Skagit County Monitoring Program

SCMP

Annual Report

2021 Water Year
(October 2020 – September 2021)

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Definitions

Ag-CAO	-	Critical Areas Ordinance: Ongoing Agriculture
Ag-NRL	-	Agricultural Natural Resource Lands
BMP	-	Best Management Practice
County	-	Skagit County
CSI	-	Clean Samish Initiative
CV	-	Coefficient of Variation
DO	-	Dissolved Oxygen
Ecology	-	Washington State Department of Ecology
EPA	-	Environmental Protection Agency
FC	-	Fecal Coliform
GMHB	-	Growth Management Hearings Board
MPN	-	Most Probable Number
NH_3	-	Ammonia
NO_3+ NO_2	-	Nitrate + Nitrite
NTU	-	Nephelometric Turbidity Units
OP	-	Ortho-Phosphorous
pH	-	Power of Hydrogen
PIC	-	Pollution Identification and Correction
QAPP	-	Quality Assurance Project Plan
RR-NRL	-	Rural Resource Natural Resource Lands
RSD	-	Relative Standard Deviation
SCC	-	Skagit County Code
SCMP	-	Skagit County Monitoring Program
7-DADMax	-	7-Day Average of Daily Maximum Temperatures
SRC	-	Site Report Card
TKN	-	Total Kjeldahl Nitrogen
TMDL	-	Total Maximum Daily Load
TP	-	Total Phosphorous
TSS	-	Total Suspended Solids
VSP	-	Voluntary stewardship Program
WQI	-	Water Quality Index
WRC	-	State of Washington Water Research Center
WY	-	Water Year

Executive Summary

Skagit County Public Works has completed the eighteenth year of water quality monitoring under the Skagit County Water Quality Monitoring Program, and this is the eighteenth annual report, for the 2021 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, *E. coli,* temperature, and/or dissolved oxygen. None of the 39 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. Streams not meeting the standards represent less-than-ideal conditions for those uses. Conditions in Skagit County range from watercourses with occasional failures to continual inability to meet the standards. The Samish and Skagit Rivers have shown drastic improvement and a strong ratio of positive to negative trends over the course of this program. Most of the substandard water quality occurs in slow-moving agricultural sloughs and in creeks that have low flow in the warmer months. Further investigation is ongoing to determine the causes of poor water quality in each case. Some cases may represent natural conditions rather than human-caused problems.

Trends analyses of water temperature, dissolved oxygen, bacterial concentrations, and other metrics reveal strong differences between watersheds and timeframes across the county. Some watersheds have mostly negative trends across an eighteen-year period but show a majority of positive trends in a more recent timeframe, such as the last five years.

Most trends in fecal coliform reduction county-wide are positive over all three analyzed time periods. This is a result of the hard work and dedication of the residents, farmers, tribes, government, environmental groups, establishing and enforcing strong regulations, and continued vision for a clean and sustainable environment that the citizens of Skagit County and the state of Washington continually portray. These improvements in water quality will continue to shine as an example for other communities and states across the country. Most dissolved oxygen trends across all timeframes across the valley show a positive increase, despite an abundant increase in water temperatures. This may suggest reductions on biological oxygen demand in the watercourses, and it is great news for salmon.

The format of this report may be used as the means to form action plans to address trends in watercourses and sampling sites. The trends maps and tabled trends summaries can paint a picture of overall water quality at each site to inform future action and to efficiently direct public resources and efforts.

The Skagit County Water Quality Monitoring Program has now collected 18 years of high-quality data. Questions on the program can be addressed to Dan Sulak at dsulak@co.skagit.wa.us or 360-416-1443

Skagit County Monitoring Program Annual Report

2021 Water Year
(October 2020-September 2021)

Introduction

The Skagit County Monitoring Program (SCMP) began in October 2003 as part of Skagit County's (County) program to assess the effectiveness of Skagit County Code (SCC) Chapter 14.24.120: Critical Areas Ordinance for Areas of Ongoing Agriculture (Ag-CAO). 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 (GMHB).

The ordinance requires farmers to "do no harm" to adjacent watercourses and relies on specific watercourse protection measures and more generalized best management practices (BMPs) to protect the watercourses instead of requiring buffers. 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 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 GMHB. 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 2021 Water Year (WY). Results from the first seventeen years of this program have been reported previously (Skagit County 2004-2020). This current report contains data and analysis from water years 2004 – 2021.

R20040211 also required the County to conduct a triennial review of the Ag-CAO, including the water quality monitoring program, to seek public comment 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 were studied. The legislature subsequently passed additional legislation to extend the "time out" to 2011. In 2011, the Washington State Legislature adopted the recommendations from one research group studying the critical areas regulations and created the Voluntary Stewardship Program (VSP). Skagit County enrolled 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 monitored by the SCMP, while **Table 1** and **Table 2** list the sampling site's names and their designations. Thirty-nine sites are currently included in the program. These sites are located primarily in agricultural zones, designated by the County as Agriculture-Natural Resource Lands (Ag-NRL) and Rural Resource-Natural Resource Lands (RR-NRL). Other sites were selected 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 SCMP was designed to determine current conditions and long-term trends in water quality at these sampling locations. The data are also suitable for determining compliance with state water quality standards.

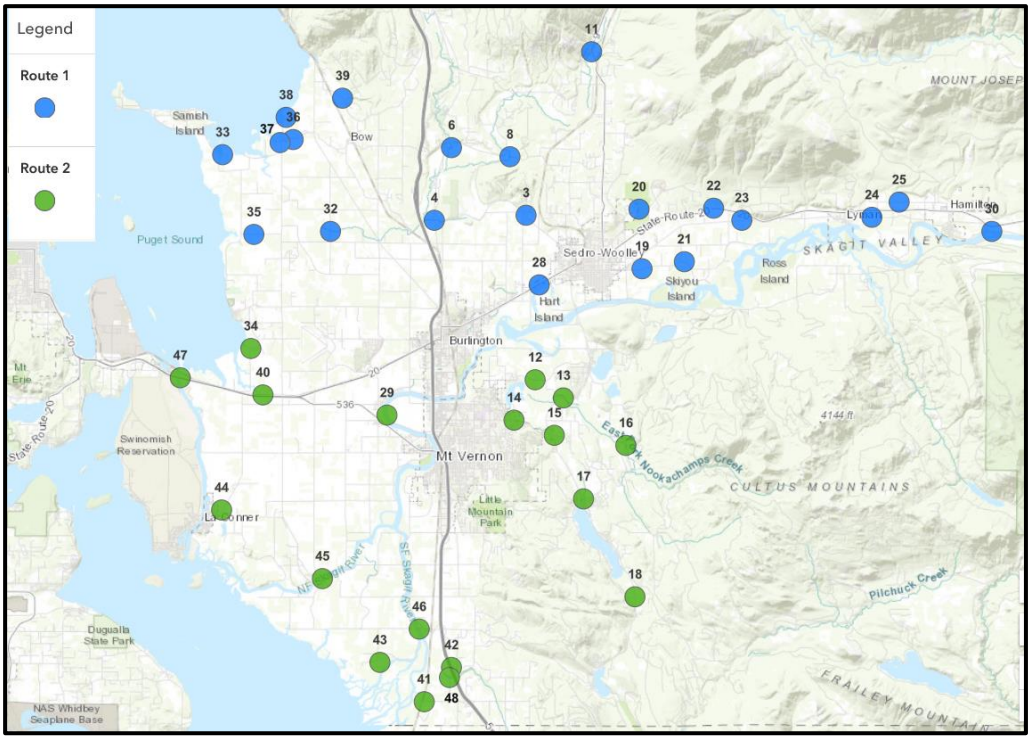


Figure 1 – Ambient sampling sites in the SCMP

A secondary purpose for some sites included in the SCMP is to provide data to the Washington State Department of Ecology (Ecology) in support of their Total Maximum Daily Load (TMDL) or water cleanup programs in Skagit County. The sites that provide TMDL data are in 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.

Table 1 - Sample site locations and types in the SCMP

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 Cem. 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
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	-122.436	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	Sullivan Slough[2]	La Conner-Whitney	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 to its current location in June, 2005. See text for details

Table 2 - Sample site type descriptions for the SCMP

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

Sample Site Revisions

Nineteen of the thirty-nine 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 are used to help interpret trends in water quality for sites continued in the SCMP. Not all 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. Several intermediate sites on the Samish River were discontinued, leaving one upstream and one downstream site on the Samish.

Three sample sites were moved from their original locations as delineated in the Quality assurance Project Plan (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 tide gate 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 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 Ecology and the Western Washington Agricultural Association. Most of the 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 (FC) readings at the site during this study were generally low. Because of the low FC readings, 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.

For the 2017 season, Skagit County re-designated 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.

Sampling Frequency

For the Skagit County ambient sampling program, samples are taken bi-weekly. Sites are sampled on one of two routes, with each route being completed every other week. All ambient sampling trips were conducted on schedule during the 2021 water year, beginning in October 2020. Sampling may have taken place on different days each week, depending on scheduling and logistics.

Clean Samish Initiative

The Clean Samish Initiative (CSI) was established by Ecology in fall 2008 to foster cooperation between local, state, tribal, and federal agencies, non-governmental groups, and citizens to address FC pollution in the Samish Bay Watershed. Excess FC pollution in the Samish River and other bay tributaries has resulted in numerous closures of the commercial shellfish beds in Samish Bay. The CSI 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 PIC project in the Samish Basin, incorporating CSI work plan elements into a program designed to locate and eliminate FC pollution in the Samish Basin.

The CSI grew out of Ecology's TMDL activities in the Samish Basin. Ecology's sampling demonstrated that the Samish River was the largest source of FC 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 determined that the river was, and continues to be, the most important pollution source for Samish Bay.

2008 Review by the 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 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 PIC program), increased use of stream discharge information, and some statistical analysis recommendations.

Funding

A proposal was submitted in February 2003 to Ecology for consideration in its 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, fiscal year 2004 through fiscal year 2008.

The Centennial Clean Water Grant, that funded the program at 75%, ended in December 2008, with the remaining 25% having come from County funds. Work since that date has been funded by Skagit County's Clean Water Program (CWP). Skagit County has received some EPA funding to address Samish Bay watershed FC issues, but the core activities of the SCMP will continue to be funded out of the CWP.

Methods

Standard water quality monitoring methods are used in the SCMP. The methods are derived from several sources, including guidance from Ecology and the EPA. A brief description of monitoring procedures follows, and detailed monitoring procedures can be found in the QAPP developed for the program (Skagit County 2004b).

Each site in the monitoring program is visited once every two weeks. At each visit, dissolved oxygen (DO), temperature, pH, turbidity, conductivity, and salinity are measured, and samples are obtained for FC determinations. Additional water samples are obtained for laboratory quantification of nutrients (total Kjeldahl nitrogen (TKN), ammonia (NH_3), nitrate (NO_3), nitrite (NO_2), total phosphorus (TP), orthophosphate (OP)), and total suspended solids

(TSS) 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 through the length of the program.

Data are collected on paper field sheets and later entered in an electronic database which is then checked for accuracy against the original data sheets. Microsoft Excel spreadsheets are used for data summary and analysis. These spreadsheets are appendices to this report and are published on the County's web site: http://www.skagitcounty.net/SCMP

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 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 SCMP 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 should be undertaken to determine if they 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 conditions that are likely caused by local circumstances.

One 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 DO. 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 SCMP 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 for this report was computed using Sanitas 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 the SCMP by the WRC. 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.

The SCMP completed trends analysis via the Seasonal Kendall's Test for 18 key parameters at each sampling location. The parameters tested include pH, DO, DO% saturation,

temperature, turbidity, FC, NH_3, NO_3+NO_2, TP, OP, TKN, and TSS. Temperature data from biweekly sampling visits were used for this analysis instead of continuous data collected during the summer months because the 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 bi-weekly visits were 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.

Three periods were analyzed for trends in this report: The 18 full years of SCMP data, the most recent ten years of data, and the most recent five years of data. Analyzing trends over three different timeframes allows a more detailed picture of what changes have been occurring across the county. For example, a creek may exhibit a small trend in increasing DO from 18 years ago as compared to now, but it may also show a strong trend in decreasing DO from five years ago as compared to now. Analyzing a combination of time periods reveals a clearer picture of what is happening than can be ascertained from a single trend over the course of 18 years.

Several sites have extended dry periods during most summers and/or are flooded during high water events and not sampled. The Sanitas trends analysis program was unable to compute trends based on 12 seasons for those sites due to the consistent lack of data for the dry or flooded periods. For those sites, trends were calculated based on four seasons, beginning in January, April, July, and October. All trends analyses on nutrient data mentioned above are also performed using four seasons, as these are only sampled quarterly.

Data used for the Seasonal Kendall's Test can be subject to autocorrelation, where each successive datum is correlated with the previous point. This situation usually occurs when samples are collected more frequently than monthly. For the SCMP, DO, temperature, and FC 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. Our approach for these parameters has been to conduct the analysis using all data and repeat the analysis using monthly averages to avoid autocorrelation. 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 all parameters, significant or not, can be found in Appendix C.

Data Quality

Quality Assurance Project Plan (QAPP)

The SCMP operates under a QAPP that was approved by Ecology in 2003. This plan details sampling strategies, equipment to be used, and all other aspects of the sampling program. Ecology approval of the QAPP was required for Skagit County to be eligible for grant funds.

Equipment Calibration and Maintenance

The turbidity meter (Lamotte Model 2020we) is calibrated the afternoon before or the morning of each sampling trip, and the reading before calibration is recorded.

The pH meter (Hanna Instruments Model 8314) is calibrated on the morning of each sampling trip. The pH meter is recalibrated during the trip if questionable results are obtained.

The DO/temperature/conductivity meter (YSI Model 2030 Pro) is calibrated for DO using the built-in calibration chamber (water-saturated air). The meter is recalibrated to local elevation at each sample site prior to sampling.

The DO 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 whenever possible with sample containers rinsed at least three times with sample water and are analyzed immediately.

Lab Samples

Laboratory samples for nutrients are collected using clean equipment and proper procedures, collected with a sampling wand from as close as possible to the the thalweg of the watercourse, and care is taken to prevent oversampling of the surface film or disturbing the bottom. For nutrient and TSS samples the sampling container is rinsed at least three times with the water to be sampled. The sample is then 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 ice until they are delivered to the lab on the same day.

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

Personnel

The project manager performs most samplings that generate data for this report. Any other staff that perform samplings and collections are adequately trained by the project manager according to EPA-approved sampling methods prior to sampling. Due to regular staff turnover and availability of assisting staff members, some staff may collect sample data only once, though repeated participation and experience with the project manager is preferred when possible.

Duplicate Analysis

Duplicate samples are collected for FC at a 20% rate and for selected nutrients at a 10% rate. Selected nutrient duplicates (TP, OP, NO_3, and/or NH_3) are intended to provide a precision estimate for all the nutrient analyses.

Table 3 summarizes the results of the duplicate analyses for the 2021 water year, using the coefficient of variation (CV) statistic. Variability in FC for the 2021 water year was 41.5, above

the original target level set out in the 2003 QAPP of 33. However, the annual average across this program is 44, with a very small annual standard deviation of 3. A score of 41 is on the very lowest end of this program's history. In this report, coefficient of variation is considered synonymous with relative standard deviation (RSD).

The high variability of the FC results may be partially due to the use of the Most Probable Number (MPN) analysis technique. This method was chosen for the SCMP 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 SCMP (Michaud 1991). The program continued using MPN when it switched to Edge Analytical in 2009 to maintain data comparability. Fecal coliform variability in the SCMP, although higher than the initial target level, is similar to that seen in other monitoring programs in Washington.

