APPENDIX C - WATER QUALITY

INTRODUCTION

The water quality analysis of the Level 1 Watershed Assessment is designed to summarize known surface water quality problems in the subbasins. The emphasis of this analysis is on those pollutants that have the most direct relationship to water quantity and fish habitat. Temperature and dissolved oxygen concentrations are two of the factors which can most directly affect fish populations. Seasonal trends along the mainstem over the past three decades are analyzed for these two parameters, as well as for total phosphorus (TP), total suspended solids (TSS), and fecal coliform levels. This assessment also provides an evaluation of water quality data obtained in the past decade from six mainstem and nine tributary ambient monitoring stations. Where 50% exceedance monthly flows are available (four mainstem stations and two tributaries), TP, inorganic nitrogen (IN), and TSS loading and yields are evaluated. Subbasin comparisons of pollutant yields can serve as a tool to focus resources on those subbasins with the highest yields. This assessment also includes a summarization of available data by subbasins.

Grays Harbor was not included in this Level 1 Assessment. Grays Harbor, at the mouth of the Chehalis watershed, has been the focus of a number of studies. The conditions within the estuary vary depending on the location, the degree of tidal and wind mixing, and degree of density stratification (Jennings, 1996). The harbor is separated into an inner harbor area and an outer harbor area, each with different water quality classifications under the water quality standards. The inner harbor is designated as a Class B water and is listed under section 303(d) of the Clean Water Act as not meeting water quality standards for fecal coliform bacteria. The outer harbor is a Class A water body. While the outer harbor is not listed as impaired on the 303(d) list for fecal coliform, there is mounting evidence that this indicator parameter may be a concern in some areas of the outer harbor (Jennings, 1996). A recently published TMDL indicated that the primary source of the fecal coliform loading was from the Chehalis River, with the Humptulips, Hoquiam, Wishkah, and Satsop rivers accounting for nearly 80% of the total loading (Pelletier, 2000). The TMDL recommended a 65% reduction in the non-point source load allocations; and the TMDL recommended wasteload allocations for the two major point sources (Weyerhaeuser Cosmpolis and Weyco) (Pelletier, 2000).

This Appendix is organized in the following order:

- Methods of Data Analysis - a description of parameters selected and methods of analysis.
- Mainstem Chehalis - an analysis of water quality at four mainstem stations and evaluation of seasonal, temporal, and river mile trends.
- Major Tributaries - a summary of available data on nine major tributaries with emphasis on the Newaukum River and the Humptulips River.
- Subbasin Analysis - a description and analysis of available data by subbasin.
- Water Quality Impairment Under the Clean Water Act - lists impaired stream segments.

- Data Limitations - a discussion of additional data needs and limitations of the analyses.
- Conclusions and Recommendations for the Level 2 Assessment - a summary of basin-wide and subbasin conclusions and recommendations for the next actions.

METHODS

Evaluation of the water quality data required selection of monitoring stations and water quality parameters, analytical techniques for data interpretation and presentation, and assumptions about the data. These are described in this section.

Ambient water quality monitoring data from WDOE were selected for the majority of the data evaluation. Station locations are shown on the basin map (Figure C-1). These data were selected because they provide the longest period of monthly or bimonthly data at a location. At a number of stations, the record is longer than 20 years. Other stations had records that were not continuous from the 1970's until the present. For example, ambient monitoring station data have not been collected from the Wynoochee and Wishkah rivers since the 1970's. Monitoring at the Montesano station on the mainstem Chehalis River was interrupted in 1992. This station is particularly critical as it represents the cumulative impacts of activities upriver of most of the tidal influence.

Where more than one ambient monitoring station was available for a subbasin, the station that was closest to the mouth of the tributary was selected. Protocols for sample collection at the WDOE ambient monitoring stations have been standardized for a number of years, increasing the comparability. Methods of chemical analyses have also been relatively standardized, although several techniques have improved since the 1970's. Thus, the WDOE ambient water quality monitoring stations were selected for the long period of record, consistent sampling locations and sampling and analytical protocols. The station locations, period of record, and parameters monitored are provided in Table C-1.

A number of parameters were selected to serve as indicators of the water quality in the basin. These include temperature, dissolved oxygen, total phosphorus, inorganic nitrogen, total suspended solids, and fecal coliform. Parameters were selected for analysis either because they were directly related to fish habitat and flow problems (dissolved oxygen (DO) and temperature), or because they are appropriate indicators of water pollution (total phosphorus (TP) and total suspended solids (TSS)), or because they are important in the basin since they are tied to a commercial industry (fecal coliform bacteria (FC)).

Table C-1. Ambient Water Quality Monitoring Station Data Assessed

River Mile	Location (Subbasin #)	Years	Flow	Temp	DO	pH	TP	NH_3	NO_{2+3}	TSS	FC	Comment
Mainstem												
101.7	Dryad (1)	77-99	x	x	x	x	x	x	x	x	x	
77.7	Claquato (4)	96-97	-	x	x	x	x	x	x	x	x	
67.5	Centralia (10)	77-93	x	x	x	x	x	x	x	x	x	
59.9	Prather Rd. (10)	94-97	x	x	x	x	x	x	x	x	x	
33.3	Porter (13)	70-99	x	x	x	x	x	x	p/s	s/p	p/s	s = sporadic 82-87 p = consistent from 82
13.15	Montesano (30)	71, 77-92	s	x	x	x	x	x	p	p	p	s = flow data sporadic p = consistent from 77
Tributaries												
3.0	S. Fork Chehalis (3)	96-97	x	x	x	x	x	x	x	x	x	
0.1	Newaukum (5-7)	92-93	x	x	x	x	x	x	x	x	x	
2.3	Skookumchuck (9)	92-93, 96-97	x	x	x	x	x	x	x	x	x	
7.1	Black (11)	90-97	-	x	x	x	x	x	-	x	x	
2.7	Satsop (15-18)	71, 74-93	s	x	x	x	x	x	p	p	p	s = sporadic p = consistent from 77
13.6	Wynoochee (20)	72-74, 76-77	p	x	x	x	s	x	-	-	p	s = sporadic
12.3	Wishkah (21)	72-74, 76-77	p	x	x	x	x	x	-	-	p	p = consistent from 76
9.3	Hoquiam (22-24)	73-74, 93-94	p	x	x	x	p	x	p	p	p	p = consistent from 83
23.6	Humptulips (25)	71-74,77-99	x	x	x	x	x	x	x	p	p	p = consistent after 80

x = Relatively consistent data; - = No data; p = partial data; s = sporadic data

The following paragraphs describe some of the guidelines used for this assessment.

- DO, temperature, and FC bacteria are compared against state water quality standards. Phosphorus becomes a pollutant of concern at higher concentrations. MacKenthun (1973) suggests that TP should not exceed a concentration of 0.05 mg/l in a stream at the point at which it enters a reservoir or lake (or for example, the Centralia Reach). For other flowing streams MacKenthun recommends that concentrations of TP not exceed 0.1 mg/L. The USEPA adopted these concentrations as guideline levels (USEPA, 1986). The USGS reported a background level of TP of 0.1 mg/l in 20 National Water Quality Assessment (NAWQA) units across the country (Mueller and Helsel, 1996).

- IN includes two chemical forms of nitrogen; ammonia-N and nitrate + nitrite (nitrate+nitrite-N). Ammonia (a by-product of animal waste) can be toxic to fish at concentrations that are temperature and pH dependent. Nitrate is also considered a pollutant of concern at high concentrations although it is a nutrient required for plant growth at lower concentrations. The USGS reported background concentrations for nitrate-N of 0.7 mg/l and for ammonia-N 0.1 mg/l (Mueller and Helsel, 1996). These concentrations were part of a NAWQA study of 20 major surface water hydrologic units across the country (Mueller and Helsel, 1996). The ratio of total nitrogen to total phosphorus (TN:TP) is an important indictor of stream health. A TN:TP ratio of less than 7 indicates a water body is no longer phosphorus limited, but nitrogen limited (Welch, 1980). Such river systems generally support a greater population of algae and aquatic macrophytes.

- No water quality standard exists for TSS, although it is somewhat related to turbidity, for which there are water quality criteria.

The three-year wet and dry season parameter averages were calculated for the Dryad, Porter, and Montesano (1970's dry season only) stations. Seasonal averages were used for upstream/downstream comparisons and comparisons over the timeframe of three decades. These ambient monitoring stations were selected for their location on the mainstem Chehalis River and the availability of three years of monthly data. Because data was only available for the last three years in the 70's, only data from the last 3 years of each decade were used for the trend analysis, to equalize the size of the data sets between decades. During the 1990's, 5 stations were routinely monitored on the mainstem. This data is assessed separately to allow for a more comprehensive look at possible trends with distance downstream. Wet and dry season averages of monthly samples obtained during the last three years of the 1970's, 1980's, and 1990's were calculated to make these comparisons. These years were selected as they span the period of record and represent the years in which the most data were available for statistical analyses. For this study, wet season data comprised samples gathered from November 1 through March 31 of a water year. Dry season samples were defined as those that were gathered between August 1 and October 31 of a water year. These data were used for the graphical presentations. Statistical comparisons of the averages were made between the decades and between the upstream and downstream stations to ascertain any differences. The student's t-test was initially used for this evaluation; however, data gaps in the period of record and large variation between the monthly grab samples caused the data to violate the assumptions of homogeneity and normal distribution of the data. Thus, statistical comparisons were made using the non-parametric Mann-Whitney test which does not assume a normal data distribution (Conover, 1980). Statistically significant differences were evaluated at the p = 0.95 level.

Many of the analytical water quality data used in this report were denoted as “qualified”. Qualification means there is less confidence that the value reported accurately represents the actual conditions. Qualified data is particularly prevalent with the fecal coliform results. Qualifiers for this parameter included indicators of “spreader colonies” and “presence of background organisms”. These qualifiers generally indicate that the reported result underestimates the actual colony forming units in the river segment. Fecal coliform data that were qualified were included in calculations of 3-year geometric means because they did not lead to an over estimate and to allow for statistical analyses. More recent fecal coliform data tended to have fewer qualifiers than older data, improving the accuracy of the data.

Results of chemical analysis were often at the limits of detection, especially for ammonia-N, but also for total phosphorus, and less so for nitrate+nitrite-N. Results qualified as at or below the detection limit provide an over estimate of the concentration in the river. To reduce the inflationary effects of data that were qualified as at or below the detection limit, averages, loads, and yields were calculated using one-half of the detection limit value. While this technique is useful for making comparisons between subbasins of the Chehalis and with other Puget Sound basins, future improvement in analytical methods would reduce the impact of this method of estimation.

To gain a better understanding of the watershed in recent years and to make use of the data available, all ambient monitoring data gathered during the 1990's at the mainstem and two tributaries were used to calculate TP loads and yields, inorganic nitrogen yields, and TSS loads and yields. Wet and dry season averages (as defined previously) were calculated from results of monthly grab samples gathered during the 1990's. Loading was calculated by multiplying the parameter concentration (mg/l) by the median monthly (50% exceedance) flow (cfs) from the USGS gage stations and adjusting for unit differences. Loading is provided in units of pounds/day (lb/day). Where flow data were not obtained at the time of sampling, USGS gage flows from a nearby station were used for the date, if other tributaries were not located between the ambient monitoring station and the gage station (e.g., Montesano). Instantaneous flows were used to calculate TP and TSS loadings at individual stations for graphical presentation.

Average annual yields were calculated for TP, IN, and TSS. Average annual yields were calculated using monthly grab sample data and averaged over the entire year to obtain a more accurate reflection of annual conditions. To obtain yields for these stations, the parameter loadings (based on median flows) were divided by the size of the drainage basin and adjusted to units of tons/year/square mile. Where the monitoring station was substantially above the mouth of the river (e.g., Humptulips River), an estimate of the basin size to the station was made from the map.

In each of the subbasins where data were available, the ratio of TN:TP was calculated from concentrations averaged across all months. TN:TP ratios were compared to the ratio of 7 recommended by Welch (1980) as the delimiter between phosphorus-limited and nitrogen-limited streams.

NPDES permitted discharges within the basin were provided from the Water Permit Life Cycle System (WPLCS) database. Based on permitted limits and assumptions made by Embry and Inkpen (1998), the total phosphorus loading from NPDES permits to the mainstem at Porter and Montesano were calculated. The median total phosphorus concentration determined for municipal wastewater treatment plants in Puget Sound of 4.2 mg/l (Embry and Inkpen, 1998) was applied to the average design flow from WPLCS to calculate loading contributions of municipal plants. Loadings were summed for discharges above the Porter station and above the Montesano station to determine their contribution to seasonal loading. These NPDES loadings are worst cast scenarios based on design flow and assumed TP concentrations and may over estimate TP loading from the NPDES dischargers.

WATER QUALITY CRITERIA

Washington State water quality criteria (WAC 173-201A) for temperature, dissolved oxygen, and fecal coliform levels vary within the Chehalis Basin. The majority of the basin is defined as Class A (excellent) waters. Exceptions to this classification include three rivers and one mainstem reach for which Class AA (extraordinary) criteria apply, and two river sections for which Class B (good) criteria apply. Surface waters rated as Class AA include the Chehalis headwaters (Subbasin 1 and 2), the upper portion of the Humptulips (Subbasin 25), the Middle, East, and West Fork Satsop (Subbasin 17 and 18), the upper Skookumchuck (Subbasin 9), and the West Fork Wishkah and southern tributaries (Subbasin 21). Surface waters rated as Class B are the lower reach Hoquiam (Subbasin 22) and the first six miles of the Wishkah (Subbasin 21). Standard criteria for the different classes are provided in Table C-2.

A notable exception to the Class A criteria on the mainstem Chehalis is the “Centralia Reach” (river mile 65.8-75.2). A natural sill in the river causes the water to “pool” upstream. This naturally slow moving reach has merited setting separate criteria for dissolved oxygen and temperature. The criteria for this reach includes a special condition stipulating that dissolved oxygen shall exceed 5.0 mg/l from June 1-September 15 and temperature shall be between 18 and 20.4°C (exact temperature standard depends on segment).

Table C-2
Washington State Water Quality Criteria.

Class	Temperature	DO	Fecal Coliform
AA	shall not exceed 16°C from human conditions or if >16°C exists naturally, no temp increase >0.3°C	shall exceed 9.5 mg/L	shall not exceed a geometric mean of 50 colonies/100mL and shall not have > 10% of all samples exceeding 100 colonies/100mL
A	shall not exceed 18°C from human conditions or if >16°C exists naturally, no temp increase >0.3°C	shall exceed 8.0 mg/L	shall not exceed a geometric mean of 100 colonies/100mL and shall not have > 10% of all samples exceeding 200 colonies/100mL
B	shall not exceed 21°C from human conditions or if >16°C exists naturally, no temp increase >0.3°C	shall exceed 6.5 mg/L	shall not exceed a geometric mean of 200 colonies/100mL and shall not have > 10% of all samples exceeding 400 colonies/100mL

MAINSTEM CHEHALIS

The three mainstem locations (Dryad, Porter, and Montesano) where data were available were used to make parameter comparisons 1) between wet and dry seasons, 2) along the mainstem, and 3) across the three decades. Subsequent discussions are presented by parameter. In addition, available TP, IN, and TSS data from the most recent decade were used to calculate loading and yield at four stations on the mainstem and two tributaries. These are also presented in the context of the parameter discussions. Finally, results of the Total Maximum Daily Load (TMDL) studies are used to summarize recent and future actions necessary to improve water quality.

Figure C-2 depicts average wet and dry season temperature with each river mile. As shown, average dry season temperatures approach the water quality criterion. Within each season, temperature is relatively constant with river mile. Temperature at the mainstem stations has changed relatively little over the last three decades; no statistically significant differences between decades were found in this analysis at p = 0.95.

While average temperatures showed no water quality criteria exceedances, temperature exceedances of samples in several of the tributaries in WRIA 23 have been reported above the 18^{o}C criterion. Table C-3 provides the maximum temperatures observed in the 1990's at the ambient monitoring stations along the mainstem. All of the maximum temperatures exceed the criterion. Dry season temperatures near and exceeding the criterion coincide with periods of the lowest flow. Elevated temperatures are not surprising based on Wampler's assessment that loss of riparian canopy was widespread over the entire Chehalis mainstem (Wampler, et al., 1993). Pickett (1994a) noted that temperatures generally increased in the upper Chehalis Basin (above Porter) as water flowed downstream. The highest temperatures were measured in the slow flowing Centralia Reach (Pickett, 1994a). The Centralia Reach is more similar to a reservoir or lake than to a river. Temperature stratification is established during the summer months, causing higher surface temperatures and prohibiting mixing between stratified layers. Dry season temperature exceedances precipitated an Upper Chehalis temperature TMDL (Butkus and Jennings, 1999).

Figure C-3 shows dissolved oxygen concentration for wet and dry seasons with each river mile for three decades. As expected, average dry season dissolved oxygen concentrations are lower than those measured during the wet season. Even, during the dry season, the average dissolved oxygen concentrations were within the water quality criterion for Class A streams of 8.0 mg/l. However, individual measurements of dissolved oxygen indicate that at some locations, the criterion is not met. Minimum concentrations from several ambient monitoring stations along the mainstem indicate that only at Dryad and Montesano did the dissolved oxygen concentration remain above the criterion. In the slow-flowing Centralia Reach area, temperature stratification and accompanying oxygen depletion occurs with depth (Pickett, 1994a). While the average dissolved oxygen concentrations appear to decline with river mile, no statistically significant differences were found. Nor were statistically significant differences found across the three decades. Because the dissolved oxygen water quality criterion is often exceeded at individual stations during the dry season, a TMDL was conducted in the upper basin WRIA 23. The TMDL recommended reductions in point and non-point sources of oxygen depleting contaminants such as biochemical oxygen demand (BOD), ammonia-N, and total phosphorus (TP) (Pickett, 1994a).

Table C-3 presents the average and the maximum total phosphorus concentrations at stations along the mainstem for the past decade. Notably, TP concentrations were highest between river mile 77.7 and 67.5 (Table C-3), as the river flows into and through the Centralia Reach. At these two stations, TP average concentrations exceeded the EPA recommended level of 0.05 mg/l (MacKenthum, 1973).

Average total phosphorus (TP) loading (based on instantaneous flow) was used to compare trends across wet and dry seasons, with river mile and across three decades (Figure C-4). The mean TP loading is greater during the wet season than during the dry season. Because of greater wet season flows and because phosphorus is sorbed onto particulates, elevated wet season TP loadings might be expected. However, this is not always the case. If a river is primarily impacted by point source pollutant loadings, the wet season load will not increase as much as those streams affected by nonpoint sources. TP loading, is almost constant with river mile. Comparisons across decades at an individual station during the wet season yielded no statistically significant differences for TP loading.

TP loading was also evaluated along the mainstem stations using 1990's data and median monthly flows from the USGS gage stations. In addition to the three stations included in the previous analysis, data for these years were available at the Prather Road station (river mile 59.9). These data are depicted graphically for the mainstem in Figure C-5. In the 1990's, both wet and dry season TP loads, generally increase in the downstream direction from Dryad to Montesano.

Table C-3. Ambient Water Quality Parameters - 1990s Data (Average and Maximum or Minimum)

River Mile	Location (Subbasin #)	Temp (°C)		DO (mg/l)		TP (mg/l)		NH_3 (mg/l)		NO_{2+3} (mg/l)		TSS (mg/l)		FC[2] (cfu/100 ml)	
		ave	max	ave	min	ave	max	ave	max	ave	max	ave	max	ave	max
Mainstem															
101.7	Dryad (1)	10.3	24.5	11.1	8.0	0.03	0.36	0.01	0.08	0.30	0.96	26	782	33	2,800
77.7	Claquato[1] (4)	10.2	20.1	10.2	7.5	0.09	0.41	0.02	0.04	0.46	0.87	20	102	61	730
67.5	Centralia (10)	12.1	21.3	9.7	5.4	0.08	0.38	0.06	0.58	0.48	1.1	16	109	47	1,000
59.9	Prather Rd. (10)	11.2	22.1	10.0	7.2	0.06	0.14	0.03	0.12	0.59	0.86	15	118	37	1,500
33.3	Porter (13)	11.4	22.1	10.1	7.1	0.05	0.19	0.02	0.08	0.68	2.13	13	95	29	1,300
13.15	Montesano (30)	12.2	20.5	10.0	8.4	0.04	0.17	0.03	0.04	0.46	0.74	14	131	43	790

[1] Sampled only in 1970's

[2] Fecal coliform average is geometric mean

The 1990's TP loading data were used to calculate TP yields for the mainstem stations. Yield provides a load per square mile of drainage. These are presented as wet and dry season averages and annual averages in Table C-4. Comparisons of yields across subbasins can be a useful tool to determine where the greatest contribution of phosphorus per square mile is originating. Along the mainstem, TP yield was highest at the Montesano station. The average annual TP yields are compared to those reported by USGS authors, Embry and Inkpen (1998) for rivers and streams in the Puget Sound and Olympic Peninsula regions. They evaluated data from the 1980's through 1993 and calculated TP yields for the major Puget Sound basins. These are presented in Table C-5 for comparison. The TP yields at the Chehalis mainstem stations are within the range of the river systems evaluated by Embry and Inkpen. The authors reported that generally the rivers on the Olympic Peninsula had lower TP yields than those found in the Puget Sound region (Embry and Inkpen, 1998).

Average and maximum ammonia-N and nitrate+nitrite-N concentrations were assessed at stations along the mainstem (Table C-3). The Centralia Reach (rm 67.5) had the highest average and maximum ammonia-N concentrations. The maximum ammonia-N concentrations at this station exceeded the USGS reported background concentrations of ammonia-N (0.1 mg/l) (Mueller and Helsel, 1996). The Porter station had the highest average and maximum nitrate+nitrite-N concentrations (Table C-3). While the maximum nitrate+nitrite-N concentration measured at the Centralia station was the second highest, it was less than half of that measured at Porter. None of the average nitrate+nitrite-N concentrations exceeded the USGS reported background concentrations for nitrate-N of 0.7 mg/l (Mueller and Helsel, 1996).

Inorganic nitrogen yields (IN yields) for the Chehalis River mainstem were calculated and are presented in Table C-4. Along the mainstem, IN yield increased in a downstream direction. In evaluating nutrient loading of Washington rivers, Embry and Inkpen (1998) also calculated inorganic nitrogen (IN) yield for Puget Sound and some Olympic Peninsula rivers. Their findings are presented in Table C-5.

Table C-4.
Total Phosphorus Loading and Yield and IN Yield along Chehalis Mainstem - 1990's Data

River Mile	Location	TP Loading (lb/day)		TP Yield (tons/yr-mi^2)		TP Yield (tons/yr-mi^2)	IN Yield (tons/yr-mi^2)
Season		Wet	Dry	Wet	Dry	Ave. Annual*	Ave. Annual*
Mainstem							
101.7	Dryad	197	8.7	0.31	0.01	0.14	1.4
59.9	Prather Rd.	1,099	105	0.23	0.02	0.12	1.5
33.3	Porter	1,851	126	0.26	0.02	0.13	1.9
13.15	Montesano	3,779	231	0.39	0.02	0.18	2.2

Average annual yield calculations based on all data available for 1990's

Table C-5. Pollutant Yields for Chehalis Basin Mainstem and Tributary Stations. Source: Embry and Inkpen, 1998

River Mile	Location	TP Yield (tons/yr-mi^2)			TSS Yield (tons/yr-mi^2)			IN Yield (tons/yr-mi^2)[1]
Season		Wet	Dry	Average	Wet	Dry	Average	Average
101.7	Dryad	0.31	0.01	0.14	343	2.3	143	1.43
59.9	Prather Rd.	0.23	0.02	0.12	90	1.1	42	1.59
33.3	Porter	0.26	0.02	0.13	107	1.3	49	1.92
13.15	Montesano	0.39	0.02	0.18	93	30	48	2.22
0.1	Newaukum	0.15	<0.01	0.08	155	11.3	7.8	2.03
23.6	Humptulips	0.41	0.03	0.2	396	6.1	186	1.15

[1] IN=inorganic nitrogen. This information is provided to allow comparisons to other basins in the Puget Sound

Average and maximum TSS concentrations at the mainstem stations are reported in Table C-3. Both average and maximum TSS concentrations were highest at the Dryad station, the uppermost ambient monitoring station in the watershed. The station at Porter had the lowest average and maximum TSS concentrations. Average wet and dry season TSS loadings were evaluated (based on instantaneous flows) at the stations along the mainstem over the last three decades (Figure C-6). As anticipated, the average TSS load is greater during the wet season than during the dry season. During the more frequent and intense wet season precipitation events, greater volumes of stormwater are generated which carry greater concentrations of solids. No trends are apparent with downstream flow during either season. Comparisons across decades during the wet season at a single station yielded no statistically significant differences for TSS loading.

