2-22-2012

Lake Padden Monitoring Project June -- December 2011 Final Rep

Andrew Majeske
Western Washington University

Robin A. Matthews
Western Washington University, robin.matthews@wwu.edu

Betsy Gross
Western Washington University

Lake Padden Water Quality Monitoring Project
June – December 2011 Final Report

Mr. Andrew Majeske
Dr. Robin A. Matthews
Mrs. Betsy Gross
Mr. David Roberts

Institute for Watershed Studies
Huxley College of the Environment
Western Washington University

February 22, 2012

Contents

List of Figures

List of Tables

1 Introduction

1.1 Background

Lake Padden is located east of Interstate 5 on the south side of Bellingham, Washington. The outflow of the lake drains into Padden Creek and is controlled by a small concrete dam. Development within the watershed includes a golf course and dog park on the eastern edge of the lake, a swimming beach and park on the north, a boat launch, three public docks, and residential development in the northern watershed. There are no nearshore homes. Recreation on the lake includes walking, hiking, swimming, and fishing for annually stocked rainbow trout (*Oncorhynchus mykiss*) and fry plants of kokanee (*O. nerka*) and cutthrout trout (*O. clarkii)* (WDFW Fish Program, 2008). Residents have expressed concern about possible deterioration of the lake's water quality and intense algal blooms in the fall.

The bedrock of the Lake Padden basin is made of massive sandstone with interbedded conglomerate and siltstone (Huntting, et al., 1961). The soils are a mixture of loam and silt loam on rough mountainous land with moderate to steep slopes (Poulson and Flannery, 1953).

Water input into Lake Padden is a combination of direct precipitation, surface water runoff via tributaries and unconfined flow, and groundwater seepage. Three unnamed intermittent tributaries drain the eastern watershed; these tributaries are normally dry during summer months. Surface water from the northwestern portion of the watershed have largely been diverted through a culvert to Padden Creek. During high runoff events, overflows from this system enter the lake through a submerged pipe at the northwest corner of the lake.

1.2 Project Goals

Our project was initiated by the citizens group People for Lake Padden (P4LP) to provide an intensive water quality study of Lake Padden. Water samples were collected between June and December 2011 by a student intern (A. Majeske). The samples were analyzed at the Institute for Watershed Studies (IWS), Western Washington University.

Lake Padden was monitored by Washington State Department of Ecology (Ecology), as part of their Water Quality Assessments of Selected Lakes within Washington State, in 1974 and 1997. The Institute for Watershed Studies has monitored Lake Padden approximately twice annually since 2006. Historical data on Lake Padden from Ecology and IWS were gathered and compared with the 2011 data to help determine whether the water quality of Lake Padden has changed over a short period of time. It is important to note, however, that the data from the different sources may not be comparable because the samples were collected and analyzed using different methods.

The goals of our study are to identify any apparent problems with the current conditions of Lake Padden, compare our results with historical information, begin to establish baseline data, determine to what degree stratification occurs, and educate and involve volunteers and policymakers in the community.

2 Sampling Procedures

Two Lake Padden sampling sites were selected at opposite ends of the lake at locations that were accessible from the shoreline (Figure 1). Conditions at both sites were similar, with trees along the bank, a near-by gravel trail, nearshore aquatic vegetation, and docks at both sites for fishing and viewing access. The eastern site was located about 50 m from a tributary that drains the northeastern area of the watershed, the western site was about 40 m from the outflow into Padden Creek. Water samples were collected from the docks at 0.3 m below the lake surface and approximately 30 m from the shoreline.

Lake Padden was sampled every other week from June through December 2011, ending in mid-December. Water temperature was measured at each site using a calibrated thermometer. Dissolved oxygen samples were collected at each site and processed in the laboratory using the Winkler method (Table 1). Water samples were collected in an acid washed 1 liter bottle and transported on ice to the laboratory to be processed for pH, conductivity, nitrogen (total, nitrate/nitrite, ammonium), and phosphorus (total and soluble). Chlorophyll samples were collected in a 1 liter opaque bottle and transported in the same manner.

Depth profiles were collected in August and November from a deep area of the lake using a small boat (Figure 1). The depth profiles were constructed using a YSI-meter, calibrated in the field prior to use, to measure temperature and dissolved oxygen. Water quality samples were collected from 0.3 m and 9 m depths and analyzed for the same parameters listed above, excluding chlorophyll.

All laboratory analysis were performed at IWS following the analytical methods listed in Table 1. To ensure quality control, ten percent of water samples were collected in duplicate to estimate variation between samples collected at the same location, depth, and time (field duplicates); ten percent of all laboratory samples were measured in duplicate to estimate analytical variation for samples from the same bottle (lab duplicates). Laboratory blanks, matrix spikes, and laboratory control/check samples were included with all analytical runs to estimate background noise and recovery of known concentrations of each analyte. The laboratory at IWS is accredited by the Quality Assurance Section of the Department of Ecology. For additional information, contact Dr. Robin Matthews, IWS Director or Ms. Joan Vandersypen, IWS Laboratory Supervisor.

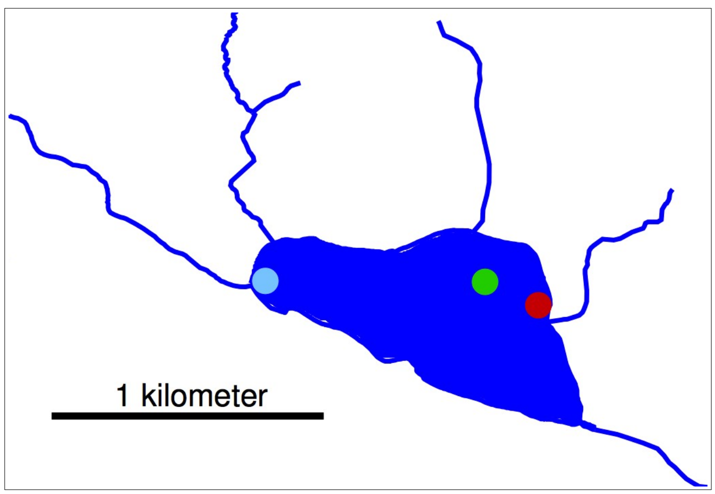

Figure 1. Lake Padden sampling sites (● = East sample location; ● = West sample location; ● = depth profile sample location).

Analyte	Abbr.	Method Reference (APHA 2005)	Detection Limit/ Sensitivity
Chlorophyll - lab	Chl	SM10200 H, acetone extraction	± 0.1 µg/L
Conductivity - lab	Cond	SM2510, lab meter	± 0.1 units
Dissolved Oxygen - lab	DO	SM4500-O C., Winkler, azide	± 0.1 mg/L
Nitrogen - ammonium	NH_3	SM4500-NH3 H., flow inject, phenate	10 µg NH_3-N/L
Nitrogen – nitrate/nitrite	NO_3	SM4500-NO3 I., flow inject, Cd reduction	10 µg NO_3-N/L
Nitrogen - total	TN	SM4500-NO3 I., flow inject, persulfate digest	10 µg N/L
pH - lab	pH	SM4500-H, electrometric lab meter	± 0.1 units
Phosphorus - soluble	SRP	SM4500-P G., flow inject	3 µg PO_4-P/L
Phosphorus - total	TP	SM4500-P G., persulfate digest	5 µg P/L
Temperature - field	Temp	SM2550 thermometer	± 0.1 ºC

Table 1. Analytical methods used for the Lake Padden monitoring project (APHA, 2005).

3 Results and Discussion

The 2011 water quality data are included in Appendix A. Quality control data are included in Appendix B and indicate good reproducibility of field and analytical measurements. Historical data from Ecology and IWS are included in Table 2. The 2011 water quality data and depth profiles are plotted with descriptive captions in Figures 2 – 13. Each caption includes a summary and interpretation of that water quality test.

When appropriate, reference lines are included on the figures to illustrate how Lake Padden water quality compares with surface water quality standards for Washington State.

With such a small dataset, longterm trends cannot be identified. Our data provide a good preliminary baseline for summer and fall water quality in Lake Padden, but additional year-long data should be collected if trend analysis is an important goal.

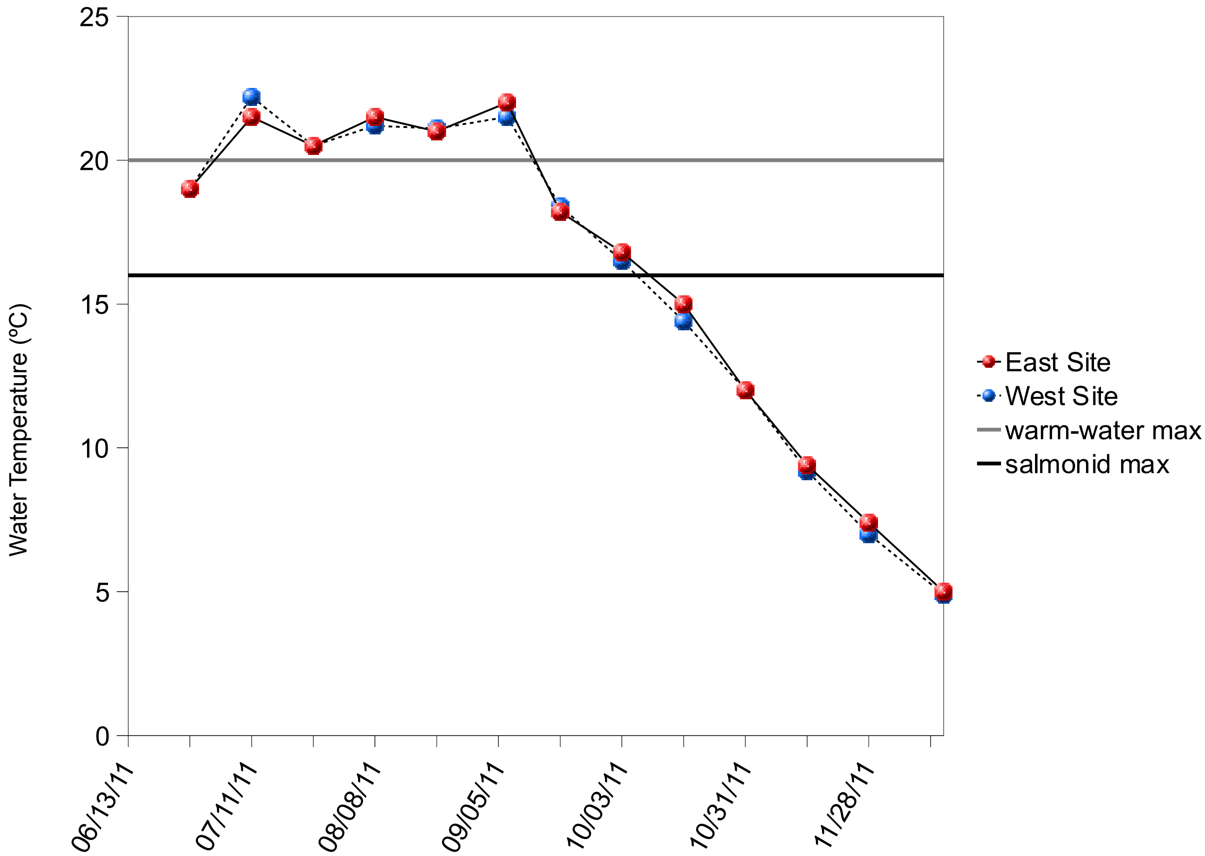

Figure 2. Lake Padden water temperature results, June – December 2011. Warmer temperatures occurred during summer and cooler temperatures during fall. Summer water temperatures exceeded the maximum level required for providing summer habitat for salmonid and indigenous warm-water fishes (horizontal grey and black lines; WAC-173-201A-200). Water temperatures might be cooler further away from the shoreline but the depth profile taken on August 29, 2011 also revealed water temperatures greater than 20 ºC from the surface down to ~5.5 m (Figure 13).

