2009 Water Quality Monitoring Report

for

Meredith, Paugus and Saunders Bays

Lake Winnipesaukee

Submitted to

Lakes Region Planning Commission

Prepared by

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1. Executive Summary

This monitoring program was conducted in support of a NH DES 319 grant awarded to the Lakes Region Planning Commission in 2008 for the development of the "Lake Winnipesaukee Watershed Management Plan, a Subwatershed Approach". In order to be able to measure potential improvements in water quality due to the implementation of best management practices as part of the management plan, data needed to be obtained to serve as an initial characterization of the water quality in the three (3) subwatershed areas under study in the grant; specifically, Meredith Bay, Paugus Bay and Saunders Bay of Lake Winnipesaukee. The monitoring design focused on tributary, near shore and deep lake samples, and followed the protocols and standard operating procedures in the quality assurance project plans (QAPP) in place with the NH Volunteer River Assessment Program (VRAP) for tributary sampling, and the UNH NH Lakes Lay Monitoring Program (LLMP) for near shore and deep lake sampling.

Selection of the tributaries, near shore and deep lake sites was done in collaboration with UNH Center for Freshwater Biology, and the local communities. Some of the tributaries and deep lake sites represent ongoing local monitoring efforts, and some sites were added as part of this study. The selection of sites was based on:

- obtaining deep lake samples from each subwatershed bay area
- samples from shallow sites located near the outlet of tributaries
- tributary sites that represent various development patterns/land uses, and/or outflows that contribute a fairly large volume of water to the lake.

The following table represents a summary of the number and type of sampling locations for each subwatershed. Each community contributed financially to the sampling study and provided input as to the number and selection of tributary sites monitored.

Table 1. 2009 Summary of sampling conducted in Meredith, Paugus, and Saunders Bays

Meredith Bay	Paugus Bay	Saunders Bay
3 Deep sites	2 Deep sites	4 Deep sites
5 Shallow sites (*2008 only)	4 Shallow sites	5 Shallow sites
5 Tributaries (*2008 only)	12 Tributaries	3 Tributaries

*Note: 2008 Meredith Bay shallow and tributary monitoring is mentioned for informational purposes only; no data analysis is included in this study.

Tributary Sampling Summary

Tributaries were monitored biweekly beginning in June and ending in September for pH, turbidity, temperature, dissolved oxygen, conductivity, and total phosphorus. As the complete report of the tributary monitoring conducted in 2009 in Paugus and Saunders Bay subwatersheds can be found in Appendix A, "2009 Lake Winnipesaukee Tributaries Water Quality Report", this report will only highlight the summary of results, site selection, rationale, and maps of the tributary monitoring.

Dissolved oxygen readings not meeting NH Class B standards were recorded at tributary station 01-XSB (refer to Table 5, Figure 4); which empties into Saunders Bay. As this tributary consistently had very low flows, it is not surprising that the dissolved oxygen readings were below the state standard. This station also had pH

readings below the Class B New Hampshire standard of 6.5 -8.0 pH units. Many of the tributary sampling sites/stations had pH values recorded below the NH Class B standard. In fact of the 85 measurements taken during the sampling season, 42 fell below the state standard.

Turbidity levels (refer to Table 6) were low for all stations sampled; the only station that recorded turbidity measurements close to or above 10 NTUs was 01-XSB. Station 01-XSB (refer to Table 5, Figure 4) was fairly stagnant at each sampling event, and exhibited iron rust in the water, which would contribute to higher turbidity readings.

Specific conductance (refer to Table 6) levels ranged from 52 to 975 us/cm in the Paugus Bay tributaries, and 55 to 493 us/cm in Saunders Bay. The higher reading of 975 us/cm was recorded at the only outfall sampled in Paugus Bay, OUT-001 at the end of Mass Ave., Laconia (refer to Table 4, Figure 3). Higher readings in an outfall would be expected due to road runoff containing salts, fertilizer, and metals. The high reading of 493 us/cm was recorded at Station 02-AHB, Adder Hole Brook, Gilford (refer to Figure 4). Adder Hole Brook is a wetland area that is fairly stagnant; it receives road runoff from Route 11.

At least one phosphorus measurement was obtained from each tributary sampling station. Although New Hampshire does not have any Class B numeric standard for total phosphorus for tributaries, the NH DES level of concern is 0.05 mg/L. Only two measurements out of 69 were above DES' level of concern; one reading at TRIB-24, Langley Brook in Laconia; and the other at TRIB-25, an unnamed tributary inlet to Moulton Cove in Laconia (refer to Figure 3).

Excerpted from the NH VRAP Tributary Report (see Appendix A):

> "Although there is no numeric standard for nitrate/nitrite, the median NO3+NO2 value for New Hampshire rivers and streams is 0.17 mg/L (based on VRAP and other NHDES data collected 2004 - 2008). Three stations (04-GSK, TRIB-013A, and TRIB-014) had one or more measurement that exceeded the NO3+NO2 state median."

Station 04-GSK (refer to Figure 4) is the most downstream site sampled on Gunstock Brook. It is located on Old Lakeshore Road; previous sampling done at this site in 2004 and 2005 also shows higher nitrate readings than the majority of other tributary sampling stations. This site is located downstream from an agricultural farming operation and fertilizers may be the source of the higher nitrate. Stations TRIB-013A and TRIB-014 (refer to Figure 3) are located in South Down along the west side of Paugus Bay in Laconia. Further monitoring and investigation of the surrounding area is needed to determine the source of higher nitrate levels.

The last parameter measured at the tributary sites was chloride. As high conductivity readings are indicative of salts, metals, and/or fertilizers, chlorides were measured to eliminate or identify salt as a possible source or cause of high conductivity readings. Of the 48 samples collected, all measurements met the NH water quality standard for chloride; 230 mg/L Chronic condition, and 860 mg/L Acute criteria. One sampling event for chlorides was collected at the outfall station, OUT-001 in Laconia (refer to Figure 3), which is not subject to the water quality standards as it is not a tributary. The chloride measurement at OUT-001 was 260 mg/L on the one occasion it was analyzed. This would not be surprising, as the outfall collects storm water road runoff from the surrounding residential area.

Near Shore and Deep Lake Sampling Summary

The months of June and July in 2009 experienced higher than average rainfall. Both months received approximately 4 inches of rain above normal; 7.62 inches were recorded at the Lakeport station for June, and 8.11 inches for July. Lake sampling did not begin until the beginning of July, with water samples collected approximately every two weeks. The Town of Meredith conducted their sampling program in collaboration with UNH's NH Lakes Lay Monitoring Program (NH LLMP), while the sampling in Paugus Bay and Saunders Bay was conducted by North Country Resource Conservation & Development Area Council in collaboration with NH Department of Environmental Services, Plymouth State University, and UNH NH LLMP.

Near shore or shallow site samples were collected in Paugus Bay and Saunders Bay to potentially determine impacts from tributary inputs and/or land use. With the higher than average rainfall in June and July, it was anticipated that the phosphorus levels seen from the shallow stations would be higher than might be normal. However, most of the results for the water samples were reported as below the detectable limit of the instrument, which for the Plymouth State lab is .002 mg/L, and for NH DES lab is .005 mg/L. These results are questionable and not consistent with expectations.

In Table 2 shown below, the median value of phosphorus for Meredith Bay was determined from the median of the median of each deep lake station; i.e. 6.4 ug/L for 1 Boat Ramp, 6.7 ug/L for 2 Church Pt., 6.9 ug/L for 2MerBay. In the case of Paugus Bay and Saunders Bay, there was not enough phosphorus data obtained to determine median values at the individual sampling stations. Therefore the median TP for Paugus and Saunders Bay was determined from all data values for shallow and deep lake sites. The value of 6.1 ug/L TP for deep lake sites in Paugus Bay was calculated as the median of seven (7) data points, and the value of 5.6 ug/L for Saunders Bay was calculated as the median of four (4) data points.

The mean chlorophyll α data was based on averaging the mean chlorophyll α data from each station. A total of 29 data points/values were analyzed for the shallow sites and 19 data points for the deep lake sites in Saunders Bay. In Paugus Bay, the two deep lake sites had five sampling events, and one deep lake site was sampled once, for a total of eleven (11) data points. The four shallow sites were also sampled five times for a total of 20 data points. For Meredith Bay, 21 data points for chlorophyll α were obtained, with 2.2 ug/L representing the mean of the 'means' for the three stations.

The mean values for Secchi Disk depth and Dissolved Color were arrived at in the same manner as the mean chlorophyll α values.

