OWEB Final Report: Grant 212-2033

Tenmile Lakes Basin Partnership

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Lists of Tables, Charts, Maps, & Photos

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Acknowledgements

The Tenmile Lakes Basin Partnership would like to thank the many contributors that assisted in designing and conducting the monitoring plan of this project, without whose cooperation, gaining a better understanding of watershed conditions would not have been possible.

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Technical Assistance

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Bob Hankins	Dean Muffett
Gary Wallace	Dennis Fritz
Jim Linwood	Elliott State Forest
Curt Haman	Brad Monson

Executive Summary

Tenmile Lakes are 303(d) listed for Aquatic Weeds and Algae, biocriteria, dissolved oxygen, and temperature. ODEQ and TLBP created a Water Quality Management Plan in 2007 to guide our efforts to meet our TMDL for weeds and algae as required by the Federal Clean Water Act. TMDLs will need to be developed for biocriteria (sedimentation), dissolved oxygen, and temperature.

The projects funded by OWEB and ODEQ with this grant started in the upper watershed with Baseline Tributary Monitoring in the summer followed by Storm Chasing in the winter. Both of these efforts resulted in the collection of baseline field parameter data, and Storm Chasing also collected nutrient and TSS data. We also conducted Continuous Stream Temperature Monitoring for several summers to determine if maximum high temperatures exceeded ODEQ biologically based numeric criteria, and if the temperature data could be used to identify priority areas for future restoration projects. As the water and sediments proceeded downstream, we collected Delta Building data at tributary mouths. Lake Sampling was done throughout every season. We sampled for nutrients and supporting field parameters at 5 standard sites and in the summer we also added grab sample sites as part of the Algae/Toxin Monitoring program. Data was shared with the Oregon Health Authority to manage Health Advisories for Harmful Algae Blooms (HABs). Sites were also set up at local boat launches to monitor for Invasive Species. Finally, Project Effectiveness Monitoring was conducted on watershed restoration projects that have been built throughout the basin.

Analysis of data collected under this grant, plus data accumulated since 2006, was initiated by compiling the 2006-2014 data. Although data results and analysis are included in each section, and are too extensive to list here, several findings were of note: The monthly average TP and TN levels in Tenmile Lakes show a rise beginning in late fall, a peak in winter, and then a steady decline throughout spring and early summer. This is what we might expect as the fall and winter rains bring nutrients down from the uplands, and then a decline in nutrients as the rains slacken off and algae increase in the spring and early summer to consume the free nutrients. What is unusual was the rise of nutrients in the summer season when there is an abundance of algae to consume them and the streams coming into the lake are nearly dry. These results indicate that future monitoring efforts to better characterize in-lake nutrient cycling would be beneficial.

We also conducted seasonal Trend analysis on the 2006-2011 data that showed a year to year decrease in levels of TP during the Fall/Winter/Spring season, but an upward trend in the summer season. From this data analysis we concluded that the rising TP levels are partly due to human activity, in particular, malfunctioning on-site septic systems. Other contributors may include sediments stored on the lake bottom, bank erosion, lawn and garden practices, and introduced fish. These high summer TP levels are a primary cause of the HAB outbreaks that we've seen in the past few years, and they fertilize the invasive species that are invading the shorelines in increasing numbers. When these large quantities of algae and macrophytes die, they settle to the bottom and decompose. The bacteria responsible for the decomposition use oxygen and, when the lake is thermally stratified, this can create anoxic conditions which promote the recycling of phosphorus from the benthic layer back into the water column. Both of these problems are the reason Tenmile Lakes are 303d listed for aquatic weeds and algae, and the reason we initiated the TMDL. Using the data collected by TLBP and ODEQ through grants such as this one, TLBP along with Tenmile Lakes Association, with support from the Coos County Board of Commissioners, and other local homeowners, have initiated an effort to form a Water Improvement District with the goals of requiring septic system inspections on all lakefront properties, overseeing needed septic repairs, initiating weed control measures, promoting riparian zone improvements along the lake shoreline, and possibly dredging the delta areas to remove accumulated sediments. If passed by the voters, this could be a major step forward in improving water quality in Tenmile Lakes.

Throughout this process we have endeavored to tie data from project components together and identify future monitoring needs that will help lead to a more comprehensive view of the entire watershed. Items such as a flow and rain gauge on Johnson Cr would help to quantify precipitation amounts and pollutant loads from the upper watershed and relate that to TSS and TP amounts coming into the lakes; assessment of bottom sediments as TP source for algae in the summer season; expanded monitoring to include other lakes within the watershed including Eel Lake; continued monitoring of nutrients, parameters and TSS to determine if TMDL goals are being achieved. These and other monitoring needs listed at the end of this report are the next steps in the continued success of this watershed program.

Watershed Program Overview

The efforts and data collection over the last 2 – 3 years has been very successful. Each of the project elements has produced good quality data and good results. The successful programs have built on themselves over the years and have begun to correlate to each other as data sets are combined to produce a better understanding of the entire watershed. The data continues to point us in the direction of how best to use our resources to improve the water quality of the streams and lakes within the watershed. Analysis of nutrient data over the last 6 years has helped to form county and statewide policies in regards to septic system regulations and will hopefully assist in creating even stronger rules in the future. This is one of the many benefits of long term projects. It is difficult to draw significant conclusions unless the quantity and quality of the data is sufficient to stand up to statistical analysis.

The data we have collected has helped keep people and animals safe from harmful algae blooms, and is providing the data necessary to help direct our future efforts to solve the problem entirely. Huge economic impacts are felt both in the business community and in personal lives when HAB advisories are put in place. Tourist activity drops for businesses already hit hard with a slow economy. Homeowners that are already having trouble with their mortgages, find it hard or impossible to sell their home when the lake is under a HAB's advisory, or when sediments from nearby tributaries are turning their lakefront home into a home on a marsh full of invasive species.

Our programs continue to evolve and adapt as we learn more and projects change according to the direction that the data leads us. Our data has been used by various agencies throughout Oregon. Our watershed is well respected and we receive calls from other agencies that ask for advice in setting up sampling programs and running sampling equipment. The local connections that we foster have given us access to land for monitoring programs and restoration projects from landowners that would normally be adamantly opposed to allowing state officials on their property.

Our outreach efforts have been very successful and include our annual State of the Lakes presentation. This annual event in Lakeside includes a BBQ and PowerPoint presentation open to everyone in the community. In 2012 and 2013, we teamed up with the Tenmile Lakes Association (TLA) and had well over 100 people attend. We spent over 2 hours educating the audience on nutrients, TSS, algae, invasive species and many other topics that were either presented in the slide show, or discussed after the presentation. TLA also paid for the BBQ and many of the other costs associated with the event. The presentation included a large section on actions that homeowners could take to help promote a healthier lake. The presentation is included on the Appendix CD: *2013 lake presentation Final 8-13-2013*. The Monitoring Coordinator makes monthly reports to the Watershed Council and pertinent items are also included on the Lakeside City Council agenda. TLBP staff regularly attends the Tenmile Lake Association meetings to give technical advice and offer suggestions for volunteer enhancement projects. We are also sought-after by local media to help with articles involving lake issues and other environmental concerns. The Monitoring Coordinator revised the website in 2013 to update and enhance the look of the site (http://tlbp.presys.com/). We included overviews of select enhancement projects, and algae bloom information including Health Advisory status. We also have links to our rain gauge data that includes: Precipitation amounts, Water & Air Temperatures, and current Lake Levels. We regularly communicate with state and local government officials about needs in our area and the results of our data collection efforts. We post our results on ODEQ's LASAR website to give anyone access to our monitoring data. Finally, we act as a local environmental information center. Nearly every day local government officials, citizens and visitors walk into our office to discuss things ranging from septic system problems, and HAB concerns, to fish management, land use and lake water quality questions. Because of our outreach and monitoring efforts, TLBP was recently awarded special recognition by the Lakeside City Council.

Project Results and Discussions

Project Components

Baseline Tributary WQ Monitoring

Within Tenmile Lakes Watershed, we have a myriad of land use activities along our tributaries. The goal of this monitoring project was to see the effects of various types of land use on water quality and to identify areas where water quality standards are not being met. With 5 years of baseline data, we have concluded our monitoring efforts and begun data analysis on Murphy Creek and Big Creek that flow into North Tenmile Lake. We started new baseline sampling projects on Adams and Johnson Creeks which are both tributaries of South Tenmile Lake and both feature agricultural and timber harvest operations. Both of these creeks have had riparian, fish passage, and fencing projects completed on them and TLBP anticipates future projects along both. From June through October, grab samples were collected at all sites (Map 1) (
Map 2) & (Table 1) (Table 2) for water temperature, dissolved oxygen, pH, conductivity, and turbidity. Sampling was limited to the summer months so TLBP could conduct data analysis and implement the storm-chasing program during the winter months. Three of the new Storm Chasing sites are also on Johnson Cr, which gave us data from both summer and winter seasons. Additional data can be seen on Appendix CD*: Trib Sites Data Submittal 2010-2011 and Trib Sites Data 2012-2013.*

Map 1, Map of Original Baseline Tributary sites:

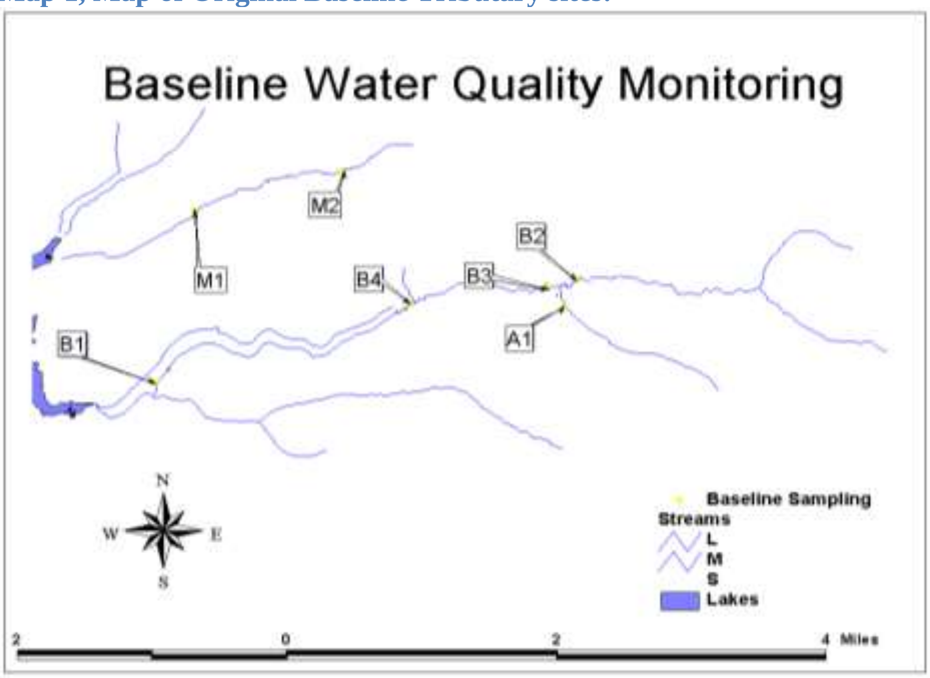


Table 1, Original Baseline Tributary Sites

Site ID #	Site Name/Location
M1	Murphy Lower
M2	Murphy Upper
B1	Big Lower
B4	Big Dam Pool
B3	Big Cr. Riffle
B2	Big Upper
A1	Alder Fork

Map 2, Map of the New Baseline Tributary Sites for 2012 & 2013:

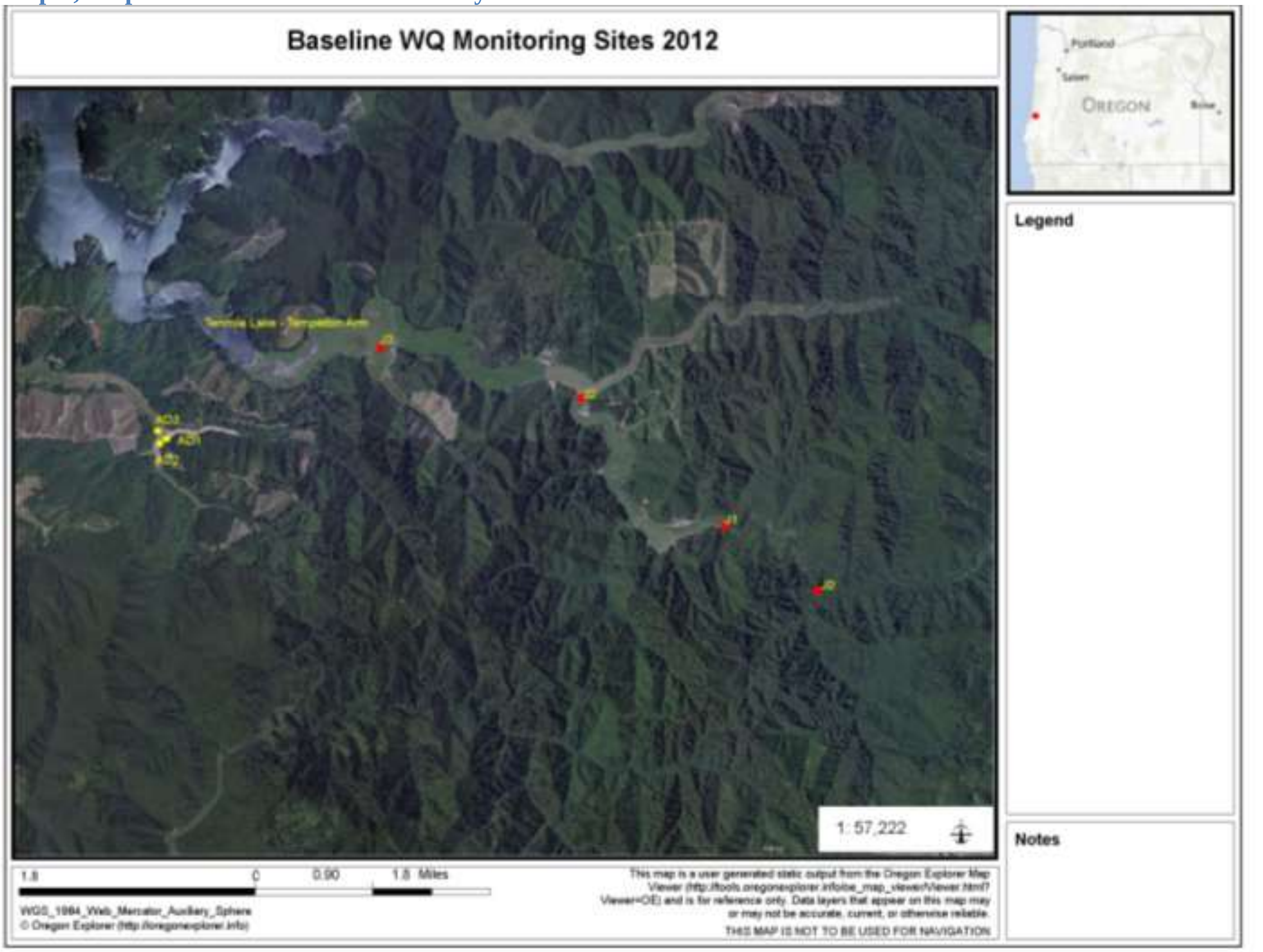
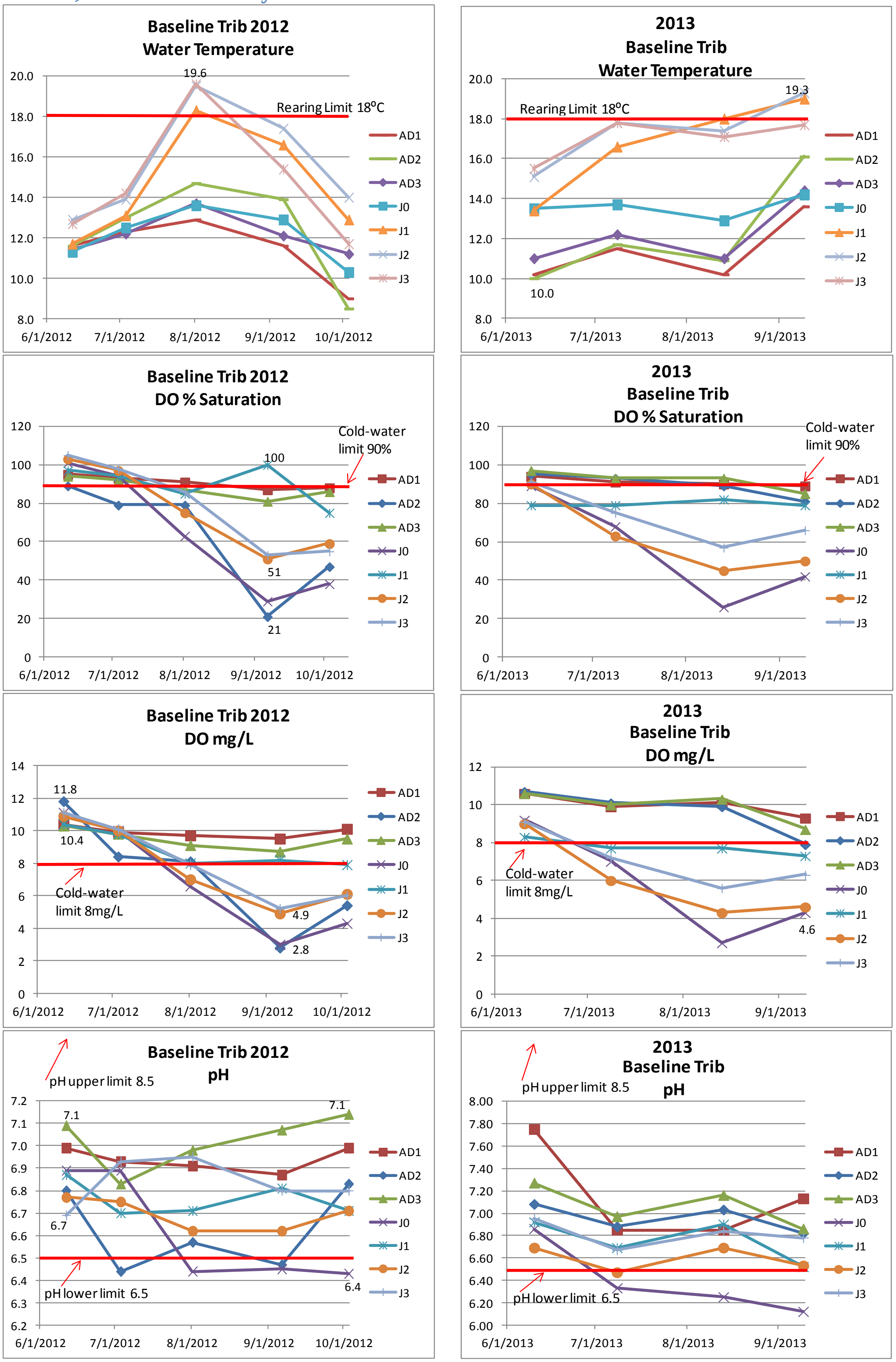


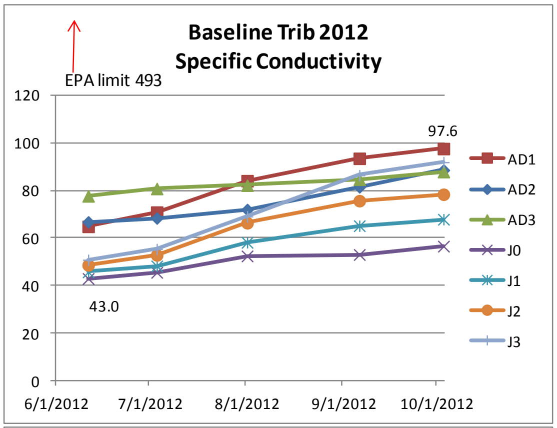
Table 2, 2012 & 2013 Baseline Tributary Sites:

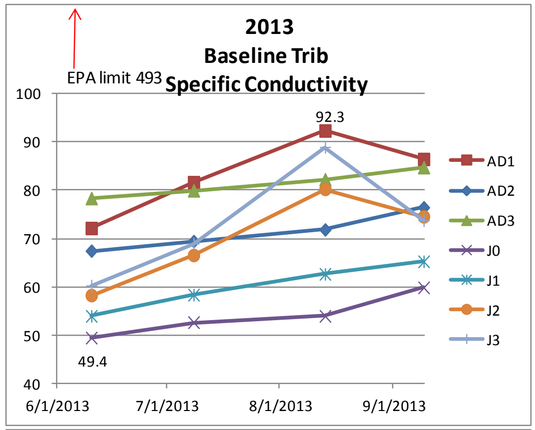
2012 Site ID	**Site Name/Location**	**UTM**
Ad3	Adams Cr. Culvert (Rt Fork)	10T0 408976 4821302
Ad2	Adams Cr. Culvert Removal (Middle Fork)	10T0 409050 4821231
Ad1	Adams Cr. Bridge (Left Fork)	10T0 409065 4821234
J0	Johnson Cr Confluence	10T0 414857 4819767
J1	Johnson Cr Hankins	10T0 414088 4820382
J2	Johnson Cr. County Bridge	10T0 412820 4821551
J3	Johnson Cr. (Fritz Bridge)	10T0 410992 4822015

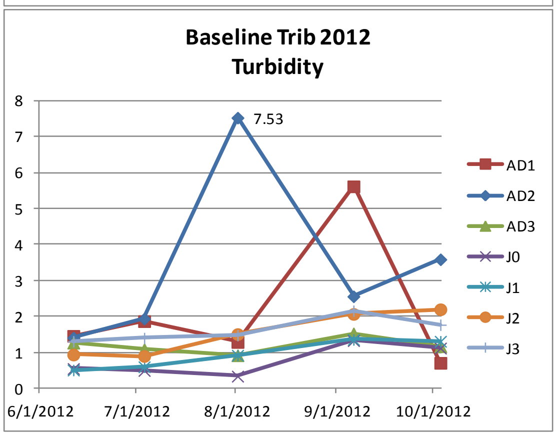
The results of our most resent (2012 & 2013) sampling seasons are shown below in (Chart 1).

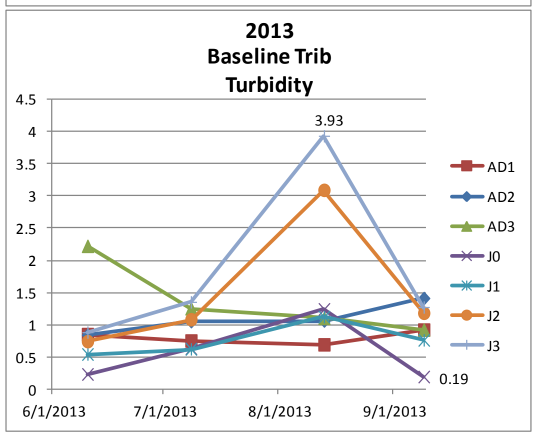
Chart 1, Baseline Tributary 2012 & 2013 Parameters:











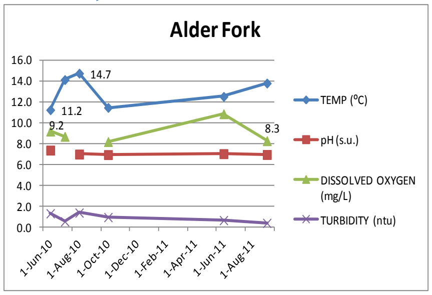
Temperatures for Johnson Cr sites, J1, J2, & J3 are all relatively high, especially for the late summer months. All three exceeded 18°C (64°F) in August 2012, and J1 and J2 surpassed the mark in Sept 2013 which is the Biologically Based Numeric Criteria for a Salmon and Trout Rearing and Migration stream*. J1 is at the Elliott Forest boundary, but the creek goes through some open bottom land between J0 and J1. J2 is just past Ag land used for grazing livestock. This area has had many restoration projects including fences and bridges, but only a limited number of riparian projects and not many of those are mature enough to be shading the steam. J3 is also in an open Ag land area. The stream hugs the southern edge of the valley, so it gets some topographic shade from the hills to the south. It also includes water from Roberts Cr which enters Johnson Cr just below J2. A few temperature measurements of Roberts Cr in the future would be useful.

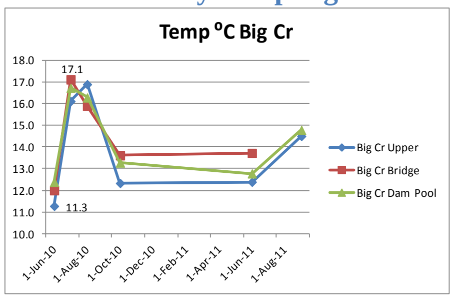
With optimal salmonid temperatures ranging between 9-14°C, Adams Cr mostly fell within this range for the entire summer in both years, as did J0 which is located in a densely forested area of Johnson Cr. Parts of Johnson Cr dry up in the summer. The actual sampling site at J0 was dry for my October 2012 sampling. We had to go up stream about 10 ft to an isolated pool to take our measurements. 2013 had cooler temperatures and a significant rainfall event (4.7 inches in 3 days) in late September (9/27 - 9/30/2013) which flooded the streams and raised the lake (3.9ft) Adams Cr has significantly better riparian cover than Johnson Cr, but low summer flows can create a need for Coho fry to seek out cool water pools.

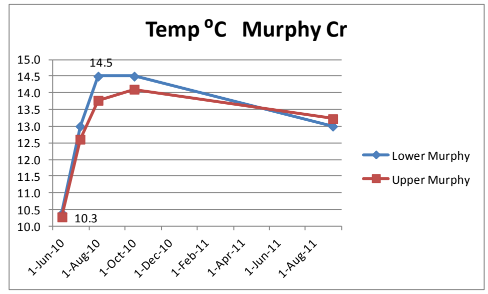
Grab temperature results from 2010 – 2011 on the creeks leading into North Tenmile Lake (Alder Fork, Big Cr, & Murphy) are shown below. None of the streams tested higher than the seven day average maximum 18°C criteria. Big Cr showed the highest temperature of 17.1° at the Big Cr Bridge. Upper Big Cr read 16.1°, resulting in longitudinal heating of 1°C per 3.3 miles for that 7/23/2010 sample date. Alder Fork is a tributary to Big Cr, above Upper Big Cr site. It showed the lowest seasonal swing from June to August, 2010, of 3.5°C. Murphy Cr is a braided channel system with no Ag land and heavy cover of Canary Grass that covers the valley floor. Its maximum temp reading was 14.5°C for both the August and October, 2010 readings. It should be noted that all of these are grab sample temperatures*.

* Biologically Based Numeric Criteria are based on 7-day maximum average readings from *continuous* temperature monitoring, not grab samples. Limits are mentioned here for reference only. Grab sample temperature values may not depict the daily temperature maxima.

Chart 2, Select charts from 2011 Baseline Tributary Sampling:







Dissolved Oxygen (DO) levels between 9-11 mg/L are considered optimal, with 7-8 being considered acceptable, and levels below 3.5 are likely fatal to salmon and most other aquatic life. During Spawning season DO> 11mg/L are ideal, with 8mg/L or 90% Saturation listed as absolute minimums. Our first readings in June, 2012 showed that all sites were at or above 10 mg/L. Adams Cr sites 1 & 3, along with J1 from Johnson Cr maintained levels at or above 8 for the entire summer with saturation levels above 75%. Sites J2 & J3 both dropped below 8 mg/L in August and reached a minimum of about 5 in early September with saturation levels near 50%. J0 and AD2 both dropped to about 3 mg/L during that same period with DO saturation at 29% and 21% respectively. As mentioned earlier, J0 was an isolated pool which probably accounts for its low DO levels. AD2 is a pool just above a beaver dam. It was in full sun with very little movement. It would be useful to sample DO levels upstream from AD2 where shade and cooler temperatures might provide cool water refugia for salmon fry. The samples from Johnson Cr (J1-J3) taken Nov 17-21, 2012 with my storm chasing data show DO's ranging from 10.0 – 10.7mg/L and saturations from 90 – 97%.

2013 data was similar to 2012. All reading were above 8mg/L in June, with Adams creek closer to 11mg/L and Johnson Cr ranging from 8.3 to 9.1mg/L. Adams Cr maintained the higher levels throughout the summer with only one reading at AD2 falling below the 8mg/L (7.9) in Sept. The beaver dam at AD2 was gone this year and although water levels were lower, the low DO levels recorded in 2012 were not present.

All Johnson Cr sites fell below 8mg/L in July and stayed there throughout the summer. The J0 pool did not dry up in 2013 and all pools were still connected on the Sept sampling date, but water movement was very slow. We collected multiple DO readings upstream from JO in ODFW spawning survey pools. These all showed readings ranging from 3.0 to 4.4mg/L. With the low DO readings shown in these pools, they could be being feed by underground springs, or simply not have enough flow to replace DO used by respiration.

Table 3, Big Cr Dam Pool DO

Big Cr Dam Pool DO	
Date	DO (mg/L)
Aug-04	5.0
Sep-05	5.8
Aug-06	5.6
Jul-07	6.5
Sep-08	7.1
Aug-09	6.5
Oct-10	5.6
Sep-11	5.3

DO levels for the North Lake creeks in 2010 and 2011 ranged from 5.3mg/L in Big Cr Dam Pool on 9/26/2011 and 5.9 in Murphy Cr on that same date, to 10.8 in Alder Cr for June 2011.

Low DO levels in the Big Cr Habitat Dam Pool might be of some concern since the pool is put in place each year for the sole purpose of creating good fish fry habitat. Eight years of data (Table 3) indicate that late summer DO levels have an average minimum of 5.9mg/L in the Big Cr Dam Pool. Data for 2013, shown in Chart 3 below, shows a continuation of this low DO trend. The first reading, 9.8mg/L, was just prior to installing the habitat dam on 7/18/2013. Just 18 days later on 8/5/2013, the DO had dropped to 7.1mg/L. By 9/5/2013 it was 6.6mg/L. Data taken upstream at the ESF boundary on 8/5 and 9/5 showed 8.4 & 7.5mg/L respectively. It should also be noted that the temperature in the pool actually dropped slightly (-0.4°C) throughout the summer, but the upstream temperature increased by 0.6°C. The 2009 continuous temperature monitoring of this site also showed the smallest 7-day average temperature swing (ΔT=0.9°C) of any site in the watershed. All of these issues could be explained if the pool is receiving water from an underground spring.

Continuous temperature monitoring of Big Cr Dam Pool is shown later. The 2009 data showed a 7-day average maximum on 7/30/2009 of 68.2°F and a minimum of 66.6°F, both above the 64.4°F (18.0°C) criteria. Future projects could involve figuring out a way to cool this pool and increase the DO levels. The pool is located in a 100% shade area, so more strategically located riparian plantings upstream may be needed to cool the water coming into the pool.

Chart 3: Big Cr Dam Pool 2013:

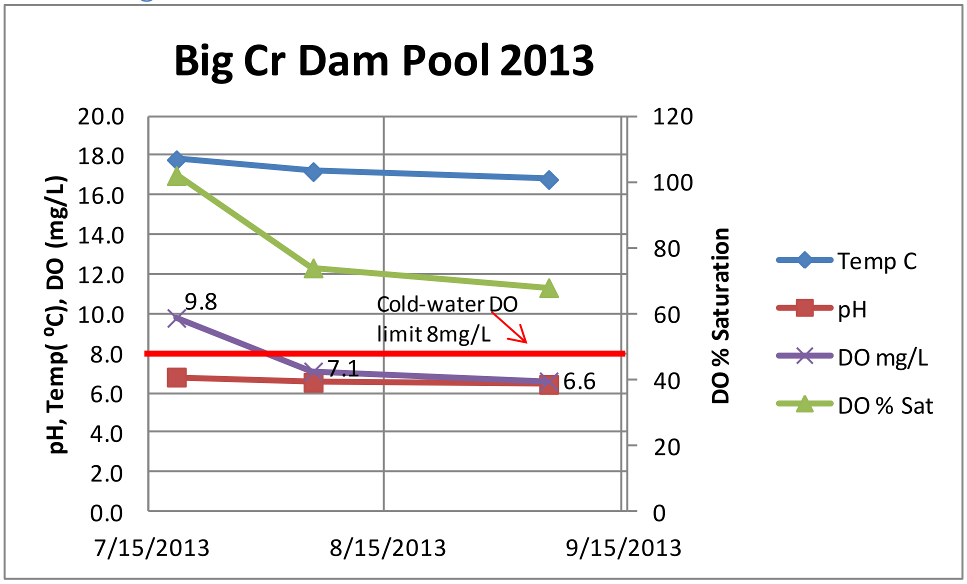


Table 4, ODEQ DO Criteria

Class	DO Concentration and Period[1] All Units are mg/L)				Use/Level of Protection
	30-D	7-D	7-Min	Min	
SalmonidSpawning		11.0 [2,3]		9.0[3] 8.0[4]	Principal use of salmonid spawning and incubation of embryos until emergence from the gravels. Low risk of impairment to cold-water aquatic life, other native fish and invertebrates.
Cold Water	8.0[5]		6.5	6.0	Principally cold-water aquatic life. Salmon, trout, cold-water invertebrates, and other native cold-water species exist throughout all or most of the year. Juvenile anadromous salmonids may rear throughout the year. No measurable risk level for these communities.
Cool Water	6.5		5.0	4.0	Mixed native cool-water aquatic life, such as sculpins, smelt, and lampreys. Waterbodies includes estuaries. Salmonids and other cold-water biota may be present during part or all of the year but do not form a dominant component of the community structure. No measurable risk to cool-water species, slight risk to cold-water species present.
Warm Water	5.5			4.0	Waterbodies whose aquatic life beneficial uses are characterized by introduced, or native, warm-water species.

No Risk	No Change from Background	The only DO criterion that provides no additional risks is "no change from background". Waterbodies accorded this level of protection include marine waters and waters in Wilderness areas.
Note: *Shaded* values present the absolute minimum criteria, unless the Department believes adequate data exists to apply the multiple criteria and associated periods. 1 30-D =30-day mean minimum as defined in OAR 340-41-006. 7-D = 7-day mean minimum as defined in OAR 340-41-006. 7-Mi = 7-day minimum mean as defined in OAR 340-41-006. Min= Absolute minimums for surface samples when applying the averaging period, spatial median of IGDO. 2 When Intergravel DO levels are 8.0 mg/L or greater, DO levels may be as low as 9.0 mg/L, without triggering a violation. 3 If conditions of barometric pressure, altitude and temperature preclude achievement of the footnoted criteria, then 95 percent saturation applies. 4 Intergravel DO criterion, spatial median minimum. 5 If conditions of barometric pressure, altitude, and temperature preclude achievement of 8.0 mg/L, then 90 percent saturation applies.		

pH range of 7-8 su is considered optimal, with 6.5 - 8.5 su identified as the water quality criterion for aquatic life. All sampling sites in June 2012 & 2013 were above the 6.5 su level, ranging from 6.7 to 7.8 su. Both AD2 and J0 dropped below 6.5 su (to 6.4 su) during the summer months 2012. J0 showed a similar trend in 2013 when it reached a low of 6.1su on September 9th. These low pH values could be indicative of pH/DO cycling. Use of a data sonde would be useful to track these parameters through a full 24 hour cycle. In late November 2012, during a storm chasing event, pH was measured on Johnson Cr at sites J1 - J3 with a range of 6.72 – 7.00 su and averaging 6.83 su.
Diel Fluctuation - Photosynthetic Processes and Dissolved Oxygen; Periphyton, Phytoplankton, and Macrophytes: Excessive growth of photosynthesizing organisms can result in significant diel fluctuations in dissolved oxygen and pH which may adversely impact aquatic life and result in water quality standards violations.
This growth can be observed in stream as; periphyton (attached diatom and algae assemblages), phytoplankton (algae and other small organisms which are suspended in the water column), and macrophytes (large rooted vascular plants, mosses, liverworts, and periphyton - such as long filaments of the green alga).
During the day, when macrophytes and algae photosynthesize and grow, carbon dioxide is consumed and oxygen produced. At night respiration dominates. Respiration occurs at a relatively constant rate both day and night and consumes oxygen and produces carbon dioxide. Respiration increases the hydrogen ion concentration, and consequently lowers the pH. Therefore, during the day as algae consume carbon dioxide pH increases, while at night as algae produce carbon dioxide pH declines.

Specific Conductivity increased at all sites throughout the summer, as would be expected during the dyer season. EPA lists a water quality bench mark for the Xeric West, “Least Disturbed” category at <493µS/cm. Our highest reading was only 97.6, so we are well below any problem levels.

Turbidity doesn’t have specific targets for these streams, but levels were very low for most sites (below 2). AD2 had an Aug 2012 high of 7ntu in the pool behind the beaver dam, but many deer tracks were observed in the mud along the bank, so it could be partially causes by wildlife using the pool as a watering source and stirring up the sediments. AD1 also had one higher reading (5.62ntu) but that could have been sampling error. The stream was so shallow at the sampling site, that it was hard to get a sample without touching the bottom. Condensation on samples vials can also be a problem when sampling cold water on warm summer days.

Turbidity readings for 2013 also showed very low turbidity with a range of 0.19 to 3.93ntu, but only 3 were above 1.5ntu. Low summertime turbidity values indicate that sedimentation and therefore Phosphorus input from the upper watershed are not a driving force behind the elevated summer Phosphorus levels seen in Tenmile Lakes during that season. It also indicates that high lake turbidity readings could be attributed more to algae than sediments.

Algae Monitoring

Our objective was, and continues to be, the determination of species composition and lake conditions that influence algal blooms in the Tenmile Lakes system. In addition, we monitored for blue-green algae and their potential toxins in coordination with the Oregon Health Authority. We monitored during the summer/fall months for algae species and toxins and started monitoring in the winter of 2013 for algae species (Identification and enumeration) at sites N16 and S3 in order to have a more complete understanding of our yearly algae cycles.

Map 3, Algae Sampling Site Locations 2012 & 2013:

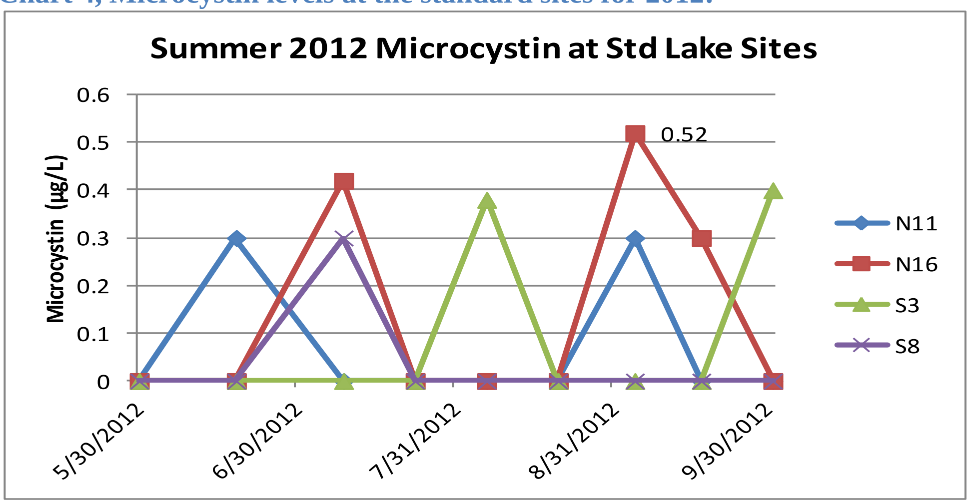
Table 5, Algae Sampling Site Locations 2012

Site ID	Site Name/Location	UTM
S3	Templeton Arm/ South Lake	10T0 409437 4822401
S8	South Lake Near Canal	10T0 405753 4824927
N16	Middle of North Lake	10T0 407191 4826591
N11	Big Creek Arm/ North Lake	10T0 410025 4827194
DD	Davis Dock/ Coleman Arm South Lake	10T0 409007 4823234
Z	Coleman Arm/South Lake	10T0 409448 4823765
LD	Litts Dock/ North Lake	10T0 407852 4826869

In 2012, we also instituted a new cyanotoxin sampling program for the summer months. We tested each of our 4 main sampling sites, and other grab sites when we spotted visual blooms (See map and site list above) for toxins using High-Performance Liquid Chromatography (HPLC) through Lake Superior State University (LSSU). They performed toxin sweeps on each sample that identified 3 toxins: Microcystin (variants LR, RR, YR, LA, LF & LW), Anatoxin-a, and

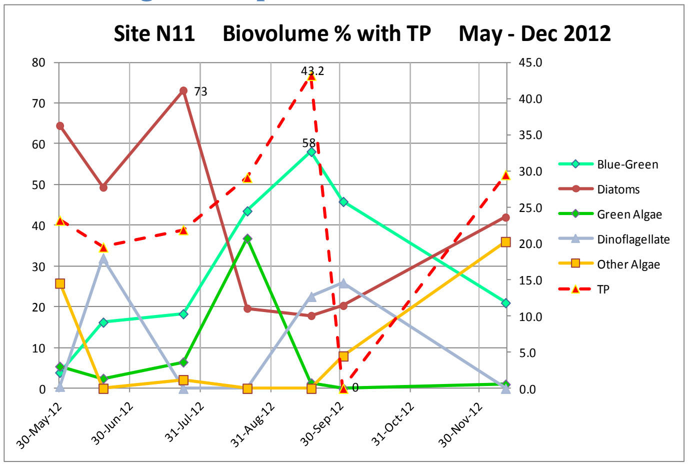
Cylindrospermopsin to a detection limit of 2µg/L. As a result, we were able to move to a toxin based reporting system for the state recreational advisories, instead of using cell counts. Past data has not shown a strong correlation between cell counts and toxin peaks, so we hope the new protocols will better protect the public health by showing actual toxin levels instead of potential toxin levels, and also give us more data on toxin levels at each standard site (Non-bloom sites) throughout the summer to evaluate overall water quality for drinking and recreation hazards.
We have included the 2010 - 2013 Algae/Toxin reports prepared by our consultant, Dr. Jacob Kann on the CD. 2013 Report link: (Appendix CD: *Tenmile_Lakes_2013_summary_report_6-4_14*) Overall, we had a good year in 2012 with no recreational advisories for the first time since 2009. Our highest level of Microcystin was 1.45µg/L, Anatoxin-a .58µg/L, and LSSU reported Cylindrospermopsin at 3.2µg/L. (LSSU repeated this test using ELISA and confirmed the presence of Cylindrospermopsin, but duplicate samples sent to OSU and GreenWater did **not** find detectible levels of that toxin.)
Chart 4 below shows the Microcystin levels at the four standard sites for 2012. No blooms were present at any standard site throughout the summer season. The highest level was only .52µg/L, but the toxin did consistently show up at low levels throughout the summer. It was present at every site, but its appearance was erratic. This data could indicate a potential for long term chronic health effects from the low, but consistent levels of Microcystin. *Recent evaluation of carcinogenesis from Microcystin exposure by the International Agency for Research in Cancer, has determined that Microcystin- LR is possibly carcinogenic to humans (Group 2B), and has been linked to incidences of human liver and colon cancer. (http://www2.epa.gov/nutrient-policy-data/cyanobacterial-harmful-algal-blooms-cyanohabs)*
The OHA Microcystin guideline for pets is .2µg/L. Since that was exceeded at some point at every standard site, pet owners should be encouraged to keep their pets out of the water throughout the summer even if blooms are not present.

