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WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

A WATER QUALITY BASED EVALUATION OF SPOKANE ADVANCED WASTEWATER TREATMENT PLANT EFFLUENT DILUTION AND RECEIVING WATER QUALITY DURING SEPTEMBER 20-22, 1988

by
Barbara Carey

Washington State Department of Ecology
Environmental Investigations and Laboratory Services Program
Surface Water Investigations Section
Olympia, Washington 98504

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ABSTRACT

On September 20-22, 1988, a receiving water study was conducted at the Spokane Advanced Wastewater Treatment Plant (AWT) on the Spokane River. The objectives were: 1) to characterize mixing of the effluent plume and 2) to make recommendations for future mixing zone boundaries. Mixing was incomplete at 300 and 1,000 feet downstream of the discharge when dilution was 20:1. Mixing was complete below the riffle area 2,600 feet downstream. A mixing zone boundary is recommended at 300 feet, despite incomplete mixing. Reduced discharge limits are recommended for ammonia, total residual chlorine and fecal coliform bacteria. Further effluent temperature and metals sampling is recommended to refine discharge limits.

INTRODUCTION

The purpose of this study was to define the mixing characteristics of the Spokane Advanced Wastewater Treatment Plant (AWT) effluent plume under low river flow and to make mixing zone recommendations for renewal of the National Pollutant Discharge Elimination System (NPDES) permit in 1991. In addition, the Ecology Eastern Regional Office (ERO) requested an evaluation of receiving water quality following recently implemented chlorine removal and monthly summer ammonia discharge limits.

BACKGROUND

Site Description

The Spokane AWT discharges into the Spokane River in a free-flowing area (RM 67.4) about three miles above the Nine-Mile Dam impoundment (Figure 1). This stretch of river is rated Class A as defined by the Water Quality Standards for Washington (Ecology, 1988a). Class A waters must meet or exceed the conditions required for all recognized beneficial uses. The Riverside State Park surrounds the AWT and extends along the river for several miles downstream of the AWT. [See Bernhardt (1985) for details on beneficial uses.]

The Spokane AWT is designed to treat a monthly average of 44 million gallons per day (MGD), although historically summer flows have rarely exceeded 32 MGD. Treated wastewater enters the river on the right bank as a turbulent surface discharge via a steep, 30-foot long, rock-lined concrete channel. Significant aeration is provided by the channel before the effluent reaches the river.

Mixing Zone Guidance

Three Ecology documents describe characteristics of mixing zones for permitted discharges:

1. Washington Water Quality Standards (Chapter 173-201 WAC; Ecology, (1988a)
2. Ecology Criteria for Sewage Works (Ecology, 1985)
3. Ecology Draft Mixing Zone Guidelines (Ecology, 1989a)

Washington's Water Quality Standards (Chapter 173-201 WAC) state that water quality criteria (or standards) do not apply in the mixing (dilution) zone. However, mixing zones should be limited so that they do not diminish aesthetic values or other beneficial uses below the Zone of Initial Dilution (ZID).

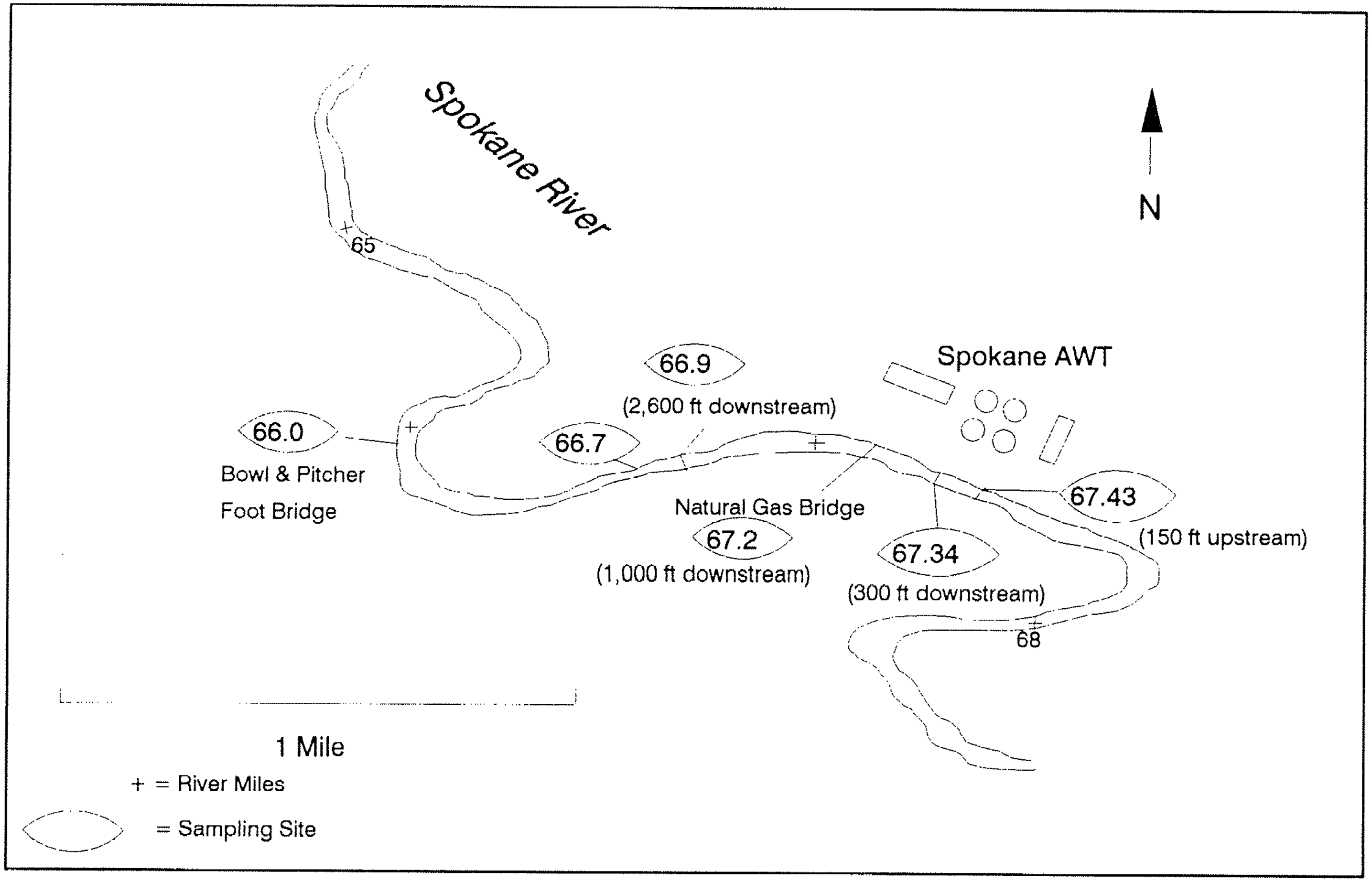

Figure 1. Map of sampling area showing sampling sites as river miles. Each sampling site is a transect perpendicular to the river except 66.7 which is a grab sampling site near the right bank.