Available 1990's TSS data were also used to calculate seasonal and annual TSS yield at mainstem and tributary stations using median flows (Table C-6). The watershed above Dryad contributes a substantially higher TSS yield (especially during the wet season) as evidenced by the higher yield than any other portion of the watershed. Average annual TSS yield at the other three mainstem stations were similar to one another.

Table C-6. Total Suspended Solids Yield along Chehalis Mainstem - 1990's Data

River Mile	Location	TSS Yield (tons/yr-mi^2)		TSS Yield (tons/yr-mi^2)
Season		Wet	Dry	Ave. Ann.*
Mainstem				
101.7	Dryad	343	2.3	143
59.9	Prather Rd.	90	1.1	42
33.3	Porter	107	1.3	49
13.15	Montesano	93	30	48

* Average annual yield calculations based on all data available for 1990's

Fecal coliform concentrations over the past decade are presented in Table C-3. The geometric mean concentrations were all less than the 100 colony forming units (cfu)/100 ml criterion. However, the maxima concentrations at all of the stations exceeded the 200 cfu/100 ml portion of the standard, with the stations at Dryad and Prather Road having the highest exceedances. Fecal coliform loading was calculated based on instantaneous flows. Average fecal coliform loadings over the last three decades are represented by river mile in Figure C-7. Seasonal differences can be attributed to higher wet season flows. Fecal coliform loading did not show statistical differences with river mile. Nor were water quality improvements or degradations statistically significant over time.

MAJOR TRIBUTARIES

Recent water quality data are available for ambient monitoring stations at or near the mouths of a number of tributaries. In WRIA 23 these include: the South Fork Chehalis River, Newaukum, Skookumchuck, and the Black rivers. In the lower watershed (WRIA 22), data are available for the Hoquiam (@ RM 9.3) and for the Humptulips (@ RM 23.6). For the Wynoochee and Wishkah rivers, data date back to the 1970's. Average and maximum or minimum concentrations for water quality parameters are presented in Table C-7.

The average temperature for the South Fork Chehalis River was the lowest of any of the tributaries, while the average temperature for the Black River was the highest. Maximum temperatures in the Black and Humptulips Rivers exceeded the water quality criterion. Maximum temperatures in the Wishkah and Wynoochee rivers also exceeded the water quality criterion in the 1970's. Dry season temperature exceedances in several of the tributaries in WRIA 23 have been reported (Pickett, 1994a). Temperature exceedances lead to the Upper Chehalis temperature TMDL (Butkus and Jennings, 1999). The study concluded that existing shade in several of the subbasins was insufficient. The TMDL recommended additional shade requirements to meet the temperature criterion, and stipulated that no additional reductions of base flow to the river be allowed (Butkus and Jennings, 1999).

Average and minimum dissolved oxygen concentrations are provided in Table C-7 for the major tributaries to the Chehalis River watershed. The Black River had the lowest average oxygen concentration and the lowest recorded minimum concentration. Dissolved oxygen deficiencies have been reported for many of the tributaries in the upper Chehalis (WRIA 23) (Table C-10). These have been attributed to high BOD and nutrient loading (Pickett, 1994a). The Upper Chehalis Dry Season TMDL noted that some portions of the mainstem Chehalis River (notably in the Centralia Reach area) had no loading capacity remaining for parameters leading to the depletion of dissolved oxygen.

Average total phosphorus concentrations were highest in the South Fork Chehalis and Black Rivers, while the Black River had the highest measured maximum TP concentration (Table C-7). TP loading and yields were calculated for the two subbasins, the Newaukum and Humptulips Rivers, based on monthly median (50% exceedance) flows. Wet TP loading in the Humptulips was more than two times higher than that in the Newaukum River (Table C-8). However, seasonal differences in TP loading were greater in the Newaukum River. TP yields were also

Table C-7. WDOE Ambient Monitoring Water Quality Program - 1990s Data Summary (except as noted) (Average and Maximum or Minimum)

River Mile	Location (Subbasin #)	Temp (^oC)		DO (mg/l)		TP (mg/l)		NH_3 (mg/l)		NO_{2+3} (mg/l)		TSS (mg/l)		FC^2 (cfu/100 ml)	
		ave	max	ave	min	ave	max	ave	max	ave	max	ave	max	ave	max
Tributaries															
3.0	S. Fork Chehalis (3)	9.5	17.5	10.5	8.0	0.05	0.08	0.02	0.05	0.56	0.77	14	80	117	540
0.1	Newaukum (5-7)	10.8	17.2	10.6	8.7	0.03	0.05	0.02	0.03	0.61	1.60	27	90	78	760
2.3	Skookumchuck (9)	10.6	16.9	10.3	9.1	0.04	0.14	0.02	0.07	0.54	1.48	8	43	41	960
7.1	Black (11)	11.2	19.7	8.5	3.3	0.05	0.17	0.03	0.16	-	-	3	12	39	1,200
2.7	Satsop (15-18)	10.0	17.9	11.2	9.6	0.02	0.11	0.01	0.05	0.23	0.60	17	170	15	110
13.6	Wynoochee[1] (20)	10.9	21	11.3	9.0	0.03	0.09	0.07	0.24	-	-	-	-	13	70
12.3	Wishkah[1] (21)	10.4	18.5	11.0	9.4	0.02	0.11	0.04	0.09	-	-	-	-	10	110
9.3	Hoquiam (22-24)	9.7	15	11.1	9.7	0.01	0.02	0.01	0.07	0.13	0.43	2	4	10	51
23.6	Humptulips (25)	9.9	21	11.2	9.0	0.02	0.29	<0.01	0.04	0.11	0.34	17	344	8	290

[1] Sampled only in 1970's

[2] Fecal coliform is calculated as a geometric mean value.

calculated for these two tributaries (Table C-8). The Humptulips had the higher average annual TP yield. This yield was the same as that reported for the Green River (Embry and Inkpen, 1998). The annual yield of the Newaukum River was similar to that reported for the Nisqually River (Embry and Inkpen, 1998).

Inorganic nitrogen concentrations are presented in Table C-7. Average and maximum ammonia-N concentrations were highest in the Black River. The Hoquiam and Satsop rivers had the lowest average ammonia-N concentrations. Nitrate+nitrite-N was not measured as consistently in the tributaries. For those subbasins where data were available, the Newaukum River had the highest average and maximum concentrations of nitrate+nitrite-N. The average nitrate+nitrite-N concentration in the South Fork Chehalis, Newaukum, and Skookumchuck approached this background concentration of 20 major surface water units across the country (Mueller and Helsel, 1996). The maximum concentrations in these three tributaries all exceeded the NAWQA background concentration of 0.7 mg/l.

Inorganic nitrogen (IN) yields were also calculated for the two tributaries where appropriate data were available. IN yield was higher in the Newaukum than in the Humptulips. The Newaukum IN yield was also slightly higher than any of the Puget Sound rivers identified by Embry and Inkpen (1998) (Table C-5).

Table C-8. Total Phosphorus Loading and Yield and IN Yield
Chehalis Tributaries - 1990's Data

River Mile	Location	TP Loading (lb/day)		TP Yield (tons/yr-mi^2)		TP Yield (tons/yr-mi^2)	IN Yield (tons/yr-mi^2)
Season		Wet	Dry	Wet	Dry	Ave. Ann. **	Ave. Ann**
0.1	Newaukum	125	5.7	0.15	<0.01	0.08	2.03
23.6	Humptulips	292	20	0.41	0.03	0.20	1.15

** Average annual yield calculations based on all data available for 1990's

Average TSS concentrations were highest in the Newaukum, Satsop, and Humptulips rivers and lowest in the Hoquiam River (Table C-8). The Humptulips River subbasin was observed to have the highest maximum TSS, which was substantially higher than any other tributary. Wet and dry season TSS yields were calculated for the Newaukum and Humptulips Rivers (Table C-9). Average annual and wet season TSS yields were substantially higher in the Humptulips than the Newaukum. The Humptulips had the highest TSS yield of any station calculated for this study. As with TP and IN yields, these differences in TSS yield could be used to prioritize activities to reduce loading within the proportionally higher subbasins.

The geometric mean of fecal coliform concentrations indicated the South Fork Chehalis had a geometric mean that exceeded the water quality criterion of 100 cfu/100ml (Table C-7). Maximum fecal coliform levels exceeded the 200 cfu/100 ml portion of the standard in all, but the Satsop and Hoquiam rivers (of those rivers with recent data). (The Wishkah and Wynoochee rivers did not appear to have a problem with fecal coliform in the 1970's, but no recent data were available.) The Black River had the highest maximum level with 1,200 cfu/100 ml.

Implementation of the wet season TMDLs on the Black River (Coots, 1994) and Upper Chehalis (WRIA 23) (Pickett, 1994) should eliminate fecal coliform exceedances in the upper river tributaries.

Table C-9. Total Suspended Solids Yield - 1990's Data

River Mile	Location	TSS Yield (tons/yr-mi^2)		TSS Yield (tons/yr-mi^2)
Season		Wet	Dry	Ave. Ann.*
0.1	Newaukum	155	11.3	7.8
23.6	Humptulips	396	6.1	186

* Average annual yield calculations based on all data available for 1990's

SUBBASINS ANALYSIS

SUBBASIN 1. CHEHALIS RIVER HEADWATERS

An ambient water quality monitoring station has been maintained at Dryad (rm 101.7) from 1977 until the present time. The more than 20 year period of record and the breadth of water quality parameters monitored assisted in providing a good understanding of water quality in this subbasin. This station is located at the base of subbasin and is, therefore, reflective of the cumulative water quality in the subbasin (Figure C-8). Monthly data are available for temperature, dissolved oxygen, pH, and flow; data are somewhat less continuous for TP, TSS, and inorganic nitrogen species. In the subsequent discussions, data are presented as individual measurements in figures, and as wet season, dry season, and annual averages over 3, and 10 year periods. Evaluation methods and the data limitations are discussed in greater detail in the first section of this appendix. Data from the long-term station are compared with more in-depth studies, such as the TMDL study (Pickett, 1994a).

Temperature at the Dryad station exceeds the water quality criterion of 18°C with some regularity (Figure C-8). No significant differences were identified between the 3-year dry season average in the 1970's and that in the 1990's. The lack of difference indicates that no improvements to (or deterioration of) temperature conditions have occurred over the past 20 years. This stretch of the river was included in the temperature TMDL (Butkus and Jennings, 1999). The study concluded that existing shade in this basin (53%) was sufficient, but recommended that no additional removal of forest canopy nor additional reductions of base flow to the river be allowed (Butkus and Jennings, 1999).

Dissolved oxygen concentrations (DO) have been consistently above the Class A water quality standard of 8.0 mg/L at the ambient station (Figure C-8). However, exceedances were observed in the summers of 1991 and 1992 (Pickett, 1994a). To maintain consistently high dissolved oxygen concentrations in this stretch of the river, the TMDL requires reductions to the carbonaceous BOD and the ammonia-N loading from both point and non-point sources (Pickett, 1994a).

Data on total phosphorus indicate that while the river is generally has TP concentrations less than 0.1 mg/L (MacKenthun 1973) for unimpaired waters. Annual spikes of TP during the wet season in this stretch of the mainstem are not uncommon. Phosphorus tends to be the limiting nutrient in this stretch of the river during the summer months of higher primary productivity. The ratio of total nitrogen to total phosphorus (TN:TP) was more than 13.4 in the critical summer months (Pickett, 1994a).

A plot of TP loading (based on instantaneous flows) for the period of record (Figure C-9) indicates an apparent trend for higher TP loading in the past decade than previously. However, comparisons of the 3-year average dry season TP loads in the 1970's and 1990's showed no statistically significant difference. Thus, average data show neither improvements nor deterioration of conditions. The TP yield at Dryad was similar to other stations along the mainstem Chehalis River (Table C-4) and is between the TP yields of the Newaukum and Humptulips Rivers (Table C-8). The TP yield at Dryad was in the range of yields reported by Embry and Inkpen (1968) for Puget Sound rivers (Table C-5).

IN yield at this station was the lowest IN yield calculated for the mainstem and was between that of the two tributaries for which IN yield was calculated (Table C-8). IN yield was also similar to the yields reported by Embry and Inkpen (1968) for Puget Sound rivers (Table C-5).

Total suspended solids concentrations have ranged from a maximum concentration of 782 mg/l to a minimum of 1 mg/l, with average and median annual concentrations of 28 mg/l and 3 mg/L, respectively. This broad variation indicates high wet season loads associated with winter run-off. Figure C-10 depicts the suspended solids loading based on instantaneous flow over the period of record including a 12-month moving average. The 12-month moving average appears to indicate that the suspended solids concentrations are generally increasing over time, although no statistically significant differences were found. TSS yield at this station was almost three times higher than measured elsewhere along the mainstem with the wet season representing a 150-fold increase over the dry season.

Fecal coliform concentrations are depicted in Figure C-11. Generally concentrations of these indicator bacteria are below the Class A water quality criterion of 100 cfu/100 ml. The geometric mean for the last decade at this station across all seasons is 32 cfu/100 ml. However, the 1994 TMDL study reported higher fecal coliform measurements between river mile 106 and 108.6. Pickett (1994a) reported concentrations between 8 and 690 CFU/100ml, with a geometric mean of 95.7 cfu/100 ml. The study attributed the elevated instances of fecal coliform concentration to the wastewater treatment plant at Pe Ell.

Landuse Impacts on Water Quality

Forest lands comprise 95% of the landuse in this subbasin, with only 3% under agricultural use and less than 1% commercial and industrial landuse categories. While the landuse would suggest little impact from human activities, the TSS yield would indicate water quality has been degraded. The elevated wet season TSS yield, coupled with the elevated dry season fecal coliform levels and temperatures reported in the TMDL (Pickett, 1994a), are a concern. The 1994 TMDL recommends reductions in ammonia-N and carbonaceous BOD from both point and non-point sources. The 1999 TMDL for temperature concluded that no additional removal of forest canopy nor additional reductions of base flow to the river be allowed (Butkus and Jennings, 1999).

Subbasin Conclusions

Identification of sources and reductions in TSS contributions to this subbasin should be a priority based on the relative standing among the segments along the mainstem Chehalis River. Implementation of the recommendations from both TMDLs should receive a high priority, including preparation of the Detailed Implementation Plan for reducing temperature (Butkus and Jennings, 1999) and identification and management of non-point sources contributing to the elevated TSS yield.

SUBBASIN 2. ELK CREEK

No ambient monitoring station is located within this basin. However, the Elk Creek Basin was studied between 1991 and 1992 in the Upper Chehalis TMDL (Pickett, 1994a). Elk Creek enters the Chehalis River at river mile 100.2, below the Dryad monitoring station (river mile 101.7). During the low flow period, the creek contributed almost one half of the flow to the mainstem below the creek's confluence (Pickett, 1994a). Field data indicate that the water quality parameters of temperature, pH, and dissolved oxygen (DO) were within the water quality criteria. During the summer months of this study, the temperature reached a high of 17.2^{o} C, but DO during this time did not drop below 9.0 mg/L (Pickett, 1994a).

Laboratory parameters indicated mostly good water quality, with the exception of fecal coliform bacteria. Pickett (1994a) reported that the station near the mouth of Elk Creek exceeded the water quality criterion of 100 cfu/100 ml in 5 of the 6 summer samples. The measurement of 2,000 cfu/100ml sample on August 27, 1991 was associated with elevations of other pollutants (BOD, TP, chloride, and total organic carbon [TOC]).

During the summer low flow period of the TMDL, total phosphorus measured as low as 0.017 mg/L in August of 1992, but as high as 0.120 in August of 1991, exceeding the recommended concentration of 0.1 mg/L for streams not flowing into reservoirs (MacKenthun, 1973).

Inorganic nitrogen (nitrate+nitrite-N plus ammonia-N) ranged between 0.068 mg/L as N and 0.099 mg/L as N, substantially below the sum of the National Water Quality Assessment (NAWQA) program's national background for nitrate-N (0.7 mg/L) plus ammonia-N (0.1mg/L) (Embry and Inkpen, 1998). Suspended solids were also low, and ranged between 1 and 6 mg/L.

Landuse Impacts on Water Quality

Landuse in this subbasin is dominated by forestland (98.4%) on which logging takes place. The agricultural uses represent only 0.6% of the landbase, which is less than the Upper Chehalis River (above Dryad) and the South Fork Chehalis River. Thus, the higher dry season TP concentrations of the Elk Creek subbasin is surprising. Pickett (1994a) suggested that the sources of fecal coliform, TP, and BOD lie between this station and the station 2.3 miles upstream.

Data Gaps

This subbasin has no routine monitoring station, although intense monitoring was conducted for the TMDL. Establishment of a routine ambient monitoring station at the mouth of Elk Creek may not be as critical as conducting intensive monitoring after implementation of actions that would reduce the oxygen depleting pollutant and TP loading.

Subbasin Conclusions

The water quality in the Elk Creek subbasin is generally good, although reductions in the sources of TP and fecal coliform are needed. Pickett (1994a) recommended that livestock access area in the vicinity of Murnen and Nine Creek and potential inadequate on-site systems near Murnen should be the starting points in identifying and remediating the sources of fecal coliform, elevated TP, and BOD concentrations.

SUBBASIN 3. SOUTH FORK OF THE CHEHALIS RIVER

The South Fork Chehalis River enters the mainstem at river mile 88. With 50 square miles of drainage, this subbasin represents only about 2% of watershed that discharges to the mainstem. An ambient water quality monitoring station 3.0 miles above the mouth of the South Fork Chehalis (monitored during water year 96-97) provides data relevant to this study.

Temperature and DO were within the water quality criteria for a Class A stream (Figure C-12) for the year measured. However, the TMDL study indicated temperature exceedances of the river in July 1991 of 1.4 and 1.6^{o}C at both stations monitored for the study (Boistfort Bridge and the Tanker Intake). Estimates of existing shade on the South Fork Chehalis River made in the 1999 TMDL study (Butkus and Jennings, 1999) were 52 %. The TMDL recommended a shade load allocation of 74 % to reduce the temperature, thus an increase of 22 % is needed in this subbasin. The TMDL also recommended an 80% reduction in the width-to-depth-ratio of the South Fork Chehalis (Butkus and Jennings, 1999). It was also noted that in-stream flow levels must remain the same and additional surface water withdrawals must not be allowed (Butkus and Jennings, 1999).

The Upper Chehalis Dry Season TMDL recommended load allocations of the oxygen depleting substances, ammonia, and carbonaceous BOD. The TMDL recommended load allocations from non-point sources at the background loadings.

Nutrient concentrations are generally low in the South Fork Chehalis River (Figure 13). Low TP concentrations were also measured during the TMDL study, ranging between 0.010 and 0.016 mg/l. TP loading (based on instantaneous flow) at the station is plotted in Figure C-14.

Inorganic nitrogen measured at the ambient monitoring station is reported in Table C-7 and depicted in Figure C-13. Ammonia-N concentrations peaked at 0.05 mg/l, less than the NAWQA background concentrations, Nitrate+nitrite-N averaged 0.56 mg/l and peaked at 0.77 mg/l, the peak slightly exceeding the recommended background nitrate concentration of 0.7 mg/L (Embry and Inkpen, 1998). During the TMDL study TN ranged between 0.23 and 1.12 mg/L as N (Pickett, 1994a). Two measurements made near Boistfort were both over 1 mg/L;

nitrate+nitrite-N represented 83% of the total nitrogen. The TN:TP ratio calculated from this data was as high as 70, an indicator that phosphorus is the limiting nutrient.

TSS concentrations at the ambient monitoring station (river mile 3.0) ranged between 1 and 80 mg/L; with the highest measurement recorded in November. The November sampling date was also the date of highest flow and a turbidity reading of 40 NTU (water quality criterion is 5 NTU). TSS loading for the 96-97 water year is graphically presented in Figure C-14.

The geometric mean FC concentration for the 96-97 water year (117 cfu/100 ml) exceeded the water quality criterion. Additionally, five of the 12 individual measurements during the 96-97 water year exceeded the 200 cfu/100ml portion of the standard (Figure C-15). Elevated levels of fecal coliform bacteria were recognized as a water quality problem in this stretch of the watershed by Pickett (1994a).

Landuse Impacts on Water Quality

While this subbasin is predominately forestland (89%), agricultural landuses (9.5%) in this subbasin are higher than in the Elk Creek of Upper Chehalis. Agricultural practices could be the source of the elevated fecal coliform, and high TP, IN, and TSS yields. Pollutant inputs were identified to this subbasin by the USFWS survey at over 15 separate locations (Wampler, et al., 1993). Cattle access was identified on over 21% of the stream/river miles in the South Fork subbasin (Wampler, et al., 1993). Numerous dairies were identified in the subbasin including one near Curtis and the monitoring station, and ten farms in the Boistfort Prairie area (Pickett, 1994a).

Data Gaps

Although the period of record at the ambient monitoring station is limited in this subbasin, implementation of the TMDL recommendations should precede additional monitoring.

Subbasin Conclusions

Water quality in the South Fork Chehalis River is degraded for temperature and fecal coliform. A detailed plan to implement an increased shading regime needs to be developed and implemented to reduce critical summer temperatures. While nutrient concentrations are not above national standards, this subbasin has the highest average TP concentrations (tied with the Black River) of any tributary in the watershed. The average nitrate+nitrite-N concentration in the South Fork Chehalis subbasin is the second highest of the tributaries measured. Improvements to the existing nutrient loading in this subbasin should focus on survey of livestock operations and improvement in farm management practices as suggested by Pickett (1994a).

SUBBASIN 4. UPPER CHEHALIS RIVER

An ambient monitoring station just above this subbasin at river mile 77.7 (Claquato) was maintained for the 96-97 water year. Data indicate two exceedances of the temperature criterion (Figure C-16). Because temperature exceedances were measured during critical low flow periods, the TMDL recommended an additional 30 % shade be provided to the river between the convergence of Elk Creek and the Newaukum River to maintain temperatures and to assist in maintaining dissolved oxygen concentrations in the river. However, additional shading along the mainstem, even in the upper reaches, may be ineffective at reducing summer temperatures due to the width of the river.

Data indicate exceedances of the dissolved oxygen criterion on the same two monitoring dates as the temperature exceedances (Figure C-16). To improve oxygen conditions in the subbasin, the TMDLs recommended not only shading but also limitations of ammonia-N and carbonaceous BOD from non-point sources to background loadings.

TP concentrations averaged 0.09 mg/l for the 96-97 water year with two monitoring dates showing TP higher than the MacKenthun (1973) recommendation of 0. 0.5 mg/l for waters flowing into a lake or reservoir similar to this stretch of river, which is slightly upstream of the Centralia Reach.

Ammonia-N and nitrate+nitrite-N concentrations averaged 0.02 mg/l and 0.46 mg/l, respectively during the 96-97 water year. Both parameters were similar to concentrations found at other mainstem stations.

The TSS concentrations ranged from a low of 4 mg/l to 102 mg/l and averaged 20 mg/l. The average TSS concentration at this station was similar to that measured at the Dryad and Newaukum River stations. Fecal coliform data for the 96-97 water year equaled or exceeded the 100 cfu/100 ml standard on three of the 12 monitoring dates, although the geometric mean was 61 cfu/100 ml. This geometric mean was greater than observed at other mainstem stations and most of the tributaries (Tables C-3 and C-7).

The following is a description of streams within this subbasin.

Bunker Creek

Pickett (1994a) provided the only substantial data on Bunker Creek and Stearns Creek that flow into the mainstem of the Chehalis at river miles 84.6 and 78.0, respectively. Bunker Creek represents less than about 2% of the flow into the Chehalis River below their confluence. Temperature was within the water quality criteria, but dissolved oxygen was consistently depressed below the 8.0 mg/l criterion during the summer months of the study. DO was measured as low as 3.3 mg/l at the sampling site. The depressed level may be a function of the low flow of the creek which ranged from 1.3 cfs in 1991, to 0.2 cfs in 1992 - likely very shallow water depth. TSS, turbidity, TOC, and BOD were also fairly high compared to other tributaries (Pickett, 1994a). TN and TP concentrations averaged 0.46 and 0.07 mg/l, respectively. The TN:TP ratio, 6.6, indicates that Bunker Creek may be nitrogen limited. Fecal coliform counts were above the 100 cfu/100 ml on both days sampled. The USFWS study (Wampler, et al., 1993) indicated that livestock access and other pollutant inputs were the causes of degradation.