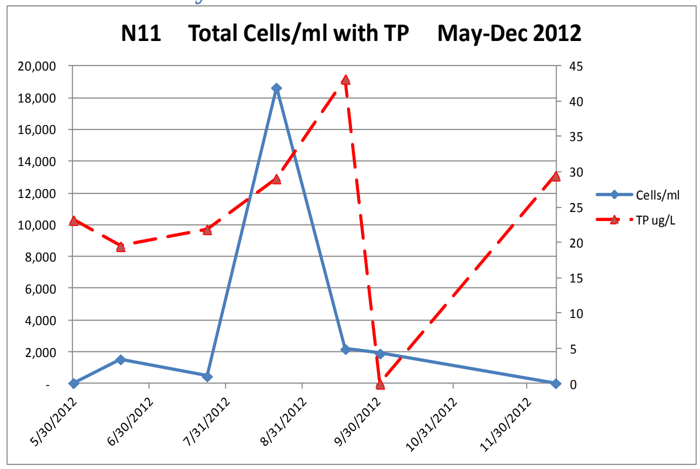
Chart 4, Microcystin levels at the standard sites for 2012:

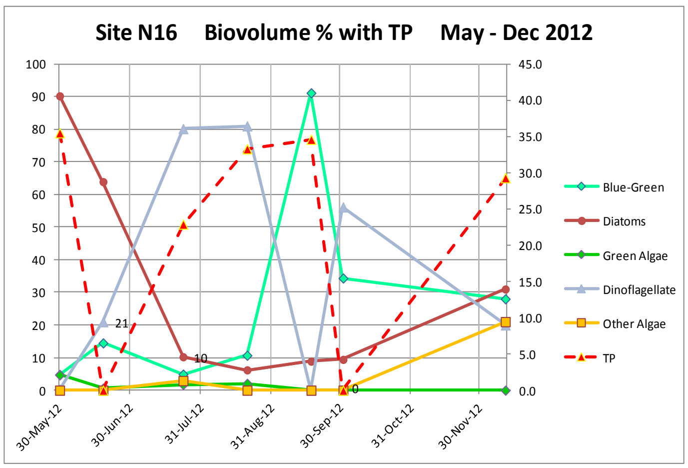


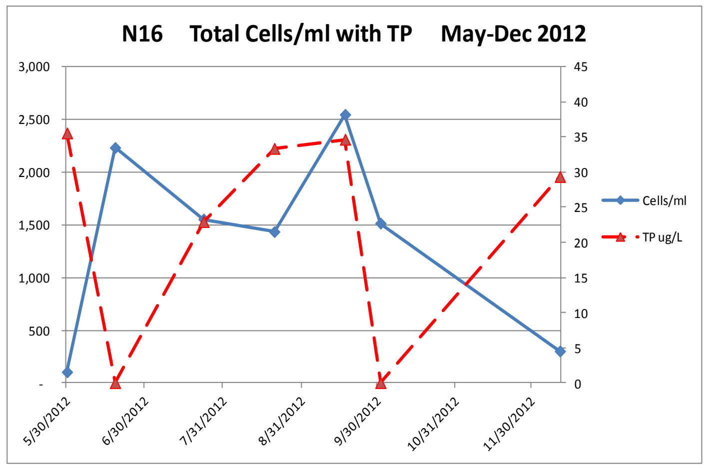
The algae data for 2012 was separated out by algal groups, and by individual species for the various potentially toxic cyanobacteria. The groups include blue-green, diatoms, green algae, dinoflagellates, and "other" as see in the graphs below. We graphed the Biovolume percents, by site, throughout the summer/fall season (See charts below). Although the different sites vary, a few observations stand out. Diatoms were the dominant biomass percent at all sites during our first sampling at the end of May, with over 90% at both N16 & S3. In early July, the dominance at most sites switched to Dinoflagellates. As summer ended, there appears to be varying competition between Aphanizomenon, green algae and a re-emergence of diatoms. We also plotted our bloom grabs at site DD. They were dominated by the cyanobacteria: Anabaena planktonica and Aphanizomenon. Neither of these is known to produce toxin in our lakes, which accounts for the lack of recreational advisories this year. (For a view of all the data, see Appendix CD: *Algae & Nutrients Summary 2012-2013.*)

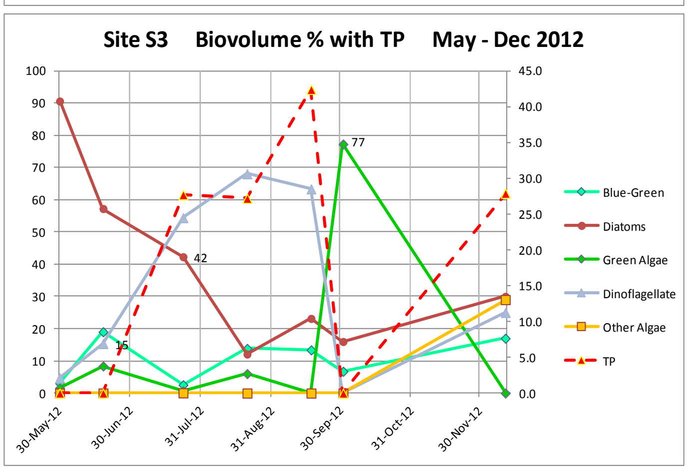
Chart 5, Algae Group Biovolume % and Total Cells/ml with TP 2012 by Site:

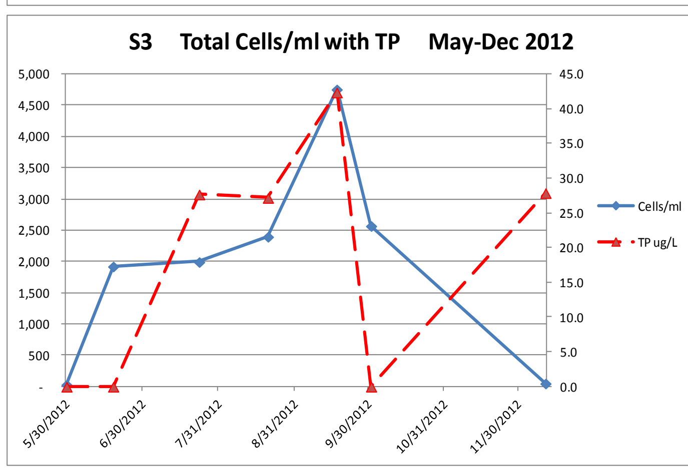


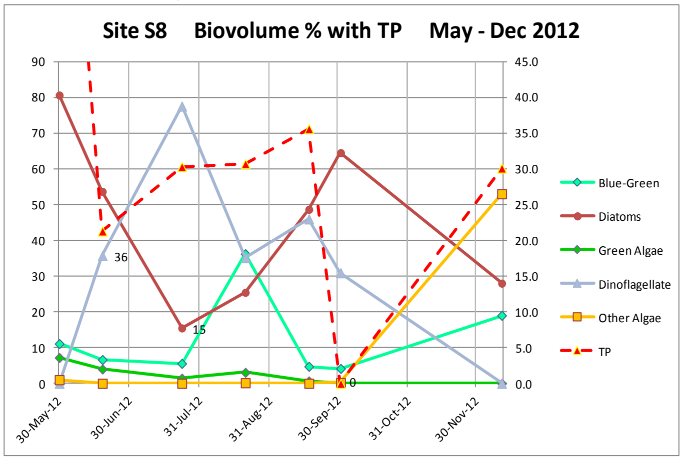


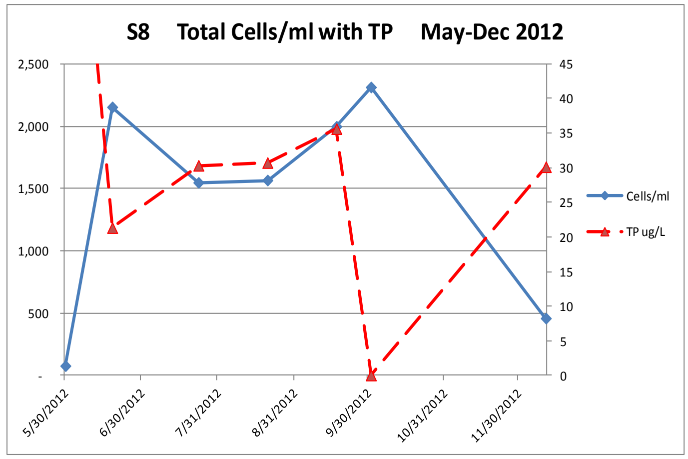


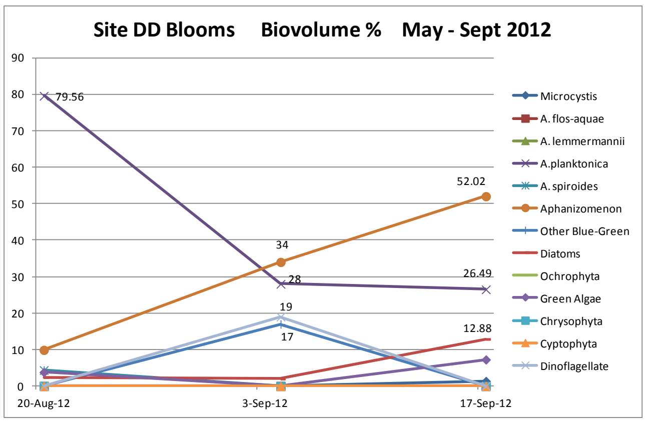








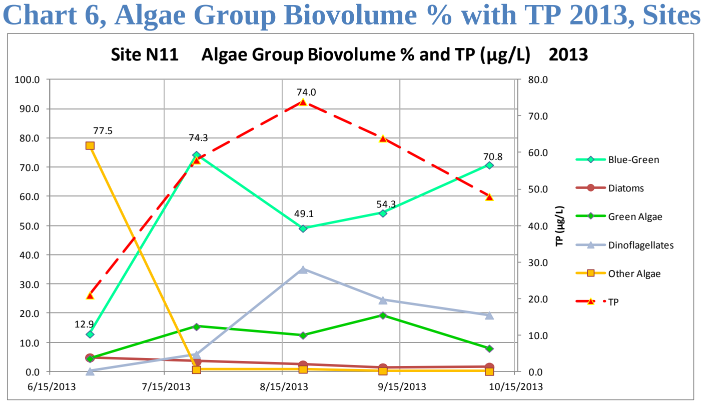


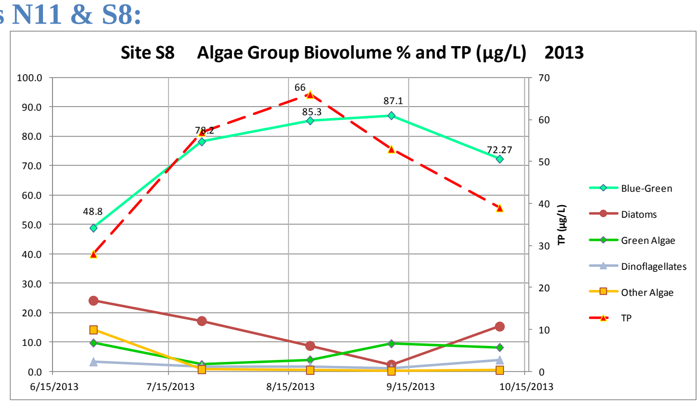


In 2013 we took algae samples every month at two sites (N16 and S3) to gain a better understanding of the yearly algae cycle. We also took algae samples at sites N11 and S8 during the summer season (June – October 2013). The charts below show the results. We used the same algae categories listed above for each site and added the TP (µg/L) as a secondary axis (red dashed line).

“Other” algae (almost always dominated by Chrysophyta) prevailed in June at site N11 but were quickly replaced by cyanobacteria in July. The Blue-greens held dominance for the rest of the summer. The dinoflagellates were more competitive at this site than any of the others. In August they held 35% of the biovolume compared to 49% for the cyanobacteria. Site S8 showed Blue-greens in the dominate spot for the entire summer, topping out in September at over 87%. TP levels were high and the cyanobacteria load corresponded to the rise in TP. This was particularly evident at Site S8.

Chart 6, Algae Group Biovolume % with TP 2013, Sites N11 & S8:



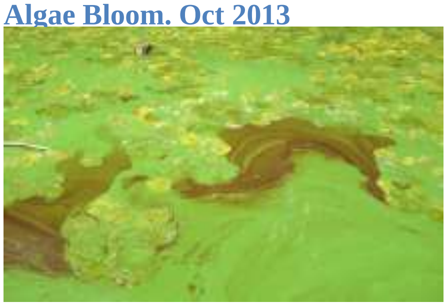


Full year (2013) sampling for sites N16 and S3 are shown in the charts below. The charts on the left show the same algal categories as those above, along with the corresponding TP levels. The charts on the right are from the same sites but represent the total biovolume in cells/ml, also charted with TP. Below those sets are the Total Biovolume charts for N16 and S3. These charts show the total biovolume of all algae groups combined (in $\mu m^3/L$) and are also charted with TP. The first thing that stands out is the dominance of Diatoms or "other algae" (once again almost entirely represented by Chrysophyta) in the early winter and throughout spring. By June, Cyanobacteria had taken the dominate position in 3 of the 4 sites (S8, S3, and N16) with N11 following in July. They remained dominate at all sites throughout the summer. At S3 the Cyanobacteria crash quickly between the November and December sampling events to be replaced by Chrysophyta at almost 90% with a concurrent total biovolume increase from 1.5 million to 2.5 million $\mu m^3/L$. This is not the case at site N16 where blue-greens continue to hold the dominate position through the end of the year. Pie Charts of N16 on three different months are shown below.

The yearly transition phase between Diatom/Chrysophyta and Cyanobacteria dominance happened in the May-June period. N16 is particularly sudden in its biovolume shift from 3.2 million $\mu m^3/L$ on 3/25/2013 to 0.4 million $\mu m^3/L$ on 4/23/2013. This corresponds to a visual clear-water phased noted during the April sampling, and Secchi depths increasing from 4.0ft in March to 16.4ft in April. It was also noted that there was a high volume (visual observation only) of zooplankton at this site, tentatively identified as daphnia. Future work should be done on this zooplankton/algae connection. The lakes' large volume of planktivorous Yellow Perch and their impact on the zooplankton population should be assessed. Past studies, like those done on Diamond Lake, have showed a connection between planktivores and high cyanobacteria populations as the fish graze on the larger zooplankton which is feeding on the cyanobacteria's competitors (Diatoms and other algae that are dominate in the spring).

High TP levels correspond to high cyanobacteria levels at all 4 sampling sites. Lower TP levels occur in spring perhaps due to the high biovolumes of Diatoms and Chrysophyta. As summer progresses, both cyanobacteria and TP levels remain high.

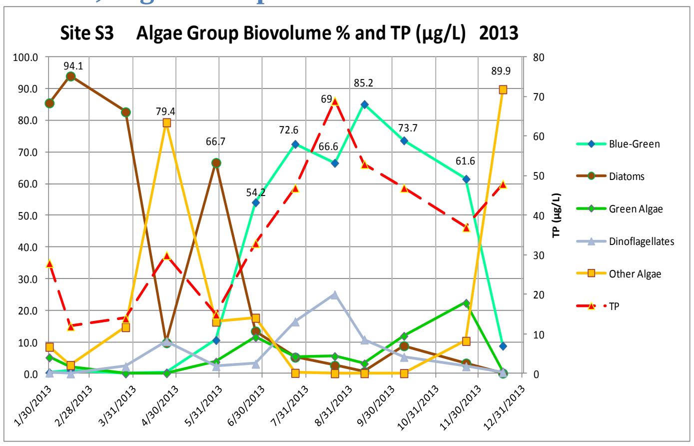
Photo 1, N Tenmile Lake Algae Bloom. Oct 2013

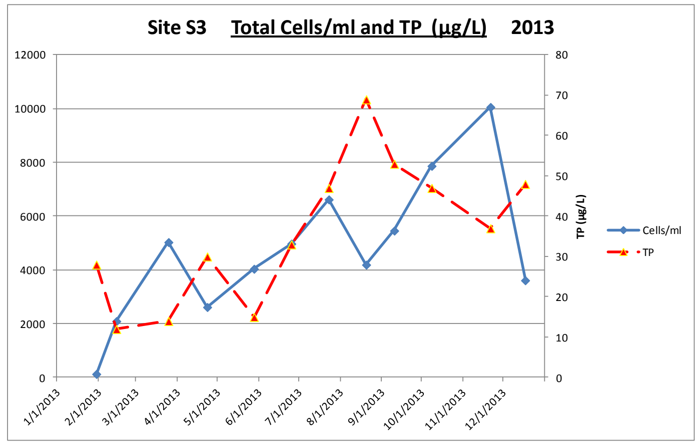


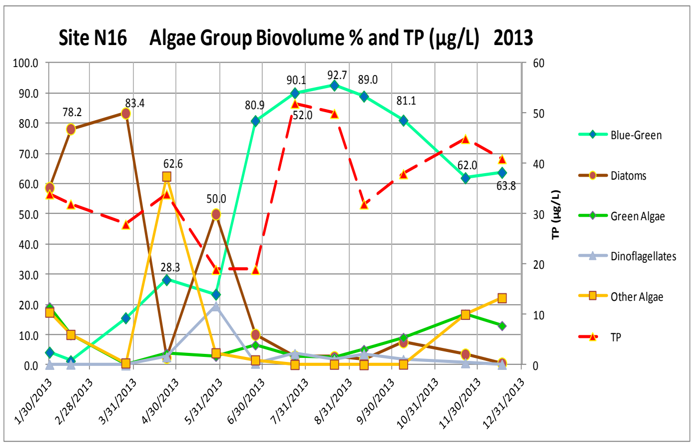
2013 was an unusual weather year in that we had heavy precipitation in late September with 7.79 inches of rain falling in a 10 day period (9/20-9/29/2013), with the lake rising 4.47ft. This was followed by predominately dry weather through December. Just before the storm, North Lake had been showing signs of an impending bloom with heavy green in the water column and a few small accumulations near docks. The heavy rain apparently brought nutrients down to North Lake, reversing the downward TP trend and creating heavy algae blooms throughout North Lake. Water samples were taken in a bloom at site LD and sent to LSSU for toxin analysis. Microcystin (MYC-LR) levels of 160µg/L were found and a HABs Recreational Advisory was issued on the lake by OHA on 10/4/2013 and lifted on 12/3/2013. A photo of the North Lake bloom is shown in photo above. South Lake was less affected by the storm event. TP levels at site S3 continued to drop as did the cyanobacteria biovolume%, although both sites showed total biovolume increases.

Overall, 2013 data was the first full-year data set for algae at two of the standard sites. Although variations should be expected from year to year, 2013 showed a clear domination by cyanobacteria in the summer and a clear domination by diatoms and other algae the rest of the year. The Charts below show a select group of the 2013 data. Including pie charts of the seasonal transition from Diatoms to Cyanobacteria. More charts are available for all 4 sites in the file: *Lakes Sites Data 2013 Main/Algae Charts tab* found on the accompanying CD.

Chart 7, Algae Group Biovolume % and Total Cells/ml with TP 2013 Sites S3 & N16:







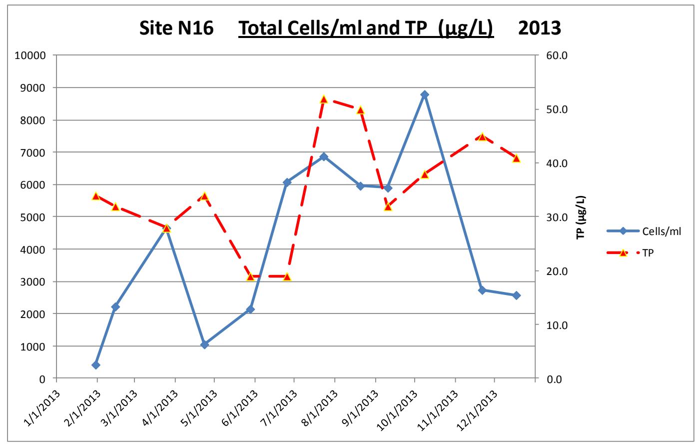
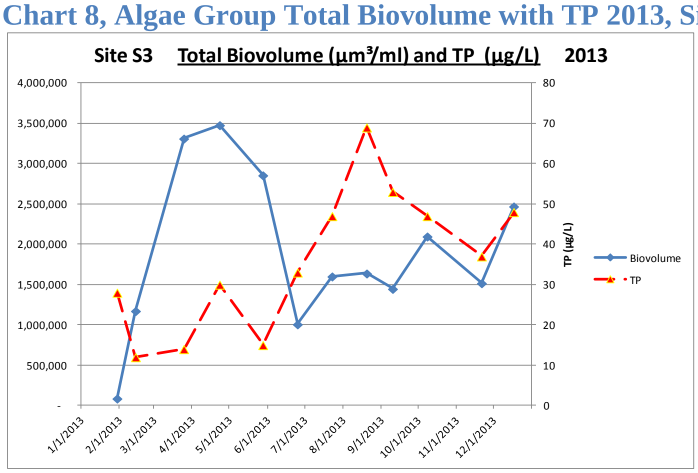


Chart 8, Algae Group Total Biovolume with TP 2013, Sites S3 & N16:



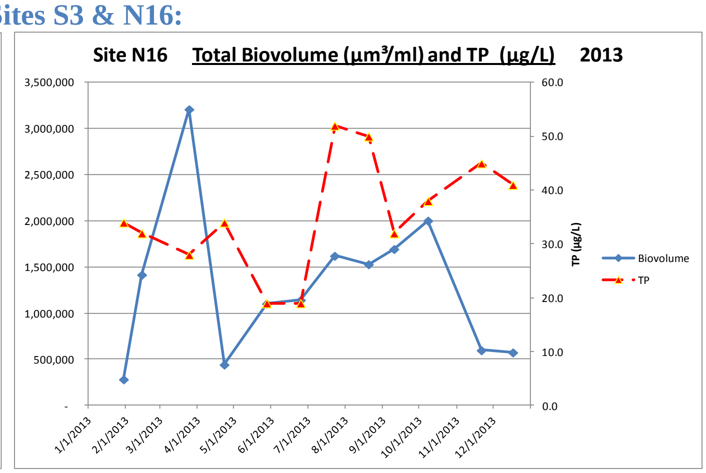
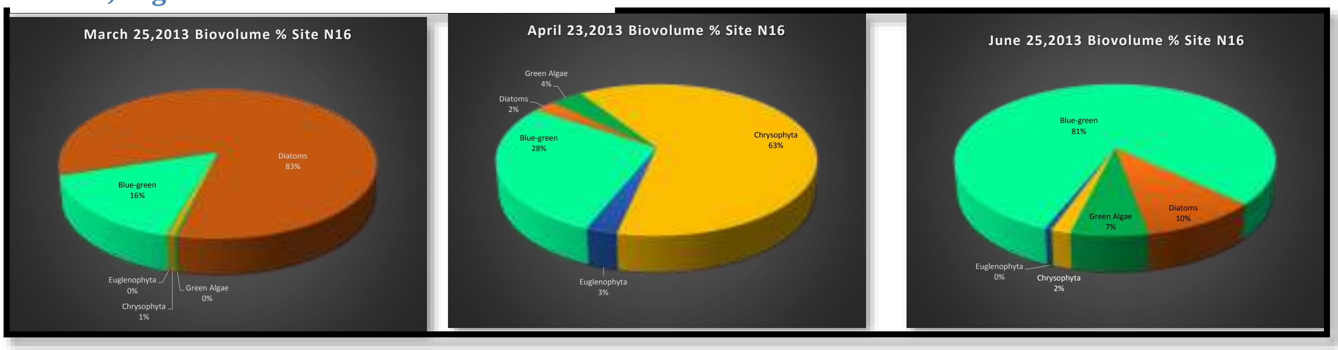


Chart 9, Algae Dominance March - June 2013:



Below is part of a correlation table developed for all 2013 parameter data, nutrient data, and algae data to see what correlations were apparent between and within the data sets. The whole table is too large to show in this document, but two sections are included below. The red shaded squares here are positive correlations (above 0.50), and the green shaded areas are negative correlation (below -0.50). Boxes have been added to those correlations discussed in the table below. To view the entire table see: *Lakes Sites Data 2013 Main/Algae Correlations tab* found on the accompanying CD.

Table 6, Correlations between Lake Parameters & Nutrients and Algae 2013

Correlations 2013 Tenmile Lakes (All 4 Standard Sites)	TEMP (°C)	pH (s.u.)	DO (% Sat)	DO (mg/L)	SPECIFIC CONDUCTIVITY (uS/cm)	TURBIDITY (ntu)	Secchi (ft)	TP (ug/l)	TN (ug/l)	TN:TP Ratio	NO3:PO4 Ratio	PO4 (ug/l)	SiO4 (ug/l)	NO3 (ug/l)	NO2 (ug/l)	NH4 (ug/l)	Chl-a (ug/l)
Total Potentially Toxic Algae (Biovolume %)	[illegible]	-0.32	0.16	-0.31	0.72	[illegible]	[illegible]	[illegible]	-0.24	[illegible]	[illegible]	0.43	-0.32	[illegible]	0.25	-0.13	[illegible]
Aphanizomenon flos-aquae (cells/ml)	0.30	-0.02	0.05	-0.16	[illegible]	0.47	-0.22	0.26	-0.25	-0.44	-0.72	0.24	-0.09	-0.49	0.30	-0.18	0.25
Aphanizomenon (Biovolume %)	0.10	0.04	-0.19	-0.28	0.41	0.11	0.21	0.20	-0.29	-0.45	-0.64	0.32	0.07	-0.46	0.04	-0.18	0.00
Woronichinia (Cells/ml)	0.06	-0.05	-0.08	-0.14	0.32	0.43	-0.27	0.26	-0.13	-0.27	-0.27	0.06	0.18	-0.27	0.25	-0.31	0.04
Woronichinia (Biovolume %)	-0.02	-0.01	-0.20	-0.20	0.26	0.27	-0.21	0.22	-0.16	-0.28	-0.43	0.13	0.22	-0.28	[illegible]	-0.36	-0.06
Other Blue-Green (Cells/ml)	0.14	0.03	0.12	0.03	-0.21	-0.17	0.12	-0.41	-0.05	0.48	0.21	-0.03	-0.25	0.07	0.25	-0.07	0.00
Other Blue-Green (Biovolume %)	-0.04	-0.02	0.07	0.09	-0.28	-0.15	0.06	-0.32	0.06	[illegible]	0.27	0.06	0.05	0.25	0.25	-0.00	-0.15
Total All Blue-green (Biovolume %)	[illegible]	-0.24	0.01	-0.39	[illegible]	[illegible]	-0.50	[illegible]	-0.34	[illegible]	[illegible]	0.34	-0.17	[illegible]	0.38	-0.28	0.43
Diatoms (Cells/ml)	-0.36	0.17	0.27	0.47	-0.49	-0.30	-0.02	-0.50	0.06	0.48	0.16	-0.39	0.05	0.32	[illegible]	0.19	-0.21
Total Diatoms (Biovolume %)	[illegible]	0.18	0.19	[illegible]	[illegible]	-0.48	0.19	[illegible]	0.45	[illegible]	[illegible]	0.05	0.23	[illegible]	0.04	0.29	-0.28

Table 7, Correlations Lake Algae 2013

Correlations 2013 Tenmile Lakes (All 4 Standard Sites)	Microcystis aeruginosa (Biovolume %)	Gloeotrichia echinulata (cells/ml)	Gloeotrichia echinulata (Biovolume %)	Anabaena flos-aquae (cells/ml)	Anabaena flos-aquae (Biovolume %)	Anabaena planktonica (cells/ml)	Anabaena planktonica (Biovolume %)	Total Anabaena (cells/ml)	Total Anabaena (Biovolume %)	Total Potentially Toxic Algae (cells/ml)	Total Potentially Toxic Algae (Biovolume %)	Aphanizomenon flos-aquae (cells/ml)	Aphanizomenon (Biovolume %)	Woronichinia (Cell/ml)	Woronichinia (Biovolume %)	Other Blue-Green (Cells/ml)	Other Blue-Green (Biovolume %)	Total All Blue-green (Biovolume %)
Total Anabaena (cells/ml)	[illegible]	0.02	0.04	-0.24	-0.22	1.00	[illegible]											
Total Anabaena (Biovolume %)	[illegible]	0.07	0.01	-0.25	-0.22	[illegible]	1.00	[illegible]										
Total Potentially Toxic Algae (cells/ml)	0.48	[illegible]	0.48	-0.17	-0.17	[illegible]	[illegible]	[illegible]	[illegible]									
Total Potentially Toxic Algae (Biovolume %)	0.49	0.29	0.28	-0.22	-0.28	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]								
Aphanizomenon flos-aquae (cells/ml)	0.42	-0.05	-0.08	-0.01	-0.04	[illegible]	0.46	[illegible]	0.46	0.18	0.44							
Aphanizomenon (Biovolume %)	0.13	-0.05	-0.01	0.14	0.19	0.17	0.20	0.17	0.20	0.11	0.18	[illegible]						
Woronichinia (Cell/ml)	0.29	-0.15	-0.16	-0.22	-0.18	0.37	0.31	0.37	0.31	0.23	0.26	0.33	0.13					
Woronichinia (Biovolume %)	0.16	-0.17	-0.17	-0.25	-0.18	0.14	0.17	0.14	0.17	0.02	0.13	0.19	0.10	[illegible]				
Other Blue-Green (Cells/ml)	-0.21	0.38	0.38	0.17	0.04	-0.13	-0.08	-0.12	-0.08	0.09	0.01	0.05	0.14	-0.21	-0.24			
Other Blue-Green (Biovolume %)	-0.16	0.29	0.29	0.06	-0.02	-0.15	-0.11	-0.16	-0.11	0.02	-0.04	-0.12	-0.09	-0.17	-0.20	[illegible]		
Total All Blue-green (Biovolume %)	0.47	0.17	0.16	-0.17	-0.12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.46	0.38	0.08	-0.11	
Diatoms (Cells/ml)	-0.26	-0.11	0.11	-0.14	-0.12	-0.37	-0.43	-0.38	-0.44	-0.37	-0.45	-0.36	-0.40	-0.29	-0.10	0.06	0.11	[illegible]
Total Diatoms (Biovolume %)	-0.36	-0.14	-0.13	-0.18	-0.14	[illegible]	[illegible]	[illegible]	[illegible]	-0.58	[illegible]	-0.49	-0.50	-0.48	-0.30	0.15	0.32	[illegible]

Table 8, Individual Lake Correlation Comments 2013

Parameter 1	Parameter 2	Correlation	Comments
Temperature	Total All Varieties Blue-green Biovolume %	0.66	Higher temperatures correlate with higher biovolumes of Cyanobacteria
Temperature	Total Potentially Toxic Algae Biovolume%	0.80	Higher temperatures correlate even higher with biovolumes of toxin producing algae. Temperature alone could account for the much of the reason toxic algae dominate in the summer
Temperature	Diatom Biovolume %	-0.56	Higher temperatures correlate with lower biovolumes of Diatoms
Specific Conductivity	Total All Varieties Blue-green Biovolume %	0.78	Higher conductivity correlates with higher biovolumes of Cyanobacteria
Specific Conductivity	Diatom Biovolume %	-0.69	Higher conductivity correlates with lower biovolumes of Diatom Could be a product of the temperature rise, as shown above, causing evaporation, rather than something inherent with conductivity itself, but strong correlations between conductivity, ionic compounds in the water, and diatoms has been shown in some studies.
Turbidity	Total Anabaena Cells/ml	0.92	Algae accounts for much of the water clarity degradation as opposed to sediment, especially in the summer when Cyanobacteria are present
Turbidity	Total Potentially Toxic Algae Biovolume%	0.85	Would it be possible to create a simple turbidity test that would signal when to check for HAB toxin levels?
Secchi Depth	Total Potentially Toxic Algae Biovolume%	-0.68	Same as above in Turbidity
TP	Total All Varieties Blue-green Biovolume %	0.59	Rise in TP is correlated with rise in Cyanobacteria
TP	Diatom Biovolume %	-0.63	Rise in TP is correlated with decline in Diatoms
TN	All other parameters	No correlations above the .50 threshold	Total Nitrogen in excess abundance and points to Phosphorus as being the limiting factor in Tenmile Lakes
NO_3	Total All Varieties Blue-green Biovolume %	-0.79	Cyanobacteria's nitrogen fixing abilities that can change nitrogen into a more useable form might factor into their summer dominance role
NO_3	Diatom Biovolume %	0.80	Diatoms might have a competitive edge when the NO_3 form of nitrogen is readily available
TN : TP Ratio **NO_3 : PO_4 Ratio**	Total All Varieties Blue-green Biovolume %	-0.68 -0.71	Supports theory that low N:P ratios favor Cyanobacteria
TN : TP Ratio **NO_3 : PO_4**	Diatom Biovolume %	0.86 0.73	Supports theory that low N:P ratios favor Cyanobacteria

Total Cells/ml **Total Biovolume %** **Total Biovolume (µm³/ml)**	Chl-a	0.22 -0.22 0.07	Surprised that the total cell counts and biovolume measurements don't correlate better to the Chl-a readings
Anabaena planktonica (Biovolume %)	Total Potentially Toxic Algae Biovolume%	0.97	This high correlation indicates that the category "Total Potentially Toxic Algae" might be misleading since Anabaena planktonica has not been associated with high toxin levels in Tenmile Lakes and that species obviously dominates that category
Diatom Biovolume %	Total All Varieties Blue-green Biovolume %	-0.72	Cyanobacteria and Diatoms don't tend to co-exist well. Competition for food/nutrients, water temperature, sunlight, fish predation of zooplankton, and toxins produced by cyanobacteria affecting the diatoms could all be factors in the struggle for dominance

Analysis of algae data from 2006-2011 began in 2012. We compiled species identification and enumeration data with the lake sampling nutrients {Total Nitrogen (TN), Total Phosphorus (TP), Nitrate (NO_3), Nitrite (NO_2), Ammonium (NH_4), Phosphate (PO_4), Silicate (SiO_4), and Chlorophyll-a (Chl-a)} and parameter data (DO, Temperature, pH, Conductivity, Turbidity, & Secchi depths).

Table 9 below show the 6-year totals of each species, per site. There is a slight propensity for the main, deeper water sites (N16 & S8) to show higher Microcystis levels, but the highest individual standard site level for the 2006-2011 period was at S8 on 9/21/2009 at 12,362cells/ml. This is well below the 40,000 cells/ml recreational advisory, and even below the level 3 drinking water advisory of 15,000cell/ml. (For a view of all the data, see Appendix CD: *Lake Sites Data 2006-2011 With Algae-Toxin*) Grab samples from visual blooms are where we see the high levels of both Microcystis and Anabaena. 6-year totals for these sites are almost all in the millions of cells/ml. Our Microcystis highest individual level was at Carlson 1 on 9/27/2010 with almost 6 million cells/ml, and a corresponding Microcystin level of 149µg/L. Our top Microcystin level was 2365µg/L at site Z, also in September of 2010, but the Microcystis level was actually lower at 2.2 Million. This shows a common trend with Microcystis and its toxin; at higher toxin levels, we always see Microcystis, but the levels of toxin do not correlate well with cells counts.

Overall, it appears that the open water areas of the lake seldom, if ever, show algae counts sufficient to initiate recreational advisories. Surface blooms are most likely not caused by differences in the micro-environments where the blooms appear, but rather are a product of wind and water currents that blow algae into areas where they get trapped and accumulate. Surface obstacles, such as weeds and docks, filter and obstruct the water flow causing the surface algae to concentrate into mats. Depending on the prevailing wind and currents at a particular location, some algae bloom problems could be mitigated by removal of surface weeds, especially the invasive white lily pads, and possibly redesigning docks that would create passages for surface scum to flow through or around. This would have the greatest chance of success if the prevailing currents were pushing the algae parallel to the shore and not directly into it. Dan Davis at site DD (Davis Dock) experimented with weed removal. Although he still had some issues when the wind blew the algae into the near-shore grasses, overall he had much less of a bloom problem in 2012 and 2013 than in 2011. This could have also been due to other factors; the algae growth in that area could have simply been less in those years compared to 2011, but it does show some potential to help lakefront homeowners deal with blooms in a proactive way and perhaps lower their adverse effects until we can solve the underlying problems that are causing the blooms.

Table 9, Blue-green Algae and Toxin Totals 2006-2011:

TOTALS 2006-2011			Anabaena	Anabaena	Anabaena	Total			Totals w/o		
Standard Sites	Microcystis	Gloeotrichia	flos-aquae	planktonica	circinalis	Anabeana	Aphanizomenon	**Totals**	Aphanizomenon	MCn	Anatoxin
N11	34,940	4,377	4,793	38,136	53	42,982	292,513	**417,794**	125,281	13	-
N16	43,906	19,276	8,225	57,100	1,254	65,456	520,922	**716,139**	195,217	1	-
S3	36,305	15,260	24,701	69,244	532	94,388	6,047,080	**6,287,510**	240,430	-	-
S8	51,955	-	2,382	63,144	949	66,427	453,101	**637,958**	184,857	-	-
North Lake TOTALS 2006-2011			Anabaena	Anabaena	Anabaena	Total			Totals w/o		
Grab Sites	Microcystis	Gloeotrichia	flos-aquae	planktonica	circinalis	Anabeana	Aphanizomenon	**Totals**	Aphanizomenon	MCn	Anatoxin
Carlson 1	8,990,532	-	-	1,547,698	-	1,547,698	115,933	**12,201,861**	12,085,928	609	0
N Lake Resort	3,214,451	-	10,270	36,158	-	46,428	3,687	**3,310,994**	3,307,307	0	0
X	7,179,725	-	469	1,859,882	-	1,860,351	3,259,846	**14,160,273**	10,900,427	676	0
South Lake TOTALS 2006-2011			Anabaena	Anabaena	Anabaena	Total			Totals w/o		
Grab Sites	Microcystis	Gloeotrichia	flos-aquae	planktonica	circinalis	Anabeana	Aphanizomenon	**Totals**	Aphanizomenon	MCn	Anatoxin
County Boat Ramp	1,529,344	-	223	2,303,111	135	2,303,469	89,506,885	**95,643,167**	6,136,282	705	0
Coleman DD	678,722	-	-	2,388,473	-	2,388,473	112,738	**5,568,406**	5,455,668	2.25	0
Z	11,589,804	-	810,648	17,305,010	56,498	18,172,156	80,136,655	**128,070,771**	47,934,116	5955.15	2.6

We also did analysis on nutrients and parameters as they relate to algae. The charts below show some of the various nutrients or parameter data graphed against algae cells counts. (More charts are included in the full spreadsheet on Appendix CD: *Lake Sites Data 2006-2011 With Algae-Toxin*)

We used Microcystis (MC) for most of the graphs since it generally has the biggest negative impact on the lakes. The scale on the left is cells/ml and the right is µg/L of the nutrient. MC is represented by the erratic blue line and the nutrient is the red line with boxes. Nutrients are collected all year including some that are collected as part of Storm Chasing events that could skew some nutrient levels higher than we would normally observe if we hadn't been specifically targeting large rainfall events.

The first chart (10) shows MC and TP. This shows a positive correlation between the two, with MC being high when TP levels are up. We had no winter data during this period, so we don't know exactly what the MC is doing in the winter, but extrapolating from the winter 2013 data presented earlier, it seems likely that the MC and other cyanobacteria are in low abundance and the dominant species are Diatoms or Chrysophyta. 2013 correlations between cyanobacteria biovolume% and TP was positive 0.59, and between Diatom biovolume % and TP was negative -0.63.

