. The old, more direct avenue can be seen just north of the newer, slightly curved avenue. This map clearly shows how much land was disturbed around the avenue. Compared to the other roads in the area, Columbus Avenue has twice the amount of open space on either side of the road. This is very likely due to cutting down trees and filling in parts of the forested wetland in order to make the land more level and support the road. There is also a housing

[1] Aerial images were collected from the map library of the Merrimack County Office of the University of New Hampshire Cooperative Extension.

site off of Columbus Avenue that was not there previously, as well as more detail about the number of roads that cross through the area around Herrick Cove. Otherwise, there is no visible physical damming or ponding of the water flow in the Columbus Avenue watershed according to this aerial image.

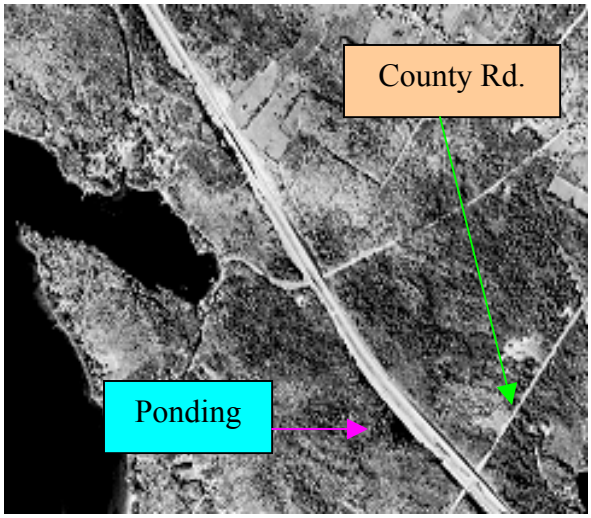


Figure 7: Columbus Avenue, 1981

An image taken seven years later in 1981 reveals that changes in the watershed have occurred over time. They are due to the highway because of its impermeable surface that has affected the way that the water would flow naturally. In Figure 7, the forested wetland is still very visible, but the old Columbus Avenue has been overgrown and is no longer visible on the map. The most significant change is the appearance of open standing water off of County Road on the south side of I-89.

The next aerial image was taken twelve years later (Figure 8). During this period, significant changes took place in and around the Columbus Avenue wetland. This is the first aerial image that shows a clear delineation of the wetland as being inundated with water. There is significant ponding taking place on both sides of Columbus Avenue and further up the tributary on both sides of I-89.

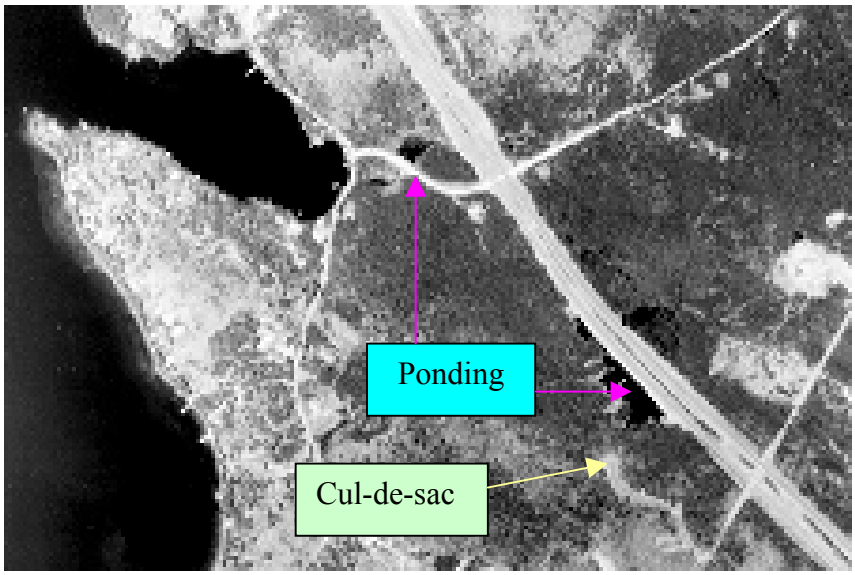


Figure 8: Columbus Avenue, 1993

Development can be seen in the form of small cleared pockets along the sides of Columbus Avenue and County Road. There is also a significant road with a cul-de-sac built right next to the upper wetland. Across the highway, the small house lot closest to the highway has extended itself further back, clearing more trees closer to the wetland on the north side of I-89.

An infrared image taken in 1999 (Figure 9) is also useful for examining how the area has changed since the highway was installed. The map details areas where trees have been cut, houses developed, and all the areas that are wetlands, not just open lake water. The map

also makes clear the distinction between the open marsh wetlands and the forested wetland areas that run between the different sites. It is interesting to note that the areas that seemed to be open ponds of water in 1993 do not show up as distinctly in 1999. Another important image we get from the infrared photo is the development along the shore of Lake Sunapee is dense in Herrick Cove.

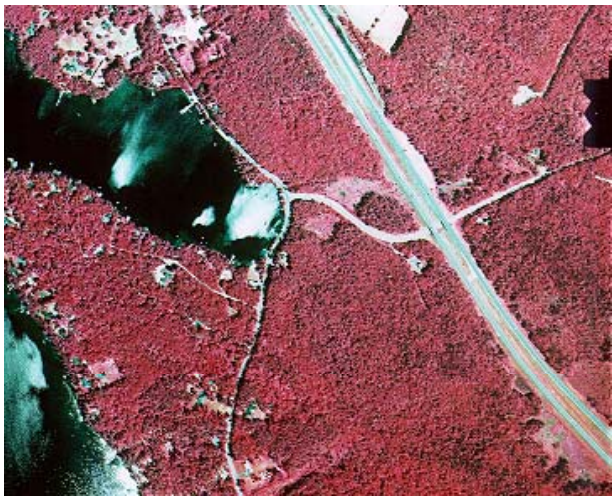


Figure 9: Columbus Avenue, 1999

Exotic Species

Another important aspect to managing the site is to know about some of the important plant species that grow there. Exotic species can present some of the greatest challenges to effective management. Two exotic species that we have found around the Columbus Avenue wetland are Purple Loosestrife and Phragmites. Both of these have the potential to take over the wetland and become a serious problem. These plants have a tendency to spread at a rapid rate and can out compete the native flora.

Figure 10: Purple Loosestrife, source: gardenweb.com

Purple Loosestrife is a perennial herb that can grow up to two meters in height when in its most favorable habitat. It belongs to the Loosestrife Family *Lythraceae* and can be called by other common names such as spiked loosestrife or rainbow weed but most commonly known as Purple Loosestrife. The plant can be recognized by several factors. The plant tends to be covered with short hairs especially in the upper part of the plant. The stem is very firm and stout and the stem has stalkless opposite or whorled leaves. These leaves are generally lance shaped but can be more oblong and narrower shaped. The length of the leaves varies from 3-10 cm each. In the mid summer is when you will see the showiest time for the plants as they bear several to many dense clusters of rose to red-purple flowers (NHDES, 1999).

Phragmites communis which means "grows in colonies," also known as common reed, is an often times unpopular grass. Phragmites seems to have been spreading in the Northeast with the general increase of industrialization and urbanization. *Phragmites communis* is classified in the grass family under *Gramineae*. This plant has a thick stalk and can grow up to thirteen feet in height. It often invades wetlands that have been filled, damned or diked, or otherwise altered. Phragmites thrives in sunny wetland habitats, it is commonly found in the moist soil of shallow brackish and freshwater marshes. It also grows along riverbanks and lakeshores, and can form floating mats in deeper water. This species is

prevalent in the disturbed and degraded soils found along roadsides, ditches and dredged areas, high salinity tends to limit its growth. Common reed is native and distributed almost worldwide; phragmites is perennial and most prevalent from July through September (Phragmites, 2002). The next section of the report will focus on the methods and procedures used for the project.

Figure 11: Phragmites communis, source: botit.botany.wisc.edu

Methods, Procedures & Results

In order to examine the multiple dimensions of this project a variety of research methodologies were used – both qualitative and quantitative. In addition to examining the dynamics of the site itself we also felt it was important to learn about how the local community views wetlands. Having that kind of information would be helpful for designing educational programs on the importance of wetlands and in order to gauge future support for other initiatives like the water impoundment project at Columbus Avenue. Our three primary research initiatives involved distributing a survey assessing knowledge of wetlands, interviews of selected individuals on the importance of wetlands and multiple water quality tests of samples taken at the site.

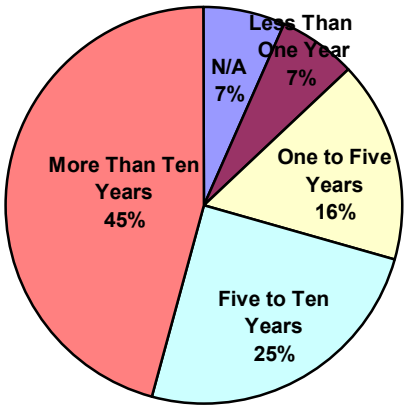
Survey

As a class we distributed a survey during the New London town meeting on March 13th, 2002. This survey (Appendix A: Survey) was aimed at assessing the knowledge and perceptions of wetlands of New London residents. We selected this group to survey primarily because it was attendees of the New London town meeting that had approved funds for the water impoundment project in March 2000. The group represented a large and active group of town residents and it would be useful to gauge their knowledge and support for future projects. It was also be useful to find out the knowledge people had about the environmental impact of I-89. The perceptions and knowledge of wetlands in the town serve as an additional reference upon which future education, policy making, and communication can be conveyed. The survey document had a series of statements about wetlands in general and the respondent was asked to circle a choice from one to five. One being the “strongly disagree” to five being the “strongly agree.” We also asked for demographic data including their education level, age, length of residence, proximity to water, and participation in any local organizations. We collected a total of 120 surveys from approximately 260 attendees. The results from these surveys were very interesting.

The Town of New London, as represented by those who participated in the survey at the 2002 town meeting, has overall interesting statistics regarding their demographics, membership to environmental organizations, their education, and their perceptions of wetlands. We also wanted to know if citizens live near wetlands or not, their ages, and how long they have resided in New London.

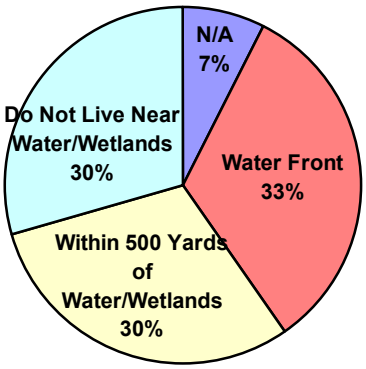
Figure 12 reveals that 45% of those who took the survey have lived in New London longer than 10 years and that 70% have lived in the town at least 5 years.

Figure 12: Years Residing in New London



Sixty-three percent of those who took the survey lived on or near wetlands (Figure 13). This was expected due to the topic of the town meeting, which focused on the reassessment of waterfront properties.

Figure 13: Residing Near Wetlands



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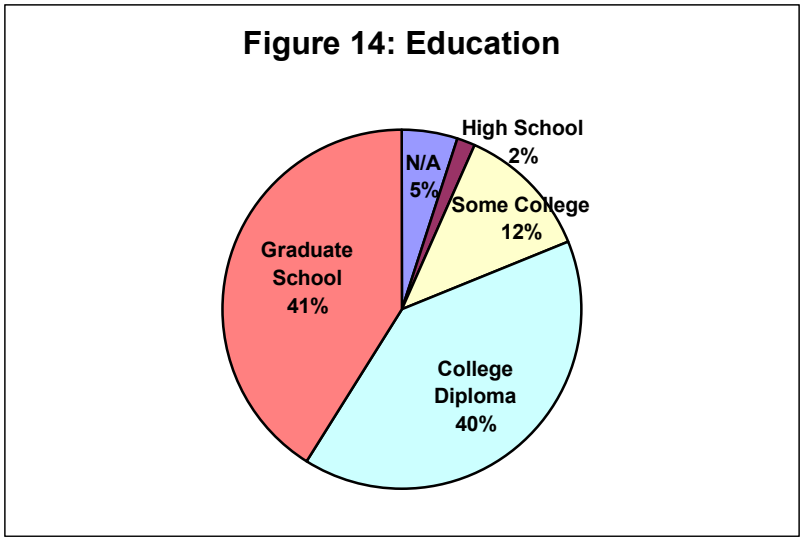
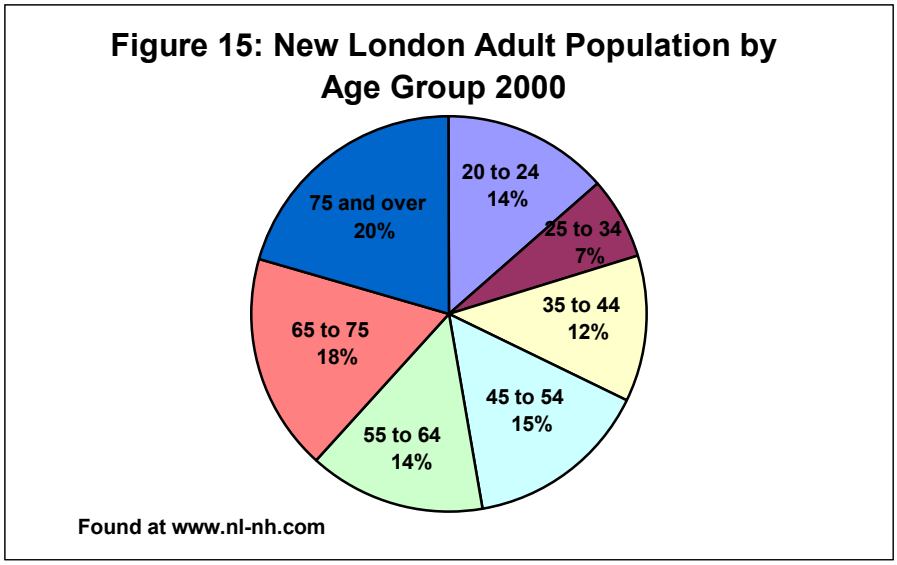
A surprising statistic reveals that most of the people who took the survey had some form of graduate (Masters or PhD) education (Figure 14). Furthermore, 81% have graduated from college. Our survey population reflected a highly educated group of people.