Table 3 - Data quality duplicate analysis for 2021 Water Year

		Coefficient of Variation (RSD)	
Parameter	**n**	**2021 Results**	**Target**
Fecal Coliform	208	41.5	33[1]
E. coli	207	50.3	33
Total Phosphorus	8	6.5	10 [2]
Orthophosphate	8	0.0	10 [2]
Nitrate	8	1.1	10 [2]
Ammonia	8	23.7	10 [2]

[1] Target precision as listed in 2003 QAPP
[2] 10% CV target was listed for all nutrients

Data Summaries and Trends Analysis

Trends were calculated for 30 measured or calculated parameters (such as monthly averages) at each of 39 sites, for a total of 1,170 tests. Of those, 399 tests showed a statistically significant trend at the 95% confidence level. Trends judged as improving or positive (e.g., increased dissolved oxygen, reduced temperature) made up 217 of the significant trends, or 54 percent. Negative or deleterious trends (e.g., reduced dissolved oxygen, increased nutrients) accounted for the remaining 182, or 46 percent of the significant trends. In relation to the global trend in acidification of surface waters, declining pH was considered a negative trend for this report. There were also statistically significant nutrient trends where the slope was zero, and these are not included in the above counts. The statistical analysis used was very sensitive, and a

slope of zero simply means that the slope was less than 0.0001 units, though the directionality as positive or negative was still given.

All trends can be found in the tables in **Appendix C**. Positive significant trends are shaded green and negative are shaded red. Trends that achieved 95% confidence in statistical significance are shaded the darkest blue in the confidence column. Some trends were very close to achieving 95% confidence but fell short. Trends that achieved 90% confidence are shaded in a slightly lighter blue, and trends that achieved 80% confidence in even lighter blue. This helps to inform the reader of all changes that may be occurring at the sampling site, even if they are not statistically significant at a 95% confidence level. Any parameters that showed a significant trend with a slope of 0 are highlighted in yellow in the slope column.

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.

Gaps in the data represent streams that were either flooded or dry at sampling time or may represent equipment malfunctions.

Site Sampling Times

The SCMP maintains sampling times as a temporal control for data analysis. The higher the precision of sampling time each week, the better. This is an exceptionally difficult task over such a long period. It is common to experience equipment problems, staff availability issues, bad weather, injuries, flat tires, closed roads, and inaccessible watercourses. Despite these obstacles, the SCMP has maintained remarkably small sampling windows across 18 years.

Route 1 - All 18 years combined					
Site	Mean	Min	Max	Range (hrs)	n
28	8:19	7:30	9:40	2:10	205
22	8:36	7:28	10:05	2:37	256
25	8:54	7:48	10:20	2:32	224
30	9:06	8:00	10:30	2:30	256
24	9:23	8:15	10:50	2:35	254
23	9:41	8:27	11:00	2:33	233
21	9:56	8:38	11:20	2:42	230
19	10:08	8:50	11:30	2:40	238
20	10:22	9:06	12:00	2:54	255
11	10:46	9:27	12:05	2:38	256
8	11:24	9:49	12:55	3:06	255
4	11:48	10:05	13:35	3:30	254
3	12:03	10:20	13:50	3:30	254
6	12:17	10:41	14:05	3:24	255
39	12:38	11:00	14:20	3:20	253
36	12:53	11:13	14:35	3:22	255
38	13:08	11:30	14:50	3:20	252
37	13:24	11:44	15:05	3:21	254
33	13:38	11:55	15:20	3:25	252
35	13:54	12:10	15:40	3:30	255
32	14:07	12:20	15:50	3:30	256

Table 4 – Historical sampling times for Route 1, which primarily samples the northern half of Skagit County. The table on the left includes all years of the program that sampling times were recorded. The table on the right is from the most recent water year.

Route 1 - Water Year 2021					
Site	Mean	Min	Max	Range (hrs)	n
28	7:52	7:35	8:20	0:45	15
22	8:08	7:28	8:40	1:12	26
25	8:28	7:48	9:00	1:12	21
30	8:42	8:00	9:20	1:20	26
24	9:00	8:15	9:40	1:25	26
23	9:20	8:27	10:00	1:33	22
21	9:37	8:38	10:20	1:42	22
19	9:50	8:50	10:30	1:40	22
20	10:04	9:06	10:50	1:44	26
11	10:29	9:27	11:15	1:48	26
8	10:50	9:49	11:40	1:51	26
4	11:10	10:05	12:05	2:00	26
3	11:32	10:20	12:45	2:25	26
6	11:44	10:41	12:30	1:49	25
39	12:02	11:00	12:50	1:50	26
36	12:19	11:13	13:05	1:52	26
38	12:34	11:30	13:20	1:50	25
37	12:54	11:44	13:50	2:06	26
33	13:12	11:55	14:00	2:05	26
35	13:28	12:10	14:15	2:05	26
32	13:42	12:20	14:25	2:05	26

Route 1 primarily samples the northern half of the county, while Route 2 primarily covers the southern half. Throughout the years, some short-term project-oriented sites were added into the sampling days, and those contributed to wider variation in sampling times for certain sites on the routes over the years.

Route 2 - All 18 years combined					
Site	Mean	Min	Max	Range (hrs)	n
29	8:19	7:00	9:44	2:44	253
40	8:47	7:35	10:13	2:38	251
34	9:01	7:50	10:26	2:36	250
47	9:15	8:05	10:40	2:35	256
44	9:33	8:30	11:00	2:30	255
45	9:58	8:55	11:40	2:45	253
43	10:18	9:00	11:56	2:56	255
46	10:33	9:10	12:07	2:57	255
41	10:48	9:25	12:30	3:05	257
48	11:01	9:35	12:47	3:12	257
42	11:16	9:45	13:04	3:19	255
18	11:45	10:10	13:40	3:30	255
17	12:01	10:25	14:00	3:35	255
16	12:23	10:40	14:19	3:39	255
15	12:43	10:55	14:46	3:51	254
13	12:57	11:05	15:01	3:56	254
12	13:11	11:20	15:30	4:10	252
14	13:30	11:30	15:30	4:00	251

Table 5 - Historical sampling times for Route 2, which primarily samples the southern half of Skagit County. The table on the left includes all years of the program that sampling times were recorded. The table on the right is from the most recent water year.

Route 2 - Water Year 2021					
Site	Mean	Min	Max	Range (hrs)	n
29	7:41	7:00	8:00	1:00	25
40	8:15	7:35	8:35	1:00	26
34	8:30	7:50	8:55	1:05	26
47	8:47	8:05	9:15	1:10	25
44	9:06	8:30	9:40	1:10	26
45	9:37	9:00	10:15	1:15	25
43	9:58	9:20	10:35	1:15	24
46	10:17	9:25	10:50	1:25	26
41	10:34	9:35	11:05	1:30	26
48	10:46	9:45	11:20	1:35	26
42	11:03	10:00	11:35	1:35	26
18	11:32	10:20	12:10	1:50	26
17	11:49	10:35	12:35	2:00	26
16	12:13	11:00	13:00	2:00	26
15	12:35	11:15	13:30	2:15	25
13	12:48	11:25	13:45	2:20	26
12	13:02	11:40	14:05	2:25	26
14	13:39	11:50	14:55	3:05	24

Annual Rainfall and Air Temperatures

Monthly precipitation totals and average air temperatures were collected from the Washington State University AgWeatherNet Mount Vernon station for the entire 18 water years of this program **(Tables 6, 7)**. Summary statistics are calculated on the right for each month and below for each year.

The 2021 water year had the third lowest recorded rainfall in the programs 18-year history. Total rainfall was 28.00 inches, 4.47 inches, or 1.14 standard deviations, below the 18-year mean of 32.47 inches. The period from March through July was particularly dry, with each of those months seeing at least 0.5 inches less rain than the average for the month.

	WY 2004	WY 2005	WY 2006	WY 2007	WY 2008	WY 2009	WY 2010	WY 2011	WY 2012	WY 2013	WY 2014	WY 2015	WY 2016	WY 2017	WY 2018	WY 2019	WY 2020	WY2021
October	5.34	2.71	4.01	1.98	4.82	1.37	5.67	1.76	1.96	3.87	1.51	6.07	3.39	5.26	5.39	2.32	4.21	3.54
November	4.66	6.84	4.20	5.61	2.68	5.55	5.31	3.74	4.67	3.89	3.48	3.90	7.85	5.99	6.22	4.20	2.14	2.92
December	2.87	4.36	3.42	3.05	3.71	3.18	1.25	3.26	1.25	3.52	2.34	3.73	7.05	3.21	3.76	3.79	3.50	4.25
January	4.01	4.11	6.54	5.47	2.75	3.79	2.81	6.01	2.92	5.13	4.70	4.69	3.21	1.62	4.79	1.81	5.90	3.71
February	1.35	3.15	3.2	2.96	2.91	1.25	1.25	1.72	4.49	2.02	3.89	2.97	4.63	3.18	5.78	2.27	4.82	4.89
March	3.44	2.77	1.51	4.52	4.36	2.24	2.16	3.37	3.77	2.10	4.45	2.51	3.88	5.01	2.79	1.35	2.84	1.61
April	0.28	4.11	3.16	0.89	2.40	2.71	2.53	3.90	4.31	4.60	3.26	1.48	2.17	3.00	4.73	2.45	1.61	1.16
May	3.65	1.73	2.24	1.09	2.09	2.22	4.57	4.17	2.4	2.58	3.68	0.60	1.27	2.36	0.35	0.88	3.13	0.87
June	1.80	1.90	1.10	1.58	2.25	0.16	1.66	0.91	3.14	1.27	1.14	0.61	2.78	0.94	1.52	1.42	3.07	0.91
July	0.61	0.74	0.82	1.27	0.64	0.51	0.05	1.39	1.3	0.00	1.29	0.11	0.59	0.01	0.04	0.83	0.83	0.00
August	6.29	2.22	0.23	0.81	2.23	0.52	1.17	0.42	0.01	1.34	0.88	1.46	2.88	0.04	0.17	0.86	0.64	0.96
September	3.27	1.96	1.78	2.36	0.50	1.31	2.87	0.87	0.14	4.10	2.64	2.12	1.32	1.59	1.36	5.24	1.07	3.18
Annual	37.57	36.6	32.21	31.59	31.34	24.81	31.30	31.52	30.36	34.42	33.26	30.25	41.02	32.21	36.90	27.42	33.76	28.00
Low	0.28	0.74	0.23	0.81	0.5	0.16	0.05	0.42	0.01	0.00	0.88	0.11	0.59	0.01	0.04	0.83	0.64	0.00
High	6.29	6.84	6.54	5.61	4.82	5.55	5.67	6.01	4.67	5.13	4.7	6.07	7.85	5.99	6.22	5.24	5.9	4.89
Mean	3.13	3.05	2.68	2.63	2.61	2.07	2.61	2.63	2.53	2.87	2.77	2.52	3.42	2.68	3.08	2.29	2.81	2.33
Mean Wet (Oct-Apr)	3.14	4.01	3.72	3.50	3.38	2.87	3.00	3.39	3.34	3.59	3.38	3.62	4.60	3.90	4.78	2.60	3.57	3.15
Mean Dry (May-Sep)	3.12	1.71	1.23	1.42	1.54	0.94	2.06	1.55	1.40	1.86	1.93	0.98	1.77	0.99	0.69	1.85	1.75	1.18
Seasonal Extremes*	1.00	2.34	3.01	2.46	2.19	3.04	1.45	2.19	2.39	1.93	1.75	3.70	2.60	3.94	6.95	1.41	2.04	2.66

Raw Data Source: WSU AgWeather Net Mount Vernon Station

	Mean	Low	High
	32.47	24.81	41.02
	0.35	0.00	0.88
	5.78	4.67	7.85
	2.71	2.07	3.42
	3.53	2.60	4.78
	1.55	0.69	3.12
	2.61	1.00	6.95

	Low	High	Mean
October	1.37	6.07	3.62
November	2.14	7.85	4.66
December	1.25	7.05	3.42
January	1.62	6.54	4.11
February	1.25	5.78	3.15
March	1.35	5.01	3.04
April	0.28	4.73	2.71
May	0.35	4.57	2.22
June	0.16	3.14	1.56
July	0.00	1.39	0.61
August	0.01	6.29	1.29
September	0.14	5.24	2.09
	0.00	7.85	2.76

No data, filled in with mean value

Neutral value is within +- 0.5 of mean

Greater than 0.5 below mean

Greater than 0.5 above mean

Table 6 - Monthly precipitation totals for the history of the Skagit County Monitoring Program. Cells are shaded blue or red to illustrate above and below average rainfall for a month, respectively. The threshold of 0.5 inches of rain to constitute an "average" shading of grey is arbitrarily chosen and does not constitute an authoritative metric. * Seasonal Extremes in the ratio of average monthly rainfall for the wet to the dry season for each year.

Some of the most interesting statistics on **Table 6** are at the bottom: The monthly mean wet and dry seasonal rainfall, and the seasonal extremes category, which divides the wet by the dry. This creates a ratio that can illustrate extremes in seasonal rainfall. Monitoring these ratios across a changing climate can be informative in monitoring changes in water quality. You can see that some years you may get a near equivalent amount of total precipitation in the wet season as the dry season, whereas a year can be as extreme as nearly seven times as much precipitation in the wet season as occurs in the dry.

Monthly temperature statistics are summarized in **Table 7.** Mean monthly temperatures for each year that are greater than 0.9°F different from the full period average are highlighted in red or blue for above or below, respectively. In the lower section of the table, the full years' average temperatures are shown and compared to the 18-year mean. Differences exceeding 0.9°F above or below the mean are again highlighted. Seven out of the 18 years exceed this difference from the average.

The Seasonal Extremes in the bottom row is the ratio of average monthly wet season temperature to average monthly dry season temperature. It is lower if the wet and dry seasons are more disparate in average temperatures, or higher if the two seasons are more alike in that year.