Chart 10, MC and TP 2006-2011:

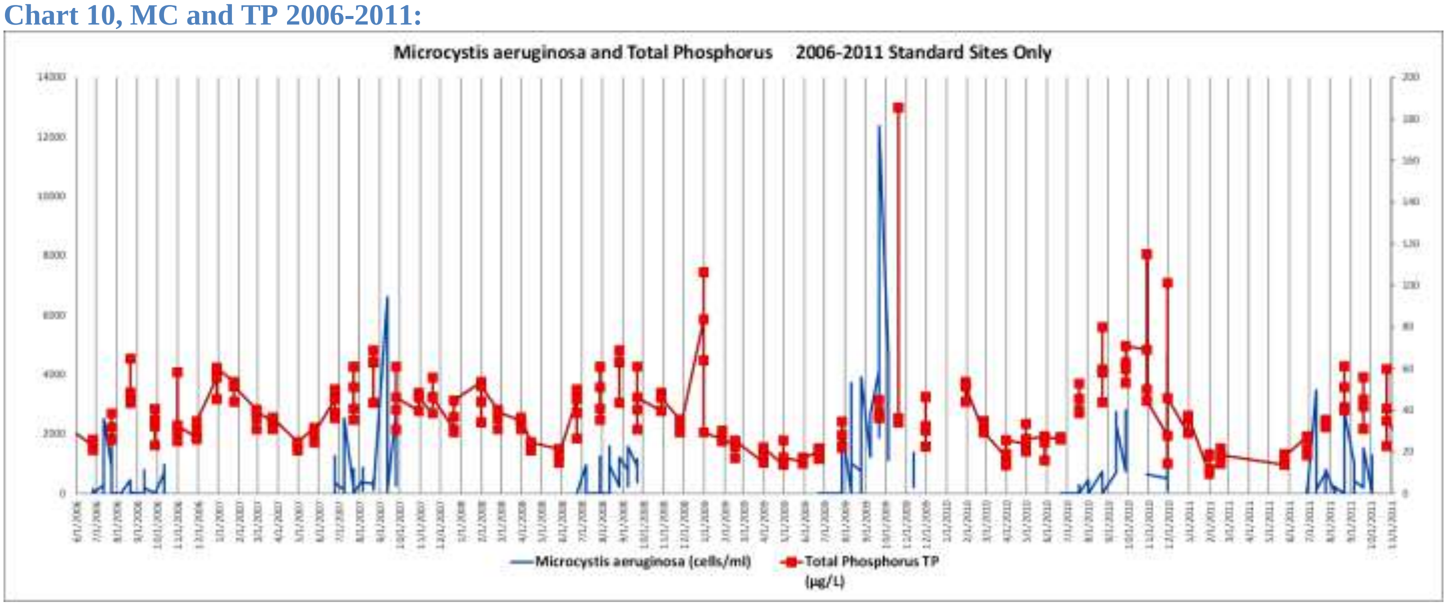


Chart 11 shows the MC vs Total Nitrogen (TN) relation. This is a negative correlation with MC being high when TN is at its minimum. This could be explained by the high levels of MC and other algae consuming the Nitrogen during the warm growing season, or MC using its Nitrogen fixing abilities to out compete other algae during low Nitrogen periods.

Chart 11, MC and TN 2006-2011:

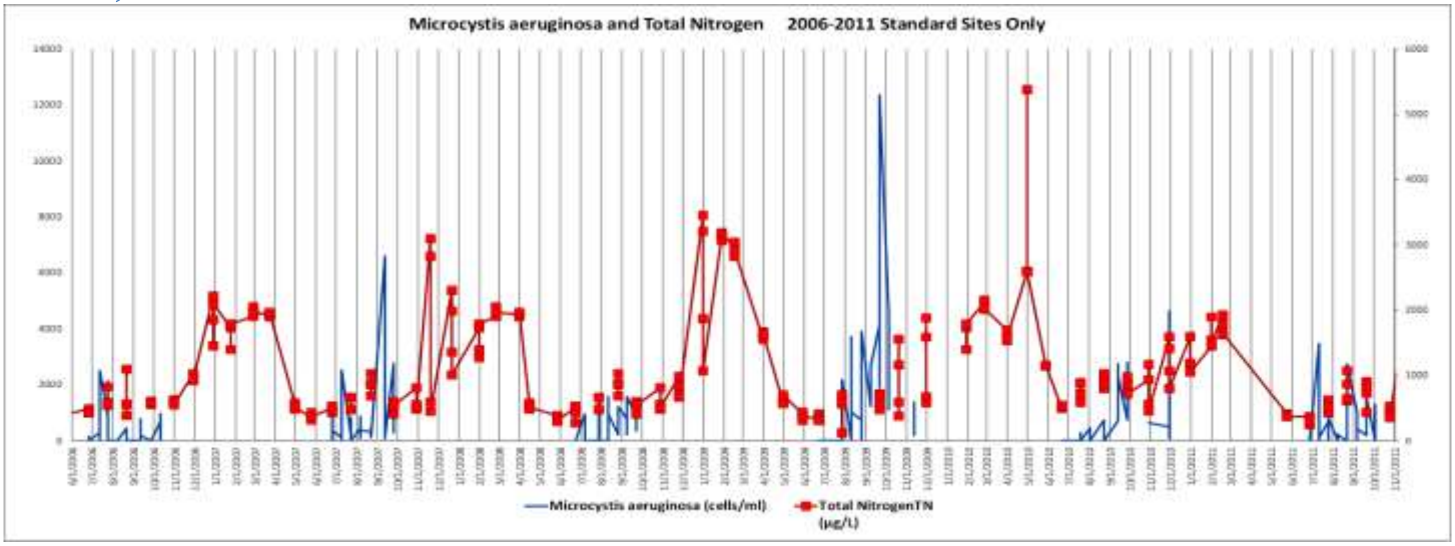


Chart 12 breaks out the Nitrogen to its most useable form, Nitrate. Clearly the MC is peaking during the lowest periods for NO3. The 2013 data shown above supports this by showing a negative -0.79 correlation between cyanobacteria and NO3.

Chart 12, MC and NO3 2006-2011:

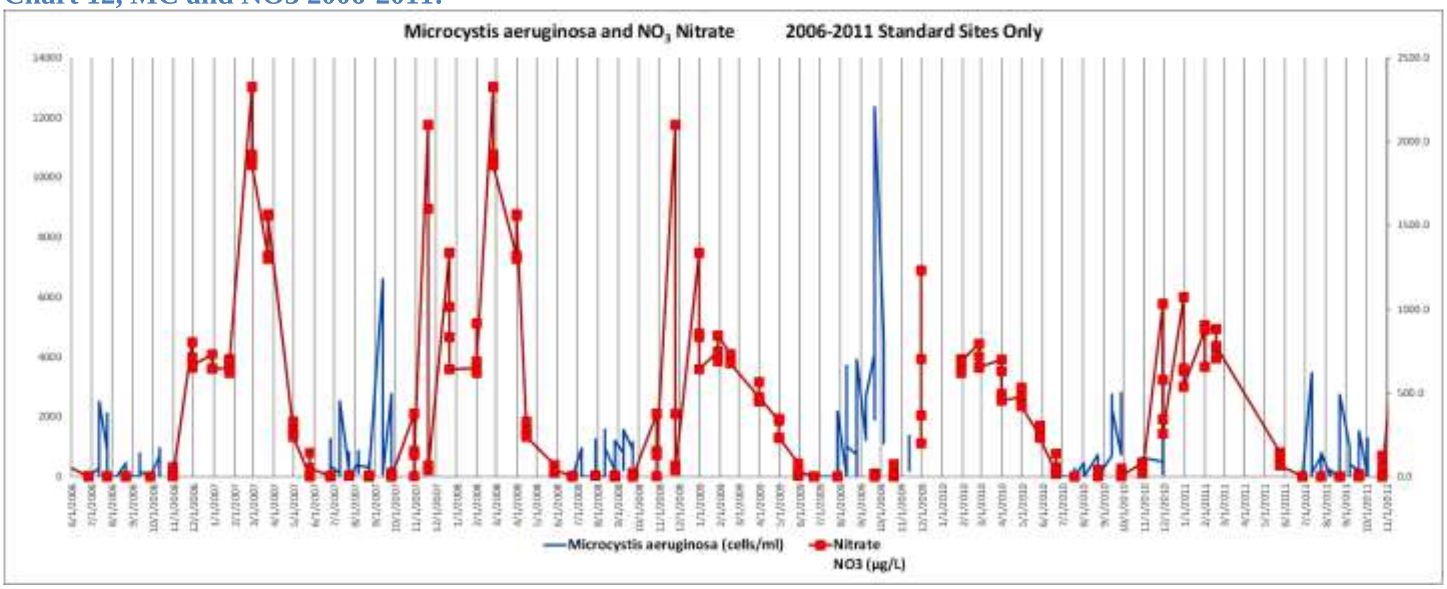


Chart 13 shows Microcystis in relation to the TN:TP ratio. Once again there is a negative correlation between the MC cell counts and the TN:TP ratio. The same can be seen even more clearly in Chart 14 with the NO3:PO4 ratio. This is once again supported by the 2013 full year data seen above. Charts 15 & 16 show the same N03:PO4 negative correlation between Anabaena (AN) and Aphanizomenon respectively. Aphanizomenon shows a slightly earlier peak than the other two, indicating that it might lose some of its competitive edge as the summer progresses, or as the NO3:PO4 ratio stays low. Although it should be noted that the scale on the Aphanizomenon chart peaks at 60,000cells/ml while the other two peak around 14,000, which matches the table seen above where Aphanizomenon 6-year totals are counted in the 100’s of thousands or even millions, while MC and AN totals are only in the 10’s of thousands.

Chart 13, MC and TN:TP Ratio:

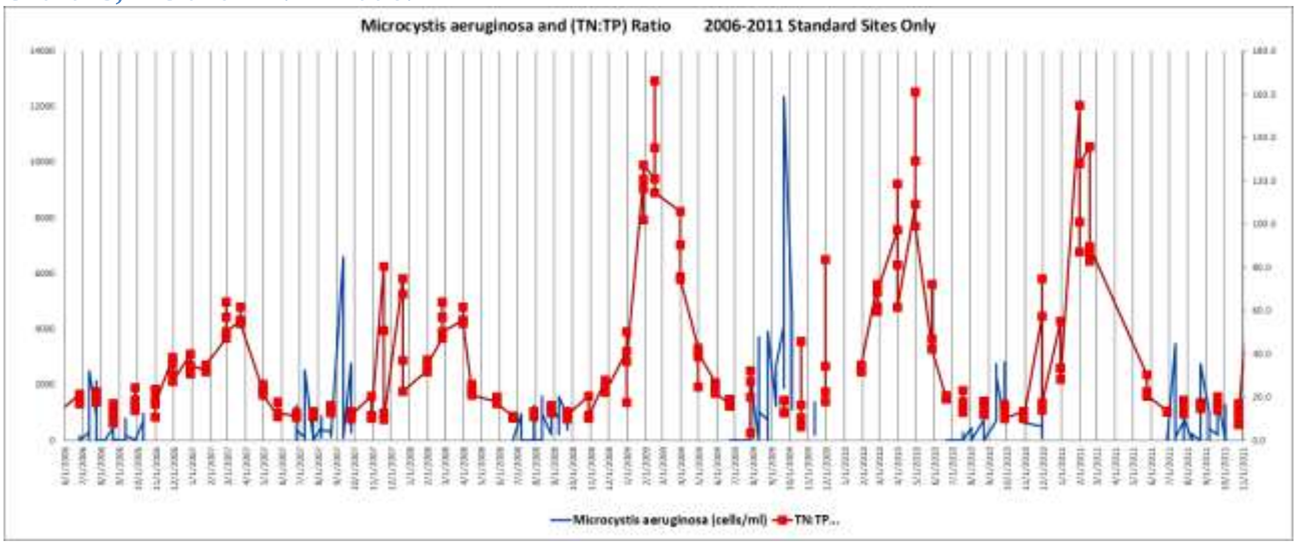


Chart 14, MC and NO3:PO4 Ratio:

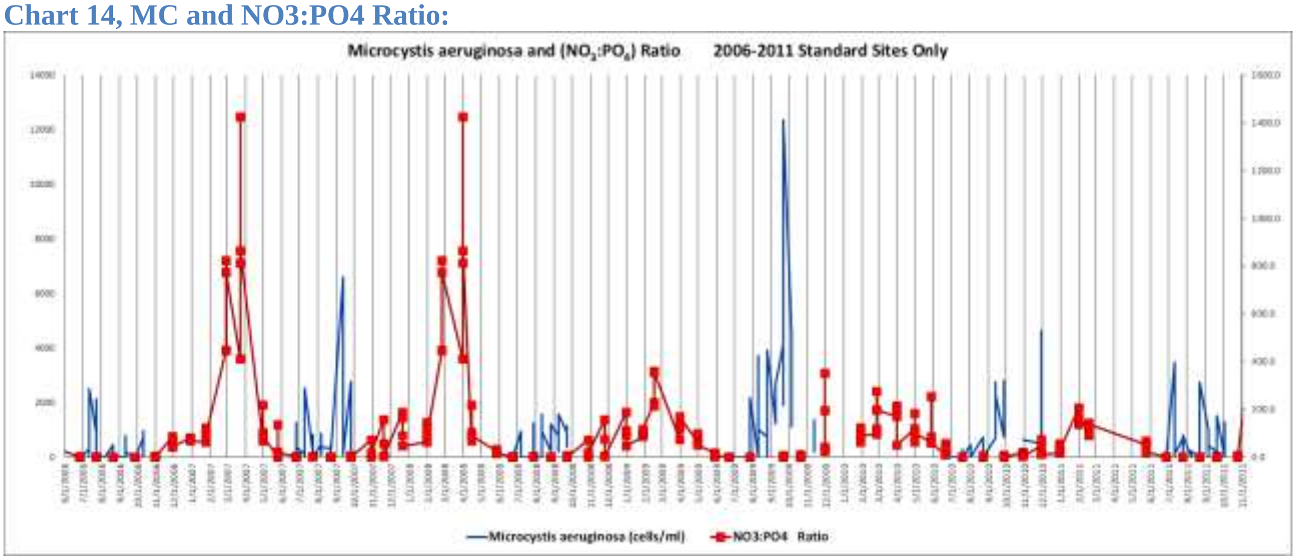


Chart 15, Anabaena and NO3:PO4 Ratio:

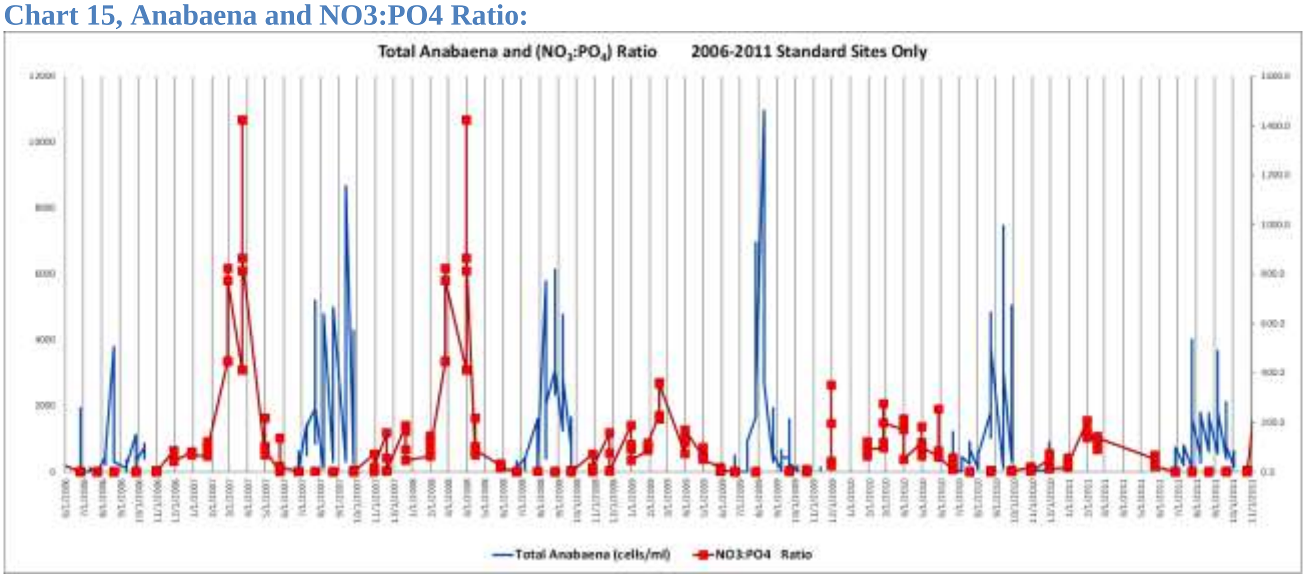


Chart 16, Aphanizomenon and NO3:PO4 Ratio:

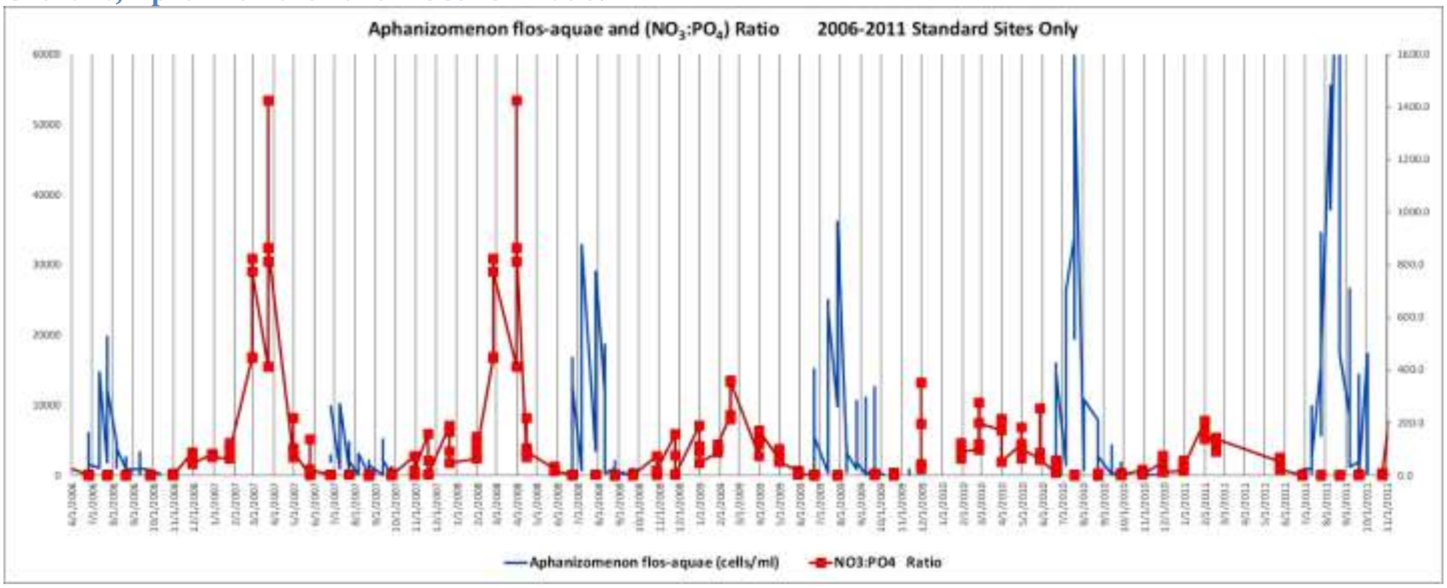


Chart 17 shows MC in relation to Water Temperature. In several cases it indicates that the highest growth rate occurs slightly after the summer temperature peak. This corresponds to our observation that we normally have our biggest blooms in mid-September.

Chart 17, MC and Water Temp:

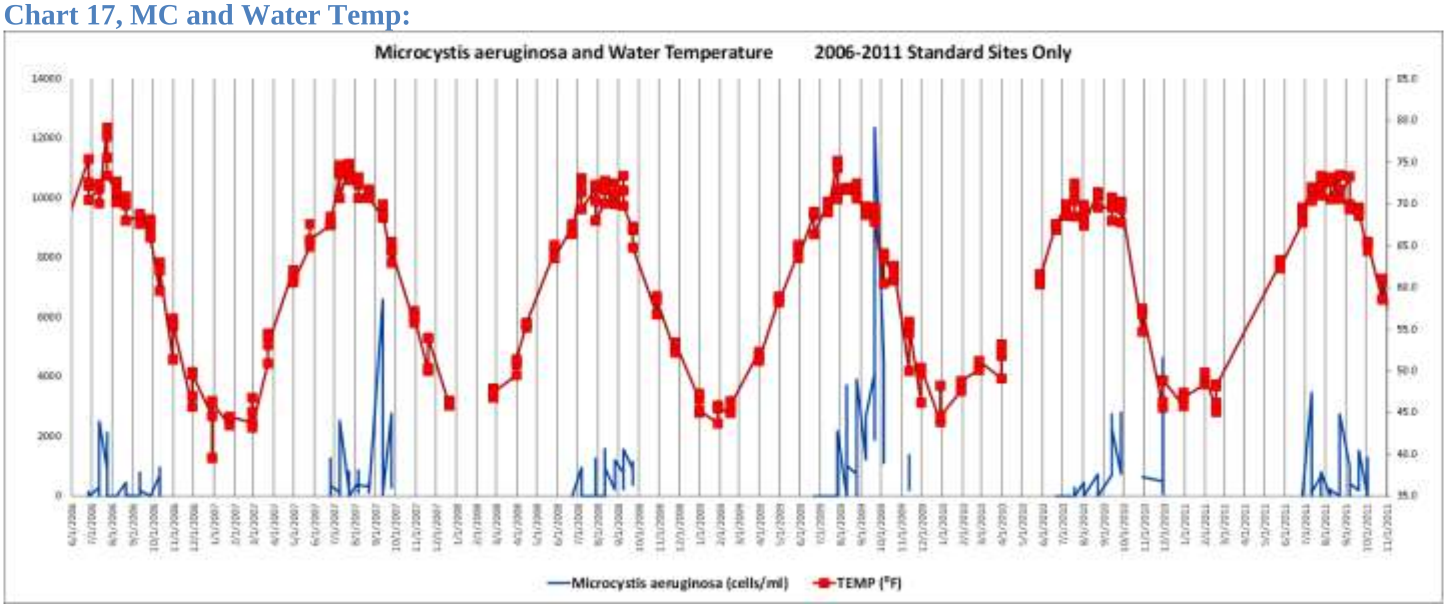
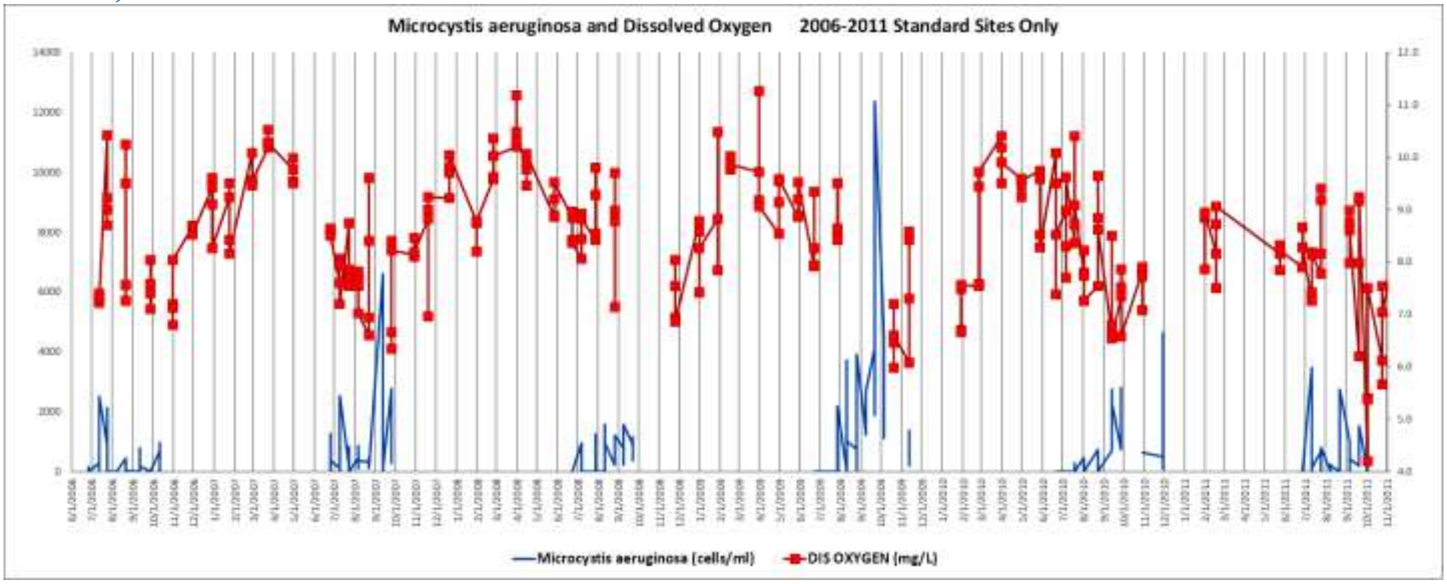


Chart 18 shows a general negative relationship between DO and cell counts. We take most of our samples in the morning, so some of the lower DO levels could be due to nightly cell respiration, and higher yearly water temperatures. The lower DO levels don't seem to have a negative effect on the algae growth rate, but could stress fish or other aquatic wildlife. 2013 data shows only a mild negative correlation of -0.39 between cyanobacteria biovolume % and DO (mg/L).

Chart 18, MC and DO 2006-2011:



Overall, Algae levels are high in the summer months and appear to be related to many different factors. Temperature, Nitrogen, and Phosphorus seem to play a key role. Low Nitrogen: Phosphorus ratios seems to be tightly correlated with blue-green algae blooms, with some research showing that certain low ratios around the 10:1 range might favor their growth over competing species, perhaps due to their nitrogen fixing abilities.

Lake Nutrient Sampling Program

The Lake Nutrient Sampling Program monitored the seasonal changes in: PO_4, NO_2, NO_3, NH_4, SiO_4, Chl a, Total Nitrogen and Total Phosphorus, and also measured the same parameters listed under algae sampling. Tenmile Cr was also included in this monitoring effort. Sampling occurred once a month, with nutrient sampling being done concurrently with algae sampling in the summer to monitor any uptake in nutrients from algae growth. It also corresponds with the lake sampling from Storm Chasing in the winter months to show effects of nutrient loading from TSS during storm runoff. This has the potential of biasing winter results slightly higher because 1-2 samples might be taken specifically to catch the higher storm runoff periods. This data was interpreted with weather and lake conditions obtained by our lake gauge station. Trend analysis was performed on the summary data to determine if TMDL goals are being achieved. When more funding becomes available, the watershed will go towards sampling both top and bottom in conjunction with continuous monitoring to get an accurate nutrient analysis throughout the water column. The current list of sampling sites is shown below. Site TC1 has a backup location at TC2 so sampling can be done at high water levels that make TC1 inaccessible. All nutrient samples are now sent to LSSU for analysis.

Map 4, Nutrient Sampling Sites:

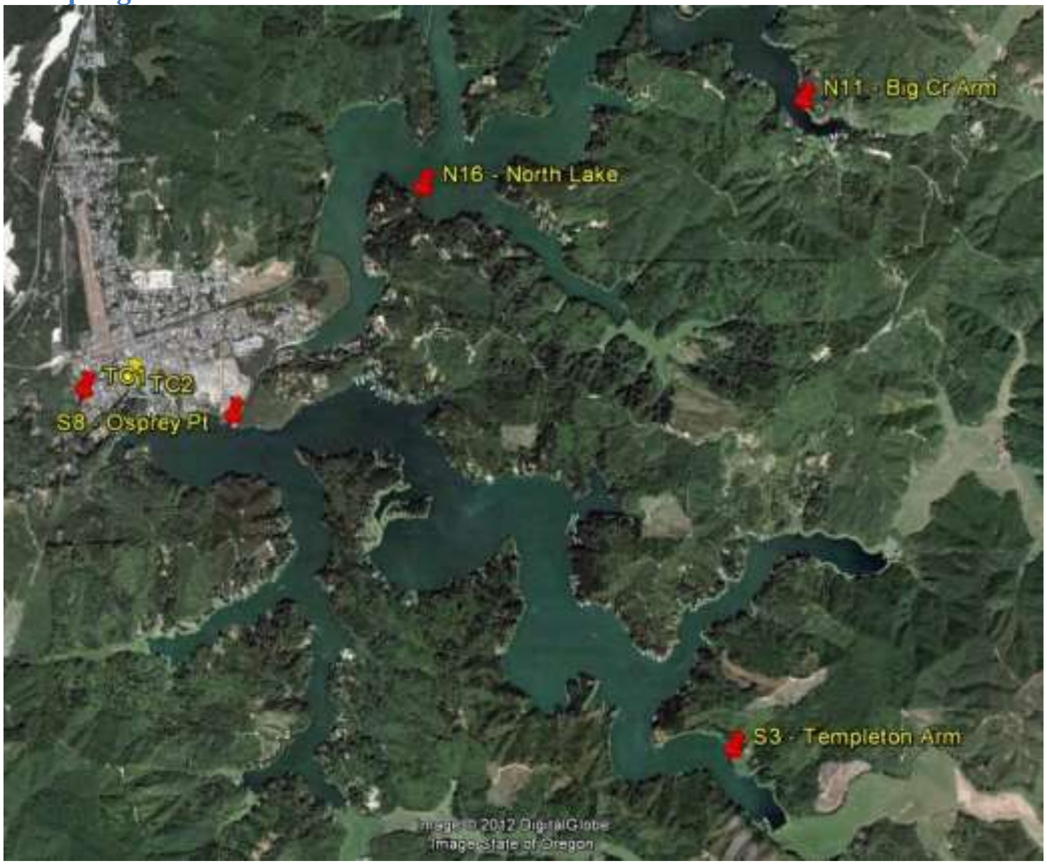


Table 10, Nutrient Sampling Sites:

Site ID #	Site Name/Location	UTM
S3	Templeton Arm/ South Lake	10T0 409437 4822401
S8	South Lake Canal	10T0 405753 4824927
N16	Middle of North Lake	10T0 407191 4826591
N11	Big Creek Arm/ North Lake	10T0 410025 4827194
TC1	Tenmile Cr.	10T0 404656 4825134
TC2	Tenmile Cr backup site – Park St Boat Ramp	10T0 405000 4825219

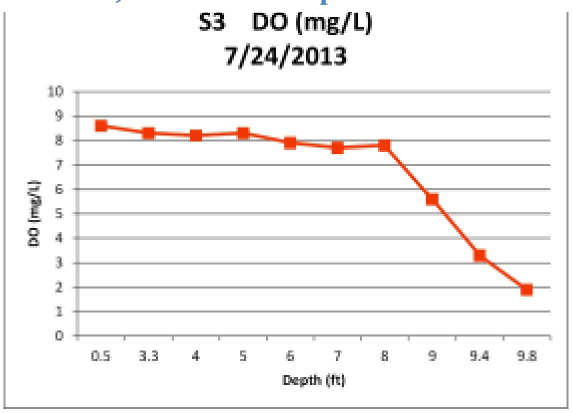
2012 and 2013 Parameter data is listed below (Charts 20 & 24). It should be noted that we had 3 larger storms in 2012. They influenced the lake and sample results to varying degrees. The first storm was from 1/16 – 1/20/2012 and dropped 8.66" of rain. The lake peaked at 17.75' on 1/21/2012, and sampling date was 1/26/2012. The second storm was from 3/19 – 3/23/2012 with a sampling date of 3/22/2012. Precipitation totaled 4.26 inches in five days. The lake crested at 11.77'. The last storm will be part of the winter 2012-2013 storm season. It was from 11/17 – 11/21/2012 and totaled 5.88". Lake sampling occurred on 11/20/2012. It qualified at a 2-yr 24-hour event. We will discuss storm data later under Storm Chasing, but these storms did influence some of the lake parameters discussed below.

Temperature (Chart 20-left) had a 2 year grab sample low of 41.7^{o}F at N11 on 12/17/13, and a high at S3 of 75.7^{o}F on 9/10/13. We had a particularly cold December in 2013 and the upper end of Big Cr Arm froze over. The 2 locations in the shallower waters near the mouths of the streams (N11 near Big Cr and S3 near Johnson Cr) show the widest range of temperatures. They were both cooler in the winter and warmer in the summer. The August 6th 2012 readings show a 2^{o}F difference as the water travels down the lake from N11 to N16 and S3 to S8. The water continues to cool as it enters

Tenmile Cr where it loses another 2^{o}F in the summer. The shift from S3 and N11 being cooler to being warmer again happened at the 4/30/12 sampling. They reversed back to being cooler on 10/22/12. Natural lake temperatures are not under a specific limit except that found in OAR 340-041-0028 (6) which states that natural lakes may not be warmed by human discharge or modification by more than 0.5 degrees Fahrenheit above the natural condition. We are unaware of any discharge or modification that would affect temperatures on either Tenmile Lake.

Dissolved Oxygen (DO) sampling was changed from using BOD bottles and titrations to using a multi-parameter probe on the May 30th, 2012 sampling. This has been a big time saver for the watershed staff, and it has shown very good Quality Control with most duplicate samples reading exactly the same or within a tenth of the original reading on all parameters. DO data is taken approximately 1 meter below the lake's surface and about 1 foot below the surface in Tenmile Cr.
DO readings for 2012 don't show a consistent pattern between sites, nor do they vary consistently throughout the year. (Chart 20-middle & right) Every site had at least one month when it had the highest reading. The lake sites generally range between 8 - 11mg/L and above 80% saturation, with several lower reading in the summer. In March, the difference between the lowest reading (10.5) and the highest reading (10.6) was only 0.1mg/L, but in September N16 came in at 10.6 and TC1 read 5.1 for a difference of 5.5mg/L. The 2012 yearly high for all sites was at S3 on 2/27/2012 at 10.9mg/L and the yearly low was at TC1 on 8/20/2012 with a reading of 4.9mg/L.
DO's for 2013 showed a high at N16 of 14.1mg/L (118%) on 2/14/13 and a low at N11 on 9/10/13 @ 10:05AM of 2.6mg/L (30%). N11 is shallow and has a great abundance of weeds.

Chart 19, DO - Water Depth Profile for Site S3:



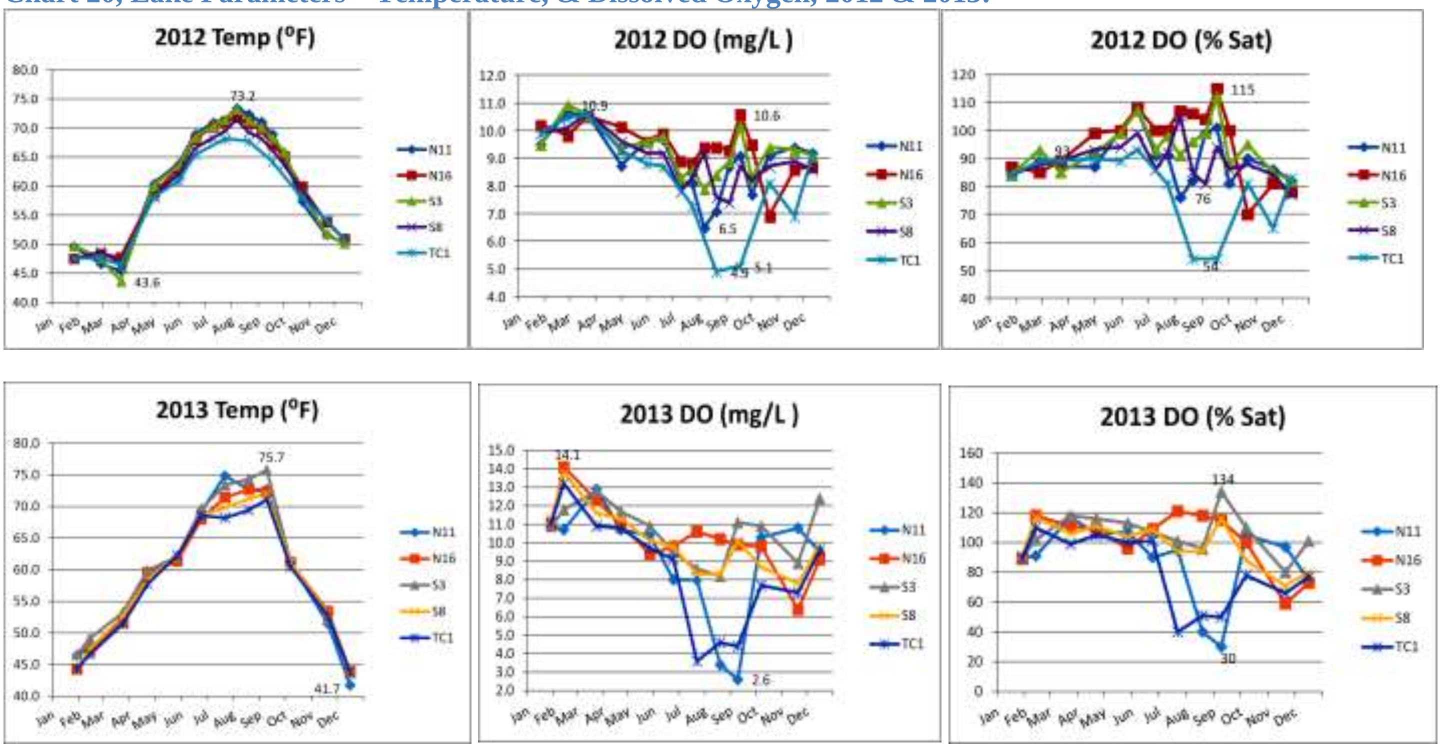
A depth/DO profile was conducted on July 24, 2013 at 10:00AM for the shallow site at S3. The resulting data is shown in Chart 19. Surface DO was 8.6mg/L (100%) and it ranged down to a final DO of 1.9mg/L (22%) at 9.8ft. The temperature profile only varied from 23.1°C at the surface to 22.3°C near the bottom, not indicative of a thermocline layer. The low benthic DO readings could indicate the conditions necessary for phosphorus recycling from the benthic sediments. ODEQ conducted a study in 2013 to explore this possibility, but the results have not yet been analyzed. TLBP has proposed a monitoring effort for the summers of 2014 & 2015 that will look at the DO, pH and Phosphorus.

The low DO readings for Tenmile Cr are probably due to the lower summer flows, lack of any rapids in the creek, and the high weed growth within the stream. There is a large invasion of both Egeria densa and Myriophyllum aquaticum (Parrot Feather) in Tenmile Creek. Future funding would support data collection on invasive macrophytes within the stream and possible control measures that could be put in place to reduce the population of these species. September 2012 TC1 data was also low at 5.1mg/L, but makes a rapid recovery in October up to 8.1mg/L. The sampling routine is also a little different in the summer. We tended to do TC1 early, before lake sampling, since the sunrise is earlier and we can get out in the field sooner. In the winter, we tend to do the lake first, and end with the creek. On 8/22/2013, extra samples were taken to look at the diel DO cycle. Table 11 below shows the results. Water coming into Tenmile Cr had DO of 8.1mg/L. Samples taken at TC1 showed 1.2mg/L (13%), 4.2mg/L (47%), and 5.3mg/L (59%) over a 9 hour period. One sample taken on top of an *Egeria densa* patch at Site TC2, showed DO at 15.2mg/L (180%) with a pH of 9.39su. ODEQ and TLBP plan on conducting a study in 2014 to look at this issue.

Table 11, Tenmile Cr Daytime DO Levels. August 22, 2013

Site	Date	Time	Depth (ft)	Temp (ºC)	DO (mg/L)	DO % Sat	pH
TC1	8/22/2013	7:35	1	21.0	1.2	13	6.24
TC1	8/22/2013	12:51	1	21.0	4.2	47	6.39
TC1 DUP	8/22/2013	12:54	1	21.0	4.3	48	6.52
TC1	8/22/2013	16:45	1	20.8	5.3	59	6.56
TC2 (Park St)	8/22/2013	13:05	0.2	23.6	15.2	180	9.39
Ringos	8/22/2013	13:24	1	21.4	8.1	92	7.51

Chart 20, Lake Parameters – Temperature, & Dissolved Oxygen, 2012 & 2013:



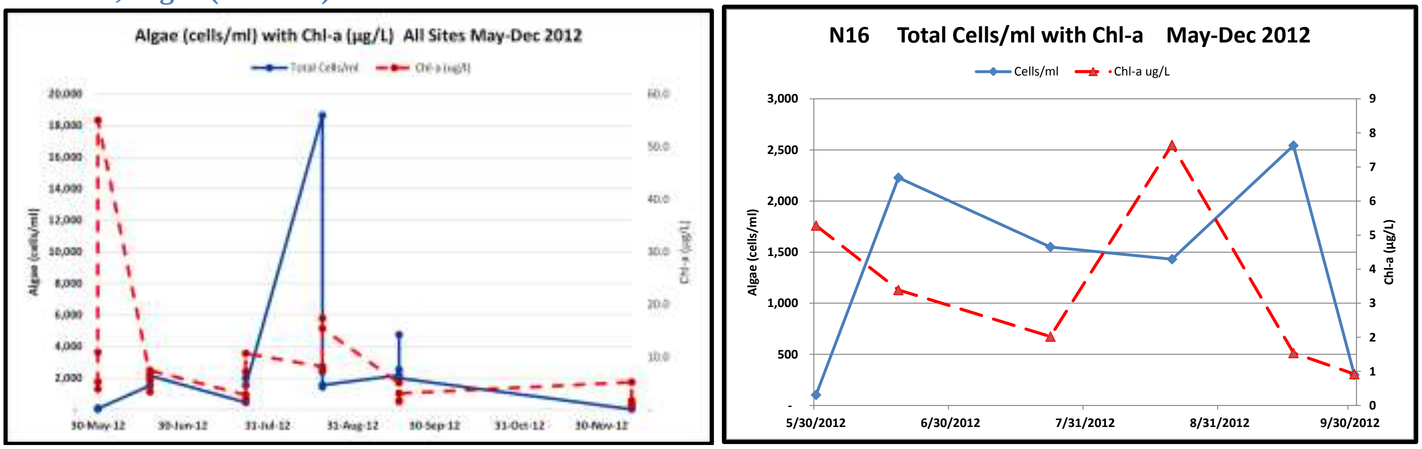
pH range of 7-8su is considered optimal, with 6.5 - 8.5su acceptable to most aquatic life. Most 2012 readings for all sites were within the 6.5-8.5 range with the majority of the data falling in the 7.0 to 7.5 range. (Chart 24-left below) Similar data is see in 2013 with the exception of Site N16 where the 7/23/13 reading was 9.27su, 8/20 was 8.88su, and after a drop to 7.45su in October, it rose again to 10.30su in November. Combined with the DO data shown earlier, this could be an indication of a diel respiration/photosynthesis cycle perhaps caused by excess algae growth, and possible Phosphorus recycling.

Specific Conductivity (Chart 24-middle) generally increased linearly throughout the year with TC1 usually the highest and S3 the lowest, until October/November when they all started dropping. The November 2012 reading was taken during the first big storm of the 2012-2013 winter season. We had a high on 3/22/12 of 95.5µS/cm, which may be a false reading from the multi-parameter probe. We later discovered that a loose connection between the probe and the meter can give inaccurate, very high results.