Stearns Creek

The flow in Stearns Creek during the 1991 and 1992 TMDL study were in the range of 2 to 4 cfs, representing less than 5% of the flow into the Chehalis River below the creek's confluence (Pickett, 1994a). Temperatures were measured above the water quality criterion of 18^{o}C and DO was consistently depressed below 8.0 mg/L. The lowest measured DO was 6.5 mg/l. Like

Bunker Creek, Stearns Creek was likely shallow during the summer months of the study. Picket (1994) reported that TSS (mean = 15 mg/l) and turbidity (mean = 16.5 NTU) in this creek were higher than in any other tributary to the river in the study. He also reported elevated levels of total dissolved solids (TDS), TOC, TP, and ammonia-N (maximum = 0.093 mg/l). TP averaged 0.37, while TN averaged 0.66. The TN:TP ratio was 1.78 which indicates a strongly nitrogen limited water body. Fecal coliform concentrations were elevated to 580 cfu/100 ml on one of the two dates sampled.

Landuse Impacts on Water Quality

Subbasin 4 is less dominated by forestlands (81%), than other upper watershed subbasins. Agricultural landuses are higher (17%), and located along the floodplain of the river. The subbasin is still relatively undeveloped with residential and urban landuses representing less than 1% of the land.

Impairments to dissolved oxygen and fecal coliform were attributed to the impact of agricultural practices that have been documented by the USFWS (Wampler, et al., 1993). This survey estimated a high percentage of stream miles were degraded by livestock practices. Agricultural practices may also be the source of the elevated TP and fecal coliform levels.

Data Gaps

A long period of water quality monitoring data is absent from this subbasin. Two recommendations for future monitoring are advisable. First, a USGS gage station should be recommended in the vicinity of the ambient monitoring station. Flows are necessary to calculate pollutant loadings and yields. Second, water quality monitoring data should continue to be collected at Claquato. Sample collection could be performed on a rotating basis, but not less frequently than every third year.

Subbasin Conclusions

Water quality is degraded in this subbasin, with exceedances of the temperature, dissolved oxygen, and fecal coliform criteria. TP concentrations are also evaluated. The fact that Bunker and Sterns Creeks are nitrogen limited also indicates that specific sources of phosphorus loading should be identified and reduced. Recommendations for the future include the flow and water quality monitoring described above and reduction or elimination of the agricultural sources of pollutants particularly from the Bunker and Stearns Creek areas.

SUBBASINS 5, 6, AND 7. SOUTH FORK, NORTH FORK, AND NEWAUKUM RIVER

These South and North Fork Newaukum Rivers and the Newaukum River (Subbasins 5, 6, and 7) converge and the combined flows are represented at the ambient monitoring station at the mouth of the Newaukum River (river mile 0.1). This ambient monitoring station at the mouth of the subbasins provides recent water quality data that reflect the cumulative impacts to the river. Data for flow, temperature, DO, pH, TP, inorganic nitrogen species, TSS, and fecal coliform are more or less continuous for the 1992 -93 water year. Two other ambient monitoring stations further upstream have more historical data. The first of these is located at river mile 4.5 and was monitored from 1972 through 1977. The second ambient monitoring station, located at river mile 11.1, was monitored for the 1974-75 water year only. Separate information on the two tributaries (North and South Forks) is lacking. Data from this station are compared to monitoring conducted by Pickett (1994a).

The combined drainage area of these three subbasins is 156 square miles, representing approximately 7% of the Chehalis River watershed drainage above the mouth. Flow at the mouth of the Newaukum River varied from a summer average low flow of 61 cfs, to average wet month flows of 985 cfs. The average low flow measured at the monitoring station during water year 92-93 is in the same range as those found by Pickett in 1991 and 1992 (1994a).

Figure C-17 indicates that temperatures at the ambient station approached, but did not exceed the water quality criterion. However, data collection during the TMDL study indicated that temperature exceeded the water quality standard of 18°C on 3 of the 6 dates measurements were taken at the mouth station in the 91-92 water year, but were within the standard during the 92-93 water year (Pickett, 1994a). While the temperature TMDL did not establish a new temperature criterion for the Newaukum River, it did recommend an additional 35% shade be provided to consistently meet the criterion (Butkus and Jennings, 1999). The Newaukum River was also determined to need to reduce the width-to-depth ratio by 72% to meet the load allocation required in the TMDL (Butkus and Jennings, 1999). How this reduction is to be accomplished was not specified.

The 92-93 water year ambient monitoring data and the TMDL data indicated that dissolved oxygen met the criterion of 8.0 mg/l at the mouth of the Newaukum River. However, depleted dissolved oxygen concentrations on the mainstem Chehalis resulted in recommendations for reduction in tributary sources of carbonaceous BOD from non-point sources to prevent summer oxygen depletions (Pickett, 1994a).

Total phosphorus concentrations at the ambient station ranged from the detection limit of 0.01 mg/l to 0.05 mg/l and averaged 0.03 mg/l, well below the 0.1 mg/l level recommended by MacKenthun (1973). The average and maximum TP concentration were at the lower end of the range of tributaries for which data were available (Table C-7). Inorganic nitrogen concentrations averaged 0.02 mg/L for ammonia-N and 0.61 mg/l for nitrate+nitrite-N. Seasonal fluctuations of the nitrate+nitrite-N are depicted in Figure C-18. Pickett (1994a) reported somewhat lower nutrient concentrations; TP averaged 0.017 mg/l and TN averaged 0.17 mg/l, indicating the river is phosphorus limited (Pickett, 1994a). The higher averages for the full water year are a result of higher wet season concentrations (Figure C-18). The average inorganic nitrogen concentrations measured in both studies were less than the NAWQA background concentrations of 0.8 mg/l (Embry and Inkpen, 1998).

The TP loading from the Newaukum River to the mainstem of the Chehalis at Porter represents only 5% of the total dry season loading, but 7% of the wet season TP loading (Table C-8). The average annual TP yield of the Newaukum River is lower than the mainstem stations of the Chehalis, but represents 62% of the yield at Porter. The TP yield compares favorably to the rivers in Puget Sound evaluated by Embry and Inkpen (1998), slightly less than the TP yield for the Deschutes (Table C-5).

The IN yield for the Newaukum River was the second highest yield, second only to the yield at Montesano. IN yield is also higher than the rivers in the Puget Sound study (Embry and Inkpen, 1998) (Tables C-5 and C-8). Ammonia loading (one component of IN) was recognized as a problem in the 1994 TMDL study (Pickett, 1994a). The TMDL recommended an 87% reduction in the non-point source load allocation for ammonia-N to the Newaukum River (Pickett, 1994a).

TSS ranged from 3 mg/l to 90 mg/l in the 92-93 water year at the ambient monitoring station at river mile 3.0. The average TSS concentration (Table C-7) is higher than any other tributary. Wet and dry season and average annual TSS yields are presented in Table C-9. The TSS yield from the Newaukum River represented 16% of the average annual yield at the Porter station. TSS yield in the Newaukum watershed is substantially lower than that in the Humptulips subbasin (Table C-9).

The Newaukum River is listed on the 303(d) list as impaired for fecal coliform. Fecal coliform levels were higher than 100 cfu/100 ml in 3 of 12 months, although the geometric mean was less than the criterion, and less than 10 % of the samples exceeded 200 cfu/100 ml standard. Elevated levels were associated with the wet season and were not, therefore, observed during the TMDL study which was conducted in the dry season (Pickett, 1994a).

Landuse Impacts on Water Quality

Landuse in Newaukum River watershed is dominated by forest (79.4%). This subbasin has a relatively high percentage of agricultural activity (17%) compared to other subbasins. Only the Black River subbasin has a higher percentage of agricultural activities. The agricultural activities are likely to be the source of the high inorganic nitrogen yield and should be identified and managed. Reductions in ammonia-N and carbonaceous BOD load were recommended to improve water quality in the Newaukum as well as along the mainstem Chehalis River. Based on the high percentage of agriculture, load reductions should focus on improving run-off from agricultural practices.

Subbasin Conclusions

Water quality in the Newaukum River subbasin is degraded for temperature and fecal coliform. In addition IN yields were higher than at Porter or Dryad. Actions taken to improve these parameters should follow the TMDL recommendations by increasing shading and reducing sources of inorganic nitrogen, predominantly ammonia loading.

SUBBASIN 8. SALZER CREEK

Despite the small size of the Salzer Creek subbasin (19 mi^2) and its relatively low flow (2 to 4 cfs during the 91 and 92 dry seasons), it has been the focus of a number of water quality investigations. There is ambient monitoring station in this subbasin, this discussion is based on limited site specific studies.

In October 1979, low dissolved oxygen was observed in the mainstem of the Chehalis River at Mellen Street in Centralia. The source of the problem was identified as the failure of a food processing wastewater pipe that resulted in a release to Salzer Creek. The wastewater was being applied to and adjacent to the creek by National Fruit Canning Company (which has since been purchased by National Frozen Foods). Low dissolved oxygen was documented in Salzer Creek for some time after the release (Johnson and Prescott, 1982 and Joy, 1984). In 1986, Ecology conducted a survey of the creek to identify point and non-point sources in the drainage and associated impacts on water quality (Crawford, 1987b). Both low dissolved oxygen and high fecal coliform levels were measured. The causes of the poor water quality were cited as poor farm management practices and infiltrations of leachate from the Centralia landfill. Stormwater runoff from the Southwest Washington Fairgrounds was also identified as a potential pollutant source to Salzer Creek (Crawford, 1987b). Actions were undertaken to correct the identified problems.

Degraded water quality persisted and was again identified in the 1994 TMDL study (Pickett, 1994a). Temperatures exceeded the 18^{o}C criterion on several occasions. The 1999 temperature TMDL adjusted the temperature criterion for Salzer Creek to 19.9 ^{o}C based on predictions of natural stream conditions (Butkus and Jennings, 1999). The temperature TMDL also recommends an additional 13 % shade be provided to the creek to maintain the adjusted criterion temperature.

Dissolved oxygen was well below the 8.0 mg/l criterion during the 91 and 92 dry seasons. In late August 1991, the creek was “virtually anoxic” (Pickett, 1994a). To maintain high dissolved oxygen concentrations in the subbasin and along the mainstem, the TMDL recommended non-point source loading for ammonia-N and carbonaceous BOD remain at background levels.

Consistently elevated conductivities (above 1,000 umhos/cm), TDS, and chlorides were greater than any other tributary and were indicative of high concentrations of dissolved pollutants (Pickett, 1994a). Nutrient levels were also elevated. TP averaged 0.09 mg/l and TN averaged 0.61 mg/l, with spikes as high as 1.2 mg/l. Sources to the creek from a sump at the Fairgrounds were as high as 12.2 mg/l TN and 0.64 mg/l TP. Fecal coliform exceeded 1,000 cfu/100 ml on three different dates (Pickett, 1994a). Pickett (1994a) recommended additional investigation of sites previously identified (Crawford 1989b) and urged corrective actions be taken to improve water quality.

Landuse Impacts on Water Quality

Salzer Creek subbasin is a relatively developed portion of the basin with almost 3% of the land as urban or commercial and industrial. Agricultural uses comprise 12.9% of the subbasin, with the remainder dominated by forestlands (83.9%). Sources of water quality degradation in the subbasin have been identified and include the fairgrounds sump, wastewater discharged by National Frozen Foods, stormwater, and potentially leachate from the Centralia Landfill.

Data Gaps

Data on the impaired quality of this subbasin is prevalent, although no routine ambient monitoring station is located in the subbasin. Future monitoring efforts should be implemented following the necessary actions required to eliminate the sources of pollutant loading.

Subbasin Conclusions

Water quality problems in the subbasin have been identified but unresolved for a number of years. Since the sources have been identified, actions to correct the water quality problems emanating from these sources should be a priority. Post-corrective action monitoring can be used to verify the results of the actions.

SUBBASIN 9. SKOOKUMCHUCK RIVER

The Skookumchuck River enters the Chehalis River at river mile 66.9. An ambient monitoring station 2.3 miles upstream of the mouth of the Skookumchuck is sampled intermittently. Data were available for water years 92-93 and 96-97. Instantaneous flows at this station ranged from a dry season low of 77 cfs to a wet season high of 910 cfs.

Ambient monitoring station temperatures did not exceed the criterion. Average temperature for the station was 10.6^{o}C, and maximum temperature was 16.9^{o}C (Table C-7). Pickett (1994a), however, found temperatures elevated above the 18^{o}C criterion on several occasions. To assist in reducing summer water temperatures, the TMDL recommends an additional 20% shade be provided to this subbasin (Butkus and Jennings, 1999).

Dissolved oxygen was not recorded at concentrations less than the criterion at the ambient monitoring station or during the TMDL study. While Pickett (1994a) indicated that oxygen depleting pollutants (BOD, TOC, and nutrients) were detected at relatively low levels, the TMDL recommended that load allocations for the oxygen depleting pollutants (ammonia-N and carbonaceous BOD) not exceed background conditions. This recommendation implies that no additional landuse activities that would increase the contribution of these constituents should be allowed.

An average TP concentration of 0.04 mg/l and an inorganic nitrogen concentration of 0.56 mg/L was measured in the ambient data. The average TP concentration at this station was exceeded only by the average concentrations on the Black and South Fork Chehalis Rivers (Table C-7). Average ammonia-N concentration at ambient station on the Skookumchuck was low. While the average nitrate+ nitrite-N concentration was among the higher tributaries and exceeded only by the Newaukum and South Fork Chehalis Rivers, it was below the NAWQA national background concentration of 0.7 mg/l (Mueller and Helsel, 1996). Pickett (1994a) noted relatively low nutrient concentrations as well.

TSS concentrations ranged from an average of 8 mg/l to a maximum of 43 mg/l. The average and maximum TSS concentrations were among the lowest of the major tributaries (Table C-7). Fecal coliform concentrations were generally within the water quality standards, with a geometric mean of 41 cfu/100 ml and a peak of 960 cfu/100 ml. Pickett (1994a) also noted low fecal coliform counts.

Hanaford Creek

Hanaford Creek is a major tributary to the Skookumchuck River. Its basin is the site of a major open-pit coal mine and power plant. Baseline conditions were assessed in Hanaford Creek watershed in 1970 and 1971 during initial operations at the mine site and in preparation for the potential impacts of the coal mine/power plant projects (McCall, 1971). Elevated turbidity and iron levels that were observed were attributed to the construction. Dissolved oxygen concentrations were less than 8.0 mg/L (the water quality criterion) at 6 of the 7 stations monitored on Hanaford Creek and at one station at the mouth of South Hanaford Creek. Temperatures at three stations exceeded the 18^{o}C criterion on at least one occasion.

Pickett (1994a) monitored temperature, dissolved oxygen, and nutrients in Hanaford Creek above the Skookumchuck River. Temperature exceeded the criterion on some dates. Dissolved oxygen levels remained above the 8.0 mg/l level even on the days of elevated temperatures (Pickett, 1994a). Nutrient concentrations were relatively low; TP and TN averaged 0.053 mg/l and 0.54 mg/l, respectively (Pickett, 1994a).

Landuse Impacts on Water Quality

As with other subbasins in the watershed, landuse is dominated by forestlands (86.5%). Agricultural activities represent 7.5% of land uses, with commercial and industrial categories representing 2.4% of the land and urban representing only 1.4% of the landuse. The lower percentage of agricultural landuse in this subbasin may be one factor in the relatively high water quality.

Data Gaps

TP, IN, and TSS loadings and yields should be calculated based on the median monthly flows (50% exceedance flows) to allow comparisons among the tributaries for prioritization of actions.

Subbasin Conclusions

The Skookumchuck River has had exceedances of the temperature criterion. Water quality in this subbasin has also been somewhat affected by contributions of TP and IN, as reflected in the slightly elevated average concentrations of these parameters. The two TMDLs have included recommendations for the Skookumchuck which are tailored predominantly to improve water quality along the mainstem Chehalis River, as well as within the Skookumchuck River itself. Implementation of the recommendations in the TMDL studies should be the main priority in this subbasin.

SUBBASIN 10. MAINSTEM NEAR CHEHALIS/CENTRALIA

The stretch of the Chehalis River between river mile 75.2 (the mouth of the Newaukum river) and river mile 66.9 (the mouth the Skookumchuck River) has been identified as the Centralia Reach. The ambient monitoring station with the longest period of record in this subbasin is river mile 67.5 near Centralia in the very slow flowing Centralia Reach, which exhibits lake-like conditions. The station was monitored from 1977 through 1993 and provides the basis for the subsequent discussion.

This section of the mainstem tends not to meet the water quality standards. Figure C-19 presents temperature over the period of record. Temperature not only exceeds the criterion of 18^{o}C but also frequently exceeded 20^{o}C. The 1999 temperature TMDL evaluated natural temperature regimes; and as a result, the water quality criteria for temperature for this stretch of river were re-established at background conditions (Butkus and Jennings, 1999). The re-established criteria are presented in Table C-10. The TMDL recommended shade requirements needed to meet the temperature criteria. These vary between 27 and 42% additional shade along this stretch of river (Butkus and Jennings, 1999).

Table C-10. Segment-Specific Water Quality Criteria Established by 1999 TMDL

Chehalis Mainstem River Mile	Water Quality Standard
73.6	18.4
70.7	18.9
69.1	19.5
67.5	20.3
66.3	20.4

The period of record shows that dissolved oxygen frequently declined below the criterion of 8.0 mg/L (Figure C-19). Reported anoxic conditions near the bottom was one of the drivers for the 1994 TMDL which limited carbonaceous BOD and ammonia-N.

Total phosphorus has ranged from 0.01 mg/l to 0.38 mg/l over the period of record. The average and median TP concentrations were 0.08 and 0.05 mg/l, respectively. Average TP concentrations along the mainstem were only exceeded at Claquato. Concentrations of greater than 0.05 mg/l for flows into a lake-like area (such as the Centralia Reach) indicate a high likelihood of poor water quality (MacKenthun, 1973). TP loading based on instantaneous flows is depicted in Figure C-20. TP loading and yield based on 50% exceedance flows was not calculated, but may demonstrate a higher average annual TP yield than at other stations along the mainstem.

Ammonia-N and nitrate+nitrite-N averaged 0.06 and 0.47 mg/l, respectively during the 1990's. Pickett (1994a) reported that this stretch of river is nitrogen limited.

TSS concentrations in the 1990's ranged from 1 mg/l to 109 mg/l, with an average of 16 mg/l. TSS loading based on instantaneous flows is depicted in Figure C-20 for the period of record.

Fecal coliform concentrations are frequently above 100 cfu/100 ml as seen in Figure C-21. Although the geometric mean for the period of record is only 47.3 cfu/100 ml, fecal coliform concentrations equaled or exceeded 200 cfu/100 ml on 21% of the sampling occasions in the 1990's data set of measurements.

Other Studies

This river reach has received intensive study due to the continuing low dissolved oxygen concentrations in this stretch. Low dissolved oxygen and high bacterial levels were observed as early as 1969 (McCall, 1970). This author reported that the Centralia Reach experienced temperature and oxygen stratification, similar to a meso- to eutrophic lake or reservoir. Improvements in the quality of the discharge from the Chehalis Wastewater Treatment Plant in

1970 resulted in higher dissolved oxygen concentrations at the surface and lower bacterial levels. However, the deepest points in the Reach were anoxic in three separate areas (McCall, 1970).

A 1972 study indicated that although the water quality had been improved by the changes at the treatment plant and oxygen levels met the water quality standards for that reach of the river, problems remained (Devitt, 1972). This study specifically mentioned access by livestock to the river and garbage dumping in some areas. Other potential sources of these problems were identified in the Sewage Drainage Basin Plan (R.W. Beck, 1975) as: failing septic systems, poor animal waste management, poor forest practices, and specific industrial point source discharges from facilities such as wood products, food processing, and meat packing.

By 1980, reports by Houck (1980) and Yake (1980) noted that the conditions of the Centralia Reach may be attributed, in part, to its natural flow patterns. A travel time of 6.4 days was estimated from the Chehalis WTP to the Mellen Street bridge. Yake concluded that this stretch of river is deep, slow, and stratified. Algal growth and respiration (resulting in oxygen utilization) is controlled by the levels of inorganic nitrogen discharged by the Chehalis WTP (nitrogen downstream of the WTP plant was 2 to 6 times higher than upstream of the plant). Johnson and Prescott (1982) also observed substantial temperature stratification, oxygen depletion to levels less than 2.0 mg/L near the bottom. They commented that the temperatures were high enough to pose a threat to salmonids. This was reiterated by a 1982 US Fish and Wildlife Service study of conditions in the Centralia Reach for chinook salmon.

An intensive survey and modeling effort of this reach of the river was conducted in 1982. Again the low velocity of the river (0.04 to 0.07 feet per second at low flow), coupled with the nutrient loading from the WTP stimulating algal growth, were identified as predominant factors contributing to depressed dissolved oxygen concentrations. It was suggested that as Salzer Creek entered the river, heterotrophic bacterial activity may have been the cause of additional oxygen depletion, rather than algal photosynthesis (Joy, 1987). To evaluate the potential impact of an increased discharge by Darigold under their NPDES permit, (Joy, 1987) modeled the additional BOD loading to the river. He concluded that no significant reduction in dissolved oxygen would results from the proposed increased load by Darigold. However, his model did not account for the impacts of nutrient loading and stimulation of algal growth on the dissolved oxygen levels in the river.

Dillenbaugh Creek

In 1986, WDOE performed an intensive survey of this creek that discharges into the Newaukum River near its mouth. The purpose of the 1986 survey was to investigate point and non-point sources of pollution to the creek that may have resulted in low dissolved oxygen levels (Pickett, 1992). The investigators found a wide variety of sources including: farming activities, including a dairy feedlot (thought to be the primary cause of low oxygen concentrations), failing septic systems adjacent to the creek (considered the major source of bacterial contamination), and industries in the Chehalis Industrial Park which contributed to temperature violations.

This creek was also included in the TMDL study (Pickett, 1994a). Flows in the creek were reported between 0.3 and 1.4 cfs during the dry season. Only one instance of a temperature exceedance of the water quality standard was recorded during the study. Noteworthy was one pH reading higher than 8.0 which was postulated to be associated with discharges from the Chehalis Industrial Park (Pickett, 1994a).

Dillenbaugh Creek has relatively high turbidity and TSS. The BOD and TOC were the second highest of any natural tributary to the mainstem; Pickett (1994) also reported that TP, TN, and chloride were also relatively high, but fecal coliform levels were low. Because elevated fecal coliform levels were measured in the upper creek, Pickett indicated concern about the rapid die-off. He hypothesized that pentachlorophenol from the American Crossarm and Conduit Superfund site adjacent to the creek may be “disinfecting” the creek near the mouth. It was recommended that additional monitoring and source control be performed as pentachlorophenol is a growth inhibitor for yearling sockeye salmon (Pickett, 1994a). In addition, he recommended a number of restoration and protection activities to improve the water quality in the creek.

Other Studies on the Mainstem below Skookumchuck

Enviroshpere Company (1982) monitored the stretch of the Chehalis between river mile 23.9 and 13.5 during the preparation for the Washington Public Power Supply System. They reported that the criteria were met for dissolved oxygen, turbidity, and temperature, except during the summer when temperatures in this section of the mainstem exceeded 18^{o}C.

Thurston County Environmental Health conducted sampling and analysis of the Chehalis River near Grand Mound during the low flow season in preparation for the proposed Grand Mound WTP. Samples were analyzed for dissolved oxygen, pH, conductivity, nutrients, BOD, TSS, and fecal coliform bacteria. All parameters met the water quality standards, except temperature. In late August 1989, temperatures between 18^{o}C and 19^{o}C were measured at two stations. Noteworthy were a dissolved oxygen concentration of 8.2 mg/L and a pH of 8.4 at the Prather Road bridge - barely meeting the standards. Nitrate+nitrite-N tended to increase in the downstream direction, while total phosphorus tended to decrease ranging between 0.1 and 0.2 mg/L (TCEH, 1989).

Landuse Impacts on Water Quality

Landuse in the Chehalis River mainstem subbasin near the cities of Centralia and Chehalis is more equitably spread across the major categories: forest lands comprise 64% of the subbasin, agricultural practices represent 20.1% of the landuse. Six percent of the subbasin is urbanized and industry and commerce represent 1.7% of the area.