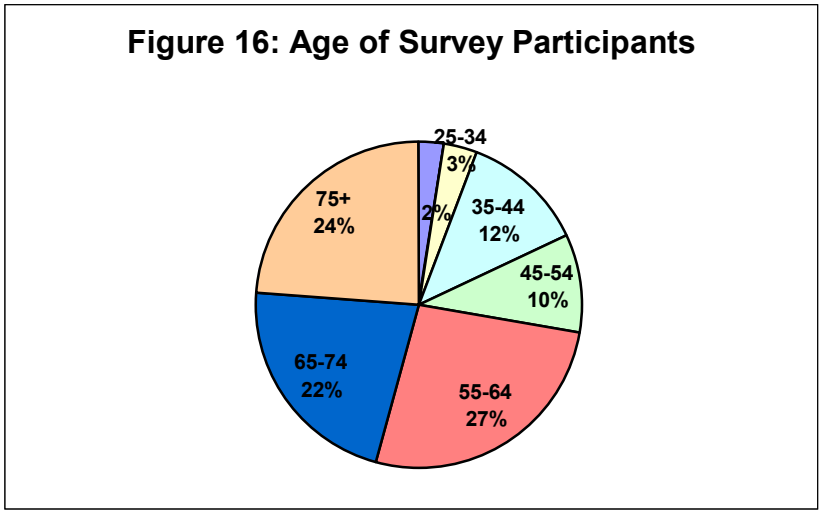


Of those who participated in the survey, more than 50% belonged to the Ausbon Sargent Land Preservation Trust, 22% belonged to The Fells and 19% belonged to the Lake Sunapee Protective Association. Many of the participants are active in organizations that can be seen as conservation minded organizations.

The Town of New London cannot be said to have a particular perception of wetlands, but the way participants answer particular questions on average helps to develop a general perception that many people of the town might share. As shown in Figure 12, most of the participants (27%) were between the ages of 55 and 65. A vast majority of those who took the survey were over the age of 55 (73%). Some bias in our survey results is evident in the fact that the largest majority of residents that were at the town meeting were over the age of fifty-five. Thus, our data does not tell us about the younger age group in New London and their knowledge of wetlands. Figure 15 shows the adult age distribution for the town of New London and Figure 16 reflects the distribution for the survey participants.

We analyzed the answers given to us on the survey using the Statistical Package for the Social Sciences (SPSS). This program helped us find out more specifically the perceptions that New London had about wetlands so we could establish conclusions. As part of our statistical analysis, we combined a series of questions that had similar attributes with each other and addressed three themes that we felt were most important. This generated three primary factors for analysis; perceptions of wetlands, knowledge of wetlands, and the environmental impact of I-89.





Factor 1: Perceptions of Wetlands

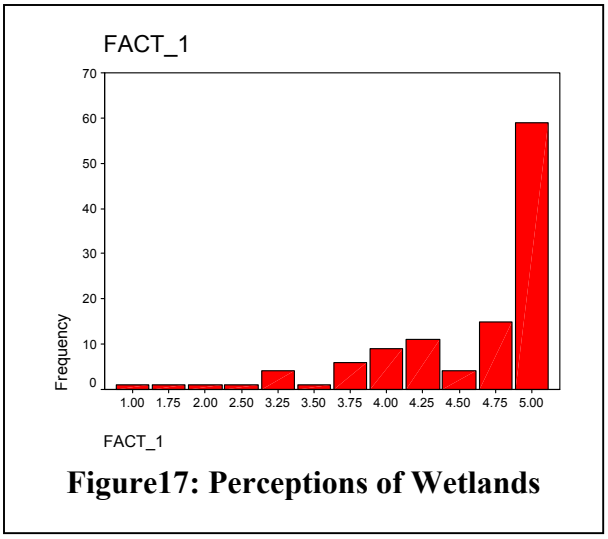


Figure17: Perceptions of Wetlands

In order to see how people view the importance and need for preservation of wetlands, the first factor was made by combining the following questions or statements from the survey (Appendix A: Survey):

4. Wetlands merit protection and preservation.
5. Wetland protection is especially important in this region.
12. Wetlands are of little importance.

By combining these three questions and analyzing the answers people gave on the survey, we could make some general conclusions about peoples perceptions of wetlands. The answer scale ranges from one to five, five being "strongly agree" with the statements and one being "strongly disagree" with the statements. Figure 17 shows that an overwhelming amount of individuals responded positively to the need for wetland preservation and protection. These responses are a positive indication that the survey participants understood the importance of wetlands and were attuned to the fact that wetlands merit protection and preservation. Also factored into this graph are those that answered negatively to question 12, which states that wetlands are of little importance, and therefore reaffirms the two other indicator questions. Figure 17 indicates that almost 60% of those who answered the survey strongly agree that wetlands are important and merit protection. Cumulatively, almost 90% agree to strongly agree. Thus the population attests to the fact that people have a positive perception of wetlands.

Factor 2: Knowledge of Wetlands

In order to see how knowledgeable people are about wetlands, another factor was made using the following questions from the survey:

3. Wetlands are important habitat for animals.
8. Wetlands are an effective means for ensuring water quality.
14. Wetlands are helpful in preventing flooding.

By combining these three questions and analyzing the answers people gave on the survey, we could make conclusions about participants' knowledge of wetlands. The answer scale again ranges from one to five. As one can see from looking at Figure 18, most respondents answered between three and five. This would indicate that most people agree to strongly agree with the statements above. The highest percentage of people answered with a five. Not one person strongly disagreed with the statements. An overall trend was that most of the people attending the town meeting were knowledgeable about wetlands.

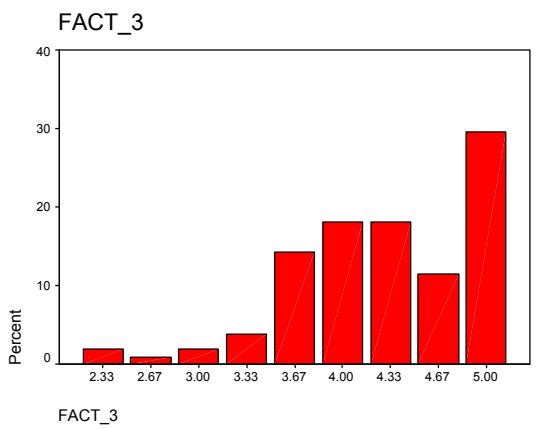


Figure 18: Knowledge of Wetlands

Factor 3: The Environmental Impact of I-89

In order to see how knowledgeable people are about the impact of I-89on Lake Sunapee, the following statement was included in the survey: "I-89 is an environmental threat to Lake Sunapee." By looking at figure 19 one can see that there is an almost perfect normal curve, displaying the distribution of agreement with the I-89 statement. Because there is no significance between people agreeing or disagreeing to this statement, we can say that of the sample surveyed, most people are uncertain of the impact that I-89 has on Lake Sunapee. Some think it has an impact, some think it does now, but most do not know.

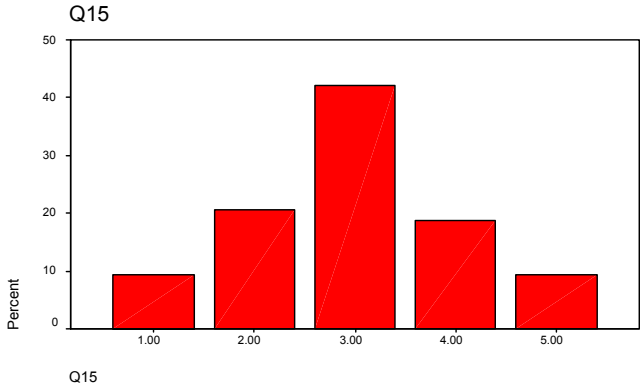


Figure 19: Environmental Impact of I-89

Furthermore, the survey results showed an interesting correlation between the level of education and their understanding of the impact of I-89. For example, 38% of respondents with a college degree stated that I-89 has no impact whereas 41% of respondents with a graduate degree state that I-89 does have an impact.

Interviews

To continue our study of residents' perceptions of wetlands in the town of New London, an in-depth interview process was completed. This was done to extend our body of qualitative knowledge. From those who indicated on the survey that they were willing to be contacted to participate in a follow up interview, we selected six individuals. We sought diverse representation based on the following criteria; proximity of residence to wetlands, length of residency in New London, education level, age, membership in environmental organizations, and perspectives on wetlands. The interviews lasted approximately 30 minutes and were tape-recorded. Confidentiality protocols to protect the identity of participants were established and approved by the Institutional Review Board at Colby-Sawyer College. A complete list of interview questions can be found in Appendix B. From these interviews we found three common themes; misunderstandings about wetlands, the need for more education about wetlands, and support for local wetland preservation initiatives.

Theme 1: Misunderstandings about Wetlands

One example of a misunderstanding about wetlands can be seen below. When asked if they had been to any of the wetlands in New London, the interviewee responded as follows:

> **Yes, I walk to the lake all the time. I have looked at them and thought oh that's what they call wetlands? I don't know. It doesn't look attractive to me. But I guess other people say that wetlands are beautiful. I will be honest I don't look at it and see beauty. It looks to me like a marshy thing that perhaps should be filled in or something. I know it seemed like whenever we were growing up it was like don't have a jug or pail of water standing around. It will draw mosquitoes; it was not good to have standing water so I thought oh that's standing water. Maybe it should be**

> **filled in some how. That is kind of my initial thought, but I know that's not supposed to happen.** (Interview 3, p. 4)

This quote shows how some people do not see wetlands as something important. They do not see an aesthetic value to the wetland and that affects their overall perception. The interviewee did understand that wetlands were good but not its unique functions and values besides being aesthetic.

Another example of the misunderstandings theme is found in the next quote. The interviewee was asked about the importance of wetlands and the response shows a lack of specific knowledge.

> **Oh, I am sure I think you are too technical for me. I don't know what they support except that without them, we need them and especially here in New Hampshire where the lakes are so important if we don't take care of the wetlands we could be in real trouble.** (Interview 1, p. 2)

Again we see that most people understand that wetlands are important but don't know necessarily why. Though it is important to have good understanding of wetlands what we found was not a bad place to start. Fortunately, we did not find anyone in particular who hated or did not understand anything about wetlands. This along with the data we found in the surveys confirms that the people of New London seem to be fairly well educated and have a view of wetlands that is on the positive side of the spectrum.

Some of our interviewees, though, knew a great deal about the functions of wetlands and had very positive perceptions of them. The following quote also shows the value of protection. The interviewee was asked if he knew any of the functions of wetlands and he responded as follows:

> **First of all I think wetlands are important because they act as a filtration for the drinking water and the ground water. The second thing that is important about wetlands is that it provides a natural habitat for birds and animals.** (Interview 4, p.3).

Theme 2: Need for More Education

In terms of education, there is a void that people in the town would like to see filled. There is a desire for more education about wetlands, perhaps wetland regulations, animal species, wetland habitats, and the functional values. For example, one interviewee commented:

> **One thing I would like to add is that I would like to see more in the way of awareness programs for the local residents.** (Interview 4, p.4)

When asked, "Do you think the community could do more for wetlands?" another interviewee responded:

> **I don't really think so. I think it's a question of education and I think they are working on it, not all the time, but the ASLPT (Ausbon Sargent Land Preservation Trust), I think they do a magnificent job…** (Interview 1, p.3)

Another comment emphasizes the need for education about wetlands:

> **I am very ignorant about wetlands… I don't really know a lot about them. I do understand a little about them but it's very basic. I am sure there is something to do with the ecosystem and there are certain animals and vegetation that depends on a wetland to survive. I understand that the basic things but beyond that I don't really know.** (Interview 3, p. 3)

Theme 3: Support for Local Wetland Preservation Initiatives

In general, the interview participants voiced support for local wetland preservation initiatives. This information could be quite useful to both the town of New London and LSPA if any future initiatives are planned. When asked about the protection of wetlands in New London, one participant provided the following two comments:

> **I think New London has done, I can't say fabulous because their heads will swell up, but I think they have done a great job realizing that you can not just build on the waterfront of a wetland that you have to have setbacks. I believe it is something like 100 to 500 feet back. Personally for the sake of anyone listening to your tape recorder I think it should be more like half a mile.** (Interview 4, p.3)

> **I think (New London) is doing a good job. I think the only thing they could do more, would be to increase or expand the area that they already have where possible. I think the fact that they have recognized the importance of wetlands has been a step forward.** (Interview 4, p.4)

So the responses shown above demonstrate the spectrum of perceptions we came across. Some range from confused to advocating for increased protection. Overall, the interviews back up the conclusions made about the town's perceptions from the surveys. Not everyone is a wetland specialist but most know that wetlands are at least supposed to be a good thing even if they do not seem attractive. New London overall has a positive report card for providing quality protection of wetland areas. People do feel that this could be expanded or the regulations set by the town could be elaborated in order to increase the amount of setbacks and protection available to wetlands and larger bodies of water.