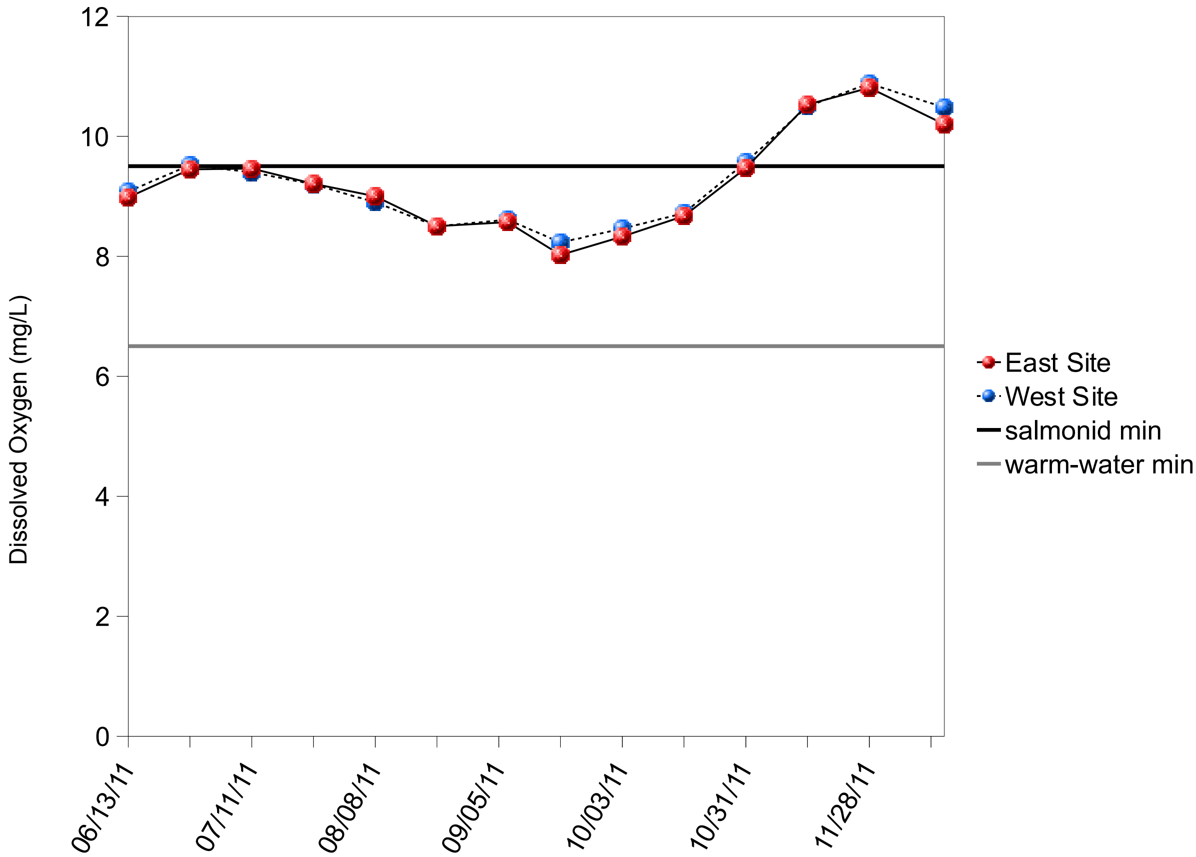

Figure 3. Lake Padden dissolved oxygen results, June – December 2011. Dissolved oxygen concentrations were generally above 8 mg/L, with higher levels during spring and fall (cold water holds more oxygen than warm water) compared to summer, when warmer temperatures and organic matter decomposition decrease oxygen levels in the water column. Summer dissolved oxygen concentrations were consistently too low to provide good summer habitat for salmonid fishes, but were suitable for indigenous warm-water fishes (horizontal grey and black lines; WAC-173-201A-200).

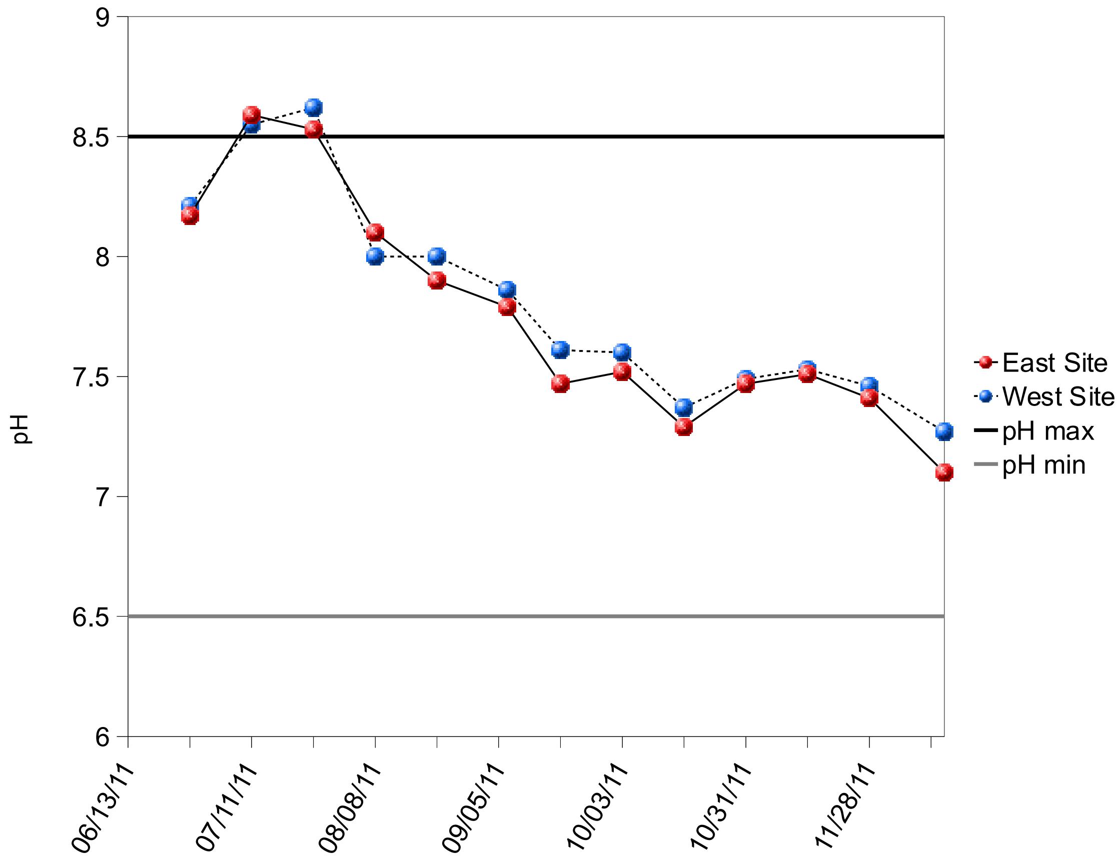

Figure 4. Lake Padden pH results, June – December 2011. As algae perform photosynthesis, carbon dioxide (CO_2) is removed from the water. This can temporarily raise pH by reducing the concentration of dissolved carbonic acid, which is formed when CO_2 reacts with water: $H_2O + CO_2 \leftrightarrow H_2CO_3$ (carbonic acid). The influence of photosynthesis is illustrated by the Lake Padden pH values, which were higher in summer compared to fall. The pH values for Lake Padden fell within the range needed to sustain salmonid and indigenous warm-water fishes except in July (horizontal grey and black lines; WAC-173-201A-200).

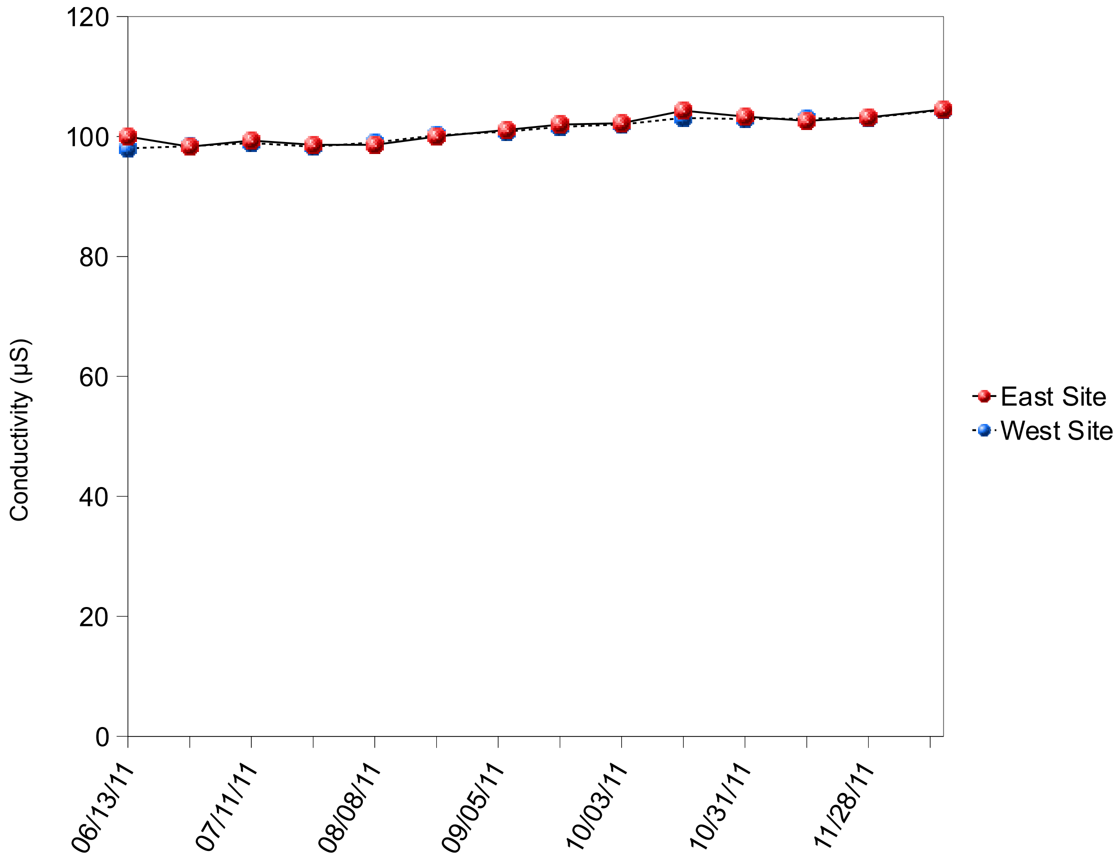

Figure 5. Lake Padden specific conductance (conductivity) results, June – December 2011. Conductivity is influenced by the type and amount of dissolved ions in the water. The soil type and land use in the watershed influence the amount of dissolved ions entering the lake via surface runoff and groundwater. Biological activity and chemical interactions determine whether dissolved ions remain in the water column. Conductivity values were relatively consistent throughout the summer and fall with a slight increase into fall which may have been the result of evaporation and consequent concentration of dissolved ions. Whether this upward trend in conductivity is seasonal or permanent requires additional year-long sampling.