Data Gaps

The river is well-studied in the subbasin and there were no apparent data gaps at this location. However, TP, IN, and TSS loadings and yields should be calculated based on median monthly (50% exceedance) flows. This would allow prioritization of activities designed to reduce pollutant loadings among the subbasins. The ambient station at Centralia should continue to be monitored for water quality parameters.

Subbasin Conclusions

This subbasin has been recognized as having an abundance of water quality problems, including elevated summer temperatures, fecal coliform levels, and low dissolved oxygen attributed to BOD and nutrient loading. Average TP and ammonia-N concentrations were among the highest along the mainstem. These water quality problems, coupled with the slow flowing conditions of the Centralia Reach, create conditions observed in a eutrophic lake or reservoir. As such it has been included in the two TMDL studies. Recommendations from these TMDLs should be implemented. While increased shading along the mainstem alone may not provide sufficient cover of the river to improve conditions due to its width, increased riparian shade along the upstream tributaries will likely improve summer temperature conditions.

Actions to improve water quality should include reductions in the oxygen depleting constituents and nutrients through revised permit conditions and implementation of agricultural and stormwater BMPs. Reductions in fecal coliform levels should be realized coincidentally with BMP implementation.

SUBBASIN 11. BLACK RIVER

Historical Studies

The Black River subbasin has been the subject of extensive study since a large fish kill occurred in August 1989 (hundreds of adult chinook were found dead in the Chehalis River near Oakville) (Pickett, 1992). Toxic materials were suspected, but never detected in significant amounts. Temperatures in the lower Black River (below RM 10) were found to exceed the water quality criteria of 18^{o}C at the surface. Dissolved oxygen concentrations below 8 mg/L were widespread (Pickett, 1992). Portions of the river were reported to support dense beds of aquatic macrophytes, which elevated levels of dissolved oxygen during midday. Total phosphorus concentrations in the lower river were in excess of 0.1 mg/L, EPA’s desired goal for the prevention of nuisance plant growth in rivers. Pickett reported alternating locations of nitrogen and phosphorus limitation on plant growth in the upper river, but a strongly phosphorous limited condition in the lower river.

A water quality screening study was conducted cooperatively between the Chehalis Confederated Tribes and WDOE, between November 1989 and June 1990 (Dickes, 1990). Dissolved oxygen concentrations did not meet the standard in November, December, and June (Dickes, 1990). The pH standard was violated between March and May falling below 6.5 (Dickes, 1990). Numerous fecal coliform exceedances were detected during wet weather months, which ultimately lead to a wet weather TMDL for fecal coliform. Total suspended solids and turbidity levels were high during a storm event in January (Dickes, 1990).

A subsequent water quality study was conducted cooperatively between the Black River Watch and Thurston County Environmental Health in 1990 and 1991. Six stations were sampled from mid-July through October, and monthly through March 1991. During this study, temperatures reached a high of 23.5^{o}C in August. Thermal stratification was identified at three stations, where dissolved oxygen near the bottoms reached a low of 0.5 mg/L. Dissolved oxygen was below the standard at all stations on several sampling events. Fecal coliform level also exceeded criteria at all stations, except the most upstream location.

TMDL Studies

The results of the water quality monitoring studies focused attention on this watershed and lead to the development of both wet and dry season TMDLs. The wet season TMDL was conducted to evaluate and recommend a plan to remediate elevated fecal coliform concentrations. The TMDL (Coots, 1994) identified land use as dominated by crop and pasture in the main basin supporting almost 9,000 head of diary cows and numerous non-commercial farms. Although five aquaculture facilities were present in the basin, only one discharged directly to the Black River. Thus, conclusions of the study were that fecal coliform exceedances were attributed primarily to poor farm practices. Study recommendations included a 92% load allocation reduction in Beaver Creek (tributary to the Black River), and between 49% and 60% load reductions in the middle reach of the Black River (river mile 11.8 to 15.2); providing assistance to local farmers through the conservation district. Other recommendations were establishment of a local watershed management committee, and identify location of the pollutant loading sources along the middle reach (Coots, 1994).

Thurston County Environmental Health (TCEH) Division has continued to monitor Beaver Creek and the Black River. The results of wet season monitoring of Beaver Creek at Highway 121 (creek mile 0.1) indicate a decrease in the fecal coliform following TMDL implementation. A geometric mean of 1,285 cfu/100 ml for wet season data from December 1992 through March 1996, versus 461 cfu/100ml for December 1996 through March 1997 (TCEH reports for water years 92-93 through 96-97) (Figure C-22). Although water quality standards were still not being met in 1997, water quality was improving. Overall, in both wet and dry seasons, TCEH reported fewer fecal coliform exceedances of the second portion of the standard (i.e., no more than 10% exceeding 200 cfu/100 ml). In the 1992-93 water year, 75% of the samples exceeded the 200 cfu/100 ml limit, while in water year 96-97 only 25% of the samples exceeded the limit.

BMP implementation plans for farms on the Black River were in place by January 1995 (Sargeant, 1996). TCEH monitored the Black River at Moon Bridge (river mile 7.1) once in March of 1996 and monthly from December 1996 through March 1997 resulting in a geometric mean of 50.48 cfu/100 ml. Fecal coliform levels were well within the compliance limits. WDOE data indicate that the geometric mean of fecal coliform during the wet season decreased from 54 prior to BMP implementation, to 36 cfu/100 ml at this station following BMP implementation, with no exceedances of the 200 cfu/100ml standard following BMP implementation.

The dry season (defined as May 1 through October 31) TMDL was also issued in the summer of 1994 (Pickett, 1994b). Numerous pollutant issues were identified during the study. The upper river (upstream of river mile 15.3) was found to be strongly influenced by extensive wetlands. In this area, dissolved oxygen was low, and organic compounds were relatively abundant, giving the river its characteristic dark color (Pickett, 1994b). In the middle slow flowing and deeper portion of the river, water quality is affected by nutrient loading (in some instances from unidentified sources) and verges on eutrohpic. Just upstream of the confluence with Mima Creek, historical releases of pollutants from the Black River Ranch had severely affected water quality in that stretch of river. The study noted that waste management practices had been improved at the ranch, resulting in improvements in the water quality by 1992. In the lower reaches of the river, the proliferation of phytoplankton (a result of nutrient loading) was reduced. Instead dense beds of macrophytes were found downstream of river mile 9.1. Parameters of concern were identified as dissolved oxygen, total phosphorus, and temperature.

A new standard for dissolved oxygen by river mile was established based on background conditions, with no significant degradation of DO allowed from any new development of point or non-point sources (i.e., no new sources of BOD loading) (Pickett, 1994b). A limit on total phosphorous was applied to the middle Black River to protect this section of the river from further deleterious effects of eutrophication (Pickett, 1994b). A load capacity, defined as the daily average TP concentration of 0.05 mg/L, was applied from river mile 9.6 to 15.1. A TP load allocation was also recommended for the Swecker Salmon farm (Pickett, 1994b). To remedy the temperature exceedances, protection and replanting of shade trees in the riparian zone from RM 10 to the mouth was proposed (Pickett, 1994b). BMP implementation and monitoring were also recommended (Pickett, 1994b). The subsequent temperature TMDL for the Upper Chehalis (Butkus and Jennings, 1999) also recommended 31% additional shade for the Black River and a 62% reduction in the wide-to-depth ratio. Implementation details of the temperature TMDL were remanded to the Chehalis Basin Partnership for development in a Detailed Implementation Plan (Butkus and Jennings, 1999).

Following the dry season TMDL implementation, changes in ammonia-N, TP, and dissolved oxygen might be expected. Figures C-23 through C-25 provide the dry season monitoring data at river mile 7.1 for pre- and post-TMDL implementation for these parameters. Although the average DO has increased slightly and the maximum TP concentration measured since December 1995 is not as high as that measured previously, significant improvements are not immediately apparent. However, data collection has been limited since the original study, and BMP implementation generally requires a number of years.

Ambient Monitoring Station Data

A long-term ambient monitoring station has been maintained on the Black River at the Moon Bridge crossing (river mile 7.1). Water quality data was collected monthly from 1990 through 1997. These data are used in the following discussion of water quality. While no flow data were available, temperature, dissolved oxygen, pH, total phosphorus, ammonia-N, total suspended solids, and fecal coliform data are available.

As seen in Figure C-26, temperature and dissolved oxygen frequently do not meet the water quality criteria of 18^{o}C and 8.0 mg/L, respectively.

Total phosphorus at this station ranged between the detection limit of 0.01 mg/l and 0.17 mg/l. The average concentration was higher than any other tributary (and equaled that of the South Fork Chehalis River (Table C-7). The maximum TP concentration was substantially higher than the EPA maximum recommended concentration of 0.1 mg/L for the prevention of nuisance plant growth in rivers, although the average concentration was 0.05 mg/l.

Ammonia-N concentrations were measured at the Moon Bridge station and averaged 0.03 mg/l-N with a maximum concentration of 0.16 mg/l. Nitrate+nitrite-N and total nitrogen have not been measured at this station. However, summer season nitrate+nitrite-N was measured during the 1991 and 1992 water years (Pickett, 1994b). The average concentrations at the Howanut Bridge station for ammonia-N was 0.02 mg/l, and for nitrate+nitrite-N, 0.92 mg/l. Total N was reported as an average of 1.08 mg/L. The TN:TP ratio (>34) during the summer at Howanut

Road Bridge would indicate that the river is strongly phosphorus limited. However, Coots (1994) reported that some segments of the river are nitrogen limited.

Total suspended solids averaged 3 mg/l, with wet season peaks of 12 mg/l. Fecal coliform levels routinely exceeded the water quality criterion. Of the 61 station measurements, 15 (~25 %) were equal to or greater than 100 cfu/100 ml, even though the geometric mean for the time period was only 39 cfu/100 ml. Most of these excursions, were associated with the wet season.

Landuse Impacts on Water Quality

Landuse impacts on the water quality of the Black River subbasin have been well documented. While a high percentage of the land (68.8%) is considered forestland, agriculture and rangeland activities represent 14.2% and 3.7% of the landuse, respectively. Wetland areas comprise 5.5% of the subbasin, some of which are immediately adjacent to the river. Urban residential, and industrial and commercial, landuses represent less than 3% of the basin. Agricultural activities have had the most profound and well-documented impacts on the water quality of the river. Fecal coliform and TP levels have been elevated from farm practices. Fecal coliform levels may also reflect failing septic systems. These impacts are being remediated through implementation of the TMDL (Pickett, 1994b). Temperature is naturally elevated by the slow meandering course of the river, but is also affected by the clearing of land for agriculture and urban development. Increased shading, recommended in the temperature TMDL should assist in reducing the temperatures of the river.

Data Gaps

The Black River subbasin has received intensive study. However, establishment of a USGS gage station at the Moon Road or Howanut Road is highly recommended. This station would provide flow data for calculation of TP, IN, and TSS yields, allowing subbasins with higher yields to receive higher priority for activities to reduce pollutant loading.

Subbasin Conclusions

The water quality in the Black River subbasin is impaired. Excursions of temperature, dissolved oxygen, and fecal coliform criteria have been commonplace. The wet and dry season TMDLs for this river and the Upper Chehalis temperature TMDL recommended non-point loading allocations and recommend actions to improve water quality. Resources in this subbasin should focus on implementing the recommended actions. Post-implementation monitoring should be directed toward identification of water quality improvements.

SUBBASIN 12. CEDAR CREEK

No ambient monitoring station is located in this subbasin. Information from the TMDL (Pickett, 1994a) is summarized here. This tributary to the mainstem enters at river mile 38.8, just upstream of the Porter ambient monitoring station. Summer flows for this creek ranged between 11 and 14 cfs, representing 3 to 5 % of the flow on the mainstem at Porter (Pickett, 1994a). Water quality in this subbasin was considered to be good. Temperatures remained below the criterion and dissolved oxygen concentrations remained well above the criterion. Only one fecal coliform measurement was greater than 100 cfu/100 ml. The low observed fecal coliform levels were attributed to the fact that there is little livestock access to the stream. The TP concentrations were never above the detection level of 0.010 mg/l. TN concentrations were also low, averaging 0.27 mg/l throughout the low flow study period (Pickett, 1994a). This creek is also phosphorus limited as evidenced by the estimated TN:TP ratio of 27.

Landuse Impacts on Water Quality

Forestlands dominate landuse within this 39 mi^2 subbasin, representing 96.1% of the area. Range land represents 2.4% of the drainage and the only agricultural activities. Wampler (1993) noted that this subbasin had one of the lowest identified percentages of streambank with livestock access impacts (Wampler, et al., 1993). The lack of agricultural and urban development may be one factor contributing to the high water quality.

Data Gaps

This subbasin has no ambient water quality monitoring station. Long-term data are needed, although limited resources may focus on post-TMDL implementation monitoring until higher priorities have been achieved.

Subbasin Conclusions

While there is limited data on the Cedar Creek subbasin, extant data indicate that the Cedar Creek subbasin had generally high water quality, with one instance of elevated fecal coliform. Future actions in this basin should focus on maintaining its water quality.

SUBBASIN 13. CHEHALIS RIVER MIDDLE REACH 2

An ambient water quality monitoring station has been maintained at Porter (RM 33.3) since 1970, and continues to be monitored on a monthly basis. Temperature excursions have occurred at this station (Figure C-27) routinely over the period of record, and frequently exceeded 20^o. During development of the temperature TMDL, it was acknowledged that natural temperature conditions in the reach were higher than the standard, and thus, the water quality criterion was adjusted to 21^{o}C at this location (Butkus and Jennings, 1999). It was also estimated that 28% additional shade would still be required to meet this higher temperature standard (Butkus and Jennings, 1999). However, additional shading alone the mainstem of the river along may not result in the needed temperature reduction during critical summer periods.

Dissolved oxygen over the period of record has rarely fallen below the standard (Figure C-27). However, dissolved oxygen excursions have been observed in other studies, which lead to a TMDL. Point and nonpoint wasteload allocations were recommended to reduce loading of oxygen depleting substances to the river (Pickett, 1994a). Wasteload allocations for ammonia-N and carbonaceous BOD are anticipated to be implemented through NPDES permits or other Clean Water Act mechanisms (Pickett, 1994a). Non-point source loadings of ammonia-N and carbonaceous BOD were recommended to be limited to background conditions above the confluence of the Skookumchuck River. No load allocations were recommended for future growth (Pickett, 1994a).

Total phosphorus ranged from 0.1 to 0.52 mg/l over the period of record and averaged 0.054 mg/l. Average TP concentration in the 1990's was 0.05 mg/l (Table C-3). Figure C-28 indicates that TP routinely approaches, and occasionally exceeds the recommended level of 0.1 mg/l

(MacKenthun, 1973). TP loading was calculated using the 1990's data and median monthly flows. Both wet and dry season TP loadings were within the continuum along the river, increasing from the headwaters to the mouth. Average annual TP yield was calculated for the river basin drainage to river mile 33.3 and found to be 0.13 tons/year-mi^2, within the range of Puget Sound rivers reported by Embry and Inkpen (1998) (Table C-5).

Ammonia-N concentration over the period of record averaged 0.054 mg/l. The average and maximum concentrations for the most recent decade are higher than for the period of record (Table C-3). Nitrate+nitrite-N concentration averaged 0.68 mg/L in the 1990's, which was higher than any other mainstem station. The inorganic nitrogen yield was calculated from the 1990's data and median monthly flows. IN yield was found to be 1.92 tons/year-mi^2. This value is within the increasing continuum from the headwaters to the mouth of the Chehalis. It is also within the range reported for Puget Sound rivers (Table C-5). Both TP and TN were measured for the 1994 TMDL study; and a TN:TP ratio of more than 20 was calculated, indicating a strongly phosphorus limited segment.

TSS was not routinely measured until after 1982. Concentrations ranged from below detection to 130 mg/l, and averaged 12.8 mg/l over the period of record. TSS yield was calculated (Table C-6) for wet and dry seasons. The wet season TSS yield was within the range of that found for the Prather Road and Montesano stations (Table C-6). Dry season TSS yield was less than the other mainstem stations. The average annual TSS yield was calculated and found to be 48.9 tons/year-mi^2, which is between the Prather Road and Montesano station levels (Table C-6).

Fecal coliform concentrations at the Porter station were not routinely measured until late 1982. Fecal coliform routinely exceeds 100 cfu/100 ml (Figure C-29). Although not statistically significant, the number of exceedances of 100 cfu level appears to be decreasing in the 1990's. The geometric mean for the 1990's is 29 cfu/100 ml.

Landuse Impacts on Water Quality

Within this subbasin, landuse is less dominated by forest lands than in other subbasins, representing only 76.5% of the landuse. Agriculture represents 12% and urban, residential, commercial, and industrial less than 2%. However, the impacts of landuse in the Chehalis River at Porter are reflective of the watershed as a whole above the Porter gage. Thus, the landuse in the upper watershed (WRIA 23) also needs to be considered. Basin-wide to the Porter station, landuse consists of 80.4% forest, 13% agricultural, and represent 1% of rangelands. Urban residential landuses comprise 1.7% of the upper watershed and commercial and industrial activities represent 0.6% of the land use. Water quality has been degraded by many of these activities. Agricultural practices contribute to the elevated nitrate+nitrite-N concentrations and fecal coliform levels. Urban development contributes nutrients, BOD, and TSS in the form of wastewater discharges, stormwater run-off, and improperly functioning septic systems.

Data Gaps

The ambient water quality monitoring station at Porter has the longest and most complete water quality data record. Data gaps are not apparent.

Subbasin Conclusions

Water quality at the Porter station is a reflection of the activities and water quality of the Upper Basin (WRIA 23). Water quality has been degraded by human activities resulting in violations of the water quality standards for temperature and dissolved oxygen. TP yield was within the range of other Puget Sound basins, although IN yield was higher than the values reported by Embry and Inkpen (1998). Implementation of TMDL recommendations is anticipated to result in the compliance with water quality criteria for dissolved oxygen, fecal coliform, and temperature (Pickett, 1994a). Collaborative efforts of local agencies and citizens, as well as the state and federal agencies, will be needed to reduce nutrients and oxygen depleting pollutants. Similarly, implementation of the increased shading for the tributaries and mainstem will require collaboration.

SUBBASIN 14. CLOQUALLUM CREEK

Cloquallum Creek is a 70 square mile subbasin that discharges to the mainstem of the Chehalis River near Elma (RM 25.2). An ambient monitoring station was located at river mile 3.0. However, water quality data on this creek are limited and not recent. The period of record for ambient flow data span three water years (71-72, 74-75, and 75-76) and includes bimonthly samples during the 71-72 water year and monthly samples thereafter. Water quality data were obtained consistently for temperature, DO, pH, ammonia-N, TP, and fecal coliform, but only the first water year for nitrate+nitrite-N; no TSS data were obtained.

Available data indicate that temperature and dissolved oxygen were well within the criteria for the Class A stream. However, the creek experienced pH excursions on five of the 72 sampling dates.

Phosphorus was generally low, but elevated a number of times, possibly associated with storm events. The TP concentration averaged 0.039 mg/l (including these two events at 0.28 mg/l and 0.29 mg/l). The average concentration is less than that recommended to prevent eutrophication. TP loading (based on instantaneous flows) also fluctuated seasonally (Figure C-30). Ammonia-N concentrations were relatively constant, except on one occasion (a peak of 0.3 mg/l) and averaged 0.07 mg/l. Fecal coliform concentrations were routinely less than 100 cfu/100 ml, with occasional wet season peaks between 260 and 420 cfu/100 ml.

Wildcat Creek

Wildcat Creek is a tributary to Cloquallum Creek. It is the receiving water for the McCleary wastewater treatment plant. A number of special studies and investigations were conducted on this creek between 1969 and 1987. Elimination of discharges from the Simpson Door plant and an upgrade of the McCleary WTP have eliminated most of the problems observed in previous studies. Kendra (1987) noted that excessive inputs of nitrogen and phosphorus had lead to eutrophication of the creek, which deserved further study. A TMDL was approved in 1993 for chlorine, fecal coliform, ammonia-N, and BOD. Following the plant upgrade and subsequent permit revisions, the previous water quality problems have been eliminated (Jennings, 1996).

Landuse Impacts on Water Quality

The Cloquallum Creek subbasin is predominated by forest which represents 89% of the landuse. Agriculture and urban activities represent only 3.2 and 2.0%, respectively. Earlier studies and TMDL implementation have reduced the previously identified sources of water quality degradation.

Data Gaps

In the 1970's, water quality data were obtained consistently for temperature, DO, pH, ammonia-N, TP, and fecal coliform, but only for one year for nitrate+nitrite-N; and no TSS data were obtained. Although this subbasin is small, water quality monitoring should be conducted to obtain data on current conditions.

Subbasin Conclusions

Current conditions are unknown. Water quality monitoring should be re-established at least on a rotating basis to ensure more adequate information on which to assess water quality. Such monitoring would ideally provide data for TP, IN, and TSS yield for comparative priority setting.

SUBBASINS 15 THROUGH 18. SATSOP RIVER AND TRIBUTARIES

The Satsop River drainage is comprised of four of the subbasins used in this study: the East Fork Satsop, Middle Fork Satsop, Decker Creek, and the Satsop River. The combined drainage of these four basins is 299 square miles. A long-term ambient water quality monitoring station is located 2.7 miles upstream of the confluence with the Chehalis River. The period of record at this station extends from October 1970 until September 1993.

Temperature generally met water quality standards, although occasional excursions have been documented (Figure C-31). Dissolved oxygen concentrations were above 8.0 mg/l for the period of record (Figure C-31).

The average TP concentration for the 1990's was 0.02 mg/l. This was the lowest concentration of any tributary to the mainstem. Only the Hoquiam River had a lower average TP concentration. The average inorganic nitrogen concentration was 0.24 mg/l, also the lowest of the rivers discharging directly to the mainstem.

Total suspended solids concentrations ranged from a wet season high of 840 mg/l to a dry season low of 1 mg/l. The maximum TSS concentration is higher than any of the other tributaries discharging to the mainstem and was exceeded only by the maximum TSS concentration of the Humptulips River. TSS loading was calculated based on instantaneous flows and is depicted in Figure C-32. Differences in wet and dry season TSS loadings were almost two orders of magnitude, indicative of high solids associated with precipitation events.

Fecal coliform concentrations were generally within the water quality standards for the period of record. The geometric mean of the fecal coliform concentrations in the early 1990's was substantially below the water quality standard at 15 cfu/100 ml, only one sample was over 100 cfu/100 ml. Prior to the 1990's, only three samples equaled or exceeded 100 cfu/100 ml. However, the Grays Harbor TMDL indicates that fecal coliform loading from the Satsop River is adding to the loading in the harbor (Pelletier, 2000). The TMDL recommended a 29% reduction in the load allocation from non-point sources in this basin.

Landuse Impacts on Water Quality

The Satsop River subbasin is dominated by forestlands, representing 95.3% of the landuse. The basin also supports agriculture a (2.2% of the landuse). Urban residential and commercial and industrial landuses combined only represent 0.3% of the basin. The high wet season TSS loading may be attributable to forest practices in the basin.

Data Gaps

The Satsop River subbasin does not have a long continuous record of water quality data. Monitoring should be continued on at least a rotational basis in this subbasin for all the conventional parameters discussed in this report. In addition, median monthly flow data should be developed to calculate TP, IN, and TSS yields. Such calculations would provide a technical basis for prioritization of actions to improve water quality.

Subbasin Conclusions

Ambient data indicate that water quality in the Satsop subbasin is in compliance with the water quality standards. Nutrient concentrations are generally lower than in other tributaries. However, TSS concentrations indicate the need for improvements during periods of high runoff. Forest practices may be the sources of these elevated loads. Specific source sites should be identified and practices to reduce pollutant loading should be implemented. The issue of fecal coliform allocation reductions should be further examined in light of the low concentrations indicated by the ambient monitoring data.

SUBBASIN 19. CHEHALIS RIVER LOWER REACH 1

This subbasin includes the stretch of the river which extends from Porter (river mile 33.3) to Satsop (river mile 20). No long term ambient water quality monitoring stations have been maintained in this river segment. However, the Montesano monitoring station is approximately seven miles further downstream. Results from that station are provided in the discussion of Subbasin 30.

SUBBASIN 20. WYNOOCHEE RIVER

Data from the Wynoochee River were available from an ambient monitoring station at river mile 13.6. Water quality data were obtained bi-monthly for water years 1972-1974 and 76-77. Water quality was generally good for the period of record, but may not represent current conditions. During the period of record, temperature exceeded the water quality criterion on only two sampling dates in July 1973 and September 1974. Dissolved oxygen was consistently above the water quality criterion.