Ecology's Criteria for Sewage Works (Ecology, 1985) provides more detailed guidelines for mixing zone allowances. For instance, mixing zone boundaries should not encompass more than 15 percent of the stream width or more than 15 percent of the volume. The upper limit of the mixing zone should be one foot below the water surface, while the length from the center line of the diffuser (if a diffuser is present) should not exceed 300 feet. In addition, the mixing zone should not extend to the shoreline.

Ecology's Water Quality Program is developing additional guidelines for establishing mixing zones. According to the draft guidelines, mixing zones should not be substituted for pollutant removal which could be accomplished by pollutant reduction, recycling, or reasonable levels of treatment (Ecology, 1989a). Mixing zones should also minimize deleterious effects on the biological community within the boundaries and avoid adverse effects on communities beyond the mixing zone. The draft guidelines state that the mixing zone should not affect other designated beneficial uses of the receiving water outside the zone nor threaten public health. In addition, the mixing zone should be less than the total stream width to allow for free passage of fish and other aquatic organisms.

Spokane's NPDES permit (No. WA-002447-3) does not include a mixing zone description. However, Bernhardt (1985) found that effluent mixing does not meet several of the Ecology (1985) requirements during summer low flow, although the point where mixing is complete was not determined.

Chlorine and ammonia discharge limits have been added to the NPDES permit since the Bernhardt (1985) study (Table 1). Chlorine is now removed by a sulfur dioxide process, while extended aeration is used for ammonia removal during the summer.

METHODS

Study methods are divided into two categories: mixing analysis techniques and receiving water quality evaluation techniques. These are described below.

Field work was conducted on September 20-22, 1988, by Barbara Carey and Lynn Singleton of Environmental Investigations and Laboratory Services (EILS) Surface Water Investigations Section and Laura Chern of EILS Toxics Investigations and Ground Water Monitoring Section. The study was coordinated with a simultaneous Class II study of the AWT conducted by EILS Compliance Monitoring Section (Hallinan, 1989).

Dilution Analysis

Conductivity and chloride were used as effluent tracers to observe mixing of the discharge plume. Specific conductance was measured in the field on September 21, 1988, above and below the discharge. Four transects perpendicular to the river flow were chosen: 150 feet upstream of the discharge, and downstream at 300, 1,000, and 2,600 feet (Figure 1). Conductivity was measured at 30-56 locations along each transect.

Table 1. Current Spokane AWT NPDES permit limits. The permit, No. WA-002447-3, expires September 30, 1991.

S1. EFFLUENT LIMITATIONS

a. Main Plant Effluent Discharge at Outfall 005A.

The monthly average quantity of effluent discharge shall not exceed 44 mgd.

After issuance date, the permittee is authorized to discharge subject to meeting the following limitations:

Parameter	EFFLUENT LIMITATIONS Monthly Average		Weekly Average	
Biochemical Oxygen Demand* (5 day)	30 mg/L,	10,500 lb/day	45 mg/L,	15,750 lb/day
Total Suspended Solids*	30 mg/L,	8,775 lb/day	45 mg/L,	13,162 lb/day
Fecal Coliform Bacteria	200/100 mL		400/100 mL	

Total Residual Chlorine shall not exceed 0.1 mg/L

pH shall not be outside the range 6.0 to 9.0

The monthly and weekly averages for BOD_5 and suspended solids are based on the arithmetic mean of the samples taken. The averages for fecal coliform are based on the geometric mean of the samples taken.

*The monthly average effluent concentration for BOD_5 and suspended solids shall not exceed 30 mg/L or 15 percent of the respective influent concentrations, whichever is more stringent.

Total Phosphorus (as P) The monthly average effluent total phosphorus (as P) concentration shall not exceed 15.0% of the monthly average influent total phosphorus (as P) concentration. The results shall be reported as percentage removal.

The maximum daily discharge shall not exceed 377 pounds/day of total phosphorus (as P). The monthly average discharge shall not exceed 275 pounds/day of total phosphorus (as P).

During any 24-hour period that the total daily flow is greater than 50 MGD, the effluent total phosphorus (as P) concentration shall not exceed 0.6 mg/L when influent total phosphorus (as P) concentration is 4.0 mg/L or less. The data for phosphorus removal for those days when the daily flow exceeds 50 MGD shall be excluded from monthly averages.

Chemical phosphorus removal to achieve the above listed effluent total phosphorus (as P) limitations shall be in effect during a variable period each year. Under no circumstance shall the chemical phosphorus removal commence later than June 1, or terminate earlier than October 15. The variable spring initiation date for chemical phosphorus removal shall be in accordance with the methodology developed by Mires and Soltero, EWU, 1983a. The variable fall termination date for chemical phosphorus removal shall be in accordance with the methodology developed by Mires and Soltero, EWU, 1983b.

Appearing as Appendix 1 to this Permit (Page 17) is the procedural guideline for determining the spring initiation and fall termination date for chemical phosphorus removal.

Table 1. (continued)

Total Phosphorus (as P) (continued)	The department retains the right to reopen this permit should applicable water quality studies and/or other information available indicate that these phosphorus limitation conditions are not maintaining acceptable water quality in Long Lake.

	EFFLUENT LIMITATIONS Weekly Average
Total Ammonia (as N)	no limitation** (November 1 - June 30)
	5,000 lb/day** (July 1 - July 31)
	2,100 lb/day** (August 1 - August 31)
	2,700 lb/day** (September 1 - September 30)
	5,000 lb/day** (October 1 - October 31)

**During the period July 1 through October 31, the daily maximum discharge of total ammonia shall not exceed 5,000 lb/day.

b. Excess Storm Water Effluent Discharge at Outfall 005B.

Flow from this discharge point to the Spokane River shall be measured.