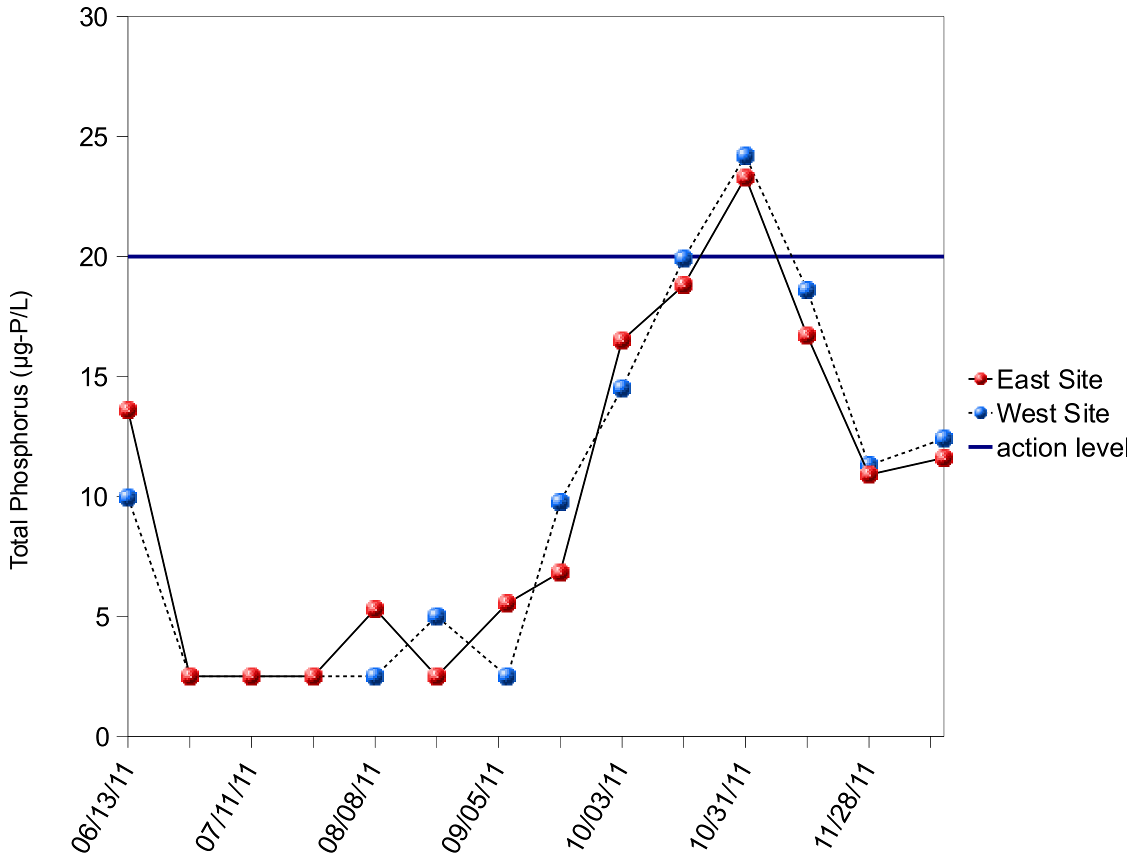

Figure 6. Lake Padden total phosphorus results, June – December 2011. Total phosphorus includes phosphorus bound in organic matter (algae and other microbiota) and dissolved or soluble phosphate. Phosphorus is generally the limiting nutrient in aquatic systems and may limit the amount of algae in a lake. Total phosphorus values exceeded the "action level" described in WAC-173-201A on October 3, 2011. Lakes with total phosphorus values above this action level may be impacted by high phosphorus and should be considered by Ecology for a more extensive water quality assessment. Phosphorus levels above this action level do not necessarily pose a threat to human health or aquatic life, but often are associated with high chlorophyll concentrations and algae blooms. Total phosphorus levels were highest during fall, likely the result of fall-turnover (See Figure 13 for a description of this process). Values below the detection limit (5 µg-P/L) are stated as half the detection limit.

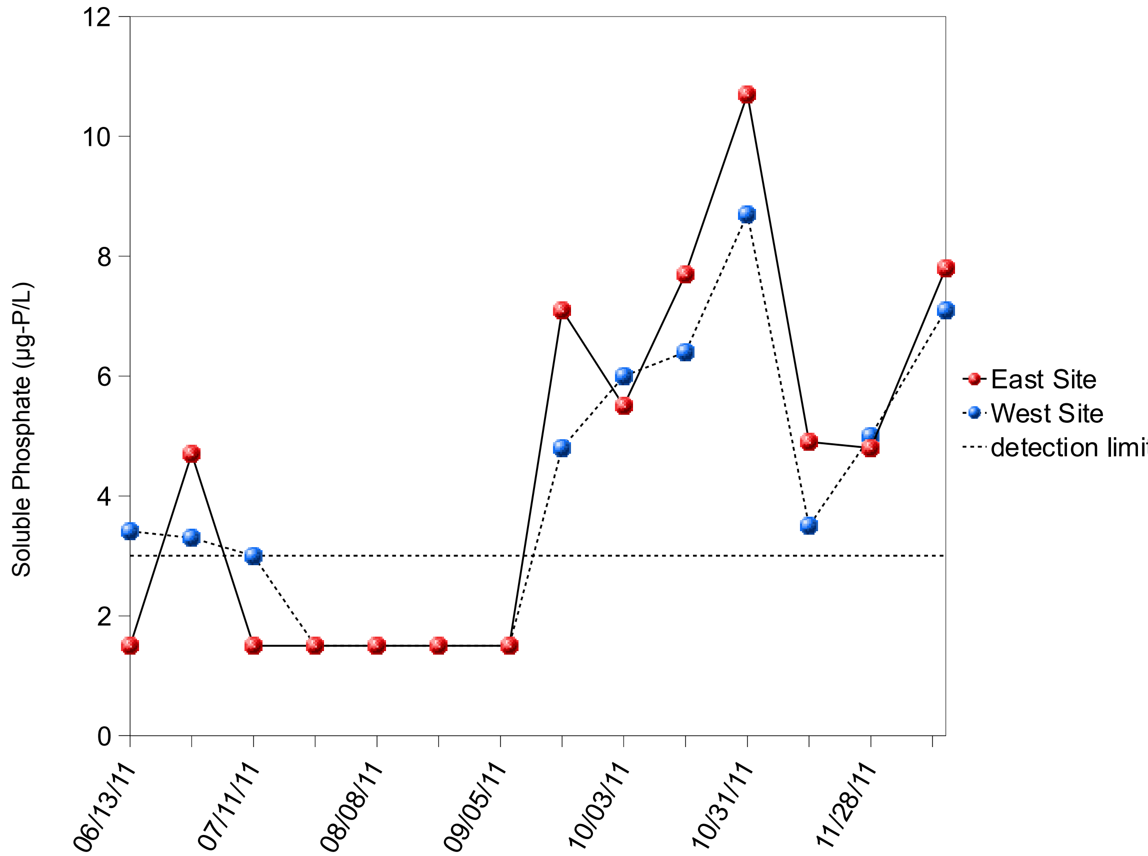

Figure 7. Lake Padden soluble phosphate results, June – December 2011. Soluble phosphate is the soluble inorganic portion of total phosphorus, and is readily available to algae and other microbiota. Soluble phosphate concentrations are usually low in the water column due to its rapid uptake by biota. Soluble phosphate concentrations in Lake Padden were lower in summer (often below the IWS analytical detection limit) compared to fall. The spikes in the fall are likely a result of fall-turnover (See Figure 13 for a description of this process). Values below the detection limit (3 µg-P/L) are stated as half the detection limit.

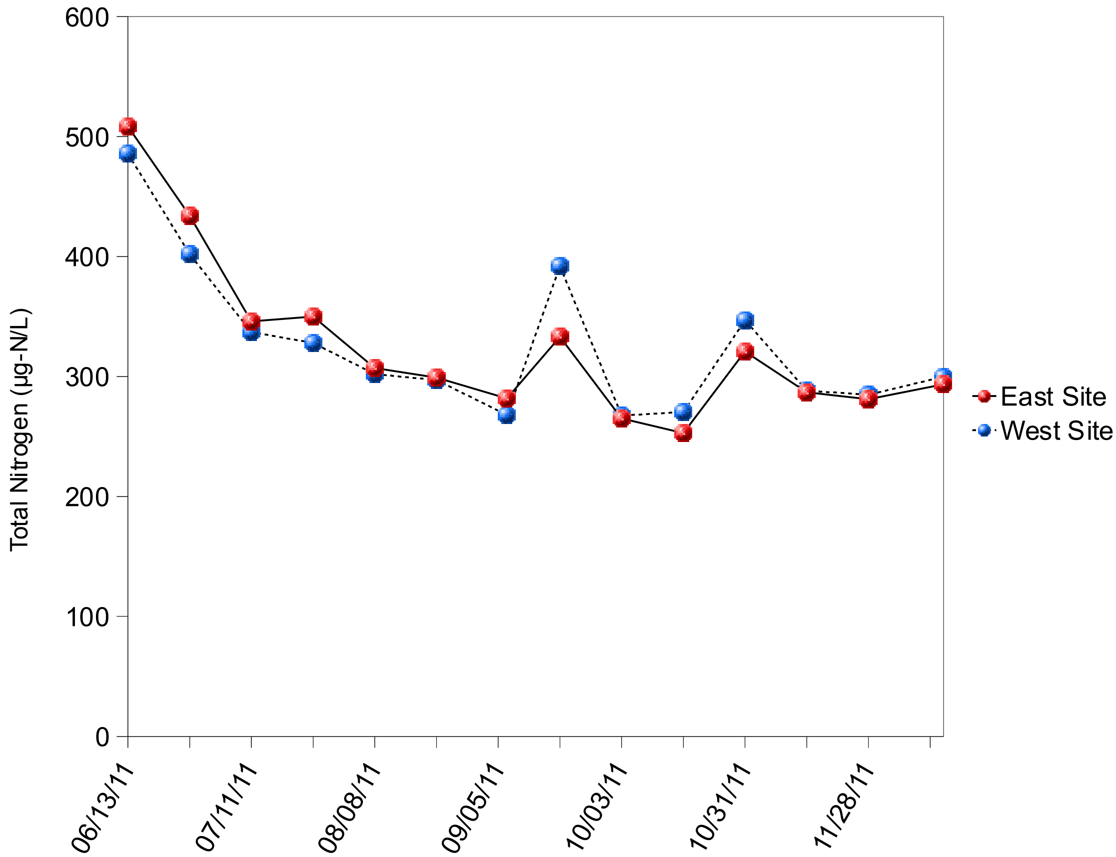

Figure 8. Lake Padden total nitrogen results, June – December 2011. Total nitrogen includes nitrogen bound in organic matter (algae and other microbiota) and dissolved inorganic nitrogen (nitrate, nitrite, and ammonium). Total nitrogen concentrations are often similar to nitrate/nitrite concentrations, especially in winter and spring because little algae is in the lake. During summer months however, the type of nitrogen that makes up total nitrogen is harder to predict. Algae that proliferate in summer take up nitrate and other forms of inorganic nitrogen during photosynthesis while decaying algae and organic matter add to organic nitrogen and ammonium concentrations. Lake Padden had its highest total nitrogen concentrations in June, which coincides with the highest nitrate/nitrite concentration (Figure 9). Total nitrogen concentrations were lower during most of the summer due to uptake of nitrate/nitrite and ammonium by algae.