	WY 2004	WY 2005	WY 2006	WY 2007	WY 2008	WY 2009	WY 2010	WY 2011	WY 2012	WY 2013	WY 2014	WY 2015	WY 2016	WY 2017	WY 2018	WY 2019	WY 2020	WY 2021
October	54.3	50.6	46.8	47.2	48.0	50.0	50.6	51.9	50.7	51.3	49.1	56.8	54.4	53.5	49.6	49.8	47.9	50.4
November	44.0	43.2	34.4	42.8	41.1	47.8	47.1	42.5	42.5	46.4	43.7	43.9	41.7	51.0	46.4	46.1	42.9	44.7
December	41.9	41.1	39.9	39.5	38.3	35.9	36.4	42.8	39.6	41.2	37.1	43.1	42.4	36.2	37.4	41.4	42.3	42.3
January	41.9	41.0	43.6	36.2	36.7	38.2	46.7	40.7	40.1	37.2	41.0	43.5	42.6	36.4	44.1	41.7	43.7	42.5
February	43.5	41.1	39.1	41.5	40.0	39.9	45.6	38.0	42.2	43.0	38.7	47.5	46.5	40.1	39.3	33.5	40.9	39.1
March	47.5	46.7	44.0	45.3	40.8	41.4	46.1	45.2	43.1	45.7	46.8	49.3	48.7	45.8	43.6	43.1	42.4	43.5
April	52.4	49.4	46.8	47.4	45.4	49.2	49.2	45.1	49.8	48.6	50.5	49.6	53.4	50.5	49.3	49.8	49.7	49.1
May	56.3	56.2	55.0	52.3	53.7	55.0	52.1	51.6	53.2	55.4	57.1	56.3	56.9	55.4	57.1	56.6	56.0	53.7
June	61.3	57.1	58.6	56.0	55.6	60.0	56.8	57.4	56.1	60.5	59.2	62.8	59.6	59.8	58.9	59.2	58.2	62.8
July	62.4	61.4	61.1	62.0	59.7	64.4	60.7	60.1	60.6	62.5	64.1	65.9	63.1	62.5	64.5	63.0	61.7	62.8
August	65.4	61.5	59.2	59.9	61.9	61.7	60.8	61.1	62.9	63.9	64.4	64.3	63.8	63.7	62.6	64.0	61.9	62.6
September	57.0	54.7	56.0	54.6	57.0	59.2	58.8	60.4	57.1	59.7	60.4	57.2	57.6	59.7	57.5	59.1	60.2	58.1
Low	41.9	41	34.4	36.2	36.7	35.9	36.4	38	39.6	37.2	37.1	43.1	41.7	36.2	37.4	33.5	40.9	39.1
High	65.4	61.5	61.1	62	61.9	64.4	60.8	61.1	62.9	63.9	64.4	65.9	63.8	63.7	64.5	64	61.9	62.8
Mean	52.3	49.9	48.0	48.2	47.4	49.4	50.2	48.8	49.2	50.5	50.2	53.0	52.1	50.4	50.3	49.8	49.8	50.3
Mean Wet (Oct-Apr)	45.5	44.0	41.3	42.1	40.8	42.2	45.4	43.5	43.0	44.1	42.7	47.4	46.1	43.8	43.4	42.6	43.4	43.8
Mean Dry (May-Sep)	59.1	56.7	56.1	55.4	55.6	58.3	56.4	56.0	56.6	58.4	59.3	59.4	59.1	58.6	58.3	58.6	58.0	58.2
Seasonal Extremes	0.77	0.77	0.74	0.76	0.73	0.72	0.81	0.78	0.76	0.76	0.72	0.80	0.78	0.75	0.74	0.73	0.75	0.75

Raw Data Source: WSU AgWeatherNet Mount Vernon Station

	Mean	Low	High
	38.13	33.5	43.1
	63.11	60.80	65.90
	49.99	47.38	53.00
	43.61	40.82	47.35
	57.66	55.37	59.35
	0.76	0.72	0.81

Low	High	Mean
46.8	56.8	50.7
34.4	51.0	44.0
35.9	43.1	39.9
36.2	46.7	41.0
33.5	47.5	41.1
40.8	49.3	44.9
45.1	53.4	49.2
51.6	57.1	55.0
55.6	62.8	58.9
59.7	65.9	62.4
59.2	65.4	62.5
54.6	60.4	58.0
33.5	65.9	50.6

No data, filled in with mean value
Neutral value is within +- 0.9 of mean
Greater than 0.9 above mean
Greater than 0.9 below mean

Table 7 - Monthly air temperature averages for the entire history of the Skagit County Monitoring Program. Cells are shaded red or blue to illustrate above and below average temperature for a month, respectively. The threshold of 0.9 degrees Fahrenheit to constitute an "average" shading of grey is arbitrarily chosen and does not constitute an authoritative metric.

Water 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.

Background

For the water years 2004-2007 and 2009-2021, 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 late June and retrieved in early September. During those years, several of the data loggers went missing by the end of each monitoring period. Some may have 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 were not very useful. 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.

In the fall of 2006, Ecology revised its water quality standards (WAC 173-201a) to comply with a request from the EPA. Included in this revision were several changes to temperature and DO standards for Skagit County watercourses. In particular, the lower Skagit River, Hansen, Nookachamps, Fisher, and Carpenter Creeks, and the upper Samish River and its tributaries were placed in the "Core salmonid spawning and rearing" use category. This change had the effect of imposing more stringent temperature and DO standards on these streams. Formerly, each of these streams was held to a 7-day average of the daily maximum temperatures (7-DADMax) standard of 17.5ºC, but with the revised standards, these streams must now meet a 7-DADMax standard of 16ºC. There were no changes to other streams in the county. Currently, Sites 3-4, 28, 32-44, 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.

Results

Table 8 shows the daily maximum temperatures for the last five years of the study, based on data collected at bi-weekly samplings. Because the state water quality standards are based on 7-DADMax, the maximums reported on **Table 8** 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 9 contains the 7-DADMax values 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 text above.

Twenty-three dataloggers were deployed for the summer of 2021. Of these, two went missing and were not recovered. The remaining 21 dataloggers were retrieved and their data analyzed.

Trends analyses reveal that in comparison to 18 years ago, at the start of this program, nine sites have shown an increase in temperature and one site has shown a decrease (**Figure 2**). Looking at the map of trends from the most recent ten years (**Figure 3**), three sites show an increase while one shows a decrease. All the sites with increasing temperatures are in the northern half of the county.

Trends from the most recent five years of data (**Figure 4**) show one significantly increasing in temperature, with no sites showing a significant decrease.

A major heat wave across the western United States in June 2021 led to high water temperatures. Out of 15 sites where data loggers were deployed at that time and subsequently recovered, 13 recorded their 7-DADMax in a span that included the dates of June 26th, 27th, and 28th, when daily high temperature records were set at the Mount Vernon AgWeatherNet station. The 7-DADMax temperature that was recorded at those sites was the highest on record for at least the last 5 years. These data contributed to more increasing and fewer decreasing trends in the 10- and 5-year time frames than were seen in the analyses done in the 2020 water year.

Ecology has developed temperature remediation plans (TMDLs) for Fisher, Carpenter, Nookachamps, and Hansen Creeks, but many other Skagit County streams also exceed temperature standards.

Table 8 - Maximum watercourse temperatures recorded from bi-weekly sampling. Cells shaded green pass state standard. There is a 0.2 allowance in the standard for variation in equipment calibration. These samplings are taken at nearly the same time of day, each week they are sampled, and do not represent the hottest temperature that each site may have reached on a given day.

Site Number	Watercourse	Location	Highest daily temperature (°C)				
			2017	2018	2019	2020	2021
3	Thomas Creek	Old Hwy 99 North	19.2	18.4	17.8	18.4	18.7
4	Thomas Creek	F&S Grade Rd	15.3	14.9	14.8	14.7	15.2
6	Friday Creek	Prairie Rd	18.6	19.2	18.0	17.8	18.8
8	Swede Creek	Grip Rd	17.8	16.9	16.5	16.2	16.2
11	Samish River	State Route 9	13.5	13.2	13.6	15.2	12.6
12	Nookachamps Creek	Swan Rd	21.1	22.5	21.0	20.1	21.8
13	E.F. Nookachamps Creek	State Route 9	19.6	21.9	19.4	18.6	24.0
14	College Way Creek	College Way	17.3	19.0	16.7	17.0	20.0
15	Nookachamps Creek	Knapp Rd	22.0	22.7	20.1	22.1	25.3
16	E.F. Nookachamps Creek	Beaver Lake Rd	18.1	19.8	17.5	17.0	20.4
17	Nookachamps Creek	Big Lake Outlet	22.8	23.6	21.3	22.5	26.9
18	Lake Creek	State Route 9	16.3	18.1	16.4	16.3	21.9
19	Hansen Creek	Hoehn Rd	17.3	17.6	18.1	18.5	18.0
20	Hansen Creek	Northern State	15.3	15.4	14.9	14.8	14.7
21	Coal Creek	Hoehn Rd	15.7	15.2	15.6	16.5	14.9
22	Coal Creek	Hwy 20	15.3	15.2	15.3	15.1	14.5
23	Wiseman Creek	Minkler Rd	15.0	14.1	14.2	15.5	15.8
24	Mannser Creek	Lyman Ham. Hwy	12.5	11.9	12.5	12.9	15.3
25	Red Cabin Creek	Hamilton Cem. Rd	11.7	11.2	11.9	12.4	11.5
28	Brickyard Creek	Hwy 20	14.5	14.3	14.7	16.2	12.1*
29	Skagit River	River Bend Rd	15.9	16.2	16.0	14.7	15.7
30	Skagit River	Cape Horn Rd	15.3	15.4	15.6	15.0	15.0
32	Samish River	Thomas Rd	20.1	19.3	18.8	18.2	19.4
33	Alice Bay Pump Station	Samish Island Rd	22.7	25.0	22.1	22.9	22.6
34	No Name Slough	Bayview-Edison Rd	21.5	27.0	25.3	24.8	25.7
35	Joe Leary Slough	D'Arcy Rd	20.3	21.3	21.4	18.9	21.2
36	Edison Slough at school	W. Bow Hill Rd	27.0	30.2	28.3	27.0	29.5
37	Edison Pump Station	Farm to Market Rd	23.6	25.5	23.3	25.8	26.6
38	North Edison Pump Sta.	North Edison Rd	22.2	24.4	22.3	20.9	23.8
39	Colony Creek	Colony Rd	16.6	17.4	15.3	20.5	16.1
40	Big Indian Slough	Bayview-Edison Rd	19.4	19.5	18.3	17.7	20.6
41	Maddox/Big Ditch	Milltown Rd	22.4	21.7	21.4	20.8	21.3
42	Hill Ditch	Cedardale Rd	22.0	20.8	20.9	21.2	21.9
43	Wiley Slough	Wylie Rd	19.6	27.2	20.2	19.3	19.2
44	Sullivan Slough	La Conner-Whitney	20.0	18.3	16.7	20.1	14.7
45	Skagit River – N. Fork	Moore Rd	16.4	16.4	17.0	15.6	16.5
46	Skagit River – S. Fork	Fir Island Rd	16.7	16.7	17.0	15.9	16.9
47	Swinomish Channel	County Boat Launch	18.5	16.1	16.2	17.0	16.3
48	Fisher Creek	Franklin Rd	13.5	15.3	14.0	14.0	15.8

*only sampled November 11 – May 11

Table 9 - Maximum seven-day average of the daily maximum temperatures (Max 7-DADMax). This data is from continuous temperature loggers (TidbiTs), with measurements taken every 30 minutes. Cells shaded green pass state standard. There is a 0.2 allowance in the standard for variation in equipment calibration.

Site Number	Watercourse	Location	Max 7-DADMax (°C)				
			2017	2018	2019	2020	2021
3	Thomas Creek	Old Hwy 99 North	20.2	20.2	n/a	19.9	22.4
4	Thomas Creek	F&S Grade Rd	16.1	17.0	16.5	16.2	n/a+
6	Friday Creek	Prairie Rd	n/a	22.6	21.3	20.0	23.95
8	Swede Creek	Grip Rd	17.6	19.0	17.8	17.4	19.0◊
11	Samish River	State Route 9	14.8	14.8	n/a	15.1	15.6
12	Nookachamps Creek	Swan Rd	22.9	23.5	23.5	21.0*	22.0◊
13	E.F. Nookachamps Creek	State Route 9	20.5	21.7	n/a	20.7	24.1
15	Nookachamps Creek	Knapp Rd	22.3	23.8	n/a	23.0	27.3
16	E.F. Nookachamps Creek	Beaver Lake Rd	20.8	22.2	20.1	n/a	23.5
17	Nookachamps Creek	Big Lake Outlet	25.5	26.5	n/a	25.6	27.8
18	Lake Creek	State Route 9	18.0	19.5	19.2	18.6	23.1*
19	Hansen Creek	Hoehn Rd	19.0	20.1	19.7	20.3	23.1*
20	Hansen Creek	Northern State	17.1	17.8	n/a	16.5	18.9
21	Coal Creek	Hoehn Rd	15.9	18.6	20.3	17.8	20.8*
22	Coal Creek	Hwy 20	n/a	17.5	16.8	16.7	18.9
24	Mannser Creek	Lyman Hamilton Hwy	13.9	13.7	13.4	14.0	16.8
30	Skagit River	Cape Horn Rd	11.9	n/a	17.1	14.8**	n/a+
32	Samish River	Thomas Rd	20.2	21.2	20.6	n/a	22.1
39	Colony Creek	Colony Rd	17.3	18.4	17.5	17.4	19.6
41	Maddox Creek/Big Ditch	Milltown Rd	24.9	25.9	25.0	24.4	22.9
42	Hill Ditch	Cedardale Rd	25.7	25.9	24.9	24.6	24.0
45	Skagit River – North Fork	Moore Rd	17.7	19.4	n/a	17.2*	n/a+
48	Fisher Creek	Franklin Rd	14.8	16.8	16.5	16.1	17.2

*Incomplete dataset, as the TidbiT probe was out of the water for some of the summer measurement period. It is possible that this value could have been higher.

**TidbiT out of water for part of season. Analysis of USGS temperature monitoring station 12200500 near Mount Vernon, in comparison to the incomplete data from SCMP site 30 infers that the actual 7-DADMax likely occurred near 16.0 °C.

+ TidbiT data logger was not recovered

◊ TidbiT not deployed until mid-July. Likely missed actual max as most other loggers recorded their maximum 7-DADMax during the final week of June into the first few days of July.

