A Department of Ecology Report

WASHINGTON STATE DEPARTMENT OF ECOLOGY

Water Quality Assessment of the Nooksack River between Brennan and North Cedarville

Abstract

Among the 62 long-term stations monitored by the Washington State Department of Ecology (Ecology) Freshwater Monitoring Unit are 16 sets of upstream and downstream stations that delineate stream reaches. Stations at the Nooksack River at Brennan and at North Cedarville comprise one of these sets. This report is the first in a series that presents results of an analysis of water quality monitoring data from these 16 stream reaches.

The lower Nooksack River is a success story for water quality management. Fecal coliform bacteria (FC), the biggest contributor to poor water quality in the lower Nooksack River among the constituents we monitor, have declined dramatically during the past 20 years. There were indications that major sediment contributions to the lower river have also declined. However, nitrogen concentrations were much higher at the lower station than at the upper, and concentrations may be increasing. Sediment additions from smaller sources in the reach may also be increasing.

The successful reductions in FC concentrations are particularly commendable given the increases in human and dairy cow populations in the reach since 1980. Vigilance will be necessary to ensure concentrations stay low and eutrophication does not increase in the face of continuing population pressures.

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Introduction

The Nooksack River at Brennan and at N. Cedarville are two of Ecology's Freshwater Monitoring Unit's (FMU) 62 long-term water quality monitoring stations. The purpose of this document is to report an analysis of the water quality data collected by the FMU at those stations. The focus of the analysis is on water quality conditions at the lower station (Brennan), the changes that occurred between stations, and temporal trends. Other data collection efforts in the basin, for example, monitoring by the Northwest Indian College (Hood, 2002), is not evaluated here.

The objective of this analysis is to identify stream reaches exhibiting water quality degradation between upstream and downstream stations or declining trends within the reach. The Nooksack is one of 16 stream reaches where the Ecology FMU has sufficient data (defined as at least five common years of data collection from October 1978 through September 2001) for a paired-station analysis (Appendix A).

Methods and Dataset Description

Water samples were collected monthly. From water year (WY; October through September) 1978 through WY 1989, samples were generally collected at the lower station about a day before the upper (and never more than 24 hours apart). Since 1989, sample collection times at the two stations have been separated by less than three hours, with the lower station always sampled first. From July through September 2001, temperature data were collected at 30-minute intervals. For a description of sampling methods, see Hallock (2001).

Water quality for the Nooksack River at Brennan and at N. Cedarville was assessed by a general review of the data, by comparing results to water quality standards (Table 1), and by a review of the Water Quality Index (WQI) results (the WQI converts results to a scale of 1 to 100 and aggregates to a single score; Hallock, in draft). I assessed changes in water quality between upstream and downstream stations by evaluating the average change in constituents between stations. I considered statistically adjusting time sensitive constituents such as temperature, pH, and dissolved oxygen to a common time (noon) if the constituent contributed to degradation or poor water quality, and if there was a statistically significant relationship between the constituent and the time of sample collection.

Table 1. Water quality criteria used to evaluate monitoring results. (Results outside the ranges indicated are considered to exceed the criterion.)

			--------Fecal Coliform---------		
Class	Temperature	Oxygen	pH	10 Percent	Geometric mean
A	<=18°C	>8.0 mg/L	6.5<=pH<=8.5	<=200	<=100

I conducted trend analyses on those constituents that contributed to poor water quality at the downstream station as well as those constituents that changed dramatically between stations. Trends reported on the *differences* between paired results are based on downstream minus upstream concentrations. There are two advantages to using this technique. First, trends (and seasonality) common to both stations are eliminated; therefore, the source of potential trends is isolated to impacts within the stream reach rather than the entire watershed. Second, the procedure reduces unexplained sources of variability common to both stations, such as laboratory bias and (to a lesser extent) changes in precision, common trends in weather and discharge, etc. Trends were evaluated using the Seasonal Kendall test when seasonality was present and the Mann-Kendall test when seasonality was absent. Adjustments were made for serial correlation when present. For all constituents (except oxygen, trends in which are not evaluated in this report), an increasing trend in the differences between upstream results and downstream results indicates degrading water quality within the evaluated stream reach while a decreasing trend indicates an improvement. Statistical significance was assumed at the 95 percent confidence level.

Some constituents were adjusted for changes in discharge by a regression of the constituent (dependent variable) and discharge (independent variable) and a second trend conducted on the residual data. For the paired results dataset, differences were calculated after the flow adjustment. Statistical analyses were performed using WQHYDRO software (Aroner, 2002).

Results and Discussion

Reach Description

The Nooksack River at Brennan station is located at river mile 3.4, one mile west of Brennan on state highway 540. The North Cedarville station is 27.4 miles further upstream at the Mount Baker Highway (542) bridge, river mile 30.8. The downstream station is 10 feet above mean sea level and the upper station is at 140 feet. The average gradient is a relatively low 0.09 percent (Figure 1).

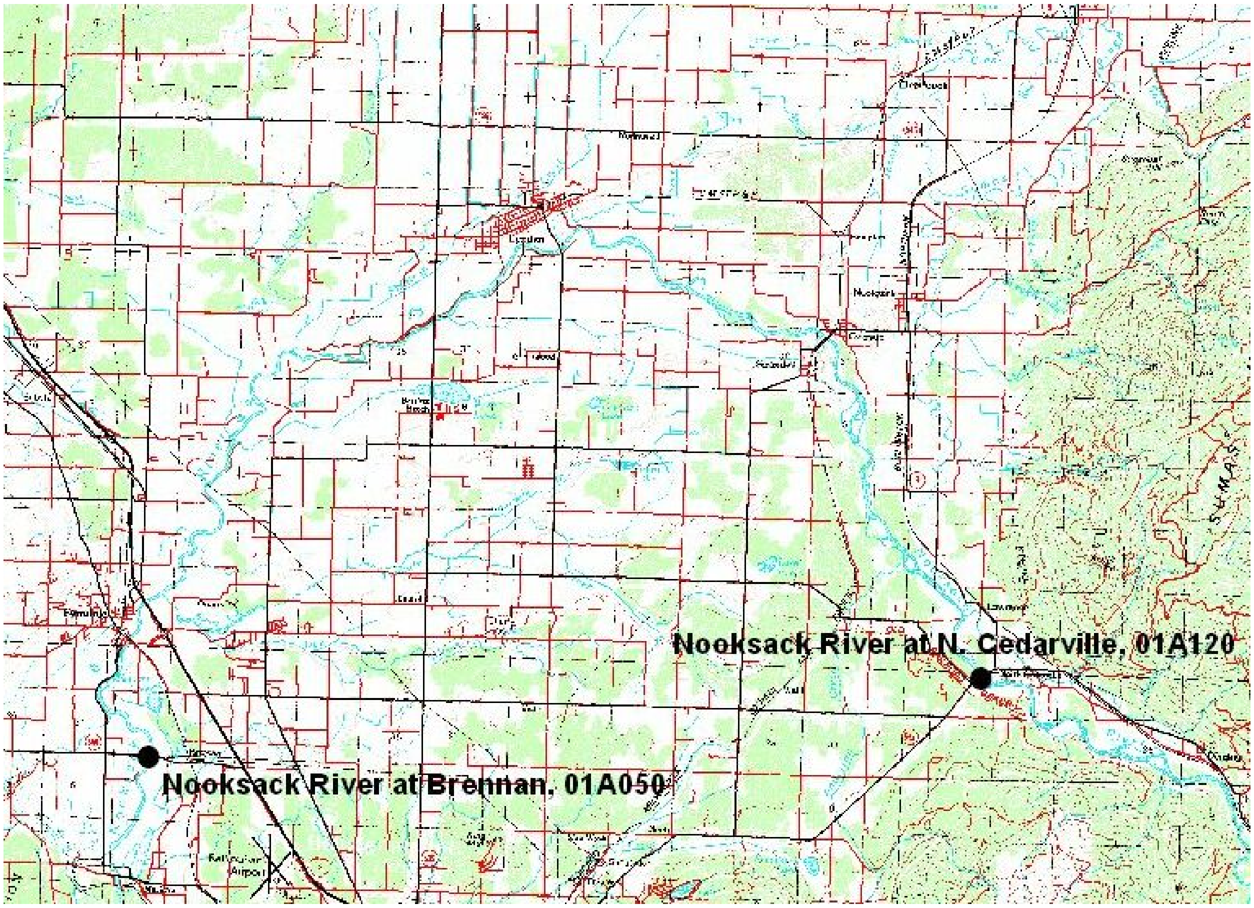

Figure 1. Map of the Nooksack River showing ambient monitoring stations at Brennan and at N. Cedarville.