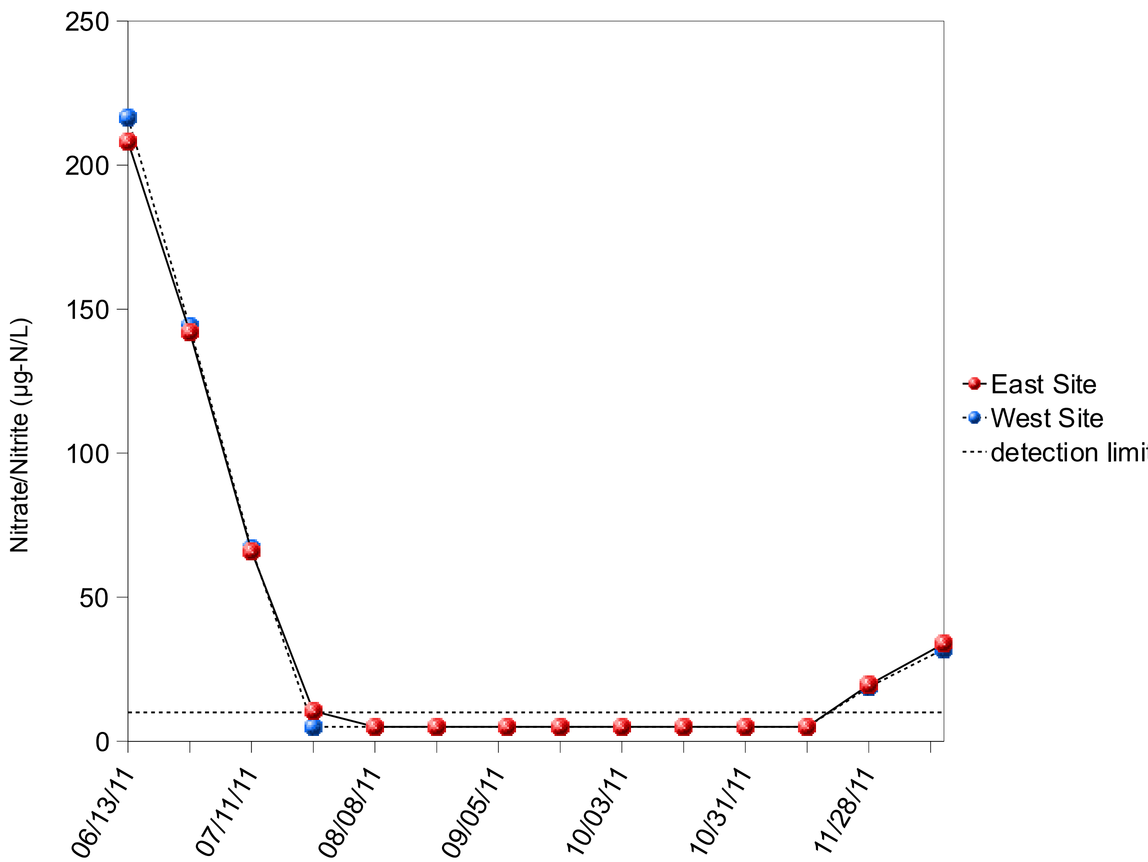

Figure 9. Lake Padden nitrate/nitrite results, June – December, 2011. Nitrate (NO_3) and Nitrite (NO_2) were measured together because nitrite concentrations are usually negligible and below analytical detection limits. Nitrate/nitrite is often the major component of dissolved inorganic nitrogen (DIN). DIN, which also includes ammonium (NH_4), is an important nutrient for most algae. When DIN concentrations are low, conditions favor cyanobacteria or bluegreen algae because cyanobacteria can use dissolved N_2 which is replenished from the atmosphere. During the summer and fall, Lake Padden nitrate/nitrite levels were very low, indicating cyanobacteria blooms were likely to occur. Cyanobacteria blooms can be a nuisance, sometimes producing foul odors and in some cases toxins. Nitrate/nitrite values below the detection limit (10 µg-N/L) are stated as half the detection limit.

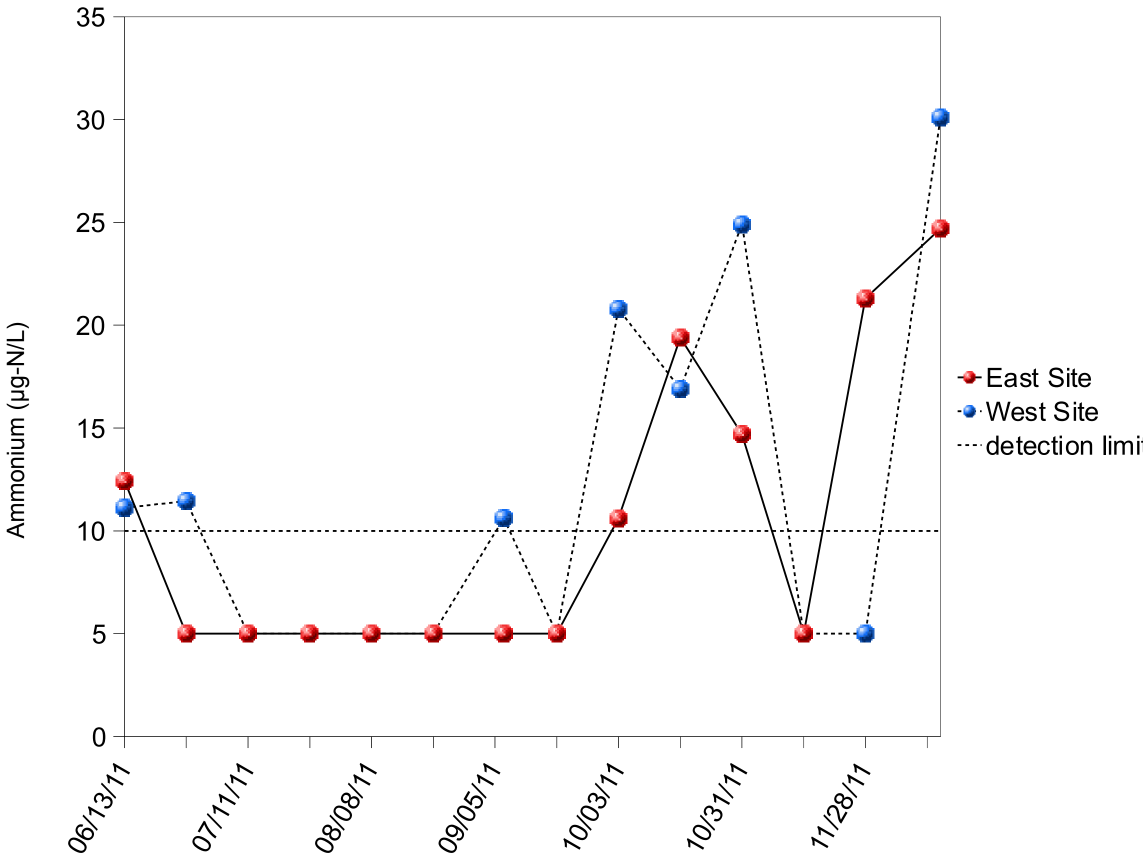

Figure 10. Lake Padden ammonium results, June – December, 2011. Ammonium concentrations are usually very low in oxygenated water and are typically associated with anaerobic conditions at the bottom of the lake. In Lake Padden, ammonium levels were near or below the IWS analytical detection limit in summer but elevated during fall. The fall spikes in ammonium may be associated with organic matter decomposition in the bottom of the lake (See data from depth profile in Appendix A). During fall turnover (See Figure 13 for a description of this process), these ammonium rich waters were brought to the lake's surface. Values below the detection limit (10 µg-N/L) are stated as half the detection limit.

