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SUMAS RIVER
RECEIVING WATER STUDY

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ABSTRACT

A survey of the Sumas River was conducted from September 24-25, 1992, to assess the impact of the city of Sumas wastewater treatment plant (WTP) effluent on the river. The receiving water study identified an effluent dilution of about 250:1, which is projected to drop to 71:1 under annual (7Q10) and summer (7Q20) design flow conditions. Fecal coliform concentrations above the WTP exceeded the water quality criterion for Class A waters, and nitrogen loadings from Johnson Creek were high, likely due to agricultural nonpoint sources. Under the survey conditions, WTP effluent did not affect downstream temperature, dissolved oxygen, or pH, however, phosphorus concentrations were altered by the effluent. Worst-case modeling predicted water quality violations for total residual chlorine (TRC) under all design conditions, and dissolved oxygen under summer design conditions. TMDL, WLAs, and LAs were recommended for ammonia, biochemical oxygen demand (BOD_5), TRC, and fecal coliform.

INTRODUCTION

The Sumas River, a Class A waterbody in Whatcom County is the receiving water for the town of Sumas wastewater treatment plant (WTP). The oxidation ditch WTP serves a population of approximately 750 and discharges to the Sumas River several hundred feet before the river crosses the United States-Canada international border (Figure 1). Water quality impacts from the discharge were unknown. An Ecology ambient monitoring site located approximately 0.4 mile downstream of the outfall at the Huntingdon Bridge frequently exceeds the Class A water quality criterion for fecal coliform of 100 organisms/100 mL of sample. It is not known if these exceedances are a result of the Sumas discharge, nonpoint sources, or both.

Land use in the Sumas River watershed is primarily agriculture, specifically dairy farming. In most areas, pasture extends to the banks of the river. Johnson Creek, a major tributary, also drains mostly agricultural land. Johnson Creek meanders through the city of Sumas before joining the Sumas River about one mile above the WTP outfall.

Ecology's Northwest Regional Office (NWRO) is in the process of reissuing the WTP discharge permit. They requested that the Watershed Assessments Section (WAS) conduct low-flow receiving water and mixing zone surveys to evaluate the impacts of the WTP discharge on river water quality. The results of this work are presented in this report. A Class II Inspection was also conducted by WAS (Glenn, 1992). The results of that inspection indicated that the WTP was performing within permit limits. The objectives of the Sumas River receiving water study are listed below:

1. Evaluate water quality impacts resulting from wastewater discharge during the summer low flow season;
2. characterize mixing of the effluent plume and establish mixing zone boundaries for the NPDES permit; and,
3. recommend permit modifications to protect the water quality of the Sumas River.

METHODS

Surveys were conducted on the Sumas River, September 24-25, 1992. Sampling stations include 1 tributary and 5 mainstem sites (Johnson Creek) (Figure 1). Three of these sites (2 mainstem and 1 tributary) were upstream of the WTP outfall and three sites were downstream. Approximately 17 percent of all samples were quality assurance related. Replicates were taken to assess field and laboratory variability.

All samples for laboratory analysis were stored on ice and shipped to arrive at the Ecology Laboratory in Manchester, Washington, within 24 hours. Laboratory analyses were performed in accordance with APHA *et al.* (1989), EPA (1983), and Huntamer and Hyre (1991). Field measurements included temperature (mercury thermometer), pH (Orion Model 250A meter and Triode™ pH electrode), conductivity (Beckman Model RB-5), dissolved oxygen (azide-modified

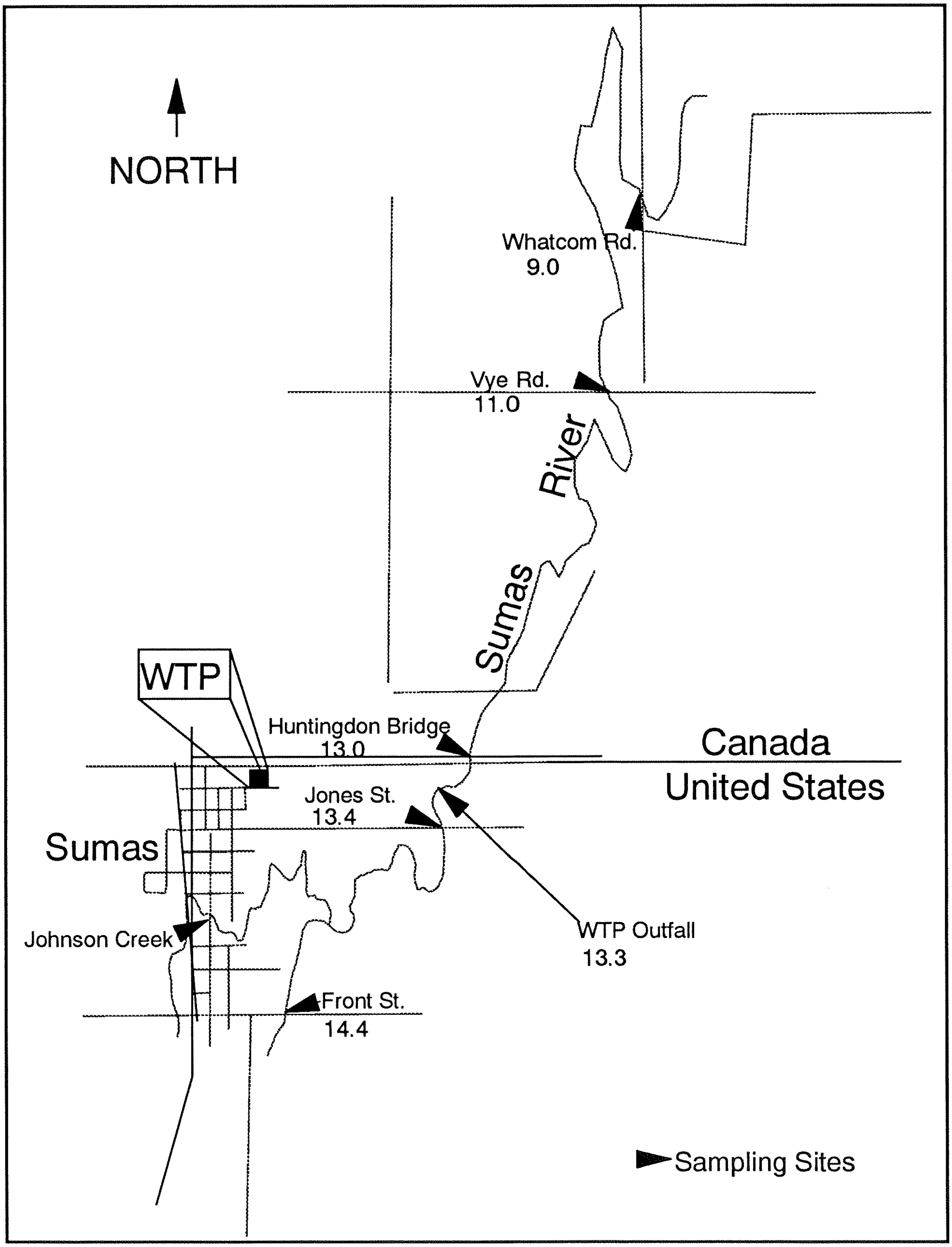

Figure 1. Map of study area with sampling locations annotated (map is not to scale).

Winkler titration), and total residual chlorine (LaMotte-Palin DPD kit). Streamflow was measured by taking cross-channel velocity measurements with a Swoffer® current meter. Sampling parameters and frequency are listed in Table 1.