After issuance date, the permittee is authorized to discharge storm water subject to meeting the following limitations:

	EFFLUENT LIMITATIONS	
Parameter	Monthly Average	Weekly Average
Fecal coliform bacteria	200/100 mL	400/100 mL

Total residual chlorine shall be maintained which is sufficient to attain the fecal coliform limits specified above. Chlorine concentrations in excess of that necessary to reliably achieve these limits should be avoided.

The excess storm water treatment facility shall be used for the retention of wastewater to the maximum extent practical. Stored wastewater shall be pumped to the secondary treatment facilities as the flow conditions allow.

c. Main Plant Emergency Bypass at Outfall 004

No discharge is authorized from this outfall except as specifically permitted in General Condition G 5.

Transect measurements were made by stretching a steel cable across the river and clamping it to the oar locks of a row boat. This allowed movement perpendicular to the river flow for sample collection and field measurements. A YSI Model 33 specific conductance/temperature meter was used to measure temperature and conductance at 10-50-foot intervals across the river and 0.5 foot depth intervals. Water quality parameters were sampled at the surface at three sites along each transect, designated Right Bank, Middle, and Left Bank. A bottom sample for water quality parameters was also collected midstream at the 300-foot transect. Table 2 summarizes the sampling data collected.

Specific conductance and chloride samples were also collected at three points along each transect for laboratory analysis. Laboratory conductivity results were used to correct for field instrument drift which increased over the course of the day (Appendix A).

In addition, three effluent grab samples for conductance and two for chloride were collected during the day.

Evaluation of Receiving Water Quality

Water quality samples were collected on September 20-22, 1988, at the sites shown in Figure 1. Although chlorine and ammonia were of primary interest, other constituents were also sampled at each station (Table 2). Temperature and pH were measured in the field using a Beckman Model 21 pH meter and thermometer on September 20 and 22. On September 21, temperature was measured with the YSI specific conductance/ temperature probe. Samples requiring laboratory analysis were stored on ice and transported to the Ecology/EPA Laboratory in Manchester within 24 hours. Laboratory analyses were performed according to either EPA (1983) or APHA, *et al.* (1985). Effluent samples collected as part of the Class II were collected and analyzed according to the same methods as the receiving water samples. However, effluent total residual chlorine (TRC) results were taken from the chlorine analyzer at the AWT, since concentrations were below the DPD field kit detection limit (0.1 mg/L).

Precipitation

The largest rainstorm of the 1988 summer season occurred in the Spokane area on September 19, the day before the survey began. Precipitation at the Spokane Airport was 0.77 inches on September 19, followed by 0.02 inches on September 20 (U.S. Weather Service, 1988). Previous to this storm, rainfall which is typically slight during the summer was below normal.

Table 2. Sampling schedule for the Spokane River study, September 20-22, 1988.

River Mile	Sampling Site*	Date	Time	Temp	pH	Cond (lab)	Cond (field)	BOD	COD	NH_3	NO_3+ NO_2	Tot P	Cl	TS	TNVS	TSS	NVSS	Fecal	TRC
67.43	Control-RB	9/20	1515	X	X	X	X			X	X	X	X					X	
		9/21	950	X	X	X	X			X	X	X	X						
67.43	Control-Mid	9/21	1010	X	X	X	X			X	X	X	X	X	X	X	X		
67.43	Control-LB	9/21	1030	X	X	X	X			X	X	X	X						
	Effluent grabs**	9/20	1520	X	X		X		X	X	X	X	X			X		X	X
		9/21	0935	X	X		X		X	X	X	X	X			X		X	X
		9/21	1350	X	X		X		X	X	X	X	X			X		X	X
	CSO Effluent Grab**	9/20	1545	X	X		X											X	X
67.34	300 ft-RB	9/21	1210	X	X	X	X			X	X	X	X					X	
67.34	300 ft-Mid-S	9/21	1230	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
67.34	300 ft-Mid-B	9/21	1245	X	X	X	X			X	X	X	X						
67.34	300 ft-LB	9/21	1310	X	X	X	X			X	X	X	X					X	
67.2	Gas Br-RB	9/20	1645	X	X		X									X			
		9/21	1520	X	X	X		X	X	X	X	X	X			X		X	
67.2	Gas Br-Mid	9/20	1635	X	X		X	X	X	X	X	X	X	X	X	X	X	X	
		9/21	1540	X	X	X	X			X	X	X	X			X		X	
67.2	Gas Br-LB	9/20	1620	X	X		X									X			
		9/21	1600	X	X	X	X			X	X	X	X			X		X	
66.9	Mix-RB	9/21	1720	X	X	X	X			X	X	X	X						
66.9	Mix-Mid	9/21	1750	X	X	X	X		X	X	X	X	X						
66.9	Mix-LB	9/21	1820	X	X	X	X			X	X	X	X						
66.7	Upper B&P Park	9/20	1745	X	X		X			X	X	X	X			X		X	
66.0	Bowl & Pitcher Bridge-RB	9/22	0910	X	X	X	X		X	X	X	X	X						
		9/20	1800	X	X		X			X	X	X	X						
	B&P Br-Mid	9/20	1810	X	X		X			X	X	X	X						
		9/22		X	X	X	X			X	X	X	X						
	B&P Br-LB	9/22		X	X	X	X			X	X	X	X						

* RB = Right Bank; Mid = Midstream; LB = Left Bank

** AWT samples collected by EILS Compliance Investigation Section

RESULTS

Dilution Analysis

Despite the large rainstorm preceding the dilution study, Spokane River flow below the AWT on September 20-22, 1988, (1,255 cfs) approached the 7Q10 low flow (1,160 cfs). Flow upstream of the AWT was calculated as the sum of: the upstream flow at the USGS City of Spokane gage (#12422500); flow at the USGS Hangman Creek mouth station (#12424000); and estimated ground water contribution (200 cfs) (Table 3). The dilution ratio during the survey, 20:1, was slightly higher than that under the maximum average weekly design conditions (17:1) but lower than the typical summer low flow conditions (23:1) (Table 3).

Table 3. Comparison of Spokane River flow at the Spokane AWT plant (RM 67.4) under 7Q10 design conditions and on 9/21/88.

Location	Flows (cfs) 7Q10 (44 MGD)	7Q10 (32 MGD)	9/21/88 (41.3 MGD)
Spokane River at Spokane (USGS gage)	888	888	990
Hangman Creek at Spokane (USGS gage)	4	4	2.6
Ground Water Inflow*	200	200	200
Spokane AWT flow	68	50	64
TOTAL	1,160	1,142	1,256.6
Dilution ratio	17:1	23:1	20:1

(upstream flow+ AWT flow/AWT flow)

* Average of two estimates for ground water inflow between the City of Spokane and the Seven Mile Bridge (RM 61.9) (Broom, 1951; Harper Owes, 1985).

