STATE-OF-THE-RIVER REPORT

FOR

THE CHEHALIS RIVER BASIN

2006 - 2009

A Water Quality Study

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Executive Summary

To better manage the Chehalis Basin, it is important to understand water quality in the Chehalis River and its tributaries. Previous studies throughout the Chehalis Basin have suggested that ambient water quality conditions range widely, and the primary water quality parameters of concern are temperature, dissolved oxygen, fecal coliform, pH and turbidity due to sediment runoff. To advance knowledge of water quality in the Chehalis Basin, we initiated a study in 2006 to collect and analyze water samples from 83 sites on a monthly basis for dissolved oxygen, pH, temperature, turbidity, and fecal coliform. During 2008, the number of sites was expanded to 94. The project was a collaborative effort of Grays Harbor College, which was responsible for study design, analysis, and reporting, and the Chehalis Tribal Natural Resources Department, which was responsible for collecting water samples and conducting chemical analyses of samples.

The criteria used to evaluate water quality were based on Washington State standards (173-201A WAC). The rationale for these standards is that water quality meeting the standards provides for the habitat needs of fish and other aquatic life, provides a safe environment for people engaged in water recreation, and provides for the production of healthy and safe seafood. The standard for pH was the range 6.5 to 8.5, with values falling outside of that range not meeting the standard. The standards for dissolved oxygen were 8 mg/L (high water quality) and 9.5 mg/L (extraordinary water quality). The standards for fecal coliform were 100 colonies/100 ml (high water quality) and 50 colonies/100 ml (extraordinary water quality). The standards for turbidity were 5 Nephelometric Turbidity Units (NTUs) above the background level (for salmon spawning) or 10 NTUs above the background level (for salmon migration and rearing). Several different temperature standards were employed, that evaluated conditions for both spawning and rearing of salmon, trout, and char (bull trout and Dolly Varden).

We found that pH generally fell within the range of 6.5 to 8.5 at all 94 monitoring sites, with very few exceptions. The study therefore suggests that water quality in the monitored streams is in good condition with respect to pH, and that pH is probably not a factor limiting distribution or abundance of fish or other aquatic life in these streams of the Chehalis River basin.

Measured dissolved oxygen concentration levels varied considerably both between sites and also depending on season. Dissolved oxygen tended to be higher in the winter and lower in the summer. This is expected, as cold water can retain a higher level of dissolved oxygen. Dissolved oxygen concentration was generally higher in tributary streams further upstream, such as the East and West Forks of the Humptulips River, the Wynoochee River, and the Skookumchuck River, and lower in the mainstem Chehalis River and tributaries at downstream sites near their confluences with the Chehalis River.

In general, the highest fecal coliform levels were often measured in streams flowing through residential areas, such as Winter Creek, which flows through Westport, Ocean Shores Creek, which flows through Ocean Shores, and Hoquiam River where it flows through the City of Hoquiam.

Turbidity tended to be highest during the winter months, particularly after storms and flood events, and lowest during the summer months. We identified two different categories of high stream turbidity conditions in Chehalis Basin streams; 1) ongoing above-average but not extreme turbidity, and 2) extreme high turbidity over a shorter interval during and following storm events. Turbidity in Johns River and Ocean Shores Creek fell into the first category, with turbidity typically ranging between 2 and 12 NTU. The second category included turbidity conditions in several streams further upstream including Waddell Creek, Salzer Creek, Middle Fork Newaukum River, West Fork Satsop River, and the Chehalis River headwaters, where turbidity ranged from 30 to over 300 NTU at some monitoring sites for one or more months during the winter and spring.

Temperature conditions were cool and met the criteria for salmon and trout rearing most consistently at sites furthest upstream and/or during the fall, winter, and spring months. At 25 monitoring sites throughout the Chehalis Basin (of 94 sites total), including most of the mainstem Chehalis River sites, temperatures exceeded the Salmonid Summer Core Criterion of 16°C in at least 80% of the samples collected during the summer. Tributary streams such as the Humptulips River, the Satsop River, the Wynoochee River, and the Skookumchuck River had lower measured temperatures during the summer, especially at monitoring sites further upstream. Fall Spawning and All-Year Rearing criteria for char (bull trout and Dolly Varden) were most consistently met in higher elevation streams of the Humptulips River watershed and the Satsop River watershed.

It can be concluded that, although there are general trends in water quality throughout the Chehalis Basin, specific needs for restoration and preservation of water quality will need to be evaluated on a site-specific basis.

Acknowledgements

This project was funded primarily by a generous grant from the Department of Ecology (Grant # G0800382). Richard Revay and Harry Pickernell with the Chehalis Tribal Natural Resources Department did the important work of collecting water samples at 94 sites throughout the Chehalis River basin, and Mr. Pickernell conducted chemical analysis of samples at the CTDNR Certified Laboratory. Don Loft conducted much of the statistical analysis and all of the geospatial analysis for this report, and created all maps of monitoring sites. We appreciate the thoughtful advice and consultation provided by David Rountry (Washington Department of Ecology), and the careful review of the document by Lee Napier (Chehalis Basin Partnership), Janel Spaulding (Grays Harbor College), and Mike Kelly (Grays Harbor College).

Photo courtesy of Chehalis Tribe Department of Natural Resources, 2007

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Introduction

Understanding water quality in the Chehalis Basin is an important component of the watershed management process. The Chehalis River Basin is a 2,660 square mile watershed located in Western Washington State (Figure 1). The Chehalis River, the second largest river in the state (the Columbia River is the largest), originates from surface runoff in the Willapa Hills region near the city of Pe Ell and flows downstream to the Grays Harbor Estuary and its confluence with the Pacific Ocean (Figure 1). Within the Chehalis Basin, there are eight counties (Thurston, Lewis, Pacific, Cowlitz, Mason, Jefferson, Grays Harbor and Wahkiakum) and one tribal reservation (The Confederated Tribes of the Chehalis Reservation).

Given its size, the Chehalis Basin is divided into the Upper and Lower Basin for management purposes. The Lower Basin is Watershed Resource Inventory Area 22 (WRIA 22), and the Upper Basin is WRIA 23. Although the Upper and Lower Basins are separated to clarify management objectives, the watershed processes in each Basin are intimately linked. Throughout both the Upper and Lower Chehalis Basin, forestlands dominate the landscape, representing 85% of the total land coverage. These forestlands are primarily owned by private timber corporations, but significant land holdings are owned by the State of Washington or by small forest landowners. The remainder of the land within the basin is comprised of agricultural (~9%), range (~2%) and urban (~2%).

Values and uses of water resources in the Chehalis Basin are widely varied. Surface and groundwater (not glacial melt) are the primary water sources for drinking, irrigation and municipal/industrial effluent treatment and dilution in the Basin. In addition to these consumptive uses, waters in the Chehalis River Basin and Grays Harbor estuary support a variety of valuable shellfish and finfish resources. The Chehalis River supports 31 stocks of salmonid species, with eight of these classified as Depressed (Washington Department of Fish and Wildlife, 2002). Grays Harbor provides habitat for various species of oysters, clams, mussels, and crabs, and 900 acres (of 9000 total acres) of the Grays Harbor estuary are farmed for shellfish. Waters of the Chehalis River Basin ecosystem also support eight species (both terrestrial and aquatic) listed as Threatened or Endangered under the Federal Endangered Species Act.

The Chehalis Basin Partnership (CBP) plays an important role in management of water resources within the Chehalis Basin. The CBP is a non-governmental volunteer organization of cities, tribes, counties, and other local organizations formed to work on water resource issues including water quantity, water quality, and fish habitat within the Chehalis River watershed (CBP, 2004a; CBP, 2004b). The CBP was formed by an intergovernmental agreement, dated August 31, 1998, for the purpose of assessing and managing the water resources of the Chehalis River Basin. The agreement designated the CBP as a Planning Unit that would coordinate efforts focusing on flood reduction, fish habitat, recreation, water quality and water quantity in the Chehalis River Basin, and examine their relationships to economic health and sustainability. Although not a formal member of the CBP, the Quinault Indian Nation is also actively involved in the management of the water resources in the Chehalis Basin.

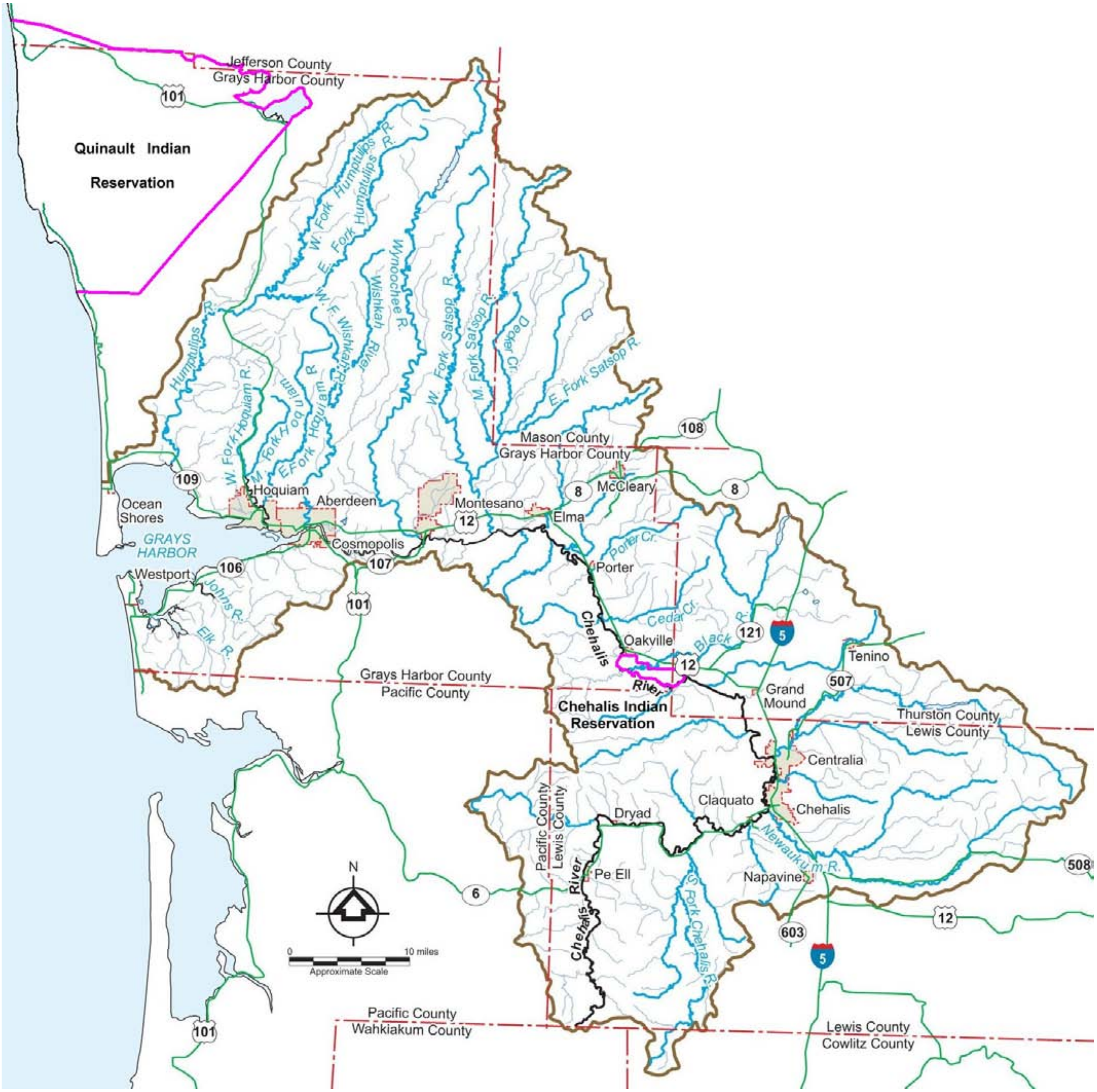


Figure 1. Map of the Chehalis River Basin. Grays Harbor County Public Services/Chehalis Basin Partnership, 2008.

To more effectively manage water resources in the Basin, the CBP and Grays Harbor County have formed three work groups, the Water Quality Committee, the Steering and Technical Advisory Committee and the Habitat Work Group. Members representing diverse stakeholder groups collaborate to solve technical issues related to water quality, and provide recommendations and technical support to the CBP related to water resources management. Collective work of the CBP and individual efforts of various stakeholder groups have resulted in a number of technical studies and management plans that guide the management of water resources in the Basin (Table 1).

The aforementioned studies suggest that ambient water quality conditions in the Chehalis Basin range from relatively undisturbed to severely impacted. These studies suggest that the primary water quality parameters of concern in the Chehalis Basin are temperature, dissolved oxygen, fecal coliform, and sediment runoff. The Total Maximum Daily Load (TMDL) studies listed above have identified 114 impaired stream segments throughout the Basin. These studies also suggest that the primary sources of water quality impairment are non-point sources, specifically runoff from urban, agricultural and commercial forestlands.

To advance knowledge of water quality in the Chehalis Basin, we initiated a study in 2006 to collect and analyze water samples from 83 sites on a monthly basis for dissolved oxygen, pH, temperature, turbidity, fecal coliform. During 2008, the number of sites was expanded to 94. The objectives of the study were to 1) provide an overall view of water quality in the Basin, including relative condition of streams with regard to the analyzed parameters; 2) identify spatial patterns and temporal trends in water quality; and 3) provide information that can be used to prioritize restoration or conservation actions in the Basin.

Salmonids in the Chehalis River Basin

Fish in the taxonomic family *Salmonidae* (salmonids) in the Chehalis River Basin include Chinook salmon, chum salmon, coho salmon, steelhead trout, coastal cutthroat trout, and char (bull trout and Dolly Varden)(Washington Dept. of Fish & Wildlife, 2002). The species of most importance for commercial and recreational fishing include the three Pacific salmon species and the steelhead trout. Bull trout were listed as a Threatened Species under the Endangered Species Act in 1999 (U.S. Fish & Wildlife Service, 2004). In the Bull Trout Recovery Plan, foraging, migration and overwintering habitat for bull trout on the southern Olympic Peninsula includes Grays Harbor, Hoquiam River, Humptulips River, and the lower Chehalis River basin including the Satsop River and the Wynoochee River (U.S. Fish & Wildlife Service, 2004).

Table 1. Summary of technical studies and management plans for the Chehalis Basin referenced throughout the document. Studies are authored by Washington Department of Ecology (WDOE), the Chehalis Basin Partnership (CBP) and the Washington State Conservation Commission (WSCC). Documents are available through the listed websites.

Technical Studies	Source/Author
7 USEPA approved TMDL studies addressing dissolved oxygen, temperature and fecal coliform throughout the upper and lower basin *Documents related to the Chehalis TMDLs are available through the Washington State Dept. of Ecology web site at http://www.ecy.wa.gov/programs/wq/tmdl/index.html.	WDOE, 2000a; 2000b; 2000c; 2001a; 2001b; 2002a; 2002b
A Biological Assessment of Streams in the Coastal Range Ecoregion and Yakima Basin, Publication # 99-302 http://www.ecy.wa.gov/pubs/99302.pdf	WDOE,1999
Chehalis Basin Level I Assessment http://www.co.grays-harbor.wa.us/info/pub_svcs/ChehalisBasin/PhaseII/	CBP, 2000
Salmon Habitat Limiting Factors in Washington State: WRIA 22 & 23 Chehalis Watershed Limiting Factors http://www.scc.wa.gov/index.php/281-WRIA-22-Lower-Chehalis-Watershed/View-category.html	WSCC, 2005
2002 Index Watershed Salmon Recovery Monitoring Report http://www.ecy.wa.gov/biblio/0203061.html	WDOE, 2002c
Chehalis Best Management Practices Evaluation Project: Final Report for Water Quality Sites, Publication #02-03-015 http://www.ecy.wa.gov/pubs/0203015.pdf	WDOE, 2002d

Management Plans	
Chehalis Basin Detailed Implementation Plan http://www.co.grays-harbor.wa.us/info/pub_svcs/ChehalisBasin/PhaseIV/index.htm	CBP, 2007
Chehalis Basin Watershed Management Plan http://www.co.grays-harbor.wa.us/info/pub_svcs/ChehalisBasin/Index.html	CBP, 2002
Chehalis Watershed Monitoring Plan and Quality Assurance Project Plan Framework http://www.chehalisbasinpartnership.org/technical/monitoring/l1_p2_watershed_monitoring_plan_qapp_12-31-03.pdf	CBP, 2003
The Chehalis/Grays Harbor Watershed Dissolved Oxygen, Temperature, and Fecal Coliform Bacteria TMDL-Detailed Implementation (Cleanup) Plan , Publication # 04-10-065 http://www.ecy.wa.gov/biblio/0410065.html	WDOE, 2004
The Chehalis Basin Salmon Habitat Restoration and Preservation Work Plan for WRIAs 22/23, 2008 Update http://www.co.grays-harbor.wa.us/info/pub_svcs/ChehalisBasin/Docs/WRIA20080922-23.pdf	CBP, 2008

Methods

Methods for site selection, sample collection and analysis are described in detail in the Quality Assurance Project Plan (QAPP) for The Comprehensive Chehalis Basin Monitoring Program (CBMP)(Lehr, 2007). The CBMP QAPP was approved by the Washington Department of Ecology (DOE) in March of 2007. All chemical measurements were performed by an accredited laboratory at the Chehalis Tribal Natural Resources Department.

Briefly, water samples were collected and analyzed on a monthly basis (i.e., one sample collected ~ every 4 weeks) from 94 sites throughout the Chehalis River Basin (Figures 2-5). Sampling of 83 sites began in November 2006, and then 11 more sites were added in January and February of 2008. Sampling continued through June 2009. Sample sites were chosen based on: **(1)** their alignment with identified goals and objectives for the Chehalis Basin; **(2)** the availability of ongoing data sets and concurrent monitoring programs; **(3)** accessibility of the sampling site; **(4)** a need for representative coverage throughout the Basin; and **(5)** location upstream and downstream of major river confluences and suspected pollutant sources. Samples were analyzed for dissolved oxygen, pH, temperature, turbidity and fecal coliform. Dissolved oxygen, pH, and temperature were all measured in the field using field deployable, *in situ* water quality probes. Turbidity and fecal coliform were measured in the laboratory, using standard techniques. Data quality was assessed using a series of positive/negative controls, replicate samples and trend analysis; this process is also described in detail in the QAPP.

Data Analysis

All water quality data was analyzed using criteria based on Washington State water quality standards (173-201A WAC). Water quality throughout the Chehalis Basin was initially assessed by comparing monthly and site-specific averages to these water quality criteria. Water quality was also assessed using a relative ranking index (described below). Monthly graphs and maps are color coded to highlight water quality at the sample sites relative to the water quality criteria, as described below and in Tables 2 and 3. Data analysis was done separately for Watershed Resource Inventory Area 22 (WRIA 22) and WRIA 23. All spreadsheet and data analysis was performed using Microsoft Excel (Microsoft, Redmond, WA). Graphs were created using SigmaPlot 10.0 (Systat Inc. San Jose, CA) and Microsoft Excel, and maps were created using ArcGIS (ESRI, Redlands, CA).

Based on ranking monitoring sites relative to water quality results for the five parameters, certain streams were selected for more detailed investigation. We used ArcGIS to produce maps showing land use and topography in the vicinity of these streams and monitoring sites, and indicating water quality at the sites using color-coded symbols.

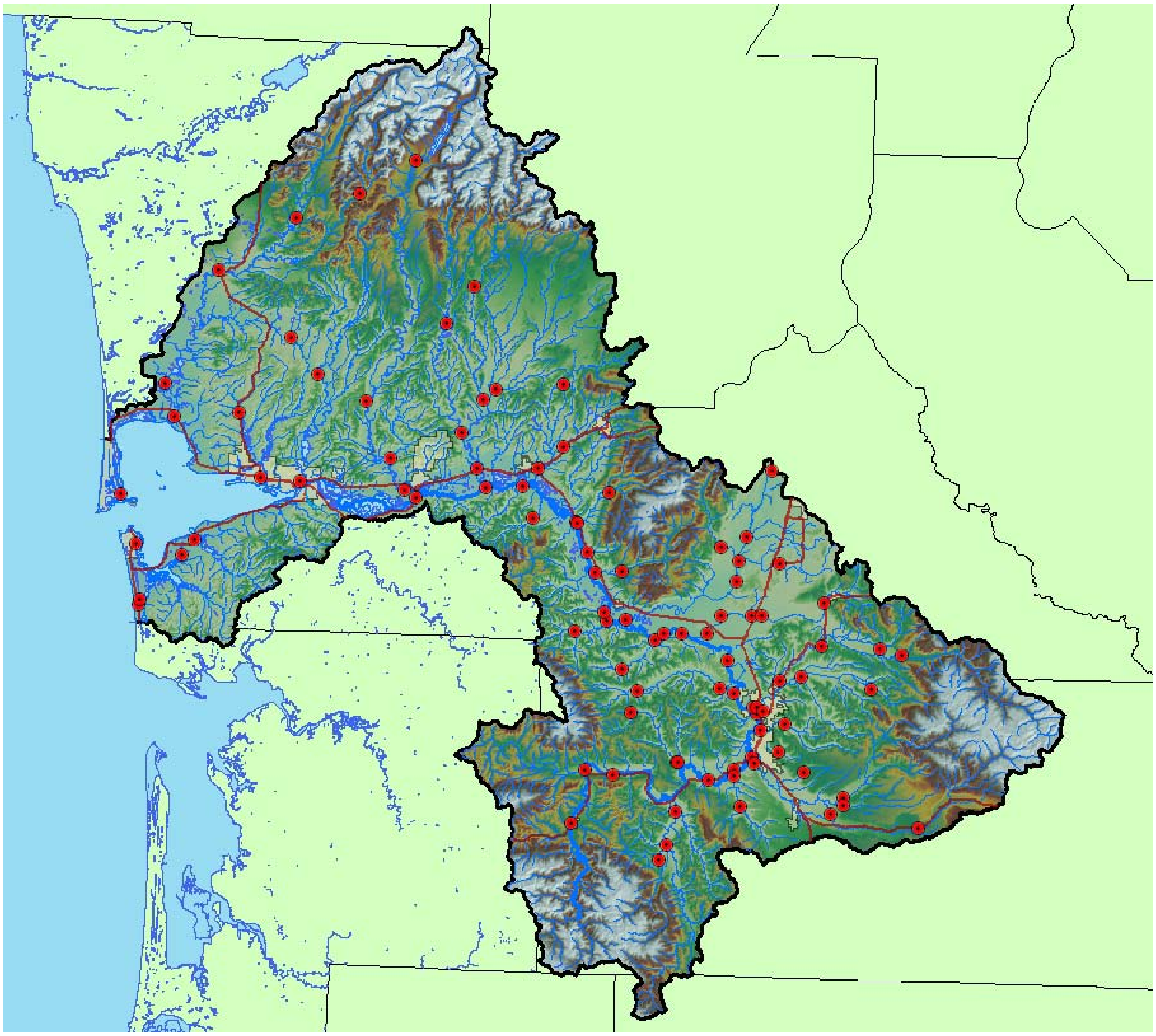


Figure 2. Water quality monitoring sites throughout the Chehalis Basin.

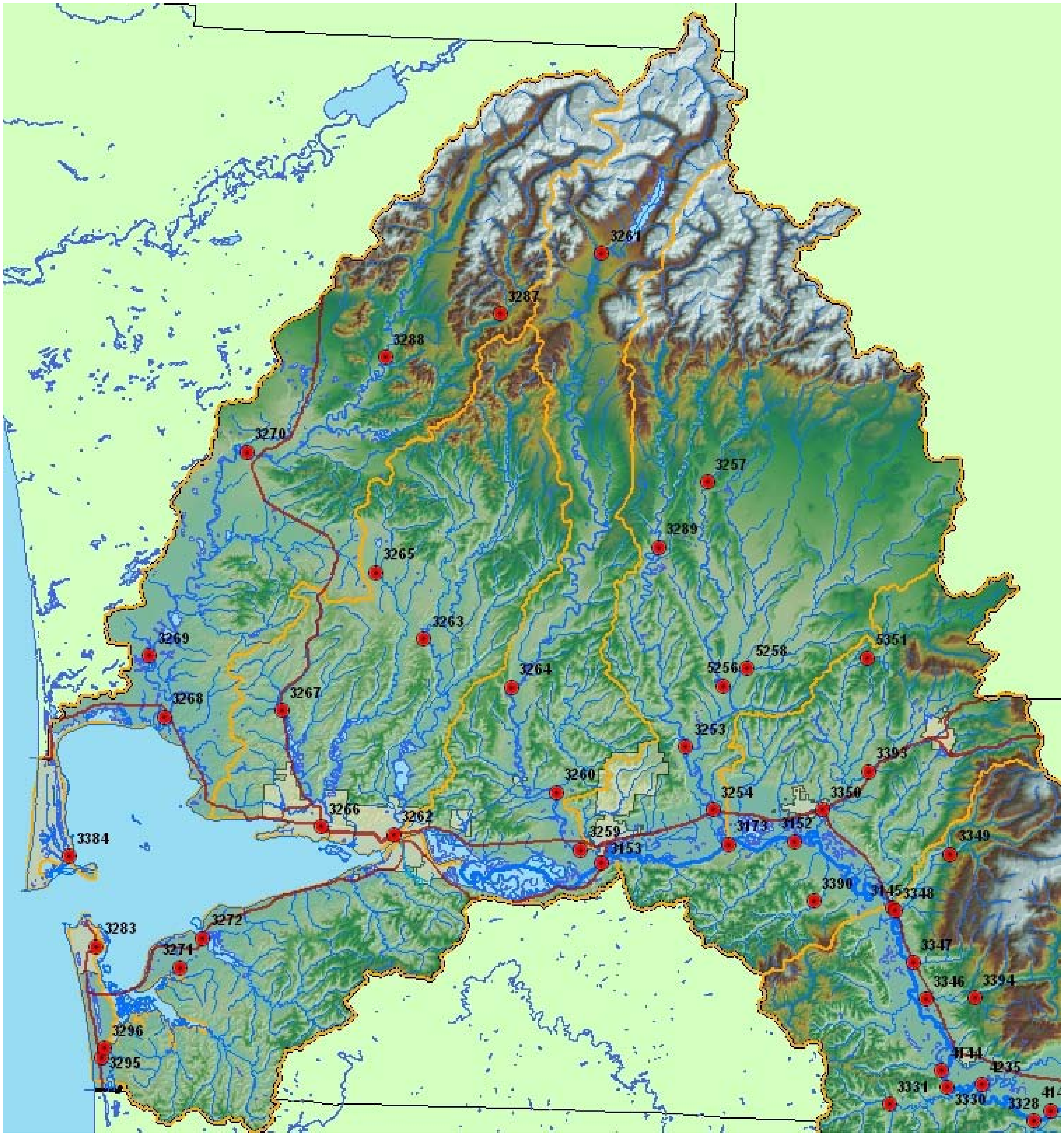


Figure 3. Monitoring sites in Watershed Resource Inventory Area 22 (WRIA 22).

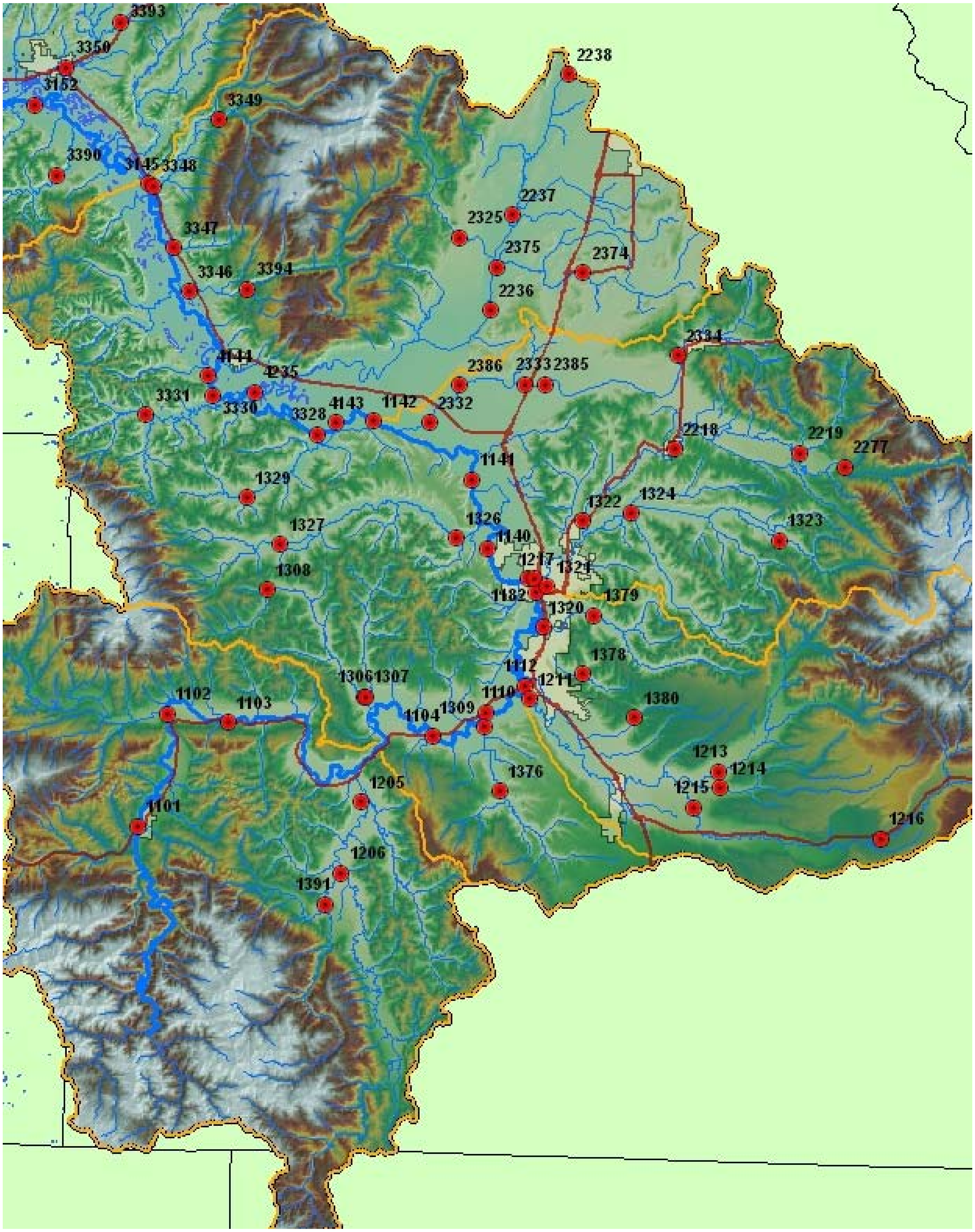


Figure 4. Monitoring sites in Watershed Resource Inventory Area 23 (WRIA 23).

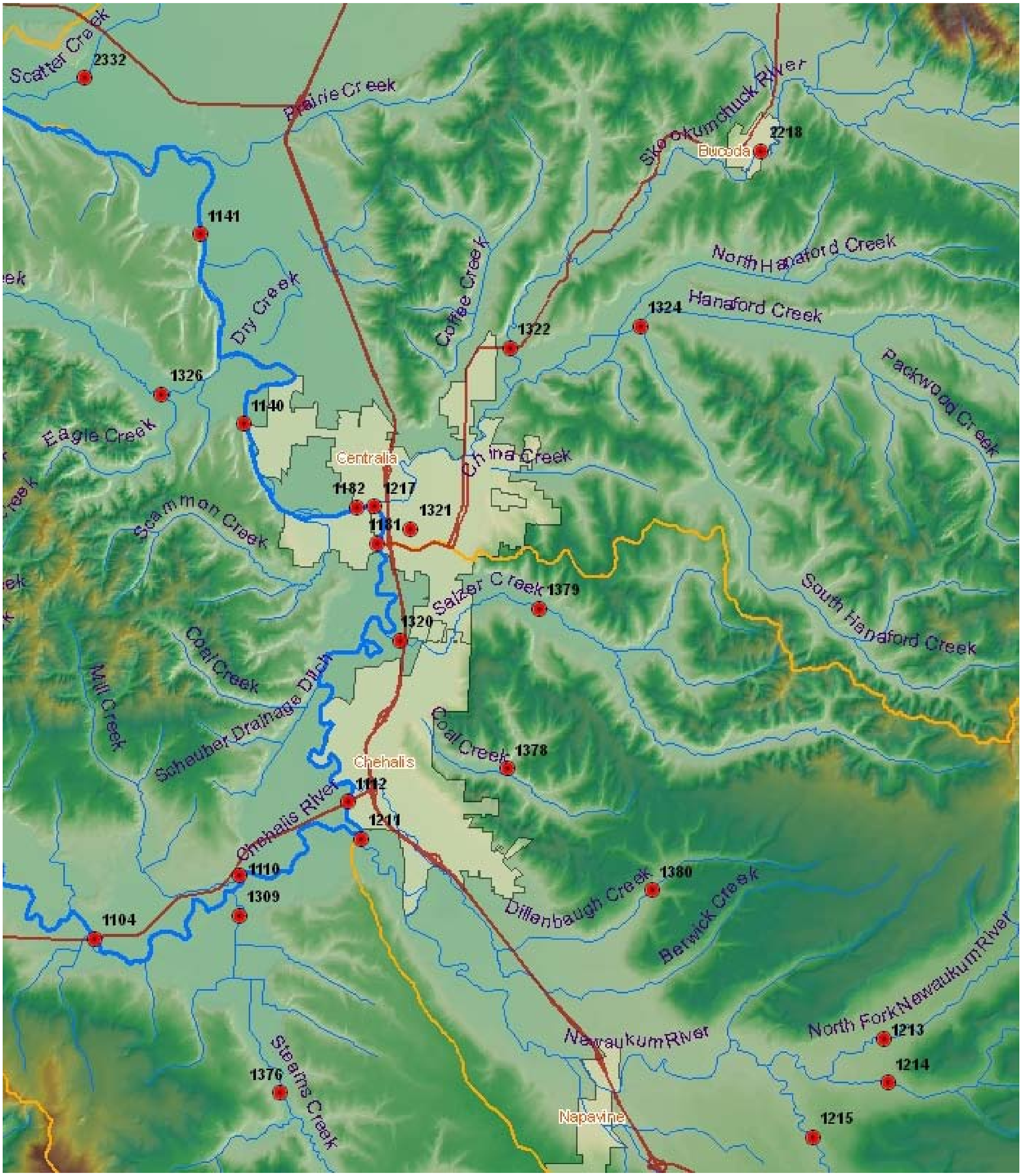


Figure 5. Monitoring sites in the Chehalis-Centralia area.

Water Quality Standards

Washington State water quality standards (generated by the Washington Dept. of Ecology) are described in detail in the Water Quality Standards for Surface Waters of the State of Washington Chapter 173-201A WAC (Wash. Dept. of Ecology, 2006). For the purposes of this study, the numerical criteria used were the same as the Washington State standards (see Tables 2 and 3). However, standards used here differ from State standards in that for this study, samples were collected once per month, and these monthly data were compared to the numerical criteria. Determination of values such as “lowest 1-day minimum” and “geometric mean” necessary for determining compliance under 173-201A WAC requires more frequent collection of samples, and is normally implemented at a specific project site. For this large scale monitoring project with 94 sample sites and monthly sample collections, comparison of monthly data to numerical criteria was most practical and useful. To assess dissolved oxygen, turbidity, and fecal coliform, data was compared to two standards representing uses of water that require high water quality (e.g. salmonid spawning, rearing and migration) and/or extraordinary water quality (e.g., oyster culture). Details on each parameter follow.

pH

The standard for pH was the range 6.5 to 8.5, with values falling outside of that range not meeting the standard. This standard has the same numerical criteria as Washington Water Quality Standards. It is also the optimum pH range for fish. Acidic water with pH values below 4.8 or alkaline water above 9.2 can injure or kill salmon and trout (Svobodová et al., 1993). PH was measured on-site.