Table 2. Summary of the sampling results for Meredith, Paugus, and Saunders Bays

	Meredith Bay	Paugus Bay		Saunders Bay	
Parameter	**Deep Lake**	**Shallow Sites**	**Deep Lake**	**Shallow Sites**	**Deep Lake**
Median Total Phosphorus (ug/L)	6.7	5.6	6.1	5.1	5.6
Mean Chlorophyll α (ug/L)	2.2	2.0	2.0	1.8	1.8
Mean Secchi Disk depth (m)	7.1		9.0		9.7
Mean Dissolved Color (CPU)	9.8	10.4	7.4	8.3	8.0

Notes:
μg/L = micrograms per liter
m = meters
CPU = chloroplatinate unit

Figure 1. 2003 aerial photograph depicting the tributary, near shore, and deep lake sampling stations for Meredith, Paugus, and Saunders Bays.

2. Introduction / Background

The total area of the Lake Winnipesaukee watershed (HUC# 0107000201) is 236,225 acres, made up of sixteen communities, with eight of the sixteen having waterfront acreage. The NH Department of Environmental Services has delineated the watershed at the HUC 12 level into ten (10) subwatersheds. Due to the size of the entire watershed, the Lakes Region Planning Commission and its partners are developing a watershed management plan on a subwatershed basis, working initially with the Meredith Bay (HUC# 010700020109), Paugus Bay (HUC# 010700020110), and Saunders Bay (HUC# 010700020107) subwatersheds. These three subwatersheds encompass land area in Center Harbor, Meredith, Laconia, and Gilford.

> "Some of the water quality issues of importance and concern to Lake Winnipesaukee are nutrients (particularly phosphorus loading and elevated nitrates), turbidity and bacteria. Elevated nutrients can be attributed to soil erosion from natural and developmental activities, loss of protective riparian buffers, poorly maintained septic systems and runoff from fertilized agricultural fields and lawns." (LWWA, 2006: "Tributary Monitoring in the Winnipesaukee Watershed")

The focus of the subwatershed management plan for Meredith, Paugus, and Saunders Bays is phosphorus loading from land based activities, with the goal of protecting the lake's water quality by implementing best management practices that will reduce or limit phosphorus inputs to the lake. It is hoped that the communities will establish local water quality goals for phosphorus for each of the three bays involved in the study. In order for the communities to make informed decisions about setting a local water quality goal for phosphorus, water quality data is needed to determine the current in-lake phosphorus levels.

The water quality of Lake Winnipesaukee has been monitored for over two decades through UNH's NH Lakes Lay Monitoring Program (LLMP). This program has provided worthwhile data for long-term trend analysis of the lake's water quality; however the three subwatersheds in this study have not had consistent monitoring occur in the last decade due to either lack of volunteers and/or financial resources. The Lakes Region Planning Commission contracted with North Country Resource Conservation & Development Area Council, Inc. to conduct the monitoring component of the Lake Winnipesaukee SubWatershed Management Plan project.

The data obtained from the 2009 water quality monitoring program provides a current assessment of the lake water quality; more specifically, the in-lake phosphorus levels for each of the three bays. The data will be used by the partners and communities to 1) establish local in-lake phosphorus goals, 2) as a benchmark to compare future water quality, and 3) as a comparison for measuring impacts from implementation of best management practices.

3. Sampling Plan Design and Rationale

North Country Resource Conservation & Development Area Council, Inc. (NCRC&D) in conjunction with NH Lakes Lay Monitoring Program (NH LLMP), and NHDES Volunteer River Assessment Program (VRAP) monitored the water quality of selected tributaries and in lake sites in Paugus Bay and Saunders Bay from June 2009 through September 2009. The water quality monitoring in Meredith Bay was conducted by the Town of Meredith and a NH LLMP volunteer monitor. Tributary and shallow site monitoring was not included in the 2009 sampling plan for Meredith Bay; however it was done in 2008, and one shallow site sampling event did occur during the 2009 sampling season.

As previously stated, the purpose of the project was to determine current in-lake phosphorus levels of the three study areas in the subwatershed management plan for the Lake Winnipesaukee Watershed. The data collected is necessary to assess nutrient loading and potential pollution threats within the three subwatershed areas.

3.1 Sampling Design and Site Maps

Selection of the tributaries was based on:

- Representation of various development patterns/land uses in subwatershed area
- Easy access for volunteers (bridges, culverts and right of ways)
- Contribute fairly large volume of output to lake
- Outlet near existing LLMP sites

Shallow sites were selected near the outlets of tributaries, coves, ponds or lakes that contribute large volumes to the lake to possibly correlate tributary nutrient loading to the near shore nutrient data.
Deep lake sites either represent historical LLMP sites, NHDES established sites, or were added to provide a more comprehensive assessment of a bay area.

Station identification codes (NH LLMP site codes as well as NHDES site codes), locations, and rationale for selection are summarized in Tables 3-5. Sampling locations are displayed in Figures 2-4.
Although North Country RC&D did not design or conduct the sampling for Meredith Bay, the sampling plan and results are being included in this report to provide data for the subwatershed plan.

Table 3: Meredith Bay Sampling Locations

NH DES STATIONID	UNH ID	STATNAME/DESCR	STATTYPE	RATIONALE/DESCRIPTION	COMMENTS
Wme01BL	1 Boat Ramp	WINNI, MEREDITH-1 BOAT RAMP (deep)	LAKE/POND	Embayed area near boat launch	active 2009
Wme02CL	2 Church Point	WINNI, MEREDITH-2 CHURCH PT (deep)	LAKE/POND	Point where inner bay area begins to open up to larger bay area	active 2009
Wme02ML	2 MerBay	WINNI, MEREDITH-2 MERBAY (deep)	LAKE/POND	Deep lake site downstream of Wme02CL	active 2009
WINMERD		WINNI, MEREDITH BAY DEEP	LAKE/POND	Deep lake site middle of Meredith Bay	Established NHDES deep lake site sampled at spring overturn on 4/2/10
	Hawkins Brook shallow	WINNI, MEREDITH – Hawkins Brook shallow	LAKE/POND	Shallow site near outlet of Hawkins Brook	sampled in 2008
	Mills Falls outlet shallow	WINNI, MEREDITH – Mills Falls canal outlet shallow	LAKE/POND	Shallow site near outlet of Mills Falls (Lake Waukewan outflow)	sampled in 2008
	Neal Brook shallow	WINNI, MEREDITH – Neal Brook shallow	LAKE/POND	Shallow site near outlet of Neal Brook on west side of middle area of bay	sampled in 2008
	Wagon Wheel shallow	WINNI, MEREDITH – Wagon Wheel shallow	LAKE/POND	Shallow site near outlet of Wagon Wheel Brook on east side, north of Wme02ML	sampled in 2008
	Mead Brook shallow	WINNI, MEREDITH – Mead Brook shallow	LAKE/POND	Shallow site near outlet of Mead Brook – end of Meredith Neck Road	sampled in 2008

01-HAW	Me1	WINNI, MEREDITH – Hawkins Brook	TRIBUTARY	Commercial development, runs by town transfer station	sampled in 2008
02-MFB	Me2	WINNI, MEREDITH – Mills Falls canal	TRIBUTARY	Outflow of Lake Waukewan	sampled in 2008
01-NBK		WINNI, MEREDITH – Neal Brook	TRIBUTARY	Seasonal and year round Residences	sampled in 2008
01-XMB		WINNI, MEREDITH – Wagon Wheel	TRIBUTARY	Seasonal and year round Residences	sampled in 2008
01-MBK		WINNI, MEREDITH – Mead Brook	TRIBUTARY	Seasonal and year round Residences	sampled in 2008