A dissolved oxygen survey was conducted on the evening of September 23 and morning of the 24th to assess dissolved oxygen sag. In order to minimize temporal variability, temperature, pH, conductivity, and dissolved oxygen were measured at all sites within a 1.5-hour period.

Mixing of the effluent plume was characterized by measuring cross-channel conductivity and chloride transects 30 and 100 feet downstream of the outfall. In addition, cross-section stream flow measurements were taken at the 30 foot transect.

QUALITY ASSURANCE/QUALITY CONTROL

All analyses were performed within the specified holding times for general chemistry and metals. These data were reported by Ecology's Manchester Laboratory as usable without qualification. However, the laboratory did qualify as unusable, due to analytical errors, the BOD_5 analyses for the Jones Road and Huntingdon Bridge sites collected on September 24. The BOD_5 data reported for the same sites on September 25 were below a detection limit of <6 mg/L. Because of the poor data quality and high detection limit of the BOD_5 results, they are not used in any calculations for this report.

Mean replicate precision is $<10\%$ for all variables except fecal coliform (approximately 35%). Historical WAS data suggest that fecal coliform precision has been between 25 to 50% (Joy *et al.*, 1991).

RESULTS AND DISCUSSION

Receiving Water Survey

Results of the receiving water survey on Sumas River are summarized in Table 2. Using the survey mean flow at the Jones Road site, just upstream of the WTP, the receiving water to effluent dilution ratio is about 250:1. This is well above the Ecology recommended dilution of 100:1 for new facilities (Ecology, 1985). Appendix A contains summary statistics for September data collected at the Huntingdon Bridge station by Ecology's Ambient Monitoring Section from 1982 through 1991. Except for TSS, turbidity, and pH all data collected during the Sumas River survey fall within the range of historical data.

The survey TSS and turbidity data indicate a possible land disturbance between the Front Street, Johnson Creek, and Jones Road sites. The WAS sampling team noted a number of road improvement projects in the city of Sumas, close to Johnson Creek, during the survey. The road improvements most probably account for the increase in TSS and turbidity at the Jones Road site.

Table 1. Sampling design for Sumas receiving water survey conducted September 24-25, 1991.

			Parameter*												
Sampling Site	**Date**	**Time**	**Flow**	**Temp**	**pH**	**Cond**	**D.O.**	**Chlor**	**FC**	**TSS**	**Hard**	**Turb**	**BOD-5**	**NUTS-5**	**Metals**
RECEIVING WATER															
RM 14.8	9/24	1050	X	X	X	X	X	-	X	X	-	X	-	X	-
	9/25	0955	X	X	X	X	X	X	X	X	-	X	-	X	-
JC 14.4	9/24	1130	X	X	X	X	X	-	X	X	-	X	-	X	-
	9/25	1025	X	X	X	X	X	X	X	X	-	X	-	X	-
RM 13.4	9/24	1020	X	X	X	X	X		X	X	-	X	X	X	X
	9/25	0845	X	X	X	X	X+	X+	X+	X+	X+	X+	X+	X+	X+
WTP 13.3															
RM 13.0	9/24	0930	X	X	X	X	X+	-	X+	X+	-	X+	X	X+	X+
	9/25	0755	X	X	X	X	X	X	X	X	X	X	X	X	X
RM 11.0	9/24	0900	-	X	X	X	X	-	X	X	-	X	-	X	X
	9/25	0735	-	X	X	X	X	X	X	X	X	X	-	X	X
RM 9.0	9/24	0815	X	X	X	X	X	-	X	X	-	X	-	X	-
	9/25	0700	X	X	X	X	X	X	X	X	-	X	-	X	-

X = Sample collected
X+ = Replicate sample collected

Temp = Temperature
Cond = Conductivity
D.O. = Dissolved Oxygen
FC = Fecal Coliform
TSS = Total Suspended Solids

BOD-5 = 5-day Biochemical Oxygen Demand
Turb = Turbidity
Chlor = Chloride
Hard = Hardness

NUTS-5 = Nutrients: ammonia, nitrate+nitrite, total persulfate nitrogen total phosphorus, soluble reactive phosphorus
Total Recoverable Metals = Lead, Zinc, Cadmium, Copper

Table 2. Results of water quality surveys conducted on Sumas River, September 24-25 1991.
(WTP effluent results are included for comparison.)

Sampling Site	River Mile	Date	Time	Flow (cfs)	Temp (C)	pH (S.U.)	Cond. (umhos/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Sat.)	TRC (mg/L)	Fecal Coliform (#/100 mL)
Johnson Creek	14.4	9/24	1130	16.9	12.1	7.7	248	8.60	80.0		150
		9/25	1025	16.2	12.9	7.9	250	8.10	76.7		200
Front St.	14.8	9/24	1050	15.4	13.0	7.8	330	8.10	76.9		280
		9/25	0955	15.3	13.5	7.8	335	7.70	73.9		140
Jones Rd.	13.4	9/24	1020	30.6	12.5	7.9	290	8.50	79.8		200
		9/25	0845	37.0	13.2	7.9	290	8.00	76.3		230
		repl.						7.95	75.7		330
Sumas WTP	13.3	9/24	1630	0.14	19.2	7.3	532			0.1	1100
effluent		9/25	0900	0.14	19.3	7.1	511	1.85	20.1	0.2	39
(composite sample 9/24-25)		9/25	24 hr				530				
Huntingdon Bridge	13.0	9/24	0930	38.1*	12.0	7.8	290	8.40	77.9		350
		repl.						8.35	77.5		240
		9/25	0755	39.9	13.1	8.0	290	8.00	76.1		400
Vye Rd.	11.0	9/24	0900		12.5	7.8	295	8.00	75.1		120
		9/25	0735		13.1	8.0	290	7.70	73.2		140
Whatcom Rd.	9.0	9/24	0815	33.5	12.2	7.9	298	7.90	73.6		69
		9/25	0700	30.6	13.1	8.0	285	7.20	68.5		88

* Derived from rating curve

Table 2. (Continued).
(WTP effluent results are included for comparison.)

Sampling Site	River Mile	Date	Time	Turb. (NTU)	TSS (mg/L)	Chloride (mg/L)	Hardness (mg/L)	BOD-5 (mg/L)	NH3-N (mg/L)	NO2-N+ NO3-N (mg/L)	TN (mg/L)	TP (mg/L)	SRP (mg/L)
Johnson Creek	14.4	9/24	1130	2.3	4				0.021	4.25	4.31	0.017	0.030
		9/25	1025	2.5	3	9.6			0.015	4.18	8.82	0.045	0.021
Front St.	14.8	9/24	1050	7.4	2				0.111	0.689	0.99	0.039	0.014
		9/25	0955	7.3	2	17.6			0.055	0.666	0.87	0.036	0.017
Jones Rd.	13.4	9/24	1020	6.4	10			*	0.034	2.42	2.70	0.038	0.025
		9/25	0845	8.2	11	14.4	134	<6	0.042	2.41	2.74	0.046	0.051
		repl.		8	12	14.3	133	<6	0.032	2.42	2.69	0.044	0.022
Sumas WTP	13.3	9/24	1630	1.7	4	39.4		5	0.066	4.01	5.15	13.15	6.60
effluent		9/25	0900	1.7	4	38.1		4	0.130	1.82	2.96	6.21	6.38
(composite sample 9/24-25)		24 hr			4	39.4		<4	0.192	2.80	4.12	6.63	6.65
Huntingdon Bridge	13.0	9/24	0930	7.3	9			*	0.036	2.36	2.62	0.080	0.035
		repl.		9.2	11				0.034	2.38	2.64	0.068	0.038
		9/25	0755	8.8	12	14.7	132	<6	0.045	2.42	2.64	0.063	0.031
Vye Rd.	11.0	9/24	0900	7.5	7				0.020	2.31	2.59	0.073	0.023
		9/25	0735	9.7	9	15.9	132		0.101	2.29	2.61	0.077	0.024
Whatcom Rd.	9.0	9/24	0815	7.6	5				0.017	2.23	2.92	0.070	0.020
		9/25	0700	11.5	7	15.9			0.037	2.25	2.55	0.061	0.021

* Data collected but not usable

In addition to TSS, Sumas River water quality above the WTP indicates other nonpoint pollution impacts to the river, probably from agricultural activities in the area. All of the sites above the WTP exceeded the fecal coliform criterion of 100 organisms/100mL of sample. These results suggest that downstream fecal coliform concentrations are most probably determined by nonpoint sources in the drainage.