Dissolved Oxygen

The standards for dissolved oxygen were 8 mg/L (high water quality) and 9.5 mg/L (extraordinary water quality). The 8mg/L standard is defined in 173-201A WAC as a level needed to provide for salmonid spawning, rearing, and migration. The 9.5 mg/L standard is defined as the level of dissolved oxygen needed to provide for char spawning and rearing. Both standards were used to evaluate all sites.

Fecal Coliform

The standards for fecal coliform were 100 colonies/100 ml (high water quality) and 50 colonies/100 ml (extraordinary water quality). The 100 colonies/100 ml standard is defined in 173-201A WAC as a level needed to provide for primary contact recreation, such as swimming, water skiing, kayaking, etc. The 50 colonies/100 ml standard is defined as a level needed for extraordinary water quality, such as waters flowing into shellfish beds that will be harvested. For the purposes of this study, both standards were used to evaluate all sites. As samples were collected only once per month, it can be assumed that at other times of the month, values were both higher and lower than the sample values. Therefore, frequency of sample fecal coliform levels exceeding 50 colonies/100 ml at monitoring sites provides a means of prioritizing sites for further investigation.

Turbidity

The standards for turbidity were 5 Nephelometric Turbidity Units (NTUs) above background (for salmon spawning) or 10 NTUs above background level (for salmon migration and rearing).

When evaluating impacts of a particular activity at a specific location on water quality, the background turbidity level is considered the natural turbidity in the absence of that activity, usually measured upstream of the activity. For this study, the background level was designated as the 35^{th} percentile of all turbidity measurements, or 2 NTU. Therefore, the standard for extraordinary water quality was 7 NTU, and the standard for high water quality was 12 NTU. These standards are not regulatory, they simply provides a basis for comparison of monitoring sites within the Chehalis River basin.

Temperature

Temperature conditions in streams of the Chehalis River basin were evaluated by season, to determine effects on habitat suitability for salmonid fishes (Table 3). We employed four standards: 1) temperature for char spawning, 2) temperature for char rearing, 3) temperature for salmon and trout spawning, and 4) core summer salmonid habitat (Table 3). As char primarily spawn from late August through November, the char spawning period was defined as Sept. 1 through November 30 for this study. Char rearing was evaluated for the entire sampling period of the study. The salmon and trout spawning period was defined as Sept. 1 to May 31. This differed from the period defined in 173-201A WAC (Sept. 15 to May 15) due to the need to maintain consistency with other aspects of the study; water samples were collected once per month, and therefore it was important to begin and end sampling periods at the beginning or end of months. The core summer salmonid habitat period was defined as June 1 to August 31.

Table 2. Summary of Washington State standards for surface water quality parameters dissolved oxygen, turbidity, pH, and fecal coliform. The numerical values of these standards were used as criteria in this study. Standards include two levels of protection that are intended to protect waters of high or extraordinary quality. The most restrictive standards are described as “high” and the least restrictive standards as “low”.

Parameter	High Standards	Description	Low Standards	Description
Dissolved Oxygen	**9.5** mg/L	Lowest 1-day minimum to protect char spawning and rearing	**8** mg/L	Lowest 1-day minimum to protect salmonid spawning, rearing and migration
Turbidity	**5** NTU Increase above background	To protect salmon spawning	**10** NTU Increase above background	To protect salmon migration and rearing
pH	**6.5** to **8.5**	To protect salmon spawning, rearing and migration	*Same*	*Same*
Fecal Coliform	**50** colonies/100 ml	Max. geometric mean, to protect for extraordinary water quality (e.g. streams flowing toward shellfish beds)	**100** colonies/100 ml	Maximum geometric mean, to protect for primary contact recreation

Table 3. Standards used to assess temperature conditions at sample sites. Categories and numerical criteria are the same as in Washington State standards, but time frames were adjusted to suit the purposes of this study (see text).

Category	Temperature	Time Period Sampled
Char spawning	9ºC (48.2ºF)	Sept. 1, 2007 – Nov. 30, 2007 Sept. 1, 2008 – Nov. 30, 2008
Char rearing	12ºC (54.6ºF)	Aug. 1 2007 – June 30, 2009
Salmon & Trout Spawning	13ºC (55.4ºF)	Sept. 1, 2007 – May 31, 2008 Sept. 1, 2008 – May 31, 2009
Core Summer Salmonid Habitat	16ºC (60.8ºF)	June 1 2007 – August 31, 2007 June 1 2008 – August 31, 2008

Relative Ranks

Relative ranks were determined by identifying the percentage of samples collected at a given site that did not meet water quality criteria for each parameter (Tables 2 and 3). Relative ranks are presented in graphs, tables, and maps. Graphic representation depicts sites according to their respective relative rank. Geographic data presentation was conducted by Don Loft, Water Quality/GIS Technician at Grays Harbor College. Each site (based on site number) was assigned a data point feature that corresponded with its latitude-longitude coordinates. Points were plotted on a Chehalis Basin hydrology GIS layer (Wash. Dept. of Ecology 100,000:1 scale). Individual data points were then color-coded based on relative rank values using a color ramping program. Points were coded such that sites that failed to meet water quality criteria most frequently were marked as bright red, and those that failed to meet water quality criteria least frequently were marked as purple, while intermediates sites were shaded in transition.

Quality Assurance/Quality Control

Calibration

All calibrations for laboratory and field analyses were performed as described in the QAPP. In the event of instrument malfunction (e.g., inability to effectively calibrate), samples were not collected. Frequency of field instrument calibration varied depending on the parameter measured and ranged from once each week to once every two weeks.

Replicate and Control Sample Analysis

Not all replicate and blank samples described in the QAPP were consistently collected and analyzed, thus making the assessment of the QA/QC goals for precision, bias and sensitivity described in the QAPP difficult. For fecal coliform, results from replicate and control sample analysis were consistent with quality goals described in the QAPP, suggesting limited potential for laboratory contamination. However, field blanks were not consistently collected and analyzed and thus, potential for field contamination cannot be effectively calculated. Similarly, replicates and/or positive and negative controls were not consistently analyzed using *in situ* monitoring instruments and thus, precision, bias and sensitivity cannot be effectively calculated.

Field measurements were not independently verified using a second analytical method. Outlier data points (i.e., data outside of the 20% long-term average) were not independently re-analyzed.

Trend Analysis

Temporal trend analysis also highlighted a QA/QC problem with the pH and dissolved oxygen data. When data was graphed by date, it was apparent that during some periods pH was more greatly influenced by date than by location (several sites showing low pH on specific dates or date ranges, and high pH on other dates or date ranges). The same phenomenon was also noted for dissolved oxygen. The strength and pattern of this correlation suggested that it resulted from instrument malfunction. pH and dissolved oxygen data collected during dates and date ranges when instrument malfunction apparently influenced results were excluded from further analysis and presentation. Complete description of the data editing process is described in Appendix 1.

Results and Discussion

Water quality throughout the Chehalis Basin varied widely depending on site, parameter and time of year. Site-specific, temporal and geographic trends are described below as they correspond to specific parameters.

Monitoring Results for pH

During the period September 24, 2007 to June 30, 2009, pH in sample streams of the Chehalis River basin fell within the range of 6.5 to 8.5, with the exception of four samples collected over the 21-month period (Figure 6). These few cases when pH fell below 6.5 were at different sites, indicating that no site had a consistent tendency toward low pH (Figures 7 and 8). These results suggest that in the streams monitored within the Chehalis Basin, pH was within the acceptable range for the duration of the sampling period September 24, 2007 to June 30, 2009, with few exceptions. Distribution of fish and other aquatic life is therefore probably not limited by pH within the monitored streams.

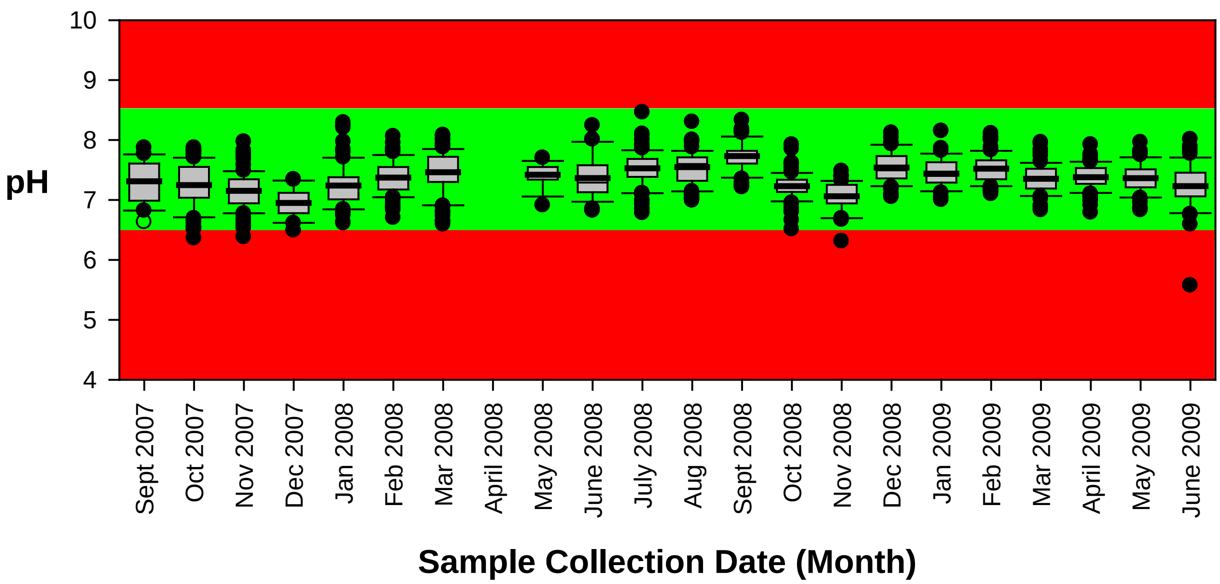


Figure 6. pH measured at all sites throughout the Chehalis River basin from September 2007 through June 2009. Thin horizontal lines indicate the medians, thick horizontal lines indicate the means, box plots encompass values between the 25th and 75th percentiles, and whiskers show 10th and 90th percentiles. Outliers below the 10th percentile or above the 90th percentile are indicated by black dots. The green area of the graph background indicates the pH range between 6.5 and 8.5 (meeting water quality criteria), and the red areas are outside of that range.

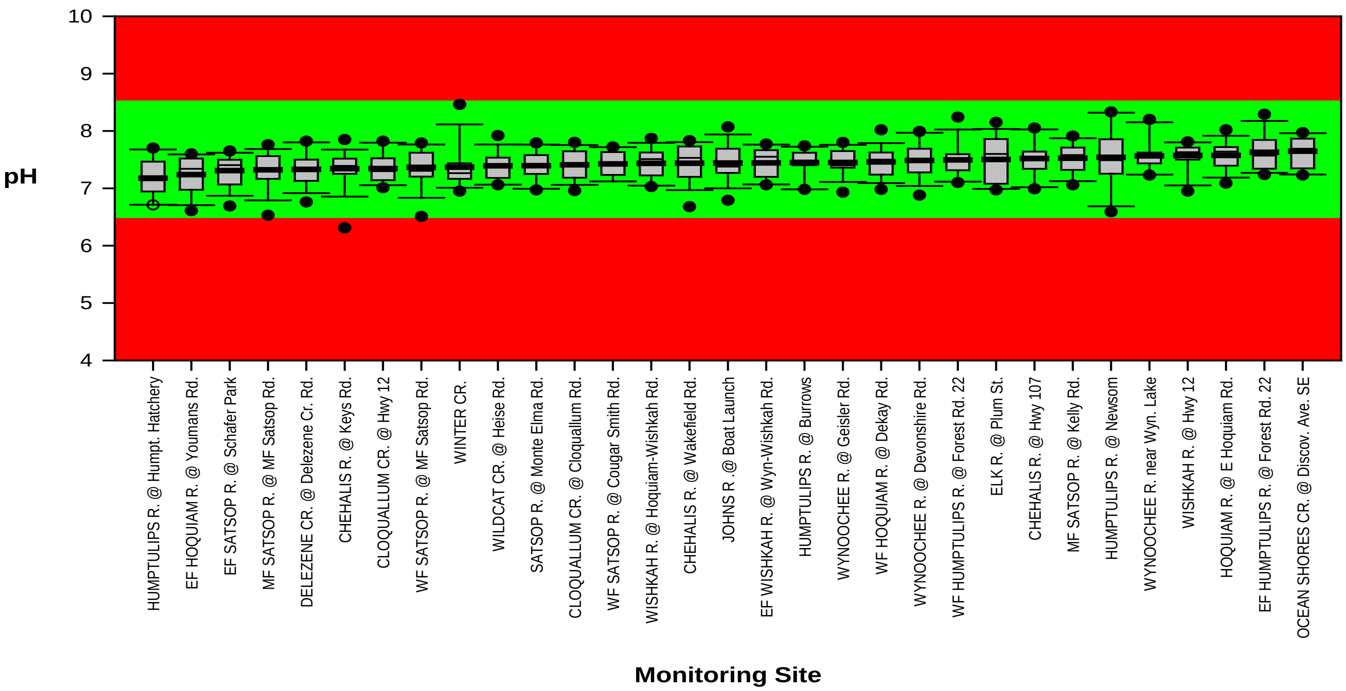


Figure 7. pH at monitoring sites in WRIA 22. Box plots as described in the caption for Figure 6.

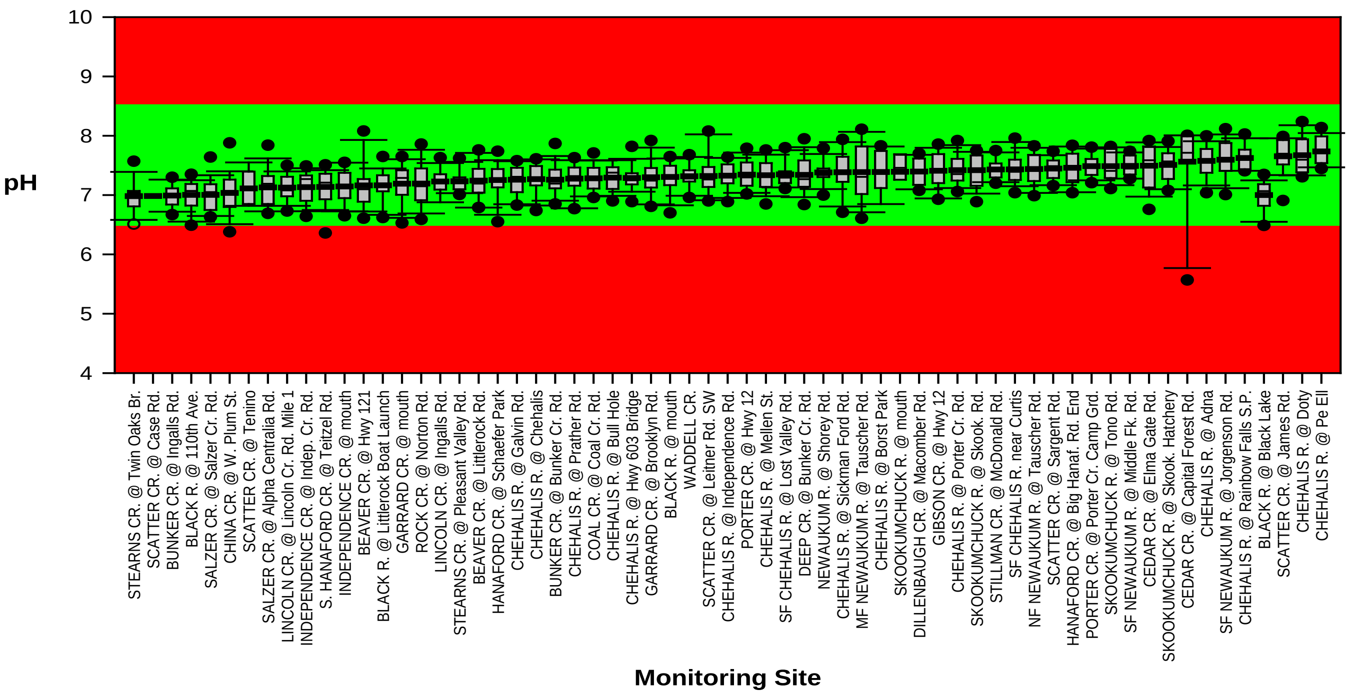


Figure 8. pH at monitoring sites in WRIA 23. Box plots as described in the caption for Figure 6.

Monitoring Results for Dissolved Oxygen

The average dissolved oxygen (DO) concentration observed throughout all months of sampling was 10.9 mg/L. Maximum DO concentrations were present during winter months and minimum concentrations during summer months (Figure 9). The very high DO levels during the winter of 2007-2008, with many values over 14 mg/L, may have been an artifact of meter malfunction or calibration problems. Values this high are generally unusual and are not likely to have occurred in a majority of sites, as was recorded in some months. Overall, 87% of samples contained higher than 8 mg/L dissolved oxygen (13% less than 8 mg/L), and 71% of samples contained higher than 9.5 mg/L dissolved oxygen (29% less than 9.5 mg/l). At five sites throughout the Chehalis River basin, more than 35% of samples contained less than 8 mg/L (Figure 10). Specific results for WRIA 22 and WRIA 23 are discussed below.

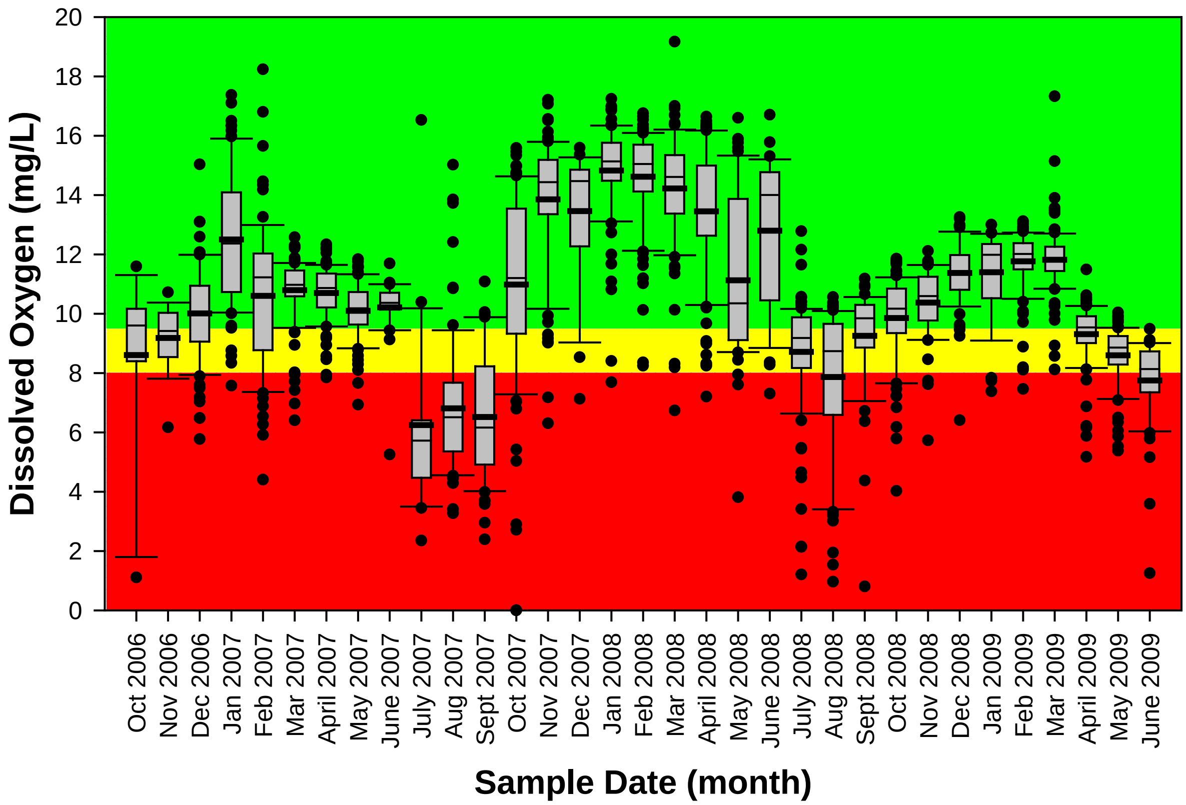


Figure 9. Dissolved oxygen concentration measured at all sites throughout the Chehalis River basin from October 2006 through June 2009. Box plots as described in the caption for Figure 6.

WRIA 22

At all monitoring sites on Humptulips River, Johns River, Elk River, Wildcat Creek, and tributaries of these streams, more than 95% of samples contained dissolved oxygen exceeding 8 mg/L (Figures 10, 11, and 12, Table 4). At seven of these sample sites, dissolved oxygen concentration in samples never fell below 8 mg/L. The sample site at Winter Creek (Site #3283) in Westport had the lowest dissolved oxygen levels in WRIA 22, with 65% of the samples below 8 mg/L, and average measured dissolved oxygen of 6.9 mg/L.

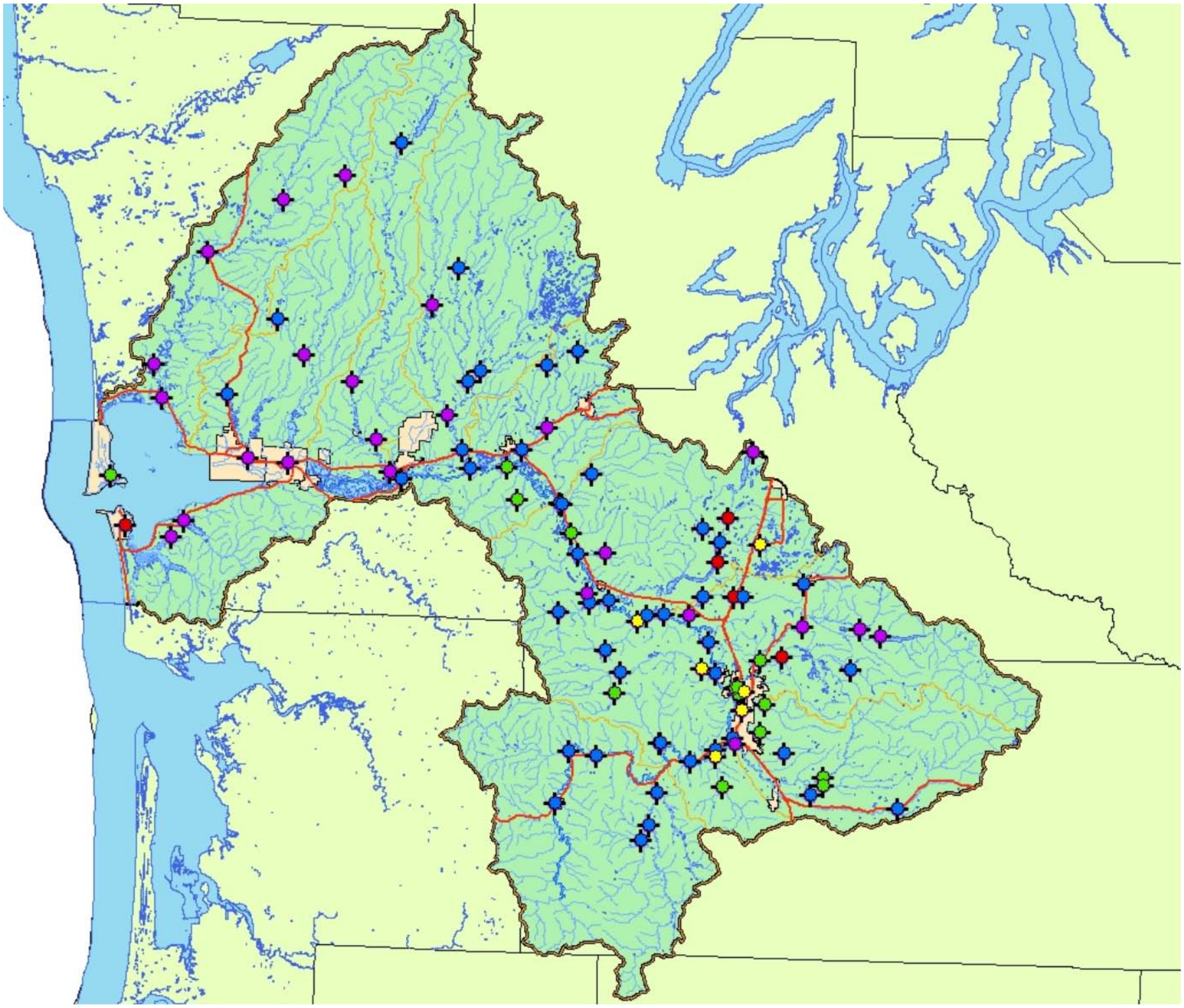


Figure 10. Map showing results of dissolved oxygen monitoring in the Chehalis Basin. Sites are ranked by the percentage of samples that contained less than 8 mg/L dissolved oxygen. Monitoring sites with consistently high dissolved oxygen (less than 5% of samples below 8 mg/L) are indicated by purple dots, and sites where 35% or more of samples had less than 8 mg/L are indicated by red dots.

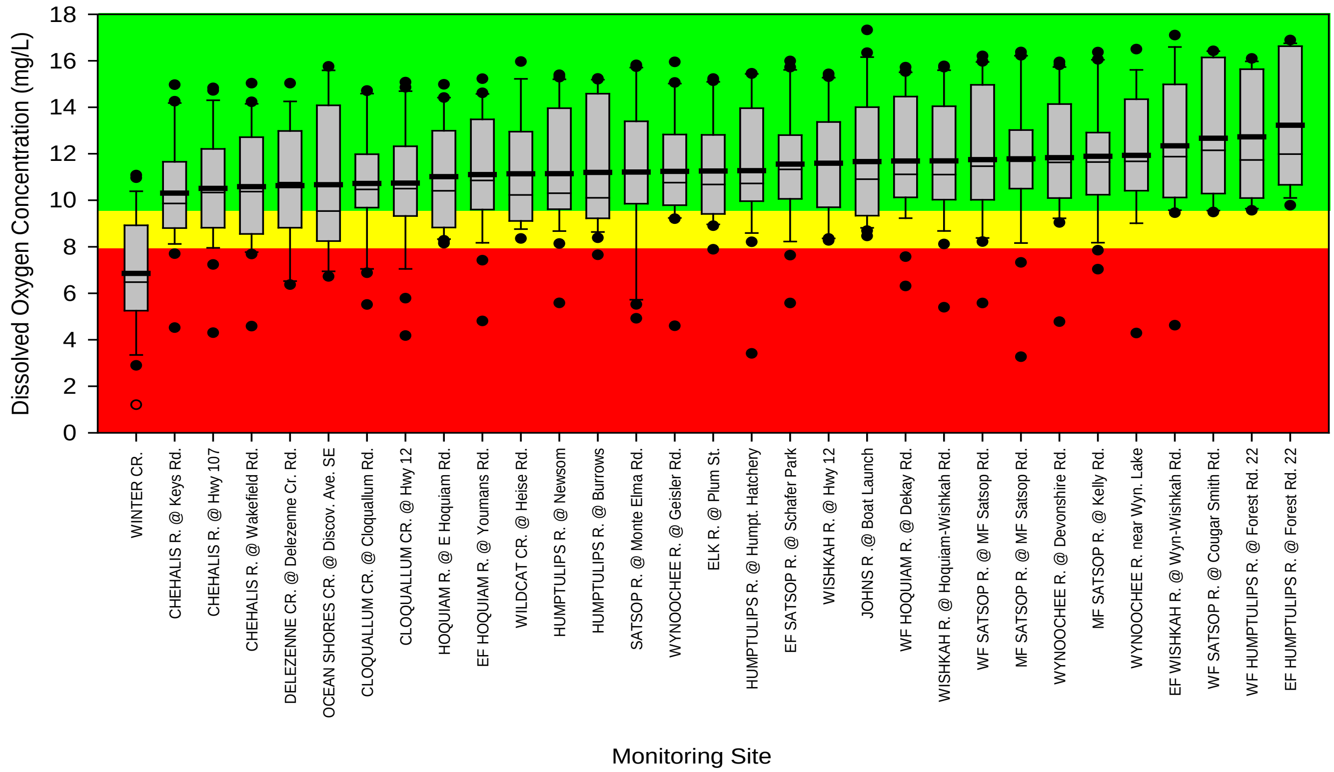


Figure 11. Dissolved oxygen at monitoring sites in WRIA 22. Box plots as described in the caption for Figure 6.

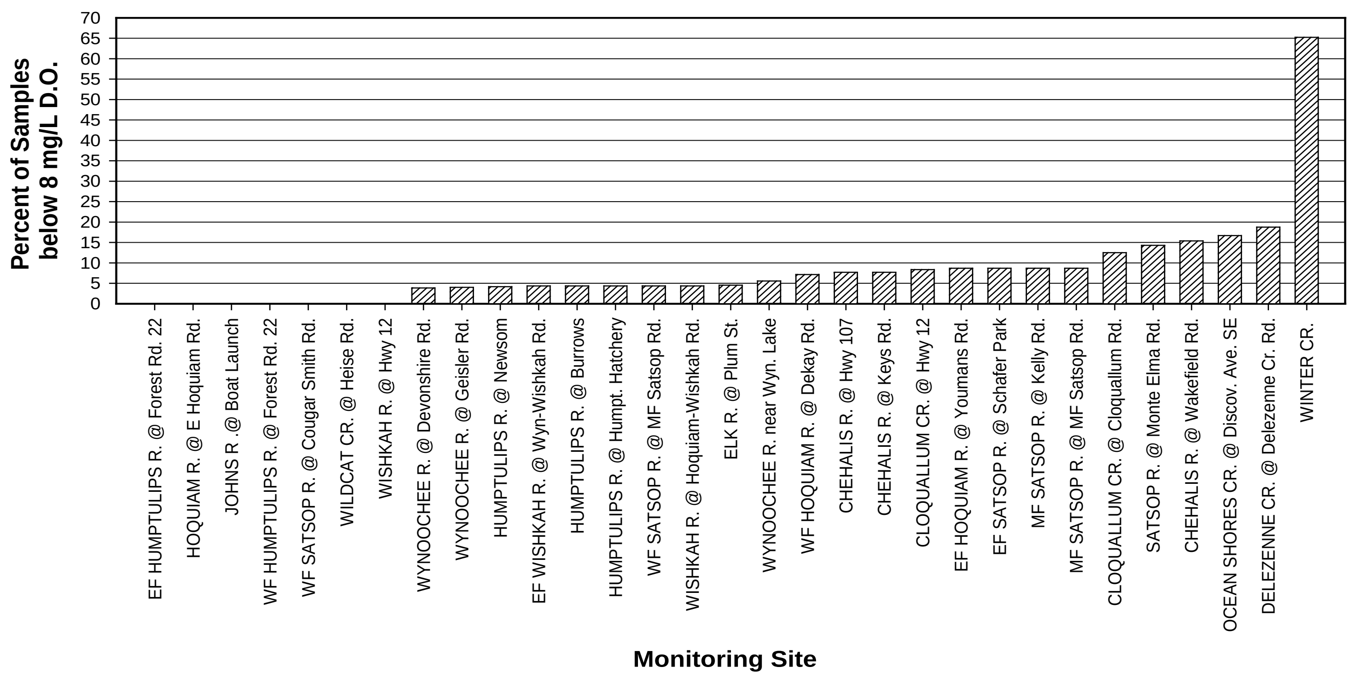


Figure 12. Monitoring sites in WRIA 22 ranked for percent samples that had dissolved oxygen concentration of less than 8.0 mg/L over the period October 18, 2006 to June 30, 2009.

Table 4. Monitoring sites in WRIA 22 ranked for percent samples that had dissolved oxygen concentration of less than 8.0 mg/L over the period October 18, 2006 to June 30, 2009.

Site #	Site Location	Records	# < 8 mg/L	% Rank
3262	WISHKAH R. @ Hwy 12	20	0	0.0
3266	HOQUIAM R. @ E Hoquiam Rd.	22	0	0.0
3272	JOHNS R .@ Boat Launch	25	0	0.0
3287	EF HUMPTULIPS R. @ Forest Rd. 22	16	0	0.0
3288	WF HUMPTULIPS R. @ Forest Rd. 22	15	0	0.0
3289	WF SATSOP R. @ Cougar Smith Rd.	11	0	0.0
3393	WILDCAT CR. @ Heise Rd.	15	0	0.0
3259	WYNOOCHEE R. @ Devonshire Rd.	26	1	3.8
3260	WYNOOCHEE R. @ Geisler Rd.	25	1	4.0
3269	HUMPTULIPS R. @ Newsom	24	1	4.2
3253	WF SATSOP R. @ MF Satsop Rd.	23	1	4.3
3263	WISHKAH R. @ Hoquiam-Wishkah Rd.	23	1	4.3
3264	EF WISHKAH R. @ Wyn-Wishkah Rd.	23	1	4.3
3268	HUMPTULIPS R. @ Burrows	23	1	4.3
3270	HUMPTULIPS R. @ Humpt. Hatchery	23	1	4.3
3271	ELK R. @ Plum St.	22	1	4.5
3261	WYNOOCHEE R. near Wyn. Lake	18	1	5.6
3267	WF HOQUIAM R. @ Dekay Rd.	28	2	7.1
3153	CHEHALIS R. @ Hwy 107	26	2	7.7
3173	CHEHALIS R. @ Keys Rd.	26	2	7.7
3350	CLOQUALLUM CR. @ Hwy 12	24	2	8.3
3257	MF SATSOP R. @ Kelly Rd.	23	2	8.7
3265	EF HOQUIAM R. @ Youmans Rd.	23	2	8.7
5256	MF SATSOP R. @ MF Satsop Rd.	23	2	8.7
5258	EF SATSOP R. @ Schafer Park	23	2	8.7
5351	CLOQUALLUM CR. @ Cloquallum Rd.	24	3	12.5
3254	SATSOP R. @ Monte Elma Rd.	21	3	14.3
3152	CHEHALIS R. @ Wakefield Rd.	26	4	15.4
3384	OCEAN SHORES CR. @ Discov. Ave. SE	12	2	16.7
3390	DELEZENE CR. @ Delezene Cr. Rd.	16	3	18.8
3283	WINTER CR.	23	15	65.2

WRIA 23

Mean dissolved oxygen concentration was above 8 mg/L at all but one monitoring site in WRIA 23 (Figure 13). At all but 10 sites, the lower 25th percentile was also above 8 mg/L, meaning that at least 75% of the samples at most sites were above this threshold level. For all sample sites on Cedar Creek and the Skookumchuck River, more than 95% of samples contained dissolved oxygen exceeding 8 mg/L (Figures 13 and 14, Table 5). There were two sites in WRIA 23 where dissolved oxygen concentration in samples never fell below 8 mg/L, Site 3394 (Cedar Creek at Capital Forest Road), and Site 4144 (Chehalis River at Sickman Ford Road).