The Nooksack River discharges to Bellingham Bay. The watershed between the two stations contains 194 square miles (23 percent of the entire 826 square mile basin), and includes the towns of Ferndale, Everson, and Lynden, as well as several smaller communities. Several creeks and lakes drain to the reach, including Fishtrap, Tenmile, and Bertrand creeks, and Wiser Lake.

The watershed between the two stations is mostly classified as agricultural or rural (Whatcom County, 1997). Land uses include dairy, poultry, and non-commercial farms with some forestry in the upper watershed. The few point sources in the reach include wastewater treatment facilities and Darigold's diary processing facility at Lynden. The populations of Lynden, Ferndale, and Everson more than doubled from 1980 to 2000, while milk cow numbers in the county have increase more slowly (Table 2). Whatcom County ranks first in the state in the number of milk cows (http://www.nass.usda.gov/wa/counties/cnty073.htm).

Table 2. Human and dairy cow population statistics (http://www.ofm.wa.gov, "2001 Agricultural Statistics" compiled by Washington Agricultural Statistics Service, and Joy, pers. comm.).

	Census Year		
Region	1980	1990	2000
Human population			
Lynden	4028	5709	9020
Ferndale	3855	5398	8759
Everson	898	1490	2035
Dairy Cow population			
Whatcom county	52,046	56,769	63,800

The main stem Nooksack River is listed on Ecology's 1998 303d list for fecal coliform bacteria (FC) and fine sediment (http://www.ecy.wa.gov/programs/wq/303d/1998/wrias/wria1.pdf). Joy (2000) conducted a Total Maximum Daily Load (TMDL) evaluation for bacteria in the lower Nooksack (see http://www.ecy.wa.gov/pubs/0003006.pdf) which removed the FC listing. Joy's work included an evaluation of bacteria contributions from tributaries in 1997 and 1998 and recommended load allocations and waste load allocations.

Water Quality Assessment

Time of Sample Collection

Of the three potentially time-sensitive constituents—temperature, pH, and oxygen—only pH exhibited a statistically significant ($p<0.05$) relationship with the time of sample collection at the lower station (Brennan), either for the full data set or for the summer months (June through September). This was in spite of the fact that the time of sampling changed from mid-morning to mid-afternoon in about 1985. At the upper station (N. Cedarville), only temperature was statistically related to time of sampling. In no case did time explain much of the variability in temperature, pH, or oxygen ($r^2<0.1$; see Figure 2), even when the relationship was statistically significant. De-seasonalizing the temperature data did not improve the relationship with time very much. Because none of these constituents are critical in the Nooksack, I elected not to adjust the data for time of collection before conducting additional analyses except for pH at Brennan. (The lack of a relationship does not mean there are no diurnal changes in these constituents, of course. This analysis is based on monthly samples, not on continuous monitoring.)

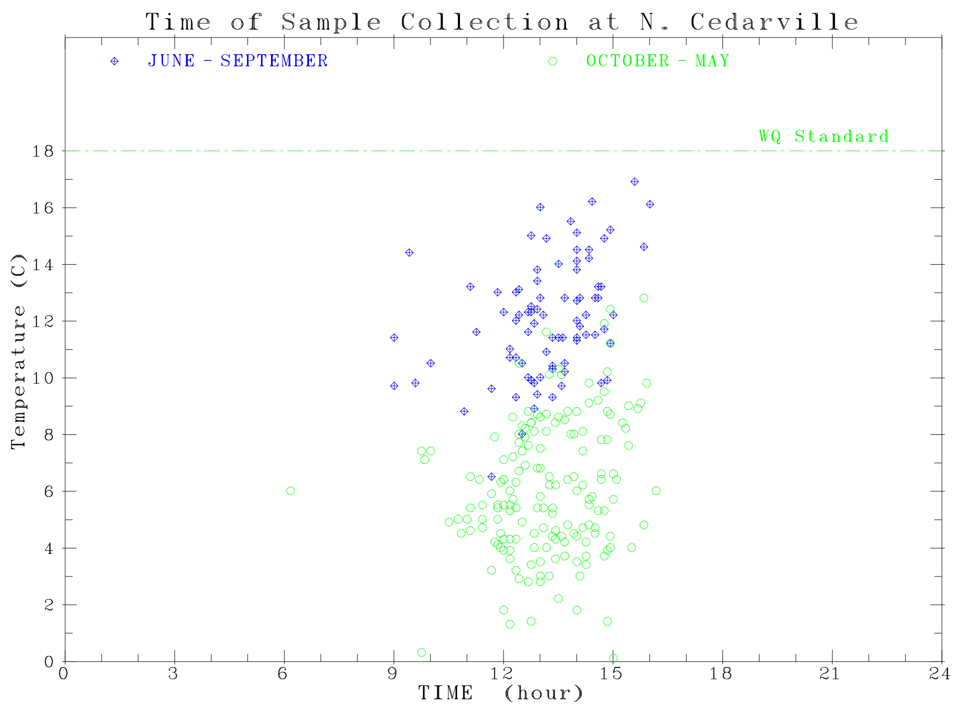

Figure 2. Temperature as a function of time of sample collection at Nooksack River at N. Cedarville.

General Overview and Upstream/Downstream Comparisons

We have collected more than 500 monthly samples from the Nooksack River at Brennan and at N. Cedarville since October 1978. Temperature and pH seldom exceeded the water quality "class A" criteria and oxygen not at all. The maximum seven day average of daily maximums from 30-minute interval temperature monitoring in 2001 was 17.4 °C at Brennan and 17.6 at N. Cedarville with no measurements exceeding the water quality criterion of 18 °C. Fecal coliform bacteria, however, exceeded the class A ten percent criterion 55 times. All but 4 of the high counts occurred at the Brennan station (Table 3). (The TMDL set station-specific targets for FC at Brennan and at N. Cedarville but the standard class A criterion is used in this evaluation.)

WQI scores were low (indicating poor water quality) for total phosphorus, suspended solids, and turbidity at both stations (Table 3). Sediment and turbidity scores were probably low, at least in part, because the Nooksack is fed by glacial runoff. Low phosphorus scores indicate concentrations were high relative to other Cascade Mountain streams; actual concentrations were not particularly high (Appendix B). In any case, scores were equally low at both stations indicating significant degradation was not occurring in the reach between the two stations. The average downstream concentration for these constituents is very nearly the same as the average upstream concentration (Table 4 and Appendix B).

FC and total nitrogen (TN), however, both had much lower WQI scores at the downstream station than at the upstream station (Table 3). The percent increase in concentration at the downstream station compared to the upstream station was more than 100 percent for all nitrogen forms, and more than 1000 percent for FC (Table 4). The higher concentrations of FC and TN at Brennan are evident in cumulative frequency distribution plots (Figures 3 and 4, respectively).