Figure 2 presents the mean nutrient data for the survey from upstream to downstream. The graph shows that changes in nitrogen variables on the Sumas River are due to the influence of Johnson Creek. Total nitrogen and nitrite-nitrate nitrogen increase from <0.1 mg/L to >2 mg/L and ammonia decreases by approximately 50% after the Johnson Creek/Sumas River confluence. Unlike the nitrogen variables, total phosphorus and ortho-phosphorus both increase after the WTP discharge. The nutrient data suggest that considerable nonpoint nitrogen loading is occurring in the Johnson Creek drainage, with the WTP adding phosphorus. If it is assumed that phosphorus is the rate limiting nutrient for plant productivity, then the WTP discharge may be causing increases in productivity downstream. This could be the case because nutrient loads generally decrease downstream of the WTP, which suggests possible uptake by plants.

Figure 3 presents the results of the morning/evening dissolved oxygen survey from upstream to downstream. Again Johnson Creek appears to have a greater influence than the WTP on the variables measured, with the exception of temperature. The small drop in temperature at Huntingdon Bridge during the evening survey is unexplainable since the effluent temperature is the same in the morning and evening. Although there is a large diurnal swing in dissolved oxygen, the data do not indicate a sag caused by WTP discharge under survey conditions.

Total recoverable metals data for lead, zinc, cadmium, and copper collected at selected sites during the survey are listed in Table 3. All of the instream data have been qualified by the laboratory. Of the instream "P" flagged values, only two cadmium values may have exceeded the criterion (chronic value), one at Huntingdon Bridge and one at Vye Road. Assuming a value of ½ the detection limit as the upstream concentration of the measured metals, calculated wasteload allocations (WLAs) based on the criteria values would be much greater than the reported effluent values found during the Class II Inspection.

The effluent plume could be discerned from the river flow by conductivity and chloride data collected 30 ft. downstream of the WTP discharge, but not 100 ft., which indicates the river and effluent are completely mixed within 100 ft. of the discharge point. Based on an average stream velocity of 0.32 feet per second, total mixing within the 100 ft. distance probably occurs in approximately five minutes.

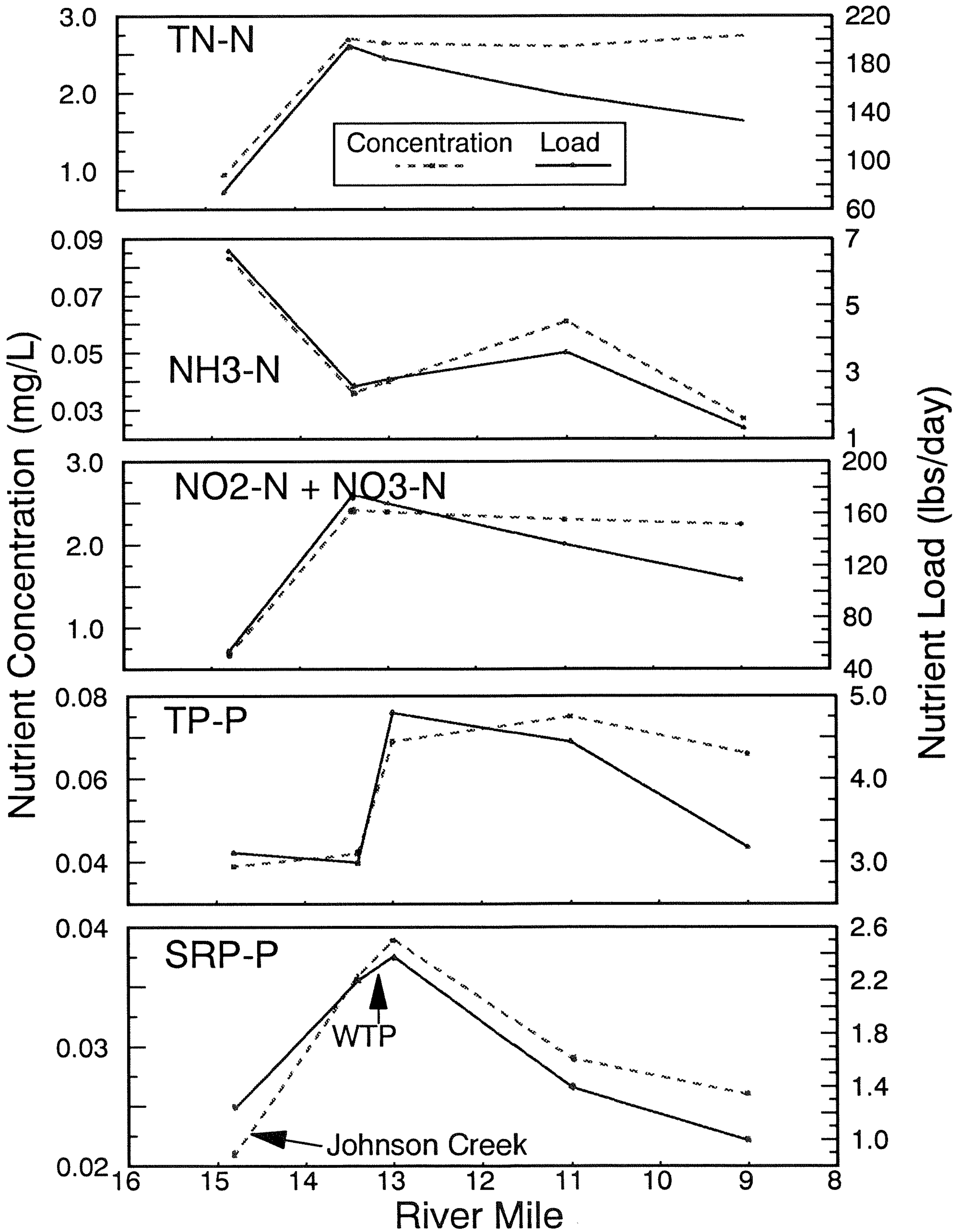

Figure 2. Nutrient concentrations and loads for Sumas River above and below the Sumas WTP. Values represent the mean concentrations for the survey.