At four sites in WRIA 23, dissolved oxygen concentration was less than 8 mg/L in more than 35% of the samples: Site 2236 (Black River at Littlerock Boat Launch), Site 2237 (Black River at 110th Ave), Site 2333 (Scatter Creek at Case Road), and Site 1324 (South Hanaford Creek at Teitzel Road), (Figures 13 and 14, Table 5). There were several sites along the Chehalis River and its tributaries in the vicinity of Chehalis and Centralia where 15-35% of samples had dissolved oxygen below 8 mg/L (Figures 10 and 14, Table 5).

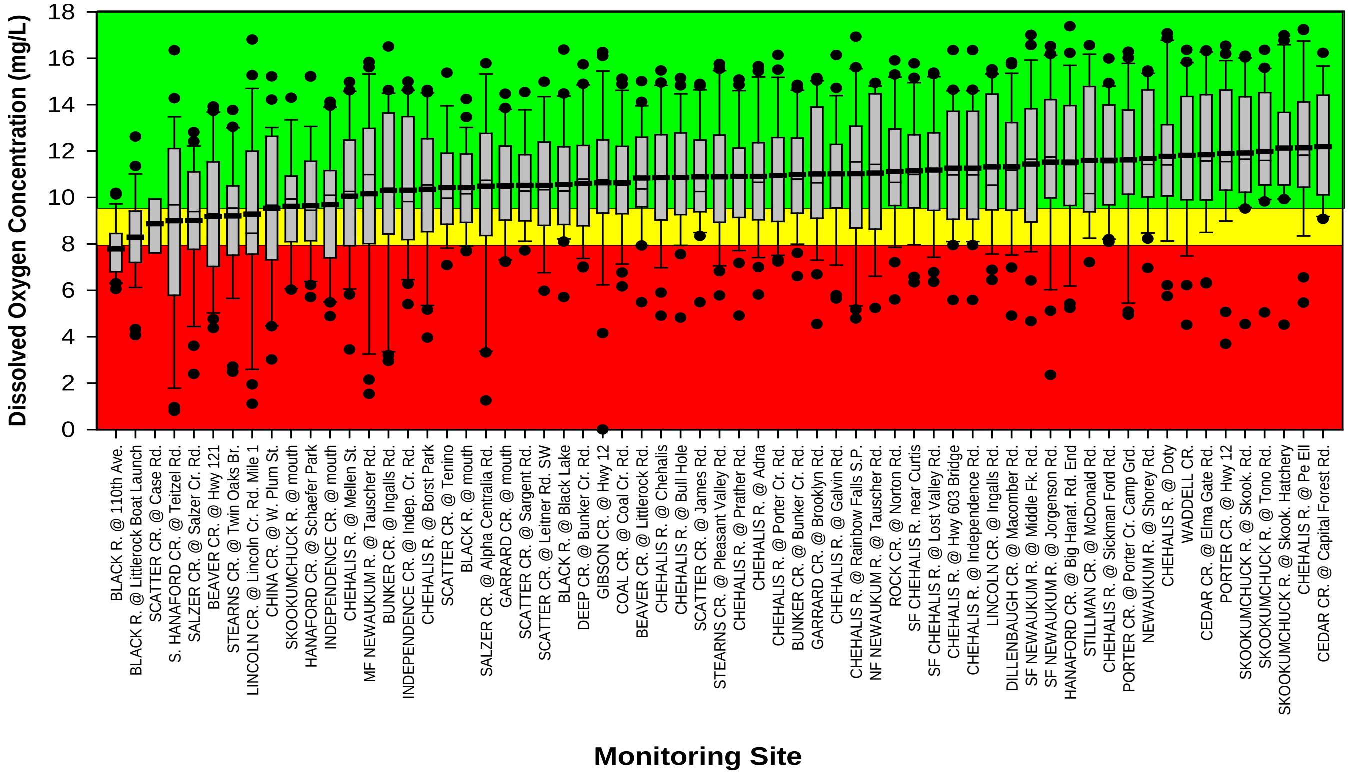


Figure 13. Dissolved oxygen at monitoring sites in WRIA 23. Box plots as described in the caption for Figure 6.

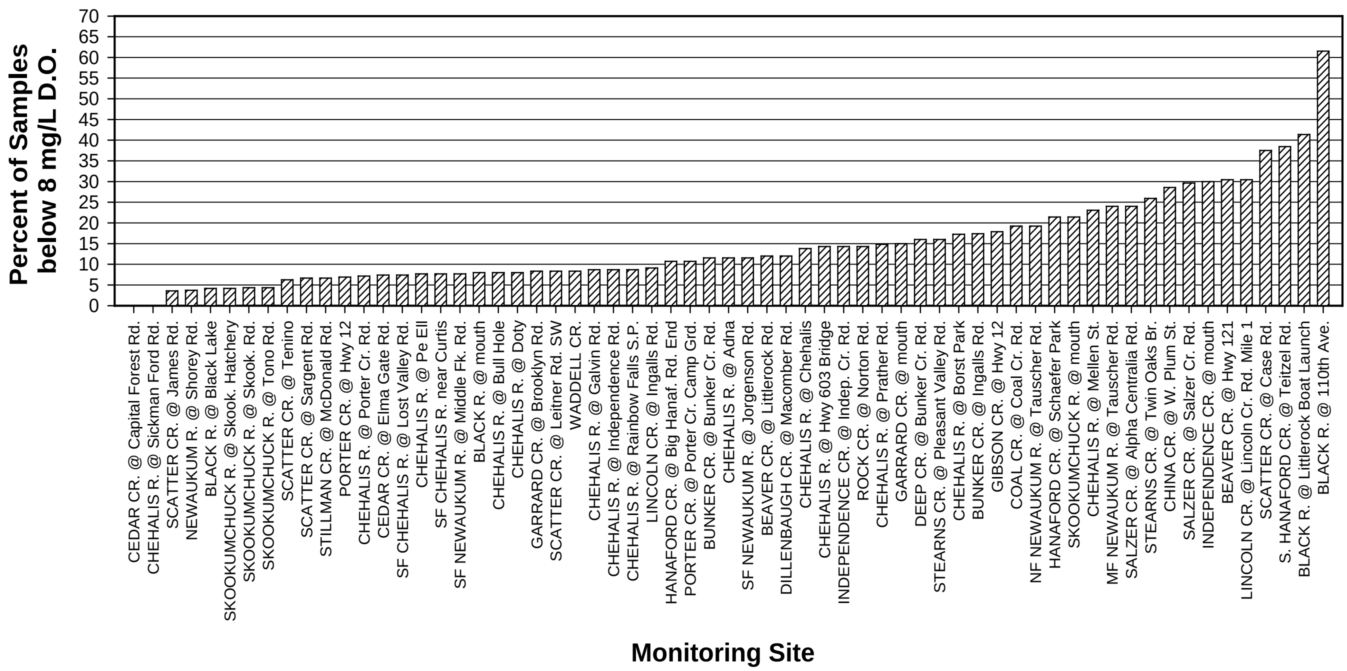


Figure 14. Monitoring sites in WRIA 23 ranked for percent samples that had dissolved oxygen concentration of less than 8.0 mg/L over the period October 18, 2006 to June 30, 2009.

Table 5. Monitoring sites in WRIA 23 ranked for percent samples that had dissolved oxygen concentration of less than 8.0 mg/L over the period October 18, 2006 to June 30, 2009.

Site #	Site Location	Records	# < 8 mg/L	% < 8 mg/L
3394	CEDAR CR. @ Capital Forest Rd.	13	0	0.0
4144	CHEHALIS R. @ Sickman Ford Rd.	21	0	0.0
2332	SCATTER CR. @ James Rd.	28	1	3.6
1211	NEWAUKUM R. @ Shorey Rd.	27	1	3.7
2238	BLACK R. @ Black Lake	24	1	4.2
2277	SKOOKUMCHUCK R. @ Skook. Hatchery	24	1	4.2
2218	SKOOKUMCHUCK R. @ Tono Rd.	23	1	4.3
2219	SKOOKUMCHUCK R. @ Skook. Rd.	23	1	4.3
2334	SCATTER CR. @ Tenino	16	1	6.3
1391	STILLMAN CR. @ McDonald Rd.	15	1	6.7
2386	SCATTER CR. @ Sargent Rd.	15	1	6.7
3348	PORTER CR. @ Hwy 12	29	2	6.9
3145	CHEHALIS R. @ Porter Cr. Rd.	28	2	7.1
1206	SF CHEHALIS R. @ Lost Valley Rd.	27	2	7.4
3346	CEDAR CR. @ Elma Gate Rd.	27	2	7.4
1101	CHEHALIS R. @ Pe Ell	26	2	7.7
1205	SF CHEHALIS R. near Curtis	26	2	7.7
1215	SF NEWAUKUM R. @ Middle Fk. Rd.	26	2	7.7
1102	CHEHALIS R. @ Doty	25	2	8.0
4143	CHEHALIS R. @ Bull Hole	25	2	8.0
4235	BLACK R. @ mouth	25	2	8.0
2325	WADDELL CR.	24	2	8.3
2385	SCATTER CR. @ Leitner Rd. SW	12	1	8.3
3331	GARRARD CR. @ Brooklyn Rd.	24	2	8.3
1103	CHEHALIS R. @ Rainbow Falls S.P.	23	2	8.7
1140	CHEHALIS R. @ Galvin Rd.	23	2	8.7
1142	CHEHALIS R. @ Independence Rd.	23	2	8.7
1327	LINCOLN CR. @ Ingalls Rd.	22	2	9.1
1323	HANAFORD CR. @ Big Hanaf. Rd. End	28	3	10.7
3349	PORTER CR. @ Porter Cr. Camp Grd.	28	3	10.7
1104	CHEHALIS R. @ Adna	26	3	11.5
1216	SF NEWAUKUM R. @ Jorgenson Rd.	26	3	11.5
1307	BUNKER CR. @ Bunker Cr. Rd.	26	3	11.5
1380	DILLENBAUGH CR. @ Macomber Rd.	25	3	12.0
2375	BEAVER CR. @ Littlerock Rd.	25	3	12.0
1112	CHEHALIS R. @ Chehalis	29	4	13.8
1110	CHEHALIS R. @ Hwy 603 Bridge	28	4	14.3
1329	INDEPENDENCE CR. @ Indep. Cr. Rd.	21	3	14.3
3392	ROCK CR. @ Norton Rd.	14	2	14.3
1141	CHEHALIS R. @ Prather Rd.	27	4	14.8
3330	GARRARD CR. @ mouth	20	3	15.0
1306	DEEP CR. @ Bunker Cr. Rd.	25	4	16.0
1376	STEARNS CR. @ Pleasant Valley Rd.	25	4	16.0

Table is continued on next page.

Table 5 continued from previous page.

Site #	Site Location	Records	# < 8 mg/L	% < 8 mg/L
1182	CHEHALIS R. @ Borst Park	29	5	17.2
1308	BUNKER CR. @ Ingalls Rd.	23	4	17.4
3347	GIBSON CR. @ Hwy 12	28	5	17.9
1213	NF NEWAUKUM R. @ Tauscher Rd.	26	5	19.2
1378	COAL CR. @ Coal Cr. Rd.	26	5	19.2
1217	SKOOKUMCHUCK R. @ mouth	14	3	21.4
1322	HANAFORD CR. @ Schaefer Park	28	6	21.4
1181	CHEHALIS R. @ Mellen St.	26	6	23.1
1214	MF NEWAUKUM R. @ Tauscher Rd.	25	6	24.0
1379	SALZER CR. @ Alpha Centralia Rd.	25	6	24.0
1309	STEARNS CR. @ Twin Oaks Br.	27	7	25.9
1321	CHINA CR. @ W. Plum St.	28	8	28.6
1320	SALZER CR. @ Salzer Cr. Rd.	27	8	29.6
3328	INDEPENDENCE CR. @ mouth	20	6	30.0
1326	LINCOLN CR. @ Lincoln Cr. Rd. Mile 1	23	7	30.4
2374	BEAVER CR. @ Hwy 121	23	7	30.4
2333	SCATTER CR. @ Case Rd.	8	3	37.5
1324	S. HANAFORD CR. @ Teitzel Rd.	26	10	38.5
2236	BLACK R. @ Littlerock Boat Launch	29	12	41.4
2237	BLACK R. @ 110th Ave.	26	16	61.5

The Black River and Scatter Creek: a Closer Look

As mentioned above, two monitoring sites on the Black River had a relatively high proportion of samples with dissolved oxygen below 8 mg/L. At Site 2237, 61.5% of the samples were below 8 mg/L, and at Site 2236, 41.4% were below 8 mg/L. The Black River is a relatively low gradient river (Figures 15 and 16). It flows from a pond, through agricultural land with a hardwood forest buffer for part of the length, through conifer forest, and then more agricultural land (Figure 16). Slow moving water exposed to sunlight is likely to have underwater vegetation and algae, particularly if there is a high nutrient input, which may result from fertilizers applied to adjacent agricultural land. Aquatic vegetation is apparent in a photo of the Black River from the Rochester-Grand Mound Communities Website (Figure 15). Slow-moving water may also have accumulations of organic debris, such as rotting leaves that fall from vegetation along the banks. Decomposing algae, aquatic vegetation, and organic debris in water bodies reduces the dissolved oxygen in the water, due to cellular respiration of the bacteria and fungi that are acting as decomposers. These are processes that may be contributing to lower dissolved oxygen in the Black River.

Figure 15. The Black River, in a photo from the Rochester-Grand Mound Communities Website. Note filamentous green algae and other aquatic vegetation in the foreground.

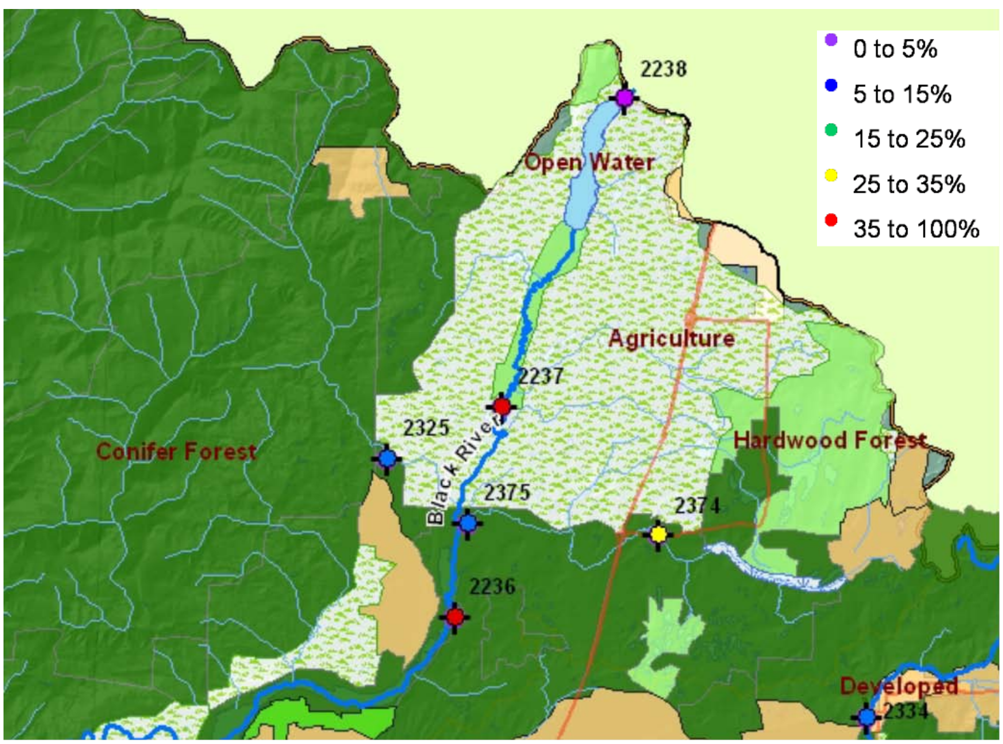


Figure 16. Land use and topography in the area of the Black River and Beaver Creek (Sites 2374 and 2375 are on Beaver Creek), and dissolved oxygen monitoring results. Sites were ranked based on the percent of samples that contained less than 8 mg/L dissolved oxygen.

South Hanaford Creek and Skookumchuck River: A Closer Look

At Site 1324 (South Hanaford Creek at Teitzel Road), 38.5% of the samples had dissolved oxygen below 8 mg/L. Upstream of the monitoring site, South Hanaford Creek flows through a non-forested low-gradient section (Figure 17). These conditions would allow for more growth of aquatic vegetation, due to slower moving water and sunlight reaching the water due to lack of shade. Decomposing aquatic vegetation could lead to lower dissolved oxygen levels.

In contrast to South Hanaford Creek, at three sites on the Skookumchuck River (2218, 2219, and 2277), dissolved oxygen levels were consistently high, and fell below 8 mg/L in only 4% of the samples (Table 5, Figure 17). The Skookumchuck River upstream of these monitoring sites flows through mainly conifer forest, with some mixed forest and agricultural land. It also receives flow from several tributaries that flow through conifer forest. Shade afforded by riparian (streamside) forest reduces sunlight penetration, and thereby reduces growth of aquatic vegetation and also keeps the water cool. These factors contribute to higher dissolved oxygen levels.

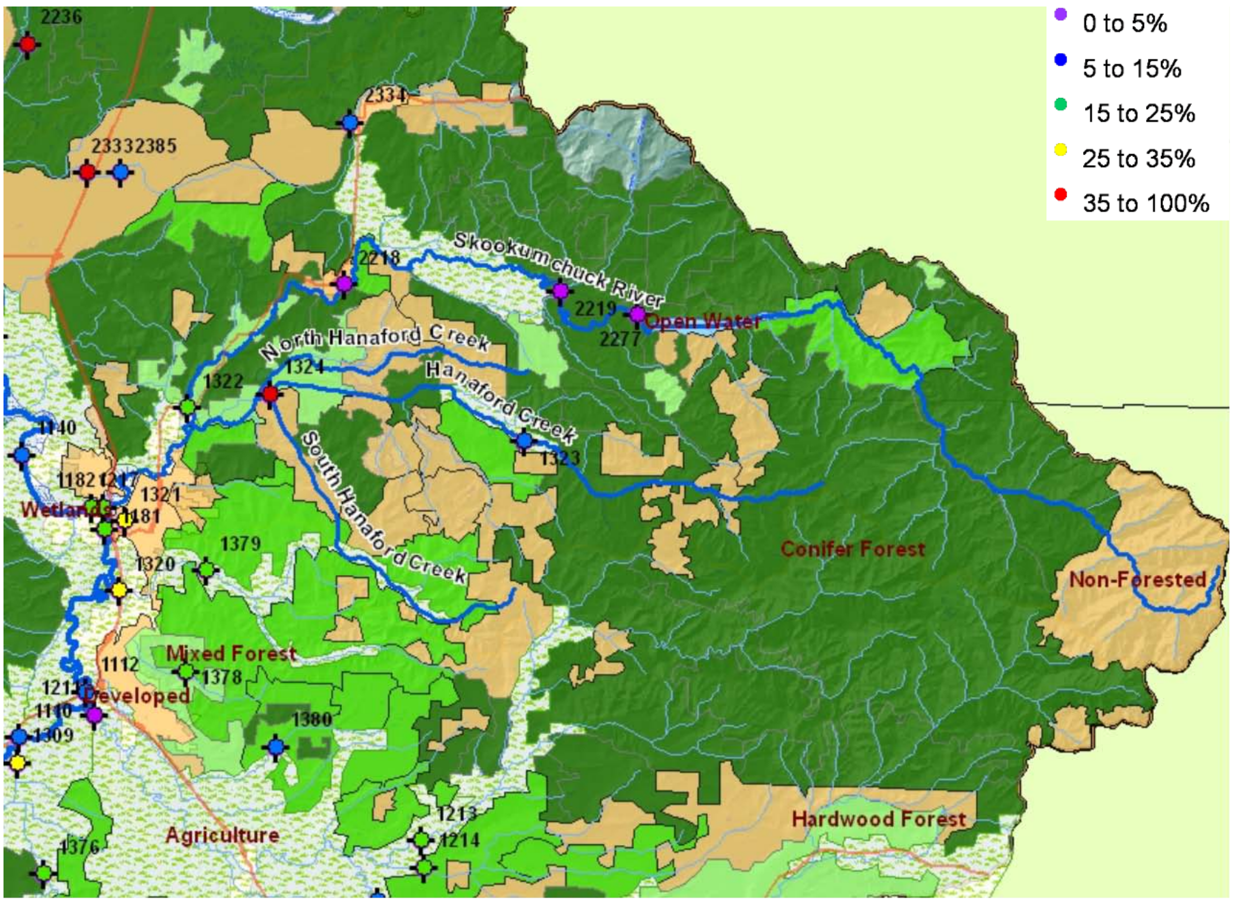


Figure 17. Land use and topography in the vicinity of Hanaford Creek and its branches, and the Skookumchuck River, and dissolved oxygen monitoring results. Sites were ranked based on the percent of samples that contained less than 8 mg/L dissolved oxygen.

Monitoring Results for Fecal Coliform

The average fecal coliform concentration observed throughout all months of sampling was 14 colonies/100ml. Fecal coliform concentrations ranged from the below detection limit (4 colonies/100 ml) to >2000 colonies/100 ml (maximum of numerable colonies) colonies/100ml. There was not a consistent seasonal pattern for fecal coliform (Figure 18). During this study, 2.6% of samples exceeded 50 colonies/100 ml, and 1.4% of samples exceeded 100 colonies/100 ml. Throughout the Chehalis Basin, there were 15 monitoring sites where more than 5% of the samples exceeded 50 colonies/100 ml (Figure 19). In Washington State Standards (173-201A WAC), 100 colonies/100 ml is the level specified to protect for primary contact recreation, and 50 colonies/100 ml is the level specified to protect for extraordinary primary contact recreation. In this study, we ranked sites based on the percentage of samples that exceeded 50 colonies/100 ml to provide a comparative indication of water quality. Details on WRIAs 22 and 23 are provided below.

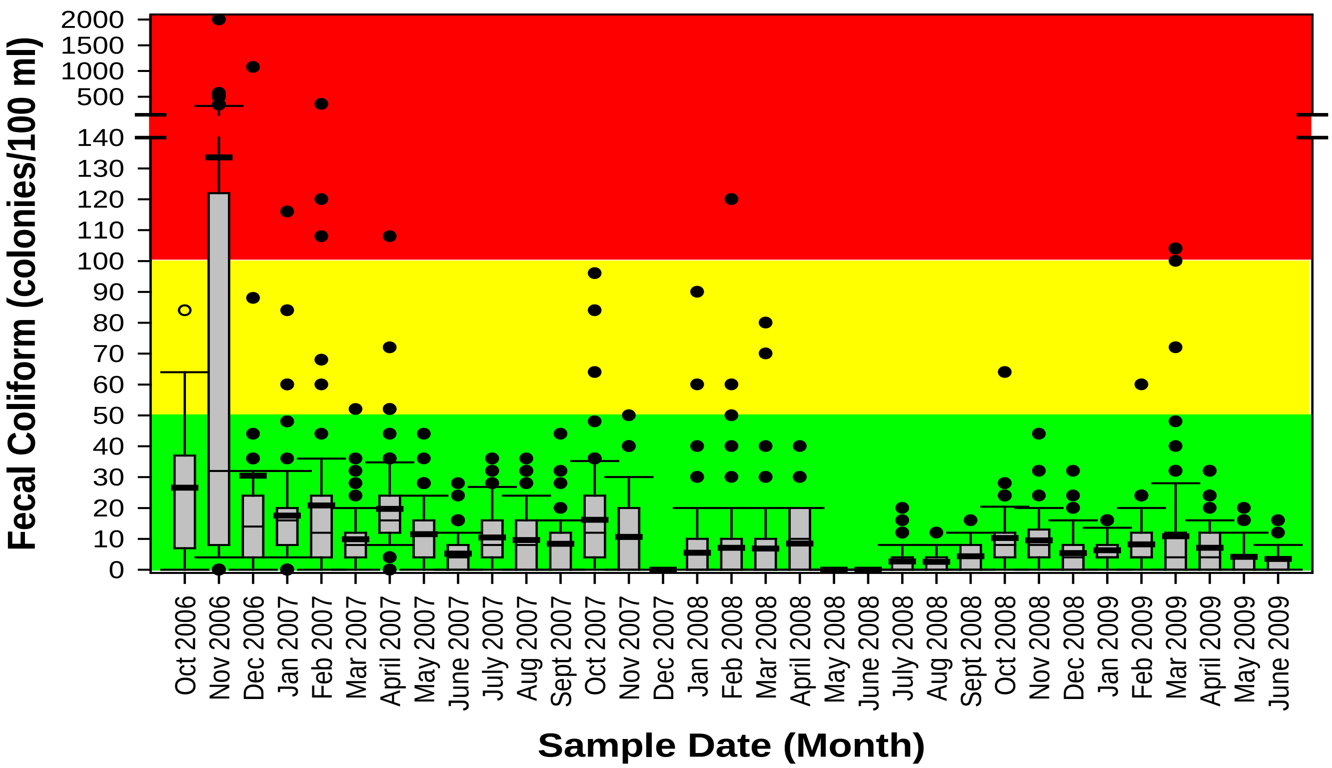


Figure 18. Fecal coliform measured at all sites throughout the Chehalis River basin from October 2006 through June 2009. Box plots as described in caption for Figure 6.

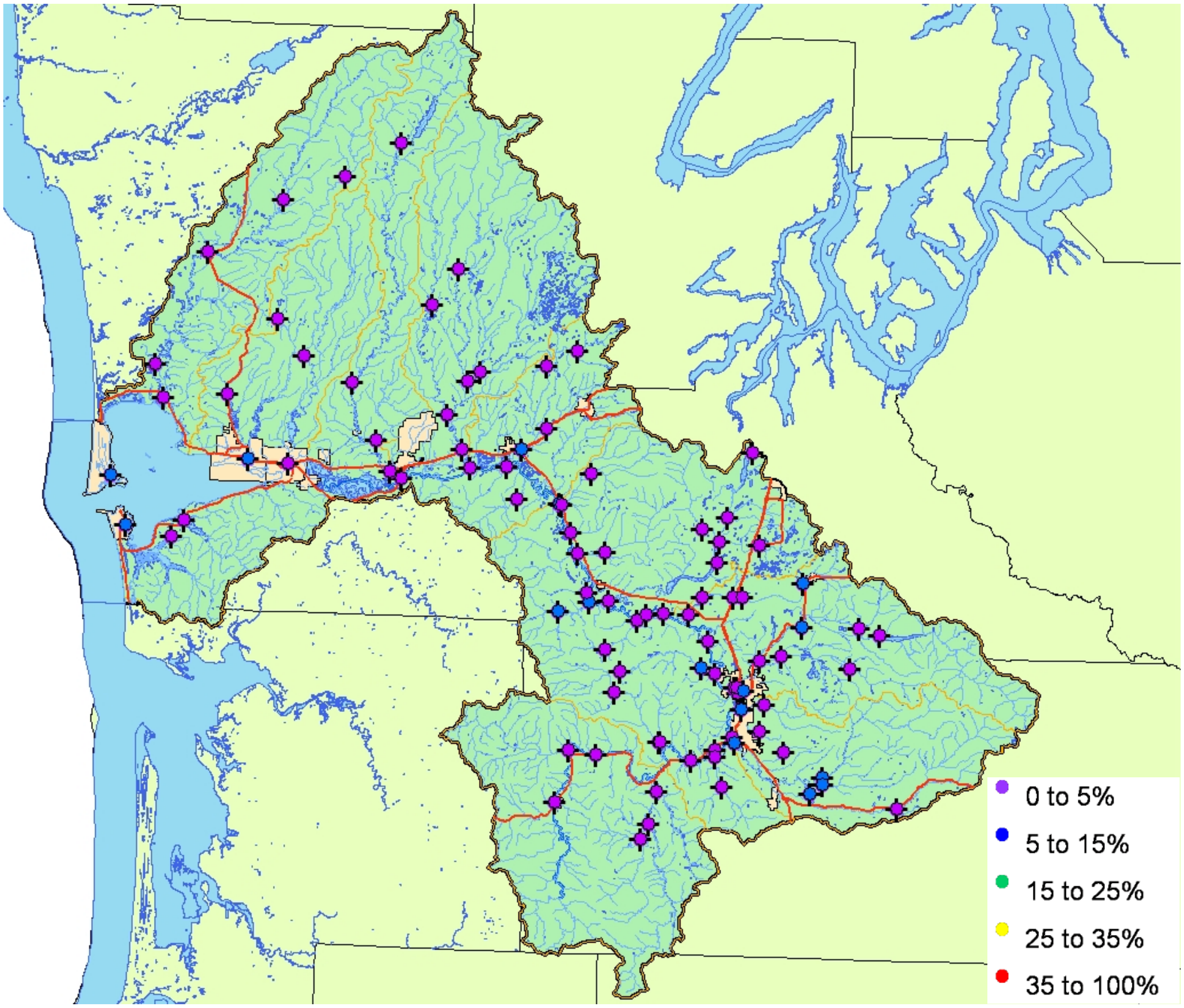


Figure 19. Map showing results of fecal coliform monitoring in the Chehalis Basin. Sites were ranked by the percentage of samples that contained more than 50 colonies/100 ml fecal coliform.

WRIA 22

Monitoring sites with the lowest mean fecal coliform levels (cleanest sites) in WRIA 22 included E. Fork Humptulips River at Forest Rd. 22, W. Fork Humptulips River at Forest Rd. 22, Delezene Creek at Delezene Creek Rd., Wildcat Creek at Heise Rd., and W. Fork Satsop River at Cougar Smith Rd. At several sites in WRIA 22, fecal coliform never exceeded 50 colonies/100 ml in water samples (Figures 20 and 21, Table 6). Sites where fecal coliform most frequently exceeded 50 colonies/100 ml included Winter Creek in Westport, Ocean Shores Creek at Discovery Avenue SE in Ocean Shores, and Hoquiam River at E. Hoquiam Road in the City of Hoquiam. Sites where fecal coliform exceeded 100 colonies/100 ml in at least 1 sample included Hoquiam River at E. Hoquiam Road, Chehalis River at Hwy. 107, and Winter Creek.

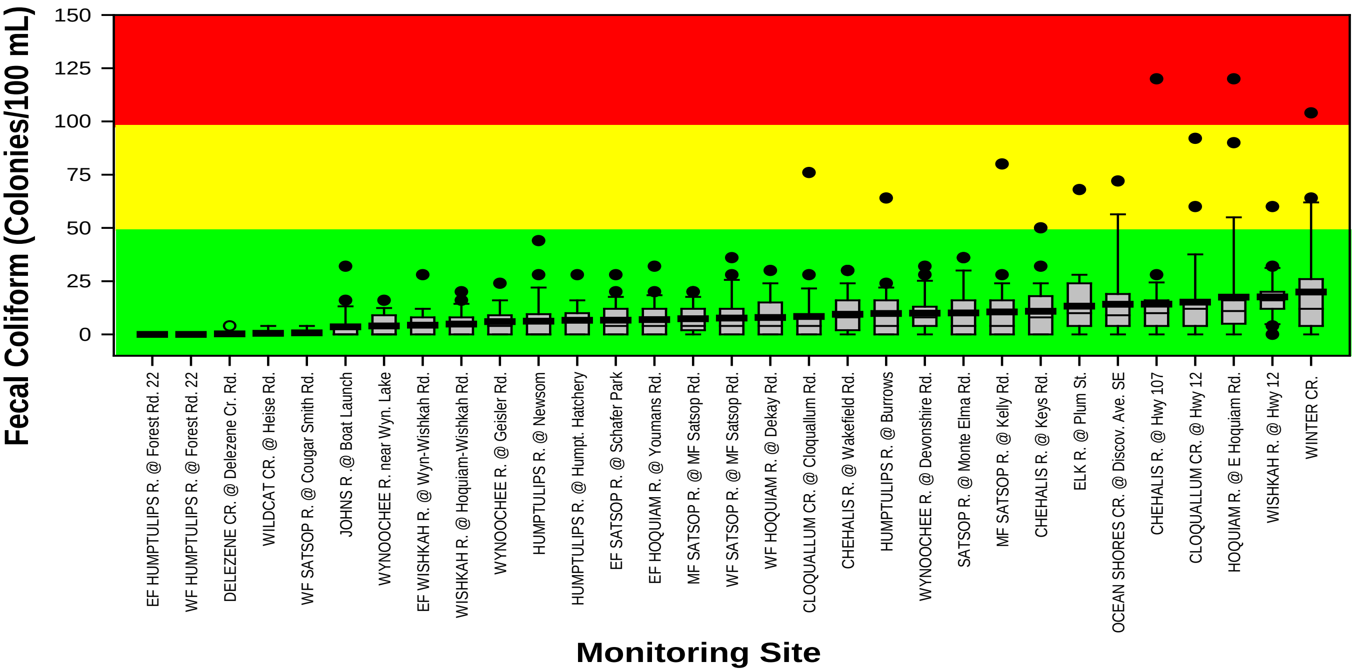


Figure 20. Fecal coliform at monitoring sites in WRIA 22. Box plots as described in the caption for Figure 6.

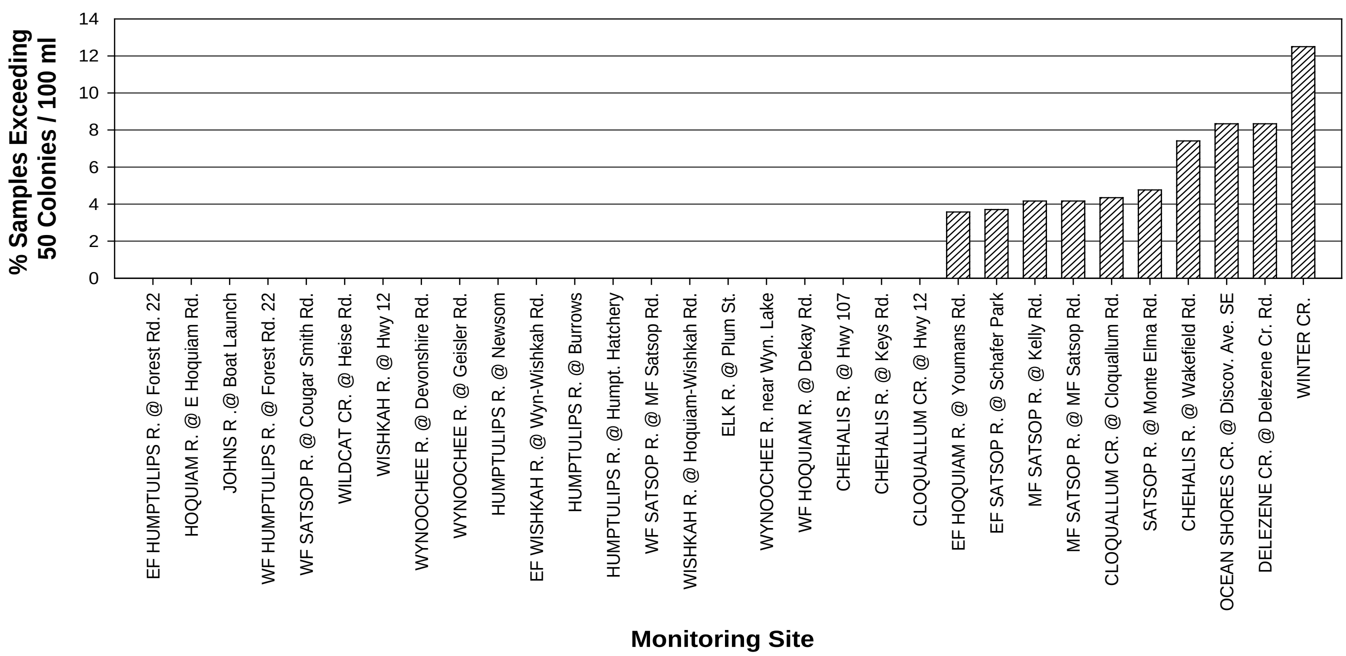


Figure 21. Monitoring sites in WRIA 22 ranked for percent samples that contained fecal coliform over 50 colonies/100 ml, over the period October 18, 2006 to June 30, 2009.