Table 3. Water quality summary for Nooksack River at Brennan and at North Cedarville data collected from October 1978 through September 2001. Water Quality Index (WQI) scores are for WY 2001. Constituents where more than ten percent of samples exceeded water quality criteria or with WQI scores less than 80 are shown in bold.

Constituent	Station	Number of Samples	Number Exceeding Criteria	Percent Exceeding Criteria	Draft WQI Score	Notes
Fecal Col. Bacteria	Brennan	263	51[a]	**19**	**78**	The maximum count was 2100J colonies/100mL
	Cedarville	247	4	2	88	
Oxygen	Brennan	269	0	0	99	
	Cedarville	250	0	0	100	
pH	Brennan	260	0	0	98	
	Cedarville	242	2	1	94	
Phosphorus, Total	Brennan	259	NA	NA	**75**	
	Cedarville	242	NA	NA	**71**	
Suspended Solids	Brennan	264	NA	NA	**75 (43)** [b]	
	Cedarville	245	NA	NA	**75 (43)** [b]	
Temperature	Brennan	271	1	0	91	
	Cedarville	251	0	0	97	
Nitrogen, Total	Brennan	94	NA	NA	**62**	Data collection of TN began in WY 1994.
	Cedarville	84	NA	NA	93	
Turbidity [b]	Brennan	264	NA	NA	**75 (46)** [b]	
	Cedarville	245	NA	NA	**75 (54)** [b]	

[a] Fecal coliform bacteria are compared to the class A "ten percent" criterion of 200 colonies/100mL.

[b] Suspended solids and turbidity WQI scores are limited to 75 in streams influenced by glaciers. The score with that limitation removed is shown in parentheses.

Table 4. Average percent increase at the downstream station over upstream station ([downstream-upstream]/upstream*100) for various water quality constituents. Percentages greater than 0 indicate an increase in the constituent at the downstream station. Those constituents exhibiting large changes (in bold) were evaluated for trends.

Constituent	Number of Pairs	Percent Change	Constituent	Number of Pairs	Percent Change
Ammonia	237	**104**	Phosphorus, Sol. Reac.	237	47
Conductivity	246	21	Phosphorus, Total	234	58
Fecal Col. Bacteria	239	**1686**	Suspended Solids	239	49
Flow	230	21	Temperature	246	8.3
Nitrate-Nitrite	158	**124**	Nitrogen, Total	82	**127**
Oxygen	244	-4.8	Turbidity	238	38
PH	237	-0.2			

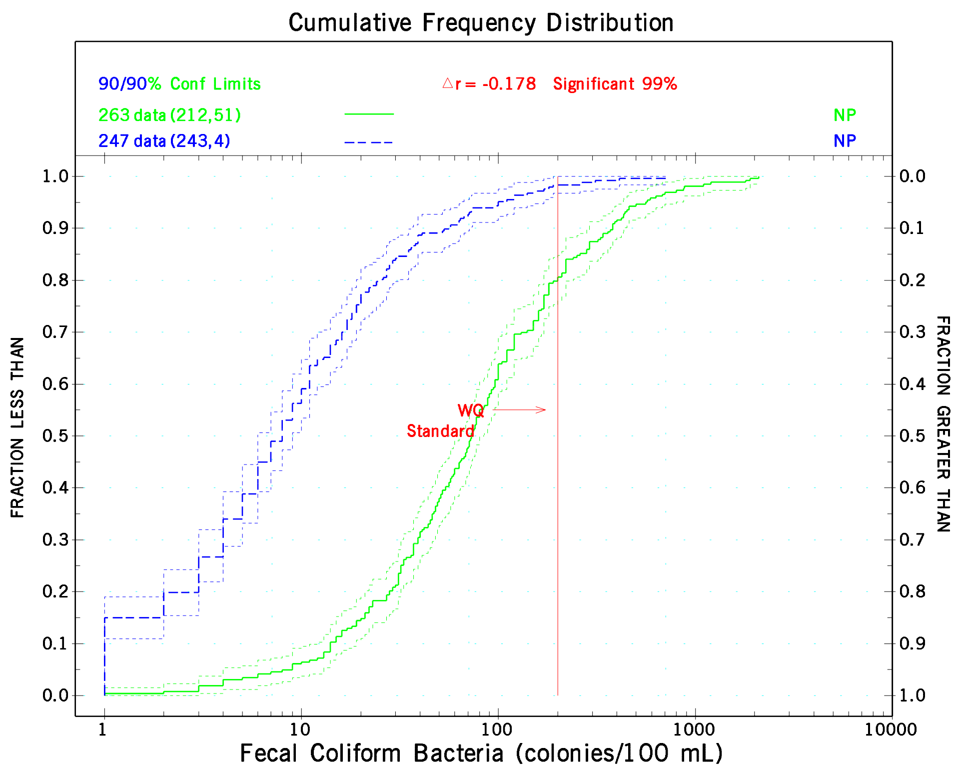

Figure 3. Cumulative frequency distribution for FC in the Nooksack River at Brennan (——) and N. Cedarville (- - -).

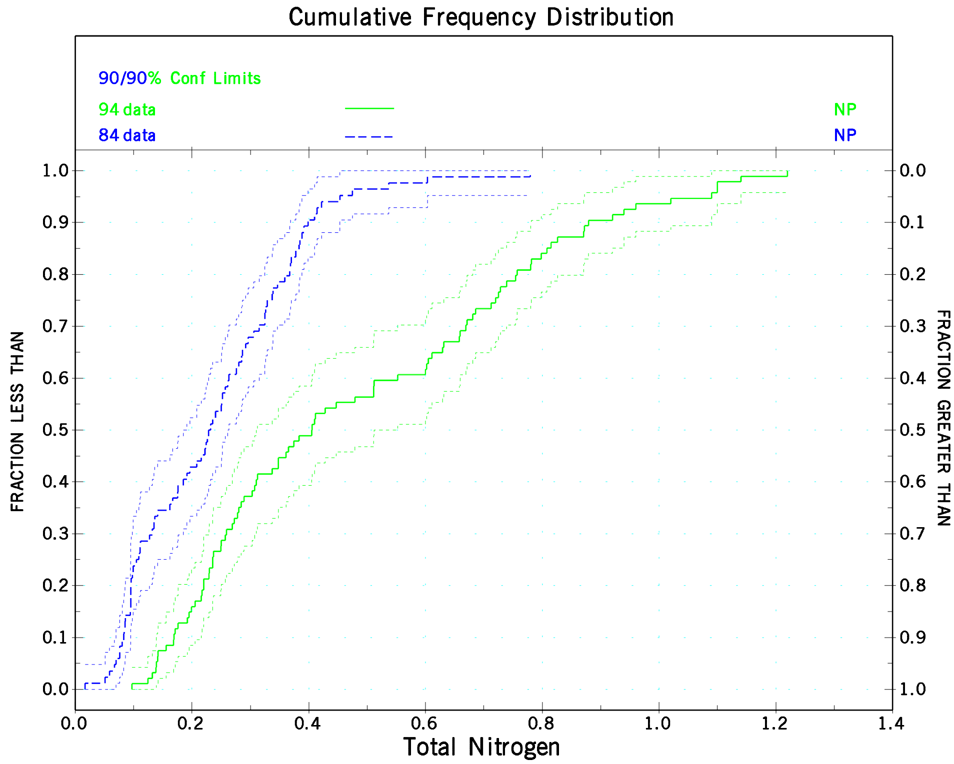

Figure 4. Cumulative frequency distribution for TN in the Nooksack River at Brennan (——) and N. Cedarville (- - -).

Trend Analysis

There were few noteworthy trends in the data, other than trends in bacteria and nitrogen forms, which are discussed in more detail below. Water temperatures cooled at the upstream station resulting in a decreasing trend in percent oxygen saturation (Table 5). Conductivity also decreased. Dissolved phosphorus appeared to decrease at both stations, but this trend is almost certainly due to improvements in analytical precision and not to environmental changes (see Hallock, 2001).