Effluent was not completely mixed at 300 feet nor at 1,000 feet downstream of the discharge, similar to conditions observed previously (Bernhardt, 1985). During the current study, both conductivity and chloride concentrations indicated complete mixing at 2,600 feet. The area where effluent appeared to be mixed is directly below an extensive riffle area.

Mixing at 300 feet (RM 67.34)

Based on conductance results, the effluent plume extended across 55 percent (80 feet) of the river width 300 feet downstream of the discharge (Figure 2). The extent of the plume exceeds the recommended 15 percent of river width, the one foot depth limit and the prohibition of unmixed effluent at the stream bank (Ecology, 1985). Eighty feet from the right bank the percent effluent was about 7.0 percent (+/-0.5) using the mean percent effluent for conductance and chloride obtained from the following equation (Gilliom and Patmont, 1982):

$$\%\ \text{Effluent} = \frac{{}^{C}\text{measured} - {}^{C}\text{background}}{{}^{C}\text{effluent} - {}^{C}\text{background}} \times 100$$

where ^{C}background = Conductivity or Chloride measured at 150 upstream of the discharge.

^{C}effluent = Mean of effluent measurements taken between 9:35 and 16:30 (Conductivity = 597 umhos/cm, s = 93; Chloride = 60.5 mg/L, s = 9.2)

^{C}measured = Conductivity or Chloride at measuring points along transects

Variability of conductivity and chloride, both from natural and measurement variability, results in a combined or propagated variability for the resulting percent effluent estimate. An analysis of the combined error for the 300-foot, mid-channel surface and bottom water samples was evaluated using a technique described in Appendix C.

The standard error (s_E) for the estimate of percent effluent was 1.6% using chloride and 1.5% using conductance at 300 feet mid-channel. Field conductance values at other sites measured at 0.5-foot depth intervals were within a range similar to those at the 300-foot mid-channel site. Therefore, variance for other sites was assumed to be similar to the s_E above. Replicates and poolable values for chloride were not available at other sites. Therefore, this error analysis could not be used for chloride estimates of percent effluent at other sites.

The error analysis above relates only to the set of measurements obtained on September 21, 1988. Variability over a longer period of time and under different effluent conditions could be significantly different.

Mixing at 1,000 feet (RM 67.2)

Mixing was incomplete 1,000 feet downstream of the AWT discharge at the "Natural Gas Foot Bridge" (Figure 3). The plume extended across the entire width of the river, although the percent effluent was much higher on the right bank (10.8% at 45 feet from the right bank) than on the left bank (4.0% at 135 feet from the right bank).

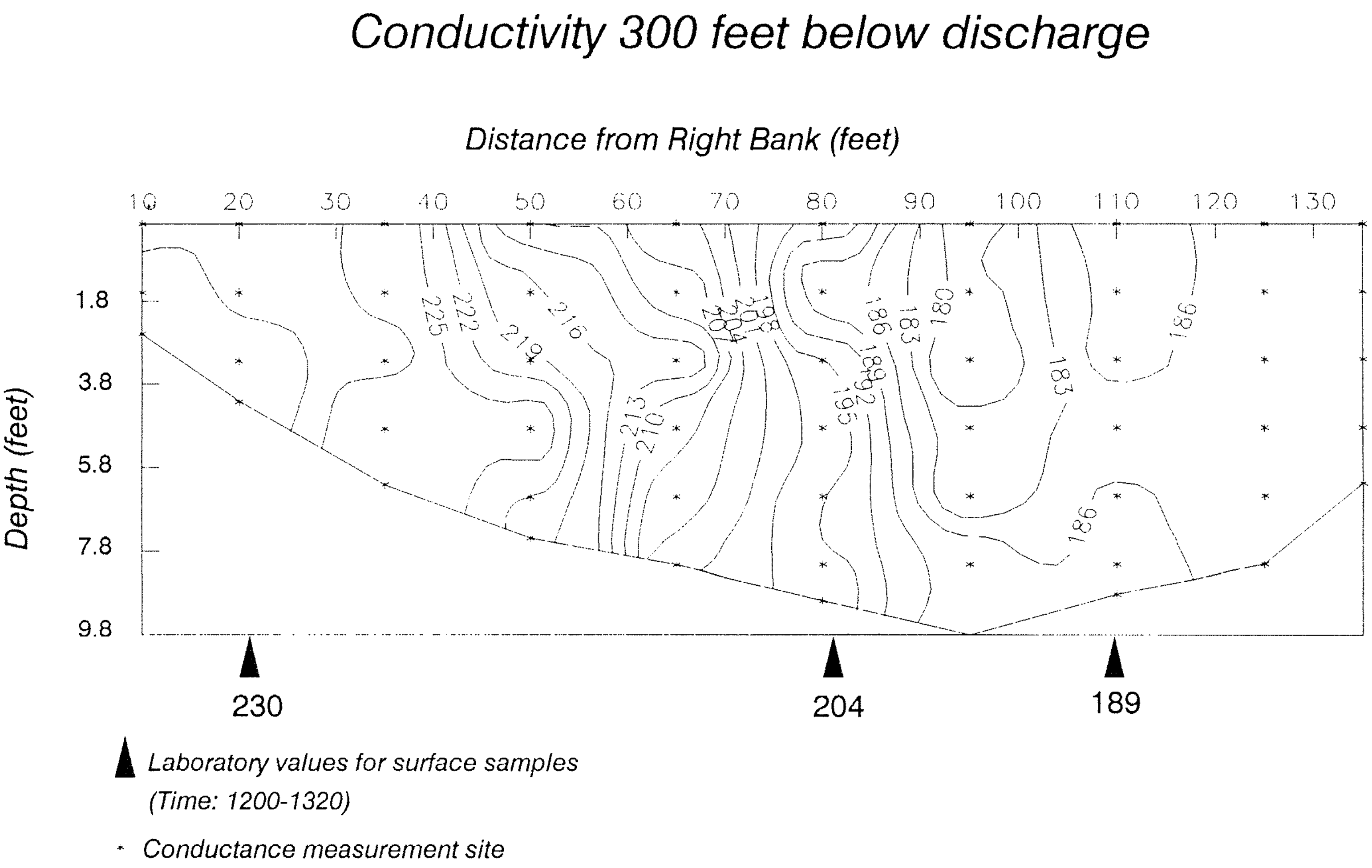

Figure 2. Specific conductance contours for the transect 300 feet downstream of the AWT discharge (RM 67.34) on September 21, 1988.