Chl-a (Chart 24-right) started in January 2012 with very low numbers near 1µg/L. They rapidly increased in late February, 2012 with N16 peaking at 28µg/L. We have a limit listed in our TMDL of 15µg/L. N16, N11, and S8 all exceeded that limit in February. During the storm sampling on 3/22/12, all sites dropped below the limit. N16 rose briefly in April to 16µg/L, then all sites dropped until June or July. Tenmile Cr and both south lake sites started rising again in July, while both north lake sites (including N16) continued dropping in July. All sites had a 2012 summer peak on August 20, with TC1 and S3 the highest at about 17µg/L, and S8 just exceeding the limit at 15.45µg/L. S8 also had one outlier on 5/30 that peaked at

55µg/L. Since all the other sites were going down and there was no particular event that we are aware of that would have caused a peak this high, it is probably a data anomaly. All data points dropped dramatically in September and were near zero again by October. Overall, all sites exceeded the 15µg/L limit at some point in 2012, but only N16 (and possibly S8) Exceeded the limit by more than a couple of points, and none maintained that level for more than one reading. For 2012 North Tenmile Lake peaked early in the year, and then fell to a relatively low summer season. South Lake peaked both in the winter and summer, with both peaks just exceeding the limit. Correlation between algae cells/ml and Chl-a for 2012, all sites combined, was a very low -0.05, meaning the relationship was almost perfectly random. Chart 21 below plots that relationship, along with site N16 shown individually.

Chart 21, Algae (Cells/ml) with Chl-a. All Sites and Individual Site N16:



Chl-a amounts for 2013 were dramatically higher than 2012. January readings showed levels all below the 15µg/L limit, and Feb-April data all hovered just above or just below that limit. Starting in May 2013, the levels jumped drastically with most reaching between 175-210µg/L. A brief dip into the 75-100µg/L range in June, then climbing again in July and August with a high at S8 of 260µg/L (17X the limit). Levels fell in September and varied throughout the remainder of the year, settling in December with values between 13 and 57µg/L. Early 2014 levels averaged around 20µg/L. These high levels of Chl-a, hovering in the 200µg/L range for most of the summer, greatly exceed Chl-a levels from past years which rarely exceeded 50µg/L. We asked the lab (LSSU) to verify the results and their calculations. They reported that all QA/QC standards where within limits for each test. Their QA/QC and test results for summer 2013 are shown below in Table 12. As in 2012, correlations were very low as noted above in Table 8. Both Biovolume/Chl-a and Cells/ml/Chl-a charts for N16 and S3, full year 2013, are shown below in Chart 22. Interesting to note that algae biovolumes in the winter exceed the summer biovolumes at both sites, but cells/ml tend to be less in the winter than in the summer. This would reflect the different types of species that are present in each season. In the N16 chart, the clear-water phase that occurred in April 2013 is very apparent.

Chart 22, Total Algae Biovolume and Chl-a. Sites N16 & S3. 2013:

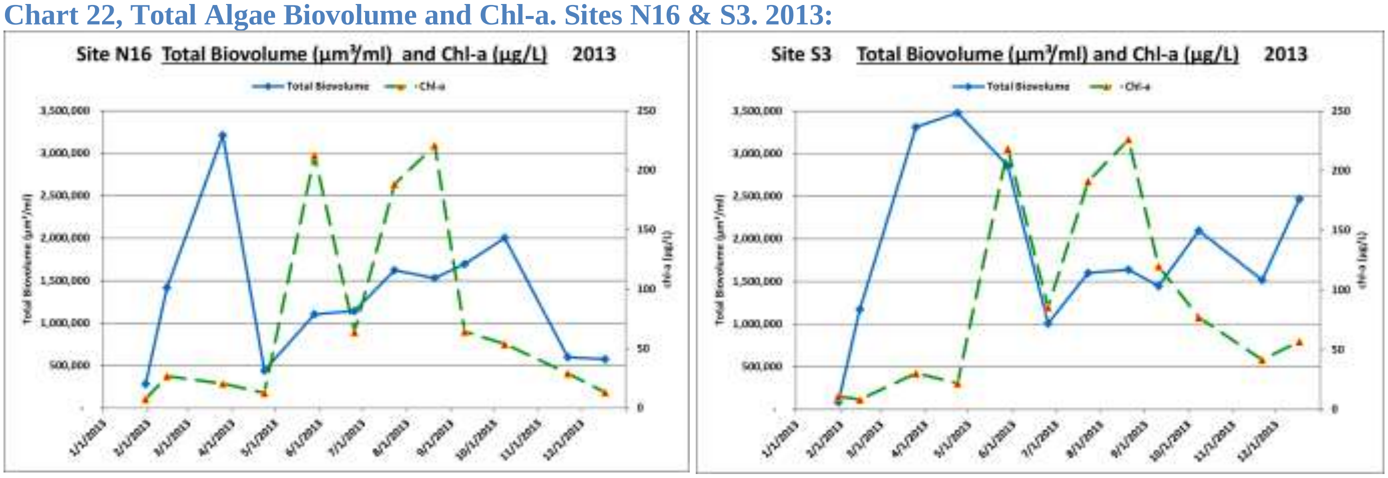
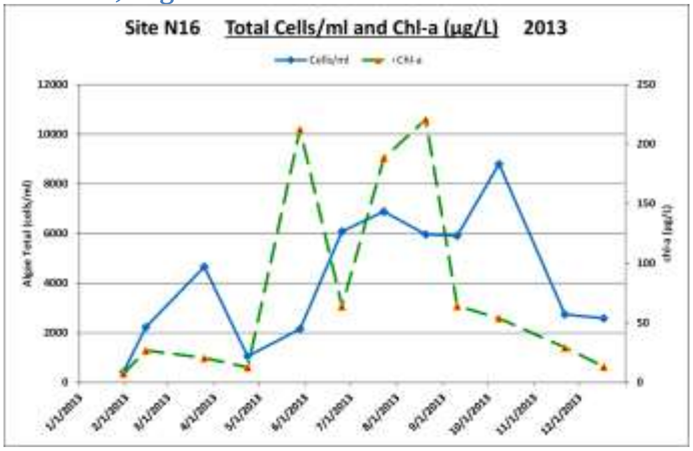


Chart 23, Algae Total Cells/ml and Chl-a. Sites N16 & S3. 2013:



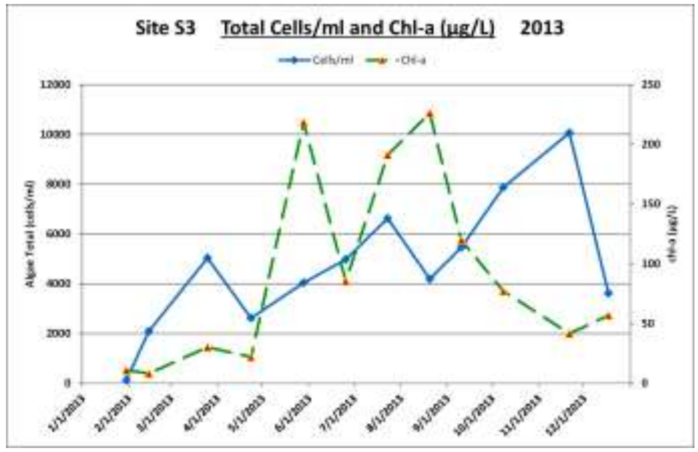


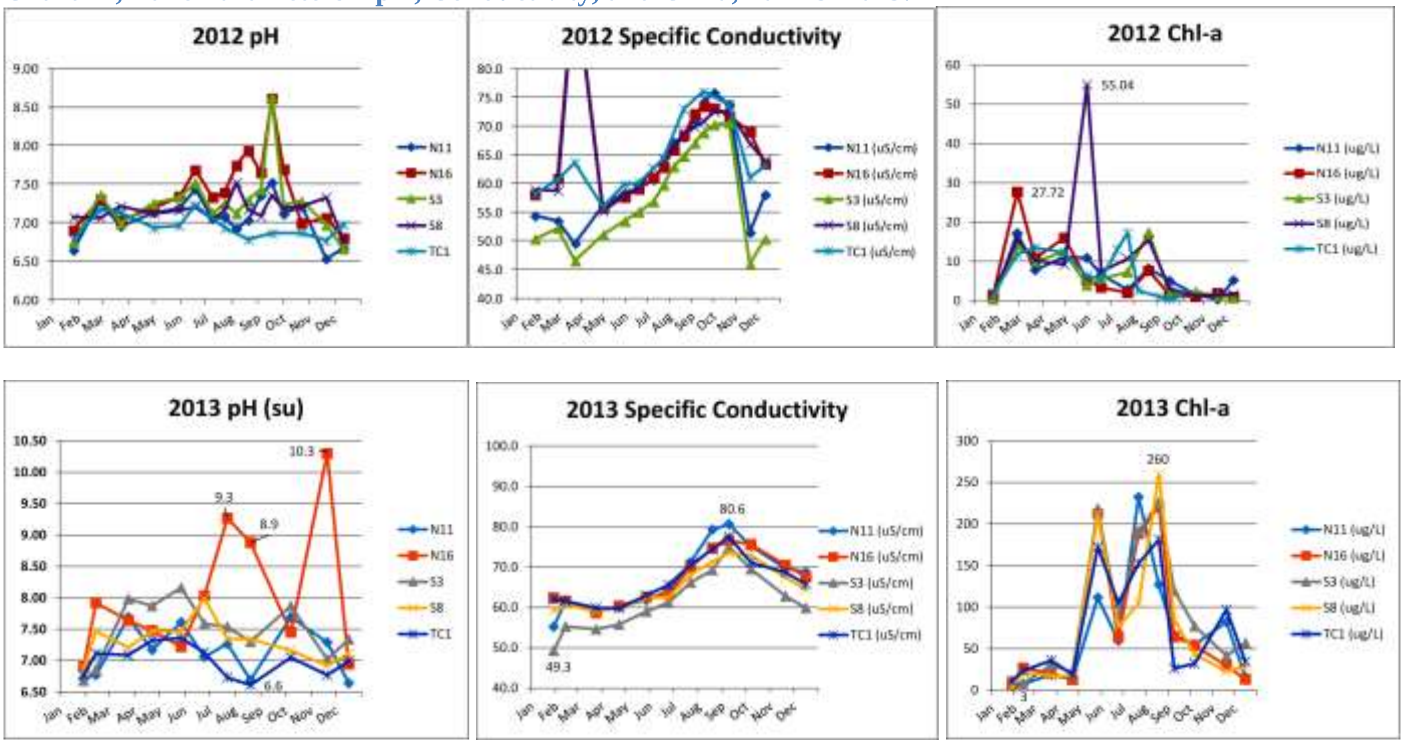
Table 12, Chl-a QA/QC & Data Report. Summer 2013

Sample Name	Date Filtered	Volume Filtered (L)	Absorbance 664 nm	Absorbance 647 nm	Absorbance 630 nm	Raw Chl-a (mg/L)	Sample Chl-a (ug/L)
LSSU Blank	na	na	0.0000	0.0000	0.0000	0.00	na
20 ppb Chl-a Std	na	na	0.0019	0.0003	0.0002	0.02	na
N16	5/28/2013	0.06	0.0840	0.0970	0.1170	0.84	111.55
N16 Dup	5/28/2013	0.06	0.1600	0.1860	0.2120	1.59	212.35
N11	5/28/2013	0.06	0.1660	0.1930	0.2230	1.65	220.27
S3	5/28/2013	0.06	0.1650	0.1940	0.2280	1.64	218.43
S8	5/28/2013	0.06	0.1610	0.1960	0.2300	1.59	211.68
TC1	5/28/2013	0.06	0.1300	0.1510	0.1760	1.29	172.52
LSSU Blank	na	na	0.0000	0.0000	0.0000	0.00	na
20 ppb Chl-a Std	na	na	0.0017	0.0006	0.0004	0.02	na
N16	6/25/2013	0.06	0.0470	0.0520	0.3590	0.45	59.75
N16 Dup	6/25/2013	0.06	0.0440	0.0500	-0.4470	0.48	64.02
N11	6/25/2013	0.06	0.0500	0.0550	0.0670	0.50	66.99
S3	6/25/2013	0.06	0.0630	0.0640	0.0780	0.64	85.57
S8	6/25/2013	0.06	0.0570	0.0620	0.0740	0.57	76.54
LSSU Blank	na	na	0.0000	0.0000	0.0000	0.00	na
20 ppb Chl-a Std	na	na	0.0019	0.0005	0.0003	0.02	na
N11	7/23/2013	0.06	0.1379	0.1474	0.1642	1.39	232.33
TC1	6/25/2013	0.06	0.0657	0.0912	0.1131	0.63	104.84
N16	7/23/2013	0.06	0.1117	0.1188	0.1357	1.13	188.31
S3	7/23/2013	0.06	0.1135	0.1211	0.1401	1.15	191.21
S8	7/23/2013	0.06	0.0622	0.0656	0.0807	0.63	104.93
S8 Dup	7/23/2013	0.06	0.0630	0.0678	0.0775	0.64	105.99
TC1	7/23/2013	0.06	0.0943	0.1238	0.1395	0.92	152.61
LSSU Blank	na	na	0.0000	0.0000	0.0000	0.00	na
20 ppb Chl-a Std	na	na	0.0021	0.0004	0.0004	0.02	na
N11	8/20/2013	0.06	0.0764	0.0884	0.1007	0.76	126.86
N16	8/20/2013	0.06	0.1319	0.1464	0.1643	1.32	220.74
N16 Dup	8/20/2013	0.06	0.1287	0.1282	0.1263	1.32	219.68
S3	8/20/2013	0.06	0.1326	0.1311	0.1521	1.36	226.21
S8	8/20/2013	0.06	0.1564	0.1813	0.2068	1.56	259.60
TC1	8/20/2013	0.06	0.1063	0.1063	0.1066	1.09	181.24

na = not applicable

Note: The Sample Chlorophyll a concentration utilizes a extration volume (8 mL May/June and 10 mL July/August) and a volume filtered (60 mL).

Chart 24, Lake Parameters – pH, Conductivity, and Chl-a, 2012 & 2013:



Turbidity and Secchi Depths are both influenced by algae growth in the summer, and algae and TSS from streams in the winter. All 3 of the major storms in 2012 are clearly visible in both the Turbidity and Secchi Charts (25) below. The timing of the lake sampling, compared to the date of the rain event, also influences the specific sites that show the highest levels of turbidity, or the corresponding low Secchi depths. Note that on the Jan 26th sampling N16, S8, and TC1 are all showing higher turbidity readings (and lower Secchi depths) than sites N11 and S3. As outlined in the first paragraph of this section, the storm ended on 1/20, but the sampling didn't occur until 1/26, so the sediment plume had already past the upper sites and traveled down to the lower sites in both lakes and into Tenmile Cr. The upper sites remained slightly elevated relative to their readings in February, so some of the residual sediment was still in the water column, but it appears that after about a week, most of the sediment has either settled out or moved on down the lake.

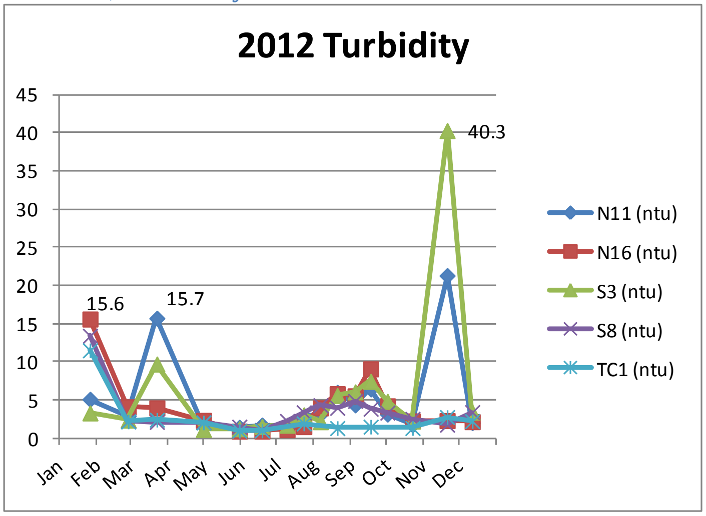
The turbidity readings for both the March and November storms show just the opposite effect. Lake sampling for both occurred 1 day before the end of the storm sampling. We can see that N11 and S3 are both peaking while N16, S8, and TC1 have remained virtually unchanged from the month before. When sampling from the boat, the sediment plumes are often readily visible with a clear demarcation between the leading edge of the plume and the rest of the lake.

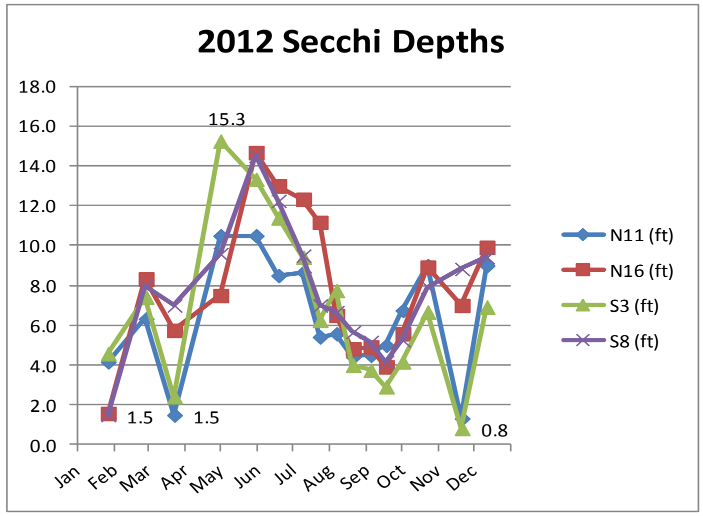
Future monitoring efforts should set up sampling sites to better quantify sediment export from the mouth of the Johnson and/or Big Cr to Tenmile Cr to monitor what volume of TSS is settling in the lake and how much is washing down Tenmile Cr to the ocean.

Winter 2012 readings at all sites showed Secchi depths of about 15ft in April and May. N11 was recorded as less, but we hit the lake bottom in May with the disc still clearly visible, and there is a severe weed problem at N11 that makes getting accurate Secchi readings problematic. It was also noted on the May data sheet for S3 that we hit bottom, but that it was very close to the Secchi depth anyway. EPA bench marks for Tropic Status list >4 meters (13ft) as Oligotrophic. Likewise, turbidity readings for April through the end of July are below the 3.69 NTU "least disturbed" level listed by the EPA for the Xeric West region, so at least for a couple of months the lakes are showing their potential.

The other peak we see in turbidity (and low in Secchi) is in September. We can see a steady climb starting in July which peaked at N16 on 9/17/2012 with a 9.07ntu turbidity reading and a corresponding Secchi depth of 3.9ft. From July to the beginning of October, all sites recorded Secchi depths between .7 to 2.1 meters (2.3 – 6.9ft) which categorizes them as Eutrophic status. During the summer months the streams leading into the lake have a minimal impact due to very low water flows. The turbidity peaks that we see at this time of year correspond to algae blooms instead of TSS.

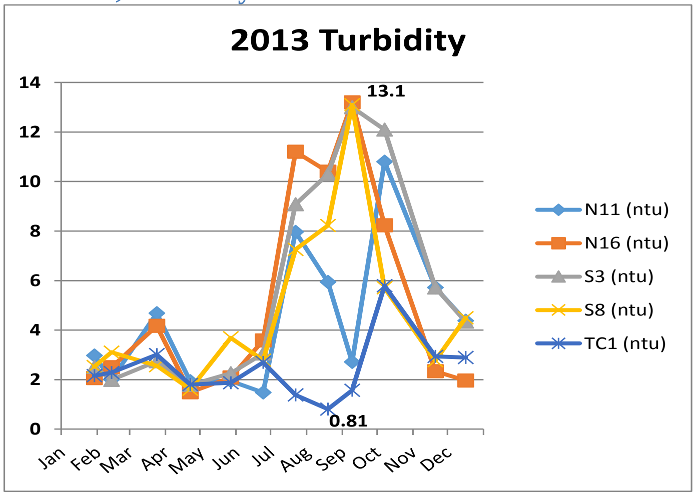
Chart 25, Turbidity & Secchi 2012:





2013 Turbidity shows a similar pattern to 2012, with a general elevated pattern in summertime readings (Chart 26). 2012 summer data ranged in the 5-10ntu area, whereas 2013 data fell more in the 10-13ntu range. The exception was N11 which was 7.96ntu in July 2013, but fell to 5.94ntu in August and 2.71ntu in September, while the other 3 lake sites continued to rise during this same period. For example S3 (the other shallow water site) on the same 3 dates: 9.08, 10.3, and 13.0ntu respectively. This was visible to the naked eye and was noted in the comment section of the data collection form. One explanation of this relatively low turbidity could be lack of available nutrients for algae growth since this area of the lake is populated by large amounts of macrophytes, mainly Egeria densa, but a careful look at the corresponding nutrient data reveals higher levels than at any of the other sites. (See Table 13 below.) The Nitrite level of 26µg/L, was the second highest of the year for the whole lake, and 1 of only 7 readings all year that was above the detection limit. So there was more nutrients available at N11 than at any of the other sites. Chl-a was 66.3µg/L at N11 vs 119.9µg/L at S3, and Algae Cells/ml at N11 was 3162cells/ml vs 5464cells/ml at S3 which corresponds to the respective turbidity readings. The only unusual negative attribute for N11 is the very low DO level of 2.6mg/L vs 11.1mg/L at S3. It could be postulated that these low DO levels are either negatively affecting all algae, or are less favorable to Cyanobacteria which is increasing the competition between Cyanobacteria and other algae that might be more tolerant of the low DO conditions. Another possibility is that the low DO levels are adversely affecting the planktivorous fish populations which normally overgraze the zooplankton, but are unable to do so in this unfavorable environment. With the reduced grazing on the non-cyanobacteria populations, that has increased the competition on the Cyanobacteria resulting in a population decrease of the normally dominate species. The algae biovolumes shown below support the idea of increased competition with N11 Cyanobacteria at 54.3% vs 85.2% at S3. The overall correlation between Turbidity and algae is most notable in the Total Cyanobacteria Biovolume% with a correlation of 0.76. In particular, Anabaena planktonica has a 0.92 correlation between Cells/ml and Turbidity, and a 0.90 correlation between Biovolume% and Turbidity.

Chart 26, Turbidity & Secchi 2013:



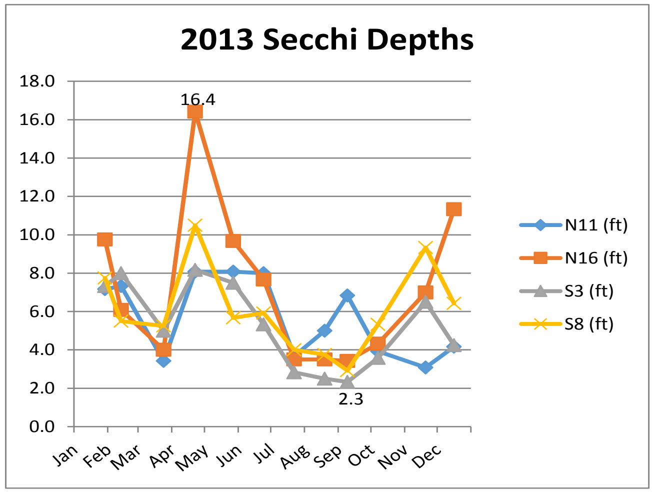


Table 13, Algae and Parameter/Nutrient Comparisons between Shallow Water Sites 9/10/2013

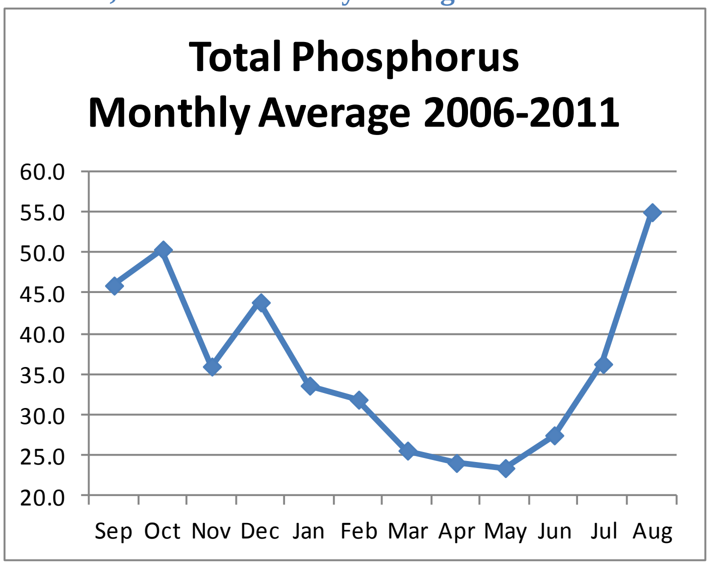
Parameter 9/10/2013	Site N11 9/10/2013	Site S3 9/10/2013
Turbidity	2.71ntu	13.0ntu
Secchi Depth	6.8ft	2.3ft
TP	64µg/L	53µg/L
TN	329µg/L	170µg/L
NO_3	60µg/L	14µg/L
NO_2	26µg/L	Below Detection Limit (<10 µg/L)
NH_4	15µg/L	Below Detection Limit (<10 µg/L)
Chl-a	66.3µg/L	119.9µg/L
Total Algae (Cells/ml)	3162cells/ml	5464cells/ml
Algae Biovolume%	Cyanobacteria: 54.3% Dinoflagellates: 24.6% Green: 19.4% Diatoms: 1.5% Other: 0.3%	Cyanobacteria: 85.2% Dinoflagellates: 10.8% Green: 3.2% Diatoms: 0.6% Other: 0.2%
Dissolved Oxygen	2.6mg/L (30%)	11.1mg/L (134%
Temperature	22.6°C	24.3°C

More Nutrient and Parameter data for 2012-2014 can be seen on Appendix CD: *Lake Sites Data 2012 MAIN Final*, *Lake Sites Data 2013 MAIN Final*, **and** *Lake Sites Data 2014 MAIN Final.*

2006 – 2011 Lake data was also compiled and analyzed for yearly cycles. We began by calculating monthly averages for all lake sites combined. The charts (27) below show the monthly averages (e.g.: Januarys for all 6 years averaged together, February data averaged for all 6 years, etc) for Total Phosphorus and Total Nitrogen. This allows us to see the broad cycles that are happening in the lake. Each graph begins in September. Both graphs show that TP and TN are relatively high in the late fall and early winter. As spring approaches, the levels drop, probably due to an increase in algae growth consuming the nutrients and diminished nutrient input from the streams. TP bottoms out in May and TN hits its low in June. We then see an unexpected upswing in both throughout the summer. Since the tributaries to the lakes are all flowing at very low levels during the summer, the nutrient input from this source is minimal. In addition, we have high summer algae levels consuming the nutrients, so we would expect to see the levels continuing to drop. These heightened nutrient levels coincide with the summer tourist season. Human activity on the lake, particularly people using their summer cabins, is one likely source of these additional nutrients. Septic systems for lakefront homeowners were shown to be a problem in a TLBP study of pre-1974 septic systems conducted in 2006 – 2007. Results showed only 20% of these septic systems were functioning properly (See chart 28 below.) The increased levels of nutrients, combined with favorable climatic conditions, create the perfect opportunity for cyanobacteria to rapidly multiply. These finding were submitted to the ODEQ to support the proposal for amending the Onsite Septic System Program rules change in October, 2012.

Other possible sources of increased summer TP include: Benthic Phosphorus recycling, Erosion from boat wakes, lawn fertilizers, and wildlife waste (fish, beaver, otter, birds, etc). TP trend analysis discussed below also points to summer activity being the major cause of continued high TP levels. Since creek inputs are too insignificant in the summer to cause the nutrient rise that we see, funding to explore other possible sources is needed. The contribution of nutrients from bottom sediments through low DO levels or, possibly stirred up from boating activities is one possible source that should be explored, especially in relation to TP.

Chart 27, TP & TN Monthly Averages 2006-2011:



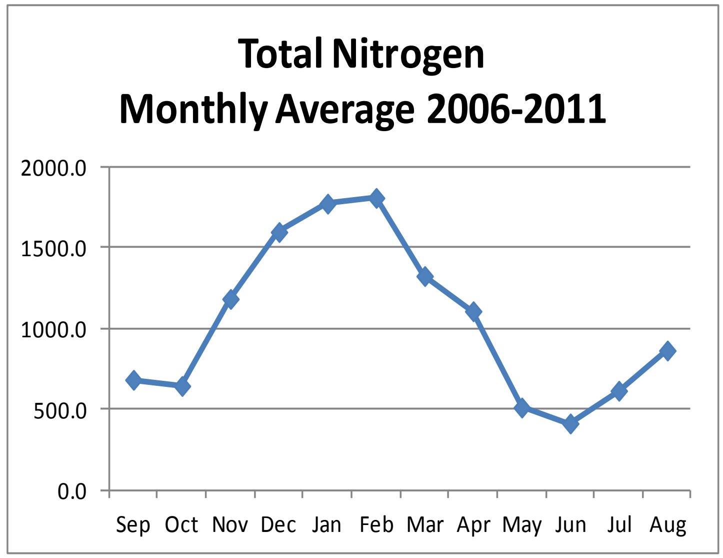
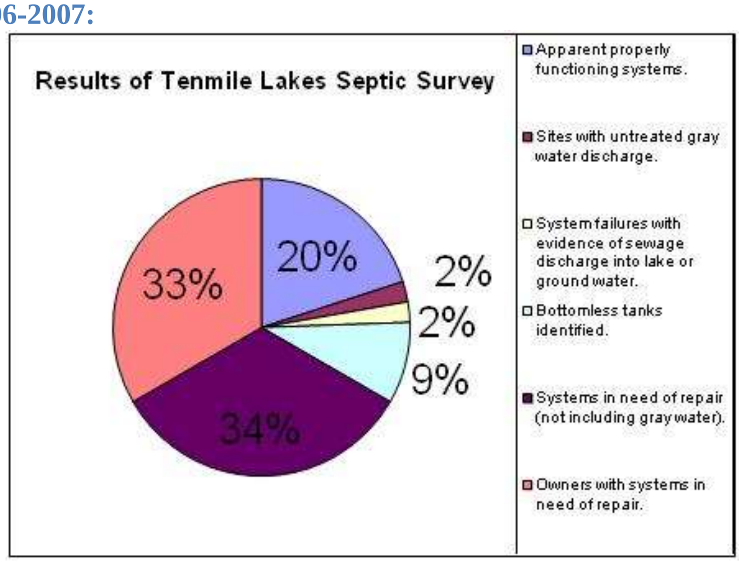


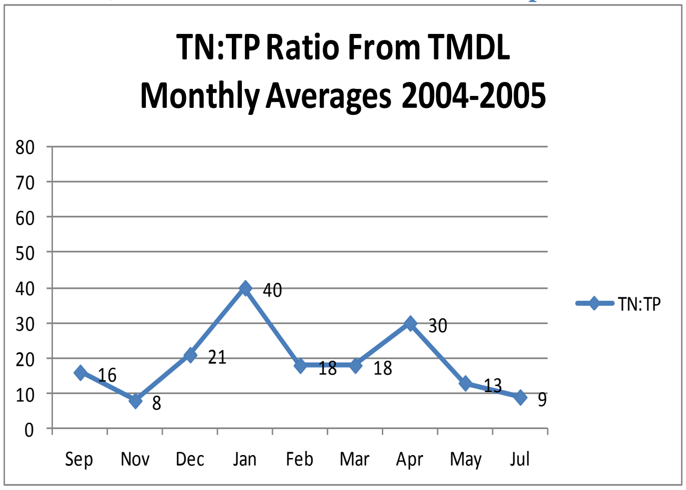
Chart 28, Septic Survey 2006-2007:

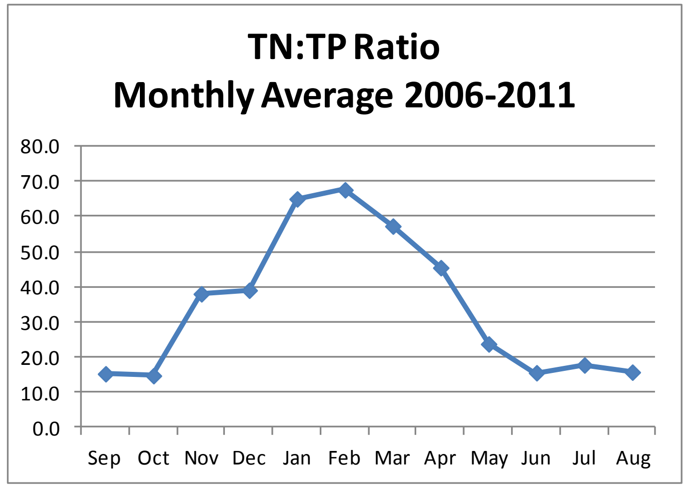


We also looked at the TN:TP Ratio monthly averages for the 6 year period. It shows a consistent level of about 15:1 that starts in June and extends all the way through October (See Chart 29-right below). If these low TN:TP Ratios are favorable to cyanobacteria, and we could alter the summertime TP coming into the lake by addressing the septic system problems, then we might be able to move this ratio out of the favorable range for cyanobacterial growth and lessen our HAB problems. Comparing the TN:TP Ratio chart from the TMDL (Chart 29-left) to our current chart, shows a significant shift upward for the more current data. Ratio highs are near 70 with lows near 15, compared to 40 and 8 with the 2004-2005 TMDL data.

Averages broken out by individual site were also charted and generally match the combined average data. Future analysis could look more closely to see if any differences are occurring between the lakes or longitudinally within each lake. Seasonality of the various parameters to see what is occurring within just the summer season alone. We will also continue to update the summary as each year's data is completed. The raw data and various other charts can be seen on the *Appendix CD: Lake Sites Data 2006-2011 Monthly Averages with Charts*).

Chart 29, TN:TP Ratio- TMDL Data Compared to 2006-2011:





We also looked at correlations between the various Monthly Average Parameters and Monthly Average Nutrients. The correlation table is shown below (Table 14). Chl-a has a strong (.95) positive correlation with Turbidity, and a -.85 negative correlation with Secchi Depth, indicating that algae are a major factor in lake clarity. Chl-a also shows good correlations with NO_2 (-.70), TP (.69), pH (.68), and Temp (.64).

Table 14, Correlations between Nutrients and Field Parameter Data 2006-2011

Correlations 2006 - 2011 Monthly Averages ALL Sites Combined	TEMP	pH	D.O.	Conductivity	Turbidity	Secchi	TP	TN	TN:TP Ratio	PO4	SiO4	NO3	NO2	NH4
pH	0.88													
D.O.	-0.47	-0.19												
Conductivity	0.57	0.42	-0.85											
Turbidity	0.63	0.66	-0.46	0.76										
Secchi	-0.41	-0.49	0.46	-0.73	-0.91									
TP	0.21	0.10	-0.68	0.83	0.74	-0.81								
TN	-0.89	-0.69	0.53	-0.52	-0.33	0.13	-0.09							
TN:TP Ratio	-0.84	-0.63	0.69	-0.77	-0.57	0.41	-0.46	0.90						
PO4	-0.52	-0.62	-0.38	0.31	-0.07	-0.08	0.54	0.34	0.04					
SiO4	0.19	0.24	-0.35	0.74	0.64	-0.67	0.66	-0.11	-0.34	0.30				
NO3	-0.95	-0.74	0.61	-0.65	-0.54	0.33	-0.28	0.95	0.93	0.34	-0.20			
NO2	-0.65	-0.75	0.24	-0.37	-0.63	0.66	-0.34	0.44	0.52	0.37	-0.08	0.55		
NH4	-0.51	-0.73	-0.10	0.08	-0.27	0.17	0.28	0.34	0.10	0.77	0.13	0.30	0.53	
Chl-a	0.64	0.68	-0.39	0.67	0.95	-0.85	0.69	-0.34	-0.55	-0.14	0.52	-0.54	-0.70	-0.35
Correlations 75% or above		Negative Correlations 75% or below												

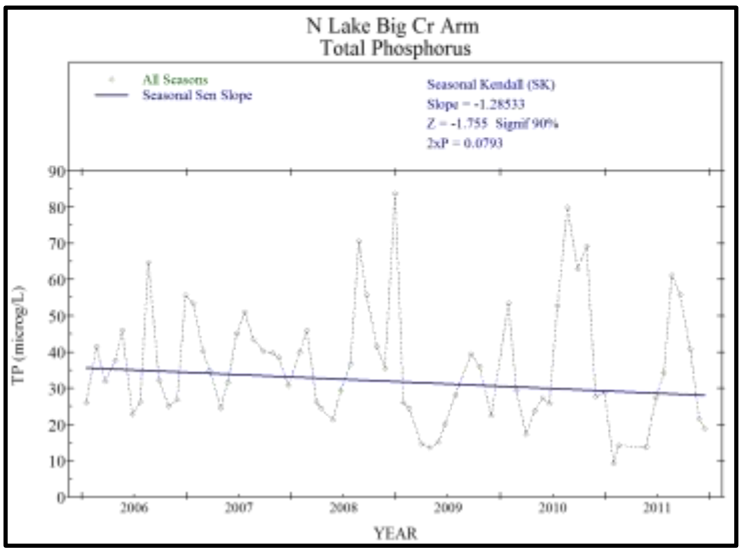
2006 – 2011 data was also analyzed for Trends. This was done for the individual data points, not the averages. We wanted to look at trends in some of the key components in the TMDL, including TP and TN. The TMDL uses the USEPA targets for TP and TN, 7.1 µg/L and 190 µg/L respectively. Steve Hanson from ODEQ, ran Seasonal Kendall (SK) tests on the 2006 – 2011 data looking for tends in the major nutrients. We found that analyzing the data by site created more statistically significant results than analyzing all the data together. Some data was able to be analyzed using all seasons together; others were broken into winter and summer components based on homogeneity.

The SK is a robust test that compares monthly data across years and gives a probability that the data is changing. The direction and magnitude of the slope are computed using a Sen Slope. The best figure to look at when determining the significance is the 2xP number. If 2xP = .0793, then there is a 7.93% chance that the observed trend is just a random error, or stated another way, there is a 92.07% confidence level that there is a real trend.

We will focus below on the two North Lake sites; N11: Big Cr Arm, close to the mouth of Big Cr, relatively shallow, many lakefront houses in close proximity to the sampling site. **N16:** North Lake main body, deeper, fewer houses.

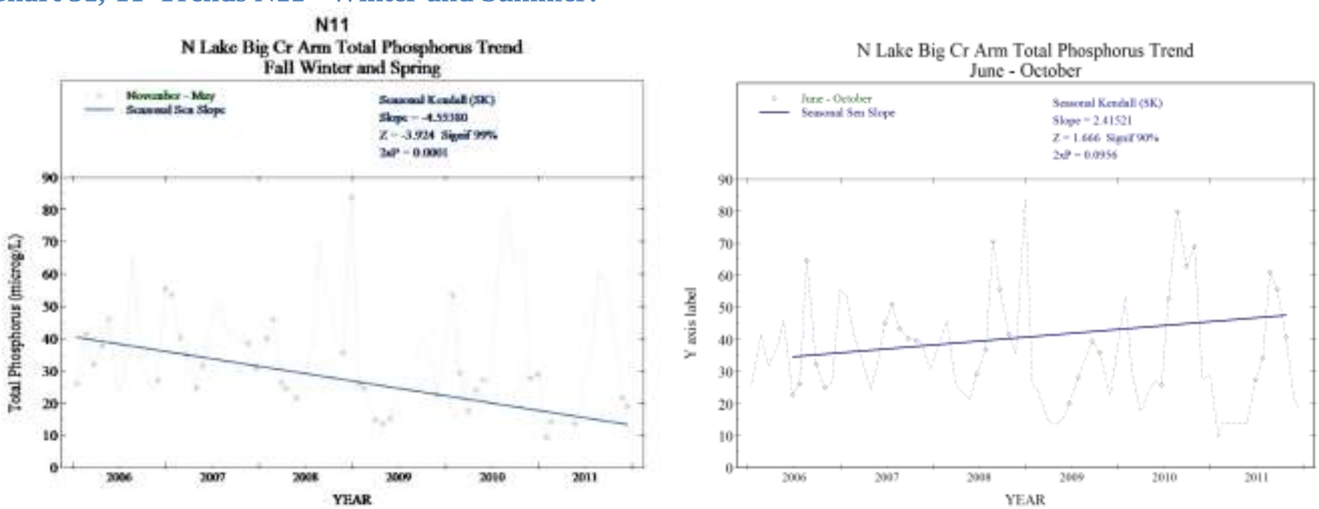
N11, All Season, TP, Chart 30 shows a slope of -1.3, significance level 90%. This indicates that the TP levels are dropping by 1.3µg/L/yr at this site. The TMDL listed station NTB's (closest to N11) yearly TP average (from 11/1998 – 1/2001) as 38µg/L. The TP limit is 7.1µg/L. The 2011 yearly average was 29.7µg/L. If we maintain a 1.3µg/L/yr decrease, we will reach our TP target limit in 17 years at site N11. But if we look closer at the data and divide the year up into a Fall/Winter/Spring (Winter) group and another group for June – October (Summer), Chart 31, we find that the Winter group is actually falling 3 times faster (-4.6µg/L/yr) than the overall yearly rate (-1.3µg/L/yr). The problem is found in the summer months that are actually on an upward trend of +2.4µg/L/yr. The winter trend has a very significant 99% confidence level. The summer confidence level is 90%. This has significant implications in that if we can reverse the summer TP spikes, or even just getting them to stay even, we could lower our TP by 4.6µg/L/yr and reach our TP limit goal in 5 years.

Chart 30, TP Trend N11 - 2006-2011



N11, All Season, TN levels are showing an increase of +18.4µg/L/Yr at 84% significance. (See [Appendix CD: Tenmile Nutrient TREND analysis ODEQ.]())

Chart 31, TP Trends N11 - Winter and Summer:



N16, TP, shows a similar trend with the All Season slope = -1.8µg/L/Yr at a very significant 95% confidence level. The Nov-May (Winter) slope = -2.7µg/L/Yr also at a very significant 99% confidence. The July – November (Summer) slope = +.81µg/L/Yr, but this was **not** significant at 80%.