Figure 2 – Eighteen-year trends in watercourse temperatures

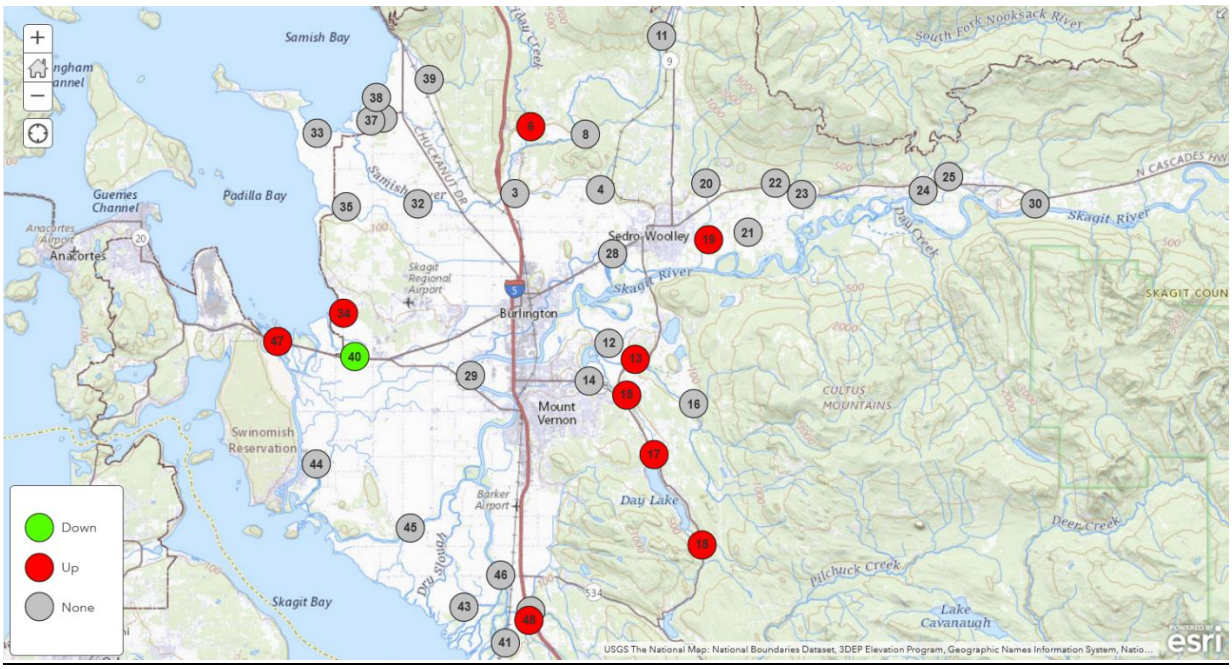


Figure 3 - Ten-year trends in watercourse temperatures

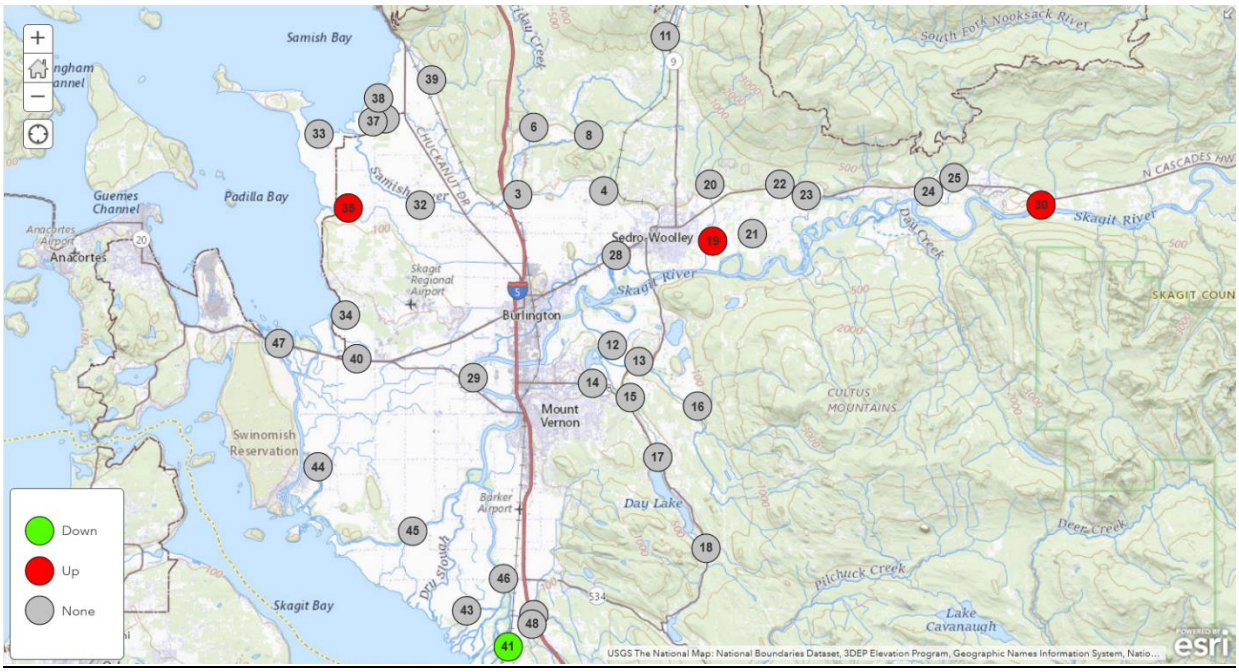
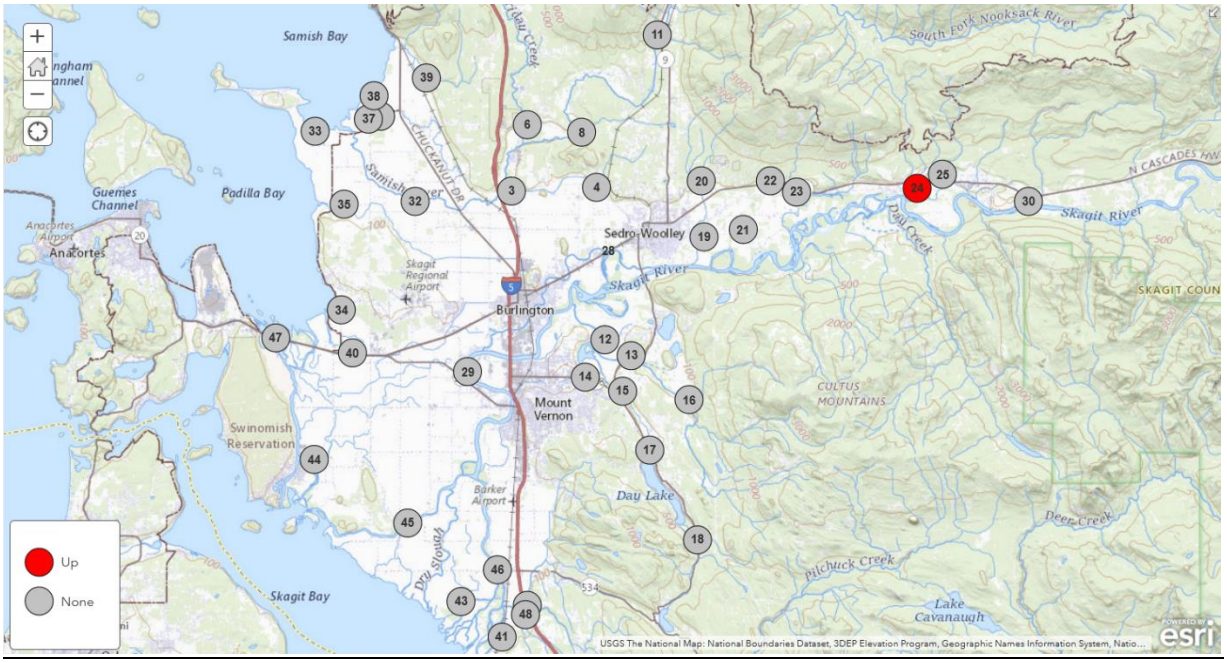


Figure 4 - Five-year trends in watercourse temperatures



Dissolved Oxygen (DO)

Dissolved oxygen measurements determine how much oxygen is available in the water for fish and other organisms.

Background

The state water quality standards for DO are based on single-day minimum measurements. For some lowland watercourses in the SCMP (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.

Results

A summary of DO readings (in mg/L) obtained during the 2021 water year is provided in **Table 10**. A summary of data from the most recent five years of this program can be found in **Table 11**.

Seven sites met the oxygen standards for the entire 2021 water year, compared to ten in 2020. Others met the oxygen standard for most of the year. In a few streams, oxygen levels show steep declines in summer. These declines are usually associated with very low flows, less velocity, and higher temperatures.

In the drainage infrastructure and lower sloughs, DO 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, night-time 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 night-time 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 are widely fluctuating DO levels, depending on the state of the algal blooms at sampling time. These fluctuations are very extreme, and data has been recorded from as low as 0% to as high as 300% typical oxygen saturation.

Trends analysis shows that in the 18 years since the program began, twelve sites have shown an increase in DO levels, while five have shown a decrease (**Figure 5**). There is a clustering of improved sites in the Samish and South Skagit watersheds. In the most recent ten years (**Figure 6**), trends show 17 sites increasing DO levels, while two are decreasing. These sites appear to be spread county-wide. In the most recent five years (**Figure 7**), trends show one site increasing DO levels, while eight sites are decreasing. These sites appear to also be spread county-wide. This decrease of sites with rising DO levels in the 5-year trends are likely influenced by the June 2021 heat wave, when high water temperatures led to low DO levels. Otherwise generally increasing DO levels are great news for water quality across the county, and possible contributions could be from lower biological oxygen demand (BOD), which can be a result of a decrease in pollution.

Table 10 - Dissolved oxygen (DO) measurements for 2021 water year. Cells shaded green pass state standard. A margin of error allowance is given at 0.2 mg/L.

Site Number	Watercourse	Location	Mean DO (mg/L)	Minimum DO (mg/L)	St. Std[1]
3	Thomas Creek	Old Hwy 99 N	6.83	6.28	8.0
4	Thomas Creek	F&S Grade Rd	11.17	7.55	8.0
6	Friday Creek	Prairie Rd	11.70	9.40	9.5
8	Swede Creek	Grip Rd	10.86	6.70	9.5
11	Samish River	State Route 9	9.12	7.13	9.5
12	Nookachamps Creek	Swan Rd	9.39	4.59	9.5
13	E.F. Nookachamps Creek	State Route 9	8.99	2.37	9.5
14	College Way Creek	College Way	9.38	5.75	9.5
15	Nookachamps Creek	Knapp Rd	7.63	0.63	9.5
16	E.F. Nookachamps Creek	Beaver Lake Rd	11.67	8.88	9.5
17	Nookachamps Creek	Big Lake Outlet	10.08	6.90	9.5
18	Lake Creek	State Route 9	11.12	8.32	9.5
19	Hansen Creek	Hoehn Rd	10.22	4.71	9.5
20	Hansen Creek	Northern State	11.48	8.81	9.5
21	Coal Creek	Hoehn Rd	11.86	8.67	9.5
22	Coal Creek	Hwy 20	12.02	10.23	9.5
23	Wiseman Creek	Minkler Rd	12.28	10.43	9.5
24	Mannser Creek	Lyman Hamilton Hwy	7.49	5.63	9.5
25	Red Cabin Creek	Hamilton Cem. Rd	11.86	9.38	9.5
28	Brickyard Creek	Hwy 20	9.65	6.52	8.0
29	Skagit River	River Bend Rd	11.30	8.96	9.5
30	Skagit River	Cape Horn Rd	11.37	9.45	9.5
32	Samish River	Thomas Rd	11.22	8.80	8.0
33	Alice Bay Pump Station	Samish Island Rd	8.80	0.41	8.0
34	No Name Slough	Bayview-Edison Rd	6.54	0.15	8.0
35	Joe Leary Slough	D'Arcy Rd	6.36	2.32	8.0
36	Edison Slough at school	West Bow Hill Rd	9.72	5.46	8.0
37	Edison Pump Station	Farm to Market Rd	6.63	0.07	8.0
38	North Edison Pump Station	North Edison Rd	3.99	0.00	8.0
39	Colony Creek	Colony Rd	10.64	6.49	9.5
40	Big Indian Slough	Bayview-Edison Rd	5.21	0.33	8.0
41	Maddox Slough/Big Ditch	Milltown Rd	5.14	0.15	8.0
42	Hill Ditch	Cedardale Rd	7.86	3.24	9.5
43	Wiley Slough	Wylie Rd	3.54	0.25	8.0
44	Sullivan Slough	La Conner-Whitney	5.41	2.09	8.0
45	Skagit River – North Fork	Moore Rd	11.37	8.56	9.5
46	Skagit River – South Fork	Fir Island Rd	11.29	9.16	9.5
47	Swinomish Channel	County Boat Launch	8.64	6.87	6.0
48	Fisher Creek	Franklin Rd	11.36	9.10	9.5

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

Table 11 - Mean dissolved oxygen (DO) levels for the most recent five years. Cells shaded green pass state standard. A margin of error allowance is given at 0.2 mg/L.

Site Number	Watercourse	Location	Mean Dissolved Oxygen (mg/L)				
			2017	2018	2019	2020	2021
3	Thomas Creek	Old Hwy 99 North	6.6	6.1	5.8	6.5	6.83
4	Thomas Creek	F&S Grade Rd	11.5	11.6	11.5	11.4	11.17
6	Friday Creek	Prairie Rd	11.8	11.6	11.6	11.4	11.70
8	Swede Creek	Grip Rd	10.6	10.8	10.7	11.0	10.86
11	Samish River	State Route 9	9.4	9.4	9.0	9.30	9.12
12	Nookachamps Creek	Swan Rd	8.4	9.0	9.4	8.5	9.39
13	E.F. Nookachamps Creek	State Route 9	10.0	10.0	9.6	8.9	8.99
14	College Way Creek	College Way	9.7	9.9	9.8	9.5	9.38
15	Nookachamps Creek	Knapp Rd	8.4	8.6	8.3	8.1	7.63
16	E.F. Nookachamps Creek	Beaver Lake Rd	11.7	11.7	12.0	11.7	11.67
17	Nookachamps Creek	Big Lake Outlet	10.2	10.4	10.2	9.7	10.08
18	Lake Creek	State Route 9	11.2	11.1	11.3	11.3	11.12
19	Hansen Creek	Hoehn Rd	10.4	10.3	10.3	10.3	10.22
20	Hansen Creek	Northern State	11.6	11.6	11.5	11.5	11.48
21	Coal Creek	Hoehn Rd	11.7	11.8	11.6	11.2	11.86
22	Coal Creek	Hwy 20	11.9	12.1	11.8	11.8	12.02
23	Wiseman Creek	Minkler Rd	12.3	12.2	12.2	11.8	12.28
24	Mannser Creek	Lyman Ham. Hwy	7.5	7.9	7.9	7.9	7.49
25	Red Cabin Creek	Hamilton Cem. Rd	12.3	12.2	12.2	11.8	11.86
28	Brickyard Creek	Hwy 20	10.2	10.4	9.5	8.3	9.65
29	Skagit River	River Bend Rd	11.4	11.4	11.1	11.4	11.30
30	Skagit River	Cape Horn Rd	11.7	11.5	11.3	11.4	11.37
32	Samish River	Thomas Rd	11.4	10.9	11.2	11.3	11.22
33	Alice Bay Pump Station	Samish Island Rd	8.2	11.1	9.2	8.6	8.80
34	No Name Slough	Bayview-Edison Rd	7.8	8.0	7.0	7.4	6.54
35	Joe Leary Slough	D'Arcy Rd	5.0	5.6	5.6	6.4	6.36
36	Edison Slough at school	W. Bow Hill Rd	10.4	11.2	8.9	8.0	9.72
37	Edison Pump Station	Farm to Market Rd	8.3	7.9	8.2	4.8	6.63
38	N. Edison Pump Station	North Edison Rd	8.4	7.5	7.4	4.0	3.99
39	Colony Creek	Colony Rd	11.0	11.0	11.1	11.0	10.64
40	Big Indian Slough	Bayview-Edison Rd	4.7	5.4	5.1	5.1	5.21
41	Maddox/Big Ditch	Milltown Rd	6.6	7.1	7.4	6.4	5.14
42	Hill Ditch	Cedardale Rd	8.3	8.9	8.5	7.9	7.86
43	Wiley Slough	Wylie Rd	4.5	5.0	4.8	4.1	3.54
44	Sullivan Slough	La Conner-Whitney	7.5	6.3	6.3	7.3	5.41
45	Skagit River – North Fork	Moore Rd	11.5	11.6	11.3	11.5	11.37
46	Skagit River – South Fork	Fir Island Rd	11.4	11.6	11.4	11.6	11.29
47	Swinomish Channel	County Boat Launch	9.0	8.8	8.8	8.7	8.64
48	Fisher Creek	Franklin Rd	11.6	11.4	11.6	11.4	11.36

Figure 5 - Eighteen-year trends in dissolved oxygen (DO)

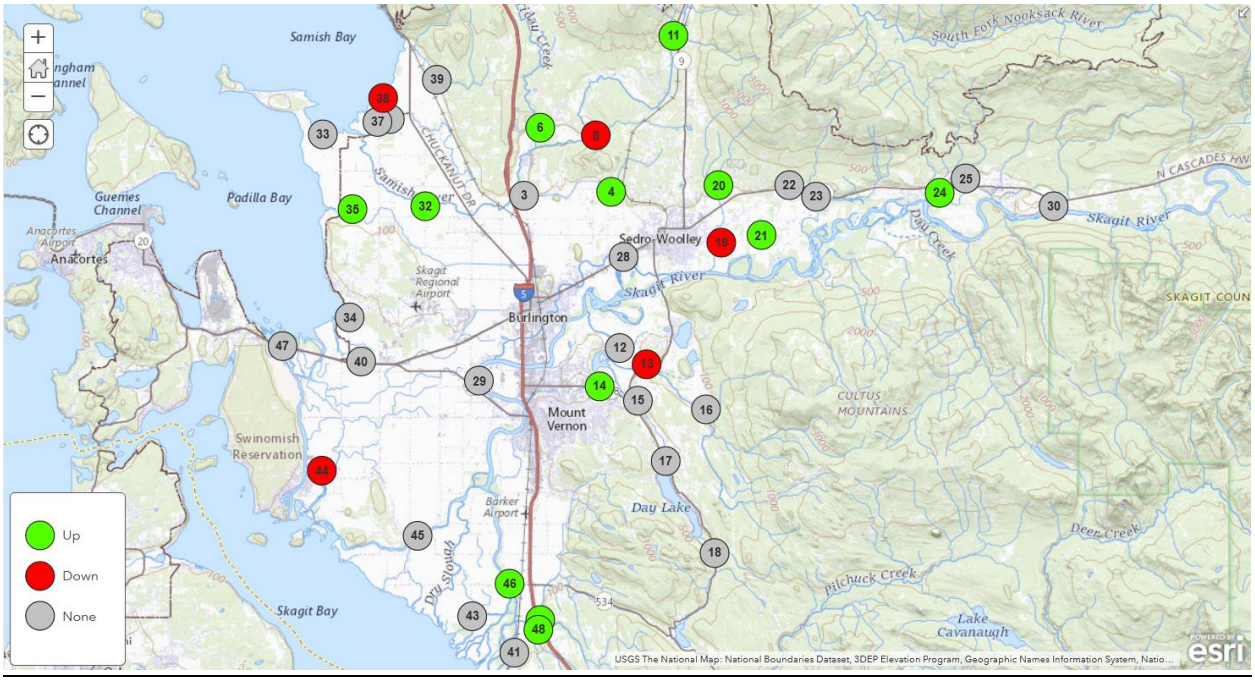


Figure 6 - Ten-year trends in dissolved oxygen (DO)