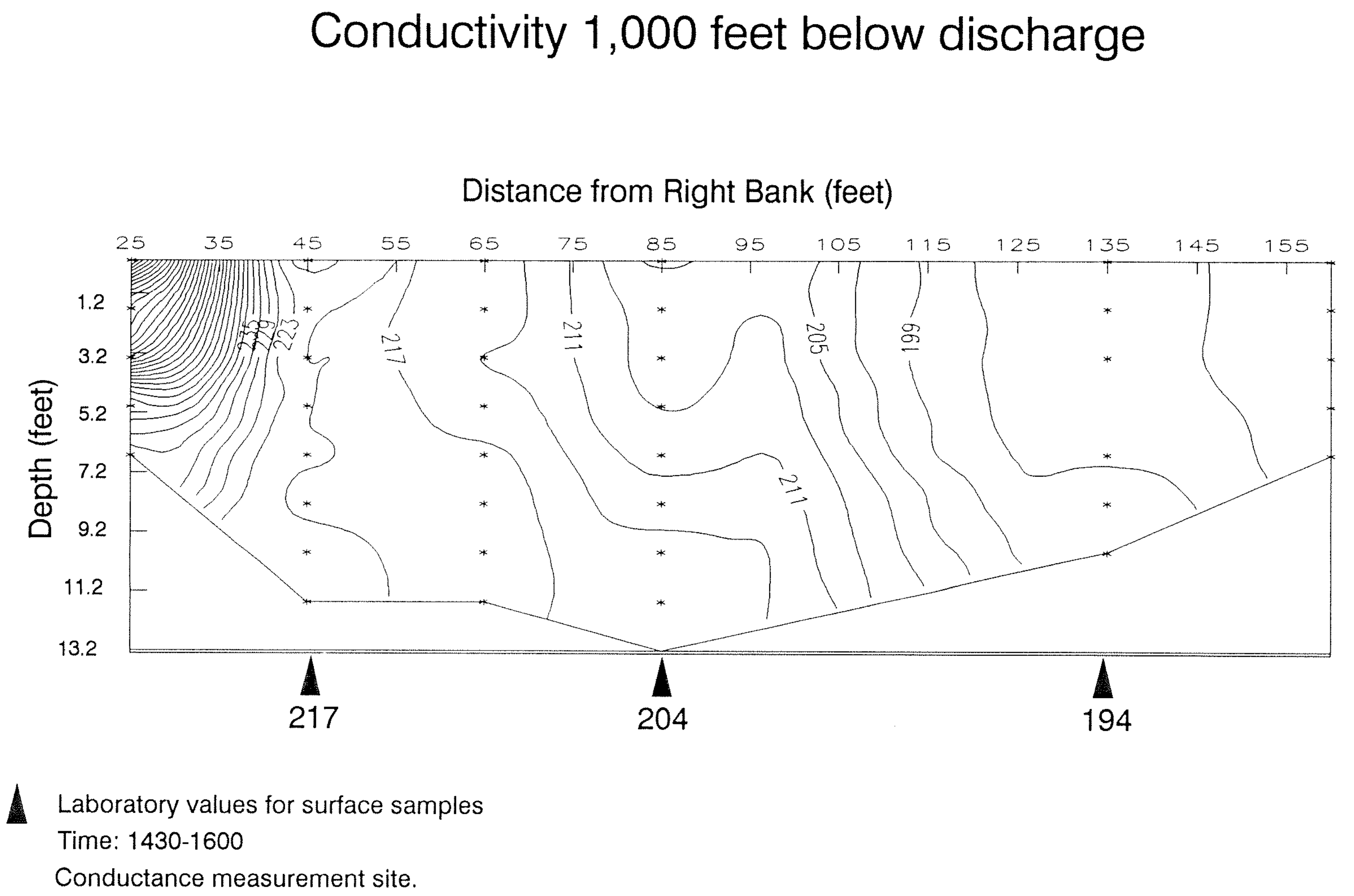

Figure 3. Specific conductance contours for the transect 1,000 feet downstream of the AWT discharge (RM 67.2) on September 21, 1988.

The high conductance values 25 feet from the right bank are open to question, since field readings were relatively unstable. On the other hand, effluent conductance variation also varied substantially during the day (490 - 660 umhos/cm) and may explain high values near the right bank.

Bernhardt (1985) obtained similar results at this location in August 1982, although the maximum percent effluent 20 feet from the right bank was 9% using conductance as a tracer. The lower percent effluent in 1982 may be at least partly due to higher dilution, 30:1 compared to 20:1 during the 1988 survey.

Mixing at 2,600 feet (RM 66.9)

Mixing was fairly complete 2,600 feet below the discharge, immediately below a riffle that extends several hundred feet (Figure 4).

The theoretical mass balance estimate and actual mixed conductivity were within 1.5%; chloride theoretical and actual concentrations within 12%. The following equation was used to calculate mixed river conductivity and chloride concentrations:

$$\text{Upstream Load} + \text{Effluent Load} = \text{Mixed Load}$$

Estimated mixed conductivity was 202 umhos/cm, while the mixed zone mean was 205 umhos/cm. The estimated mixed chloride concentration, 5.0 mg/L, was also close to the mean measured in the mixed zone, 5.6 mg/L.

Upstream mixing (RM 67.43)

Conductance measurements indicate that the WTP effluent dispersed at least 150 feet upstream of the discharge to about 10 feet from the right bank (Figure 5). Conductivity and chloride levels beyond the nearshore area (15 feet from the right bank to the left bank) were similar to previously reported background levels and considered representative of current background levels. Additional stormwater discharges above the study area could possibly have contributed to elevated tracer levels along the right bank, although observed upstream water and foam movement suggest mainly treatment plant influence.

Receiving Water Quality

Discharge from the AWT met all permit requirements during the survey except fecal coliform bacteria (FC) (Table 4). Ammonia, TRC and FC results are discussed below. Permit limits for these constituents are also evaluated in light of the dilution analysis.