Chart 32, TP Trend N16 - 2006-2011

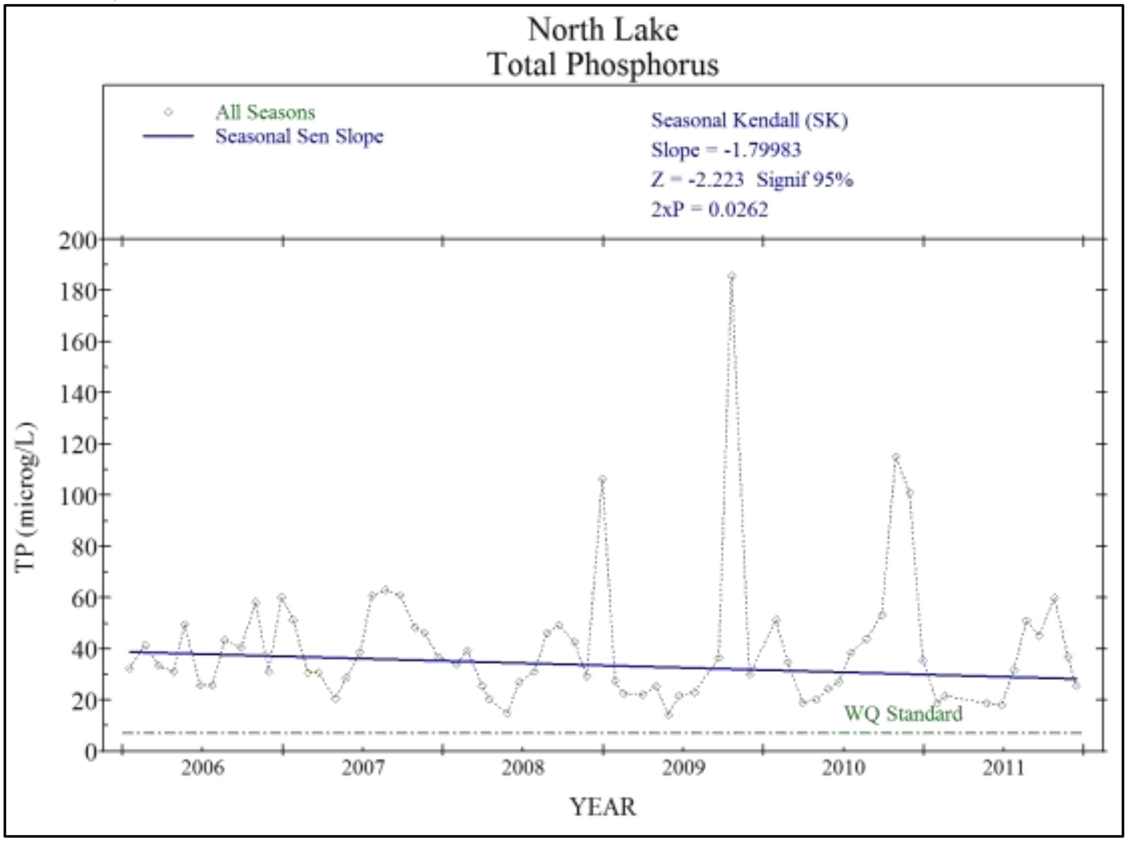
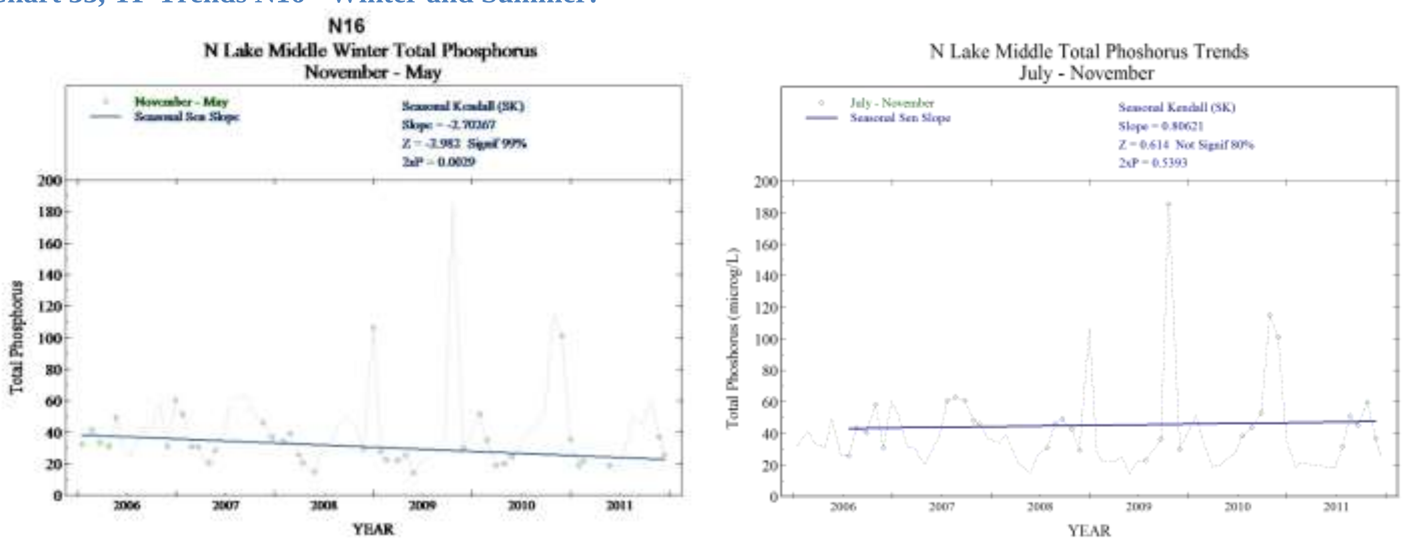


Chart 33, TP Trends N16 - Winter and Summer:



Other parameters that we did trend analysis on included: Turbidity, DO, Chl-a, NH_4, $N0_3$, PO_4, SiO_4, TN:TP Ratio, and Secchi Depth. All of these can be viewed on the Appendix CD: Tenmile Nutrient TREND analysis ODEQ.
Below is a parameter summary produced by Steve Hanson at ODEQ.

Turbidity

N11 has a decreasing trend (80%) that fails the homogeneity test for months. The monthly values do not show a clear seasonal pattern, so we did not run a separate trend for seasons. There is strong seasonality. Visually Jun-Oct stand out but Oct-Dec all have relatively high variance based on the monthly box plots. N16 did not demonstrate a trend and demonstrated seasonal heterogeneity. The monthly statistics showed that January and May had significant decreasing trends but no other months demonstrated a significant trend. Both the South lake sites had significant decreasing trends and no significant seasonality. The Tenmile Creek site showed no significant trend and had seasonal heterogeneity where October had significant decreasing trend and March and April had increasing trends.

N:P Ratio

N11 has a strongly significant Z* and p* for decreasing in October and not significant (80%) in July.
N16 monthly Z and p values show only November has a significant negative trend.
S3 is straight forward trend
S8 has negative trends in October and somewhat in September and November.
TC1- fall has negative trends with November having a significant trend.
Overall trends show increasing N:P ratios in all sites but October and November values often show a decreasing trend, at all sites except S3 these fall decreasing trends caused significant monthly heterogeneity.

- ** The Z score is a test of statistical significance that helps you decide whether or not to reject the null hypothesis. The p-value is the probability that you have falsely rejected the null hypothesis. Very high or a very low (negative) Z scores, associated with very small p-values, are found in the tails of the normal distribution. When you perform a feature pattern analysis and it yields small p-values and either a very high or a very low (negative) Z score, this indicates it is very UNLIKELY that the observed pattern is some version of the theoretical spatial random pattern represented by your null hypothesis.* *http://resources.esri.com/help/9.3/arcgisengine/java/Gp_ToolRef/spatial_statistics_toolbox/what_is_a_z_score_what_is_a_p_value.htm*

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Only N16 and S3 had significant trends and these were both decreasing trends. For S3 there was seasonal heterogeneity with October and November having significant decreasing trends but the remaining trends were not significant and some months were positive.

Silica

N11 increasing trend with slight heterogeneity with negative trends that are not significant in January and February. N16 is not significant (p=0.24), but again has negative, insignificant trends in Jan and Feb. Both South Lake sites had significant positive trend in Silica using a seasonal Kendall test but showed a more significant trend without using the seasonal form of the test. TC has negative trend in Dec and Feb.

Chl-a

All sites but N16 showed significant positive trends in Chl-a. There was no significant seasonal heterogeneity at any sites.

Overall, the data is showing significant trends in many of our nutrients. TP appears to be declining overall and might show more significant gains if we could slow the summer input levels. TN appears to be increasing, but more data analysis is needed on that nutrient. Chl-a is also increasing, although 2012 had no HAB alters, and our quantity of Cyanobacteria was lower this year. Turbidity showed some negative trends. Since Chl-a trends are going up, but Turbidities are trending down, we could conclude that the overall sediments are decreasing since algae and sediments function together to determine turbidity. This might also be supported by the downward trend of TP.

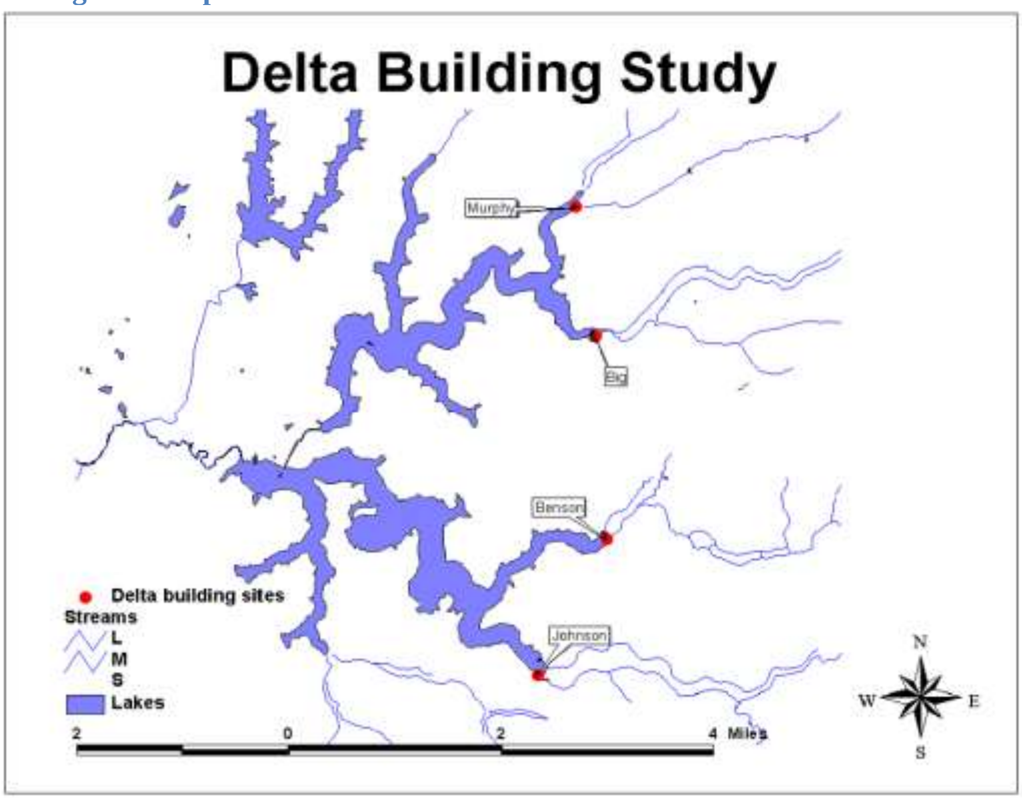
Delta Building

The Delta Building project was instigated to measure and analyze sediment accumulation rates at the tributary mouths on Big Cr, Murphy Cr, Benson Cr, and Johnson Cr. Unfortunately, this project has run into many obstacles, and the data analysis has proved difficult. This project locates a photo/measuring point up on the delta and then measures the length, and width of the delta along certain transects. The transect points were marked using 4inch square caps that attached to rebar. These were driven into the ground with the cap remaining just below the surface. The following year we would locate the caps using a surveyor's metal detector and measure how much sediment had accumulated on top, and also re-measure the length and width of the delta to determine if it had expanded.

Although much of our basic methodology was sound, many practical matters have obstructed the usefulness of this project. The first problem is locating the original measuring/photo point. T-bar markers have been removed by vandals as have the metal caps. Many measurement points have been overgrown with thick alder groves and cannot be reached. Big Cr Arm is so overgrown with lake weeds that we couldn't even reach the delta this year, let alone the measuring point. The measurements need to be done at an exact lake level; even a few inches of lake elevation change can translate into feet of longitudinal measurements, especially in the areas with gradual sloping banks at the water's edge. Finally, after the data is collected, we had difficulty finding a practical way of translating all of the various 3-demensional measurements into a form that was understandable. A good 3D graphing program might work to at least give a good visual representation, but the cost of such programs have proven prohibitive with our budget constraints.

Although a quantitative analysis of the data might not be practical, selective use of data points and photographic records of each delta can still allow us to achieve much of what we had hoped to learn.

Map 5, Delta Building Sites Map:



Johnson Cr Delta is located at the end of Templeton Arm. This delta has grown very little according to our measurements. When it was visited in 2011, many of the marker caps were sitting on top of the ground. Some had been vandalized, but they were able to be seen because there wasn't any sediment on top of them. We believe the sediments are being carried out further into the lake due to the flow volume and velocity of Johnson Cr., so the sediments are fanning out along the bottom of the lake, rather than accumulating on top of the delta. The Cr also washed out a portion of the delta behind the photo point giving it a second path during high flows.

Photo 2, Johnson Cr Delta: 2004, 2011, Survey cap on surface:

Benson Cr Delta is at the end of Coleman Arm. This delta has shown significant growth. Starting in 2004 with a length of 74ft, by 2010 it had grown to 171ft. Maximum accumulation on top of cap was recorded at 22inches.

Photo 3, Benson Cr Delta: 2004, 2008, 2011:

Big Cr Delta is on Big Cr Arm. This is by far the delta that has shown the greatest accumulations. The delta build up in this area has been so bad that boat ramps lead to land during low water periods, and the lake weeds are now able to fill in most of the top end of the arm in summer. The survey for 2012 was cancelled when we couldn't get the boat through the lake weeds to the delta photo point and wading was extremely difficult in the deep, soft, muddy bottom. These problems have caused hardships for the lakefront landowners. Summer boating is nearly impossible and most of the houses are for sale, but with little interest. This end of the arm is slowly turning into a wetland area. This may eventually be beneficial for the overall lake water quality as the wetland begins to filter Big Cr stream input.

Photo 4, Big Cr Delta: 2007 Composite, 2011, 2012:

Murphy Cr Delta is at the end of Carlson Arm. Murphy Cr is a braided channel stream with no agricultural activity. The bottom land is tall Canary grass. This acts as a wetland and is used as a control area for our TMDL. The delta has remained essentially unchanged since it was first surveyed. In 2012 we found one of the original rebar stakes. It was underwater, but not under sediment.

Photo 5, Murphy Cr Delta: 2006 and 2012:


Over the length of this project, the creek mouths have shown that this is a very dynamic environment. Benson Creek has been the steadiest in delta building. It has either increased in size, or in sediment accumulation every year. Murphy Creek has not changed since we first tried to monitor it in 2004. The wetland it contains has done an effective job in reducing sediment input into the lake. Johnson Creek has changed every year, just not in the way we assumed it would. Though there is a large amount of sediment input from this system, Johnson Creek flow is so great in the winter that it is spreading the sediment further out into the arm of the lake. The flow volume and velocity of this creek is also so great that is constantly changing the physical dimensions of the delta. It might be better to do depth reading further out in the lake, though aquatic macrophytes might interfere with this type of sampling. The Big Creek increase in sediment deposited on the survey markers was dramatic, and in 2010, the willow growth exceeded 10 ft. in some spots. This site seems to be creating a new wetland. The 2004-2010 report showing previous measurements is on the Appendix CD*:* *Delta Building>>Delta Building 2004-2010*.

Delta building also creates preferred depth for colonization of invasive weeds. Not only do these weeds create navigation problems for boaters and aesthetic issues for homeowners, but they also contribute to Phosphorus recycling when the weeds die and the decomposition creates anoxic conditions in the benthic layer.

Because of the physical and practical difficulties of this project, we would propose to continue the project as a photo survey only, every 5 years or so. The photographic record is useful for outreach efforts and gives us some record of what the deltas are doing. Perhaps every 5 years we could do basic length measurements if the measuring point can be accessed. The lake elevation for future efforts should be a constant 6.43ft. If funding were available, Lidar imagining would be another possibility.

Invasive Species Monitoring

Our objective is the rapid detection of target invasive species. With over 80% of Tenmile Lakes aquatic plants being non-native, invasive species have long been a problem in the lakes. We established 4 monitoring sites that coincide with the 4 most popular boat launching sites on the lake. We installed settlement substrates, and monitored them monthly during the busy summer recreational season, and every other month for the rest of the year. Target species are: Zebra mussels (*Dreissena polymorpha*), Quagga mussels (*Dreissena bugensis*), and New Zealand Mud Snails (*Potamopyrgus antipodarum*). One settling plate went missing from the county dock and was re-installed in April, 2012. This emphasized the need to make sure they are securely fastened to the dock, and as obscure as possible to prevent vandalism. These sites area also used for check points that allow for voluntary examination of vessels entering the waterway for invasive species, and to educate the public about the problems associated with the introduction of invasive species into the Tenmile Lakes. A boat spray off station was built in 2013 near the county dock. This will further enhance our efforts to educate the public and keep invasive species out of Tenmile Lakes.

Our outreach efforts also include helping lakefront homeowners identify and eradicate invasive species. We are currently testing different methods of controlling *Egeria densa* around docks and shorelines. One method is simply pulling the weed using a rake from the shoreline. The roots come out easily with this method and results after two years show considerably less *Egeria,* and native plants returning to the open area. The second method involves placing road cloth on the bottom of the lake, covering the Egeria. The goal would be to find a method that would be relatively easy for landowners to do and be effective in controlling the invasive species.

Table 15 is the invasive species monitoring data for 2013 & 2014. None of the target species were found.

Table 15, Invasive Species Monitoring 2013 & 2014:

2/12/2013	North Lake Resort	A	A	A	Few Amphipods, 1 snail (native), 2 very small limpets
2/12/2013	Ospery Point	A	A	A	More Amphipods than other sites, odd seed pod like item
2/12/2013	County Park	A	A	A	Few Amphipods
2/12/2013	Lakeside Marina	A	A	A	Few Amphipods, odd seed pod like item here too.
4/11/2013	North Lake Resort	A	A	A	Few Amphipods, several snails (native), 3 damselfly larvae, bryozoans
4/11/2013	Ospery Point	A	A	A	Amphipods , odd incased insect, large mouth bass fry
4/11/2013	County Park	A	A	A	Few Amphipods
4/11/2013	Lakeside Marina	A	A	A	Few Amphipods, egg cluster
6/3/2013	North Lake Resort	A	A	A	1 large dragonfly larvae, clear egg case, large native snail
6/3/2013	Ospery Point	A	A	A	A few damselfly larvae at each station, Not many amphipods, lots of 3-4mm long worms
6/3/2013	County Park	A	A	A	A few damselfly larvae at each station, Not many amphipods, lots of 3-4mm long worms
6/3/2013	Lakeside Marina	A	A	A	A few damselfly larvae at each station, Not many amphipods, lots of 3-4mm long worms
7/2/2013	North Lake Resort	A	A	A	Worms, Sponges (White & Green), 2 different snails (native)
7/2/2013	Ospery Point	A	A	A	Small limpets, Many worms, Damslefly larvae, Sponge, Egg mass
7/2/2013	County Park	A	A	A	Not many amphipods, lots of 3-4mm long worms
7/2/2013	Lakeside Marina	A	A	A	Not many amphipods, lots of 3-4mm long worms
8/12/2013	North Lake Resort	A	A	A	
8/12/2013	Ospery Point	A	A	A	
8/12/2013	County Park	A	A	A	
8/12/2013	Lakeside Marina	A	A	A	
12/19/2013	North Lake Resort	A	A	A	Not many amphipods
12/19/2013	Ospery Point	A	A	A	Not many amphipods
12/19/2013	County Park	A	A	A	Not many amphipods
12/19/2013	Lakeside Marina	A	A	A	Small bass hiding in tube
2/27/2014	North Lake Resort				Couldn't reach trap site due to high water
2/27/2014	Ospery Point	A	A	A	Some gelatenous bryozoans
2/27/2014	County Park	A	A	A	
2/27/2014	Lakeside Marina	A	A	A	Covered with gelatenous bryozoans
6/11/2014	North Lake Resort	A	A	A	Large native snail
6/12/2014	Ospery Point	A	A	A	Large dragonfly larvae
6/13/2014	County Park	A	A	A	
6/14/2014	Lakeside Marina	A	A	A	

In August of 2013, an outreach effort was organized using volunteers to help pull out invasive species (Parrot Feather) along the canal. Parrot Feather is becoming more prolific especially in the canal and large mats can be seen in Tenmile Cr. We have also conducted a pre-canal dredging plant survey which will give us a tool to see how dredging effects the macrophyte population, both immediately after dredging and in the future. During our 2012 annual outreach BBQ and presentation we talked about invasive species, and a questionnaires afterwards reveled that people were interested in even more information on this subject, so at our 2013 presentation we collected both native and invasive species and made an informational display to help people identify them. We also talked about possible techniques to use to control weeds around docks including mats that are being used by the USFS to cover weeds in select areas. Because of the widespread distribution of weeds on the lakes, a lake-wide solution will be difficult to obtain. Hopefully exploring methods that people can use on their own property will help them and serve to lessen the overall problem.

Effectiveness Monitoring

Our Objectives are to evaluate and monitor OWEB funded projects, to fulfill contractual obligations, and to determine if projects achieved initial objectives. This is a bi-annual survey of our projects: fish passage (includes bridges and culverts), and riparian fencing. We have extended our riparian planting monitoring to once/5 yrs. Most of the fish passage and fencing projects will be monitored for 2 years; the timeframe TLBP is contractually obligated to monitor. Once this 2yr period is completed, projects will be removed from the list. New projects will be added as restoration grants are awarded and implemented. Some projects, due to their unique location and/or design, will be monitored beyond 2yrs. These surveys involved visiting a photo point to record current status of the project with a camera, and filling out a monitoring data sheet.

Fish Passage Map and locations are shown below for 2011-2012 sites (Map 6, Table 16). Monitoring has been an effective way to determine maintenance needs and to provide input for future projects. All fish passage projects are meeting their objectives, and maintenance needs were minimal. The most common problems are having some rip-rap washed down into the stream from the base of the eco-blocks and occasional erosion of the approaches during high flood waters. Photo 6 shows a pre-implementation shot and a follow-up monitoring shot on Monson Bridge #1. The reporting form for this visit is also shown below (Table 17). Reports are created for each site that document the process from pre-implementation to final monitoring reports.

Map 6, Fish Passage Monitoring Sites 2012:

Photo 6, Example of Before & After Bridge Project:

Table 16, Fish Passage Monitoring Sites 2012:

Site/Location	UTM
House Gulch	10T0414427 4828660
Swanson 6	10T0413179 4821166
Adams Cr Culvert 4	10T0409041 4821337
Shutters 6	10T0406822 4821020
Shutters 7	10T0407036 4820933
Fritz 2	10T0410478 4822317
Fritz 3	10T0411098 4822406
Hankins 3	10T0414095 4820413
Monson 1	10T0411694 4822125
Monson 2	10T0412041 4821825

Table 17, Fish Passage Monitoring Form:

Tenmile Watershed Bridge Monitoring Form.
Monitoring Date: 04/23/2012
Monitoring Personnel: Richard Litts & Mike Mader

Project Name.	Monson Bridge #1
Project Goals.	To reduce erosion, sediment delivery and improve fish passage.
Bridge location.	UTM: 10T0411708 4822135 Johnson Cr. North side of field between Fritz & Johnson property. Downstream from Monson#2.
Current sediment delivery. High-Med-Low	Low Water Depth at bridge is 3'9"
Current bridge condition.	Excellent
Current/approach condition.	Excellent
Armoring and fill condition.	Good – missing some armoring on the north side
Erosion/scouring above project site?	Small amount of erosion was observed on south side.
Maintenance records/dates. Bridge observations. Goal Observations.	Field observer indicates that this is a new bridge. This site is meeting our project goals. Bridge and approach held up well with the flood waters. It was also observed assisting livestock during high water. Few fish observed. Large number of Rough Skinned Newts.

Map 7 below shows the 4 fish passage projects that were built in 2013 and that are currently being monitored. These included 2 sites on Roberts Creek and 2 on Adams creek. All 4 were successfully implemented and performed well during the winter storms in early 2014. Photos of each bridge are included below the map.

Map 7, New Fish Passage Sites Constructed in 2013:

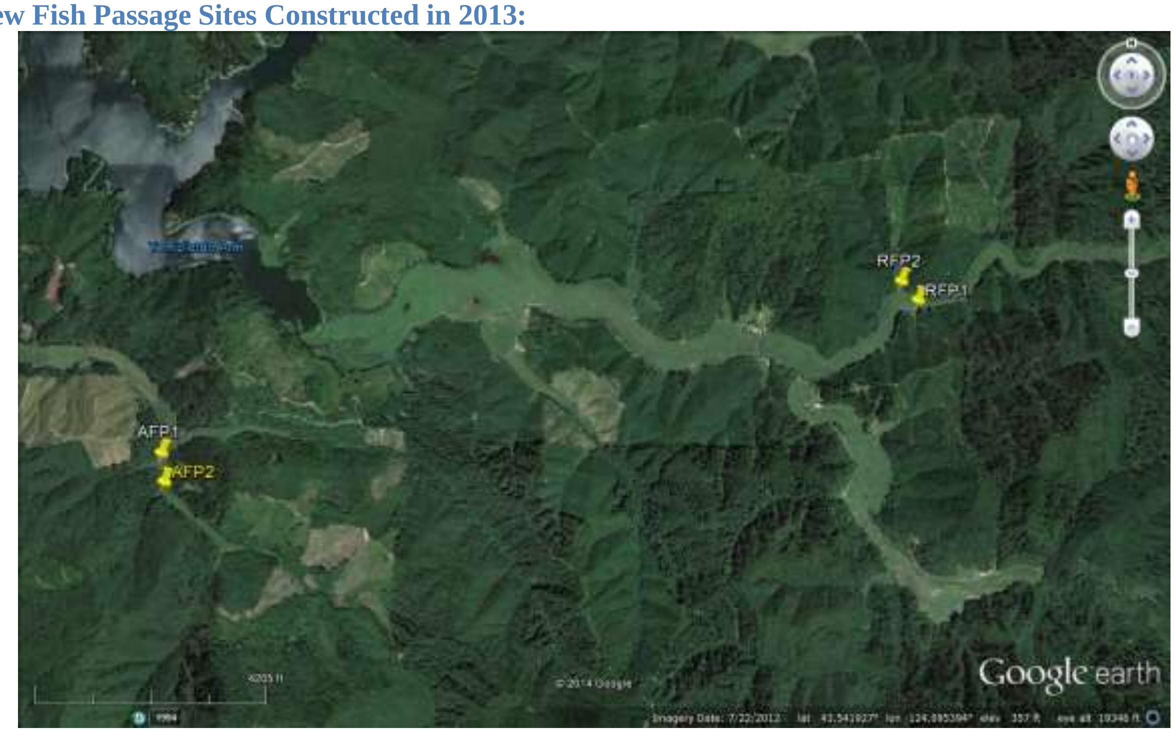


Photo 7, Adams Cr Fish Passage #1 & #2:


Photo 8, Roberts Cr Fish Passage #1 & #2:


Fence Monitoring Maps and locations for 2011-2013 are shown below. Fencing projects are very effective in keeping livestock away from streambanks. Erosion still occurs depending on the flow rate and sinuosity of the stream, but fences protect grasses and riparian plantings, giving them time to grow and provide effective stabilization. Maintenance is needed to repair barbwire and remove debris on fences after flooding. One section of fence line had to be moved after a small landslide undercut part of the fence. Landowners do maintenance with help from TLBP staff. Fence design has held up very well, even under high flood water conditions. Project Report showing Swanson Fence #6 Project Monitoring Form and photos of completed sections and flood conditions can also be seen below. This monitoring project is now complete.

Photo 9, Fence Monitoring; Big Cr & Johnson Cr:

Table 18, Fence Monitoring 2011-2013

Site Name/Location	UTM
Big Cr.	10T0414507 4828636
House Gulch	10T0414427 4828660
Plum Gulch	10T0414946 4828951
Swanson 6	10T0412972 4821368

Table 19, Fence Monitoring Form:

Tenmile Watershed Restoration Project Monitoring Form.
Monitoring Date: 4/23/2012
Monitoring personnel: Richard Litts & Mike Mader

Project Name.	Swanson Fence #6
Project Goals.	To reduce erosion, lessen sediment delivery into stream, and increase bank stability by excluding livestock from this reach.
Project type and location.	Exclusion fence for this project runs from the county bridge on Templeton Rd up to Swanson Bridge #2.
Current vegetation type and growth. %	Native pasture grasses. 100% (Some dead blackberries)
Current project condition.	Good – A lot of flood debris on the bottom wires, and a few broken wires. Posts held up well.
Current in-stream temperature and flow condition.	^{0}F Med Flow (Temperature probe broken)
Erosion % at project site.	20%
Maintenance records/dates. Field observations. Goal Observations.	Cutthroat fry observed. Maintenance needed to remove flood debris from fence wires and fix those areas where debris broke through.

Photo 10, Swanson Fence#6:

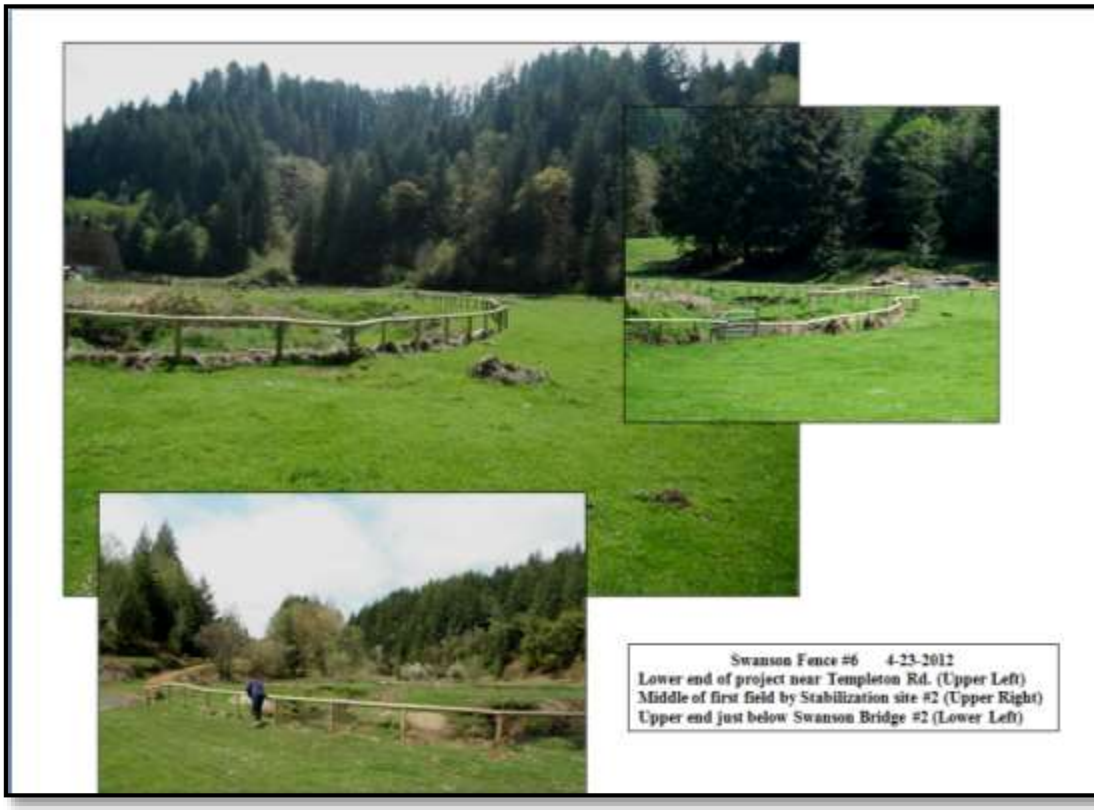
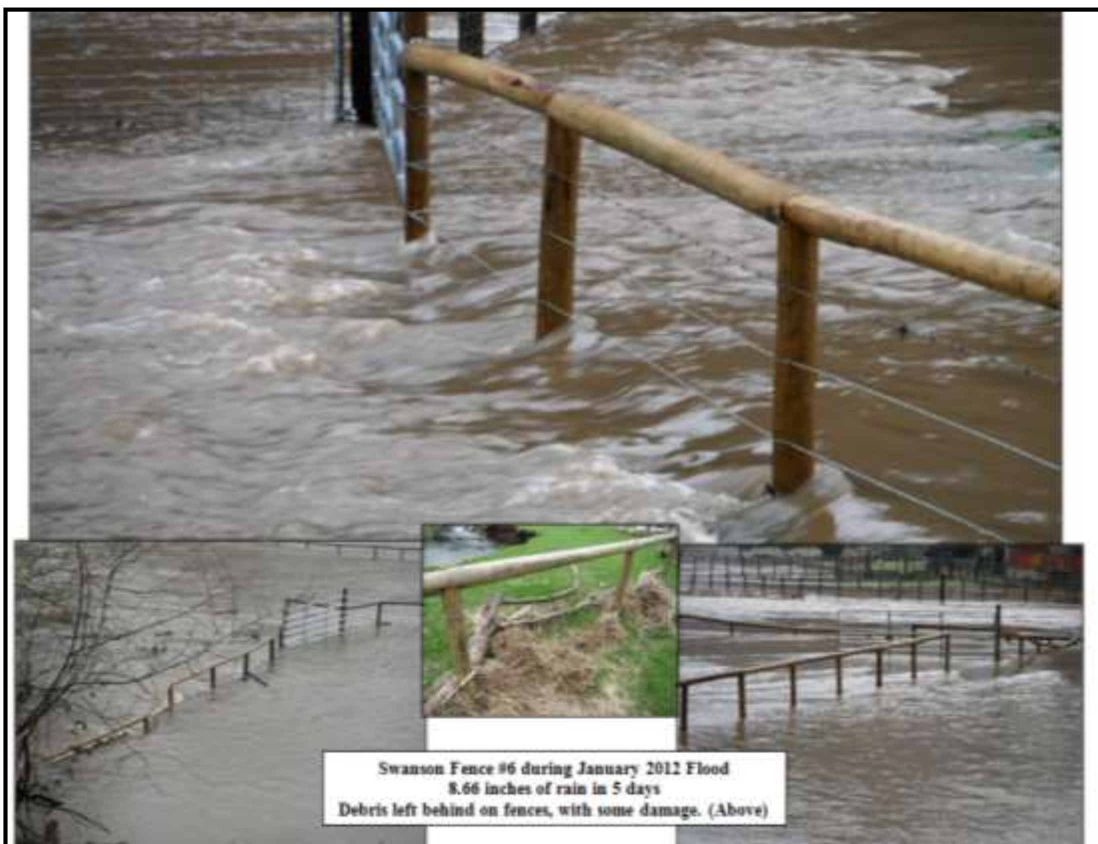


Photo 11, Swanson Fence #6 During Flooding 2012:



Riparian monitoring sites for 2012 and 2013 can be seen below (Map 8 & Table 20). Riparian plantings have in general been very successful. Photos below from House Gulch show one site that has been a total success. Creek shading is near 100%, bank stabilization is excellent, and small salmon fry are abundant. We have determined that on riparian projects, yearly monitoring is not needed and have moved our monitoring schedule to once every 5 years. Exceptions may be made for newly planted areas to monitor for predation and initial survival rates. Our initial planting at Hatchery Cr was destroyed by cattle that broke through the fence and damaged almost all of the trees. They were replanted in 2012 and growing well in 2013 with a nearly 100% survival rate. It has also been found that Spruce trees do better in high predation areas. Presumably their stiff needles are less desirable to elk, deer and other predators. We have also noted problems with Spruce Weevils damaging the tops of some trees. This should be watched in the future. We also did thinning in the Big Cr area to allow for more growth room of the maturing trees. Big Cr monitoring projects are complete, but Hatchery, Johnson, and Wilkins Cr will continue on into 2014. We are also doing a future monitoring project on House Gulch to check for stream temperatures, and shade cover to determine the overall level of success that the riparian project had on the stream.

Much of the success of riparian zone plantings can be attributed to the cooperation that we receive from landowners. Relationships formed between TLBP staff and landowners are a crucial component to getting the projects started. Our greatest successes happen when we can combine fish passage projects with fencing and riparian projects as was done at House Gulch. Trust allows us continued access to monitor all of these projects including Storm Chasing and Baseline Tributary monitoring.

Map 8, Riparian Monitoring Map:

Table 20, Riparian Monitoring Sites:

Site/Location	UTM
House Gulch	10T0414427 4828660
Plum Gulch	10T0414946 4828951
Big Cr. 4	10T0414507 4828636
Big Cr. Mid	10T0414362 4828526
Big Cr. (Upper A)	10T0415501 4828825
Hatchery Cr	10T0413268 4820411
Johnson Cr (Hankins)	10T0414021 4820363
Wilkins Cr Riparian	10T0411356 4830338

More Monitoring Reports can be seen on the Appendix CD: *Project Evaluation Reports*>>Various Files.

Photo 12, Plum Gulch Riparian Before (1999) & After (2012):

Photo 13, House Gulch Riparian, Fencing, and Fish Passage Projects 2012

Storm Chasing

Storm Chasing Winter 2012

Storm Chasing has been conducted since 2005. Sampling occurs when the forecast predicts precipitation in excess of 2 inches in a 24 hour period. We have had 4 active sites: Blacks Cr., Benson Cr., Big Cr., and Bowron Cr. All of these are tributaries of North Tenmile Lake. We wanted to shift some of our data collecting efforts to South Tenmile Lake and tie them into the restoration work that has been done on some of the Ag land properties. To accomplish this goal, and still keep the tasks manageable, we ended the data collection efforts on Blacks Cr. and Benson Cr., and added 3 sites on Johnson Cr. (See Maps 9 & 10 below)

The sites on Johnson Cr. were chosen for their relationship to upstream land use and upstream habitat restoration projects that have been completed or that we would like to propose for future restoration. Johnson Cr. flows into South Tenmile Lake about half mile east of our standard lake sampling site S3. We also monitor the delta building activity at the site where Johnson Cr. enters the lake.

The first new site was identified as Johnson #1 (J1). It is located at the border of the Elliott State Forest (ESF), with timberland to the east, and Hankins and Swanson Ag land (cattle) to the west. It is on Johnson Cr. within the upper Johnson Cr. riparian planting site. The site showed the water quality as affected by forestry land use and acted as an initial point of reference for the water quality at the lower sites.

The second site was identified as Johnson #2 (J2). It is located under the county bridge on Templeton Valley Road, and approximately 1.8 stream miles downstream from J1. It is also just above the confluence with Roberts Cr. Extensive fish passage and fencing work has been done on the Hankins and Swanson properties upstream from this site. This includes a total of 9 bridges, 4 culverts, 4 miles of fencing projects, and 2 riparian plantings. This land is actively used for livestock grazing. The goal for this site was to assess the impact that these projects have had on sediment discharge (TSS) and nutrients.

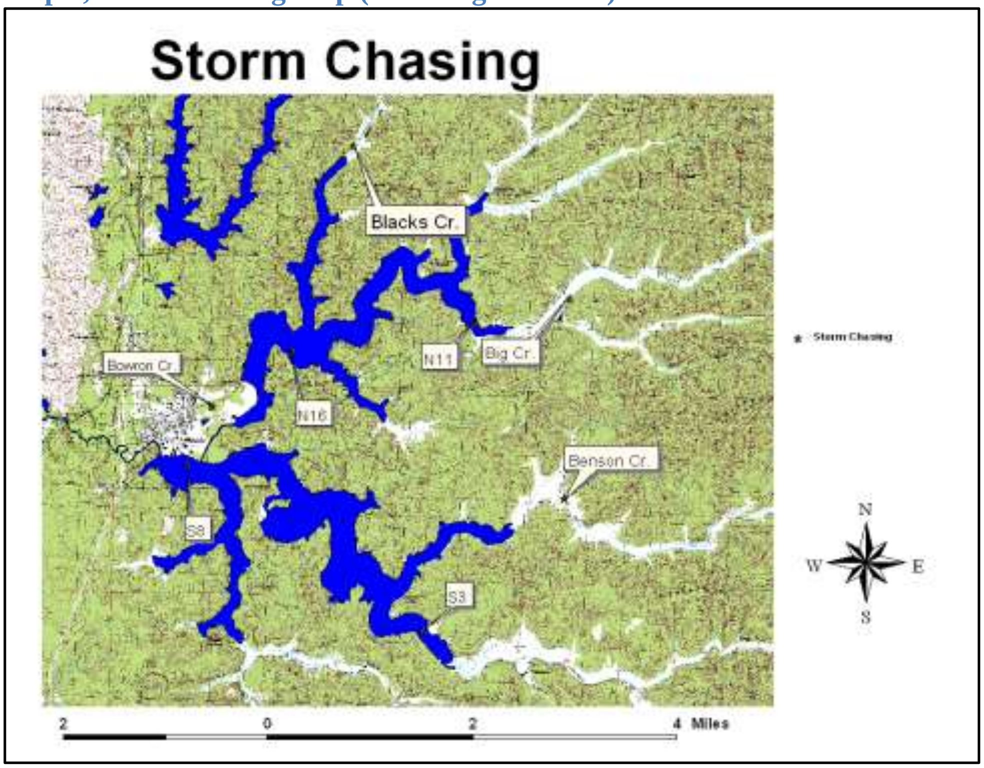
The third site was identified as Johnson #3 (J3). It is located near Fritz Bridge #1, 1.3 miles downstream from J2, and 1.4 miles upstream from Templeton Arm of South Tenmile Lake. Johnson Cr. has two channels in this area located on either side of the Ag land and at the base of the hills to either side. This site is on the south side of the fields on the main Johnson Cr. channel. The land between here and the Swanson site is also active Ag used for livestock grazing. It has had no fish passage, no fencing, and 3 riparian projects completed on it. The goal for this site was to compare it to the upstream Swanson site (J2) to see if the sedimentation rate was higher for Ag land that has not had as much restoration work done on it. Roberts Creek flows into Johnson Cr. just below Site #2. It is also active Ag land with Cattle. It has no fencing or bridges until the summer of 2013 when 2 bridges were added just below the ESF land.