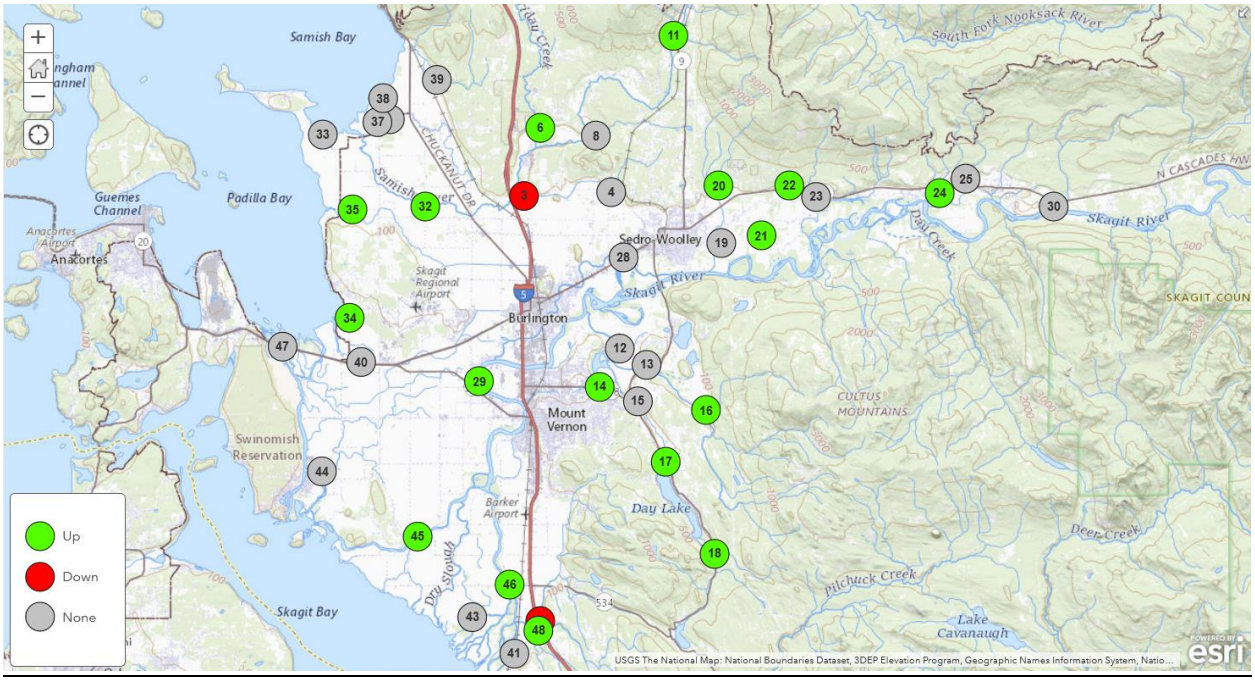
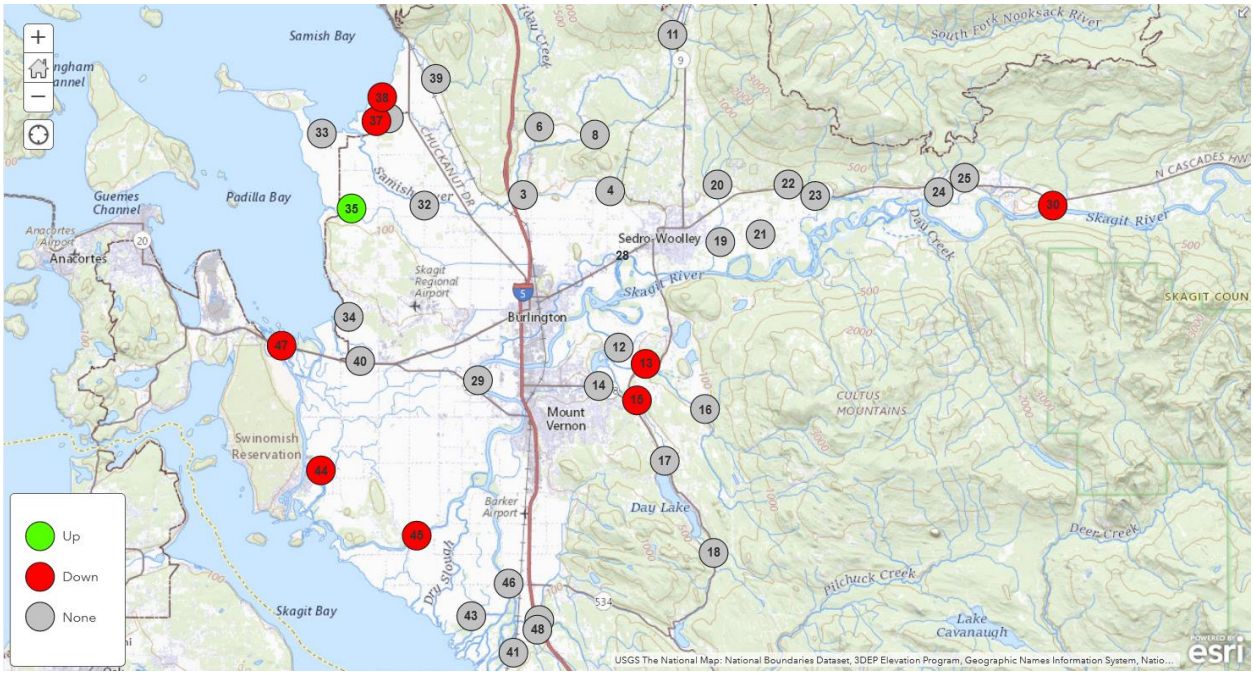


Figure 7 - Five-year trends in dissolved oxygen (DO)



Fecal Coliform (FC) and *Escherichia (E.) coli* (EC)

Fecal coliform is a group of enteric bacteria from warm-blooded animals. *E. coli* is one of the specific bacteria species within that group. Although FC and EC measurements do not directly quantify disease-causing organisms, they serve as an indicator of the possible presence of such bacteria, viruses, and protozoa. The sources of FC and EC organisms reaching the watercourses of Skagit County may include runoff from failing septic tanks, livestock operations, wildlife, recreationists, and pets.

Background

Samples for FC measurements were taken at each site during each visit and were submitted to the Skagit County Health Department Water Lab (2003-2008) or Edge Analytical (2009-2021) for analysis by the most probable number (MPN) method. Beginning in the 2021 water year, samples submitted to Edge Analytical were also analyzed for EC by the MPN method.

State standards for these bacteria are based on the geometric mean of the samples as well as the percent of the samples that exceed given criteria. Prior to 2020, state standards for recreational water contact of fresh water were set for FC as follows. For most of the watercourses in the SCMP (sites 3-20, 28-29, 31-46, 48), FC was not to exceed a geometric mean of 100 MPN per 100mL, with no more than 10% of the measurements exceeding 200 MPN per 100 mL. For the upriver sites (sites 21-25, 30), the standard was a geometric mean of 50 MPN, with no more than 10% of the measurements exceeding 100 MPN. Those standards expired on December 31, 2020. Primary contact recreation bacteria criteria are now

based on EC. For all freshwater sites, EC must not exceed a geometric mean of 100 MPN per 100 mL, with not more than 10% of all samples exceeding 320 MPN per 100 mL. 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.

The SCMP now collects and reports data for both FC and EC. FC measurements allow for comparison to historic data and assessment of progress on TMDLs that were written based on the now expired FC standards. EC results allow for determination of whether sites are meeting current water quality criteria.

Results

For the 2021 water year, 14 sites met the old FC standard based on ambient sampling for the entire water year (**Table 12**), compared to 19 sites in 2020. Meanwhile, 24 sites met the new EC standard for the 2021 water year (**Table 13**). Most sites that did not meet the standards did so due to having more than 10% of samples with FC counts over 200 MPN and/or with EC counts greater than 320 MPN. Over the past five years, the particular sites meeting and exceeding standards has been fairly consistent (**Table 14**). The new state standards are designed to better indicate when contact with the water may pose a threat to human health, and seeing that more sites meet those criteria is a positive sign for assessing Skagit County's water quality.

Trends analysis shows that in the 18 years since the program began, eight sites have shown improvement through a decline in FC counts, while four sites have shown deterioration through an increase in FC counts (**Figure 8**). There is a clear clustering of improved sites in the Samish Bay watershed, relative to the rest of the county. In the most recent ten years, two sites have shown improvement, while two sites have shown deterioration (**Figure 9**). In the most recent five years, one site has shown improvement, while two sites have shown significantly increased FC counts (**Figure 10**).

Table 12 - Fecal coliform (FC) results (MPN/100ml) for 2021 water year. Cells shaded green pass state standard.

Site Number	Watercourse	Location	n	Geometric mean (MPN)[1]	% > 100 or 200[1]
3	Thomas Creek	Old Hwy 99 N	26	64	27
4	Thomas Creek	F&S Grade Rd	26	169	42
6	Friday Creek	Prairie Rd	25	29	0
8	Swede Creek	Grip Rd	26	51	12
11	Samish River	State Route 9	26	23	8
12	Nookachamps Creek	Swan Rd	26	77	19
13	E.F. Nookachamps Creek	State Route 9	26	51	23
14	College Way Creek	College Way	24	214	63
15	Nookachamps Creek	Knapp Rd	25	57	16
16	E.F. Nookachamps Creek	Beaver Lake Rd	26	37	19
17	Nookachamps Creek	Big Lake Outlet	26	22	4
18	Lake Creek	State Route 9	26	51	27
19	Hansen Creek	Hoehn Rd	21	65	10
20	Hansen Creek	Northern State	26	60	15
21	Coal Creek	Hoehn Rd	20	90	40
22	Coal Creek	Hwy 20	26	9	8
23	Wiseman Creek	Minkler Rd	22	17	9
24	Mannser Creek	Lyman Hamilton Hwy	26	19	4
25	Red Cabin Creek	Hamilton Cemetery Rd	20	7	5
28	Brickyard Creek	Hwy 20	14	50	7
29	Skagit River	River Bend Rd	25	13	12
30	Skagit River	Cape Horn Rd	26	4	0
32	Samish River	Thomas Rd	26	41	4
33	Alice Bay Pump Station	Samish Island Rd	26	63	19
34	No Name Slough	Bayview-Edison Rd	26	113	38
35	Joe Leary Slough	D'Arcy Rd	26	100	19
36	Edison Slough at school	W. Bow Hill Rd	26	68	23
37	Edison Pump Station	Farm to Market Rd	26	154	50
38	N. Edison Pump Station	North Edison Rd	25	198	44
39	Colony Creek	Colony Rd	26	55	31
40	Big Indian Slough	Bayview-Edison Rd	26	125	27
41	Maddox/Big Ditch	Milltown Rd	26	85	19
42	Hill Ditch	Cedardale Rd	26	121	31
43	Wiley Slough	Wylie Rd	25	112	20
44	Sullivan Slough	La Conner-Whitney Rd	26	123	35
45	Skagit River – North Fork	Moore Rd	25	9	0
46	Skagit River – South Fork	Fir Island Rd	26	13	0
47	Swinomish Channel	County Boat Launch	25	6	0
48	Fisher Creek	Franklin Rd	26	82	23

[1] Now expired state water quality standards for fecal coliform required 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. Cells shaded green represent sites that pass state standards.

Table 13 – *E. coli* (EC) results (MPN/100ml) for 2021 water year. Cells shaded green pass state standard.

Site Number	Watercourse	Location	n	Geometric mean (MPN)	% > 320
3	Thomas Creek	Old Hwy 99 N	26	39	15
4	Thomas Creek	F&S Grade Rd	26	109	23
6	Friday Creek	Prairie Rd	25	16	0
8	Swede Creek	Grip Rd	26	29	4
11	Samish River	State Route 9	26	12	0
12	Nookachamps Creek	Swan Rd	26	52	4
13	E.F. Nookachamps Creek	State Route 9	26	35	15
14	College Way Creek	College Way	24	113	29
15	Nookachamps Creek	Knapp Rd	25	30	0
16	E.F. Nookachamps Creek	Beaver Lake Rd	26	27	12
17	Nookachamps Creek	Big Lake Outlet	26	16	4
18	Lake Creek	State Route 9	26	33	15
19	Hansen Creek	Hoehn Rd	21	40	5
20	Hansen Creek	Northern State	26	22	4
21	Coal Creek	Hoehn Rd	20	60	20
22	Coal Creek	Hwy 20	26	5	0
23	Wiseman Creek	Minkler Rd	22	10	0
24	Mannser Creek	Lyman Hamilton Hwy	26	12	0
25	Red Cabin Creek	Hamilton Cemetery Rd	20	4	0
28	Brickyard Creek	Hwy 20	14	30	0
29	Skagit River	River Bend Rd	25	9	4
30	Skagit River	Cape Horn Rd	26	4	0
32	Samish River	Thomas Rd	25	27	0
33	Alice Bay Pump Station	Samish Island Rd	26	24	0
34	No Name Slough	Bayview-Edison Rd	26	52	8
35	Joe Leary Slough	D'Arcy Rd	26	43	8
36	Edison Slough at school	W. Bow Hill Rd	26	33	15
37	Edison Pump Station	Farm to Market Rd	26	60	19
38	N. Edison Pump Station	North Edison Rd	25	113	36
39	Colony Creek	Colony Rd	26	36	15
40	Big Indian Slough	Bayview-Edison Rd	26	44	12
41	Maddox/Big Ditch	Milltown Rd	26	56	15
42	Hill Ditch	Cedardale Rd	26	52	15
43	Wiley Slough	Wylie Rd	24	65	4
44	Sullivan Slough	La Conner-Whitney Rd	26	52	8
45	Skagit River – North Fork	Moore Rd	25	7	0
46	Skagit River – South Fork	Fir Island Rd	26	9	0
47	Swinomish Channel	County Boat Launch	25	4	0
48	Fisher Creek	Franklin Rd	26	44	19

Table 14 - Geometric mean FC results for most recent five years (MPN/100ml). Cells shaded green pass state standard.

