Skagit County Monitoring Program
Annual Report - 2016 Water Year
(October 2015 – September 2016)

Flooded field with birds

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Skagit County Water Quality Monitoring Program – 2016 Water Year Annual Report

Executive Summary

Skagit County has completed the thirteenth year of water quality monitoring under the Skagit County Water Quality Monitoring Program. This program was established to help determine if the Skagit County Critical Areas Ordinance for Ongoing Agriculture (SCC 14.24.120) was sufficient to protect water quality in areas of ongoing agriculture. Forty monitoring stations were established in agricultural areas as well as reference locations outside of the agricultural zones. Monitoring began in October 2003 and is continuing. Reports are published after each water year (October 1- September 30). This report is the thirteenth annual report, for the 2016 water year.

Data collected during this project indicates that many Skagit County streams, within and outside of the agricultural areas, do not meet state water quality standards for fecal coliform, temperature, and/or dissolved oxygen. None of the 40 sites has met all water quality standards for the entire project, although some sites meet the standards most of the time. The standards are developed to protect salmonid populations, recreation, and downstream shellfish resources, so streams not meeting the standards represent less-than-ideal conditions for those uses. Conditions in Skagit County streams range from watercourses with occasional failures to a pattern of continual inability to meet the standards. Most of the substandard water quality occurs in tributaries to the Skagit River and in the Samish Basin, while the Skagit River itself meets most standards on most occasions. Further investigation will be necessary to determine the causes of poor water quality in each case. Some cases may represent natural conditions rather than human-caused problems.

A major focus of the program is the determination of trends in water quality both within and outside of the agricultural zones. Based on court decisions that the Growth Management Act requires protection of critical areas, but not restoration, the county uses trends monitoring as a method to determine whether water quality conditions are deteriorating in the county. Trends analysis for the 13 years of the program reveals a mixed pattern of beneficial and deleterious trends both inside and outside of the agricultural areas. While many watercourses both inside and outside of the agricultural areas show declining trends in water quality, stations in the Samish Basin show a higher proportion of improving trends, especially in fecal coliform bacteria. County water quality enhancement programs have focused on the Samish Basin, so improving trends there show that the programs are resulting in improved water quality.

Skagit County data has also proved useful to Ecology in their water cleanup (Total Maximum Daily load or TMDL) efforts, especially the Samish Bay Watershed Fecal Coliform TMDL. Skagit County, in cooperation with many local and state partners through the Clean Samish Initiative, is comprehensively addressing pollution in the Samish Bay Watershed. County data, supplemented by volunteer data, has shown severe fecal coliform contamination in many areas of the watershed. The County has received EPA funding to address Samish Bay Watershed pollution issues and is working in partnership with the Washington State Department of Ecology, the Skagit Conservation District, local tribes, and other partners in locating properties with possible pollution sources and seeking cooperative solutions to those problems.

The Washington State Department of Ecology used Skagit County data from the South Fork Skagit River to determine that additional monitoring for the County's NPDES Phase II Stormwater Permit was not necessary. In most cases, water bodies with TMDLs require additional monitoring in association with the stormwater permits, but County data showed that the South Fork Skagit had improved substantially since the TMDL went into effect, and that additional stormwater monitoring was not necessary at the time of permit issuance.

County staff participate in local and regional technical groups and in training of volunteer monitoring groups. Staff also give numerous presentations throughout the year to interested organizations. Fecal coliform results are displayed on a map on the Skagit County web page: http://www.skagitcounty.net/Departments/PublicWorksCleanWater/main.htm. Skagit County staff sponsor many community outreach events and participate in other events organized by partner organizations.

The program was supported through 2008 by a Centennial Clean Water grant from the Department of Ecology. Grant match and all current funding is provided by Skagit County's Clean Water Program. All monitoring is governed by an Ecology-approved Quality Assurance Project Plan.

The Skagit County Water Quality Monitoring Program has collected 13 years of high-quality data. Questions on the program can be addressed to Rick Haley at rickh@co.skagit.wa.us or 360-416-1400.

Skagit County Monitoring Program Annual Report

2016 Water Year
(October 2015-September 2016)

Introduction

The Skagit County Monitoring Program started in October 2003, as part of Skagit County's program to assess the effectiveness of Skagit County Code Chapter 14.24.120, Critical Areas Ordinance for Areas of Ongoing Agriculture. The revised ordinance (Skagit County Ordinance O20030020) was passed by the Skagit County Board of Commissioners in June 2003 in response to a Compliance Order from the Western Washington Growth Management Hearings Board.

The ordinance requires farmers to "do no harm" to adjacent watercourses, and relies on specific Watercourse Protection Measures and more generalized Best Management Practices to protect the watercourses instead of requiring buffers on the streams. The associated Skagit County Resolution R20030210 committed the County to conduct water quality monitoring in the agricultural areas as one method of assessing if the County's ordinance was sufficient to protect the aquatic resources in agricultural areas. The resolution was subsequently amended in June 2004 as Resolution R20040211 in response to additional Compliance Orders from the Western Washington Growth Management Hearings Board. This second resolution provided details about the water quality monitoring program in addition to other topics not associated with water quality. Included in R20040211 is the requirement for annual reporting on the water quality monitoring program. This document is intended to satisfy that requirement for the 2016 Water Year.

R20040211 also required the County to conduct a triennial review of the Critical Areas Ordinance for Areas of Ongoing Agriculture, including the water quality monitoring program, to seek public comment on the regulations and monitoring program, and to make changes if necessary. However, the State of Washington passed SSB 5248 in 2007, which placed a "time out" on changes to critical areas regulations impacting agriculture until 2010 while the statewide issues regarding agricultural regulation are studied. The legislature subsequently passed additional legislation to extend the "time out" to 2011. In 2011, Washington State Legislature adopted the recommendations from one research group studying the critical areas regulations and created the Voluntary Stewardship Program (VSP). Skagit County decided to enroll in the program in 2012. Any county that enrolled agreed to maintain existing critical areas protections and ensure streams are protected using voluntary measures.

Sampling Locations

Figure 1 is a map with the sampling sites in the Skagit County Monitoring Program marked. Tables 1 and 2 list the sampling sites and site descriptions for the Skagit County Monitoring Program. Forty sites are currently included in the Program. These sites are located primarily in the agricultural zones (Agriculture-Natural Resource and Rural Resource). Other sites are located to provide context to, and comparisons with, the sites in the agricultural zones. These

include sites located just upstream or downstream of agricultural areas or in streams draining suburban watersheds.

The monitoring program was designed to determine current conditions and long-term trends in water quality at the sampling locations. The data is also suitable for determining compliance with state water quality standards.

A secondary purpose for some of the sites included in the monitoring program is to provide data to the Washington State Department of Ecology in support of their TMDL or Water Cleanup programs in Skagit County. The sites that provide TMDL data are also in the agricultural zones and are integral to the determination of trends and conditions in those areas. Active Water Cleanup plans in Skagit County include the Lower Skagit Tributaries Temperature TMDL, the Samish Bay Watershed Fecal Coliform TMDL, and the Lower Skagit River Fecal Coliform TMDL. Improvements made as a result of the latter program indicate that the Lower Skagit River is a candidate for removal from Ecology's Impaired Waters list.

This year, for the first time in the program, we redesignated two sites to better reflect current land use patterns: Site 16 (East Fork Nookachamps Creek) was moved from Ag-Upstream to Ag-Midstream due to some agricultural activity directly upstream of the sample location. Site 23 (Wiseman Creek) was moved from Ag-Midstream to Ag-Upstream due to the cessation of agricultural activities upstream of the sample location.

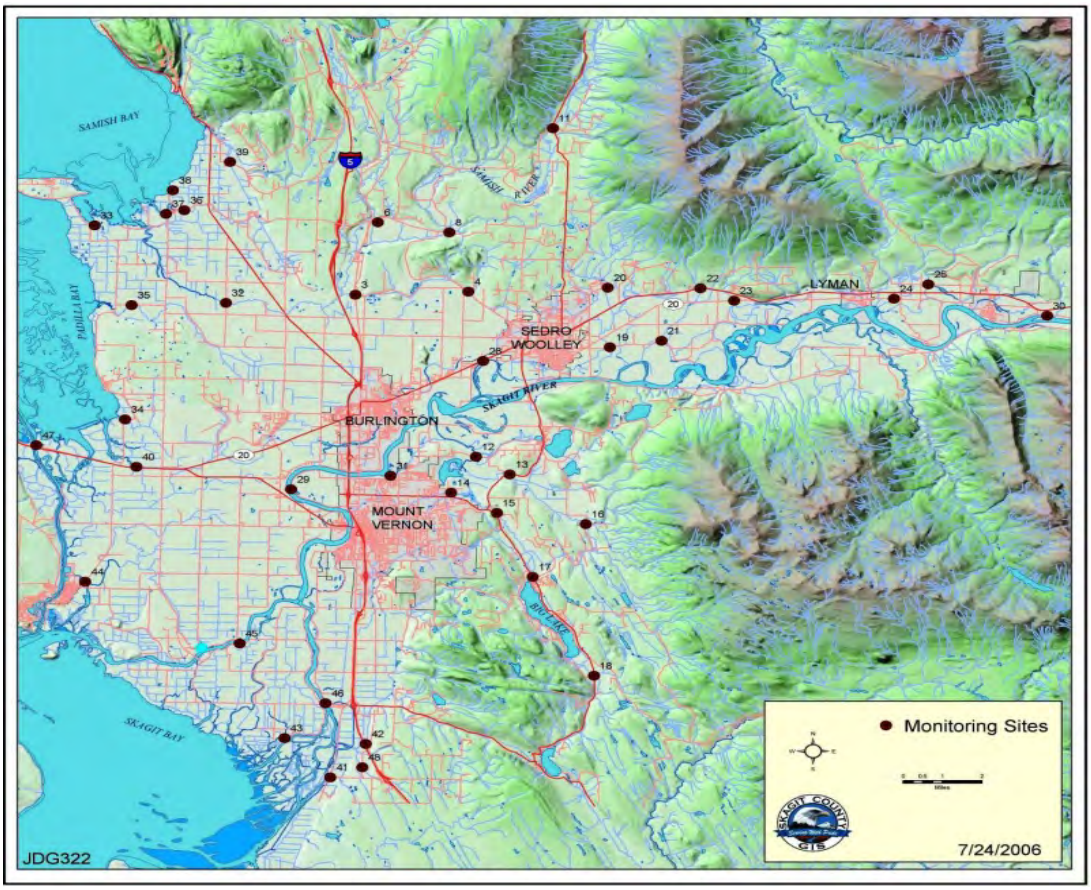


Figure 1. Sample Sites in the Skagit County Monitoring Program
Refer to Tables 1 and 2 for site locations and descriptions.

Table 1. Sample Sites for Skagit County Monitoring Program

Site Number	Watercourse	Location	Latitude	Longitude	Site Type[1]
3	Thomas Creek	Old Hwy 99 N	48.526	-122.339	3
4	Thomas Creek	F&S Grade Rd	48.528	-122.276	2
6	Friday Creek	Prairie Rd	48.559	-122.327	4
8	Swede Creek	Grip Rd	48.555	-122.287	3
11	Samish River	State Route 9	48.602	-122.231	1
12	Nookachamps Creek	Swan Rd	48.454	-122.270	3,6
13	E.F. Nookachamps Creek	State Route 9	48.446	-122.251	3,6
14	College Way Creek	College Way	48.436	-122.286	4
15	Nookachamps Creek	Knapp Rd	48.429	-122.258	2,6
16	E.F. Nookachamps Creek	Beaver Lake Rd	48.424	-122.208	2,6
17	Nookachamps Creek	Big Lake Outlet	48.400	-122.237	1,6
18	Lake Creek	State Route 9	48.356	-122.202	1,6
19	Hansen Creek	Hoehn Rd	48.504	-122.197	3,6
20	Hansen Creek	Northern State	48.531	-122.199	1,6
21	Coal Creek	Hoehn Rd	48.507	-122.169	3
22	Coal Creek	Hwy 20	48.531	-122.149	1
23	Wiseman Creek	Minkler Rd	48.526	-122.130	1
24	Mannser Creek	Lyman Hamilton Hwy	48.528	-122.041	2
25	Red Cabin Creek	Hamilton Cemetery Rd	48.534	-122.023	1
28	Brickyard Creek	Hwy 20	48.497	-122.268	4
29	Skagit River	River Bend Rd	48.439	-122.372	5,6
30	Skagit River	Cape Horn Rd	48.521	-121.960	5
31	Drainage Dist 20 floodgate	Francis Rd	48.445	-122.317	3
32	Samish River	Thomas Rd	48.521	-122.410	3
33	Alice Bay Pump Station	Samish Island Rd	48.555	-122.483	3
34	No Name Slough	Bayview-Edison Rd	48.468	-122.464	3
35	Joe Leary Slough	D'Arcy Rd	48.520	-122.462	3
36	Edison Slough at school	W. Bow Hill Rd	48.562	-122.435	3
37	Edison Pump Station	Farm to Market Rd	48.561	-122.444	3
38	North Edison Pump Station	North Edison Rd	48.572	-122.441	3
39	Colony Creek	Colony Rd	48.581	-122.401	2
40	Big Indian Slough	Bayview-Edison Rd	48.447	-122.457	3
41	Maddox Slough/Big Ditch	Milltown Rd	48.309	-122.346	3
42	Hill Ditch	Cedardale Rd	48.324	-122.327	3
43	Wiley Slough	Wylie Rd	48.326	-122.372	3
44	Rexville Pump Station	Summer's Drive	48.366	-122.419	3
	Sullivan Slough[2]	La Conner-Whitney Rd	48.395	-122.485	3
45	Skagit River – North Fork	Moore Rd	48.364	-122.416	5,6
46	Skagit River – South Fork	Fir Island Rd	48.342	-122.349	5,6
47	Swinomish Channel	County Boat Launch	48.455	-122.512	7
48	Fisher Creek	Franklin Rd	48.320	-122.328	3,6

[1]See Table 2 for site type descriptions

[2]Site 44 was moved in June, 2005. See text for details

Table 2. Sample Site Type Descriptions for Skagit County Monitoring Program

Site Type Number	Description	Number of Sites[1]
1	Ag-upstream: Located to determine status/trends at upstream end of agricultural areas.	6
2	Ag-midstream: Located to determine status/trends in the middle of agricultural areas.	6
3	Ag-downstream: Located to determine status/trends at downstream end of a watercourse in agricultural areas.	20
4	Reference: Located to determine status/trends in a non-agricultural area, such as urban/suburban or rural reserve, for comparison with agricultural area results.	3
5	Skagit River: Located to determine status/trends in the mainstem Skagit River or the forks. The Skagit may show effects from a wide variety of sources.	4
6	TMDL: Located to provide information for the Department of Ecology's TMDL efforts.	12
7	Swinomish Channel: Located to provide a water quality baseline for Swinomish Channel	1

[1]Some sites have more than one type designation

Nineteen of the 40 sites (sites 3-25) are continued from the Skagit County Baseline Monitoring Project (Skagit County 2004a). The Baseline Project used nearly identical methods to monitor water quality at 27 sites. Five additional sites were part of the Samish Bay Watershed Water Quality Monitoring Program (Skagit County 2003). The data from the Baseline and Samish Projects will be used to help interpret trends in water quality for sites continued in the Skagit County Monitoring Program. Not all of the Baseline sites could be continued into the current program due to limited resources and the need to expand the current program into the Skagit Delta, where there were no Baseline sites. In particular, several intermediate sites on the Samish River were discontinued, leaving one upstream and one downstream site on the Samish.

A proposal was submitted in February 2003 to the Department of Ecology for consideration in their FY 2004 Centennial Clean Water Grants program. The proposal was accepted and a grant of nearly $500,000 was awarded to support five years of the monitoring program, FY 2004 through FY 2008.

Results from the first ten years of this program have been reported previously (Skagit County 2004c, Skagit County 2006, Skagit County 2007, Skagit County 2008, Skagit County 2009, Skagit County 2010, Skagit County 2011, Skagit County 2012, Skagit County 2013, Skagit County 2014). This report contains data and analysis from water years 2004 – 2016.

Methods

Standard water quality monitoring methods are used in the Skagit County Monitoring Program. The methods are derived from several sources, including the Department of Ecology and the U.S. Environmental Protection Agency. A brief description of monitoring procedures follows, and detailed monitoring procedures can be found in the Quality Assurance Project Plan developed for the program (Skagit County 2004b).

Each site in the monitoring program is visited every two weeks. At each visit, dissolved oxygen, temperature, pH, turbidity, conductivity, and salinity are measured and samples are obtained for fecal coliform determinations. Additional water samples are obtained for laboratory quantification of plant nutrients (total nitrogen, ammonia, nitrate, nitrite, total phosphorus and orthophosphate) and total suspended solids on a quarterly basis. Stream discharge was measured at selected sites as time and staffing permitted through 2008.

The sample routes are designed so that each station is visited at approximately the same time of day on each visit, to minimize the effects of diurnal variation in water quality parameters on overall data variability.

Data collected is entered into a custom database, and then is checked for accuracy against the original data sheets. Output from the database is exported into Excel® spreadsheets for data summary and analysis. These spreadsheets are also published on the County's web site: http://www.skagitcounty.net/SCMP

Activity Summary

Weekly Sampling

Weekly sampling on a regular schedule is often referred to as "ambient sampling" to distinguish it from storm sampling that occurs in response to rain events. All weekly sampling trips were conducted on schedule during the 2016 water year, beginning in October 2014. Sampling normally took place on Tuesdays, but occasionally took place on other days to accommodate holiday and laboratory schedules. Occasionally samples are taken on different days because of flooding or other acts of nature. Sampling activities are illustrated in Figure 2.

Storm Sampling

As part of the Clean Samish Initiative, Skagit County conducts additional water quality sampling in the Samish Basin during significant rain events. Data collected during these rain events is not included in the tabulation of regular sampling events to preclude undue influence of storm events on Trends Analysis. Storm event sampling is reported on the County web site at: http://www.skagitcounty.net/Departments/PublicWorksCleanWater/samplearchive.htm

Funding

The Centennial Clean Water Grant that funded the program at 75% ended in December 2008, with the remaining 25% coming from County funds. Subsequent work was funded by Skagit County's Clean Water Program. Skagit County has received EPA funding to address Samish Bay Watershed fecal coliform issues, but the core activities of the Skagit County Monitoring Program will continue to be funded out of the Clean Water Program.

Figure 2. Intern Mattie Michalek takes a water sample at Coal Creek

Sample Site Revisions

Three sample sites were moved from the original location as delineated in the QAPP. Site 35 on Joe Leary Slough was moved approximately 3,500 feet upstream from Bayview-Edison Road to D'Arcy Road to solve right-of-entry problems. Site 40 on Big Indian Slough was moved approximately 2,800 feet upstream to solve right-of-entry problems and to move away from the tidegate and associated saltwater intrusion. These two changes were made prior to any sampling. Site 42 on Hill Ditch/Carpenter Creek was moved approximately 4,300 feet upstream because the original site at Pioneer Highway was subject to backwater from the Skagit River, and in early samples it was determined that primarily Skagit River water was being sampled instead of Hill Ditch/Carpenter Creek water. These changes were approved by the Department of Ecology as revisions to the QAPP in 2003 and 2004.

In June 2005, the sample site at Rexville Pump Station (Site 44), at the east end of the Sullivan Slough watershed, was moved to the west end of Sullivan Slough, at La Conner-Whitney Road. This move was made in consultation with the Department of Ecology and the Western

Washington Agricultural Association. The majority of flow from that system discharges through the west end into Swinomish Channel. The Rexville Pump Station site was initially chosen because it was cited as a possible fecal coliform source in the Lower Skagit Fecal Coliform TMDL (Pickett 1997). However, fecal coliform readings at the site during this study were generally low, and coupled with the infrequent discharges from the pump station, it was determined that sampling efforts would be better spent nearer the outlet of the slough.

2008 Review of Skagit County Water Quality Program by State of Washington Water Research Center

Skagit County contracted with the State of Washington Water Research Center (WRC) for a review of its water quality program. The WRC Review Report draft was received in March, 2008, and the final report was received in June 2008. The report is available on the Skagit County web site at: www.skagitcounty.net/SCMP.

Skagit County is implementing the report recommendations as the budget allows. Recommendations that have already been incorporated into the program include expansion of the sampling program to better identify pollution source locations (through the County's Pollution Identification and Correction program), increased use of stream discharge information, and some of the statistical recommendations.

Data Summary

Graphs and tables on the following pages report results from the Skagit County Monitoring Program for dissolved oxygen, temperature, and fecal coliform. Please note that each graph within a series may have a different scale due to differences between sample sites. Full data listings for each sampling event at each sample site are included in Appendix A. A summary of water quality results for each sample site is included in Appendix B.

The graphs are meant to give an overall picture of the water quality at a given site over time. They are not intended to fully describe the conditions at that site, only to give an "at a glance" indication of the conditions over the course of the project. Detailed descriptive statistics are included in the summary tables and in Appendix B. Results of the Trends Analysis are described in the Data Analysis section that follows the Data Summary.

Temperature

Water temperature governs the metabolic rate of aquatic organisms. Excessive temperature can serve as a stress on fish and other cold-water organisms, and extreme temperatures can be lethal.

For the water years 2004-2007 and 2009-2016, temperatures were measured with Stowaway Tidbit® data loggers from Onset Computer Company. These devices were set to measure water temperature every half hour. They are normally deployed in June and retrieved in late August or early September. During those years, several of the data loggers were missing at the end of each monitoring period. Some had apparently been lost due to channel changes associated with heavy rains in late summer, while others may have been vandalized. For the 2008 water year, a

computer programming error resulted in the data loggers measuring temperature for only two weeks in late June and early July. Since annual peak temperatures occur later in the summer, the 2008 data logger data was not very useful. However, temperatures are also measured at each sampling visit, and this data is displayed in the tables and graphs on the following pages for all years of the program. Readers interested in the continuous temperature data collected in 2004-2007 can access those graphs in the 2007 Water Year Annual Report at this web address: www.skagitcounty.net/scmp.

Table 3 shows the daily maximum temperatures for the last five years of the study, based on data collected at biweekly samplings. Because the state water quality standards are based on 7-day average maximums (7-DAMs), the maximums reported on Table 3 are not directly comparable to the state temperature standard, but are displayed here as an indication of the relative condition of each stream and for comparison of the temperature conditions from year to year.

Table 4 contains the 7-day average maximums for those sample sites where continuous temperature data is available. These data are directly comparable to the state water quality standards as described on the table and in the next paragraph.

In the fall of 2006, the Washington State Department of Ecology revised its water quality standards (WAC 173-201a) to comply with a request from the U.S. Environmental Protection Agency. Included in this revision were several changes to temperature and dissolved oxygen standards for Skagit County watercourses. In particular, the lower Skagit River, Hansen, Nookachamps, Fisher, and Carpenter Creeks, and the upper Samish River and tributaries were placed in the "Core salmonid spawning and rearing" use category. This change had the effect of imposing more stringent temperature and dissolved oxygen standards on these streams. Formerly, each of these streams was held to a 7-DAM standard of 17.5ºC, but with the revised standards these streams must now meet a 7-DAM standard of 16ºC. There were no changes to other streams in the county. Currently, Sites 3-4, 28, 31-44, and 48 are held to the 17.5 ºC standard, while all other sites are held to the 16ºC standard, including marine Site 47.

In addition to changes in the general standard, the revisions to the state temperature standards in 2006 also added spawning period temperature standards to some streams in the county. Portions of the Samish River, Friday Creek, Hansen Creek, Lake Creek, and East Fork Nookachamps Creek have a 13ºC limit from February 15 to June 15 to protect steelhead spawning and egg incubation. The Skagit River upstream from Sedro-Woolley has a 13ºC limit from September 1 through May 15 to protect spawning and egg incubation for several salmonids.

After a very dry 2015 water year, 2016 had higher than normal precipitation. This resulted in higher stream flows and less time as dry channels for the streams that normally go dry.

Four of the 22 sites with continuous temperature monitoring had a maximum 7-day average maximum temperature that did not exceed the EPA water quality standard in 2016, compared with two of 18 sites in 2015. Data loggers were deployed in a few other sites but were missing by the end of the summer. Temperature dataloggers are generally not deployed in agricultural drainage ditches.

Trends Analysis had revealed many sites with significant declines in temperature between 2004 and 2012. Most of these significant declines had disappeared by the end of 2013. For 2016, there was one station with significant declining temperatures and 14 stations with increasing temperatures, compared to nine stations with increasing temperature at the of 2015. Many salmonid-bearing streams in Skagit County exceed temperature standards each summer. Ecology has developed temperature remediation cleanup plans (TMDLs) for Fisher, Carpenter, Nookachamps, and Hansen Creeks, but many other Skagit County streams also exceed temperature standards.

Graphs on the pages following Table 4 show the temperature data collected during biweekly visits. Gaps in the data represent streams that were either dry or flooded at sampling time.

Table 3. Temperature Results Done
Maximum temperature recorded during biweekly sampling for watercourses in the last five years of the Skagit County Monitoring Program

Site Number	Watercourse	Location	Highest daily temperature (°C)				
			2012	2013	2014	2015	2016
3	Thomas Creek	Old Hwy 99 North	20.2	18.9	20.2	20.1	19.6
4	Thomas Creek	F&S Grade Rd	16.3	16.2	16.3	16.6	15.9
6	Friday Creek	Prairie Rd	19.3	19.7	19.7	19.8	20.1
8	Swede Creek	Grip Rd	18.1	17.9	18.1	18.2	17.8
11	Samish River	State Route 9	15.8	17.2	17.2	14.6	14.1
12	Nookachamps Creek	Swan Rd	20.8	21.9	24.8	21.4	21.4
13	E.F. Nookachamps Creek	State Route 9	17.8	19.9	23.4	20.4	19.1
14	College Way Creek	College Way	16.9	16.7	20.8	18.0	17.7
15	Nookachamps Creek	Knapp Rd	21.3	22.5	23.1	21.8	21.8
16	E.F. Nookachamps Creek	Beaver Lake Rd	16.9	18.3	20.5	19.0	18.7
17	Nookachamps Creek	Big Lake Outlet	22.3	23.5	24.4	23.0	21.9
18	Lake Creek	State Route 9	15.8	17.0	18.7	17.2	16.3
19	Hansen Creek	Hoehn Rd	18.4	18.1	18.4	19.0	18.1
20	Hansen Creek	Northern State	16.2	15.6	16.2	15.6	15.3
21	Coal Creek	Hoehn Rd	17.5	16.3	17.5	16.9	16.1
22	Coal Creek	Hwy 20	15.6	15.4	15.7	15.5	14.6
23	Wiseman Creek	Minkler Rd	16.2	14.5	16.2	14.1	15.2
24	Mannser Creek	Lyman Hamilton Hwy	15.0	12.9	15.0	12.5	12.1
25	Red Cabin Creek	Hamilton Cemetery Rd	12.5	11.7	12.5	13.9	11.8
28	Brickyard Creek	Hwy 20	17.5	18.6	18.6	14.9	16.7
29	Skagit River	River Bend Rd	16.6	15.4	16.6	17.6	16.6
30	Skagit River	Cape Horn Rd	15.3	15.0	15.3	16.3	14.8
31	DD20 near floodgate	Francis Rd	19.2	19.4	19.4	13.7	15.2
32	Samish River	Thomas Rd	20.0	19.9	20.2	21.6	20.7
33	Alice Bay Pump Station	Samish Island Rd	27.2	25.5	27.2	25.9	23.4
34	No Name Slough	Bayview-Edison Rd	23.4	22.2	25.6	21.1	25.9
35	Joe Leary Slough	D'Arcy Rd	20.6	24.0	24.0	21.8	20.5
36	Edison Slough at school	W. Bow Hill Rd	32.4	29.8	32.4	30.1	27.6
37	Edison Pump Station	Farm to Market Rd	26.5	27.5	27.5	26.8	26.3
38	North Edison Pump Station	North Edison Rd	25.4	25.6	25.6	26.1	22.4
39	Colony Creek	Colony Rd	16.6	18.2	18.2	18.1	17.1
40	Big Indian Slough	Bayview-Edison Rd	15.6	16.2	22.1	18.7	17.3
41	Maddox Slough/Big Ditch	Milltown Rd	18.1	20.1	23.7	22.0	21.4
42	Hill Ditch	Cedardale Rd	20.2	22.5	23.1	21.7	21.3
43	Wiley Slough	Wylie Rd	21.9	21.5	21.9	21.2	20.1
44	Sullivan Slough	La Conner-Whitney Rd	20.8	17.2	21.7	19.6	18.1
45	Skagit River – North Fork	Moore Rd	17.2	16.0	17.2	18.1	17.3
46	Skagit River – South Fork	Fir Island Rd	17.6	16.3	17.6	18.3	17.7
47	Swinomish Channel	County Boat Launch	17.2	15.7	18	16.8	17.0
48	Fisher Creek	Franklin Rd	14.4	14.6	14.6	14.3	13.4

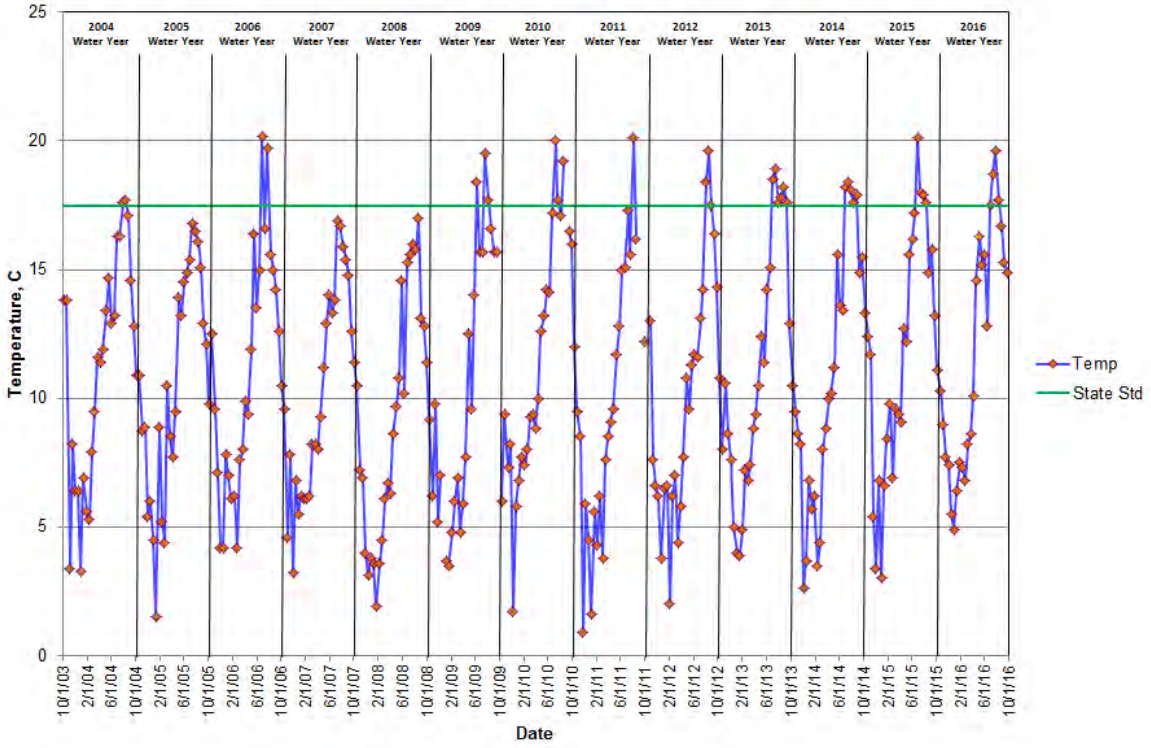
Data from biweekly site visits

Table 4. Five-Year Temperature Results Summary
Maximum 7-day average maximum temperatures for 2011-2016 of the Skagit County Monitoring Program

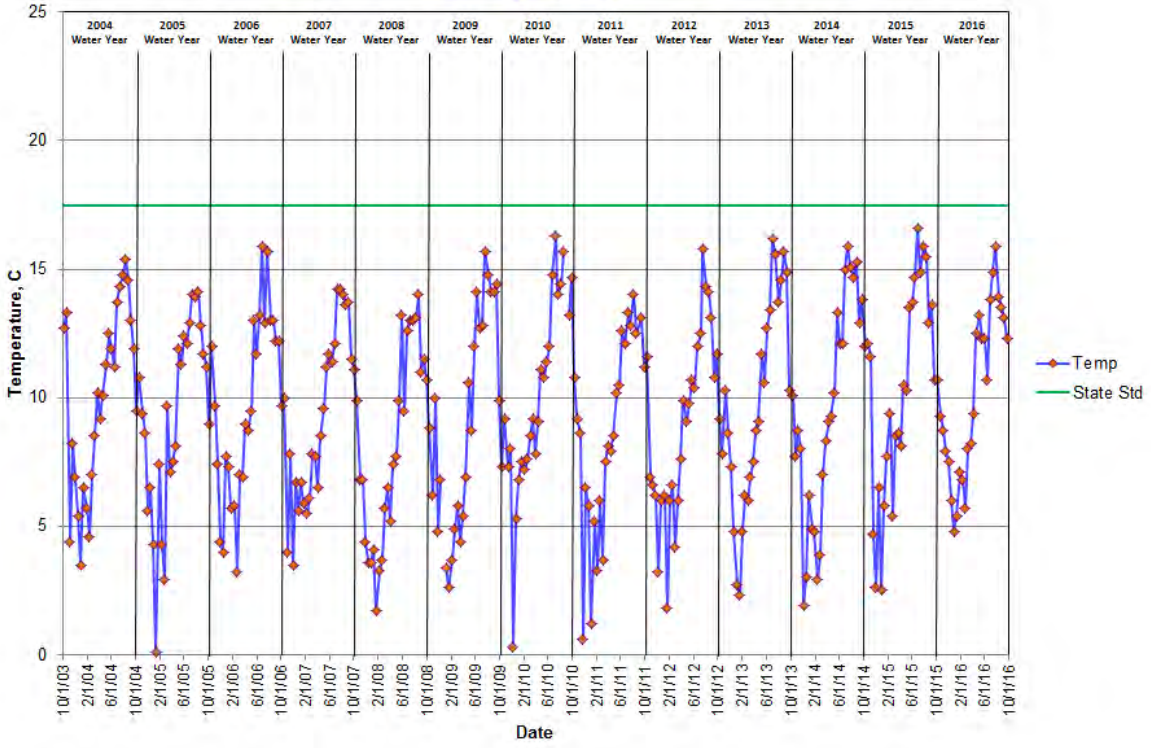
Site Number	Watercourse	Location	Max. 7DAM (°C)				
			2012	2013	2014	2015	2016
3	Thomas Creek	Old Hwy 99 North	22.9	n/a	21.6	21.5	21.2
4	Thomas Creek	F&S Grade Rd	n/a	16.4	n/a	17.8	16.7
6	Friday Creek	Prairie Rd	19	19.3	n/a	22.9	21.6
8	Swede Creek	Grip Rd	n/a	17.9	19.8	20.4	18.4
11	Samish River	State Route 9	n/a	13.3	15.3	15.4	14.8
12	Nookachamps Creek	Swan Rd	n/a	n/a	n/a	n/a	23.5
13	E.F. Nookachamps Creek	State Route 9	17.7	n/a	n/a	23.3	20.8
14	College Way Creek	College Way	n/a	17.7	n/a	n/a	n/a
15	Nookachamps Creek	Knapp Rd	n/a	21.9	n/a	24.7	23.3
16	E.F. Nookachamps Creek	Beaver Lake Rd	n/a	n/a	n/a	23.4	21.2
17	Nookachamps Creek	Big Lake Outlet	n/a	24.7	26.4	27.1	25.2
18	Lake Creek	State Route 9	17.5	17.4	n/a	n/a	18.2
19	Hansen Creek	Hoehn Rd	19.2	n/a	n/a	21.2	21.1
20	Hansen Creek	Northern State	n/a	n/a	n/a	n/a	16.3
21	Coal Creek	Hoehn Rd	17.5	16.8	n/a	n/a	20.0
22	Coal Creek	Hwy 20	16.8	16.6	n/a	18.9	17.4
23	Wiseman Creek	Minkler Rd	n/a	n/a	19.6	n/a	n/a
24	Mannser Creek	Lyman Hamilton Hwy	13.9	13.2	13.3	14.2	17.2
25	Red Cabin Creek	Hamilton Cemetery Rd	n/a	n/a	n/a	n/a	n/a
28	Brickyard Creek	Hwy 20	n/a	n/a	n/a	n/a	n/a
29	Skagit River	River Bend Rd	n/a	n/a	n/a	n/a	n/a
30	Skagit River	Cape Horn Rd	n/a	n/a	n/a	17.1	15.2
31	DD 20 near floodgate	Francis Rd	n/a	n/a	n/a	n/a	n/a
32	Samish River	Thomas Rd	n/a	19.5	20.4	22.7	n/a
33	Alice Bay Pump Station	Samish Island Rd	n/a	n/a	n/a	n/a	n/a
34	No Name Slough	Bayview-Edison Rd	n/a	n/a	n/a	n/a	n/a
35	Joe Leary Slough	D'Arcy Rd	n/a	n/a	n/a	n/a	n/a
36	Edison Slough at school	W. Bow Hill Rd	n/a	n/a	n/a	n/a	n/a
37	Edison Pump Station	Farm to Market Rd	n/a	n/a	n/a	n/a	n/a
38	North Edison Pump Station	North Edison Rd	n/a	n/a	n/a	n/a	n/a
39	Colony Creek	Colony Rd	17.4	17.1	19.2	19.4	18.3
40	Big Indian Slough	Bayview-Edison Rd	21.9	n/a	n/a	n/a	n/a
41	Maddox Slough/Big Ditch	Milltown Rd	n/a	22.4	n/a	25.4	21.1
42	Hill Ditch	Cedardale Rd	n/a	23.8	n/a	27.3	25.9
43	Wiley Slough	Wylie Rd	n/a	n/a	n/a	n/a	n/a
44	Sullivan Slough	LaConner-Whitney Rd	n/a	n/a	n/a	n/a	n/a
45	Skagit River – North Fork	Moore Rd	n/a	n/a	n/a	n/a	18.7
46	Skagit River – South Fork	Fir Island Rd	n/a	n/a	n/a	n/a	n/a
47	Swinomish Channel	County Boat Launch	n/a	n/a	n/a	n/a	n/a
48	Fisher Creek	Franklin Rd	n/a	14.4	n/a	16.1	15.1

Data from continuous temperature data loggers

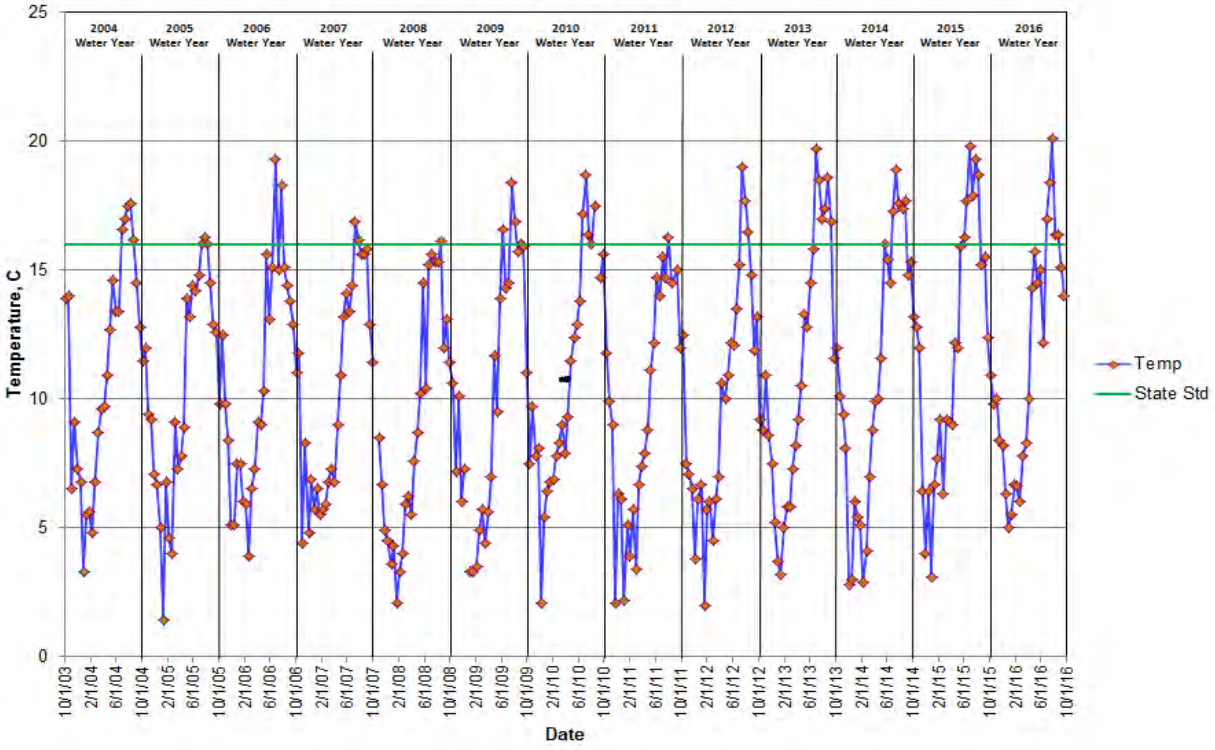
Thomas Creek at Highway 99 - Site 3
Temperature



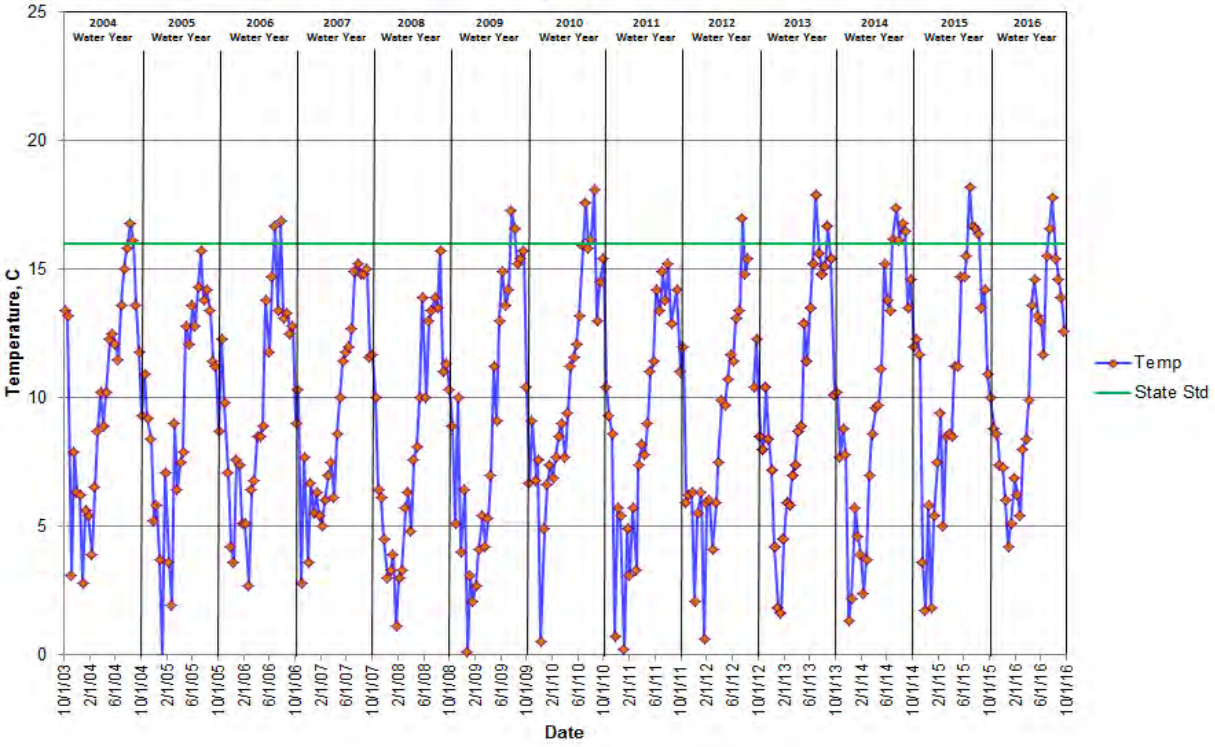
Thomas Creek at F&S Grade Road - Site 4
Temperature



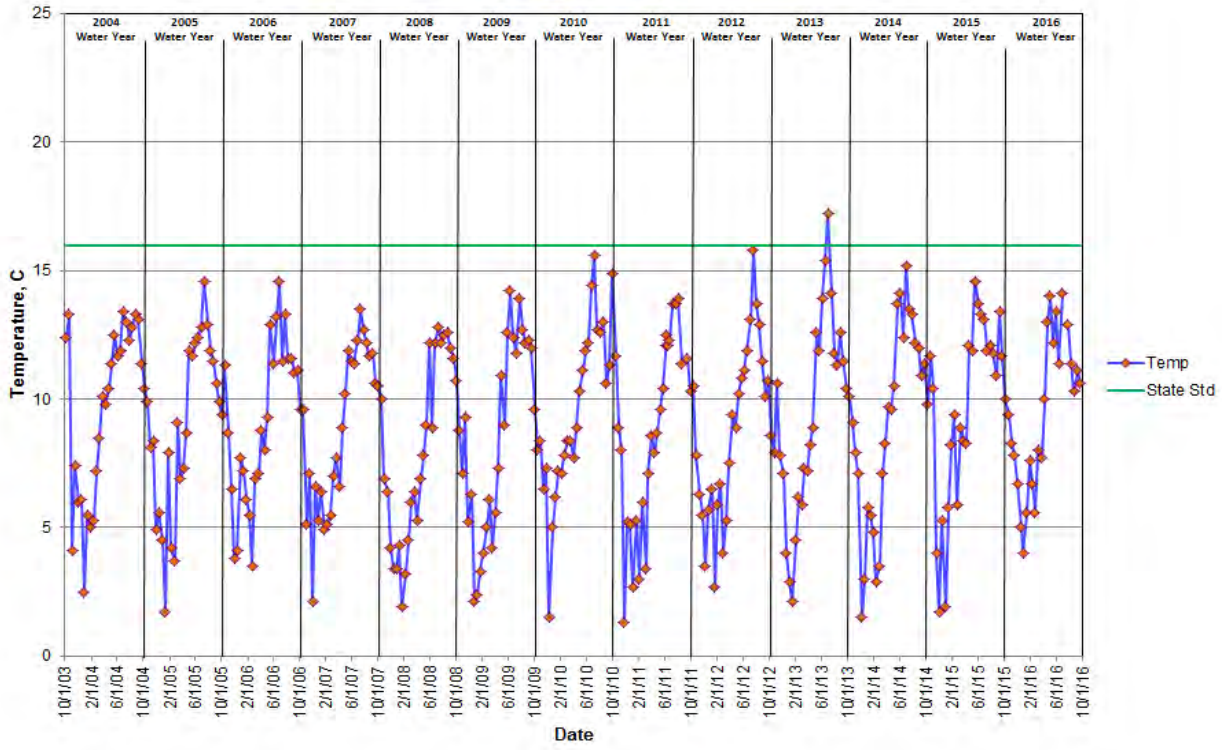
Friday Creek at Prairie Road - Site 6
Temperature



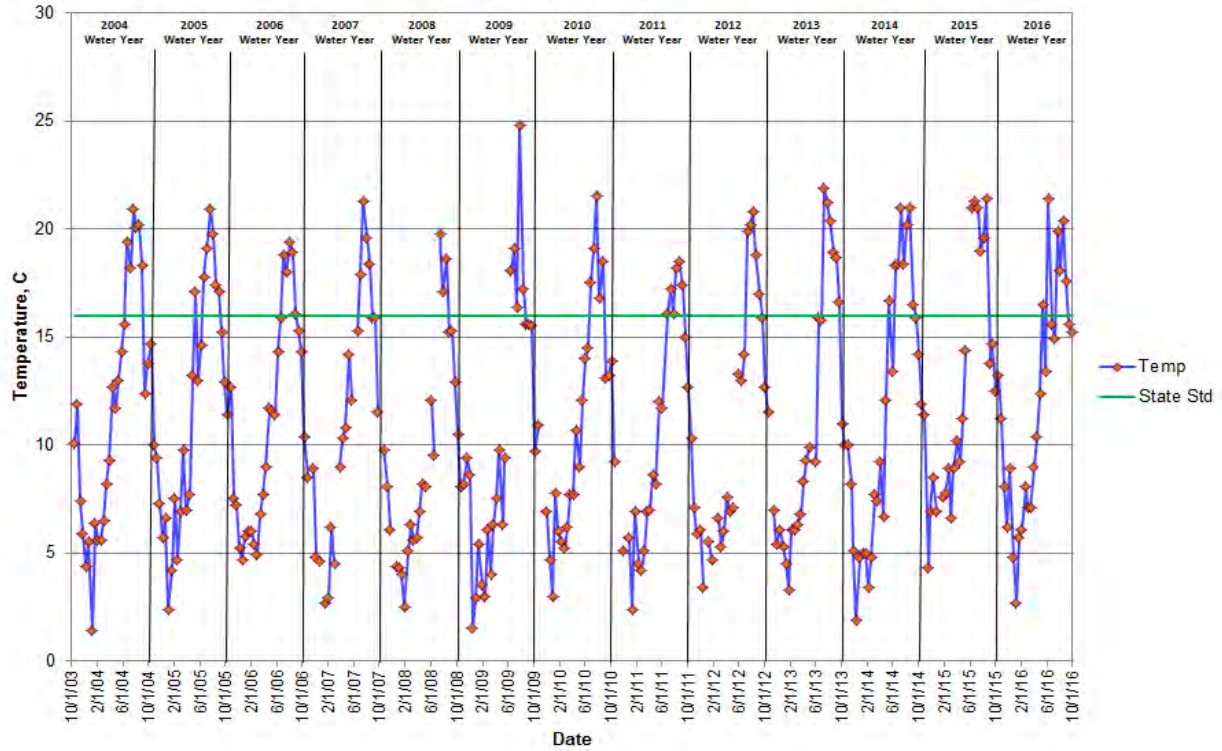
Swede Creek at Grip Road - Site 8
Temperature



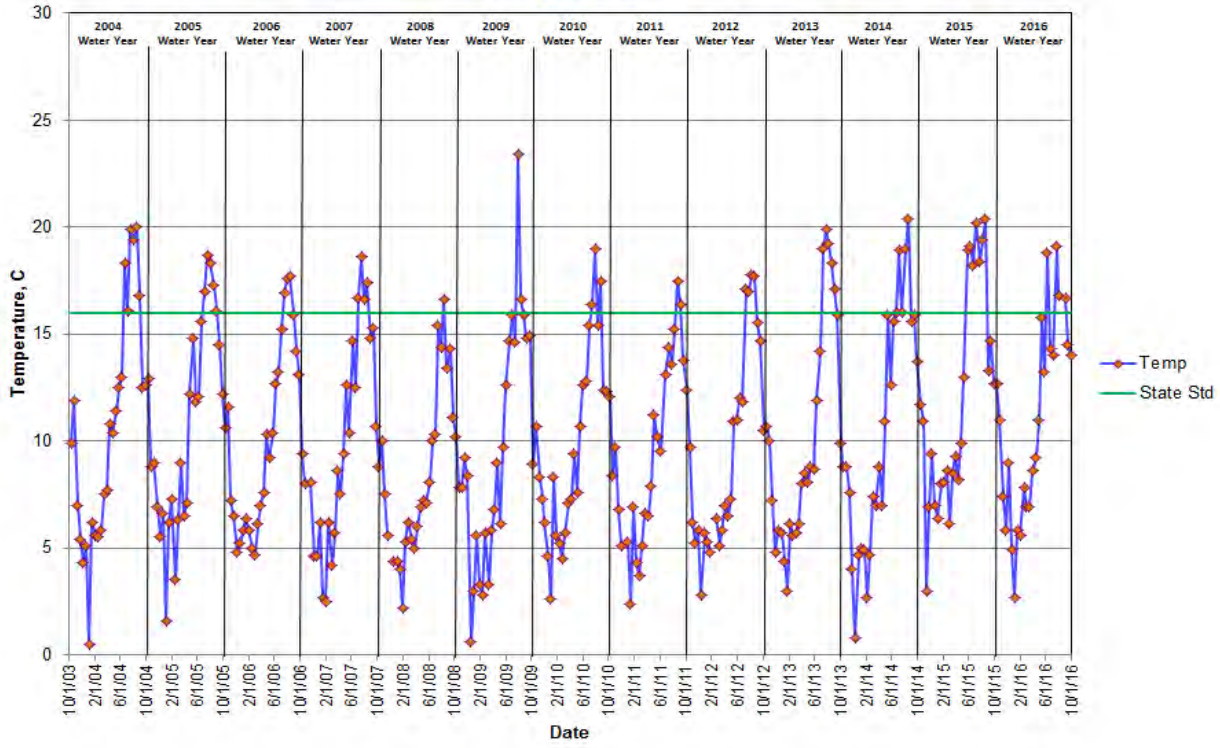
Samish River at Highway 9 - Site 11
Temperature



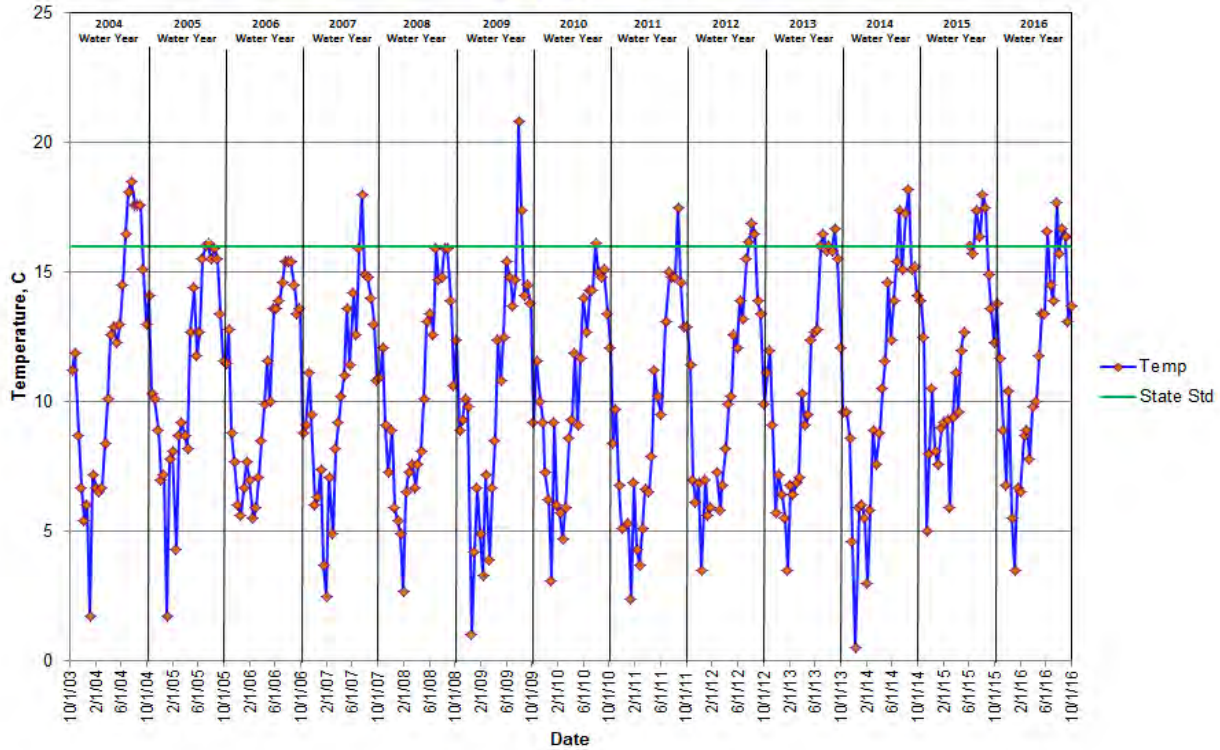
Nookachamps Creek at Swan Road - Site 12
Temperature