There is always the opposite feeling, which may seem antiquated, but frankly is still a powerful influence in the way people perceive wetlands and this is that they are not very pleasing to look at. This perception shows that there is a need for education or perhaps a need for information, not to change people's perception, but to let them know that aesthetics, which are highly personal, may not be as valuable as the other purposes for which only wetlands can serve.

To help educate people who have these misunderstandings and lack of knowledge the community partners could try to educate about the specific functions of wetlands. This could be accomplished by having a signboard and pamphlets at the Columbus Avenue site and at the recreational wetlands in the area. For example wetlands like Esther Currier have maps of the property and some interesting facts, but they might benefit from some additional educational material.

Water Sampling

Since the beginning of October, water samples have been taken at four sites (830.00, 830.15, 830.20, and 830.70) predetermined by the LSPA (see Figure 20). Two bottles of water were regularly taken. One large bottle for several tests (pH, conductivity and turbidity) and a small bottle for phosphorus testing. When there was significant flow we also used a flow meter to calculate the volume of water going over the dam at the site (830.15 in Figure 20). These quantitative tests are important because they each help determine different trends over time and the overall health of the wetland system. The samples were analyzed at the Colby-Sawyer LSPA laboratory.

Figure 20: Sample Sites

We tested for pH because it is a basic quality indicator and has synergistic effects. It also helps determine the toxic effects of substances. A small change in pH can be detrimental

to some animals and plant life. A pH meter was used to find the level of pH. According to the New Hampshire Department of Environmental Services (NHDES), a pH around the range of 6.0 to 9.0 is acceptable anything above or below can be harmful. Many things can affect pH including agricultural runoff, rainfall and more (NHDES, 2002). The pH helps to describe how acidic the water is at one point within the wetland. "pH is a logarithmic measure of the hydrogen ion concentration on a scale ranging from 0 to 14," (Mackie, 2000, p. 572). Water acidity is important to consider because it is a simple indicator of water quality. The level of the pH in the water limits many aquatic organisms, such as macroinvertibrates and fish, as well as plants. In terms of the chemistry that takes place in wetland environment, pH is also a key variable in the complex equation that determines how a wetland functions. By analyzing the pH on its own, factors that might influence the acidity or number of hydrogen ions can be identified along the path that the water travels from the source of the watershed to Lake Sunapee.

Conductivity is the measure of the ability of a solution to carry out an electric current. It also determines the total dissolved solids in the water. The information we gathered on conductivity can be used to determine the overall ionic effect of the water source as well as the physiological effects on animals and plant life. A conductivity meter is used to test the amount of conductivity and the temperature of the water. The NHDES (2002) says that the optimal range for conductivity is around one hundred parts per million (ppm).

Turbidity is the measure of sediments in the water. Suspended sediments will settle out in slow water. That is why wetlands are useful in trapping sediments. High turbidity can give the water either a clear or cloudy appearance. Turbidity can affect the temperature and the dissolved oxygen of the water. It can interfere with mixing and decrease the dispersion of oxygen and nutrients to deeper layers. The instrument used to test for turbidity is a turbidity meter. This instrument requires that a sample of the water be placed in a small glass jar and placed into the meter where a beam of light shines through it and the meter reads the ability of the light to shine through. The higher the turbidity the greater the number, turbidity over five NTUs is generally considered high by the NHDES (2002).

Total phosphorus readings were also taken. These tests are important because although some phosphates are good for fish and plant life an excess of phosphates entering into a system can cause algae and plants to grow in excess and can cause a system to become choked up and water quality will decrease. The levels of phosphorus can be disturbed or accelerated by such things as nearby farms and wastewater treatment facilities (NHDES, 2002).

We performed these tests every Monday from October through April. In March we began to add dissolved oxygen data and started a new test site (830.30 in Figure 20). This was done in order to better assess the wetland dynamics between 830.70 and 830.20. Dissolved oxygen is the measurement of the amount of oxygen that is dissolved in water solution. Oxygen can get in the water from the surrounding air, aeration and as a waste product from photosynthesis. Dissolved oxygen should not exceed 110% as this can be harmful to aquatic life. An adequate amount of dissolved oxygen is necessary because it is important to all forms of life. Low dissolved oxygen readings can result in fish kills (Kentucky Volunteer Water Watch Program, 2002).

As well as dissolved oxygen, we measured flow whenever it was high enough. To be able to take flow readings the level of water needed to be over two and a quarter inches high

over the dam. Then we used a flow meter given to us by the Conservation Commission and measured the flow to determine the amount of water going over the dam.

We were also responsible for the testing of water during storm events. The guidelines of a storm event are very specific. According to NHDES guidelines, there must be 0.5 inches of rain in six hours following three dry days and sampling must take place within two hours of the event. The reason we tested during storm events was because it is important to see how the water is disturbed by such events. During the project we only had one storm event on October 15th.

pH

Examination of the pH in conjunction with other variables such as conductivity (total dissolved solids), turbidity (total suspended solids), total phosphorous, and dissolved oxygen all help to create an overall image of how water moves through the wetlands and how its quality is affected at certain points within the wetland.

This path is a winding route that crisscrosses I-89 and Columbus Avenue. There are six distinct wetlands that water passes through before it reaches Herrick Cove. Two are just above site 830.70 (see Figure 20) and both feed into the culvert that crosses under the interstate. They run directly along the highway and are influenced by highway runoff even though they are further up in the watershed than all the other wetlands. There was recent construction and development above the wetlands here on County Road this past summer that should be taken into consideration as well. Water will speed up when it reaches site 830.70 as it is concentrated through the large culverts.

Figure 21: Nearby Development

On the other side of the highway is a third wetland that is extensive in size and area, approximately twice the size of the Columbus Avenue wetland. Water spreads out and slows down significantly due to the vast area and amount of wetland vegetation. There are mostly sedges, bur reed, and cattails here. On the upper ledge of this wetland there is construction taking place where a large amount of dirt is being exposed (Figure 21). This wetland is affected somewhat by the highway, but most of its shore rests on wooded banks that are either undisturbed or abut the construction. Adjacent to the construction and within the watershed of this wetland is a cattle farm (Figure 22). Livestock are a huge potential source of phosphorous loading.

Figure 22: Nearby Cattle Farm

The water then flows into a forested wetland where it is under constant shading. Large glacial erratics, moss, leaves, and fallen trees all serve as cover for the water as it winds through the woods, partly underground, but visible from the surface. This area also has more recent standing snags, suggesting that the area may be getting more water than it was previously. The forested wetland also takes the water away from the highway by more than

50 feet. Forested wetlands have been suggested to be nutrient sinks in terms of their ability to remove nitrogen and phosphorous from the water column (Mitsch & Gosselink, 2000, p.117). In five previously conducted studies of forested wetland mitigation, it was found that total phosphorous and nitrogen outflow were reduced by 98% and 90% compared with the water that flowed into the forested wetland (Mitsch & Gosselink, 2000, p. 117). The stream then heads through a piece of private property on Columbus Avenue where the water speeds up and channelizes as it approaches the culvert leading under Columbus Avenue.

The water moves quite rapidly under Columbus Avenue to site 830.30. After this there is a fourth open wetland that, again, slows and spreads the water before it passes under the interstate again. This wetland is adjacent to Burpee Hill and collects all water from the Burpee Hill cut along the highway. This is a shrub-scrub wetland with extensive amounts of phragmites. The water then passes to site 830.20, which is the start of the Columbus Avenue wetland that the class is studying. This wetland has more open areas and is home to muskrats. The water spreads out and slows down before it passes over the dam at site 830.15.

There is a final, more shrub scrub woody wetland that takes the water past a privately owned seasonal summer camp with an outhouse that isn't more than 30 feet from the lakes edge. Here at site 830.00, the water makes its last trip down some rocks and under Route 103A into Lake Sunapee. By looking at the data collected between October and April (Table 2), one can make some general comparisons and overall observations of how the water is being changed as it moves down the watershed.

The calculated means (**mean -**)generally indicate what the average pH was for the given site. Site 830.7 has the highest mean, or closest to neutral pH and site 830.3 has the lowest mean pH. Between these two sites are a vast wetland, construction, snowmobile trails, a forested wetland, and over 200 yards of highway running parallel to the water's course. The mean pH then rises between 830.3 and 830.2. Even though they are fairly close together, there is a small wetland between the two and the water also runs under the highway. The mean pH is lower once again between 830.2 and 830.15, which are only separated by the Columbus Avenue wetland and the dam built at site 830.15. The mean pH rises slightly between 830.15 and 830.0, which are points separated by a small shrub scrub wetland. There are many factors at work in this small watershed that can impact pH.

Some of the following hypotheses apply directly to what is happening to the pH in the watershed. First, acid rain is a prevalent influence on the acidity of the water in the watershed. Inputs of sulfuric and nitric acid can lower the pH of rain to well below 5.6. In fact, anything lower than this is an indicator of definite human-induced acidification (Mackie, 2000, p. 570). Acid rain can be neutralized in areas with a high buffering capacity in their bedrock, but in most areas of New England, the soil and bedrock is mostly granite based, which will actually depress the pH even lower than 5.6 (Mackie, 2000, p. 574). However, rain is equally distributed across the entire area and cannot be sited as the reason for a lower pH at one site and not influence the pH at another.

The mean pH may not be the best indicator of how water quality is being affected; therefore a confidence interval is used to determine what pH is most certain to occur in this wetland, given that the same conditions are experienced during the same period of year. For site 830.7, the confidence interval suggests that the water would 99% of the time be within satisfactory standards for lake quality water. All the remaining sites have an interval that falls within endangered status. Site 830.15 is the most prominent site in this category, because it

Table 2
pH Data

pH							Weekly Averages	Weekly Averages	Weekly Averages
Date	**Sample**	**830.00**	**830.15**	**830.20**	**830.30**	**830.70**	**Snow**	**Precipitation**	**Temp**
1-Oct	pH	6.30	6.02	6.16		6.42		1.26	62.50
8-Oct	pH	5.99	5.82	5.95		6.18		0.04	53.70
17-Oct	pH	5.91	5.94	6.15		6.20		0.50	54.00
22-Oct	pH	5.68	5.78	5.86		6.16		0.03	44.80
29-Oct	pH	6.22	5.96	6.15		6.50		0.36	44.20
5-Oct	pH	6.38	6.14	6.26		6.54	0.10	0.49	44.10
12-Nov	pH	6.12	6.03	6.02		6.39	0.20	0.04	33.10
19-Nov	pH	6.22	5.98	6.05		6.46		0.03	38.00
26-Nov	pH	6.07	6.02	6.24		6.15		0.37	38.70
3-Dec	pH	6.21	6.19	6.18		6.30		0.55	41.00
10-Dec	pH	5.94	5.89	6.02		6.15	2.00	0.23	37.20
17-Dec	pH	6.07	5.96	5.88		6.19	2.40	1.28	30.50
22-Dec	pH	6.35	6.08	6.22		6.31	2.50	0.24	29.60
31-Dec	pH		6.11	6.21				0.25	24.10
7-Jan	pH		5.90	5.94			10.10	1.00	23.40
14-Jan	pH	5.90	5.93	6.00		6.05	4.70	0.26	26.20
21-Jan	pH	5.65	5.84	5.94		5.87	4.90	0.21	21.40
28-Jan	pH	6.05	6.06	6.04		5.93	0.00	0.13	31.90
4-Feb	pH	5.74	5.79	5.84		5.83	6.50	1.30	22.40
11-Feb	pH	5.75	5.88	5.84		5.73	4.20	1.01	19.70
18-Feb	pH	6.06	6.05	5.99			4.90	0.91	23.80
25-Feb	pH	5.59	5.44	5.49				0.35	31.40
4-Mar	pH	5.61	5.65	5.62		6.08	0.40	0.58	33.14
11-Mar	pH	5.53	5.58	5.57	5.52	5.93	0.70	0.34	32.90
18-Mar	pH	5.99	6.00	6.05	5.93	6.32		0.22	32.60
26-Mar	pH	5.92	5.97	5.99	6.05	5.93	7.30	1.96	28.30
1-Apr	pH	5.53	5.65	5.61	5.56	5.98		0.85	35.30
8-Apr	pH	5.84	5.92	5.88	5.81	6.28		0.15	35.70

Date	Sample	830.00	830.15	830.20	830.30	830.70	Snow	Precipitation	Temp
15-Apr	pH	4.97	5.07	4.98	4.97	5.42		1.55	53.00
22-Apr	pH	6.18	6.21	6.1	6.12	6.31	2.20	0.22	55.90
29-Apr	pH	6.02	6.05	6.01	5.97	6.25	0.50	0.97	39.40
Total	pH	171.79	182.91	184.24	45.93	165.86			
Mean	pH	5.92	5.90	5.94	5.74	6.14			
Median	pH	5.99	5.96	6.00	5.87	6.18			
Mode	pH	5.99	6.02	6.15	#N/A	5.93			
Variance	pH	0.09	0.05	0.07	0.14	0.07			
SD	pH	0.31	0.23	0.27	0.38	0.26			
CV		0.05	0.04	0.04	0.07	0.04			
Data #		29	31	31	8	27			
N-1		28	30	30	7	26			
sq root n		5.3851648	5.56776436	5.5677644	2.8284271	5.1961524			
SD/sq root n		0.0568496	0.04182525	0.0478537	0.1341699	0.0494062			
t value		2.467	2.457	2.457	2.998	2.479			
CI		0.1402479	0.10276463	0.1175765	0.4022414	0.122478			
Mean +		6.06	6.00	6.06	6.14	6.27			
Mean -		**5.78**	**5.80**	**5.83**	**5.34**	**6.02**			

Standard		
	Satisfactory	6.0-8.0
	Endangered	5.5-6.0
	Critical	5.0-5.4
	Acidified	<5.0

can be said with 99% confidence that the water from this site will be entirely within the endangered status category throughout the fall, winter, and spring. Besides just the physical movement of the water through the watershed, other factors, such as climate, can also affect pH.