Site Number	Watercourse	Location	2017	2018	2019	2020	2021
3	Thomas Creek	Old Hwy 99 N	63	47	50	37	64
4	Thomas Creek	F&S Grade Rd	107	138	131	94	169
6	Friday Creek	Prairie Rd	29	39	28	26	29
8	Swede Creek	Grip Rd	40	53	29	54	51
11	Samish River	State Route 9	14	12	11	15	23
12	Nookachamps Creek	Swan Rd	79	56	45	56	77
13	E.F. Nookachamps Creek	State Route 9	41	22	38	42	51
14	College Way Creek	College Way	172	83	113	192	214
15	Nookachamps Creek	Knapp Rd	62	63	64	50	57
16	E.F. Nookachamps Creek	Beaver Lake Rd	28	22	22	19	37
17	Nookachamps Creek	Big Lake Outlet	12	14	17	10	22
18	Lake Creek	State Route 9	24	26	41	39	51
19	Hansen Creek	Hoehn Rd	53	57	62	29	65
20	Hansen Creek	Northern State	50	48	37	45	60
21	Coal Creek	Hoehn Rd	53	65	63	49	90
22	Coal Creek	Hwy 20	18	13	11	7	9
23	Wiseman Creek	Minkler Rd	10	18	10	14	17
24	Mannser Creek	Lyman Hamilton Hwy	15	13	14	12	19
25	Red Cabin Creek	Hamilton Cemetery Rd	12	5	6	10	7
28	Brickyard Creek	Hwy 20	42	45	53	13	50
29	Skagit River	River Bend Rd	9	9	7	9	13
30	Skagit River	Cape Horn Rd	3	5	4	4	4
32	Samish River	Thomas Rd	48	41	58	55	41
33	Alice Bay Pump Station	Samish Island Rd	30	24	33	42	63
34	No Name Slough	Bayview-Edison Rd	65	59	48	88	113
35	Joe Leary Slough	D'Arcy Rd	91	108	93	72	100
36	Edison Slough at school	W. Bow Hill Rd	97	56	49	106	68
37	Edison Pump Station	Farm to Market Rd	317	214	188	291	154
38	North Edison Pump Station	North Edison Rd	148	148	113	127	198
39	Colony Creek	Colony Rd	57	61	58	36	55
40	Big Indian Slough	Bayview-Edison Rd	43	81	47	92	125
41	Maddox Slough/Big Ditch	Milltown Rd	87	52	46	64	85
42	Hill Ditch	Cedardale Rd	42	51	48	111	121
43	Wiley Slough	Wylie Rd	68	82	74	56	112
44	Sullivan Slough	La Conner-Whitney Rd	127	67	45	107	123
45	Skagit River – North Fork	Moore Rd	7	8	4	6	9
46	Skagit River – South Fork	Fir Island Rd	13	13	9	11	13
47	Swinomish Channel	County Boat Launch	6	6	4	7	6
48	Fisher Creek	Franklin Rd	69	78	56	60	82

Figure 8 - Seventeen-year trends in fecal coliform (FC)

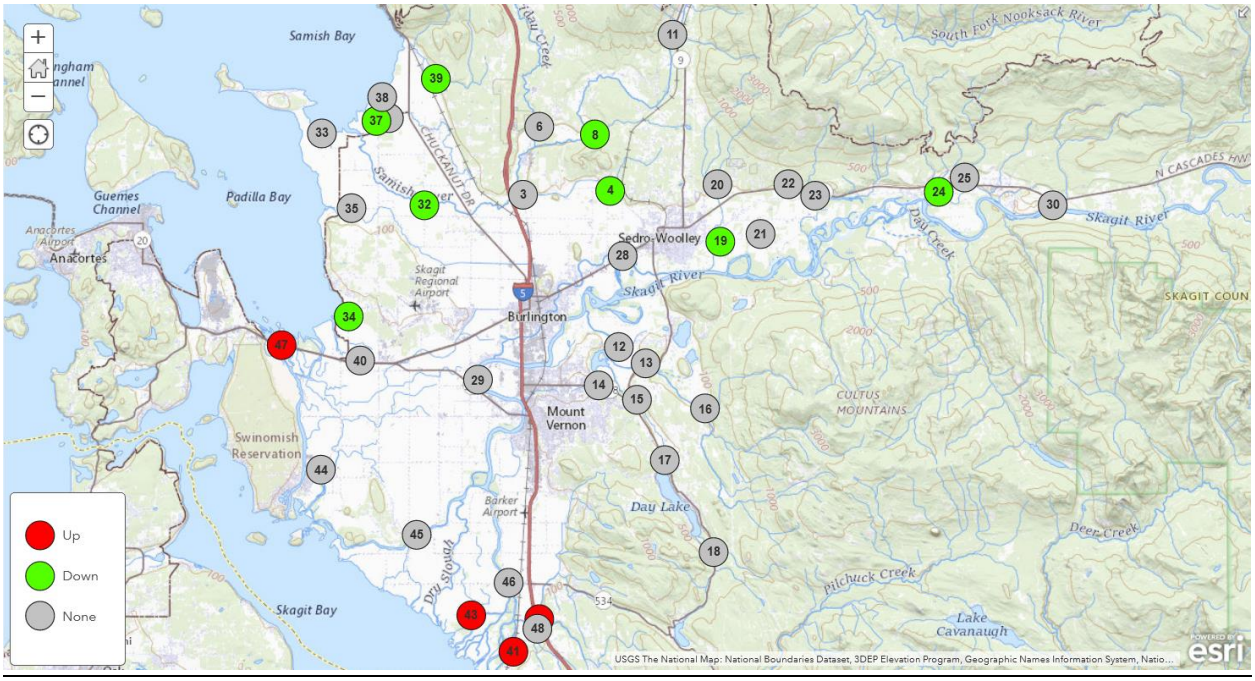


Figure 9 - Ten-year trends in fecal coliform (FC)

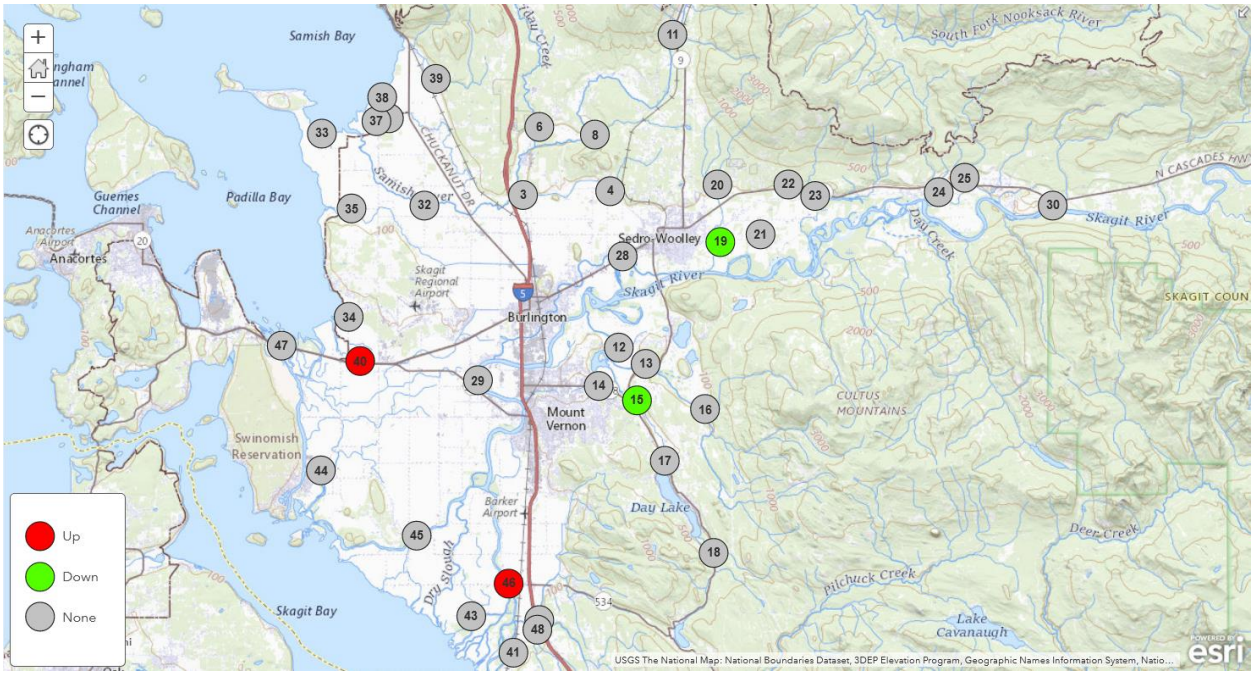
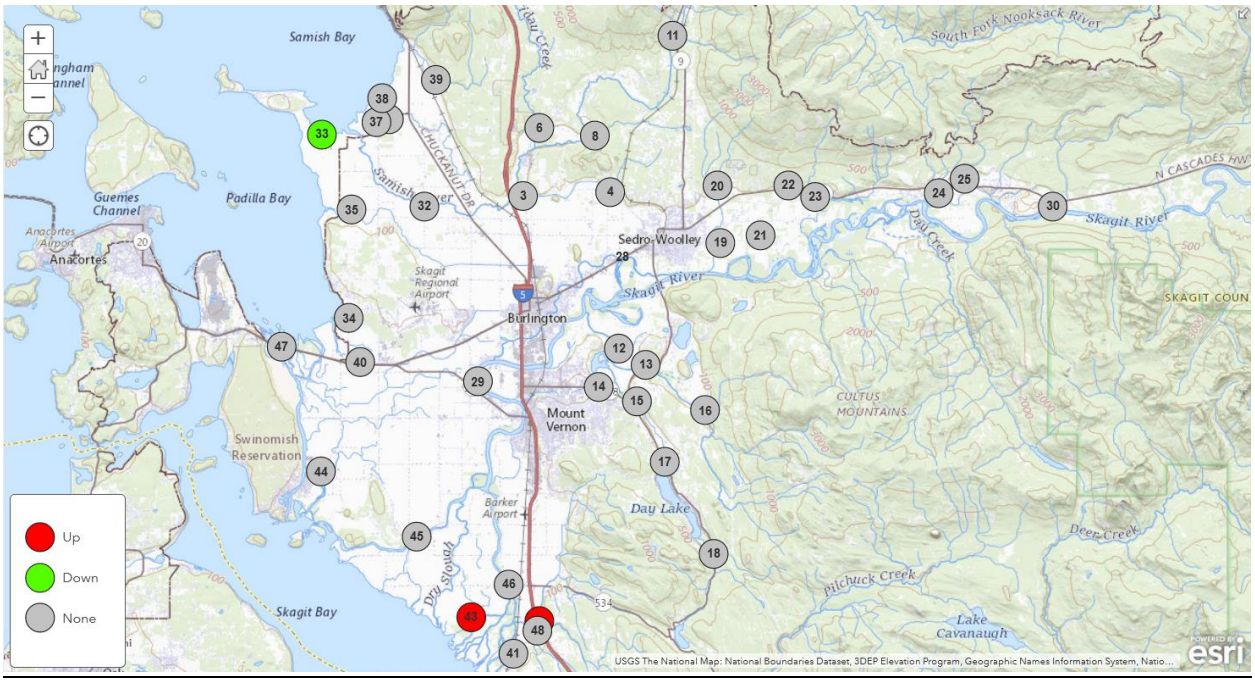


Figure 10 - Five-year trends in fecal coliform (FC)



Nutrients

Nutrient levels in watercourses help determine the potential for algal activity. Excessive nutrient levels can lead to large blooms of algae which can increase DO levels during the day when algae are photosynthesizing. These blooms lead to large decreases in DO at night when the algae are respiring and when the algae die and decompose. Nutrients from freshwater sources discharged into Puget Sound bays can contribute to marine algal blooms as well. Algal blooms can become harmful to recreationists when there are cyanobacteria present, which make ingestion of the water toxic to humans and their pets.

Background

From the beginning of the program in water year 2004 up until the close of water year 2008 nutrients were sampled monthly. After the close of the grant from Ecology, maintaining monthly sampling of all nutrients was deemed too cost-prohibitive for the ongoing project budget. Quarterly sampling began at that time to allow for trend determinations in four- rather than twelve-season.

The subsequent section of this report covering Water Quality Index (WQI) is generated with contribution of this quarterly nutrient data. Therefore, since water year 2008, WQI data has been a four-season metric for this report.

Results

Water samples for measurement of nutrients were taken at each station quarterly. Samples were analyzed by Edge Analytical of Burlington, WA. Quarterly sampling brings with it a large caveat: these trends results are determined by a single sample on one day of an entire three-month period. While imperfect, this is still valuable for identifying and analyzing possible trends. If the conditions of the watercourses sampled were truly randomly assorted based on sampling, with too great of an intermittence (3 months) to have value, then running a trends analysis should show no discernible trend in the data. Any direction of the data would be determined as non-existent or non-significant. The trends analyses returning a large number of significant trends across the county, even with incredibly small slopes (e.g. parts per billion per year) shows that this sampling remains valuable at the three month interval.

Some of these trends are statistically significant even though the actual change in nutrient levels observed in the watercourse is incredibly small. When interpreting data, it is important to take into consideration the actual change over time of that nutrient in the watercourse, as is provided in the tables in **Appendix C**. For example, over the eighteen-year course of this program, a nutrient at a site may have increased by half of a milligram per liter (part per million), or at a different site it may have increased by one microgram per liter (part per billion), or less. Despite this, both analyses could show statistically significant increases in this nutrient on a map.

Table 15 gives mean nutrient values for selected parameters for the 2021 water year. All nutrient values are included in **Appendix A**, with summary statistics found in **Appendix B**, and trends analyses in **Appendix C**.

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, pH, and other factors for each individual ammonia measurement.

The following trends analyses were performed only on the 18-year dataset, representing the entire length of this program's monitoring:

Total Kjeldahl Nitrogen shows a decrease at six sites, and an increase at no sites, with no obvious clustering pattern (**Figure 11**).

Total Phosphorous shows an increase at 11 sites, and a decrease at one site (**Figure 12**). The sites showing increasing phosphorous levels are observed across the valley.

Orthophosphate shows an increase at 15 sites, and a decrease in zero sites (**Figure 13**). This is a very negative trend map and was the worst overall trend among the nutrients measured.

Ammonia levels have gone down at 16 sites around the county with no sites showing an increasing trend. The decreases are observed across the valley (**Figure 14**).

Nitrate + Nitrite levels have decreased at 12 sites spread across the county and have increased at only one site, the Swinomish Channel (**Figure 15**).

Overall, phosphorous (total and ortho) is the only nutrient showing an increase across the valley. Combination of all significant nutrient trends shows a total of 35 positive trends, or decreases, and 27 negative trends, or increases, with 26 of those being phosphorous. Phosphorous is a common "limiting nutrient" for algal blooms in the natural environment, which means that when an excess of phosphorous shows up in the watercourse, it is often the only thing required to trigger an algal bloom.

Table 15 - Mean nutrient values (mg/L) for 2021 water year

Site Number	Watercourse	Location	Total Kjeldahl Nitrogen [1]	Total Phosphorus	Ammonia	Nitrate + Nitrite
3	Thomas Creek	Old Hwy 99 N	0.73	0.11	0.09	0.58
4	Thomas Creek	F&S Grade Rd	0.34	0.06	0.02	1.17
6	Friday Creek	Prairie Rd	0.30	0.05	0.02	0.52
8	Swede Creek	Grip Rd	0.34	0.05	0.02	0.46
11	Samish River	State Route 9	0.25	0.05	0.02	0.31
12	Nookachamps Creek	Swan Rd	0.35	0.05	0.02	0.34
13	E.F. Nookachamps Creek	State Route 9	0.32	0.05	0.02	0.38
14	College Way Creek	College Way	0.36	0.06	0.03	0.43
15	Nookachamps Creek	Knapp Rd	0.55	0.12	0.07	0.32
16	E.F. Nookachamps Creek	Beaver Lake Rd	0.25	0.05	0.01	0.38
17	Nookachamps Creek	Big Lake Outlet	0.28	0.05	0.01	0.27
18	Lake Creek	State Route 9	0.31	0.05	0.01	0.44
19	Hansen Creek	Hoehn Rd	0.30	0.05	0.02	0.47
20	Hansen Creek	Northern State	0.29	0.05	0.01	0.57
21	Coal Creek	Hoehn Rd	0.32	0.06	0.01	0.79
22	Coal Creek	Hwy 20	0.27	0.05	0.01	0.69
23	Wiseman Creek	Minkler Rd	0.38	0.05	0.01	1.05
24	Mannser Creek	Lyman Hamilton Hwy	0.25	0.05	0.01	0.20
25	Red Cabin Creek	Hamilton Cem. Rd	0.25	0.05	0.01	0.56
28	Brickyard Creek	Hwy 20	0.49	0.05	0.03	0.87
29	Skagit River	River Bend Rd	0.25	0.05	0.01	0.10
30	Skagit River	Cape Horn Rd	0.25	0.08	0.01	0.09
32	Samish River	Thomas Rd	0.30	0.06	0.02	0.66
33	Alice Bay Pump Station	Samish Island Rd	2.13	0.66	0.65	3.09
34	No Name Slough	Bayview-Edison Rd	0.97	0.63	0.06	0.20
35	Joe Leary Slough	D'Arcy Rd	1.42	0.43	0.45	1.13
36	Edison Slough at school	W. Bow Hill Rd	0.78	0.26	0.03	2.84
37	Edison Pump Station	Farm to Market Rd	1.96	0.77	0.70	2.77
38	N. Edison Pump Station	North Edison Rd	2.98	1.69	1.04	2.62
39	Colony Creek	Colony Rd	0.43	0.11	0.03	1.20
40	Big Indian Slough	Bayview-Edison Rd	0.77	0.13	0.29	0.52
41	Maddox/Big Ditch	Milltown Rd	1.10	0.23	0.37	0.91
42	Hill Ditch	Cedardale Rd	0.42	0.06	0.04	0.58
43	Wiley Slough	Wylie Rd	1.38	0.15	0.76	0.64
44	Sullivan Slough	La Conner-Whitney	1.16	0.21	0.68	0.64
45	Skagit River – North Fork	Moore Rd	0.25	0.06	0.01	0.10
46	Skagit River – South Fork	Fir Island Rd	0.25	0.05	0.02	0.10
47	Swinomish Channel	County Boat Launch	0.25	0.07	0.05	0.16
48	Fisher Creek	Franklin Rd	0.64	0.19	0.03	0.56