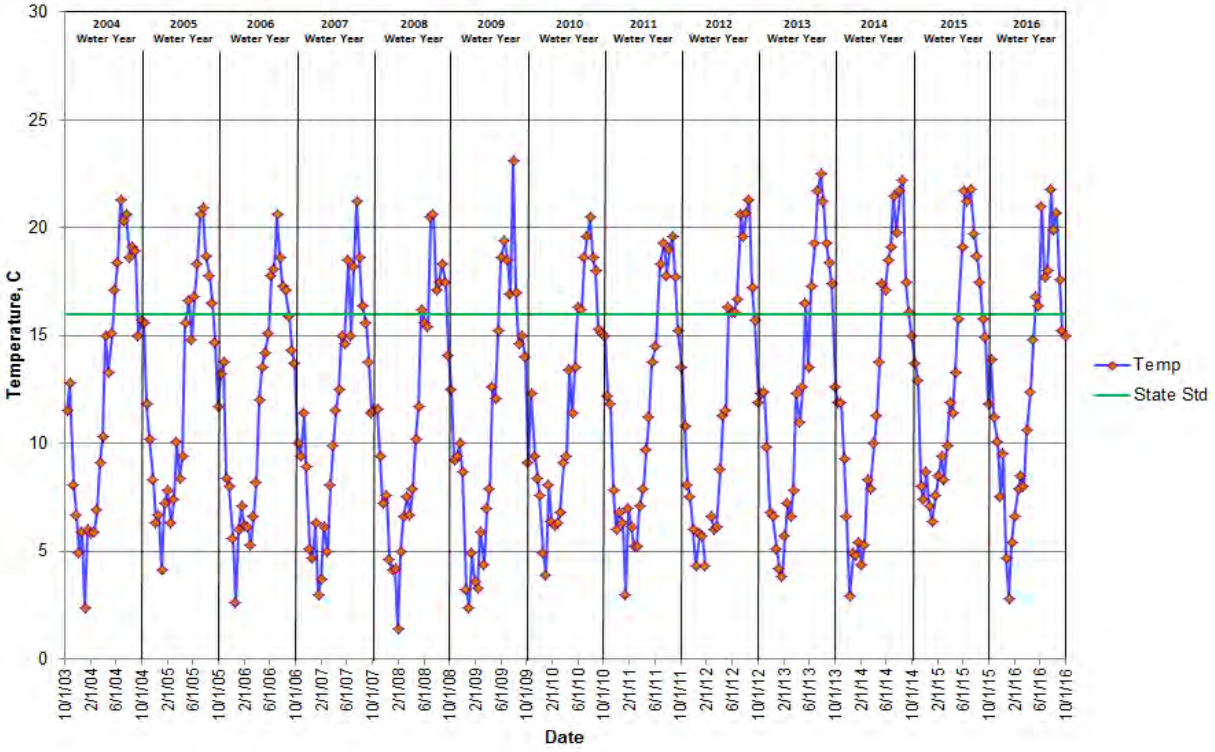
East Fork Nookachamps Creek at Highway 9 - Site 13
Temperature



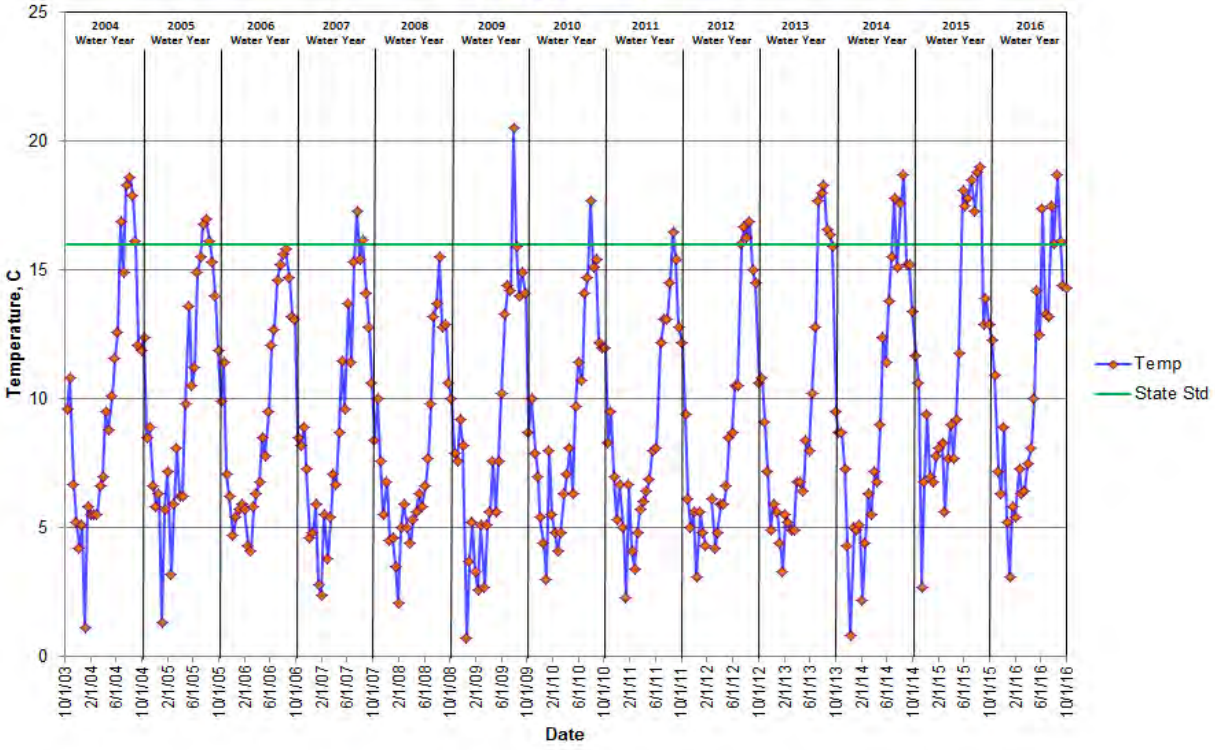
College Way Creek at College Way - Site 14
Temperature



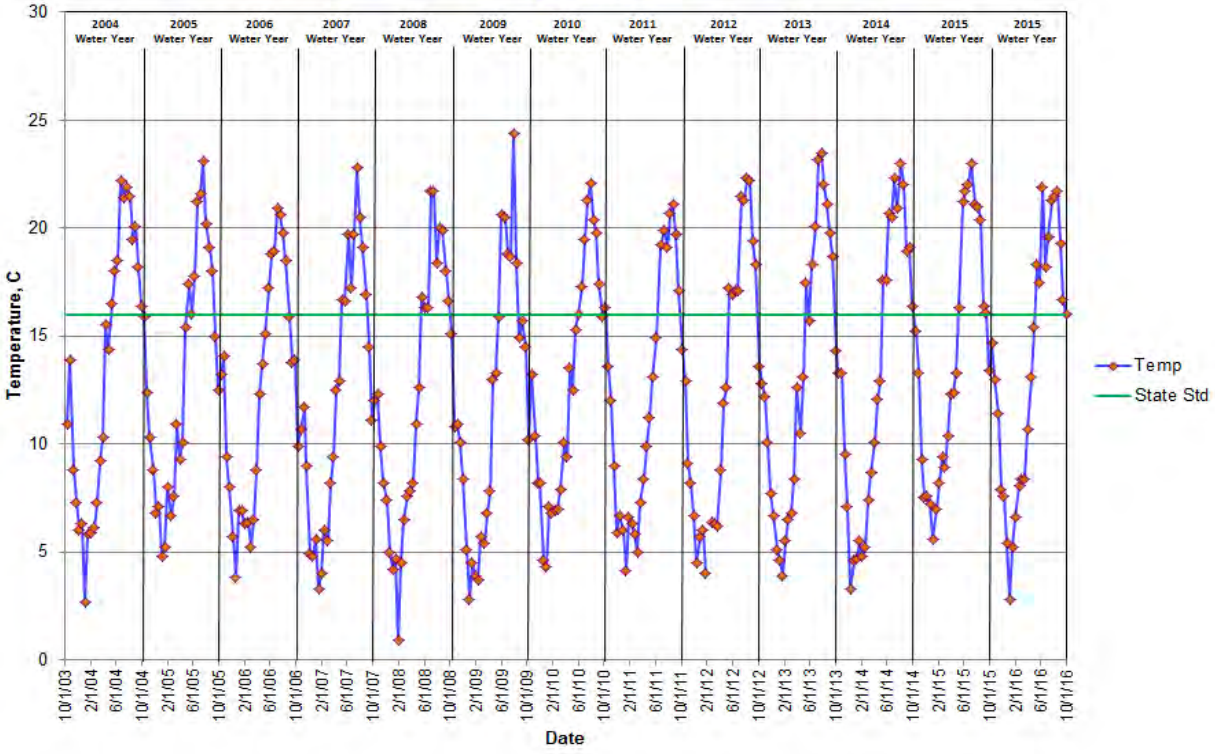
Nookachamps Creek at Knapp Road - Site 15
Temperature



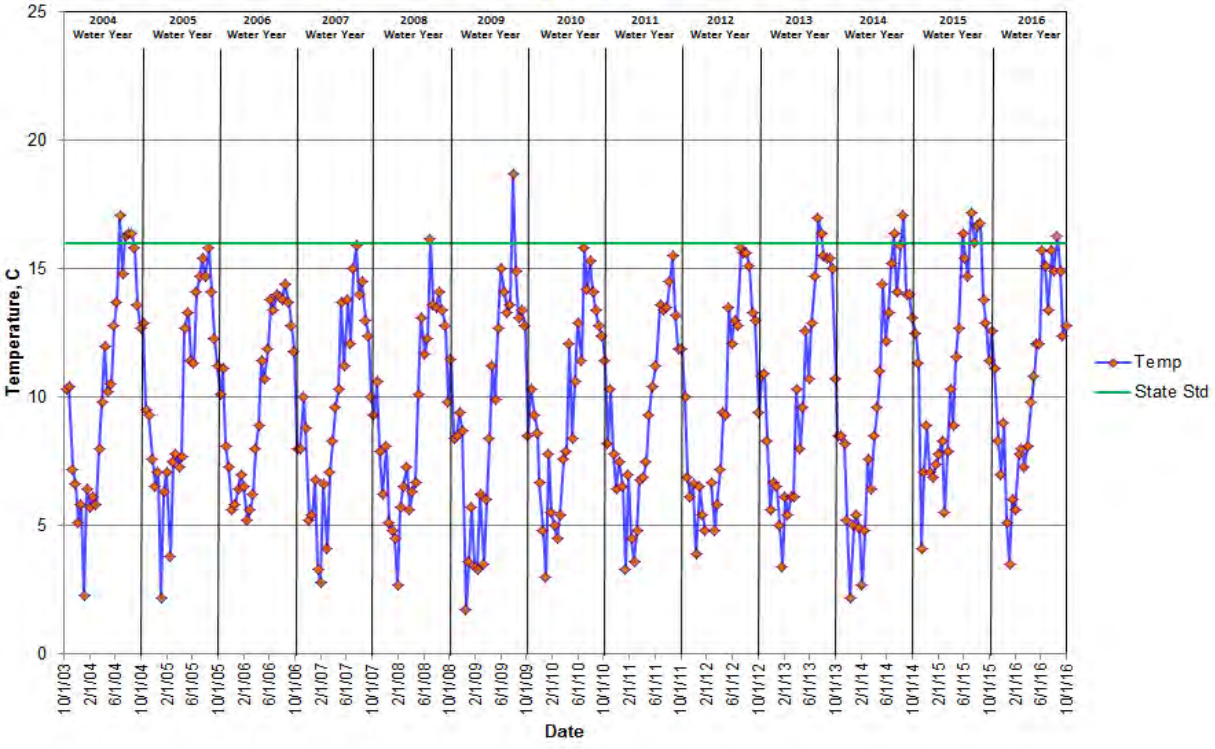
East Fork Nookachamps Creek at Beaver Lake Road - Site 16
Temperature



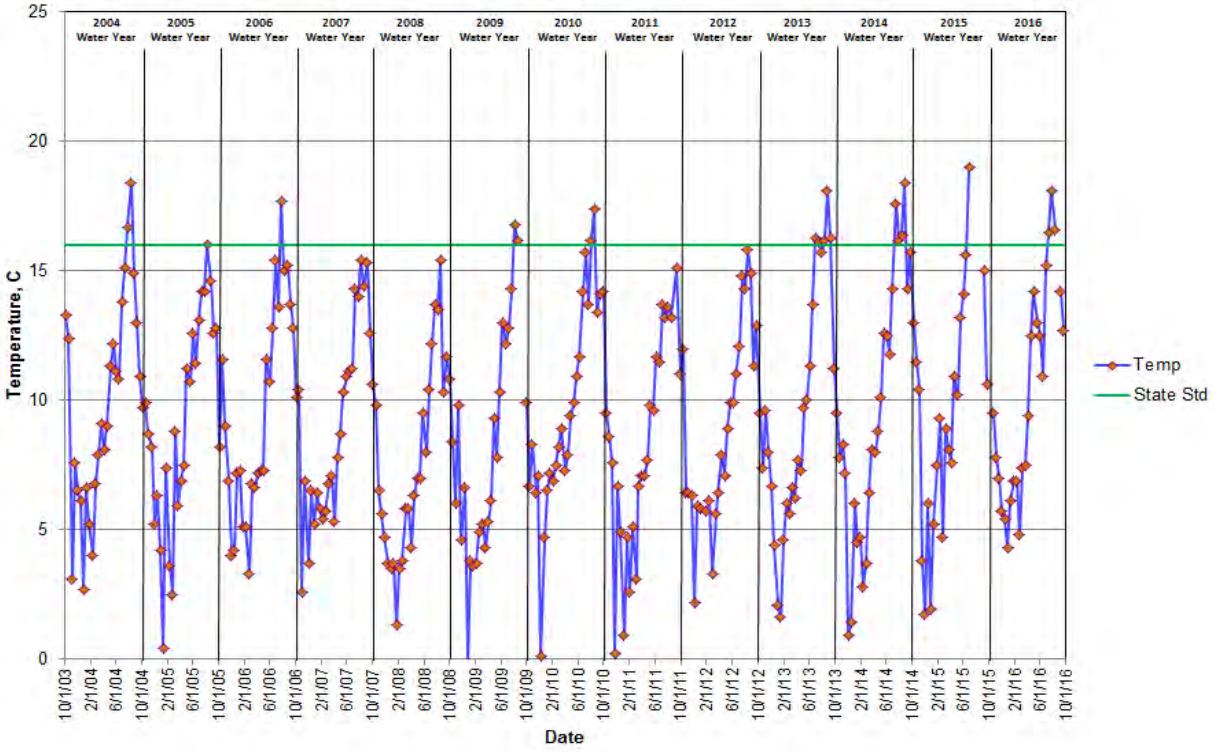
Nookachamps Creek at Big Lake Outlet - Site 17
Temperature



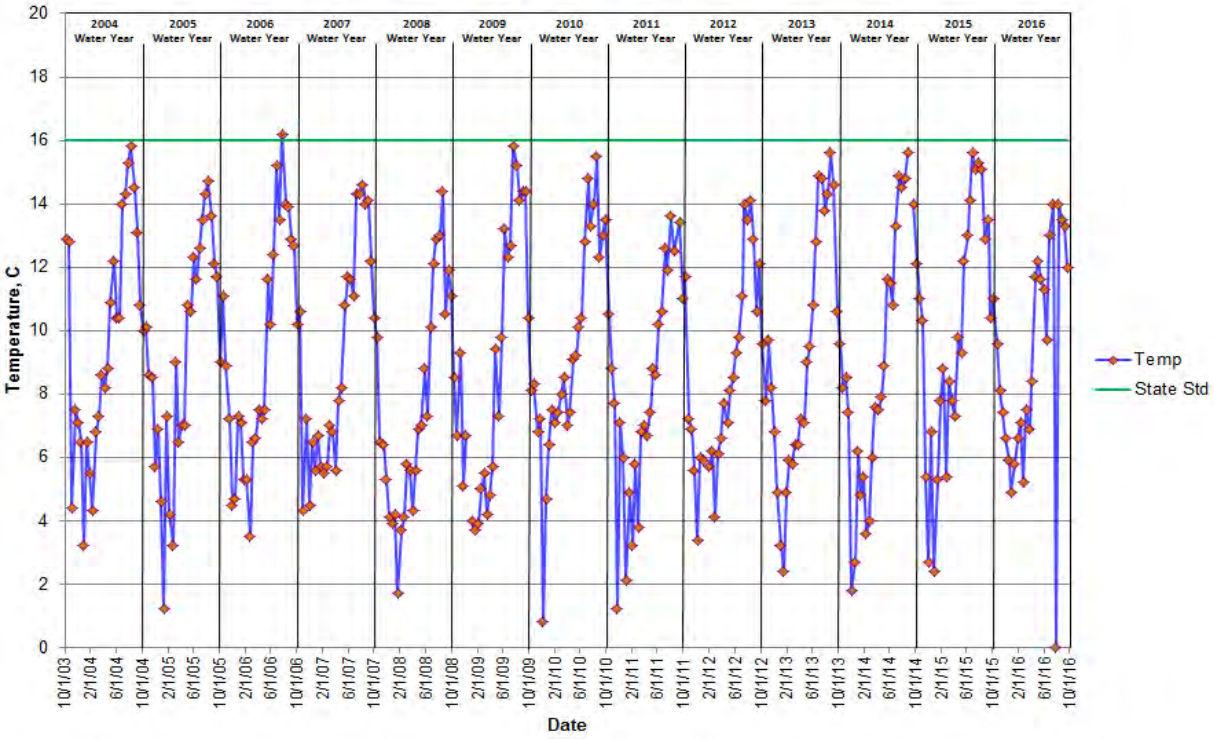
Lake Creek at Highway 9 - Site 18
Temperature



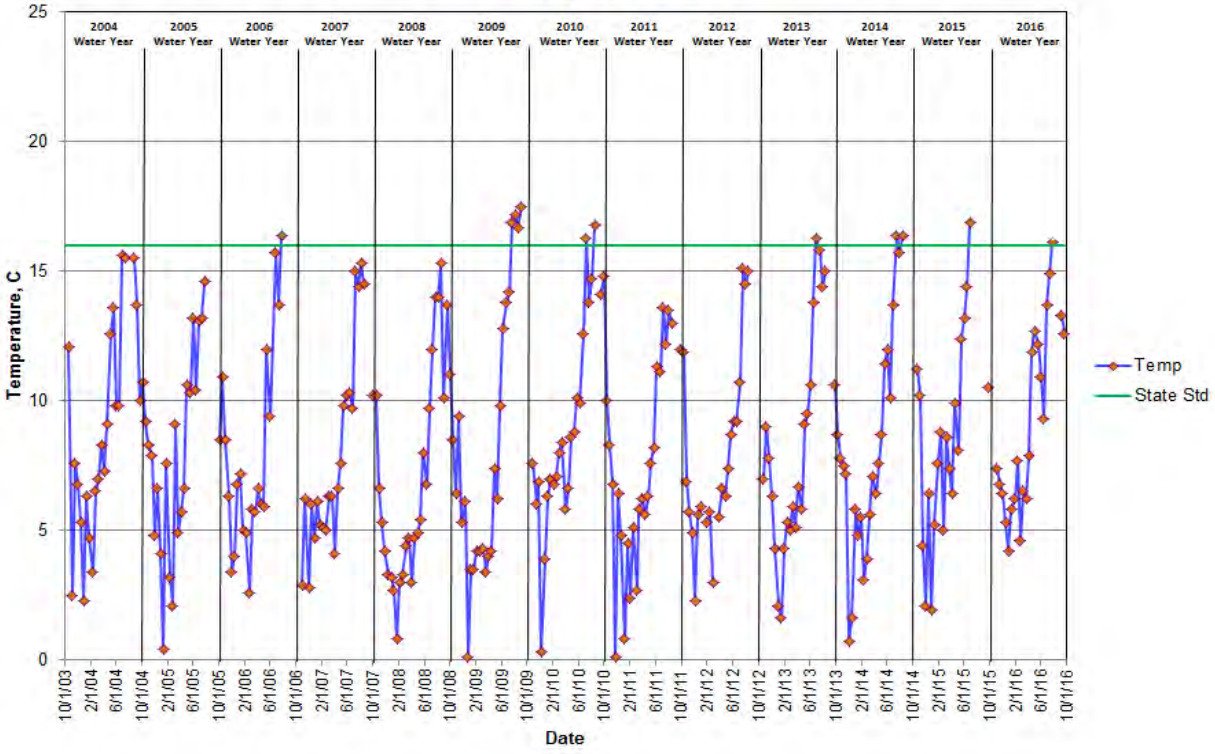
Hansen Creek at Hoehn Road - Site 19
Temperature



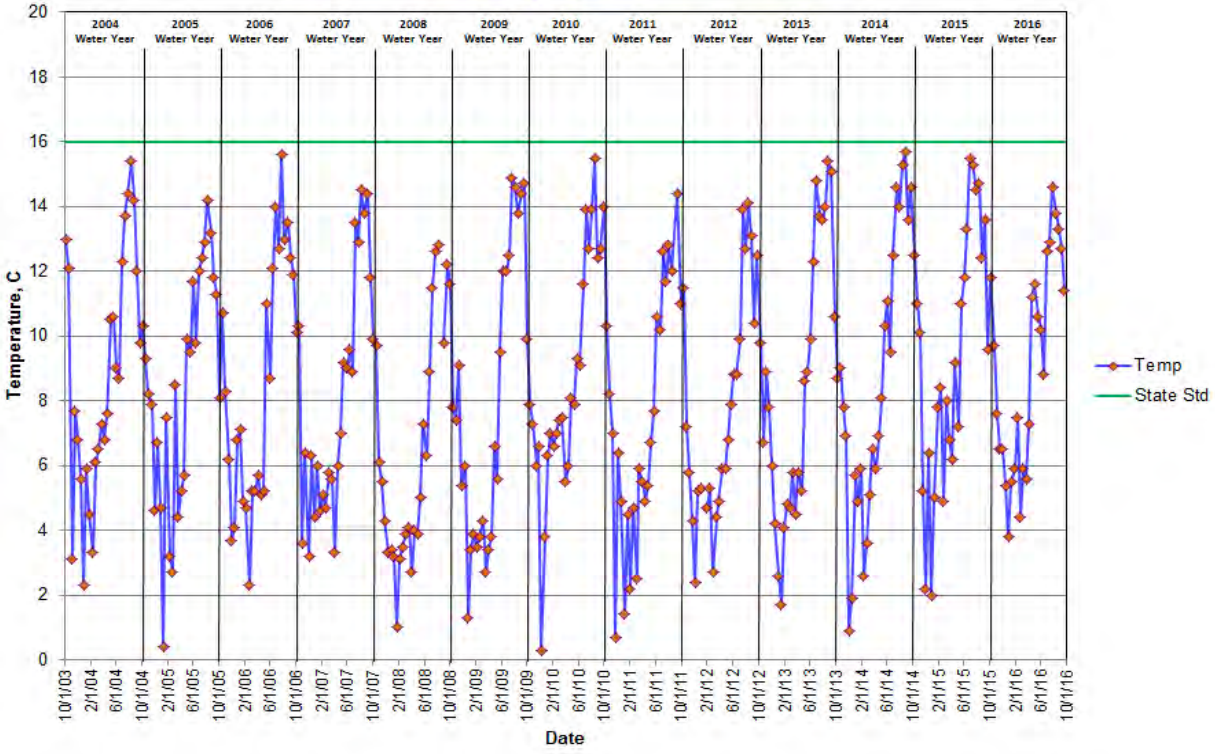
Hansen Creek at Northern State Hospital - Site 20
Temperature



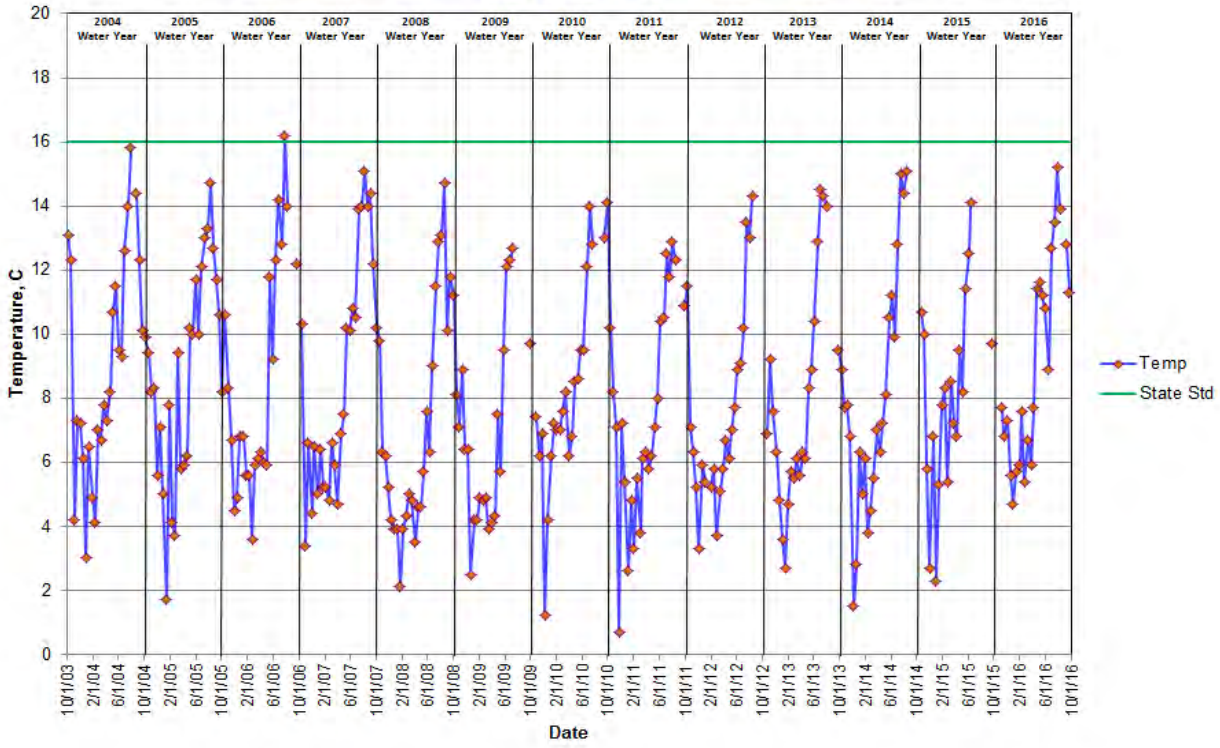
Coal Creek at Hoehn Road - Site 21
Temperature



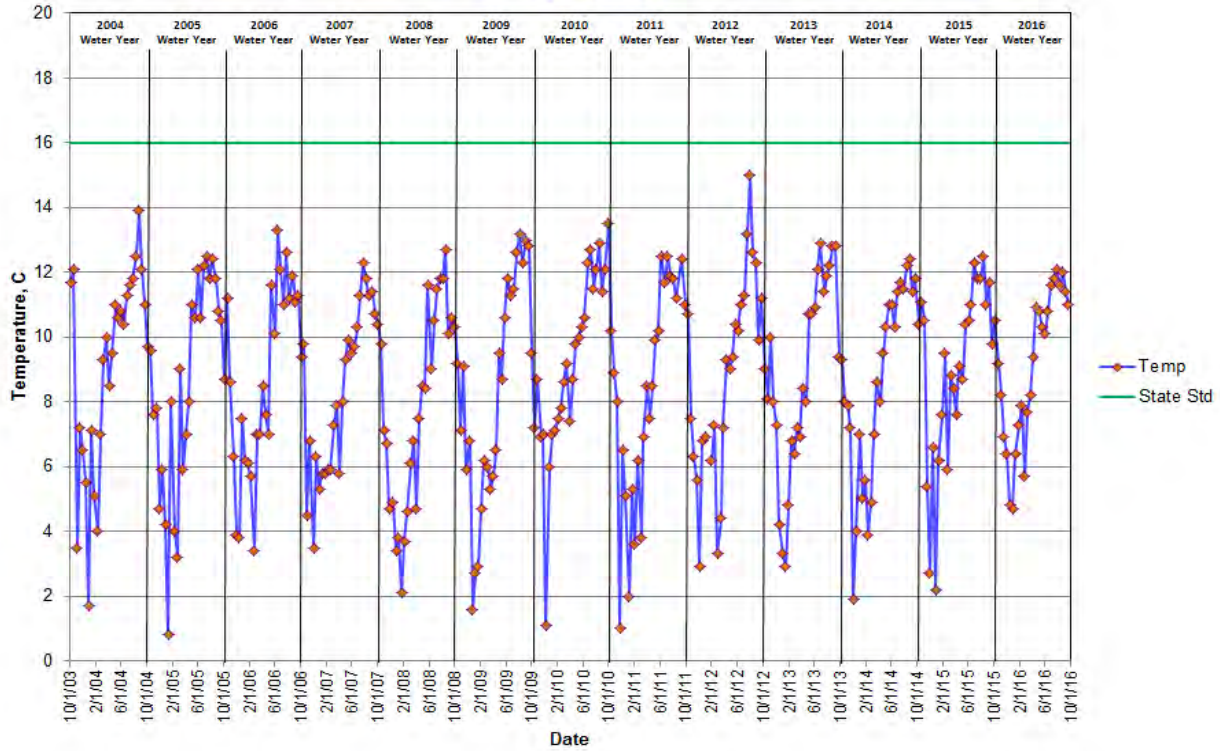
Coal Creek at Highway 20 - Site 22
Temperature



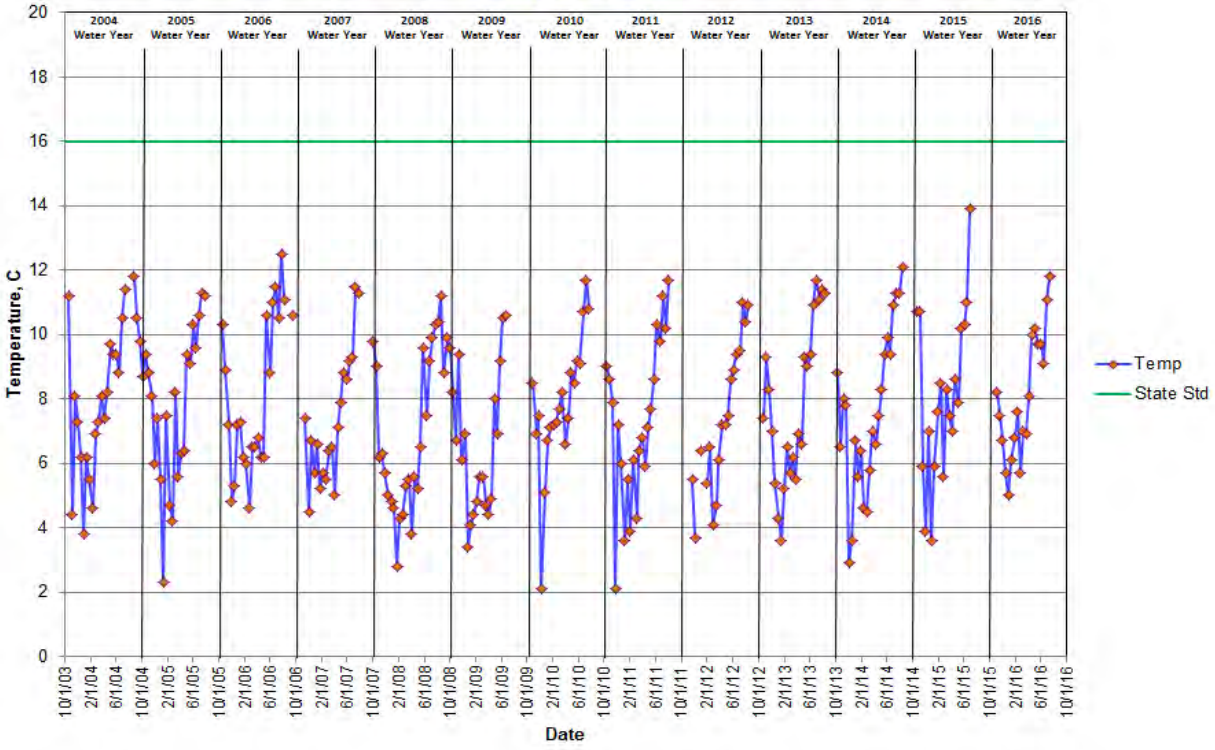
Wiseman Creek at Minkler Road - Site 23
Temperature



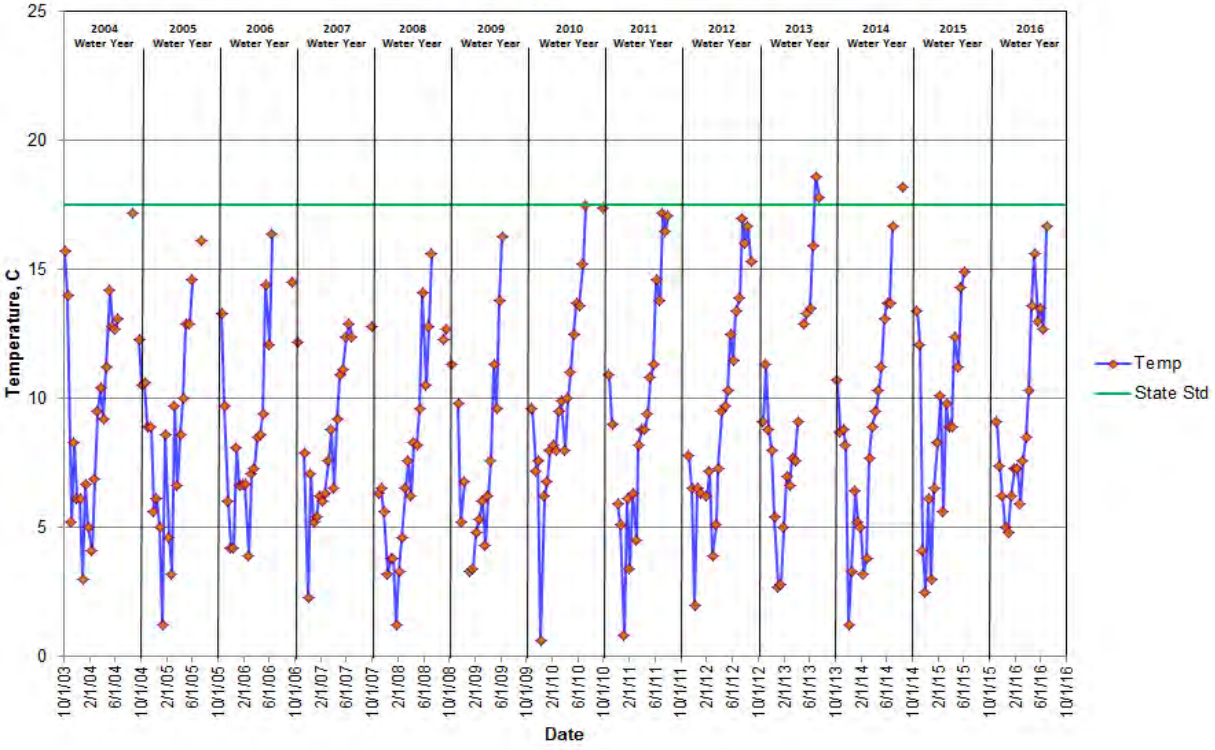
Mannser Creek at Lyman-Hamilton Highway - Site 24
Temperature



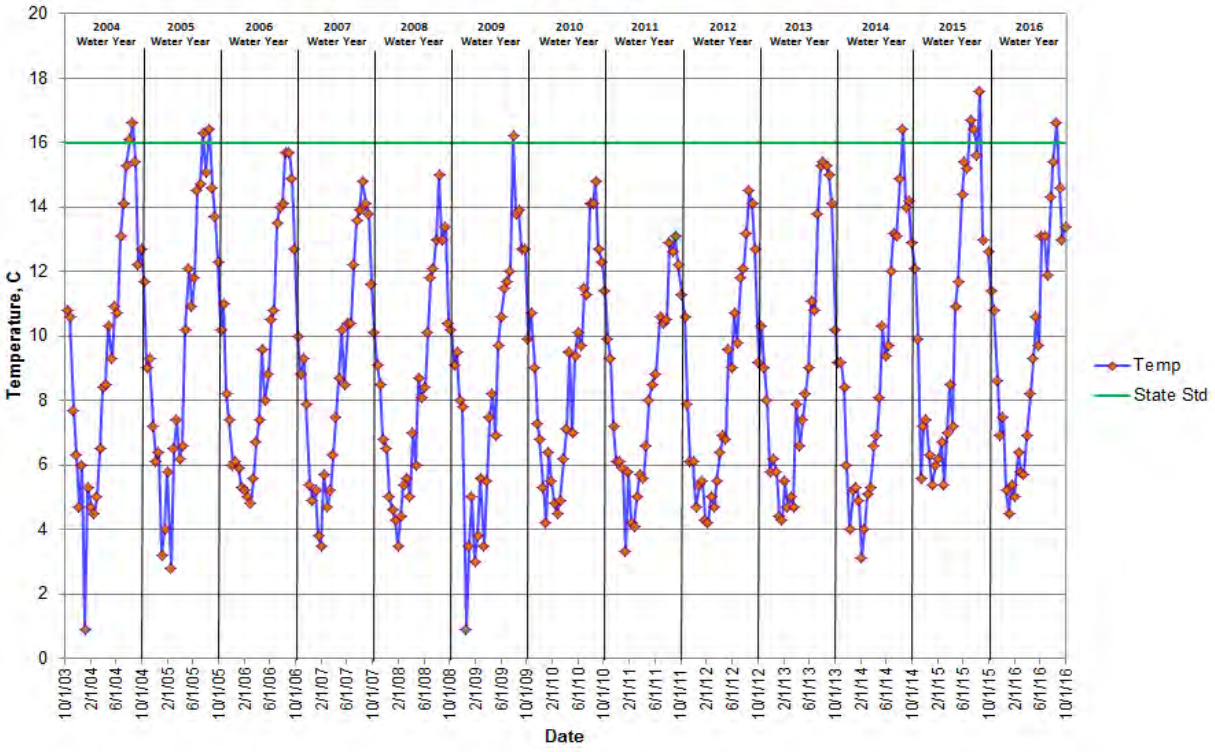
Red Cabin Creek at Hamilton Cemetery Road - Site 25
Temperature



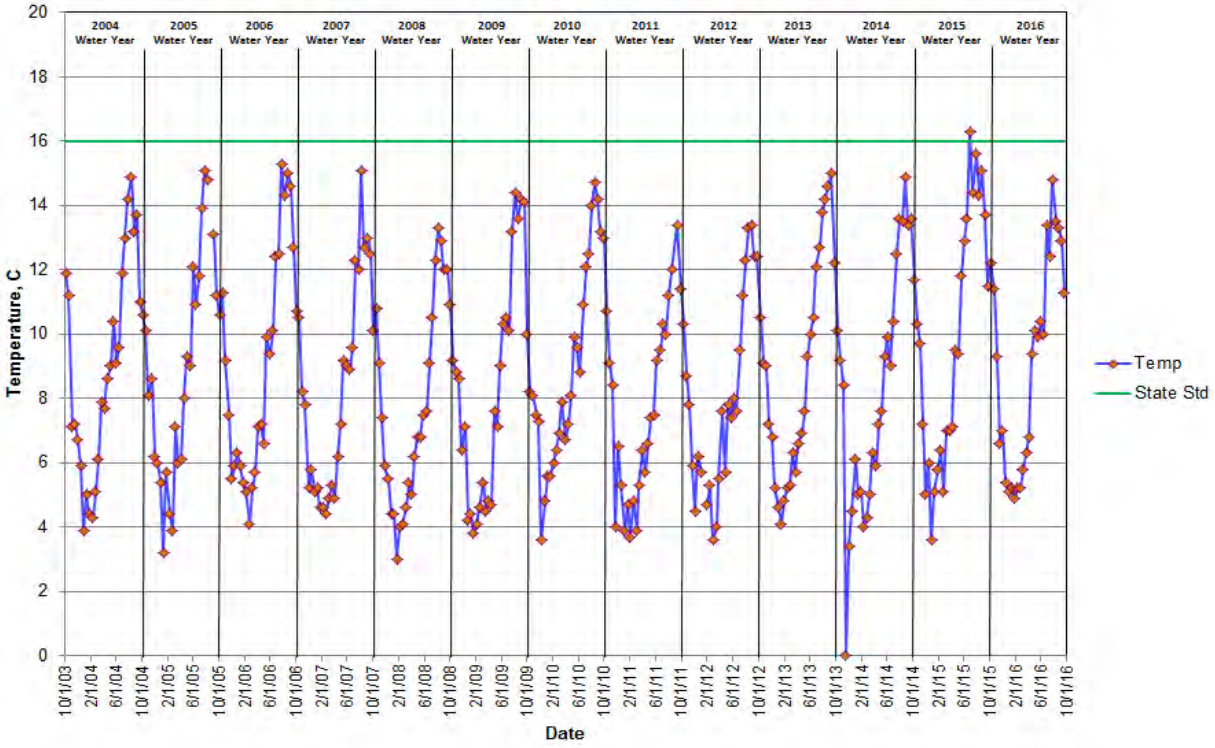
Brickyard Creek at Highway 20 - Site 28
Temperature



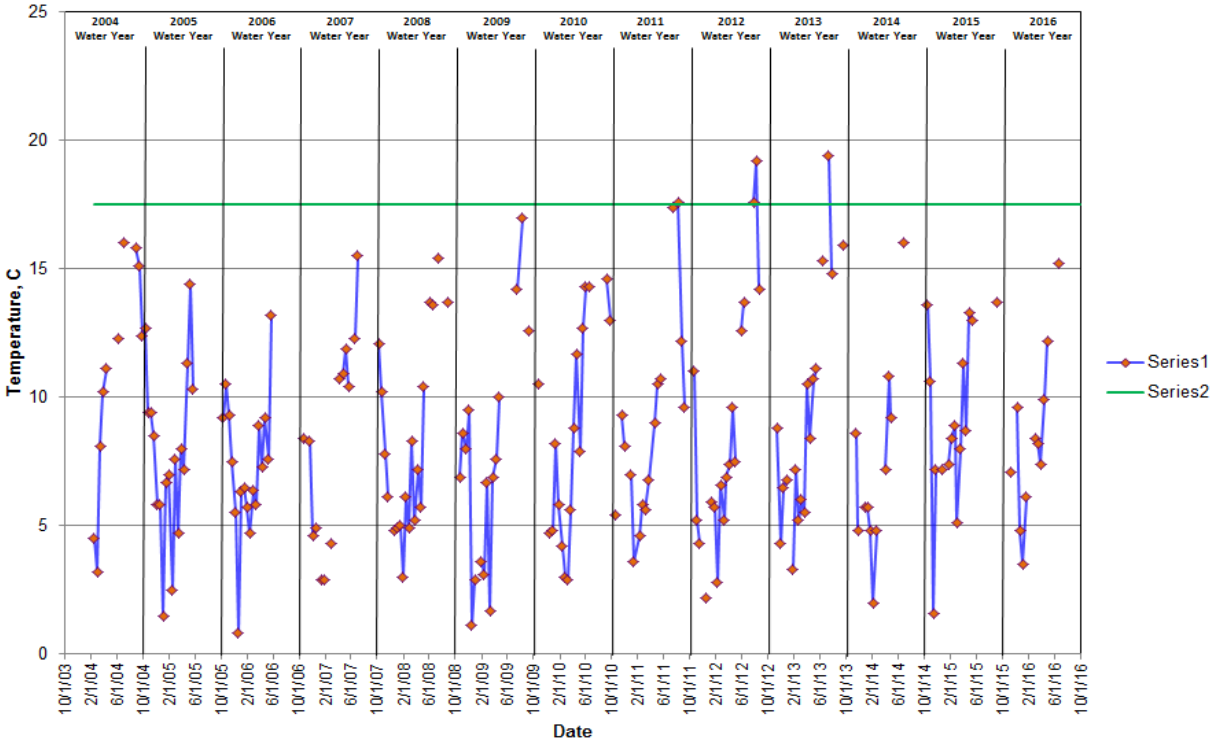
Skagit River at River Bend Road - Site 29
Temperature



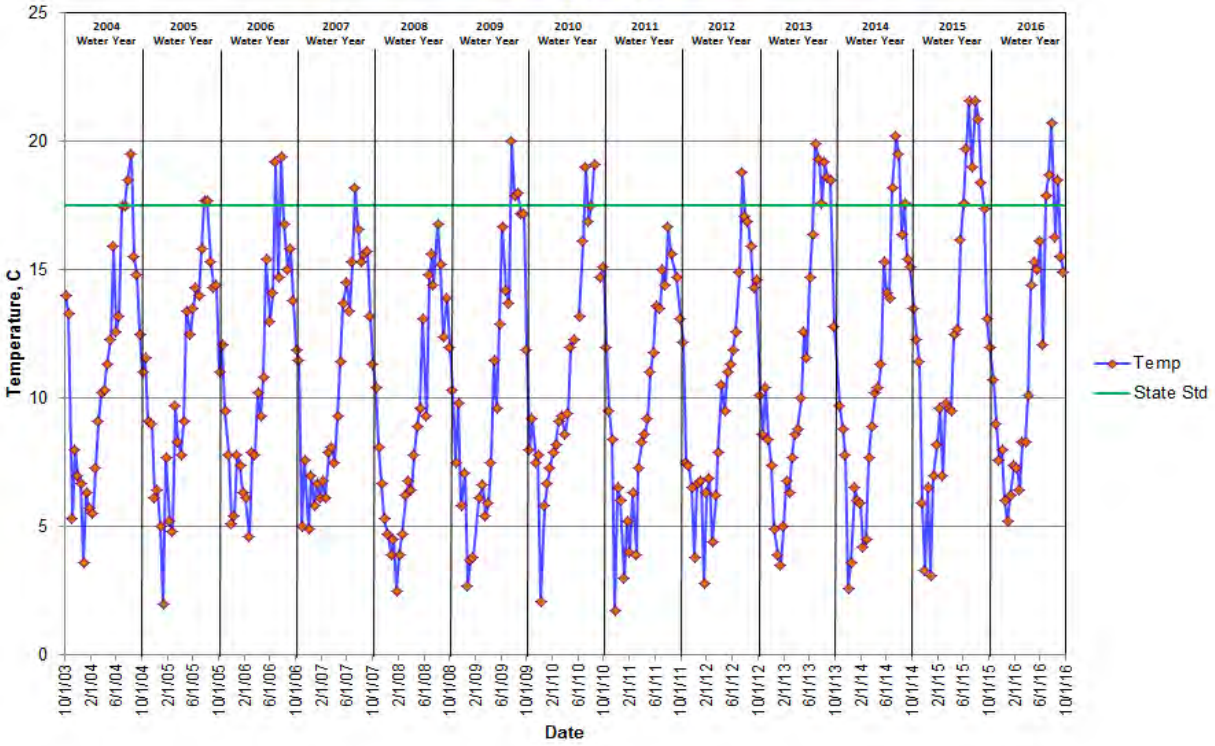
Skagit River at Cape Horn Road - Site 30
Temperature



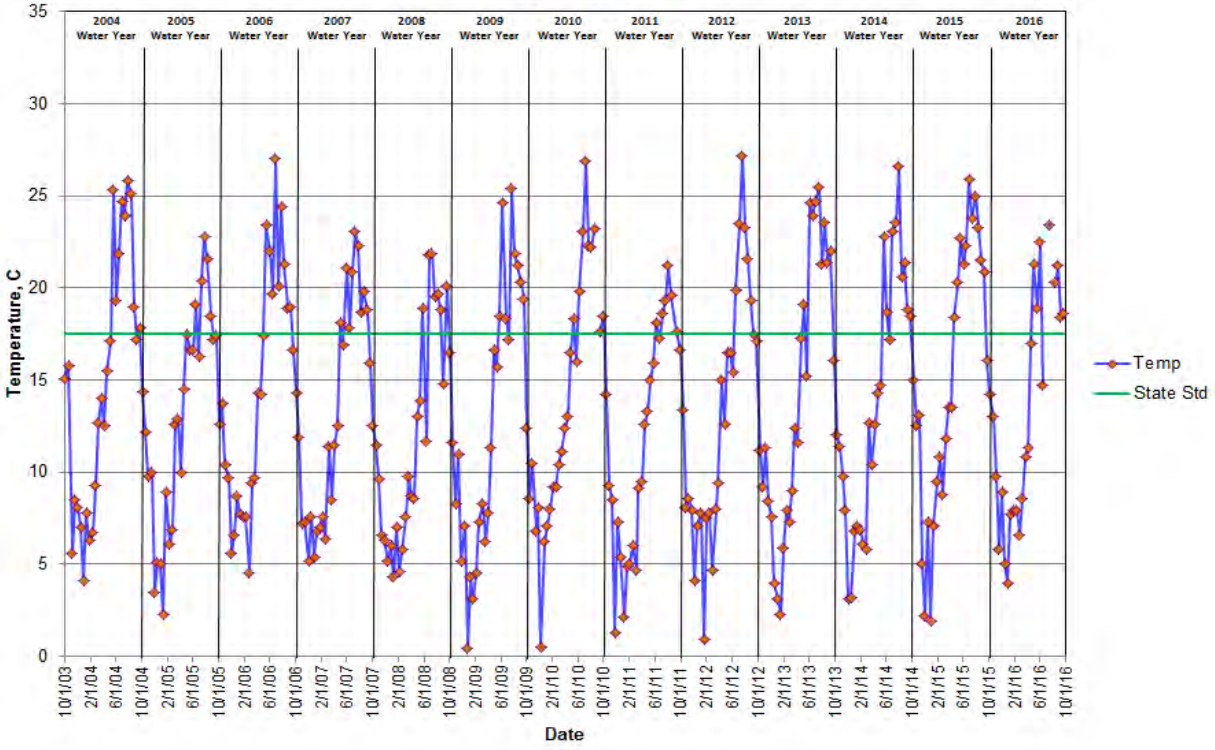
Drainage District 20 Ditch at Floodgate - Site 31
Temperature



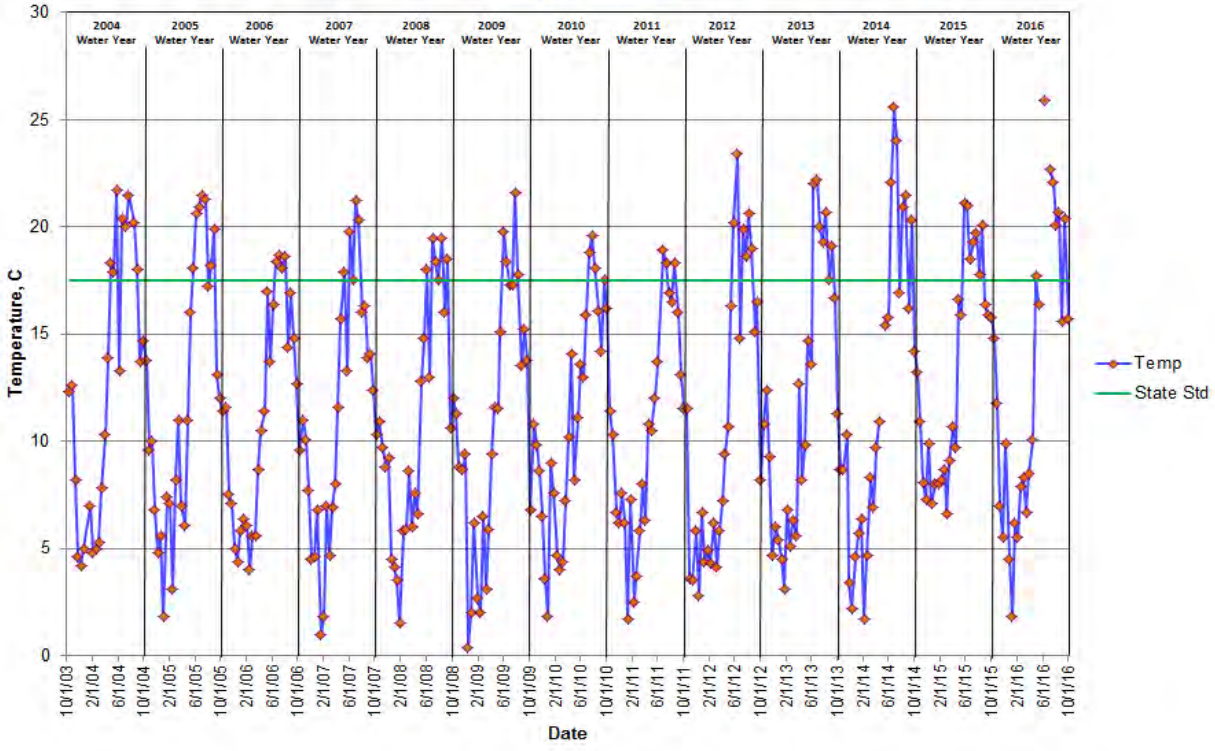
Samish River at Thomas Road - Site 32
Temperature



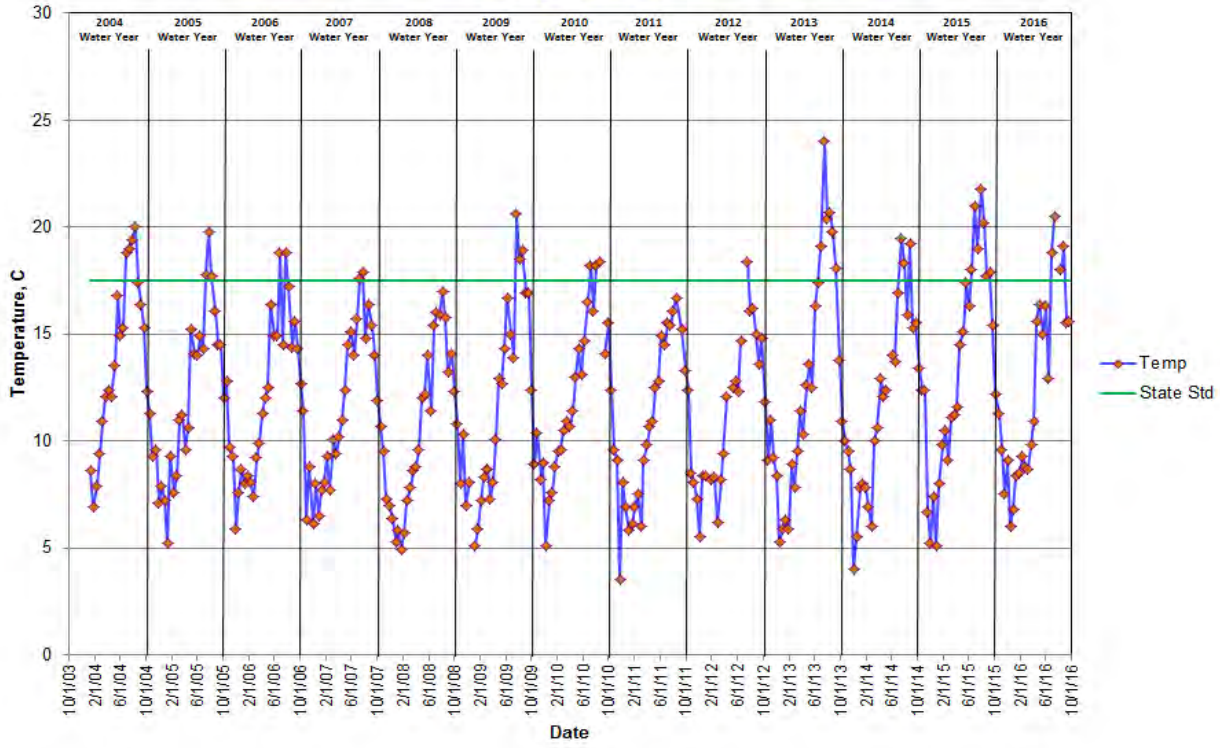
Alice Bay Pump Station - Site 33
Temperature