Figure 23 shows how this information can be broken down into time frames in order to describe what is going on over the course of the season. From October 1 to November, the pHs readings are spread out and move fairly consistent with one another. The key feature is that they mimic the weekly collected precipitation, rising and falling in sync over this time. A general trend is that site 830.7 has the highest pH and site 830.15 has the lowest. From late November throughout the rest of the winter, the fluctuations in pH no longer mimic the weekly total in precipitation. The pH and precipitation do follow one another, but there is an almost delayed

effect that is occurring. In other words, precipitation will go up, such as between December 10 and December 17, but the pH will actually go down between those two weeks. The following week of December 22, even though precipitation has gone down, the pH has risen considerably at most points. This trend continues, somewhat, between December and April 8.

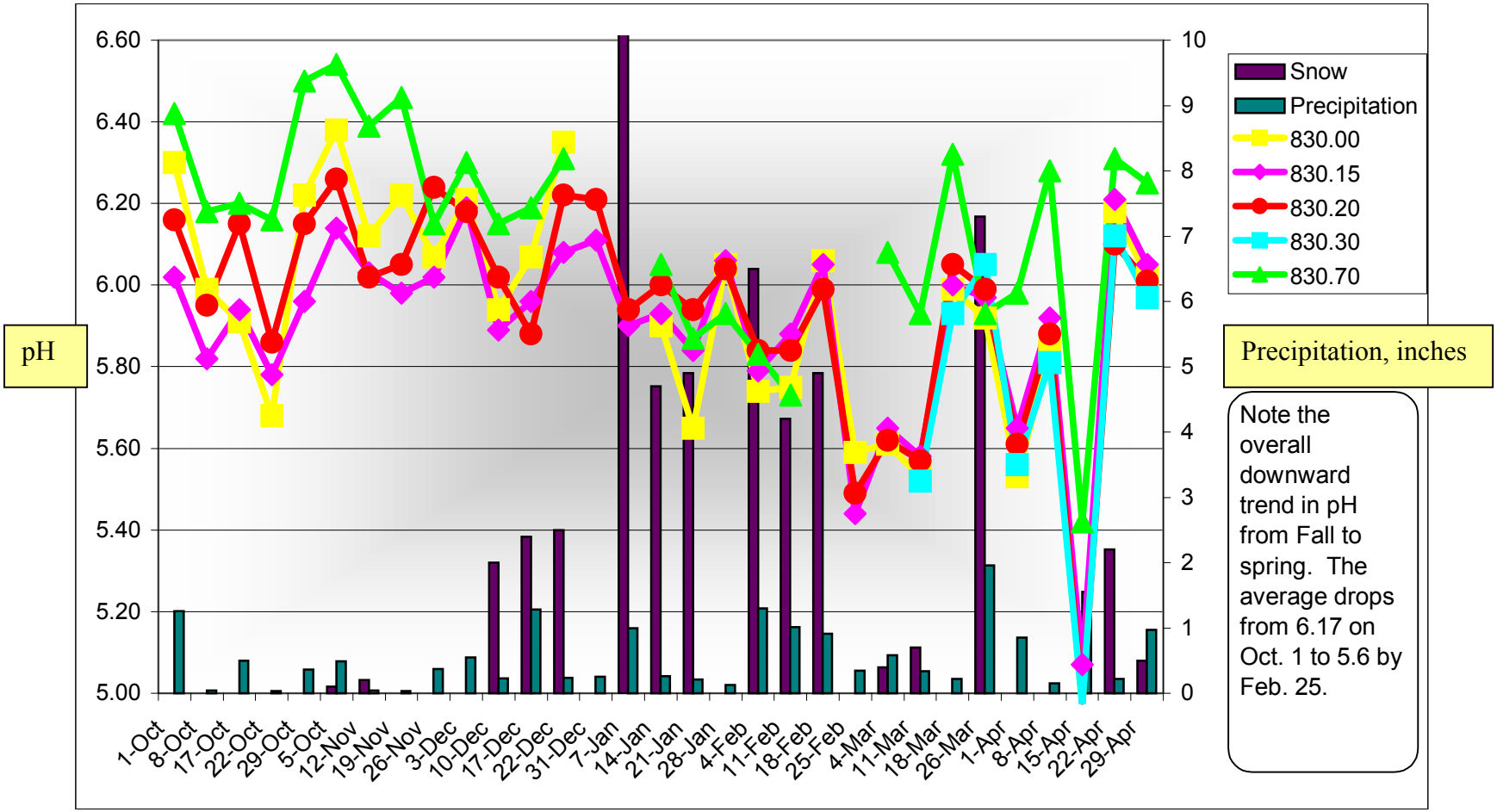


Figure 23: pH, Precipitation and Snow

Another distinction that can be made using Figure 23 is that the pH of all points is much closer together between December 22 and February 25. This is an important indicator that whatever influences were acting upon the water to spread the pH out as it flowed down the watershed, these influences are no longer active during the winter. One would hypothesize that because the ground is frozen during the winter, that whatever precipitation falls, either snow or rain, will hit the surface and immediately fall into the water column and travel directly to the lake. Because the ground is frozen and there is no biological activity, little to no alterations are occurring in the water's acidity. From February to April, the pH for site 830.7 separates again, rising above the other sites, but still following their general patterns in rising and falling.

Perhaps snow plays into the overall picture of pH in the watershed. Using Figure 23 again, the first area that can be flagged in the snow and pH comparison is the movement of site 830.2 on December 17. Site 830.2 has a lower pH than the other three sites and is moving down while the others are rising. Then on December 22, the pH of site 830.2 rises dramatically and meets the other sites. One can ascertain that this is either a skewed data collection or somehow the wetlands before this point were not mitigating the pH, but those that are after point 830.2 were mitigating. November 26 is another date where site 830.2 is acting peculiar, because the pH is higher than any other site and increasing while the others are mostly decreasing. This is one of the few times that this occurs, and could again be a fluke, or it might suggest a delayed buffering that takes place in the wetlands between 830.2 and 830.7. pH decreases on the weeks with heavier snow that are followed by a week of little to no snow, such as January 7, February 4, and March 26. This supports a theory that if there was no snow in the watershed from the week before, the snow entering it during that week forced the pH down significantly.

After careful analysis of the data described in the pH line graphs, several conclusions can be made about the relationship between the four testing sites and precipitation with regards to their pH. The strongest overall line movement trends, in terms of rising and falling pH and precipitation are observed from October 1 to December 3. A general association between the four testing sites, in terms of patterns of movement is seen throughout the entire graph. In fact, precipitation mimics these trends from October to about December 3. From December 3 to March 3, there is a change in relationships between the four testing sites, as well as precipitation. This suggests variations in terms of fall conditions and winter or frozen conditions.

During the fall, the sites that had the most similar pH results were 830.15 and 830.20 (Figure 24). A deduction can be made that the pH is least affected between these two points during fall conditions. So too could this be applied lightly to sites 830.00 and 830.70, except that they have three other sites between them. Generally speaking, pH decreases between site 830.70 and 830.20, it is then slightly reduced at 830.15, and then it is increased at 830.00 during fall conditions. Throughout the fall, as precipitation decreased over a week, so did pH; as precipitation increased, so did pH, which indicates a strong correlation between the two.

The winter reveals a slowing of the trends as well as an overall decrease of pH levels at all the sites. There is still some correlation between the peaks in precipitation and the peaks in pH, it just happens at a delayed rate. The delay ranges from one to three weeks and can be attributed to rain being caught in the ice and snow or not traveling at a regular

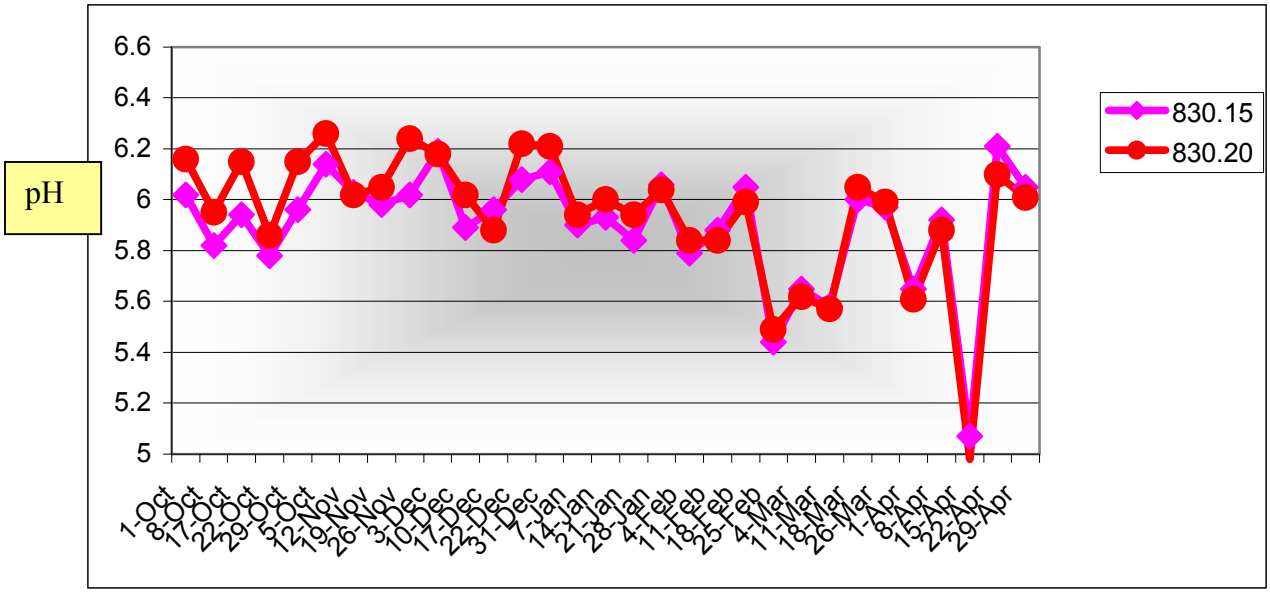


Figure 24: pH at Sites 830.15 and 830.20

velocity. Between December 31 and January 25, there is a definite decrease in difference between all four testing sights. This means that the pH levels were closer together throughout the winter season. The order in which trends were observed during the fall no longer exists during the winter.

Surface runoff during spring melt can cause an increase in the acidity of stream water. During melt events in the winter "hydrogen ions migrate to the base of the snow pack and become highly concentrated there." (Mackie, 2000, p. 574). What happens between winter and spring is that the surface snow will heat up and melt before the ground thaws. This, in theory should cause a huge spring pH depression in streams and wetlands. Mackie (2000) notes that these periods vary from stream to stream and year to year. They last usually only a short period, perhaps one week, which is marked by a sharp drop in pH that can cause "shock" on all aquatic organisms.

Looking at the pH data for all sites (Table 2), this sharp drop can be seen on April 15, when all the sites were at their lowest pH for the entire year. The highest recording is site 830.70 with a pH of 5.42, all the other sites go down to or below 5.00. This is particularly crucial when one considers that the pH entering the lake at site 830.00 is 4.97 and hydrogen ions become toxic to fish when the pH falls below 5.5 (Mackie, 2000, p. 574).

Overall observations that can be made about the pH data would be that precipitation usually increases pH, precipitation is affected by winter conditions, and that weather conditions affect the pH mostly in the fall and possibly the spring. One last observation that should be made is that the overall amount of precipitation from December 10 to February 25 was far greater than that from October 1 to December 10. One might conclude then that the decrease in pH in winter could be because of an increase in precipitation and periodic snow melts. pH is most important when used in conjunction with phosphorous in order to describe how phosphorous is moving or cycling in the wetland.

Phosphorus

Wetlands and watersheds contain a series of chemical cycles that transport, transform, and transfix nutrients, sediments, and plant matter. These are living cycles that fluctuate with the season, amount of precipitation, plant and species life, as well as the geochemistry of the watershed. Most nutrients are tied up or attached to sediments and peat. Phosphorus for example travels with inorganic and organic matter that is flowing down the stream. Most plants that grow in wetlands will obtain their nutrients from sediments, while phytoplankton depend on dissolved nutrients in the water column. Plants bring nutrients from anaerobic zone to above ground, where plankton take nutrients out of water column, die and deposit them in anaerobic sediments (Mitsch & Gosselink, p. 124).