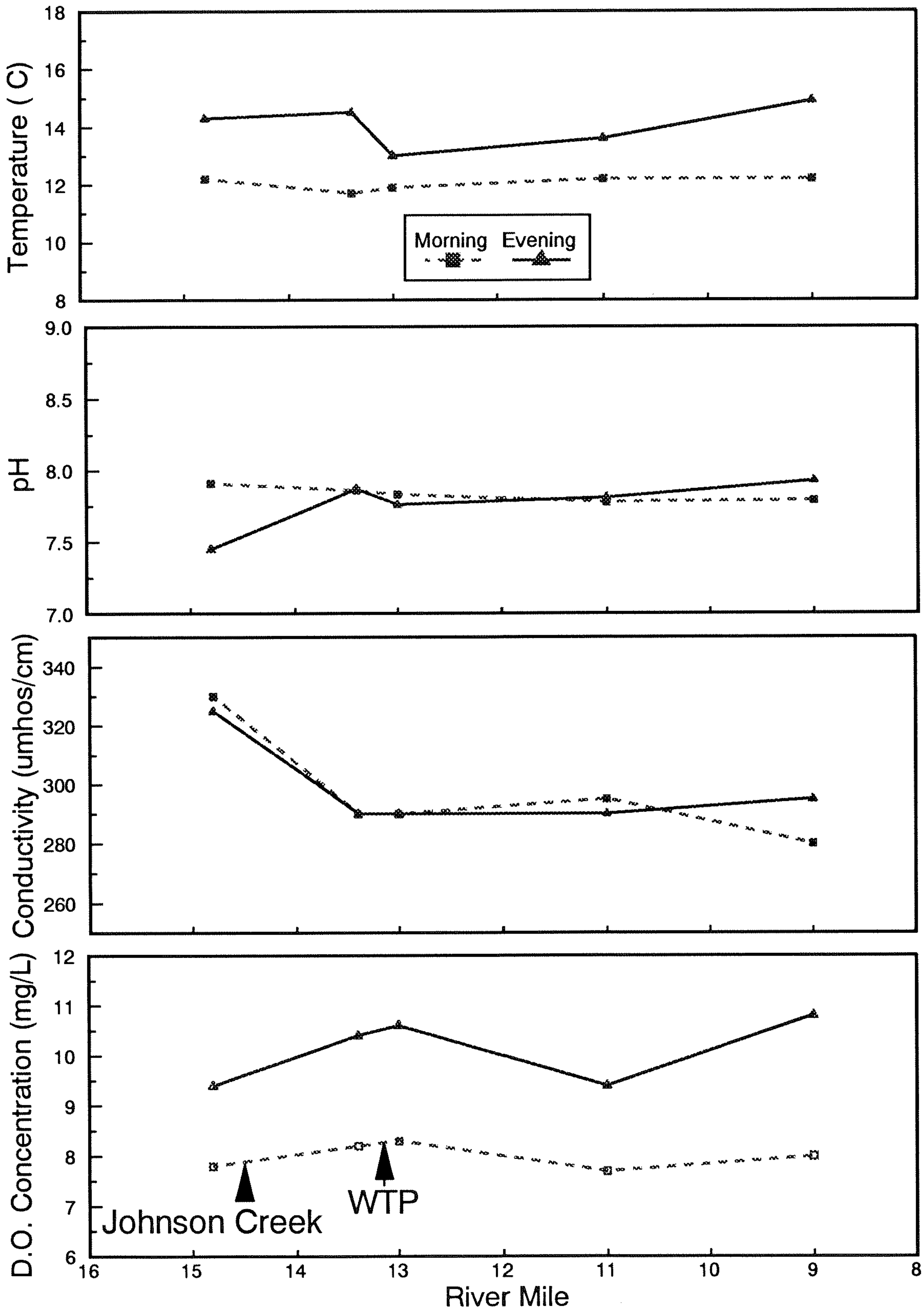

Figure 3. Results of the early morning and evening dissolved oxygen survey on Sumas River on the evening of September 23 and morning of the 24th.

Table 3. Total recoverable metals data in μg/L for Sumas River and Sumas WTP effluent.

Sampling Site	Date	Total Recoverable Metals			
		Lead	Zinc	Cadmium	Copper
Jones Rd.	9/24	1.0P	4.0U	2.0U	3.0U
	9/25	1.0U	4.0U	2.0U	3.0U
	repl.	1.0U	4.0U	2.0U	3.0U
WTP effluent[a]	9/25	1.3P	72.3	2.0U	4.9P
Huntingdon Bridge	9/24	1.9P	4.6P	2.0U	3.0U
	repl.	1.0U	4.0U	2.2P	3.0U
	9/25	1.1P	7.1P	2.2U	4.3P
Vye Rd.	9/24	1.0U	4.0U	2.0U	3.0U
	9/25	1.3P	5.6P	2.2P	3.0U
Metals Criterion[b]					
Acute		116.3	148.1	5.4	23.0
Chronic		4.5	134.1	1.4	15.0

[a] = From 24 hr composite sample.
[b] = A hardness concentration of 132 mg/L was used for all criteria calculations.
U = Not detected at or above the reported result.
P = Detected above instrument detection limit but below the established minimum quantification limit.

Total Maximum Daily Load (TMDL) Analyses

A TMDL analysis determines a waterbody's loading capacity, or the amount of pollution it can naturally assimilate without impairing water quality and limiting beneficial uses. TMDLs can be used as a management tool to control the discharge of pollutants to surface waters to the level necessary to protect water quality standards. Once established, the TMDL for a given pollutant is apportioned between point sources as wasteload allocations (WLAs) and nonpoint sources as load allocations (LAs). The allocations are implemented through NPDES permits and nonpoint source controls. A reserve may be set aside to provide a margin of safety for a sensitive water body or to accommodate future growth. The following TMDL analyses for Sumas River make recommendations for ammonia, BOD_5, chlorine, and fecal coliform.

The first step in conducting a TMDL analysis is to establish appropriate design conditions. Design conditions are usually defined as critical conditions of design streamflow, WTP flow at design capacity, and effluent quality at current NPDES permit limits. In addition, stream water quality conditions such as temperature, pH, and other parameters may also play a role.

Since the volume of streamflow usually determines the assimilative capacity of a stream relative to other design conditions, it is important to establish appropriate critical flow conditions. Most states have historically used the low flow 7Q10 statistic as the critical design flow condition. Applying a 7Q10 on an annual basis states that the minimum annual 7-day average flow drops below the 7Q10 with a probability of 0.1 (*i.e.*, once in 10 years). The problem with this statistic is that it limits annual discharge based on single seasonal conditions, which can be overly restrictive in different seasons. However, if alternative flow statistics are applied, EPA states that the same or lower annual failure frequency should be equivalent to that of the 7Q10 (EPA, 1984).

In the following analysis of Sumas River, both annual and semiannual flow statistics are used; May through October (summer) and November through April (winter) for the semiannual flow. For an annual failure probability of 0.10, the equivalent return period for the semiannual time interval is 7Q20 for each of the two periods (EPA 1984). The flow statistics and other critical conditions used to establish WLAs and LAs are listed in Table 4.

Table 4. Design conditions used in determining ammonia, BOD, chlorine, and fecal coliform impacts on Sumas River.

Design Parameters	Critical Flow Intervals		
	7Q10 (Annual)	7Q20 (May-Oct)	7Q20 (Nov-Apr)
Steam Flow (cfs)[a]	13.3	13.2	25.5
WTP discharge (cfs)[b]	0.19	0.19	0.19
Temperature (°C)[c]	17.5	18.4	12.6
pH[c]	8.2	8.2	7.9

[a] Provided by Environment Canada, derived from Huntingdon bridge BC, gauging station records, then subtracting average daily WTP flow (e.g., 13.5_{7Q10} - 0.17_{WTP} = 13.3_{7Q10} cfs upstream of WTP).

[b] WTP flow design criteria listed in NPDES permit.

[c] Derived from Ecology's Huntingdon Bridge ambient monitoring station record and represents the value at the 95th percentile.