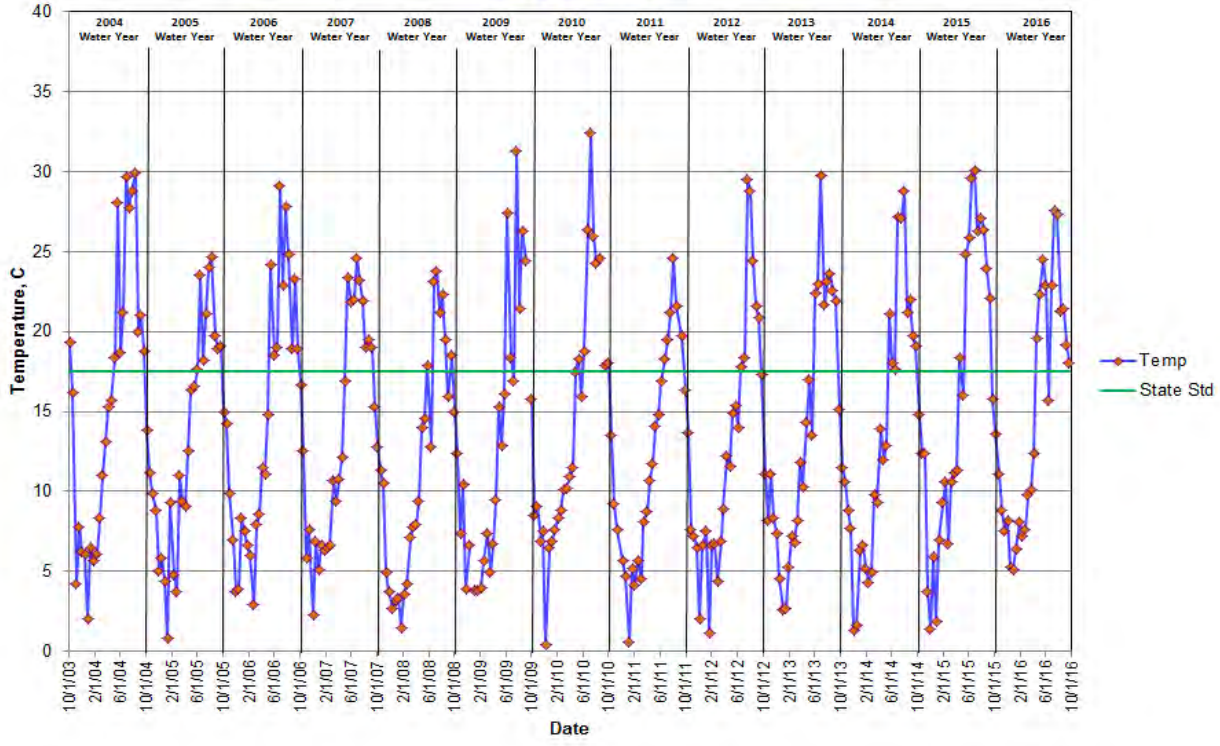
No Name Slough at Bayview-Edison Road - Site 34
Temperature



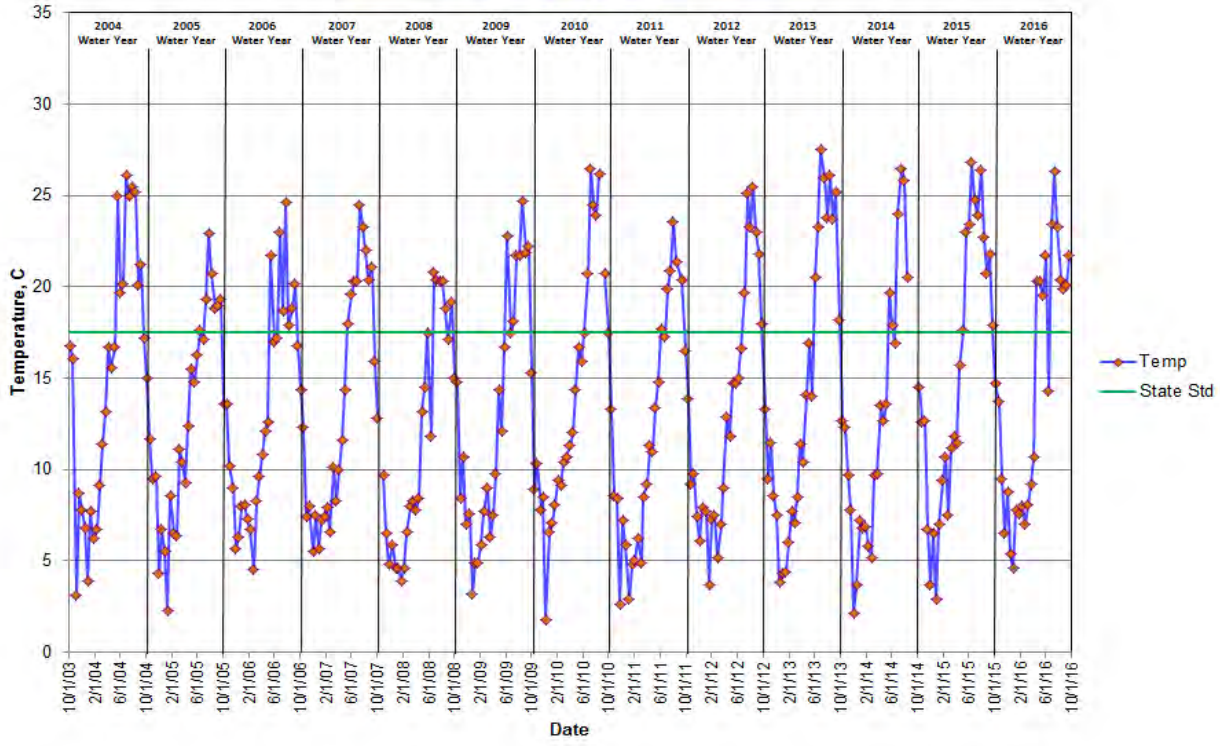
Joe Leary Slough at D'Arcy Road - Site 35
Temperature



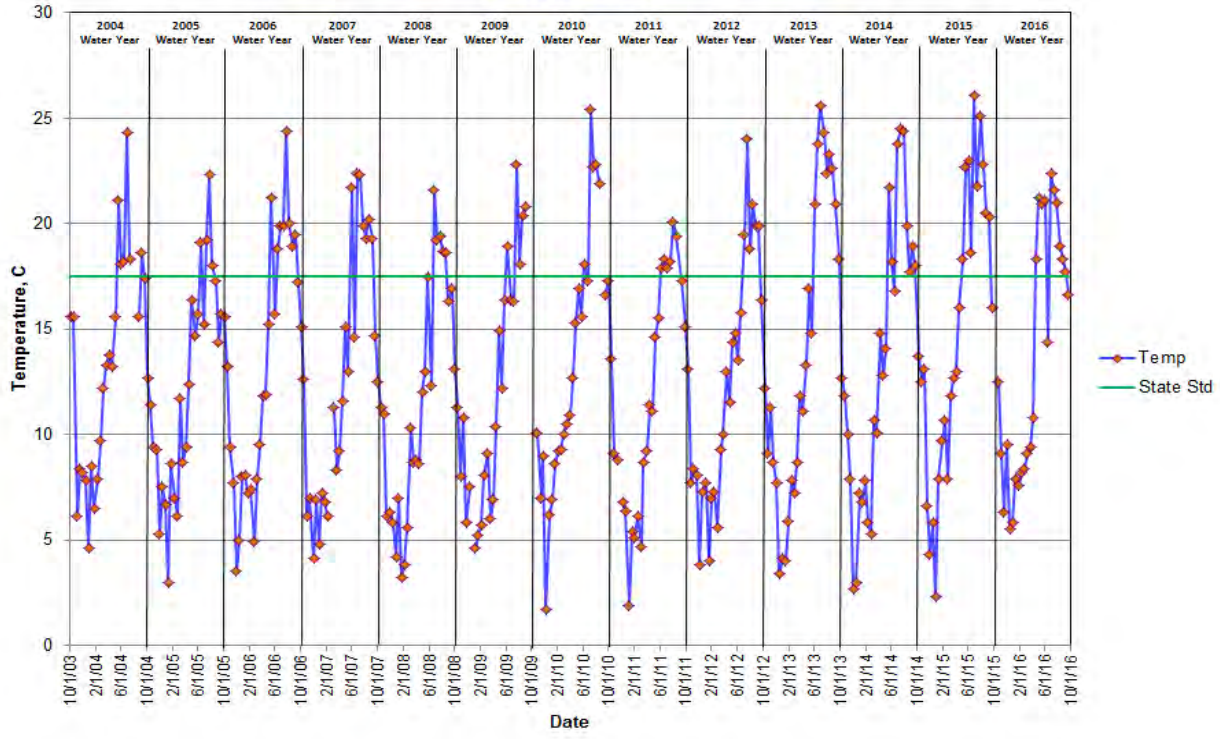
Edison Slough at Edison School - Site 36
Temperature



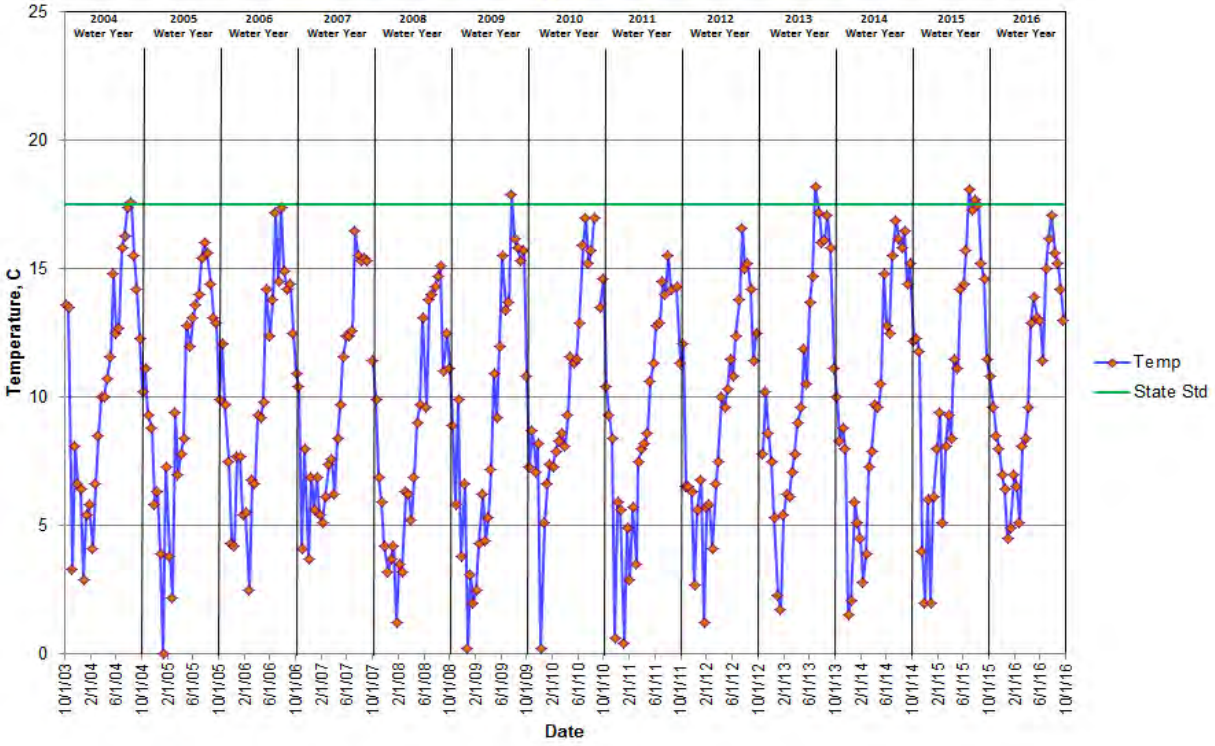
Edison Pump Station - Site 37
Temperature



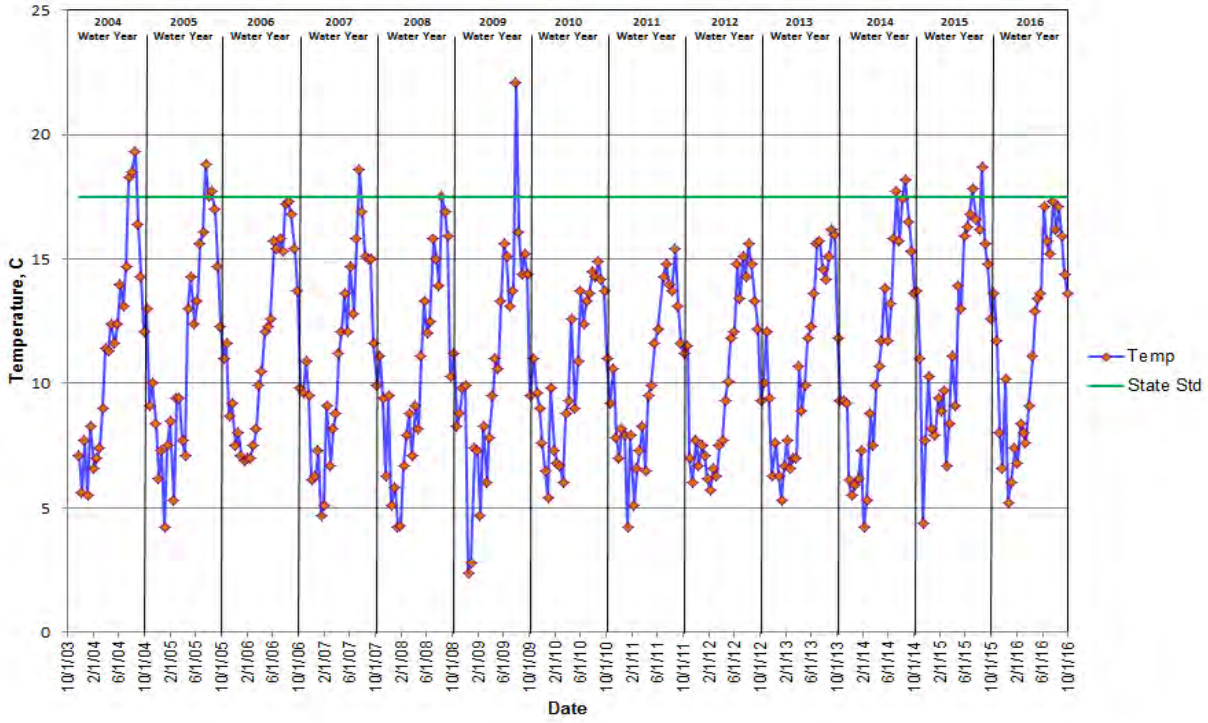
North Edison Pump Station - Site 38
Temperature



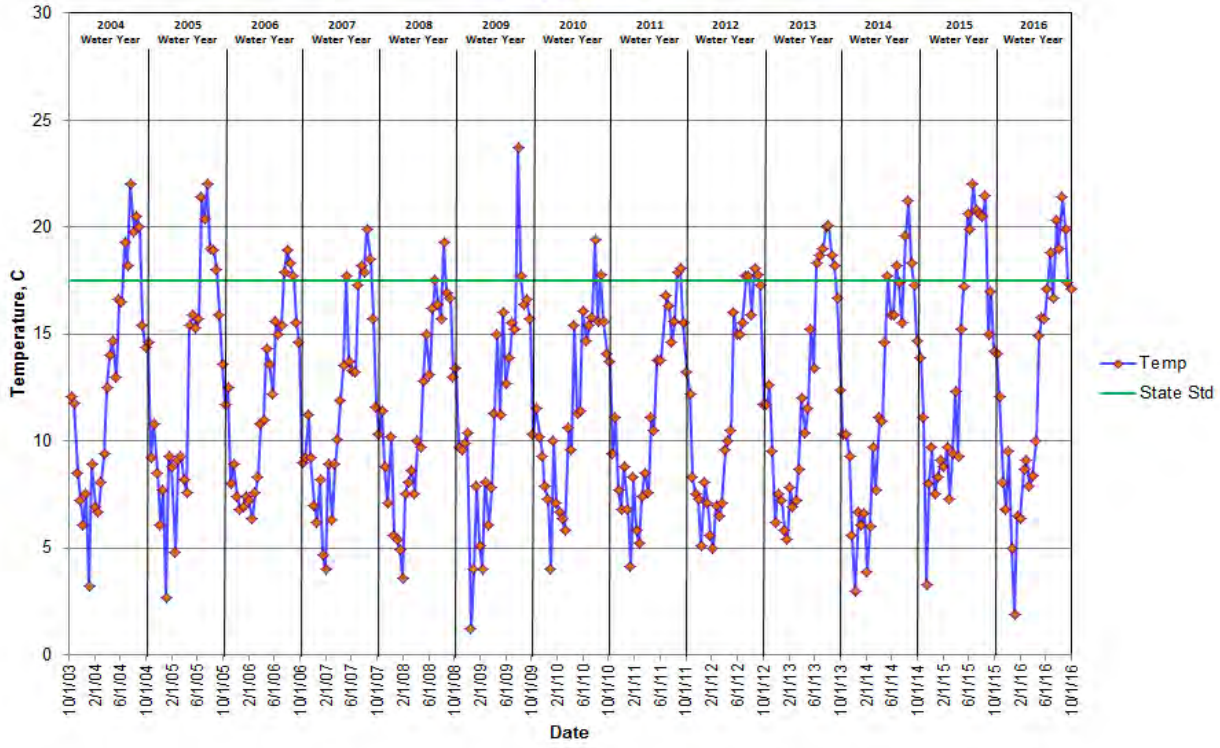
Colony Creek at Colony Road - Site 39
Temperature



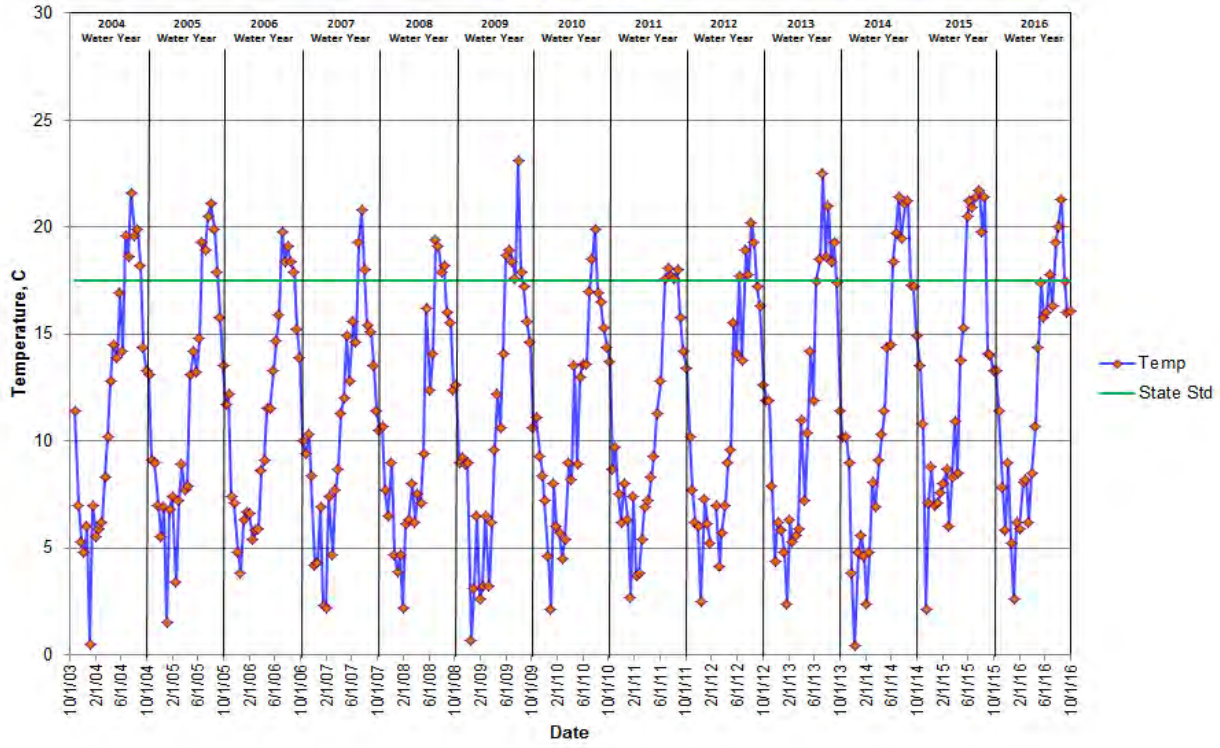
Big Indian Slough at Highway 20 Truck Scales - Site 40
Temperature



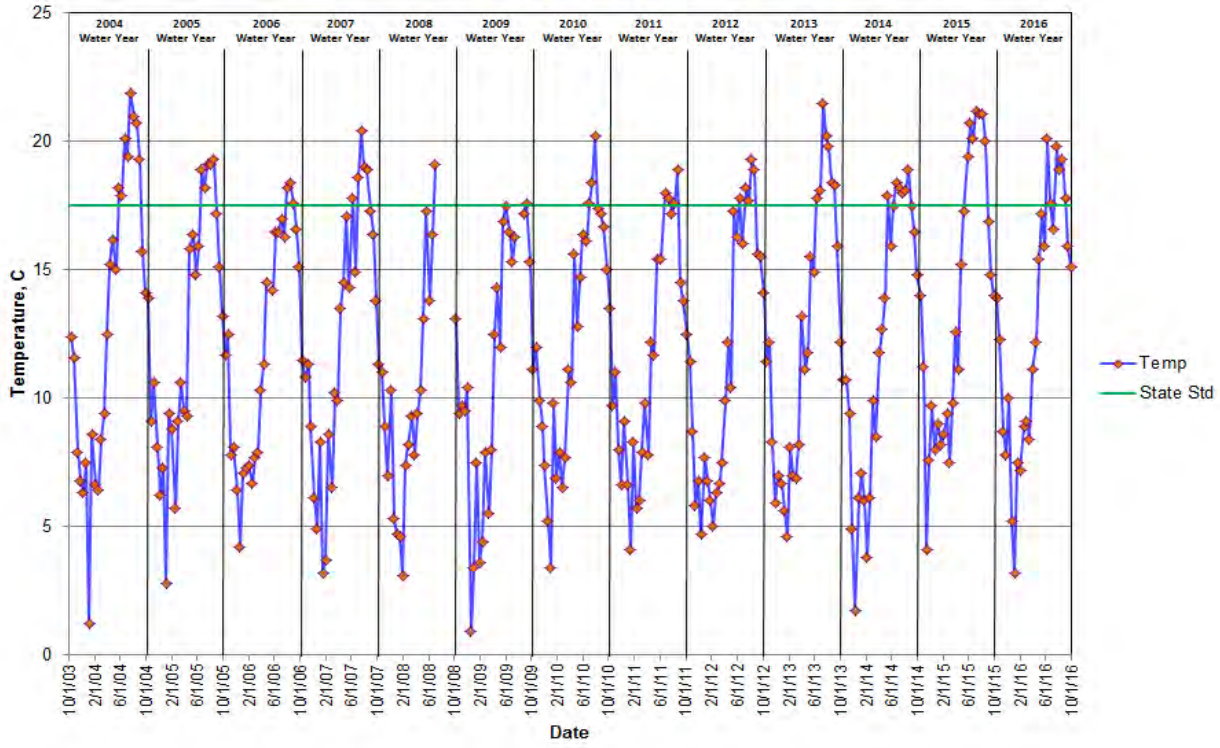
Maddox Creek/Big Ditch at Milltown Road - Site 41
Temperature



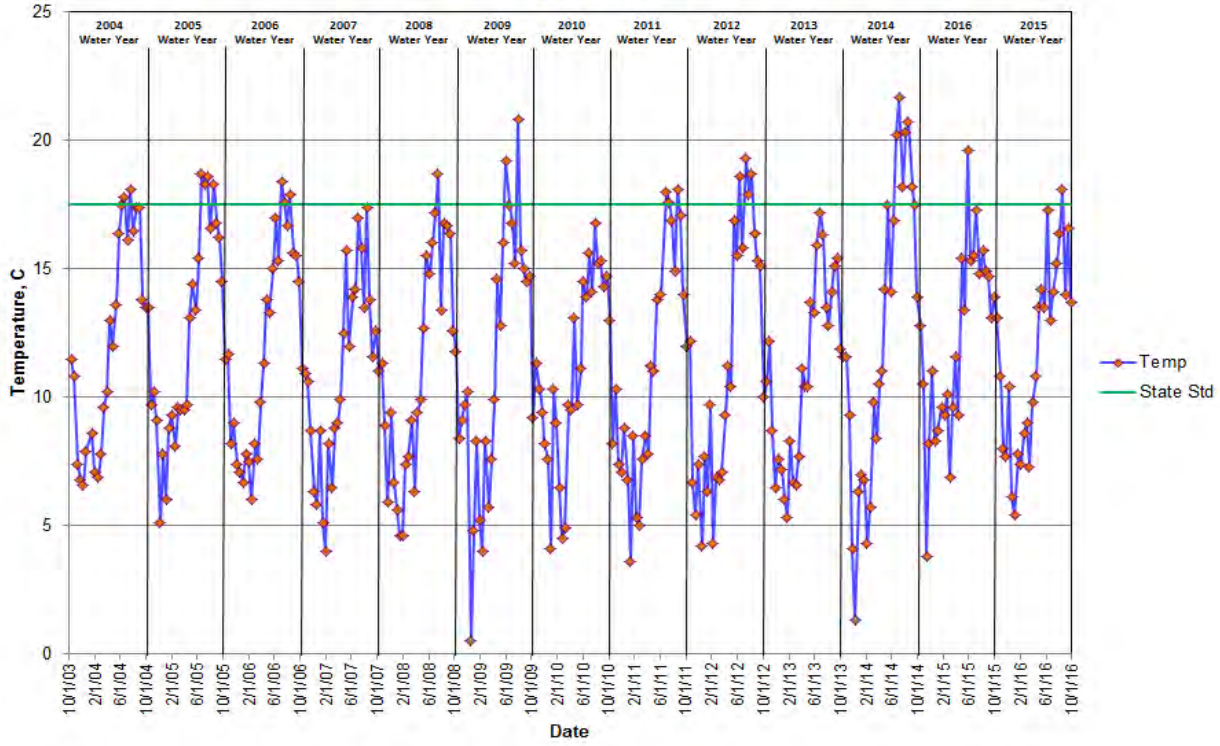
Carpenter Creek/Hill Ditch at Cedardale Road - Site 42
Temperature



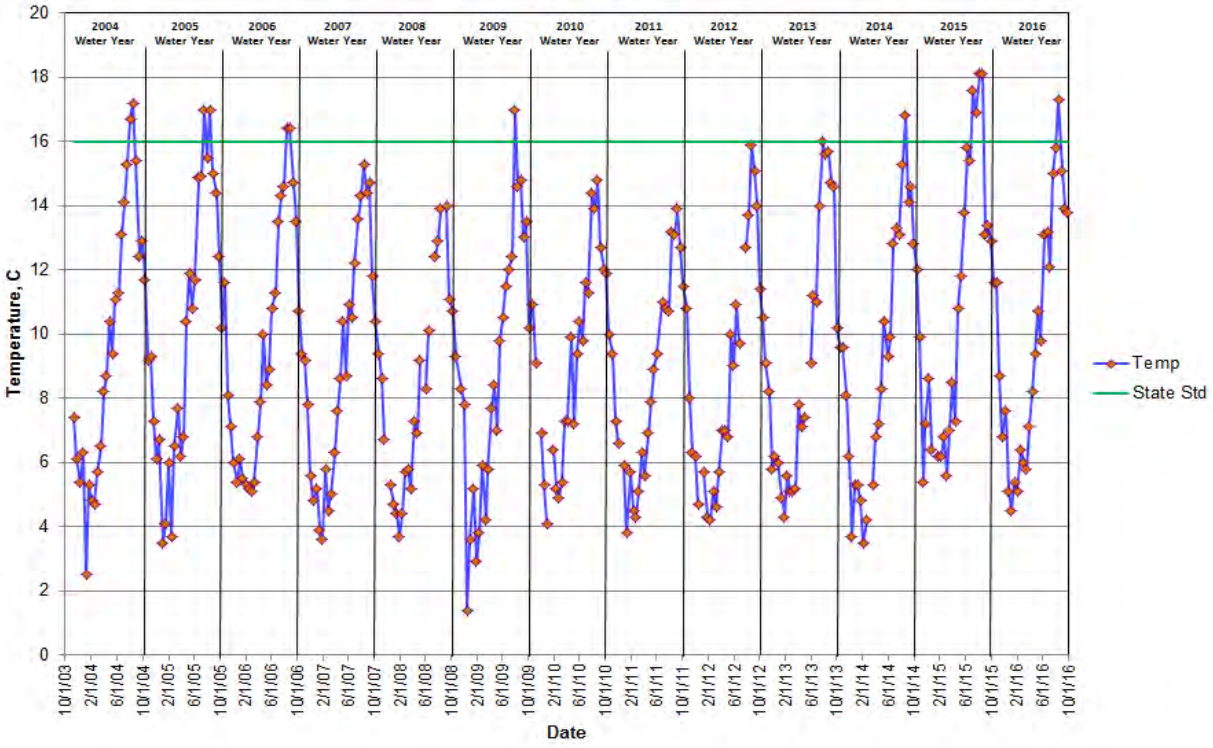
Wiley Slough at Wylie Road - Site 43
Temperature



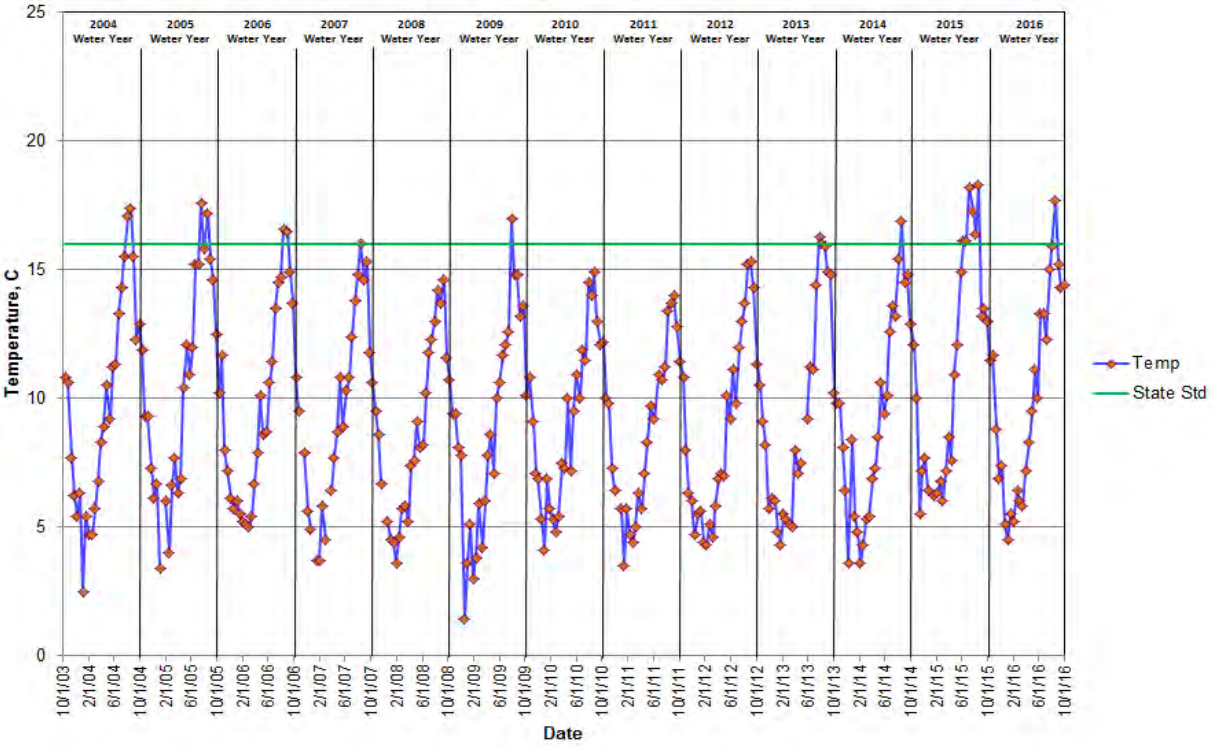
Sullivan Slough at LaConner-Whitney Road - Site 44
Temperature



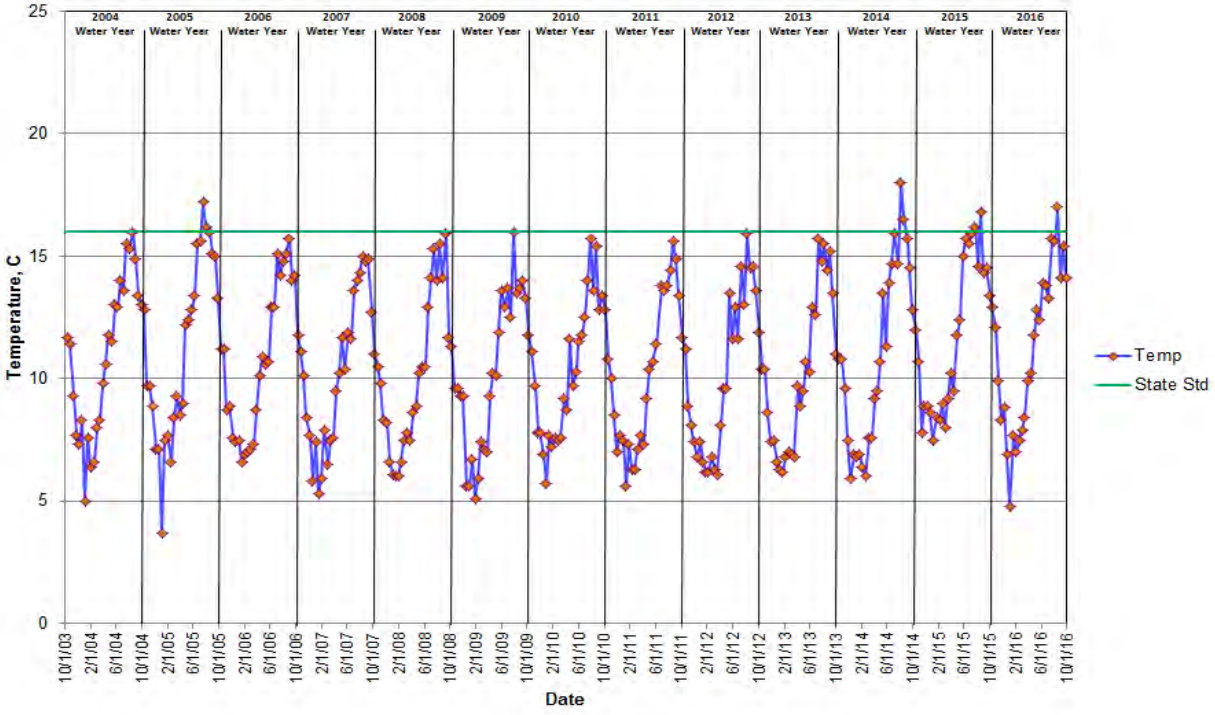
North Fork Skagit River near Moore Road - Site 45
Temperature



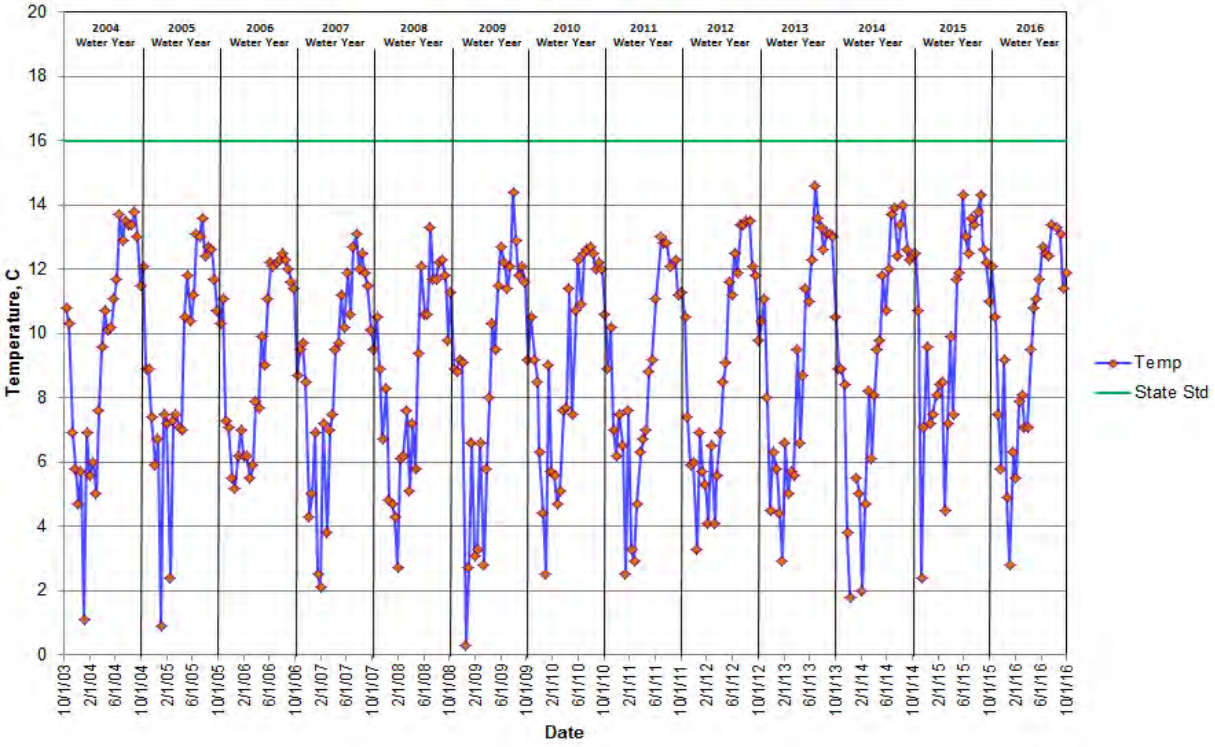
South Fork Skagit River at Conway Boat Ramp - Site 46
Temperature



Swinomish Channel at County Boat Ramp - Site 47
Temperature



Fisher Creek at Franklin Road - Site 48
Temperature



Dissolved Oxygen

Dissolved oxygen (DO) measurements determine how much oxygen is available in the water for fish and other organisms. DO measurements were taken with a meter at each site during each visit, except in rare instances of equipment malfunction. A summary of DO readings (in mg/L) obtained during the 2016 water year is provided in Table 5. Table 6 summarizes data from the last five years of the study. The pages following Table 6 contain graphs illustrating dissolved oxygen levels at all sample sites for the 2004-2016 water years. Gaps in the data represent streams that were either flooded or dry at sampling time, or may represent equipment malfunctions.

The state water quality standards for dissolved oxygen are based on single-day minimum measurements. For some lowland watercourses in the Skagit County Monitoring Program (Sites 3-4, 28, 31-44, and 48), the minimum standard is 8.0 mg/L. For the marine site (Site 47), the standard is 6.0 mg/L. For all other sites, the standard is 9.5 mg/L. The solubility of oxygen in water is inversely related to temperature, so that higher temperatures frequently result in lower dissolved oxygen values.

Seven sites met the oxygen standards in the 2016 water year – compared to six sites in 2015 and only one site in 2014. Others met the oxygen standard for most of the year. In a few streams, oxygen levels showed steep declines in summer as can be seen by the graphs on the following pages. These declines are usually associated with very low flows.

In the drainage infrastructure and lower sloughs, dissolved oxygen levels can be greatly influenced by algal activity. During large algae blooms, the oxygen produced during photosynthesis can lead to very high oxygen levels during the day. However, at those same times, nighttime oxygen levels can be very low as the large populations of algae turn from producing oxygen to consuming it. Because our oxygen readings are taken during the day, the monitoring program does not account for these nighttime oxygen reductions. During times when algae blooms are dying off, the decomposition of the dying algae can lead to very low oxygen levels both day and night. The results, as can be seen in the graphs of the drainage sites, are widely fluctuating dissolved oxygen levels depending on the state of the algal blooms at sampling time.

Table 5. Dissolved Oxygen Results
Summary of Dissolved Oxygen (DO) measurements in the Skagit County Monitoring Program 2016 Water Year

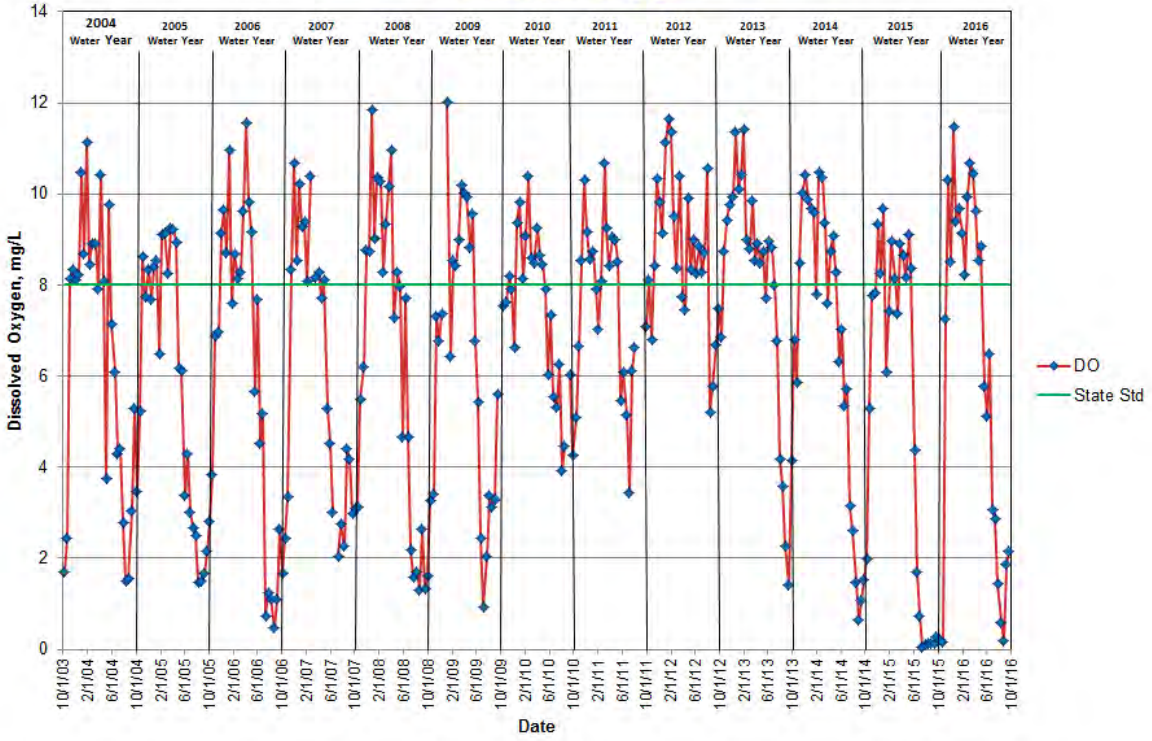
Site Number	Watercourse	Location	Mean DO (mg/L)	Minimum DO (mg/L)	St. Std[1]
3	Thomas Creek	Old Hwy 99 N	6.23	0.17	8.0
4	Thomas Creek	F&S Grade Rd	11.24	9.76	8.0
6	Friday Creek	Prairie Rd	11.38	9.71	9.5
8	Swede Creek	Grip Rd	10.37	6.45	9.5
11	Samish River	State Route 9	8.66	6.65	9.5
12	Nookachamps Creek	Swan Rd	9.06	6.26	9.5
13	E.F. Nookachamps Creek	State Route 9	9.87	7.80	9.5
14	College Way Creek	College Way	9.04	5.34	9.5
15	Nookachamps Creek	Knapp Rd	7.74	1.54	9.5
16	E.F. Nookachamps Creek	Beaver Lake Rd	11.27	9.00	9.5
17	Nookachamps Creek	Big Lake Outlet	9.58	6.98	9.5
18	Lake Creek	State Route 9	10.77	8.24	9.5
19	Hansen Creek	Hoehn Rd	10.17	7.52	9.5
20	Hansen Creek	Northern State	11.27	9.61	9.5
21	Coal Creek	Hoehn Rd	11.21	8.68	9.5
22	Coal Creek	Hwy 20	11.58	9.89	9.5
23	Wiseman Creek	Minkler Rd	11.60	8.87	9.5
24	Mannser Creek	Lyman Hamilton Hwy	7.00	4.89	9.5
25	Red Cabin Creek	Hamilton Cemetery Rd	12.08	11.33	9.5
28	Brickyard Creek	Hwy 20	9.22	5.91	8.0
29	Skagit River	River Bend Rd	11.03	9.03	9.5
30	Skagit River	Cape Horn Rd	11.20	7.64	9.5
31	Drainage District 20 floodgate	Francis Rd	7.42	3.01	8.0
32	Samish River	Thomas Rd	10.91	9.21	8.0
33	Alice Bay Pump Station	Samish Island Rd	10.28	3.59	8.0
34	No Name Slough	Bayview-Edison Rd	7.58	0.00	8.0
35	Joe Leary Slough	D'Arcy Rd	5.40	3.54	8.0
36	Edison Slough at school	West Bow Hill Rd	9.91	2.59	8.0
37	Edison Pump Station	Farm to Market Rd	8.64	3.35	8.0
38	North Edison Pump Station	North Edison Rd	10.35	3.07	8.0
39	Colony Creek	Colony Rd	10.69	7.63	8.0
40	Big Indian Slough	Bayview-Edison Rd	4.07	0.51	8.0
41	Maddox Slough/Big Ditch	Milltown Rd	7.77	3.54	8.0
42	Hill Ditch	Cedardale Rd	8.99	5.17	9.5
43	Wiley Slough	Wylie Rd	5.27	0.69	8.0
44	Sullivan Slough	La Conner-Bayview Rd	6.24	2.56	8.0
45	Skagit River – North Fork	Moore Rd	11.00	8.37	9.5
46	Skagit River – South Fork	Fir Island Rd	11.28	9.13	9.5
47	Swinomish Channel	County Boat Launch	8.53	6.47	6.0
48	Fisher Creek	Franklin Rd	10.98	8.71	9.5

[1]Washington State Water Quality Standard per WAC 173-201A

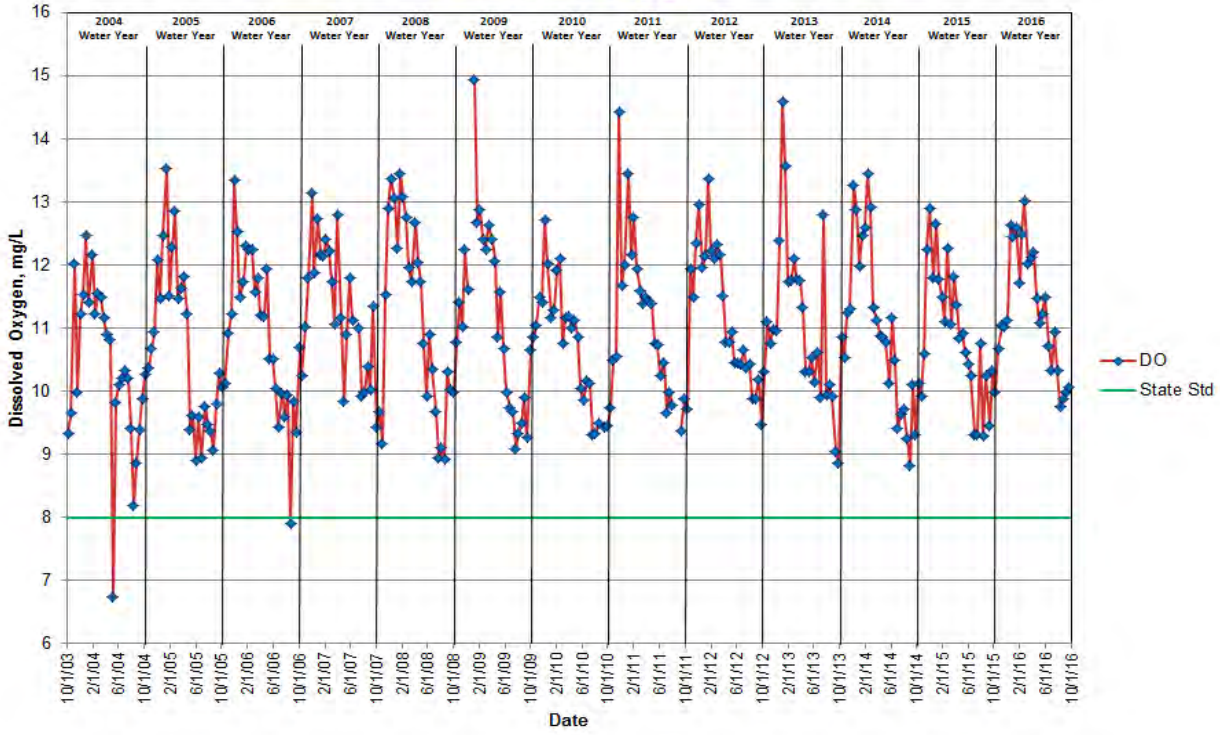
Table 6. Dissolved Oxygen Results Summary
Mean Dissolved Oxygen levels for five years of the Skagit County Monitoring Program

Site Number	Watercourse	Location	Mean Dissolved Oxygen (mg/L)				
			2012	2013	2014	2015	2016
3	Thomas Creek	Old Hwy 99 North	8.7	7.9	6.9	5.4	6.2
4	Thomas Creek	F&S Grade Rd	11.2	11.1	11.0	10.9	11.2
6	Friday Creek	Prairie Rd	11.2	11.0	11.1	10.8	11.4
8	Swede Creek	Grip Rd	10.7	10.7	10.8	10.3	10.4
11	Samish River	State Route 9	8.6	8.7	8.5	8.3	8.7
12	Nookachamps Creek	Swan Rd	8.9	9.5	9.3	8.0	9.1
13	E.F. Nookachamps Creek	State Route 9	9.5	10	9.9	9.0	9.9
14	College Way Creek	College Way	8.9	8.8	9.2	8.5	9.0
15	Nookachamps Creek	Knapp Rd	8.0	8.0	8.1	7.3	7.7
16	E.F. Nookachamps Creek	Beaver Lake Rd	11.3	11.5	11.4	10.7	11.3
17	Nookachamps Creek	Big Lake Outlet	9.9	9.7	9.9	9.1	9.6
18	Lake Creek	State Route 9	10.6	10.8	11.0	10.5	10.8
19	Hansen Creek	Hoehn Rd	10.2	9.9	10.4	9.8	10.2
20	Hansen Creek	Northern State	11.0	11.1	11.1	10.7	11.3
21	Coal Creek	Hoehn Rd	11.0	10.9	11.0	10.8	11.2
22	Coal Creek	Hwy 20	11.7	11.6	11.8	11.2	11.6
23	Wiseman Creek	Minkler Rd	11.9	11.8	11.8	11.8	11.6
24	Mannser Creek	Lyman Hamilton Hwy	5.6	6.0	6.4	7.2	7.0
25	Red Cabin Creek	Hamilton Cemetery Rd	11.8	11.6	11.7	11.4	12.1
28	Brickyard Creek	Hwy 20	9.2	9.0	9.1	8.8	9.2
29	Skagit River	River Bend Rd	11.4	11.0	11.1	10.6	11.0
30	Skagit River	Cape Horn Rd	11.3	10.9	11.2	10.9	11.2
31	DD20 near floodgate	Francis Rd	7.6	7.3	8.0	5.7	7.4
32	Samish River	Thomas Rd	10.8	10.8	10.7	10.4	10.9
33	Alice Bay Pump Station	Samish Island Rd	8.9	8.4	9.2	9.3	10.3
34	No Name Slough	Bayview-Edison Rd	7.0	5.9	6.6	6.6	7.6
35	Joe Leary Slough	D'Arcy Rd	5.4	5.5	5.2	5.3	5.4
36	Edison Slough at school	W. Bow Hill Rd	9.1	9.3	8.8	8.7	9.9
37	Edison Pump Station	Farm to Market Rd	8.7	6.7	6.9	6.0	8.6
38	North Edison Pump Station	North Edison Rd	5.7	7.8	7.2	6.5	10.4
39	Colony Creek	Colony Rd	10.8	10.7	10.8	10.2	10.7
40	Big Indian Slough	Bayview-Edison Rd	5.5	5.2	5.1	4.3	4.1
41	Maddox Slough/Big Ditch	Milltown Rd	5.8	5.2	5.9	5.7	7.8
42	Hill Ditch	Cedardale Rd	8.4	9.4	8.0	8.9	9.0
43	Wiley Slough	Wylie Rd	4.6	5.6	5.0	5.3	5.3
44	Sullivan Slough	La Conner-Whitney Rd	7.0	6.4	6.9	6.7	6.2
45	Skagit River – North Fork	Moore Rd	11.4	11.2	11.3	10.7	11.0
46	Skagit River – South Fork	Fir Island Rd	11.2	11.2	11.2	10.8	11.3
47	Swinomish Channel	County Boat Launch	8.8	8.6	8.7	8.4	8.5
48	Fisher Creek	Franklin Rd	11.1	10.9	11.0	10.7	11.0

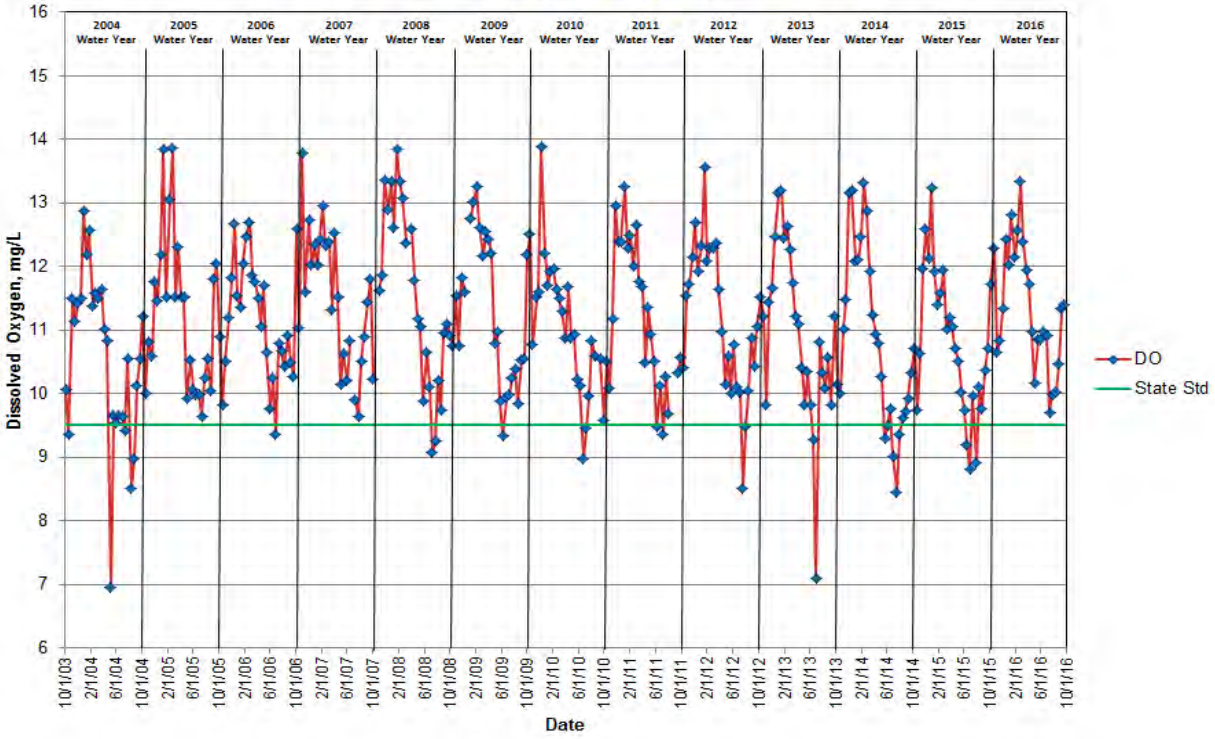
Thomas Creek at Highway 99 - Site 3
Dissolved Oxygen