We followed the standard protocols listed in our QAPP for Storm Chasing. Analysis is for TSS and nutrients. In order to gain a baseline for this data, and to gain a better understanding of standard winter conditions, we did a 24 hour, sampling run during “standard low winter flow” characterized by no significant rain for a period of at least 7 days in mid-winter. This lower-water sampling will ensure that the water is all channelized within the main channel and not flowing over the open fields as it does during high water storm events. We also conducted a, 24 hour, sampling event of a “typical” winter storm that raised the creek level to the bank edges, but didn’t significantly flood the surrounding fields. These extra sampling events gave us data on the normal winter creek activity that, when combined with the storm chasing data, will give a better picture of the sedimentation and nutrient activity that occurs during the winter season. Johnson Cr has a very low flow during the summer months, so sedimentation is not a large factor after the winter season. We labeled storms starting in Nov 2011 with #1 and will continue to label them consecutively from year to year.

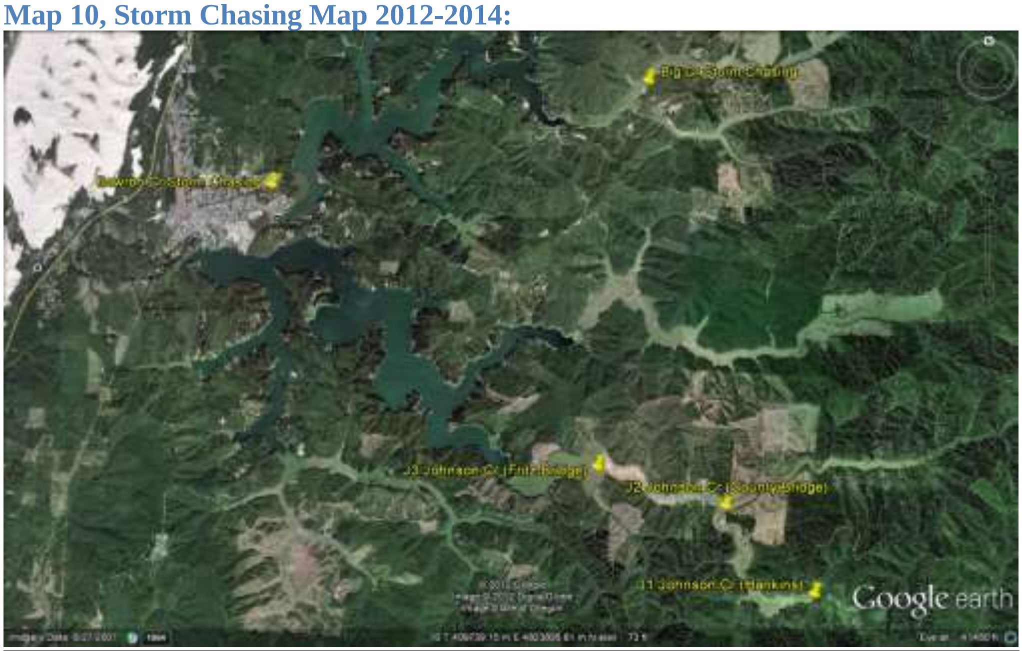
We are continuing to monitor Big Cr and Bowron Cr. Big Cr is a large contributor of TSS in the winter and has had significant impact on the Big Cr Arm of North Tenmile Lake. Bowron Cr is the site that we monitor for Urban TSS impact on the Lakes. The water from Bowron Cr flows through the city of Lakeside, OR and receives storm water runoff.

For the winter season of 2012 we sampled 2 storms and did the baseline monitoring twice on Johnson Cr. The 2 storms were each sampled for 4 days, taking samples every 4 hours. The bottles were kept in ice during and after the storm until the nutrient samples were sent out (in a cooler – next day delivery) on the day after the storm ended. No storms were caught in 2013, and Storm #4 was sampled in January 2014.

Map 9, Storm Chasing Map (including lake sites) Prior to 2012:



Map 10, Storm Chasing Map 2012-2014:



Winter 2012 Storm Data:

Storm Event #1: 11/21 – 11/25/2011

Table 21, Weather Data Storm #1:

Average Accumulation for 2006-2011 during that same period = 1.48"
Accumulation for this storm = 3.78" Max 1 hr = .61" on 11/23/11 at 08:00
24 hour, 2-year event at North Bend weather station = 2.68"
Maximum 24 hr accumulation for this event = 2.39" as measured at the Lakeside gauge, therefore this was short of a 2-year event by approximately .29 inches.

Chart 34, Precipitation Chart Storm #1:

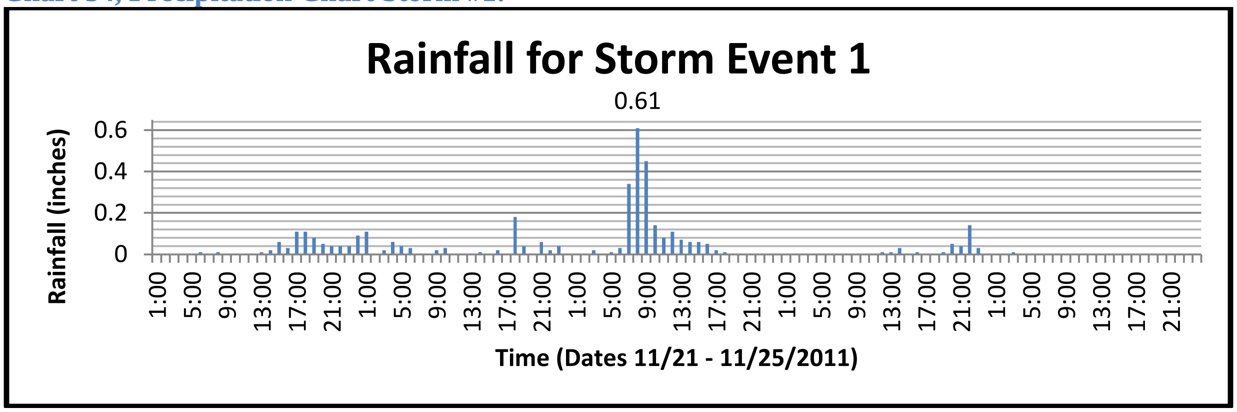


Photo 14, Big Cr Storm #1:

Photos are from Big Cr site on 11/22/2011. Note field in background has flooded areas, but is not under water.

Photo 15. Big Cr Bridge, Storm #1

Total Suspended Solids (TSS) results are shown below (Chart 35). Note that the graph scale varies dramatically between sites. Big Cr showed the most TSS with a peak of 240mg/L, followed by Benson Cr at 164.5, Blacks Cr at 36 and Bowron at 24. Total Phosphorus (TP) Vs TSS graphs are also shown below (Chart 36). Note the difference with Bowron Cr versus the other sites. Since Bowron Cr is getting runoff from urban landscape, the TSS and TP peak much quicker in relation to the rainfall timing, although the maximum TSS is less.

Chart 35, TSS from All Individual Sites, Storm #1:

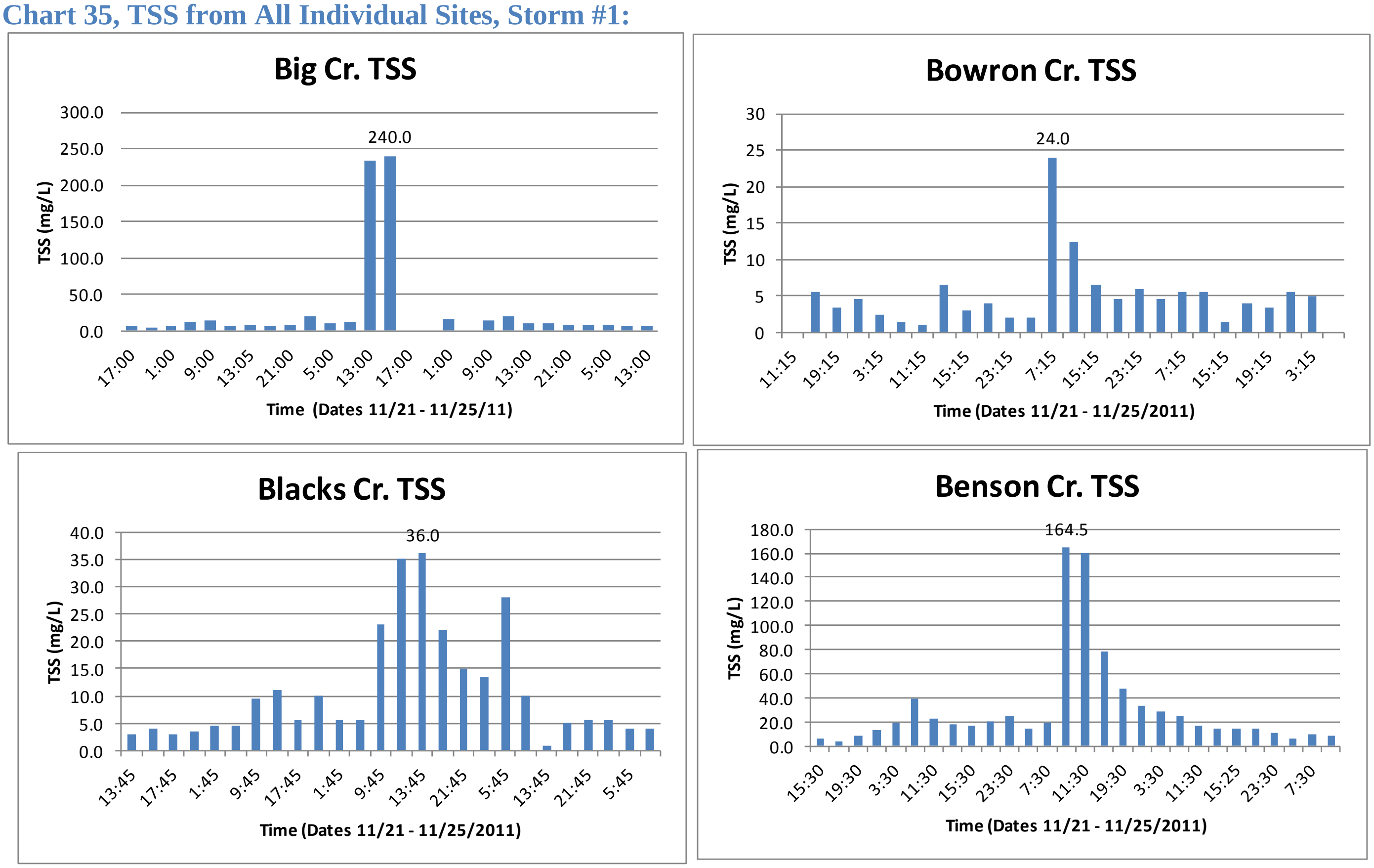
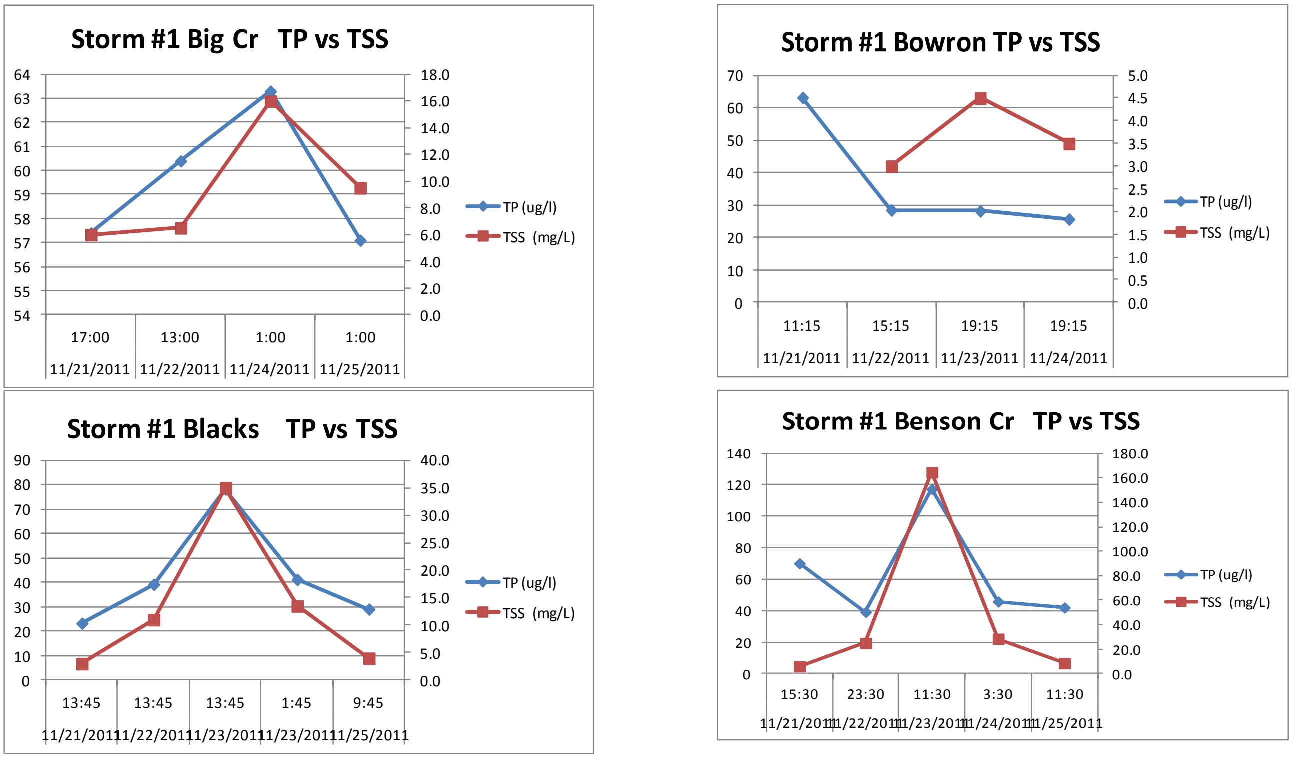


Chart 36, TP vs TSS All Individual Sites, Storm #1:



Below are shown (Table 22) basic Excel Correlation tables on the various parameters correlated to each other parameter. The closer the number is to 1, the more correlated the items are, numbers close to 0 mean no correlation is present. This is for Storm Event #1. There is a good correlation between TSS and TP for every site except the urban runoff site at Bowron Cr. This could be because there is not as much loose soil in the urban environment to transport the TP. There was a high correlation between TSS and Nitrogen at the Bowron site, possibly due to fertilizer runoff. The only other consistent correlation is a negative correlation between TSS and SiO4. Below the correlation tables is a simplified summary of these tables using arrows to indicate correlation strength (Table 23).

Table 22, Storm Chasing TSS and Nutrient Correlations, Storm #1:

Correlations Blacks Cr

	TP (ug/l)	TN (ug/l)	PO4 (ug/l)	SiO4 (ug/l)	NO3 (ug/l)	NO2 (ug/l)	NH4 (ug/l)	TSS (mg/L)
TP (ug/l)	1							
TN (ug/l)	0.410238	1						
PO4 (ug/l)	0.963815	0.437881	1					
SiO4 (ug/l)	-0.9168	-0.631161	-0.93806	1				
NO3 (ug/l)	0.281385	0.9888264	0.313381	-0.51016	1			
NO2 (ug/l)	-0.14618	0.5318654	0.073223	-0.2193	0.558432	1		
NH4 (ug/l)	0.392944	-0.186424	0.473061	-0.15014	-0.21546	-0.19141	1	
TSS (mg/L)	0.996969	0.4266472	0.961957	-0.90164	0.303565	-0.1522	0.438867	1

Correlations Benson Cr

	TP (ug/l)	TN (ug/l)	PO4 (ug/l)	SiO4 (ug/l)	NO3 (ug/l)	NO2 (ug/l)	NH4 (ug/l)	TSS (mg/L)
TP (ug/l)	1							
TN (ug/l)	0.358948	1						
PO4 (ug/l)	0.329175	0.6621532	1					
SiO4 (ug/l)	-0.68073	-0.826324	-0.86066	1				
NO3 (ug/l)	-0.40822	0.6866461	0.286571	-0.21422	1			
NO2 (ug/l)	0.488697	-0.441586	0.198363	-0.12768	-0.86321	1		
NH4 (ug/l)	-0.29286	0.1629812	0.7394	-0.29374	0.276074	0.181684	1	
TSS (mg/L)	0.884524	0.6666222	0.603486	-0.90992	-0.07802	0.252738	-0.07448	1

Correlations Big Cr								
	TP (ug/l)	*TN (ug/l)*	*PO4 (ug/l)*	*SiO4 (ug/l)*	*NO3 (ug/l)*	*NO2 (ug/l)*	*NH4 (ug/l)*	*TSS (mg/L)*
TP (ug/l)	1							
TN (ug/l)	0.941658	1						
PO4 (ug/l)	0.194709	-0.060532	1					
SiO4 (ug/l)	-0.95077	-0.999595	0.041746	1				
NO3 (ug/l)	0.887172	0.9744179	-0.26258	-0.9722	1			
NO2 (ug/l)	0.86971	0.7570058	-2.9E-16	-0.77147	0.789793	1		
NH4 (ug/l)	-0.64001	-0.677188	0.522233	0.679717	-0.81066	-0.8528	1	
TSS (mg/L)	0.730666	0.9129118	-0.43471	-0.90223	0.953072	0.576782	-0.7189	1

Correlations Bowron Cr								
	TP (ug/l)	*TN (ug/l)*	*PO4 (ug/l)*	*SiO4 (ug/l)*	*NO3 (ug/l)*	*NO2 (ug/l)*	*NH4 (ug/l)*	*TSS (mg/L)*
TP (ug/l)	1							
TN (ug/l)	-0.29239	1						
PO4 (ug/l)	0.521211	-0.85647	1					
SiO4 (ug/l)	0.830208	-0.6497	0.901438	1				
NO3 (ug/l)	-0.37876	0.9787451	-0.78765	-0.63561	1			
NO2 (ug/l)	-0.84031	-0.269746	-0.01613	-0.4474	-0.16048	1		
NH4 (ug/l)	-0.23404	0.2193322	-0.65221	-0.60689	0.058437	0.056024	1	
TSS (mg/L)	0.092266	0.9995408	-0.86957	-0.74314	0.975798	-0.99863	0.209062	1

Table 23, Relative Correlations between TSS and Nutrients by Site

Storm #1 Correlations with TSS by Site	TP	TN	PO4	SiO4	NO3	NO2	NH4
Blacks Cr							
Benson Cr							
Big Cr							
Bowron Cr							

: >+0.75 positive correlation, : between +0.50 and + .075, : between +0.25 and +.050

: No significant correlation: between -0.25 and +0.25

: <-0.75 negative correlation, : between -.50 and -0.75, : between -0.25 and -.050

Storm Event #1 data and charts can be found on Appendix CD: *Storm Chasing TSS data Event#1 11-21-2011*, and *Rain Gauge Storm Event 1 Nov 2011*.

Storm Event #2: 3/19 – 3/23/2012

Event #2 was a larger event than #1. It had a steady rain with two peaks, but the maximum peak was only .16"/hr, whereas event #1 had a larger peak at .61"/hr.

Table 24, Weather Data Storm #2:

Average 2003-2011, 5-day accumulation during that same period = .93"
Accumulation for this storm during event hours = 4.07" Max 1 hour = .16" on 3/20/2012 at 19:00
24 hour, 2-year event at North Bend weather station = 2.68"
Maximum 24 hr accumulation for this event = 2.62" So this was just short of a 2-year event*

Chart 37, Precipitation Chart Storm #2:

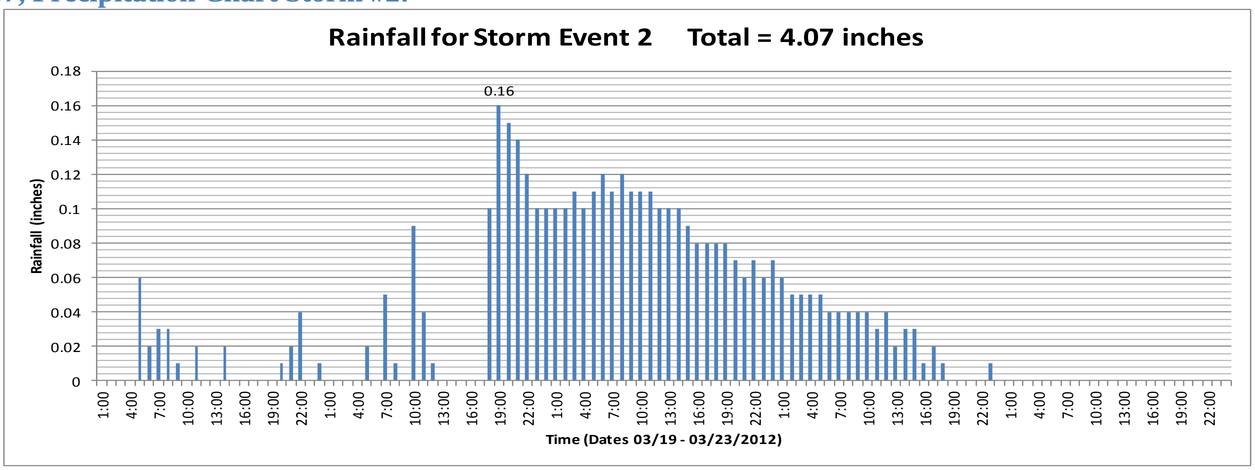


Photo 16, J2-3/21/12 (left), J1 - 3/20/12 (rt), Storm #2:

TSS and TP data from Storm#2:

Once again, TSS and TP tracked well together (Chart 38), with the exception of J2, which actually had a high negative correlation. J1 was just the opposite with an almost perfect .99 correlation. We've shown the summary correlation chart below (Table 25) that combines data from all sites. TSS and TP are the ones that show the highest correlation.

Chart 38, TP vs TSS All Sites, Storm #2:

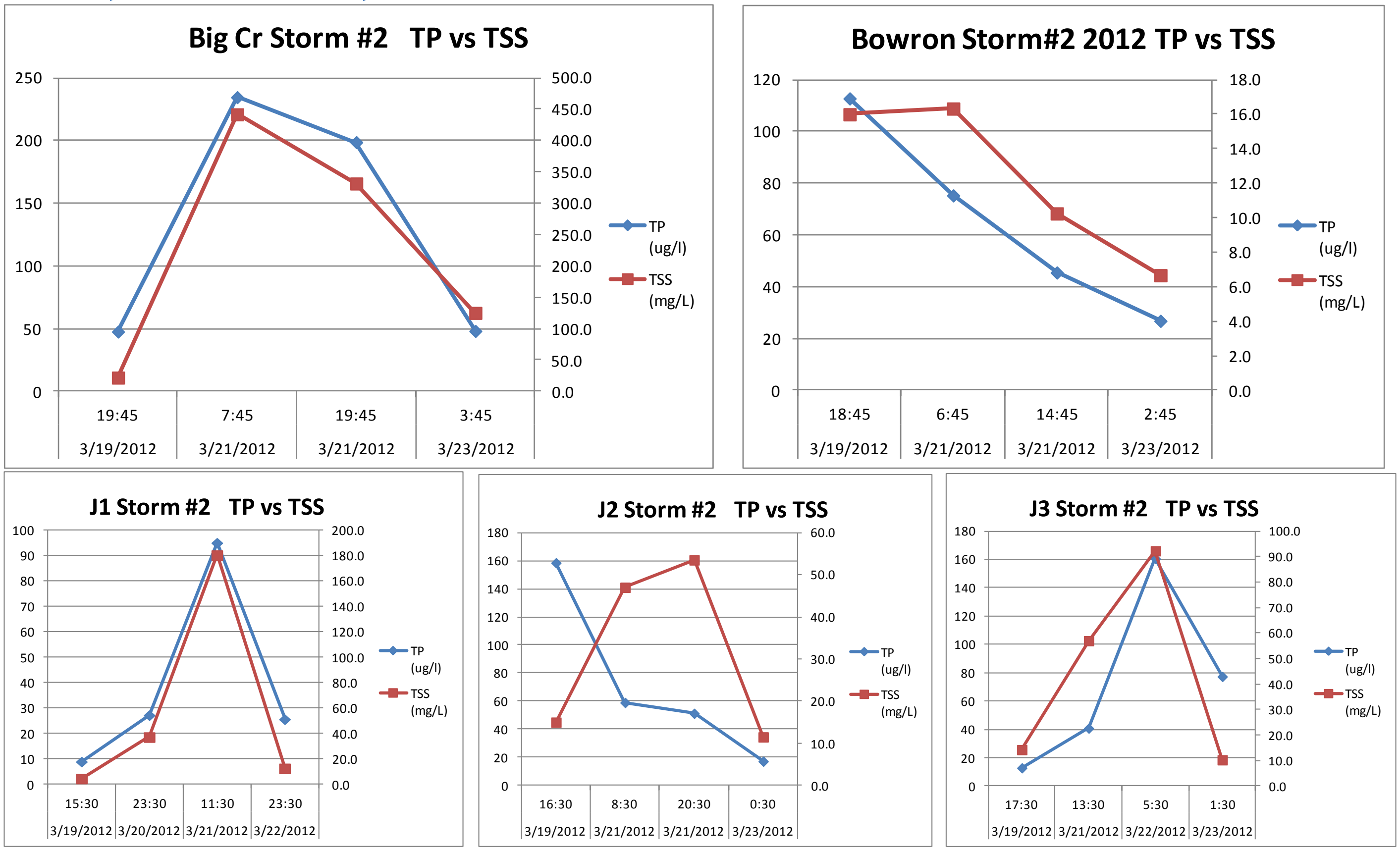


Table 25, Storm Chasing TSS and Nutrient Correlations, Storm #2:

Correlations ALL Sites Combined Storm#2						
	TP (ug/l)	*TN (ug/l)*	*SiO4 (ug/l)*	*NO3 (ug/l)*	*NH4 (ug/l)*	*TSS (mg/L)*
TP (ug/l)	1					
TN (ug/l)	-0.24485482	1				
SiO4 (ug/l)	-0.11879062	0.407251	1			
NO3 (ug/l)	-0.23499496	0.444419	0.6422914	1		
NH4 (ug/l)	-0.1634253	0.610908	0.7106398	0.487651	1	
TSS (mg/L)	0.7656605	-0.15135	-0.212845	-0.22259	-0.10169	1

Storm Event #2 data and charts can be found on Appendix CD: *Storm Chasing TSS data Event#2 3-19-2012*, and *Rain Gauge Storm Event 2 March 2012.*

Johnson Creek Focus

Our new sites at Johnson Cr have shown some interesting data. It is the first time we have been able to compare differing land uses within the same basin. It also has a stretch of stream (between J1 and J2) that has had significant fencing work completed on it, along with other improvements such as bridges and riparian plantings. The area between J2 and J3 has had no fencing projects. Both are active cattle ranches.

We completed 2-24hr baseline sampling events to get an idea of what the streams are doing when we are not having a large storm. The first one was completed on 2/6-2/7/12, after a period of no rain for about 5 days prior to sampling (Chart 40 left). J1 and J2 did not show a large difference in TSS between the 2 sites. J3 had much larger TSS loads at all time periods than either of the upstream sites (Chart 39 left).

The second baseline sampling event was on 2/22-2/23/12. This was sampled after what we considered an average rainy period, but not intense enough to qualify as a “Storm Event.” The precipitation chart is shown below (Chart 40 right). The results showed (Chart 39 right) that the water coming in from the Elliot Forest averaged 20.4 mg/L, it then dropped to 15.2 after going through the improved ag-land, but came back up at J3 and even exceeded the original forest readings.

Chart 39, TSS for Johnson Cr. Winter Low Water (left) and "Average" Storm (right) 2012:

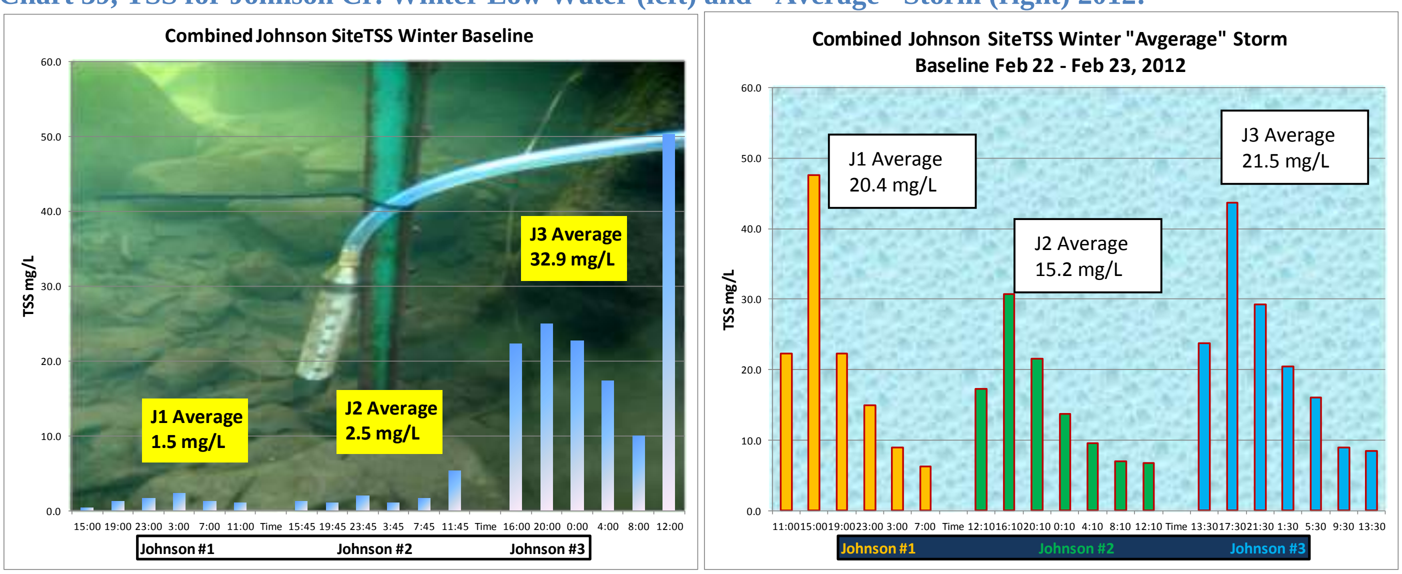
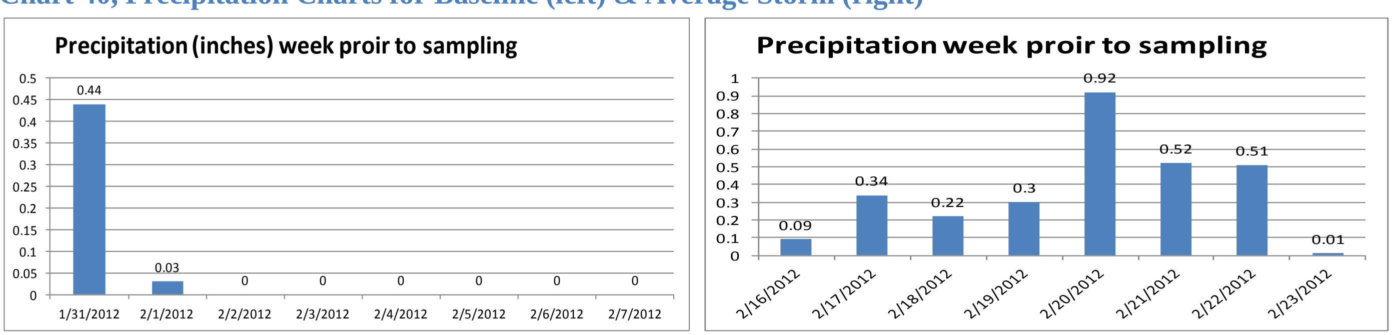


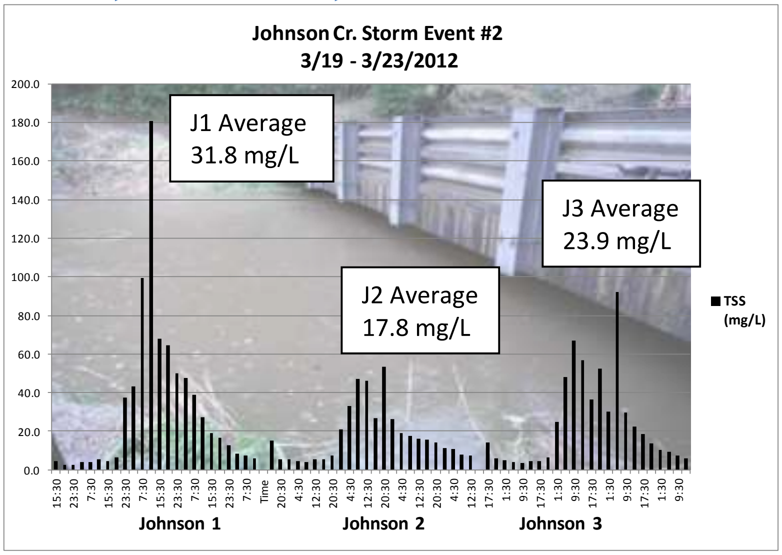
Chart 40, Precipitation Charts for Baseline (left) & Average Storm (right)



Baseline data and charts can be found on Appendix CD: *Johnson Cr Baseline avg storm TSS Data 02-22-2012, and Johnson Cr Baseline TSS Data 02-06-2012.*

Storm Event #2 showed a similar tend to our "average" storm. Elliot Forest TSS averaged 31.8 mg/L with a peak of 180.7 mg/L. Site J2 dropped to 17.8 with a 53.5 peak. J3 jumped back up to a mean of 23.9 and peaked at 92.3 (Chart 41).

Chart 41, Johnson Cr TSS, Storm #2 2012



Storm Event #3 occurred between 11/17/2012 – 11/21/2012.

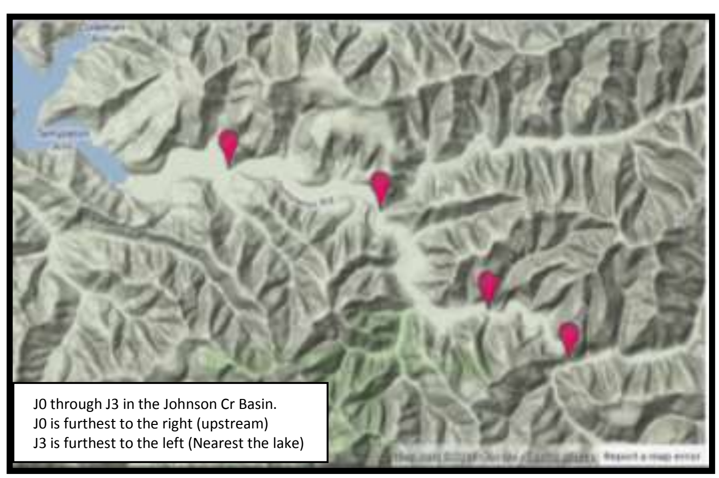
One interesting component of these results is the drop we're seeing at the J2 site and the subsequent rise at the J3 site. There are several plausible explanations for this including differences in the stream channels between sites, differences in the gradient, and the improvements made to the stream above J2 with our fencing and other restoration projects.

As water comes off of the hills in small tributaries, the gradient will be much steeper than in the lower ag-lands and the flow would be greater, but as it hits the main channel at the bottom of the basin, the flow is more dependent on how far downstream the measurement is made (as the smaller tributaries continue to add more volume.) Using the USGS StreamStat website, we were able to estimate the peak flow during a 24hr-2yr return interval (See Table 26 & Map 11 below). Site J0 is located about a mile above J1. The flow predictions confirm a steady increase in flow from J0 through J3. With an increasing flow you would expect the bank erosion effects to get increasingly worse as you travel downstream, therefore the TSS should be steadily increasing, but this is not what we're seeing at J2 where we actually see a drop in TSS, so we can conclude that flow alone is not responsible for our findings.

Table 26, Storm Chasing Sites StreamStat Data:

Comparison of Tenmile Basin StreamStat Data					
Basin	Drainage Area (Sq Miles)	24hr-2yr Return	Flow (ft^3/s) at 24-2 peak	Mean Elevation	Mean Slope
J0	6.27	3.20	474	765	28.1
J1	7.17	3.19	536	726	27.9
J2	9.16	3.16	670	658	27.3
J3	16.1	3.17	1150	640	26.6
Big Cr	8.45	3.28	649	670	26.1
Bowron Cr	0.59	3.03	39.5	131	10.3
Blacks Cr	3.15	3.19	207	329	21
Benson Cr	8.84	3.18	630	595	25.2

Map 11, Johnson Cr Sites – StreamStat



The gradient or slope of Johnson Cr from J0 to J3 is shown in the table and elevation plot below (Chart 42 & Table 27). Note that in the mile from J0 to J1 there is only about 4 feet of elevation change. This is actually less than the slopes for the area between J1 and J3. This indicates that the bottom of the basin doesn't really start at the Elliott Forest/ag-land interface. The water running off of the steep forest lands and tributaries has a chance to slow down before it reaches the ag-land property. This could indicate that the water coming from the forest might have an even higher TSS than reported, since it has about a mile of slower water to settle out before it reaches the J1 site. It is unclear at this point why the forest land would have the higher amounts. Most logging roads have been decommissioned, and no logging is currently underway in this basin. This is scheduled to change. In early 2014 parts of the ESF were put up for sale. Several parcels are located above Johnson Cr on the slopes above the Ag land. Another parcel is located in the Big Cr and Benson Cr drainage. Unless wide setbacks are used during timber harvest in these areas, it is likely that TSS amounts will increase dramatically into Tenmile Lakes.

Chart 42, Johnson Cr Site Elevations from J0 to J3:

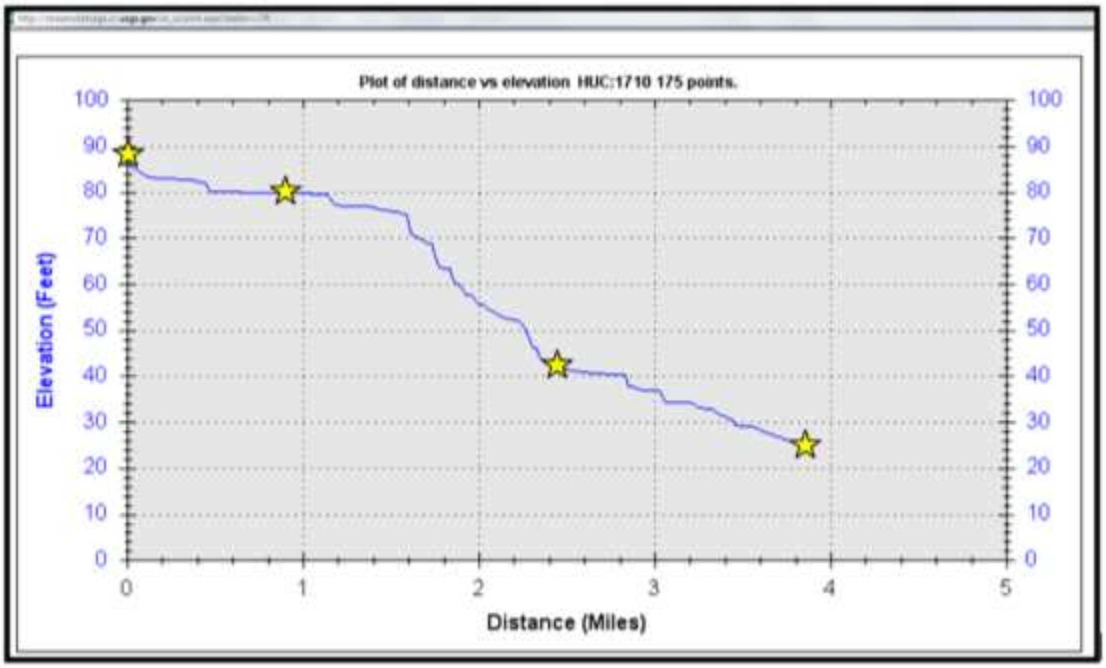


Table 27, Johnson Cr Site Elevations and Channel Slopes:

Site	Elevation	River Mile	Elevation Change (Ft)	Distance btw Sites (Ft)	Slope btw Sites (%)
J0	85	5.99			
J1	81.3	5.11	3.7	4646.4	0.08
J2	43.5	3.57	37.8	8131.2	0.46
J3	24.2	2.1	19.3	7761.6	0.25
Total Change	60.8	3.89		20539.2	0.30

Stream channel morphology is another possible factor. If the stream is contained within narrow, high banks the hydrologic pressures will be greater than if the streambed is wide, or if it goes overbank quickly during high flows. The higher water pressures will erode the banks and create more TSS. The longitudinal shape of the streams also has an impact. A straight channel will allow the water to flow more quickly than a sinuous channel. We have not done streambed measurements to determine the exact channel morphology along Johnson creek, but observational data may help to give a broad overview.

J0 to J1: The streambed is fairly broad and has areas where it can go overbank quickly. It meanders in a natural bed. According to the USGS elevation chart, the slope in this area is .08%.