Figure 11 - Eighteen-year trends in Total Kjeldahl Nitrogen (TKN)

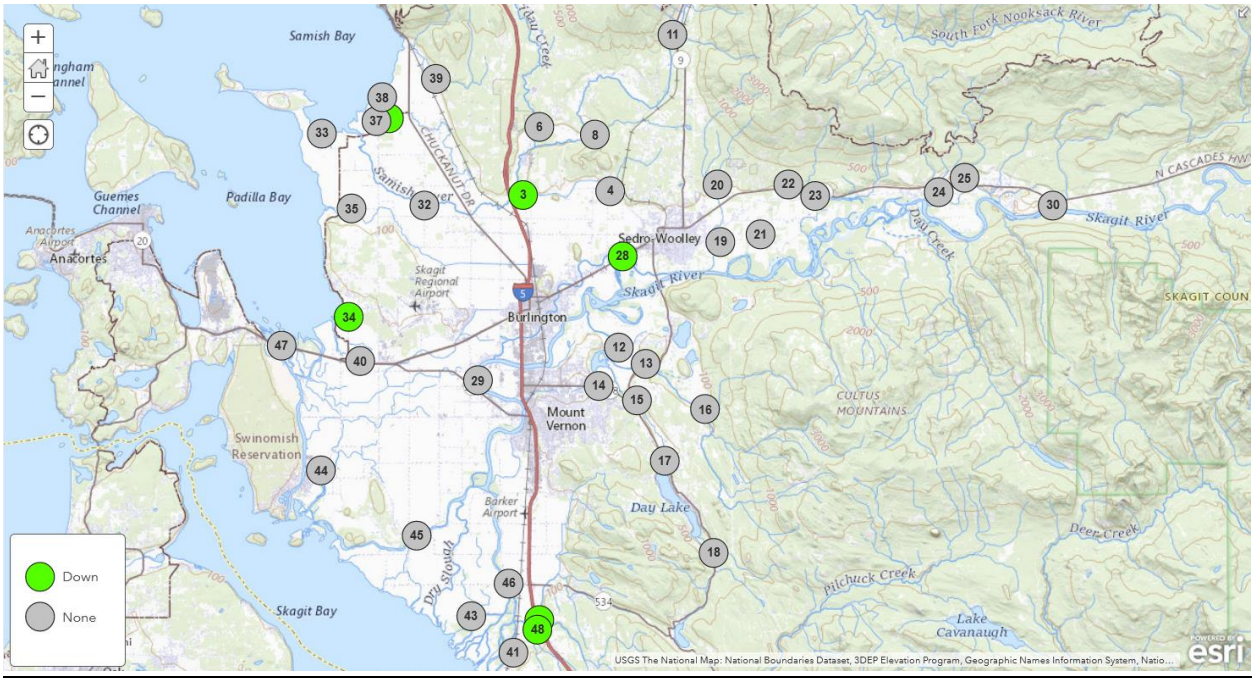


Figure 12 - Eighteen-year trends in Total Phosphorous (TP)

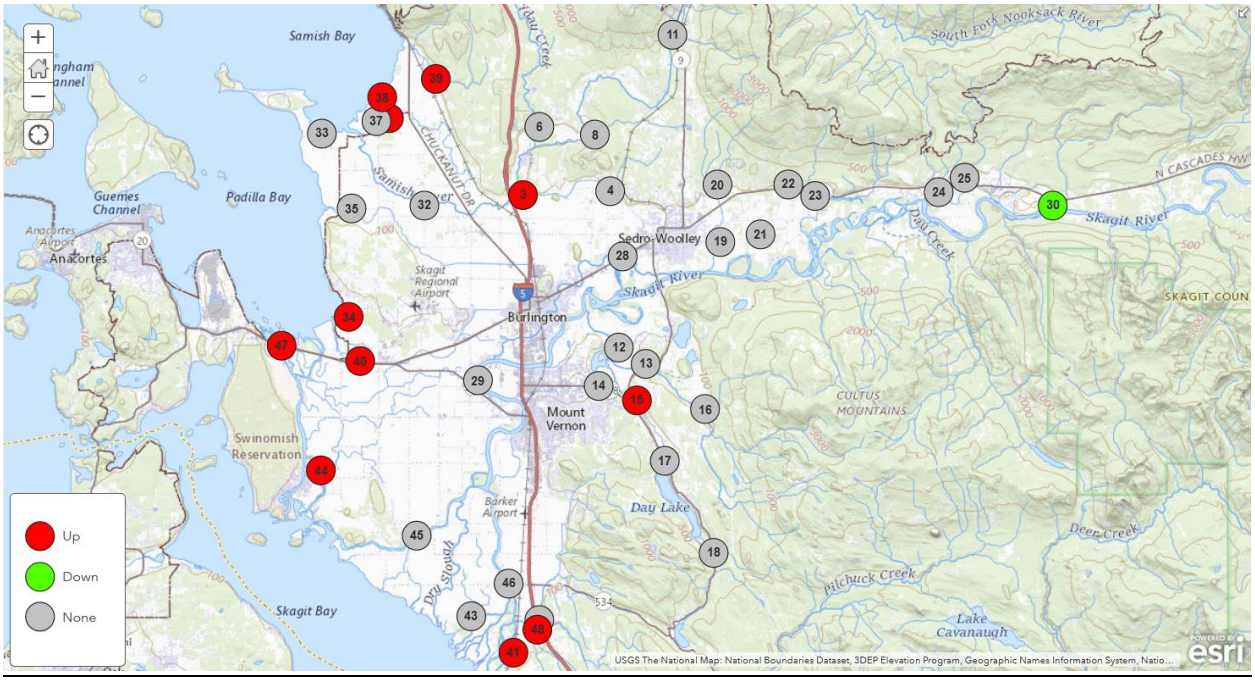


Figure 13 - Eighteen-year trends in Ortho-phosphorous (OP)

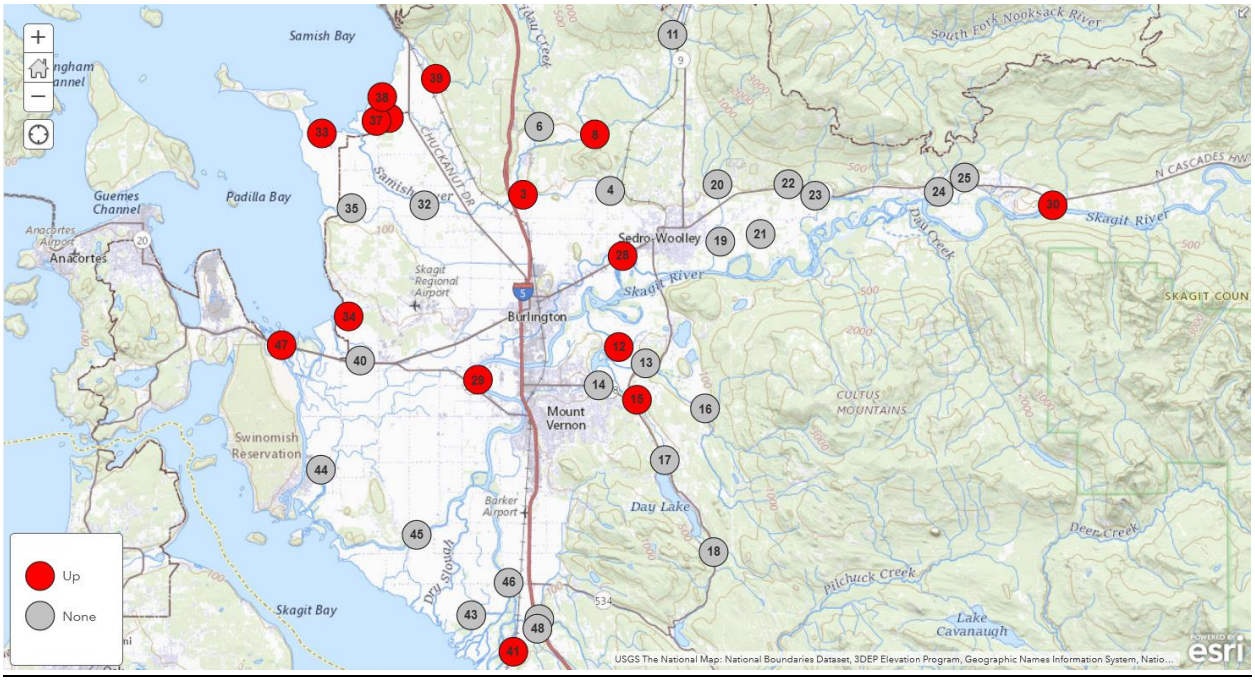


Figure 14 - Eighteen-year trends in Ammonia (NH_3)

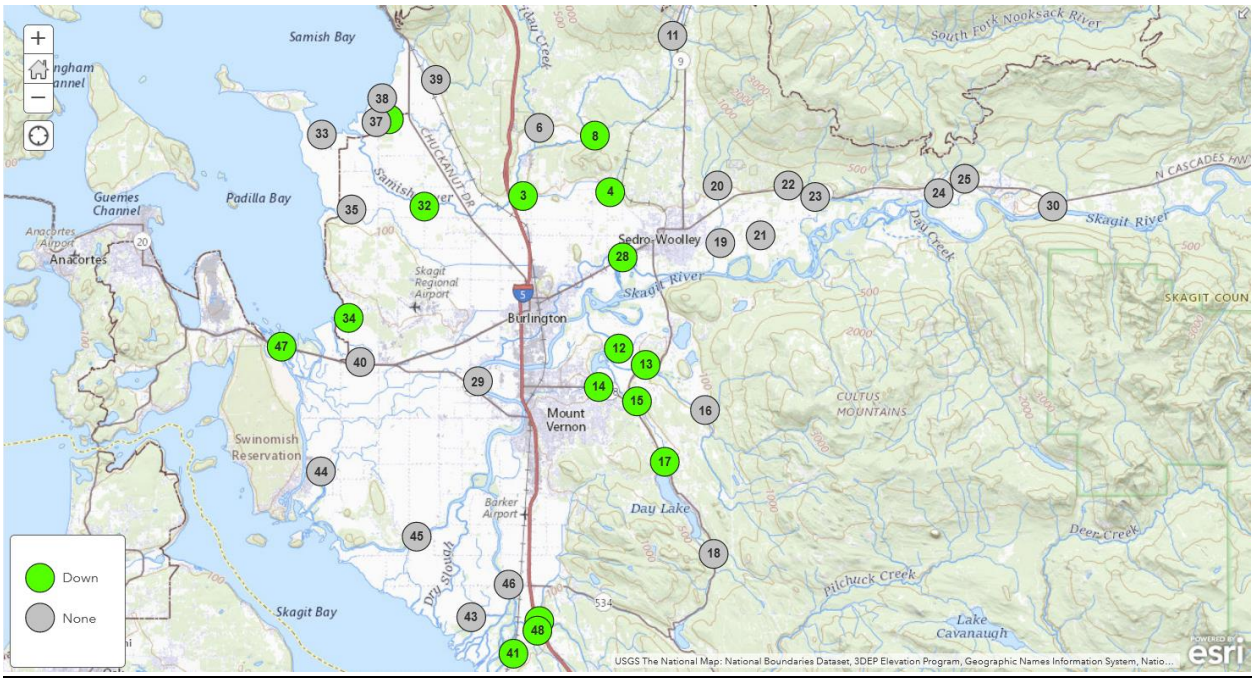
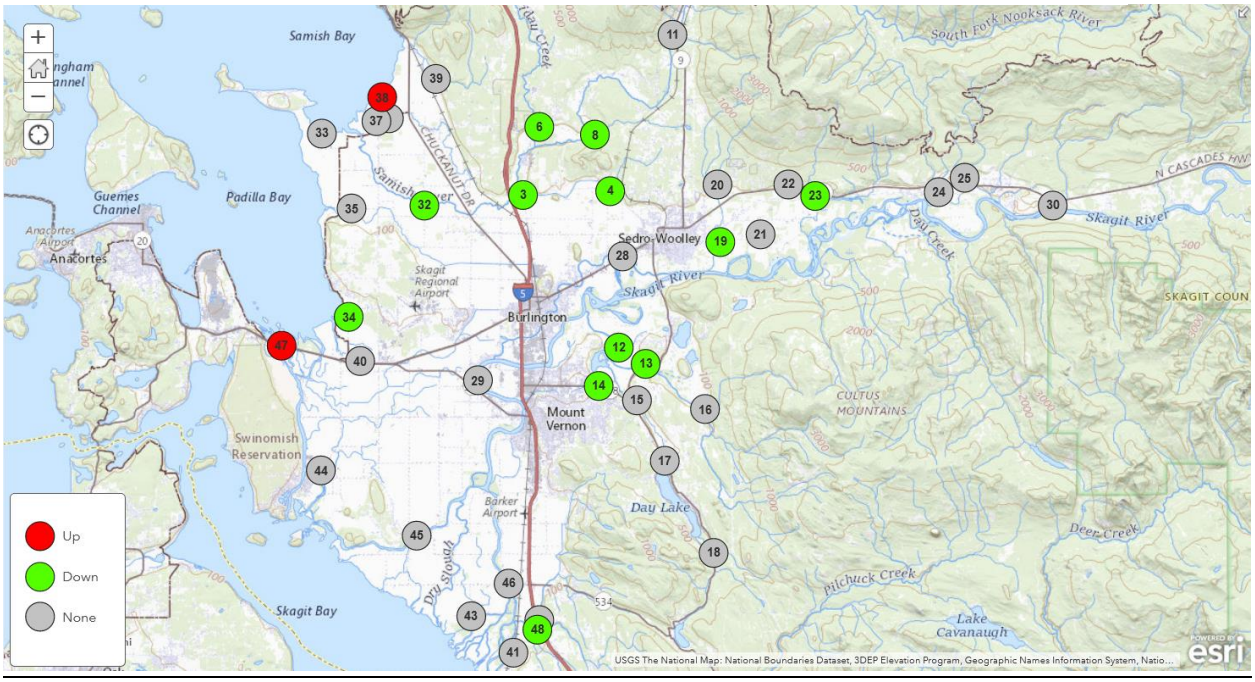


Figure 15 - Eighteen-year trends in Nitrate and Nitrite ($NO_3 + NO_2$)