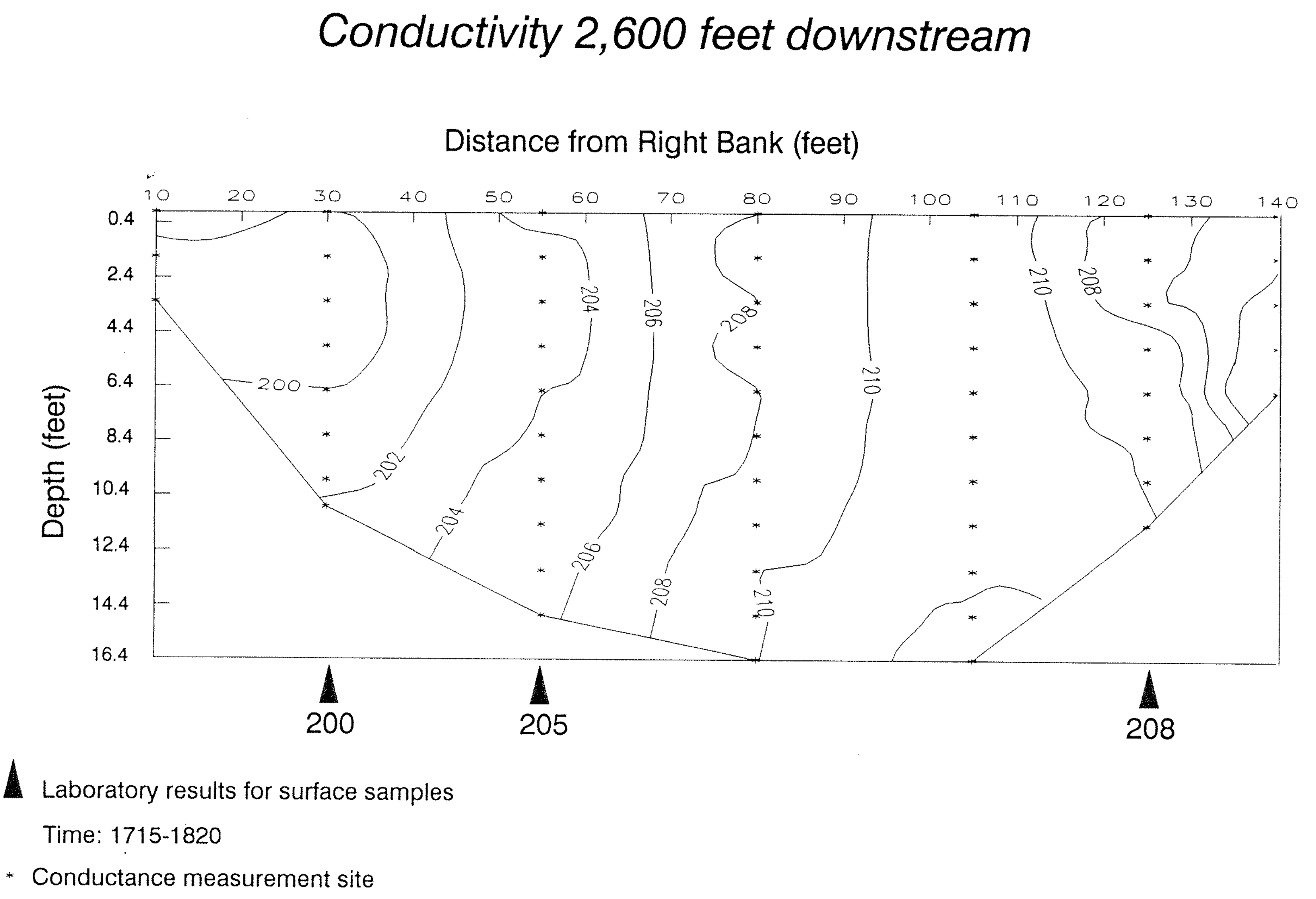

Figure 4. Specific conductance contours for the transect 2,600 feet downstream of the AWT discharge (RM 66.9) on September 21, 1988.