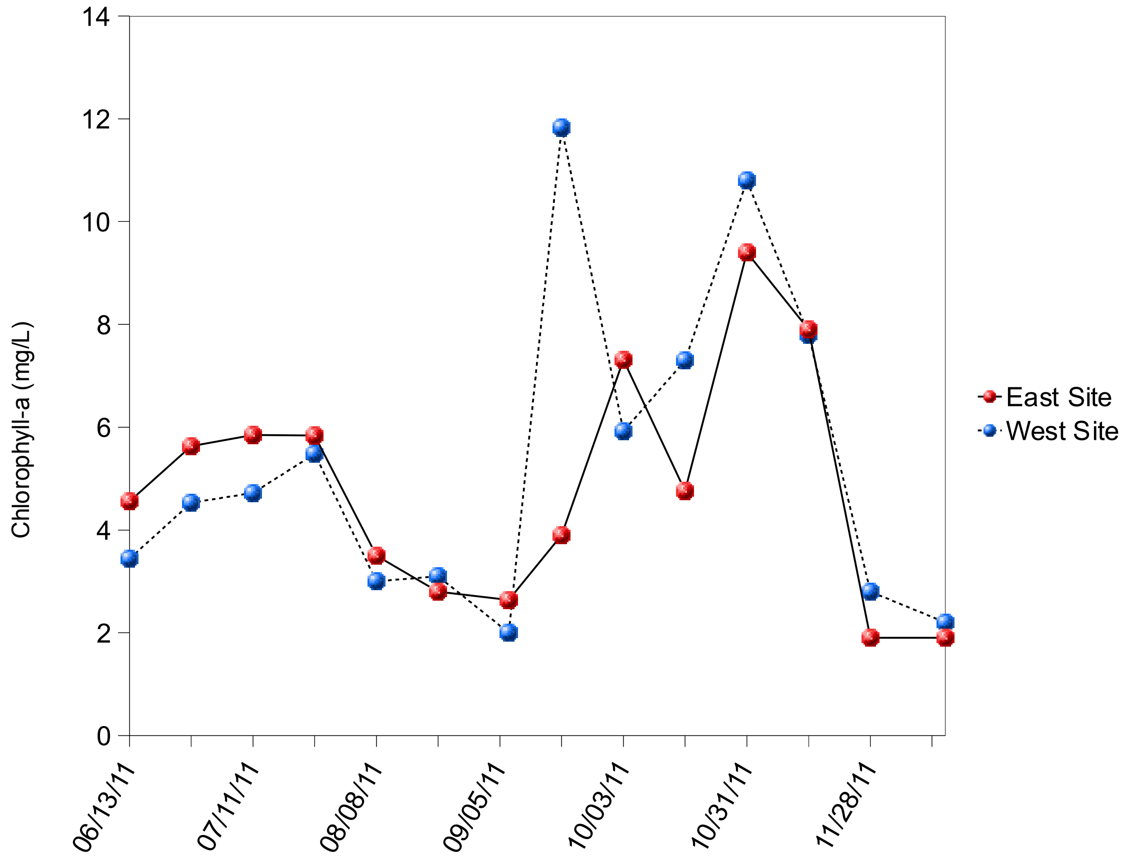

Figure 11. Lake Padden chlorophyll results, June – December, 2011. Chlorophyll is the primary photosynthetic pigment in algae and is generally the best indicator of the amount of algae present. Different algae groups thrive at different times during the year. Lake Padden had three major spikes in chlorophyll concentrations; early summer, late summer/early fall, and mid-fall. Based on algal patterns in local lakes, the chlorophyll spikes in Lake Padden may represent blooms of diatoms and golden algae in June/July, followed by a mix of green algae and cyanobacteria in September/October (R. Matthews, pers comm.).

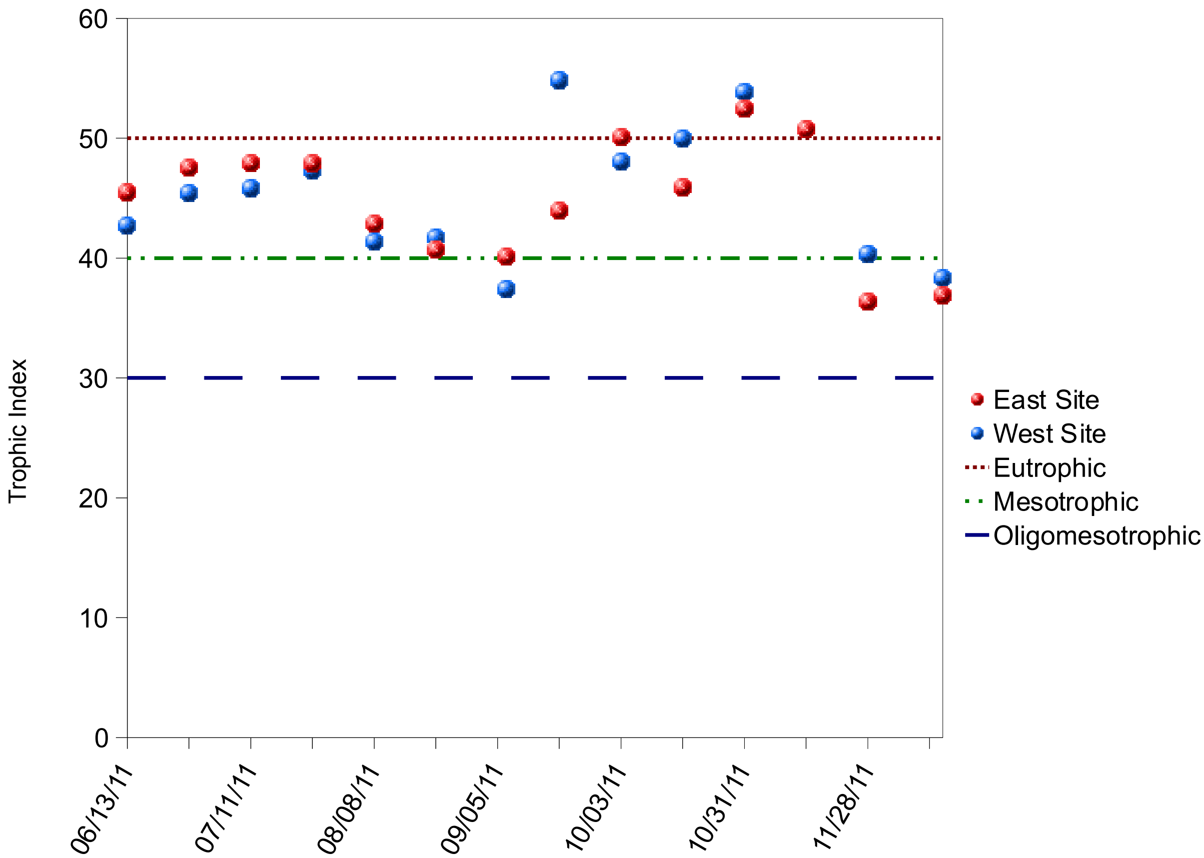

Figure 12. Carlson's Trophic State Index for Lake Padden, June – December 2011. Carlson's Trophic State Index is a tool used to classify the trophic state of lake based on the chlorophyll concentrations during peak algal growth (generally late summer and early fall). Lakes with low concentrations of chlorophyll are biologically unproductive or *oligotrophic* (TSI_{chl} <30); lakes that have high chlorophyll concentrations are biologically productive or *eutrophic* (TSI_{chl} >50); lakes with chlorophyll concentrations that fall between these classifications are moderately productive or *mesotrophic* (TSI_{chl} 40 – 50) or *oligomesotrophic* (TSI_{chl} 30 – 40). Carlson's Trophic State Index is calculated as: $TSI_{chl} = 9.81 * \ln(Chl, \mu g/L) + 30.6$. Lake Padden TSI_{chl} values were within or near the mesotrophic range. The east sample site TSI_{chl} values were usually higher than the West site during summer and the opposite was true during fall.

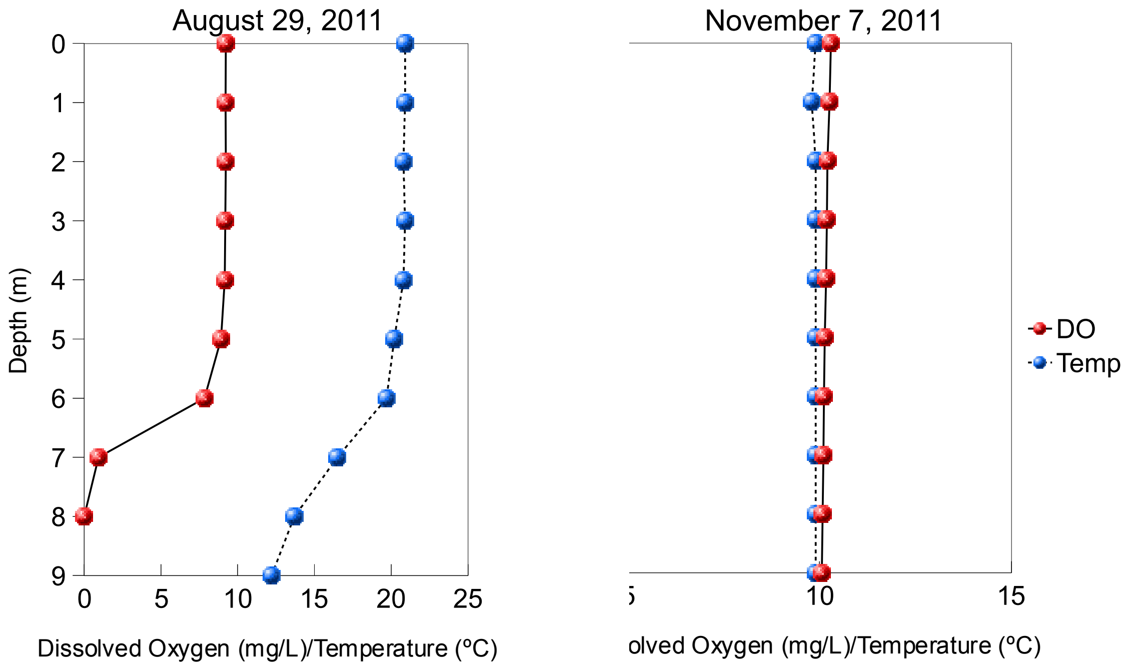

Figure 13. Lake Padden depth profile results for August 29 and November 7, 2011. Lakes in temperate regions commonly undergo thermal stratification during summer. Two layers form due to density differences associated with temperature; the *epilimnion* (the top) and the *hypolimnion* (the bottom). The two-dimensional boundary between these two layers, known as the *thermocline*, effectively isolates the hypolimnion from the oxygenated epilimnion. The amount of oxygen in the hypolimnion is then finite. If enough organic matter is present in the hypolimnion, decomposition will use up the available oxygen and the hypolimnion will become *anoxic* (lacking oxygen). This is a natural cycle in many lakes but can be made more severe by human influence (addition of nutrients from fertilizers used at the golf course, feces deposited at the dog park, and development within the watershed). An anoxic hypolimnion results in less fish habitat available in summer. In addition, anoxic conditions cause nutrients to be released from the sediments, which can give rise to algae blooms. On August 29, Lake Padden was thermally stratified. The thermocline occurred at ~6.5 m and the hypolimnion was anoxic. By November, seasonal winds and decreasing temperatures in the epilimnion allowed the two layers to become mixed. In 1974, Lake Padden was also stratified during summer and the hypolimnion was anoxic (Dion et al., 1976), suggesting that the anoxia is not a recent phenomenon. Water quality data for this sampling site are included in Appendix A. Ammonium and total phosphorus concentrations were higher in the hypolimnion compared to the epilimnion on August 29 due to anoxic conditions of the hypolimnion.