It should be noted that using design annual or summer flows for the river and WTP discharge reduces the receiving water to effluent dilution ratio to 71:1. This is below the Ecology recommended dilution of 100:1 cited earlier, which means the river looses a significant portion of its assimilative capacity under critical design conditions.

Ammonia

Instream and effluent ammonia concentrations found during the survey were well below acute and chronic toxicity criteria of 6.836 and 1.315 mg/L, respectively. However, effluent ammonia concentrations would be expected to increase if the existing permit limits for BOD_5 are reached, and may become critical under design conditions. Therefore, it is appropriate to determine permit limits for ammonia.

Un-ionized ammonia concentrations and criteria calculations based on the design conditions listed in Table 4 are presented in Appendix B. Upstream survey mean ammonia concentrations are used as one of the input background conditions. The proposed design criteria calculated in Appendix B were then projected to permit limits by first applying proposed mixing zone regulations (Chapter 173-201 WAC, May 22, 1992, draft), and then calculating the water quality-based permit limits and WLAs based on EPA (1991) recommended methods (Appendix C). The mixing zone dilution factors applied were:

$$\text{Acute Criterion Dilution Factor} = (Q_{WTP} + 0.025(7Q10))/Q_{WTP}$$
$$\text{Chronic Criterion Dilution Factor} = (Q_{WTP} + 0.25(7Q10))/Q_{WTP}$$

Where Q_{WTP} equals the WTP design flow.

Calculated criteria, WLAs, and suggested ammonia permit limits are presented in Table 5. Table 6 presents the ammonia TMDL and recommended allocations for Sumas River. Unallocated loads are simply the difference between the TMDL and allocations. The reason for this residual is that the mixing zone requirements limit ammonia discharge, which is less than the total assimilative capacity of the river. Unallocated loading can be set aside for future allocations or as a safety factor.

Biochemical Oxygen Demand (BOD)

A Streeter-Phelps analysis of the critical dissolved oxygen sag under design conditions was used to determine the BOD_5 permit limit necessary to maintain the Class A river oxygen standard of 8.0 mg/L (Appendix D). The analysis was accomplished using the recommended acute ammonia WLAs as contributing to nitrogenous BOD (NBOD), and then varying the carbonaceous BOD (CBOD) concentration such that a river oxygen level of 8.0 mg/L could be maintained. The upstream dissolved oxygen concentration was set at 89% saturation for the design temperature. This represents the mean daily dissolved oxygen saturation observed during the survey. At design conditions, dissolved oxygen was predicted to drop to 8.07, 7.89 and 9.35 mg/L for the annual, summer, and winter design conditions, respectively. Under the annual and winter scenarios, existing technology-based permit limits will not reduce river dissolved oxygen below the standard. However, the summer design condition does predict a dissolved oxygen violation due to WTP discharge. In order to maintain the 8.0 mg/L standard under summer design conditions, the $CBOD_5$ effluent concentration could not exceed 19 mg/L.

Table 5. Ammonia criteria, WLA, and suggested permit limits.

Criterion, WLA, or Permit Limits (mg N/L)	Critical Flow Intervals		
	7Q10 (Annual)	7Q20 (May-Oct)	7Q20 (Nov-Apr)
Acute Ammonia Criterion	3.61	3.61	6.84
Chronic Ammonia Criterion	0.585	0.549	1.32
Acute (one-hour) WLA[a]	9.82	9.76	29.5
Chronic (four-day) WLA	10.1	9.39	43.9
Daily Maximum Permit Limit	9.82	9.76	29.5
Monthly Average Permit Limit	4.90	4.90	14.7

[a] More limiting long-term average than chronic value, consequently permit limitations based on acute WLA.

Table 6. TMDL for ammonia and allocations for background/nonpoint and NPDES discharge based on alternative design conditions.

Load Allocations	NH_3-N (lbs/day)		
	7Q10 (Annual)	7Q20 (May-Oct)	7Q20 (Nov-Apr)
Total Maximum Daily Load (TMDL)	42.6	39.6	182
Nonpoint/Background Load Allocation (LA)	2.51	2.49	4.81
Sumas WTP Waste Load Allocation (WLA)[a]	10.1	10.0	30.2
Unallocated Load	30.0	27.1	147

[a] Load calculated using acute waste load allocation value and WTP design flow

An alternative to only reducing the summer BOD_5 permit limit is also presented in Appendix D. In order to maintain the 8.0 mg/L standard, the alternative scenario requires reducing the proposed summer ammonia standard from 9.76 to 5 mg/L and $CBOD_5$ from 45 to 33 mg/L. Reducing both limits may be a more desirable alternative, because the plant already has both low effluent ammonia and BOD_5 concentrations. Water quality criteria and suggested BOD_5 permit limits based on this analysis are presented in Table 7. Table 8 presents the BOD_5 TMDL and recommended allocations for Sumas River.

The annual and winter TMDL listed in Table 8 were determined by increasing the effluent $CBOD_5$ until the downstream critical dissolved oxygen concentration dropped to 8.0 mg/L. The additional loading was then assigned to the unallocated category. As with ammonia, the unallocated loading can be set aside for future allocations or as a safety factor.

In the design condition modeling described above, there was one noteworthy assumption: upstream BOD_5 is only 2 mg/L. It is common practice to assume a value of ½ the analyte detection limit for parameters below detection limits. However, as discussed in the QA section, the detection limit for BOD_5 was high, and using ½ the detection limit (3 mg/L) in the modeling would leave the river with no assimilative capacity for BOD under the annual or summer design conditions. In other Whatcom County watersheds with agricultural activity, investigators have found instream BOD_5 concentrations to be $\leq$ 2 mg/L (Tetra Tech, Inc. 1989). In addition, Plotnikoff and Michaud (1991) found BOD_5 levels to be $\leq$ 3 mg/L at most monitoring stations in Portage Creek, which like Sumas' watershed, is mostly agriculture. Consequently, 2 mg/L was assumed to be a reasonable upstream BOD_5 concentration.

Table 7. Dissolved oxygen criteria and BOD_5 WLA and suggested permit limits.

Criterion, WLA, or Permit Limits (mg/L)	Critical Flow Intervals			
	7Q10 (Annual)	7Q20 (May-Oct)	7Q20[a] (May-Oct)	7Q20 (Nov-Apr)
Class A Criterion	8.0	8.0	8.0	8.0
Weekly Average	45	19	33	45
Monthly Average	30	13	22	30

[a] Alternative summer permit limits; requires reducing ammonia limit to 5 mg/L.

Table 8. TMDL for BOD_5 and recommended allocations for background/nonpoint and NPDES discharge based on alternative design conditions.

Load Allocations	BOD_5 (lbs/day)			
	7Q10 (Annual)	7Q20 (May-Oct)	7Q20[a] (May-Oct)	7Q20 (Nov-Apr)
Total Maximum Daily Load (TMDL)	204	163	178	1,215
Nonpoint/Background Load Allocation (LA)	144	144	144	275
Sumas WTP Waste Load Allocation (WLA)	46	19	34	46
Unallocated Load	17	0	0	894

[a] Alternative summer allocation; requires reducing ammonia permit limit to 5 mg/L.

Total Residual Chlorine

Chlorine criteria, WLAs, and permit limits were calculated using the same design conditions and assuming chlorine is conservative. Appendix E contains calculated permit limits and WLAs based on EPA (1991). Based on survey effluent measurements, TRC would exceed the proposed daily permit limits under both annual and seasonal design conditions.