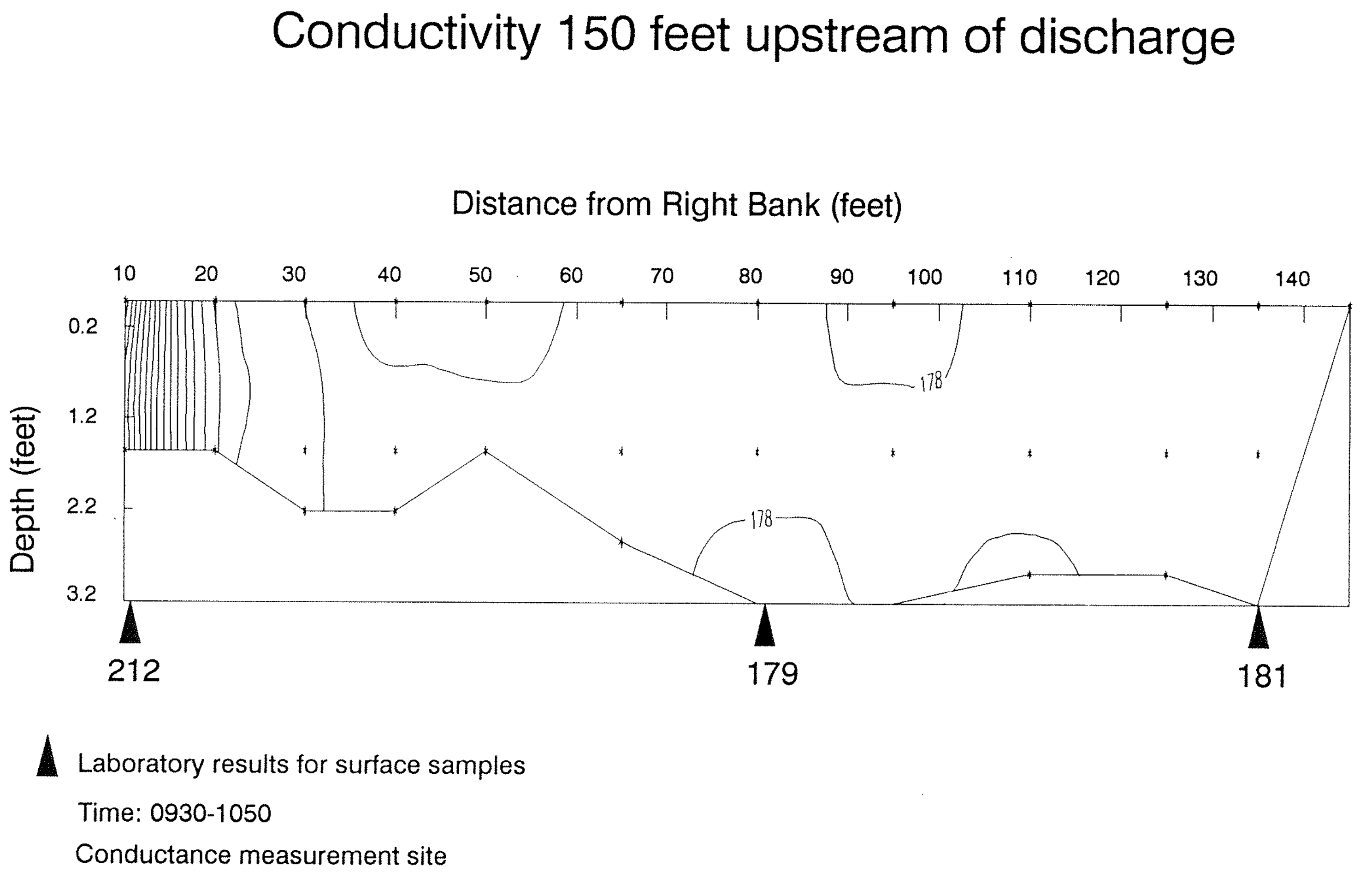

Figure 5. Specific conductance contours for the transect 150 feet upstream of the AWT discharge (RM 67.43) on September 21, 1988.

Table 4. Results of dilution and receiving water samples collected in the Spokane River in the vicinity of the Spokane AWT on September 20-22, 1988.

River Mile	Station	Date	Time	Temperature (°C)	pH	Specific Conduc (Lab) umhos/cm	Specific Conduc (Field) (umhos/cm)***	BOD_5 (mg/L)	COD (mg/L)	Ammonia-N (mg/L)	Un-ionized Ammonia-N (mg/L)	Nitrate+Nitrite-N (mg/L)	Total Phosphorus (mg/L)	Chloride (mg/L)	Total Solids (mg/L)	Total Nonvolatile Solids (mg/L)	Total Suspended Solids (mg/L)	Nonvolatile Suspended Solids (mg/L)	Fecal Coliform Bacteria (#/100 ml)	Total Residual Chlorine (mg/L)
67.43	Control-RB	9/20	1515	13.4	8.5	184	142			0.017	0.001	0.548	0.032	2.5					>7,200	
		9/21	950	12.5	7.6	178	177			0.195	0.002	0.811	0.046	1.8						
67.43	Control-Mid	9/21	1010	12.7	7.6	179	177			<0.01	0.000	0.516	0.016	1.9	160	70	4	2		
67.43	Control-LB	9/21	1030	12.7	7.7	181	177			<0.01	0.000	0.503	0.017	1.7						
	Effluent++	9/20	1520	16.9/15.3*	7.1		440		32	1.62		1.73	0.49	52			6		13	0.065**
	Grabs	9/21	0935	16.70	7.4		490		22	1.84		3.80	0.45	67			8		57	0.085**
		9/21	1350	18.10	7.2		660		20	0.20		4.62	0.22	54			4		>2,400	0.075**
	Composite++	9/21-22	24-hr			600		9	29	2.78		2.29	0.66	63	390	320	8	2	50	2.5
	CSO Effluent Grab	9/20	1545	15.3	7.1		330												21	
67.34	300'-RB	9/21	1210	14.0	7.8	230	231			0.128	0.002	0.886	0.063	9.8						
67.34	300'-Mid-S	9/21	1230	13.6	8.1	204	204	<3	6	0.053	0.002	0.669	0.032	5.8	140	70	2	<1	37	
67.34	300'-Mid-B	9/21	1245	13.7		200	200			0.057	0.002	0.676	0.032	4.9						
67.34	300'-LB	9/21	1310	14.0	7.8	189	189			0.016	<.0005	0.541	0.020	2.90					47	
67.2	Gas Br-RB	9/20	1645	15.1	7.8		161										3		3,800	
		9/21	1520	14.7	8.1	217					NA	0.538	NA	7.5			4		39	
67.2	Gas Br-Mid	9/20	1635	15.2	7.6		154	3	10	0.024	<.0005			4.60	190	58	3	3		
		9/21	1540	14.2	8.6	205	204	<3	7	0.139	0.013	0.669	0.049	5.4			3		32	
67.2	Gas Br-LB	9/20	1620	15.1	7.9		152										4			
		9/21	1600	14.1	8.7	194	194			0.111	0.013	0.594	0.026	4.0			3			
66.9	Mix-RB	9/21	1720	14.3		200	200			0.173	0.020+++	0.691	0.036	5.6						
66.9	Mix- Mid	9/21	1750	14.2		205	205		9	0.176	0.020+++	0.700	0.036	5.5						
66.9	Mix-LB	9/21	1820	14.2		208	208			0.207	0.024+++	0.655	0.038	5.7						
66.7	Upper B&P Pk	9/20	1745	13.6	8.4		161		9	0.028	0.002	0.720	0.044	5.3						
66.0	B&P Br-RB	9/22	910	11.3	7.5	200	199			0.111	0.001	0.545	0.049	4.1						
66.0	B&P Br-M	9/20	1800	13.7	8.5		199			0.027	0.002	0.800	0.046	5.0						
		9/20	1810		8.5		199			0.028	0.002	0.788	0.043	4.9						
		9/22		11.4	7.5	203	199			0.112	0.001	0.508	0.054	3.9						
66.0	B&P Br-LB	9/22		11.6	7.5	204	199			0.106	0.001	0.556	0.049	4.0						

* AWT Effluent/Stormwater detention pond effluent

** Measurements recorded from Spokane AWT continuous meter.

*** Specific Conductance measurements from RM 67.34, 67.2, and 66.9 on 9/21/88 are corrected based on laboratory results. See Appendix D for uncorrected data.

\+ RB = Right Bank; Mid = Midstream; LB = Left Bank

++ Effluent samples collected by EILS Compliance Investigation Section

+++ pH at RM 672 (pH - 8.7) used to calculate un-ionized ammonia concentration.

NA: Data not available

Ammonia

Current permit limits during low flow months:

Ammonia measurements were within chronic and acute toxicity criteria limits at all sites during the study (Chronic criterion: 4-day average not be exceeded more than once in three years; Acute criterion: one-hour average not to be exceeded more than once in three years [EPA, 1986]). Since ammonia loading during the survey was only 34% of the September permit limit, downstream ammonia concentrations were estimated for maximum ammonia permit loading. Table 5 shows current weekly ammonia permit limits (based on mean daily loading). The daily permit maximum from July 1 through October 31 is 5,000 lb/day.