Date			Temp ºC	DO mg/L	pH	Cond µS	TP µg-P/L	SRP µg-P/L	TN µg-N/L	NO_3 µg-N/L	NH_3 µg-N/L	Chl µg/L
Current 2011 (June – December)		min	4.9	8.0	7.1	98.0	2.5	1.5	252.9	5.0	5.0	1.8
		max	22.2	10.9	8.6	104.5	24.2	10.7	508.5	216.4	30.1	11.8
Year	Month											
2011	June		19.4	10.2	8.1	98.3	2.5	4.1	422.0	145.0	11.2	5.1
2010	March		8.2	**11.9**	7.5	102.8	11.3	3.7	438.0	125.8	5.0	NA
	June		16.5	9.8	7.9	100.4	2.5	3.1	336.0	5.0	8.7	10.6
2009	April		13.7	10.1	7.7	**97.2**	11.0	3.5	**555.0**	**300.8**	10.4	2.7
	August		21.0	8.2	8.2	103.0	7.4	2.1	337.0	5.0	7.4	4.8
2008	May		11.3	**12.1**	8.0	99.0	9.8	1.5	404.1	114.7	12.1	8.4
	August		**22.8**	8.8	8.2	104.4	2.5	1.5	338.6	5.0	5.0	4.4
2007	April		11.3	10.0	7.1	**91.2**	14.6	6.8	**548.7**	**323.3**	27.9	3.0
	August		20.6	8.3	7.5	**97.3**	9.4	3.5	348.5	5.0	15.6	4.8
2006	September		20.6	9.3	7.8	99.2	18.0	3.9	291.7	5.0	7.3	NA
1997[1]	June		NA	NA	NA	NA	13.0	NA	380.0	NA	NA	NA
	September		NA	NA	NA	NA	18.0	NA	**200.0**	NA	NA	3.0
1974[2]	February		**4.4**	**13.2**	7.6	**71.0**	15.0	2.0	NA	***530.0**	***50.0**	2.9
	May		12.7	**11.0**	7.4	**74.0**	11.0	4.0	NA	***400.0**	***40.0**	2.0
	July		18.0	9.6	7.3	**78.0**	8.0	2.0	NA	***230.0**	***50.0**	**1.5**
	September		19.0	9.0	7.6	**80.0**	8.0	1.0	NA	0.0	***40.0**	2.0

[1] – Smith et al. (1997)

[2] – Dion et al. (1976)

Table 2. Historical data for Lake Padden (1974 – 2011). Most of the historical values from IWS (2006 – 2011) and Washington State Department of Ecology (1974 – 1997) fell within the minimum and maximum values measured during our June – December 2011 study. Some historical samples were collected during spring and could not be compared to our data set. Values in bold exceeded our range; values with an asterisk (*) may not be comparable to our current data. Total nitrogen measured on September 1997 was lower than recent data and may be total kjeldahl nitrogen, which does not include nitrate/nitrite. Conductivity appears to have increased since 1974, and chlorophyll values were lower in the summer of 1974, but these differences may simply represent analytical variation.

4 Online Resources

4.1 Lake Associations and Related Information

- Washington Lake Protection Association
  www.walpa.org

- North American Lake Management Society
  www.nalms.org

- How to Form a Lake Association
  www.ecy.wa.gov/programs/wq/plants/lakes/LakeAssociation.html

4.2 Lake Management Documents

- The Washington Lake Book
  www.ecy.wa.gov/programs/wq/plants/lakes/BookContents.html

- About Lake Management
  www.nalms.org/home/lake-management/about-lake-management

- Best Management Practices for Lakes
  www.ecy.wa.gov/programs/wq/plants/algae/lakes/BestManagementPractices.html

- Waterline
  www.walpa.org/waterline

- Lake Whatcom watershed pledge
  www.cob.org/services/environment/education

- Lake-Friendly Gardening
  lakewhatcom.wsu.edu/gardenkit

- Shoreline Management
  www.ecy.wa.gov/programs/wq/plants/lakes/ShorelineMgt.html

4.3 Blue-Green Algae Information

- Cyanobacteria (Blue-Green Algae)
  www.doh.wa.gov/ehp/algae/default.htm

- Algae Control Program
  www.ecy.wa.gov/programs/wq/plants/algae/lakes/AlgaeInformation.html

- Freshwater Algae Control Program (and how to report blooms)
  www.ecy.wa.gov/programs/wq/plants/algae/monitoring/index.html

5 Literature Cited

APHA (2005). Standard Method for the Examination of Water and Wastewater, 21st Edition. American Public Health Association, American Water Works Association, and Water Environment Federation, Washington, DC.

Dion, N., Bortleson, G., McConnell, J., Innes, J. (1976). Data on Selected Lakes in Washington. Water-Supply Bulletin 42, Part 5

Huntting, M. T., Bennett, W. A. G., Livingston, V. E. Jr., Moen, W. S. (1961). Geologic Map of Washington: Washington Division of Mines and Geology, scale 1:500,000. Washington Geology. Dept. of Natural Resources, Division of Geology and Earth Resources, 1997. Vol. 25

Institute for Watershed Studies. Lake Studies. Small Lakes Project. Lake Padden. Retrieved January 2, 2012, from http://www.wwu.edu/iws/.

Poulson, E., Flannery, R. (1953). Soil survey, Whatcom County, Washington. USDA Soil Survey. U.S. Govt. Print. Off.

Smith, K., Parsons, J., Hallock, D. (1997). Water Quality Assessments of Selected Lakes within Washington State. Washington State Department of Ecology Environmental Assessment Program. Pub. No. 00-03-009

WDFW Fish Program. (2008). 2008 Hatchery Trout Stocking Plan for Washington Lakes and Streams. Washington Department of Fish and Wildlife Publications.

Appendix A

Lake Padden Water Quality Data (June – December 2011)

East Site – AM1

Date	Temp	DO	pH	Cond	Chl
Jun 13, 2011	NA	9.0	NA	100.0	4.6
Jun 27, 2011	19.0	9.5	8.2	98.3	5.6
Jul 11, 2011	21.5	9.5	8.6	99.3	5.9
Jul 25, 2011	20.5	9.2	8.5	98.6	5.8
Aug 8, 2011	21.5	9.0	8.1	98.6	3.5
Aug 22, 2011	21.0	8.5	7.9	100.0	2.8
Sep 7, 2011	22.0	8.6	7.8	101.1	2.6
Sep 19, 2011	18.2	8.0	7.5	102.0	3.9
Oct 3, 2011	16.8	8.3	7.5	102.2	7.3
Oct 17, 2011	15.0	8.7	7.3	104.3	4.8
Oct 31, 2011	12.0	9.5	7.5	103.3	9.4
Nov 14, 2011	9.4	10.5	7.5	102.6	7.9
Nov 28, 2011	7.4	10.8	7.4	103.2	1.9
Dec 15, 2011	5.0	10.2	7.1	104.5	1.9

Date	TP	SRP	TN	NO_3	NH_4
Jun 13, 2011	13.6	<3	508	208.1	12.4
Jun 27, 2011	<5	4.7	434	142.0	<10
Jul 11, 2011	<5	<3	346	66.0	<10
Jul 25, 2011	<5	<3	350	10.5	<10
Aug 8, 2011	5.3	<3	307	<10	<10
Aug 22, 2011	<5	<3	299	<10	<10
Sep 7, 2011	5.6	<3	282	<10	<10
Sep 19, 2011	6.8	7.1	333	<10	<10
Oct 3, 2011	16.5	5.5	265	<10	10.6
Oct 17, 2011	18.8	7.7	253	<10	19.4
Oct 31, 2011	23.3	10.7	321	<10	14.7
Nov 14, 2011	16.7	4.9	287	<10	<10
Nov 28, 2011	10.9	4.8	281.1	19.6	21.3
Dec 15, 2011	11.6	7.8	293.6	33.9	24.7

Temperature (Temp, ºC)
Dissolved Oxygen (DO, mg/L)
pH (pH units)
Conductivity (Cond, µS)
Chlorophyll (Chl, µg/L)

Total Phosphorus (TP, µg-P/L)
Soluble phosphate (SRP, µg-P/L)
Total Nitrogen (TN, µg-N/L)
Nitrate/nitrite (NO_3, µg-N/L)
Ammonium (NH_4, µg-N/L)

West Site – AM2

Date	Temp	DO	pH	Cond	Chl
Jun 13, 2011	NA	9.1	NA	98.0	3.4
Jun 27, 2011	19.0	9.5	8.2	98.4	4.5
Jul 11, 2011	22.2	9.4	8.6	98.9	4.7
Jul 25, 2011	20.5	9.2	8.6	98.3	5.5
Aug 8, 2011	21.2	8.9	8.0	99.0	3.0
Aug 22, 2011	21.1	8.5	8.0	100.2	3.1
Sep 7, 2011	21.5	8.6	7.9	100.8	2.0
Sep 19, 2011	18.4	8.2	7.6	101.6	11.8
Oct 3, 2011	16.5	8.5	7.6	102.0	5.9
Oct 17, 2011	14.4	8.7	7.4	103.1	7.3
Oct 31, 2011	12.0	9.6	7.5	102.9	10.8
Nov 14, 2011	9.2	10.5	7.5	103.0	7.8
Nov 28, 2011	7.0	10.9	7.5	103.1	2.8
Dec 15, 2011	4.9	10.5	7.3	104.4	2.2

Date	TP	SRP	TN	NO_3	NH_4
Jun 13, 2011	10.0	3.4	486	216.4	11.1
Jun 27, 2011	<5	3.3	402	144.0	11.5
Jul 11, 2011	<5	3.0	337	67.0	<10
Jul 25, 2011	<5	<3	328	<10	<10
Aug 8, 2011	<5	<3	302	<10	<10
Aug 22, 2011	5.0	<3	297	<10	<10
Sep 7, 2011	<5	<3	268	<10	10.6
Sep 19, 2011	9.8	4.8	392	<10	<10
Oct 3, 2011	14.5	6.0	268	<10	20.8
Oct 17, 2011	19.9	6.4	270	<10	16.9
Oct 31, 2011	24.2	8.7	347	<10	24.9
Nov 14, 2011	18.6	3.5	288	<10	<10
Nov 28, 2011	11.3	5.0	284.7	18.8	<10
Dec 15, 2011	12.4	7.1	299.8	32.0	30.1

Temperature (Temp, ºC)
Dissolved Oxygen (DO, mg/L)
pH (pH units)
Conductivity (Cond, µS)
Chlorophyll (Chl, µg/L)

Total Phosphorus (TP, µg-P/L)
Soluble phosphate (SRP, µg-P/L)
Total Nitrogen (TN, µg-N/L)
Nitrate/nitrite (NO_3, µg-N/L)
Ammonium (NH_4, µg-N/L)

Depth Profiles

Date	Depth (m)	YSI DO	Winkler DO	Temp	pH	Cond	Chl	NH_4	TN	NO_3	TP	SRP
Aug 29, 2011	0	9.2	8.7	20.9	8.1	100.1	NA	<10	287	<10	5.6	<3
	1	9.2	NA	20.9	NA	NA	NA	NA	NA	NA	NA	NA
	2	9.2	NA	20.8	NA	NA	NA	NA	NA	NA	NA	NA
	3	9.2	NA	20.9	NA	NA	NA	NA	NA	NA	NA	NA
	4	9.2	NA	20.8	NA	NA	NA	NA	NA	NA	NA	NA
	5	8.9	8.3	20.2	NA	NA	NA	NA	NA	NA	NA	NA
	6	7.9	NA	19.7	NA	NA	NA	NA	NA	NA	NA	NA
	7	0.9	NA	16.5	NA	NA	NA	NA	NA	NA	NA	NA
	8	0.0	NA	13.7	NA	NA	NA	NA	NA	NA	NA	NA
	9	0.0	0.2	12.2	6.8	112.9	NA	107.8	385	<10	26.5	7.7
	0	9.2	NA	20.8	NA	NA	NA	NA	NA	NA	NA	NA
Nov 7, 2011	0	10.3	9.8	9.9	7.5	102.4	NA	16.3	272.8	<10	21.2	7.4
	1	10.3	NA	9.8	NA	NA	NA	NA	NA	NA	NA	NA
	2	10.2	NA	9.9	NA	NA	NA	NA	NA	NA	NA	NA
	3	10.2	NA	9.9	NA	NA	NA	NA	NA	NA	NA	NA
	4	10.2	NA	9.9	NA	NA	NA	NA	NA	NA	NA	NA
	5	10.1	9.8	9.9	NA	NA	NA	NA	NA	NA	NA	NA
	6	10.1	NA	9.9	NA	NA	NA	NA	NA	NA	NA	NA
	7	10.1	NA	9.9	NA	NA	NA	NA	NA	NA	NA	NA
	8	10.1	NA	9.9	NA	NA	NA	NA	NA	NA	NA	NA
	9	10.1	9.8	9.9	7.5	103.1	NA	<10	302.6	<10	21.4	5.3
	10	10.1	NA	9.9	NA	NA	NA	NA	NA	NA	NA	NA