Total phosphorus concentrations remained below 0.1 mg/l on all dates sampled, and averaged 0.026 mg/l. Ammonia-N averaged 0.07 mg/l over the period of record. Nitrate+nitrite-N measurements were obtained only on six dates during one water year and averaged 0.14 mg/l. TSS data were not obtained at this monitoring station. Fecal coliform levels were obtained only during the 76-77 water year. During that year, fecal coliform levels were well below the water quality criteria, ranging between 2 and 70 cfu/100 ml. The recently published TMDL for Grays Harbor did not recommend reduction of the fecal coliform load allocation in this subbasin (Pelletier, 2000).

Landuse Impacts on Water Quality

Landuse in this subbasin is dominated by forestland, representing 94.5% of the land cover. Agriculture represent 3.2% of the landuse, and only a minor amount of landuse comprised the urban and residential category (0.4%). The activities in this subbasin had not adversely affect water quality in the 1970's.

Data Gaps

No recent data were identified for this subbasin. The ambient monitoring station in this subbasin needs to be re-established to obtain recent water quality data. Collection of data should include consistent collection of the major water quality parameters discussed in this study.

Subbasin Conclusions

Conclusions about the current water quality conditions cannot be determined because no recent data were available. Re-establishment of a monitoring station is recommended to provide an understanding of current water quality conditions.

SUBBASIN 21. WISHKAH RIVER

Data for the Wishkah River are minimal and not recent. Water quality and flow data were gathered at an ambient station at river mile 12.3 for water year 1976-77. Temperature, dissolved oxygen, pH, total phosphorus, and ammonia-N data were gathered in water years 72-73 and 73-74. Water quality in the Wishkah River was relatively good in the 1970's. Temperature exceeded the water quality criterion only on one sampling event in the three years of collected data. Dissolved oxygen remained high. The TP ranged from 0.02 mg/l to 0.11 mg/l and averaged 0.02 mg/l. Ammonia-N concentrations ranged from 0.02 to 0.09 mg/l and averaged 0.04 mg/l as N. Nitrate+nitrite-N data were not collected. TSS data were not collected. Fecal coliform data were collected only for water year 76-77 and exceeded 100 cfu/ 100 ml on one occasion. The geometric mean for the year was 19.4 cfu/100 ml. However, the recently published TMDL for Grays Harbor (Pelletier, 2000) indicated that fecal coliform from the Wishkah River was one of the more significant contributors of fecal coliform loading to the harbor. A reduction in the load allocation for this tributary of 62% was recommended.

Landuse Impacts on Water Quality

Landuse in this subbasin is dominated by forestland, which represents 91% of the land cover. Wetlands represent 3.2% of the landcover, which is greater than the 1% in agricultural use and 2.1% in urban residential use.

Data Gaps

The ambient monitoring station in this subbasin needs to be re-established to obtain recent water quality data. Collection of data should include the inorganic nitrogen species of nitrate+nitrite-N, and TSS for which there were no data gathered previously.

Subbasin Conclusions

There are not recent data and limited historical data on the Wishkah River subbasin. The recent TMDL, however, indicates the need for fecal coliform reductions from non-point sources. However, given the very low bacteria concentrations measured at this site, this reduction goal needs to be re-examined. Future actions in this basin should focus on re-establishing ambient water quality monitoring and identifying and reducing the sources of fecal coliform contamination.

SUBBASIN 22, 23, AND 24. HOQUIAM RIVER

The subbasins the East Fork, Middle Fork, and Hoquiam Rivers are represented by the ambient station at river mile 9.3 on the West Fork Hoquiam River. Although this station is below the confluence of the Middle Fork Hoquiam, and above the confluence with the East Fork Hoquiam River, it represents the best available data. Some water quality data were gathered at this monitoring station bi-monthly in water years 1972 through 1974, and monthly in water year 1993-1994.

Water quality in this subbasin is very good. Temperature, dissolved oxygen, and pH met or exceeded the water quality criteria established for a Class A stream. Total phosphorus data were gathered during all sampling events. Total phosphorus ranged between 0.01 and 0.14 mg/L and averaged 0.02 mg/l, which is well below recommended levels. They were lower than any other subbasins in this study.

Ammonia-N concentrations were also low ranging from 0.01 to 0.07 mg/l as N. Ammonia-N averaged 0.02 mg/l as N in water year 93-94. Nitrate+nitrite-N were measured in the 93-94 water year and averaged 0.13 mg/l as N. IN concentrations were lower in the Hoquiam River than in any other subbasin, except the Humptulips River.

TSS concentrations were very low ranging between 1 and 4 mg/l and averaging 2 mg/l during water year 93-94. TSS load was also lower than in any other river within the watershed (Table C-8).

Fecal coliform data were obtained only during the 93-94 water year. Results indicated extremely low fecal coliform. The geometric mean of all months was 10.2 cfu/100 ml and did not exceed 51 cfu/100ml. However, the recently released fecal coliform TMDL for Grays Harbor indicates that fecal coliform from the Hoquiam contributes adversely to the quality of the harbor (Polluter, 2000). The TMDL recommended a 58% reduction in load allocation near the mouth and load allocations reduction of 37% and 14% for the West Fork Hoquiam River and East Fork Hoquiam River, respectively.

Landuse Impacts on Water Quality

This subbasin is less highly forested that its adjacent subbasin, the Humptulips, with 88.9% of the land categorized in forestlands. Much of this land was and continues to be actively logged. Wetlands represent the second highest category of landuses, comprising 5.4% of the subbasin. Agricultural uses are minimal, and represented only as range land (0.2%). Urban landuses comprise approximately 3%, combining urban residential and commercial and industrial landuses.

Data Gaps

Although this basin does not have a long continuous record of water quality data, monitoring has been conducted in the early 1990's. Monitoring at the ambient station should be updated and should be continued on at least a rotational basis in this subbasin for the parameters discussed in this report.

Subbasin Conclusions

Water quality at the Hoquiam River monitoring station was within the water quality standards, and nutrient levels were among the lowest measured. However, fecal coliform within the Hoquiam subbasin has been identified as a contributor to the degraded conditions of Grays Harbor. However, given the very low bacteria concentrations measured at this site, this reduction goal needs to be re-examined. Monitoring at the ambient station should be continued at least on a rotating basis and median monthly flows should be derived to calculate TP, IN, and TSS loads and yields.

SUBBASIN 25. HUMPTULIPS RIVER

The water quality monitoring station on the Humptulips River is at river mile 23.6 representing approximately 130 square miles of the 244 square mile drainage. Data have been gathered at the ambient water quality monitoring station since the early 1970's, providing a nearly continuous record for most of the water quality parameters of interest. Early in the record, data were gathered bimonthly from 1971 through 1974. The record was interrupted from 1974 until 1979; thereafter, water quality data were obtained on a monthly basis.

Water quality standard exceedances have occurred in the Humptulips River. The temperature at the monitoring station is generally less than the 18^{o}C criterion, but excursions are not uncommon (Figure C-33). An apparent downward trend in the 1990's is indicated in the figure by the 12-month moving average. Farther upstream in the watershed a TMDL to reduce stream temperature is being undertaken as part of a collaborative watershed analysis (Dieu, pers. comm.).

Dissolved oxygen at the monitoring station has consistently been above the Class A water quality criterion of 8.0 mg/L (Figure C-33).

Total phosphorus concentrations varied seasonally with wet season events producing higher TP concentrations. The mean TP concentration in the 1990's was 0.02 mg/l with peak concentrations as high as 0.29 mg/l and low concentrations at 0.004 mg/l. The average concentration is lower than those found in other subbasins with recent data, except for the Hoquiam River. TP loading based on instantaneous flows is plotted for the period of record in Figure C-34. Seasonal variations are large; the average wet season TP loading was more than 14 times that of the dry season during the 1990's (Table C-8). Average annual TP yield for the 1990's was 0.20 tons/year-mi^2, the highest of all the station in the Chehalis River system for which TP yields were calculated (Table C-4 and C-8). However, this yield may be an artifact of the extremely high wet season flows.

Ammonia-N was monitored throughout most of the period of record. More recently (during the 1990's), ammonia-N concentrations averaged 0.01 mg/l and ranged as high as 0.04 mg/l. Recent nitrate+nitrite-N concentrations ranged from the detection limit (0.01 mg/l) to 0.34 mg/l and averaged 0.11 mg/l. Average annual inorganic nitrogen yield for the 1990's was 1.15 tons/year-mi^2, lower than the Newaukum River and lower than the other Chehalis mainstem stations. The average annual IN yield for the upper portion of this watershed was within the range reported by Embry and Inkpen (1998) (Table C-5).

TSS concentrations in the 1990's data set at this monitoring station ranged from 1 mg/l to 344 mg/l showing wide variations with season. The TSS loading based on instantaneous flows is depicted for the period of record in Figure C-34. While TSS loading appears to decline with time, no statistical differences were found. The TSS yields provided in Table C-8 indicated that the Humptulips River had the highest TSS yield of any of the tributaries to the Chehalis River system.

Fecal coliform data also show wide seasonal variations (Figure C-35). There are many exceedances of the 100 cfu/100 ml standard, but few excursions over the 200 cfu/100ml criterion. The geometric mean for data gathered in the 1990's was 8 cfu/100 ml, while for the entire period of record, the geometric mean is 7 cfu/100 ml. Although fecal coliform levels at the monitoring station were low, fecal coliform loading from this river was determined to represent the most significant impact to Grays Harbor, second only to the mainstem of the Chehalis River (Pelletier, 2000). The TMDL requires a 67% reduction in load allocation from non-point sources in this basin.

Landuse Impacts on Water Quality

This subbasin is highly forested with 95.7% of the land categorized in forestlands. Only subbasins 2 (Elk Creek) and 12 (Cedar Creek) have higher percentages of forestlands. Agricultural and urban landuses comprise less than 2% combined. Much of this land was and continues to be actively logged. Removal of trees and development and use of logging roads may contribute to this subbasin having the highest TSS yield of all the segments of the Chehalis River system. The elevated TP yield may be a consequence of the elevated TSS; phosphorous is often sorbed to particulates in freshwater systems.

Data Gaps

This river has a long continuous record of water quality data from a station in the central portion of the subbasin. This station should be maintained and continue to be monitored.
As resources allow water quality in the lower basin could be monitored on a rotational basis.

Subbasin Conclusions

Water quality in the Humptulips, has been adversely affect by human activities, predominantly logging. In the Upper Humptulips a temperature TMDL is in progress. The elevated TSS yield in this subbasin indicates that logging activities may be degrading water quality. Because this subbasin had the highest TSS yield of any of the Chehalis River tributaries, it should be a high priority for implementing BMPs that will reduce the TSS load. TP yield was also highest among those stations analyzed, but may be an artifact of the extremely high wet season flows. This hypothesis needs to be investigated. Because fecal coliform loading from this river represents a significant impact to Grays Harbor, sources should be identified and eliminated.

SUBBASINS 26 THROUGH 29 - ELKS RIVER, JOHNS RIVER, NEWSKAH CREEK, AND CHARLEY CREEK

No water quality data were identified from these subbasins

SUBBASIN 30 CHEHALIS RIVER - LOWER REACH 2

An ambient water quality monitoring station is maintained on the mainstem at river mile 13.15 near Montesano. This station represents the water quality in the stretch below the confluence with the Satsop River, but just above the confluence with the Wynoochee River at river mile 13. Water quality at this station is somewhat influenced by the estuary, but best represents the cumulative effects of upstream activities. This station was monitored once or twice a month from November 1970 until September 1971, then monthly from October 1977 until September 1992. Generally consistent data are available for temperature, dissolved oxygen, and pH. TP and TSS samples were collected somewhat less continuously; flow, nitrogen species, and fecal coliform data were collected sporadically. In the subsequent discussions, data are presented as individual measurements in figures, and as wet season, dry season, and annual averages over the last decade.

The temperature and dissolved oxygen for the ‘77 to ‘92 period of record are plotted in Figure C-36. Numerous exceedances of the Class A water quality criterion for temperature are evident from the figure. Dissolved oxygen, however, did not decline to less than the 8.0 mg/l criterion during the same period (Figure C-36).

Total phosphorus concentrations are depicted graphically in Figure C-37. It is noteworthy that the concentration of TP varied over one and a half orders of magnitude, averaging 0.045 mg/l, but peaking at 0.17 mg/l. TP loadings and yields were calculated based on the median monthly flow (50% exceedance flow). Wet season TP loading (3,779 lb/day) was higher than any other mainstem station (Table C-4). Dry season TP loading was also higher at the Montesano station (Table C-4). The TP yield was calculated assuming that half of Subbasin 30 drainage was represented at this station. The average annual TP yield was 0.18 tons/year-mi^2, which represents the highest mainstem yield. This yield compares favorably with the lower TP yields found for the major rivers systems in Puget Sound by Embry and Inkpen (1998) (Table C-5).

Results of monthly samples of ammonia-N concentrations are also depicted in Figure C-37. As with TP, ammonia-N is quite variable. Average ammonia-N and nitrate+nitrite-N were within the range of other mainstem stations. The average annual IN yield is higher than any other upstream station and is slightly higher than the range reported by Embry and Inkpen (1998) (Tables C-4 and C-4).

TSS concentrations in the 1990's ranged between 1 and 131 mg/l and averaged 14 mg/L. Wet and dry season TSS yields were determined for the most recent data. Wet season yield was approximately three times the dry season yield (Table C-6). Average annual TSS yield was calculated to be 48 tons/year-mi^2, similar to that estimated for the Porter station.

Fecal coliform samples were obtained on most sampling dates between 1977 and 1992. While the geometric mean was less than the criterion, numerous exceedances of the 100 cfu/100 ml standard were evident over the 1977 to 1992 sampling period (Figure C-38).

Landuse Impacts on Water Quality

Urban landuse comprises a relatively high percentage (10.5%) of the subbasin immediately surrounding the ambient monitoring station, with forestlands representing only 58.8%. However, because water quality at this station represents the cumulative impacts of all activities upstream, landuse in the entire basin above this station important. Forestland comprises the largest percent of the landuse in the basin at 82.7%, with agricultural uses only representing an average of 10.7% of the use and urbanized areas representing less than 2% of the area.

Data Gaps

Water quality monitoring at the Montesano station was relatively complete until the early 1990's. Monthly monitoring at this station should be re-established to evaluate efforts to improve water quality throughout the watershed. Establishment of a USGS monitoring station coincident with the water quality monitoring station would assist in data analysis.

Subbasin Conclusions

Exceedances of the water quality standard have been observed in this subbasin for temperature and fecal coliform. In addition, nutrient yields were higher than other mainstem stations. Because this subbasin represents the cumulative impacts of all the upstream subbasins, activities to improve water quality in those subbasins should improve the water quality in this subbasin as well. However, sources of evaluated fecal coliform, total phosphorus, and inorganic nitrogen within the drainage surrounding the station could include stormwater from urban areas, septic systems, and agricultural runoff. Specific sources should be identified and eliminated.

WATER QUALITY IMPAIRMENT UNDER CWA

Water quality is impaired in the Chehalis River watershed. Under the Clean Water Act (CWA), WDOE biennially publishes a state-wide list of all water bodies that have impaired water quality, commonly referred to as the 303(d) list. Water quality is impaired in 25 segments of the Chehalis River watershed (Table C-11). The most prevalent cause of impairment is elevated fecal coliform levels. Nineteen of the segments are listed as impaired for this reason. Low summer dissolved oxygen concentrations and elevated summer temperatures have resulted in the listing of 11 and 9 segments, respectively.

Table C-11. 303(d) Listed Water Segments in the Chehalis River Watershed

Water body Segment No.	Name	Subbasin #	Parameters Violating Water Quality Standards			
			Fec. Coli.	DO	Temp.	Other
WA 23-1108	Elk Creek	2	x			
WA 23-1106	South Fork Chehalis River	3	x		x	
WA 23-1104	Bunker Creek	4	x	x		
WA 23-1102	Stearns Creek	4		x		
WA 23-1100	Chehalis River	4	x	x	x	
WA 23-1080	Newaukum River, North Fork	6	x			
WA 23-1070	Newaukum River	7	x		x	
WA 23-1028	Berwick Creek	10	x			
WA 23-1027	Dillenbaugh Creek	10	x	x	x	
WA 23-1024	Coal Creek	10	x	x		
WA 23-1023	Salzer Creek	8	x	x		
WA 23-1020	Chehalis River	10	x	x	x	
WA 23-1019	Lincoln Creek	10		x		
WA 23-1018	Scatter Creek	13	x		x	
WA 23-1017	Independence Creek	13		x		
WA 23-1014	Garrard Creek	13		x		
WA 23-1015	Black River	11	x	x	x	
WA 23-2021	Littlerock Ditch	11	x			
WA 23-2020	Beaver Creek	11	x			
WA 23-2010	Mima Creek	11	x			
WA 22-4040	Chehalis River	19	x		x	
WA 22-1010	Humptulips River	25	x		x	
WA 22-9030	Duck Lake	30				TP
WA 22-0030	Inner Grays Harbor	30	x			pH

POINT AND NON-POINT SOURCES OF POLLUTANT LOADING

NPDES permitted discharges within the basin were provided from the Water Permit Life Cycle Permit System (WPLCS) database. These are listed with locations in Table C-12. Based on permitted limits and assumptions made by Embry and Inkpen (1998), the total phosphorus loadings from NPDES permits to the mainstem at Porter and Montesano were calculated. The median total phosphorus concentration estimated for municipal wastewater treatment plants in Puget Sound of 4.2 mg/l (Embry and Inkpen, 1998) was applied to the average design flow from WPLCS to calculate loading contributions of municipal plants. Loadings were summed for discharges above the Porter station and above the Montesano station. The cumulative permitted TP loading to mainstem at Porter is 377 lb/day. While this represents only 13% of the wet season TP loading, it represents more than 100% of the average dry season TP loading. Similarly, at Montesano, the cumulative TP loading from the municipal and industrial wastewater treatment plants is 427 lb/day (16% of the total wet season load and almost three times the dry season load). These NPDES contributions to the TP loads represent the potential for plants discharging at design capacity year-round and over estimate actual contributions. They were calculated based on discharging at design capacity and regional median concentrations. Despite this caveat, a more accurate evaluation of cumulative TP loading may be useful in improving water quality of the river, which is generally phosphorus limited (Pickett, 1994a).

Table C-12. Municipal and Industrial NPDES Dischargers to Chehalis Basin and Estimated, Permitted TP Loading

Facility Name	WRIA	Latitude	Longitude	Flow (MGD)	TP (mg/l)	TP Load (lb/day)
Municipal						
Pe Ell STP	23	46^{o} 43'38"	123^{o}18'7"	0.12	4.2[a]	4.0
Cedar Creek DOC STP	23	46^{o}53'1"	123^{o}8'20"	0.07	4.2[a]	2.4
Centralia TP	23	46^{o} 42'47"	122^{o}58'34"	4.3	4.2[a]	150
Chehalis STP	23	46^{o} 39'38"	122^{o}59'2"	2[c]	4.2[a]	69.9
Ground Mound STP	23	47^{o} 47'17"	123^{o}1'57"	0.07	4.2[a]	2.4
McCleary STP	22	47^{o} 3'18"	123^{o}16'29"	0.75	4.2[a]	26.2
Elma STP	22	47^{o} 0'2"	123^{o}25'22"	0.33	4.2[a]	11.5
Montesano STP	22	46^{o} 52'55"	123^{o}36'3"	0.36	4.2[a]	12.6
Aberdeen STP	22	46^{o} 57'57"	123^{o}49'35"	8.75	4.2[a]	306
Hoquiam STP	22	46^{o} 58'20"	123^{o}55'19"	4	4.2[a]	140
Ocean Shores STP	22	46^{o} 55'56"	124^{o}9'28"	2.2[c]	4.2[a]	75.2
Westport STP	22	46^{o} 54'23"	124^{o}7'0"	1	4.2[a]	35.0
Industrial						
Lewis Co. Water Dist. 2	23	46^{o} 34'23"	122^{o}43'44"	0.08	ND	NC
Trans Centralia Generation	23	46^{o} 45'21"	122^{o}51'39"	4.82	ND	NC
Trans Centralia Mining	23	46^{o} 45'32"	122^{o}45'32"	NL	ND	NC
Domsea Rochester	23	46^{o}49'23"	123^{o}0'11"	3.86	ND	NC
NW Seafarms Black River	23	46^{o} 50'29"	123^{o}7'29"	3.77	4.2[a]	131.8
Gull Industries	23	46^{o} 58'55"	123^{o}53'12"	<0.01	ND	NC
Associated Seafoods Co.	22	46^{o}57'5"	124^{o}48'0"	0.22	ND	NC
Meroins Seafood	22	46^{o}54'22"	124^{o}6'28"	0.32	4.2[a]	7.6
Ocean Spray Markham	22	46^{o}54'15"	123^{o}59'50"	0.03	ND	NC
Quality Veneer & Lumber	22	47^{o}0'0"	123^{o}54'17"	0.03	ND	NC
Washington Crab	22	46^{o} 54'30"	124^{o}6'56"	0.17	ND	NC
Washington Crab & Bottomfish	22	46^{o} 54'24"	124^{o}26'27"	0.13	ND	NC
Westfarm Foods	22	46^{o} 39'54"	122^{o}58'32"	0.48	11.5[av]	45.9

a = assumption based on data of Embry and Inkpen (1998)
av = average limit
NC = No calculation able to be made

ND = No data
NL = No limit

Recognized non-point sources of pollution to the watershed include agricultural and forest practices, urban stormwater, and failing septic systems (Pickett, 1994a). Landuse within the basin is dominated by forestlands (82.7%). Logging activities in these areas can contribute suspended solids to the streams. The high TSS yield in the Humptulips subbasin is likely associated with such activities. This subbasin is dominated by forestlands (representing more than 95% of the landuse) which are heavily logged. Logging may also contribute to the elevated TSS yield in the Chehalis headwaters (above Dryad), which is approximately 95% forestlands and moderately heavily logged.

Intensive agricultural activities have been recognized contributors of fecal coliform, BOD, TP, and nitrogen loading to the mainstem and a number of tributaries. The high TP and IN yields at Montesano may be attributed to agricultural practices in the basin between Porter and Montesano. Likewise the elevated IN yield of the Newaukum River may be attributable, in part, to agricultural activities. Agricultural activities represented 17% of the landuse in this subbasin.

Water quality in the Black River, which is also agricultural (agricultural represents 20% of the landuse) had the highest average TP concentration. The Black River also had the highest maximum levels of fecal coliform, which can be attributed to agricultural as well as other activities.

Urbanized areas represent less than 2% of the watershed to its interception with estuary waters at Montesano. Urban activities can increase the suspended solids and TP and IN loading to the river. The TMDL in the Upper Chehalis (WRIA 23) identified the need to reduce ammonia-N and carbonaceous BOD from stormwater by 100% (Pickett, 1994a). In urbanized areas without municipal sewers, failing septic systems can result in fecal coliform and nitrate loading of a stream segment. Both the Black River and Upper Chehalis TMDLs (Coots, 1994 and Pickett 1994a&b) identified fecal coliform loading from urban and rural-residential landuses, such as failing septic systems, stormwater, and farming activities (hobby farms).

DATA GAPS AND LIMITATIONS

While the Chehalis River watershed is one of the more highly monitored basins in Washington, water quality data do not comprehensively represent all subbasins across the watershed. A number of the subbasins lack ambient water quality monitoring stations. These include the subbasins of the south shore of Grays Harbor (Elks River, Johns River, Newskah Creek, and Charley Creek), Cedar Creek, and Salzer Creek. Ambient monitoring stations are present in the other major river tributaries to the Chehalis, although a number of the tributaries to these subbasins are absent. For example, Decker Creek and the Middle Fork Satsop River, Middle and East Fork of the Hoquiam, and the North and South Forks of the Newaukum River have not water quality monitoring stations. Thus, water quality cannot be characterized in each of the subbasins.

In some of the subbasins, water quality data are sporadic and/or may not represent current conditions. For example, ambient monitoring station data have not been collected from the Wynoochee and Wishkah rivers since the 1970's. These stations should be re-established.

Likewise, monitoring at the Montesano station on the mainstem Chehalis River was interrupted in 1992. This station is particularly critical as it represents the cumulative impacts of activities upriver of most of the tidal influence.