Table 6. Monitoring sites in WRIA 22 ranked for percent samples that exceeded the fecal coliform level of 50 colonies/100 ml over the period October 18, 2006 to June 30, 2009.

Site #	Site Location	Records	# samples > 50 colonies/100 ml	% Rank
3152	CHEHALIS R. @ Wakefield Rd.	29	0	0.0
3173	CHEHALIS R. @ Keys Rd.	29	0	0.0
3253	WF SATSOP R. @ MF Satsop Rd.	25	0	0.0
3254	SATSOP R. @ Monte Elma Rd.	24	0	0.0
3259	WYNOOCHEE R. @ Devonshire Rd.	26	0	0.0
3260	WYNOOCHEE R. @ Geisler Rd.	25	0	0.0
3261	WYNOOCHEE R. near Wyn. Lake	18	0	0.0
3263	WISHKAH R. @ Hoquiam-Wishkah Rd.	23	0	0.0
3264	EF WISHKAH R. @ Wyn-Wishkah Rd.	23	0	0.0
3265	EF HOQUIAM R. @ Youmans Rd.	23	0	0.0
3267	WF HOQUIAM R. @ Dekay Rd.	28	0	0.0
3269	HUMPTULIPS R. @ Newsom	24	0	0.0
3270	HUMPTULIPS R. @ Humpt. Hatchery	24	0	0.0
3272	JOHNS R .@ Boat Launch	26	0	0.0
3287	EF HUMPTULIPS R. @ Forest Rd. 22	16	0	0.0
3288	WF HUMPTULIPS R. @ Forest Rd. 22	15	0	0.0
3289	WF SATSOP R. @ Cougar Smith Rd.	11	0	0.0
3390	DELEZENE CR. @ Delezene Cr. Rd.	16	0	0.0
3393	WILDCAT CR. @ Heise Rd.	15	0	0.0
5256	MF SATSOP R. @ MF Satsop Rd.	25	0	0.0
5258	EF SATSOP R. @ Schafer Park	25	0	0.0
3153	CHEHALIS R. @ Hwy 107	28	1	3.6
5351	CLOQUALLUM CR. @ Cloquallum Rd.	27	1	3.7
3257	MF SATSOP R. @ Kelly Rd.	24	1	4.2
3268	HUMPTULIPS R. @ Burrows	24	1	4.2
3271	ELK R. @ Plum St.	23	1	4.3
3262	WISHKAH R. @ Hwy 12	21	1	4.8
3350	CLOQUALLUM CR. @ Hwy 12	27	2	7.4
3266	HOQUIAM R. @ E Hoquiam Rd.	24	2	8.3
3384	OCEAN SHORES CR. @ Discov. Ave. SE	12	1	8.3
3283	WINTER CR.	24	3	12.5

WRIA 23

Monitoring sites with the lowest mean fecal coliform levels (cleanest sites) in WRIA 23 included Cedar Creek at Capital Forest Rd., Stillman Creek at McDonald Rd., Scatter Creek at Sargent Rd., and Rock Creek at Norton Rd (Figure 22). There were several sites in WRIA 23 where fecal coliform never exceeded 50 colonies/100 ml in water samples (Figures 22 and 23, Table 7). Sites where fecal coliform most frequently exceeded 50 colonies/100 ml included Newaukum River at Shorey Road, and China Creek at W. Plum Street. The monitoring site at Newaukum River at Shorey Road is just south of the City of Chehalis, and China Creek flows through the City of Centralia.

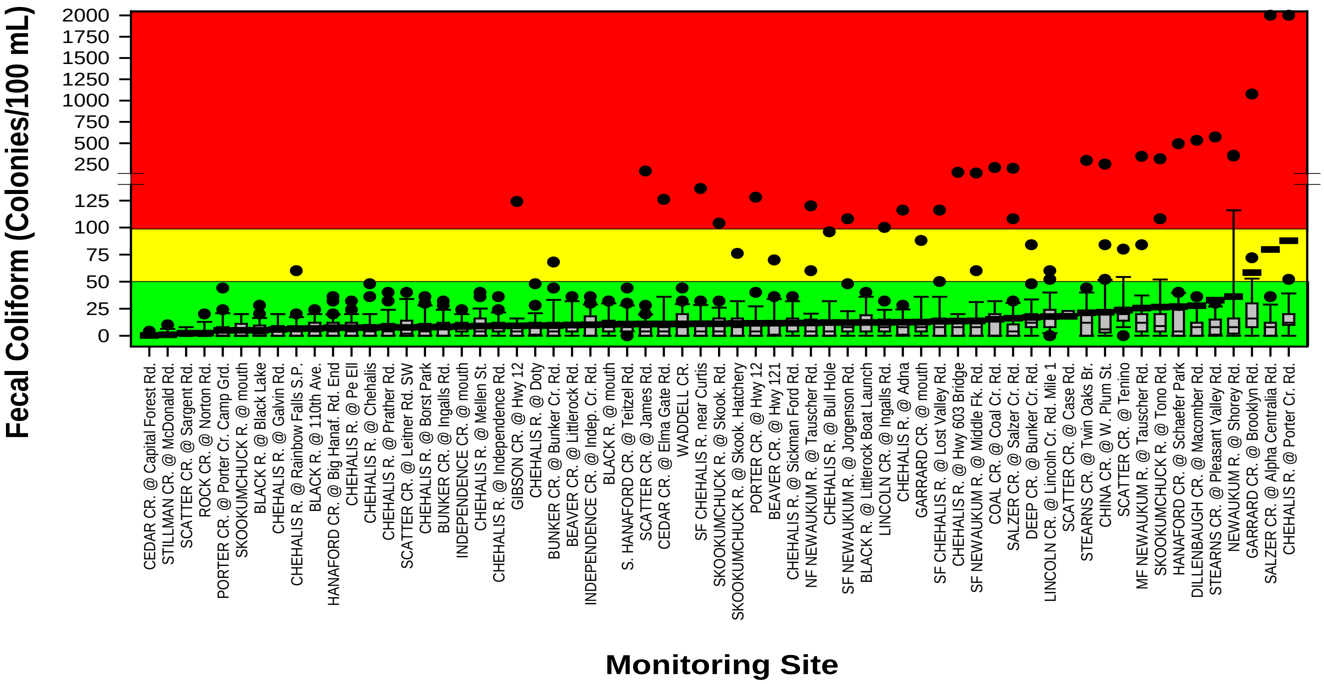


Figure 22. Fecal coliform at monitoring sites in WRIA 23. Box plots as described in the caption for Figure 6.

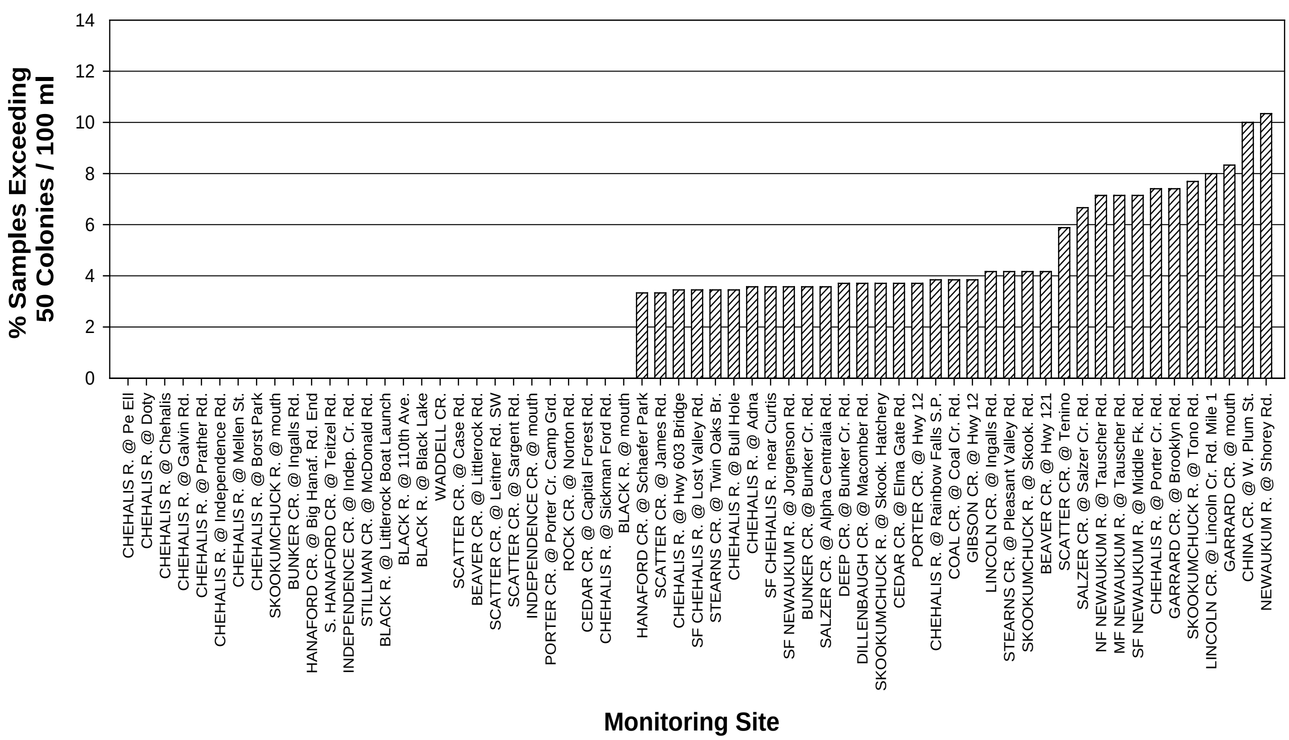


Figure 23. Monitoring sites in WRIA 23 ranked for percent samples that contained fecal coliform over 50 colonies/100 ml, over the period October 18, 2006 to June 30, 2009.

Table 7. Monitoring sites in WRIA 23 ranked for percent samples that exceeded the fecal coliform level of 50 colonies/100 ml over the period October 18, 2006 to June 30, 2009, showing the number of records and the number of samples that exceeded 50 colonies/100ml.

Site #	Site Location	Records	# samples > 50 colonies/100 ml	% Rank
1101	CHEHALIS R. @ Pe Ell	29	0	0.0
1102	CHEHALIS R. @ Doty	28	0	0.0
1112	CHEHALIS R. @ Chehalis	29	0	0.0
1140	CHEHALIS R. @ Galvin Rd.	25	0	0.0
1141	CHEHALIS R. @ Prather Rd.	29	0	0.0
1142	CHEHALIS R. @ Independence Rd.	25	0	0.0
1181	CHEHALIS R. @ Mellen St.	28	0	0.0
1182	CHEHALIS R. @ Borst Park	29	0	0.0
1217	SKOOKUMCHUCK R. @ mouth	16	0	0.0
1308	BUNKER CR. @ Ingalls Rd.	24	0	0.0
1323	HANAFORD CR. @ Big Hanaf. Rd. End	30	0	0.0
1324	S. HANAFORD CR. @ Teitzel Rd.	29	0	0.0
1329	INDEPENDENCE CR. @ Indep. Cr. Rd.	21	0	0.0
1391	STILLMAN CR. @ McDonald Rd.	15	0	0.0
2236	BLACK R. @ Littlerock Boat Launch	28	0	0.0
2237	BLACK R. @ 110th Ave.	27	0	0.0
2238	BLACK R. @ Black Lake	28	0	0.0
2325	WADDELL CR.	26	0	0.0
2333	SCATTER CR. @ Case Rd.	8	0	0.0
2375	BEAVER CR. @ Littlerock Rd.	27	0	0.0
2385	SCATTER CR. @ Leitner Rd. SW	12	0	0.0
2386	SCATTER CR. @ Sargent Rd.	15	0	0.0
3328	INDEPENDENCE CR. @ mouth	23	0	0.0
3349	PORTER CR. @ Porter Cr. Camp Grd.	27	0	0.0
3392	ROCK CR. @ Norton Rd.	15	0	0.0
3394	CEDAR CR. @ Capital Forest Rd.	13	0	0.0
4144	CHEHALIS R. @ Sickman Ford Rd.	25	0	0.0
4235	BLACK R. @ mouth	29	0	0.0
1322	HANAFORD CR. @ Schaefer Park	30	1	3.3
2332	SCATTER CR. @ James Rd.	30	1	3.3
1110	CHEHALIS R. @ Hwy 603 Bridge	29	1	3.4
1206	SF CHEHALIS R. @ Lost Valley Rd.	29	1	3.4
1309	STEARNS CR. @ Twin Oaks Br.	29	1	3.4
4143	CHEHALIS R. @ Bull Hole	29	1	3.4
1104	CHEHALIS R. @ Adna	28	1	3.6
1205	SF CHEHALIS R. near Curtis	28	1	3.6
1216	SF NEWAUKUM R. @ Jorgenson Rd.	28	1	3.6
1307	BUNKER CR. @ Bunker Cr. Rd.	28	1	3.6
1379	SALZER CR. @ Alpha Centralia Rd.	28	1	3.6
1306	DEEP CR. @ Bunker Cr. Rd.	27	1	3.7
1380	DILLENBAUGH CR. @ Macomber Rd.	27	1	3.7
2277	SKOOKUMCHUCK R. @ Skook. Hatchery	27	1	3.7

Table is continued on next page.

Table 7, continued from previous page.

Site #	Site Location	Records	# samples > 50 colonies/100 ml	% Rank
3346	CEDAR CR. @ Elma Gate Rd.	27	1	3.7
3348	PORTER CR. @ Hwy 12	27	1	3.7
1103	CHEHALIS R. @ Rainbow Falls S.P.	26	1	3.8
1378	COAL CR. @ Coal Cr. Rd.	26	1	3.8
3347	GIBSON CR. @ Hwy 12	26	1	3.8
1327	LINCOLN CR. @ Ingalls Rd.	24	1	4.2
1376	STEARNS CR. @ Pleasant Valley Rd.	24	1	4.2
2219	SKOOKUMCHUCK R. @ Skook. Rd.	24	1	4.2
2374	BEAVER CR. @ Hwy 121	24	1	4.2
2334	SCATTER CR. @ Tenino	17	1	5.9
1320	SALZER CR. @ Salzer Cr. Rd.	30	2	6.7
1213	NF NEWAUKUM R. @ Tauscher Rd.	28	2	7.1
1214	MF NEWAUKUM R. @ Tauscher Rd.	28	2	7.1
1215	SF NEWAUKUM R. @ Middle Fk. Rd.	28	2	7.1
3145	CHEHALIS R. @ Porter Cr. Rd.	27	2	7.4
3331	GARRARD CR. @ Brooklyn Rd.	27	2	7.4
2218	SKOOKUMCHUCK R. @ Tono Rd.	26	2	7.7
1326	LINCOLN CR. @ Lincoln Cr. Rd. Mile 1	25	2	8.0
3330	GARRARD CR. @ mouth	24	2	8.3
1321	CHINA CR. @ W. Plum St.	30	3	10.0
1211	NEWAUKUM R. @ Shorey Rd.	29	3	10.3

Monitoring Results for Turbidity

The average turbidity observed throughout all months of sampling was 7.3 NTU. Turbidity ranged from 0 to 992 NTU. Turbidity was highest during the winter months, particularly after storms and flood events, and lowest during the summer months (Figure 24). Overall, 91% of samples contained less than 12 NTU (9% more than 12 NTU), and 81% of samples contained less than 7 NTU (19% more than 7 NTU). At twelve sites throughout the Chehalis River basin, more than 35% of samples contained more than 7 NTU (Figure 25). Specific results for WRIA 22 and WRIA 23 are discussed below.

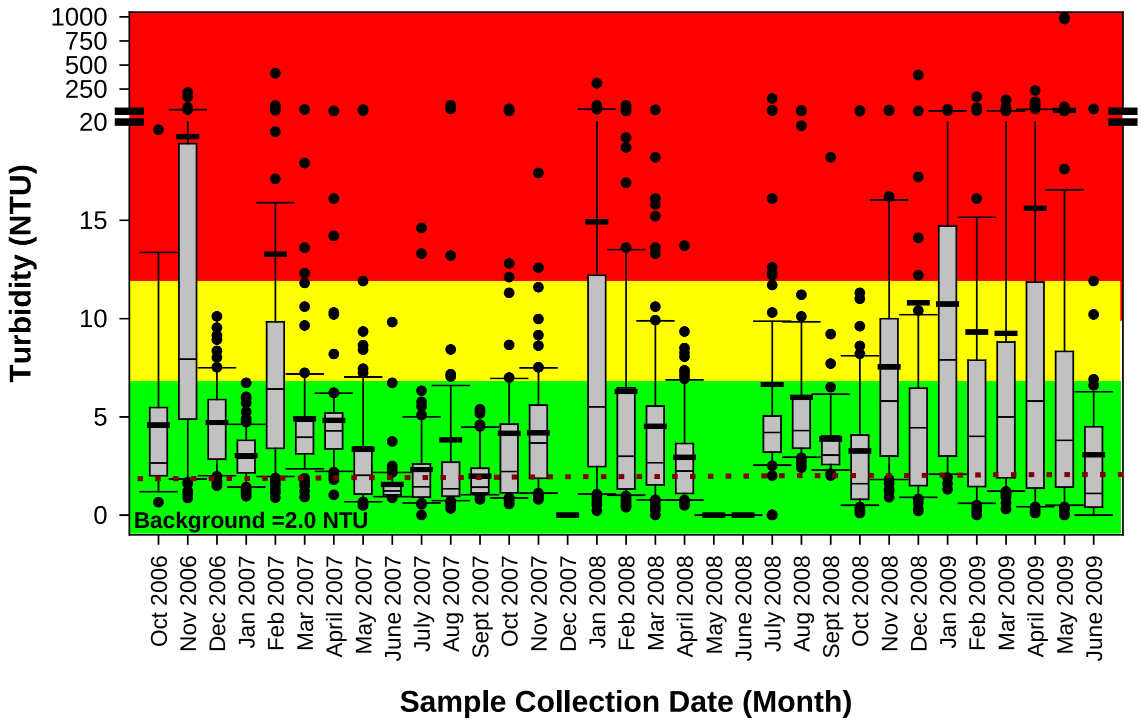


Figure 24. Turbidity measured at all sites throughout the Chehalis River basin from October 2006 through June 2009. Box plots as described in the caption for Figure 6.

WRIA 22

Monitored streams with consistently the lowest turbidity included E. Fork Hoquiam River, W. Fork Hoquiam River, W. Fork Humptulips River, and Wildcat Creek (Figures 26 and 27, Table 8). Monitoring sites that most frequently had turbidity higher than 7 NTUs included Winter Creek and W. Fork Satsop River. Sites with the highest mean turbidity (over 12 NTU) included W. Fork Satsop River at Cougar Smith Road, W. Fork Satsop River at Middle Fork Satsop Road, Middle Fork Satsop River at Middle Fork Satsop Rd., and Satsop River at Monte Elma Road. The mean turbidity may be highly influenced by a small number of samples with very high turbidity levels. Therefore, it is not always the case that sites with high mean turbidity also have high percentage of samples with turbidity exceeding 7 NTUs or 12 NTUs. Both metrics (mean turbidity and percent of samples exceeding standard) are valuable for assessing the effects of turbidity on aquatic habitats. If there is a high turbidity over a short duration, suspended solids may settle and fine sediments in the substrate may increase, leading to degraded spawning habitat. If there is a high level of turbidity that continues over a long period, this will have more direct effects on fish, causing reduced ability of fish to see and capture prey, and causing reduced respiratory function of gills.

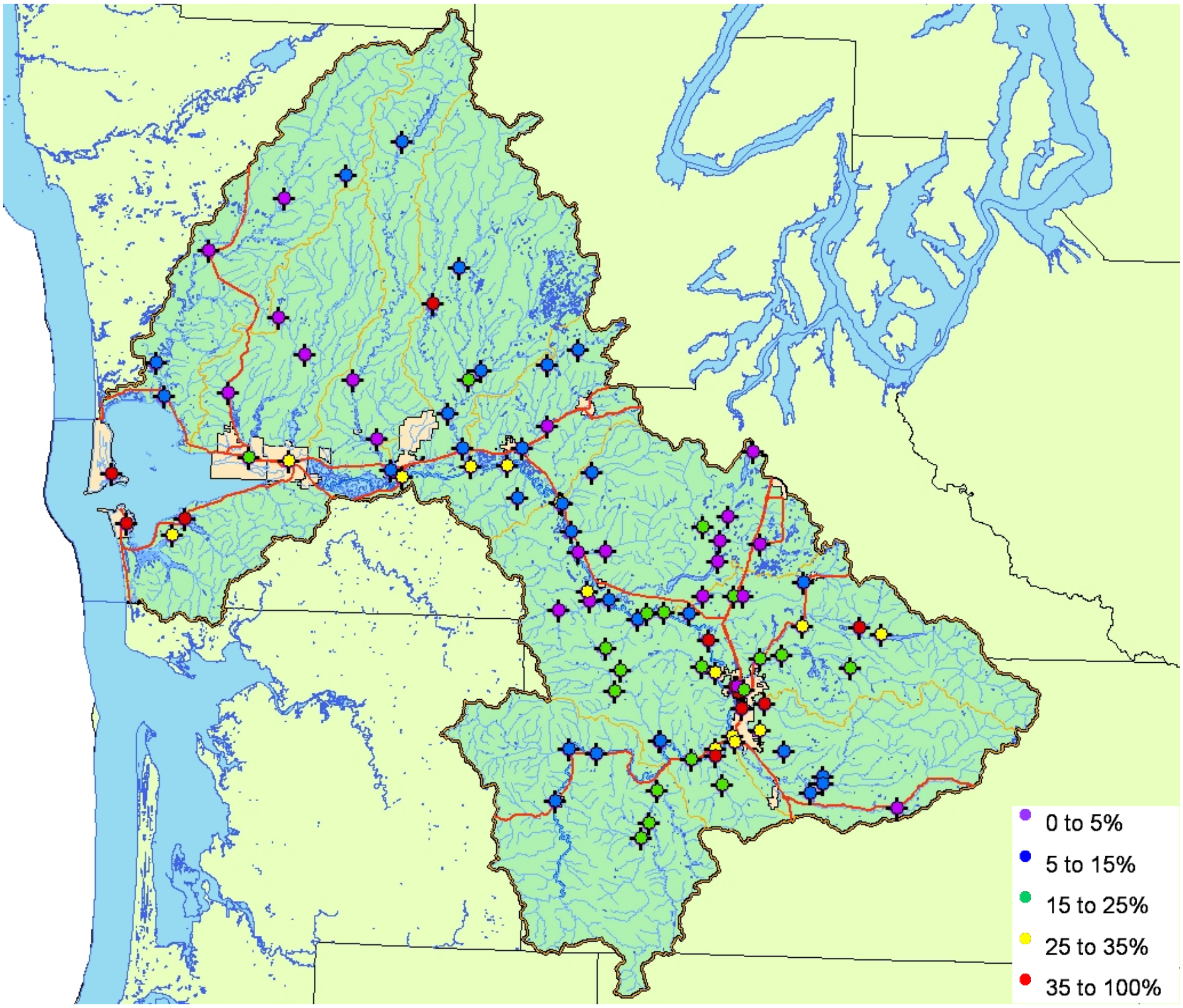


Figure 25. Map showing results of turbidity monitoring in the Chehalis Basin. Sites are ranked by the percentage of samples that contained more than 7 NTU.

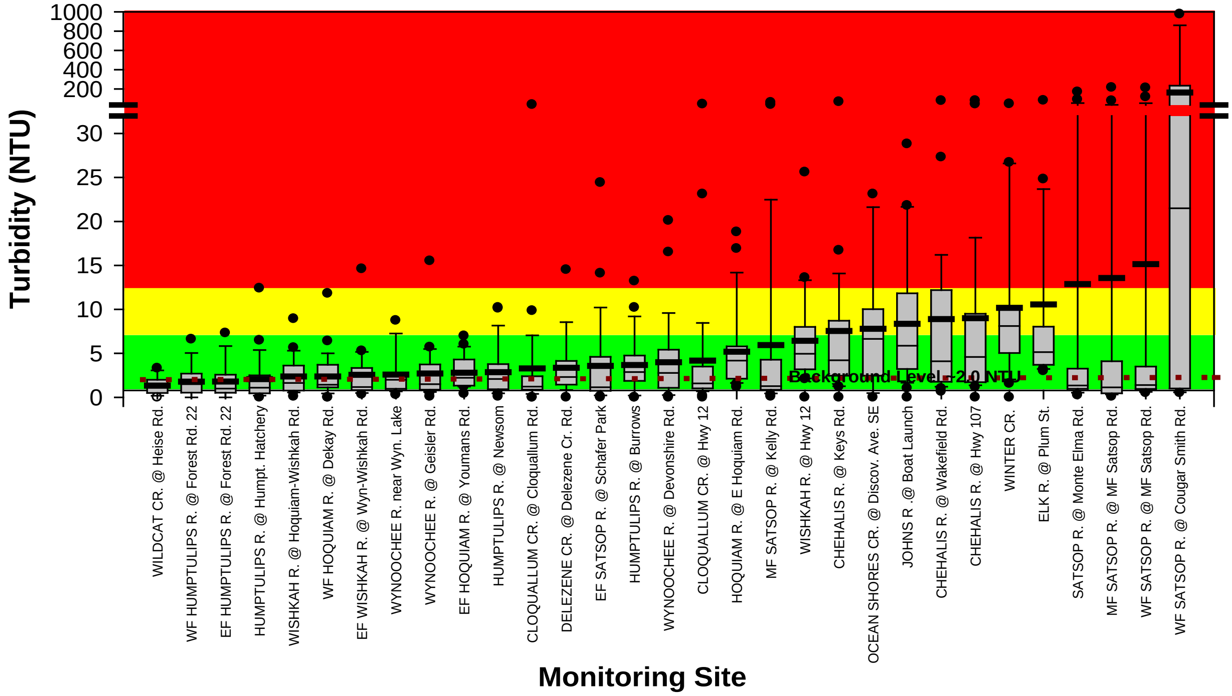


Figure 26. Turbidity at monitoring sites in WRIA 22. Box plots as described in the caption for Figure 6. Dashed red line indicates 2 NTU, the defined background turbidity level.

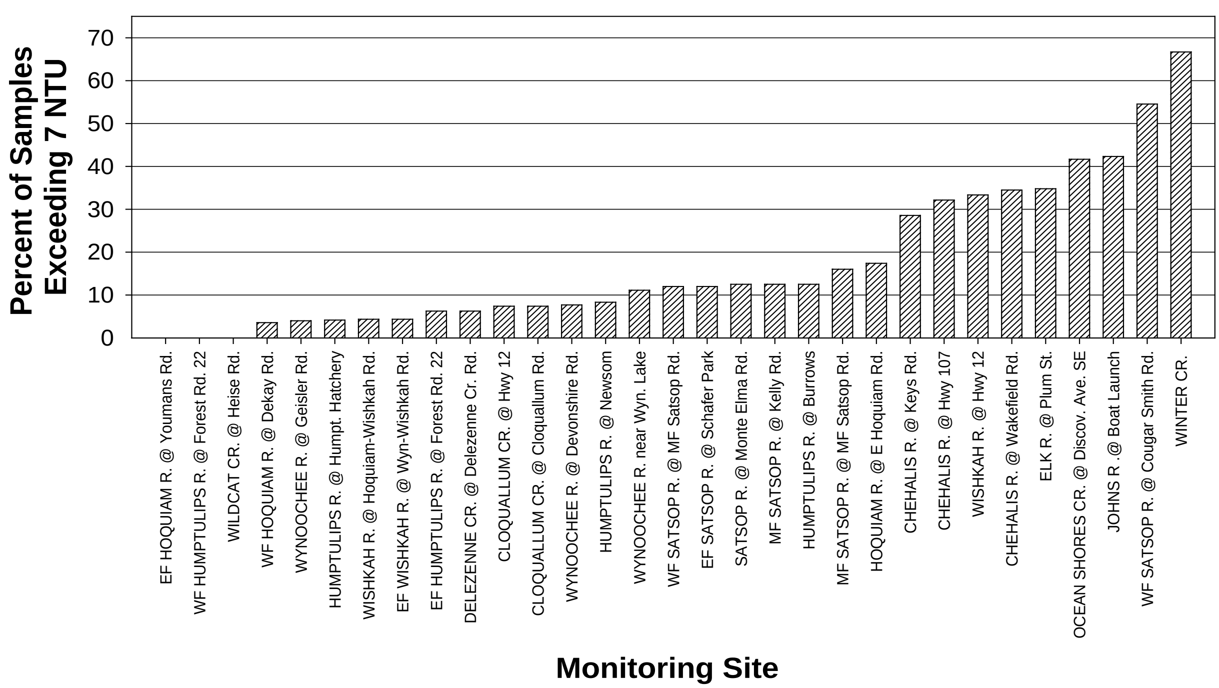


Figure 27. Monitoring sites in WRIA 22 ranked for percent samples that contained turbidity over 7 NTU, over the period October 18, 2006 to June 30, 2009.

Table 8. Monitoring sites in WRIA 22 ranked for percent samples that exceeded turbidity of 7 NTU over the period October 18, 2006 to June 30, 2009, the percent samples with more than 7 NTU for each site, and the average turbidity (NTU) for each site.

Site #	Site Location	Records	# > 7 NTU	% > 7 NTU	Average NTU
3265	EF HOQUIAM R. @ Youmans Rd.	23	0	0.0	2.8
3288	WF HUMPTULIPS R. @ Forest Rd. 22	15	0	0.0	1.8
3393	WILDCAT CR. @ Heise Rd.	15	0	0.0	1.3
3267	WF HOQUIAM R. @ Dekay Rd.	28	1	3.6	2.4
3260	WYNOOCHEE R. @ Geisler Rd.	25	1	4.0	2.7
3270	HUMPTULIPS R. @ Humpt. Hatchery	24	1	4.2	2.1
3263	WISHKAH R. @ Hoquiam-Wishkah Rd.	23	1	4.3	2.4
3264	EF WISHKAH R. @ Wyn-Wishkah Rd.	23	1	4.3	2.6
3287	EF HUMPTULIPS R. @ Forest Rd. 22	16	1	6.3	1.8
3390	DELEZENE CR. @ Delezene Cr. Rd.	16	1	6.3	3.4
3350	CLOQUALLUM CR. @ Hwy 12	27	2	7.4	4.2
5351	CLOQUALLUM CR. @ Cloquallum Rd.	27	2	7.4	3.3
3259	WYNOOCHEE R. @ Devonshire Rd.	26	2	7.7	4.0
3269	HUMPTULIPS R. @ Newsom	24	2	8.3	2.9
3261	WYNOOCHEE R. near Wyn. Lake	18	2	11.1	2.6
3253	WF SATSOP R. @ MF Satsop Rd.	25	3	12.0	15.1
5258	EF SATSOP R. @ Schafer Park	25	3	12.0	3.6
3254	SATSOP R. @ Monte Elma Rd.	24	3	12.5	12.9
3257	MF SATSOP R. @ Kelly Rd.	24	3	12.5	5.9
3268	HUMPTULIPS R. @ Burrows	24	3	12.5	3.7
5256	MF SATSOP R. @ MF Satsop Rd.	25	4	16.0	13.6
3266	HOQUIAM R. @ E Hoquiam Rd.	23	4	17.4	5.2
3173	CHEHALIS R. @ Keys Rd.	28	8	28.6	7.5
3153	CHEHALIS R. @ Hwy 107	28	9	32.1	9.0
3262	WISHKAH R. @ Hwy 12	21	7	33.3	6.4
3152	CHEHALIS R. @ Wakefield Rd.	29	10	34.5	8.9
3271	ELK R. @ Plum St.	23	8	34.8	10.6
3384	OCEAN SHORES CR. @ Discov. Ave. SE	12	5	41.7	7.8
3272	JOHNS R .@ Boat Launch	26	11	42.3	8.4
3289	WF SATSOP R. @ Cougar Smith Rd.	10	5	50.0	82.6
3283	WINTER CR.	24	16	66.7	10.2

Winter Creek: A Closer Look

At Winter Creek in Westport, monitoring results showed that relative to other monitored sites in WRIA 22, Winter Creek had lower dissolved oxygen, higher fecal coliform, and higher turbidity. 65.2% of the samples collected had dissolved oxygen less than 8 mg/L, 12.5% of samples had fecal coliform more than 50 colonies/100 ml, and 66.7% of samples had turbidity greater than 7 NTU. Winter Creek is a low gradient creek that flows through a residential area for most of its length (Figure 28 and Figure 29). It receives nutrient inputs from residential fertilizer runoff, pet and yard waste. These nutrient inputs contribute to growth of algae (Figure 28b). Decomposing algae and organic matter likely contribute to low dissolved oxygen levels. The high fecal coliform levels in Winter Creek are currently being investigated. Fecal material from pets may contribute to high fecal coliform levels. Eroding banks likely contribute to turbidity in Winter Creek.

a. View upstream b. View across stream

Figure 28. Winter Creek downstream of the residential area. Note filamentous green algae growing on and next to the tire in the photo at right. Photos by Don Loft.

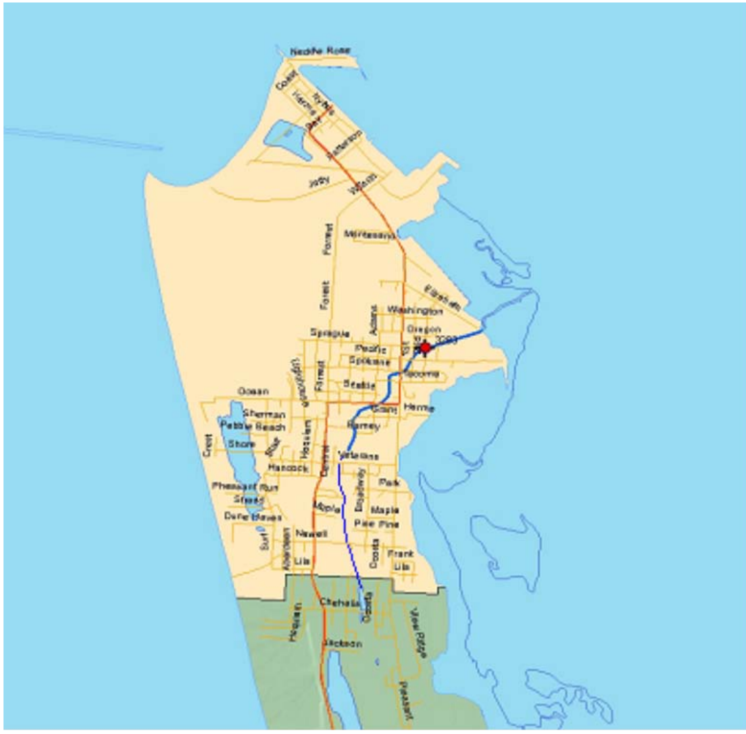


Figure 29. Winter Creek flows from a small man-made lake (Fake Lake), through a residential area in Westport, then through an intertidal area and into Grays Harbor where it meets the Pacific Ocean. The Winter Creek monitoring site 3283 is indicated by the red dot.