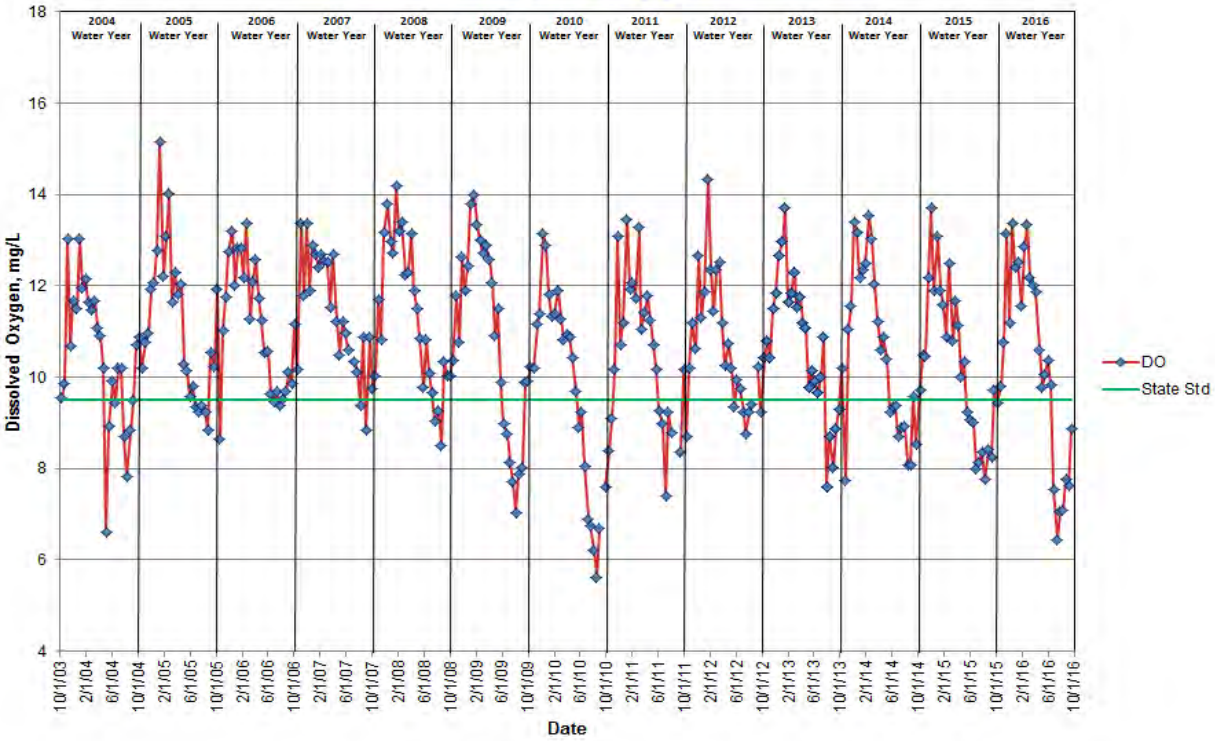
Thomas Creek at F&S Grade Road - Site 4
Dissolved Oxygen



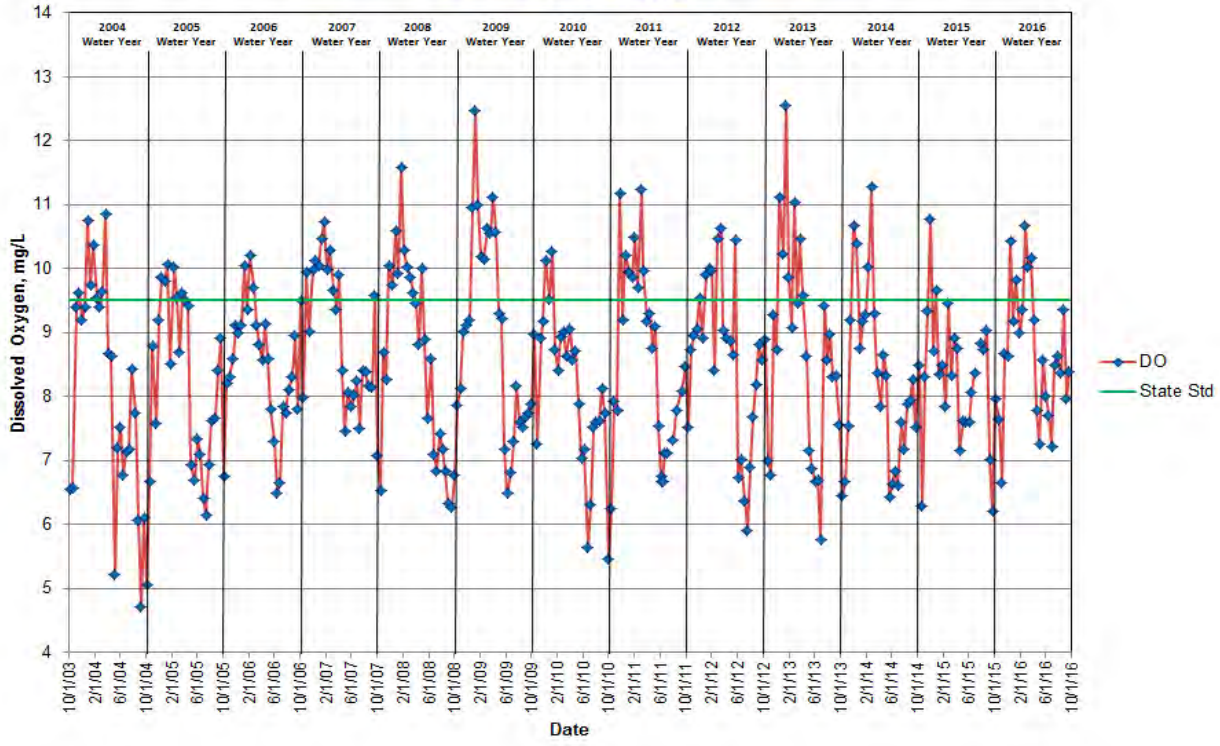
Friday Creek at Prairie Road - Site 6
Dissolved Oxygen



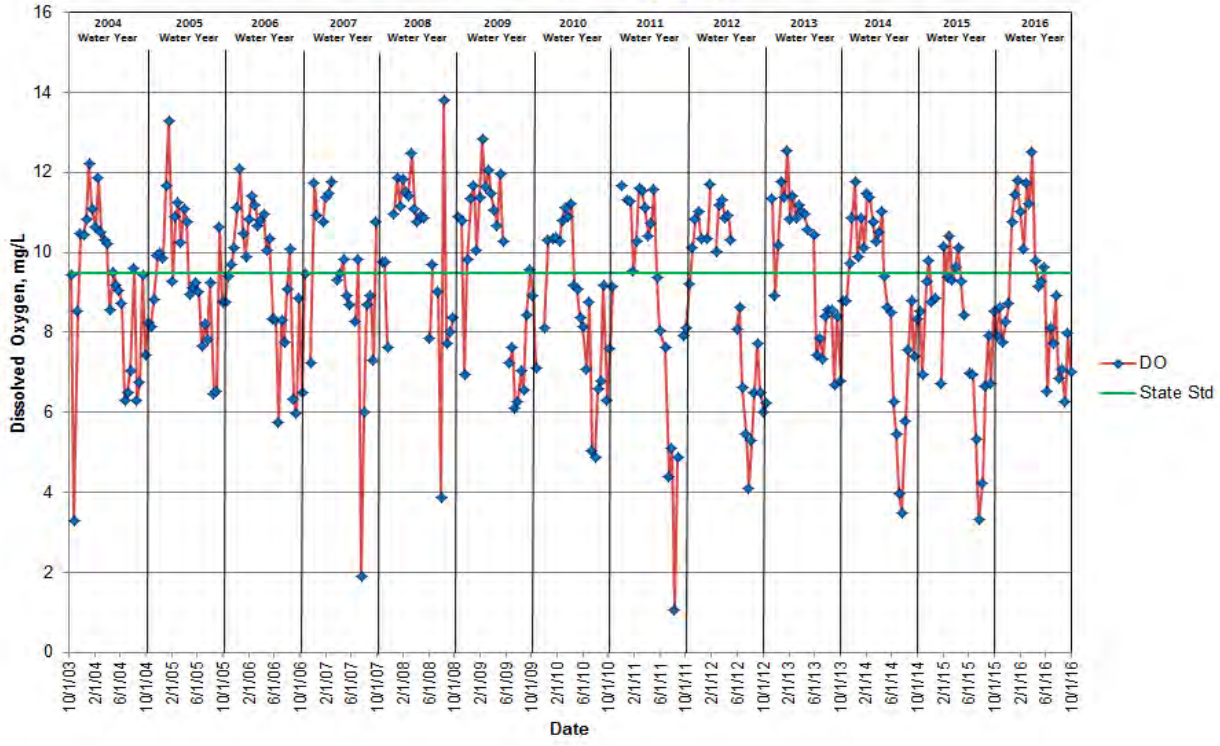
Swede Creek at Grip Road - Site 8
Dissolved Oxygen



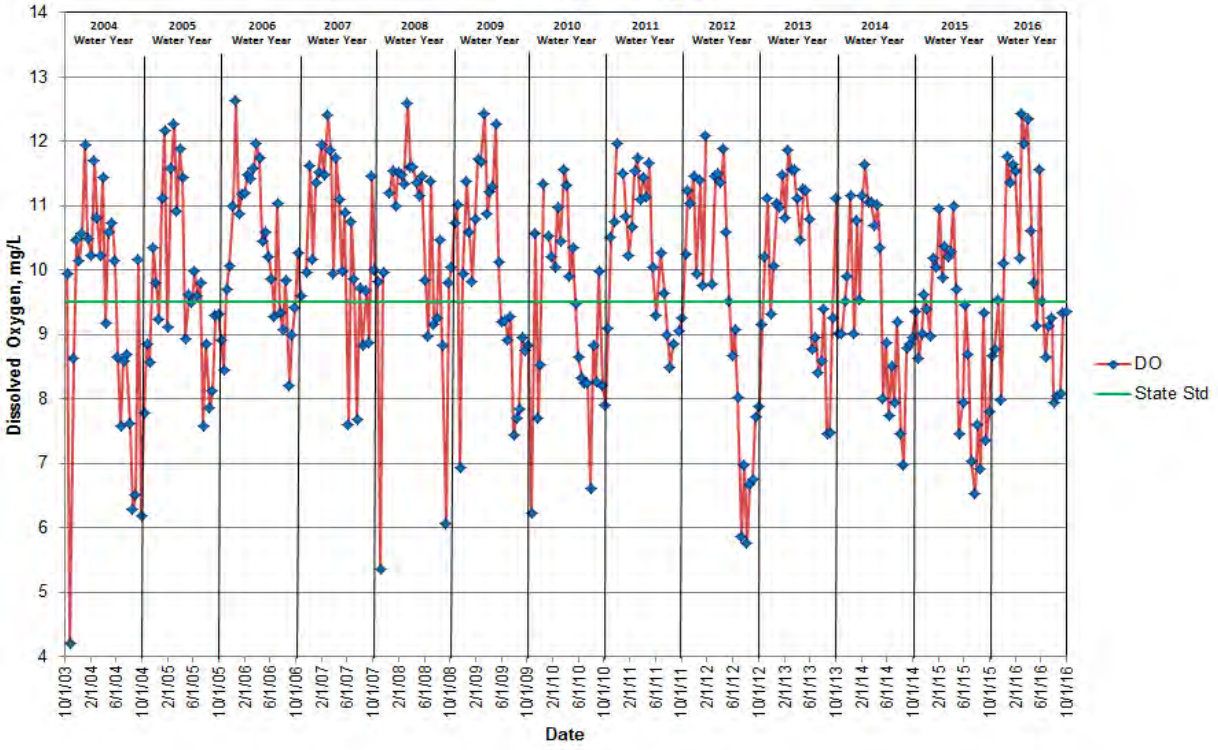
Samish River at Highway 9 - Site 11
Dissolved Oxygen



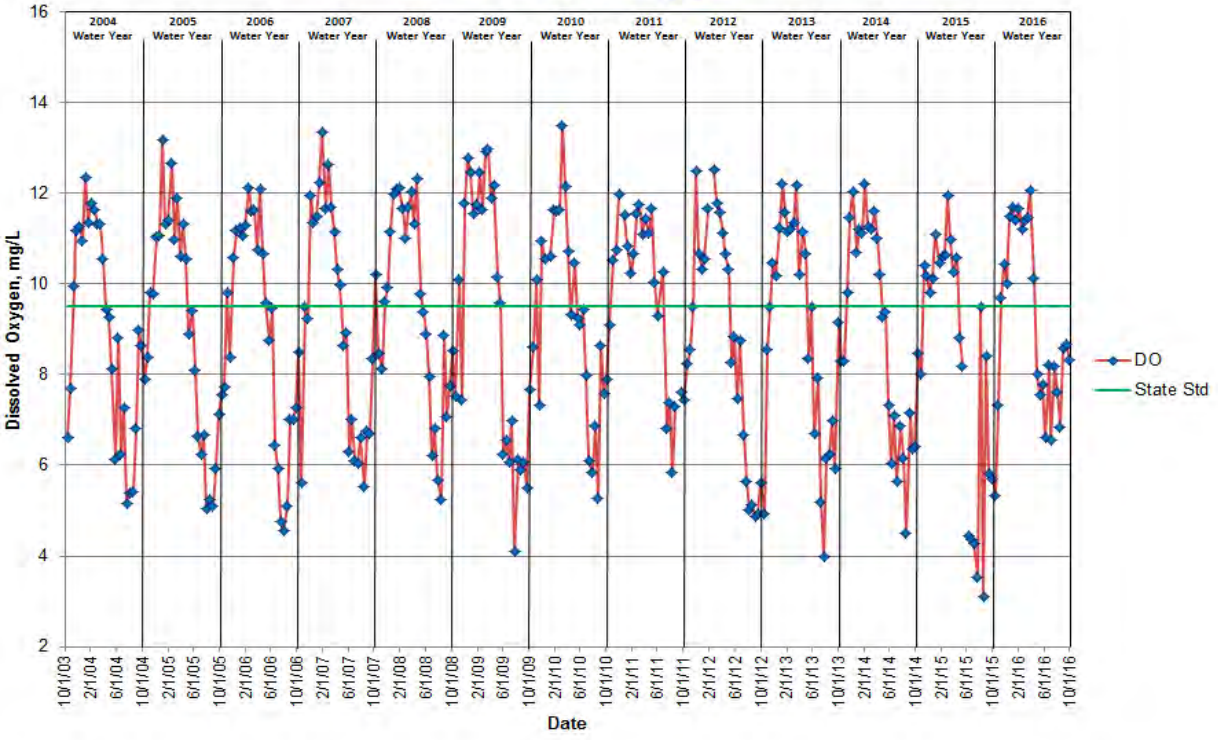
Nookachamps Creek at Swan Road - Site 12
Dissolved Oxygen



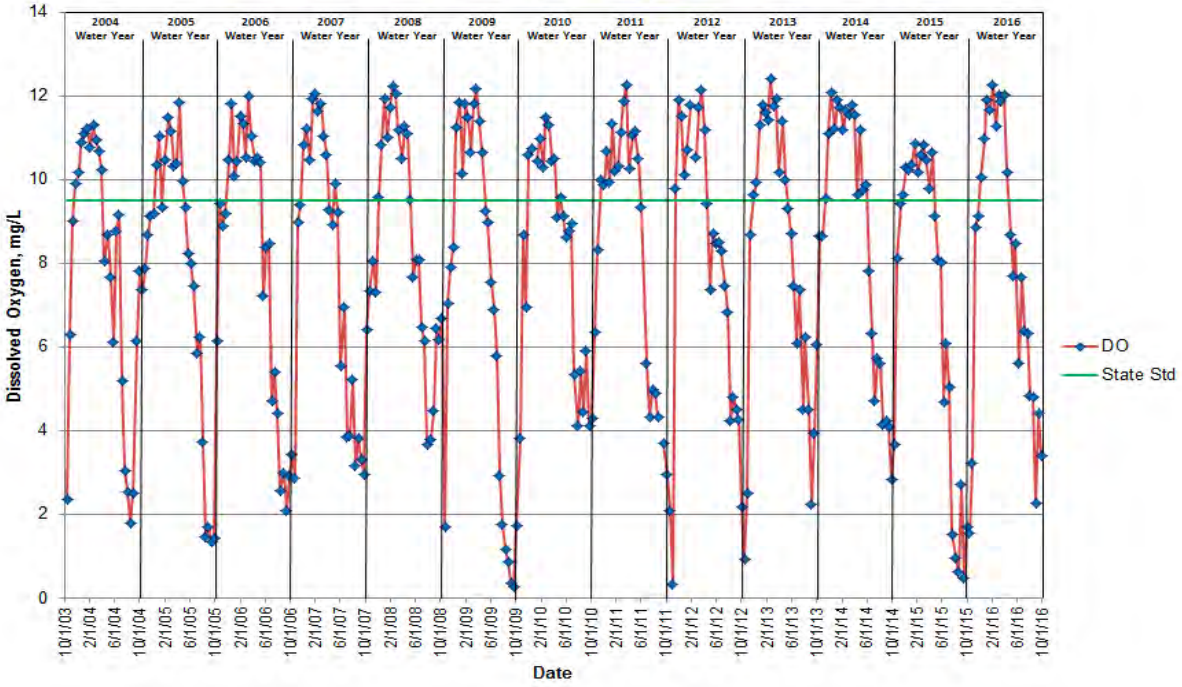
East Fork Nookachamps Creek at Highway 9 - Site 13
Dissolved Oxygen



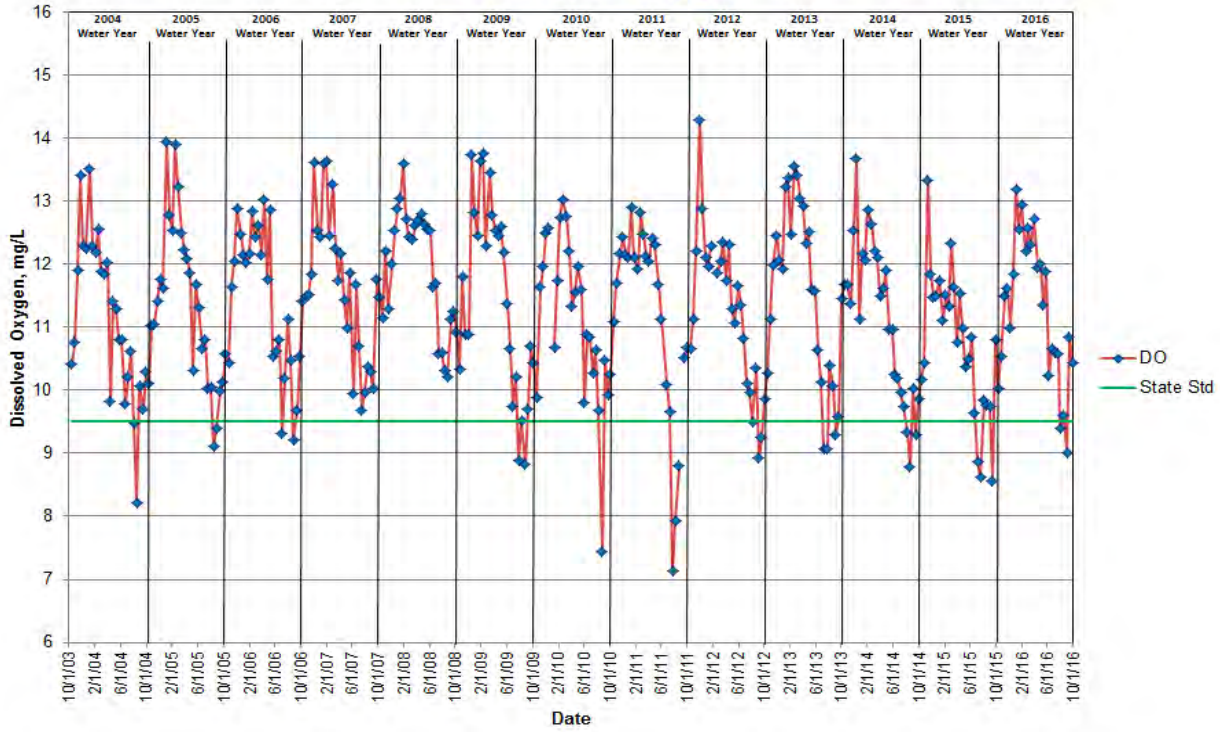
College Way Creek at College Way - Site 14
Dissolved Oxygen



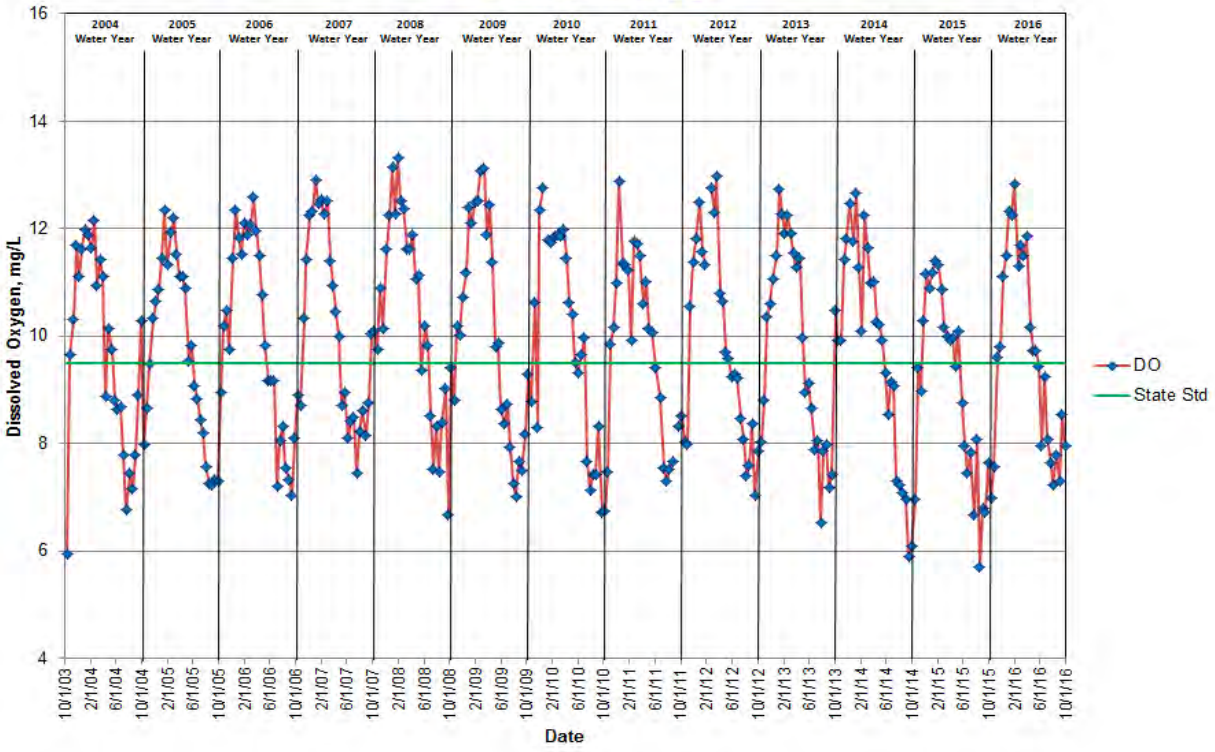
Nookachamps Creek at Knapp Road - Site 15
Dissolved Oxygen



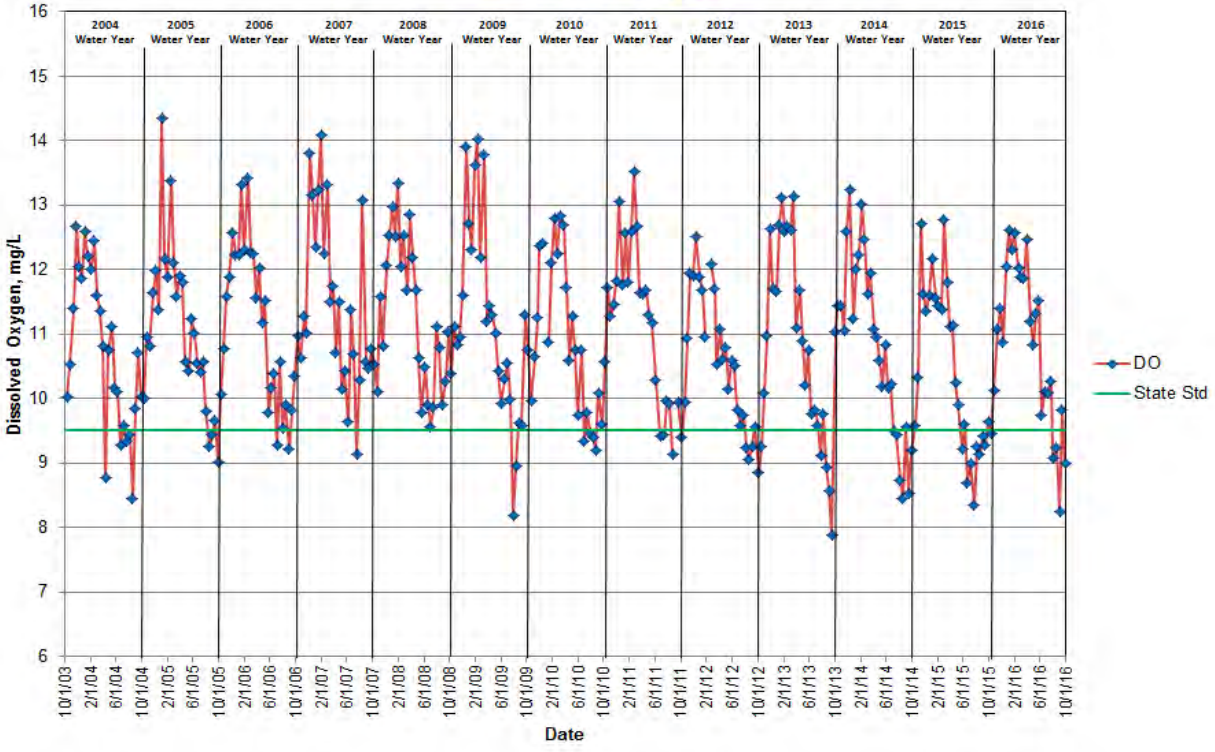
East Fork Nookachamps Creek at Beaver Lake Road - Site 16
Dissolved Oxygen



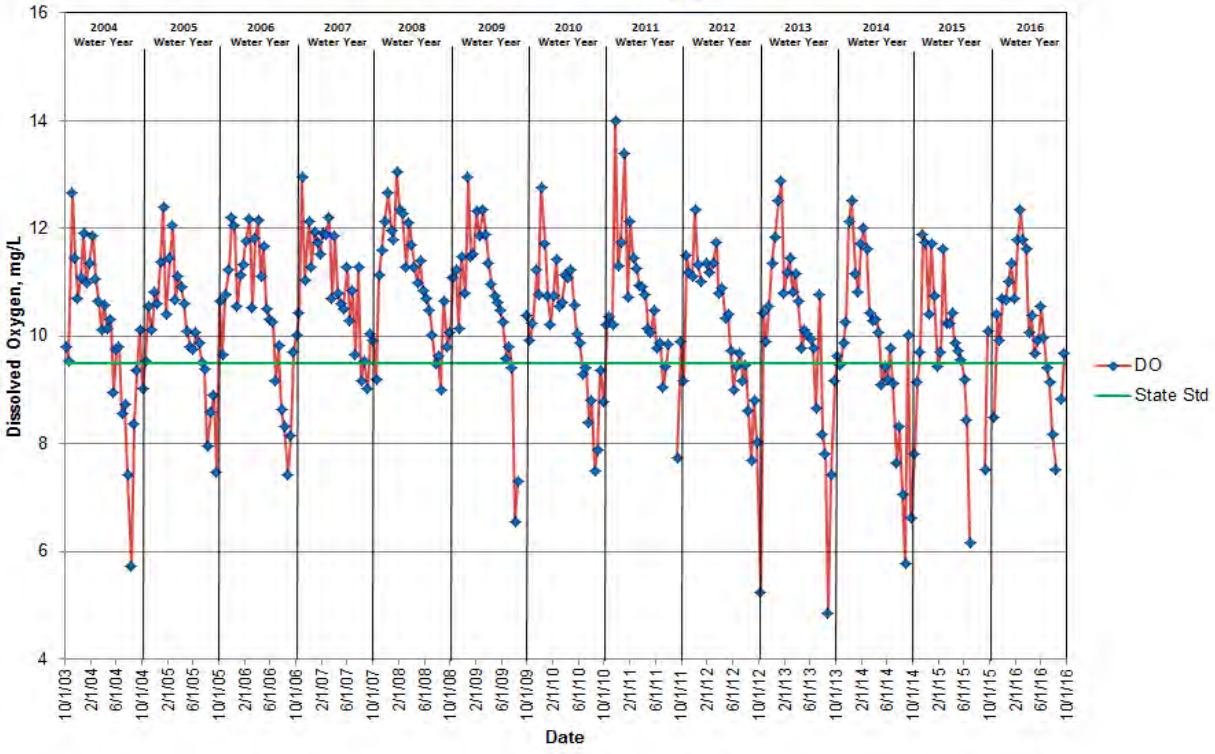
Nookachamps Creek at Big Lake Outlet - Site 17
Dissolved Oxygen



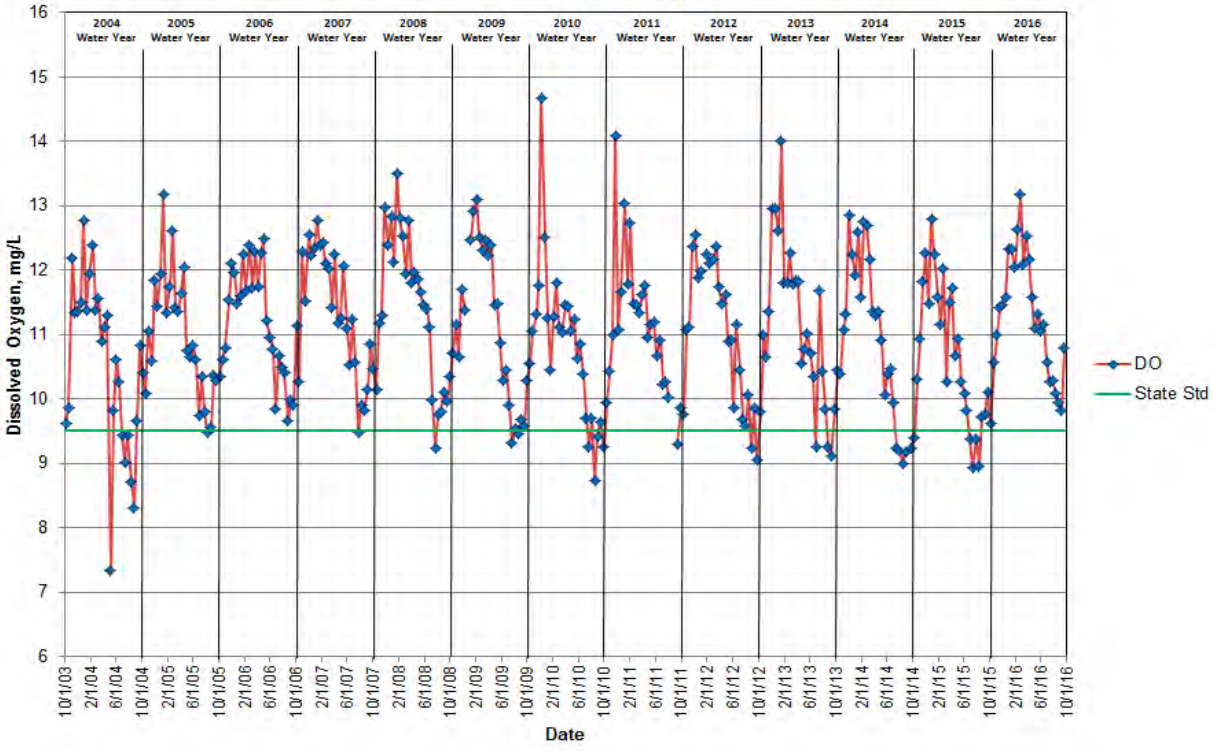
Lake Creek at Highway 9 - Site 18
Dissolved Oxygen



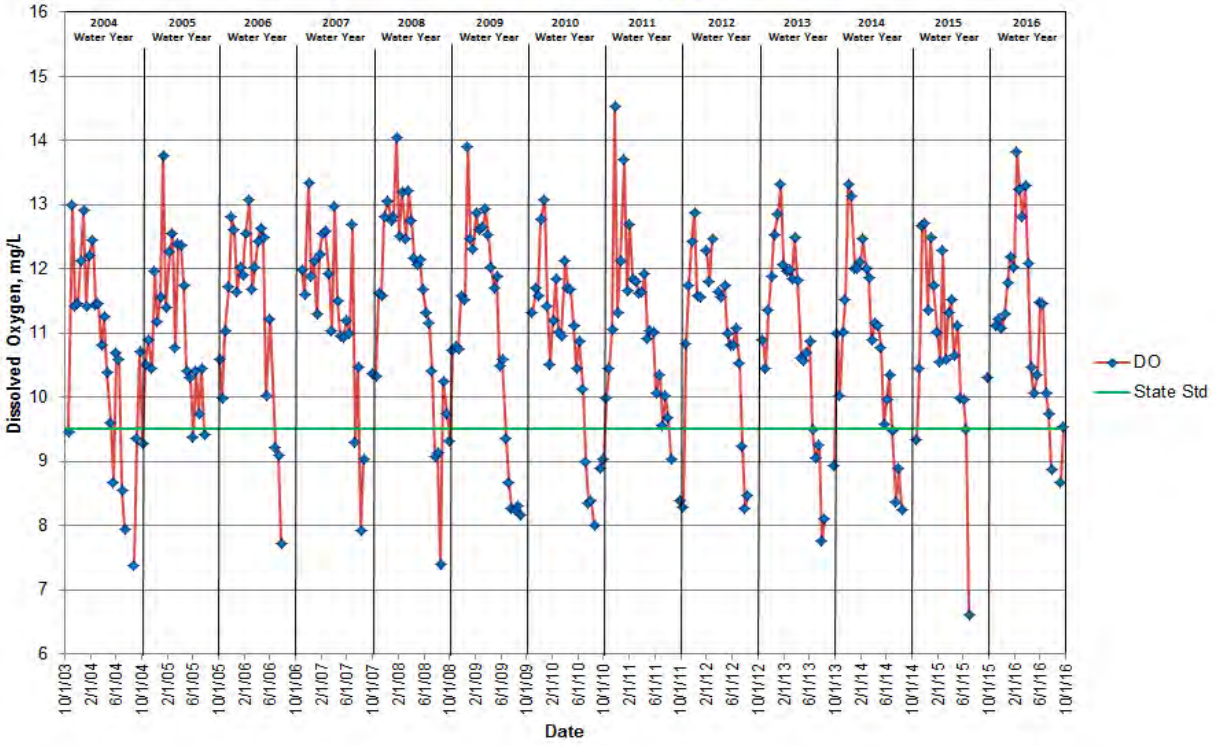
Hansen Creek at Hoehn Road - Site 19
Dissolved Oxygen



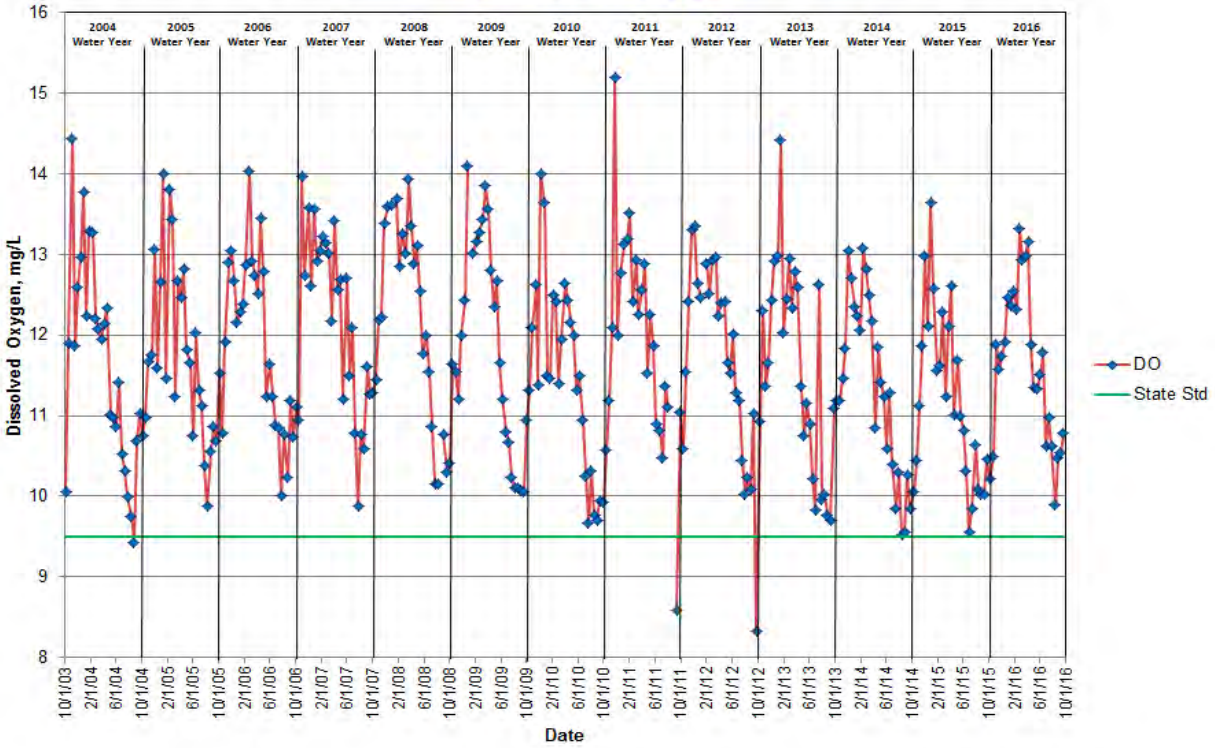
Hansen Creek at Northern State Hospital - Site 20
Dissolved Oxygen



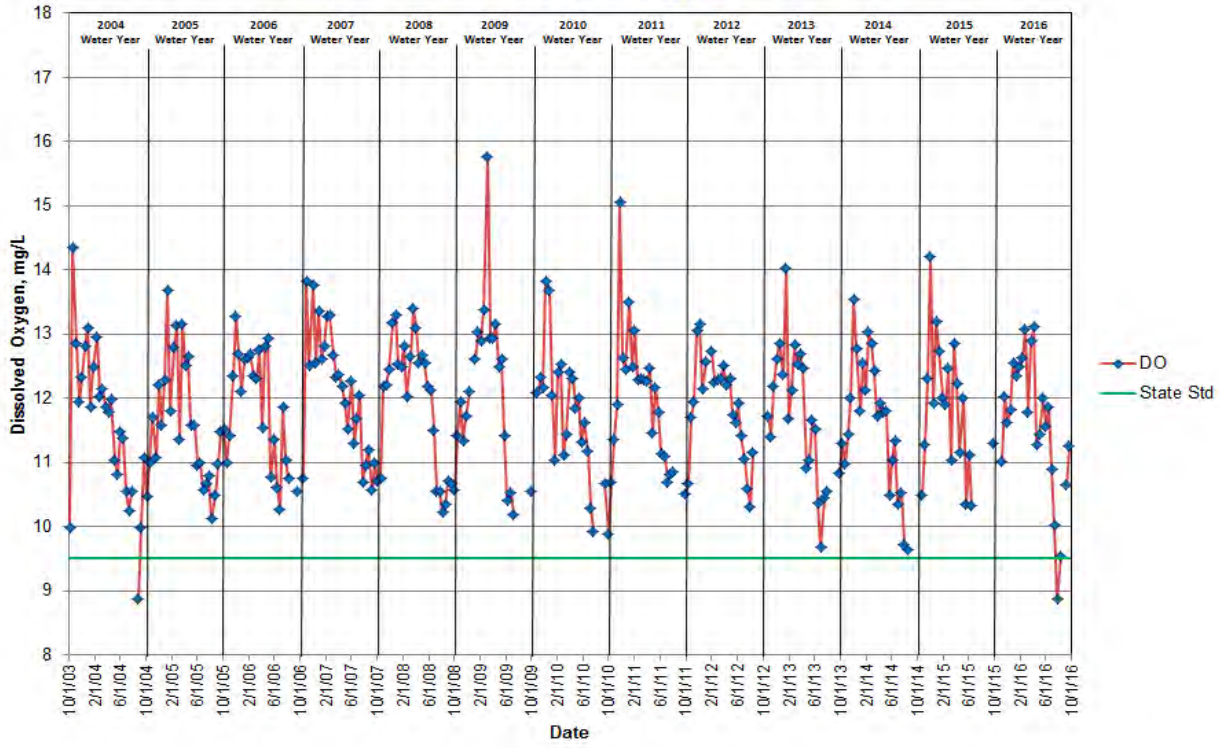
Coal Creek at Hoehn Road - Site 21
Dissolved Oxygen



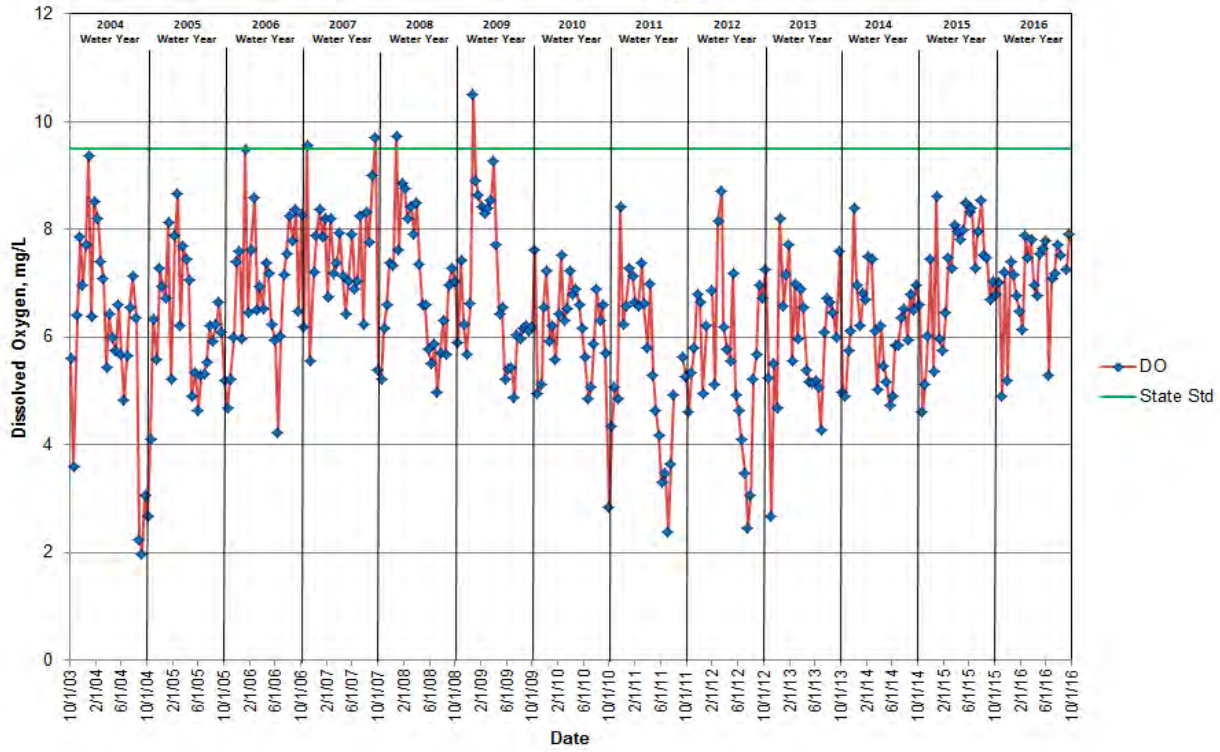
Coal Creek at Highway 20 - Site 22
Dissolved Oxygen



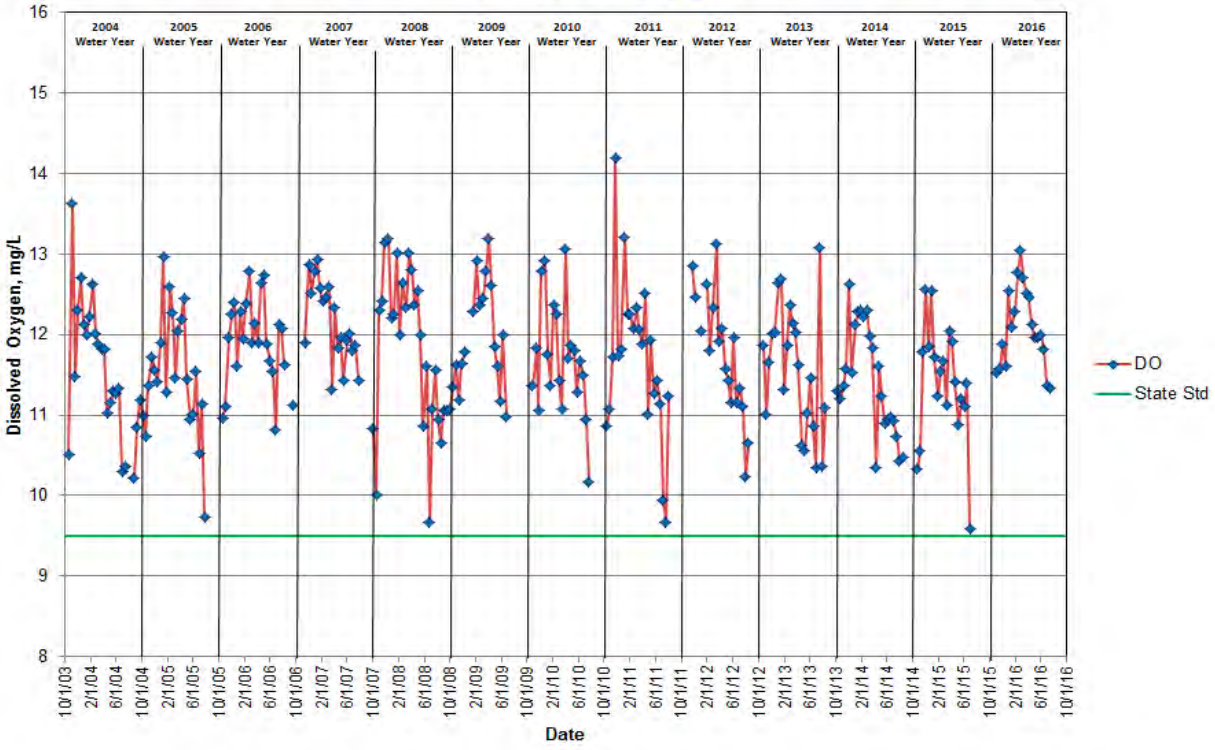
Wiseman Creek at Minkler Road - Site 23
Dissolved Oxygen



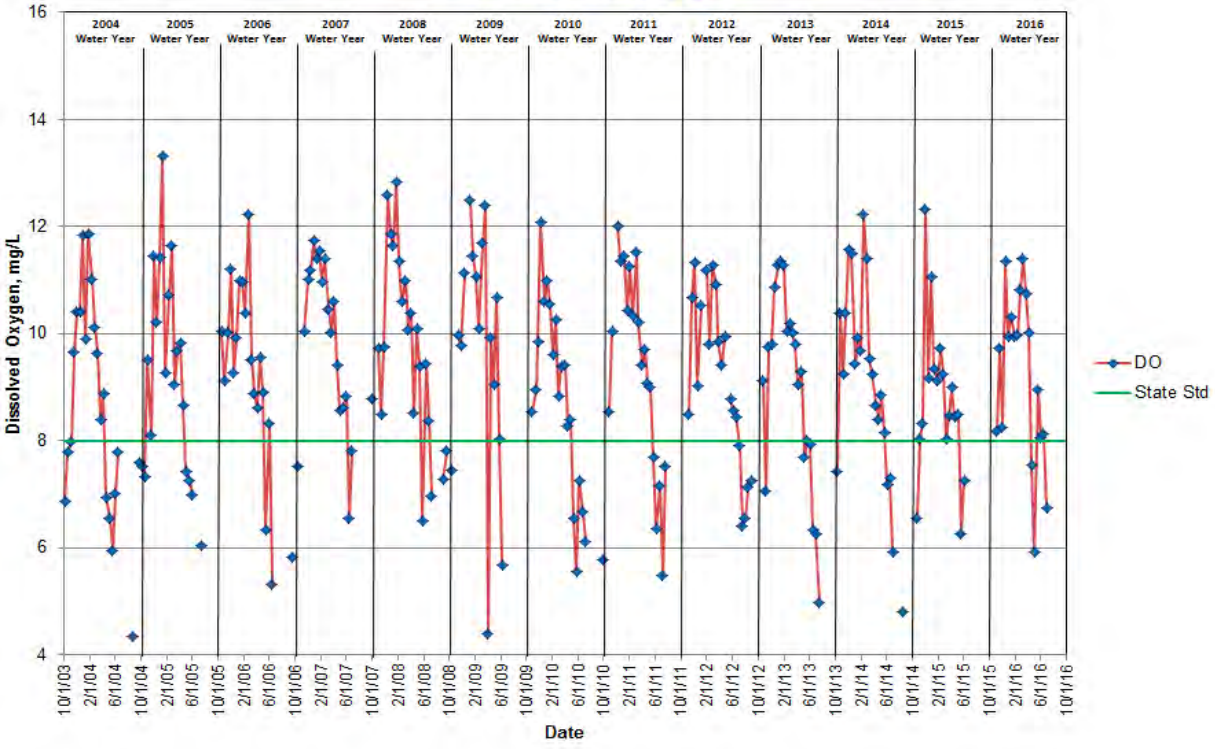
Mannser Creek at Lyman-Hamilton Highway - Site 24
Dissolved Oxygen



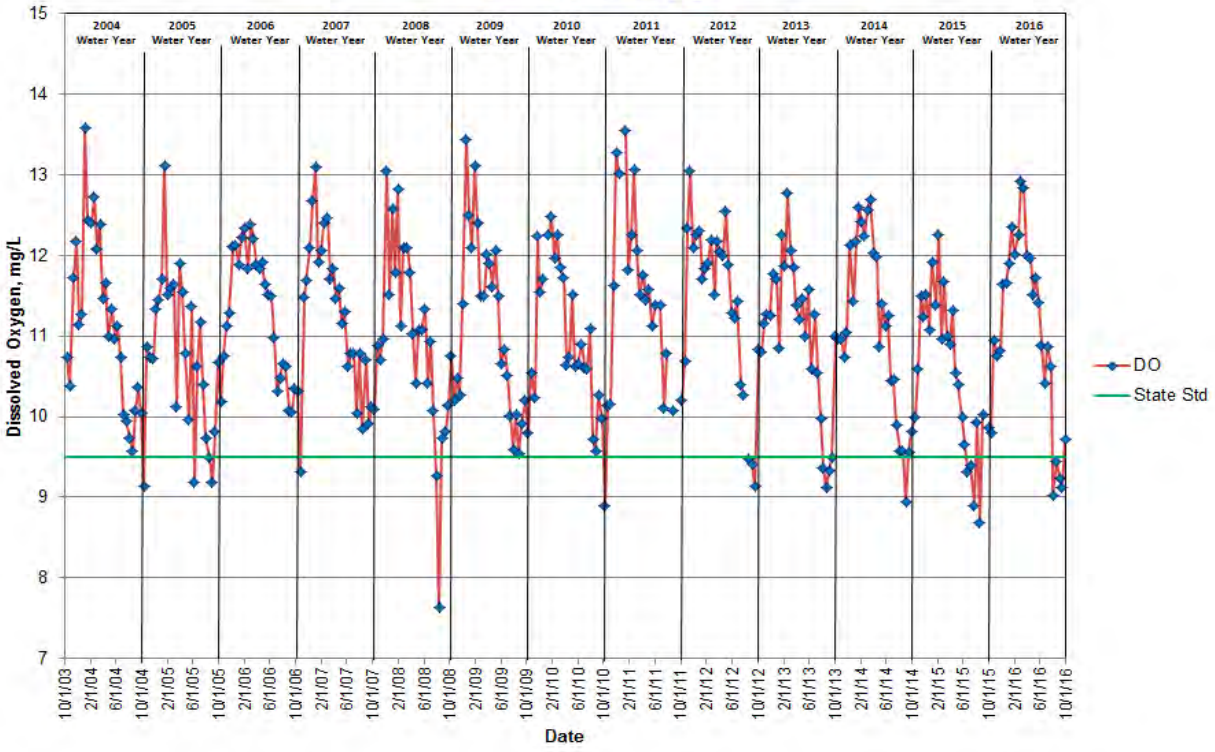
Red Cabin Creek at Hamilton Cemetery Road - Site 25
Dissolved Oxygen



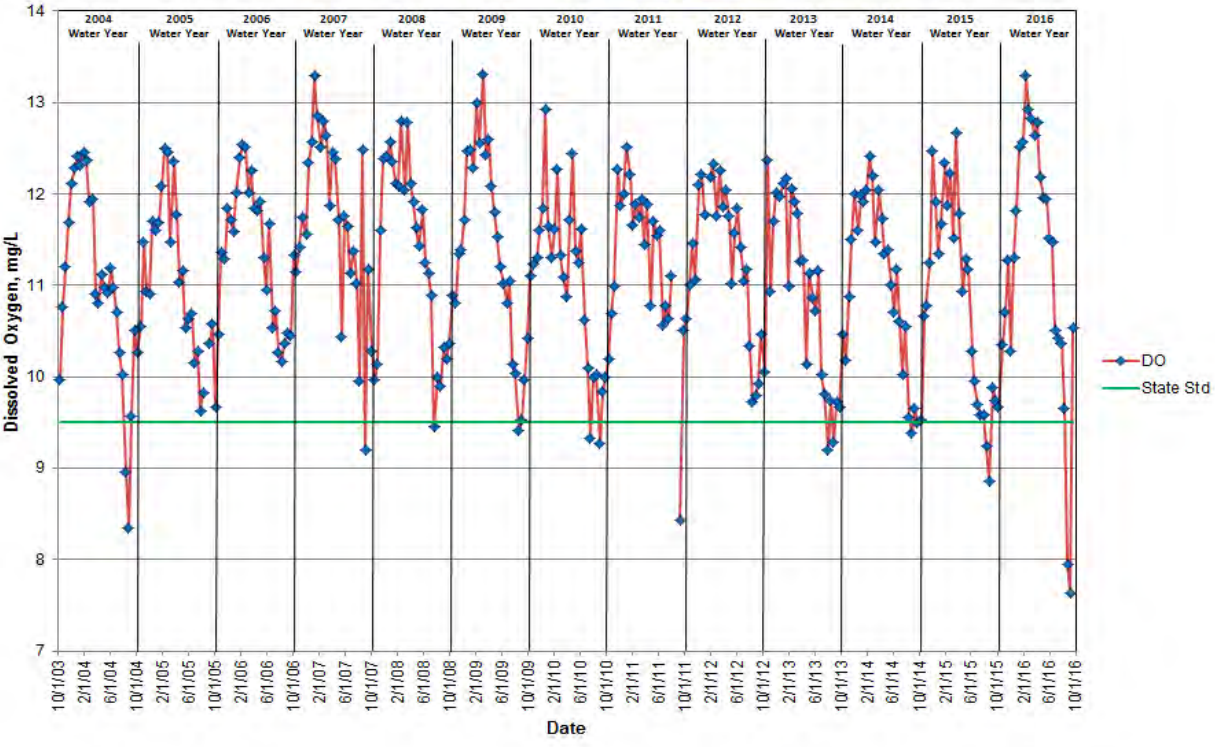
Brickyard Creek at Highway 20 - Site 28
Dissolved Oxygen