Figure 2: Meredith Bay near shore and deep lake sampling locations

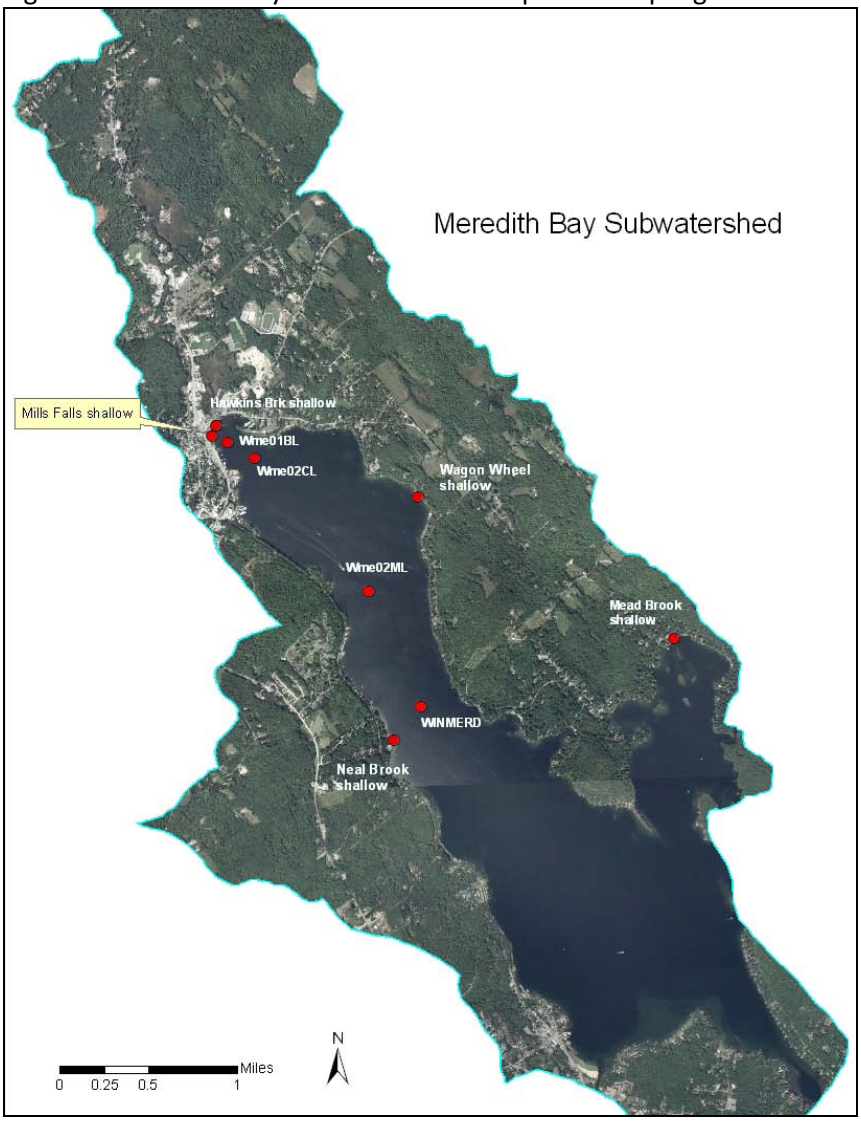

Table 4. Paugus Bay Sampling Locations

NH DES STATION ID	STATNAME/ DESCRIPTION	STATTYPE	RATIONALE/DESCRIPTION
BAY-029	MIDDLE PAUGUS BAY	LAKE/POND	UPSTREAM OF LACONIA WATER WORKS INTAKE
PAULAC1D	PAUGUS BAY - STATION 1 DEEP SPOT	LAKE/POND	DEEP LAKE SITE
LRPCPBMC1	PAUGUS BAY - MOULTON COVE SHALLOW	LAKE/POND	NEAR OUTLET OF MOULTON COVE, POTENTIAL LARGE VOLUME INPUT TO BAY
LRPCPBPC1	PAUGUS BAY - PICKEREL COVE SHALLOW	LAKE/POND	NEAR OUTLET OF PICKEREL COVE, SOURCE OF LARGE VOLUME INPUT TO BAY
LRPCPBLC1	PAUGUS BAY - LANGLEY COVE SHALLOW MIDDLE OF LANGLEY COVE	LAKE/POND	COVE WITH MILFOIL INFESTATION
LRPCPBBB1	PAUGUS BAY - BLACK BRK SHALLOW	LAKE/POND	SHALLOW SITE NEAR SPINNAKER COVE AND OUTLET OF BLACK BROOK. MILFOIL ISSUE
OUT-001	OUTFALL PIPE OF STORM DRAIN AT END OF MASS AVE. SOUTHWEST SIDE OF BAY	OUTFALL	DENSE RESIDENTIAL AREA
TRIB-011	STREAM DISCHARGES THROUGH A PIPE ADJACENT TO RAILROAD TRACKS, NEAR INTERSECTION PAUGUS PARK RD AND NORTH ST	TRIBUTARY	TRIBUTARY RUNS THROUGH GOLF COURSE POTENTIAL SOURCE PESTICIDES, FERTILIZERS
TRIB-012	DRAINAGE DITCH ADJACENT TO RAILROAD TRACK, NORTH ON PAUGUS PARK ROAD.	TRIBUTARY	POTENTIAL SECOND TRIBUTARY COLLECTING RUNOFF FROM GOLF COURSE
TRIB-013A	UPSTREAM OF OUTERBRIDGE DRIVE IN SOUTH DOWN DEVELOPMENT	TRIBUTARY	RUNOFF FROM DENSE RESIDENTIAL DEVELOPMENT
TRIB-014	OUTLET OF PONDS TO PAUGUS BAY THROUGH SOUTH DOWN (WEST SIDE OF BAY)	TRIBUTARY	DETENTION PONDS RECEIVING TRIBUTARY FLOW THROUGH SOUTH DOWN COMMUNITY BEFORE OUTLET TO BAY
TRIB-016	PAUGUS BAY STATE FOREST TRIBUTARY, NORTHWEST SIDE OF BAY	TRIBUTARY	REPRESENTS FORESTED LAND USE – MAY BE USED AS REFERENCE SITE
TRIB-018	INLET TO PICKEREL COVE –NORTHWEST SIDE OF BAY	TRIBUTARY	TRIBUTARY DRAINS LARGE WETLAND AREA
TRIB-019	OUTLET OF PICKEREL COVE, NORTHWEST SIDE OF BAY	TRIBUTARY	SEASONAL & YEAR ROUND HOMES. POTENTIAL TO CONTRIBUTE LARGE VOLUME OF FLOW TO BAY
BB1	BLACK BROOK-1, UPSTREAM SIDE OF CULVERT ENTRANCE TO WALMART	TRIBUTARY	OUTLET OF LILY POND
TRIB-21	BLACK BROOK-GILFORD PLAZA, SOUTHEAST SIDE OF BAY (behind CVS)	TRIBUTARY	RUNOFF FROM LARGE COMMERCIAL AREAS. SITE ADJACENT TO REMEDIATED LEAKING UNDERGROUND GASOLINE TANK SITE (FORMER GAS STATION
TRIB-22	OUTLET OF BLACK BROOK, UNION AVE, SOUTHEAST SIDE OF BAY	TRIBUTARY	TRIBUTARY FLOWS ALONG ROUTE 11, AND UNION AVE. RUNOFF FROM LARGE COMMERCIAL AND IMPERVIOUS AREAS
TRIB-24	LANGLEY BROOK, EAST SIDE OF PAUGUS BAY, EMPTIES INTO LANGLEY COVE. DRAINS LARGE WETLAND UPSTREAM	TRIBUTARY	STREAM HAS ORIGIN IN LARGE WETLAND, TRAVELS MOSTLY THROUGH FORESTED AREA UNTIL NEARS OUTLET - RESIDENTIAL AREAS
TRIB-25	UNNAMED TRIB, INLET TO MOULTONS COVE, UPSTREAM SIDE OF HILLIARD RD.	TRIBUTARY	NEW DEVELOPMENT PROPOSED UPSTREAM.

Figure 3. Paugus Bay Subwatershed Sampling Locations – Tributary, Near Shore, and Deep Lake

Table 5. Saunders Bay Sampling Locations

STATIONID	UNH ID	STATNAME/DESCRIPTION	STATTYPE	RATIONALE/DESCRIPTION
WGI02GL	GI2	WINNI, GOV. ISL-GI2	LAKE/POND	Shallow site southwest side of Governor's Island
WGI05GL	GI5	WINNI, GOV. ISL-GI5	LAKE/POND	Shallow site southeast side of Governor's Island
WGI0BGL	GIB	WINNI, GOV. ISL-GIB	LAKE/POND	Established LLMP deep site
WGI0CGL	GIC	WINNI, GOV. ISL-GIC	LAKE/POND	Established LLMP deep site
WGI0DGL	GID	WINNI, GOV. ISL-GID	LAKE/POND	Established LLMP deep site
WINGGILD		LK WINNIPESAUKEE, GOV ISLAND-DEEP SPOT	LAKE/POND	Established NHDES deep site
LRPCSB2	SB2	WINNI, SAUNDERS BAY-STATION 2	LAKE/POND	middle of Saunders Bay
LRPCSB3	SB3	WINNI, SAUNDERS BAY-STATION 3, shallow	LAKE/POND	outlet of Mountain View Marina
LRPCSB4	SB4	WINNI, SAUNDERS BAY-STATION 4 shallow	LAKE/POND	near outlet of Adder Hole Brook
LRPCSB5	SB5	WINNI, SAUNDERS BAY-STATION 5 shallow	LAKE/POND	near outlet of unnamed trib 01-XSB
04-GSK	Gi1	GUNSTOCK BROOK - OLD LAKESHORE RD	TRIBUTARY	empties into Mountain View marina
06-GSK		GUNSTOCK BROOK - HENDERSON RD	TRIBUTARY	upstream site from 04-GSK
12-GSK		GUNSTOCK BROOK - HOYT RD	TRIBUTARY	first road crossing of stream downstream from sand & gravel ops
01-AHB		ADDER HOLE BROOK	TRIBUTARY	brook and large wetland flows behind B'Maes and along Harris Shore Rd.
02-AHB		ADDER HOLE BROOK	TRIBUTARY/ WETLAND	sampling at foot bridge behind Fireside Inn
01-XSB		UNNAMED STREAM	TRIBUTARY	unnamed stream flows from wetland near abandoned landfill -outlets near Laconia/Gilford T/L

Figure 4. Saunders Bay Sampling Locations

3.2 Sampling Parameters and Rationale

Tributaries were monitored for pH, turbidity, temperature, dissolved oxygen, conductivity, total phosphorus, nitrite/nitrates and chlorides.