Satsop River Watershed: A Closer Look

Turbidity can be assessed both by the percent of samples that exceeded the 7 NTU criterion, and by the average turbidity. At monitoring site 3289 on West Fork Satsop River at Cougar Smith Road, turbidity was above 7 NTU in 50.0% of samples collected, and average turbidity at that site was 82.6 NTU. This high average turbidity resulted from a series of high turbidity measurements during the winter and spring of 2008-2009. It should be noted that monitoring at this site didn't begin until January 2008, so fewer samples were collected than at many other monitoring sites. Therefore the samples with high turbidity may have had a disproportionate effect on the results, but are in any case indicative of high turbidity during the sampled period. Another indicator of high turbidity in the Satsop River watershed is that all monitoring sites in WRIA 22 with average turbidity greater than 12 NTU were within this watershed. These sites included 3253 and 3289 on the West Fork Satsop River, 5256 on the Middle Fork Satsop River, and 3254 on the mainstem Satsop River.

The primary land use in the upper Satsop River watershed and along tributary streams is commercial timber production, while farms and pasturelands predominate in the lower elevation river valleys (Chehalis River Council, 2000a). Most land in the watershed is owned by timber companies, with smaller proportions of National Forest, State, County, Municipal, and privately owned lands. The topography is steep in the upper watershed, with slopes exceeding 65% at many locations, contributing to high erosion and mass wasting hazards (Figure 30). Logging road densities are high, ranging from 4 to over 5 miles of road per square mile. Older roads built using sidecast construction on unstable midslopes have resulted in high risk of slope failure and erosion. Resulting landslides often reach streams, causing increased turbidity and accumulation of fine sediment on stream beds.

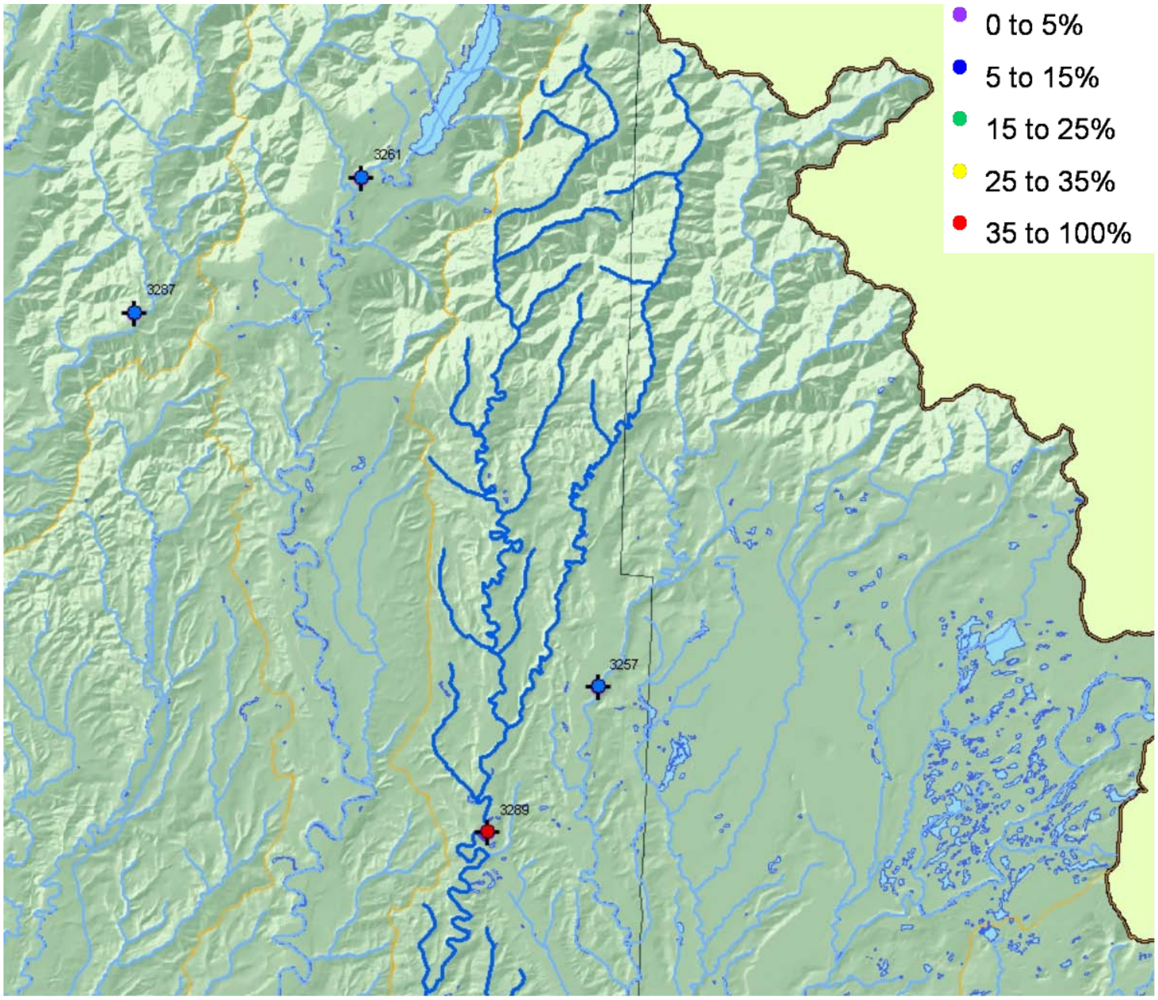


Figure 30. Topography of the West Fork Satsop River drainage upstream of Site 3289. High light/dark contrast indicates steep slopes. Monitoring sites are ranked relative to the percent samples that exceeded turbidity of 7 NTU.

WRIA 23

Monitoring sites with consistently the lowest turbidity in WRIA 23 included Cedar Creek at Capital Forest Road, Scatter Creek at Leitner Road SW, Scatter Creek at Sargent Road, and Beaver Creek at Littlerock Rd. (Figures 31 and 32, Table 9). Monitoring sites that most frequently had turbidity higher than 7 NTU included Salzer Creek at Alpha Centralia Rd., Salzer Creek at Salzer Creek Rd., and Stearns Creek at Twin Oaks Bridge (Table 9). Sites with the highest mean turbidity included Waddell Creek, Stearns Creek at Twin Oaks Bridge, Newaukum River at Tauscher Rd, Salzer Creek at Alpha Centralia Rd., and Salzer Creek at Salzer Creek Rd (Figure 31).

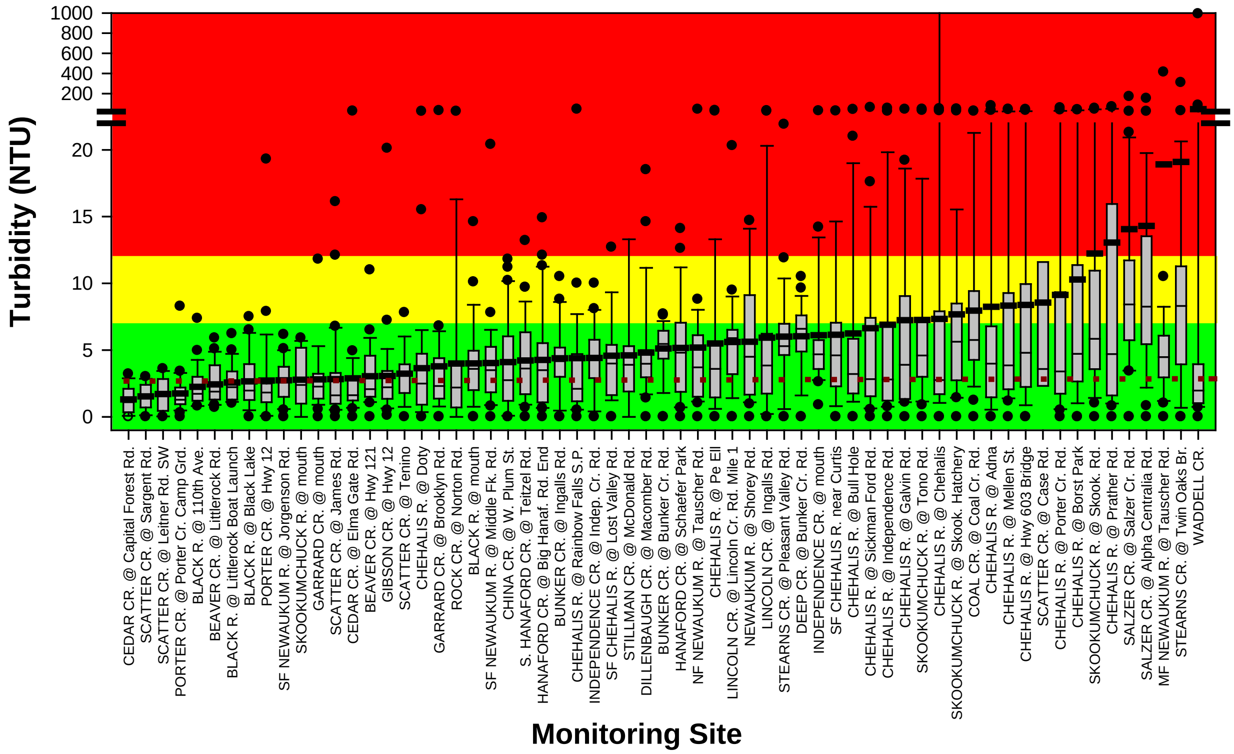


Figure 31. Turbidity at monitoring sites in WRIA 23. Box plots as described in the caption for Figure 6. Dashed red line indicates 2 NTU, the defined background turbidity level.

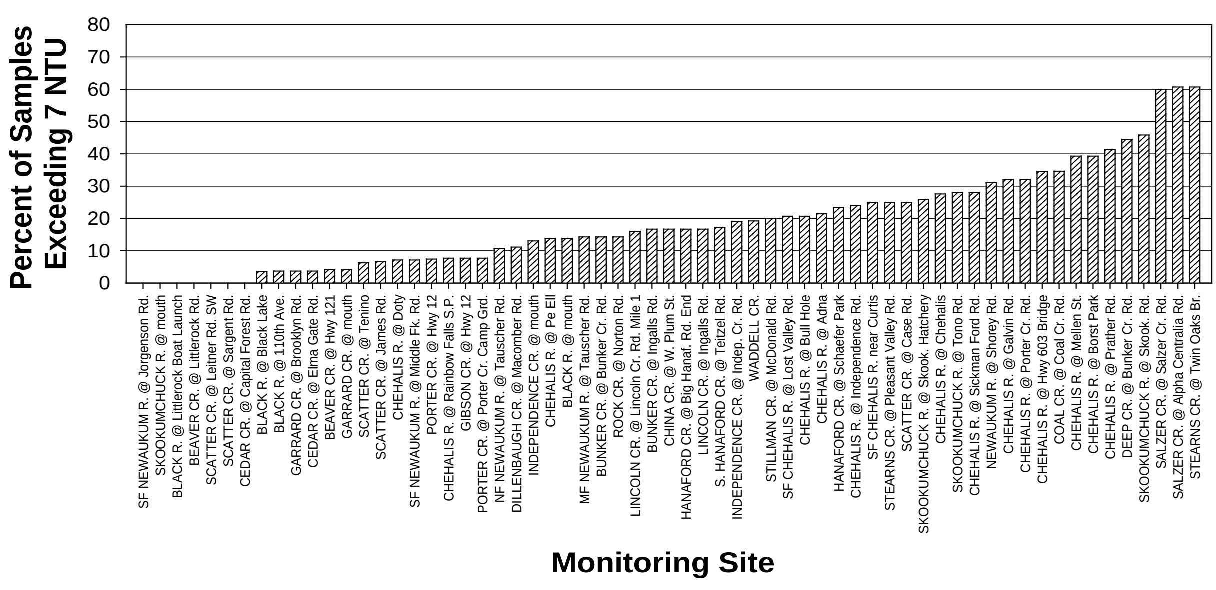


Figure 32. Monitoring sites in WRIA 23 ranked for percent samples that contained turbidity over 7 NTU, over the period October 18, 2006 to June 30, 2009.

Table 9. Monitoring sites in WRIA 23 ranked for percent samples that exceeded turbidity of 7 NTU over the period October 22, 2006 to June 30, 2009, the percent samples with more than 7 NTU for each site, and the average turbidity (NTU) for each site.

Site #	Site Location	Records	# > 7 NTU	% > 7 NTU	Average NTU
1216	SF NEWAUKUM R. @ Jorgenson Rd.	28	0	0.0	2.7
1217	SKOOKUMCHUCK R. @ mouth	16	0	0.0	2.8
2236	BLACK R. @ Littlerock Boat Launch	28	0	0.0	2.6
2375	BEAVER CR. @ Littlerock Rd.	27	0	0.0	2.4
2385	SCATTER CR. @ Leitner Rd. SW	12	0	0.0	1.7
2386	SCATTER CR. @ Sargent Rd.	15	0	0.0	1.5
3394	CEDAR CR. @ Capital Forest Rd.	13	0	0.0	1.3
2238	BLACK R. @ Black Lake	28	1	3.6	2.7
2237	BLACK R. @ 110th Ave.	27	1	3.7	2.3
3331	GARRARD CR. @ Brooklyn Rd.	27	1	3.7	3.8
3346	CEDAR CR. @ Elma Gate Rd.	27	1	3.7	2.9
2374	BEAVER CR. @ Hwy 121	24	1	4.2	3.0
3330	GARRARD CR. @ mouth	24	1	4.2	2.8
2334	SCATTER CR. @ Tenino	16	1	6.3	3.2
2332	SCATTER CR. @ James Rd.	30	2	6.7	2.8
1102	CHEHALIS R. @ Doty	28	2	7.1	3.6
1215	SF NEWAUKUM R. @ Middle Fk. Rd.	28	2	7.1	4.0
3348	PORTER CR. @ Hwy 12	27	2	7.4	2.7
1103	CHEHALIS R. @ Rainbow Falls S.P.	26	2	7.7	4.4
3347	GIBSON CR. @ Hwy 12	26	2	7.7	3.1
3349	PORTER CR. @ Porter Cr. Camp Grd.	26	2	7.7	2.1
1213	NF NEWAUKUM R. @ Tauscher Rd.	28	3	10.7	5.2
1380	DILLENBAUGH CR. @ Macomber Rd.	27	3	11.1	4.8
3328	INDEPENDENCE CR. @ mouth	23	3	13.0	6.1
1101	CHEHALIS R. @ Pe Ell	29	4	13.8	5.5
4235	BLACK R. @ mouth	29	4	13.8	4.0
1214	MF NEWAUKUM R. @ Tauscher Rd.	28	4	14.3	18.9
1307	BUNKER CR. @ Bunker Cr. Rd.	28	4	14.3	5.1
3392	ROCK CR. @ Norton Rd.	14	2	14.3	4.0
1326	LINCOLN CR. @ Lincoln Cr. Rd. Mile 1	25	4	16.0	5.6
1308	BUNKER CR. @ Ingalls Rd.	24	4	16.7	4.4
1321	CHINA CR. @ W. Plum St.	30	5	16.7	4.1
1323	HANAFORD CR. @ Big Hanaf. Rd. End	30	5	16.7	4.3
1327	LINCOLN CR. @ Ingalls Rd.	24	4	16.7	5.9
1324	S. HANAFORD CR. @ Teitzel Rd.	29	5	17.2	4.2
1329	INDEPENDENCE CR. @ Indep. Cr. Rd.	21	4	19.0	4.4
2325	WADDELL CR.	26	5	19.2	47.2
1391	STILLMAN CR. @ McDonald Rd.	15	3	20.0	4.6
1206	SF CHEHALIS R. @ Lost Valley Rd.	29	6	20.7	4.6
4143	CHEHALIS R. @ Bull Hole	29	6	20.7	6.2
1104	CHEHALIS R. @ Adna	28	6	21.4	8.3
1322	HANAFORD CR. @ Schaefer Park	30	7	23.3	5.2

Table is continued on next page.

Table 9, continued from previous page.

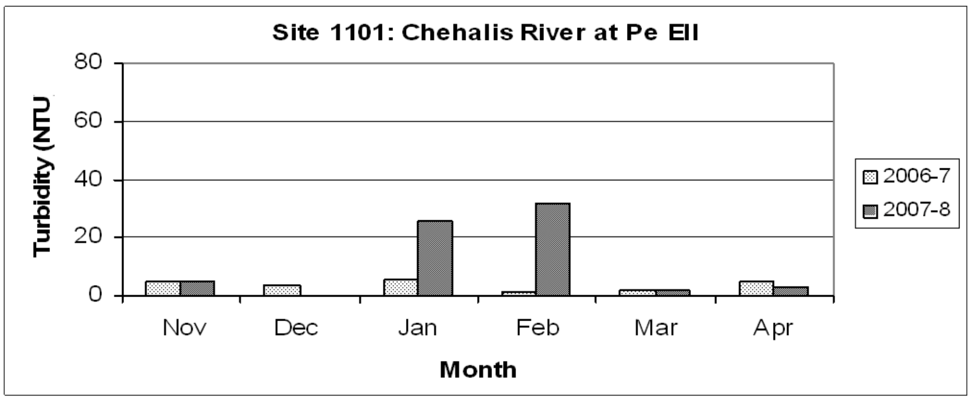
Site #	Site Location	Records	# >7 NTU	% > 7 NTU	Average NTU
1142	CHEHALIS R. @ Independence Rd.	25	6	24.0	6.9
1205	SF CHEHALIS R. near Curtis	28	7	25.0	6.2
1376	STEARNS CR. @ Pleasant Valley Rd.	24	6	25.0	6.0
2333	SCATTER CR. @ Case Rd.	8	2	25.0	8.6
2277	SKOOKUMCHUCK R. @ Skook. Hatchery	27	7	25.9	7.7
1112	CHEHALIS R. @ Chehalis	29	8	27.6	7.3
2218	SKOOKUMCHUCK R. @ Tono Rd.	25	7	28.0	7.3
4144	CHEHALIS R. @ Sickman Ford Rd.	25	7	28.0	6.6
1211	NEWAUKUM R. @ Shorey Rd.	29	9	31.0	5.6
1140	CHEHALIS R. @ Galvin Rd.	25	8	32.0	7.2
3145	CHEHALIS R. @ Porter Cr. Rd.	25	8	32.0	9.1
1110	CHEHALIS R. @ Hwy 603 Bridge	29	10	34.5	8.4
1378	COAL CR. @ Coal Cr. Rd.	26	9	34.6	8.0
1181	CHEHALIS R. @ Mellen St.	28	11	39.3	8.3
1182	CHEHALIS R. @ Borst Park	28	11	39.3	10.3
1141	CHEHALIS R. @ Prather Rd.	29	12	41.4	13.1
1306	DEEP CR. @ Bunker Cr. Rd.	27	12	44.4	6.0
2219	SKOOKUMCHUCK R. @ Skook. Rd.	24	11	45.8	12.2
1309	STEARNS CR. @ Twin Oaks Br.	29	17	58.6	14.1
1320	SALZER CR. @ Salzer Cr. Rd.	30	18	60.0	14.3
1379	SALZER CR. @ Alpha Centralia Rd.	28	17	60.7	20.6

Effects of the December 1-3 2007 Storms on Turbidity in the Upper Chehalis River Basin

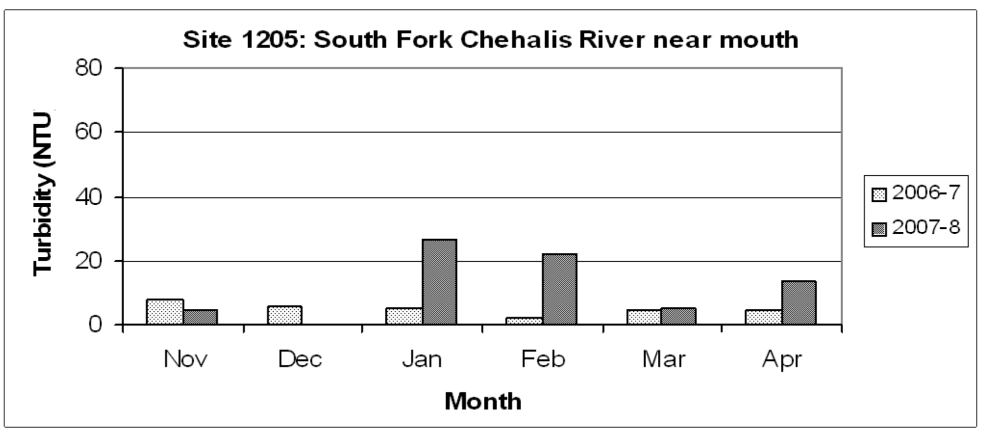
On December 1-3, 2007, a major storm in Western Washington brought snow and strong winds followed by heavy rains. In the Chehalis River headwaters area in the vicinity of Pe Ell, nearly 20 inches of rain fell within a 48-hour period. The soil became saturated, and intense flooding and more than 1,500 landslides in the headwaters area followed (Sarikhan et al., 2008). The Chehalis River rose until flood waters were up to 10 ft deep over Interstate Highway 5 at Chehalis and Centralia on December 3, and the highway was closed through Dec. 6. The turbidity of the water increased during the storms, and for the next few months following the storms.

As part of this project, water samples were collected from several monitoring sites in the upper Chehalis River Basin in the months leading up to and following these storms in December 2007. Due to flooding and consequent difficulty accessing monitoring sites, no samples were collected in December 2007. The collected samples provided a means to evaluate the effects of the 2007 storms on turbidity in the Upper Chehalis River basin. Samples collected the previous winter, when there was not major flooding, provide a comparison. Results of turbidity monitoring are shown for each of the two winters 2006-7 and 2007-8, with measured turbidity for each of the two years shown side by side for each month (November through April).

Turbidity ranged from approximately 20 NTU to nearly 80 NTU in January 2008 at these monitoring sites (Figures 33 and 34). It was likely higher in December, but no measurements were possible. In the months following the storm, turbidity declined, reaching the background level seen in the previous spring by March or April, three to four months after the storm event.

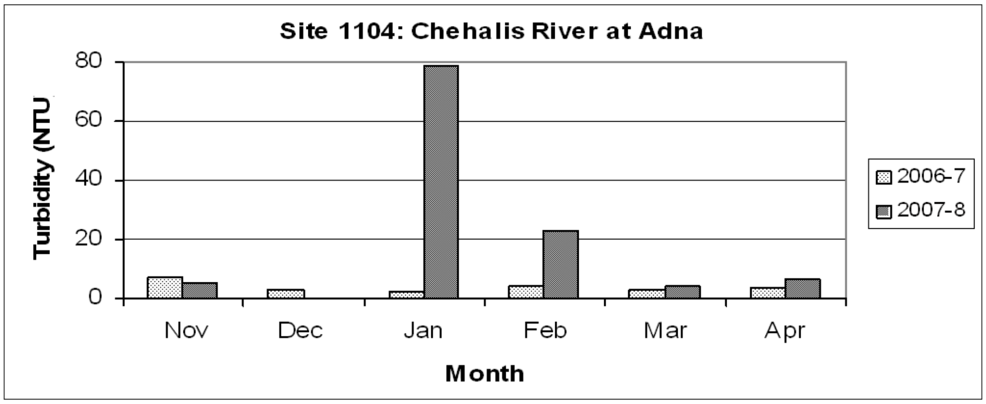


a. Site 1101

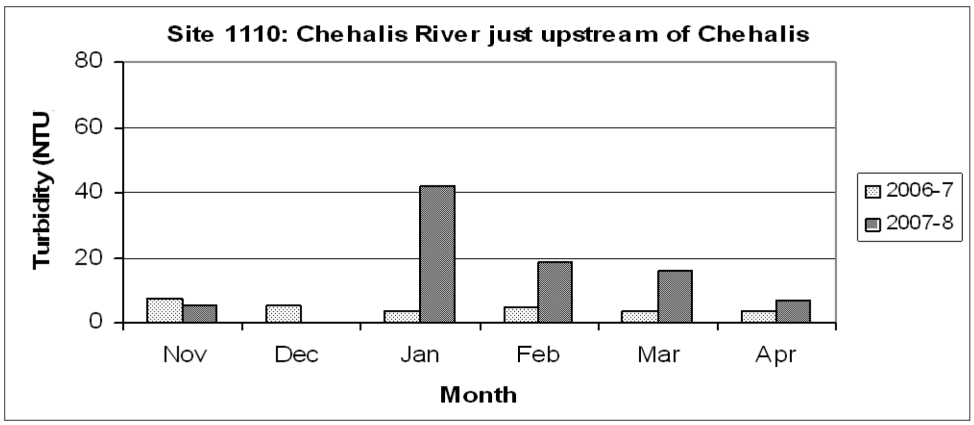


b. Site 1205

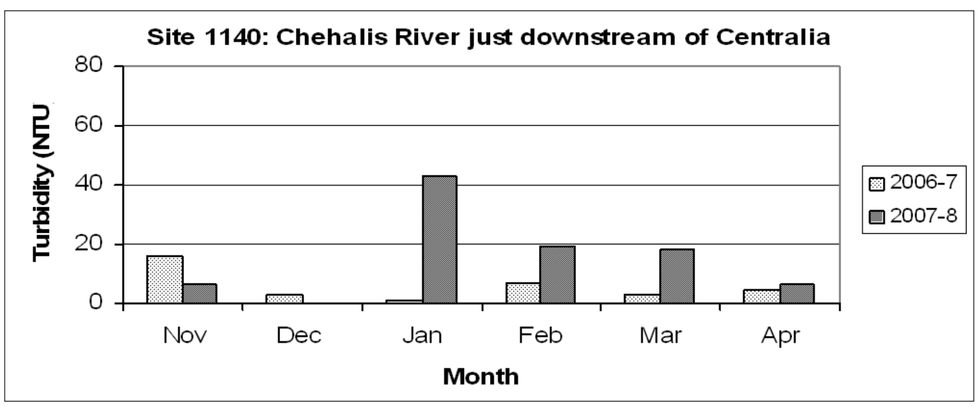
Figure 33. Turbidity at a) Site 1101, on the Chehalis River at Pe Ell, upstream of the confluence with the South Fork Chehalis River, and b) Site 1205, on the South Fork Chehalis River near the mouth.



a. Site 1104



b. Site 1110



c. Site 1140

Figure 34. Turbidity at a) Site 1104, on the Chehalis River at Adna, downstream of the confluence with the South Fork Chehalis River, b) Site 1110, on the Chehalis River just upstream of Chehalis, and c) Site 1140, Chehalis River just downstream of Centralia.

Causes of increased turbidity and suspended fine sediment
Many landslides in the Chehalis headwaters area brought fine sediment into streams. A combination of several factors are likely to have contributed to these landslides, including high rainfall that saturated soils, geological factors, thin soil layers over bedrock, impermeable bedrock, steep concave slopes, timber harvest within the last 15 years, and reduced slope stability due to logging road construction on steep slopes (Brooks et al., 1991; Chamberlin et al., 1991; Furniss et al., 1991; Montgomery & Dietrich, 1994; WADNR, 2004; Phillips & Marden, 2004; Sarikhan et al., 2008). It is well established that the root systems underlying forests increase soil stability (Phillips & Marden 2004). Following timber harvest, roots die and begin to rot, and several field investigations have shown a 2-10 fold increase in the incidence of landslides within 15 years following timber harvest on steep forested terrain (Wu et al., 1979; Jakob, 2000; Guthrie, 2002; Phillips & Marden, 2004). High rainfall events are the most common factor triggering landslides on these vulnerable areas (Glade, 1998; Phillips & Marden, 2004). In the Chehalis headwaters area, roads were an initiation point for many landslides (Sarikhan et al., 2008). Of the 1,614 landslides that were identified in the Chehalis River headwaters area, 547 were in clearcuts (0–5 years old), 104 were in young stands (5–15 years old), 403 were in submature timber (15–50 years old), 0 were in mature timber (50+ years), and 560 were near forest roads (Sarikhan et al., 2008). Other sources of suspended fine sediments in the Chehalis River included surface and rill erosion from flooded farm fields, and eroding stream banks overcome by the flood waters (NRCS, 2003; Sarikhan et al., 2008; CRBFA, 2009).

Consequences of increased turbidity and suspended fine sediment
Turbidity can cause negative effects on salmon and trout at levels of 18-70 NTU, when fish have not acclimated to these turbidity levels (Gregory, 1992; Bash et al., 2001). Turbidity or suspended sediment can affect the physiology, behavior, or habitat of fish. It can lead to gill trauma, reduced reproductive success and growth, reduced success in foraging, delayed migration, and when fine sediment accumulates on the stream bottom, reduction in spawning habitat or damage to redds[1] (Bjorn & Reiser, 1991; Bash et al, 2001).

Monitoring Results for Water Temperature

As described in the Methods section, monitoring sites were evaluated using different temperature criteria, depending on season and category of fish (salmonid fish species and char fish species).

Seasonal Temperature Pattern Relative to Salmon and Trout Spawning and Rearing

During the summers of 2007 and 2008, temperatures rose above the *Core Summer Salmonid Habitat* criterion of 16ºC (60.8ºF) at several monitoring sites during July and August (Figure 35). The salmonid *Spawning* temperature criterion of 13ºC (55.4ºF) was not met at most sites during September 2007, May 2008, and September 2008. However, most sites had adequately cool temperatures for salmonid spawning, below 13ºC, during October 2007 through April 2008, and October 2008 through May 2009.

[1] The term *redd* refers to the nest that salmon and trout make when burying their eggs in the gravel on the stream bottom.

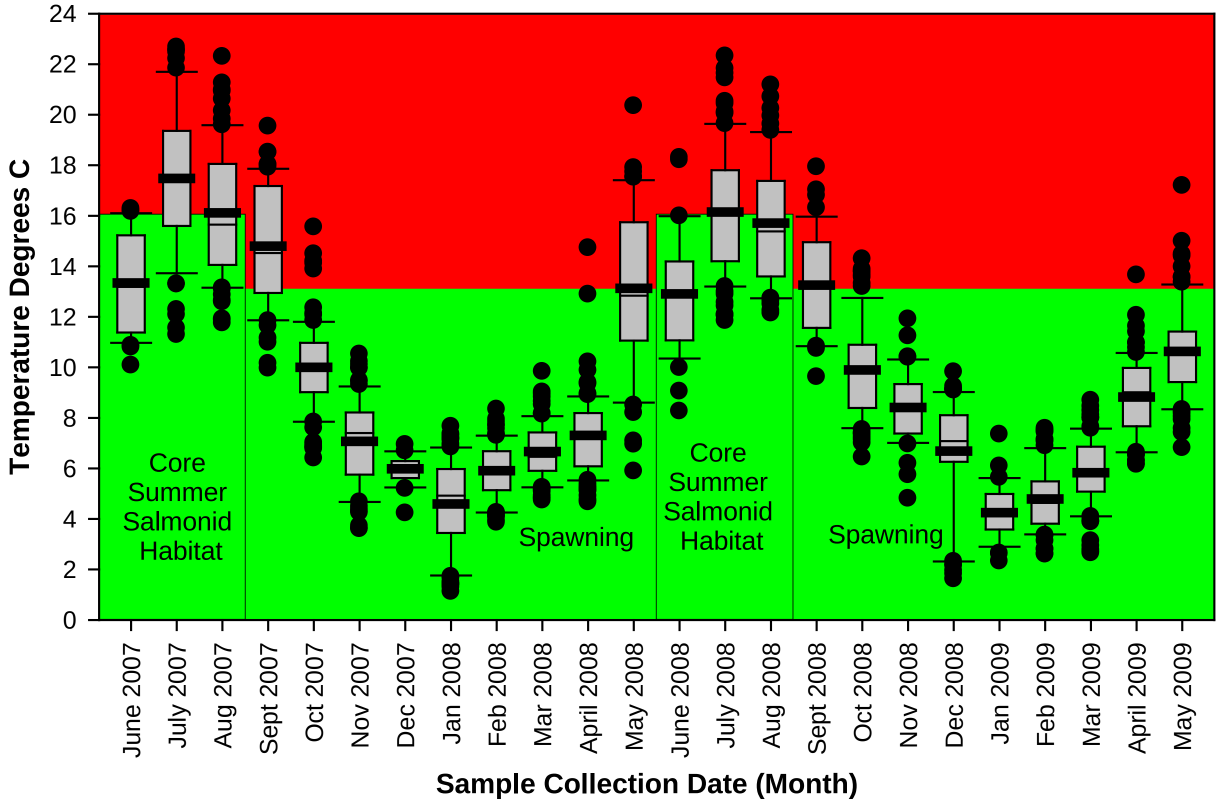


Figure 35. Average monthly temperatures in the Chehalis River basin relative to the Spawning temperature criterion of 13°C (55.4°F) and Core Summer Salmonid Habitat temperature criterion of 16°C (60.8°F). Box plots as described in caption for Figure 6.

Evaluation of Water Temperature at Specific Monitoring Sites Relative to Salmon and Trout Spawning and Rearing

Temperature Conditions for Fall-Winter-Spring Salmon & Trout Spawning

Temperature monitoring indicated that most monitoring sites throughout the Chehalis River basin had temperatures suitable for salmon and trout spawning during at least 85% of the spawning periods investigated (Figure 36).