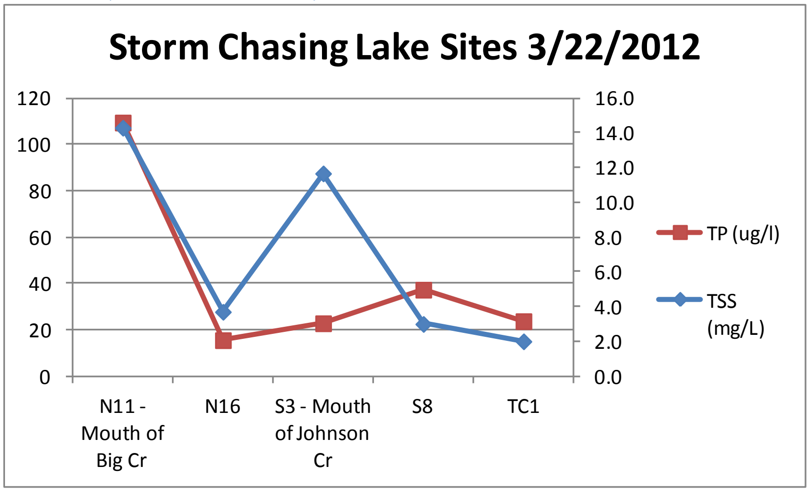
J1 to J2: Historically the stream was ditched to the side of the valley, but it crosses from the south to the north side of the valley, and in many areas it meanders into the middle with some large s curves. We have observed erosion at these corners, and it would also slow the flow. After flood events, there can be a large amount of debris and sediments left in the fields, so we know that some settling is occurring. The stream banks are more defined than in the previous section. They are not deep, so the stream can go overbank fairly quickly during large storm events. This section has had fences installed to keep out the cattle, bridges for fish passage and stream crossing, streambank stabilization on some of the curves, and some small stretches of riparian plantings. According to the USGS elevation chart, the slope in this area is .46%.

J2 to J3: The stream has been ditched to both sides of the valley with the south side being the larger channel. There is very little meandering for this section. The stream is deeper than in the previous 2 sections, so it will go overbank later. Roberts Cr also comes in just downstream from J2. This will add volume to the creek. The land up Roberts Cr and down to J3 is all active livestock grazing land. There is visual evidence of bank erosion all along this section. No fences have been used in this area. According to the USGS elevation chart, the slope in this area is .25%.

Overall, the slopes in this area are all relatively minor and probably do not play a major role in any changes that we are seeing between the 3 sites. The upland forest area will have larger slopes which may influence the water coming into J0, but even that has almost a mile of the least sloped area to slow down before reaching the J1 sampling site. Future efforts should be made to sample the water above the J0 confluence and above the lowlands located between J0 & J1. This data could be compared to the TSS at J1 to better characterize the input from actual forested lands. The stream channel morphology characteristics probably have more influence on the TSS than the slope. The J1 to J2 area's characteristics would tend to slow the water both in terms of the greater sinuosity and its greater width to depth ratio. The relatively low banks compared to the J2 to J3 section also allows for easier overbank flows into the pasture lands. Water can then be filtered and slowed even more as it goes through the grasses of the pasture. The addition of the fences, bridges, riparian plantings, and other watershed improvements that keep cattle out of the streams and off the streambanks, has a stabilizing effect on the soils around the stream, so it is contributing less sediments during the high flow periods. When the water passes J2 and reaches the unprotected streambanks on the way to J3, its flow is unobstructed due to the straighter path of the stream, its deeper channel. The higher velocity flows hit the unprotected streambanks causing a higher level of erosion and higher TSS readings at J3.

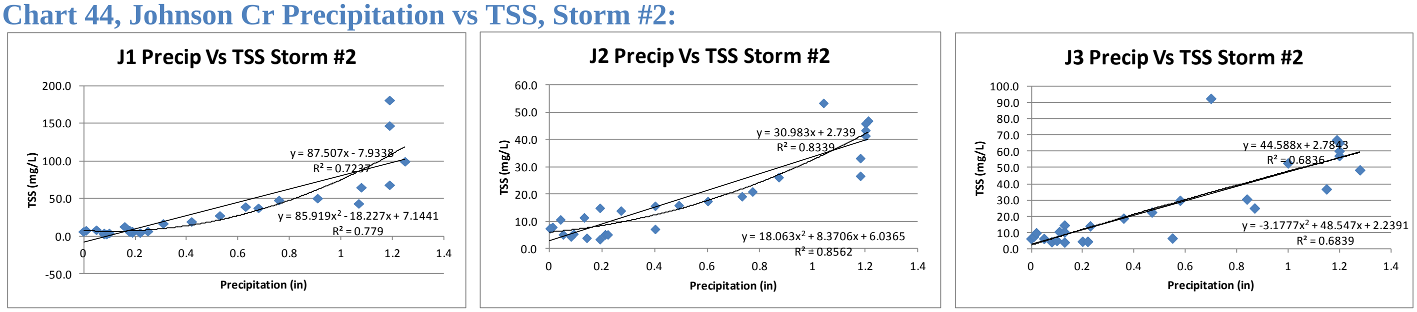
Much more work is needed in the Johnson Cr basin to fully understand the dynamics of the basin. These are only the first set of results for this area and future sampling events may alter our interpretations, but the results so far have been interesting and may point to direct evidence that the watershed projects done in this area are having a direct impact on the TSS that works its way down into Tenmile Lake. Phosphorus is the limiting nutrient in the lake, and influences the harmful algae blooms and invasive weed growth that we see in the summer. Since we show a correlation between TSS and TP, the more we can control the sediments in the tributaries, the greater effect we will have on the negative impacts that the excessive TP has on the lakes. These benthic sediments contribute Phosphorus to the lake when DO and pH cycle under anaerobic conditions. The lake graph below (Chart 43) is from a sampling at the end of Storm Event #2. Note that the TSS is highest at the mouths of the two tributaries, N11-Big Cr, and S3-Johnson Cr.

Chart 43, Lake Sites TSS, Storm #2



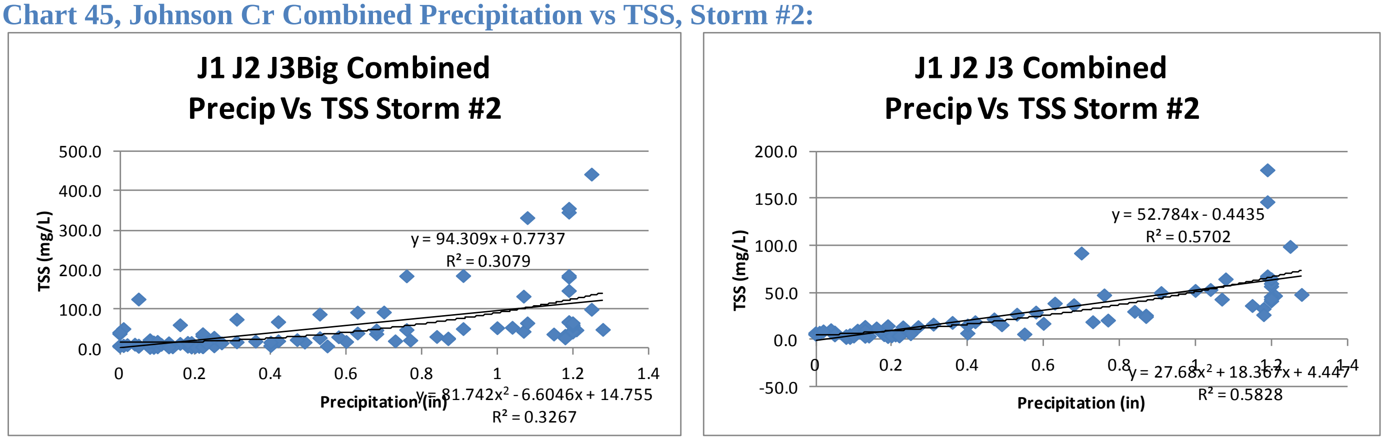
We have also tried to correlate the precipitation amounts with the TSS totals to see if we could produce a predictive graph that would give approximate TSS amounts for any given rainfall total (Charts 44 & 45).

Chart 44, Johnson Cr Precipitation vs TSS, Storm #2:



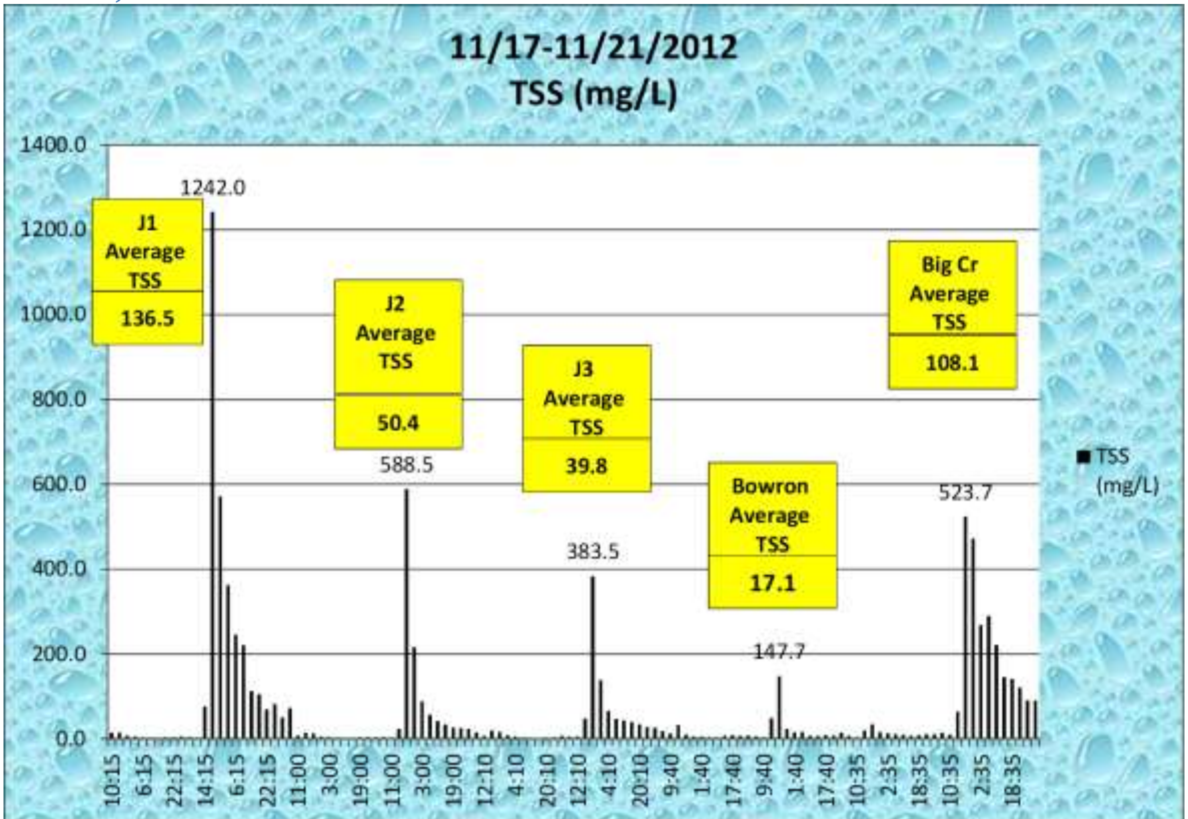
We plotted TSS vs Precipitation and added a Trend line from Excel. The upper line formulas are for the linear trend lines, the lower formulas in each graph are for polynomial tend lines. R^2 range from .68 to .86 for the individual sites. We also ran these same charts for all the Johnson Cr sites combined, and for Big Cr combined with all Johnson Cr sites. The Johnson Cr R^2 value drops to .57 and when we combine Big Cr the R^2 value goes all the way down to .31. These values indicate that predicting TSS from precipitation is a difficult task, but is clearly better when narrowed down to a specific site. As we collect more data in the future, we can test to see if the added data helps or hinders this prediction formula.

Chart 45, Johnson Cr Combined Precipitation vs TSS, Storm #2:



Storm Event #3 occurred between 11/17/2012 and 11/21/2012. The summary of rain totals and TSS correlations are shown below.

Chart 46, Storm #3 Charts & Tables



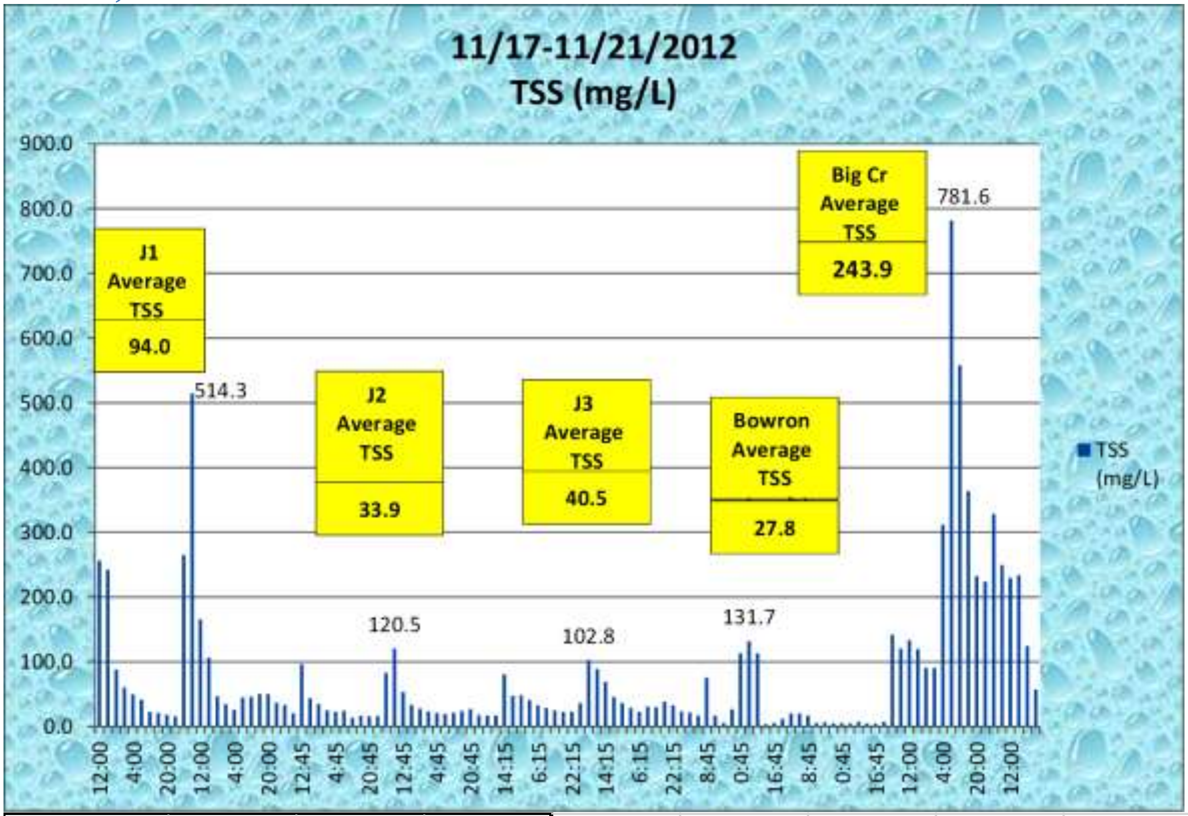
5 Day Total	5.88	inches
Actual Event Time Total	5.22	inches

Maximum 24 hour accumulated total occurred on 11/20/12 at 05:00. Total = 2.98in
2Yr - 24Hr Return Period for N. Bend = 2.68in. This event exceeded that amount by .30in*
Highest 1 hour total occurred on 11/19/12 at 18:00. Total = .40

Event #3 Site Name	Correlation: TSS to 6hr Rain Totals		Correlation: TSS to 12hr Rain Totals	Correlation: TSS to 24hr Rain Totals
Big Cr	0.68		0.85	0.76
Bowron	4hr=0.67	6hr=0.57	0.30	0.10
Johnson #1	0.81		0.76	0.53
Johnson #2	0.78		0.71	0.44
Johnson #3	0.74		0.73	0.50

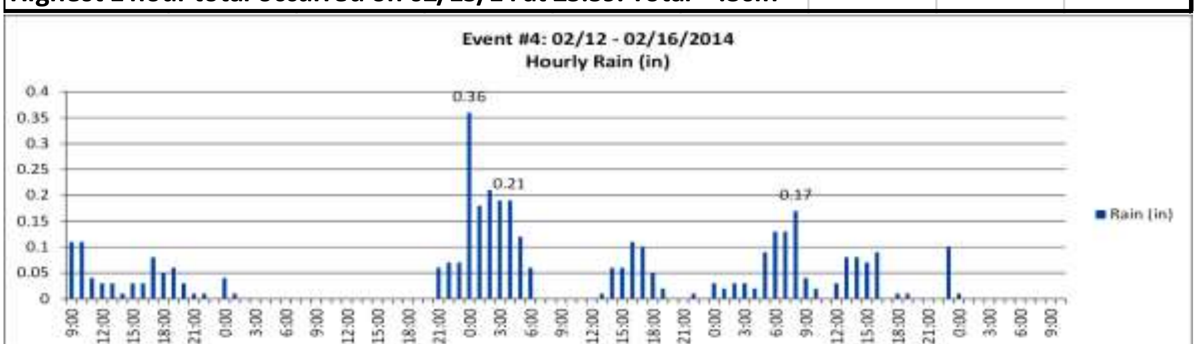
Storm Event #4 occurred between 2/12/2014 and 2/16/2014. The summary of rain totals and TSS correlations are shown below.

Chart 47, Storm #4 Charts & Tables



5 Day Total		4.6	inches
Actual Event Time Total		3.95	inches

Maximum 24 hour accumulated total occurred on 02/14/14 at 19:00. Total = 1.92in
2Yr - 24Hr Return Period for N. Bend = 2.68in, So this event fell short of that amount by .76in*
Highest 1 hour total occurred on 02/13/14 at 23:59. Total = .36in



Event #4 Site Name	Correlation: TSS to 6hr Rain Totals		Correlation: TSS to 12hr Rain Totals	Correlation: TSS to 24hr Rain Totals
Big Cr	0.22		0.65	0.53
Bowron	4hr= -0.11	6hr= -0.13	-0.15	0.00
Johnson #1	0.52		0.82	0.48
Johnson #2	0.60		0.82	0.47
Johnson #3	0.45		0.82	0.66

Correlation graphs and other information on each individual storm event can be found on the accompanying CD.

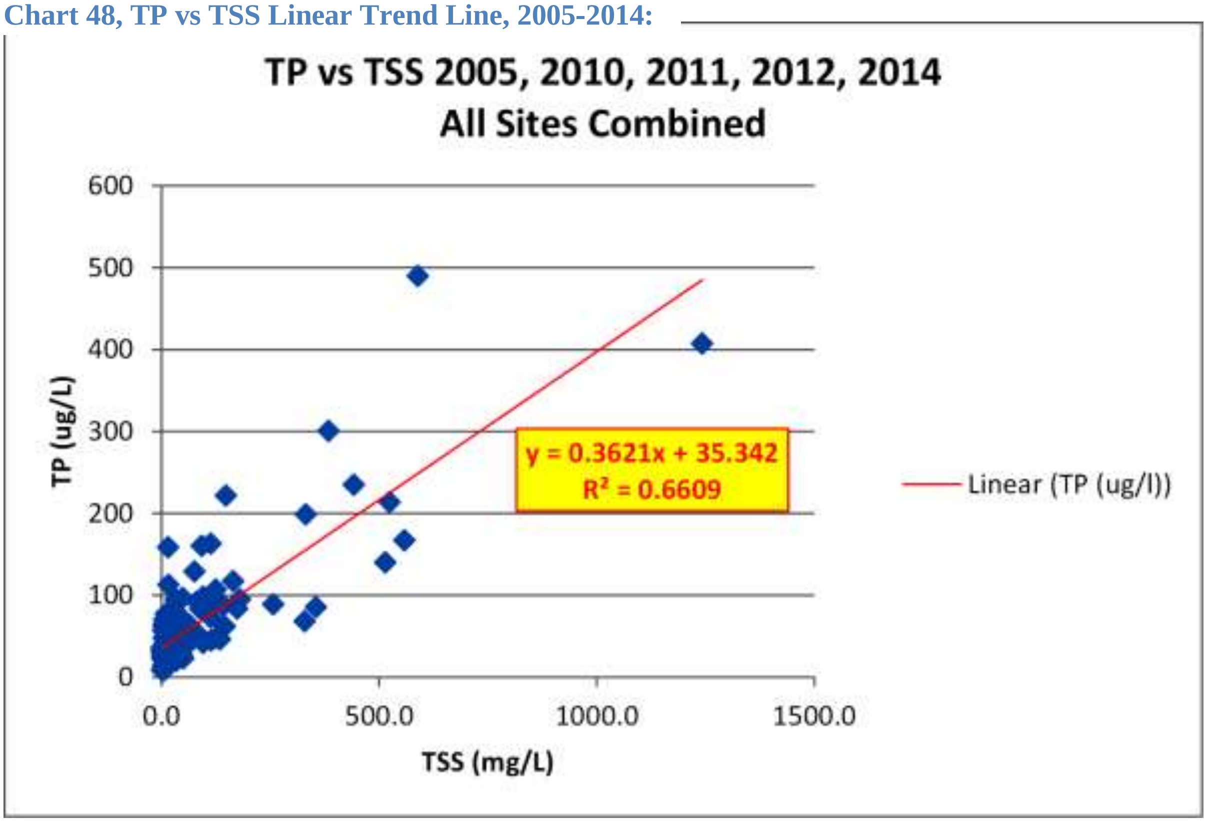
2005-2014 Storm Chasing Data

In addition to analyzing the storm data for individual years, we also compiled the data that has been collected since 2005 to look for trends and correlations. Nutrient data was collected during storms for the years 2005, 2010, 2011, 2012, and 2014. No storm were captured during the 2013 season. The nutrients that we sampled include: Total Phosphorus (TP), Total Nitrogen (TN), Phosphate (PO_4), Silicate (SiO_4), Nitrate (NO_3), Nitrite (NO_2), Ammonia (NH_4), and TSS. When comparing nutrient data to TSS values, we only used the TSS data that matched up with its corresponding nutrient data from the same sampling time. Below is a correlation table (28) that compared all of the nutrient parameters from all dates and all sites to TSS and all the other parameters to see what correlations surfaced. The strongest correlation was for TSS and TP at 0.81. TSS and TN had almost no relation with a -0.10. This corroborates that TP is tied to TSS. We also graphed this relationship (Chart 48) which shows a linear trend line with an R^2 value of 0.66.

Table 28, Correlations - TSS and Nutrients, 2005-2014, All Storm Chasing Sites Combined:

2005, 2010-2014 Correlations	TP (ug/l)	TN (ug/l)	PO4 (ug/l)	SiO4 (ug/l)	NO3 (ug/l)	NO2 (ug/l)	NH4 (ug/l)	TSS (mg/L)
TP (ug/l)	1							
TN (ug/l)	-0.10	1						
PO4 (ug/l)	0.17	-0.23	1					
SiO4 (ug/l)	0.44	-0.11	0.04	1				
NO3 (ug/l)	0.05	0.71	0.05	0.06	1			
NO2 (ug/l)	-0.01	0.25	0.15	-0.03	0.11	1		
NH4 (ug/l)	0.09	0.41	0.13	0.04	0.31	0.54	1	
TSS (mg/L)	0.81	-0.10	0.16	0.64	0.06	0.00	0.09	1

Chart 48, TP vs TSS Linear Trend Line, 2005-2014:



2005-2014 Correlations for Nutrient parameters, TSS and Precipitation per individual site. **Only includes TSS and precipitation data for those times with corresponding nutrient data.** The correlations are stronger when each site is looked at individually. Once again, TSS and TP show the most consistent nutrient correlation, and 12 hour precipitation correlates better than 24 hour totals with both TP and TSS. (Table 29)

Table 29, Correlations between Nutrients, TSS & Precipitation. 2005-2014, All Individual Storm Chasing Sites:

Blacks Correlations Storm Chasing 2005, 2010,2011	**TP (ug/l)**	**TN (ug/l)**	**PO4 (ug/l)**	**SiO4 (ug/l)**	**NO3 (ug/l)**	**NO2 (ug/l)**	**NH4 (ug/l)**	**TSS (mg/L)**
TSS (mg/L)	0.69	0.37	-0.19	0.15	0.01	0.48	0.40	
24 Hour Precipitation	0.57	0.30	0.33	-0.08	0.30	0.24	0.18	0.60
12 Hour Precipitation	0.66	0.28	0.41	-0.06	0.30	0.14	0.11	0.64
Benson Correlations Storm Chasing 2005, 2010,2011	**TP (ug/l)**	**TN (ug/l)**	**PO4 (ug/l)**	**SiO4 (ug/l)**	**NO3 (ug/l)**	**NO2 (ug/l)**	**NH4 (ug/l)**	**TSS (mg/L)**
TSS (mg/L)	0.61	0.30	0.12	-0.20	-0.04	0.17	0.12	
24 Hour Precipitation	0.54	0.33	0.14	-0.12	0.29	-0.06	0.10	0.66
12 Hour Precipitation	0.69	0.27	0.19	-0.16	0.10	-0.07	0.13	0.82
Bowron Correlations Storm Chasing 2010,2011, 2012, 2014	**TP (ug/l)**	**TN (ug/l)**	**PO4 (ug/l)**	**SiO4 (ug/l)**	**NO3 (ug/l)**	**NO2 (ug/l)**	**NH4 (ug/l)**	**TSS (mg/L)**
TSS (mg/L)	0.93	-0.16	0.52	0.04	0.11	0.42	0.50	
24 Hour Precipitation	0.13	-0.03	0.19	-0.22	0.12	0.26	-0.10	0.22
12 Hour Precipitation	0.27	-0.02	0.11	-0.18	0.00	0.29	0.03	0.29
Big Cr Correlations Storm Chasing 2005, 2010,2011, 2012,2014	**TP (ug/l)**	**TN (ug/l)**	**PO4 (ug/l)**	**SiO4 (ug/l)**	**NO3 (ug/l)**	**NO2 (ug/l)**	**NH4 (ug/l)**	**TSS (mg/L)**
TSS (mg/L)	0.85	-0.10	0.44	0.15	0.12	0.47	0.64	
24 Hour Precipitation	0.57	-0.02	0.28	-0.10	0.18	0.33	0.22	0.44
12 Hour Precipitation	0.67	-0.17	0.52	-0.07	0.14	0.42	0.38	0.61
Johnson #1 Correlations Storm Chasing 2012,2014	**TP (ug/l)**	**TN (ug/l)**	**PO4 (ug/l)**	**SiO4 (ug/l)**	**NO3 (ug/l)**	**NO2 (ug/l)**	**NH4 (ug/l)**	**TSS (mg/L)**
TSS (mg/L)	0.99	-0.19	n/a	0.88	0.50	n/a	0.93	
24 Hour Precipitation	0.60	-0.23	n/a	0.34	0.08	n/a	0.41	0.53
12 Hour Precipitation	0.75	-0.24	n/a	0.43	0.00	n/a	0.54	0.73
Johnson #2 Correlations Storm Chasing 2012,2014	**TP (ug/l)**	**TN (ug/l)**	**PO4 (ug/l)**	**SiO4 (ug/l)**	**NO3 (ug/l)**	**NO2 (ug/l)**	**NH4 (ug/l)**	**TSS (mg/L)**
TSS (mg/L)	0.92	0.05	n/a	0.29	0.43	n/a	0.90	
24 Hour Precipitation	0.25	0.01	n/a	0.06	-0.21	n/a	0.40	0.42
12 Hour Precipitation	0.50	-0.23	n/a	0.00	-0.24	n/a	0.57	0.63
Johnson #3 Correlations Storm Chasing 2012,2014	**TP (ug/l)**	**TN (ug/l)**	**PO4 (ug/l)**	**SiO4 (ug/l)**	**NO3 (ug/l)**	**NO2 (ug/l)**	**NH4 (ug/l)**	**TSS (mg/L)**
TSS (mg/L)	0.89	-0.11	n/a	0.26	-0.11	n/a	0.94	
24 Hour Precipitation	0.60	-0.32	n/a	0.12	-0.15	n/a	0.44	0.53
12 Hour Precipitation	0.63	-0.39	n/a	0.15	-0.25	n/a	0.64	0.71

We also correlated precipitation with TSS for the period 2005, 2010-2014 using 3 different rain accumulation intervals: 24, 12 and 6 hours. This was done by using the time that the TSS sample was collected and summing the hourly rain totals for the previous 24, 12 or 6 hours. The precipitation totals are from the rain gauge on South Tenmile Lake near Ringo's Marina. It should be noted that the TSS/Precipitation correlations above only include TSS /Precipitation data if there was corresponding nutrient data taken at the same time. The correlations in Table 30 are from the entire data set for every TSS/Precipitation reading made for every storm and represents significantly more data.

The first thing to note is the higher correlation between TSS and the 12 hour interval as opposed to the normal 24 hour interval. This was true at every site, although J2 had its best correlation at the 6 hour accumulation, and Bowron correlated best at the 1 hour period (at a weak 0.22). Bowron receives runoff from an urban environment, the City of Lakeside, so we would expect the response to be much faster due to the impervious nature of the houses, sidewalks and pavement which forces water to drain from the surface instead of soaking into the sediments.

Table 30, first row, shows the correlation for ALL sites, all years combined and was a relatively weak 0.46. When all sites and all storm events are combined, there is too much variability to find a consistent correlation. Blacks Cr was also weak at a 0.43 correlation. The other 5 sites all showed stronger correlations above 0.60. These correlations indicate that higher TSS levels are associated with higher precipitation amounts, with a response time of approximately 12 hours.
It would be useful to have an equation that would relate precipitation amounts to TSS. This would enable us to predict sediment loading into Tenmile Lakes by just looking at rain gauge data. The TSS and 12 hour precipitation data were graphed and a trend line added. (See charts below.) The All Sites data (Chart 49) showed a relatively weak linear R^2=0.26. The equation shows that during storm events for every inch of rain we get approximately 100mg/L of sediment. The low R^2 indicates that there is a great deal of variability in the data. For instance, at J3 0.95" of rain produced 36.3mg/L of TSS, but at Big Cr 0.95" rain produced 557.8mg/L TSS, so the next step is to look at the sites individually to see if that reduces some of the variability.
The Big Cr data (Chart 50-left) was slightly stronger with a linear R^2= 0.39 and the strongest linear relationship was at J1 (Chart 50-right) with an R^2=0.45. The relationship between Precipitation and TSS may not be linear, so we also plotted the 2nd order polynomial trend line. In all cases, this was a better fit and gave slightly higher R^2 values. Johnson #1 for example, moved from 0.45 to 0.59, and with a 6th order polynomial the J1 R^2 value moved up to 0.69, but this high a value is not found throughout the other sites. (All charts and tables can be found on the attached CD under the file name: *Storm Chasing Combined 2005-2014.xlsx)*
Overall, there is good evidence that TSS is correlated to precipitation, but finding a mathematical equation that explains that relationship is a much harder task. The variability seen in the data shows that TSS quantities are related to more than just precipitation amounts. Timing of the rain probably has a large influence. If an inch of rainfall occurs at the beginning of a storm when the land is dry, it will have less impact than if it falls after it has already been raining for a few days and the soils are saturated. The timing of when the creeks go over-bank and flood the fields would also affect the TSS results. We are also using a rain gauge located on Tenmile Lake instead of in the fields and nearby forests where we are sampling. Local variations in rainfall amounts and their timing could have a dramatic impact on the correlations and our ability to find an adequate mathematical relationship. We are currently looking for funding that would allow us to establish weather and gaging stations at select locations within the watershed. The gaging station would give us the flow data necessary to calculate the amount of sediment entering the lake from the upper watershed.

Table 30, TSS and Precipitation Correlations, Storm Chasing Sites 2005-2014:

Site Name	Data Collection Years	6hr Precipitation/TSS Correlation		12hr Precipitation /TSS Correlation	24hr Precipitation /TSS Correlation
All Sites Combined	2005, 2010-2014	0.41		0.46	0.38
Bowron Cr	2005, 2010-2014	1hr = 0.22	6hr = 0.18	0.11	0.07
Blacks Cr	2005, 2010, 2011	0.39		0.43	0.35
Benson Cr	2005, 2010, 2011	0.49		.061	0.51
Big Cr	2005, 2010-2014	0.47		0.63	0.58
Johnson #1	2012-2014	0.67		0.67	0.48
Johnson #2	2012-2014	0.65		0.58	0.40
Johnson #3	2012-2014	0.59		0.63	0.49

Chart 49, 12 Hour Rainfall and TSS. 2005-2014:

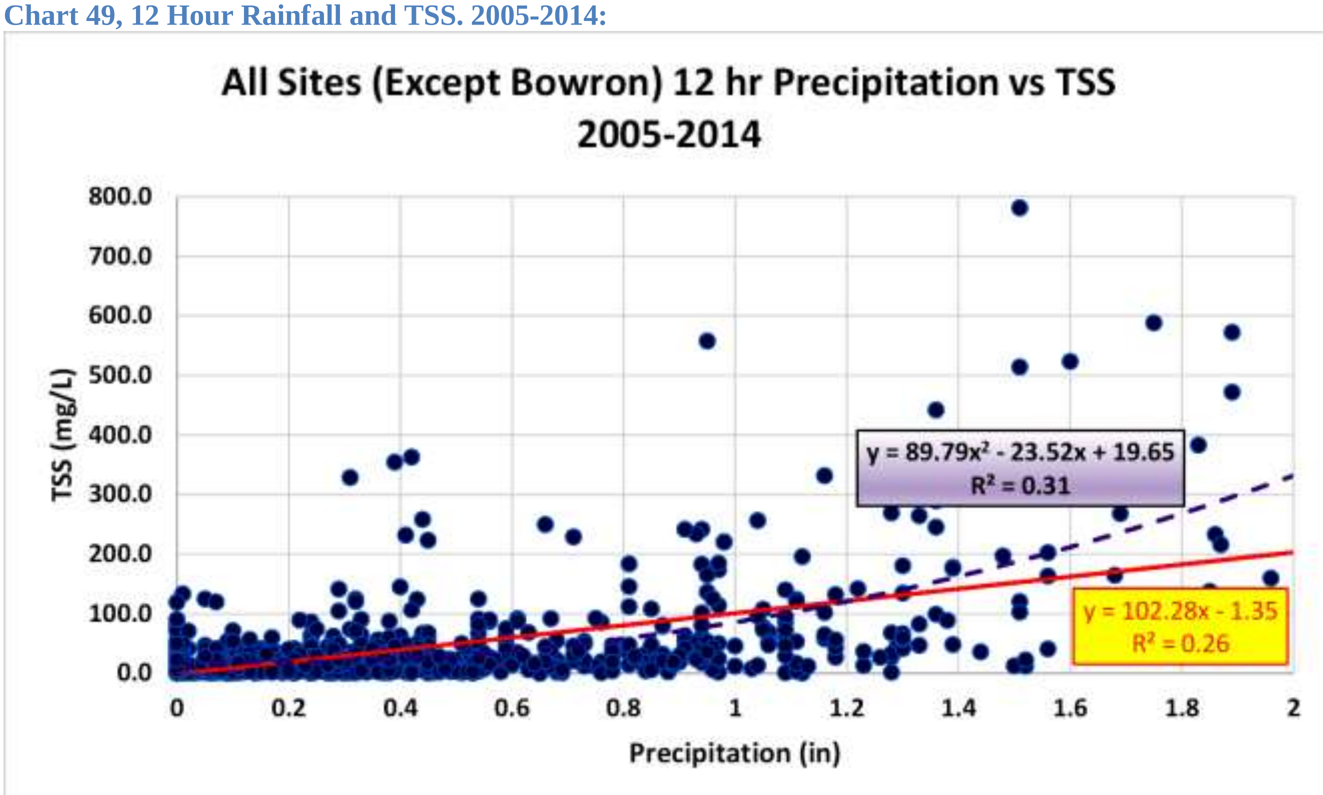
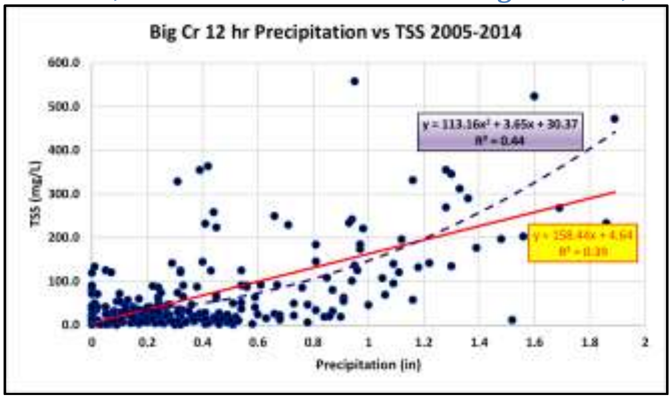
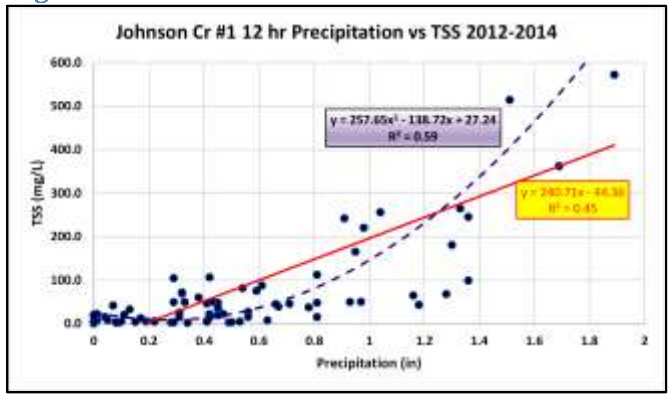


Chart 50, 12 Hour Rainfall and TSS. Big Cr & J1, through 2014:

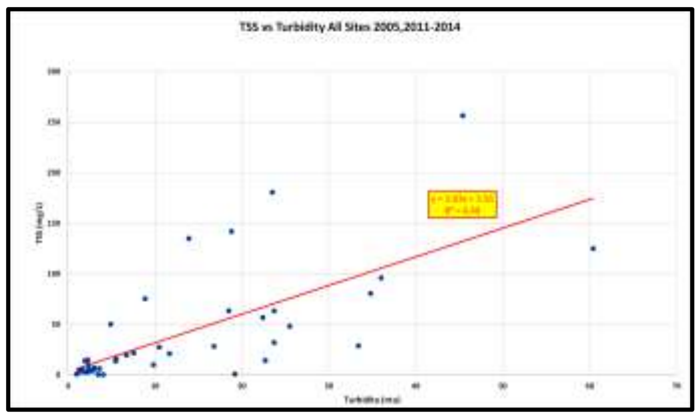




Another idea that would simplify sampling is if we could relate the relatively easy to measure Turbidity, to TSS amounts. The following chart (51-left) shows the correlations between Turbidity and TSS at each of the sampling locations. With the exception of Bowron and Blacks, the correlations are very good, topping out at 0.99 for J2. Chart 51 (below-right) shows the data for All Sites combined. The R^2=0.49. More analysis could lead to a better mathematical fit. More turbidity samples taken from each TSS sampling bottle could greatly enhance the sampling quantity and lead to a better understanding of this correlation and if a mathematical model could be derived to accurately predict TSS from Turbidity samples alone.

Chart 51, Turbidity & TSS Correlations 2005, 2011-2014:

Site Name	Turbidity/TSS Correlation
All Sites Combined	0.70
Bowron	0.36
Blacks	-0.40
Benson	0.69
Big	0.60
Johnson #1	0.98
Johnson #2	0.99
Johnson #3	0.88



Finally, we wanted to look at nutrients listed in the TMDL from 2004-2005 and compare them with the 2005-2012 averages for Phosphorus and Nitrogen at each individual basin that corresponded to our sampling sites. SWAT modeling was used to predict many of the TMDL numbers. As we get more real data, we can try to adjust the model to more accurately reflect the values that we see from our sampling data. This can then improve the model for all the basins in the watershed including those that we have not sampled.

TSS values in Table 31 below are shown in 2 columns: The first one is the TSS average for only those times that we had corresponding nutrient data. The second column is the average for ALL TSS data values at that site. This set has many more data points, and the first set will be skewed high because we tend to pick the samples at the peak of the storm to run some of the nutrient analysis on. Values can also depend on the intensity of the storm that was originally sampled for the TMDL compared to the ones sampled later. Comparing the 2005-2014 All Samples Average to the TMDL Average we find that Benson and Johnson Creeks are similar, Blacks and Bowron Creeks are much lower than estimated, and Big Cr is currently over twice as high as the original TMDL figures. We also added a Rank number to see how the creeks compared to each other. In the original sampling for the TMDL, Bowron was ranked as having the highest mg/L average of all sites, but for the 2005-2014 range, Bowron came in 2nd lowest with an average of only about a third of the previous

total. Big Cr moved to the top with about twice the previous average. This confirms what we see in the field. Big Cr is usually highly turbid throughout the storm event, whereas Bowron peaks early at a lower level, then runs less turbid for the remainder of the event.
Total Phosphorus results show a similar trend in Bowron Cr where our current average of 63.8µg/L is about 4 times less than the TMDL average of 250µg/L. Most of the other sites also showed less TP than in the TMDL SWAT model estimates. Nitrate (NO_3) were significantly higher at all sites. Blacks was estimated at 60µg/L in the TMDL but our sampling results show an average of 1284 (21 times higher.) The other site's Nitrate levels ranged from 2-5 times higher. Future grant requests could include funding support to run a new SWAT model to give the model a wider set of data to use for its calculations.