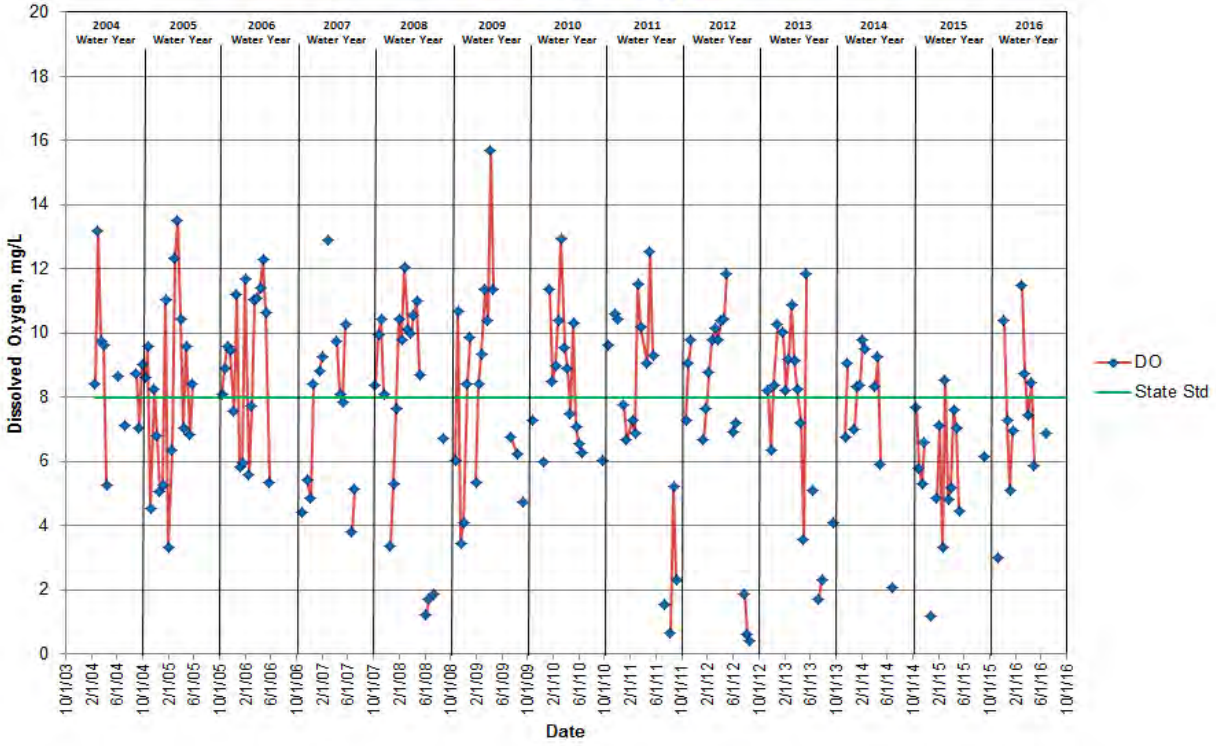
Skagit River at River Bend Road - Site 29
Dissolved Oxygen



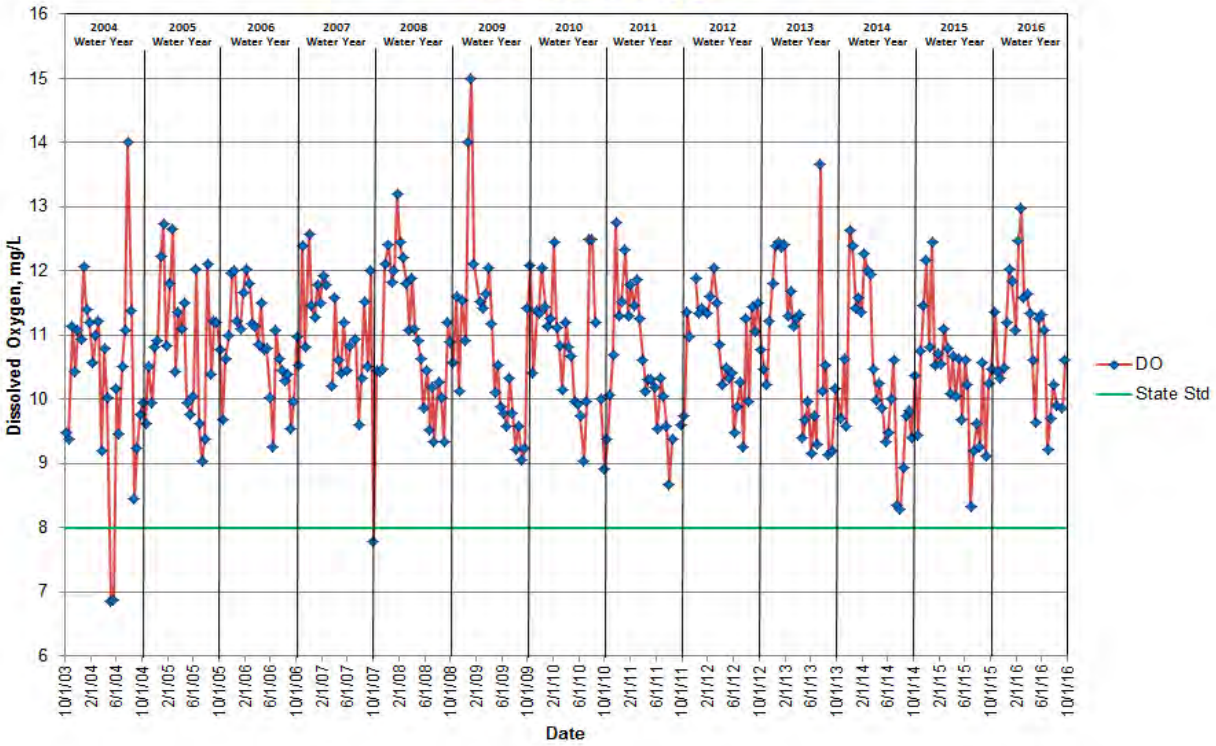
Skagit River at Cape Horn Road - Site 30
Dissolved Oxygen



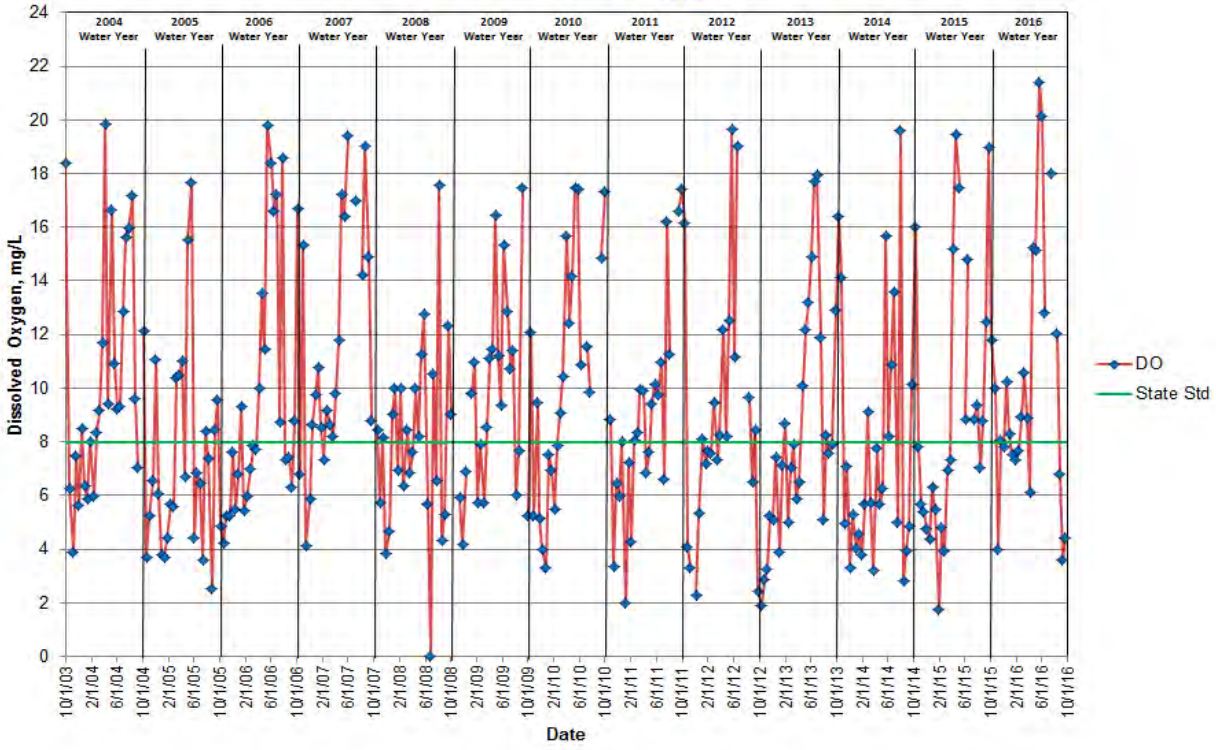
Drainage District 20 Ditch at Floodgate - Site 31
Dissolved Oxygen



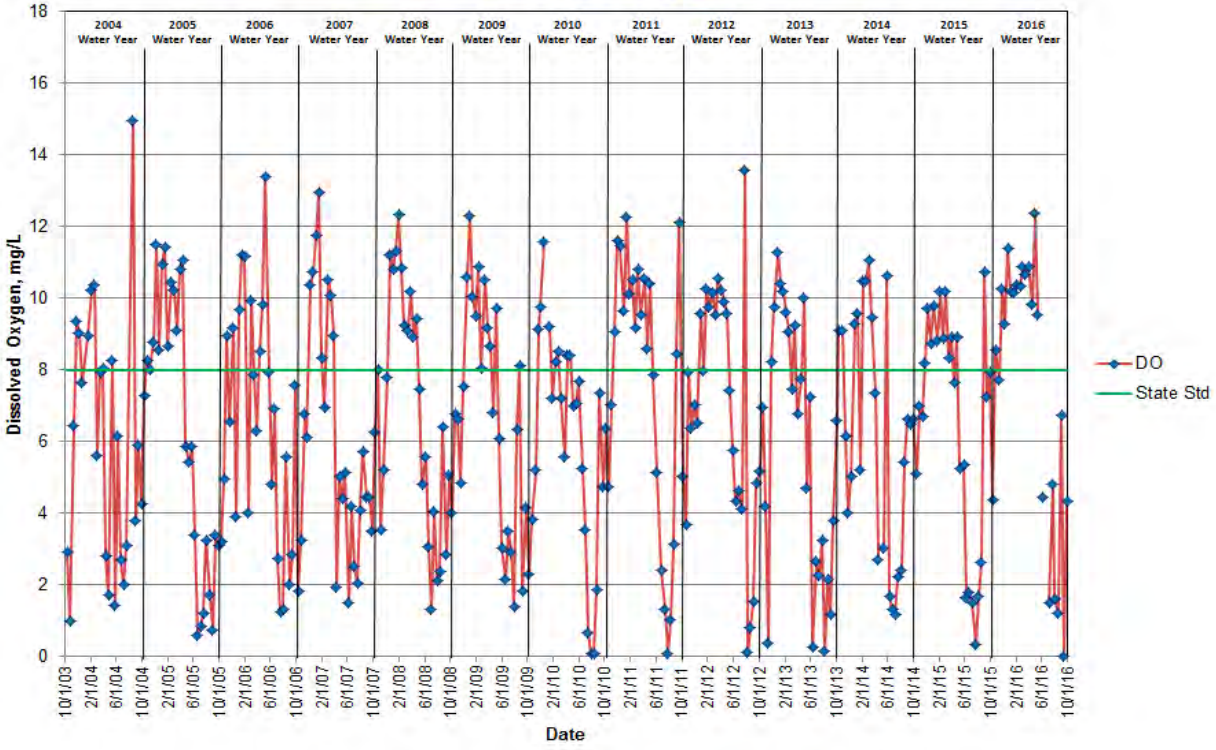
Samish River at Thomas Road - Site 32
Dissolved Oxygen



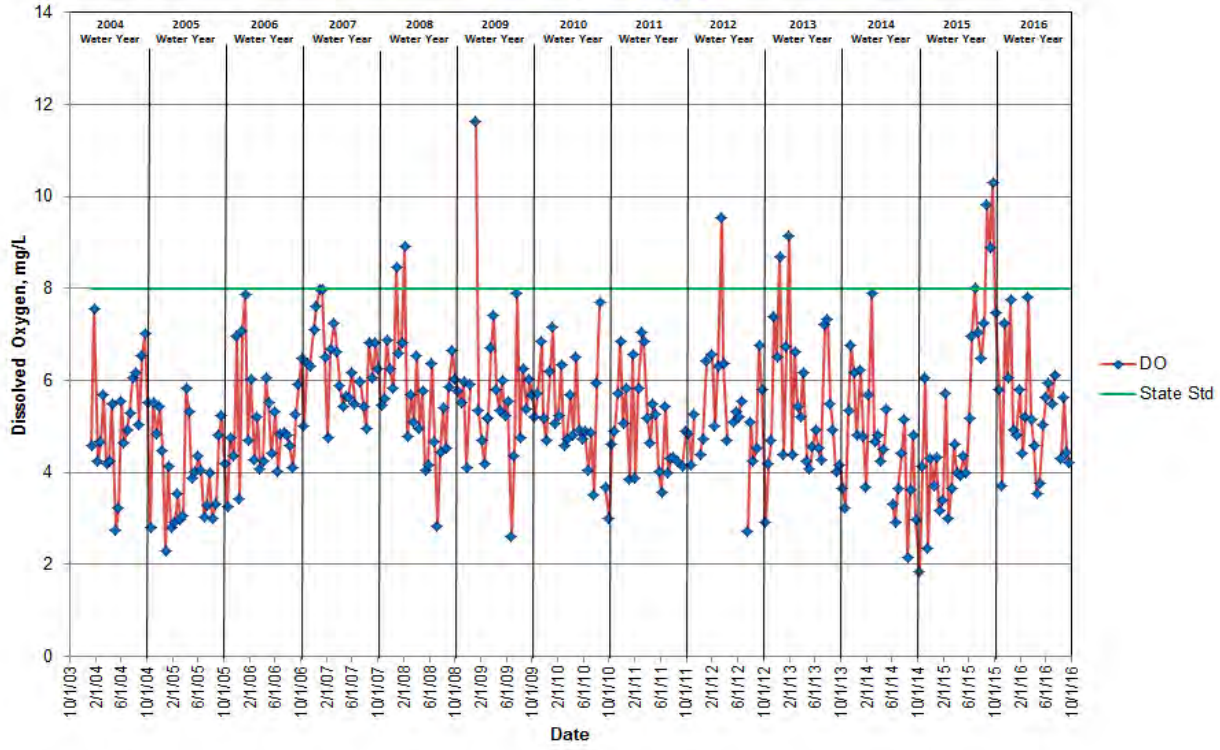
Alice Bay Pump Station - Site 33
Dissolved Oxygen



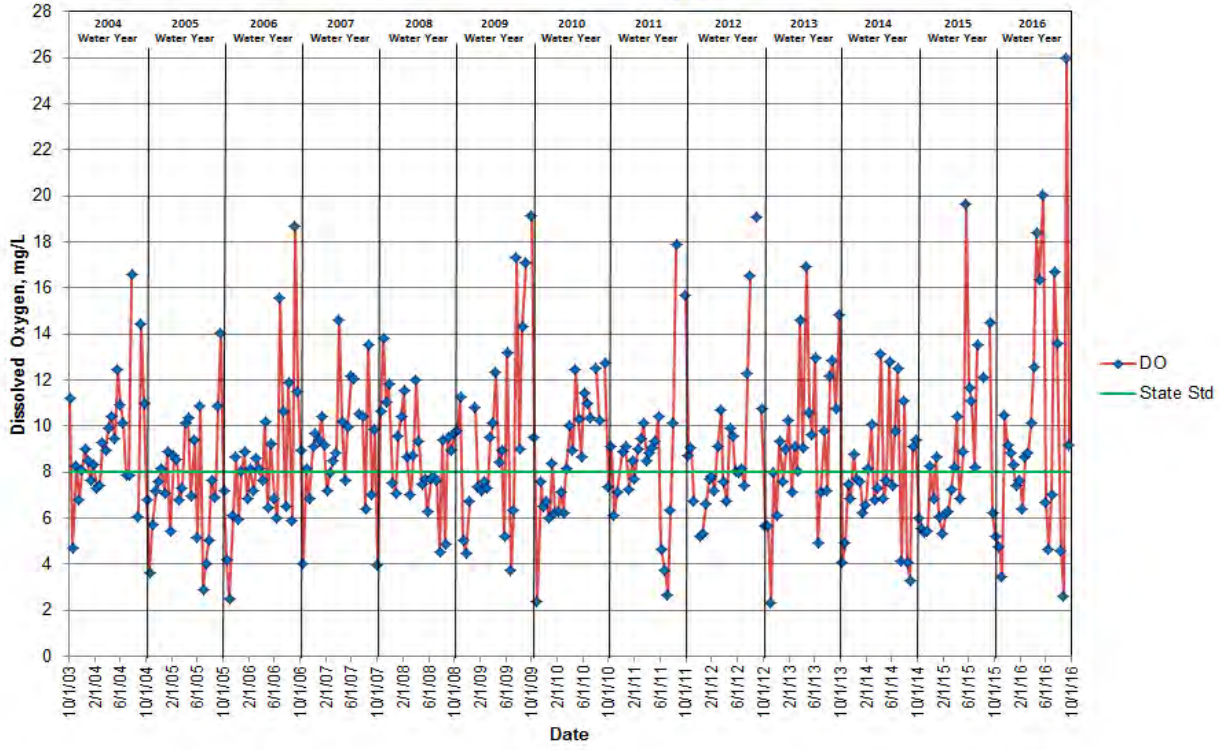
No Name Slough at Bayview-Edison Road - Site 34
Dissolved Oxygen



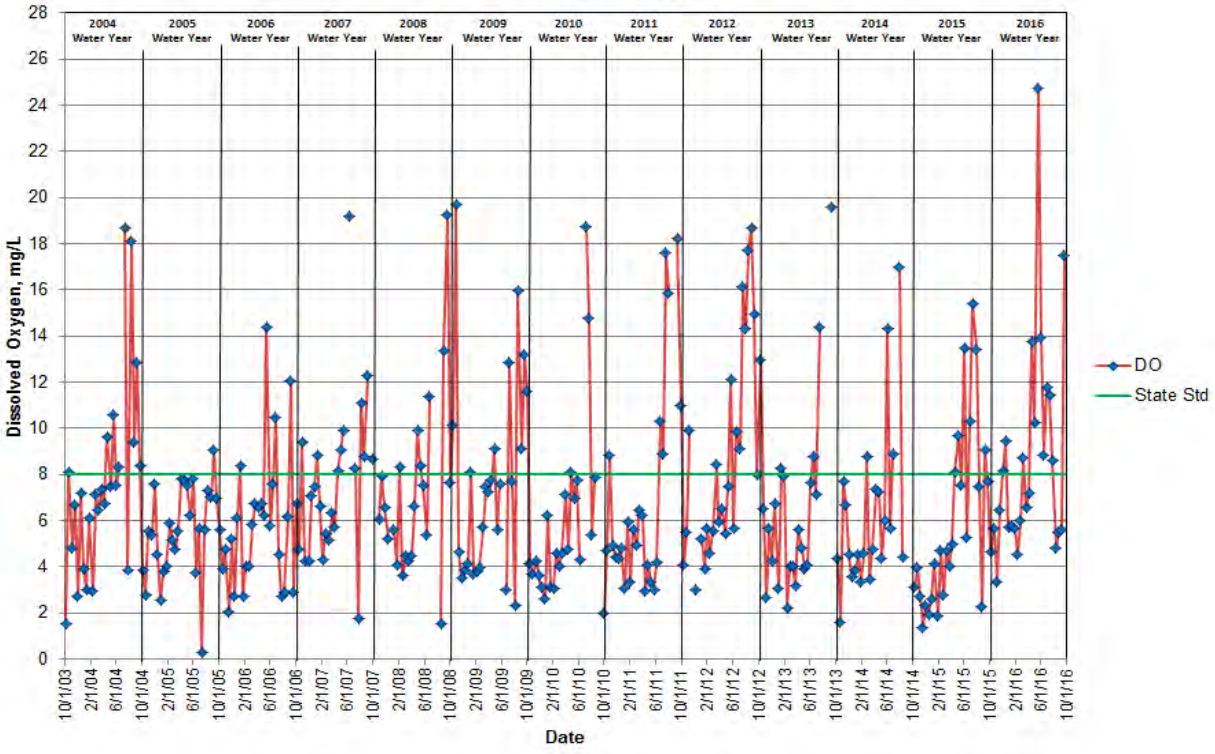
Joe Leary Slough at D'Arcy Road - Site 35
Dissolved Oxygen



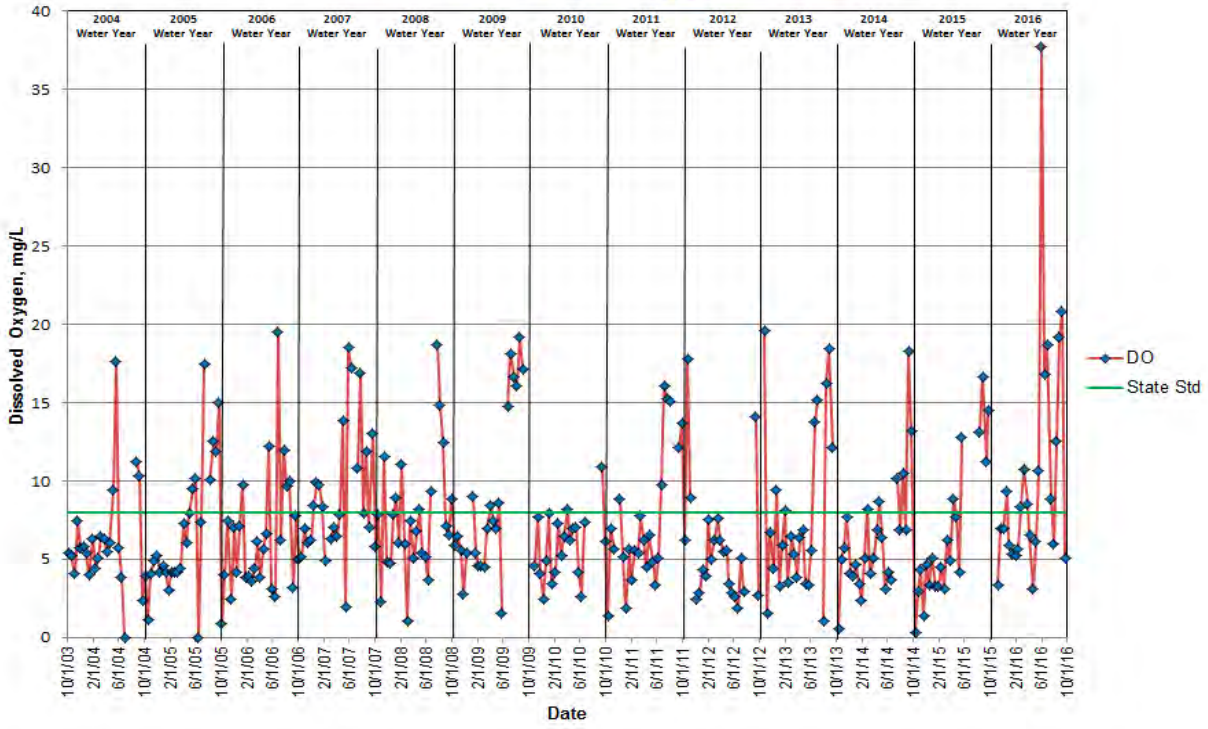
Edison Slough at Edison School - Site 36
Dissolved Oxygen



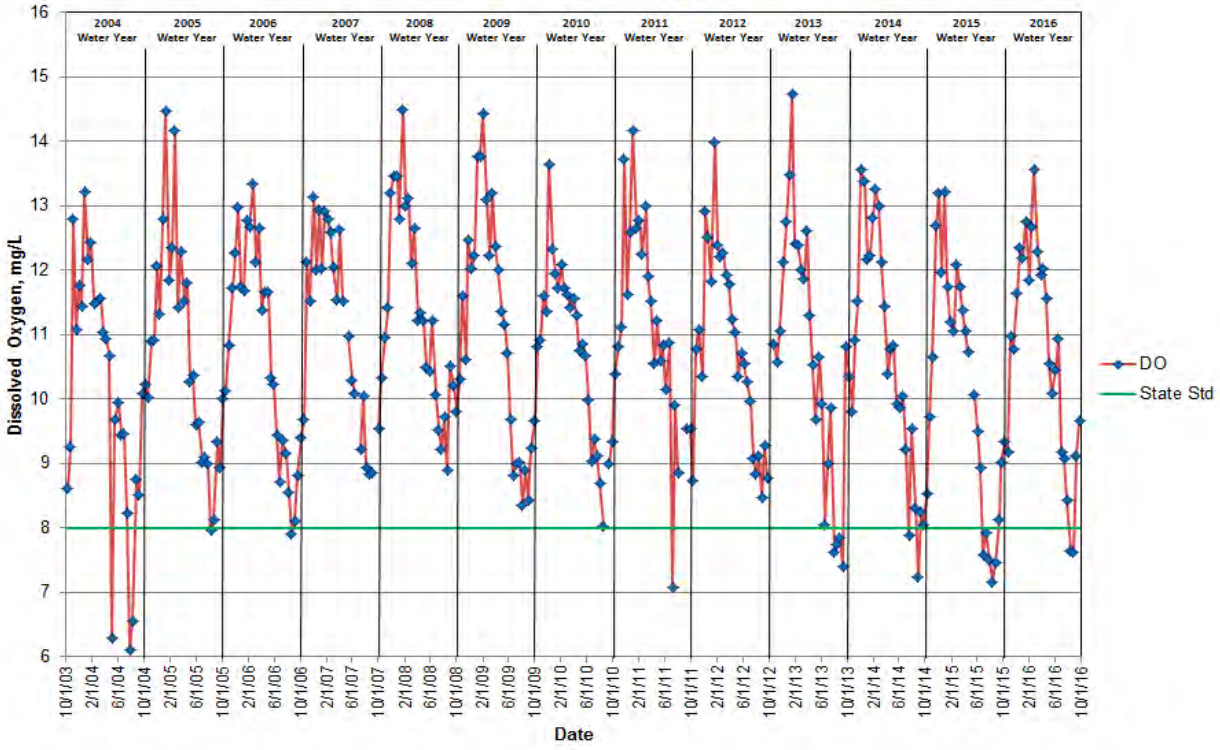
Edison Pump Station - Site 37
Dissolved Oxygen



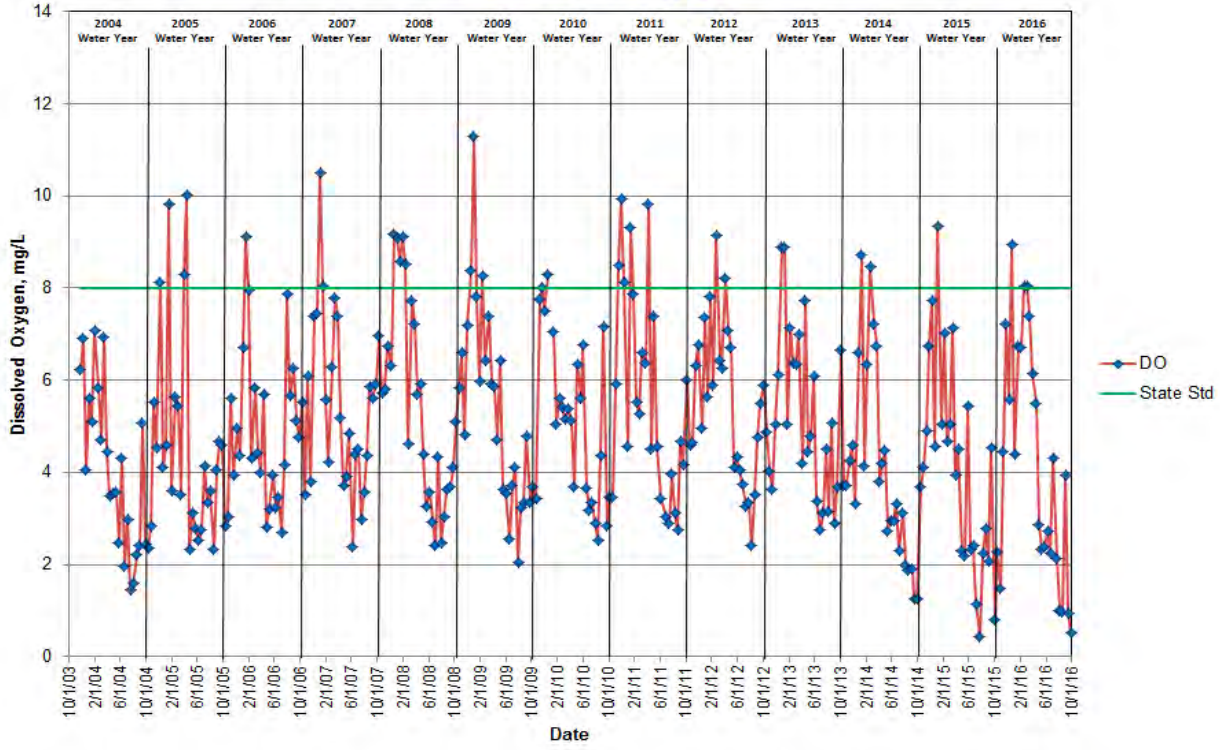
North Edison Pump Station - Site 38
Dissolved Oxygen



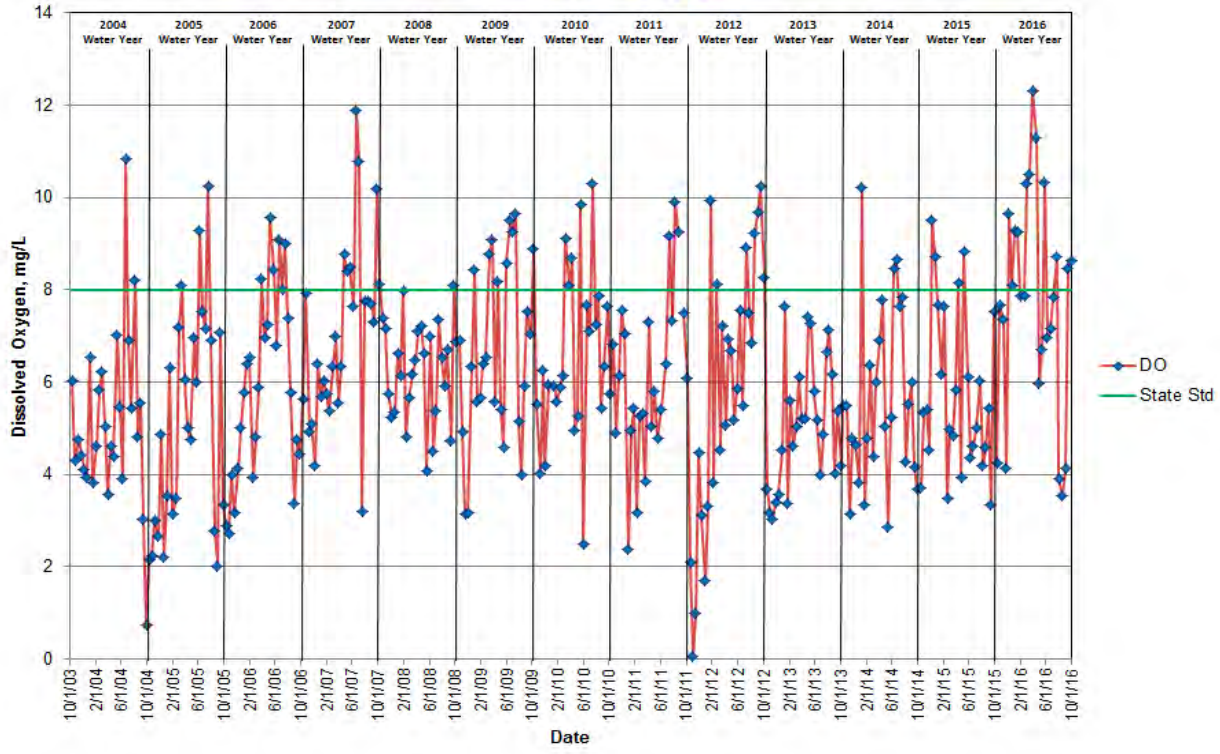
Colony Creek at Colony Road - Site 39
Dissolved Oxygen



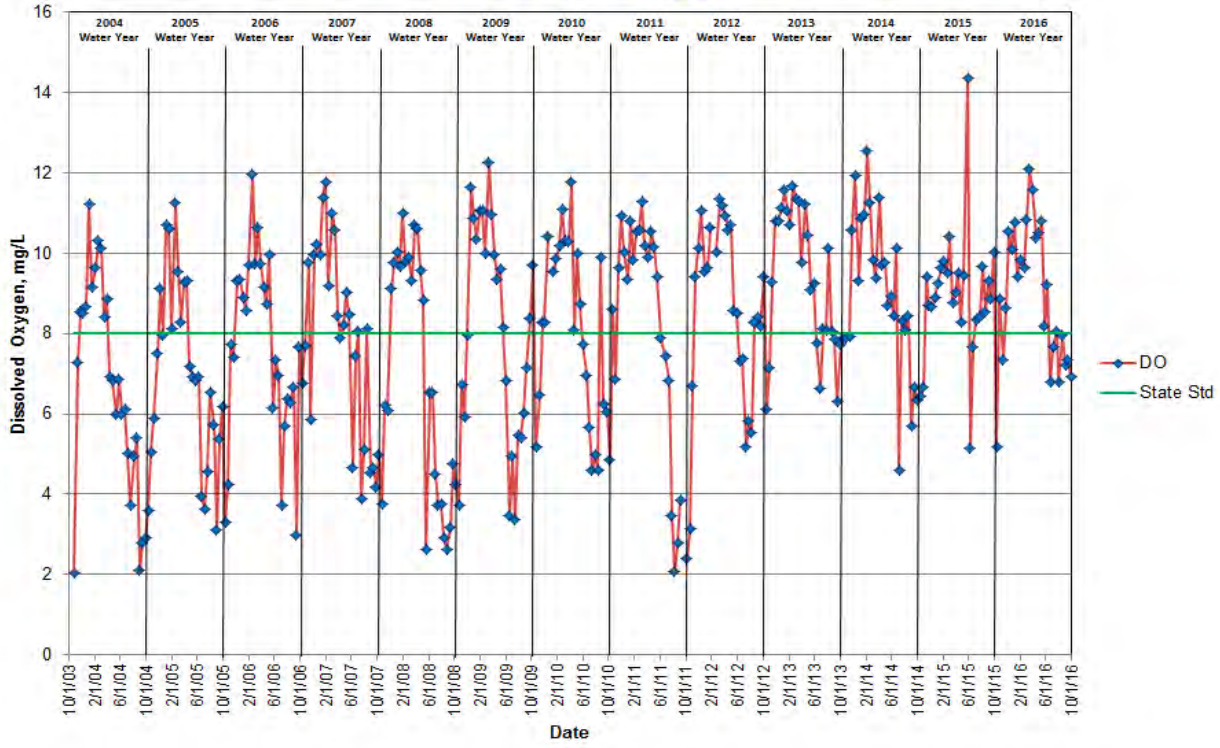
Big Indian Slough at Highway 20 Truck Scales - Site 40
Dissolved Oxygen



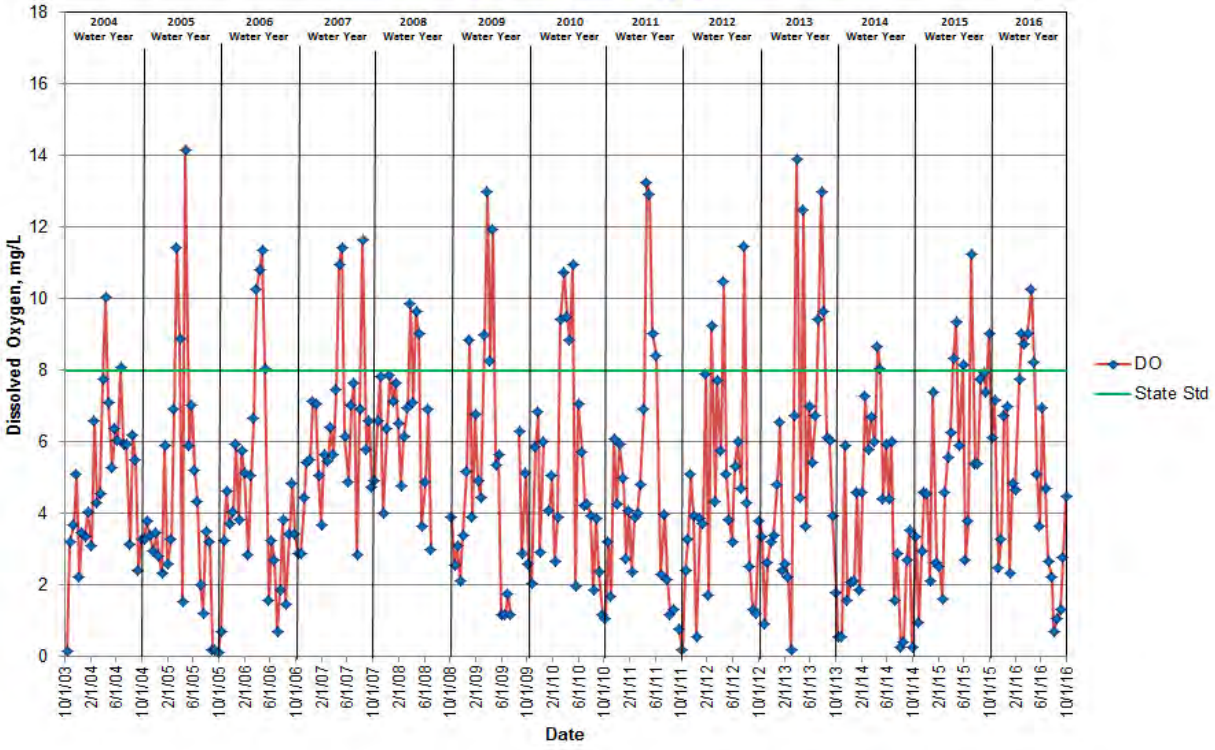
Maddox Creek/Big Ditch at Milltown Road - Site 41
Dissolved Oxygen



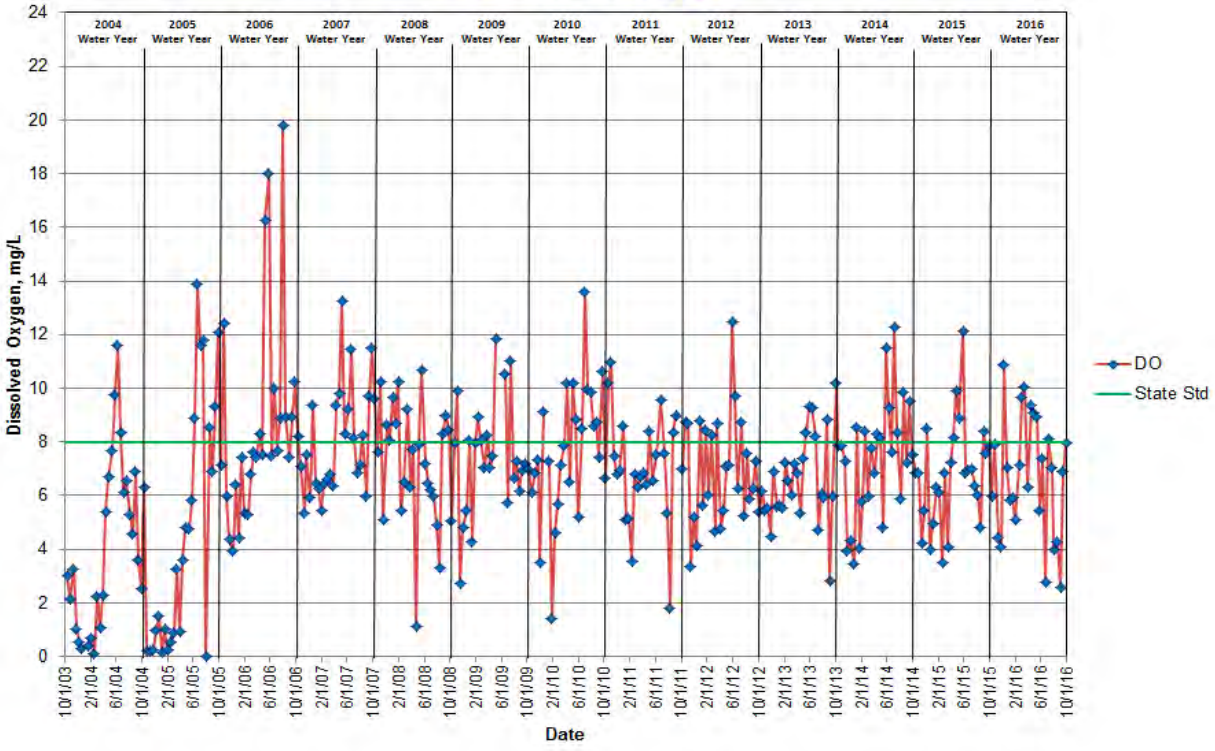
Carpenter Creek/Hill Ditch at Cedardale Road - Site 42
Dissolved Oxygen



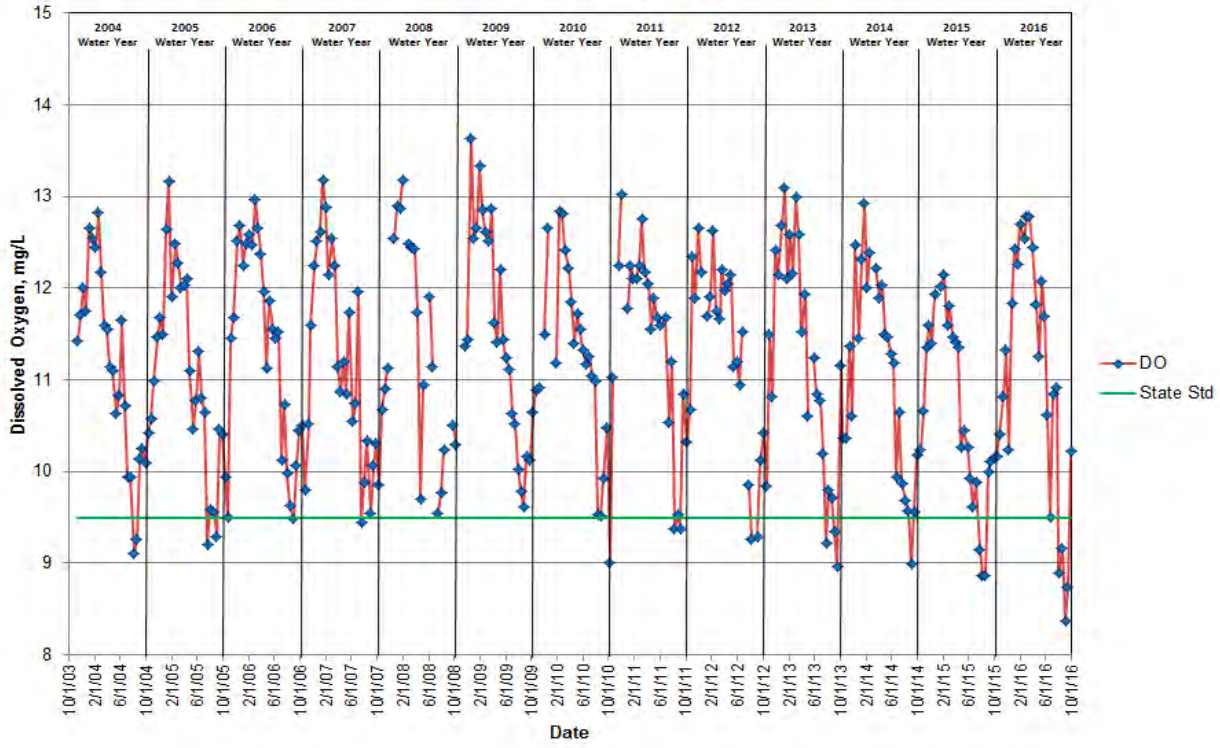
Wiley Slough at Wylie Road - Site 43
Dissolved Oxygen



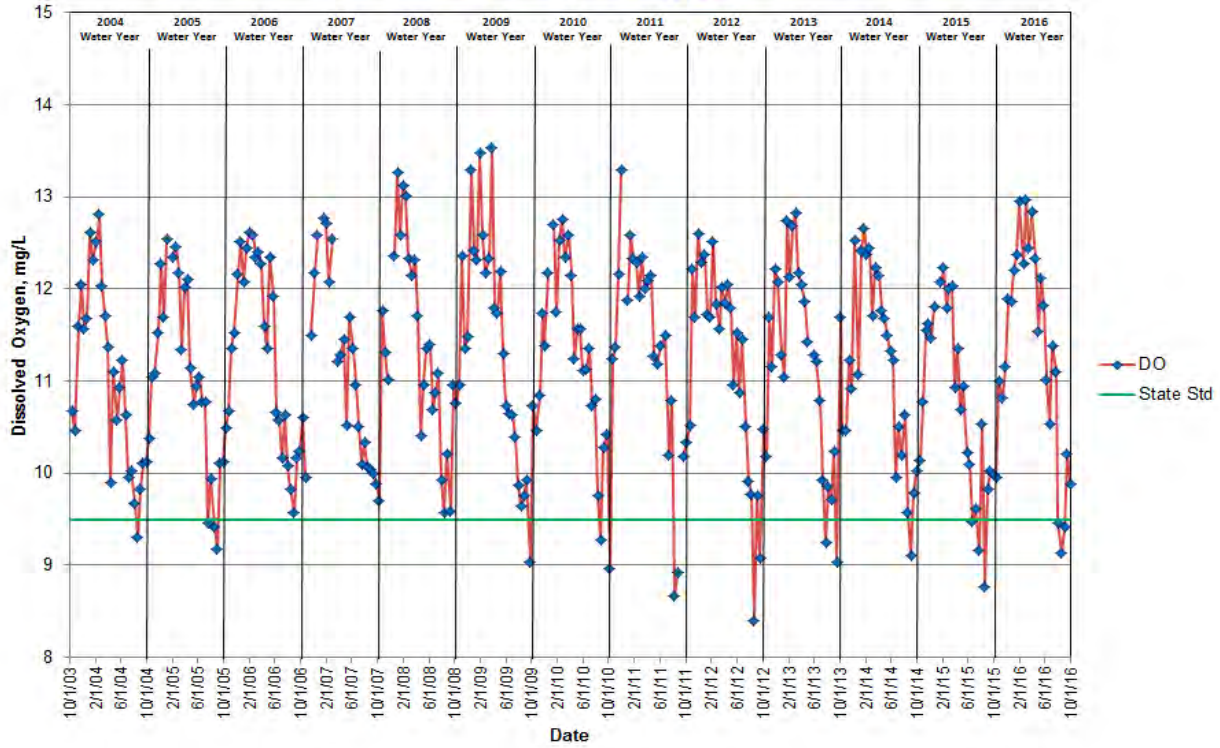
Sullivan Slough at LaConner-Whitney Road - Site 44
Dissolved Oxygen



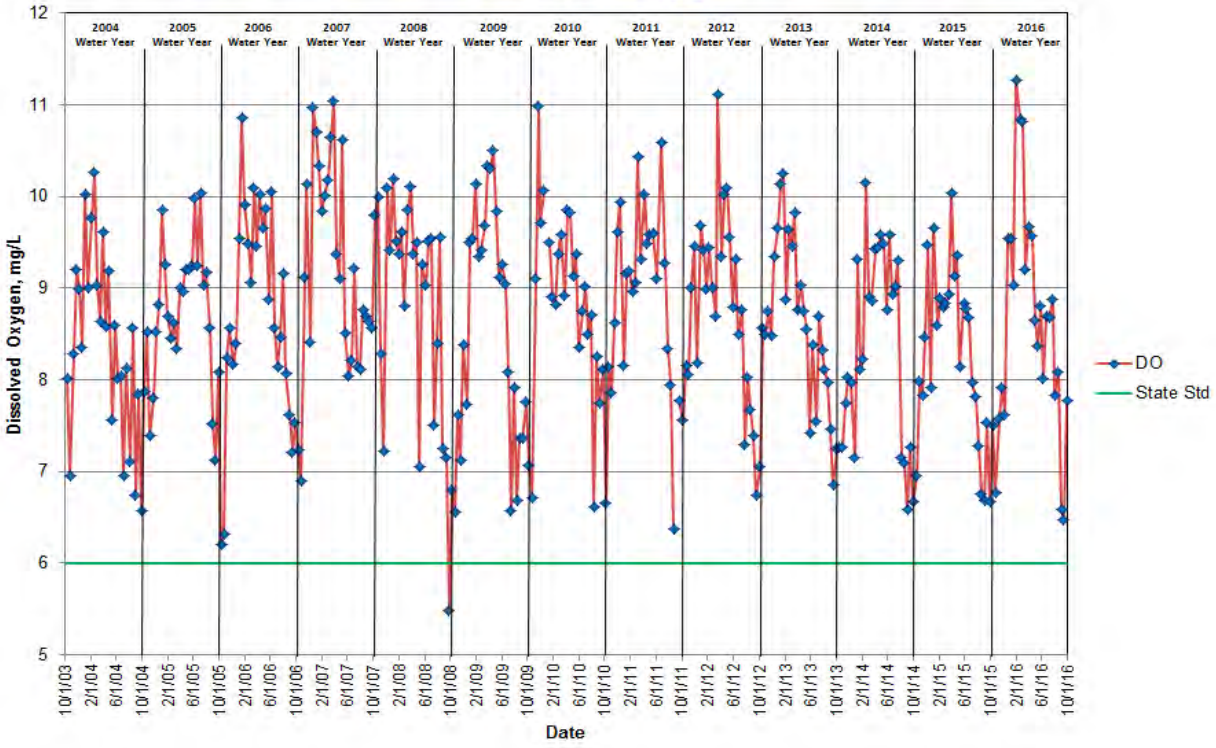
North Fork Skagit River near Moore Road - Site 45
Dissolved Oxygen



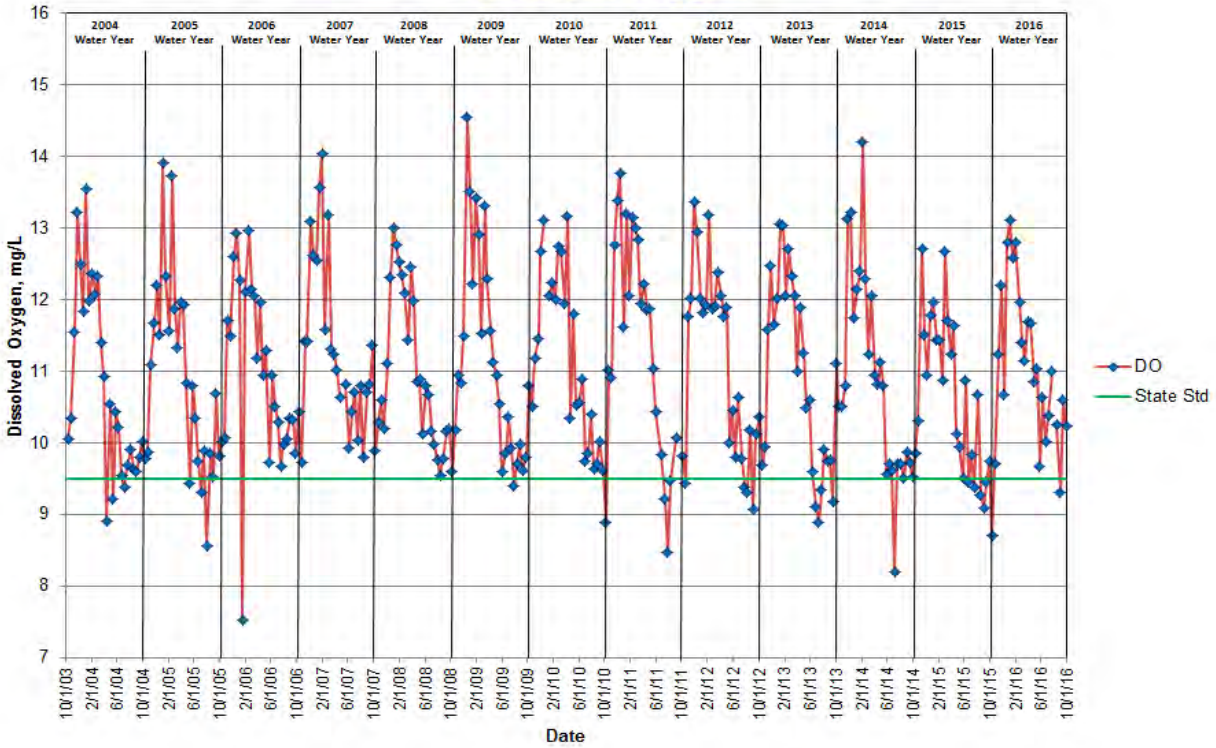
South Fork Skagit River at Conway Boat Ramp - Site 46
Dissolved Oxygen



Swinomish Channel at County Boat Ramp - Site 47
Dissolved Oxygen



Fisher Creek at Franklin Road - Site 48
Dissolved Oxygen



Fecal Coliform

Fecal coliform is a measurement of the amount of enteric bacteria from warm-blooded animals present in a watercourse. Although fecal coliform measurements do not directly quantify disease-causing organisms, they serve as an indicator of the possible presence of such bacteria, viruses, and protozoa.

Samples for fecal coliform measurements are taken at each site during each visit and submitted to the Skagit County Health Department Water Lab (2003-2008) or Edge Analytical (2009-2016) for analysis by the Most Probable Number method.

Fecal coliform measurements for the 2016 water year, in "most probable number" (mpn) per 100 ml, are summarized in Table 7. State standards for fecal coliform are based on the geometric mean of the samples as well as the percent of the samples that exceed given criteria. For most of the watercourses in the Skagit County Monitoring Program (sites 3-20, 28-29, 31-46, 48), fecal coliform is not to exceed a geometric mean of 100 mpn, with no more than 10% of the measurements exceeding 200 mpn. For the upriver sites (sites 21-25, 30), the standard is a geometric mean of 50 mpn, with no more than 10% of the measurements exceeding 100 mpn. For the marine site (site 47), a more stringent standard of 14 mpn with no more than 10% exceeding 41 mpn is enforced to protect shellfish beds.

Table 8 gives the geometric mean fecal coliform at each site for the last five years of the study. For the 2016 water year, 13 sites met the standard based on ambient sampling for the entire water year, which is more than the seven sites in 2015. Most sites that did not meet the standard did so due to having more than 10% of samples with fecal coliform counts in excess of 200 mpn. Storm sampling in the Samish Basin also continues to show excessive fecal coliform during rain events.

The 2008 water year was marked by several incidents of high fecal coliform counts at County monitoring stations in the Samish Bay Watershed. Each incident was triggered by moderate to heavy rainfall. These high counts resulted in at least four closures of the Samish Bay shellfish beds to commercial harvest. The most serious incident resulted in a mandatory closure of Samish Bay in response to a sample count of 17,000 mpn units/100 mL from the Samish River at Thomas Road on April 29, 2008.

The 2009, 2010, and 2011 water years saw continued high fecal coliform counts in the Samish River and elsewhere in the Samish Bay Watershed, and many additional closures of shellfish beds. County and Storm Team volunteer monitoring continued to document the relationship between high rainfall events and excess fecal coliform. This ongoing situation prompted the Washington State Department of Ecology to initiate the Clean Samish Initiative in 2009, a partnership of over 20 Federal, State, and County governmental organizations as well as shellfish industry and non-profit groups. This effort is aimed at making immediate improvements in the Samish Bay Watershed fecal coliform situation. Although state standard exceedances and shellfish bed closures continued during 2016, average fecal coliform counts and loading of bacteria to Samish Bay have declined (see Trends discussion below).

The sources of fecal coliform organisms reaching the watercourses of Skagit County could include runoff from failing septic tanks, livestock operations, wildlife, recreationists, and pets. Methods to identify bacterial sources through DNA testing or other innovative strategies are under development but are expensive and not necessarily ready for widespread application. Skagit County did complete a Microbial Source Tracking (DNA) testing project in 2011. Results from that study indicated high frequency of ruminant and avian sources, and less frequent human input. Skagit County received grant funding from EPA to support a program to identify sources of fecal coliform pollution in the Samish Basin through a Pollution Identification and Correction program similar to Kitsap County's program. This program is now in full operation. A full report of Clean Samish Initiative activities will be published separately.

Graphs on the pages following Table 8 illustrate fecal coliform levels for water years 2003-2016 at each of the sample sites. The scale on each graph differs in order to fully illustrate the variability at each site.