At the lower station, pH increased over the period. This was an artifact of the change in time of sampling, however. Once pH results were adjusted to a common sample time the trend disappeared.

Finally, the data suggest a mixed message with regard to sediment. Concentrations increased at the lower station and decreased at the upper station, but neither trend was significant. However, an increasing trend in the *difference* between stations was significant (2p<0.008; Figure 5) indicating degradation within the reach. Flow-adjusted data indicated a decreasing trend at the upper station and no trend in the difference between stations (Table 5). The trend result for the flow-adjusted difference was highly seasonal, however; for the late winter-spring runoff period (Feb-May), there was a significant increasing trend ($p=.017$).

On the other hand, since 1990 there have been no instances where the downstream concentration was much (>300 mg/L) greater than the upstream concentration compared to six instances prior to 1990. In other words, sediment additions to the reach have increased overall, but the number of events resulting in exceptionally large sediment additions has decreased. This may indicate that the major sediment sources have been contained to some degree but that smaller sediment sources have increased. (Time of travel is not considered; samples at upper and lower stations do not represent the same slug of water. Therefore, this analysis is suggestive but not conclusive; sediment distributions are notoriously patchy.)

Table 5. Trends in ambient monitoring data collected by Ecology from WY 1978 through 2001 (unless otherwise specified).

STATION	Station ID	Slope	Slope (% of median per year)	2-tailed probability	Significant (95%)	Statistital Test Used[a]
Temperature						
Nooksack at Brennan	01A050	-0.019	-0.21	5.07E-01	No	skwc
Nooksack at N Cedarville	01A120	-0.082	-0.93	2.36E-03	**Yes** ↓	skwc
Upstream/Downstream Difference	01ADiffs	0.06	NA	7.64E-04	**Yes** ↑	skwc
Flow						
Nooksack at Brennan	01A050	12.5	0.42	5.37E-01	No	skwc
Nooksack at N Cedarville	01A120	21.7	0.8	2.65E-01	No	skwc
Upstream/Downstream Difference	01ADiffs	8.6	NA	1.03E-01	No	skwc
Conductivity						
Nooksack at Brennan	01A050	-0.369	-0.37	1.10E-01	No	skwc
Nooksack at N Cedarville	01A120	-0.553	-0.65	1.24E-02	**Yes** ↓	skwc
Upstream/Downstream Difference	01ADiffs	0.147	NA	3.74E-02	**Yes** ↑	skwoc
Oxygen						
Nooksack at Brennan	01A050	0	0	8.52E-01	No	skwc
Nooksack at N Cedarville	01A120	0	0	7.26E-01	No	skwc
Upstream/Downstream Difference	01ADiffs	0	NA	7.90E-01	No	skwc
Percent Saturation						
Nooksack at Brennan	01A050	-0.088	-0.09	2.63E-01	No	skwc
Nooksack at N Cedarville	01A120	-0.235	-0.24	1.61E-02	**Yes** ↓	skwc
Upstream/Downstream Difference	01ADiffs	0.100	NA	5.05E-02	No	skwc
PH						
Nooksack at Brennan	01A050	0.009	0.12	7.44E-03	**Yes** ↑	skwc
--- (adj. to common time)	01A050	0.001	0.02	4.50E-01	No	skwc
Nooksack at N Cedarville	01A120	0	0	2.17E-01	No	skwc
Upstream/Downstream Difference	01ADiffs	0.006	NA	6.71E-02	No	skwc
Suspended Solids						
Nooksack at Brennan	01A050	0.095	0.32	8.08E-01	No	skwc
Flow-adjusted		-1.11	NA	2.38E-01	No	skwc
Nooksack at N Cedarville	01A120	-0.114	-0.42	5.49E-01	No	skwc
Flow-adjusted		-2.03	NA	4.28E-02	**Yes** ↓	skwc
Upstream/Downstream Difference	01ADiffs	0.665	NA	7.84E-03	**Yes** ↑	skwc
Flow-adjusted		0.259	NA	5.07E-01	No	skwc
Flow-adjusted, Feb-May		1.47	NA	1.74E-02	**Yes** ↑	skwoc

STATION	Station ID	Slope	Slope (% of median per year)	2-tailed probability	Significant (95%)	Statistital Test Used[a]
Nitrogen, Total (collected since October, 1993)						
Nooksack at Brennan	01A050	0.002	0.62	5.82E-01	No	skwoc
Nooksack at N Cedarville	01A120	0	-0.19	9.56E-01	No	skwc
Upstream/Downstream Difference	01ADiffs	0	NA	1	No	skwoc
Nitrogen, Ammonia						
Nooksack at Brennan	01A050	-0.0009	-2.59	9.21E-04	**Yes** ↓	skwc
Nooksack at N Cedarville	01A120	0	0	1.32E-03	**Yes** ↓	mkwc
Upstream/Downstream Difference	01ADiffs	0	NA	1.97E-01	No	skwc
Nitrogen, Nitrate+Nitrite						
Nooksack at Brennan	01A050	0.0017	0.59	8.80E-02	No	skwoc
Nooksack at N Cedarville	01A120	-0.0013	-0.65	1.87E-01	No	skwc
Upstream/Downstream Difference	01ADiffs	0.0036	NA	1.74E-05	**Yes** ↑	skwoc
Phosphorus, Total						
Nooksack at Brennan	01A050	0.0001	0.28	2.02E-01	No	skwoc
Nooksack at N Cedarville	01A120	0.0002	0.61	6.11E-02	No	mkwc
Upstream/Downstream Difference	01ADiffs	0	NA	6.91E-01	No	skwc
Phosphorus, Sol. Reactive						
Nooksack at Brennan	01A050	0	0	5.02E-10	**Yes** ↓	skwoc
Nooksack at N Cedarville	01A120	0	0	5.56E-05	**Yes** ↓	mkwc
Upstream/Downstream Difference	01ADiffs	0	NA	4.12E-03	**Yes** ↑	skwc
TN : TP Ratio (collected since October, 1993)						
Nooksack at Brennan	01A050	-0.02	-2.00	3.52E-01	No	skwc
Turbidity						
Nooksack at Brennan	01A050	-0.04	-0.23	7.77E-01	No	skwc
Nooksack at N Cedarville	01A120	-0.1	-0.62	5.67E-01	No	skwc
Upstream/Downstream Difference	01ADiffs	0.149	NA	7.39E-02	No	skwc
Fecal Coliform Bacteria						
Nooksack at Brennan	01A050	-3.69	-3.08	2.79E-08	**Yes** ↓	skwoc
Nooksack at N Cedarville	01A120	0	0	6.01E-01	No	skwoc
Upstream/Downstream Difference	01ADiffs	-3.42	NA	2.06E-08	**Yes** ↓	skwoc

[a] The Seasonal Kendall (sk) test was used when seasonality was present in the data (2p>0.25), otherwise, the Mann-Kendall (mk) test was used. Trend tests were corrected for serial correlation (wc) when present (2p>0.25) otherwise no correction was used (woc).