The proposed mixing zone regulations and aquatic life criteria allow for a small discharge of chlorine if dilution is adequate. However, on-site measurement of these low values is not practical given the relatively high detection limit of the chlorine test kit used by most plant operators. Despite the measurement limitations, a TMDL and WLA are appropriate for chlorine because it is possible to measure the permit levels if a more sophisticated test is used. Still, these levels probably cannot be achieved without provision of dechlorination. Chlorine criteria, WLAs, and permit limits are presented in Table 9. Table 10 presents the chlorine TMDL and allocations for Sumas River.

As with ammonia, TRC unallocated loads are simply the difference between the TMDL and allocations. Again, the reason for this residual is that the mixing zone requirements limit chlorine discharge, which is less than the total assimilative capacity of the river. Unallocated loading can be set aside for future allocations or as a safety factor.

Table 9. Chlorine criteria, WLA and suggested permit limits.

Criterion, WLA, or Permit Limits (mg/L)	Critical Flow Intervals		
	7Q10 (Annual)	7Q20 (May-Oct)	7Q20 (Nov-Apr)
Acute Chlorine Criterion	0.019	0.019	0.019
Chronic Chlorine Criterion	0.011	0.011	0.011
Acute (one-hour) WLA[a]	0.052	0.052	0.082
Chronic (four-day) WLA	0.202	0.200	0.376
Daily Maximum Permit Limit	0.052	0.052	0.082
Monthly Average Permit Limit	0.026	0.026	0.041

[a] More limiting long-term average than chronic value, consequently permit limitations based on acute WLA.

Table 10. TMDL for TRC and recommended allocations for background/nonpoint and NPDES discharge based on alternative design conditions.

Load Allocations	TRC (lbs/day)		
	7Q10 (Annual)	7Q20 (May-Oct)	7Q20 (Nov-Apr)
Total Maximum Daily Load (TMDL)	0.80	0.79	1.52
Nonpoint/Background Load Allocation (LA)	0.00	0.00	0.00
Sumas WTP Waste Load Allocation (WLA)[a]	0.05	0.05	0.08
Unallocated Load	0.75	0.74	1.44

[a] Load calculated using acute waste load allocation value and WTP design flow.

Fecal Coliform

A mass-balance calculation (fecal coliform modeled as a conservative substance) using the geometric mean of the Jones Road station survey data and effluent fecal coliform permit value (400 fc/100 mL) predicted a downstream fecal coliform concentration of 239 fc/100 mL under annual design conditions, which exceeds the Class A water quality criterion of 100 fc/100 mL. If existing permit limits for fecal coliform are retained in the new permit, nonpoint/background sources would need to be allocated a maximum load of 94 fc/100 mL in order to be within the standard. Even if the effluent is removed from the stream, nonpoint/background bacteria levels will still be 237 fc/100 mL. Therefore, unless nonpoint/background sources of fecal coliform loading are controlled, the stream is unlikely to meet the water quality standard.

SUMMARY AND CONCLUSIONS

- Receiving water to effluent dilution was about 250:1 during the survey, but under 7Q10 and design WTP flows the ratio would drop to 71:1 under annual and summer design conditions. This is less than Ecology guidelines for new treatment works.

- A considerable increase in TSS was seen within the study area. It was most likely due to road construction which occurred during the survey.

- Increased nitrogen concentrations in the Sumas River are due to nitrogen loads from Johnson Creek. The nitrogen levels found in Johnson Creek are most likely due to nonpoint pollution in its drainage, specifically from dairy farming.

- A morning and evening dissolved oxygen survey indicated a strong diurnal change in dissolved oxygen, however, the WTP effluent did not appear to affect river dissolved oxygen under survey conditions.

- All sampling stations upstream of the WTP violated the Class A criterion for fecal coliform concentrations. It is believed that nonpoint sources from agricultural activities are causing the violations.

- Phosphorus concentrations increase in the river due to high concentrations in the WTP effluent.

- Other than phosphorus, the results of the receiving water study do not indicate an impact on Sumas River water quality by the WTP.

TMDL Analyses

- A worst-case analysis based on annual and seasonal design riverflow (7Q10 or 7Q20), WTP flow at design capacity, and effluent quality at permit limits projected water quality criteria violations for TRC under all design conditions, and dissolved oxygen under summer design conditions.

- A simple mass-balance equation for fecal coliform under 7Q10 design conditions, WTP flow at design capacity, and effluent fecal coliform levels at permit levels indicate that nonpoint/background fecal coliform contributions would have to be reduced in order for the Sumas River to meet the Class A water quality standard.

RECOMMENDATIONS

- Increased nitrogen and fecal coliform concentrations in the Sumas River are most likely due to nonpoint pollution upstream of the WTP. Nonpoint sources of fecal coliform must be controlled in order for the river to meet the Class A fecal coliform standard. Sources of nitrogen in the Johnson Creek Watershed should be controlled in order to reduce possible nitrate ground water contamination and reduce nitrogen loads in the Sumas River.

- Dechlorination or an alternative method of disinfection is needed to avoid chlorine toxicity in Sumas River.

- The seasonal WLAs and water quality-based permit limits suggested in this report should be incorporated into the Sumas NPDES permit to prevent water quality violations under critical design conditions of low river flow and WTP build-out.

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APPENDICES

Appendix A. Summary statistics for September ambient monitoring data from 1982-1991 records, Ecology station 01D070 (Huntingdon Bridge, BC).

	Cond. (μmhos/cm)	DO (mg/L)	Fecal Coliform (#/100 mL)	NH3-N (mg/L)	NO2-N+ NO3-N (mg/L)
N OF CASES	10	10	10	8	4
MINIMUM	243	8.0	1	0.030	2.100
MAXIMUM	310	10.5	6400	0.210	2.700
RANGE	67	2.5	6399	0.180	0.600
MEDIAN	291	9.4	180	0.051	2.755

	SRP (mg/L)	pH (S.U.)	DO% Sat.	Temp (°C)	TP (mg/L)
N OF CASES	9	10	10	10	8
MINIMUM	0.040	7.0	74.1	11.4	0.060
MAXIMUM	0.070	7.8	94.2	14.8	0.120
RANGE	0.030	0.8	20.1	3.4	0.060
MEDIAN	0.050	7.6	87.3	12.4	0.091

	TSS (mg/L)	Turb. (NTU)
N OF CASES	8	8
MINIMUM	0.6	2
MAXIMUM	7.0	9
RANGE	6.4	7
MEDIAN	4.5	4

Appendix B. Ammonia Criteria based on temperature and pH design conditions

Calculation Of Un-ionized Ammonia Concentration and Criteria.
Based on EPA Gold Book (EPA 400/5-86-001). Lotus File AMMONIA.WK1

INPUT **

	Annual	Summer	Winter
1. Sample Ambient Temperature (deg C; 0<T<30) ....:	17.5	18.4	12.6
2. Sample Ambient pH (6.5<pH<9.0) ....:	8.20	8.20	7.90
3. Sample Total Ammonia (ug N/L) ....:	35.0	35.0	35.0
4. Acute TCAP (Salmonids present- 20; absent- 25) ....:	20	20	20
5. Chronic TCAP (Salmonids present- 15; absent- 20) ....:	15	15	15