According to Mitsch and Gosselink's characteristics of high and low nutrient wetlands, Columbus Avenue qualifies as a high nutrient wetland. This means that most of the inflow of nutrients comes from surface and ground water. Columbus Avenue can serve as both a sink and a source of nutrients and is usually an exporter of detritus (Mitsch & Gosselink, 2000, p. 123).

During the growing season, the rate at which emergent and submerged vegetation take up nutrients from the water and sediments increases. "Increased microbiological immobilization of nutrients and uptake by algae and epiphytes also lead to a retention of inorganic forms of nitrogen and phosphorous." Due to the die off of such plants an export of nutrients, either through leaf litter or leaching, can be expected in the fall and early spring. Most wetlands act as nutrient sinks in the summer and sometimes fall, but as nutrient sources in the spring (Mitsch & Gosselink, p. 119). The pattern of a wetland acting as a sink or a source is dependent on hydrologic conditions such as the anaerobiosis in the sediments and the activity of the biota, and in particular the emergent macrophytes (Mitsch & Gosselink, p. 120). Therefore it becomes most logical that the wetland be used to metabolize nutrients during the times in which flow and nutrient loading are the highest, namely the early spring and again in the fall.

Nutrient budgets are the key to understanding whether a wetland will act as a sink or source for nutrients like nitrogen and phosphorus. For most wetlands there is an inflow and an outflow of nutrients. Generally speaking, whatever flows into a wetland will flow out of it eventually; a wetland mainly withholds a nutrient for a short period of time or converts it from one form to another. It is important to understand that this type of nutrient cycling allows humans to be able to decide during which seasons the lake will encounter most nutrient runoff, based on when and where dams are placed in a watershed.

All the factors within a wetland that would retard nutrients from entering the outflow include uptake by the living biomass, conversion to peat and then being buried within the wetlands deep sediments. In most cases, the plants die and are reabsorbed into the wetland or flow out of the wetland, sediments are disturbed and whatever nutrients they are carrying also reenter the wetland. These nutrients flow out in the surface water, subsurface flow, or even into the atmosphere.

Nitrogen is a limiting factor in algae growth in streams and wetlands. Algae and plant growth is driven by nitrogen and phosphorus. If they grow in a wetland, they die in the fall and flow into the lake or are broken down by bacteria, which causes just the phosphorous to flow into the lake. Plants will not take up phosphorus if they are not getting enough nitrogen as well (Simpson, 2002).

Eutrophication begins by a limiting factor. Phosphorus is absorbed by plants, while the plants are alive and growing, they make the water cleaner. In a wetland plants die and decompose, thus whatever phosphorous they removed from the water, they are adding back to the water. Decomposition is one of the biggest producers of phosphorus in a wetland (Simpson, 2002).

"The precipitation of the metal phosphates and the adsorption of phosphates onto ferric or aluminum hydroxides and oxides are believed to both result from the same chemical forces, namely those involved in the forming of complex ions and salts," (Mitsch & Gosselink, p. 106). Metals and phosphorus need to be examined together in order to decide how they are best mitigated. Because they can found in a number of forms, either suspended in the water column (under acidic conditions), bound to sediments and organics, or locked inside the cells of organic matter, different methods should be addressed to mitigate each form in which phosphorus can be found.

For sediment locked phosphorus, sedimentation be slowing down the water, adding more biomass, and creating a shallow water column all prove to be the best methods of removing both phosphorus, as well as the suspended solids. Plants are the preferred mitigation device for phosphorus because they take the phosphorous out of the water column in the most efficient manner. Plants adsorb phosphorous on their surfaces and are most productive during spring bloom out when their consumption rate is about 80% (Simpson, 2002). During the entire growing season or spring and summer, plant consumption of phosphorus is still higher than 50%. Otherwise, most phosphorus will reenter the water column as soon as these plants die during the fall. During this time, before it becomes too cold, bacteria and microbiological organisms will decompose the plant matter, releasing the phosphorus that had been stored in the plant since spring.

For rapid decomposition, oxygen is required. Decomposition is very ineffective under anaerobic conditions. The more H+ (or the higher the pH) in a solution the more they can free up manganese, iron, and aluminum from a solid phase to a solution phase, which is how they will bind most easily with phosphorus (Simpson, 2002).

In the Columbus Avenue wetland, phosphorus is said to be seen in low to average levels leaving the wetland. Data from April 15 can be used to demonstrate not only how phosphorus moves through the wetland, but also the relationship between phosphorus and pH. On this date the amount of phosphorus entering the wetland exceeded that which was leaving the wetland. This was also the date of the spring pH depression. As previously discussed, phosphorus adsorption to clay or other particles is higher under acidic conditions. Therefore, one could hypothesize that the phosphorus entering the wetland was attached to larger particles that, because of the heavy flow where carried by the water to the wetland, but then were settled out over the area of slow moving water created by the dam. This trend generally occurs on a smaller scale throughout the year, where the total phosphorus entering the wetland is higher than that leaving. April 15 is just the extreme perfect example of how keeping the dam at its highest during the spring season works best to mitigate phosphorus loading. Phosphorus data is especially meaningful when flow data can be gathered as well in order to predict nutrient loading in Lake Sunapee.

Flow

The staff gauge can become an extremely useful tool for future study of the wetland. LSPA, as well as this class have used a flow meter and other flow testing methods to record flow data in conjunction with the water level at the staff gauge. Instead of taking valuable time to calculate flow readings, one could easily achieve flow data in the future simply by reading the gauge. This could be in conjunction with sample taking, but after a few years of extensive study, even by just reading the gauge, one may be able to determine the flow from the wetland into the lake.

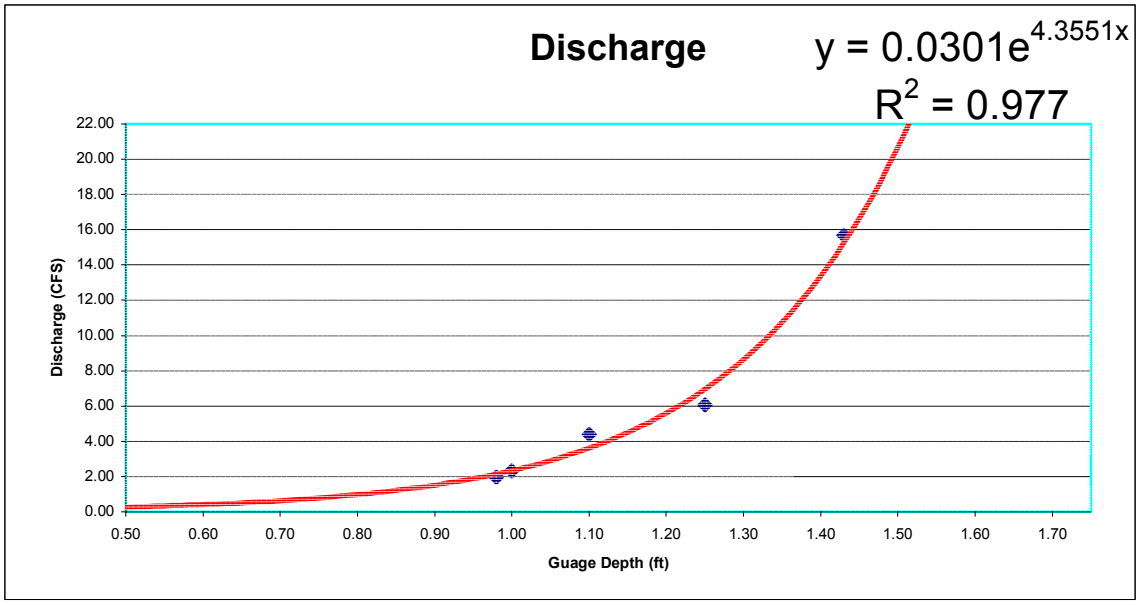


Figure 25: Flow

Conductivity

Conductivity is the measure of total dissolved solids (TDS); these are ions or charged particles. Dissolved ions are used to portray the degree of pollution in wastewater. TDS is measured in seamans per centimeter using a conductivity meter. In the Table 3 are the means for conductivity for the five sites that we tested between October 1, 2001 and April 29, 2002.

Table 3
Conductivity Means

830.00	830.15	830.20	830.30	830.70
383.97	405.4839	380.4129	223.0875	263.837

It should be noted that site 830.30 was not added until March 11, 2002. These figures indicate that from site 830.00, which is the closest site to Lake Sunapee and is at the bottom of the watershed to site 830.15, which is, where the water impoundment structure is located,

there is a dramatic decrease in amount of TDS. Continuing up the watershed the conductivity levels are higher at site 830.20, which is just after the stream then goes under I-89, then at site 830.30, which is located at a culvert just after the stream passes under Columbus Avenue for the first time. At the very top of the watershed, site 830.70 has more dissolved solids than does the water flowing at site 830.30.

From site 830.70 to site 830.15, with the exception of site 830.30, a large increase takes place. This could be because the stream flows underneath I-89 and picks up more dissolved solids from the highway's runoff. There are other wetlands between site 830.70 and 830.20, which could add TDS to the water by picking up other precipitates that the wetland may have in it. Another hypothesis could be made based on the land disruption (development and farm activity) between sites 830.70 and 830.20.

Interestingly when early spring arrives there is a dramatic decline in conductivity. This may be because of the increase in spring runoff along with rain events that could dilute the ions in the water causing lower amounts of conductivity in the water. Figure 26 indicates how early spring precipitation impacts conductivity at sites 830.00 and 830.15. The data in Figure 26 clearly indicate that with the increase of water from precipitation and runoff that dilution is occurring in terms of levels of conductance within the water between these two sites in the watershed. When precipitation levels are low, conductivity levels are high, but when the precipitation levels increase, dilution occurs causing lower conductivity levels. This could also portray thawing of ice and snow within the watershed that could also cause levels of water to increase, adding to the dilution effect.

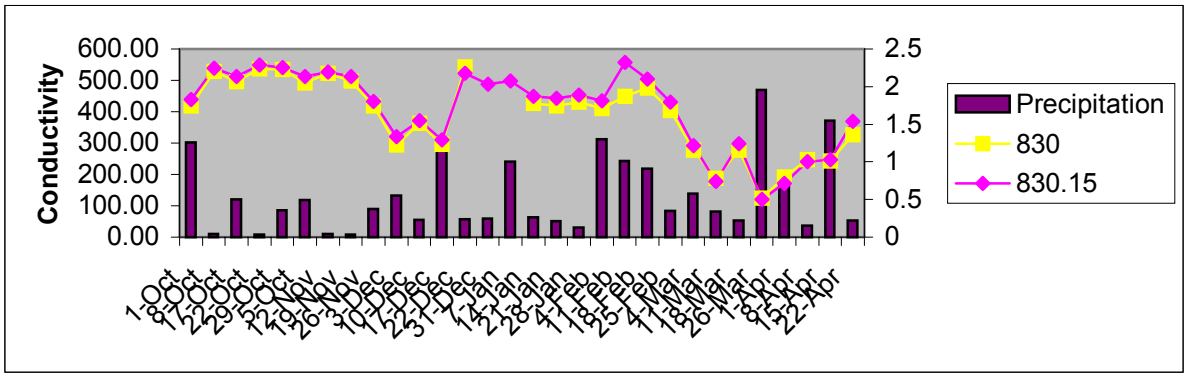


Figure 26: Precipitation and 830.00 and 830.15

Seasonally the interesting point between precipitation and sites 830.15 and 830.20 again occurs in early spring. There is little correlation between precipitation and the fluctuation of conductivity at either the dam or before the water enters the Columbus Avenue Wetland. When decomposition occurs or when the wetland is frozen and is dried out the leftover salts or ions are remain in the wetland. This could suggest that the wetland intermediately slows conductivity down when it is frozen and then dried out based on the particular season. This would also make the dam seem to have a periodic effect on the level of conductivity exiting the wetland. When spring thaw occurs, the particulates that are frozen are released creating more dissolved solids in the water column. When the water is not frozen, during other parts of the year, it can be hypothesized that conductivity will be lower because they are more diluted and have not been stored for a long period of time.

There are fewer TDS going into Lake Sunapee during the winter, because the particulates are frozen in the wetland. However, in the fall, after hurricane season and in the spring during runoff, more or the same amount of TDS are leaving the wetland than entering it because there is a higher water column which dilutes the TDS in the wetland and carries them into the lake. The dam does inhibit the passage of TDS into the lake during the spring because of the high water levels. Without the dam, there would be an even greater level of TDS getting into the lake.

Turbidity- Total Suspended Solids

The velocity of the water resource largely determines the composition of the suspended load. Suspended loads are carried in both the gentle currents of lentic (lake) waters and the fast currents of lotic (flowing) waters. Even in flowing waters, the suspended load usually consists of grains less than 0.5 mm in diameter. Suspended loads in lentic waters usually consist of the smallest sediment fractions, such as silt and clay. Some general principles of turbidity are that it can be very detrimental to a water system because if the suspended sediment is high in carbon content the biochemical oxygen demand (BOD) levels will decrease. The level of BOD is crucial in determining water quality, in that the bacteria responsible for decomposition of organic material need a supply of oxygen. While the presence of suspended solids can be detrimental it can also be a good thing. Sediments are capable of transadsorbing loads of adsorbed nutrients like pesticides, heavy metals and other toxins. Deposition of sediments can result in the removal of nutrients and toxins to the environment, where either plant uptake of nutrients can occur or where toxins and other substances will have time to undergo slow decomposition. In wetland systems where little reworking of the soil occurs there is a possibility of permanently removing toxins from the system. Thus, one of the major functions of a wetland is the removal of suspended sediment from water moving through the wetlands. Flow rate is decreased as the water moves more by sheet flow than channelized flow. The resulting decrease in velocity and the presence of vegetation promote the fallout of suspended particles.