Samples that were taken were not consistently analyzed for all of the major water quality parameters, most often TSS and nitrate+nitrite-N were omitted. Similarly, data needed to calculate loading were not always obtained simultaneously. If no USGS gage station exists in the vicinity from which median monthly flows (50% exceedances) could be calculated, yield comparisons among subbasins cannot be made. Both of these situations are evidenced in the time series figures presented in this study. For ambient stations in which sampling efforts have continued, the water quality parameter list has been augmented to include the formerly missing analyses. For example, TSS and the inorganic nitrogen species that were often lacking in past data collection efforts, have become more routine analyses in the past decade.

The water quality data collected is primarily in the form of “grab” samples that represent one point in time and not necessarily the range of conditions. Data sets with longer periods of record generally compensate for this lack. However, for parameters that experience a critical seasonal or diurnal fluctuation, data may be missing during periods of greatest concern. Data may also be missing during storm events, which would be useful for identifying specific problem times and areas.

Despite the data gaps and limitations, the trends observed in the basin are useful for prioritizing actions and accompanying verification monitoring to demonstrate improvements.

RECOMMENDATIONS

Water quality in the Chehalis River and its tributaries is impaired and has been recognized as such in numerous studies beginning in the early 1980's. Temperature and dissolved oxygen exceedances of water quality standards are common along the mainstem and tributaries from the headwaters to the Montesano station. Dissolved oxygen concentrations have been reduced by oxygen depleting pollutants (carbonaceous BOD and ammonia-N) along the mainstem and in tributaries above the Porter station. Contributions of TP and inorganic nitrogen, nutrients that limit the overabundance of algae and aquatic macrophytes, have been recognized here and elsewhere as contributors to the eutrophication of the Chehalis River stream segments. The information gathered and analyzed in this report is summarized in the subsequent narrative text in tabular form by subbasin in Table C-13.

Elevated temperatures, including exceedances of the water quality criteria, have been identified in the tributaries and along the mainstem above Porter. While the TMDL addresses the issue of temperature with broad increased shading recommendations, the details of implementing temperature improvement activities is left to the Chehalis Basin Partnership. Those subbasins and river segments requiring the highest percentage increase in shading should be prioritized for earliest action. In developing the Detailed Implementation Plan, the CBP may want to carefully consider the improvements of increased shading of the mainstem will provide. Due to the river's width, shading resources may be better focused along the tributaries. As the Humptulips TMDL comes to completion, its recommendations also should be implemented on a priority basis.

Table C-13. Summary of Parameters Evaluated and Next Actions Identified by Subbasin

Subbasin	Location	Temp	DO	TP	IN	TSS	FC	Yield	Mon./Gage	Next Actions
Mainstem										
1	Dryad	TMDL	TMDL	M*	L*	M*	V			I&C (TSS)
4	Claquato	TMDL	TMDL	H	M	M	V	N	UR	Calc Yields; I&C (TP, BOD, FC)
10	Centralia	TMDL	TMDL	H	H	M	V	N	UR	Calc Yields; I&C (TP, BOD, IN, FC); Shade
10	Prather Rd.	TMDL	TMDL	L*	L*	M*	V		U	I&C (BOD, FC); Shade
13	Porter	TMDL	TMDL	L*	M*	M*	V			I&C (BOD, FC); Shade
30	Montesano	V	C	M*	H*	M*	V		**U**	I&C (IN, FC)
2	Elk Creek	TMDL	TMDL	L	L	L	V	N	ER/G	Establish Monitoring
Tributaries										
3	S. Fork Chehalis	TMDL	TMDL	M	H	M	V	N	U	Calc Yields; I&C (IN); Shade
5-7	Newaukum	TMDL	TMDL	L*	H*	L*	V		U	I&C (IN); Shade
8	Scatter Creek	TMDL	TMDL	H	H	NI	V		ER	Control sources
9	Skookumchuck	TMDL	TMDL	M	H	L	V	N	U	Calc Yields; I&C (IN, FC)
11	Black	TMDL	TMDL	M	NI	L	V	N	U/G	Gage; I&C (TP, BOD, FC)
12	Cedar Creek	C	C	L	L	NI	C	N	E/G	Establish Monitoring
15-18	Satsop	C	C	L	L	M	V	N	U	I&C (FC)
20	Wynoochee	NI	NI	NI	NI	NI	C	N	**U**	Update Monitoring
21	Wishkah	NI	NI	NI	NI	NI	V	N	**U**	Update Monitoring; I&C (FC)
22-24	Hoquiam	C	C	L	L	L	V	N	UR	I&C (FC)
25	Humptulips	TMDL	C	M*	L*	H*	V			I&C (TSS, FC)
26	Elks River	NI	NI	NI	NI	NI	NI	N	E	Establish Monitoring
27	Johns River	NI	NI	NI	NI	NI	NI	N	E	Establish Monitoring
28	Newskah Creek	NI	NI	NI	NI	NI	NI	N	E	Establish Monitoring
29	Charley Creek	NI	NI	NI	NI	NI	NI	N	E	Establish Monitoring

NOTES:

TMDL = violations to be addressed per TMDL;
C = in compliance with standard;
V = violation of water quality standard;
H, M, L = high, moderate, low pollutant concentration, asterisk (*) indicates assessment based on yield;
N = yields based on monthly 50% exceedance flows need to be calculate;
E = establish monitoring;
ER = Establish monitoring on rotating schedule;
U = Update monitoring (if bold **U**, high priority);
G = USGS flow gage needed;
NI = no information;
I&C = Identification and control;
UR = Update monitoring on rotating schedule.

Dissolved oxygen concentrations of less than 8.0 mg/l are associated with elevated summer temperatures, as well as carbonaceous BOD and ammonia-N loading in WRIA 23. The TMDL has identified the need for point and non-point source controls and in some instances identifies specific point sources and non-point activities that will require control. Table C-13 summarizes the subbasins in which identification and controls are needed. For non-point sources, a collaborative effort among state and local entities will be required to effectively reduce pollutant loading.

Other than the Black River, there were no tributaries where both temperature and dissolved oxygen did not meet standards. However, this combination of high temperatures and low DO's existed throughout most of the mainstem of the river. This represents a critical set of conditions for fish health and survival.

The comparisons of pollutant yields at four mainstem stations and two tributaries can serve as a prioritization scheme on which to focus resources for actions that will reduce pollutant loading. TP yields were highest at the Montesano station on the Chehalis mainstem and in the Humptulips River. Although these yields were within the lower end of the range reported by Embry and Inkpen (1998), actions to identify and control sources in these drainages could prevent further degradation. Inorganic nitrogen yields were higher than the Embry and Inkpen ranges at the Montesano and Porter stations along the mainstem and in the Newaukum River. Ammonia-N loading has already been identified as one of the oxygen depleting pollutants of concern in the Upper Chehalis, above Porter (Pickett, 1994a), but elevated nitrogen yields in the Newaukum and along the mainstem drainage between Porter and Montesano could be used to focus resources in those two areas initially. Finally, TSS yields were substantially higher in the Humptulips River and somewhat elevated above Dryad. These results coupled with the 303(d) listing of many stream segments in the upper and lower basin indicate that actions to reduce pollutant loading are needed.

While data gaps exist in a number of subbasins, these gaps do not preclude implementation of water quality improvement activities. Trends observed in the basin are useful for prioritizing actions necessary to improve water quality. Thus, recommendations for a Level 2 watershed assessment are divided into three categories. First, TP, IN, and TSS yields should be calculated based on monthly 50% exceedance flows or estimated from available data. Second, a comparison of the yields among subbasins should be used to prioritize subbasins for identification and control of pollutant sources. The subbasins with the highest pollutant yields and identified sources (e.g. identified non-point sources in the TMDLs), activities to reduce pollutant loading should be undertaken. For example, in the Humptulips subbasin where TSS yield was substantially higher than other basins, resources should focus on reducing these pollutant sources. Actions identified in the TMDL recommendations should also be focused on those subbasins with the greatest yields. Where a problem has been identified in numerous previous studies (e.g., specific pollutant sources in Scatter Creek), actions should be assigned and implemented as soon as feasible. This is an adaptive management strategy that would focus resources on basins of more degraded water quality, while conducting targeted monitoring where no (or outdated) data exist.

An outcome of the Grays Harbor bacteria TMDL was recommendation for FC bacterial load reductions in rivers that already have quite low bacteria concentrations. These recommendations should be examined against other watershed priorities.

Monitoring should include the subbasins that discharge to the south shore of Grays Harbor, as well as updating water quality data for the Wynoochee and Wishkah Rivers. The Wynoochee and Wishkah Rivers may be more affected by human activities, making them a higher priority for monitoring. While the south shore subbasins are not highly developed, obtaining at least a minimal amount of baseline data is advisable. This targeted approach would ensure that basins with higher pollutant yields specified in this study are appropriately identified and prioritized for action. Where activities are implemented to improve water quality, follow-up monitoring should be conducted to ensure that actions resulted in the anticipated improvements and that water quality improvements are documented.

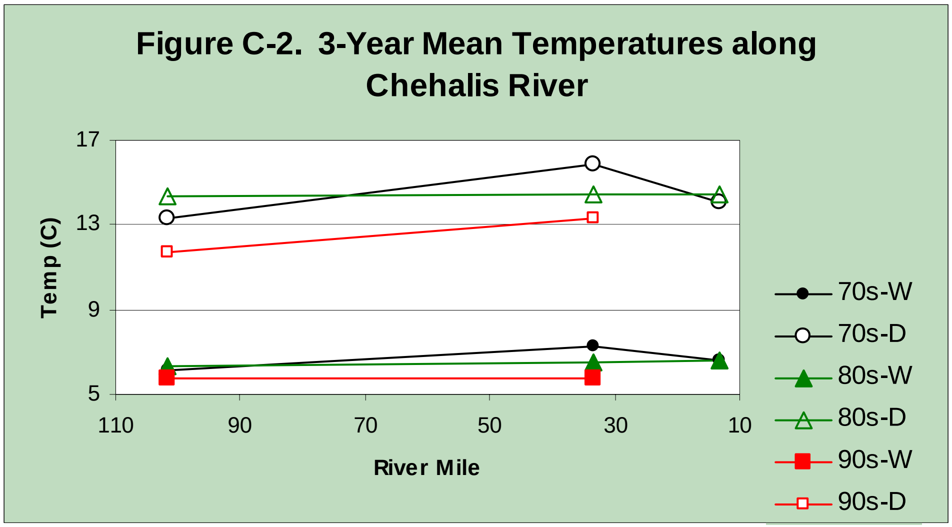


Figure C-2. 3-Year Mean Temperatures along Chehalis River

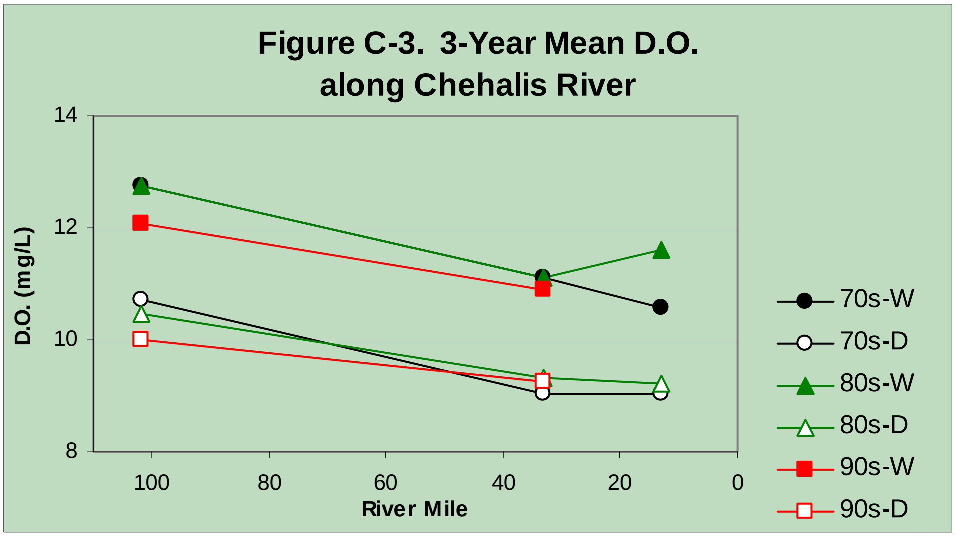


Figure C-3. 3-Year Mean D.O. along Chehalis River

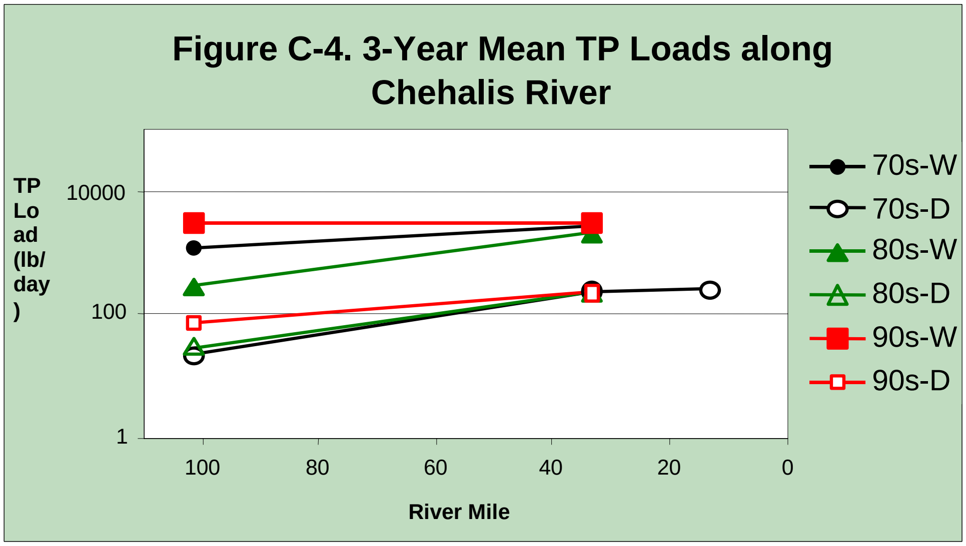


Figure C-4. 3-Year Mean TP Loads along Chehalis River

Figure C-5. Chehalis River Mean TP Loading in 90s

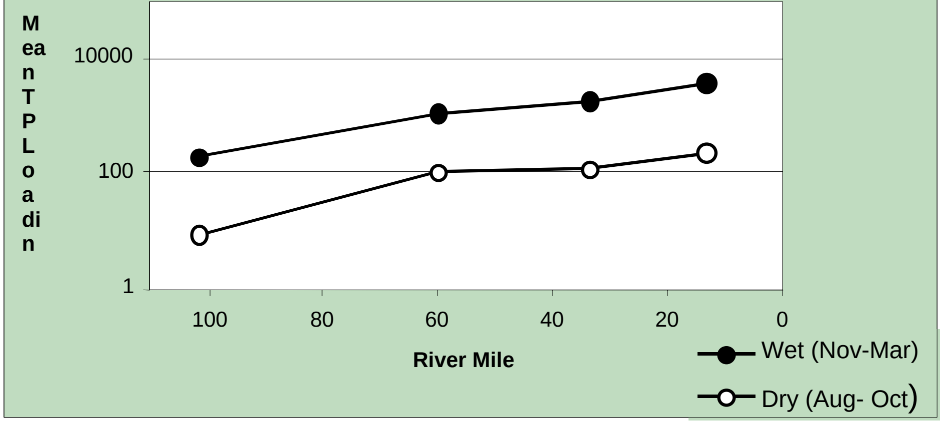


Figure C-6. 3-Year Mean TSS Loading along Chehalis River

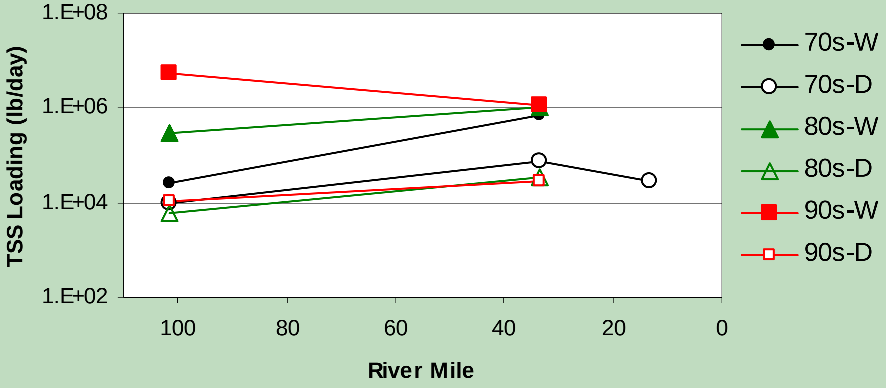


Figure C-7. 3-Year Geometric Mean Fecal Coliform Loads

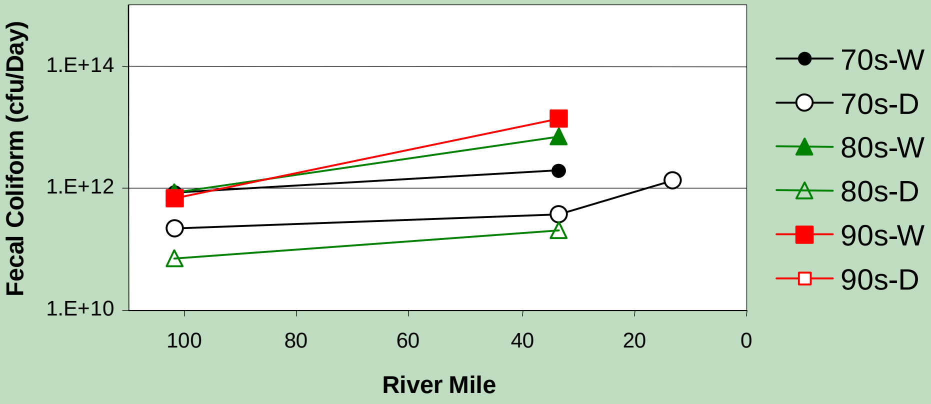


Figure C-8. Chehalis at Dryad
Temperature & D.O.

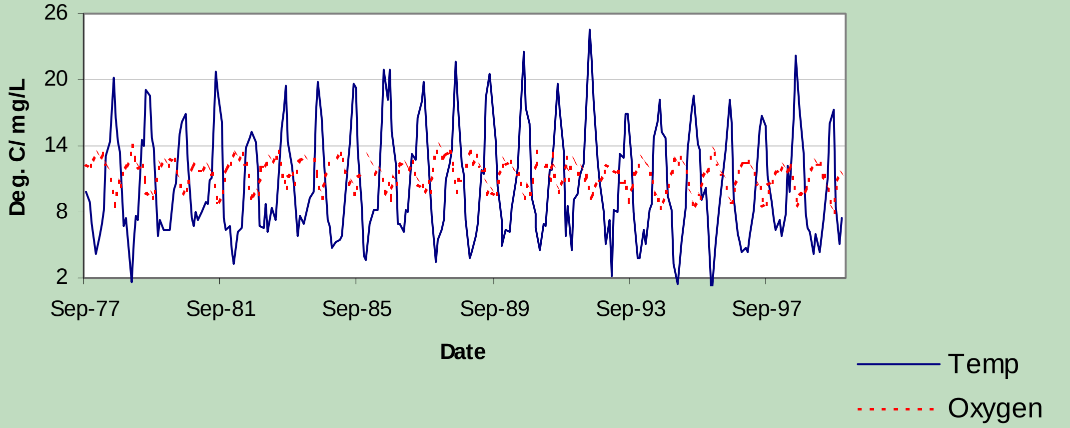


Figure C-9. Chehalis at Dryad
TP Loading

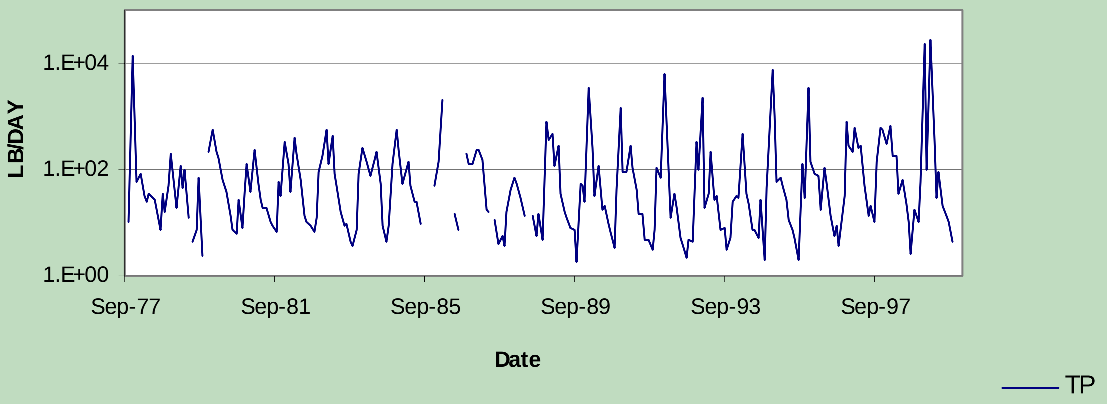
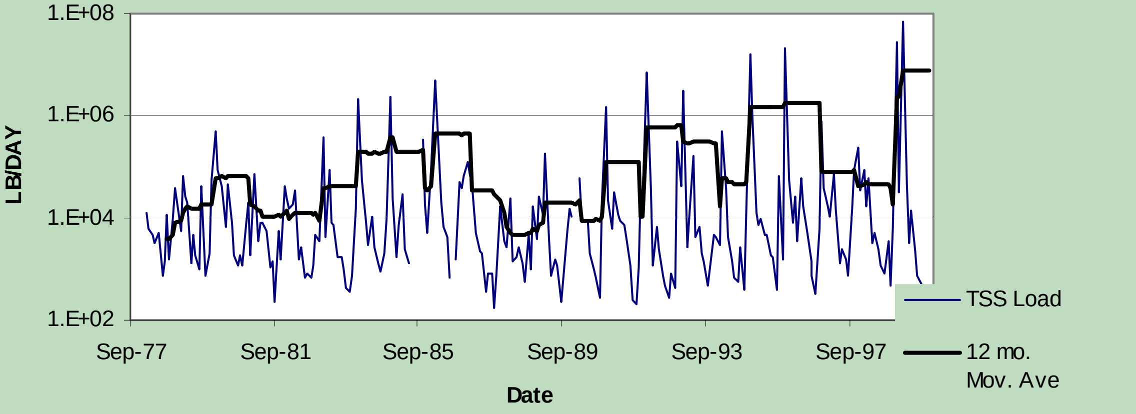


Figure C-10. Chehalis at Dryad
TSS Loading



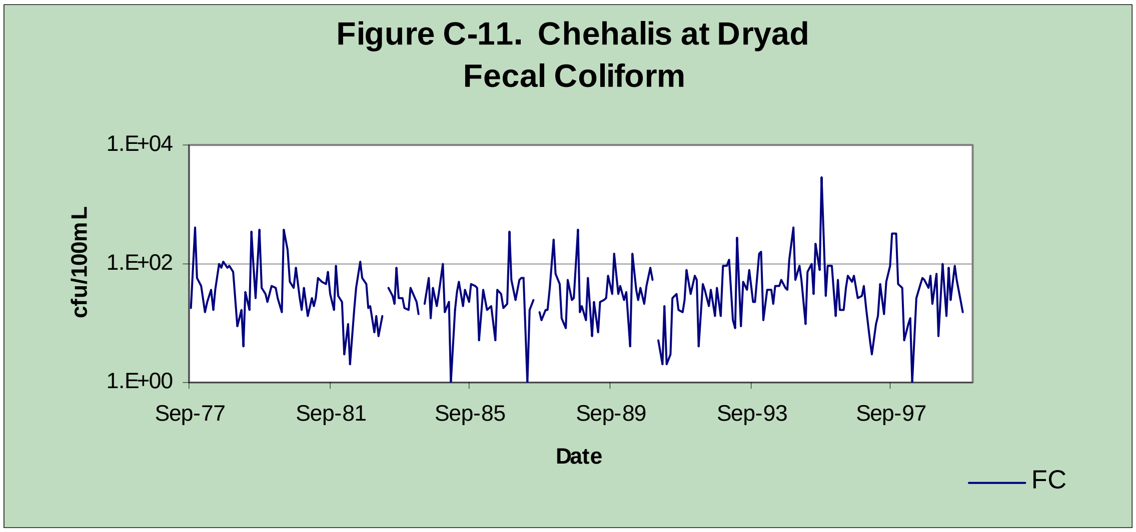


Figure C-11. Chehalis at Dryad
Fecal Coliform

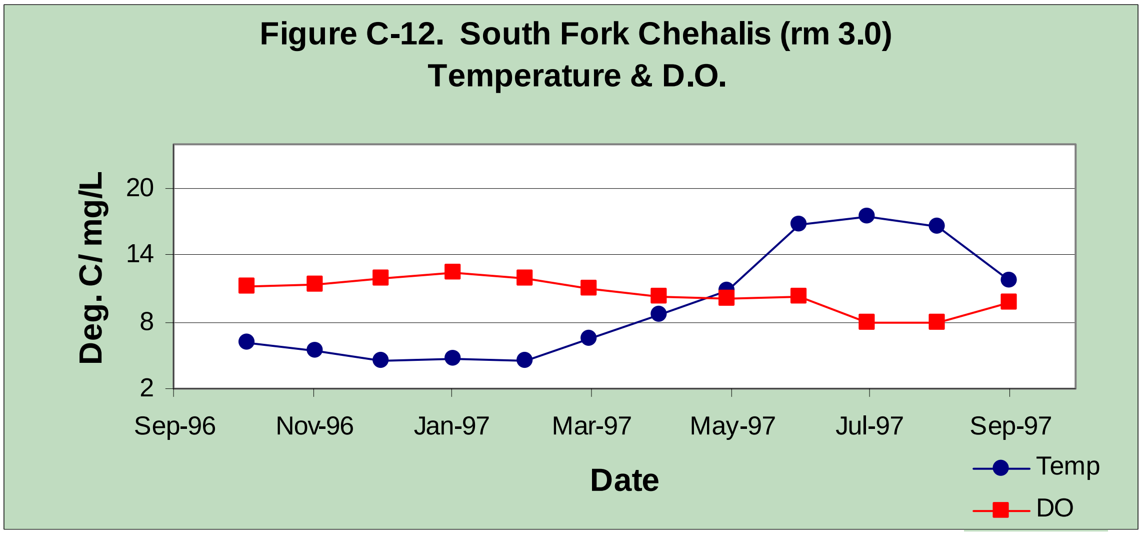


Figure C-12. South Fork Chehalis (rm 3.0)
Temperature & D.O.