Near shore and deep lake sites were monitored for water clarity, total phosphorus, chlorophyll α, and dissolved color.

Table 6. Parameters Measured and Rationale

Parameter		Rationale
	State WQ Standard	**Field or In Situ Test**
pH	6.5-8.0	pH affects the chemical and biological processes in water which is important to the survival and reproduction of fish and aquatic life. A high pH indicates alkaline conditions, and a low pH indicates acidic conditions.
Turbidity	Shall not exceed naturally occurring conditions	A measurement of the amount of suspended particles in the water. High turbidity affects water clarity, aquatic life, and is an indication of potential sediment loading.
Dissolved Oxygen	5 mg/L and >75% saturation	The presence of dissolved oxygen is vital to bottom-dwelling organisms as well as fish and amphibians. Aquatic plants and algae produce oxygen in the water during the day, and consume oxygen during the night. Bacteria utilize oxygen both day and night when they process organic matter into smaller and smaller particles.
Conductivity	NA	High values may indicate excess levels of nutrients, salts, and/or metals.
Temperature	NA	Critical parameter for aquatic life. Temperature is impacted by lack of vegetation (shade), percent of impervious surface contributing stormwater, rate of flow, etc.
Water Clarity		Secchi disk depth is a measure of the water transparency. Transparency values greater than 4 meters are considered typical of clear, unproductive lakes.
Lab Analysis		
Chloride	Acute – 860 mg/L Chronic – 230 mg/L	Excess levels can indicate the presence of salts from road salt or such things as fertilizers. Excess levels may be toxic to aquatic life
Nitrate/nitrite	NA	Excessive levels can indicate the presence of fertilizers, herbicides, and/or pesticides, and human or animal waste.
Total Phosphorus	8 ug/L for Oligotrophic class	Excessive levels promote algal growth. Phosphorus is found in detergents, fertilizers, decay of plant material, and sediments.
Chlorophyll α	<3.3 ug/L	Measurement of the standing crop of phytoplankton. Used as indication of productivity of a waterbody.
Dissolved Color		The dissolved color of lakes is generally due to dissolved organic matter from humic substances. Dissolved color is measured on a comparative scale that uses standard chloroplatinate dyes and is designated as a color unit, or CPU. Water begins to display a visible yellow color at about 20 CPUs, while a distinct color is visible at 40 units. Very tea colored wetlands would be in the 100's (personal communication with Bob Craycraft, UNH CFB)

Notes:

mg/L = milligrams per liter
ug/L = micrograms per liter
NA = Not applicable
CPU = chloroplatinate units

3.3 Sampling Methods

Detailed sampling methods for tributary sampling can be found in the NHDES Volunteer River Assessment Program Quality Assurance Project Plan, and for lake sampling in the NH LLMP Quality Assurance Project Plan. Efforts were made to collect both tributary and lake samples on a biweekly basis beginning the end of June 2009. Five to six samples were collected at each sampling location.

Water quality monitoring was conducted from June to September for tributaries. In-situ measurements of water temperature, dissolved oxygen, pH, turbidity and specific conductance were taken using handheld meters. Samples for total phosphorus, nitrate/nitrite, and chloride were taken using bottles supplied by the NHDES laboratory and were stored on ice during transport from the field to the lab.

In lake sampling was conducted from July to September 2009 on a biweekly basis for Paugus and Saunders Bays. Sampling in Meredith Bay was done approximately on a weekly basis beginning in mid July. Water samples were collected from the epilimnion (upper surface layer). Phosphorus samples for Meredith Bay were processed by UNH's lab. Phosphorus samples for Paugus and Saunders Bays were taken initially to the Plymouth State University lab for analysis. The procedure was changed in the mid to late sampling season due to instrumentation difficulties; and phosphorus samples were then taken directly to the NH DES lab for analysis.

In lake water samples collected, filtered, and processed for chlorophyll α and dissolved color were transported to UNH Center for Freshwater Biology lab for analysis for all three subwatersheds.

4. Results and Analysis

This section provides a summary of the results for near shore, and in lake sampling for Meredith, Paugus, and Saunders Bay. The raw lab analyses are provided in Appendices B and C. As mentioned earlier, the NHDES VRAP report is provided in Appendix A for the results on the tributary monitoring.

The five month period of May through September 2009 was the seventeenth wettest on record according to the National Oceanic and Atmospheric Administration with 22.89" of precipitation. The month of June was extremely wet, with a total precipitation of 7.62 inches of rain recorded at the Lakeport station; 4.01 inches above normal precipitation (http://www.erh.noaa.gov/er/gyx/climo/rr6jun09.html). In July, the Lakeport station recorded 8.11 inches rainfall, which was 3.93 inches above normal precipitation. Frequent and large rain events produce increased runoff from the watershed potentially resulting in higher in lake phosphorus concentrations.

The discussion and concepts of lake measurements presented is excerpted from the NH Lakes Lay Monitoring Program (NH LLMP).

Water Clarity (*excerpted from NH LLMP*)

"Water Clarity is measured by observing the depth at which the secchi disk disappears from view. The deeper the depth at disappearance, the more transparent the lake water is, allowing for greater light penetration. Secchi disk measurements are taken at the deep lake sites; depth readings greater than 4 meters are considered typical of clear, unproductive lakes while values less than 2.5 meters are generally indicative of highly productive lakes."

Chlorophyll α (Chl α)(*excerpted from UNH NH LLMP*)

"Chlorophyll α concentration is a measurement of the standing crop of phytoplankton and is often used to classify lakes into categories of productivity called trophic states. Eutrophic lakes are highly productive with large concentrations of algae and aquatic plants due to nutrient enrichment. Characteristics include accumulated organic matter in the lake basin and lower dissolved oxygen in the bottom waters. Summer chlorophyll α concentrations average above 7 mg m^3 (7 milligrams per cubic meter or 7 parts per billion). Oligotrophic lakes have low productivity and low nutrient levels and average summer chlorophyll α concentrations are generally less than 3 mg m^3. These lakes generally have cleaner bottoms and high dissolved oxygen levels throughout."

Dissolved Color (*excerpted from UNH NH LLMP*)

"The dissolved color of lakes is generally due to dissolved organic matter from humic substances, which are naturally occurring polyphenolic compounds leached from decayed vegetation. Highly colored or "stained" lakes have a "tea" color. Such substances do not threaten water quality except as they diminish sunlight penetration into deeper waters. Increases in dissolved water color can be an indication of increased development within the watershed as many land clearing activities (construction, deforestation, and the resulting increased run-off) add additional organic material to lakes. Natural fluctuations of dissolved color occur when storm events increase drainage from wetland areas within the watershed.

As suspended sediment is a difficult and expensive test to undertake, both dissolved color and chlorophyll α data are important when interpreting the secchi disk transparency.

Dissolved color is measured on a comparative scale that uses standard chloroplatinate dyes and is designated as a color unit or ptu. Lakes with color below 10 ptu are very clear, 10 to 20 ptu are slightly colored, 20 to 40 ptu are lightly tea colored, 40 to 80 ptu are tea colored and greater than 80 ptu indicates highly colored waters. Generally the majority of New Hampshire lakes have color between 20 to 30 ptu."

Total Phosphorus (*excerpted from NH LLMP*)

> "Of the two nutrients most important to the growth of aquatic plants, nitrogen and phosphorus, it is generally observed that phosphorus is the more limiting to plant growth, and therefore the more important to monitor and control. Phosphorus is generally present in lower concentrations, and its sources arise primarily through human related activity in the watershed. Nitrogen can be fixed from the atmosphere by many bloom-forming blue-green bacteria, and thus is difficult to control. The total phosphorus includes all dissolved phosphorus as well as phosphorus contained in or adhered to suspended particulates such as sediment and plankton. As little as 10 ppb (parts per billion) of phosphorus in a lake can cause an algal bloom.

Generally, in more pristine lakes, phosphorus values are higher after spring melt when the lake receives the majority of runoff from its surrounding watershed. The nutrient is used by the algae and plants which in turn die and sink to the lake bottom causing surface water phosphorus concentrations to decrease as summer progresses. Lakes with nutrient loading from human activities and sources (agriculture, logging, sediment erosion, septic systems, etc.) will show greater concentrations of nutrients as the summer progresses or after major storm events."