Turbidity is a unit of measurement quantifying the degree to which light traveling through a water column is scattered by the suspended organic (including algae) and inorganic particles. The scattering of light increases with a greater suspended load. Turbidity is commonly measured in Nephelometric Turbidity Units (NTU), but may also be measured in Jackson Turbidity Units (JTU). For this project it was measured using NTU's. According to the New Hampshire Department of Environmental Services anything over 5 NTU is considered high and the maximum turbidity for New Hampshire Lakes and Ponds is a NTU of 22 (NHDES, 2002). According to the data collected from October 2001 to April 2002 there were no turbidity readings out of the safe range. Except on outlier on December 17th at Site 830.2.

From the data collected we have come up with some preliminary hypotheses about how our wetland filters out suspended solids. If you look at Figure 27 you will see the results for turbidity through the spring. The first thing that is evident is that in times of low rain the turbidity seems to higher or the same at the dam (site 830.15) and lower at the highway (site 830.2). One would think that site 830.2 right off the side of the highway should have higher turbidity readings. On low flow days it doesn't seem to work this way, it works the opposite.

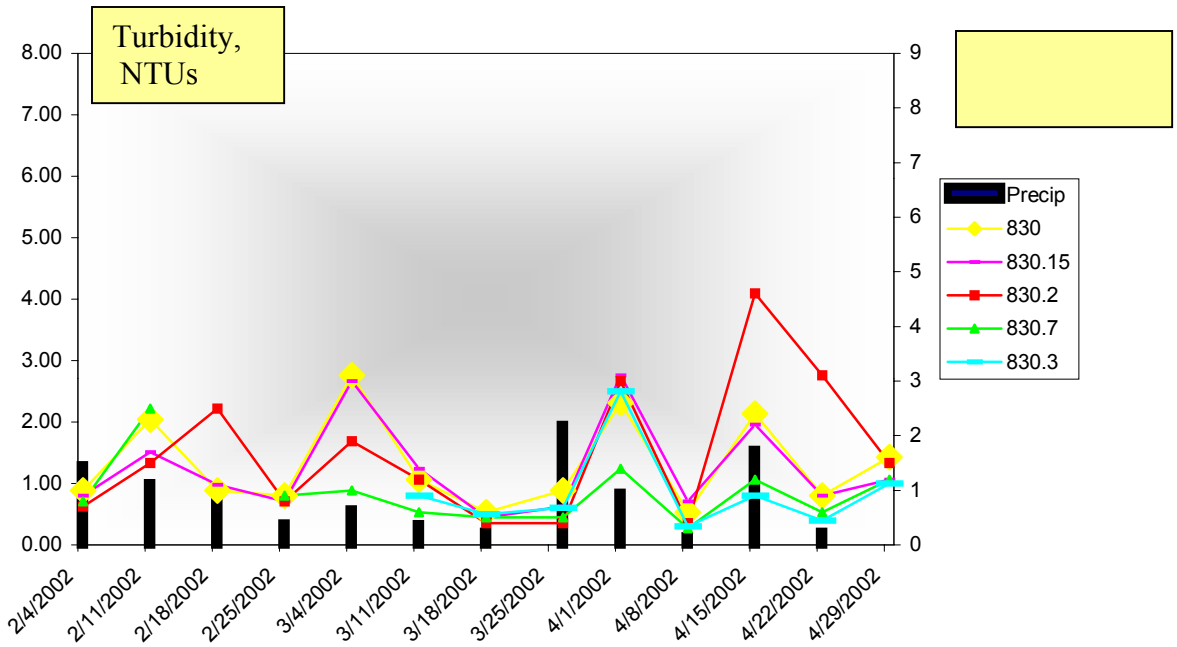


Figure 27: Precipitation and Turbidity, Spring 2002

After site 830.2 the wetland flows into a fairly large channel system then flows into the larger open water area before the water travels over the dam. The hypothesis is that turbidity readings are higher at the dam at low precipitation. This is because the water picks up velocity coming through the culvert, gets beyond a sand lens and hits an area where sediments have been dropped in the past. It then has enough velocity to resuspend some of these materials and continues to carry them through the system and over the dam. When doing a correlation between 830.15 and 830.2 there is no relationship between the two sites meaning that something is happening between 830.2 and 830.15, which supports the hypothesis.

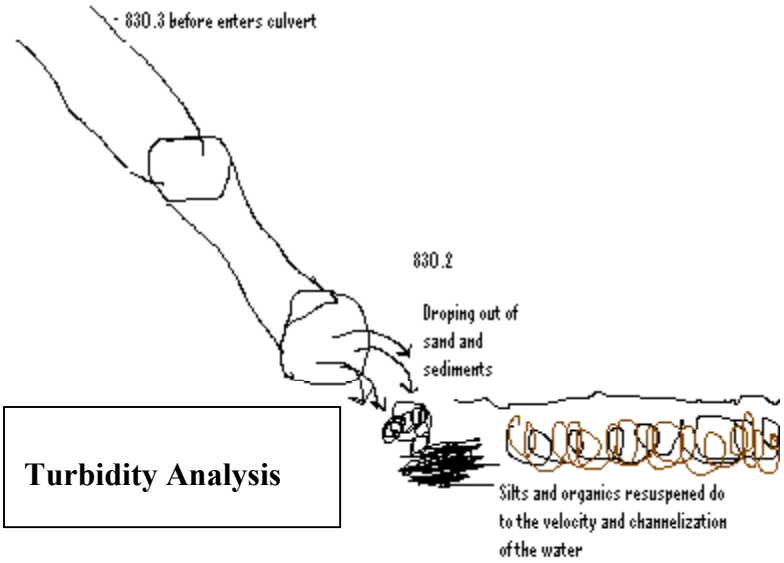


Figure 19 shows us a rough drawing of this conclusion. When there are large amounts of precipitation we see the opposite occurring. The turbidity seems to be higher at site 830.2 by the highway and decreases by the dam. The idea is when there are large amounts of rain it raises the level of the stream enough so that the water starts flows over the banks (what is called bank full) and spreads the water column out. As

stated above sheet flow is much better at filtering out suspended solids because it slows the water down and allows it to settle out some of the materials. Also by being in contact with more plant materials any suspended solids may be taken up by the plants and used as nutrients. These trends occur in the spring and fall showing that turbidity is highly influenced by amount of precipitation.

The fall is not as obvious as the spring and has a few different trends that do not correlate with the first hypothesis. One important date that does support the hypothesis is on the 17th of December (See Appendix C: Water Sampling Data). This turbidity reading was a very big outlier. One might hypothesis that the outlier could have been caused by many things. One idea is that since there was a good deal of snow that week the combination of snow and precipitation may have caused the highway department to salt and sand extra. The high reading may have been a result of this. As well as the possibility that something could have flushed from higher in the watershed. Something like construction could have been a factor. From our knowledge we can't really make any conclusions about the outlier reading. One can say by looking at this high outlier yes; the wetland is doing its job. When looking at the reading on the 17th and comparing 830.2 and 830.15 one can see the huge mitigation and settling that must have occurred to settle out the high reading.

During just the winter months and into the early spring we see the turbidity of 830.15 and 830.2 staying close linked together and nothing dramatic occurring because no hugely significant precipitation has occurred at that time and the ground is frozen leaving any turbidity and sediments from the soil trapped up till spring.

For the means of turbidity there are several ways that the wetland can do the job of mitigating out the total suspended solids. For the wetland to filter out as much as possible a plan may be to lower the banks so that even in lower precipitation the water can spread out and settle suspended solids better. One suggestion would be that perhaps the dam should have had a third board. When looking at turbidity as a factor one can see that the wider and slower the water column, the more settling out capacity the wetland has. Right now there are to many instances of substances coming into the wetlands and not getting filtered out. Some other ways one could slow the channelization and velocity of the water are putting in plants to slow water down, building series of small stone weirs, smaller banks by digging out wetland and anything that makes the water spread and slow down.

Discussion

Limitations of the Project

While the investigators for this project sought to make their analysis as comprehensive as possible, all projects experience limitations and problems. For this project the results of our survey and interviews are limited in that our pool of participants only reflects people who attended the New London Town Meeting in 2002. While this group provided us with helpful information is was biased in terms of several factors such as age, level of education and living in close proximity to the water. To test our findings further we would need to survey a population that better represents the area.

With our water quality analyses we tried to follow storm events but we did not follow regular precipitation events, rather we stuck to a weekly sampling schedule each Monday. In terms of data collection the first limitation we encountered was time. This was a limitation because we only sampled data between October 1, 2001 and April 29, 2002. This is only late

fall through early spring and doesn't account for the other five months of the year. Further limitations in chronology include the fact that this project was only done for one year versus a series of years.

Weather was an extreme limitation because this year was the second driest fall and winter ever recorded in New Hampshire history (National Weather Service, 2002). This brought about such inconsistencies as non-representative flow data for a typical season, few storm events and diminished spring runoff. This indicates that this season would be an outlier season when comparing it to other precipitation scales. During the winter we also encountered ice which forced us to either not sample at that site or to drill through the ice to collect a sample. Tributary sampling is usually not conducted by LSPA in the winter. Because of the lack of consistent weather readings from a local weather station proximal to the sample sites, weather data had to be gathered from Lebanon, NH. (www.accuweather.com)

Our sampling was limited based on the number of tests we could do. For example we were not able to test for iron, magnesium and calcium or other hard metals and pollutants. Halfway through the project we added a fifth site (830.30) and began testing for flow data over the dam also added were dissolved oxygen and phosphorus.

Throughout the course of our project we encountered limitations in our methodologies. For example for flow monitoring before and after the wetland a stream profile and surface velocity method was used to calculate the flow of water entering and existing the wetland. This method is not as precise as using a flow meter because it is affected by wind, in climate weather and human error. In water sampling and field-testing there is always a chance of human error.

Management Plan

There is no one definite conclusion that can be drawn to the analysis of the Columbus Avenue wetland. However we can provide three suggestions in managing the future of the wetland.

Option 1: Leave boards up all year long for phosphorus retention purposes

This management plan is cost effective and not labor intensive. As seen this past spring leaving the boards at the dam at their highest level slows down and spreads out the water column, helping to mitigate and attenuate phosphorus. The negative aspect of this option is that the wetland is constantly inundated with water. This does not allow for nitrogen removal because it doesn't allow for aeration of the wetland soil. And by slowing down the nitrogen cycle it will in fact cause a decrease in the wetlands ability to cycle phosphorus.

Option 2: Remove one board for one year after spring runoff.

By removing one board allows for some aeration of the wetland soils. This helps remove nitrogen from the system and retains some phosphorus in the process.

Option 3: Remove both boards twice a year, once after spring runoff and replaced in early fall, then removed again after hurricane season and replaced prior to spring runoff.

The third management plan works best to mitigate phosphorus at the time when it is most likely to flow into Herrick Cove, during the spring and fall when there is heavy precipitation. This plan gives the wetland time to dry out during the summer growing season when most of the phosphorus would be taken up by plants and allow for nitrogen aeration. Furthermore leaving the boards down during the summer as well as during the winter months

provides needed absorption room for hurricane season and spring runoff. This method would increase the wetlands ability to act as a sink during periods of high nutrient inflow. This plan is recommended because it allows for a balance between maintaining the nitrogen cycle in the wetland and phosphorus entering the lake. This plan helps to achieve an active and diverse wetland. This also helps the second wetland directly below Columbus Avenue by giving it annual fluctuations in water levels so it doesn't dry up and lose its mitigating potential.

Future Research & Recommendations

Future research should include a consistent sampling schedule for turbidity, conductivity, pH, phosphorus, and dissolved oxygen on a weekly basis for a period longer than one year. Sampling should also include a monthly iron, magnesium and heavy metals test. Sample sites should be established in the upper regions of the watershed along seasonal streambeds and tributaries, specifically for the testing of spring runoff for point source pollution.

Other recommendations would include adding more barriers to the wetland. Future research may include adjusting the level of the mortarboards at the dam; this would be done to explore how the wetland reacts to different levels of water and its ability to perform positive functional values of a wetland. Make conclusions regarding the difference between removing one board or both boards at the dam and how that affects the function of the wetland.

In the future there should be another plant inventory to determine how species have changed since the dam was erected and the location of the mortar boards were established. Explore the option of adding wetland plants that have a high uptake of phosphorus, nutrients and other particulates to the wetland. Also, exotic species such as phragmites and purple loose strife should be closely monitored to prevent over population and spread to other areas of the Lake Sunapee region. In general, it would be good to conduct a biotic and ecosystem inventory for the site.

A political recommendation would be to curb if not stop all development in the watershed. This would also include placing higher restrictions on wastewater treatment and septic systems. Eliminate the use of outhouses and or direct sewage input into the area around Lake Sunapee and this watershed. Isolate the rock cut on Burpee Hill in order to determine the precise water quality that is coming from this particular place.