OUTPUT ***

	Annual	Summer	Winter
1. Intermediate Calculations:			
Acute FT ....:	1.19	1.12	1.67
Chronic FT ....:	1.41	1.41	1.67
FPH ....:	1.00	1.00	1.05
RATIO ....:	16	16	16
pKa ....:	9.48	9.45	9.64
Fraction Of Total Ammonia Present As Un-ionized ......:	4.9752%	5.3003%	1.7790%
2. Sample Un-ionized Ammonia Concentration (ug N/L) ....:	1.7	1.9	0.6
3. Un-ionized Ammonia Criteria:			
Acute (1-hour) Un-ionized Ammonia Criterion (ug N/L) .:	179.8	191.4	121.7
Chronic (4-day) Un-ionized Ammonia Criterion (ug N/L) :	29.1	29.1	23.4
4. Total Ammonia Criteria:			
Acute Total Ammonia Criterion (ug N/L) ....:	3,614	3,610	6,843
Chronic Total Ammonia Criterion (ug N/L) ....:	585	549	1,316

****

Appendix C. Total Ammonia Water Quality Based Permits in mg/L
(based on EPA 505/2-90-001. LOTUS Worksheet WQBP-CON.WK1)

INPUT **

	Permit Limits Based On		
	Annual 7Q10	Summer 7Q20	Winter 7Q20
1. Water Quality Standards/Criteria (Concentration)			
Acute (one-hour) Criteria	3.614	3.610	6.843
Chronic (n-day) Criteria	0.585	0.549	1.316
2. Upstream Receiving Water Concentration			
Upstream Concentration for Acute Condition	0.035	0.035	0.035
Upstream Concentration for Chronic Condition	0.035	0.035	0.035
3. Dilution Factors (1/(Effluent Volume Fraction))			
Acute Receiving Water Dilution Factor at Design.........	2.734	2.721	4.321
Chronic Receiving Water Dilution Factor at Design	18.339	18.209	34.208
4. Coefficient of Variation for Effluent Concentration (use 0.6 if data are not available)	0.600	0.600	0.600
5. Number of days (n1) for chronic average (usually four or seven; four is recommended)	4	4	4
6. Number of samples (n2) per month to base permit on	4	4	4

OUTPUT **

	Annual 7Q10	Summer 7Q20	Winter 7Q20
1. Z Statistics			
LTA Derivation (99%tile)	2.326	2.326	2.326
Daily Maximum Permit Limit (99%tile)	2.326	2.326	2.326
Monthly Average Permit Limit (95%tile)	1.645	1.645	1.645
2. Calculated Waste Load Allocations (WLA's)			
Acute (one-hour) WLA	9.820	9.762	29.451
Chronic (n1-day) WLA	10.121	9.394	43.855
3. Back-Calculation of Long Term Averages (LTA's)			
Sigma (same for acute and chronic)	0.5545	0.5545	0.5545
Mu for Acute WLA	0.9946	0.9887	2.0929
Mu-n1 for Chronic WLA	1.6318	1.5573	3.0981
Mu for Chronic WLA	1.5212	1.4466	2.9874
LTA for Acute (one-hour) WLA	3.1529	3.1344	9.4561
LTA for Chronic (n1-day) WLA	5.3383	4.9548	23.1306
Most Limiting LTA (minimum of acute and chronic)	3.1529	3.1344	9.4561
4. Derivation of Permit Limits From Limiting LTA			
Mu for daily maximum permit limit	0.9946	0.9887	2.0929
Mu-n2 for monthly average permit limit	1.1052	1.0994	2.2036
Sigma^2-n for monthly avg permit limit	0.0862	0.0862	0.0862
Daily Maximum Permit Limit	9.820	9.762	29.451
Monthly Average Permit Limit	4.895	4.866	14.680

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Appendix D. Oxygen demand based on design conditions and permit limits.

STREETER-PHELPS ANALYSIS OF CRITICAL DISSOLVED OXYGEN SAG (DOSAG.WK1)

INPUT **

	BOD & NH3 Permit Limits Annual 7Q10	BOD & NH3 Permit Limits Summer 7Q20	BOD & NH3 Permit Limits Summer 7Q20	Lower BOD & NH3 Permit Limits Summer 7Q20	BOD & NH3 Permit Limits Winter 7Q20
1. EFFLUENT CHARACTERISTICS					
Discharge (cfs)	0.19	0.19	0.19	0.19	0.19
CBOD5 (mg/L)	45	45	19	33	45
NBOD (mg/L) (NH3*4.57)............................	44.88	44.61	44.61	22.85	134.59
Dissolved Oxygen (mg/L)	1.85	1.85	1.85	1.85	1.85
Temperature (deg C)	19.3	19.3	19.3	19.3	19.3
2. RECEIVING WATER CHARACTERISTICS					
Upstream Discharge (cfs)	13.33	13.23	13.23	13.23	25.53
Upstream CBOD5 (mg/L)	2.0	2.0	2.0	2.0	2.0
Upstream NBOD (mg/L)	0.16	0.16	0.16	0.16	0.16
Upstream Dissolved Oxygen (mg/L)	8.44	8.29	8.29	8.29	9.41
Upstream Temperature (deg C)	17.5	18.4	18.4	18.4	12.6
Elevation (ft NGVD)	40	40	40	40	40
Downstream Average Channel Slope (ft/ft)	0.000613	0.000613	0.000613	0.000613	0.000613
Downstream Average Channel Depth (ft)	1.33	1.33	1.33	1.33	1.33
Downstream Average Channel Velocity (fps)	0.354	0.354	0.354	0.354	0.354
3. REAERATION RATE (Base e) AT 20 deg C (day^-1)	6.36	6.36	6.36	6.36	6.36

Reference	Applic. Vel (fps)	Applic. Dep (ft)	Suggest Value	Suggest Value	Suggest Value	Suggest Value	Suggest Value
Churchill	1.5 - 6	2 - 50	2.63	2.63	2.63	2.63	2.63
O'Connor and Dobbins	.1 - 1.5	2 - 50	5.03	5.03	5.03	5.03	5.03
Owens	.1 - 6	1 - 2	6.36	6.36	6.36	6.36	6.36
Tsivoglou-Wallace	.1 - 6	.1 - 2	0.90	0.90	0.90	0.90	0.90

4. BOD DECAY RATE (Base e) AT 20 deg C (day^-1)	2.88	2.89	2.89	2.89	2.10

Reference	Suggest Value	Suggest Value	Suggest Value	Suggest Value	Suggest Value
Wright and McDonnell, 1979	2.88	2.89	2.89	2.89	2.10

OUTPUT **

1. INITIAL MIXED RIVER CONDITION					
CBOD5 (mg/L)	2.6	2.6	2.2	2.4	2.3
NBOD (mg/L)	0.8	0.8	0.8	0.5	1.2
Dissolved Oxygen (mg/L)	8.3	8.2	8.2	8.2	9.4
Temperature (deg C)	17.5	18.4	18.4	18.4	12.6
2. TEMPERATURE ADJUSTED RATE CONSTANTS (Base e)					
Reaeration (day^-1)	6.00	6.13	6.13	6.13	5.34
BOD Decay (day^-1)	2.57	2.69	2.69	2.69	1.50
3. CALCULATED INITIAL ULTIMATE CBODU AND TOTAL BODU					
Initial Mixed CBODU (mg/L)	3.8	3.8	3.3	3.6	3.4
Initial Mixed Total BODU (CBODU + NBOD, mg/L)	4.6	4.6	4.1	4.1	4.6
4. INITIAL DISSOLVED OXYGEN DEFICIT					
Saturation Dissolved Oxygen (mg/L)	9.48	9.31	9.31	9.31	10.57
Initial Deficit (mg/L)	1.14	1.11	1.11	1.11	1.21
5. TRAVEL TIME TO CRITICAL DO CONCENTRATION (days).....	0.13	0.13	0.12	0.11	0.03
6. DISTANCE TO CRITICAL DO CONCENTRATION (miles).......	0.76	0.77	0.67	0.66	0.18
7. CRITICAL DO DEFICIT (mg/L)..........................	1.41	1.42	1.31	1.31	1.22
8. CRITICAL DO CONCENTRATION (mg/L)....................	8.07	7.89	8.00	8.00	9.35

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Appendix D. Oxygen demand based on design conditions and permit limits.