Total phosphorus concentrations are one of the initial focuses of the watershed management plan, as phosphorus is considered the most limiting nutrient for plant growth in freshwater. New Hampshire has recently set nutrient water quality standards for lakes and ponds based on trophic status. The table below summarizes the criteria developed for supporting aquatic life designated use. Increased levels of phosphorus result in more nutrient available for plant growth; which can be correlated through the measurement of Chl α.

Table 7. Total Phosphorus (TP) and Chlorophyll α Criteria for Aquatic Life Designated Use

Trophic State	TP (ug/L)	Chl α(ug/L)
Oligotrophic	< 8.0	< 3.3
Mesotrophic	<= 12.0	<= 5.0
Eutrophic	<= 28	<= 11

4.1 Meredith Bay

Water Clarity

Secchi disk measurements were only taken at the deep lake sites. The average reading for each of the three sites was above 4.0 meters, with the shallower site, "1 Boat Ramp", located nearer to shore having the lowest secchi disk readings.

Table 8. Water Clarity Data Summary for the Meredith Bay deep lake sampling stations

UNH Station ID	# Samples Collected	Seasonal Average (meters)	Data Range (m)
1 Boat Ramp	7	6.3	5.1 – 7.4
2 Church Pt	8	7.3	6.3 – 8.2
2 MerBay	5	7.8	6.8 – 8.2

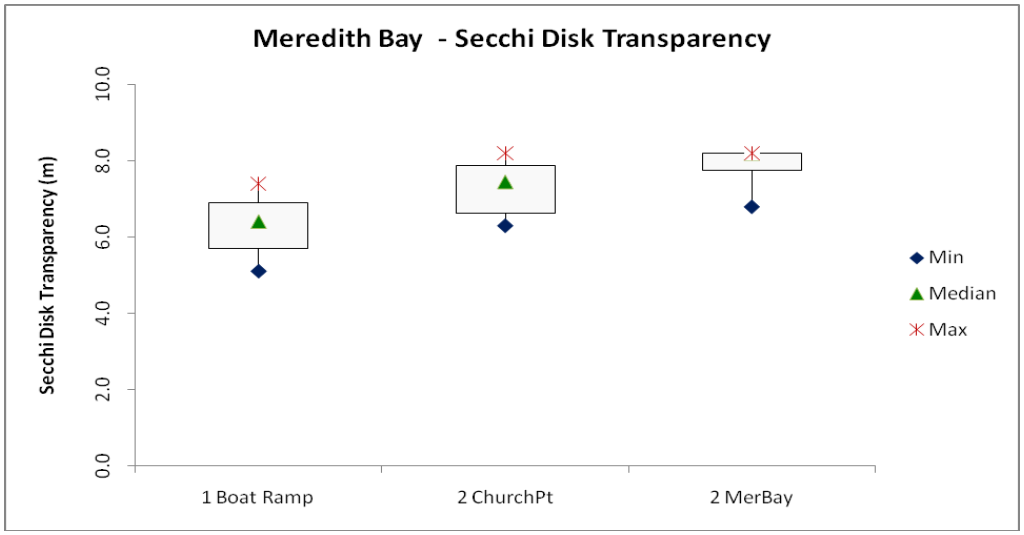

Figure 5. Box and whisker plot showing secchi disk transparency comparison among deep lake stations during the summer of 2009 sampling season. The box area depicts the lower 25th and upper 75th percentile of values.

Dissolved Color

Table 9. Dissolved Color Data Summary for Meredith Bay

Station ID	#Samples Collected	Mean Dissolved Color (CPU)	Data Range
1 Boat Ramp	8	11.3	7.8 – 15.6
2 Church Pt	8	9.2	7.8 – 12.2
2 MerBay	5	8.2	7.0 – 9.6

Total Phosphorus (TP) and Chlorophyll α (Chl α)

The town of Meredith sampled lake sites only in 2009. The first sampling date of the season, July 17th, included the five shallow near shore sites; however, the town decided to discontinue near shore sampling for the remainder of the sampling season.

Table 10. Total Phosphorus and Chlorophyll α data summary for Meredith Bay

UNH Station ID	#Samples Collected	Median TP (ug/L)	Data Range	Mean Chl α	Data Range
1 Boat Ramp	8	6.4	5.3 – 12.1	2.7	1.8 – 3.8
2 Church Pt	8	6.7	4.6 – 11.5	2.1	1.6 – 2.7
2 MerBay	5	6.9	4.7 – 9.5	1.9	1.4 – 2.3
Hawkins Brook shallow	1		8.1		5.2
Mead Brook shallow	1		7.1		1.7
Neal Brook shallow	1		8.9		2.4
Wagon Wheel shallow	1		7.6		2.3
Waukewan outlet	1		8.0		2.6

Note: Total Phosphorus and chlorophyll α were processed and analyzed at the UNH lab.

The seasonal total phosphorus concentrations were generally below the state standard of 8 ug/L; however the first sampling event on July 17 resulted in the highest TP measurement observed for "1 Boat Ramp" of 12.1 ug/L and the second highest measurement for "2 Church Pt"; of 8.5 ug/L. The single sampling event for the shallow sites on July 17th resulted in total phosphorus levels from 7.1 to 8.9 ug/L.

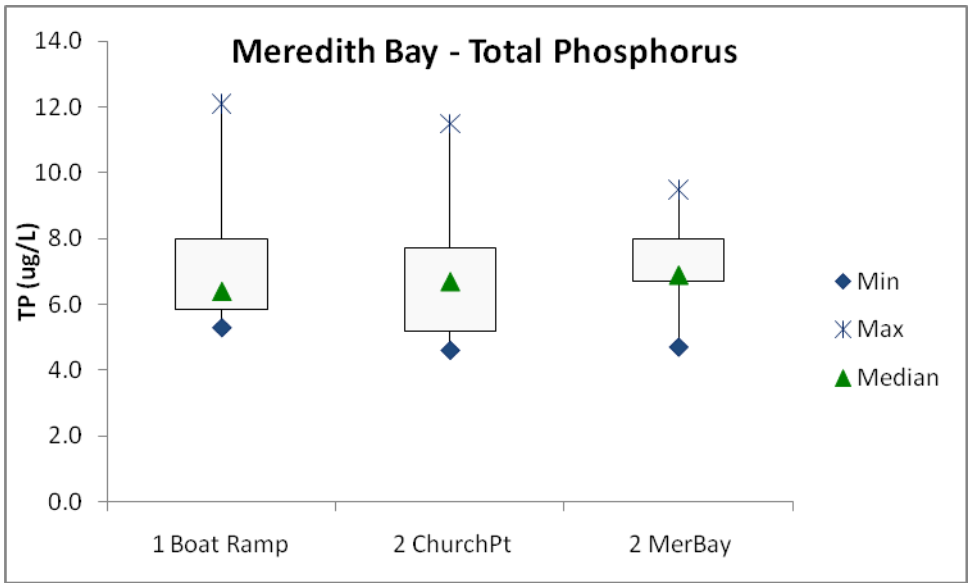

Figure 6. Box and whisker plot showing total phosphorus comparison among deep lake stations in Meredith Bay for the summer 2009 sampling season. The box area depicts the lower 25th and upper 75th percentile of values.

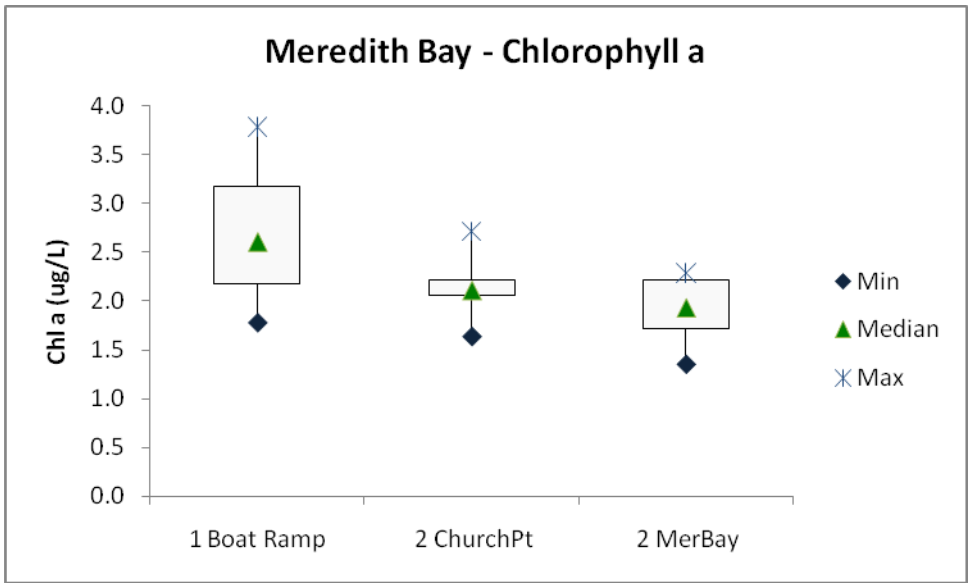

Figure 7. Box and whisker plot showing chlorophyll a comparison among deep lake stations in Meredith Bay for the summer 2009 sampling season. The box area depicts the lower 25th and upper 75th percentile of values.