Table 7. 2016 Fecal Coliform Results
Summary of Fecal Coliform Readings in Skagit County Monitoring Program
2016 Water Year

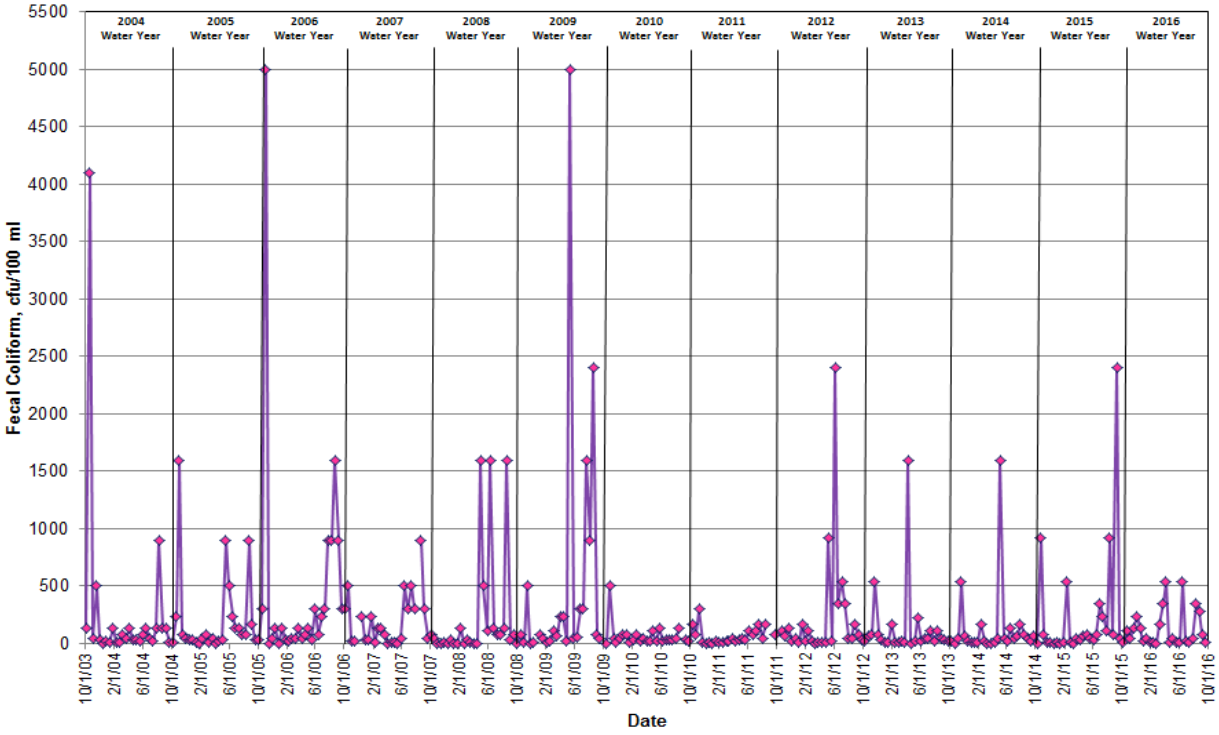
Site Number	Watercourse	Location	Number	Geometric mean (mpn)[1]	% > 100 or 200[1]
3	Thomas Creek	Old Hwy 99 N	26	49	23
4	Thomas Creek	F&S Grade Rd	26	138	38
6	Friday Creek	Prairie Rd	26	34	4
8	Swede Creek	Grip Rd	26	59	8
11	Samish River	State Route 9	26	26	0
12	Nookachamps Creek	Swan Rd	27	65	11
13	E.F. Nookachamps Creek	State Route 9	27	59	19
14	College Way Creek	College Way	26	106	31
15	Nookachamps Creek	Knapp Rd	27	54	4
16	E.F. Nookachamps Creek	Beaver Lake Rd	27	44	19
17	Nookachamps Creek	Big Lake Outlet	27	16	0
18	Lake Creek	State Route 9	27	50	19
19	Hansen Creek	Hoehn Rd	24	114	46
20	Hansen Creek	Northern State	24	35	15
21	Coal Creek	Hoehn Rd	22	84	45
22	Coal Creek	Hwy 20	26	22	15
23	Wiseman Creek	Minkler Rd	23	12	13
24	Mannser Creek	Lyman Hamilton Hwy	26	12	12
25	Red Cabin Creek	Hamilton Cemetery Rd	19	6	5
28	Brickyard Creek	Hwy 20	18	33	11
29	Skagit River	River Bend Rd	27	14	15
30	Skagit River	Cape Horn Rd	26	6	4
31	Drainage Dist 20 floodgate	Francis Rd	11	15	0
32	Samish River	Thomas Rd	25	54	12
33	Alice Bay Pump Station	Samish Island Rd	24	54	21
34	No Name Slough	Bayview-Edison Rd	25	71	24
35	Joe Leary Slough	D'Arcy Rd	25	98	36
36	Edison Slough at school	W. Bow Hill Rd	26	120	38
37	Edison Pump Station	Farm to Market Rd	26	386	69
38	North Edison Pump Station	North Edison Rd	25	264	60
39	Colony Creek	Colony Rd	26	76	23
40	Big Indian Slough	Bayview-Edison Rd	27	29	7
41	Maddox Slough/Big Ditch	Milltown Rd	27	61	22
42	Hill Ditch	Cedardale Rd	27	43	4
43	Wiley Slough	Wylie Rd	27	106	26
44	Sullivan Slough	La Conner-Bayview Rd	27	157	44
45	Skagit River – North Fork	Moore Rd	27	6	4
46	Skagit River – South Fork	Fir Island Rd	27	9	4
47	Swinomish Channel	County Boat Launch	27	6	0
48	Fisher Creek	Franklin Rd	26	92	23

[1] State water quality standards for fecal coliform requires water bodies to have a geometric mean of less than 50 (sites 21-25,30) or 100 (sites 3-20,28-29, 31-46, 48) colony forming units (cfu) or Most Probable Number (mpn) per 100 ml and less than 10% of the samples >100 (sites 21-25,30) or >200 cfu (sites 3-20,28-29, 31-46, 48). Marine locations (site 47) are required to be <14 cfu with no more than 10% >41 cfu.

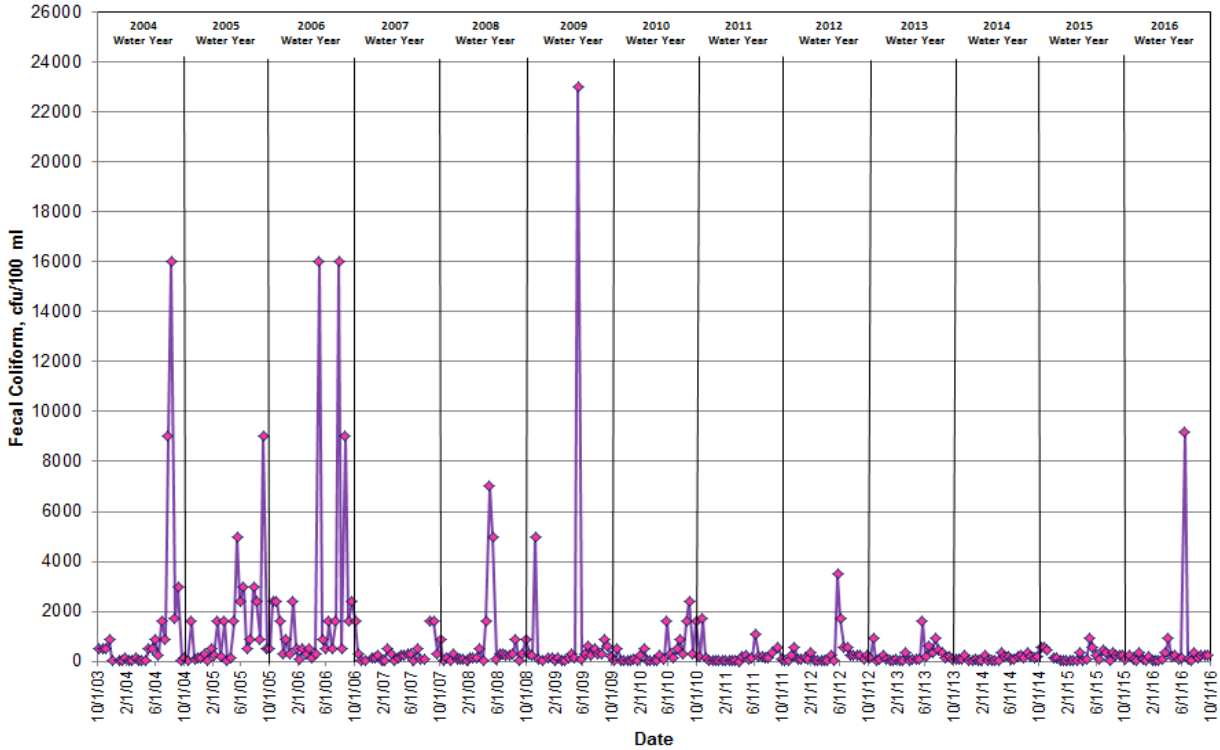
Table 8. Five-Year Fecal Coliform Results Summary
Geometric mean fecal coliform levels (mpn/100 mL) for the last five years of the Skagit County Monitoring Program

Site Number	Watercourse	Location	2012	2013	2014	2015	2016
3	Thomas Creek	Old Hwy 99 N	61	41	37	46	49
4	Thomas Creek	F&S Grade Rd	139	134	84	133	138
6	Friday Creek	Prairie Rd	44	31	28	36	34
8	Swede Creek	Grip Rd	57	51	34	63	59
11	Samish River	State Route 9	15	14	10	13	26
12	Nookachamps Creek	Swan Rd	47	68	54	107	65
13	E.F. Nookachamps Creek	State Route 9	47	55	48	64	59
14	College Way Creek	College Way	90	131	101	148	106
15	Nookachamps Creek	Knapp Rd	99	58	49	93	54
16	E.F. Nookachamps Creek	Beaver Lake Rd	25	32	19	25	44
17	Nookachamps Creek	Big Lake Outlet	11	15	9	23	16
18	Lake Creek	State Route 9	36	48	41	41	50
19	Hansen Creek	Hoehn Rd	87	67	186	71	114
20	Hansen Creek	Northern State	43	46	34	45	35
21	Coal Creek	Hoehn Rd	95	59	66	91	84
22	Coal Creek	Hwy 20	20	13	15	19	22
23	Wiseman Creek	Minkler Rd	15	11	13	7	12
24	Mannser Creek	Lyman Hamilton Hwy	15	12	11	17	12
25	Red Cabin Creek	Hamilton Cemetery Rd	7	7	10	12	6
28	Brickyard Creek	Hwy 20	67	41	58	34	33
29	Skagit River	River Bend Rd	9	7	5	10	14
30	Skagit River	Cape Horn Rd	3	4	5	5	6
31	Drainage District 20 floodgate	Francis Rd	33	17	11	83	15
32	Samish River	Thomas Rd	52	42	47	50	54
33	Alice Bay Pump Station	Samish Island Rd	51	70	63	27	54
34	No Name Slough	Bayview-Edison Rd	110	131	64	171	71
35	Joe Leary Slough	D'Arcy Rd	56	125	120	63	98
36	Edison Slough at school	W. Bow Hill Rd	64	66	102	105	120
37	Edison Pump Station	Farm to Market Rd	87	267	197	166	386
38	North Edison Pump Station	North Edison Rd	205	148	285	222	264
39	Colony Creek	Colony Rd	55	54	81	91	76
40	Big Indian Slough	Bayview-Edison Rd	55	43	32	119	29
41	Maddox Slough/Big Ditch	Milltown Rd	70	104	95	123	61
42	Hill Ditch	Cedardale Rd	76	81	67	104	43
43	Wiley Slough	Wylie Rd	63	118	45	109	106
44	Sullivan Slough	La Conner-Bayview Rd	88	176	75	179	157
45	Skagit River – North Fork	Moore Rd	6	7	6	7	6
46	Skagit River – South Fork	Fir Island Rd	7	7	7	12	9
47	Swinomish Channel	County Boat Launch	7	0	5	5	6
48	Fisher Creek	Franklin Rd	56	138	50	96	92

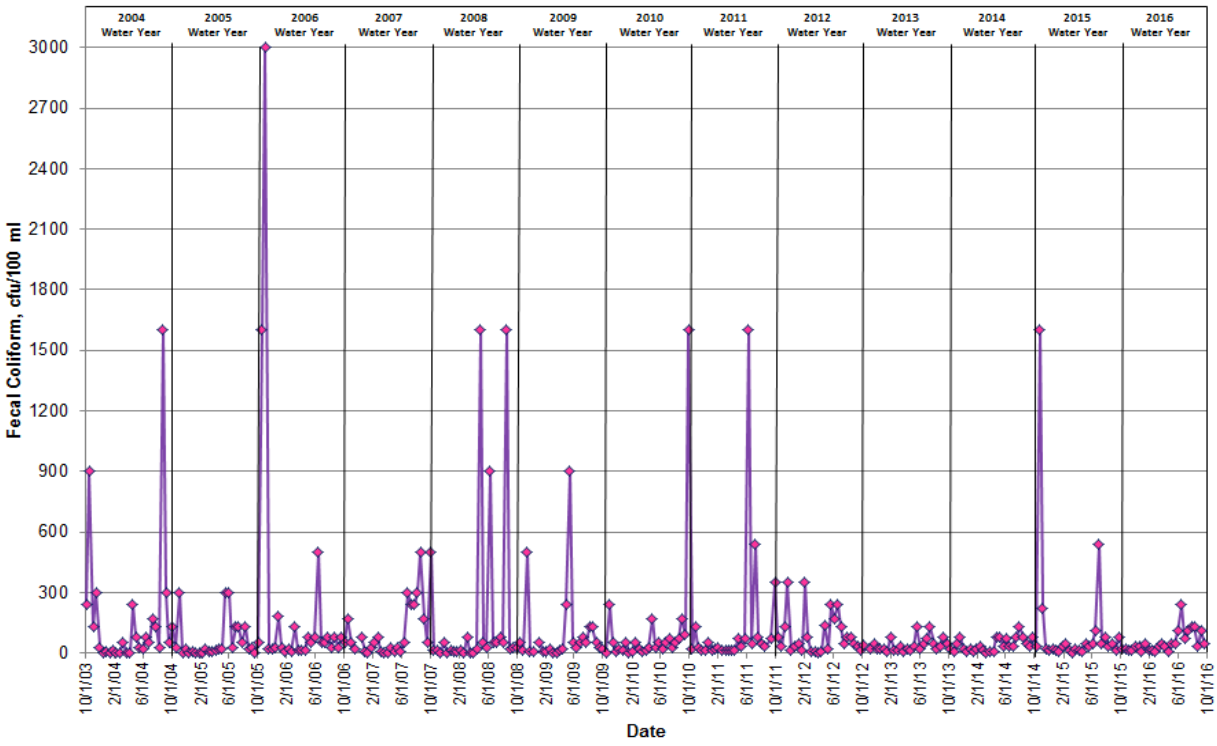
Thomas Creek at Highway 99 - Site 3
Fecal Coliform



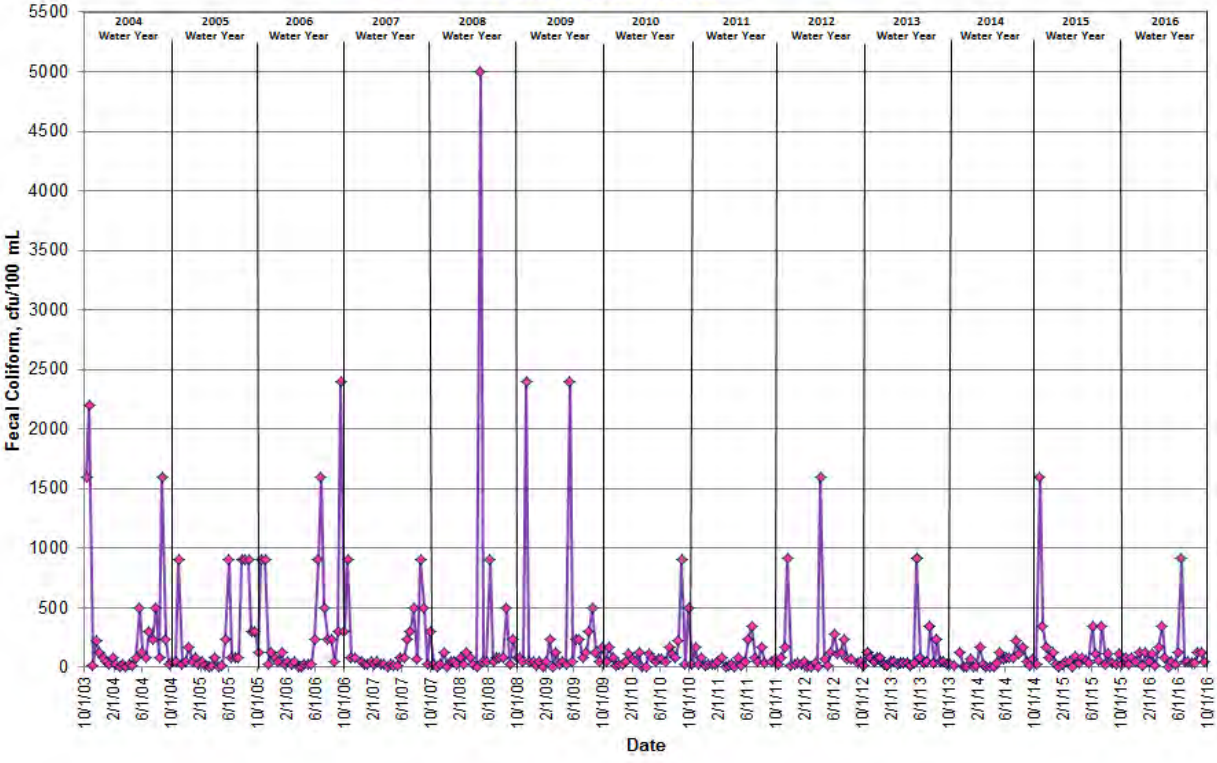
Thomas Creek at F&S Grade Road - Site 4
Fecal Coliform



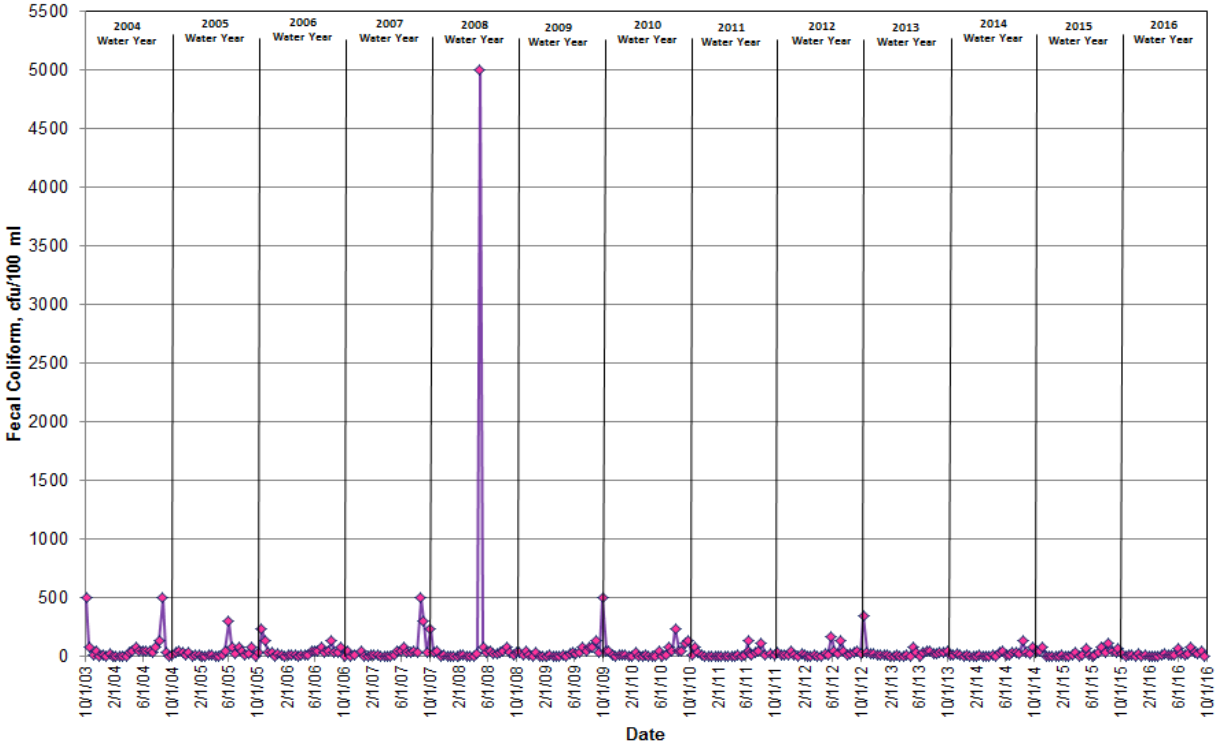
Friday Creek at Prairie Road - Site 6
Fecal Coliform



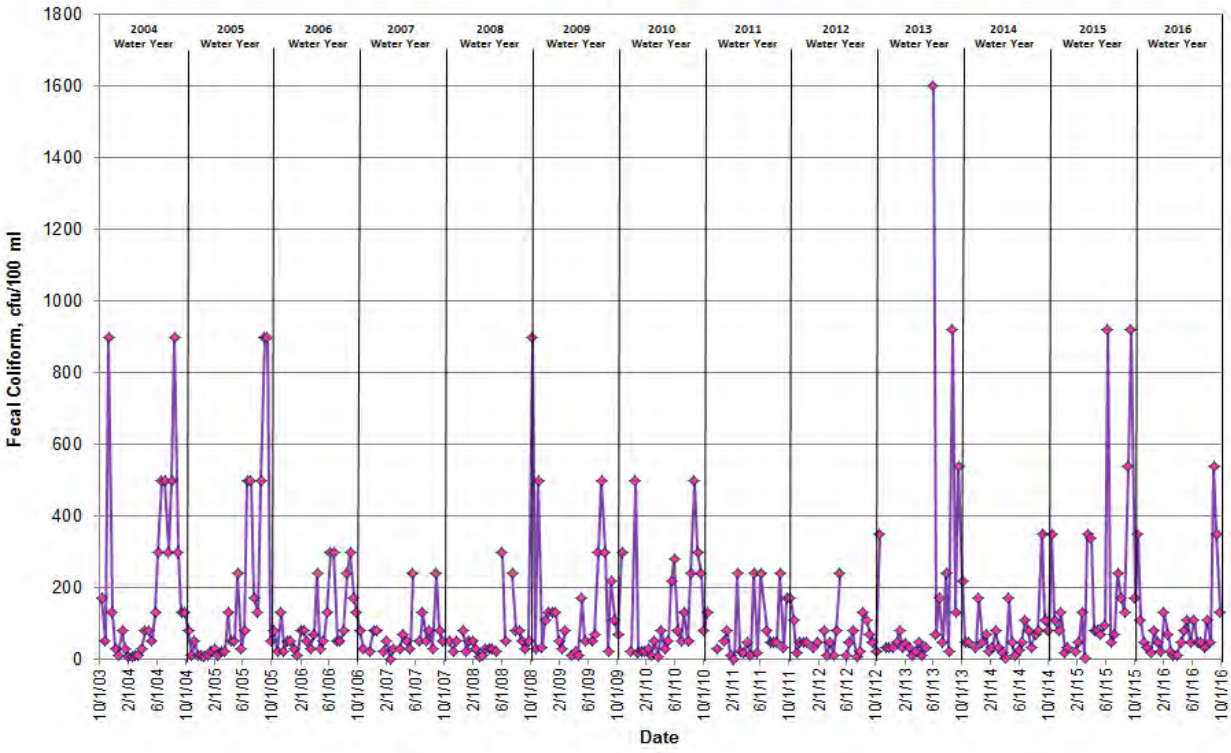
Swede Creek at Grip Road - Site 8
Fecal Coliform



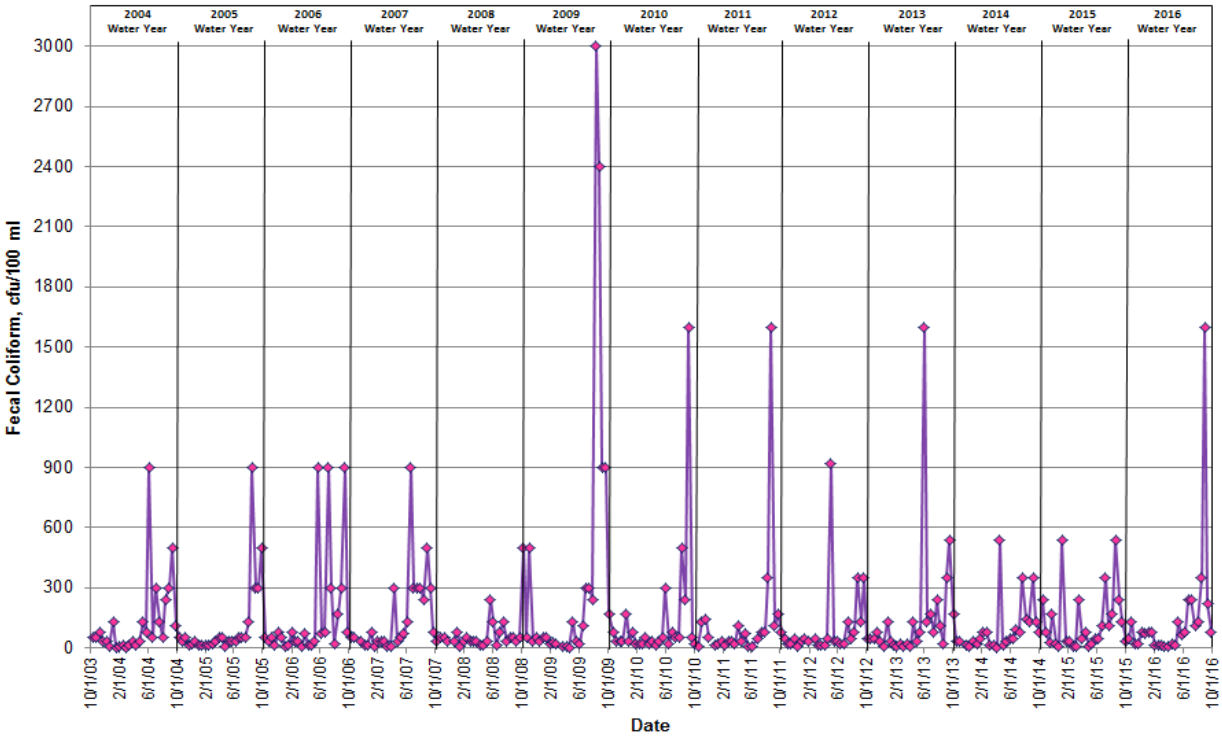
Samish River at Highway 9 - Site 11
Fecal Coliform



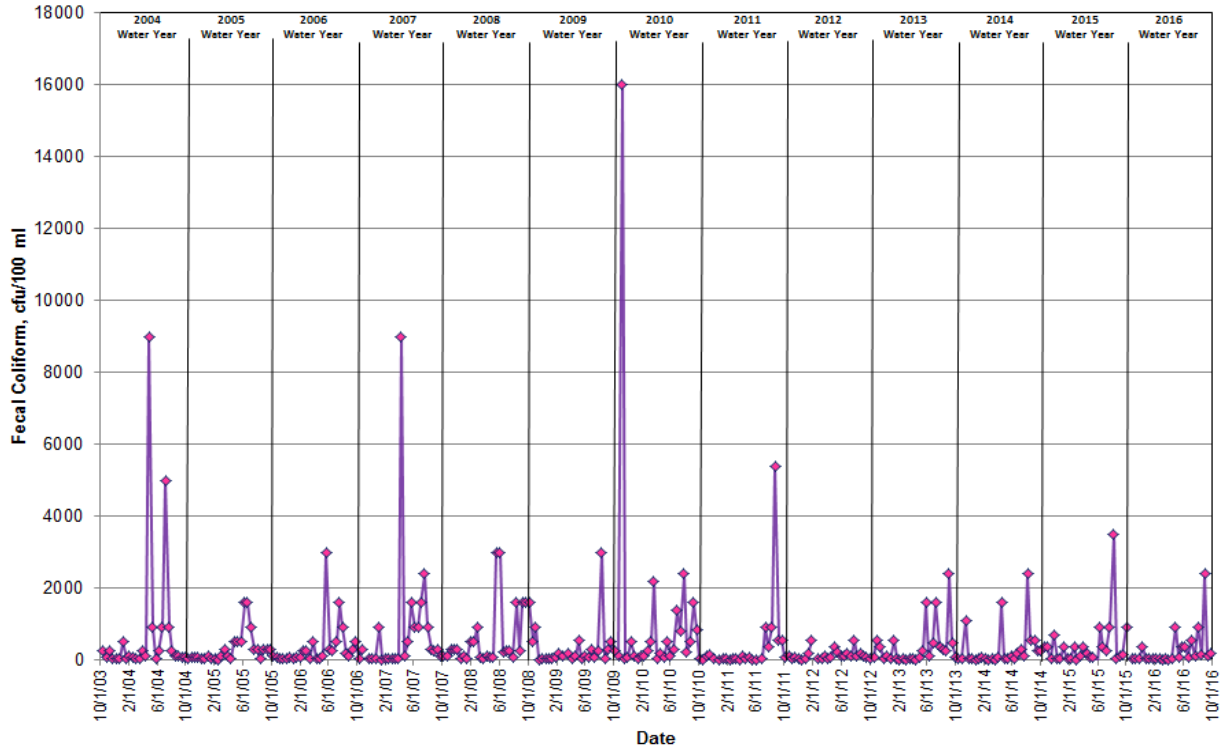
Nookachamps Creek at Swan Road - Site 12
Fecal Coliform



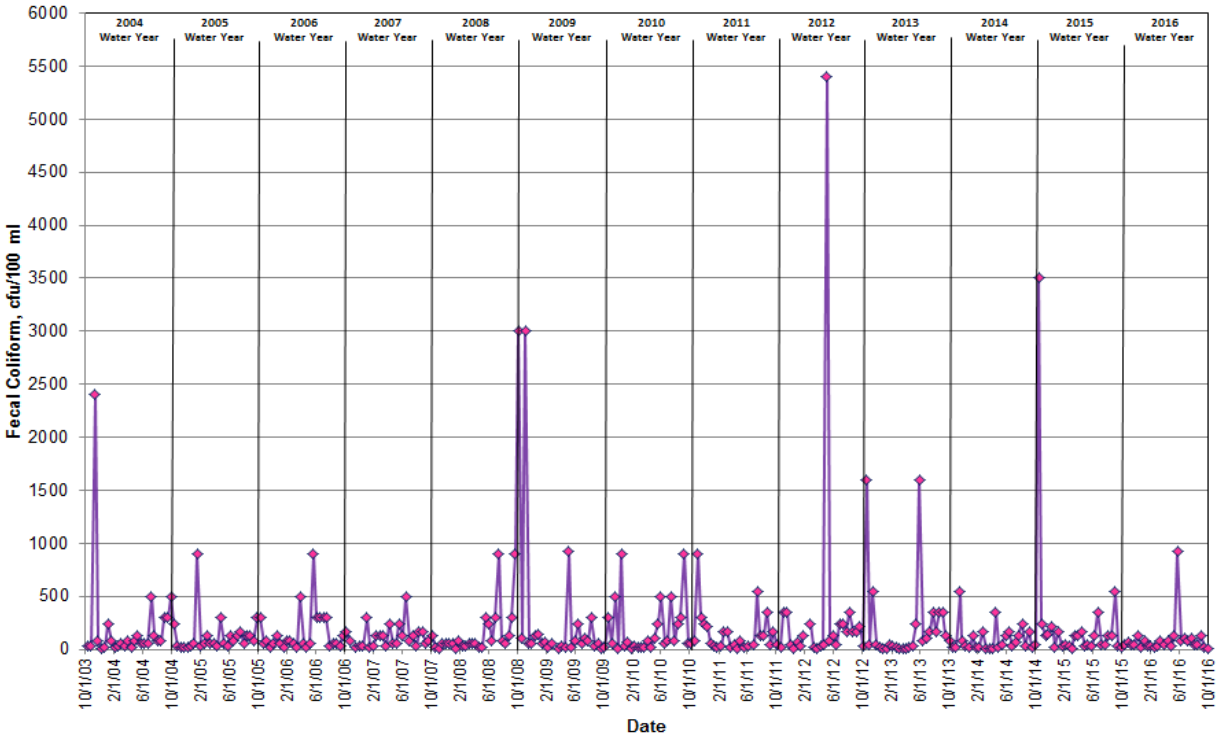
East Fork Nookachamps Creek at Highway 9 - Site 13
Fecal Coliform



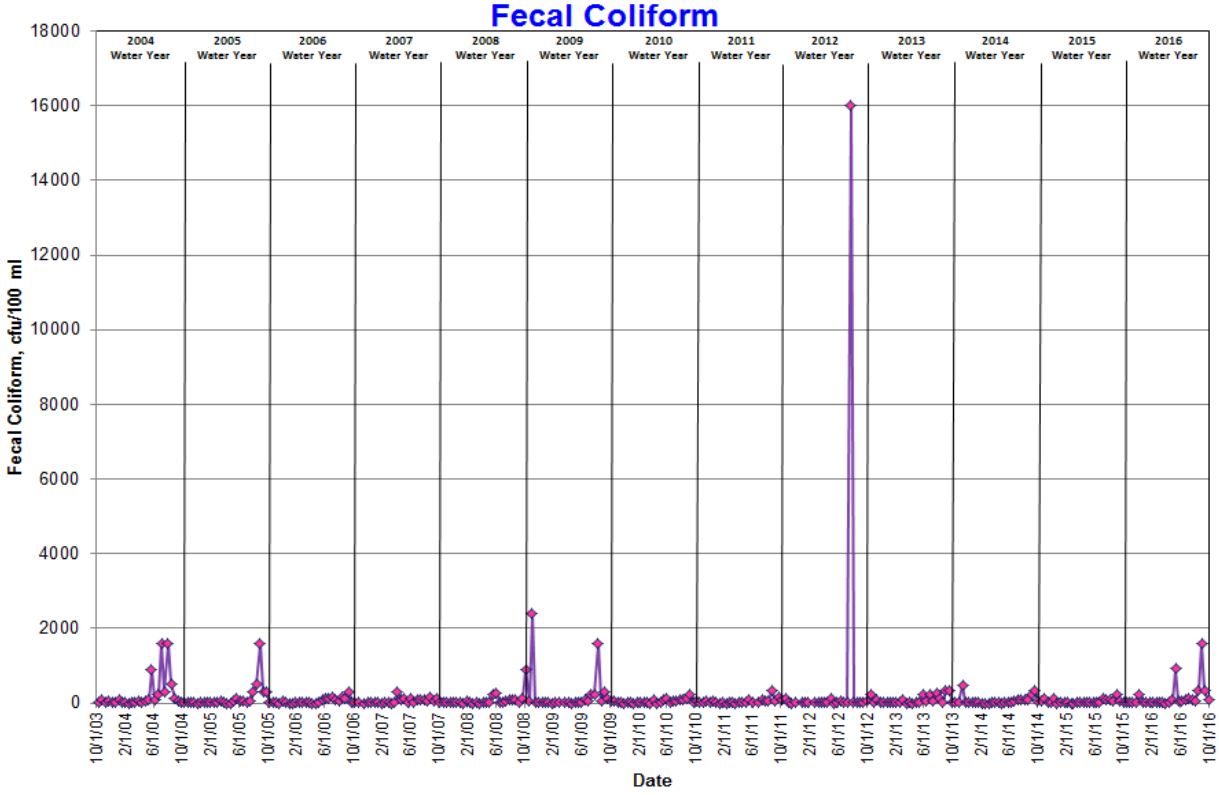
College Way Creek at College Way - Site 14
Fecal Coliform



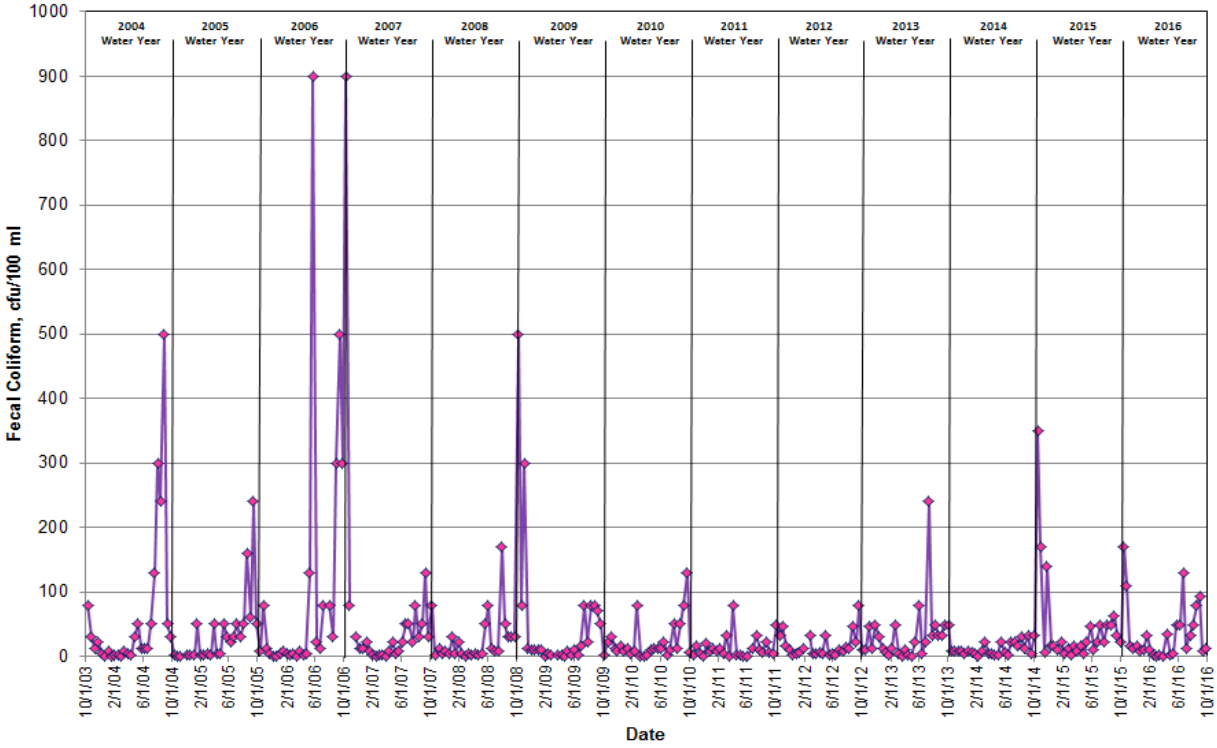
Nookachamps Creek at Knapp Road - Site 15
Fecal Coliform



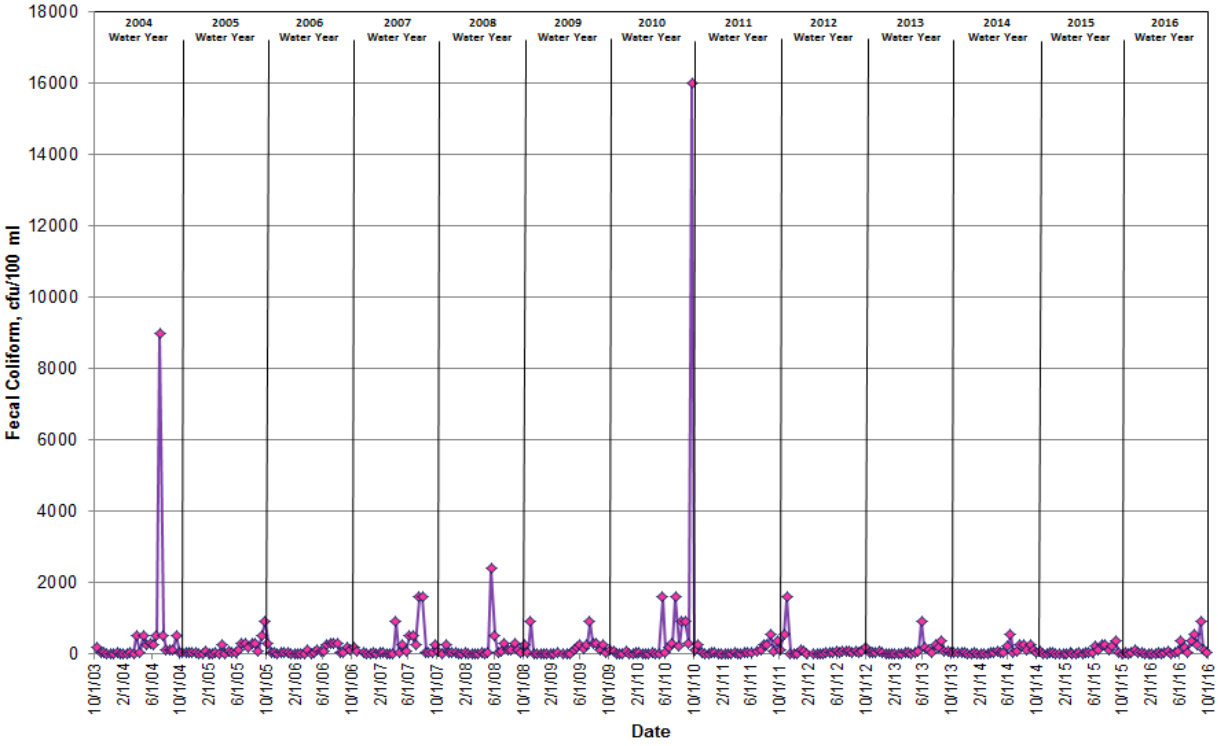
East Fork Nookachamps Creek at Beaver Lake Road - Site 16
Fecal Coliform



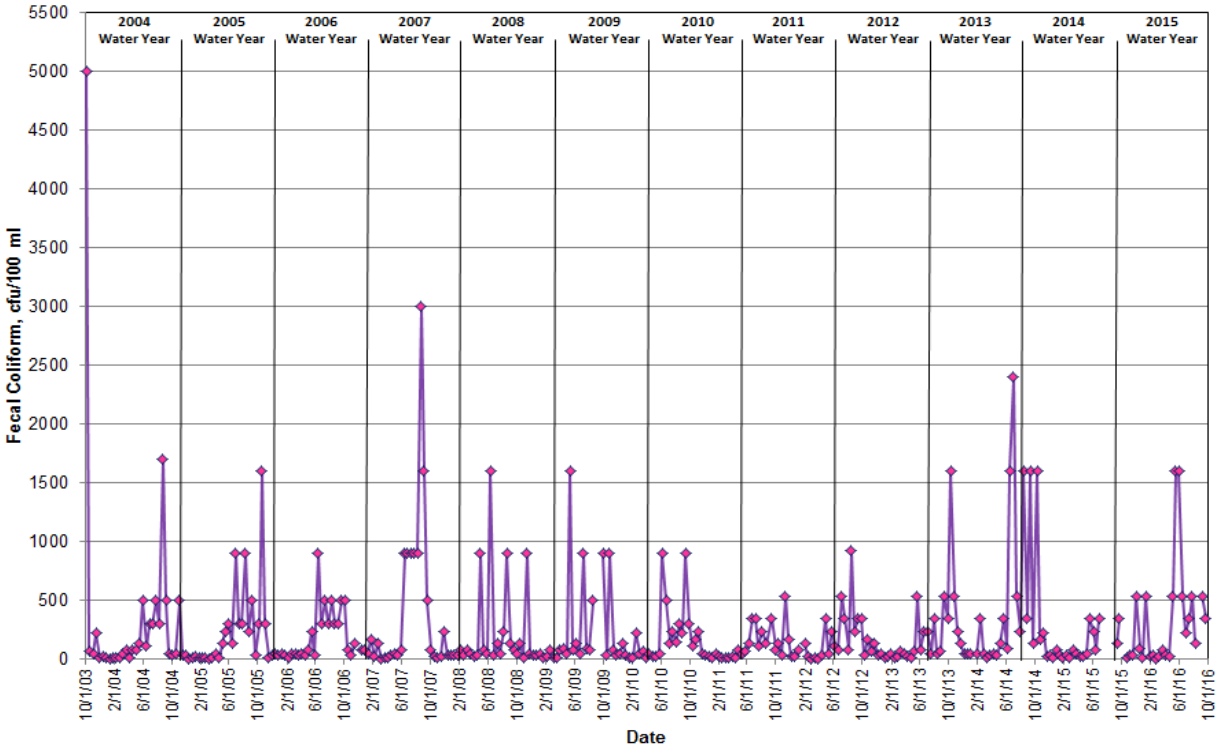
Nookachamps Creek at Big Lake Outlet - Site 17
Fecal Coliform



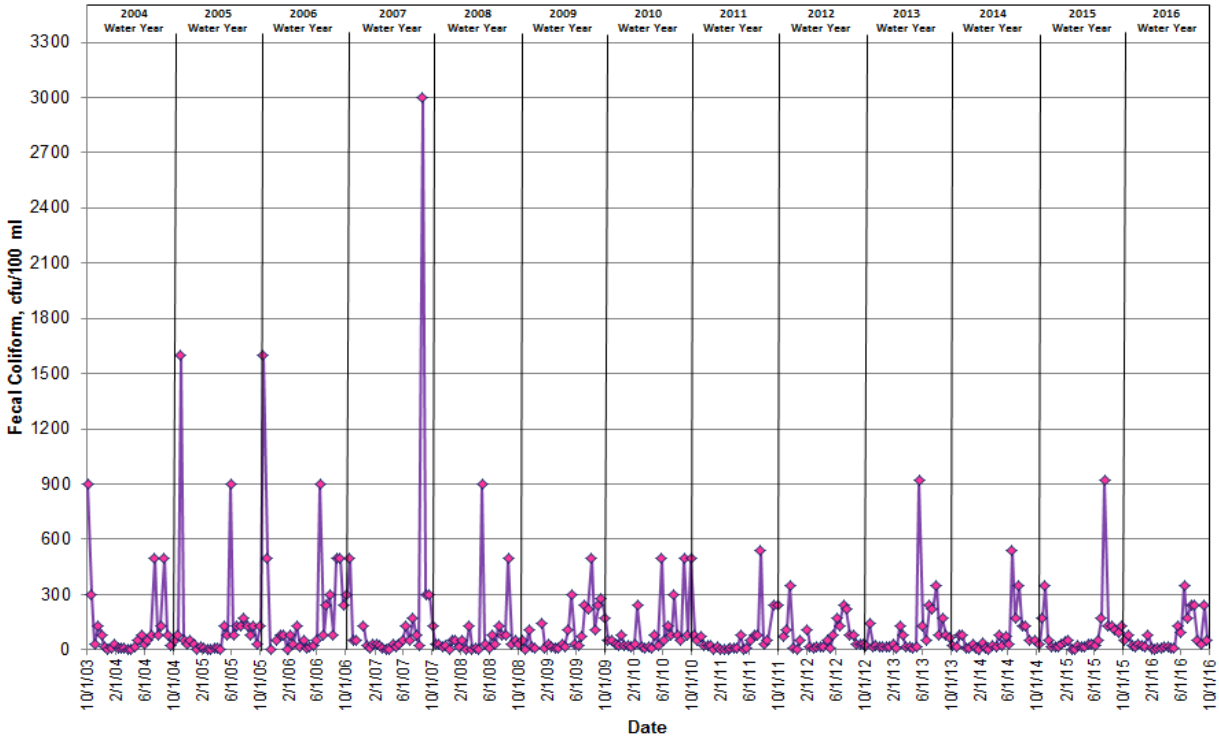
Lake Creek at Highway 9 - Site 18
Fecal Coliform



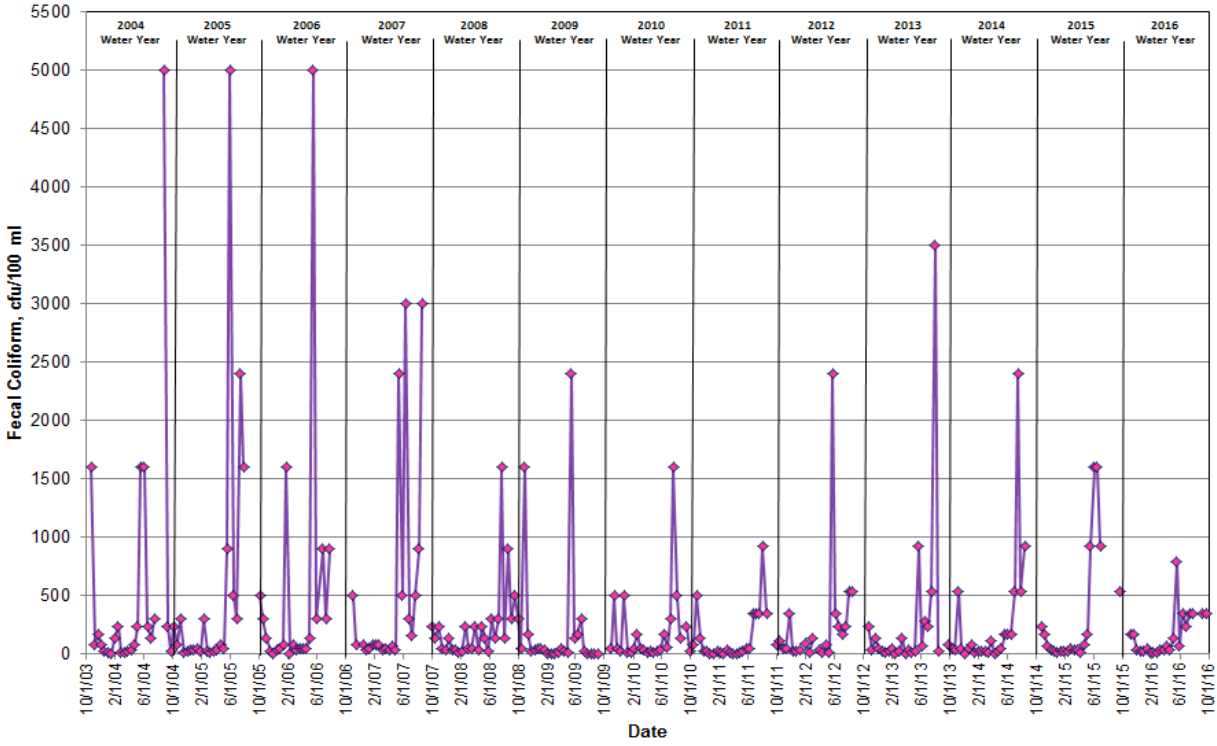
Hansen Creek at Hoehn Road - Site 19
Fecal Coliform



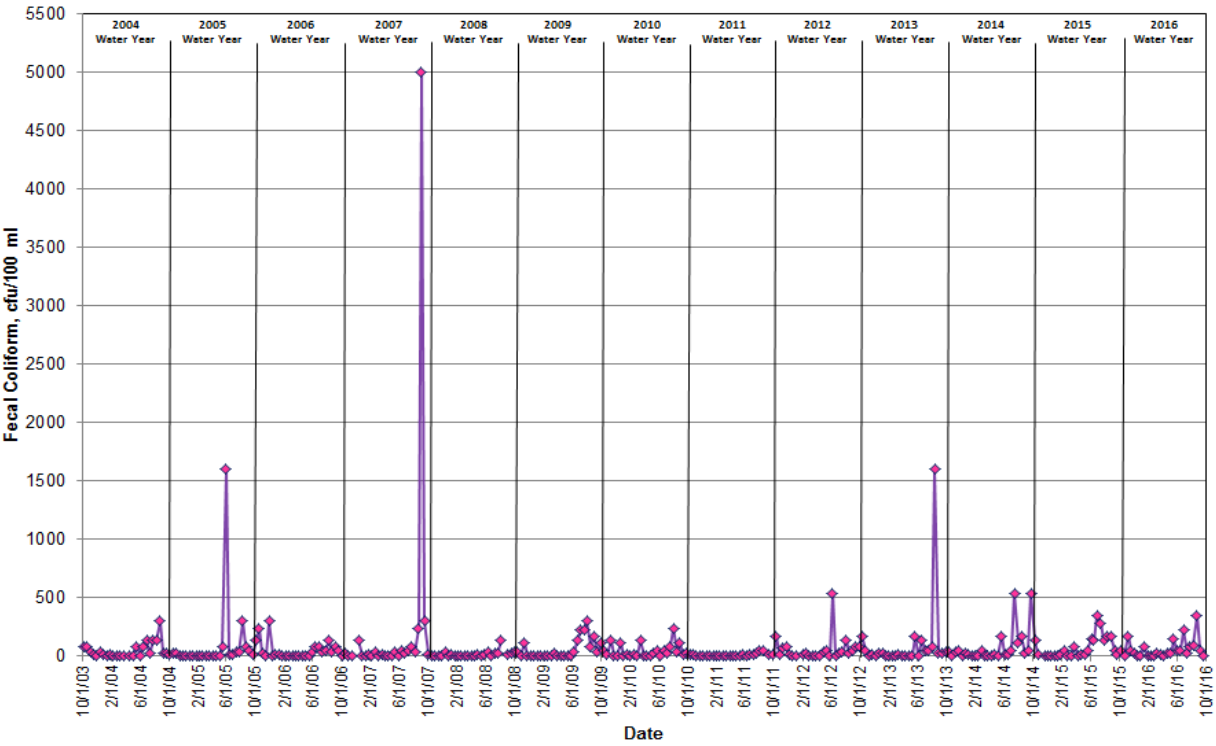
Hansen Creek at Northern State Hospital - Site 20
Fecal Coliform



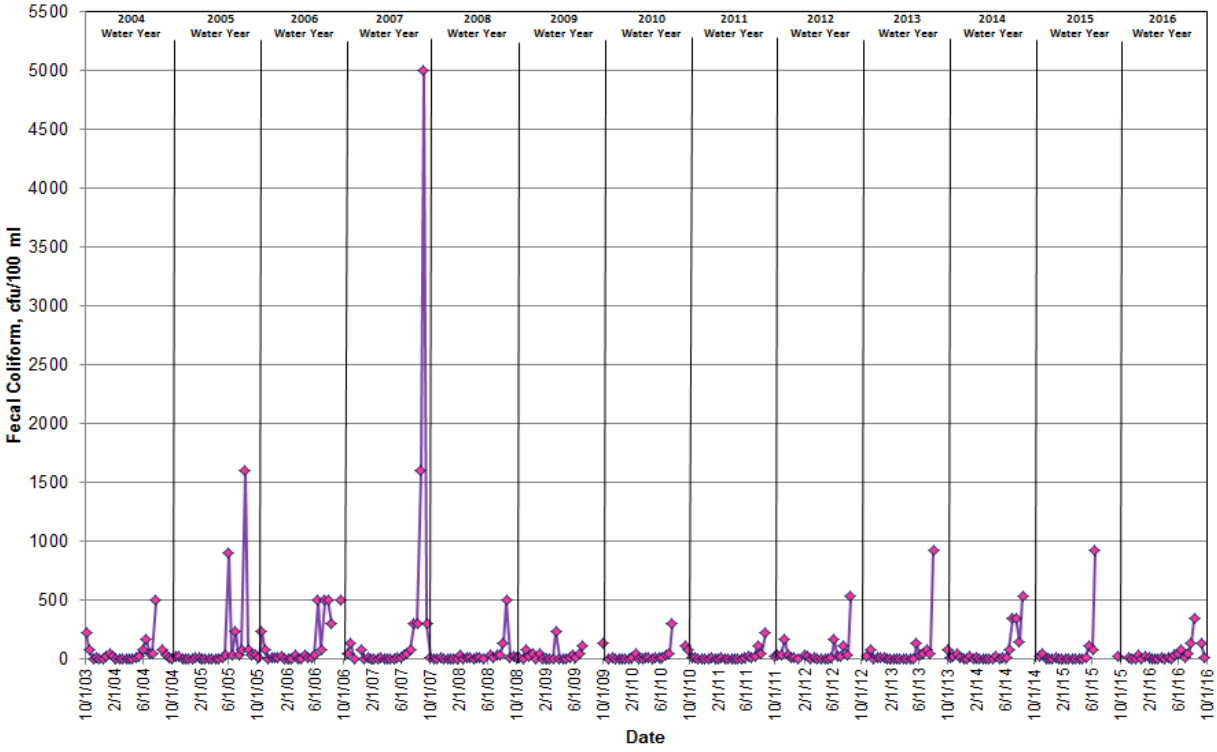
Coal Creek at Hoehn Road - Site 21
Fecal Coliform