If this project were to be replicated at another site a thorough and comprehensive study of the wetland and watershed would be required. Specific factors that one would want to look at before altering the landscape would include, size of watershed, seasonal and annual flow, turbidity, conductivity, pH, dissolved oxygen, wildlife, macro invertebrates watershed development, parts per million (phosphorus and metals) of pollutants entering and exiting the watershed system being examined. After the factors have been examined a preliminary management planned should be established and examined before any alterations are done to the landscape. Decisive factors that would determine if additional work should begin are dependent upon who will be responsible for managing and maintaining the project before and after completion, long term post construction study and data collection, input from local constituents and stakeholders.

Summary and Conclusions

Overall this project was unique because it incorporated various community partners and Colby-Sawyer College. This project may serve as a resource for future and other pollution attenuation projects based specifically around highway runoff, watershed quality and use of natural wetlands as a mitigation tool for pollutant loading in atrophic lakes. The project also provides useful information regarding the level of understanding and support for wetland initiatives in the area. Working with the results form the survey and interview we can state that the community has a positive perception and good knowledge of wetlands, however, there is not a good understanding of the impact of I-89. There is also a good degree of support for local organizations working on wetland and conservation issues and a desire for additional educational programs.

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Appendix A

Wetland Survey

We are students in the Community and Environmental Studies Program at Colby-Sawyer College. We are conducting this survey as part of a yearlong project that focuses on water quality in the Lake Sunapee watershed. The data collected from the survey and interviews will contribute to the development of a comprehensive report and educational materials, which will be provided to the New London Conservation Commission as well as the Lake Sunapee Protection Association. This study will take place in two stages, the initial stage will involve a survey and second stage will involve a follow up interview of selected survey respondents.

This survey is voluntary and you may refuse to participate. Any information obtained, which could identify you, will be kept strictly confidential. This information may be published in professional journals or presented at professional meetings, but your identity will be kept strictly confidential.

General Information

- ___I live on/own water front property ___I live within 500 yards of water/wetlands ___ I do not live near water/wetlands
- ___I have lived here for less than 1 year ___I have lived here for 1-5 years
  ___I have lived here for 5-10 years ___I have lived here more than 10 years ___I am a seasonal resident of the area
- Highest level of education attained: High School (GED)___ Some College___ College Diploma___
  Graduate/Masters/PhD___
- I am: 18-25___ 25-35___ 35-45___ 45-55___ 55-65___ 65-75___ 75 and older___
- Are you active in any of the following organizations? Circle all that apply.
  - *Ausbon Sargent Land Preservation Trust*
  - *Friends of the John Hay National Wildlife Refuge, The Fells*
  - *Lake Sunapee Protective Association*
  - *Other(Please specify)* _____

Wetland Information

Write down 2 words that you would use to describe wetlands: _____ _____

Please tell us the degree to which you agree or disagree with the following statements.
Please circle what you think is the best answer.

5 – Strongly Agree 4 – Agree 3 – Neither agree nor disagree 2 – Disagree 1 – Strongly Disagree

1. Wetlands are important to me because they are beautiful.	5	4	3	2	1
2. Wetlands are easy to replace.	5	4	3	2	1
3. Wetlands are important habitats for animals.	5	4	3	2	1
4. Wetlands merit protection and preservation.	5	4	3	2	1
5. Wetland protection is especially important in this region.	5	4	3	2	1
6. I support the use of public funds to preserve wetlands.	5	4	3	2	1
7. Communities should permit the development of wetlands for economic growth.	5	4	3	2	1
8. Wetlands are an effective means of ensuring water quality.	5	4	3	2	1
9. There are too many wetlands in this region.	5	4	3	2	1

Please Turn Over

	5 – Strongly Agree	*4 – Agree*	*3 – Neither agree nor disagree*	*2 – Disagree*	*1 – Strongly Disagree*
10. Wetland preservation is best left to the government.	5	4	3	2	1
11. I can't influence wetland preservation in my community.	5	4	3	2	1
12. Wetlands are of little importance.	5	4	3	2	1
13. Wetlands are a primary breeding spot for mosquitoes and other nuisances.	5	4	3	2	1
14. Wetlands are helpful in preventing flooding.	5	4	3	2	1
15. I-89 is an environmental threat to Lake Sunapee.	5	4	3	2	1
16. There are now just as many wetlands as there were twenty years ago.	5	4	3	2	1
17. We should actively try to increase the acreage of wetlands?	5	4	3	2	1

Would you be willing to be contacted to participate in a 30-minute follow-up interview? If yes, please provide the following information.

Name:

Phone:

E-Mail:

From those who indicate they are willing to be contacted to participate in a follow up interview, we will select six individuals seeking diverse representation of the following criteria: proximity of residence to wetlands, length of residency in New London, education level, age, membership in environmental organizations, and perspectives on wetlands.

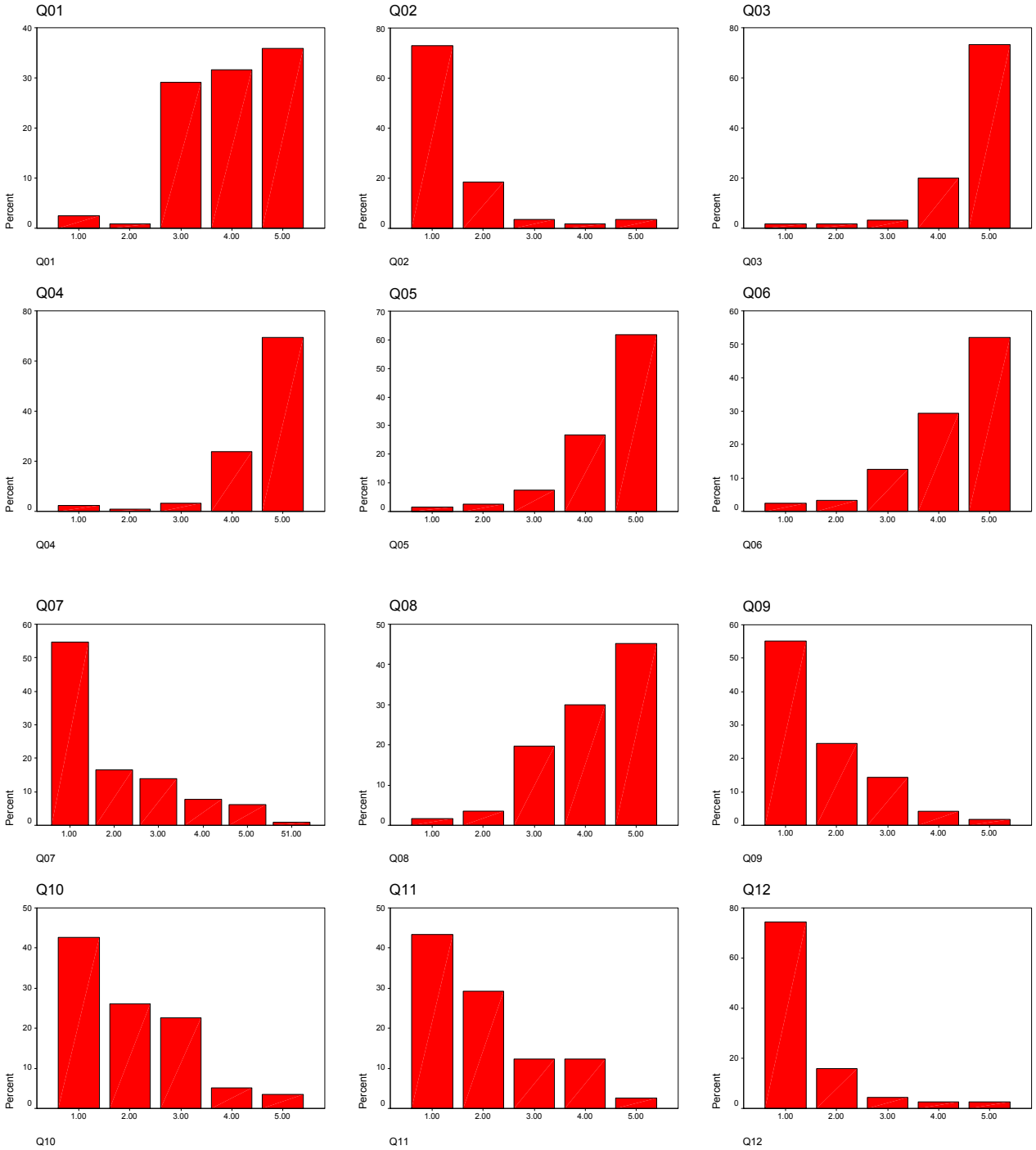
Thank you for your participation!

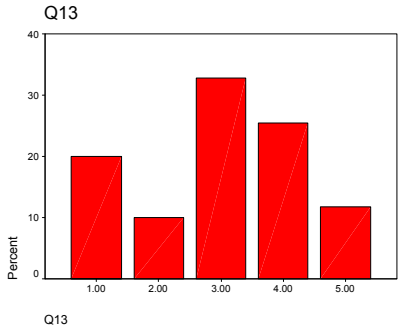
Please return to students at the display table or to the Institute for Community and Environment, Colby-Sawyer College, 100 Main St. New London, NH 03257.
Fax: 603-526-3429

Survey Data

Breakdown of actual answers to each question.

1 – Strongly Disagree, 2 – Disagree, 3 – Neither Agree Nor Disagree, 4 – Agree, 5 – Strongly Agree




Q13
Percent
0
10
20
30
40
1.00
2.00
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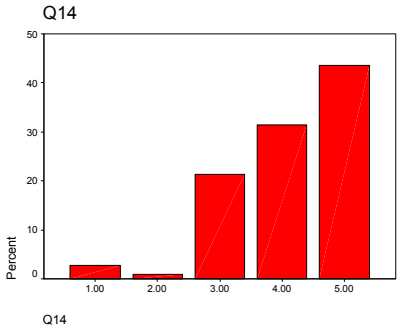
5.00
Q13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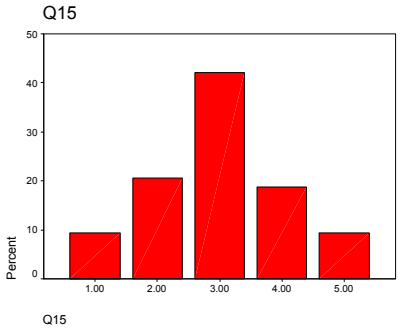
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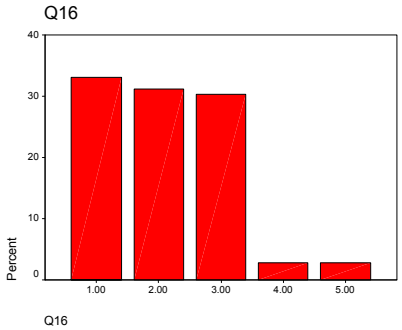
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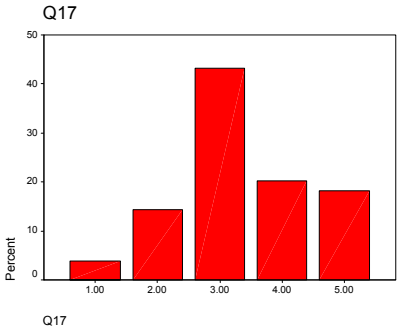
Q16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2.00
3.00
4.00
5.00
Q17

Appendix B

Assessing Wetland Knowledge

Interview Questions

How long have you lived here?

Tell me about the place where you live (is it wooded, near water and what is attractive about it to you?)

Describe the place where you grew up and its importance to you?

How has New London changed since you moved here?

Has I-89 had a major impact on major features of the town?

Do you believe that the addition of I-89 has had an environmental impact on the town of New London?

Do you know some of the functions of wetlands?

How are they protected?

Do you know of any wetlands in New London?

Have you visited any of them?

Do you feel that wetlands are important to you, your family, and the community? How?

Do you feel New London protects important habitats for animals including wetlands?

Do you think the community could do more for wetlands?

Do you have any questions for me?

Is there anything else you would like to add?

Informed Consent Form: Interviews

Title of project: Assessing Wetland Knowledge

Name of investigator: Tom Remmers 526-3276, Morgan Jenkins 526-3160, Thad Soulé 526-3940

Phone: Faculty Sponsors John Callewaert 526-3793 or Leon Malan 526-3632

Invitation to Participate:

Based on your consent to be contacted for a follow up interview, you have been selected to participate in a follow-up interview. The following information is provided to help you make an informed decision of whether or not to participate. If you have any questions, please do not hesitate to ask.

Purpose:

The purpose of this study is to determine the extent of residents' knowledge about wetlands. The reason we are doing this study is for our Community and Environmental Studies project, which focuses on non-point source water impoundment/pollution attenuation in New London near the intersection of Columbus Avenue and route 103A. The data collected from the interview will contribute to the development of a comprehensive report and educational materials, which will be provided to the New London Conservation Commission, as well as the Lake Sunapee Protection Association.

Subjects:

From those who indicated on the survey that they were willing to be contacted to participate in a follow up interview, we selected six individuals, seeking diverse representation of the following criteria: proximity of residence to wetlands, length of residency in New London, education level, age, membership in environmental organizations, and perspectives on wetlands.