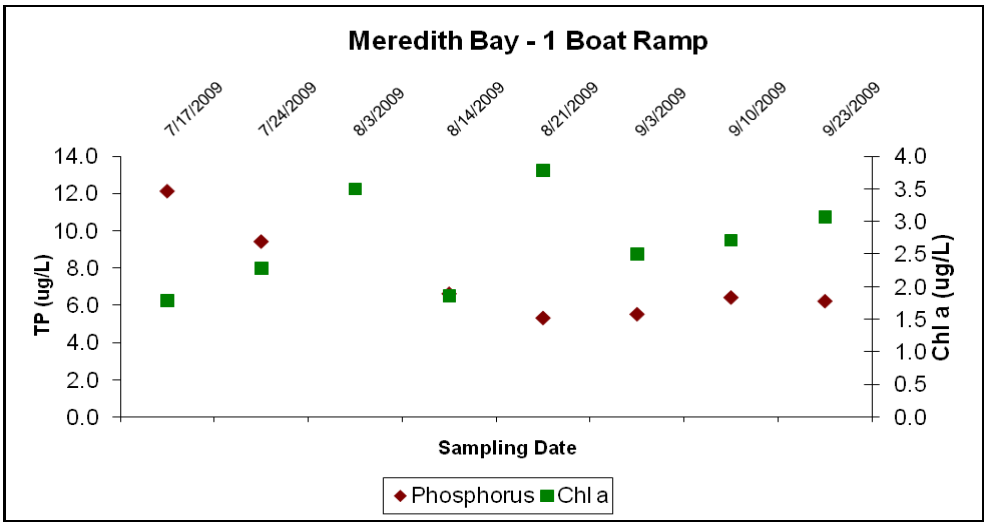

Figure 8. 2009 Total Phosphorus and Chl a seasonal data for Station "1 Boat Ramp"

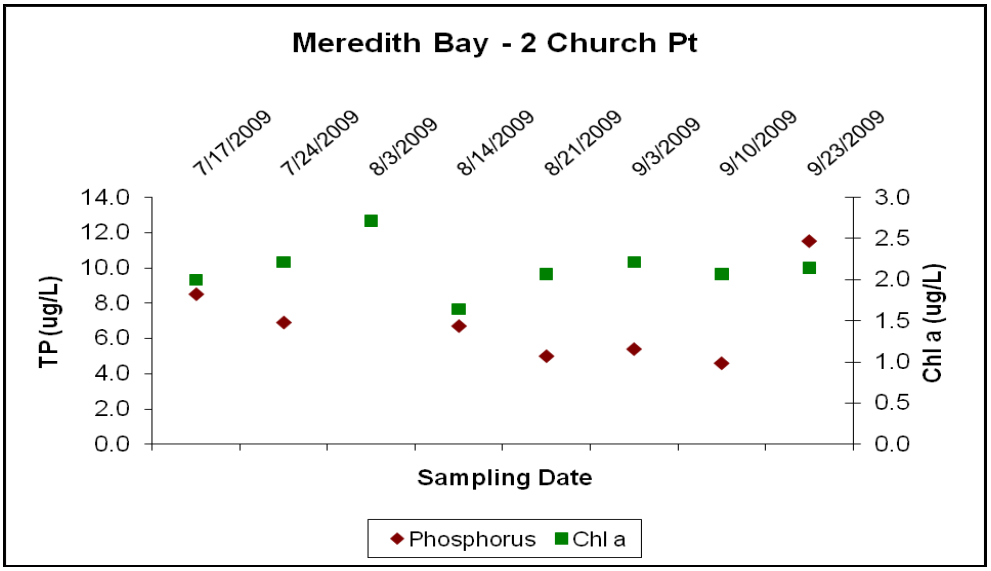

Figure 9. 2009 Total Phosphorus and Chl a seasonal data for Station "2 Church Pt"

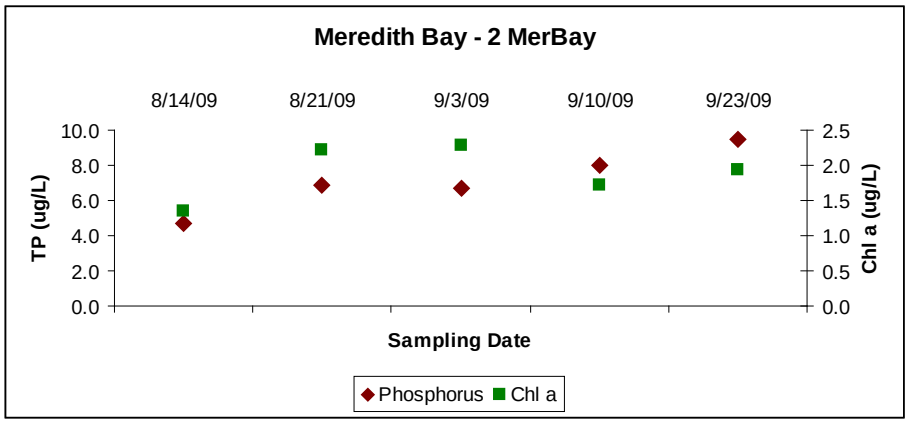

Figure 10. 2009 Total Phosphorus and Chl a seasonal data for Station "2 MerBay"

4.2 Paugus Bay

Sampling in Paugus Bay was conducted beginning in June for tributary monitoring and July for in lake stations. The results for the in lake phosphorus, chlorophyll α, dissolved color and water clarity will be reported here. The detailed results and report for the tributary sampling can be found in Appendix A.

Water Clarity

Secchi disk measurements were only taken at the deep lake sites. Station "Bay029" is located approximately in the middle of Paugus Bay, site "PAULAC1D" is upstream from "Bay029", and represents the deepest area in the bay. At least 5 readings/measurements were taken at each site; both sites were above 4.0 meters for all measurements.

Table 11. Water Clarity data summary for the Paugus Bay Deep lake sampling stations

Station ID	# Samples Collected	Seasonal Average (meters)	Data Range (meters)
BAY029	6	9.1	8.3-10.3
PAULAC1D	5	8.8	7.3-10.3
PAULAC2D	1		7.2

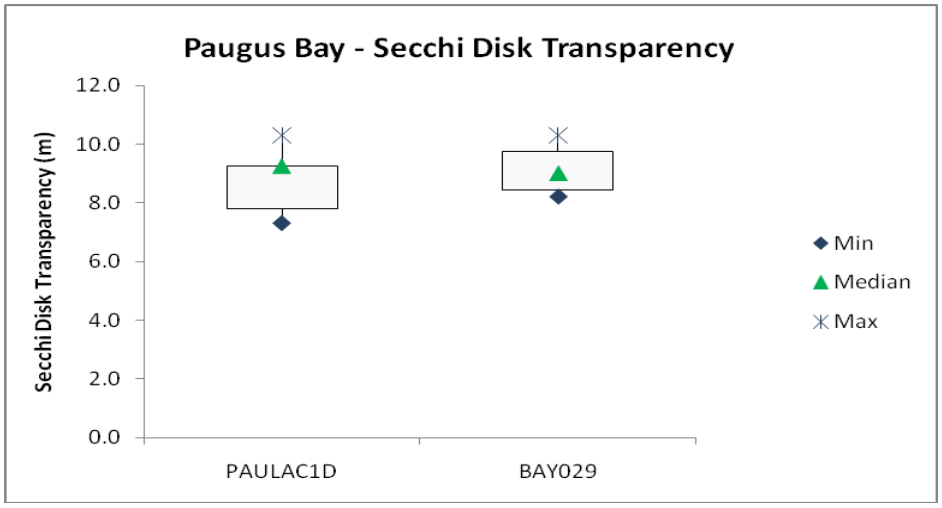

Figure 11. Box and whisker plot showing secchi disk transparency comparison among the two deep lake stations on Paugus Bay sampled during the summer of 2009. The box area depicts the lower 25th and upper 75th percentile of values.

Dissolved Color

Water samples were analyzed for dissolved color by the UNH lab. The mean dissolved color for all stations was below 20 CPUs, and below 10 CPUs for the majority of sites indicating relatively clear water. The four shallow sites showed the highest coloration, which is probably influenced by the vegetation found at those sites.