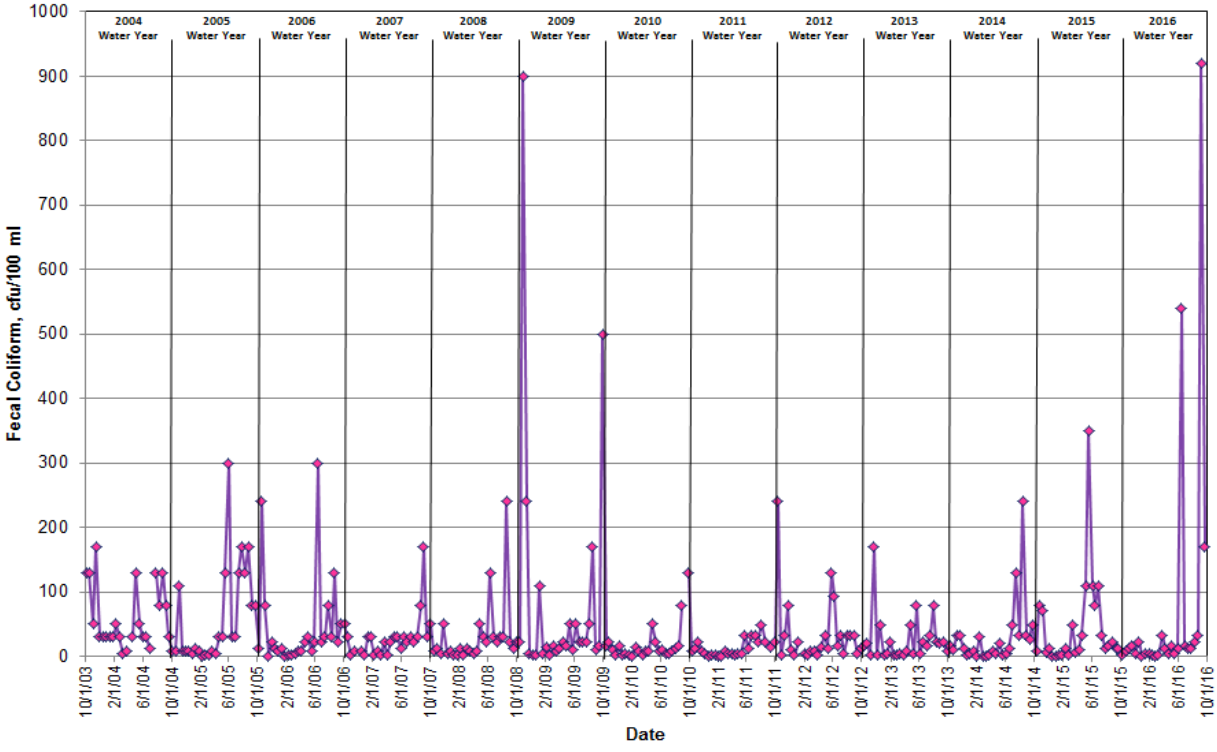
Coal Creek at Highway 20 - Site 22
Fecal Coliform



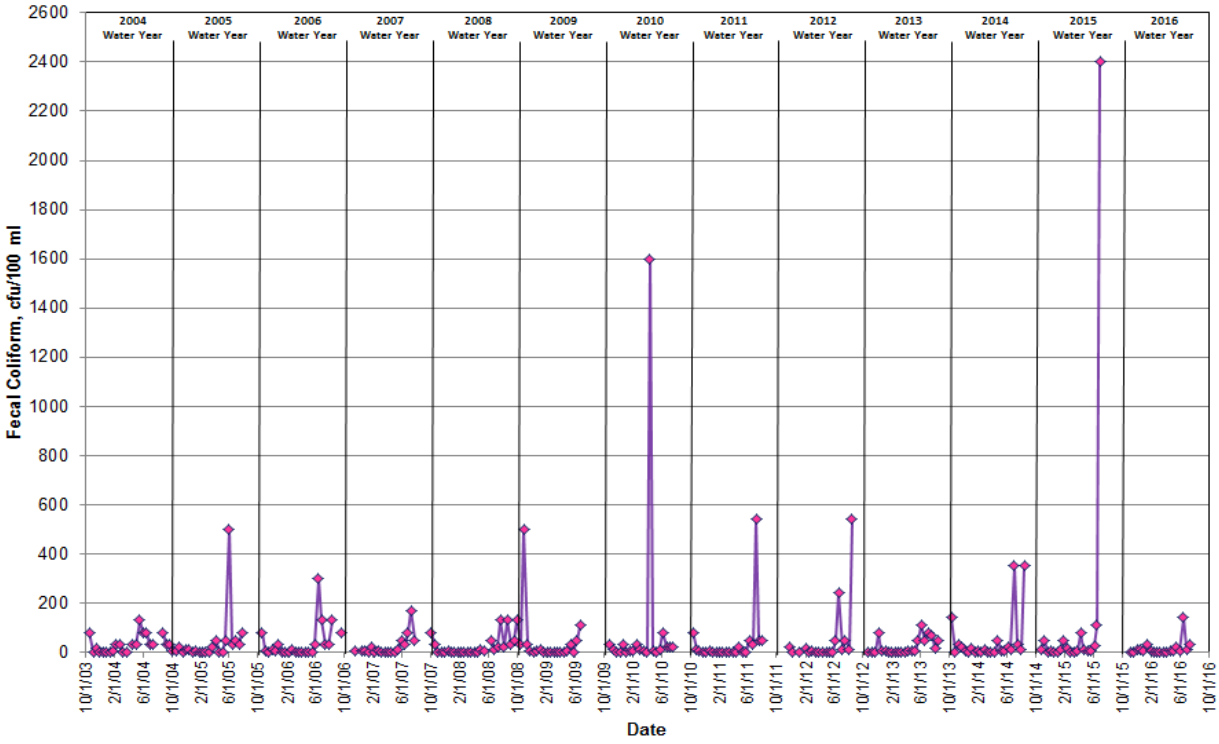
Wiseman Creek at Minkler Road - Site 23
Fecal Coliform



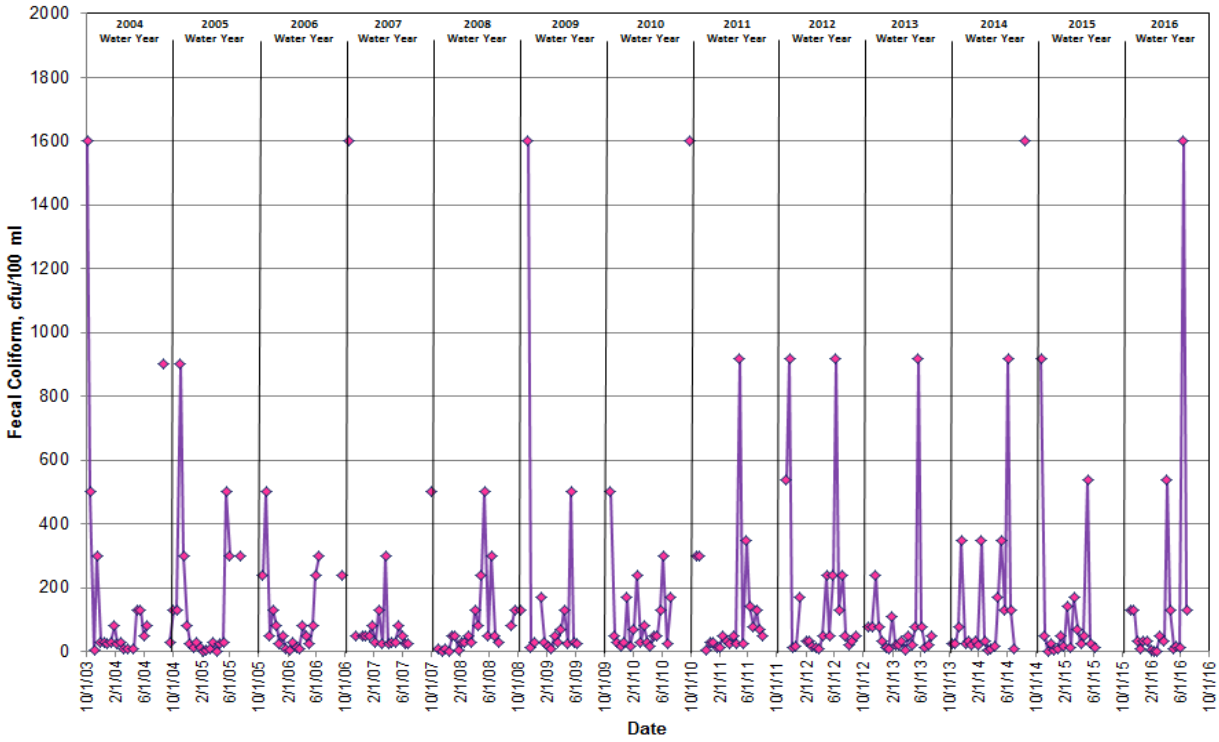
Mannser Creek at Lyman-Hamilton Highway - Site 24
Fecal Coliform



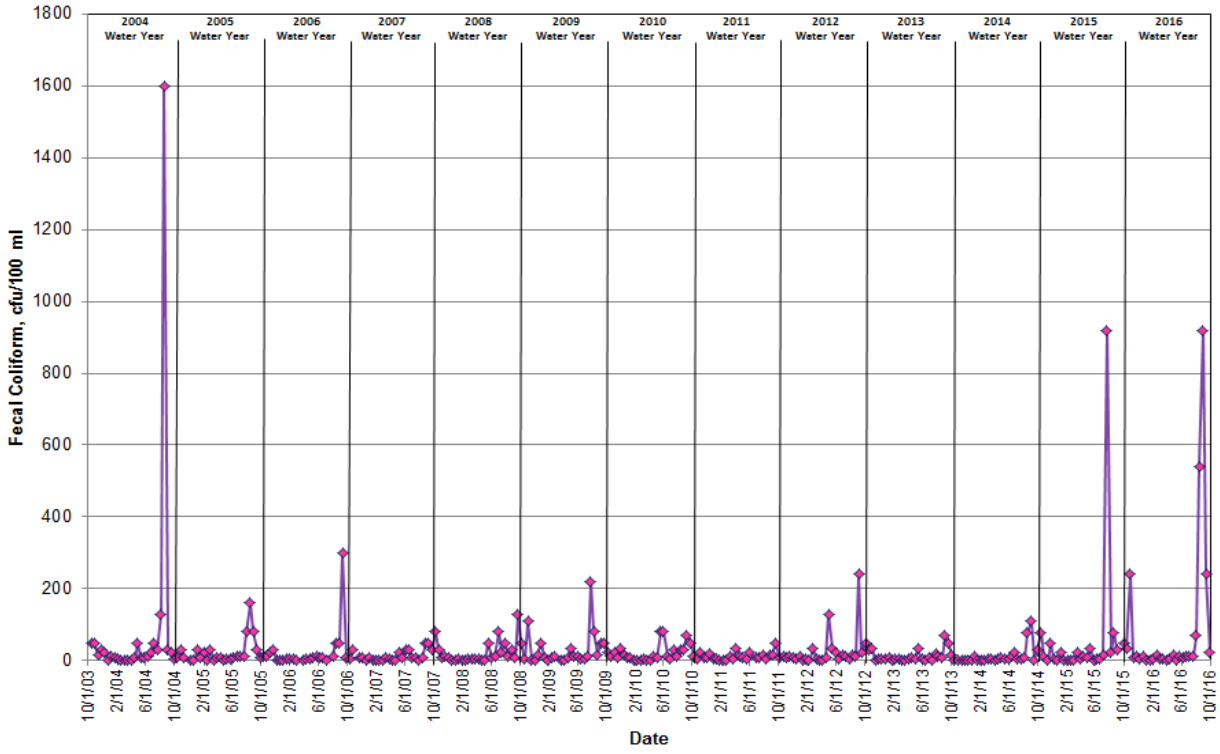
Red Cabin Creek at Hamilton Cemetery Road - Site 25
Fecal Coliform



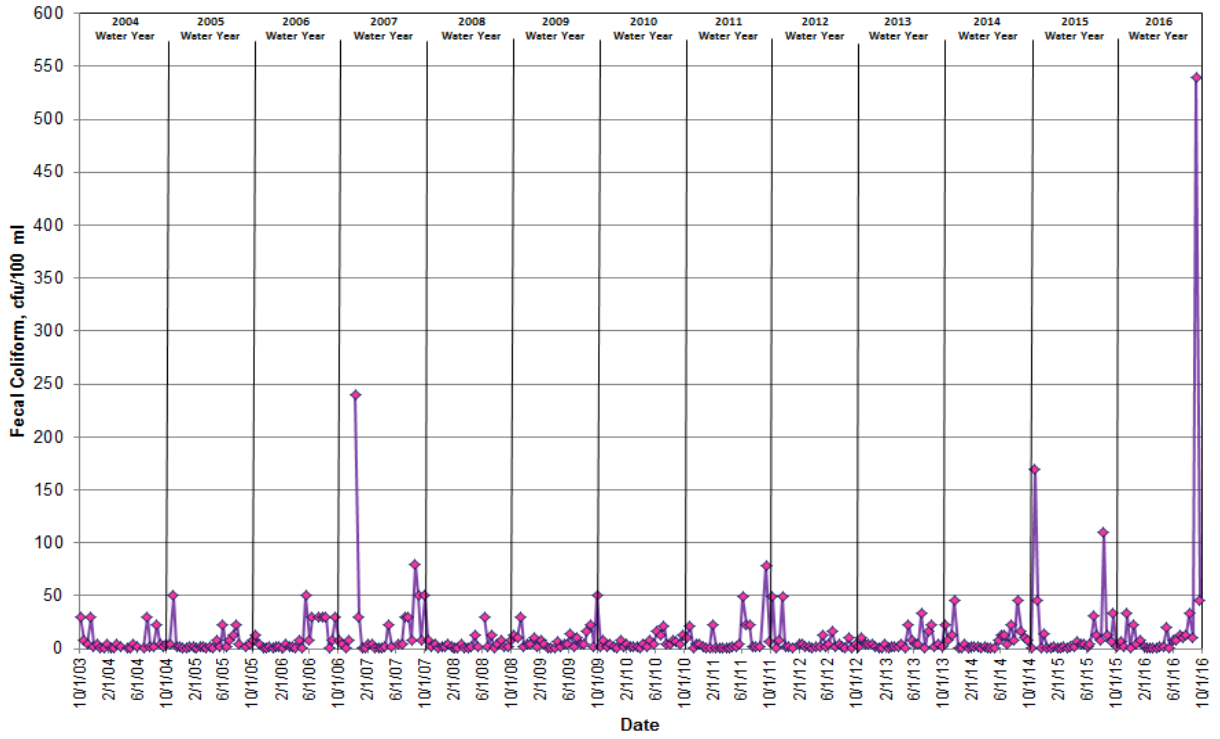
Brickyard Creek at Highway 20 - Site 28
Fecal Coliform



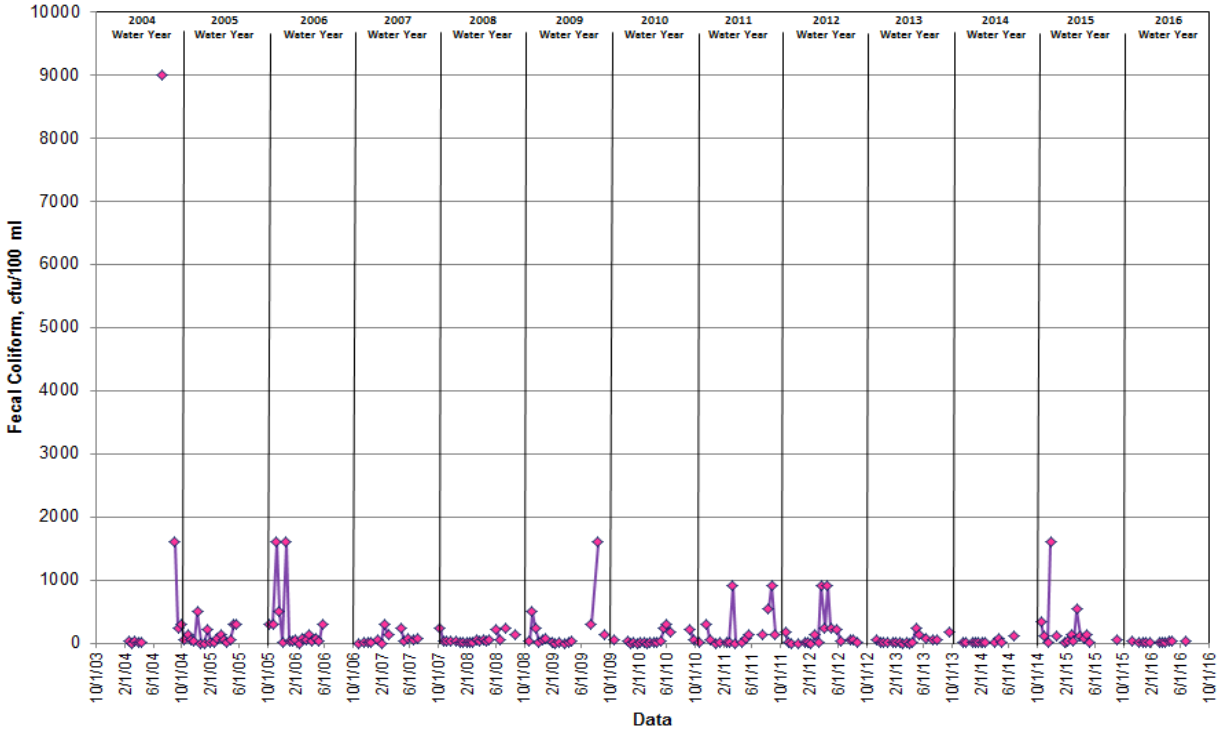
Skagit River at River Bend Road - Site 29
Fecal Coliform



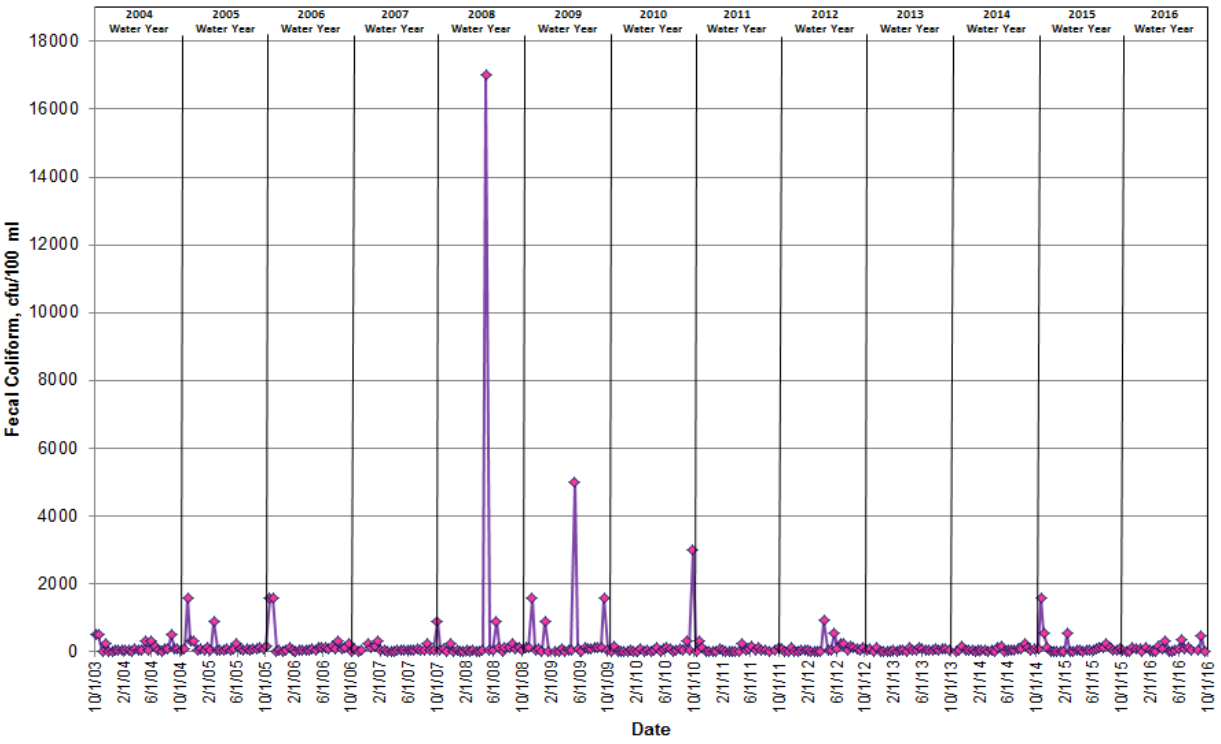
Skagit River at Cape Horn Road - Site 30
Fecal Coliform



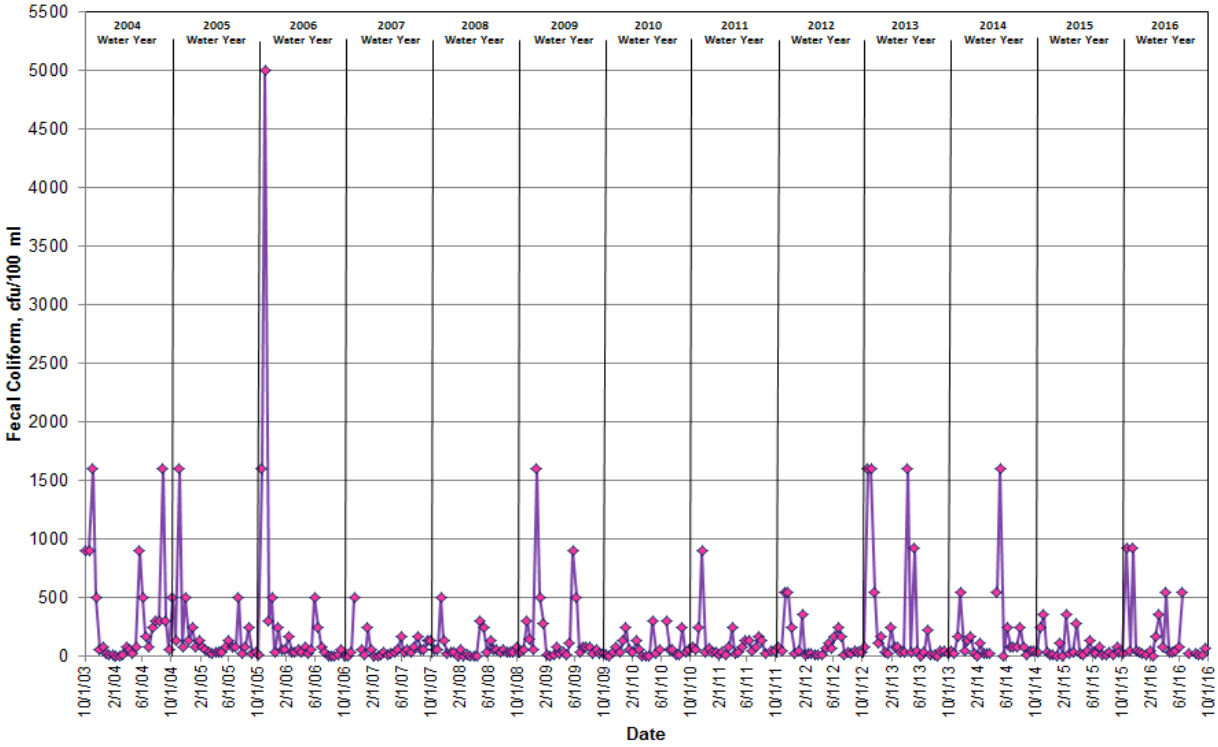
Drainage District 20 Ditch at Floodgate - Site 31
Fecal Coliform



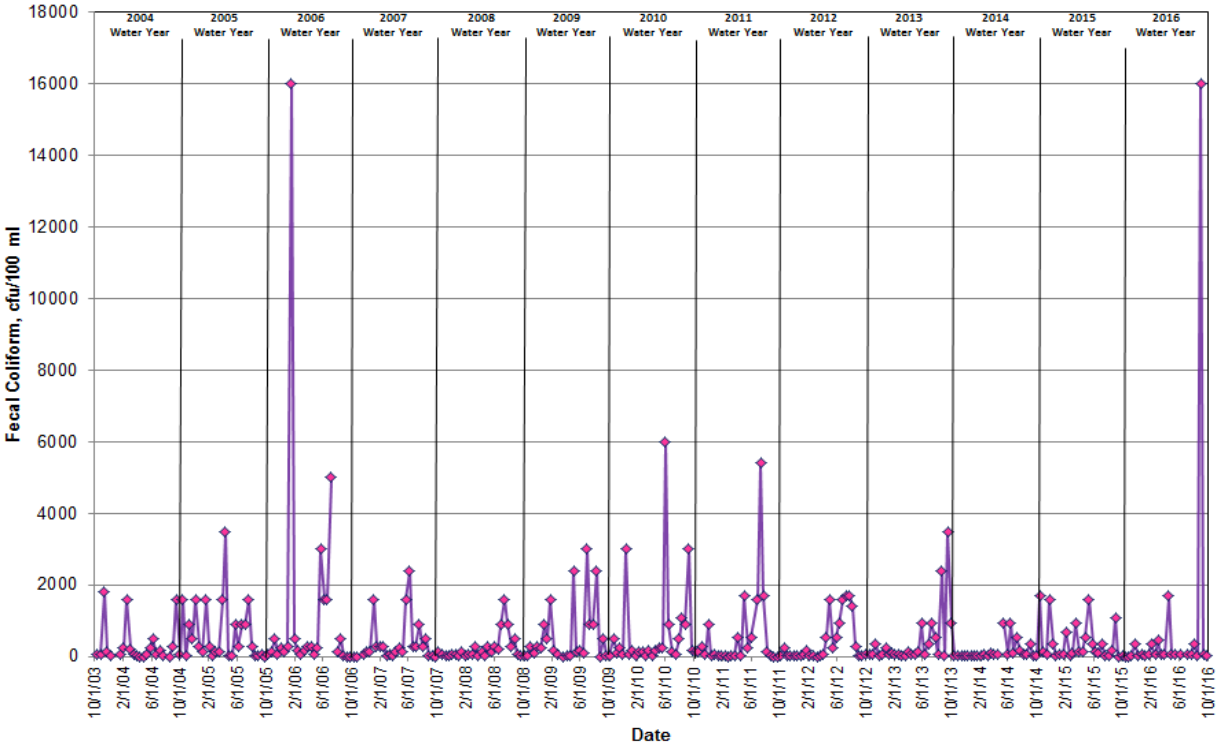
Samish River at Thomas Road - Site 32
Fecal Coliform



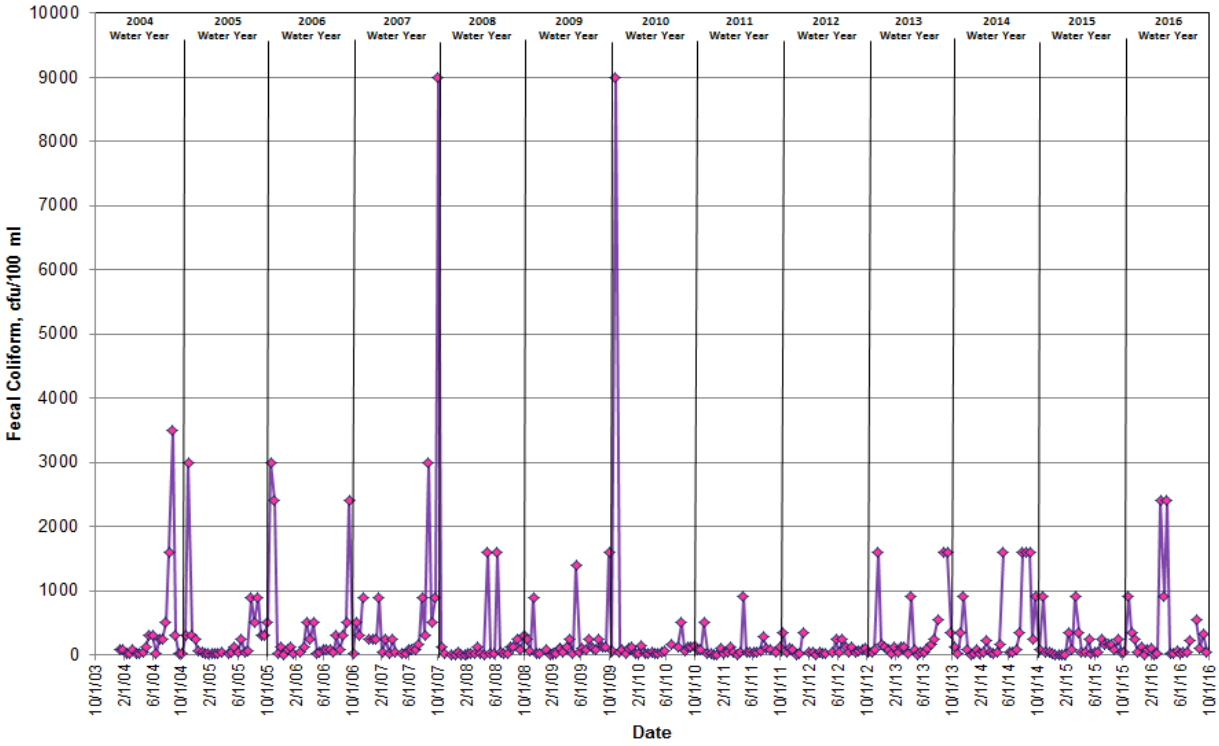
Alice Bay Pump Station - Site 33
Fecal Coliform



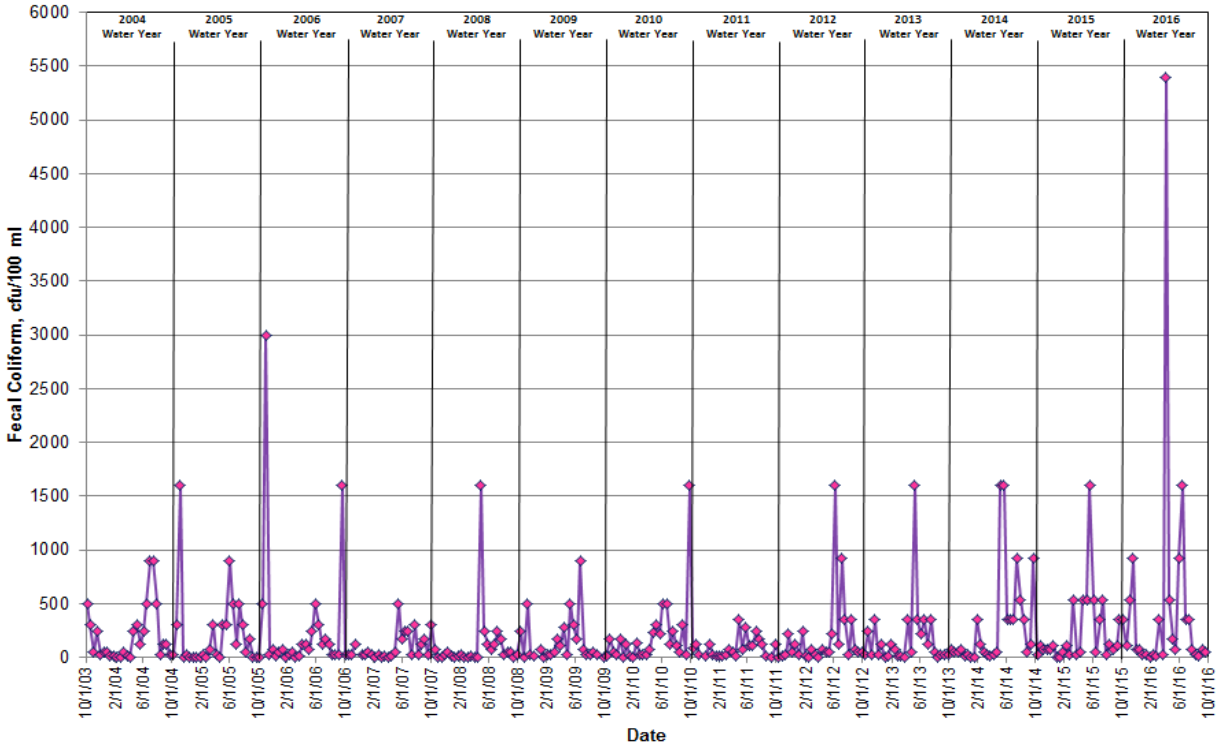
No Name Slough at Bayview-Edison Road - Site 34
Fecal Coliform



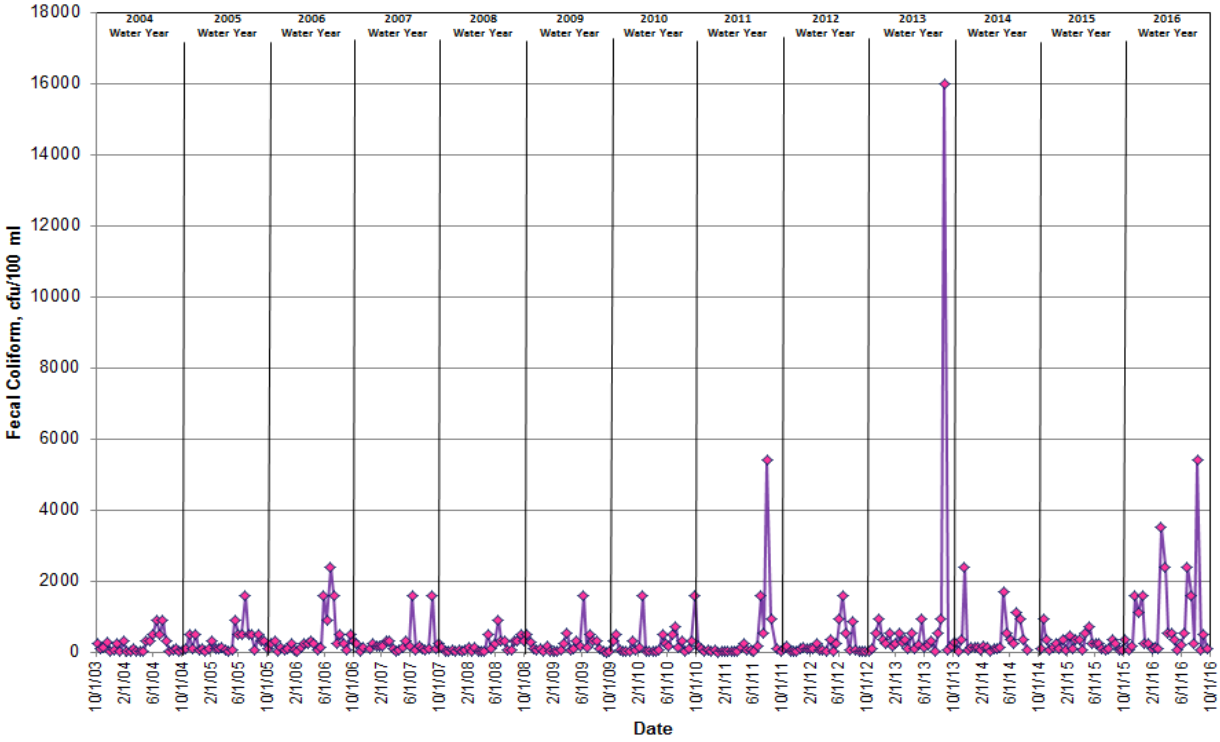
Joe Leary Slough at D'Arcy Road - Site 35
Fecal Coliform



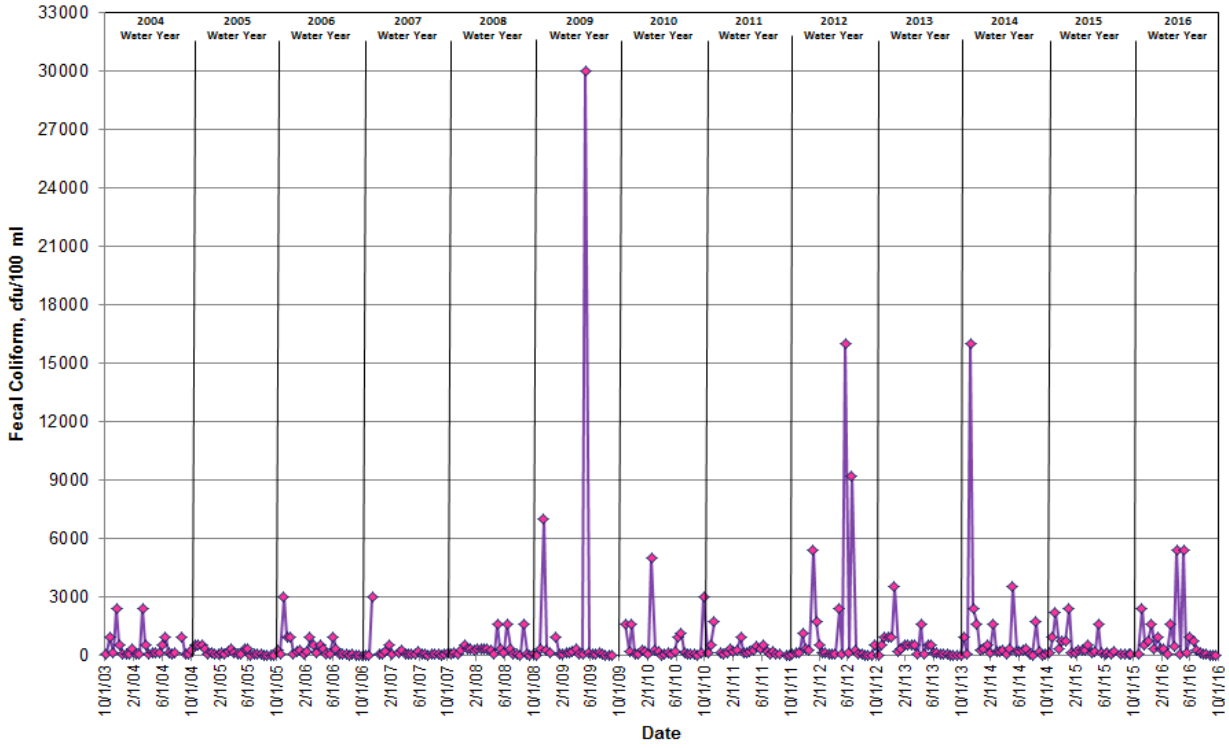
Edison Slough at Edison School - Site 36
Fecal Coliform



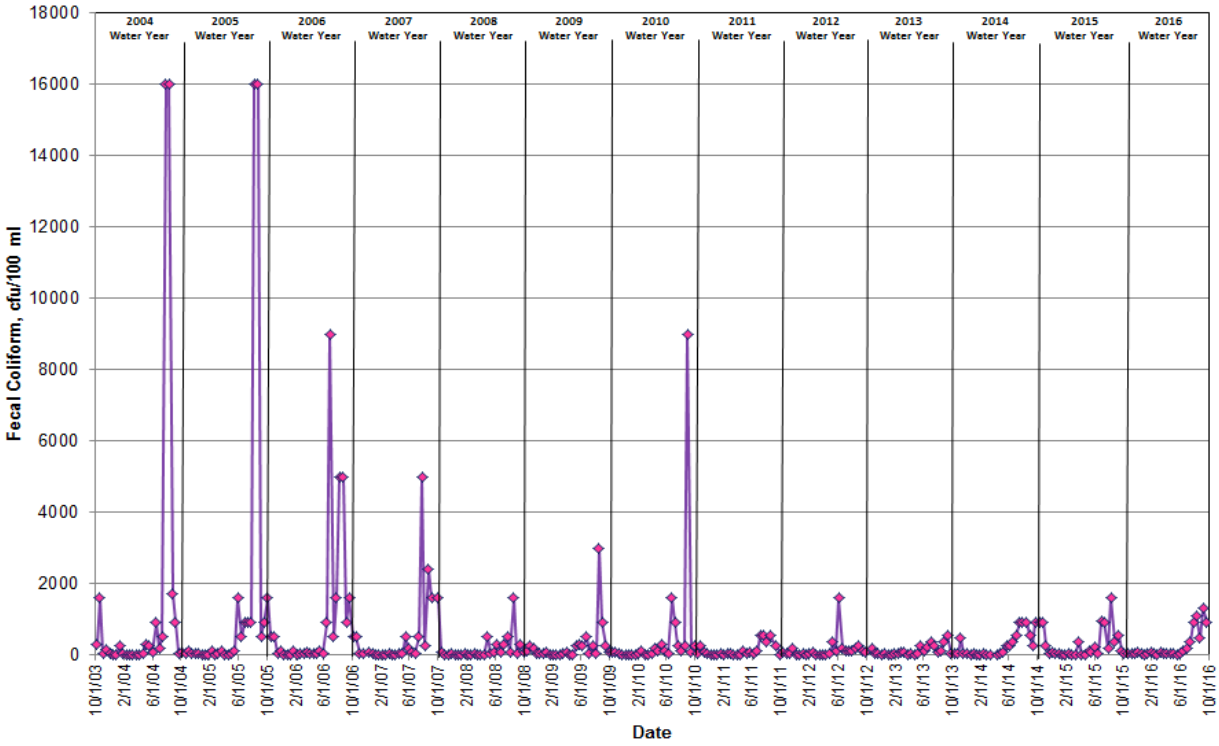
Edison Pump Station - Site 37
Fecal Coliform



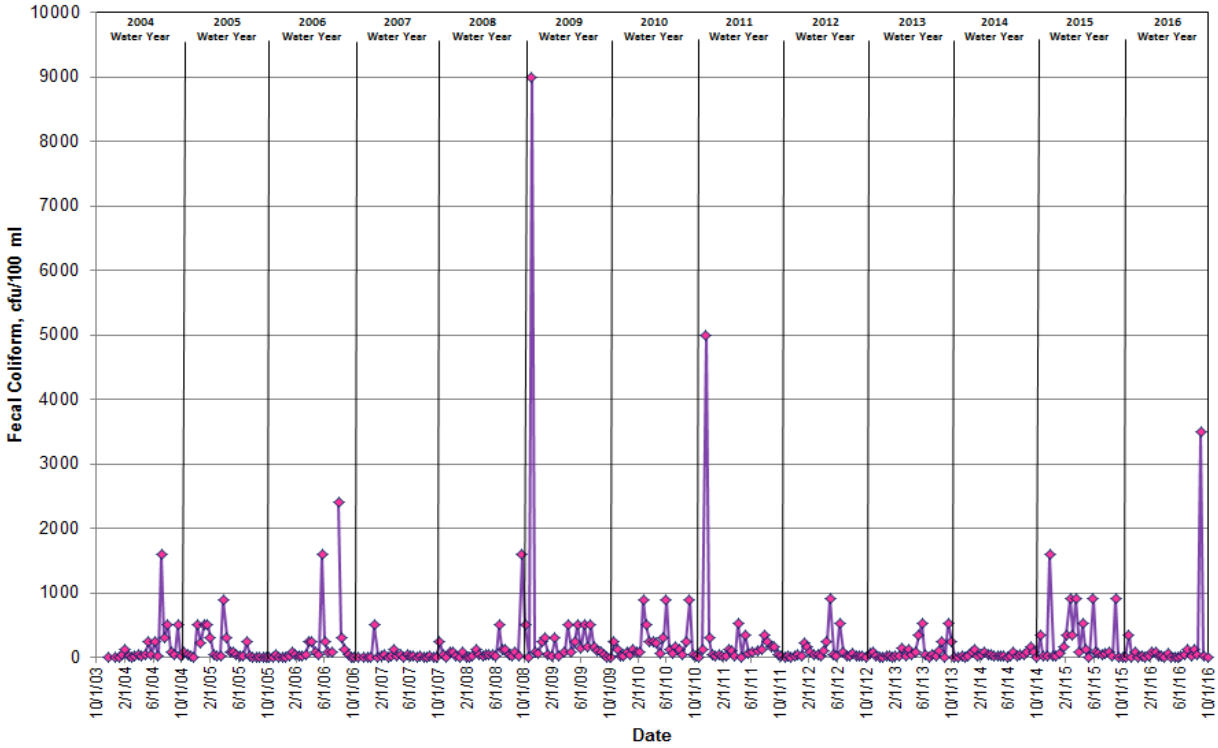
North Edison Pump Station - Site 38
Fecal Coliform



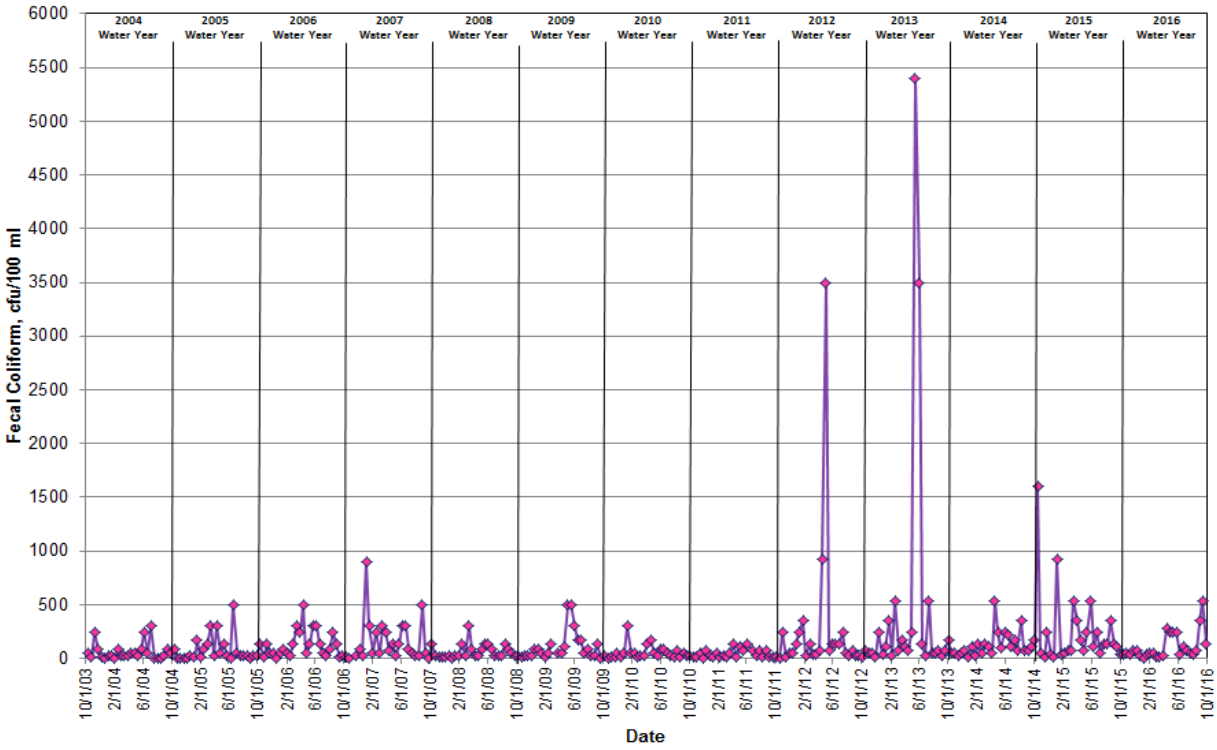
Colony Creek at Colony Road - Site 39
Fecal Coliform



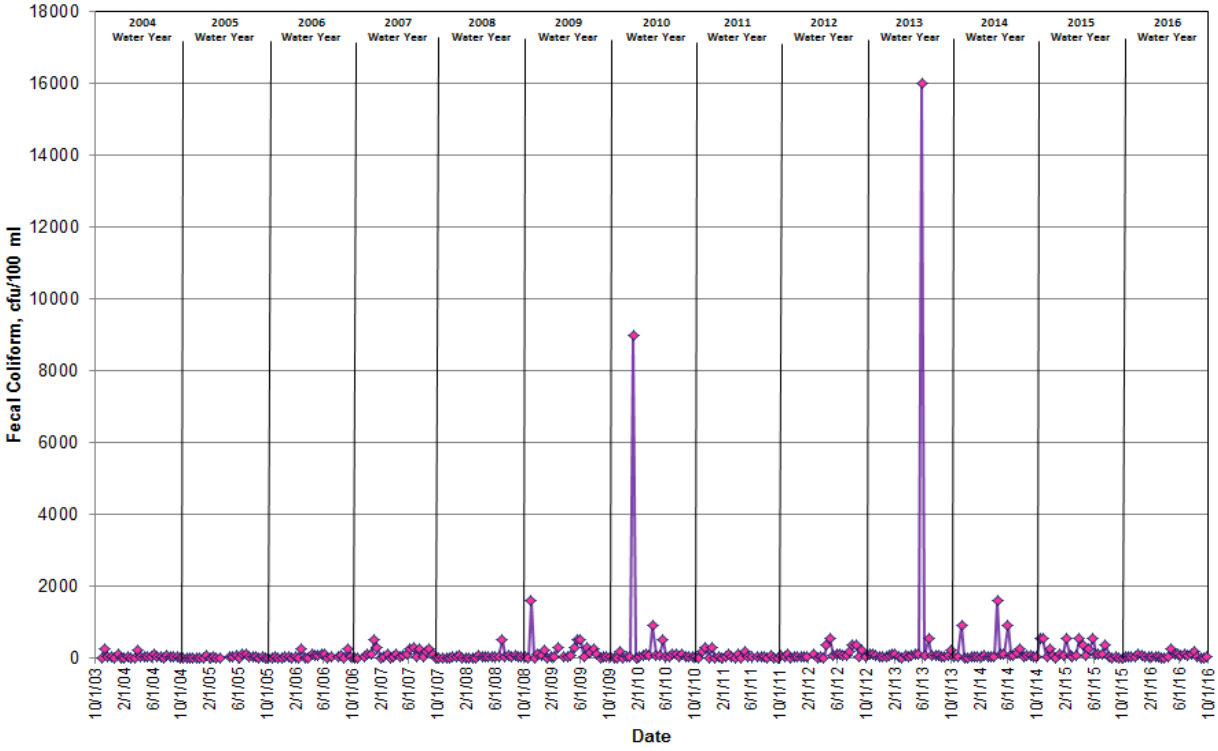
Big Indian Slough at Highway 20 Truck Scales - Site 40
Fecal Coliform



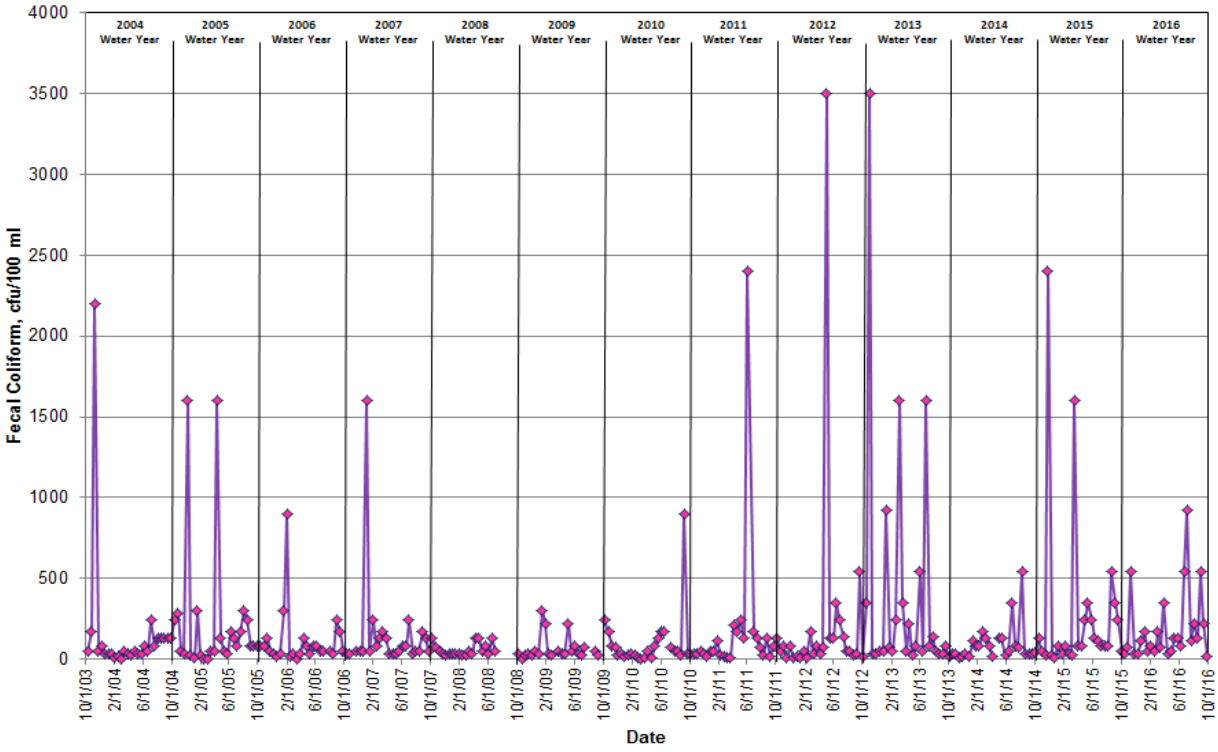
Maddox Creek/Big Ditch at Milltown Road - Site 41
Fecal Coliform



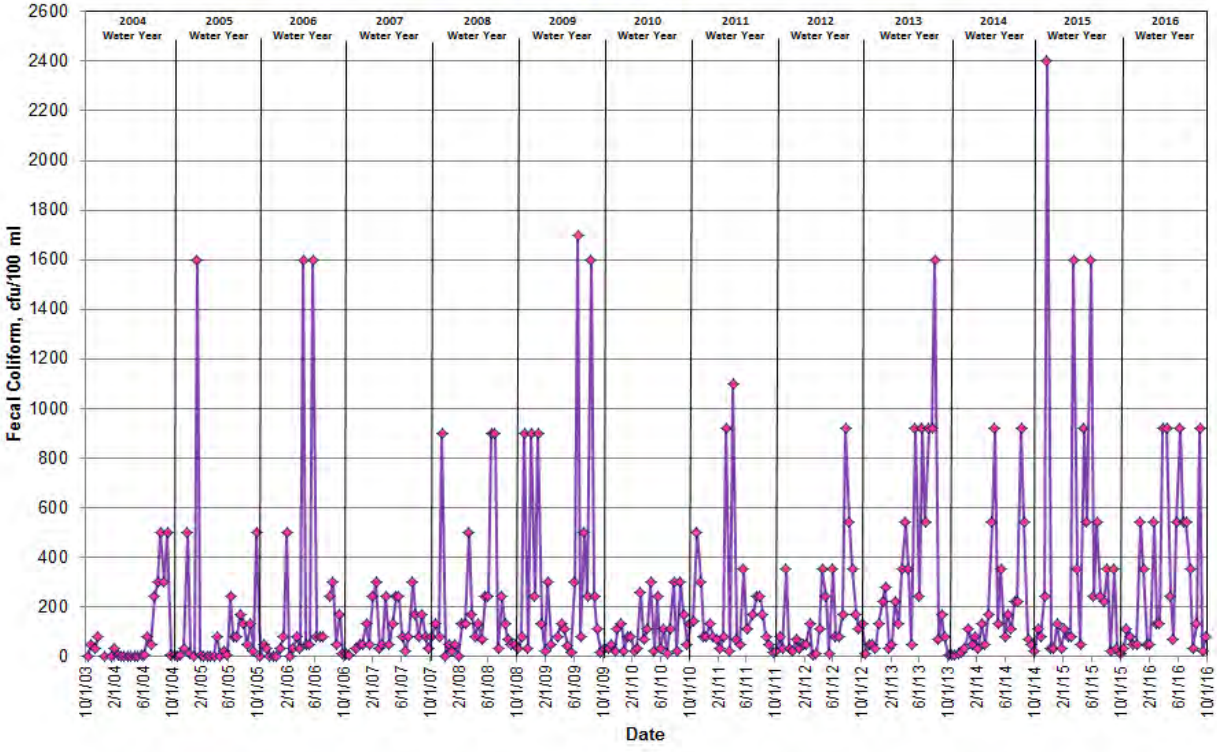
Carpenter Creek/Hill Ditch at Cedardale Road - Site 42
Fecal Coliform