Other Parameters

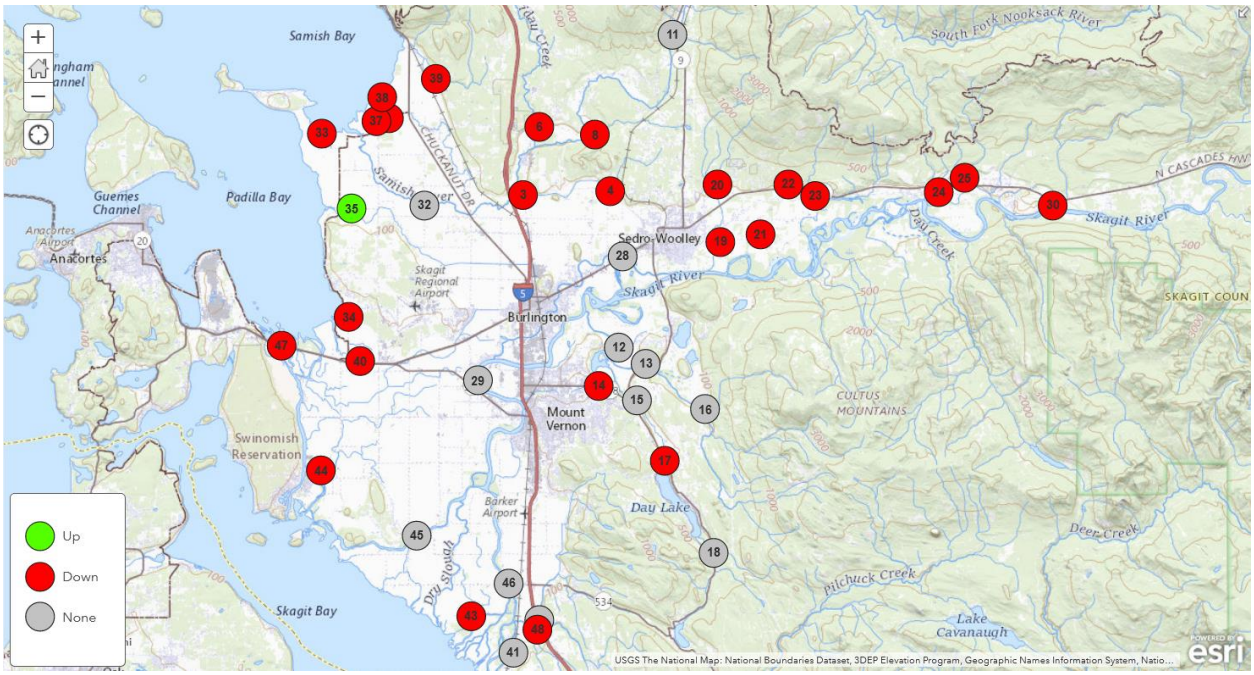
The SCMP also measures pH during each visit to each site. Measurement of pH shows whether a watercourse is within the range that supports aquatic life. In general, pH in the SCMP has been within state standards.

Discharge measurements were made up until 2008 in selected locations and were intended to provide a general indication of the flow regime for that watercourse and as an aid in interpreting other water quality parameters. As Ecology has added several stream gauges in the area, Skagit County has de-emphasized performing manual discharge measurement.

Eighteen-year trends analysis on pH across Skagit County revealed 25 sites with significantly decreasing pH and one site with an increase (**Figure 16**).

All measurements for these parameters are available in **Appendix A** and are summarized in **Appendix B**.

Figure 16 - Eighteen-year trends in pH



Summary Statistics of Significant Trends across Skagit County

To construct a bird's-eye view of what trends are occurring across Skagit County, two summary tables were created. These summary tables were populated from the site-specific tables provided in **Appendix C**. These tables take into account all trends analyses from the 18-year data (18 trends), the ten-year data (six trends), and the five-year data (six trends), combined, for a total of 30 possible significant trends. The results on these tables are biased toward the temperature and FC parameters, as they account for six of the 30 total trends in the group, and biased even further toward DO, as it accounts for eight total categories. Other parameters populate one or two categories each. For this report, positive trends were listed as: Increase in pH, increase in DO, increase in DO% saturation, decrease in temperature, decrease in turbidity, decrease in FC, decrease in nutrients, and decrease in TSS. Negative, or deleterious trends, were considered as the opposite of these statements.

The first table (**Table 16**) arranges all ambient monitoring sites by their percentage of positive significant trends as a ratio of total significant trends. Some sites recorded fewer than ten significant trends, while others recorded over twenty. The first table does not arrange by the number of trends total, but simply by how positively or negatively a particular site is trending overall. The sites in the county that have the highest ratio of positive trends are listed at the top, and the sites exhibiting the highest ratio of negative trends are at the bottom. This table is a quick reference for overall improving or deteriorating water quality for a site.

The second table (**Table 17**) arranges all ambient sampling monitoring sites by their total number of significant trends recorded. Some sites recorded fewer than ten significant trends, while others recorded over twenty. The second table does not arrange by the ratio of positive or negative trends recorded, but simply by the amount of significant change that is occurring at that site. This table is a quick reference for identifying which sites around the county are experiencing the most significant statistical change in water quality, and which sites are not. Sites located at the top of the table are those that have had their water quality parameters change the most.

Table 13 - Summary Statistics of Significant Trends, by Positive/Negative

Site		Significant Trends				Category
		Total	Positive	Negative	% Positive	
Samish River	32	13	13	0	100	Ag - Down
Samish River	11	10	10	0	100	Ag - Up
Skagit River	45	9	8	1	89	Skagit - Low
Joe Leary Slough	35	14	12	2	86	Ag - Down
Thomas Creek	4	13	11	2	85	Ag - Up
Nookachamps Creek	12	6	5	1	83	Ag - Down
Coal Creek	21	11	9	2	82	Ag - Down
Skagit River	46	10	8	2	80	Skagit - Low
Hansen Creek	20	9	7	2	78	Ag - Up
College Way Creek	14	11	8	3	73	Ref - Urban
Skagit River	29	7	5	2	71	Skagit - Mid
Friday Creek	6	10	7	3	70	Ref - RR
Wiseman Creek	23	6	4	2	67	Ag - Up
Coal Creek	22	6	4	2	67	Ag - Up
Brickyard Creek	28	3	2	1	67	Ref - Urban
Fisher Creek	48	14	9	5	64	Ag - Down
No Name Slough	34	19	12	7	63	Ag - Down
EF Nookachamps	16	8	5	3	63	Ag - Mid
Nookachamps Creek	15	10	6	4	60	Ag - Mid
Lake Creek	18	5	3	2	60	Ag - Up
Swede Creek	8	12	7	5	58	Ag - Down
Mannser Creek	24	14	8	6	57	Ag - Mid
Skagit River	30	14	8	6	57	Skagit - Up
Colony Creek	39	8	4	4	50	Ag - Down
Alice Bay Pump	33	9	4	5	44	Ag - Down
Maddox/Big Ditch	41	13	5	8	38	Ag - Down
Hill Ditch/Carpenter	42	16	6	10	38	Ag - Down
Hansen Creek	19	16	6	10	38	Ag - Down
Red Cabin Creek	25	8	3	5	38	Ref - RR
Thomas Creek	3	11	4	7	36	Ag- Down
Edison Slough	36	7	2	5	29	Ag - Down
EF Nookachamps	13	11	3	8	27	Ag - Down
Nookachamps Creek	17	8	2	6	25	Ag - Up
S. Edison Pump	37	8	2	6	25	Ag - Down
N. Edison Pump	38	12	2	10	17	Ag - Down
Swinomish Channel	47	12	2	10	17	Ref - Marine
Big Indian Slough	40	7	1	6	14	Ag - Mid
Sullivan Slough	44	9	0	9	0	Ag - Down
Wiley Slough	43	10	0	10	0	Ag - Down

4

Table 147 - Summary Statistics of Significant Trends, by Total Count

Site		Significant Trends				Category
		Total	Positive	Negative	% Positive	
No Name Slough	34	19	12	7	63	Ag - Down
Hansen Creek	19	16	6	10	38	Ag - Down
Hill Ditch/Carpenter	42	16	6	10	38	Ag - Down
Joe Leary Slough	35	14	12	2	86	Ag - Down
Fisher Creek	48	14	9	5	64	Ag - Down
Mannser Creek	24	14	8	6	57	Ag - Mid
Skagit River	30	14	8	6	57	Skagit - Up
Samish River	32	13	13	0	100	Ag - Down
Thomas Creek	4	13	11	2	85	Ag - Up
Maddox/Big Ditch	41	13	5	8	38	Ag - Down
Swede Creek	8	12	7	5	58	Ag - Down
Swinomish Channel	47	12	2	10	17	Ref - Marine
N. Edison Pump	38	12	2	10	17	Ag - Down
Coal Creek	21	11	9	2	82	Ag - Down
College Way Creek	14	11	8	3	73	Ref - Urban
Thomas Creek	3	11	4	7	36	Ag- Down
EF Nookachamps	13	11	3	8	27	Ag - Down
Samish River	11	10	10	0	100	Ag - Up
Skagit River	46	10	8	2	80	Skagit - Low
Friday Creek	6	10	7	3	70	Ref - RR
Nookachamps Creek	15	10	6	4	60	Ag - Mid
Wiley Slough	43	10	0	10	0	Ag - Down
Skagit River	45	9	8	1	89	Skagit - Low
Hansen Creek	20	9	7	2	78	Ag - Up
Alice Bay Pump	33	9	4	5	44	Ag - Down
Sullivan Slough	44	9	0	9	0	Ag - Down
EF Nookachamps	16	8	5	3	63	Ag - Mid
Colony Creek	39	8	4	4	50	Ag - Down
Red Cabin Creek	25	8	3	5	38	Ref - RR
S. Edison Pump	37	8	2	6	25	Ag - Down
Nookachamps Creek	17	8	2	6	25	Ag - Up
Skagit River	29	7	5	2	71	Skagit - Mid
Edison Slough	36	7	2	5	29	Ag - Down
Big Indian Slough	40	7	1	6	14	Ag - Mid
Nookachamps Creek	12	6	5	1	83	Ag - Down
Coal Creek	22	6	4	2	67	Ag - Up
Wiseman Creek	23	6	4	2	67	Ag - Up
Lake Creek	18	5	3	2	60	Ag - Up
Brickyard Creek	28	3	2	1	67	Ref - Urban

Water Quality Index (WQI)

The Water Quality Index is a tool developed by 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 be summarized to give a site an overall score for a water year. The parameters included in the WQI are DO, temperature, pH, turbidity, suspended solids, FC, 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 40-79 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 SCMP during the 2021 water year are summarized in **Table 18 and** are mapped geographically in **Figure 17**. WQI scores over the length of this program are categorized for the years 2009-2021 in **Table 19**. 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.

Over the course of the SCMP, the number of sites in the Lavender (Lowest Concern) category has increased somewhat since 2012, while the number of sites in the Red (Highest Concern) category has held steady. Streams and ditches in the Red category can have either one water quality parameter that is well below standards or several categories that are below standards.

Water quality during storm events remains problematic as the results from storm event monitoring in the Samish Basin associated with the CSI continue to show excessive fecal coliform concentrations.

Table 15 - Water Quality Index (WQI) results for the 2021 Water Year

Site Number	Watercourse	Location	Overall Score*
3	Thomas Creek	Old Hwy 99 N	44
4	Thomas Creek	F&S Grade Rd	75
6	Friday Creek	Prairie Rd	89
8	Swede Creek	Grip Rd	82
11	Samish River	State Route 9	86
12	Nookachamps Creek	Swan Rd	70
13	E.F. Nookachamps Creek	State Route 9	73
14	College Way Creek	College Way	62
15	Nookachamps Creek	Knapp Rd	49
16	E.F. Nookachamps Creek	Beaver Lake Rd	89
17	Nookachamps Creek	Big Lake Outlet	74
18	Lake Creek	State Route 9	87
19	Hansen Creek	Hoehn Rd	86
20	Hansen Creek	Northern State	90
21	Coal Creek	Hoehn Rd	84
22	Coal Creek	Hwy 20	96
23	Wiseman Creek	Minkler Rd	93
24	Mannser Creek	Lyman Hamilton Hwy	69
25	Red Cabin Creek	Hamilton Cem. Rd.	97
28	Brickyard Creek	Hwy 20	75
29	Skagit River	River Bend Rd	83
30	Skagit River	Cape Horn Rd	86
32	Samish River	Thomas Rd	86
33	Alice Bay Pump Station	Samish Island Rd	34
34	No Name Slough	Bayview-Edison Rd	37
35	Joe Leary Slough	D'Arcy Rd	18
36	Edison Slough	W. Bow Hill Rd	50
37	Edison Pump Station	Farm to Market Rd	23
38	N. Edison Pump Station	North Edison Rd	1
39	Colony Creek	Colony Rd	79
40	Big Indian Slough	Bayview-Edison Rd	44
41	Maddox Slough/Big Ditch	Milltown Rd	27
42	Hill Ditch	Cedardale Rd	57
43	Wiley Slough	Wylie Rd	10
44	Sullivan Slough	La Conner-Whitney	18
45	Skagit River – North Fork	Moore Rd	86
46	Skagit River – South Fork	Fir Island Rd	87
47	Swinomish Channel	County Boat Launch	63
48	Fisher Creek	Franklin Rd	87

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

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

Figure 17 - Color coded map of 2021 WQI results

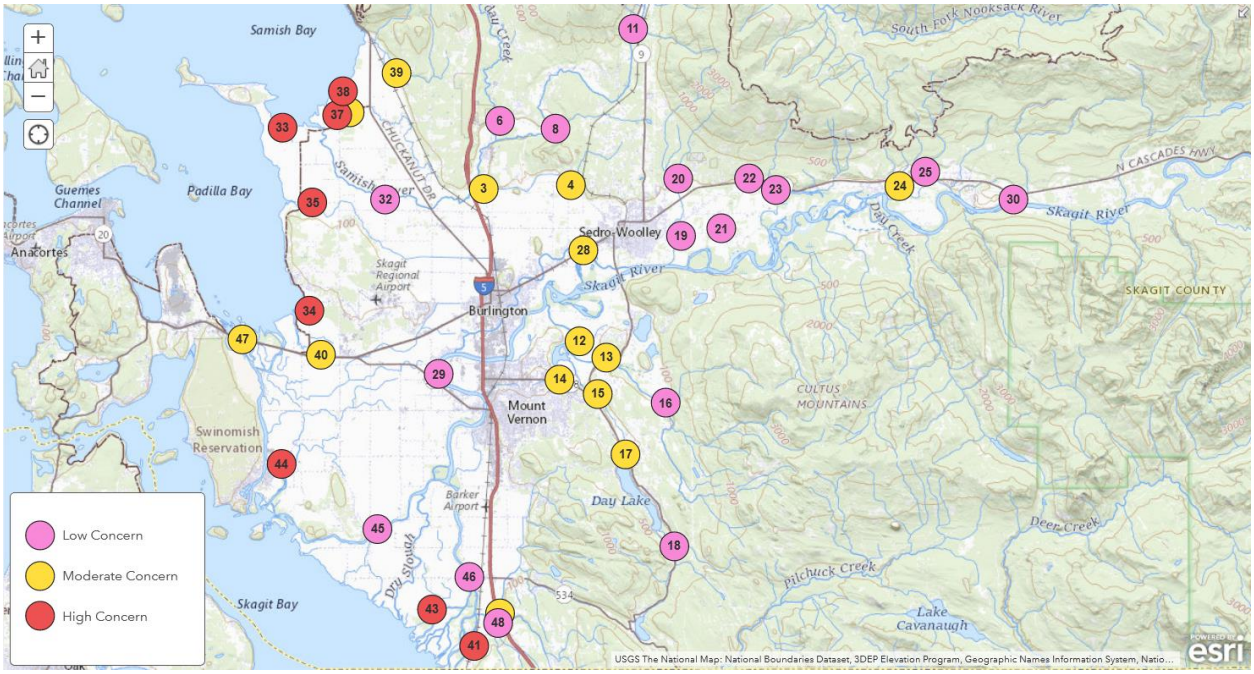


Table 16 - Number of sites in each WQI category

Year	Lavender (80-100)	Light yellow (40-79)	Red (1-40)
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
2017	20	8	12
2018*	23	6	10
2019*	15	12	12
2020*	15	14	10
2021*	17	14	8

*39 sites sampled from 2018 forward

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