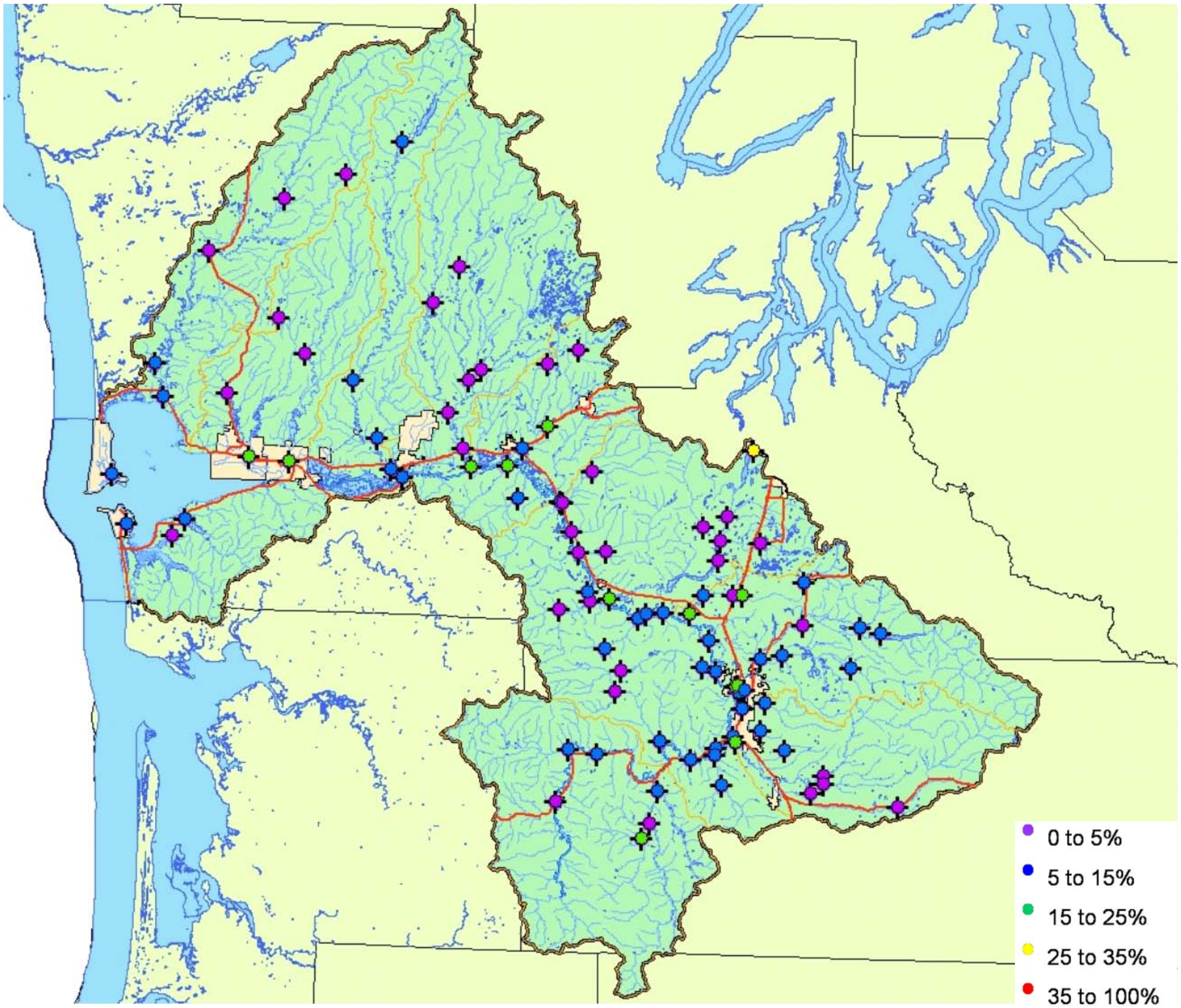


Figure 36. Fall-Winter-Spring salmon & trout spawning temperature conditions in the Chehalis River basin. Monitoring sites were ranked relative to the percentage of samples that exceeded 13°C during the spawning period of September through May 2007-2008 and 2008-2009.

In WRIA 22, monitoring sites with the highest incidence of temperatures exceeding 13°C during the salmonid spawning periods were along the Chehalis River near Elma, 3152-Chehalis River at Wakefield Road and 3173-Chehalis River at Keys Road (Figure 37, Table 10). In WRIA 23, most of the monitoring sites with the highest incidence of temperatures exceeding 13°C were also along the Chehalis River, while the sites with the coolest temperatures were further upstream (Figure 38, Table 11). Most salmonid fish species spawn in smaller streams and not in larger rivers. However, Chinook salmon may spawn in larger rivers, so distribution and/or timing of Chinook salmon spawning may be limited by temperature in the mainstem Chehalis River.

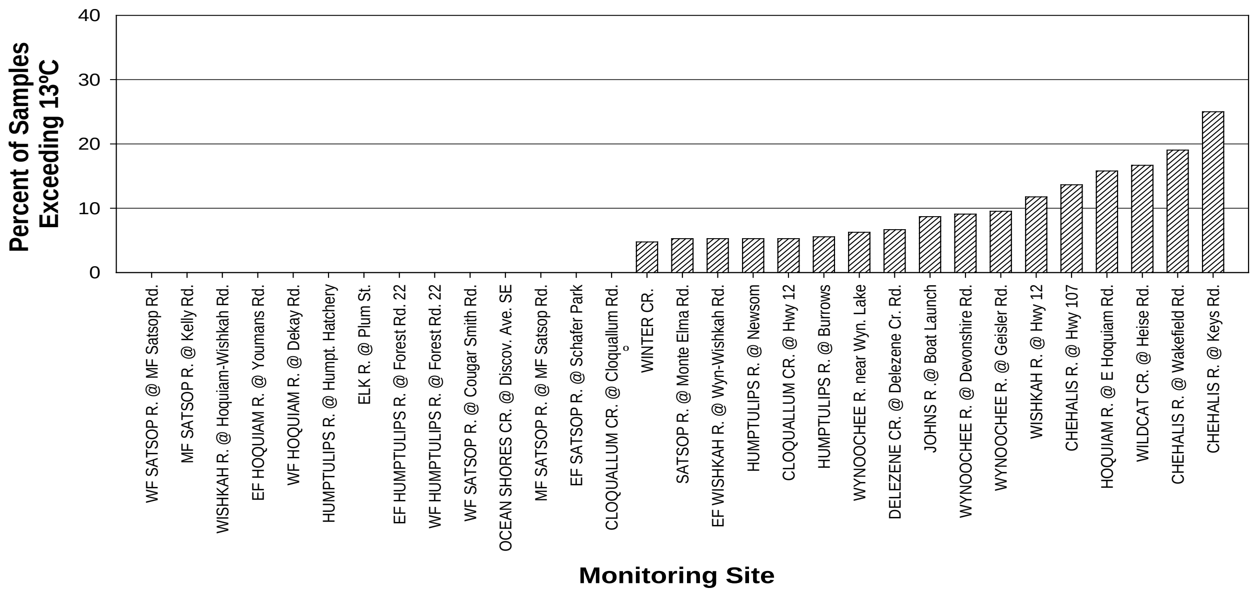


Figure 37. *Temperatures for Fall-Winter-Spring salmon & trout spawning, WRIA 22*. Monitoring sites were ranked relative to the percentage of samples that exceeded 13°C during monitored spawning periods.

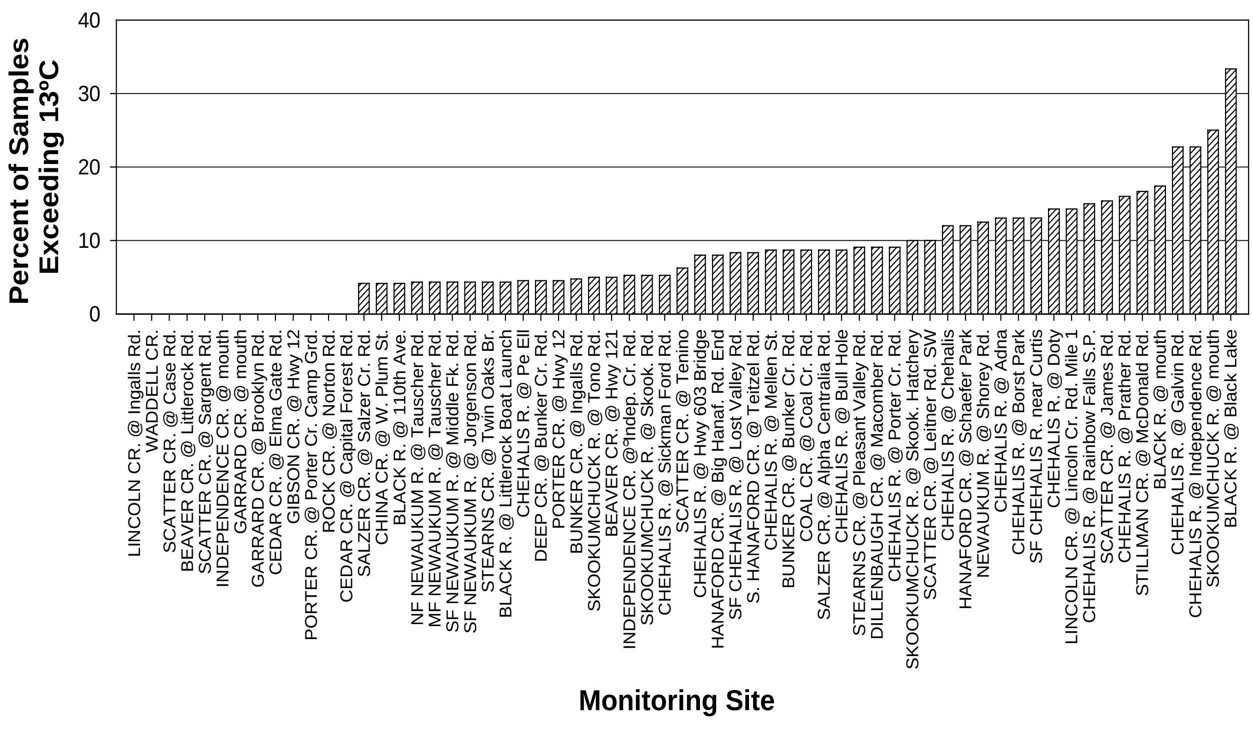


Figure 38. *Temperatures for Fall-Winter-Spring salmon & trout spawning, WRIA 23*. Monitoring sites ranked as described above.

Table 10. *Temperatures for Fall-Winter-Spring salmon & trout spawning, WRIA 22.* Monitoring sites were ranked relative to the percentage of samples that exceeded 13°C during the monitored spawning periods, the number of records analyzed, and the number above 13°C.

Site #	Site Location	Records	# >13ºC	% > 13ºC
3253	WF SATSOP R. @ MF Satsop Rd.	21	0	0.0
3257	MF SATSOP R. @ Kelly Rd.	20	0	0.0
3263	WISHKAH R. @ Hoquiam-Wishkah Rd.	19	0	0.0
3265	EF HOQUIAM R. @ Youmans Rd.	19	0	0.0
3267	WF HOQUIAM R. @ Dekay Rd.	23	0	0.0
3270	HUMPTULIPS R. @ Humpt. Hatchery	19	0	0.0
3271	ELK R. @ Plum St.	20	0	0.0
3287	EF HUMPTULIPS R. @ Forest Rd. 22	13	0	0.0
3288	WF HUMPTULIPS R. @ Forest Rd. 22	12	0	0.0
3289	WF SATSOP R. @ Cougar Smith Rd.	10	0	0.0
3384	OCEAN SHORES CR. @ Discov. Ave. SE	9	0	0.0
5256	MF SATSOP R. @ MF Satsop Rd.	21	0	0.0
5258	EF SATSOP R. @ Schafer Park	21	0	0.0
5351	CLOQUALLUM CR. @ Cloquallum Rd.	20	0	0.0
3283	WINTER CR.	21	1	4.8
3254	SATSOP R. @ Monte Elma Rd.	19	1	5.3
3264	EF WISHKAH R. @ Wyn-Wishkah Rd.	19	1	5.3
3269	HUMPTULIPS R. @ Newsom	19	1	5.3
3350	CLOQUALLUM CR. @ Hwy 12	19	1	5.3
3268	HUMPTULIPS R. @ Burrows	18	1	5.6
3261	WYNOOCHEE R. near Wyn. Lake	16	1	6.3
3390	DELEZENE CR. @ Delezene Cr. Rd.	15	1	6.7
3272	JOHNS R .@ Boat Launch	23	2	8.7
3259	WYNOOCHEE R. @ Devonshire Rd.	22	2	9.1
3260	WYNOOCHEE R. @ Geisler Rd.	21	2	9.5
3262	WISHKAH R. @ Hwy 12	17	2	11.8
3153	CHEHALIS R. @ Hwy 107	22	3	13.6
3266	HOQUIAM R. @ E Hoquiam Rd.	19	3	15.8
3393	WILDCAT CR. @ Heise Rd.	12	2	16.7
3152	CHEHALIS R. @ Wakefield Rd.	21	4	19.0
3173	CHEHALIS R. @ Keys Rd.	20	5	25.0

Table 11. *Temperatures for Fall-Winter-Spring salmon & trout spawning, WRIA 23*. Monitoring sites were ranked relative to the percentage of samples that exceeded 13°C during the spawning periods of Oct.-May 2006-2007, Sept.- May 2007-2008 and Sept.-May 2008-2009.

Site #	Site Location	Records	# >13ºC	% >13ºC
1327	LINCOLN CR. @ Ingalls Rd.	20	0	0.0
2325	WADDELL CR.	20	0	0.0
2333	SCATTER CR. @ Case Rd.	9	0	0.0
2375	BEAVER CR. @ Littlerock Rd.	21	0	0.0
2386	SCATTER CR. @ Sargent Rd.	12	0	0.0
3328	INDEPENDENCE CR. @ mouth	17	0	0.0
3330	GARRARD CR. @ mouth	20	0	0.0
3331	GARRARD CR. @ Brooklyn Rd.	21	0	0.0
3346	CEDAR CR. @ Elma Gate Rd.	22	0	0.0
3347	GIBSON CR. @ Hwy 12	23	0	0.0
3349	PORTER CR. @ Porter Cr. Camp Grd.	22	0	0.0
3392	ROCK CR. @ Norton Rd.	11	0	0.0
3394	CEDAR CR. @ Capital Forest Rd.	10	0	0.0
1320	SALZER CR. @ Salzer Cr. Rd.	24	1	4.2
1321	CHINA CR. @ W. Plum St.	24	1	4.2
2237	BLACK R. @ 110th Ave.	24	1	4.2
1213	NF NEWAUKUM R. @ Tauscher Rd.	23	1	4.3
1214	MF NEWAUKUM R. @ Tauscher Rd.	23	1	4.3
1215	SF NEWAUKUM R. @ Middle Fk. Rd.	23	1	4.3
1216	SF NEWAUKUM R. @ Jorgenson Rd.	23	1	4.3
1309	STEARNS CR. @ Twin Oaks Br.	23	1	4.3
2236	BLACK R. @ Littlerock Boat Launch	23	1	4.3
1101	CHEHALIS R. @ Pe Ell	22	1	4.5
1306	DEEP CR. @ Bunker Cr. Rd.	22	1	4.5
3348	PORTER CR. @ Hwy 12	22	1	4.5
1308	BUNKER CR. @ Ingalls Rd.	21	1	4.8
2218	SKOOKUMCHUCK R. @ Tono Rd.	20	1	5.0
2374	BEAVER CR. @ Hwy 121	20	1	5.0
1329	INDEPENDENCE CR. @ Indep. Cr. Rd.	19	1	5.3
2219	SKOOKUMCHUCK R. @ Skook. Rd.	19	1	5.3
4144	CHEHALIS R. @ Sickman Ford Rd.	19	1	5.3
2334	SCATTER CR. @ Tenino	16	1	6.3
1110	CHEHALIS R. @ Hwy 603 Bridge	25	2	8.0
1323	HANAFORD CR. @ Big Hanaf. Rd. End	25	2	8.0
1206	SF CHEHALIS R. @ Lost Valley Rd.	24	2	8.3
1324	S. HANAFORD CR. @ Teitzel Rd.	24	2	8.3
1181	CHEHALIS R. @ Mellen St.	23	2	8.7
1307	BUNKER CR. @ Bunker Cr. Rd.	23	2	8.7
1378	COAL CR. @ Coal Cr. Rd.	23	2	8.7

Table is continued on next page.

Table 11, continued from previous page.

Site #	Site Location	Records	# >13ºC	% > 13ºC
1379	SALZER CR. @ Alpha Centralia Rd.	23	2	8.7
4143	CHEHALIS R. @ Bull Hole	23	2	8.7
1376	STEARNS CR. @ Pleasant Valley Rd.	22	2	9.1
1380	DILLENBAUGH CR. @ Macomber Rd.	22	2	9.1
3145	CHEHALIS R. @ Porter Cr. Rd.	22	2	9.1
2277	SKOOKUMCHUCK R. @ Skook. Hatchery	20	2	10.0
2385	SCATTER CR. @ Leitner Rd. SW	10	1	10.0
1112	CHEHALIS R. @ Chehalis	25	3	12.0
1322	HANAFORD CR. @ Schaefer Park	25	3	12.0
1211	NEWAUKUM R. @ Shorey Rd.	24	3	12.5
1104	CHEHALIS R. @ Adna	23	3	13.0
1182	CHEHALIS R. @ Borst Park	23	3	13.0
1205	SF CHEHALIS R. near Curtis	23	3	13.0
1102	CHEHALIS R. @ Doty	21	3	14.3
1326	LINCOLN CR. @ Lincoln Cr. Rd. Mile 1	21	3	14.3
1103	CHEHALIS R. @ Rainbow Falls S.P.	20	3	15.0
2332	SCATTER CR. @ James Rd.	26	4	15.4
1141	CHEHALIS R. @ Prather Rd.	25	4	16.0
1391	STILLMAN CR. @ McDonald Rd.	12	2	16.7
4235	BLACK R. @ mouth	23	4	17.4
1140	CHEHALIS R. @ Galvin Rd.	22	5	22.7
1142	CHEHALIS R. @ Independence Rd.	22	5	22.7
1217	SKOOKUMCHUCK R. @ mouth	8	2	25.0
2238	BLACK R. @ Black Lake	21	7	33.3

Temperature for Core Summer Salmonid Habitat

The Core Summer Salmonid temperature criterion of 16ºC (60.8ºF) was exceeded more than 35% of the time during the summer months June 1-August 31 in 2007 and 2008 at several of the monitoring sites throughout the Chehalis River basin (Figure 39). The warmer temperatures mainly occurred in July and August (Figure 35). The three sites along the mainstem Chehalis River were warmer than most tributary waters, with temperature exceeding 16ºC in 100% of the samples.

In WRIA 22, temperature at most of the monitoring sites never exceeded 16°C (Figure 40, Table 12). The monitoring sites with the highest incidence of temperatures exceeding 16°C during the summer were the three monitoring sites on the mainstem Chehalis River, and the site on Hoquiam River at Hoquiam Road, near the mouth. In WRIA 23, most of the monitoring sites exceeded 16°C in at least 35% of the samples collected during the summer months (Figure 41, Table 13). At 21 monitoring sites in WRIA 23, including most of the mainstem Chehalis River sites, temperatures exceeded 16°C in at least 80% of the samples collected during the summer.

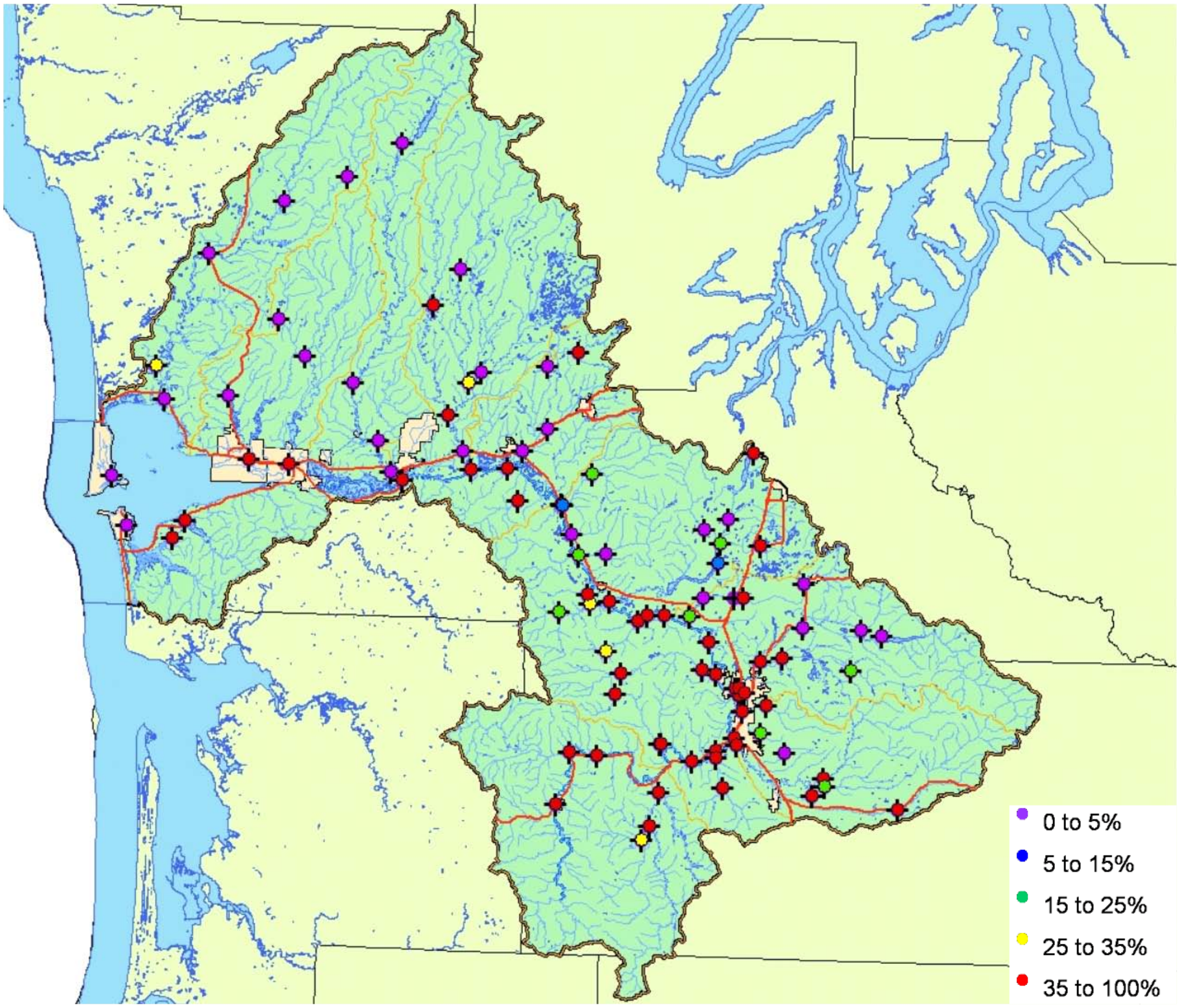


Figure 39. Core Summer Salmonid temperature conditions in the Chehalis River basin. Monitoring sites were ranked relative to the percentage of samples that exceeded 16°C (60.8°F) during the summer months June 1 – August 31, 2007 and 2008.

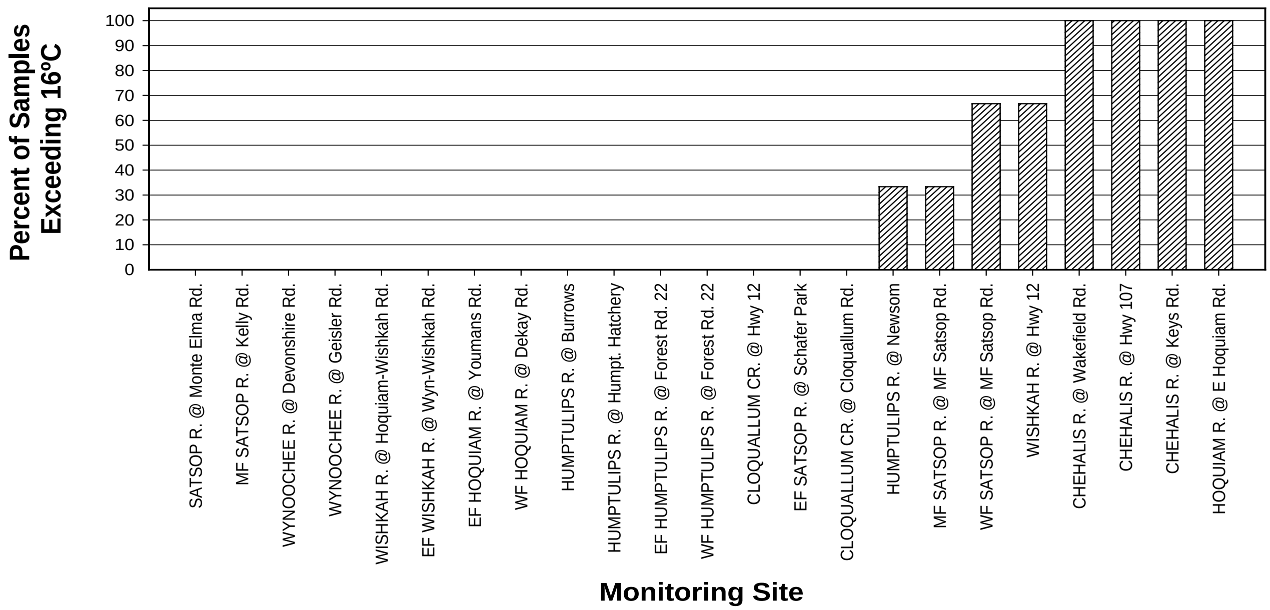


Figure 40. *Salmonid Summer Core Temperatures, WRIA 22.* Monitoring sites were ranked relative to the percentage of samples that exceeded 16°C (60.8°F) during June 1 – August 31, 2007 and 2008.

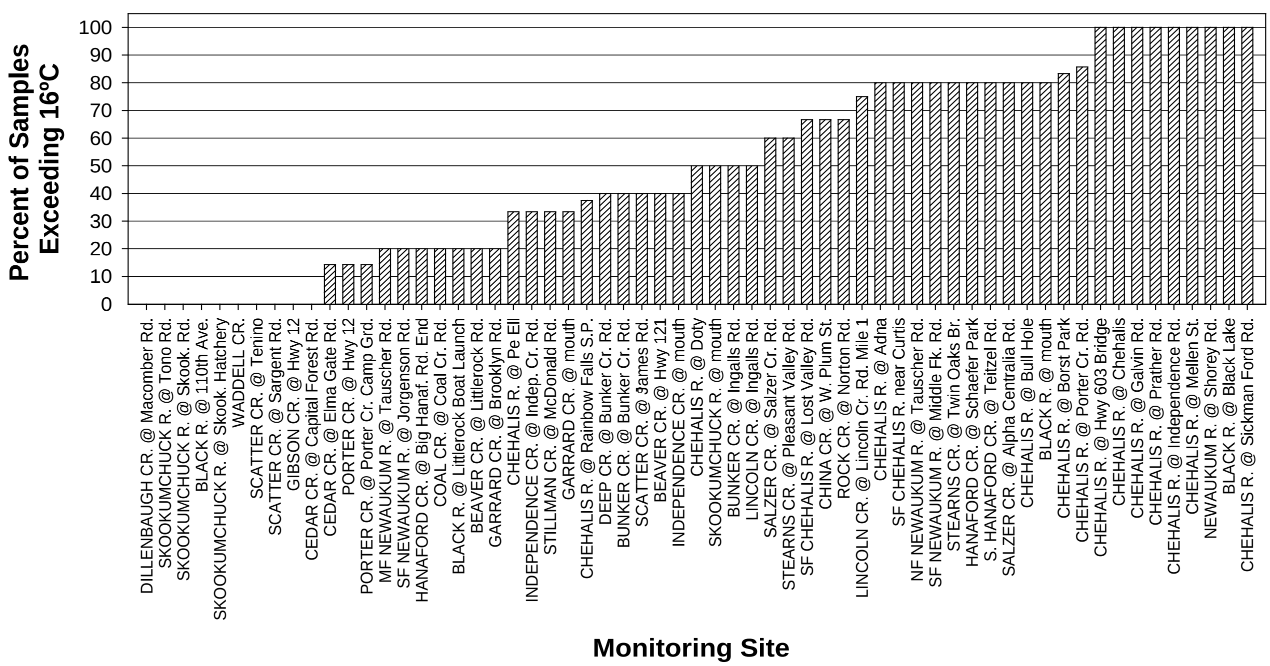


Figure 41. Salmonid Summer Core Temperatures, WRIA 23. Monitoring sites were ranked relative to the percentage of samples that exceeded 16°C during June 1 – August 31, 2007 and 2008.

Table 12. Salmonid Summer Core Temperature conditions in WRIA 22. Monitoring sites were ranked relative to the percentage of samples that exceeded 16°C (60.8°F) during the summer periods of June 1 – August 31, 2007 and 2008.

Site #	Site Location	Records	# > 16ºC	% > 16ºC
3254	SATSOP R. @ Monte Elma Rd.	4	0	0.0
3257	MF SATSOP R. @ Kelly Rd.	3	0	0.0
3259	WYNOOCHEE R. @ Devonshire Rd.	4	0	0.0
3260	WYNOOCHEE R. @ Geisler Rd.	4	0	0.0
3263	WISHKAH R. @ Hoquiam-Wishkah Rd.	4	0	0.0
3264	EF WISHKAH R. @ Wyn-Wishkah Rd.	4	0	0.0
3265	EF HOQUIAM R. @ Youmans Rd.	4	0	0.0
3267	WF HOQUIAM R. @ Dekay Rd.	5	0	0.0
3270	HUMPTULIPS R. @ Humpt. Hatchery	4	0	0.0
3283	WINTER CR.	3	0	0.0
3287	EF HUMPTULIPS R. @ Forest Rd. 22	3	0	0.0
3288	WF HUMPTULIPS R. @ Forest Rd. 22	3	0	0.0
3350	CLOQUALLUM CR. @ Hwy 12	6	0	0.0
3384	OCEAN SHORES CR. @ Discov. Ave. SE	3	0	0.0
3393	WILDCAT CR. @ Heise Rd.	3	0	0.0
5258	EF SATSOP R. @ Schafer Park	4	0	0.0
5351	CLOQUALLUM CR. @ Cloquallum Rd.	5	0	0.0
3269	HUMPTULIPS R. @ Newsom	5	1	20.0
5256	MF SATSOP R. @ MF Satsop Rd.	4	1	25.0
3268	HUMPTULIPS R. @ Burrows	5	2	40.0
3253	WF SATSOP R. @ MF Satsop Rd.	4	2	50.0
3153	CHEHALIS R. @ Hwy 107	4	3	75.0
3266	HOQUIAM R. @ E Hoquiam Rd.	4	3	75.0
3173	CHEHALIS R. @ Keys Rd.	5	4	80.0
3152	CHEHALIS R. @ Wakefield Rd.	5	5	100.0
3271	ELK R. @ Plum St.	3	3	100.0
3272	JOHNS R .@ Boat Launch	3	3	100.0

Table 13. Salmonid Summer Core temperature conditions in WRIA 23. Monitoring sites were ranked relative to the percentage of samples that exceeded 16°C (60.8°F) during the summer periods of June 1 – August 31, 2007 and 2008.

Site #	Site Location	Records	# >16ºC	% >16ºC
1380	DILLENBAUGH CR. @ Macomber Rd.	5	0	0.0
2218	SKOOKUMCHUCK R. @ Tono Rd.	5	0	0.0
2219	SKOOKUMCHUCK R. @ Skook. Rd.	5	0	0.0
2237	BLACK R. @ 110th Ave.	3	0	0.0
2277	SKOOKUMCHUCK R. @ Skook. Hatchery	5	0	0.0
2325	WADDELL CR.	5	0	0.0
2334	SCATTER CR. @ Tenino	1	0	0.0
2386	SCATTER CR. @ Sargent Rd.	3	0	0.0
3347	GIBSON CR. @ Hwy 12	6	0	0.0
3394	CEDAR CR. @ Capital Forest Rd.	3	0	0.0
3346	CEDAR CR. @ Elma Gate Rd.	7	1	14.3
3348	PORTER CR. @ Hwy 12	7	1	14.3
3349	PORTER CR. @ Porter Cr. Camp Grd.	7	1	14.3
1214	MF NEWAUKUM R. @ Tauscher Rd.	5	1	20.0
1216	SF NEWAUKUM R. @ Jorgenson Rd.	5	1	20.0
1323	HANAFORD CR. @ Big Hanaf. Rd. End	5	1	20.0
1378	COAL CR. @ Coal Cr. Rd.	5	1	20.0
2236	BLACK R. @ Littlerock Boat Launch	5	1	20.0
2375	BEAVER CR. @ Littlerock Rd.	5	1	20.0
3331	GARRARD CR. @ Brooklyn Rd.	5	1	20.0
1101	CHEHALIS R. @ Pe Ell	6	2	33.3
1329	INDEPENDENCE CR. @ Indep. Cr. Rd.	3	1	33.3
1391	STILLMAN CR. @ McDonald Rd.	3	1	33.3
3330	GARRARD CR. @ mouth	3	1	33.3
1103	CHEHALIS R. @ Rainbow Falls S.P.	8	3	37.5
1306	DEEP CR. @ Bunker Cr. Rd.	5	2	40.0
1307	BUNKER CR. @ Bunker Cr. Rd.	5	2	40.0
2332	SCATTER CR. @ James Rd.	5	2	40.0
2374	BEAVER CR. @ Hwy 121	5	2	40.0
3328	INDEPENDENCE CR. @ mouth	5	2	40.0
1102	CHEHALIS R. @ Doty	6	3	50.0
1217	SKOOKUMCHUCK R. @ mouth	6	3	50.0
1308	BUNKER CR. @ Ingalls Rd.	4	2	50.0
1327	LINCOLN CR. @ Ingalls Rd.	4	2	50.0
1320	SALZER CR. @ Salzer Cr. Rd.	5	3	60.0
1376	STEARNS CR. @ Pleasant Valley Rd.	5	3	60.0
1206	SF CHEHALIS R. @ Lost Valley Rd.	6	4	66.7

Table is continued on next page.

Table 13, continued from previous page.

Site #	Site Location	Records	# >16ºC	% > 16ºC
1321	CHINA CR. @ W. Plum St.	6	4	66.7
3392	ROCK CR. @ Norton Rd.	3	2	66.7
1326	LINCOLN CR. @ Lincoln Cr. Rd. Mile 1	4	3	75.0
1104	CHEHALIS R. @ Adna	5	4	80.0
1205	SF CHEHALIS R. near Curtis	5	4	80.0
1213	NF NEWAUKUM R. @ Tauscher Rd.	5	4	80.0
1215	SF NEWAUKUM R. @ Middle Fk. Rd.	5	4	80.0
1309	STEARNS CR. @ Twin Oaks Br.	5	4	80.0
1322	HANAFORD CR. @ Schaefer Park	5	4	80.0
1324	S. HANAFORD CR. @ Teitzel Rd.	5	4	80.0
1379	SALZER CR. @ Alpha Centralia Rd.	5	4	80.0
4143	CHEHALIS R. @ Bull Hole	5	4	80.0
4235	BLACK R. @ mouth	5	4	80.0
1182	CHEHALIS R. @ Borst Park	6	5	83.3
3145	CHEHALIS R. @ Porter Cr. Rd.	7	6	85.7
1110	CHEHALIS R. @ Hwy 603 Bridge	5	5	100.0
1112	CHEHALIS R. @ Chehalis	5	5	100.0
1140	CHEHALIS R. @ Galvin Rd.	3	3	100.0
1141	CHEHALIS R. @ Prather Rd.	4	4	100.0
1142	CHEHALIS R. @ Independence Rd.	3	3	100.0
1181	CHEHALIS R. @ Mellen St.	5	5	100.0
1211	NEWAUKUM R. @ Shorey Rd.	5	5	100.0
2238	BLACK R. @ Black Lake	5	5	100.0
4144	CHEHALIS R. @ Sickman Ford Rd.	5	5	100.0

Seasonal Temperature Pattern Relative to Char Spawning and Rearing

At most monitoring sites throughout the Chehalis River Basin, water temperatures exceeded the Char Rearing criterion of 12ºC (54.6ºF) during the summer months, and often by a considerable margin (Figure 42). During the analyzed char spawning periods, temperatures at all monitoring sites exceeded the Char Spawning temperature criterion of 9ºC (48.2ºF) during September, and at most sites, water temperature was also warmer than 9ºC in September. In November, most sites had temperatures below 9ºC, and were within the acceptable temperature range for char spawning.