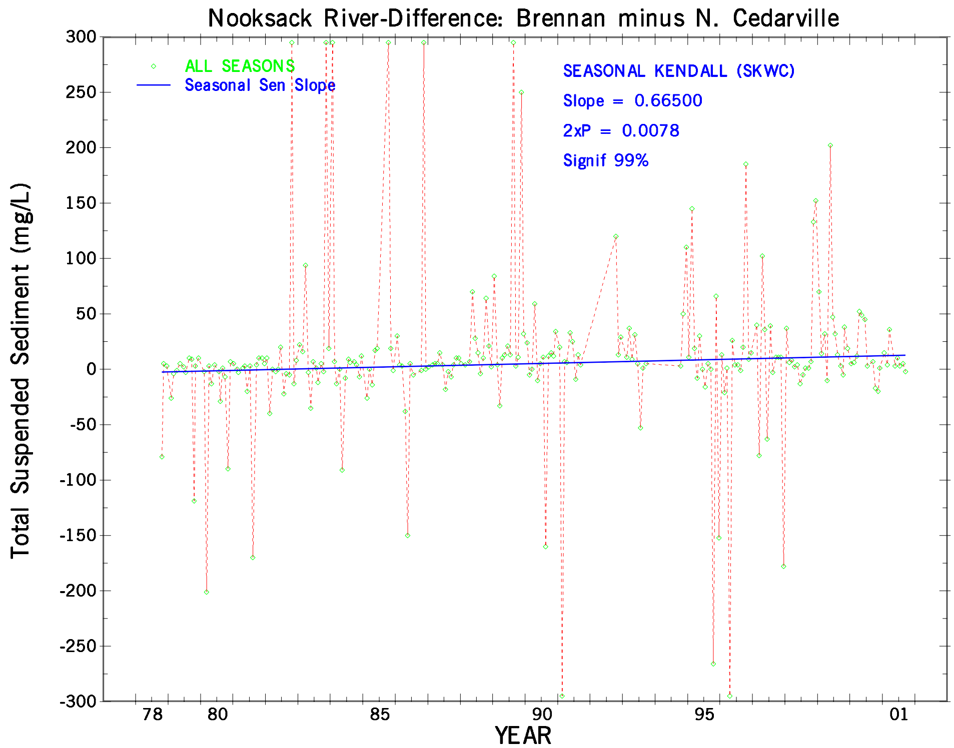

Figure 5. Trend in the difference in total suspended sediment between Nooksack River at Brennan and at N. Cedarville. Six values greater than +300 mg/L are shown as 300 and two values < -300 mg/L are shown as -300. Positive numbers indicate greater concentrations at Brennan.

Fecal Coliform Bacteria

There was a significant decreasing trend in bacteria counts at the lower station (Table 6 and Figure 6). There was no trend at the upstream station and the trend in the difference between stations was similar to the downstream trend. The trends were similar across different months; that is, one season didn't display different trends than another season.

There was no seasonality in the underlying data, either; the distribution was similar across all months, with a slightly (but not significantly) higher percentage of counts exceeding the "ten percent" criterion during the fall months (Figure 7). Nor were FC counts correlated with discharge.

Joy (2000) did not find a significant trend in ambient data collected between October 1991 and September 1997. Extending his analysis through September 2001, the declining trend in recent data is significant at the 95 percent confidence level (Table 6). In fact, as of September 2001, the running 12-month geometric mean was below the adopted TMDL target criterion of 39 colonies/100mL (Figure 8). The decline in FC since 1978, and especially since the early 1990s, is clear and encouraging. However, FC concentrations have shown a historical pattern of declining and then increasing again.

There have been a number of management activities in the basin that may have contributed to the decreasing trend in FC. Although the number of dairy cows in Whatcom county has steadily increased since 1980 (except for a large dip in the mid-1980s when the federal dairy program ended), the number of dairy farms has decreased by 50 percent while the average herd size has tripled (data from Joy, pers. comm. and http://www.whatcomfarm.org/factsandtrivia.txt citing "Federal Milk Market Administrator, WA DHIA, WSU Cooperative Extension"). Efficiencies in scale may have led to better manure management. Also, Ecology and Whatcom County began watershed monitoring and outreach programs in the mid-1980s. The Washington Dairy Nutrient Management Plan was implemented in 1998, and starting in 1999 manure application to fields of bare ground or corn stubble was prohibited in Whatcom County from September to March (Joy 2000).

Table 6. Trend assessment results from the Nooksack River for FC (colonies/100mL) based on WY 1978 through 2001 (except where noted). Serial correlation was not significant so the Seasonal Kendall test without correction for serial correlation was used. The "difference" dataset consists of downstream minus upstream counts (decreasing trend=improvement).

Dataset	Slope (units/year)	2-tailed probability	Significant (95%)	Seasonality: Trend Results	Seasonality: Data Series
Brennan	-3.7 (5.1%)	P < 0.001	**Yes** ↓	No	No (p > 0.50)
Brennan>WY1991	-4.7 (9.8%)	P < 0.012	**Yes** ↓	No	No (p > 0.10)
N. Cedarville	-0.0 (0.0%)	P > 0.60	No	No	No (p > 0.50)
Difference	-3.4 (NA)	P < 0.001	**Yes** ↓	No	No (p > 0.50)

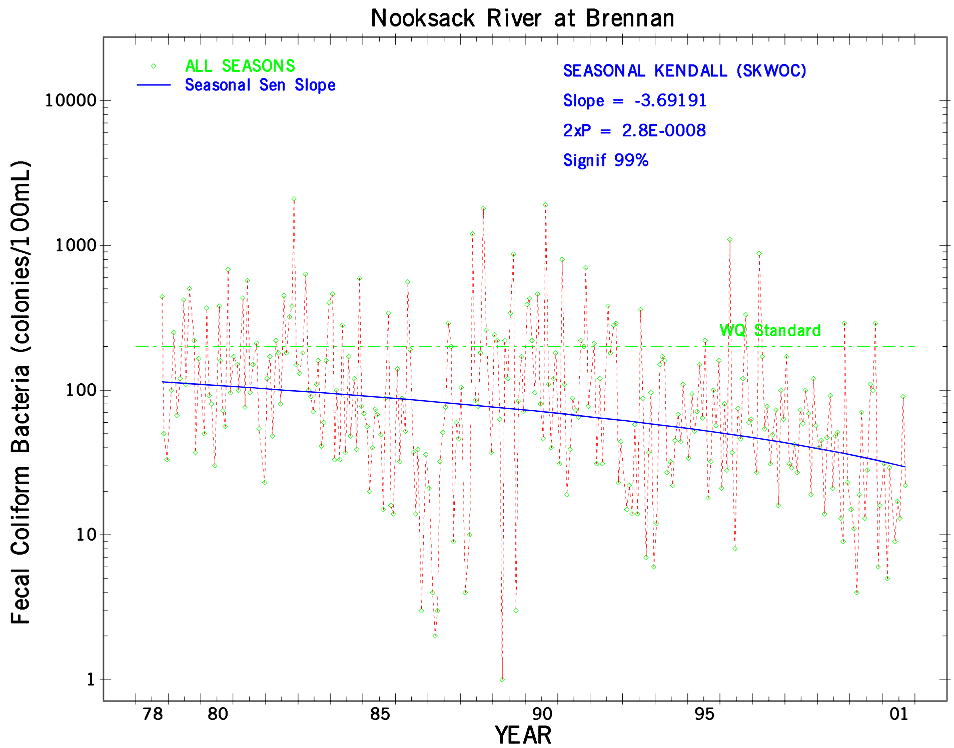

Figure 6. Trend in FC at Nooksack River at Brennan. The trend line is curved because the y-axis is logarithmic.