Procedures:

If you decide to participate in this research project, we will be asking you a series of questions about wetlands while keeping your individual information confidential. If you decide to participate with the interview process, it will take an estimated 30 minutes. Then the CES 302 class will analyze the data collected and your individual information will be confidential. This data will then be synthesized into the final report and will help us to determine the best method for communicating and educating the public. This benefits the Columbus Avenue wetland project for the New London Conservation Commission and the Lake Sunapee Protection Association.

Timetable:

If participating in this interview expect to spend 20-30 minutes while answering questions.

Confidentiality:

Any information obtained during this study, which could identify you, will be kept strictly confidential. This information may be published in professional journals or presented at professional meetings, but your identity will be kept strictly confidential.
The information collected in this study will be stored in a locked room and will be destroyed after a period of five years. The interviewees will not be identified in the interview transcripts.

Right to Refuse or Withdraw:

You may refuse to participate. You may change your mind about being in the study and quit after the study has started. If the study design or use of the data is changed, you will be informed and your consent obtained for the revised research study.

Questions:

If you have any questions at this time, please ask them. If you have additional questions later, Tom Remmers, Morgan Jenkins, Thad Soulé we will be happy to answer them at Colby-Sawyer College 100 Main St. New London, NH 03257. Please call our faculty sponsors if any specific or urgent questions need to be addressed. Our sponsors are Leon Malan at 526-3632 or John Callewaert at 526-3793.

Your signature below indicates that you have voluntarily decided to participate in this research project as a subject and that you have read and understand the information provided above.

_____ _____
Subject's signature Date

_____
Subject's printed name

In my judgment, the subject is voluntarily and knowingly giving informed consent to participate in this research study.

_____ _____
Investigator's signature Date

_____ _____
Investigator's printed name Date

Storm Event

Date	Site	Conduct.	Turbidity
15-Oct	830.00	552	5.9
15-Oct	830.15	567	9.4
15-Oct	830.20	567	6.7

Weekly Sampling

Turbidity

Site	1-Oct	8-Oct	17-Oct	22-Oct	29-Oct	5-Oct	12-Nov	19-Nov	26-Nov	3-Dec	10-Dec	17-Dec	22-Dec	31-Dec	7-Jan	14-Jan	21-Jan	28-Jan	4-Feb	11-Feb	18-Feb	25-Feb	4-Mar	11-Mar	18-Mar	26-Mar	1-Apr	8-Apr	15-Apr	22-Apr	29-Apr
830.00	3.1	3.2	3.2	3.1	4.3	3.6	1.6	1.8	2.5	1.3	2.2	1.4	1.9			1.8	2.1	1.3	1.0	2.3	1.0	0.9	3.1	1.2	0.6	1.0	2.6	0.6	2.4	0.9	1.6
830.15	3.6	4.8	3.6	4.4	6.3	4.4	1.8	1.9	2.4	1.1	2.5	1.3	1.7	3.0	2.6	1.8	2.1	1.3	0.9	1.7	1.1	0.8	3.0	1.4	0.5	0.7	3.1	0.8	2.2	0.9	1.2
830.20	3.1	2.5	2.4	2.0	2.3	3.2	5.5	2.6	3.0	0.9	1.3	74	1.5	2.1	1.8	1.8	1.1	0.9	0.7	1.5	2.5	0.9	1.9	1.2	0.4	0.4	3.0	0.4	4.6	3.1	1.5
830.30																								0.8	0.5	0.6	2.5	0.3	0.8	0.4	1.0
830.70	1.2	2.2	2.2	1.3	0.8	2.0	0.3	0.8	0.7	0.4	0.6	1.0	1.1			2.8	2.8	2.1	0.8	2.5			1.0	0.6	0.5	0.5	1.4	0.3	1.2	0.6	1.2

Conductivity

Site	1-Oct	8-Oct	17-Oct	22-Oct	29-Oct	5-Oct	12-Nov	19-Nov	26-Nov	3-Dec	10-Dec	17-Dec	22-Dec	31-Dec	7-Jan	14-Jan	21-Jan	28-Jan	4-Feb	11-Feb	18-Feb	25-Feb	4-Mar	11-Mar	18-Mar	26-Mar	1-Apr	8-Apr	15-Apr	22-Apr	29-Apr
830.00	418	529	495	537	535	491	522	498	418	294	363	296	542			427	418	431	411	448	476	404	277	187	278	124.1	191	298	242	326	310
830.15	438	539	512	550	540	512	526	512	432	320	371	311	523	488	498	450	443	453	434	558	504	430	291	177	297	121	171	295	247	370	311
830.20	420	567	512	585	549	523	596	624	492	284	353	235	406	435	461	431	414	380	320	447	421	371	257	167	234	118.8	165	240	246	268	271
830.30																								165	240	123.7	167	241	247	272	275
830.70	348	396	250	425	456	353	371	351	147	143	255	143	282			321	449	295	325	153			252	153	230	119.7	87.9	247	126	236	209

pH

Site	1-Oct	8-Oct	17-Oct	22-Oct	29-Oct	5-Oct	12-Nov	19-Nov	26-Nov	3-Dec	10-Dec	17-Dec	22-Dec	31-Dec	7-Jan	14-Jan	21-Jan	28-Jan	4-Feb	11-Feb	18-Feb	25-Feb	4-Mar	11-Mar	18-Mar	26-Mar	1-Apr	8-Apr	15-Apr	22-Apr	29-Apr
830.00	6.30	5.99	5.91	5.68	6.22	6.38	6.12	6.22	6.07	6.21	5.94	6.07	6.35			5.9	5.65	6.05	5.74	5.75	6.06	5.59	5.61	5.53	5.99	5.92	5.53	5.84	4.97	6.18	6.02
830.15	6.02	5.82	5.94	5.78	5.96	6.14	6.03	5.98	6.02	6.19	5.89	5.96	6.08	6.11	5.9	5.93	5.84	6.06	5.79	5.88	6.05	5.44	5.65	5.58	6	5.97	5.65	5.92	5.07	6.21	6.05
830.20	6.16	5.95	6.15	5.86	6.15	6.26	6.02	6.05	6.24	6.18	6.02	5.88	6.22	6.21	5.94	6	5.94	6.04	5.84	5.84	5.99	5.49	5.62	5.57	5.05	5.99	5.61	5.88	4.98	6.10	6.01
830.30																								5.52	5.93	6.05	5.56	5.81	4.97	6.12	5.97
830.70	6.42	6.18	6.20	6.16	6.50	6.54	6.39	6.46	6.15	6.30	6.15	6.19	6.31			6.05	5.87	5.93	5.83	5.73			6.08	5.93	6.32	5.93	5.98	6.28	5.42	6.31	6.25

Total Phosphorus

Site	28-Jan	4-Feb	11-Feb	18-Feb	25-Feb	4-Mar	11-Mar	18-Mar	26-Mar	1-Apr	8-Apr	15-Apr	22-Apr	29-Apr
830.00	0.014	0.012	0.021	0.010	0.011	0.023	0.015	0.007	0.006	0.021	0.008	0.021		
830.15	0.013	0.011	0.017	0.009	0.016	0.022	0.015	0.008	0.006	0.024	0.008	0.021		
830.20	0.016	0.014	0.018	0.019	0.012	0.020	0.015	0.007	0.007	0.027	0.008	0.055		
830.30							0.015	0.008	0.007	0.026	0.008	0.020		
830.70	0.019	0.031	0.025			0.011	0.012	0.005	0.007	0.016	0.007	0.014		

D.O Water	11-Mar	18-Mar	26-Mar	1-Apr	8-Apr	15-Apr	22-Apr	29-Apr
830	12.8	13.3	14.2	12.9	13.1	10.1	11.3	12
830.15	13.3	13.9	13.3	12.7	12.3	9.1	10.1	10.9
830.2	13.2	15.4	13.9	13.3	12.6	9.3	10.3	11.5
830.3	12.7	14.8	13.4	12.7	12	8.2	9.7	11
830.7	13.2	11.1	10	13.5	11.5	9.5	7.9	10.3

D.O Air	11-Mar	18-Mar	26-Mar	1-Apr	8-Apr	15-Apr	22-Apr	29-Apr
830	16.1	14.8	13.2	14.4	12.5	7.7	13.3	11.5
830.15	3.1	14.9	14	13	11.6	8.6	13.3	12.2
830.2	13.6	15.3	14.8	12.5	11.4	8.8	13.5	11.3
830.3	12.2	13	15.5	12.1	99.3	8.5	10.3	9.9
830.7	15.8	12.4	14.6	11.9	11.6	8.9	11.6	12.2

Temp Water	11-Mar	18-Mar	26-Mar	1-Apr	8-Apr	15-Apr	22-Apr	29-Apr
830	0.5	0.4	0.9	2.6	4.2	10.6	4.9	5.3
830.15	0.7	0.5	0.9	2.7	4.7	10.0	4.3	5.7
830.2	0.6	0.5	0.7	2.2	3.8	9.3	5.5	4.8
830.3	0.4	0.3	0.3	1.8	3.2	9.0	5.8	4.6
830.7	0.9	0.6	0.4	3.3	5.0	10.0	3.8	4.9

Temp Air	11-Mar	18-Mar	26-Mar	1-Apr	8-Apr	15-Apr	22-Apr	29-Apr
830	-1.3	-0.2	3.2	9.4	6.3	21.8	2.1	6.6
830.15	3	0	1.5	7.7	8.9	17	1.4	5.2
830.2	2.2	1.7	0.6	8.4	9.8	15.4	2.6	7.3
830.3	4.9	5.5	0.1	7.9	16.9	18.9	9.5	14.1
830.7	-0.9	3.4	-0.3	7.7	8.7	15.9	5.5	5.6

Sat % Water	11-Mar	18-Mar	26-Mar	1-Apr	8-Apr	15-Apr	22-Apr	29-Apr
830	89%	92%	99%	95%	101%	94%	88%	94%
830.15	90%	95%	93%	94%	96%	81%	78%	87%
830.2	91%	106%	97%	95%	95%	81%	81%	89%
830.3	86%	101%	93%	90%	89%	71%	77%	85%
830.7	93%	76%	69%	101%	90%	84%	60%	80%

Sat % Air	11-Mar	18-Mar	26-Mar	1-Apr	8-Apr	15-Apr	22-Apr	29-Apr
830	105%	101%	98%	100%	101%	88%	96%	94%
830.15	97%	102%	100%	107%	99%	89%	95%	96%
830.2	99%	109%	103%	107%	100%	88%	98%	94%
830.3	95%	104%	107%	101%	94%	92%	90%	97%
830.7	105%	93%	99%	100%	100%	90%	92%	97%

Flow Measurements	11-Mar	18-Mar	26-Mar	1-Apr	3-Apr	8-Apr	15-Apr	22-Apr
830.15								
depth at weir	3.6 inches	2 inches	1.75 inches	8.5inches	4.4inches	2.5 inches	5 inches	1'3/4"
volume	1.13 sq.ft.	N/A	N/A	3.34 sq.ft	1.38 sq.ft.	.78 sq.ft.	1.57 sq.ft.	Too Low
flow	4.74cfs	N/A	N/A	15.7cfs	6.08cfs	2.34cfs	4.394cfs	
staff gauge	ice	ice	ice	1.43	1.25	1	1	0.9

2.25 inches are needed to calculate flow

Appendix D
Student Biographies

Tom Remmers, from Centerville MA, is a senior in the Community and Environmental Studies program and is minoring in English. During the summer of 2001, Tom completed an internship with the Randolph Mountain Club. For his senior capstone project Tom is designing an interpretative trail for a parcel of land in New London recently placed in a conservation easement with the Ausbon Sargent Land Preservation Trust.

Morgan Jenkins, from Southwick MA, is a junior in the Community and Environmental Studies program and is minoring in Business Administration. This summer, Morgan will complete an internship in Boston with the Mystic River Watershed Association. The internship program is part of Tufts University River Institute.

Thad Soulé, from Wilmington DE, is a junior and is pursuing a double major in History Society and Culture and Community and Environmental Studies. This summer, Thad will return for a second year to complete an environmental internship at the John Hay National Wildlife Refuge in Newbury, NH.

Appendix E

Community and Environmental Studies Program Overview

The Community & Environmental Studies (CES) program at Colby-Sawyer College provides students with the opportunity to understand, integrate, and apply multiple disciplines and different ways of thinking with a high level of concern for the preservation and sustainability of the Earth and its resources. Our graduates are prepared and encouraged to act on their informed environmental concerns in their homes, places of work, and communities.

The CES program boasts several essential features that provide students with a unique and exciting learning experience. First, the program is pre-professional and designed to provide students with the necessary "hands-on" skills one needs to step from college directly into the work force. The program is also designed to prepare students for graduate training in a number of fields. Second, many CES projects are linked very closely with the local community. Students interact directly with individuals and businesses in the local area and develop an important sense of community for themselves and their college. Third, many experiences in the program are student driven. Students play a key role in determining which questions and issues are important as well as the proper methods for addressing those issues.

The third year is the defining characteristic of the Community and Environmental Studies program. Rather than choosing from a series of 300-level course options, all students majoring in Community and Environmental Studies take CES 301/302 for 18 total credit hours during the third year. In addition to traditional classroom and laboratory exercises, students are immersed in an in-depth, yearlong analysis of a local environmental problem or issue with detailed fieldwork and extended site visits. This structure allows students to work at length on a complex problem while developing important skills in group-oriented tasks to a degree that is not obtainable in traditional courses.

For more information, please contact:

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