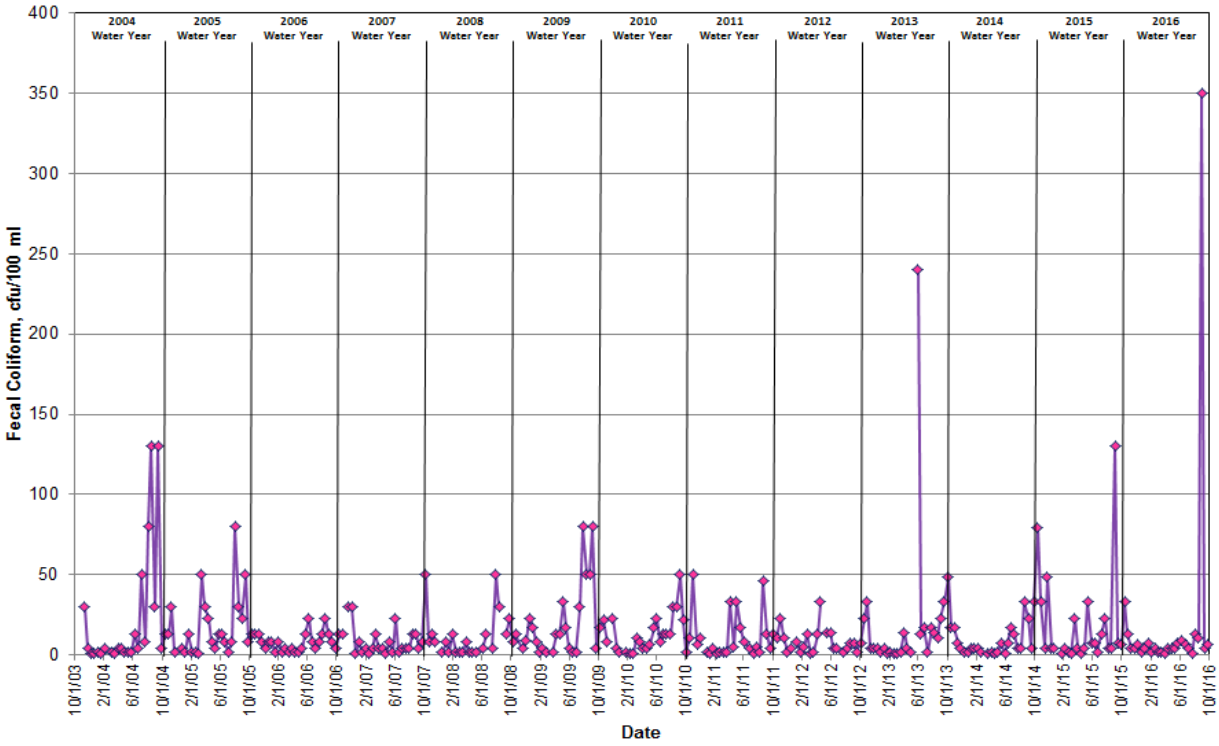
Wiley Slough at Wylie Road - Site 43
Fecal Coliform



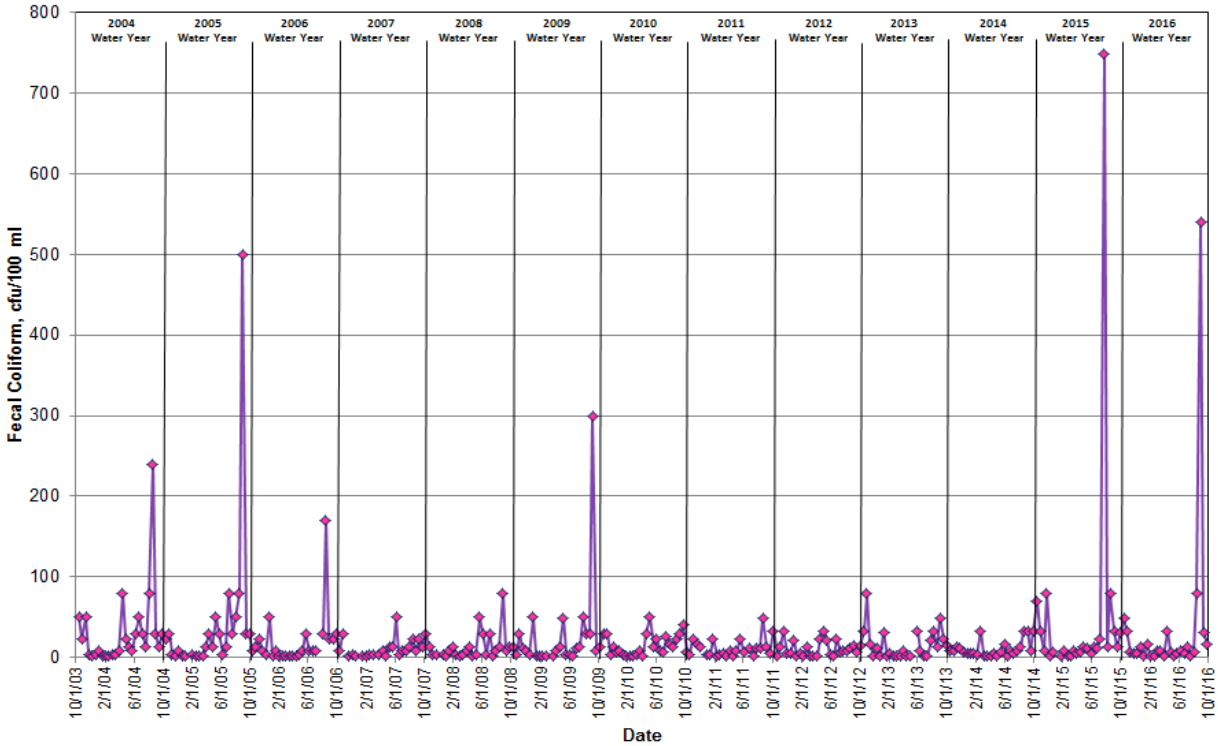
Sullivan Slough at LaConner-Whitney Road - Site 44
Fecal Coliform



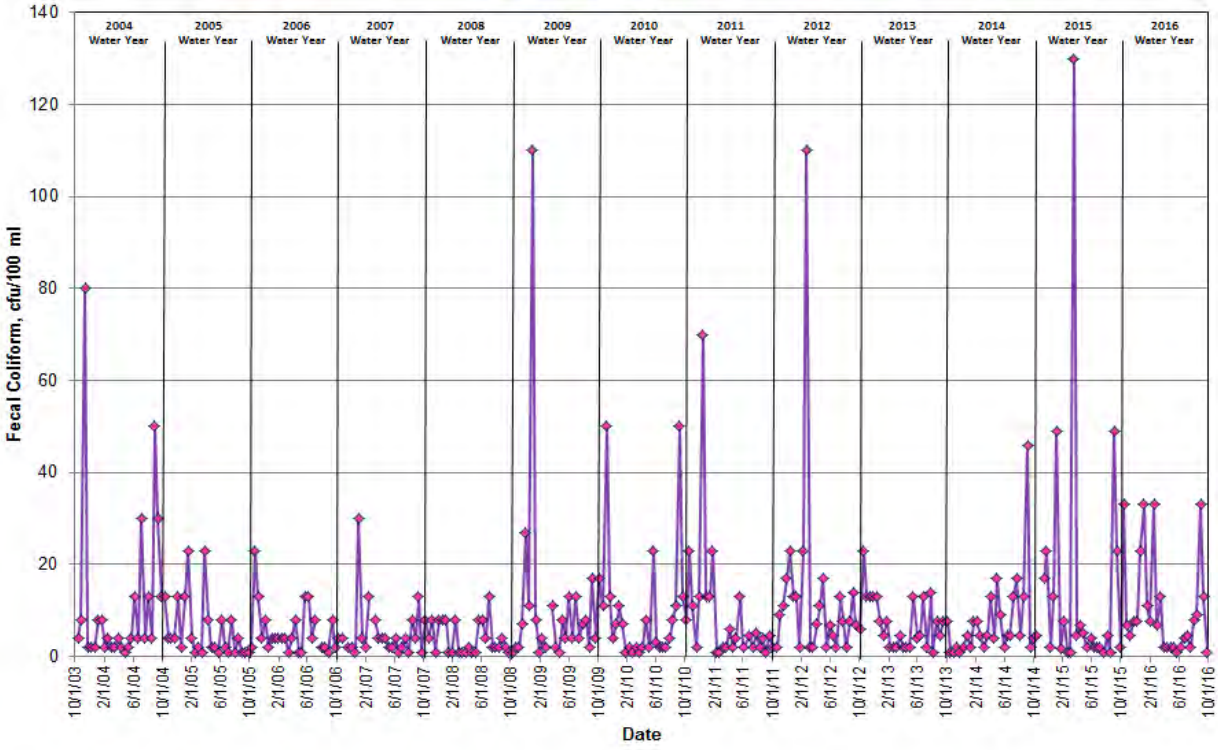
North Fork Skagit River near Moore Road - Site 45
Fecal Coliform



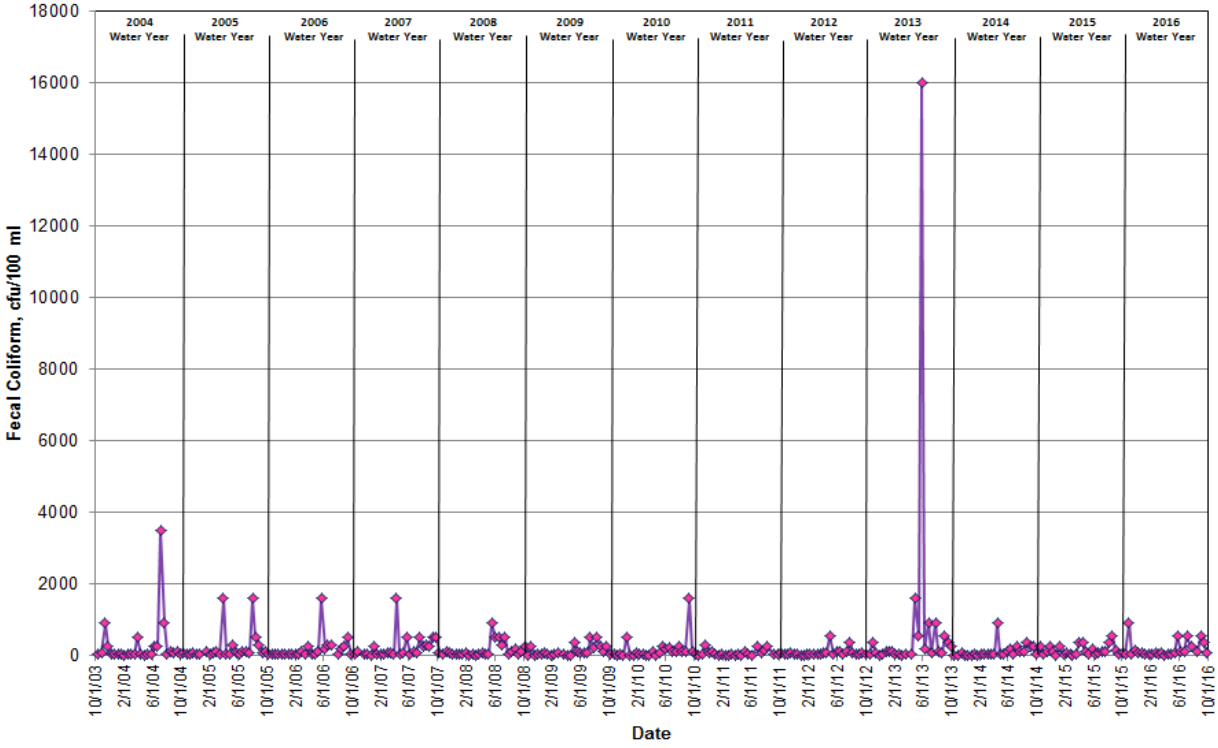
South Fork Skagit River at Conway Boat Ramp - Site 46
Fecal Coliform



Swinomish Channel at County Boat Ramp - Site 47
Fecal Coliform



Fisher Creek at Franklin Road - Site 48
Fecal Coliform



Nutrients

Water samples for measurement of plant nutrients were taken at each station quarterly. Samples were analyzed by Edge Analytical of Burlington, WA. Table 9 gives mean nutrient values for selected parameters for the 2016 water year. All nutrient values are included in Appendix A, with summary statistics found in Appendix B.

Nutrient levels in watercourses help determine the potential for algal activity. Excessive nutrient levels can lead to large blooms of algae, which can increase dissolved oxygen levels during the day but lead to large decreases in dissolved oxygen at night when the algae are respiring, and also when the algae die and decompose. Nutrients from freshwater sources discharged into Puget Sound bays can contribute to marine algal blooms as well.

Most of the natural streams in the program showed moderate levels of total nitrogen, ammonia, and total phosphorus. The drainage infrastructure sampling sites generally had higher levels of nutrients compared to the stream stations.

There are no numeric state standards for nutrients as factors in algal blooms. However, the state has both acute and chronic water quality standards for ammonia toxicity that are calculated from the ammonia level combined with the water temperature and pH for each individual ammonia measurement. Calculation of ammonia standards for a few individual readings suggests that some Skagit County watercourses would exceed the state standards on some occasions.

Table 9. 2016 Nutrient Results
Mean Nutrient Values (Mg/L) for watercourses in the Skagit County Monitoring Program, 2016 Water Year

Site Number	Watercourse	Location	Total Nitrogen[1]	Total Phosphorus	Ammonia	Nitrate + Nitrite
3	Thomas Creek	Old Hwy 99 N	0.48	0.07	0.03	0.54
4	Thomas Creek	F&S Grade Rd	0.53	0.08	0.01	1.02
6	Friday Creek	Prairie Rd	0.34	0.03	0.01	0.53
8	Swede Creek	Grip Rd	0.43	0.06	0.01	0.45
11	Samish River	State Route 9	0.26	0.02	0.01	0.30
12	Nookachamps Creek	Swan Rd	0.42	0.09	0.04	0.27
13	E.F. Nookachamps Creek	State Route 9	0.33	0.03	0.02	0.23
14	College Way Creek	College Way	0.35	0.05	0.02	0.27
15	Nookachamps Creek	Knapp Rd	0.56	0.10	0.05	0.33
16	E.F. Nookachamps Creek	Beaver Lake Rd	0.24	0.02	0.01	0.27
17	Nookachamps Creek	Big Lake Outlet	0.40	0.04	0.03	0.33
18	Lake Creek	State Route 9	0.26	0.02	0.01	0.46
19	Hansen Creek	Hoehn Rd	0.32	0.04	0.01	0.40
20	Hansen Creek	Northern State	0.32	0.03	0.03	0.29
21	Coal Creek	Hoehn Rd	0.29	0.04	0.01	0.54
22	Coal Creek	Hwy 20	0.25	0.02	0.01	0.35
23	Wiseman Creek	Minkler Rd	0.28	0.06	0.01	0.80
24	Mannser Creek	Lyman Hamilton Hwy	0.47	0.11	0.01	0.26
25	Red Cabin Creek	Hamilton Cemetery Rd	0.25	0.04	0.01	0.45
28	Brickyard Creek	Hwy 20	0.40	0.06	0.01	0.51
29	Skagit River	River Bend Rd	0.25	0.02	0.01	0.06
30	Skagit River	Cape Horn Rd	0.25	0.02	0.01	0.07
31	Drainage Dist 20 floodgate	Francis Rd	0.59	0.07	0.12	0.51
32	Samish River	Thomas Rd	0.36	0.06	0.01	0.66
33	Alice Bay Pump Station	Samish Island Rd	2.60	1.19	1.20	0.77
34	No Name Slough	Bayview-Edison Rd	1.05	0.30	0.05	0.26
35	Joe Leary Slough	D'Arcy Rd	1.18	0.19	0.58	0.94
36	Edison Slough at school	W. Bow Hill Rd	1.74	0.86	0.12	0.49
37	Edison Pump Station	Farm to Market Rd	2.68	0.95	0.79	0.49
38	North Edison Pump Station	North Edison Rd	2.48	1.35	1.04	0.71
39	Colony Creek	Colony Rd	0.37	0.09	0.01	0.93
40	Big Indian Slough	Bayview-Edison Rd	0.84	0.11	0.24	0.49
41	Maddox Slough/Big Ditch	Milltown Rd	0.82	0.22	0.10	0.41
42	Hill Ditch	Cedardale Rd	0.46	0.06	0.04	0.49
43	Wiley Slough	Wylie Rd	1.42	0.26	0.67	0.36
44	Sullivan Slough[2]	La Conner-Whitney Rd	1.42	0.30	0.98	0.45
45	Skagit River – North Fork	Moore Rd	0.25	0.02	0.01	0.06
46	Skagit River – South Fork	Fir Island Rd	0.25	0.02	0.01	0.07
47	Swinomish Channel	County Boat Launch	0.29	0.12	0.05	0.23
48	Fisher Creek	Franklin Rd	0.43	0.29	0.04	0.57

[1]Total Kjeldahl Nitrogen

Other Parameters

The Skagit County Monitoring Program also measures pH, conductivity, and salinity during each visit to each site. Conductivity and salinity are measured to help interpret other water quality parameters. Measurement of pH shows whether a watercourse is within the range that supports aquatic life. In general, pHs in the Skagit program have been within state standards.

Discharge measurements are made in selected locations and are intended to provide a general indication of the flow regime for that watercourse and as an aid in interpreting other water quality parameters. As the Department of Ecology has added several stream gauges in our area, Skagit County has de-emphasized discharge measurement.

Although results for these parameters are not discussed in detail in the main report, all measurements are available in Appendix A and are summarized in Appendix B.

Water Quality Index

The Water Quality Index (WQI) is an indicator developed by the Washington State Department of Ecology as an overall indicator of water quality at a given site. The Index compares typical water quality parameters with established standards and yields a single, unitless number between 1 and 100 to describe the overall water quality of a site at the time of sampling. The Index can then be summarized in a number of ways to give a site an overall score for a water year. The parameters included in the WQI are dissolved oxygen, temperature, pH, turbidity, suspended solids, fecal coliform, and nutrients.

The WQI is best used to answer general questions about the condition of watercourses, such as "What is the general condition of this stream?" or "How does this stream compare to others in the area?" (Hallock 2002). Because the index is a distillation of many parameters, it is unsuitable for answering detailed questions concerning the water quality of an individual stream. As is demonstrated by the Samish River, a stream can have an adequate WQI score based on ambient sampling, but significant pollution problems revealed by storm sampling.

Ecology rates streams with WQI Overall Score of 80 or greater "of lowest concern." Streams with ratings of 40-80 are considered "of moderate concern," while scores less than 40 are considered "of highest concern."

Water Quality Index calculations for the sample sites in the Skagit County Monitoring Program during the 2016 water year are summarized in Table 10 and categorized for the years 2006-2016 in Table 11. Note that although the WQI was designed for freshwater bodies, we have applied the index to the Swinomish Channel monitoring site (Site 47), which is primarily marine. This allows trend detection over time at this station, but the WQI for Site 47 should not be compared to the freshwater sites.

The WQI results show that several watercourses in the study area fall into the "highest concern" category. Most, but not all, are agricultural drainages with little summer flow that are not considered salmonid habitat.

Table 10. 2016 Water Quality Index Results
Water Quality Index (WQI) determinations for watercourses in the Skagit County Monitoring Program, 2016 Water Year

Site Number	Watercourse	Location	Mean WQI	Overall Score*	Max	Min
3	Thomas Creek	Old Hwy 99 N	60	53	81	38
4	Thomas Creek	F&S Grade Rd	62	52	94	1
6	Friday Creek	Prairie Rd	88	85	96	72
8	Swede Creek	Grip Rd	69	61	95	39
11	Samish River	State Route 9	84	80	94	70
12	Nookachamps Creek	Swan Rd	75	67	96	50
13	E.F. Nookachamps Creek	State Route 9	81	75	98	59
14	College Way Creek	College Way	79	73	97	61
15	Nookachamps Creek	Knapp Rd	59	48	93	27
16	E.F. Nookachamps Creek	Beaver Lake Rd	91	88	99	82
17	Nookachamps Creek	Big Lake Outlet	78	71	98	55
18	Lake Creek	State Route 9	87	84	97	74
19	Hansen Creek	Hoehn Rd	77	71	96	56
20	Hansen Creek	Northern State	83	79	96	49
21	Coal Creek	Hoehn Rd	80	76	95	64
22	Coal Creek	Hwy 20	96	95	98	90
23	Wiseman Creek	Minkler Rd	92	90	99	79
24	Mannser Creek	Lyman Hamilton Hwy	42	31	76	9
25	Red Cabin Creek	Hamilton Cemetery Rd	93	93	100	81
28	Brickyard Creek	Hwy 20	77	77	94	44
29	Skagit River	River Bend Rd	94	93	98	90
30	Skagit River	Cape Horn Rd	94	92	99	84
31	Drain Dist 20 Floodgate	Francis Rd	67	67	85	43
32	Samish River	Thomas Rd	84	80	95	73
33	Alice Bay Pump Station	Samish Island Rd	30	23	51	3
34	No Name Slough	Bayview-Edison Rd	51	51	70	20
35	Joe Leary Slough	D'Arcy Rd	16	13	26	1
36	Edison Slough	W. Bow Hill Rd	46	34	83	1
37	Edison Pump Station	Farm to Market Rd	9	7	16	1
38	N. Edison Pump Station	North Edison Rd	22	19	32	16
39	Colony Creek	Colony Rd	86	83	95	68
40	Big Indian Slough	Bayview-Edison Rd	22	15	45	1
41	Maddox Slough/Big Ditch	Milltown Rd	53	39	95	16
42	Hill Ditch	Cedardale Rd	80	75	97	55
43	Wiley Slough	Wylie Rd	19	13	38	3
44	Sullivan Slough	La Conner-Bayview Rd	28	8	85	1
45	Skagit River – North Fork	Moore Rd	91	89	97	84
46	Skagit River – South Fork	Fir Island Rd	94	93	99	90
47	Swinomish Channel	County Boat Launch	90	88	97	77
48	Fisher Creek	Franklin Rd	89	87	94	83

*Note: Overall score is the mean of the three lowest monthly scores (Hallock 2002)

Color code: Lowest Concern (>80 Overall Score), Moderate Concern (40-80), Highest Concern (<40)

Table 11. Number of sites in Water Quality Index (WQI) categories for Skagit County Monitoring Program
Total number = 40 sites

Year	Green (WQI ≥ 80)	Yellow (WQI 40-79)	Red (WQI <40)
2006	3	15	22
2007	6	17	17
2008	10	13	17
2009	17	11	12
2010	13	19	8
2011	20	9	11
2012	13	16	11
2013	15	14	11
2014	16	13	11
2015	16	13	11
2016	15	15	10

Over the course of the Skagit County Monitoring Program, the number of sites in the Green (or "Lowest Concern" category has generally increased while the number of sites in the Red (or "Highest Concern" category decreased early in the study and has held steady the last few years. Streams and ditches in the Red category can have either one water quality parameter that is well below standards or several categories that are.

Water quality during storm events remains problematical as the results from storm event monitoring in the Samish Basin associated with the Clean Samish Initiative continue to show excessive fecal coliform concentrations. More information on Samish water quality is included below.

Data Analysis

Summary statistics for all measured parameters at each sampling site can be found in Appendix B. These statistics can be used as a general indication of water quality conditions at each station. However, water quality conditions vary greatly at each station over time and the summary statistics should not be used as a sole indicator of water quality.

A primary goal of the Skagit County Monitoring Program is to detect trends in water quality over time. The purpose of the trends analysis is to provide indications of whether water quality in agricultural areas is improving, staying the same, or deteriorating. Once trends are detected, efforts could be undertaken to determine if the trends are caused by local activities or by regional conditions such as changes in climate. By comparing trends at stations inside and outside of the agricultural areas and by monitoring climate conditions, it should be possible to determine those conditions that seem to be caused by local circumstances.

One important statistical tool in trends monitoring is the Seasonal Kendall's Test. This test is designed to determine overall trends in water quality for parameters that vary seasonally, such as temperature and dissolved oxygen. The Seasonal Kendall's Test has been widely employed for

similar purposes in Washington, Oregon, and throughout the country (e.g. Cude 2002, Ehinger 1993, Holdeman et al 2003). Most parameters measured in the Skagit County Monitoring Program have seasonal variation, caused by our local climate which produces comparatively high water flows and low temperatures in the winter and spring, and lower flows with higher temperatures in the summer and early fall.

The Seasonal Kendall's Test was computed using WQStat Plus software (Intelligent Design Technologies, 1998). For most analyses, twelve seasons were designated, starting with the beginning of each month. This approach was recommended in the review of Skagit County's water quality monitoring program by the WRC. Exceptions are noted below. Observations below detection limits were replaced with one-half of the detection limit per the software user manual. The software was able to ignore missing data, so no accommodation for missing data was necessary.

Skagit County has completed trends analysis via the Seasonal Kendall's Test for 19 key parameters or calculated factors at each sampling location. The parameters tested include pH, dissolved oxygen, percent oxygen saturation, temperature, turbidity, fecal coliform, ammonia, nitrate+nitrite, total phosphorus, orthophosphate, total Kjeldahl nitrogen (TKN, an estimate of the total available nitrogen), total suspended solids, and water quality index. Temperature data from biweekly sampling visits were used for this analysis instead of continuous data collected during the summer months because the Seasonal Kendall's Test is not designed for summer-only data. Skagit County continues to examine methods for determining trends in the continuous temperature data. Since the temperature data from biweekly visits was collected at the same time of day for any individual station, the trends analysis should not be biased by differences caused by sampling time of day.

The period used for trends analysis was the 13 full years of Skagit County Monitoring Program data. This period was chosen to coincide with the implementation of the Critical Areas Ordinance for Areas of Ongoing Agriculture (Skagit County Ordinance O20030020).

Several sites have extended dry periods during most summers and/or are flooded during high water events and not sampled. The WQStat trends analysis program was unable to compute trends based on 13 seasons for those sites due to the lack of data for the dry or flooded periods. For those sites, trends were calculated based on four seasons, starting with January, April, July, and October. Trends in WQI were calculated based on four seasons for some additional sites due to lack of summer nutrient data.

Data used for the Seasonal Kendall's Test can be subject to "autocorrelation," where each successive data point is correlated with the previous point (Dave Hallock, Washington Department of Ecology). This situation usually occurs when samples are collected more frequently than monthly. For the Skagit County Monitoring Program, dissolved oxygen, temperature, and fecal coliform data are collected biweekly. Tests are available to detect autocorrelation but in some cases may be confounded by the very seasonality we are trying to accommodate (Dave Hallock, Washington Department of Ecology). Our approach for these parameters has been to conduct the analysis using all data, and repeat the analysis using monthly averages to avoid autocorrelation (Mike Barber, Washington State Water Research Center).

There were very few differences between these two calculations. In the cases where there are differences, it would probably be prudent to use the monthly averages.

A summary of Seasonal Kendall's Test results for those parameters showing a significant trend is provided in Table 12. Complete trends analysis results can be found in Appendix C. These results are discussed in the following section.

Table 12. Trends Analysis Results
Summary of Significant Trends Detected in Skagit County Monitoring Program
2004-2016 Water Years

Site	Parameter	N	Slope	Z	Improving Trends	Deleterious Trends
3	DO	331	0.050	2.029	increasing oxygen	
	DO % sat	332	0.558	2.874	increasing oxygen	
	Temp	334	0.093	2.299		increasing temperature
	Turb	304	0.309	3.384		increasing turbidity
	MTB	159	0.372	2.304		increasing turbidity
	FC	332	-1.304	-2.708	decreasing fecal coliform	
	MFC	167	-2.746	-2.397	decreasing fecal coliform	
	OP	95	0.002	2.929		increasing phosphate
4	pH	318	-0.025	-6.572		
	MpH	166	-0.025	-4.876		
	DO	335	0.027	2.991	increasing	
	MDO	169	0.036	3.057	increasing oxygen	
	DO % sat	336	0.242	4.284	increasing oxygen	
	MDO % sat	169	0.255	4.304	increasing oxygen	
	Temp	337	0.050	2.189		increasing temperature
	Turb	308	-0.249	-3.364	decreasing turbidity	
	MTB	160	-0.300	-2.634	decreasing turbidity	
	FC	334	-16.00	-6.383	decreasing fecal coliform	
	MFC	167	-26.10	-5.325	decreasing fecal coliform	
6	pH	316	-0.018	-4.169		
	MpH	166	-0.017	-3.297		
	Temp	336	0.085	3.199		increasing temperature
	MT	169	0.082	2.330		increasing temperature
	WQI	94	-0.294	-2.335		decreasing WQI
8	pH	318	-0.010	-2.544		
	DO	335	-0.057	-4.423		decreasing oxygen
	MDO	169	-0.052	-3.724		decreasing oxygen
	DO % sat	336	-0.366	-4.726		decreasing oxygen
	MDO % sat	169	-0.391	-3.562		decreasing oxygen
	Temp	338	0.086	2.722		increasing temperature
	MT	169	0.092	2.298		increasing temperature
	FC	336	-1.709	-3.814	decreasing fecal coliform	
	MFC	169	-3.871	-3.247	decreasing fecal coliform	
	NH3	96	-0.001	-2.103	decreasing ammonia	
11	pH	320	0.016	3.517		
	MpH	166	0.017	2.706		
	Turb	310	-0.044	-2.426	decreasing turbidity	
	MTB	159	-0.056	-2.229	decreasing turbidity	
	FC	337	-0.199	-3.296	decreasing fecal coliform	
	MFC	167	-0.596	-3.234	decreasing fecal coliform	
12	pH	297	0.024	5.689		
	MpH	161	0.021	3.620		
	DO	314	-0.050	-2.787		decreasing oxygen
	MDO	168	-0.087	-3.371		decreasing oxygen
	DO % sat	316	-0.328	-3.027		decreasing oxygen
	MDO % sat	167	-0.389	-2.430		decreasing oxygen
	Temp	318	0.071	2.453		increasing temperature
13	pH	290	0.013	2.639		
	MpH	151	0.013	2.051		
	MDO	156	-0.040	-1.995		decreasing oxygen
	WQI	92	-0.401	-2.207		decreasing WQI

Table 12 (cont.)

Site	Parameter	N	Slope	Z	Improving Trends	Deleterious Trends
14	pH	315	-0.015	-4.090		
	MpH	165	-0.014	-3.108		
	MDO	169	-0.046	-2.866		decreasing oxygen
	MDO % sat	169	-0.276	-2.315		decreasing oxygen
	MT	159	-0.140	-3.147	decreasing temperature	
	Turb	310	-0.105	-4.036	decreasing turbidity	
	MTB	159	-0.140	-3.147	decreasing turbidity	
	FC	334	-1.886	-2.573	decreasing fecal coliform	
	NO2+NO3	95	-0.008	-2.370	decreasing nitrate/nitrite	
	NH3	95	-0.004	-2.565	decreasing ammonia	
	WQI	92	-1.241	-3.621		decreasing WQI
15	pH	317	0.026	5.540		
	MpH	165	0.025	4.588		
	DO % sat	335	0.262	2.438	increasing oxygen	
	Temp	337	0.082	3.096		increasing temperature
	MT	169	0.159	4.646		increasing temperature
	MFC	169	2.691	2.696		increasing fecal coliform
	NO2+NO3	97	0.005	2.004		increasing nitrate/nitrite
	TP	97	0.002	3.715		increasing phosphorus
	OP	97	0.003	4.138		increasing phosphate
	WQI	92	-1.791	-4.428		decreasing WQI
16	DO	335	-0.029	-2.873		decreasing oxygen
	MDO	169	-0.043	-3.550		decreasing oxygen
	Temp	338	0.097	3.467		increasing temperature
	MT	169	0.061	4.207		increasing temperature
	Turb	312	0.036	2.710		increasing turbidity
17	DO	335	-0.027	-2.483		decreasing oxygen
	MDO	169	-0.062	-4.033		decreasing oxygen
	DO % sat	336	-0.201	-2.330		decreasing oxygen
	MDO % sat	169	-0.326	-3.450		decreasing oxygen
	Temp	338	0.075	2.865		increasing temperature
	MT	169	0.163	4.597		increasing temperature
	Turb	312	0.089	6.074		increasing turbidity
	MTB	160	0.095	4.540		increasing turbidity
	WQI	93	-0.426	-4.215		decreasing WQI
18	pH	317	0.017	4.030		
	MpH	165	0.017	2.786		
	DO	335	-0.036	-3.641		decreasing oxygen
	MDO	169	-0.051	-4.128		decreasing oxygen
	DO % sat	336	-0.231	-3.610		decreasing oxygen
	MDO % sat	169	-0.251	-3.076		decreasing oxygen
	Temp	338	0.066	2.635		increasing temperature
	MT	169	0.110	3.822		increasing temperature
	WQI	93	-0.331	-3.741		decreasing WQI
19	DO	328	-0.053	-4.653		decreasing oxygen
	MDO	168	-0.047	-3.293		decreasing oxygen
	DO % sat	329	-0.349	-4.783		decreasing oxygen
	MDO % sat	168	-0.345	-4.291		decreasing oxygen
	Temp	329	0.070	2.487		increasing temperature
	Turb	300	0.076	2.666		increasing turbidity
	WQI	92	-0.593	-3.281		decreasing WQI
20	pH	317	-0.010	-2.075		
21	FC	295	-0.777	-2.231	decreasing fecal coliform	
	MFC	157	-2.433	-2.187	decreasing fecal coliform	

Table 12 (cont.)

Site	Parameter	N	Slope	Z	Improving Trends	Deleterious Trends
22	pH	318	-0.032	-4.306		
	MpH	164	-0.030	-3.286		
	DO	335	-0.042	-4.210		decreasing oxygen
	MDO	168	-0.030	-2.774		decreasing oxygen
	DO % sat	336	-0.244	-4.673		decreasing oxygen
	MDO % sat	169	-0.231	-3.438		decreasing oxygen
	MFC	166	0.336	2.473		increasing fecal coliform
23	pH	285	-0.025	-4.936		
	MpH	144	-0.033	-3.939		
	DO	301	-0.020	-2.141		decreasing oxygen
	NO3+NO2	91	-0.020	-2.740	decreasing nitrate/nitrite	
24	Turb	310	0.059	4.747		increasing turbidity
	MTB	160	0.060	3.411		increasing turbidity
	FC	334	-0.665	-4.500	decreasing fecal coliform	
	MFC	168	-0.885	-3.392	decreasing fecal coliform	
	NO3+NO2	97	0.006	2.346		increasing nitrate/nitrite
25	pH	263	-0.022	-3.466		
	MpH	135	-0.029	-2.951		
	MDO % sat	138	-0.238	-2.601		decreasing oxygen
	Turb	251	0.017	4.237		increasing turbidity
28	TKN	73	-0.012	-2.035	decreasing nitrogen	
	OP	73	0.001	1.960		increasing phosphate
	NH3	73	-0.004	-2.924	decreasing ammonia	
	WQI	73	-0.501	-3.467		decreasing WQI
29	MDO	168	-0.032	-2.839		decreasing oxygen
	DO % sat	322	-0.134	-2.009		decreasing oxygen
	MT	169	0.068	2.605		increasing temperature
	Turb	300	-0.213	-3.474	decreasing turbidity	
	MTB	160	-0.205	-2.528	decreasing turbidity	
30	DO	336	-0.020	-2.331		decreasing oxygen
	DO % sat	337	-0.100	-2.083		decreasing oxygen
	Turb	309	-0.176	-3.320	decreasing turbidity	
	MTB	160	-0.288	-2.819	decreasing turbidity	
31	MpH	123	-0.033	-2.562		
	DO	190	-0.161	-3.063		decreasing oxygen
	MDO	125	-0.147	-2.132		decreasing oxygen
	DO % sat	191	-1.366	-3.234		decreasing oxygen
	MDO % sat	127	-1.486	-3.209		decreasing oxygen
	MTB	115	-0.353	-2.076	decreasing turbidity	
	MFC	125	-2.201	-2.585	decreasing fecal coliform	
	NH3	58	-0.006	-2.967	decreasing nitrate/nitrite	
32	pH	314	0.024	4.955		
	MpH	167	0.024	3.353		
	Temp	338	0.079	2.859		increasing temperature
	FC	338	-0.199	-2.296	decreasing fecal coliform	
	MFC	167	-1.969	-2.051	decreasing fecal coliform	
	NH3	98	-0.004	-3.194	decreasing ammonia	
33	TKN	96	0.079	2.552		increasing nitrogen
	OP	95	0.019	3.178		increasing phosphate

Table 12 (cont.)

Site	Parameter	N	Slope	Z	Improving Trends	Deleterious Trends
34	pH	315	-0.016	-2.628		
	MpH	165	-0.016	-2.155		
	Temp	334	0.099	2.462		increasing temperature
	MT	167	0.181	3.772		increasing temperature
	Turb	308	-0.202	-2.058	decreasing turbidity	
	MTB	158	-0.440	-2.841	decreasing turbidity	
	TP	95	0.005	2.286		increasing phosphorus
	OP	95	0.005	2.255		increasing phosphate
	NH3	95	-0.015	-4.909	decreasing ammonia	
35	pH	304	0.036	7.305		
	MpH	161	0.037	5.722		
	Turb	297	-0.602	-2.806	decreasing turbidity	
	MTB	155	-0.875	-2.517	decreasing turbidity	
36	FC	338	1.363	2.639		increasing fecal coliform
	TP	96	0.007	3.079		increasing phosphorus
	OP	96	0.005	2.478		increasing phosphate
	NH3	96	-0.012	-3.247		increasing ammonia
37	FC	337	4.106	2.428		increasing fecal coliform
	MFC	168	6.642	2.240		increasing fecal coliform
	OP	96	0.013	2.848		increasing phosphate
38	Temp	331	0.078	2.077		
	FC	331	5.411	4.352		
	MFC	168	9.162	3.442		
	NO3+NO2	96	0.008	2.176		increasing nitrate/nitrite
	OP	96	0.035	4.449		increasing phosphate
39	pH	314	-0.015	-3.765		
	MpH	167	-0.012	-2.027		
	OP	96	0.003	3.469		increasing phosphate
40	TP	96	0.0004	2.180		increasing phosphorus
41	pH	317	0.013	3.759		
	MpH	165	0.018	3.575		
	MT	168	0.100	2.794		increasing temperature
	Turb	313	0.528	7.349		increasing turbidity
	MTB	159	0.414	4.390		increasing turbidity
	FC	337	2.661	3.873		increasing fecal coliform
	MFC	168	3.635	2.982		increasing fecal coliform
	TP	97	0.006	3.464		increasing phosphorus
	OP	97	0.003	3.179		increasing phosphate
42	pH	315	0.020	4.779		
	MpH	162	0.021	3.990		
	DO	334	0.184	8.306	increasing oxygen	
	MDO	166	0.188	6.455	increasing oxygen	
	DO % sat	335	1.580	9.819	increasing oxygen	
	MDO % sat	168	1.510	8.099	increasing oxygen	
	Temp	337	0.080	2.730		increasing temperature
	Turb	311	0.109	5.005		increasing turbidity
	MTB	158	0.103	2.882		increasing turbidity
	FC	332	2.557	5.006		increasing fecal coliform
	MFC	167	3.261	3.648		increasing fecal coliform
	OP	97	0.002	2.823		increasing phosphate
43	MT	164	0.100	3.263		increasing temperature
	Turb	305	0.333	4.593		increasing turbidity
	MFC	164	2.865	2.170		increasing fecal coliform

Table 12 (cont)

Site	Parameter	N	Slope	Z	Improving Trends	Deleterious Trends
44	pH	275	-0.022	-3.661		
	MpH	143	-0.018	-2.441		
	DO	290	-0.137	-3.824		decreasing oxygen
	MDO	146	-0.145	-3.159		decreasing oxygen
	DO % sat	293	-1.482	-4.118		decreasing oxygen
	MDO % sat	148	-1.462	-2.604		decreasing oxygen
	MT	147	0.078	2.107		increasing temperature
	Turb	270	0.335	2.080		increasing turbidity
	FC	293	4.946	3.458		increasing fecal coliform
	MFC	147	8.109	3.092		increasing fecal coliform
	TP	77	0.010	3.826		increasing phosphorus
	WQI	69	-3.254	-3.495		decreasing WQI
45	pH	302	0.046	6.645		
	MpH	163	0.043	4.903		
	MDO	164	-0.031	-2.873		decreasing oxygen
	MDO % sat	167	-0.117	-2.102		decreasing oxygen
	MT	167	0.074	2.852		increasing temperature
	Turb	298	-0.271	-4.063	decreasing turbidity	
	MTB	156	-0.372	-3.073	decreasing turbidity	
46	pH	287	0.038	5.387		
	MpH	150	0.035	3.628		
	DO % sat	302	-0.150	-2.784		decreasing oxygen
	MDO % sat	155	-0.126	-2.355		decreasing oxygen
	Turb	279	-0.319	-4.080	decreasing turbidity	
	MTB	145	-0.363	-3.089	decreasing turbidity	
	NO3+NO2	89	0.003	2.465		increasing nitrate/nitrite
47	pH	318	-0.036	-8.534		
	MpH	165	-0.037	-6.330		
	DO	336	-0.025	-2.011		decreasing oxygen
	MDO	167	-0.046	-2.732		decreasing oxygen
	MT	168	0.070	3.268		increasing temperature
	MFC	168	0.176	2.268		increasing fecal coliform
	NO3+NO2	97	0.006	2.763		increasing nitrate/nitrite
	TP	97	0.001	4.330		increasing phosphorus
	OP	97	0.004	4.425		increasing phosphate
	WQI	81	-0.501	-2.529		decreasing WQI
48	MDO	167	-0.030	-2.256		decreasing oxygen
	Temp	337	0.051	2.987		increasing temperature
	MT	168	0.094	4.271		increasing temperature
	TKN	96	-0.019	-2.813	decreasing nitrogen	
	TP	97	0.003	2.499		increasing phosphate
	NH3	97	-0.005	-5.347	decreasing ammonia	

Notes: N = Number of data points
Slope = Magnitude and direction of trend in original units per year
Z = Calculated Kendall's statistic, Z > 1.960 or < -1.960 means statistically significant trend at 95% confidence level
M = Monthly, e.g. MDO represents the Kendall's statistic calculated on monthly means instead of individual biweekly data, in order to control for autocorrelation

Trends analysis results and discussion

Trends were calculated for 19 measured or calculated parameters (such as monthly averages) at each site, for a total of 760 tests. Of those, 255 tests showed a statistically significant trend at the 95% confidence level. Trends judged as improving (e.g. increased dissolved oxygen, reduced temperature) made up 61 of the significant trends. Deleterious trends (e.g. reduced dissolved oxygen, increased nutrients) accounted for 144 of the significant trends. The remaining 50 trends were increasing or decreasing pH or monthly pH. There were also statistically significant nutrient trends where the slope was zero that are not included in this count. A value judgment was not made for those trends as their implications are not clear at this point. These results are very similar to the 2015 water year, when there were 59 improving trends and 152 deleterious trends.

Because the overall list of significant trends included many redundant items (e.g. biweekly dissolved oxygen and monthly average dissolved oxygen), an abbreviated list, using only the unique trends involving the monthly averages (for pH, dissolved oxygen, temperature, and turbidity) plus the nutrient data and total suspended solids which were already monthly or quarterly, was also looked at for summary statistics. We eliminated any significant pH trends, and nutrient trends with a slope of zero. This data set included 9 parameters at 40 sites for a total of 360 analyses. In this selected data set, there were 125 significant trends, with 35 trends identified as representing improved conditions and 90 identified as deleterious. The proportion of improving trends was slightly lower in the ag sites (25%) than in the non-ag sites (30%). This differs from the 2015 water year when the proportion of improving trends was higher in the ag sites (32%) than in the non-ag sites (21%). In the Samish Basin, where the focus of the Clean Samish Initiative has been the reduction of fecal coliform pollution, there were five sites with improving trends in fecal coliform, two sites with worse fecal coliform, and four sites with no significant trend in fecal coliform.

Last year's report indicated 36 improving and 92 declining trends for this data set. It is important to remember that these statistics are calculated over the life of the study, so while the 2016 water year may account for the differences between current and past results, the calculated trends are representative of the entire study from October 2003 to September 2016.

At the end of the 2012 water year, twenty-two of the 40 stations showed a significant declining trend in monthly mean water temperature over the life of the study. By the end of the 2015 water year, no stations showed a significant declining trend in monthly mean water temperature, and five sites had significantly increasing monthly mean water temperature. Further increasing temperature trends were found with the inclusion of the 2016 water year data, so by this point there were 16 sites with significantly increasing water temperature. This likely reflects a series of hot, dry summers with abundant sunshine rather than habitat declines since there are no known reductions in riparian canopy in the affected areas.

Two of the 40 sites showed a significant increasing trend in mean monthly dissolved oxygen over the life of the study through 2016, one less than last year. The same three sites showed a significant increasing trend in monthly oxygen percent saturation, which takes temperature into account. This indicates that dissolved oxygen improved at those sites independent of any

temperature reduction. There were 14 stations with a declining trend in dissolved oxygen, and 13 sites showed declining percent saturation, and increase from 11 sites at the end of 2015.

Eight sites showed a significantly decreasing trend in monthly fecal coliform, including five sites in the Samish basin, while 10 sites had significantly increasing fecal coliform. Both of these counts are increases from last year. Two of the sites (Sites 37 and 38) with increasing fecal coliform was in the Samish Basin. These sites are agricultural pump stations that discharge directly to Samish Bay. Fecal coliform reduction efforts in the Samish Basin have focused on the Samish River watershed and there were five sites with declining fecal coliform in that area.

No sites showed a significant increasing trend in Water Quality Index (WQI), which was also the case last year. Eleven sites showed a decreasing trend in WQI, two more than last year. This is an indicator that overall water quality could be declining. Some of that decline could be due to two consecutive years of summer drought bringing high temperatures and lower dissolved oxygen.

Many of the deleterious trends were increases in nutrient values. Increased nutrients can lead to excessive blooms of algae, which can upset food webs and lead to dissolved oxygen depletion. In extreme cases, ammonia levels can be high enough to produce direct toxicity. Ammonia toxicity is tied to pH and temperature, so the toxicity of a particular reading must be assessed individually. A spot check of Skagit County ammonia data indicates that observed levels in the drainage infrastructure may occasionally approach chronically toxic levels. There were also many cases where a statistically significant trend in nutrient values was found, but the calculated slope for the nutrient was zero. This is seen as a statistical anomaly based on the number of "ties" in the data, in our case samples that had no detectable nutrients (Younos, 2001). These cases were not included in the tabulation of improving or deleterious trends.

Trend statistics are tools to help us understand changing conditions in our watercourses, but do not completely describe the condition of a watercourse. Many of the sites with no significant trends or improving trends in water quality parameters still do not meet state water quality standards, and therefore still qualify as areas of concern. Many Skagit County sites remain on Ecology's Impaired Waters list. As previously discussed, high fecal coliform levels in the Samish Bay watershed have led to closures of shellfish beds and loss of revenue for shellfish growers. Dissolved oxygen and temperature conditions are still substandard in many watercourses, resulting in less than ideal rearing conditions for salmonids and other aquatic life.

Data Quality

This section details the steps taken to ensure high quality data in the Skagit County Monitoring Program, and the results of quality control checks.

Sampling Plan (Quality Assurance Project Plan, or QAPP)

The Skagit County Monitoring Program operates under a QAPP approved by Ecology in 2003. This plan details sampling strategies, equipment to be used, and all other aspects of the sampling

program, and Ecology approval was required in order for Skagit County to access grant funds. The plan forms the basis for all sampling activities. The plan may be viewed at:

https://www.skagitcounty.net/PublicWorksSurfaceWaterManagement/Documents/QAplanfinal103003.pdf

Quality Control Measures

Field meter calibration - Field meters are calibrated according to manufacturer's recommendations, or more often as needed.

The turbidity meter (Lamotte 2020we) is calibrated the afternoon before or the morning of each sampling trip, and the reading before calibration is recorded. For 41 recorded calibrations during this period, the average deviation from the calibration standard was 1.4%. This reflects meter drift between the calibration the afternoon before the sampling trip and the next calibration a week later. It is likely that meter drift during the sampling day is substantially less than 1.4%.

The pH meter (YSI 100A) is calibrated on the morning of each sampling trip, then left on throughout the sampling trip. The pH meter is recalibrated during the trip if questionable results were obtained. The meter rarely deviated more than 0.02 pH units from the calibration standard.

The dissolved oxygen/temperature/conductivity meter (YSI Model 2030 Pro) is calibrated for dissolved oxygen using the built-in calibration chamber (water-saturated air). The meter is recalibrated to local elevation at each sample site. For several weeks during the 2005 water year, Skagit County recorded the meter deviation from the calibration target for those occasions when the deviation exceeded 1%. During that period, meter deviation exceeded that value 89 times out of 180 sample sites (49%). Average deviation for those 89 calibrations was 2.6%. Since the meter was recalibrated at each sample site, the actual meter drift before use was something less than 1%.

The dissolved oxygen meter probe is deployed in areas with sufficient current (> 0.5 fps) to produce reliable results, or the probe is stirred to produce adequate velocity across the membrane. Samples for pH and turbidity are obtained from the thalweg of the stream with sample containers rinsed at least twice with sample water, and are analyzed immediately.

Lab Samples

Laboratory samples are collected using clean equipment and proper procedures. Samples for nutrient and suspended solids analysis are collected with a sampling wand from the thalweg of the watercourse, and care is taken to prevent oversampling of the surface film or disturbing the bottom. The sampling container is rinsed twice with the water to be sampled. The sample is then obtained and poured into the bottles provided by the contract lab, Edge Analytical of Burlington, WA, an Ecology-certified laboratory. Samples are capped and placed in a cooler with water ice until they are picked up by the lab on the same day.

Samples for fecal coliform are collected directly into sterile fecal coliform bottles and transported under ice to the laboratory within eight hours of collection.

Quality Control Review

Data from field sheets and lab reports is entered into the Skagit County Water Quality Database. Once all the data for a given date is entered, a printout from the database is produced and compared to the original field and lab data sheets. Any data entry errors are then corrected in the database.

Personnel

The Project Manager has over 30 years of experience monitoring water quality in the freshwater environment. The Project Manager is present on over 80% of the sampling trips and personally trained all other personnel involved.

Duplicate Analysis

Because water quality is constantly changing in streams, duplicate analysis is not attempted for parameters determined in the field – dissolved oxygen, temperature, conductivity, salinity, and turbidity. Instead, we rely on maintenance and calibration of the field meters according to manufacturer's recommendations and experienced field staff to produce reliable field data.

Duplicate samples are collected for fecal coliform at a 20% rate and for selected nutrients at a 10% rate. Selected nutrient duplicates (total phosphorus, orthophosphate, nitrate, and/or ammonia) are intended to provide a precision estimate for all the nutrient analyses.

Table 13 summarizes the results of the duplicate analyses for the 2016 water year. Variability in fecal coliform, nitrate, and total phosphate were above target levels, but similar to what was seen in previous years except for nitrate, which was much higher than previous years. The high nitrate value was greatly influenced by a single sample where the duplicate greatly exceeded the main sample.

The high variability of the fecal coliform results is at least partially due to the use of the Most Probable Number (MPN) analysis technique (Don Lennartson, Washington State Department of Health (retired), personal communication). This method was chosen for the Skagit County Monitoring Program because the Skagit County Health Department laboratory was certified for the method, and because it is reportedly more reliable for samples with high turbidity, which are often encountered in the Skagit County Monitoring Program (Michaud 1991). We continued using MPN when we switched to Edge Analytical in 2009 to maintain data comparability. Fecal coliform variability in the Skagit County Monitoring Program, although higher than the initial target level, is similar to that seen in other studies in Washington (Paul Pickett, Washington State Department of Ecology, personal communication). The reasons for the higher nutrient variability are unknown at this point.

Table 13. 2016 Data Quality Results
Coefficients of Variation for parameter with duplicates in the
Skagit County Monitoring Program, 2016 Water Year

		Coefficient of Variation (CV %)	
Parameter	**N**	**2016 Results**	**Target CV (%)[1]**
Fecal Coliform	108	43	33
Total Phosphorus	10	14	10 [2]
Orthophosphate	7	11	10 [2]
Nitrate	14	26	10 [2]
Ammonia	3	0	10 [2]

[1] Target precision as listed in QAPP

[2] 10% CV target was listed for all nutrients

Data Quality Summary

The Skagit County Monitoring Program produces reliable data that is suitable for the intended purposes, including assessment of current conditions and trends. Data is collected according to an Ecology-approved Quality Assurance Project Plan. Field parameters are analyzed using calibrated meters and consistent sampling methods. Laboratory samples are handled correctly and analyzed in Ecology-certified laboratories. The database is rechecked for data entry errors. Experienced personnel are involved with every aspect of data collection and analysis. The information collected in the Skagit County Monitoring Program should be considered high quality data.

Skagit County Water Quality Monitoring for the Clean Samish Initiative

Overview

The Clean Samish Initiative was established by Ecology in the fall of 2008 to foster cooperation between local, state, and federal agencies, non-governmental groups, and citizens to address fecal coliform pollution in the Samish Bay Watershed. Excess fecal coliform pollution in the Samish River and other bay tributaries has resulted in numerous closures of the commercial shellfish beds in Samish Bay. The Clean Samish Initiative participants (over 20 organizations) developed a work plan that included education and outreach, detailed water quality sampling to locate pollution sources, referrals of landowners to resource agencies for pollution abatement, and enforcement of water quality and land use regulations if necessary. Skagit County applied for and received EPA funding in 2010 to conduct a Pollution Identification and Correction (PIC) project in the Samish Basin, incorporating Clean Samish work plan elements into a program designed to locate and eliminate fecal coliform pollution in the Samish Basin.

The Clean Samish Initiative grew out of Ecology's TMDL activities in the Samish Basin. Ecology sampling demonstrated that the Samish River was the largest source of fecal coliform bacteria to Samish Bay. While some of the independent Samish Bay tributaries (e.g. Edison Slough and Colony Creek) and agricultural drainages also contribute bacterial pollution to Samish Bay, the comparatively high discharge rate of the river combined with occasional high coliform counts meant that the river was and continues to be the most important pollution source for Samish Bay.

Activities

Numerous PIC water quality sampling, education, and outreach activities continued during the 2016 water year, and will be summarized in a separate Clean Samish Initiative report. In addition, County staff, in cooperation with the Department of Ecology, have conducted site visits in areas where water quality sampling results indicate pollution sources are present. These visits form the core of the PIC program and are summarized in the separate quarterly Clean Samish reports.

Water quality sampling in the Samish consists of storm event sampling and investigatory sampling, in addition to the ambient sampling reported here. Storm event sampling consists of watershed-wide sampling during storm events in order to characterize the event and locate stream reaches with elevated fecal coliform counts. Investigatory sampling involves samples that may be taken in conjunction with investigations of specific areas or properties.

Samish sampling results are available on the County web site at this address:
http://www.skagitcounty.net/Departments/PublicWorksCleanWater/samplearchive.htm

Annual Report Summary

The Skagit County Monitoring Program completed the thirteenth water year of sampling in September 2016. Standard water quality parameters were collected biweekly at 40 sites in watercourses in both agricultural and non-agricultural areas. Results indicated that many watercourses did not meet state water quality standards for one or more parameters. Trend analysis revealed a pattern of both improving and deteriorating trends, with more deleterious trends evident in the past two years. Skagit County has taken a leading role in addressing water quality problems in the area through the Clean Samish Initiative.

The program was substantially funded through the 2008 water year by a Centennial Clean Water Grant from the Washington State Department of Ecology. Currently, all project funding comes from Skagit County's Clean Water Program.

Figure 3. Chinook salmon in the Samish River

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