Temperature (Temp, ºC)
Dissolved Oxygen (DO, mg/L)
pH (pH units)
Conductivity (Cond, µS)
Chlorophyll (Chl, µg/L)

Total Phosphorus (TP, µg-P/L)
Soluble phosphate (SRP, µg-P/L)
Total Nitrogen (TN, µg-N/L)
Nitrate/nitrite (NO_3, µg-N/L)
Ammonium (NH_4, µg-N/L)

Appendix B

Lake Padden Quality Control Data (June – December 2011)

QC Test	Month	Day	Year	DO	pH	Cond	Chl	TP	SRP	TN	NO_3	NH_4
qc site	6	13	2011	AM1	NA	AM2	AM1	AM1	AM1	AM1	AM1	AM1
qc1	6	13	2011	9.0	NA	100	4.6	13.6	2.6	508.5	208.1	12.4
qc2	6	13	2011	9.0	NA	99	4.5	13.3	4.0	508.4	209.9	13.9
check1 value	6	13	2011	NA	NA	NA	NA	12.5	10.0	NA	100.0	50.0
check1 measured	6	13	2011	NA	NA	NA	NA	11.7	11.8	NA	103.7	46.9
check2 value	6	13	2011	NA	NA	NA	NA	50.0	50.0	NA	500.0	250.0
check2 measured	6	13	2011	NA	NA	NA	NA	50.8	50.7	NA	502.0	262.9
sample spiked	6	13	2011	NA	NA	NA	NA	AM2	AM2	AM2	AM2	AM2
% spike recovery	6	13	2011	NA	NA	NA	NA	95.0	90.0	97.0	97.0	108.0
blank	6	13	2011	NA	NA	NA	NA	<5	<3	<20	<10	<10
qc site	6	27	2011	AM1	AM1	AM2	AM2	NA	AM2	NA	AM2	NA
qc1	6	27	2011	20.2	8.2	98	4.6	NA	3.3	NA	143.8	NA
qc2	6	27	2011	20.2	8.2	98	4.5	NA	4.2	NA	144.1	NA
check1 value	6	27	2011	NA	8.0	147	NA	12.5	10.0	250.0	100.0	50.0
check1 measured	6	27	2011	NA	8.0	148	NA	11.2	10.7	278.5	99.7	50.8
check2 value	6	27	2011	NA	NA	NA	NA	50.0	50.0	1000.0	500.0	250.0
check2 measured	6	27	2011	NA	NA	NA	NA	50.3	48.8	1038.0	498.0	257.5
sample spiked	6	27	2011	NA	NA	NA	NA	NA	NA	NA	NA	NA
% spike recovery	6	27	2011	NA	NA	NA	NA	NA	NA	NA	NA	NA
blank	6	27	2011	NA	NA	NA	NA	<5	<3	<20	<10	<10
qc site	7	11	2011	AM2	AM2	AM2	AM1	AM1	NA	NA	NA	AM1
qc1	7	11	2011	9.4	8.6	99	5.8	2.5	NA	NA	NA	1.8
qc2	7	11	2011	9.4	8.6	99	5.9	5.3	NA	NA	NA	4.8
check1 value	7	11	2011	NA	8.0	147	NA	12.5	10.0	250.0	100.0	50.0
check1 measured	7	11	2011	NA	8.0	148	NA	11.2	10.7	278.5	99.7	50.8
check2 value	7	11	2011	NA	NA	NA	NA	50.0	50.0	1000.0	500.0	250.0
check2 measured	7	11	2011	NA	NA	NA	NA	50.3	48.8	1038.0	498.0	257.5
sample spiked	7	11	2011	NA	NA	NA	NA	AM2	AM1	AM2	AM1	AM2
% spike recovery	7	11	2011	NA	NA	NA	NA	110.0	91.0	95.0	94.0	116.0
blank	7	11	2011	NA	NA	NA	NA	<5	<3	<20	<10	<10
qc site	7	25	2011	AM2	AM2	AM2	AM2	AM1	NA	AM1	NA	NA
qc1	7	25	2011	9.2	8.6	98	5.6	4.4	NA	349.5	NA	NA
qc2	7	25	2011	9.2	8.6	98	5.4	6.7	NA	389.2	NA	NA
check1 value	7	25	2011	NA	8.0	147	NA	12.5	10.0	250.0	100.0	50.0
check1 measured	7	25	2011	NA	8.0	148	NA	11.2	9.7	278.5	97.4	50.8
check2 value	7	25	2011	NA	NA	NA	NA	50.0	50.0	1000.0	500.0	250.0
check2 measured	7	25	2011	NA	NA	NA	NA	50.3	48.5	1038.0	490.2	257.5
sample spiked	7	25	2011	NA	NA	NA	NA	NA	NA	NA	NA	NA
% spike recovery	7	25	2011	NA	NA	NA	NA	NA	NA	NA	NA	NA
blank	7	25	2011	NA	NA	NA	NA	<5	<3	<20	<10	<10

Temperature (Temp, ºC)
Dissolved Oxygen (DO, mg/L)
pH (pH units)
Conductivity (Cond, µS)
Chlorophyll (Chl, µg/L)

Total Phosphorus (TP, µg-P/L)
Soluble phosphate (SRP, µg-P/L)
Total Nitrogen (TN, µg-N/L)
Nitrate/nitrite (NO_3, µg-N/L)
Ammonium (NH_4, µg-N/L)

QC Test	Month	Day	Year	DO	pH	Cond	Chl	TP	SRP	TN	NO_3	NH_4
qc site	8	8	2011	AM2	AM1	AM1	AM1	AM2	AM1	AM2	AM1	NA
qc1	8	8	2011	8.9	8.1	99	3.4	0.9	1.4	302.1	4.3	NA
qc2	8	8	2011	8.9	8.2	99	3.7	4.9	1.9	318.9	4.1	NA
check1 value	8	8	2011	NA	8.0	147	NA	12.5	10.0	250.0	100.0	50.0
check1 measured	8	8	2011	NA	8.0	148	NA	12.1	9.7	285.2	97.4	48.8
check2 value	8	8	2011	NA	NA	NA	NA	50.0	50.0	1000.0	500.0	250.0
check2 measured	8	8	2011	NA	NA	NA	NA	50.2	48.5	1055.9	490.2	235.1
sample spiked	8	8	2011	NA	NA	NA	NA	NA	NA	NA	NA	NA
% spike recovery	8	8	2011	NA	NA	NA	NA	NA	NA	NA	NA	NA
blank	8	8	2011	NA	NA	NA	NA	<5	<3	<20	<10	<10
qc site	8	22	2011	AM1	AM2	AM2	AM2	AM1	NA	AM1	NA	AM1
qc1	8	22	2011	8.5	8.0	100	3.3	3.8	NA	299.3	NA	-0.5
qc2	8	22	2011	8.5	7.9	100	3.0	1.2	NA	284.6	NA	-1.4
check1 value	8	22	2011	NA	8.0	147	NA	12.5	10.0	250.0	100.0	50.0
check1 measured	8	22	2011	NA	8.0	147	NA	12.1	9.7	285.2	97.4	48.8
check2 value	8	22	2011	NA	NA	NA	NA	50.0	50.0	1000.0	500.0	250.0
check2 measured	8	22	2011	NA	NA	NA	NA	50.2	48.5	1055.9	490.2	235.1
sample spiked	8	22	2011	NA	NA	NA	NA	AM1	AM1	AM1	AM1	AM2
% spike recovery	8	22	2011	NA	NA	NA	NA	98.0	90.0	95.0	96.0	110.0
blank	8	22	2011	NA	NA	NA	NA	<5	<3	<20	<10	<10
qc site	8	29	2011	AM3-5	AM3-9	AM3-9	NA	AM3-9	NA	AM3-9	NA	AM3-9
qc1	8	29	2011	8.3	6.8	113	NA	26.5	NA	384.9	NA	107.8
qc2	8	29	2011	8.3	6.8	113	NA	22.9	NA	357.0	NA	116.7
check1 value	8	29	2011	NA	8.0	147	NA	12.5	10.0	250.0	100.0	50.0
check1 measured	8	29	2011	NA	8.0	147	NA	12.7	9.8	284.8	98.7	56.4
check2 value	8	29	2011	NA	NA	NA	NA	50.0	50.0	1000.0	500.0	250.0
check2 measured	8	29	2011	NA	NA	NA	NA	49.0	50.0	1049.8	499.1	259.3
sample spiked	8	29	2011	NA	NA	NA	NA	NA	NA	NA	NA	NA
% spike recovery	8	29	2011	NA	NA	NA	NA	NA	NA	NA	NA	NA
blank	8	29	2011	NA	NA	NA	NA	<5	<3	<20	<10	<10
qc site	9	7	2011	LW10	AM2	AM2	AM1	AM1	AM1	AM1	AM1	NA
qc1	9	7	2011	9.0	7.9	101	2.7	5.6	1.3	281.7	5.4	NA
qc2	9	7	2011	9.2	7.9	101	2.6	5.6	3.1	329.5	5.3	NA
check1 value	9	7	2011	NA	8.0	147	NA	12.5	10.0	250.0	100.0	50.0
check1 measured	9	7	2011	NA	8.0	148	NA	12.7	9.8	284.8	98.7	56.4
check2 value	9	7	2011	NA	NA	NA	NA	50.0	50.0	1000.0	500.0	250.0
check2 measured	9	7	2011	NA	NA	NA	NA	49.0	50.0	1049.8	499.1	259.3
sample spiked	9	7	2011	NA	NA	NA	NA	NA	AM1	NA	AM1	AM2
% spike recovery	9	7	2011	NA	NA	NA	NA	NA	93.0	NA	95.0	123.0
blank	9	7	2011	NA	NA	NA	NA	<5	<3	<20	<10	<10

Temperature (Temp, ºC)
Dissolved Oxygen (DO, mg/L)
pH (pH units)
Conductivity (Cond, µS)
Chlorophyll (Chl, µg/L)
Total Phosphorus (TP, µg-P/L)
Soluble phosphate (SRP, µg-P/L)
Total Nitrogen (TN, µg-N/L)
Nitrate/nitrite (NO_3, µg-N/L)
Ammonium (NH_4, µg-N/L)