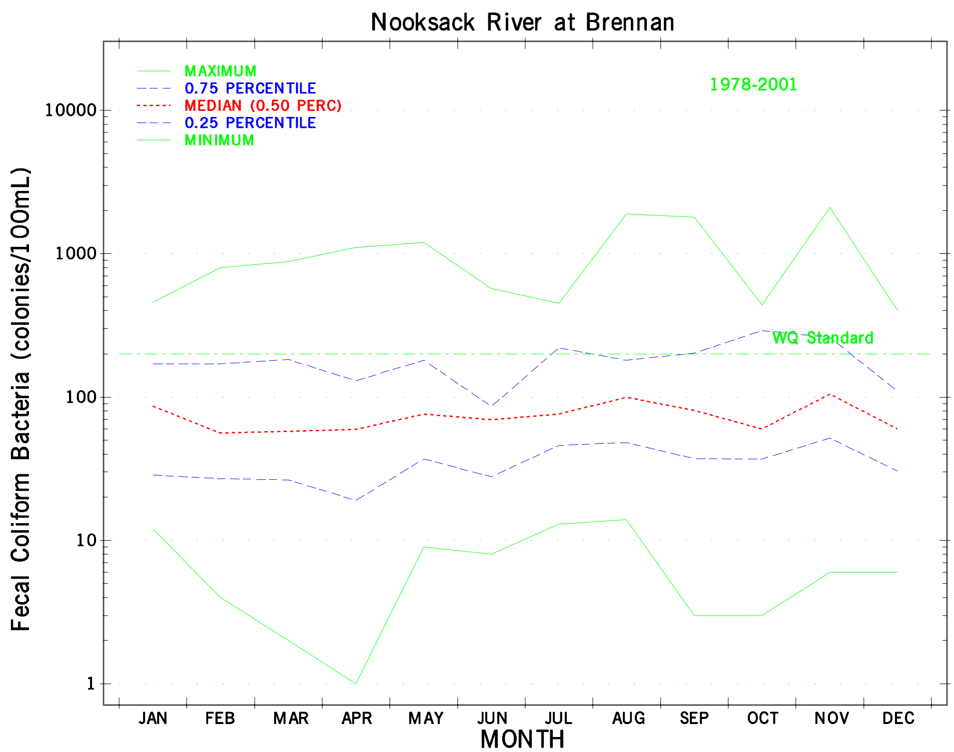

Figure 7. Seasonal distribution of FC data at Nooksack River at Brennan.

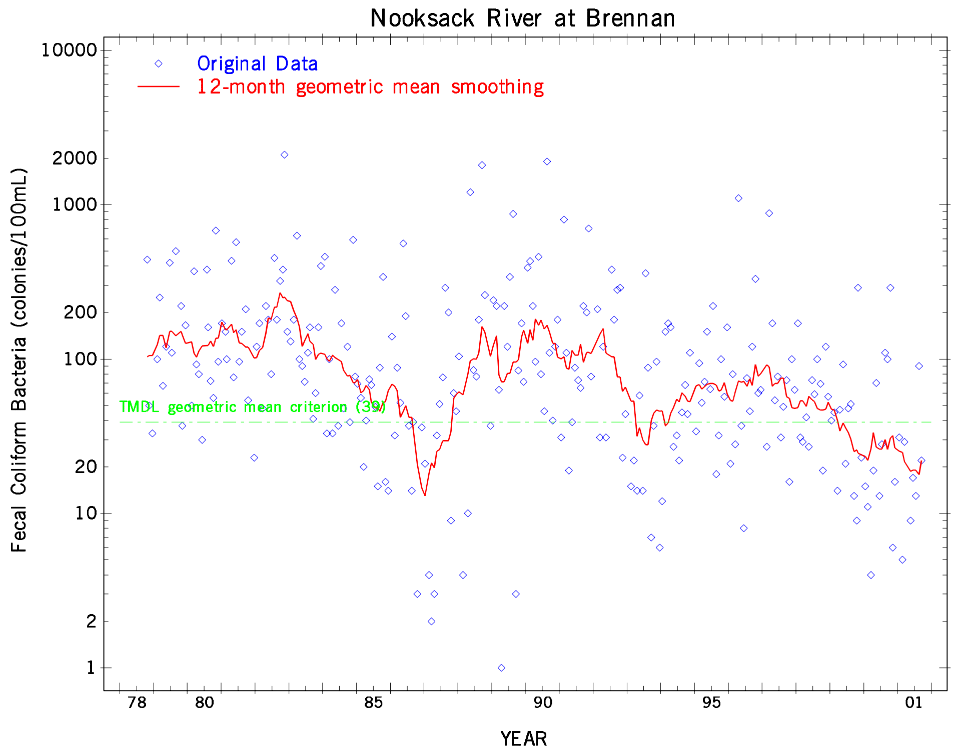

Figure 8. Twelve-month running geometric mean of FC data at Nooksack at Brennan.

Nitrogen Forms

Changes in nitrogen forms were not as clear as the trends seen in the FC data. There were no significant trends in TN—but we did not begin collecting TN data until WY 1993 (Table 7).

The ratio of TN to total phosphorus (TP) was quite low (mean=13, median=10), which suggests nitrogen limitation in the Nooksack River. Nitrogen is typically the limiting nutrient in marine systems. Although there was a decreasing trend in ammonia concentration at both stations, this almost certainly is an artifact of a change in laboratories (see Hallock, 2001): results at most monitoring stations were "noisy" prior to the mid-1980s. Also, there was no ammonia trend in the difference between stations, indicating that even if this apparent reduction in ammonia is real, the reduction is not related to watershed activities between Brennan and N. Cedarville.

The difference between stations in nitrate plus nitrite, on the other hand, showed an increasing trend indicating contributions from nitrate plus nitrite sources between stations increased during the period (Figure 9). We did not collect nitrate plus nitrite in the early and mid-1980s; however, the trend for WY 1988 through 2001 is similar to the overall trend (slope=0.0025, $2p<0.05$).

Nitrate plus nitrate, and, indeed, all nitrogen forms, were highly seasonal with concentrations much greater in the winter than in the summer (Figure 10). This may be due to nitrogen uptake by plants during the growing season and runoff and ground water discharge as transport mechanisms for nitrogen loading to the stream. There was no seasonality in the trend results, however, with all months showing an increasing trend. There was a poor correlation between nitrate plus nitrite and discharge; discharge explained only four percent of the variability ($p<0.05$), and adjusting for discharge did not affect the trend.

Identification of nitrogen sources is beyond the scope of this report. Inkpen (1998) reported that more than 90% of inorganic nitrogen inputs to the Nooksack River were from animal wastes and agricultural fertilizers.

Table 7. Trend assessments results from the Nooksack River for nitrogen forms (mg/L) based on WY 1978 through 2001 (WY 1993 through 2001 for TN). Except where noted otherwise, serial correlation was not significant and the Seasonal Kendall test for trend without correction for serial correlation was used. The “difference” dataset consists of downstream minus upstream counts (increasing trend=degradation).

				Seasonality	
Dataset	Slope (units/year)	2-tailed probability	Significant (95%)	Trend Results	Data Series
			Total Nitrogen		
Brennan	+0.0025 (0.6%)	>0.58	No	No	**Yes** (p < 0.01)
N. Cedarville	-0.0004 (0.2%)	>0.96	No	No	**Yes** (p < 0.01)
Difference	+0.0003 (NA)	1.0	No	No	**Yes** (p < 0.01)
			Nitrate plus Nitrite Nitrogen		
Brennan	+0.0017 (0.9%)	>0.09	No	No	**Yes** (p < 0.01)
N. Cedarville	-0.0013 (1.6%)	>0.19[a]	No	No	**Yes** (p < 0.01)
Difference	+0.0036 (NA)	<0.0001	**Yes** ↑	No	**Yes** (p < 0.01)
			Ammonia Nitrogen		
Brennan	-0.0009 (3.8%)	<0.001	**Yes** ↓	No	**Yes** (p < 0.01)
N. Cedarville	-0.0000 (0.0%)[b]	<0.002[a]	**Yes** ↓	No	No (p > 0.50)
Difference	-0.0000 (NA)[b]	>0.20[a]	No	No	**Yes** (p < 0.01)

[a] Based on the Seasonal Kendall test with correction for serial correlation .

[b] A slope of 0 can occur when there are a large number of identical results such as occurs with results below detection limits.