Table 31, Storm Chasing Nutrient Averages 2005-2014 Compared to Averages in TMDL SWAT Model, All Sites:

Site Name	2005-2014 Average w/nutrients TSS		2005-2014 Average All Samples TSS		TMDL 2004-2005 Average TSS (mg/L)		2005-2014 Average TP (µg/L)	TMDL 2004-2005 Average TP (µg/L)	2005-2014 Average NO_3 (µg/L)	TMDL Average NO_3 (µg/L)
	(mg/L)	Rank	(mg/L)	Rank	(mg/L)	Rank				
Benson	41.4	3	28.6	3	28.46	3	45.8	100	1772	370
Big Cr	142.2	1	70.5	1	32.95	2	73.9	90	1230	360
Blacks	9.6	5	7.5	5	25.30	5	35.2	30	1284	60
Bowron	25.4	4	15.4	4	45.54	1	63.8	250	755	370
Johnson (J3)	65.1	2	33.2	2	26.00	4	68.6	90	1042	390

Storm Chasing Summary

The Johnson Cr site additions have produced some interesting data. The higher levels of TSS coming in from the Elliott Forest were unexpected. The trends are showing a lessening of the sediment as it proceeds through the Ag lands. It is also of note that the Ag lands that have had stream enhancement projects completed on them are showing less TSS throughput than the unimproved lands. These are very preliminary results and will require several more years of data collection to find any verifiable trends, or to make any assessments as to what is the causing the variations. We will apply for funding of a gauge station on Johnson Cr at the J2 site to give us flow data throughout the year. This would allow us to correlate flow with precipitation and tie it into TSS and TP with the eventual goal of being able to estimate tons of TSS entering into Tenmile Lake and TP levels, given any precipitation event, if there is a predictable correlation between them. Using the USGS StreamStat data, we hope to be able to combine flow data, slopes, and other parameters into a comprehensive view of this basin.
Correlation statistics indicate that TSS, TP, and precipitation generally show the strongest correlations. The weakest of these correlations is from Bowron Cr which is representative of the city run-off, and would be expected to respond differently. It shows a faster TSS peak than the other streams, but generally less total volume. It would be ideal to find a predictive formula for determining TSS and/or TP levels from precipitation. This will require much more work with the data. The best chance is to look at each stream individually and perhaps separate the data into lower flow levels and higher flow levels.
We also compiled storm chasing data from 2005-2014 and looked for tends and comparisons to Swat model predictions and target goals to see if any progress is being made to meet those goals. Preliminary findings indicate a large variation with both TSS and TP. Big Cr has TSS data 2 times higher than listed in the TMDL, but TP levels 18% lower. Bowron Cr has levels of both TSS and TP that are much lower than TMDL figures. All NO_3 figures appear to be higher than predicted in all basins. Future analysis may indicate a need to re-run the SWAT model to better predict the watershed loads, or the need for a wider range of storm data to get a more comprehensive look at what the streams are doing under various conditions. Data sets for nutrients tend to be small because we only do 3-4 samples/site/storm, and only about 2

storms/year. This should be an on-going effort with emphasis placed on Johnson Cr data, especially if the rain gauge project goes forward.

More data and charts can be found on Appendix CD.

Continuous Temperature Monitoring

The temperature-monitoring network was designed to collect water temperature data from June through mid-Oct (±). Temperature data was collected using continuous recorders (Hobo & Vemco Temps), set at 30-minute intervals, and deployed at the sites shown in Map 12 & Table 32 below. Monitoring sites were selected according to the recommendations described in Chapter 3 of the OWEB Monitoring Guidebook focusing on areas of varying land use to determine their impacts on stream temperatures. The project was stopped in 2011 due to ODEQ shifting our focus to analysis of existing data. . This data failed on QA/QC checks, with some temperature audits not matching probe temperatures. ODEQ is still evaluating the data to determine final ranking.

Map 12, Continuous Stream Temperature Monitoring Map:

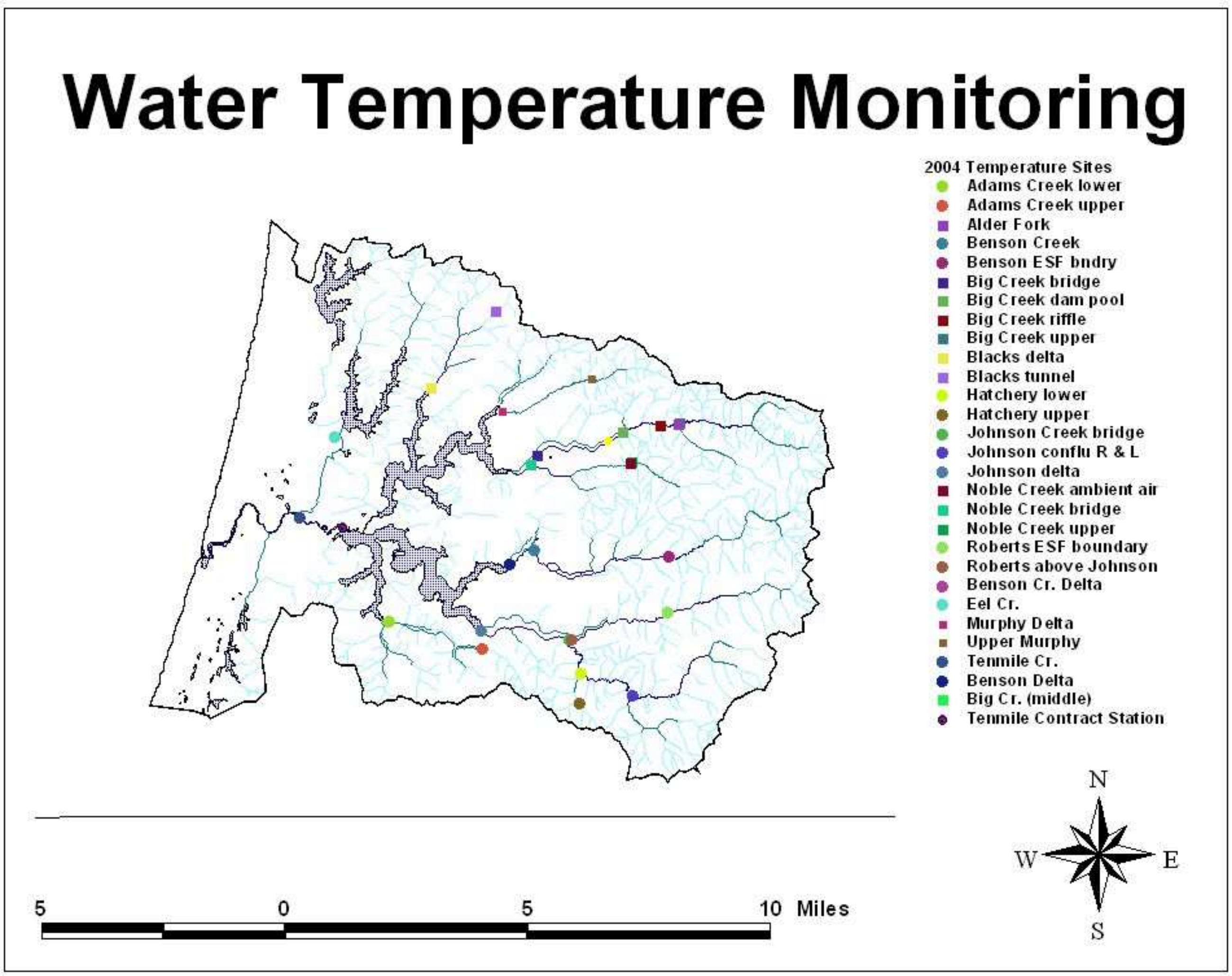


Table 32, Continuous Temp Monitoring Site List:

Site ID #	Site Name/Location	UTM
1	Eel Cr.	10T0 405000 4827888
2	Blacks Delta	10T0 408011 4829439
3	Upper Blacks Cr.	10T0 410175 4832039
4	Murphy Lower	10T0 411991 4829369
5	Murphy Upper	10T0 412666 4829671
6	Big Cr. Bridge	10T0 414356 4827244
7	Big Cr. Middle	10T0 414285 4828041
8	Big Dam Pool	10T0 414357 4828086
9	Big Cr. Riffle	10T0 416092 4828456
10	Big Upper	10T0 416277 4288447
11	Alder Fork	10T0 416214 4828310
12	Noble Bridge	10T0 411354 4826892
13	Noble Upper	10T0 414684 4827089
14	Noble Ambient air	10T0 414684 4827089
15	Benson Cr. Delta	10T0 410708 4823508
16	Benson Cr. Bridge	10T0 411529 4824126
17	Benson Cr. ESF boundary	10T0 416017 4824047
18	Johnson delta	10T0 409780 4821441
19	Johnson Bridge	10T0 412822 4821128
20	Johnson Conf R&L	10T0 414997 4819360
21	Roberts above Johnson	10T0 412902 4821186
22	Roberts ESF	10T0 416418 4824127
23	Adams Lower	10T0 406846 4821594
24	Adams Upper	10T0 410355 4820236
25	Hatchery Lower	10T0 413220 4819944
26	Hatchery Upper	10T0 413072 4819197
27	Tenmile Cr.	10T0 404673 4824692
28	Tenmile Contract Station	10T0 405186 4824664

<u>Temperature Data Interpretation</u>

TLBP's temperature monitoring goals are: Temperature 7-day average maximum assessments are designed to allow evaluation of data relative to the state of Oregon's temperature biologically based numeric criteria (BBNC). While this is an important area of focus, continuous temperature data sets can also provide valuable information which will allow characterization of site thermal regimes. The derivation of this biologically pertinent information from temperature data will help in the characterization and quantification of management related changes in the thermal regime. It is also a useful tool to determine restoration priorities and to place temperature data in a context where fish stressors can be better quantified. Temperature ranges and daily changes can impact fish in many ways including feeding time and competition for cool water refugia. Also looking at the time spent in adverse conditions is critical. If the stream warms up for only a short time in the middle of the day it will be much less stressful on fish than if it exceeds temperature thresholds for a majority of the day for multiple weeks.

Temperature data was evaluated to provide the following information:

1. Seasonal maximum date and value
2. Seasonal minimum date and value
3. Seasonal maximum delta temperature date and value
4. 7 day average maximums date and value
5. 7 day average minimums value and delta temperature
6. Number of days when temperature exceeded 55, 64, and 70 degrees
7. Number of hours when temperature exceeded 55, 64, and 70 degrees

ODEQ sets temperature BBNC for salmon/trout rearing and migration streams at a 7-day average maximum (7-DAM) of 18°C or 64.4°F. We collected data from 2008 to 2010. Year 2009 is shown below and the other 2 years' data can be seen on Appendix CD: *<u>Continuous Temp Monitoring>> 2008 summary Sorted</u>* *and* *<u>2010 summary Sorted</u>*. 2009 data shows that most sites exceeded the 7-DM temperature by anywhere from 0.2 – 7.1°F. The exceptions were all in the upper stream reaches: Benson Elliott State Forest (ESF), Alder Fork (also in ESF), and Upper Blacks. The other three sites that only exceeding the limit by a few tenths are: Adams Cr – both forks, and Upper Murphy which is also in the ESF. These sites also correspond with the lowest values on the Days Exceeding Temp Thresholds (DETT) of 64°F.

All three of the bridge sites showed higher 7-DM temperatures as did the Big Cr Dam Pool and Roberts ESF. Johnson Cr Bridge showed the highest 7-DM temperature at 71.5°F and the most DETT at 92 days. This channel is in the middle of the valley, so it receives little shade from the southern mountains and has only a few young TLBP seedlings in its riparian zones.

7-Day Delta Temperatures (DT) can indicate specific areas that would benefit from riparian projects. High DT values indicate that the sun is warming the water throughout the day and then cooling off again at night. When riparian zones are planted in these areas, they can create a larger impact than in areas with smaller DT's. Adams Cr sites showed the largest DT's with the Upper Right Fork having a 21.3°F spread.

The Hour Exceeding Temperature Thresholds (chart 52 below) shows that most sites were below the 64°F threshold for a large amount of the time. The probes were in-field for approximately 3600 hours (~5 months). For 2009, Johnson Cr exceeded the threshold the most at 1474 hours or about 41% plus another 2% over the 70°F threshold. The next closest was Big Cr Dam Pool at 13.6% over the 64°F threshold, and Big Cr Bridge at 8%. No other sites had significant hours over the 70°F threshold. Overall, this represents a moderately good state for fish rearing within the Tenmile watershed.

With more funding, future projects could Identify streams with high 7-DM temperatures and then do more extensive continuous temperature monitoring along the length of the stream to locate the best places for new riparian projects.

Chart 52, 2009 Data and Seasonal Maximum Temperature Chart:

Chart Summary 2009

Site Name		Start Date	Stop date	Seasonal Maximum		Seasonal Minimum		Seasonal Max ΔT		7-Day averages			
	Sub-Basin			Date	Value	Date	Value	Date	Value	Date	Maximum	Minimum	ΔT
Adams Upper Right Fork	4	05/29/09	10/25/09	10/09/09	71.5	10/11/09	39.8	10/09/09	25.3	10/08/09	64.7	43.5	21.3
Adams Lower Right Fork	4	05/29/09	10/25/09	09/11/09	66.6	10/06/09	45.4	09/21/09	11.8	08/16/09	64.6	55.6	9.0
Roberts ESF	6	05/20/09	10/17/09	07/28/09	70.0	10/11/09	47.4	07/20/09	10.8	07/28/09	68.4	59.4	9.0
Johnson Cr. Bridge	6	05/23/09	10/14/09	07/28/09	73.8	10/12/09	51.7	07/01/09	7.3	07/29/09	71.5	67.8	3.8
Benson ESF	7	05/20/09	11/05/09	07/28/09	63.0	10/11/09	44.9	05/20/09	4.5	07/30/09	62.4	59.7	2.6
Benson Bridge	7	05/20/09	12/29/09	07/28/09	68.7	12/09/09	20.4	12/09/09	12.7	07/29/09	67.4	62.8	4.6
Benson Delta	7	05/30/09	11/01/09	07/28/09	69.4	10/12/09	47.4	07/01/09	13.9	07/29/09	65.1	58.0	7.2
Alder Fork	10	05/24/09	10/21/09	07/28/09	64.5	10/11/09	46.9	05/28/09	7.5	07/29/09	62.8	58.8	4.0
Big Cr Upper	10	05/23/09	10/22/09	07/28/09	66.6	10/11/09	46.9	06/08/09	8.8	07/29/09	65.4	61.0	4.4
Big Cr. Dam Pool	10	05/24/09	10/21/09	07/29/09	69.3	10/12/09	45.7	05/28/09	10.7	07/30/09	68.2	66.6	1.6
Big Cr. Bridge	10	05/23/09	10/22/09	07/28/09	70.0	10/12/09	45.1	07/01/09	7.6	07/29/09	67.9	62.7	5.1
Blacks Upper	15	05/20/09	10/05/09	07/28/09	63.8	10/05/09	44.5	08/26/09	9.4	07/30/09	62.5	57.7	4.8
Blacks Delta	15	05/21/09	10/17/09	07/28/09	68.1	05/21/09	47.7	05/28/09	8.3	07/27/09	66.1	60.5	5.6
Murphy Upper	18	05/30/09	10/26/09	07/28/09	67.7	10/05/09	45.4	07/28/09	9.3	07/29/09	64.7	58.6	6.1

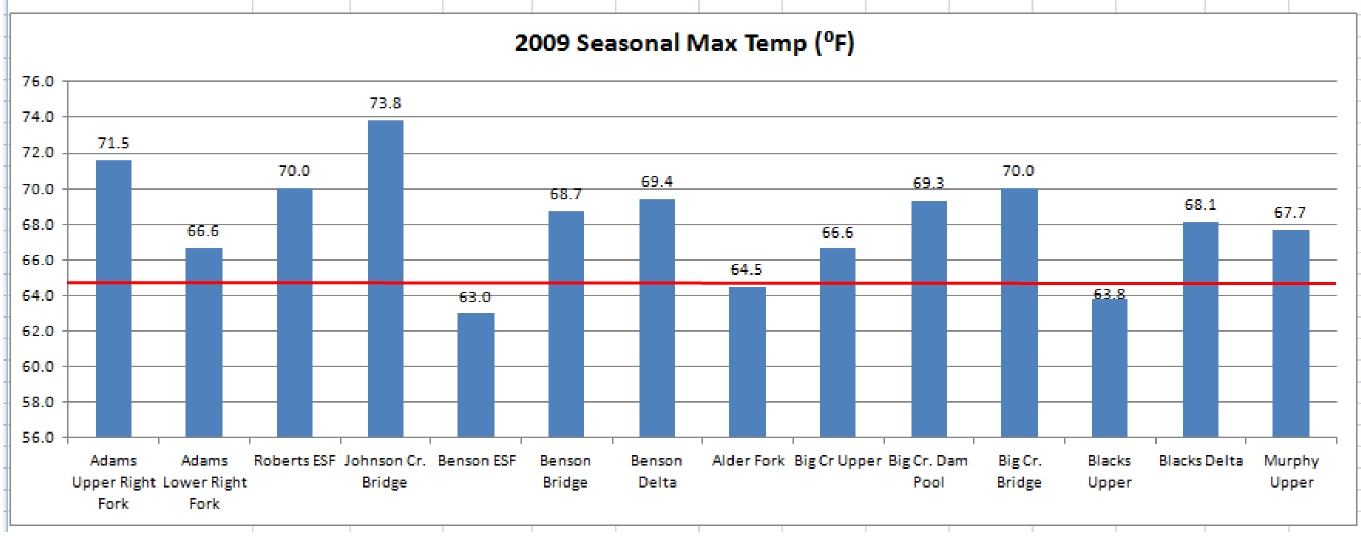


Chart 53, 7-Day Average Maximum Temperatures, All Sites, 2009:

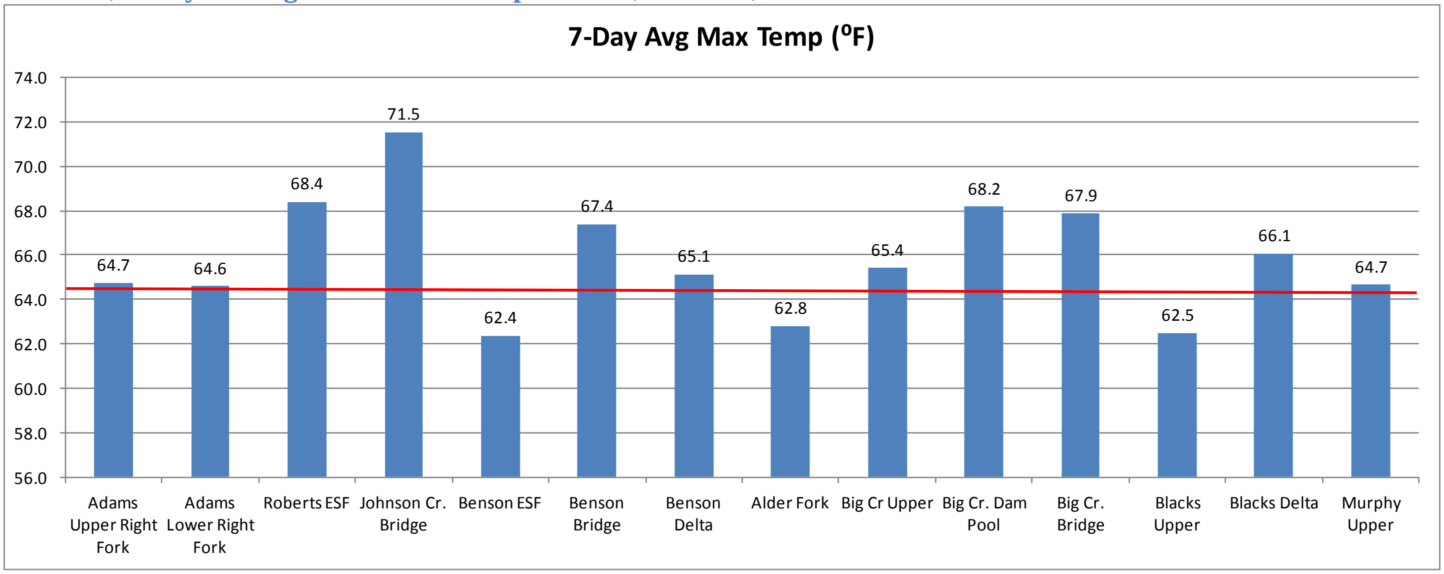


Chart 54, 7-Day Delta Temperatures, All Sites, 2009

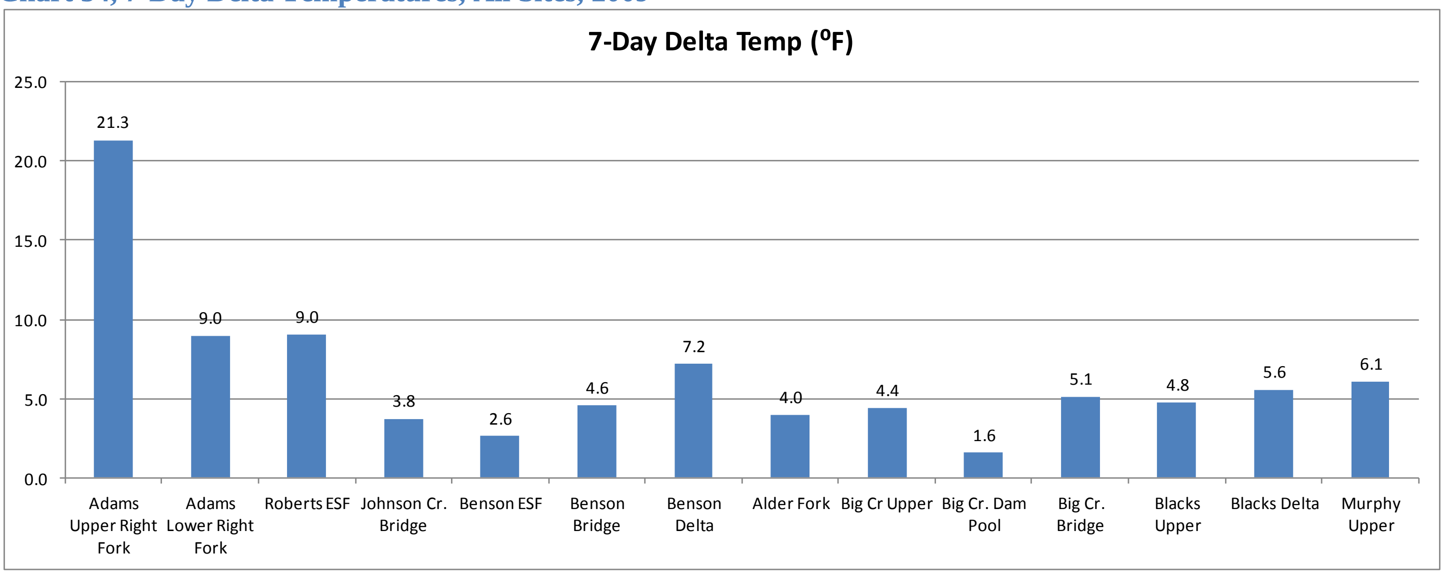


Table 33, 2009 High Temperature Data:

Site Name	Days > 55 F	Days > 64 F	Days > 70 F	Hours > 55 F	Hours > 64 F	Hours > 70 F	Warmest day of 7-day max Date	Maximum	Minimum	Agency
Adams Upper Right Fork	51	11	1	415	19	1	10/09/09	71.5	46.3	tlbp
Adams Lower Right Fork	105	11	0	1747	53	0	08/13/09	65.9	58.2	tlbp
Roberts ESF	135	31	0	2615	89	0	07/28/09	70.0	59.3	tlbp
Johnson Cr. Bridge	141	92	12	3239	1474	81	07/28/09	73.8	68.0	tlbp
Benson ESF	125	0	0	2550	0	0	07/28/09	63.0	58.7	tlbp
Benson Bridge	143	26	0	3151	182	0	07/28/09	68.7	62.9	tlbp
Benson Delta	130	8	0	2604	31	0	07/28/09	69.4	56.8	tlbp
Alder Fork	120	1	0	2248	5	0	07/28/09	64.5	58.9	tlbp
Big Cr Upper	131	14	0	2620	46	0	07/28/09	66.6	61.1	tlbp
Big Cr. Dam Pool	131	30	0	2928	490	0	07/29/09	69.3	67.4	tlbp
Big Cr. Bridge	135	37	0	3045	297	0	07/28/09	70.0	62.4	tlbp
Blacks Upper	114	0	0	1775	0	0	07/28/09	63.8	56.5	tlbp
Blacks Delta	130	15	0	2769	86	0	07/28/09	68.1	61.2	tlbp
Murphy Upper	115	4	0	2069	21	0	07/28/09	67.7	58.4	tlbp

Chart 55, Days Exceeding 7-day Maximum Temperature Thresholds, 2009:

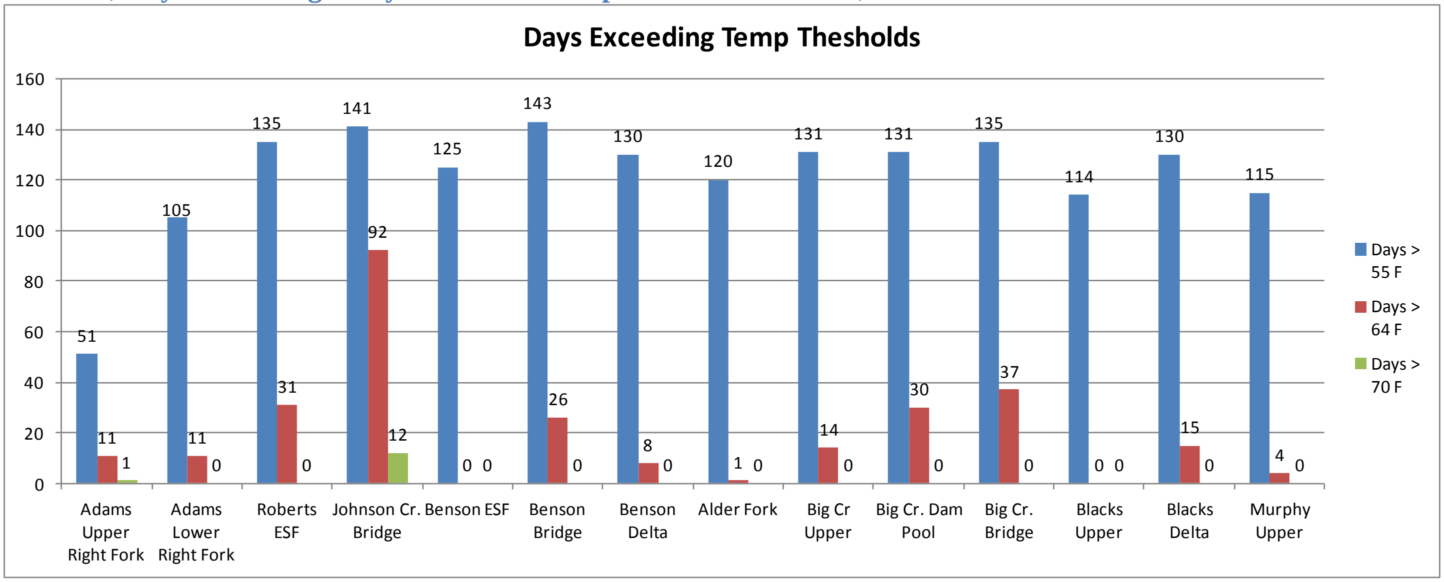
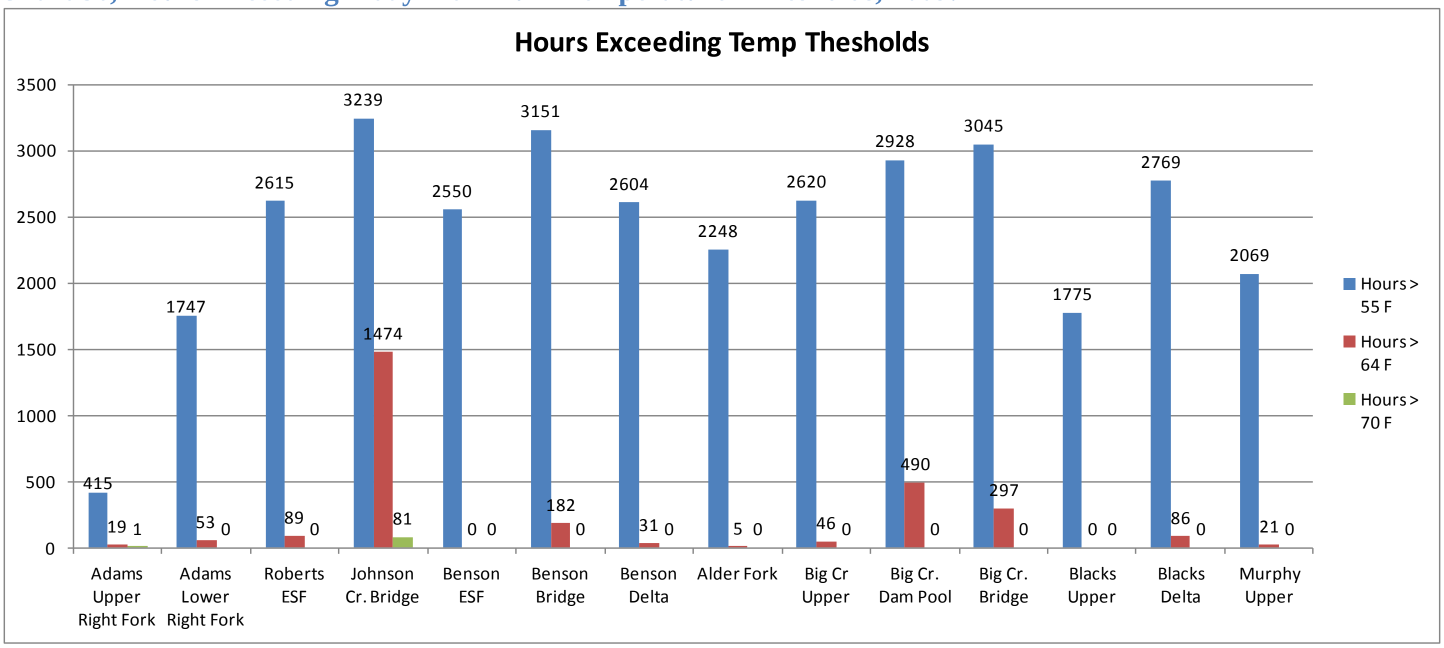


Chart 56, Hours Exceeding 7-day Maximum Temperature Thresholds, 2009:



Continuous Temperature Monitoring Summary

Throughout all 3 years, the majority of sites that we monitored showed levels exceeding the ODEQ 7-Day Avg Max temperature limit. In 2008, 12 of 20 where high; 2009, 11 of 14; and 2010, 10 of 17 exceeded the limit. The corresponding minimums on those 7-Day Avg readings show that in a few instances even the minimum temperatures exceeded the 64.4°F limit. Delta T median was about 5°F for all sites, for each year, with a range from 1.6°F to 21.3°F. Hours Exceeding Temperature Thresholds ranged from 0 at many of the ESF sites, Murphy Cr, and Adams Cr; to 1457 hours at the Johnson Cr Bridge. Areas with large DT's should be considered for riparian funding in the future, as well as creeks that show large longitudinal temperature changes between ESF sites and downstream sites that are near the lakes. The Creeks with the best records were Murphy, Adams, and Blacks. The worst creeks appear to be Johnson and Big Cr. Future projects could focus on these 2 streams with multiple probes from the ESF to the mouth. Analyzing maximum temperatures and DT data could help form a basis for funding these enhancement projects.

Some data was lost due to broken temperature probes, probes being lost or stolen, and probes getting out of the water due to animals, vandalism, or extremely low water levels. Future efforts should put a large emphasis on careful placement of probes to minimize these issues.

Lessons Learned

- Changing our DO method from BOD bottles and titrating to the use of a multi-parameter probe has been a great time saver, and we get more consistent results. I would recommend this change to any watershed that does DO samples on a regular basis.
- Utilize ODEQ Volunteer Monitoring Coordinator to assist in data QA/QC tasks; equipment operation, maintenance, and calibration; and statistical data analysis.
- Assess/re-assess monitoring site locations in terms of what your final data goals are. Determine if they can be tied into other current projects to give a more comprehensive view of the overall watershed. Also take into account the suitability and accessibility of a site during different seasons. (Are water levels too low in the summer to get a good sample? Will high-water conditions in the winter limit accessibility to the site?) Finally, access sites in terms of vandalism and potential animal destruction problems.
- Send duplicate split samples to multiple labs to assess the quality of data from your standard lab. Split samples sent to multiple labs can produce a surprising variance in results for nutrients, algae ID/enumeration, and toxin analysis.
- Compare costs at different labs to determine the best value. There is a very large difference in costs between various labs. We also consolidated all of our testing into one lab which also saves money on shipping costs.
- Question outlier data at time of sampling, if possible. We found that one of the readings from our multi-parameter probe would show as very high if the cable connection was not secured tightly. Also things like fogged glass on turbidity sample vials (due to very cold water) could greatly change the readings at certain times of the year.
- When dealing with unique and difficult monitoring projects, such as Delta Building, determine usefulness of data compared to time and cost of collecting the data. Can the final data be presented in an understandable way? Are the practical considerations of collecting the data appropriate? Is there a better method to collect the data, like Lidar? Accept when a project is not working as planned and either make appropriate changes to it or cancel the program all together.
- Utilize monitoring efforts to identify maintenance needs on restoration projects.
- Riparian plantings do not need to be monitored every year. After the first year or two, changing to once every 5 years should be sufficient.
- Ensure that spare equipment and batteries are readily available when using time sensitive equipment such as auto-samplers.
- Be aware of driving in fields after rain events. Conditions can change quickly from one day to the next.
- Highly recommend using pre-weighed TSS filters. They are more accurate and save a huge amount of time.
- If sharing lab space at a partner agency, call ahead to arrange for lab time that does conflict not with their schedule.
- When using auto-samplers, schedule the start times at appropriate intervals to allow you to be at each site when they take the auto-sample, so you can collect duplicate samples at the same time.

Future Monitoring Needs

- Flow and rain gauge in Johnson Cr Basin and Big Cr Basin
- Assess nutrient contribution of lake bottom sediments to the TP levels. Determine causes of high TP levels in the summer season.
- Longitudinal sampling of TSS in Tenmile Lakes from the mouths of Big Cr and Johnson Cr to Tenmile Creek to determine settlement rate throughout the lakes and how much TSS is leaving the system through Tenmile Cr.
- Temperature monitoring in Roberts Cr
- Assess impacts of non-native fish on water quality and blue-green algae dominance.
- TSS Storm Chasing in Roberts Cr above confluence with Johnson Cr below site J2 to determine impact of the Roberts Cr tributary to the J3 storm chasing site.
- Longitudinal continuous temperature monitoring on Upper Big Cr above the Big Cr Dam habitat Pool to determine why pool has high temperatures and low DO.
- Assess how invasive macrophytes are impacting water quality parameters such as DO in Tenmile Cr.
- Utilize 3-D graphing program to plot delta building data.
- Data analysis and time with ODEQ personnel for protocol and data evaluation.
- Continue monitoring of nutrients, parameters, and TSS to determine if TMDL goals are being achieved.
- Expand monitoring efforts to Eel Lake, which is the water source for Lakeside, and other lakes within the Tenmile Basin.
- Work with ODFW to determine impacts of cormorant predation on lake fish populations, especially Coho smolts.
- Macroinvertebrate Monitoring
- Shade monitoring

Effectiveness Monitoring Project
Final Report Metrics Form

OWEB receives a portion of its funds from the federal government and is required to report how its grantees have used those funds. The information you provide in the following form will be used for federal and state reporting purposes. Please complete all portions of the form below as they apply to your project.

If you have any questions, please contact Cecilia Noyes, OWEB Federal Reporting Coordinator, at 503-986-0204 or cecilia.noyes@state.or.us

1. **Reports Prepared:** Identify reports prepared by the project (include the project completion report submitted to OWEB, progress reports, and other non-OWEB reports).

Title	Author(s)	Date
Tenmile Lakes 2012 & 2013 Summary Reports	Dr. Jacob Kann	Feb 12 & June 13
State of Lakes Presentation	TLBP	Aug 2012 Aug 2013
319 Mid Year Report 074-12	TLBP	Jan 2013
2012 Lake Summary Reports	M & D Environmental	2013
Tenmile Lakes QAPP Update 2013	TLBP	Oct 2013
Final Report 074-12	TLBP	June 2014

8 # of reports (number of reports shown in table above).

2. **Comprehensive Monitoring Strategy or Program and Cooperating Organizations:**
2.a) Is this project a part of a comprehensive monitoring strategy/program? See explanation below*

☒ **Yes** ☐ **No**

If yes, provide the name of the comprehensive monitoring strategy/program. If this project is not part of a comprehensive monitoring strategy/program, enter NONE below.

Tenmile Lakes Quality Assurance Project Plan (TLBP Oct 2013) Name of document (Author, date, title, source, source address in Endnote citation format)

2.b) Identify Organizations cooperating with this project by concurrently conducting field work on other components of a Comprehensive Monitoring Strategy or Program.

Organization Name	Organization Name
Lakeside Water District	
Oregon Dept. Fish & Wildlife	
Oregon Dept. of Environmental Environmental	
Conferderedated Tribes	

4 # of cooperators (number of cooperators shown in table above).

**The intent of questions 2.a and 2.b are to capture information on larger-scale or comprehensive monitoring efforts conducted by multiple entities (usually under an overarching or cooperative plan). The assumption is cooperating entities are working together to collect various aspects of integrated information (usually concurrently). For example, an OWEB funded project collected the salmon abundance/distribution data component of a salmon habitat restoration plan while other entities were collecting water quality, and/or habitat attribute data for the same comprehensive plan. Question 2.a asks for the name of the plan(s) and question 2.b asks for the name of the other entities involved in the cooperative collection of the data called for in that plan. If these questions are not relevant to this project enter 'None' for question 2.a and for 2.b answer 'None' for the cooperator names and 0 for the number of cooperators.*

3. **Total amount of area monitored under this monitoring project.** If monitoring the same location or stream reach multiple times do not report the sum of area or length metric for each monitoring event. For example if the project monitors a 13 mile stream reach twice per year for 3 years you should report the metric as 13 stream miles.

   113 Miles of stream monitored

   96 Acres monitored

4. **Identify the type of monitoring conducted and the area or stream length monitored.** (See Application Instructions for descriptions.) Check all that apply.

Monitoring Type	Acres Monitored	Stream miles monitored
☒ Baseline		113
☒ Effectiveness of Restoration		113
☐ Effectiveness of Forest Management Strategies		
☒ Implementation		113
☒ Status and Trend		113

☐ Other (explain):		

5. **Identify the parameters monitored and the area or stream length monitored.** (See Instructions for Monitoring application for more detailed descriptions) Check all that apply.

Parameter Monitored	Acres Monitored	Stream miles monitored
☒ Adult fish presence/absence/abundance/distribution survey(s)		113
☐ Juvenile fish presence/absence/abundance/distribution survey(s)		
☐ Salmon/steelhead harvest monitoring		
☐ Instream habitat surveys		
☐ Macroinvertebrates		
☒ Noxious weeds	3200	
☒ Other Biological Monitoring (bird counts, amphibian surveys)	3200	
☐ Riparian vegetation		
☐ Spawning surveys		
☐ Upland vegetation		
☒ Water quality		113
☐ Water quantity		
☐ Other (explain):		

6. If you checked Water Quality above, exactly which parameters did you monitor? Check all that apply.

☐ Bacteria	☒ pH	☒ Temperature
☒ Dissolved Oxygen	☐ Pesticides	☐ Toxics
☒ Nitrates	☒ Phosphorus	☒ Turbidity
☐ Heavy Metals (name): ______	☒ Nutrients (name): TN, TP, PO4, NO2, NO3, SiO4, NH4	
☒ Other (explain): Chl-a		

7. If you checked Riparian or Upland Vegetation above, exactly which parameters did you monitor? Check all that apply.

☐ Canopy cover	☒ Invasive species presence/absence	☐ Plant survival
☒ Percent cover	☐ Other (explain): ______	

Final Total Project Funding/Match Form | **Oregon Watershed Enhancement Board (OWEB)**

This form documents all project funding, including match funds, and is required at the completion of an OWEB grant. The information you provide in this form will be used for required federal and state reporting purposes.

OWEB Project Name: Tenmile Lakes Monitoring 2012 -2014 **OWEB Grant #212-2033**

Funding Source	Funding Identifier*	Actual Cash Contribution	Donated / In-Kind Labor	Donated / In-Kind Materials	Volunteers Worked	Volunteers Hourly Rate	Volunteer Value**	General Description***
OWEB	enter OWEB # above	$ 117,608.10	n/a	n/a	n/a	n/a	n/a	OWEB Cash
Other Organizations								
		$ 250.00	$	$ 9,750.00			$ -	Boat Rental /Copying/ ect.
ODEQ T/A		$	$ 500.00	$			$ -	
ODEQ 319 program		$ 20,000.00	$	$			$ -	#076-12
Coos Bay BLM		$	$	$ 8,000.00			$ -	Storm sampling equip loan
South Slough Lab		$	$	$ 8,000.00			$ -	Algae sampling lab space
M&D Environmental		$	$ 1,000.00	$			$ -	Lab sampling
USFS Algae Equipment		$	$	$ 8,000.00			$ -	Aglae sampling
WSC Volunteers		$	$	$	300	15	$ 4,500.00	Committee/Landowners/TLA
		$	$	$			$ -	
		$	$	$			$ -	
		$	$	$			$ -	
		$	$	$			$ -	
Total Dollar Amount		$ 137,858.10	$ 1,500.00	$33,750.00	300		$ 4,500.00	

Total Project Costs $ 177,608.10 Total dollar value of OWEB's contribution, other organizations' cash contributions, and donated/in-kind services (which is the total of all labor, materials and volunteer's value).

Total Non-OWEB Funds $ 60,000.00 Total dollar value of other organizations' cash contributions, and donated/in-kind services (which is the total of all labor, materials, and volunteer's value).

OWEB Project Match $ 60,000.00 Total dollar value claimed as OWEB match. You are required to show a minimum of 25% match to the OWEB cash

Public Database Submittals 2014

Name	Date modified
Storm Chasing Combined 2005-2014 Final.xlsx	5/21/2014 9:56 AM
Storm Chasing TSS & Rain Data Event3 Nov 2012 Final.xlsx	5/21/2014 10:09 AM
TLBP Lake Sites Data 2013 MAIN Final.xlsx	5/21/2014 8:12 AM
TLBP Storm Chasing TSS Data Event 4 Feb 2014 Final.xlsx	5/21/2014 8:23 AM
TLBP Trib Data 2013 Final.xlsx	5/21/2014 8:00 AM