Table 12. Dissolved Color data summary for Paugus Bay

Station ID	#Samples Collected	Mean Dissolved Color (CPU)	Data Range
PAULAC1D	5	7.5	7.0 – 8.7
PAULAC2D	1		9.6
BAY029	5	7.3	6.1 – 8.7
LRPCPBBB1	5	7.8	7.0 – 9.6
LRPCPBLC1	5	10.8	6.1 – 19.1
LRPCPBMC1	5	8.0	4.3 – 13.0
LRPCPBPC1	5	15.1	6.1 – 33.9

Total Phosphorus (TP) and Chlorophyll α (Chl α)

Water samples collected in Paugus Bay and Saunders Bay were taken to the Center for the Environment lab at Plymouth State University (PSU) for phosphorus analysis. As a key partner in the Winnipesaukee Watershed Management Plan project, PSU agreed to analyze 100 water samples at no cost to the project. Unfortunately, the head staff person at PSU's lab left employment as sampling began, and a NH DES intern was brought in to run the lab on a part time basis. During the sampling season problems arose with the instrument that analyzes total phosphorus, requiring samples to be brought to the NHDES lab in Concord.

As mentioned previously, results obtained from the Plymouth State lab were not consistent with expectations. The summer season was an especially rainy one, and most of the lab data results received from PSU showed no phosphorus detected or below detectable limit of 0.002 mg/L. Compared to results obtained from the Meredith Bay sampling, and personal communication with the UNH lab on other lake data, it appears that the PSU lab data may not be valid.

Table 13. Total Phosphorus and Chlorophyll a data summary for Paugus Bay

Station ID	#Samples Collected	Median TP (ug/L)	Data Range*	Mean Chl α (ug/L)	Data Range
PAULAC1D	5	6.0	ND, 6.0, 6.4, 5.2	2.0	1.6 – 2.3
PAULAC2D	1	----	6.6		1.6
BAY029	5	6.1	ND, 6.0, 6.1, 7.7	2.0	1.6 – 2.6
LRPCPBBB1	5	5.6	ND, 5.9, 5.3	2.0	1.4 – 3.4
LRPCPBLC1	5	----	ND, 5.6	2.2	1.4 – 3.8
LRPCPBMC1	5	5.4	ND, 5.6, 5.1	1.7	1.1 – 2.0
LRPCPBPC1	5	----	ND	2.0	1.4 – 2.4

Note:

ND = Not detected, below detectable limit

* Data range reports all phosphorus results received.

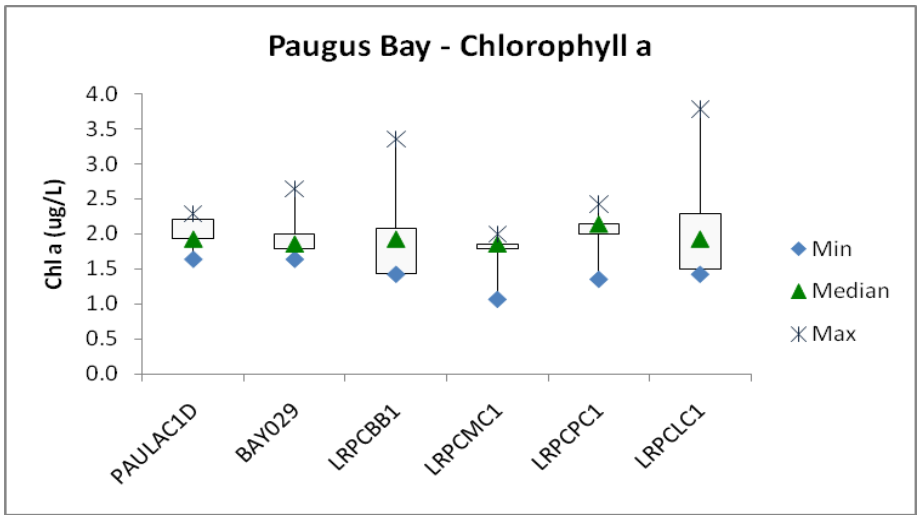

Figure 12. Box and whisker plot showing the comparison of Chlorophyll α among the stations in Paugus Bay for the 2009 summer sampling season. The box area depicts the lower 25th and upper 75th percentile of values.

The graphs below show the total phosphorus (TP) and chlorophyll a data for the two deep lake sites by sampling date. TP values reported as below detection or not detected are not shown in the graphs.

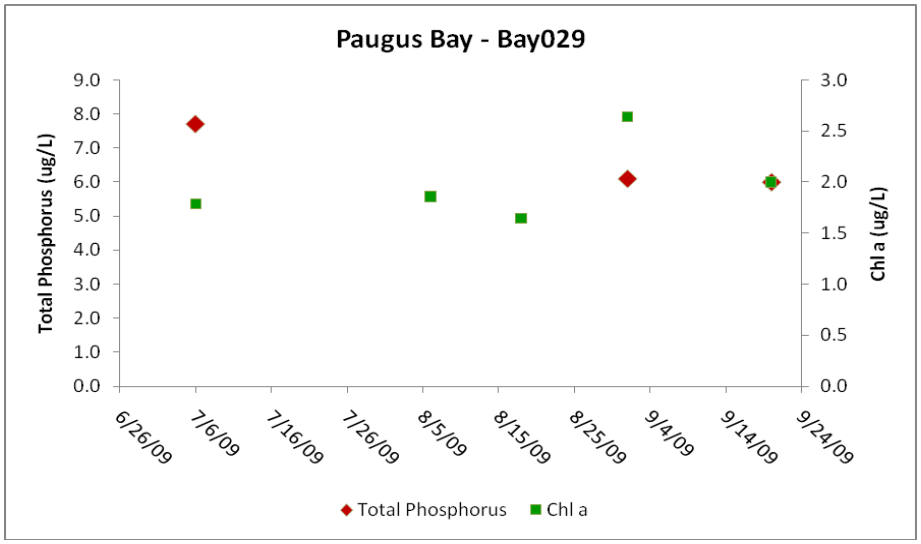

Figure 13. 2009 Total Phosphorus and Chl α seasonal data for Station "Bay029"

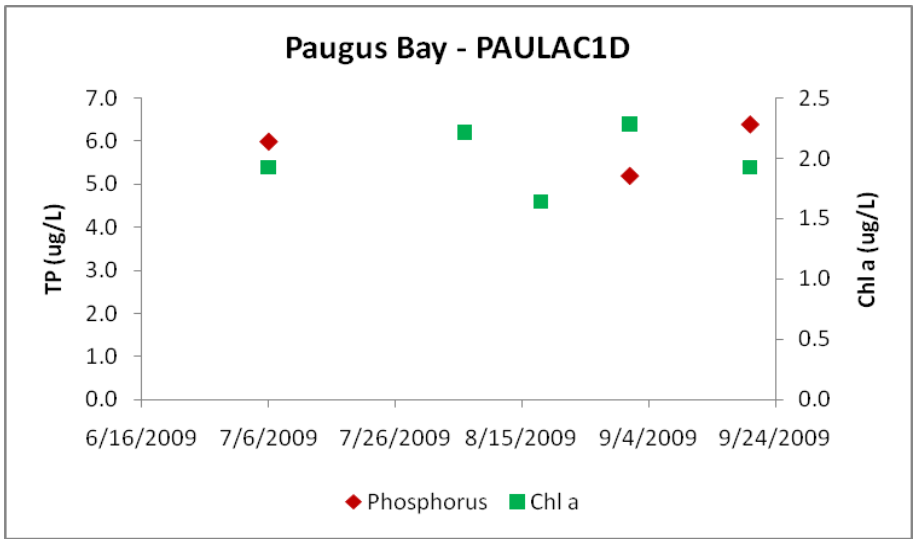

Figure 14. 2009 Total Phosphorus and Chl a seasonal data for Station "PAULAC1D"

4.3 Saunders Bay

Sampling in Saunders Bay was conducted beginning in July for in-lake stations. The results for the in lake phosphorus, chlorophyll α and water clarity will be reported here. Tributary monitoring results can be found in Appendix A.

Water Clarity

Secchi disk measurements were only taken at the deep lake sites. The four deep lake sites all had readings above 9.0 m for the seasonal average. Station "WGI0CGL", the deepest of the four sites at approximately 90'; only had two readings taken due to the difficulty encountered anchoring at this site.