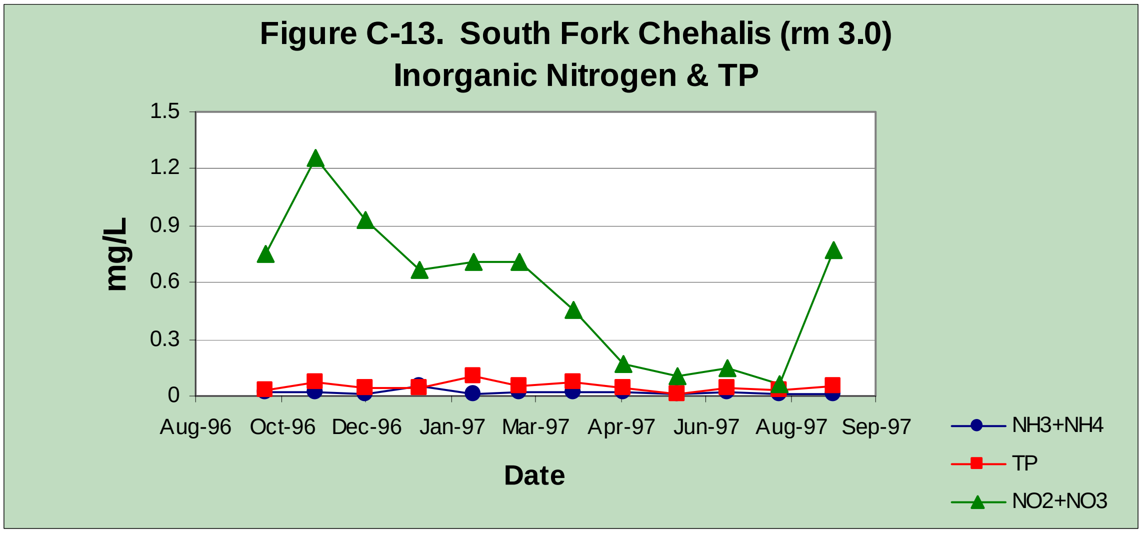


Figure C-13. South Fork Chehalis (rm 3.0)
Inorganic Nitrogen & TP

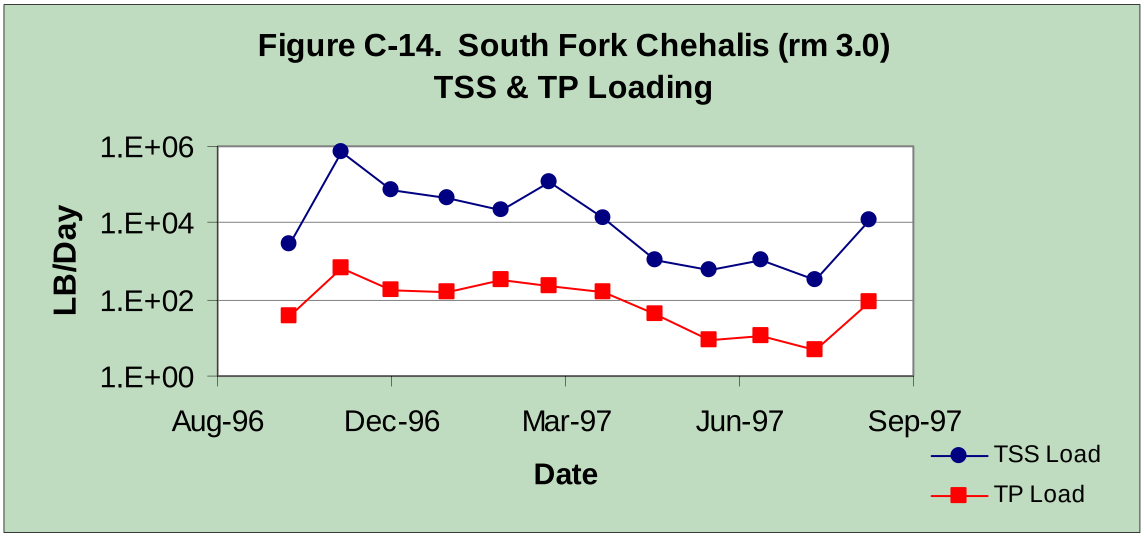


Figure C-14. South Fork Chehalis (rm 3.0)
TSS & TP Loading

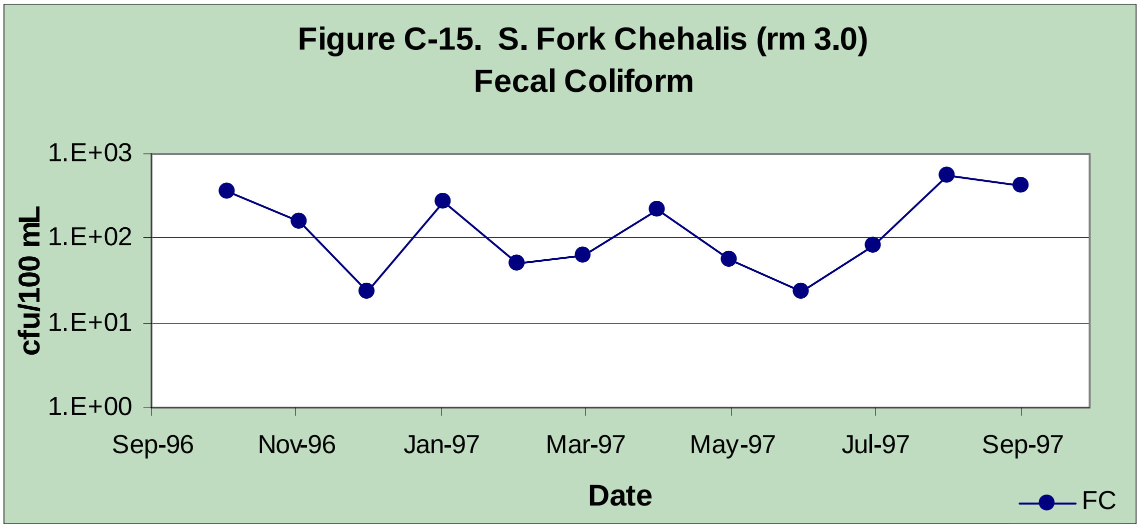


Figure C-15. S. Fork Chehalis (rm 3.0)
Fecal Coliform

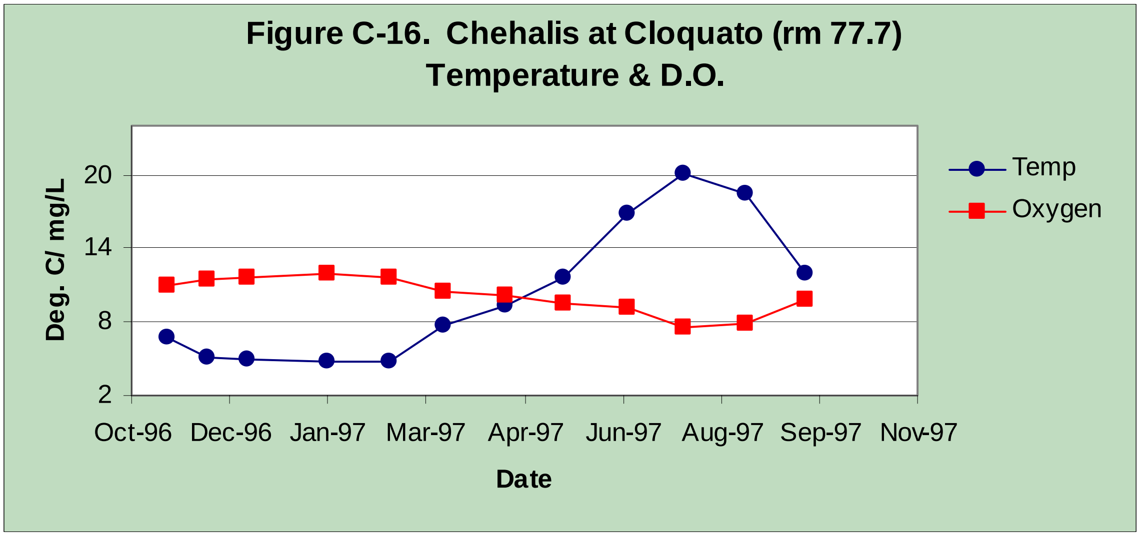


Figure C-16. Chehalis at Cloquato (rm 77.7)
Temperature & D.O.

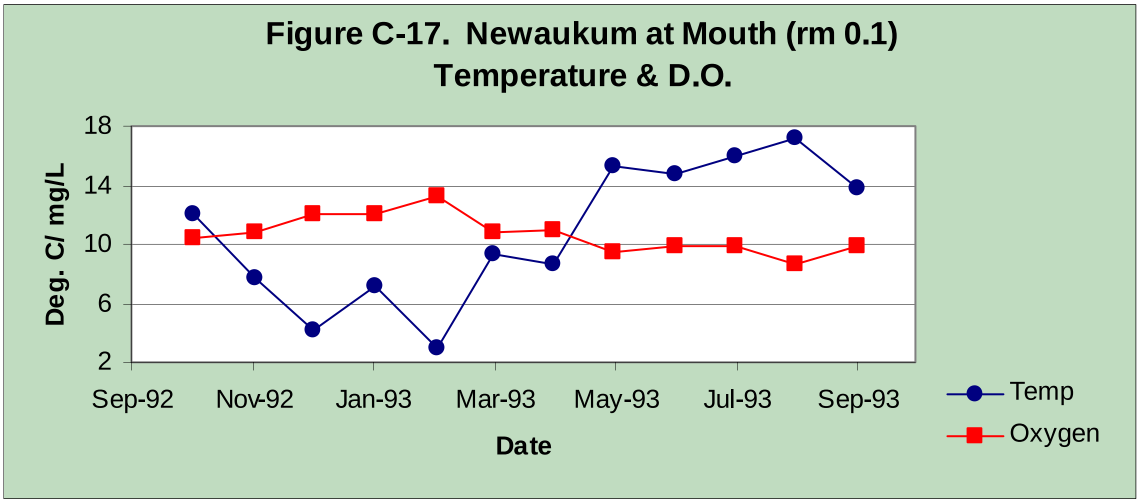


Figure C-17. Newaukum at Mouth (rm 0.1)
Temperature & D.O.

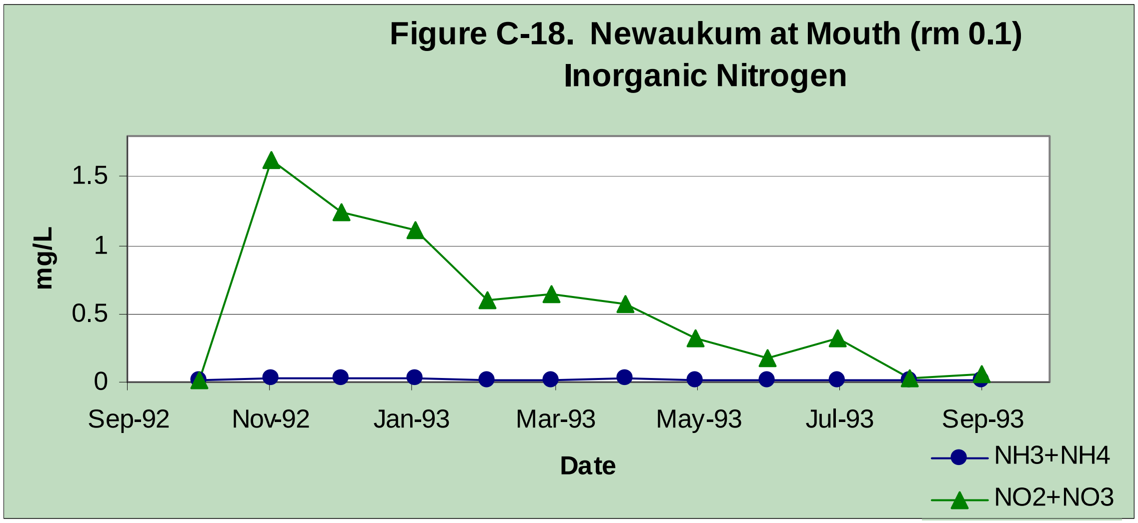


Figure C-18. Newaukum at Mouth (rm 0.1)
Inorganic Nitrogen

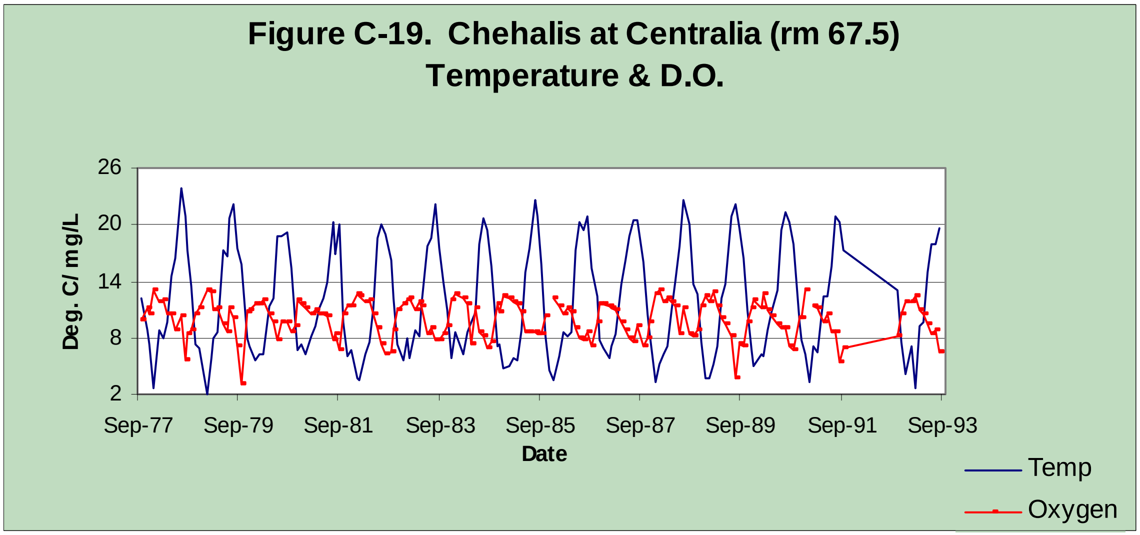


Figure C-19. Chehalis at Centralia (rm 67.5)
Temperature & D.O.

Figure C-20. Chehalis at Centralia (rm 67.5)
TP & TSS Loading

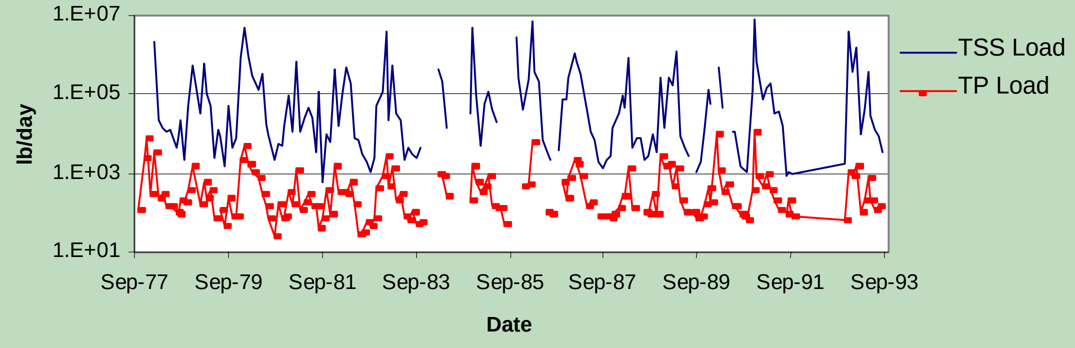


Figure C-21. Chehalis at Centralia (rm 67.5)
Fecal Coliform

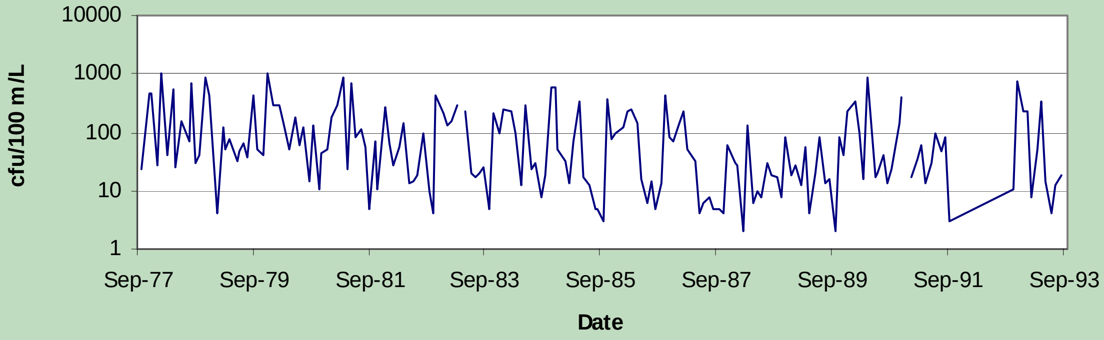
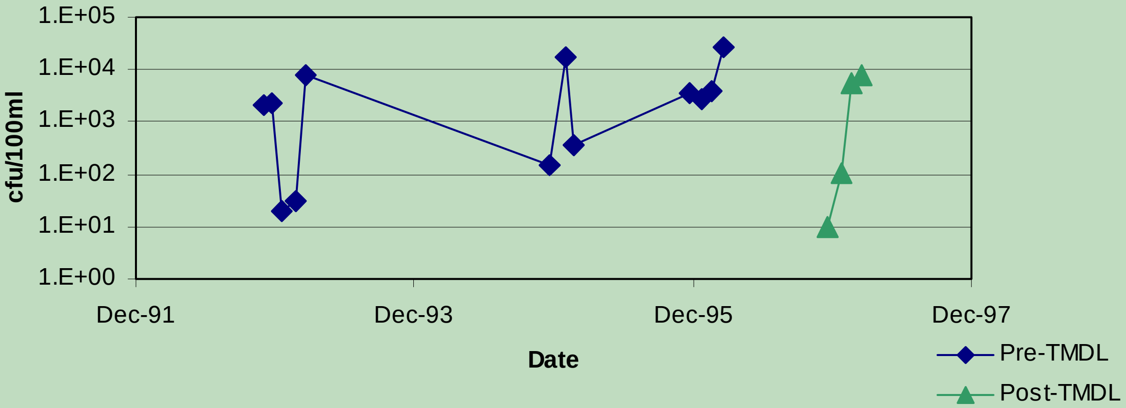


Figure C-22. Beaver Creek at Hwy 121 (cm 0.1)
Wet Season Fecal Coliform (TCEH data)



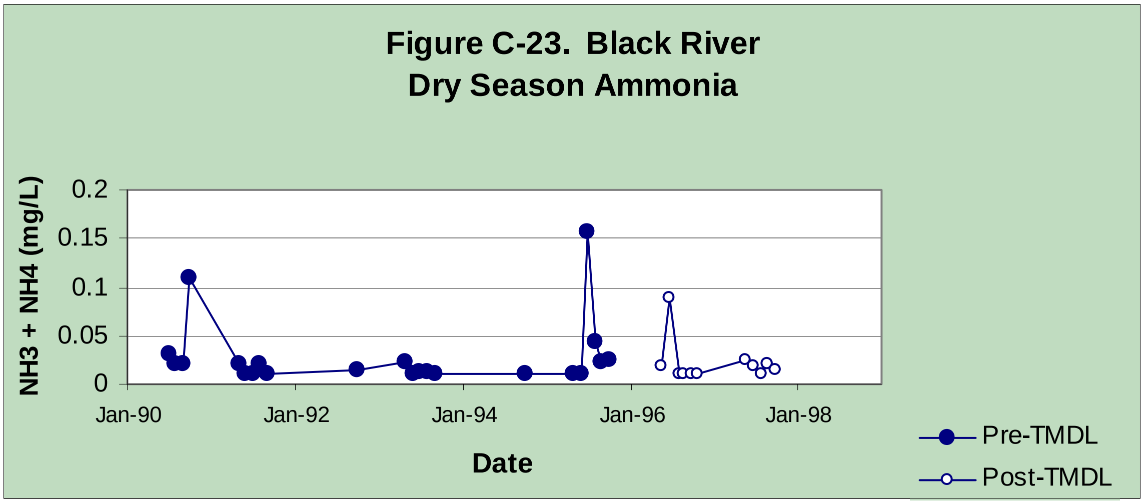


Figure C-23. Black River
Dry Season Ammonia

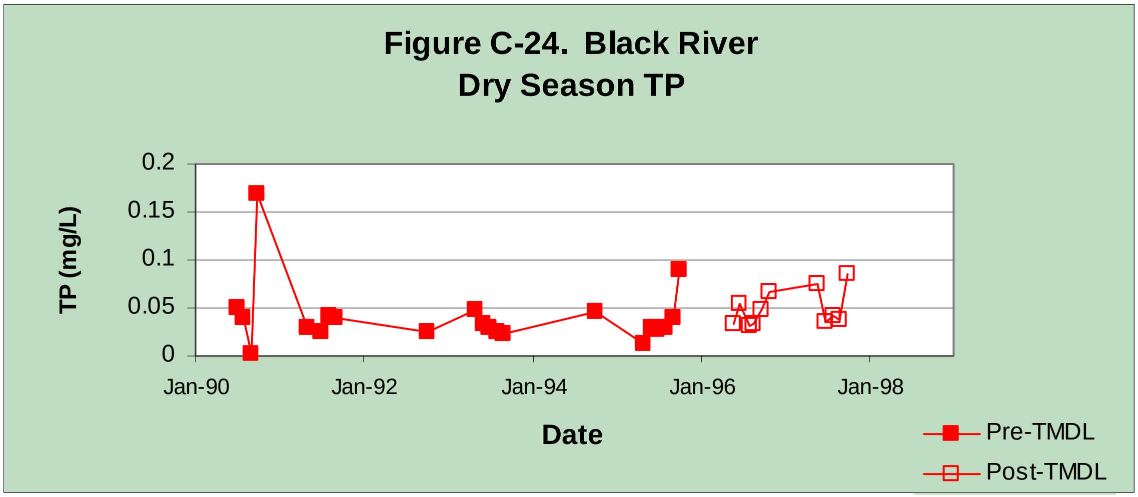


Figure C-24. Black River
Dry Season TP

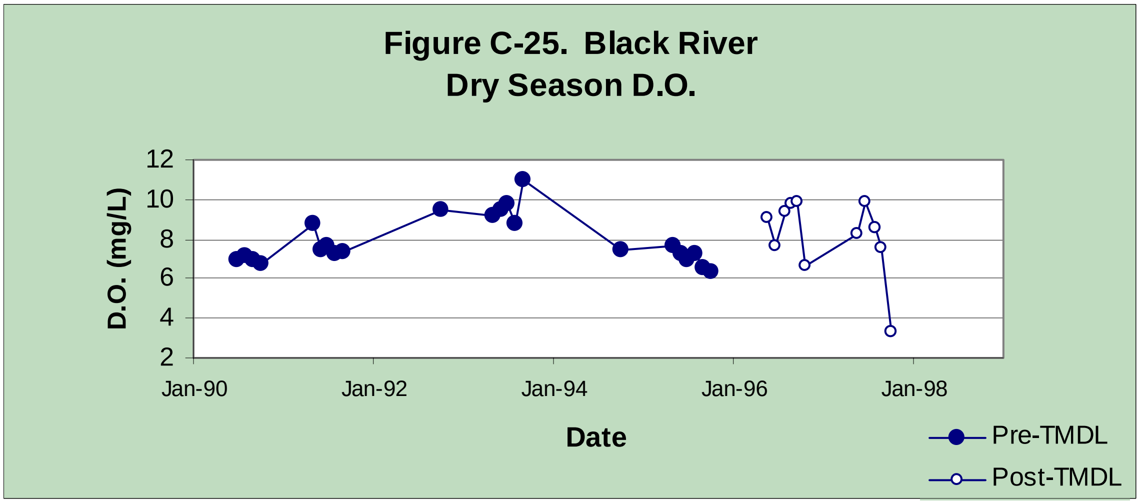


Figure C-25. Black River
Dry Season D.O.