STREETER-PHELPS ANALYSIS OF CRITICAL DISSOLVED OXYGEN SAG (DOSAG.WK1)

INPUT **

	BOD & NH3 Permit Limits Annual 7Q10	BOD & NH3 Permit Limits Summer 7Q20	BOD & NH3 Permit Limits Summer 7Q20	Lower BOD & NH3 Permit Limits Summer 7Q20	BOD & NH3 Permit Limits Winter 7Q20
1. EFFLUENT CHARACTERISTICS					
Discharge (cfs)	0.19	0.19	0.19	0.19	0.19
CBOD5 (mg/L)	45	45	19	33	45
NBOD (mg/L) (NH3*4.57)	44.88	44.61	44.61	22.85	134.59
Dissolved Oxygen (mg/L)	1.85	1.85	1.85	1.85	1.85
Temperature (deg C)	19.3	19.3	19.3	19.3	19.3
2. RECEIVING WATER CHARACTERISTICS					
Upstream Discharge (cfs)	13.33	13.23	13.23	13.23	25.53
Upstream CBOD5 (mg/L)	2.0	2.0	2.0	2.0	2.0
Upstream NBOD (mg/L)	0.16	0.16	0.16	0.16	0.16
Upstream Dissolved Oxygen (mg/L)	8.44	8.29	8.29	8.29	9.41
Upstream Temperature (deg C)	17.5	18.4	18.4	18.4	12.6
Elevation (ft NGVD)	40	40	40	40	40
Downstream Average Channel Slope (ft/ft)	0.000613	0.000613	0.000613	0.000613	0.000613
Downstream Average Channel Depth (ft)	1.33	1.33	1.33	1.33	1.33
Downstream Average Channel Velocity (fps)	0.354	0.354	0.354	0.354	0.354
3. REAERATION RATE (Base e) AT 20 deg C (day^-1)	6.36	6.36	6.36	6.36	6.36

Reference	Applic. Vel (fps)	Applic. Dep (ft)	Suggest Value	Suggest Value	Suggest Value	Suggest Value	Suggest Value
Churchill	1.5 - 6	2 - 50	2.63	2.63	2.63	2.63	2.63
O'Connor and Dobbins	.1 - 1.5	2 - 50	5.03	5.03	5.03	5.03	5.03
Owens	.1 - 6	1 - 2	6.36	6.36	6.36	6.36	6.36
Tsivoglou-Wallace	.1 - 6	.1 - 2	0.90	0.90	0.90	0.90	0.90

4. BOD DECAY RATE (Base e) AT 20 deg C (day^-1)	2.88	2.89	2.89	2.89	2.10
Reference	Suggest Value	Suggest Value	Suggest Value	Suggest Value	Suggest Value
Wright and McDonnell, 1979	2.88	2.89	2.89	2.89	2.10

OUTPUT ***

1. INITIAL MIXED RIVER CONDITION					
CBOD5 (mg/L)	2.6	2.6	2.2	2.4	2.3
NBOD (mg/L)	0.8	0.8	0.8	0.5	1.2
Dissolved Oxygen (mg/L)	8.3	8.2	8.2	8.2	9.4
Temperature (deg C)	17.5	18.4	18.4	18.4	12.6
2. TEMPERATURE ADJUSTED RATE CONSTANTS (Base e)					
Reaeration (day^-1)	6.00	6.13	6.13	6.13	5.34
BOD Decay (day^-1)	2.57	2.69	2.69	2.69	1.50
3. CALCULATED INITIAL ULTIMATE CBODU AND TOTAL BODU					
Initial Mixed CBODU (mg/L)	3.8	3.8	3.3	3.6	3.4
Initial Mixed Total BODU (CBODU + NBOD, mg/L)	4.6	4.6	4.1	4.1	4.6
4. INITIAL DISSOLVED OXYGEN DEFICIT					
Saturation Dissolved Oxygen (mg/L)	9.48	9.31	9.31	9.31	10.57
Initial Deficit (mg/L)	1.14	1.11	1.11	1.11	1.21
5. TRAVEL TIME TO CRITICAL DO CONCENTRATION (days)	0.13	0.13	0.12	0.11	0.03
6. DISTANCE TO CRITICAL DO CONCENTRATION (miles)	0.76	0.77	0.67	0.66	0.18
7. CRITICAL DO DEFICIT (mg/L)	1.41	1.42	1.31	1.31	1.22
8. CRITICAL DO CONCENTRATION (mg/L)	8.07	7.89	8.00	8.00	9.35

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Appendix E. Total Residual Chlorine Water Quality Based Permits in mg/L
(based on EPA 505/2-90-001. LOTUS Worksheet WQBP-CON.WK1)

INPUT **

	Permit Limits Based On		
	Annual 7Q10	Summer 7Q20	Winter 7Q
1. Water Quality Standards/Criteria (Concentration)			
Acute (one-hour) Criteria	0.019	0.019	0.019
Chronic (n-day) Criteria	0.011	0.011	0.011
2. Upstream Receiving Water Concentration			
Upstream Concentration for Acute Condition	0.000	0.000	0.000
Upstream Concentration for Chronic Condition	0.000	0.000	0.000
3. Dilution Factors (1/{Effluent Volume Fraction})			
Acute Receiving Water Dilution Factor at Design.........	2.734	2.721	4.321
Chronic Receiving Water Dilution Factor at Design	18.339	18.209	34.208
4. Coefficient of Variation for Effluent Concentration (use 0.6 if data are not available)	0.600	0.600	0.600
5. Number of days (n1) for chronic average (usually four or seven; four is recommended)	4	4	4
6. Number of samples (n2) per month to base permit on	4	4	4

OUTPUT **

1. Z Statistics			
LTA Derivation (99%tile)	2.326	2.326	2.326
Daily Maximum Permit Limit (99%tile)	2.326	2.326	2.326
Monthly Average Permit Limit (95%tile)	1.645	1.645	1.645
2. Calculated Waste Load Allocations (WLA's)			
Acute (one-hour) WLA	0.052	0.052	0.082
Chronic (n1-day) WLA	0.202	0.200	0.376
3. Back-Calculation of Long Term Averages (LTA's)			
Sigma (same for acute and chronic)	0.5545	0.5545	0.5545
Mu for Acute WLA	-4.2473	-4.2521	-3.7896
Mu-n1 for Chronic WLA	-2.2837	-2.2908	-1.6602
Mu for Chronic WLA	-2.3943	-2.4014	-1.7709
LTA for Acute (one-hour) WLA	0.0167	0.0166	0.0264
LTA for Chronic (n1-day) WLA	0.1064	0.1056	0.1985
Most Limiting LTA (minimum of acute and chronic)	0.0167	0.0166	0.0264
4. Derivation of Permit Limits From Limiting LTA			
Mu for daily maximum permit limit	-4.2473	-4.2521	-3.7896
Mu-n2 for monthly average permit limit	-4.1367	-4.1415	-3.6790
Sigma^2-n for monthly avg permit limit	0.0862	0.0862	0.0862
Daily Maximum Permit Limit	0.052	0.052	0.082
Monthly Average Permit Limit	0.026	0.026	0.041

****