Table 14. Water Clarity data summary for the Saunders Bay deep lake sampling stations

Station ID	# Samples Collected	Seasonal Average (meters)	Data Range (m)
LRPCSB2	6	9.4	8.5 – 10.0
WGI0DGL (GID)	6	9.5	8.4 – 11.2
WGI0CGL (GIC)	2	9.9	9.3, 10.6
WGI0BGL (GIB)	5	10	9.3 – 11.6

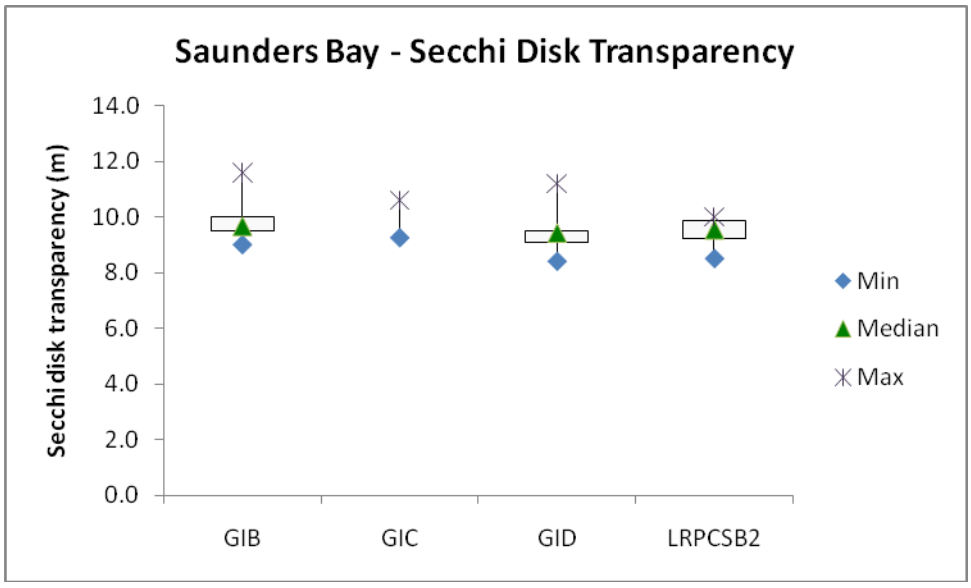

Figure 15. Box and whisker plot showing comparison of secchi disk transparency among the deep lake stations in Saunders Bay for the 2009 sampling season. The box area depicts the lower 25th and upper 75th percentile of values.

Dissolved Color

Water samples were analyzed for dissolved color by the UNH lab.

Table 15. Dissolved Color data summary for Saunders Bay

Station ID	#Samples Collected	Mean Dissolved Color (CPU)	Data Range
WGI0BGL (GIB)	5	8.0	7.0 – 9.6
WGI0CGL (GIC)	2	9.1	8.7, 9.6
WGI0DGL (GID)	6	7.7	6.1 – 8.7
WGI02GL (GI2)	6	7.5	6.1 – 9.6
WGI05GL (GI5)	6	7.7	7.0 – 8.7
LRPCSB2	6	7.2	5.2 – 8.7
LRPCSB3	6	9.8	7.8 – 13.0
LRPCSB4	6	9.1	7.8 – 11.3
LRPCSB5	5	7.3	6.1 – 8.7

Total Phosphorus (TP) and Chlorophyll α (Chl α)

Limited total phosphorus data was obtained for the 2009 sampling season in Saunders Bay shown in Table 16 below. However, chlorophyll α data, which was obtained for all sampling dates at all stations, shows the mean chl α value for both shallow and deep lake sites ranging from 1.3 to 2.0 ug/L.

Table 16. Total Phosphorus and Chlorophyll a data summary for Saunders Bay

Station ID	#Samples Collected	Median TP (ug/L)	Data Range	Mean Chl α (ug/L)	Data Range
WGI0BGL (GIB)	5		ND	1.9	1.6 – 2.3
WGI0CGL (GIC)	2		ND, 5.7	1.3	0.8, 1.9
WGI0DGL (GID)	6		ND, 6.3	1.9	1.3 – 3.2
WGI02GL (GI2)	6		ND	1.8	1.3 – 2.2
WGI05GL (GI5)	6		ND	1.5	0.8 – 2.3
LRPCSB2	6		ND, 5.4, 5.4	2.0	1.4 – 2.4
LRPCSB3	6		ND, 6.0	1.8	1.3 – 2.5
LRPCSB4	6		ND, 5.0	1.9	1.4 – 2.5
LRPCSB5	5		ND, 5.1	2.0	1.1 – 2.9

Note:
ND – not detected (below the detectable limit)

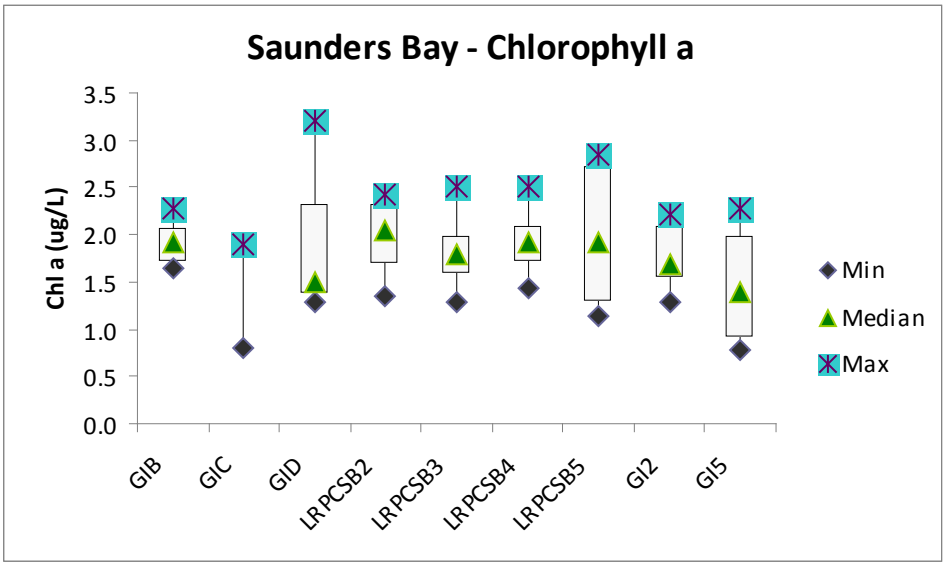

Figure 16. Box and whisker plot showing comparison of chlorophyll α data among stations in Saunders Bay for the 2009 sampling season. The box area depicts the lower 25th and upper 75th percentile of values.

5.0 Discussion

Water quality monitoring of near shore and deep lake sites was conducted during the 2009 summer season in order to acquire data regarding the water quality conditions of the Meredith Bay, Paugus Bay, and Saunders Bay subwatershed areas. A lack of existing water quality data for Paugus Bay and Saunders Bay highlighted the need for a monitoring component in the subwatershed management plan. Although policy decisions cannot be made based on one year's data, the data does provide an indication of where current phosphorus levels are within the three subwatershed bays.

Although phosphorus data was incomplete for Paugus and Saunders Bays, the limited results obtained indicate that the phosphorus and chlorophyll α values for the three subwatershed bay areas are in the acceptable range for an oligotrophic lake, classified as a high quality water; below 8.0 ug/L TP, and below 3.3 ug/L chlorophyll α (see Table 2).

Meredith Bay had the most complete phosphorus data for the sampling season. As can be seen in Figures 6 and 7, the range of phosphorus and chlorophyll α values decreased as the sampling station moved from near shore to the deeper lake site; however the median value for all three sites differed only by 0.2-0.3 ug/L. The two stations located in inner Meredith Bay had the highest phosphorus values during the season, 12.1 ug/L at 1 Boat Ramp, and 11.5 ug/L at 2 Church Pt.; although 1 Boat Ramp recorded its high value at the beginning of the sampling season, and 2 Church Pt. recorded its high value at the end of the season.

For Paugus Bay, the mean chlorophyll α value for all six sampling stations was fairly consistent, 2.0 ug/L for four of the six stations. The same similarity in chlorophyll α values was observed in Saunders Bay, where four deep lake sites and five shallow sites were sampled. It is unfortunate that phosphorus data were not obtained for all the sampling events, as one of the objectives of the study was to observe and quantify differences in phosphorus levels between near shore and deep lake sites.

6.0 Use of Study and Next Steps

The water quality monitoring conducted in 2009 for Meredith, Paugus, and Saunders Bays provides limited initial data for the communities to use in several ways;

- as a current assessment of the water quality
- as a benchmark to monitor changes in water quality as part of a long term trend analysis
- as a benchmark to compare water quality after implementation of best management practices and restoration of impaired sites

In order to use the data for the above purposes, it is recommended that the communities, volunteers, and sponsors, continue to monitor the bays each year as part of UNH's NH Lakes Lay Monitoring Program. Due to some of the issues encountered during 2009 with lab analyses, it is especially important that the monitoring continue for the near shore and deep lake sites to obtain accurate data in Paugus Bay and Saunders Bay.

As communities hope to be able to correlate land use with phosphorus loading to the lake, it is important to continue tributary monitoring in the three subwatersheds. Paugus Bay and Saunders Bay had active tributary monitoring programs in 2009; with anticipation that it will continue in the future.

To better quantify potential pollutant loads from tributaries, future monitoring should try to obtain flow data for each of the major tributaries in each subwatershed.

APPENDIX A

2009 Lake Winnipesaukee Tributaries Water Quality Report

APPENDIX B

Laboratory Data Results