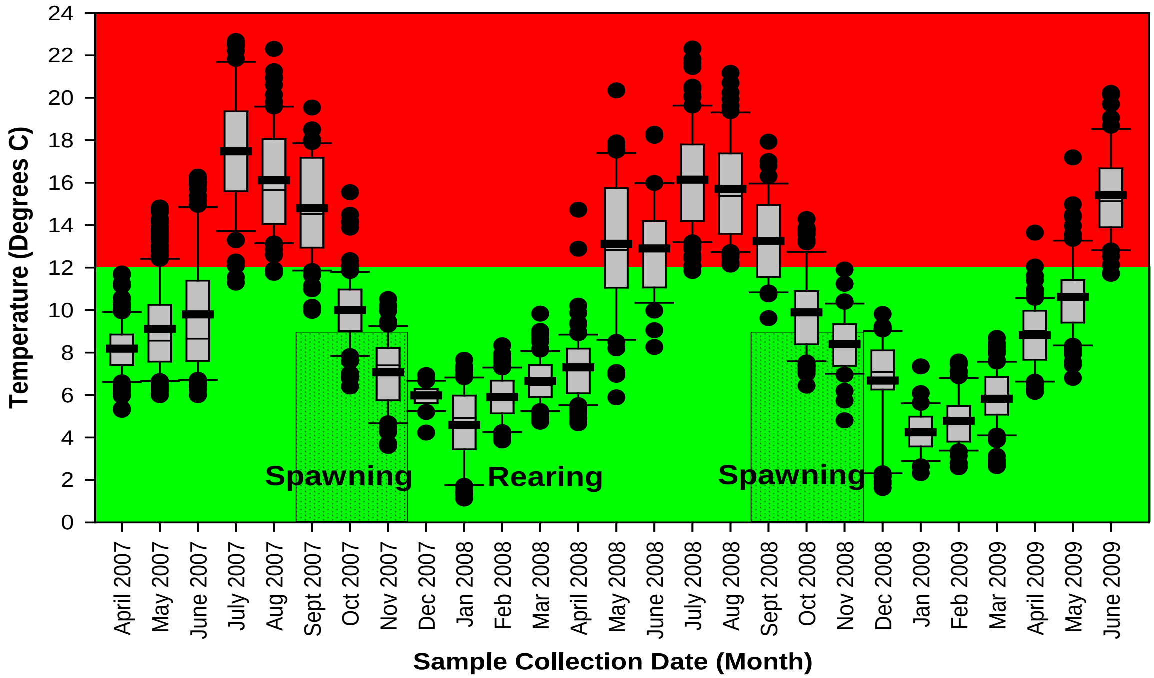


Figure 42. Average monthly temperatures in the Chehalis River basin relative to the Char Spawning Temperature Criterion of 9°C (48.2°F) and the Char Rearing temperature criterion of 12ºC (54.6°F). Box plots as described in the caption for Figure 6.

Evaluation of Water Temperature at Specific Monitoring Sites Relative to Char Spawning and Rearing

Temperature Conditions for Fall Char Spawning

WRIA 22

During the monitored char spawning periods, streams in WRIA 22 where temperature measurements were most consistently below 9°C included the Humptulips River, East Fork Humptulips River, Satsop River, Middle Fork Satsop River, West Fork Satsop River, East Fork Satsop River, Delezene Creek, and West Fork Hoquiam River (Figure 43, Table 14). Less than 35% of the measurements taken in these streams were above 9ºC during the fall char spawning periods, indicating that temperatures were adequately cool for char spawning at least in October and November (if not September), at these monitoring sites.

WRIA 23

In WRIA 23, only a few isolated monitoring locations had cool fall water temperatures with less than 35% of the temperature measurements below 9°C (Figure 44, Table 15). These included sites on Scatter Creek, Deep Creek Bunker Creek, and Independence Creek.

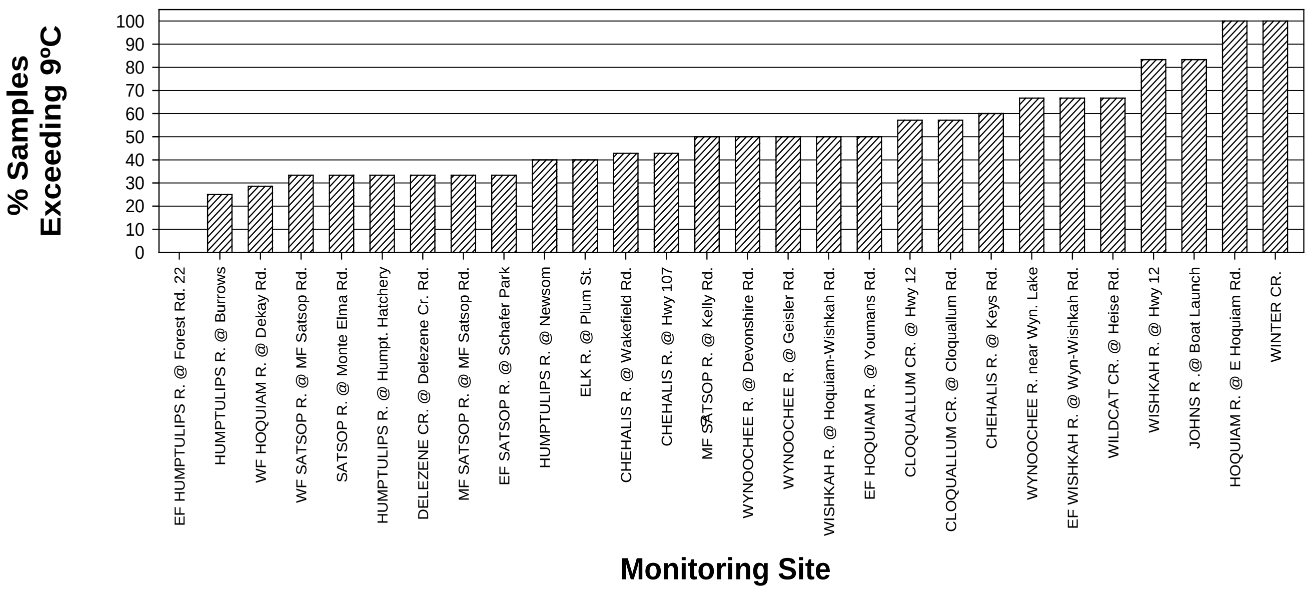


Figure 43. *Char Spawning Temperatures, WRIA 22*. Monitoring sites were ranked relative to the percent of samples that exceeded 9°C during Sept. 1 – Nov. 31, 2007 and 2008 Sites with lower % rank provided longer time periods with suitable spawning temperatures for char.

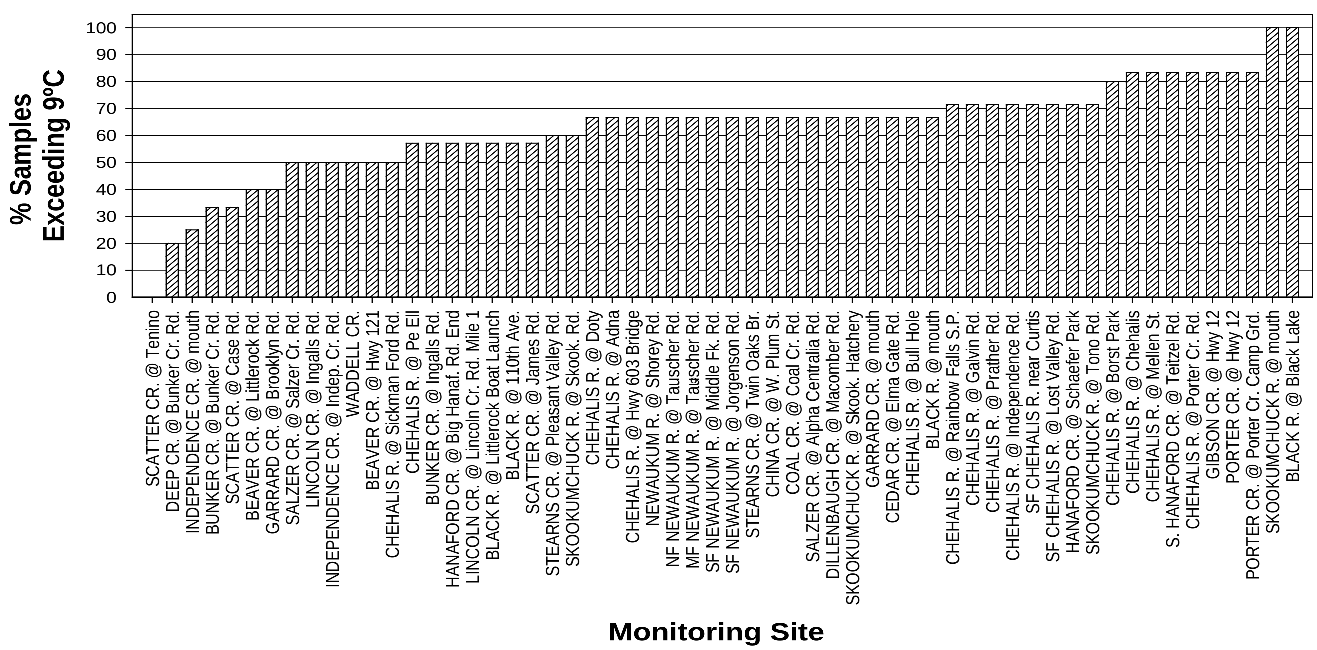


Figure 44. *Char Spawning Temperatures, WRIA 23*. Monitoring sites were ranked relative to the percent of samples that exceeded 9°C during Sept. 1 – Nov. 31, 2007 and 2008.

Table 14. Temperatures for Char Spawning, WRIA 22. Monitoring sites were ranked relative to the percentage of samples that exceeded 9ºC (48.2ºF) during the spawning periods of Sept.-Nov. 2007, and Sept.-Nov. 2008.

Site #	Site Location	Records	# >9ºC	% > 9ºC
3287	EF HUMPTULIPS R. @ Forest Rd. 22	3	0	0.0
3268	HUMPTULIPS R. @ Burrows	4	1	25.0
3267	WF HOQUIAM R. @ Dekay Rd.	7	2	28.6
3253	WF SATSOP R. @ MF Satsop Rd.	6	2	33.3
3254	SATSOP R. @ Monte Elma Rd.	6	2	33.3
3270	HUMPTULIPS R. @ Humpt. Hatchery	6	2	33.3
3390	DELEZENE CR. @ Delezene Cr. Rd.	3	1	33.3
5256	MF SATSOP R. @ MF Satsop Rd.	6	2	33.3
5258	EF SATSOP R. @ Schafer Park	6	2	33.3
3269	HUMPTULIPS R. @ Newsom	5	2	40.0
3271	ELK R. @ Plum St.	5	2	40.0
3152	CHEHALIS R. @ Wakefield Rd.	7	3	42.9
3153	CHEHALIS R. @ Hwy 107	7	3	42.9
3257	MF SATSOP R. @ Kelly Rd.	6	3	50.0
3259	WYNOOCHEE R. @ Devonshire Rd.	6	3	50.0
3260	WYNOOCHEE R. @ Geisler Rd.	6	3	50.0
3263	WISHKAH R. @ Hoquiam-Wishkah Rd.	6	3	50.0
3265	EF HOQUIAM R. @ Youmans Rd.	6	3	50.0
3350	CLOQUALLUM CR. @ Hwy 12	7	4	57.1
5351	CLOQUALLUM CR. @ Cloquallum Rd.	7	4	57.1
3173	CHEHALIS R. @ Keys Rd.	5	3	60.0
3261	WYNOOCHEE R. near Wyn. Lake	3	2	66.7
3264	EF WISHKAH R. @ Wyn-Wishkah Rd.	6	4	66.7
3393	WILDCAT CR. @ Heise Rd.	3	2	66.7
3262	WISHKAH R. @ Hwy 12	6	5	83.3
3272	JOHNS R .@ Boat Launch	6	5	83.3
3266	HOQUIAM R. @ E Hoquiam Rd.	6	6	100.0
3283	WINTER CR.	5	5	100.0

Table 15. Temperatures for Char Spawning, WRIA 23. Monitoring sites were ranked relative to the percentage of samples that exceeded 9ºC (48.2ºF) during the spawning periods of Sept.-Nov. 2007, and Sept.-Nov. 2008.

Site #	Site Location	Records	# >9ºC	% >9ºC
2334	SCATTER CR. @ Tenino	3	0	0.0
1306	DEEP CR. @ Bunker Cr. Rd.	5	1	20.0
3328	INDEPENDENCE CR. @ mouth	4	1	25.0
1307	BUNKER CR. @ Bunker Cr. Rd.	6	2	33.3
2333	SCATTER CR. @ Case Rd.	3	1	33.3
2375	BEAVER CR. @ Littlerock Rd.	5	2	40.0
3331	GARRARD CR. @ Brooklyn Rd.	5	2	40.0
1320	SALZER CR. @ Salzer Cr. Rd.	6	3	50.0
1327	LINCOLN CR. @ Ingalls Rd.	6	3	50.0
1329	INDEPENDENCE CR. @ Indep. Cr. Rd.	6	3	50.0
2325	WADDELL CR.	4	2	50.0
2374	BEAVER CR. @ Hwy 121	6	3	50.0
4144	CHEHALIS R. @ Sickman Ford Rd.	4	2	50.0
1101	CHEHALIS R. @ Pe Ell	7	4	57.1
1308	BUNKER CR. @ Ingalls Rd.	7	4	57.1
1323	HANAFORD CR. @ Big Hanaf. Rd. End	7	4	57.1
1326	LINCOLN CR. @ Lincoln Cr. Rd. Mile 1	7	4	57.1
2236	BLACK R. @ Littlerock Boat Launch	7	4	57.1
2237	BLACK R. @ 110th Ave.	7	4	57.1
2332	SCATTER CR. @ James Rd.	7	4	57.1
1376	STEARNS CR. @ Pleasant Valley Rd.	5	3	60.0
2219	SKOOKUMCHUCK R. @ Skook. Rd.	5	3	60.0
1102	CHEHALIS R. @ Doty	6	4	66.7
1104	CHEHALIS R. @ Adna	6	4	66.7
1110	CHEHALIS R. @ Hwy 603 Bridge	6	4	66.7
1211	NEWAUKUM R. @ Shorey Rd.	6	4	66.7
1213	NF NEWAUKUM R. @ Tauscher Rd.	6	4	66.7
1214	MF NEWAUKUM R. @ Tauscher Rd.	6	4	66.7
1215	SF NEWAUKUM R. @ Middle Fk. Rd.	6	4	66.7
1216	SF NEWAUKUM R. @ Jorgenson Rd.	6	4	66.7
1309	STEARNS CR. @ Twin Oaks Br.	6	4	66.7
1321	CHINA CR. @ W. Plum St.	6	4	66.7
1378	COAL CR. @ Coal Cr. Rd.	6	4	66.7
1379	SALZER CR. @ Alpha Centralia Rd.	6	4	66.7
1380	DILLENBAUGH CR. @ Macomber Rd.	6	4	66.7
2277	SKOOKUMCHUCK R. @ Skook. Hatchery	6	4	66.7
3330	GARRARD CR. @ mouth	6	4	66.7
3346	CEDAR CR. @ Elma Gate Rd.	6	4	66.7
4143	CHEHALIS R. @ Bull Hole	6	4	66.7

Table is continued on next page.

Table 15, continued from previous page.

Site #	Site Location	Records	# >13ºC	% > 13ºC
4235	BLACK R. @ mouth	6	4	66.7
1103	CHEHALIS R. @ Rainbow Falls S.P.	7	5	71.4
1140	CHEHALIS R. @ Galvin Rd.	7	5	71.4
1141	CHEHALIS R. @ Prather Rd.	7	5	71.4
1142	CHEHALIS R. @ Independence Rd.	7	5	71.4
1205	SF CHEHALIS R. near Curtis	7	5	71.4
1206	SF CHEHALIS R. @ Lost Valley Rd.	7	5	71.4
1322	HANAFORD CR. @ Schaefer Park	7	5	71.4
2218	SKOOKUMCHUCK R. @ Tono Rd.	7	5	71.4
1182	CHEHALIS R. @ Borst Park	5	4	80.0
1112	CHEHALIS R. @ Chehalis	6	5	83.3
1181	CHEHALIS R. @ Mellen St.	6	5	83.3
1324	S. HANAFORD CR. @ Teitzel Rd.	6	5	83.3
3145	CHEHALIS R. @ Porter Cr. Rd.	6	5	83.3
3347	GIBSON CR. @ Hwy 12	6	5	83.3
3348	PORTER CR. @ Hwy 12	6	5	83.3
3349	PORTER CR. @ Porter Cr. Camp Grd.	6	5	83.3
1217	SKOOKUMCHUCK R. @ mouth	3	3	100.0
2238	BLACK R. @ Black Lake	6	6	100.0

Temperature Conditions for All-Year Char Rearing

Throughout the Chehalis River basin during the period of this study, temperatures exceeded the All-Year Char Rearing Criterion of 12ºC (54.6°F) in from 0% to 42% of measurements at different monitoring sites (Figures 45, 46, 47, and Tables 16 and 17). Streams with temperatures most consistently cool enough for char rearing were in WRIA 22, and included the Humptulips River, East Fork Humptulips River, West Fork Humptulips River, East Fork Satsop River, Middle Fork Satsop River, Delezene Creek, and West Fork Hoquiam River. Less than 15% of the measurements taken in these streams were above 12ºC during the period of this study.

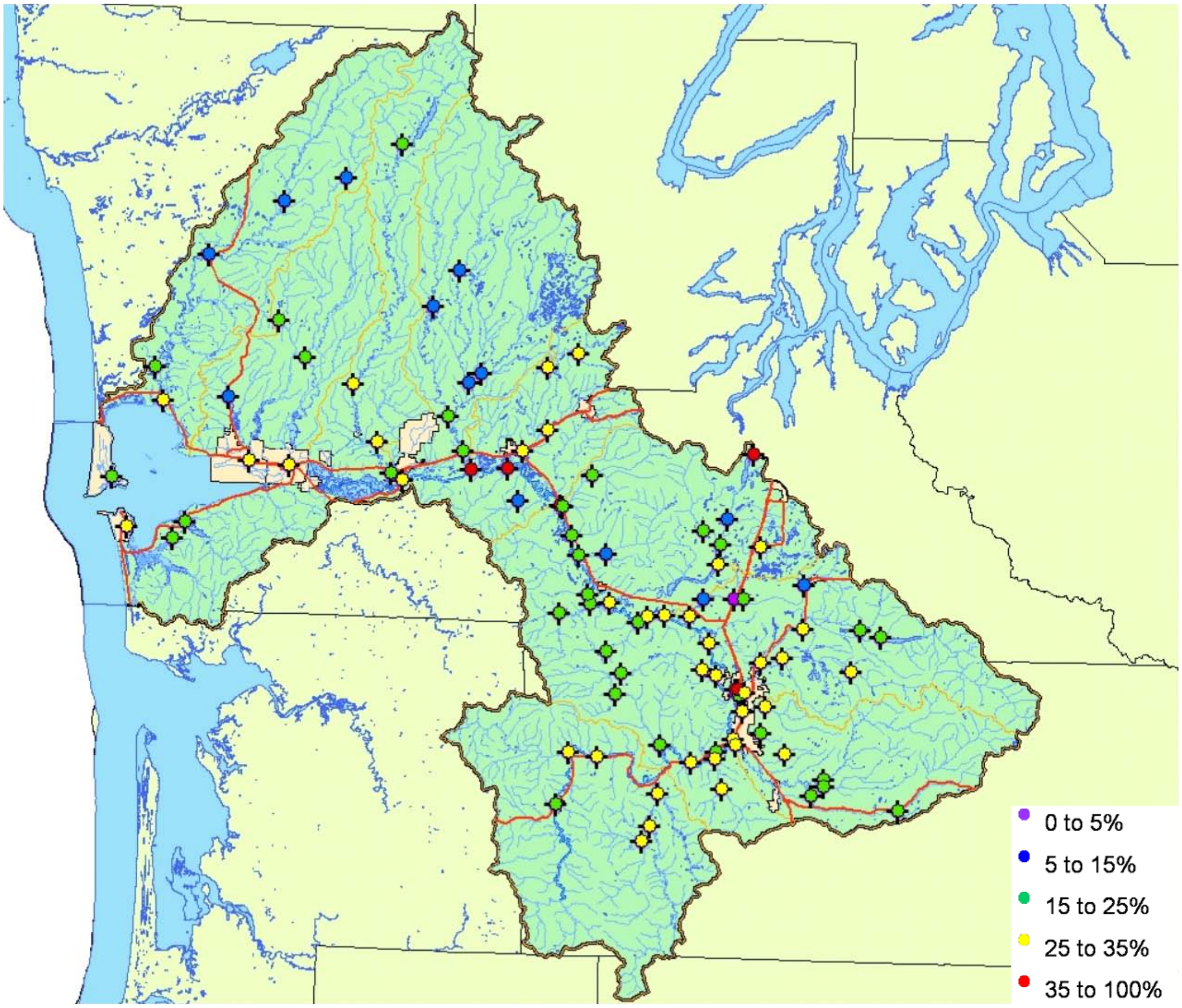


Figure 45. All-Year Char Rearing temperature conditions in the Chehalis River basin. Monitoring sites were ranked relative to the percentage of samples that exceeded 12°C during the entire study period of October 15 2006 through June 31, 2009.

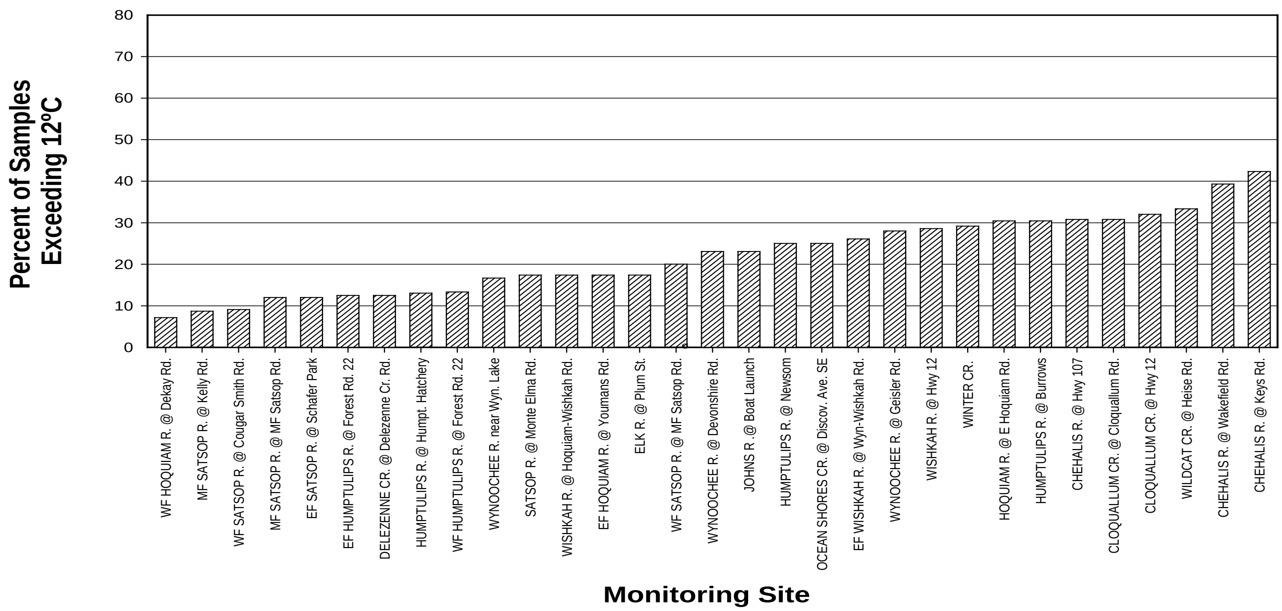


Figure 46. *All-Year Char Temperatures, WRIA 22*. Monitoring sites were ranked relative to the percent of samples that exceeded 12°C during the entire study period October 2006 – June 2009.

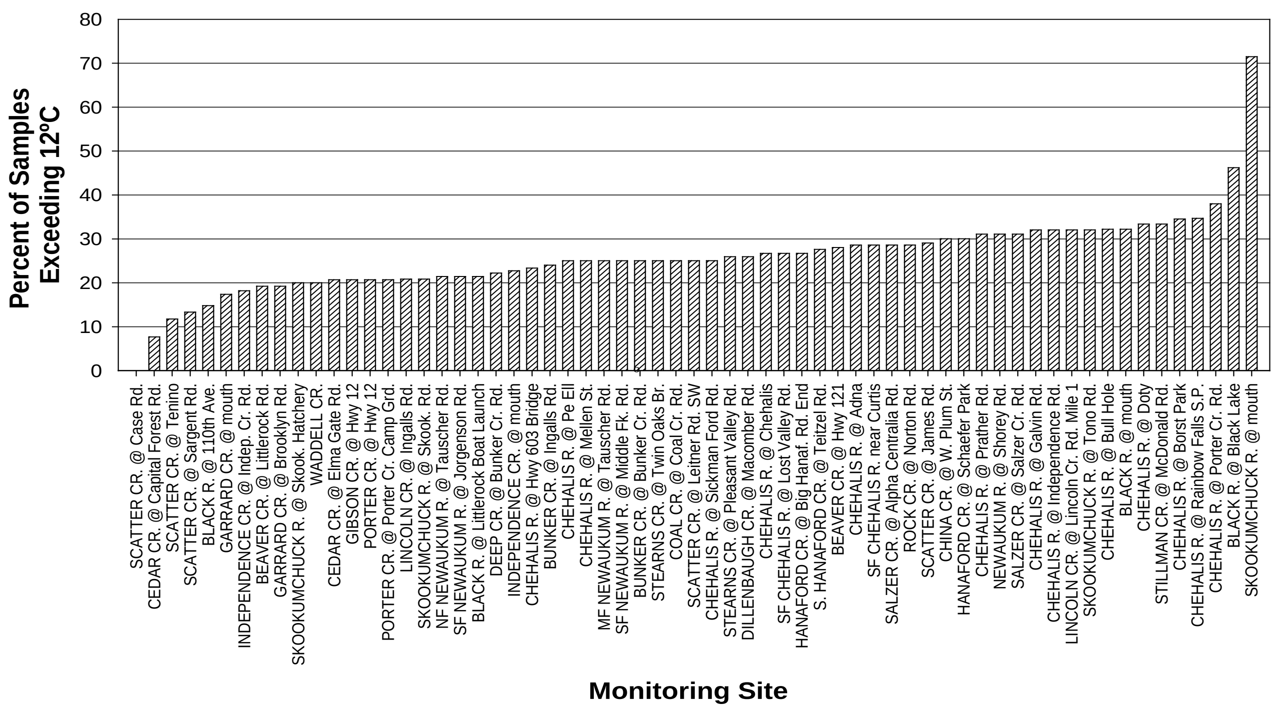


Figure 47. *All-Year Char Temperatures, WRIA 23*. Monitoring sites were ranked relative to the percent of samples that exceeded 12°C during the entire study period October 2006 – June 2009.

Table 16. Temperatures for Char Rearing: Monitoring sites in WRIA 22 ranked for percent samples that exceeded 12 ºC over the period October 22, 2006 to June 30, 2009.

Site #	Site Location	Records	# >12º	% >12º
3267	WF HOQUIAM R. @ Dekay Rd.	28	2	7.1
3257	MF SATSOP R. @ Kelly Rd.	23	2	8.7
3289	WF SATSOP R. @ Cougar Smith Rd.	11	1	9.1
5256	MF SATSOP R. @ MF Satsop Rd.	25	3	12.0
5258	EF SATSOP R. @ Schafer Park	25	3	12.0
3287	EF HUMPTULIPS R. @ Forest Rd. 22	16	2	12.5
3390	DELEZENE CR. @ Delezene Cr. Rd.	16	2	12.5
3270	HUMPTULIPS R. @ Humpt. Hatchery	23	3	13.0
3288	WF HUMPTULIPS R. @ Forest Rd. 22	15	2	13.3
3261	WYNOOCHEE R. near Wyn. Lake	18	3	16.7
3254	SATSOP R. @ Monte Elma Rd.	23	4	17.4
3263	WISHKAH R. @ Hoquiam-Wishkah Rd.	23	4	17.4
3265	EF HOQUIAM R. @ Youmans Rd.	23	4	17.4
3271	ELK R. @ Plum St.	23	4	17.4
3253	WF SATSOP R. @ MF Satsop Rd.	25	5	20.0
3259	WYNOOCHEE R. @ Devonshire Rd.	26	6	23.1
3272	JOHNS R .@ Boat Launch	26	6	23.1
3269	HUMPTULIPS R. @ Newsom	24	6	25.0
3384	OCEAN SHORES CR. @ Discov. Ave. SE	12	3	25.0
3264	EF WISHKAH R. @ Wyn-Wishkah Rd.	23	6	26.1
3260	WYNOOCHEE R. @ Geisler Rd.	25	7	28.0
3262	WISHKAH R. @ Hwy 12	21	6	28.6
3283	WINTER CR.	24	7	29.2
3266	HOQUIAM R. @ E Hoquiam Rd.	23	7	30.4
3268	HUMPTULIPS R. @ Burrows	23	7	30.4
3153	CHEHALIS R. @ Hwy 107	26	8	30.8
5351	CLOQUALLUM CR. @ Cloquallum Rd.	26	8	30.8
3350	CLOQUALLUM CR. @ Hwy 12	25	8	32.0
3393	WILDCAT CR. @ Heise Rd.	15	5	33.3
3152	CHEHALIS R. @ Wakefield Rd.	28	11	39.3
3173	CHEHALIS R. @ Keys Rd.	26	11	42.3

Table 17. Temperatures for Char Rearing: Monitoring sites in WRIA 23 ranked for percent samples that exceeded 12 ºC over the period October 22, 2006 to June 30, 2009.

Site #	Site Location	Records	# >12º	% > 12º
2333	SCATTER CR. @ Case Rd.	9	0	0.0
3394	CEDAR CR. @ Capital Forest Rd.	13	1	7.7
2334	SCATTER CR. @ Tenino	17	2	11.8
2386	SCATTER CR. @ Sargent Rd.	15	2	13.3
2237	BLACK R. @ 110th Ave.	27	4	14.8
3330	GARRARD CR. @ mouth	23	4	17.4
1329	INDEPENDENCE CR. @ Indep. Cr. Rd.	22	4	18.2
2375	BEAVER CR. @ Littlerock Rd.	26	5	19.2
3331	GARRARD CR. @ Brooklyn Rd.	26	5	19.2
2277	SKOOKUMCHUCK R. @ Skookumchuck Hatchery	25	5	20.0
2325	WADDELL CR.	25	5	20.0
3348	PORTER CR. @ Hwy 12	30	6	20.0
3346	CEDAR CR. @ Elma Gate Rd.	29	6	20.7
3347	GIBSON CR. @ Hwy 12	29	6	20.7
3349	PORTER CR. @ Porter Cr. Camp Grd.	29	6	20.7
1327	LINCOLN CR. @ Ingalls Rd.	24	5	20.8
2219	SKOOKUMCHUCK R. @ Skook. Rd.	24	5	20.8
1213	NF NEWAUKUM R. @ Tauscher Rd.	28	6	21.4
1216	SF NEWAUKUM R. @ Jorgenson Rd.	28	6	21.4
1306	DEEP CR. @ Bunker Cr. Rd.	27	6	22.2
3328	INDEPENDENCE CR. @ mouth	22	5	22.7
1110	CHEHALIS R. @ Hwy 603 Bridge	30	7	23.3
1308	BUNKER CR. @ Ingalls Rd.	25	6	24.0
1101	CHEHALIS R. @ Pe Ell	28	7	25.0
1181	CHEHALIS R. @ Mellen St.	28	7	25.0
1214	MF NEWAUKUM R. @ Tauscher Rd.	28	7	25.0
1215	SF NEWAUKUM R. @ Middle Fk. Rd.	28	7	25.0
1307	BUNKER CR. @ Bunker Cr. Rd.	28	7	25.0
1378	COAL CR. @ Coal Cr. Rd.	28	7	25.0
2385	SCATTER CR. @ Leitner Rd. SW	12	3	25.0
4144	CHEHALIS R. @ Sickman Ford Rd.	24	6	25.0
1376	STEARNS CR. @ Pleasant Valley Rd.	27	7	25.9
1380	DILLENBAUGH CR. @ Macomber Rd.	27	7	25.9
1112	CHEHALIS R. @ Chehalis	30	8	26.7
1206	SF CHEHALIS R. @ Lost Valley Rd.	30	8	26.7
1323	HANAFORD CR. @ Big Hanaf. Rd. End	30	8	26.7
2236	BLACK R. @ Littlerock Boat Launch	30	8	26.7
1309	STEARNS CR. @ Twin Oaks Br.	29	8	27.6
1324	S. HANAFORD CR. @ Teitzel Rd.	29	8	27.6
2374	BEAVER CR. @ Hwy 121	25	7	28.0
1104	CHEHALIS R. @ Adna	28	8	28.6

Table is continued on next page.

Table 17, continued from previous page.

Site #	Site Location	Records	# >12º	% Rank
1205	SF CHEHALIS R. near Curtis	28	8	28.6
1379	SALZER CR. @ Alpha Centralia Rd.	28	8	28.6
3392	ROCK CR. @ Norton Rd.	14	4	28.6
2332	SCATTER CR. @ James Rd.	31	9	29.0
1321	CHINA CR. @ W. Plum St.	30	9	30.0
1322	HANAFORD CR. @ Schaefer Park	30	9	30.0
1141	CHEHALIS R. @ Prather Rd.	29	9	31.0
1211	NEWAUKUM R. @ Shorey Rd.	29	9	31.0
1320	SALZER CR. @ Salzer Cr. Rd.	29	9	31.0
1140	CHEHALIS R. @ Galvin Rd.	25	8	32.0
1142	CHEHALIS R. @ Independence Rd.	25	8	32.0
1326	LINCOLN CR. @ Lincoln Cr. Rd. Mile 1	25	8	32.0
2218	SKOOKUMCHUCK R. @ Tono Rd.	25	8	32.0
4143	CHEHALIS R. @ Bull Hole	28	9	32.1
4235	BLACK R. @ mouth	28	9	32.1
1102	CHEHALIS R. @ Doty	27	9	33.3
1391	STILLMAN CR. @ McDonald Rd.	15	5	33.3
1103	CHEHALIS R. @ Rainbow Falls S.P.	26	9	34.6
1182	CHEHALIS R. @ Borst Park	30	11	36.7
3145	CHEHALIS R. @ Porter Cr. Rd.	29	11	37.9
2238	BLACK R. @ Black Lake	26	12	46.2
1217	SKOOKUMCHUCK R. @ mouth	15	11	73.3

Char Habitat in the Humptulips River and Satsop River Watersheds: A Closer Look

Perhaps the most important environmental factor limiting the distribution of bull trout and Dolly Varden in Washington is water temperature. Based on this study, the Humptulips River watershed and Satsop River watershed provide the most suitable temperatures for char within the Chehalis River Basin (Figures 48 and 49).

Humptulips River Watershed

Both the East Fork and West Fork of the Humptulips River originate in the Olympic National Forest (Chehalis River Council, 2000b). Due to the wide riparian buffers stipulated by the Northwest Forest Plan, and the decrease in logging activity in National Forests since the early 1990s, the streams of the upper Humptulips River sub-basin are primarily bordered by mature conifer forest (Figure 48). Most of the sub-basin downstream of the National Forest is privately owned commercial forestland, with some pastureland and cropland. Washington State Forest Practice Rules regulate timber harvest on private lands, and these rules require riparian buffers that vary depending on whether the stream is fish-bearing, the size of the stream, and the soil type. However, the required no-harvest riparian buffers are for the most part at least 90 ft wide. These factors likely contribute to maintaining relatively cool temperatures in streams of the Humptulips River watershed.