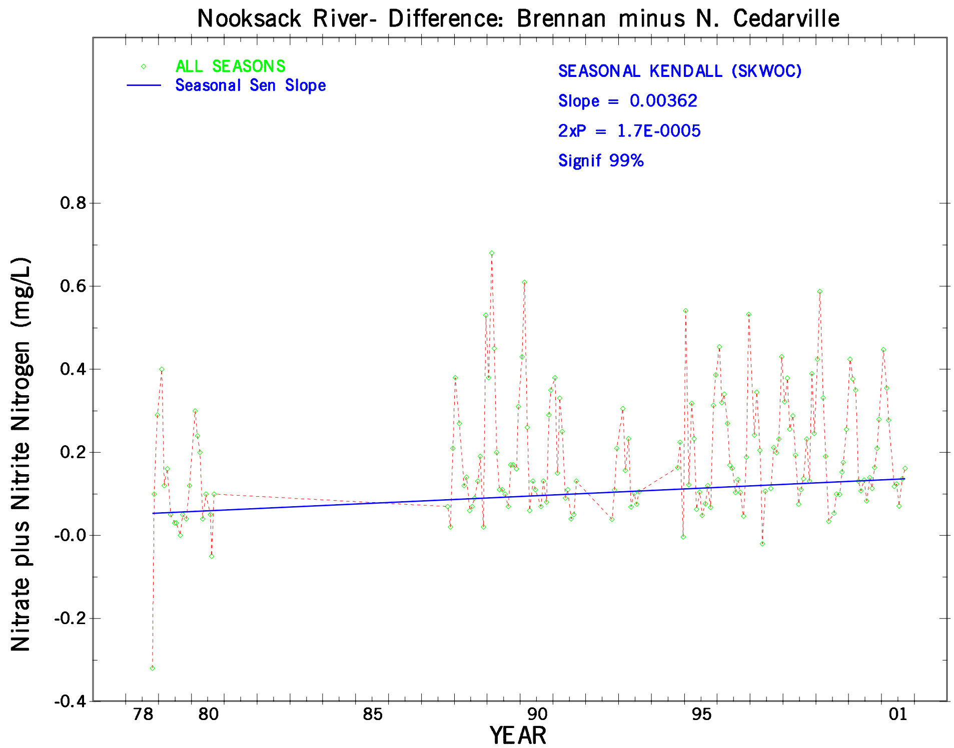

Figure 9. Trend in the difference in nitrate plus nitrite nitrogen between Nooksack River at Brennan and at N. Cedarville.

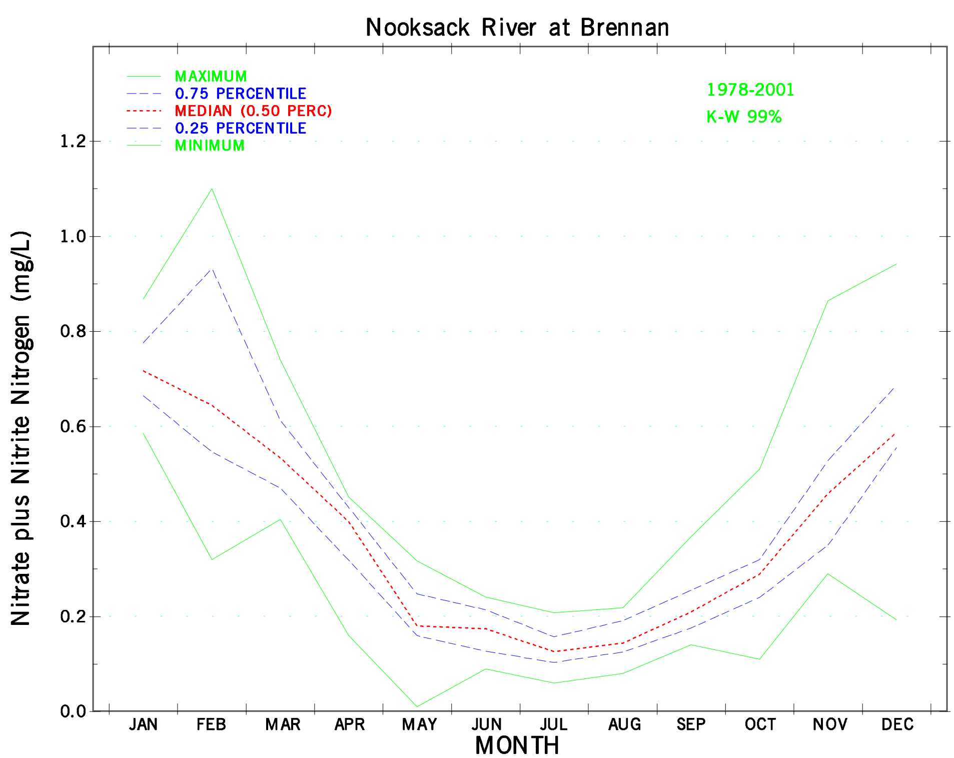

Figure 10. Seasonal distribution of nitrate plus nitrite nitrogen data at Nooksack River at Brennan.

Conclusions

FC concentrations were the biggest contributor to poor water quality in the lower Nooksack River among the constituents we monitor. However, concentrations have been declining over both 20 and 10-year periods, in spite of dramatic increases in human population and smaller increases in the population of dairy cows. This is a clear success story. The historical record indicates a pattern of lower counts followed by years of higher counts. Vigilance is necessary to ensure counts stay low, particularly in the face of continuing population pressures.

Nitrogen forms (TN, ammonia, and nitrate plus nitrite) were much higher at the lower station than at the upper. There were no significant trends at either of the two stations during the period evaluated, but nitrate plus nitrite increased at the downstream station relative to the upstream station. TN:TP ratios were low indicating TN was more likely than TP to have been the nutrient limiting productivity. Productivity-related water quality constituents at the downstream station should continue to be monitored and an evaluation of trends in eutrophication measures (such as nitrogen and chlorophyll) in Bellingham Bay would be helpful to further quantify the effects of nutrient loading. Newton, et al. (1998) reported low dissolved oxygen near the mouth of the Nooksack River, but their data were insufficient to assess the degree of human impact. If increasing eutrophication is identified, consideration should be given to management of anthropogenic nitrogen sources to the lower river.

The data indicate an increasing trend in total suspended sediment concentrations overall at the lower station relative to the upper station; however, there have been fewer events in recent years where concentrations were much higher at the downstream station. This may indicated that large sediment sources in the reach have been reduced, while smaller sources have been increasing. Because of time-of-travel issues, however, this cannot be confirmed.

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Appendix A

River and stream ambient monitoring stations defining stream reaches selected for analysis. The "Years" column indicates the number of complete water years sampled since October 1978 common to all stations in a system.

System	Years	Station		Status
Nooksack	20	01A050	Nooksack R @ Brennan	This report
		01A120	Nooksack R @ No Cedarville	
Skagit	22	03A060	Skagit R nr Mount Vernon	
		04A100	Skagit R @ Marblemount	
Stillaguamish	20	05A070	Stillaguamish R nr Silvana	
		05A090	SF Stillaguamish @ Arlington	
		05B070	NF Stillaguamish @ Cicero	
Snohomish	20	07A090	Snohomish R @ Snohomish	
		07C070	Skykomish R @ Monroe	
		07D130	Snoqualmie R @ Snoqualmie	
Cedar	20	08C070	Cedar R @ Logan St/Renton	
		08C110	Cedar R nr Landsburg	
Green	20	09A080 &	Green R @ Tukwila &	
		09A090	@ 212 St. nr Kent	
		09A190	Green R @ Kanaskat	
Puyallup	16	10A070	Puyallup R @ Meridian St	
		10A110	Puyallup R @ Orting	
Deschutes	15	13A060	Deschutes R @ E St Bridge	
		13A150	Deschutes R nr Rainier	
Chehalis	22	23A070	Chehalis R @ Porter	
		23A160	Chehalis R @ Dryad	
Snake	9	33A050	Snake R nr Pasco	
		35A150	Snake R @ Interstate Br	
Palouse	6	34A070	Palouse R @ Hooper	
		34A170	Palouse R @ Palouse	
		34B110	SF Palouse R @ Pullman	
Yakima	15	37A090	Yakima R @ Kiona	
		37A190	Yakima R @ Parker	
Wenatchee	22	45A070	Wenatchee R @ Wenatchee	
		45A110	Wenatchee R nr Leavenworth	
Methow	20	48A070	Methow R nr Pateros	
		48A130 &	Methow R nr Twisp &	
		48A140	Methow R @ Twisp	
Okanogan	16	49A070	Okanogan R @ Malott	
		49A190	Okanogan R @ Oroville	
Spokane	22	54A120	Spokane R @ Riverside State Pk	Draft due approx.
		57A150 &	Spokane R @ Stateline Br &	July 31, 2002
		57A190	Spokane R nr Post Falls	