QC Test	Month	Day	Year	DO	pH	Cond	Chl	TP	SRP	TN	NO_3	NH_4
qc site	9	19	2011	AM1	AM1	AM1	AM2	AM2	AM1	AM2	AM1	NA
qc1	9	19	2011	8.0	7.5	102	12.2	9.8	7.1	391.9	4.3	NA
qc2	9	19	2011	8.0	7.5	102	11.5	10.6	5.6	367.0	4.9	NA
check1 value	9	19	2011	NA	8.0	147	NA	12.5	10.0	250.0	100.0	50.0
check1 measured	9	19	2011	NA	8.0	149	NA	12.7	9.7	284.8	98.4	56.4
check2 value	9	19	2011	NA	NA	NA	NA	50.0	50.0	1000.0	500.0	250.0
check2 measured	9	19	2011	NA	NA	NA	NA	49.0	49.0	1049.8	487.5	259.3
sample spiked	9	19	2011	NA	NA	NA	NA	AM1	NA	AM1	NA	NA
% spike recovery	9	19	2011	NA	NA	NA	NA	124.0	NA	101.0	NA	NA
blank	9	19	2011	NA	NA	NA	NA	<5	<3	<20	<10	<10
qc site	10	3	2011	AM2	AM1	AM1	AM1	AM2	NA	AM2	NA	AM2
qc1	10	3	2011	8.5	7.5	102	7.4	14.5	NA	267.5	NA	20.8
qc2	10	3	2011	8.5	7.6	103	7.2	15.0	NA	262.8	NA	13.4
check1 value	10	3	2011	NA	8.0	147	NA	12.5	10.0	250.0	100.0	50.0
check1 measured	10	3	2011	NA	8.0	150	NA	13.3	9.7	297.6	98.4	53.4
check2 value	10	3	2011	NA	NA	NA	NA	50.0	50.0	1000.0	500.0	250.0
check2 measured	10	3	2011	NA	NA	NA	NA	50.7	49.0	1069.8	487.5	248.3
sample spiked	10	3	2011	NA	NA	NA	NA	NA	NA	NA	NA	AM2
% spike recovery	10	3	2011	NA	NA	NA	NA	NA	NA	NA	NA	106.0
blank	10	3	2011	NA	NA	NA	NA	<5	<3	<20	<10	<10
qc site	10	17	2011	AM1	AM2	AM2	AM2	AM1	NA	AM1	NA	NA
qc1	10	17	2011	8.7	7.4	103	7.8	18.8	NA	252.9	NA	NA
qc2	10	17	2011	8.6	7.4	104	6.6	20.6	NA	257.8	NA	NA
check1 value	10	17	2011	NA	8.0	147	NA	12.5	10.0	250.0	100.0	50.0
check1 measured	10	17	2011	NA	8.0	148	NA	13.3	9.7	297.6	98.4	53.4
check2 value	10	17	2011	NA	NA	NA	NA	50.0	50.0	1000.0	500.0	250.0
check2 measured	10	17	2011	NA	NA	NA	NA	50.7	49.0	1069.8	487.5	248.3
sample spiked	10	17	2011	NA	NA	NA	NA	AM2	AM2	AM2	AM2	NA
% spike recovery	10	17	2011	NA	NA	NA	NA	92.0	89.0	96.0	93.0	NA
blank	10	17	2011	NA	NA	NA	NA	<5	<3	<20	<10	<10
qc site	10	31	2011	LW3	AM1	AM1	AM1	AM2	AM1	AM2	AM1	NA
qc1	10	31	2011	9.2	7.5	103	9.3	24.2	10.7	346.8	8.4	NA
qc2	10	31	2011	9.0	7.5	103	9.3	23.5	11.8	339.0	6.7	NA
check1 value	10	31	2011	NA	8.0	147	NA	12.5	10.0	250.0	100.0	50.0
check1 measured	10	31	2011	NA	8.0	149	NA	14.7	10.6	267.7	98.6	48.8
check2 value	10	31	2011	NA	NA	NA	NA	50.0	50.0	1000.0	500.0	250.0
check2 measured	10	31	2011	NA	NA	NA	NA	52.7	50.2	1055.2	507.8	246.9
sample spiked	10	31	2011	NA	NA	NA	NA	NA	NA	NA	NA	NA
% spike recovery	10	31	2011	NA	NA	NA	NA	NA	NA	NA	NA	NA
blank	10	31	2011	NA	NA	NA	NA	<5	<3	<20	<10	<10

Temperature (Temp, ºC)
Dissolved Oxygen (DO, mg/L)
pH (pH units)
Conductivity (Cond, µS)
Chlorophyll (Chl, µg/L)
Total Phosphorus (TP, µg-P/L)
Soluble phosphate (SRP, µg-P/L)
Total Nitrogen (TN, µg-N/L)
Nitrate/nitrite (NO_3, µg-N/L)
Ammonium (NH_4, µg-N/L)

QC Test	Month	Day	Year	DO	pH	Cond	Chl	TP	SRP	TN	NO_3	NH_4
qc site	11	7	2011	AM3-9	AM3-9	AM3-9	NA	AM3-9	NA	AM3-9	NA	AM3-0
qc1	11	7	2011	9.8	7.5	103	NA	21.4	NA	302.6	NA	16.3
qc2	11	7	2011	9.8	7.6	103	NA	22.1	NA	285.7	NA	13.2
check1 value	11	7	2011	NA	8.0	147	NA	12.5	10.0	250.0	100.0	50.0
check1 measured	11	7	2011	NA	8.0	148	NA	14.7	10.6	267.7	98.6	48.8
check2 value	11	7	2011	NA	NA	NA	NA	50.0	50.0	1000.0	500.0	250.0
check2 measured	11	7	2011	NA	NA	NA	NA	52.7	50.2	1055.2	507.8	246.9
sample spiked	11	7	2011	NA	NA	NA	NA	AM3-0	NA	AM3-0	NA	NA
% spike recovery	11	7	2011	NA	NA	NA	NA	96.0	NA	98.0	NA	NA
blank	11	7	2011	NA	NA	NA	NA	<5	<3	<20	<10	<10
qc site	11	14	2011	AM1	AM1	AM1	AM2	AM1	NA	AM1	NA	NA
qc1	11	14	2011	10.5	7.5	103	7.5	16.7	NA	286.7	NA	NA
qc2	11	14	2011	10.5	7.5	103	8.0	17.5	NA	302.1	NA	NA
check1 value	11	14	2011	NA	8.0	147	NA	12.5	10.0	250.0	100.0	50.0
check1 measured	11	14	2011	NA	8.0	149	NA	14.7	10.6	267.7	98.6	48.8
check2 value	11	14	2011	NA	NA	NA	NA	50.0	50.0	1000.0	500.0	250.0
check2 measured	11	14	2011	NA	NA	NA	NA	52.7	50.2	1055.2	507.8	246.9
sample spiked	11	14	2011	NA	NA	NA	NA	NA	AMFD	NA	AMFD	AM1
% spike recovery	11	14	2011	NA	NA	NA	NA	NA	90.0	NA	95.0	115.0
blank	11	14	2011	NA	NA	NA	NA	<5	<3	<20	<10	<10
qc site	11	28	2011	AM2	AM1	AM1	AM1	AM1	NA	AM1	NA	AM1
qc1	11	28	2011	10.9	7.4	103	1.7	10.9	NA	281.1	NA	21.2
qc2	11	28	2011	10.9	7.5	103	2.0	9.8	NA	274.0	NA	22.2
check1 value	11	28	2011	NA	8.0	147	NA	12.5	10.0	250.0	100.0	50.0
check1 measured	11	28	2011	NA	8.0	149	NA	10.9	9.8	275.1	97.9	42.9
check2 value	11	28	2011	NA	NA	NA	NA	50.0	50.0	1000.0	500.0	250.0
check2 measured	11	28	2011	NA	NA	NA	NA	56.9	48.5	1036.0	496.9	231.9
sample spiked	11	28	2011	NA	NA	NA	NA	AM2	AM2	AM2	AM2	AM2
% spike recovery	11	28	2011	NA	NA	NA	NA	96.0	97.0	92.0	96.0	107.0
blank	11	28	2011	NA	NA	NA	NA	<5	<3	<20	<10	<10
qc site	12	15	2011	AM1	AM2	AM2	AM2	AM1	AM1	AM1	AM1	NA
qc1	12	15	2011	10.2	7.3	104	2.2	11.6	7.8	293.6	33.9	NA
qc2	12	15	2011	10.2	7.3	104	2.3	11.9	6.8	308.8	32.4	NA
check1 value	12	15	2011	NA	8.0	147	NA	12.5	10.0	250.0	100.0	50.0
check1 measured	12	15	2011	NA	8.0	148	NA	10.9	9.8	275.1	97.9	42.9
check2 value	12	15	2011	NA	NA	NA	NA	50.0	50.0	1000.0	500.0	250.0
check2 measured	12	15	2011	NA	NA	NA	NA	56.9	48.5	1036.0	496.9	231.9
sample spiked	12	15	2011	NA	NA	NA	NA	NA	NA	NA	NA	NA
% spike recovery	12	15	2011	NA	NA	NA	NA	NA	NA	NA	NA	NA
blank	12	15	2011	NA	NA	NA	NA	<5	<3	<20	<10	<10

Temperature (Temp, ºC)
Dissolved Oxygen (DO, mg/L)
pH (pH units)
Conductivity (Cond, µS)
Chlorophyll (Chl, µg/L)

Total Phosphorus (TP, µg-P/L)
Soluble phosphate (SRP, µg-P/L)
Total Nitrogen (TN, µg-N/L)
Nitrate/nitrite (NO_3, µg-N/L)
Ammonium (NH_4, µg-N/L)

Field Duplicate Data

Site	Month	Day	Year	pH	Cond	NH_4	TN	NO_3	TP	SRP
AM1	7	11	2011	8.6	99.3	<10	346.1	66.4	<5	<3
AM1_FD	7	11	2011	8.6	99.2	<10	376.0	66.9	<5	3.5
AM2	8	22	2011	8.0	100.2	<10	297.1	<10	5.0	<3
AM2_FD	8	22	2011	8.0	100.1	<10	297.3	<10	<5	<3
AM1	10	3	2011	7.5	102.2	10.6	265.0	<10	16.5	5.5
AM1_FD	10	3	2011	7.5	102.6	13.6	311.2	<10	16.3	5.1
AM2	11	14	2011	7.5	103.0	<10	288.2	<10	18.6	3.5
AM2_FD	11	14	2011	7.6	103.2	<10	294.6	<10	21.7	4.2

Temperature (Temp, ºC)
Dissolved Oxygen (DO, mg/L)
pH (pH units)
Conductivity (Cond, µS)
Chlorophyll (Chl, µg/L)

Total Phosphorus (TP, µg-P/L)
Soluble phosphate (SRP, µg-P/L)
Total Nitrogen (TN, µg-N/L)
Nitrate/nitrite (NO_3, µg-N/L)
Ammonium (NH_4, µg-N/L)