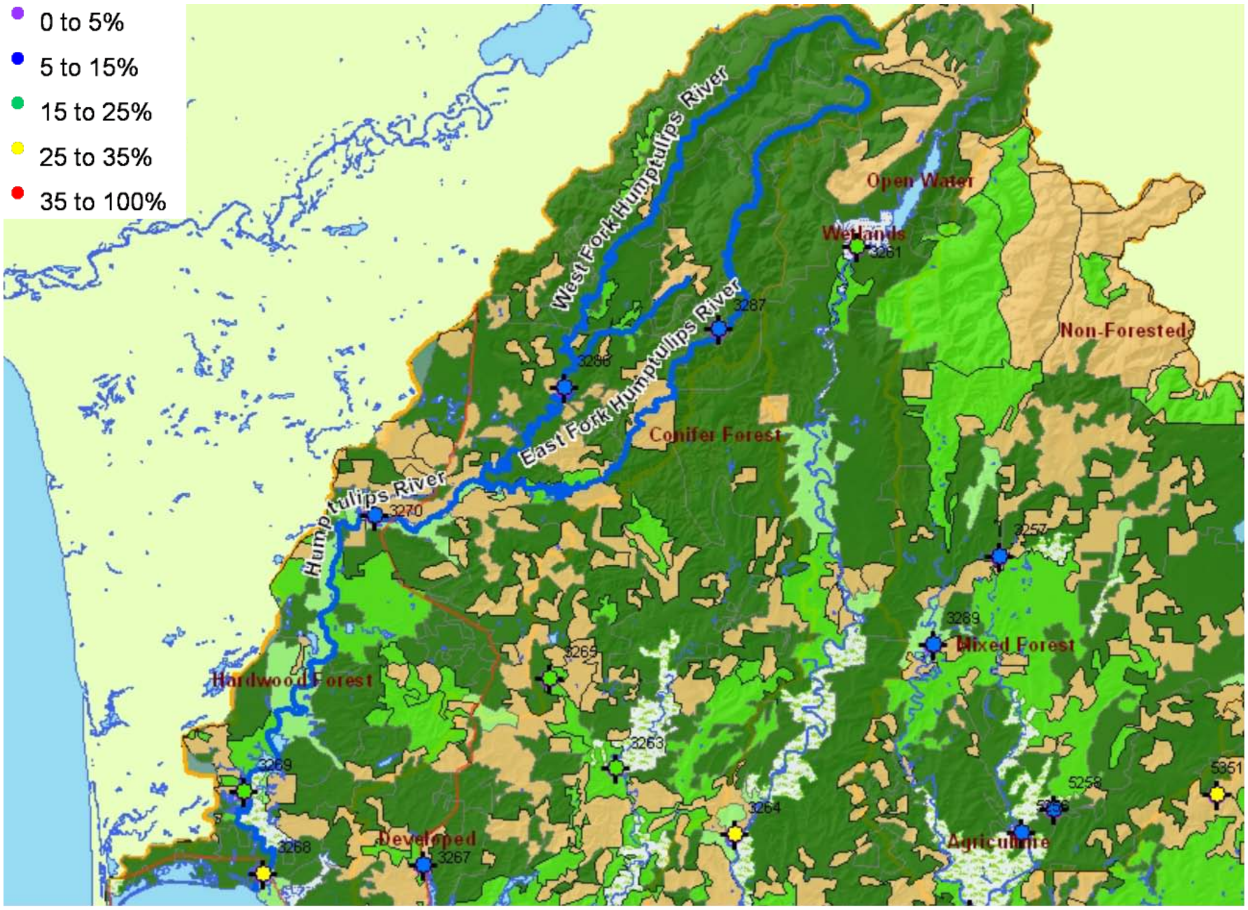


Figure 48. Land use and topography in the Humptulips River watershed, and results of temperature monitoring. Sites are ranked relative to the percent of samples that exceeded the All-Year Char Rearing Criterion of 12ºC.

Satsop River Watershed

As mentioned in the section on Turbidity, the primary land use in the upper Satsop River watershed and along tributary streams is commercial timber production, while farms and pasturelands predominate in the lower elevation river valleys (Figure 49). As the corporate-owned timber producing lands of the upper watershed are regulated by Washington Forest Practice Rules, no-harvest riparian buffers provide shade to streams, helping to maintain cool temperatures.

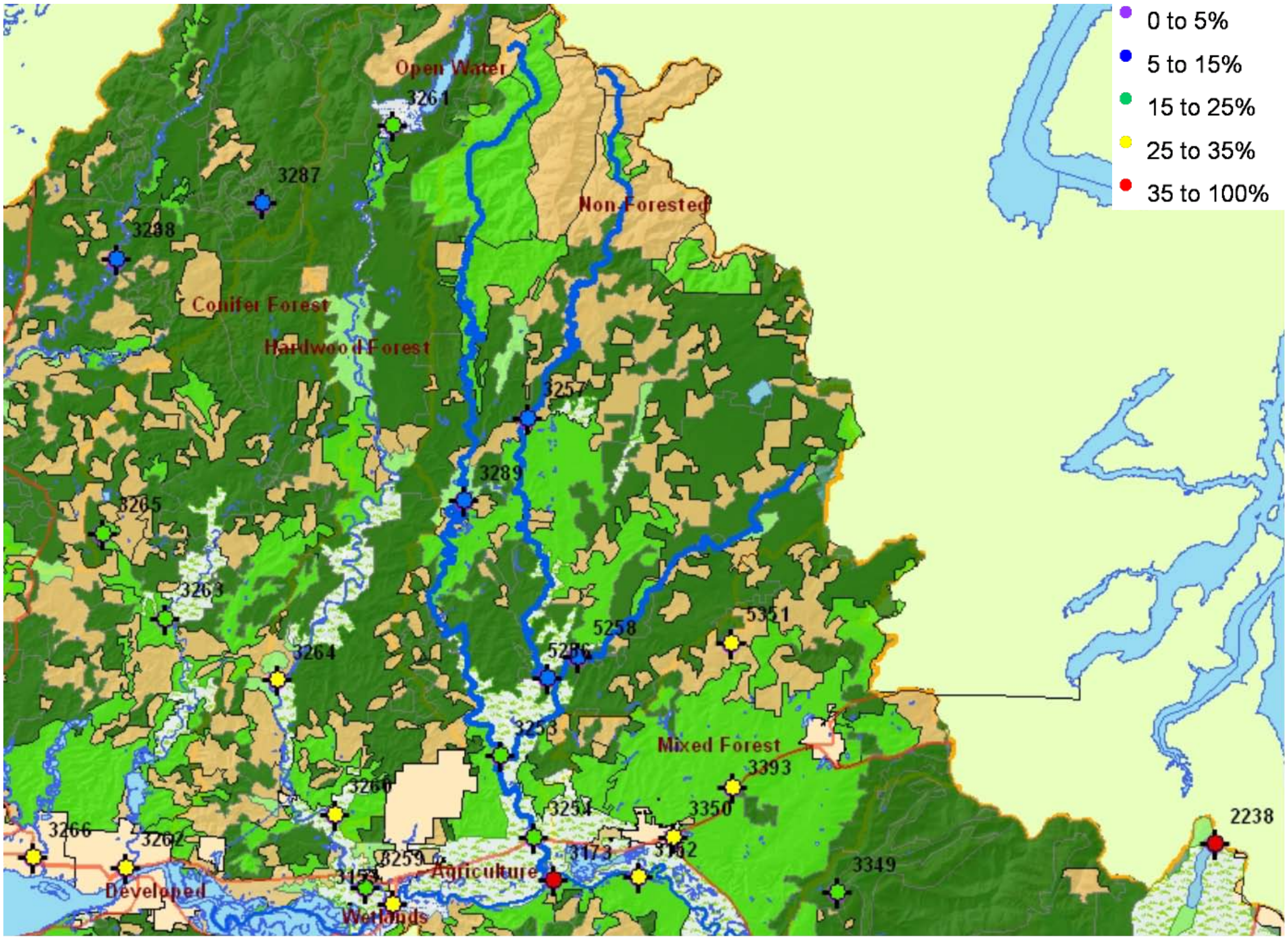


Figure 49. Land use and topography in the Satsop River Sub-Watershed, and results of temperature monitoring. Sites are ranked relative to the percent of samples that exceeded the All-Year Char Rearing Criterion of 12ºC.

Conclusions

Results from this study suggest there is a wide range of water quality conditions in the Chehalis Basin, ranging from relatively undisturbed to severely degraded. This conclusion is consistent with previous water quality studies within the Basin. This study also suggests that the determination of water quality health is to some extent dependent on the specific standard used.

We found that pH generally fell within the range of 6.5 to 8.5 at all monitoring sites, with very few exceptions. The study therefore suggests that water quality in the monitored streams is in good condition with respect to pH, and that pH is not limiting to distribution or abundance of fish or other aquatic life in these streams of the Chehalis River basin.

Dissolved oxygen level varied considerably both between sites and also depending on season. Dissolved oxygen tended to be higher in the winter and lower in the summer. Dissolved oxygen concentration was also generally higher in tributary streams further upstream than in the mainstem Chehalis River. During the summer, dissolved oxygen was low at several monitoring sites along the Chehalis River, particularly in the vicinity of the cities of Chehalis and Centralia. Other locations with low dissolved oxygen included the Black River, a tributary that joins the Chehalis River from the north, flowing between Rochester and Oakville, and Winter Creek, a small creek in Westport. These streams are low gradient streams that, due to land use in these areas, may be affected by nutrient inputs from fertilizers applied to adjacent lands. High nutrient levels in streams likely contribute to growth of algae and other aquatic vegetation. The decomposition of algae and other organic material in streams leads to lower dissolved oxygen levels. These processes are likely factors in the low measured dissolved oxygen concentrations in these streams.

In general, the highest fecal coliform levels were often measured in streams flowing through residential areas. Examples include Winter Creek, which flows through Westport, Ocean Shores Creek, which flows through Ocean Shores, Hoquiam River where it flows through the City of Hoquiam, Newaukum River where it flows past the City of Chehalis, and China Creek, which flows through the City of Centralia. The higher fecal coliform levels in residential areas may result from the higher concentration of pet waste that gets into the streams in these areas. Outreach and education efforts to encourage proper disposal of pet waste could potentially help to reduce these fecal coliform levels.

Turbidity tended to be highest during the winter months, particularly after storms and flood events, and lowest during the summer months. We employed two methods of analyzing turbidity in this study, including ranking and graphing monitoring sites based on the percent of samples that exceeded 7 NTU, and ranking and graphing sites based on average turbidity levels. Using these two methods, we identified two different categories of high stream turbidity conditions in Chehalis Basin streams; ongoing above-average turbidity, that resulted in a high frequency of samples with turbidity higher than the criteria of 7 NTU; and extreme high turbidity over a shorter interval during and following storm events, which resulted in high average turbidity.

Among the streams falling into the first category were low gradient streams, sometimes influenced by inflow of tidal marine waters, such as Elk River and Johns River. Although the turbidity in these streams was often above 7 NTU, it rarely exceeded 12 NTU, and thus these streams still provided suitable habitat for salmon, steelhead, and other fish with regard to turbidity. Among the streams falling into the second category were high gradient streams or streams receiving inflow from high gradient streams, such as West Fork Satsop River, Salzer Creek, Stearns Creek, Waddell Creek, and the upper portion of the Chehalis River. During winter storms with high rainfall in the winters of 2007-2008 and 2008-2009, slope failures and landslides occurred in some steep valleys high in headwater streams of the Chehalis Basin. Resulting debris flows contributed to the high turbidity in these streams. Flooding of farm fields is likely to have also resulted in erosion and subsequent inflow of turbid water with high levels of suspended fine sediment into streams. Some increase in turbidity during winter storms is unavoidable, but effects can be significantly decreased by the employment of Best Management Practices in forestry, logging road construction, and soil conservation in agriculture.

Results of temperature monitoring in the Chehalis River Basin showed that the most frequent warm water temperatures, in exceedance of salmonid temperature criteria, occurred during July and August along the mainstem Chehalis River and in larger tributaries near their confluences with the Chehalis River. The monitoring sites furthest upstream for the most part had the coolest water. Based on these results, summer habitat conditions for salmon and trout appear to be less than optimal in the Chehalis River. In a comparison of sub-basins within the Chehalis River Basin, several monitoring sites on the upper Humptulips River, Wynoochee River, Satsop River, and Skookumchuck River watersheds had consistently cool temperatures in the summer. Maintenance and enhancement of streamside riparian forests to provide shade will help maintain cool temperature conditions in these streams.

Recommendations

Observations throughout this study have led to a series of recommendations to improved water quality and water quality monitoring in the Chehalis Basin:

1) Develop community-based water quality goals based to improve specific water quality parameters based on present water quality status.
2) Investigate the possibility of utilizing the *Enterococcus* endpoint instead of fecal coliform to evaluate tidally influenced sites.
3) Identify the presence and magnitude of variations in water quality between monthly sampling events. This variation could be assessed using data collected with long-term deployment monitoring probes currently operated by the Chehalis Tribal Department of Natural Resources.
4) Identify quantitative relationships between land use, Best Management Practices to reduce water pollution, and water quality.
5) With the aid of the information provided in this report, develop reach-specific restoration and preservation priorities that target priority water quality parameters.

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APPENDIX I

Data Editing for the Chehalis Basin Watershed Implementation Plan Water Quality Monitoring Project

Editing the pH data

To see long-term trends in pH, data spanning the years 1992-2009 were examined for the 18 long-term monitoring sites using a scatter plot. Values were generally between 6 and 8, except for a few outliers for most of the time series (Figures A1 and A2). This was also true for the full set of 94 sample sites sampled from October 2006 through June 2009 (Figure A3). We concluded that during time periods when many pH values were outside the range 6 to 8, the pH meter must not have been operating correctly. Such time periods included October 24, 2006 to September 17, 2007, February 26 2008, April 1 to May 14, 2008, and March 24-25, 2009. Data collected during these periods at all sampling sites were excluded from further analysis and reporting. The dataset used for analysis and reporting is shown in Figure A4.

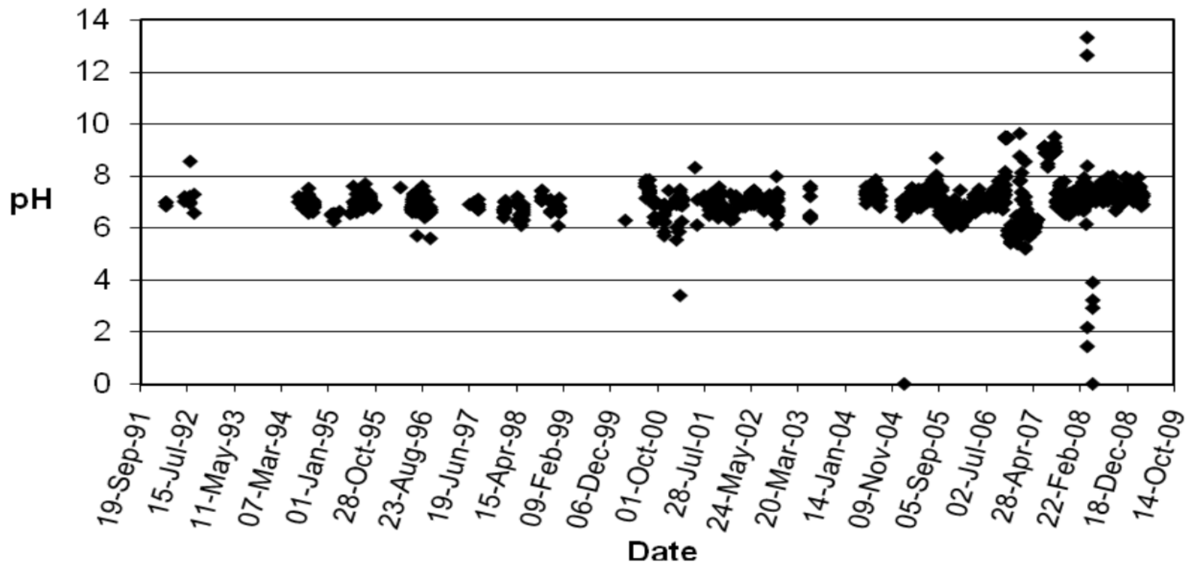

Figure A1. Results of water quality monitoring of pH at 18 long-term sites, 1992 – 2009.

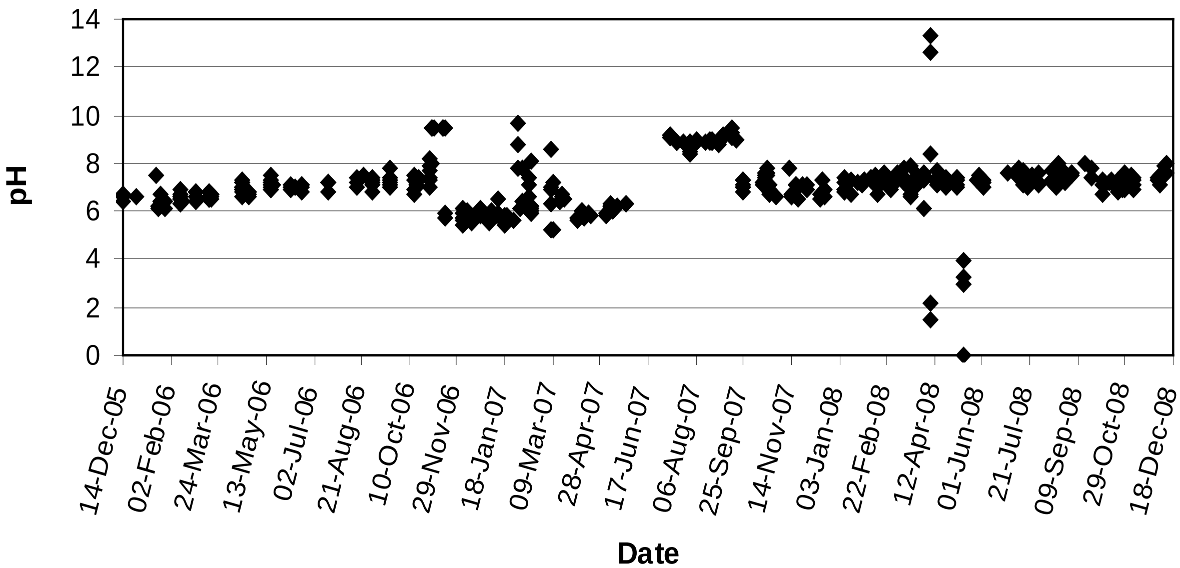

Figure A2. Results of water quality monitoring of pH at 18 long-term sites, December 2005 – December 2008, possibly erroneous data included (focusing on problematic periods November 2006–Sept. 2007 and April–May 2008).

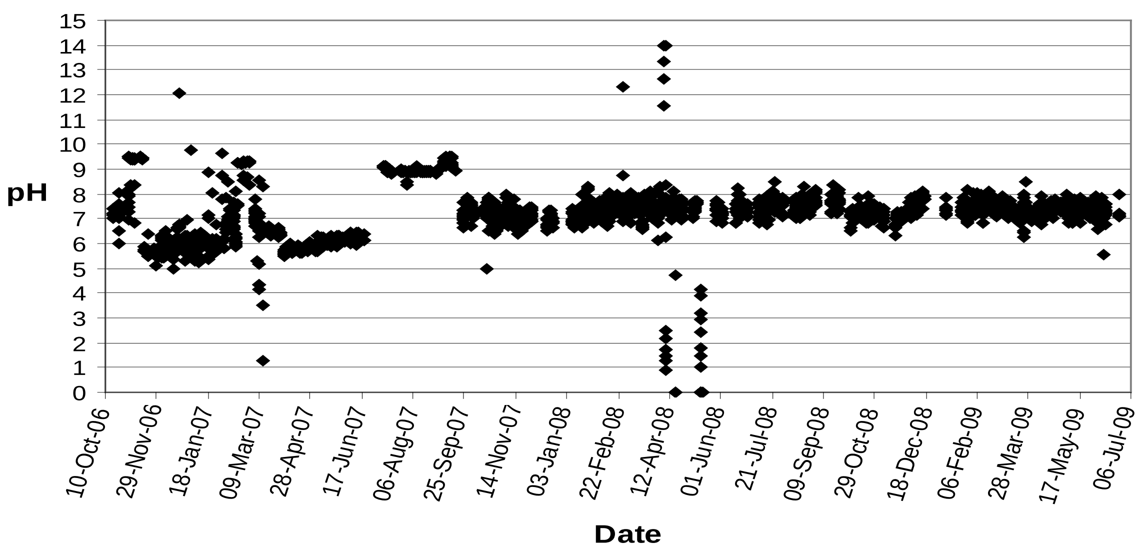

Figure A3. Results of water quality monitoring of pH at 94 sites, October 2006 – June 2009, possibly erroneous data included. Note the same pattern of problematic periods November 2006–Sept. 2007 and April–May 2008).

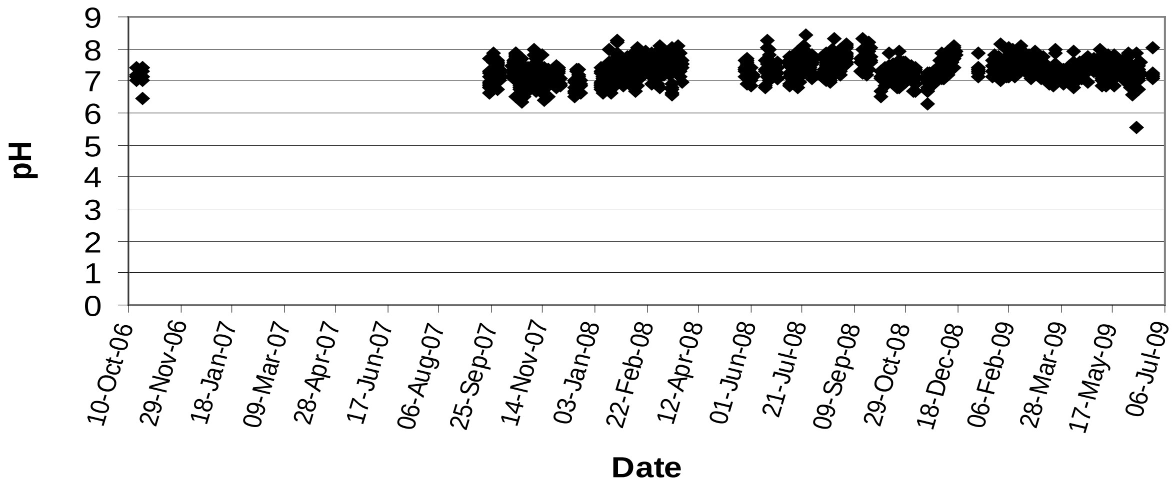

Figure A4. Results of water quality monitoring of pH at 94 sites, October 2006 – June 2009, possibly erroneous data excluded.

Editing the Dissolved Oxygen Data

Data were examined for the 94 sample sites over the period October 2006 to June 2009. Values were for the most part between 5 and 17 mg/L, with higher dissolved oxygen levels in winter and lower levels in summer (Figure A5). On certain dates and date ranges, there were extreme low or high values for several sites, suggesting that on those dates there may have been equipment malfunction.

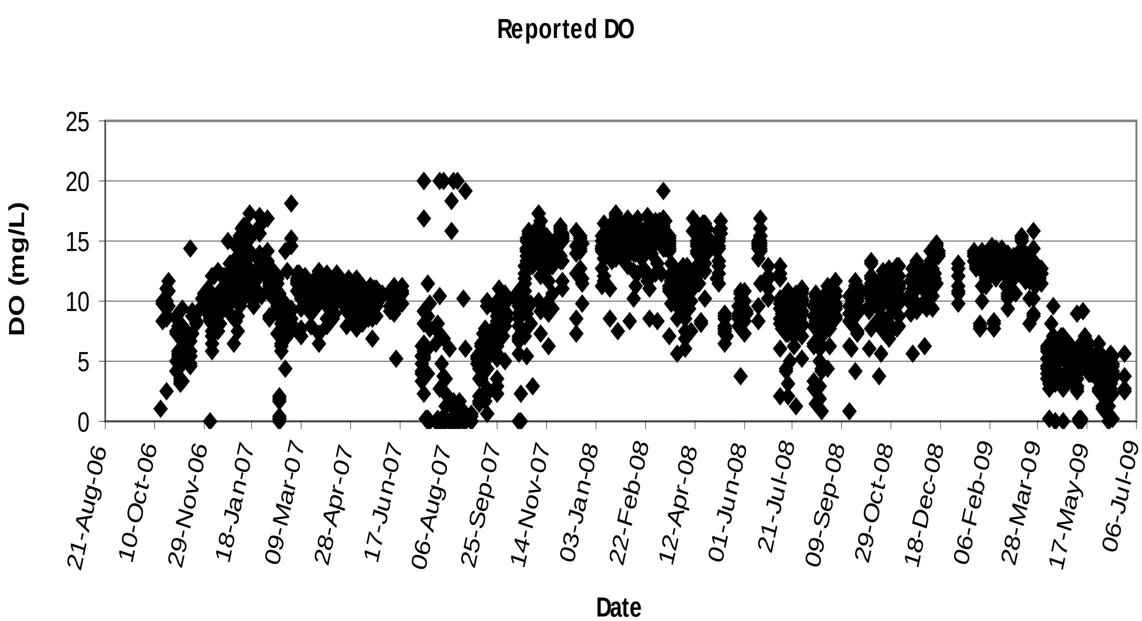

Figure A5. Unedited dissolved oxygen data for the period October 2006 to June 2009.

There were also values of DO (mg/L) that were lower than expected relative to DO (% saturation) for the same water sample. To investigate this further, DO (% saturation) was plotted versus DO (mg/L), excluding samples where one or the other parameter was not reported (Figure A6). This plot shows the pattern of the increase in DO (% saturation) with increasing DO (mg/L), which gradually spreads apart at the high end due to the effects of temperature and atmospheric pressure. This is a mathematical relationship. DO (% saturation) can be calculated using input values of DO (mg/L), water temperature, and elevation (which influences atmospheric pressure). Figure A6 also shows several values that do not fit correctly within the pattern, particularly values of DO (mg/L) ranging from 0 to 7 mg/L that have higher than expected % saturation values. These values are necessarily erroneous, either in one or the other parameter. However, most of these values are below the normal range of DO (mg/L), which ranges from 5.4 to 14.8 (Purdue University Center for Earth and Environmental Science website http://www.cees.iupui.edu/education/Workshops/Project_Seam/water_quality.htm, accessed July 28, 2009). Therefore, it was concluded that the % saturation values were more likely to be correct than the mg/L values. Consequently, the % saturation values were used, along with values of water temperature and elevation, to calculate DO (mg/L) for all water samples where % saturation and temperature were recorded, using equations described by Mortimer (1956), and on the website http://www.waterontheweb.org/under/waterquality/oxygen.html. Calculated values of DO (mg/L) that fell within the normal range 5.4 mg/L to 14.8 mg/L were used for all further analysis. If calculated values of DO were below 5.4 mg/L or above 14.8 mg/L, then each of these values were compared to the corresponding measured value of DO, and the value (calculated or measured) that was within the normal range or closer to it was considered the most likely to be accurate and used for further analysis. For comparison with the original plot, DO (% saturation) was plotted versus calculated and edited DO (mg/L), excluding samples where one or the other parameter was not reported (Figure A7).

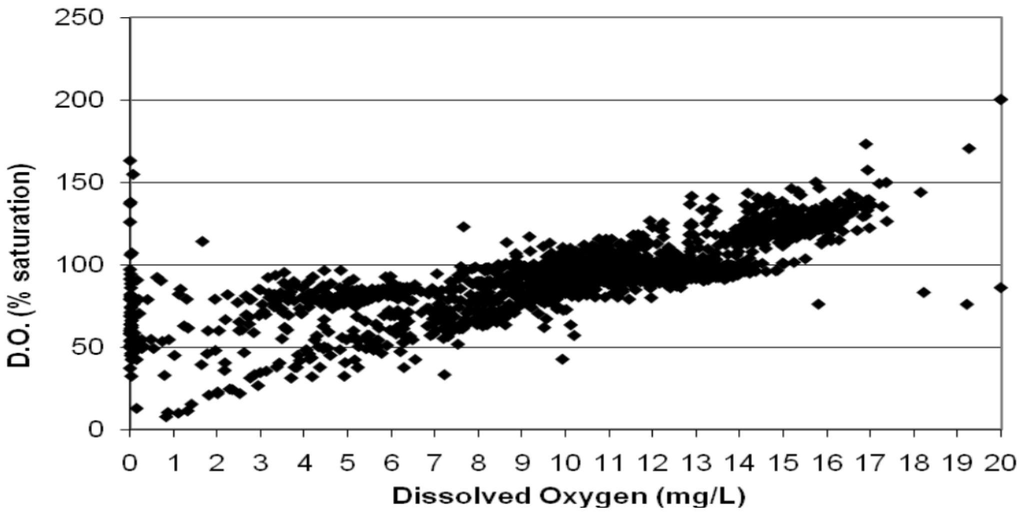

Figure A6. Dissolved oxygen (% saturation) plotted versus dissolved oxygen (mg/L) as reported.

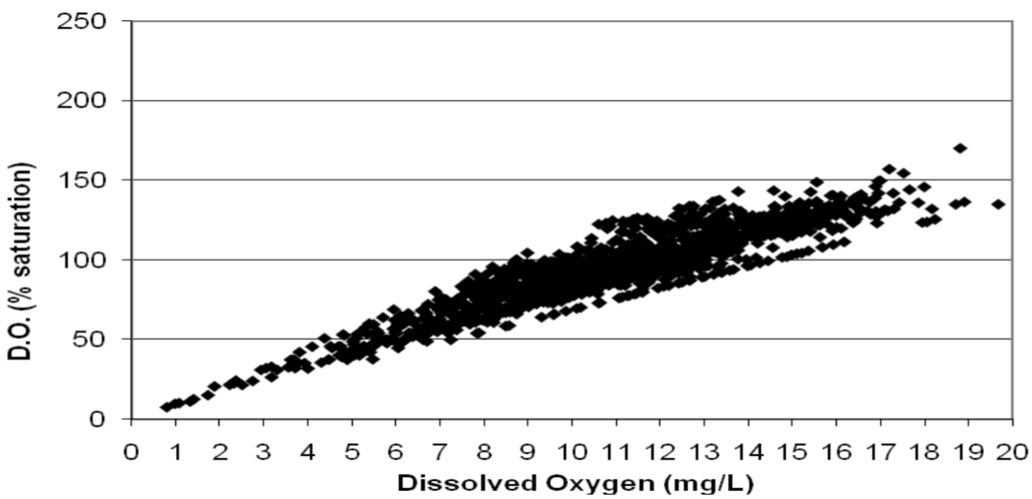

Figure A7. Dissolved oxygen (% saturation) plotted versus dissolved oxygen (mg/L) as calculated based on % saturation, elevation, and temperature.

Data were also examined site by site to evaluate the potential for equipment error. Where extreme low values occurred (< 4 mg/L), results were compared to data from other years at the same site if long-term data were available. Where possible, these low values were also compared with data collected on the same stream at a nearby location by Washington Department of Ecology. In cases where it was determined likely that equipment malfunction had caused extreme low values on a particular date or date range, all data collected on that date or date range were excluded from further analysis or reporting, except where noted (Table A1). For the period September 24 to October 5, 2007, reported DO (mg/L) were used instead of calculated DO (mg/L) based on DO (% saturation) due to extreme and erroneous reported values of % saturation during that period, concurrently with reported DO (mg/L) values within the typical range of 5.4-14.7 mg/L. Edited data used for further analysis are shown in Figure A8.

Table A1. Dates when data was excluded from analysis due to equipment problems. On dates where only data from certain sites was excluded, those sites are specifically named.

Date	Details
November 1-16, 2006	35 of 59 values outside typical range of 5.4 to 14.8 mg/L
February 14-15, 2007	8 of 9 values ranged from 0.0 to 2.1 mg/L
June 19, 2007	3 of 4 values ranged from 19.6 to 23.5
July 13-31, 2007	29 of 44 values less than 1 mg/L
August 10, 2007	Site 3262: 20 mg/L and 15832% saturation reported
	Site 3266: 0.0 mg/L and 28393% saturation reported
August 17, 2007	Site 3271: 0.4 mg/L and 6362% saturation reported
	Site 3272: 0.0 mg/L and 21804% saturation reported
	Site 3283: 1.6 mg/L and 478% saturation reported
August 22, 2007	Site 1324: 0.01 mg/L and 535% saturation reported
August 28, 2007	Site 3268: 0.00 mg/L and 1185% saturation reported
September 5, 2007	Site 1324: 1.56 mg/L and 305% saturation reported

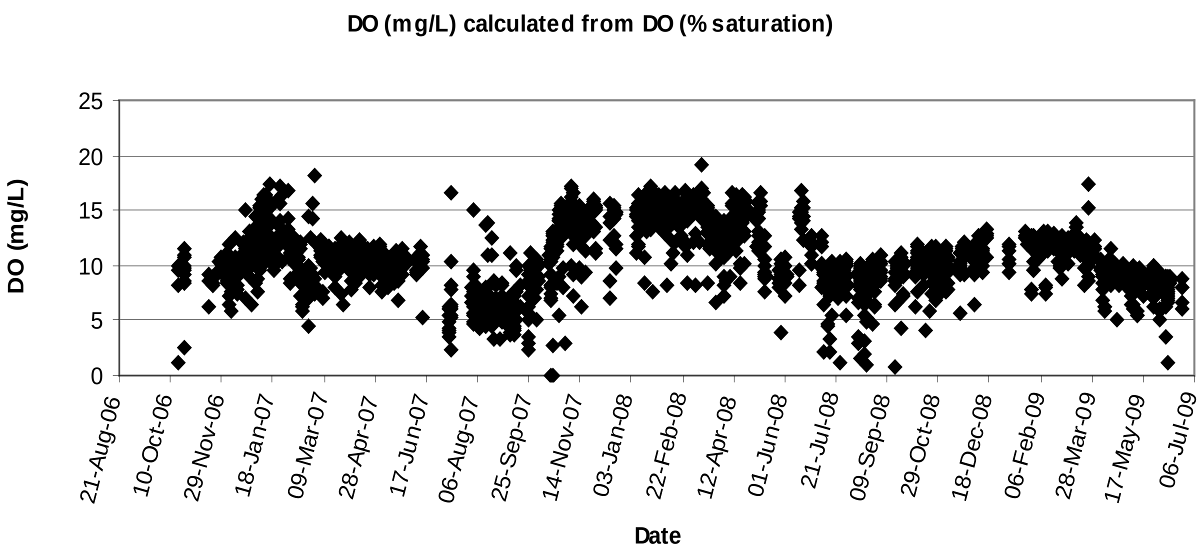

Figure A8. Dissolved oxygen (mg/L) for the period October 2006 to June 2009, calculated using dissolved oxygen (% saturation), water temperature, and elevation, edited to remove erroneous values.

Reference

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