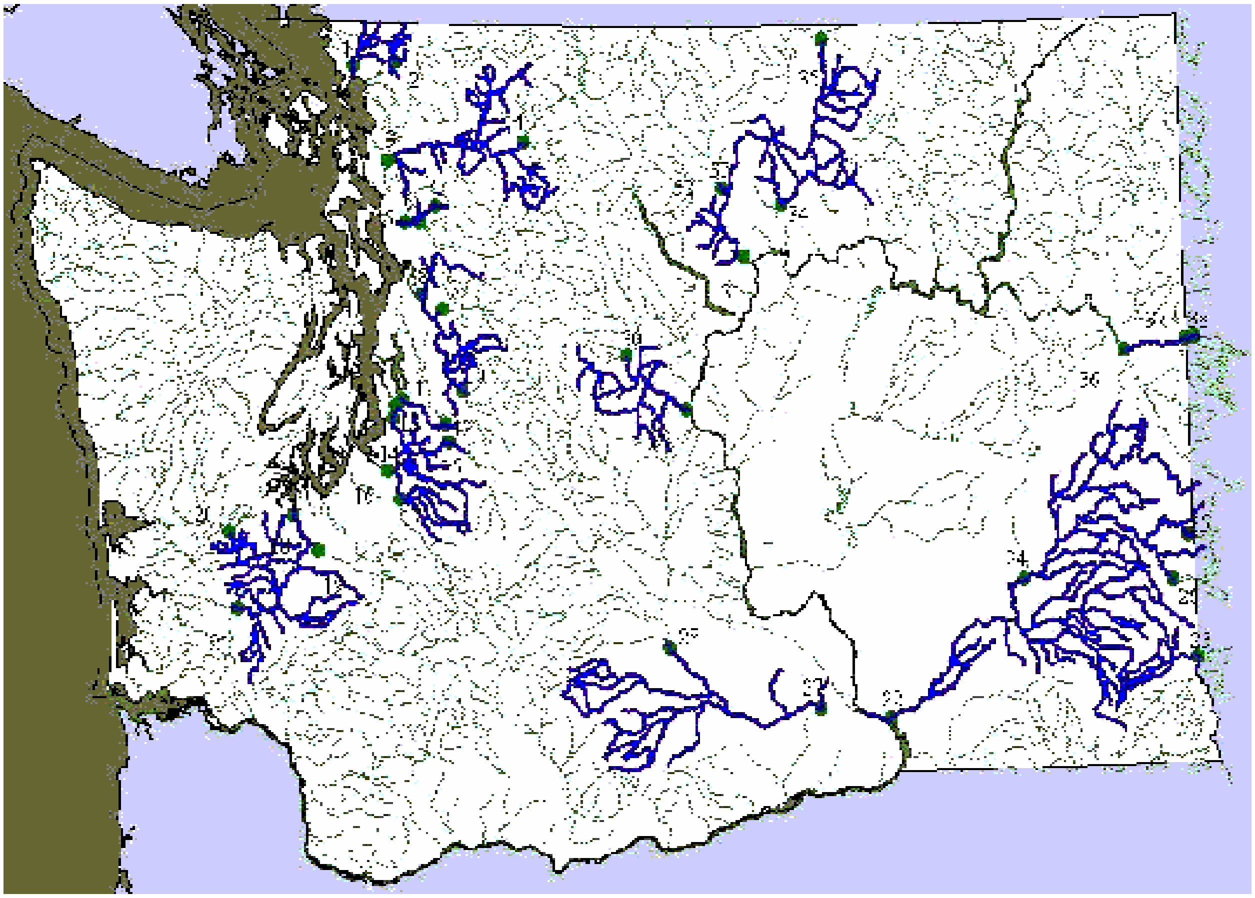

Figure 1. Washington State map showing stream segments bounded by Ecology monitoring stations.

Appendix B

Distribution of data for various constituents collected monthly at Nooksack River at Brennan and at North Cedarville (30-minute interval temperature data are not included).

Station Name	Number of Observations	Minimum	PERCENTILES 10	25	50 (median)	75	90	Maximum
Temperature (°C)								
Brennan	271	0.1	4.0	5.6	8.8	12.6	15.4	18.4
N. Cedarville	251	0.1	3.7	5.0	7.9	11.0	13.0	16.9
Flow (cfs)								
Brennan	259	500	1390	2140	3080	5000	7150	22900
N. Cedarville	235	476	1292	1930	2870	4540	6512	18800
Conductivity (µsiemens)								
Brennan	271	38	68	81	96	112	125	159
N. Cedarville	251	29	58	68	78	92	105	130
Oxygen (mg/L)								
Brennan	269	8.9	9.9	10.6	11.1	11.9	12.7	14.1
N. Cedarville	250	9.6	10.8	11.2	11.8	12.4	13.1	14.2
Percent Oxygen Saturation (%)								
Brennan	258	81.5	91.3	93.8	96.2	98.9	102.3	113.4
N. Cedarville	239	88.3	94.2	96.8	99.1	102.9	105.5	112.7
pH (standard units)								
Brennan	260	6.7	7.2	7.4	7.5	7.7	7.8	8.3
N. Cedarville	242	6.0	7.2	7.4	7.6	7.7	7.8	8.6
Suspended Solids (mg/L)								
Brennan	264	1	10	16	30	67	156	2600
N. Cedarville	245	1	6	13	26	55	196	2080
Total Nitrogen (mg/L)								
Brennan	94	0.097	0.169	0.235	0.406	0.721	0.899	1.220
N. Cedarville	84	0.017	0.082	0.106	0.230	0.335	0.405	0.779

Station Name	Number of Observations	Minimum	PERCENTILES 10	25	50 (median)	75	90	Maximum
Ammonia (mg/L)								
Brennan	262	0.01	0.01	0.01	0.02	0.04	0.07	0.22
N. Cedarville	246	0.01	0.01	0.01	0.01	0.02	0.04	0.42
Nitrate+nitrite (mg/L)								
Brennan	183	0.01	0.12	0.18	0.32	0.54	0.71	1.10
N. Cedarville	166	0.01	0.05	0.08	0.18	0.28	0.35	0.70
Phosphorus (mg/L)								
Brennan	259	0.01	0.02	0.03	0.04	0.06	0.10	0.79
N. Cedarville	242	0.01	0.01	0.02	0.03	0.04	0.08	0.87
	Turbidity (NTU)							
Brennan	264	1	5	8	17	35	69	1600
N. Cedarville	245	1	3	8	15	32	82	1000
Fecal Coliform Bacteria (colonies/100 mL)								
Brennan	263	1	14	32	73	170	380	2100
N. Cedarville	247	1	1	3	8	19	56	720
Time of sample collection								
Brennan	271	0600	0820	0920	1330	1440	1549	1850
N. Cedarville	252	0610	1140	1220	1310	1415	1455	1610