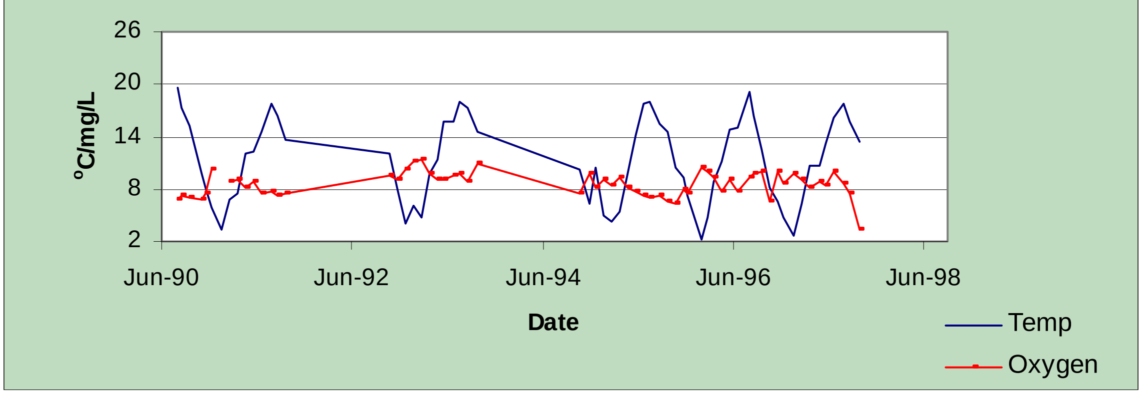


Figure C-26. Black River (rm 7.1)
Temperature & D.O.

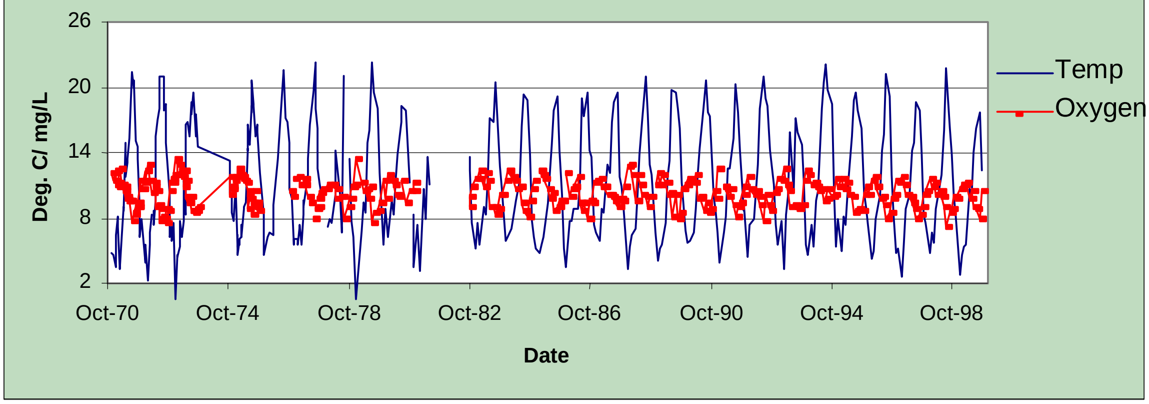


Figure C-27. Chehalis - Porter (rm 3.33)
Temperature & D.O.

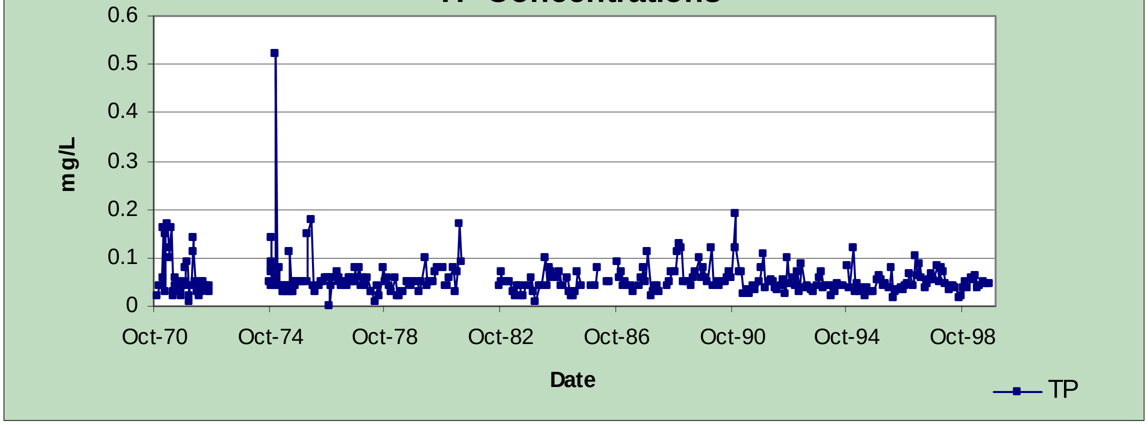


Figure C-28. Chehalis at Porter (rm 33.3)
TP Concentrations

Figure C-29. Chehalis at Porter (rm 33.3) Fecal Coliform

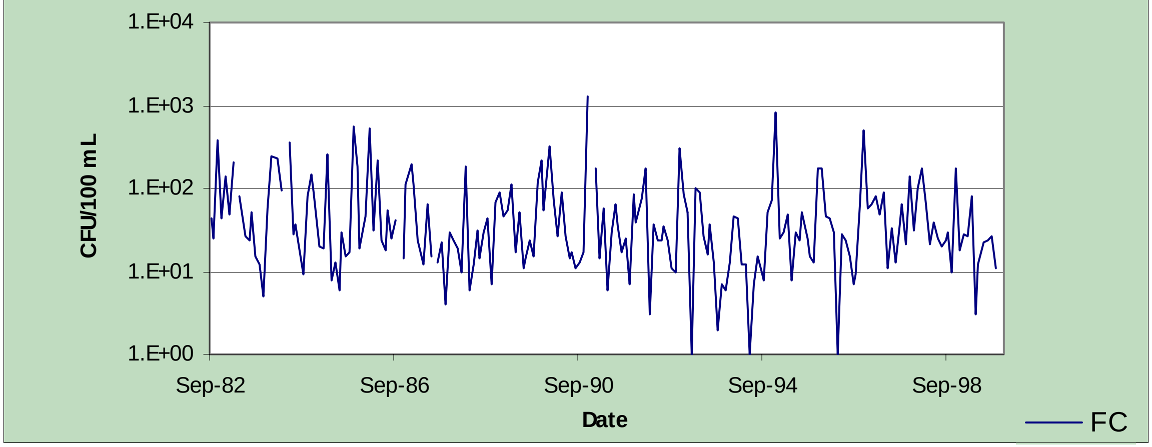


Figure C-30. Cloquallum Creek (cm 3.0) TP Loading

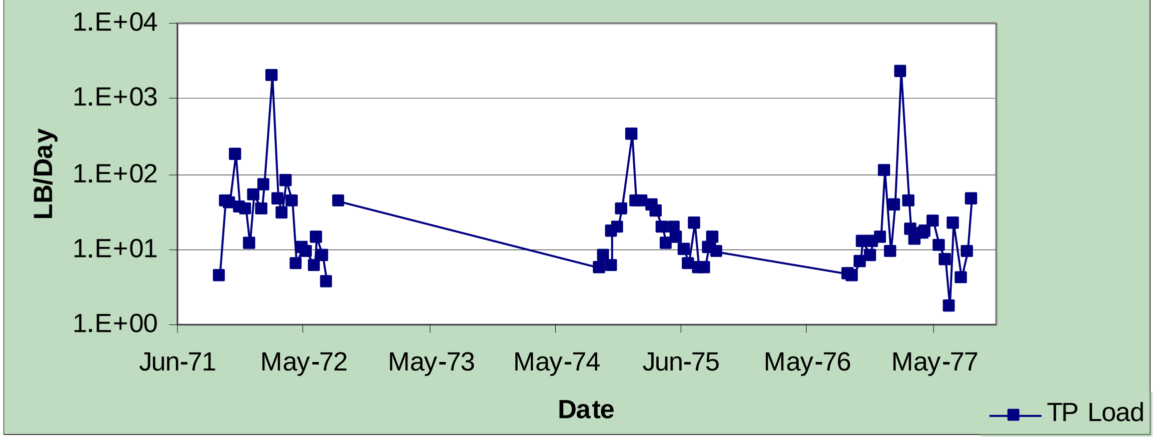
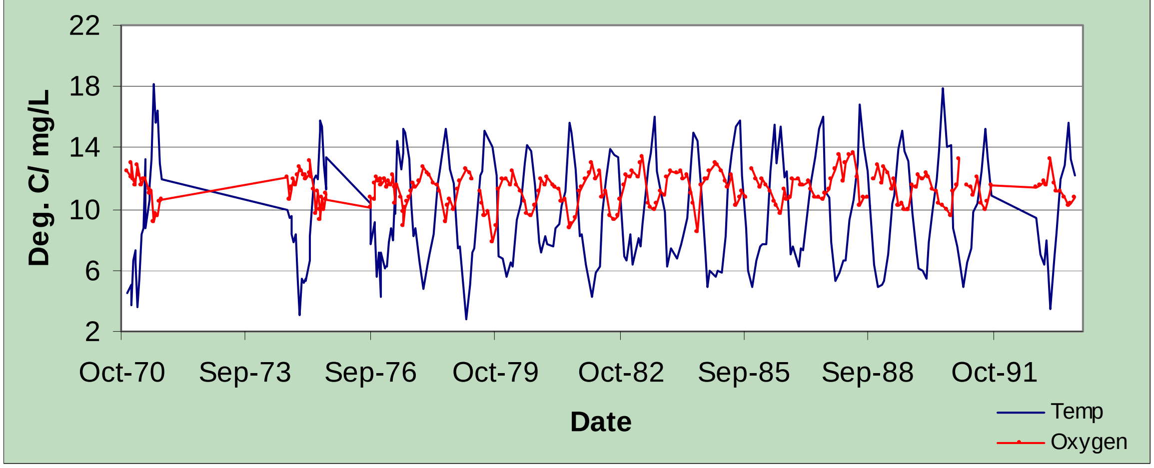


Figure C-31. Satsop River (rm 2.7) Temperature & D.O.



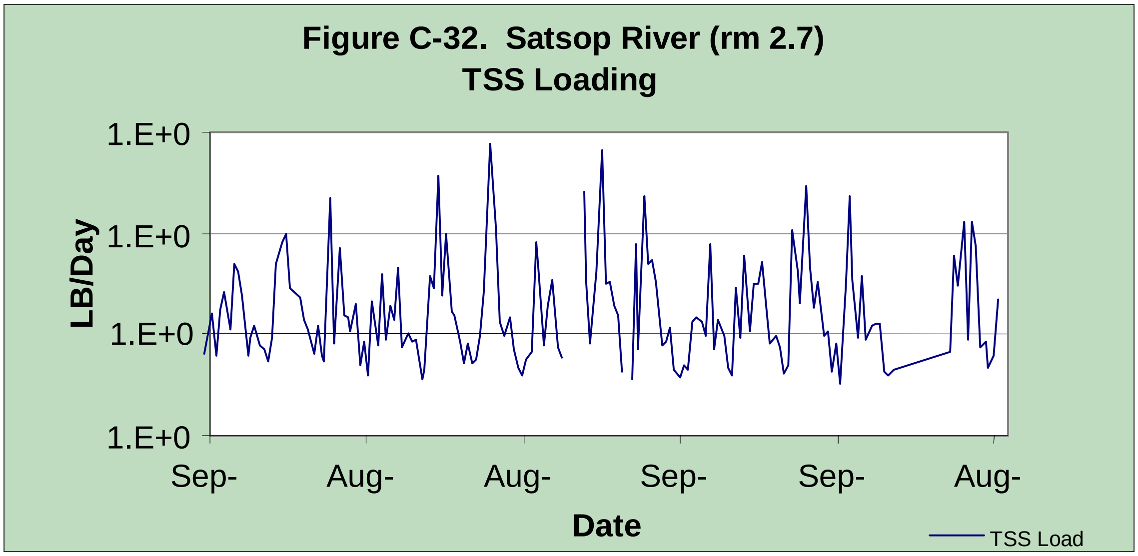


Figure C-32. Satsop River (rm 2.7)
TSS Loading

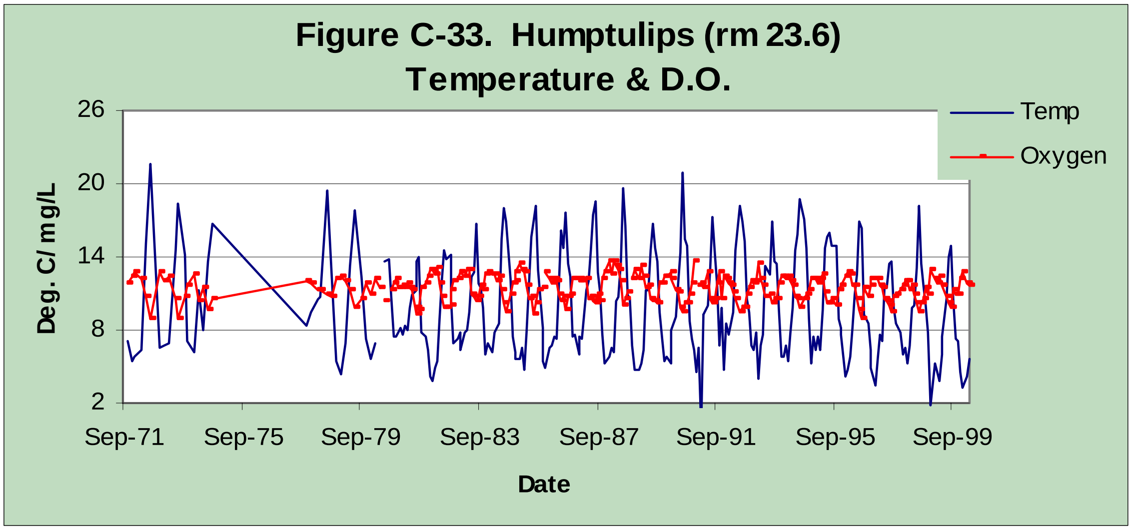


Figure C-33. Humptulips (rm 23.6)
Temperature & D.O.

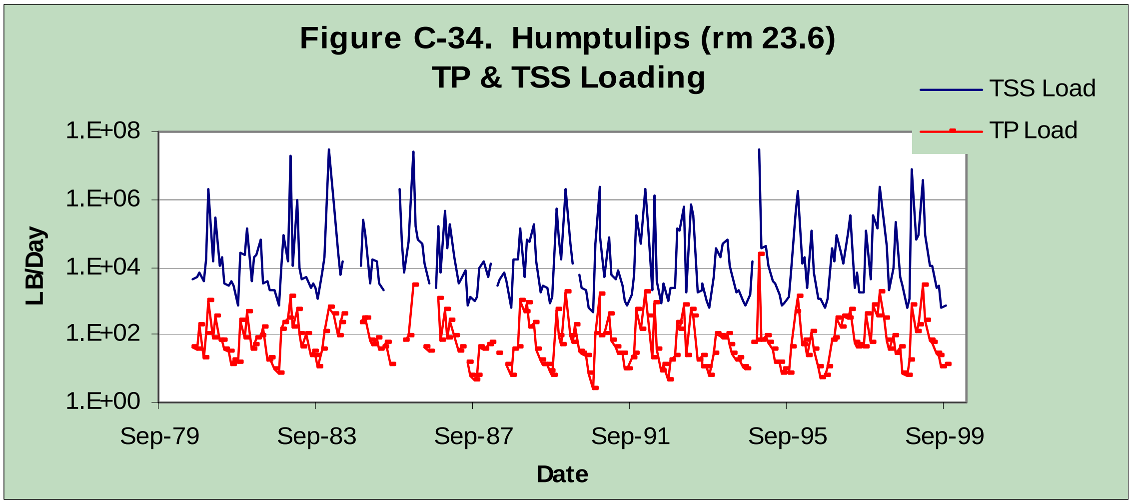


Figure C-34. Humptulips (rm 23.6)
TP & TSS Loading

Figure C-35. Humptulips (rm 23.6)
Fecal Coliform

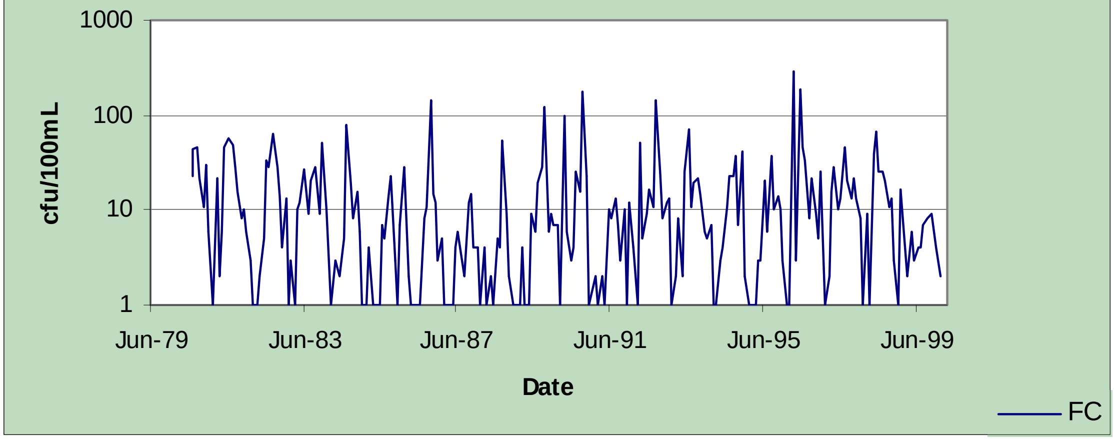


Figure C-36. Chehalis at Montesano (rm 13.15)
Temperature & D.O.

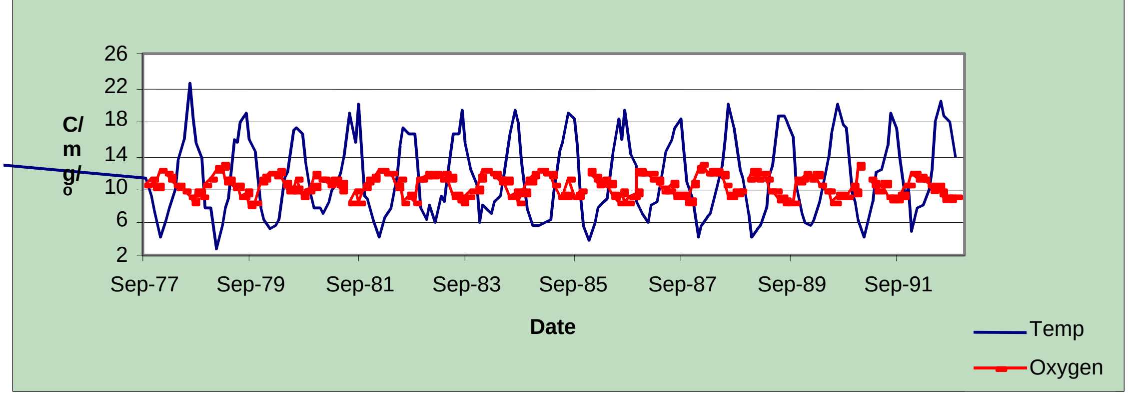
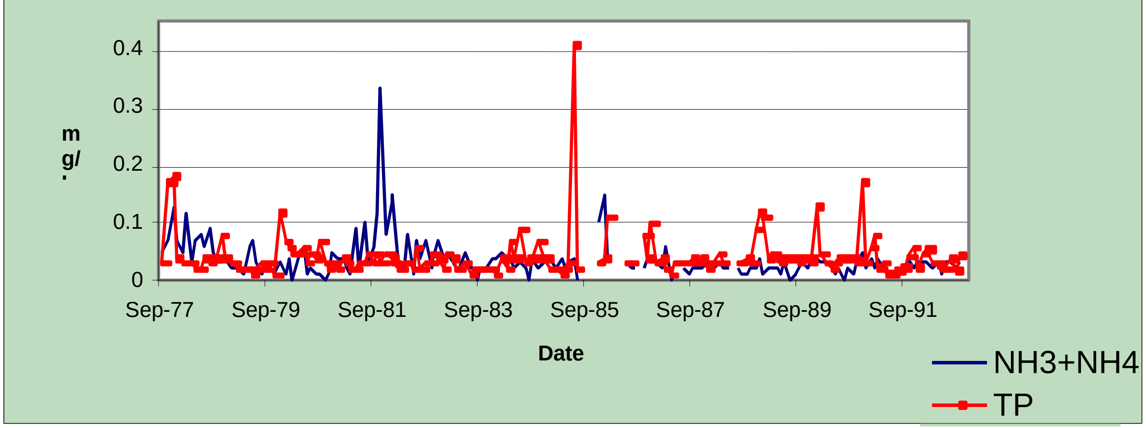


Figure C-37. Chehalis at Montesano (rm 13.15)
TP & Ammonia



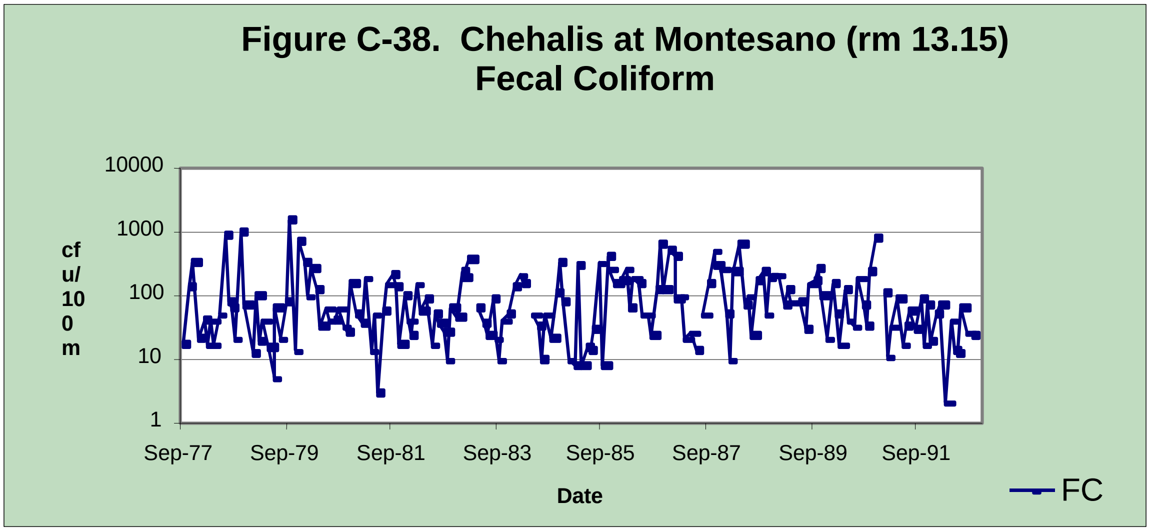


Figure C-38. Chehalis at Montesano (rm 13.15)
Fecal Coliform

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