Table 5. Current permit limit actions for total ammonia-nitrogen.

Date	Effluent Limitation (weekly average)
November 1 - June 30	No limitation
July 1 - 31	5,000 lbs/day
August 1 - 31	2,100 lbs/day
September 1 - 30	2,700 lbs/day
October 1 - 31	5,000 lbs/day

Effluent ammonia loading was assumed to be at the weekly permit limit of 2,700 lbs/day. The percent effluent at any point along a river transect was assumed to be the same as that found during this study. These assumptions may not be adequately conservative, since the current daily maximum permitted loading is 5,000 lbs/day, and effluent dilution may also be lower at the design flow (44 MGD).

Since upstream ammonia loading during the study was negligible, it was assumed that the upstream contribution is always negligible. Under these conditions the ammonia chronic toxicity criterion would be violated at almost all sites (300, 1,000, and 2,600 feet downstream) across the width of the river (Table 6). Moreover, the acute un-ionized ammonia criterion would be exceeded if the daily maximum limit of 5,000 lb/day were used.

Ammonia limits to account for delayed mixing:

In order to determine appropriate water quality-based effluent limits for ammonia that take into account delayed mixing, the following assumptions were made:

1. The critical period for un-ionized ammonia toxicity is the low flow period: July-October.

Table 6. Actual and projected ammonia concentrations downstream of the Spokane AWT compared to chronic and acute toxicity criteria. Ammonia loading from the AWT on September 21, 1988, was 929 lb/day (34% of the weekly maximum allowable loading).

Distance Downstream of Discharge (ft)*	Ammonia-N (mg/L) 9/21/88	Estimated percent effluent	Chronic/Acute Ammonia-N Levels at pH and Temper-ture on 9/21/88** (mg/L)	Chronic/Acute Ammonia-N Levels at high pH and Temperature*** (mg/L)	Projected Ammonia-N on 9/21/88 if 100% of Weekly Allowable Ammonia Load Discharged (2,700 lb/day) (mg/L)****
300-RB	0.128	14.0	1.09/5.70	0.16/1.17	0.376
300-MID (surface)	0.053	7.0	1.11/5.75	0.16/1.17	0.156
300-MID (bottom)	0.057	5.6	1.11/5.75	0.16/1.17	0.168
300-LB	0.016	2.3	1.09/5.70	0.16/1.17	0.047
1,000-RB	0.250+	10.6	0.36/1.89	0.16/1.17	0.735+
1,000-MID	0.139	6.7	0.36/1.89	0.16/1.17	0.409
1,000-LB	0.111	4.0	0.36/1.89	0.16/1.17	0.326
2,600-RB	0.173	6.2	0.36/1.89++	0.16/1.17	0.509
2,600-MID	0.176	6.8	0.36/1.89++	0.16/1.17	0.518
2,600-LB	0.207	7.4	0.36/1.89++	0.16/1.17	0.609

(Underlined values exceed chronic toxicity criteria (4-day average not to be exceeded more than once in three years.)

* RB = Right Bank; MID = Midstream; LB = Left Bank

** U.S. EPA (1986)

*** High pH and temperature are the highest values observed at the Ecology Riverside State Park ambient water quality monitoring station (15 years of monthly data).

**** Assumed ammonia concentration in receiving water was directly proportional to effluent loading, i.e., 9/21/88 ammonia concentration = 34% of ammonia concentration when full limit discharged, since loading was 34% of allowable loading. Upstream ammonia concentration was undetectable.

\+ Projected value, since ammonia sample result was unacceptable. Projection is the mean of two estimated values that use extrapolated effluent ammonia concentration from 1,000 -MID and -LB and percent effluent from chloride estimate. These two values were multiplied by the percent effluent at 1,000-RB and a mean calculated from them.

++ pH not measured at 2,600 feet; pH estimated as 8.5 based on values at 1,000 feet.

2. Either chronic or acute toxicity criteria should be used to determine discharge limits--whichever produces the lower limit.

3. The 15-year record for monthly temperature and pH of the Spokane River at Riverside State Park (1973-88) is representative of river conditions at the AWT discharge and can be used to determine chronic and acute toxicity criteria for ammonia.

4. Monthly 90% exceedence levels for temperature and pH data (#3) are adequately protective for determining ammonia limits in the discharge area.

5. Ammonia loading from upstream is negligible.

6. Spokane River flow is at or near 7Q10 conditions.

7. Daily composite ammonia samples (20/month) collected in the effluent stream are representative of average daily ammonia concentrations.

8. Estimates for ammonia discharge limits incorporate effluent variation according to procedures in Ecology (1989b) and EPA (1985).

9. Because mixing is incomplete 300 feet downstream, the percent effluent along the right bank may reach 17-20 percent during low river flow and design AWT discharge (i.e., dilution of 5:1 to 5.9:1).

10. Toxicity from other constituents is negligible.

Ammonia discharge limits using acute and chronic toxicity criteria:

Daily and monthly average discharge limits were calculated using acute toxicity criteria for comparison with results of chronic criteria estimates using the following four step process:

1. Determine effluent variability,
2. Determine monthly acute and chronic criteria,
3. Define the long-term average acceptable ammonia concentration at the point of compliance, and
4. Determine the average monthly and daily maximum discharge limits and chose the limit which is most protective.

The analysis which follows resulted in a recommendation for an acute criterion based discharge limit. The acute criterion must be met somewhere within the mixing zone (Ecology, 1989b). More specifically, acute criteria must be met within 10% of the distance from the edge of the outfall to the edge of the regulatory mixing zone (EPA, 1985). If the recommended mixing zone of 300 feet is assumed for the Spokane AWT, then the acute criteria would have to be met 30 feet from the outfall. Violations of this requirement more than once every three years are likely if:dilution at 30 feet is assumed to be 2:1; the effluent ammonia concentration equals that in the composite collected on September 21-22, 1989 (2.78 mg/L), and the temperature (19.8°C) and pH (8.8) are in the high range for this stretch of river (Table 6). Under these circumstances the acute ammonia-N criterion would be 1.17 mg/L and the estimated concentration at 30 feet 1.39 mg/L.

The likelihood of both acute (30 feet) and chronic (300 feet) criteria violations with the existing discharge indicate that the effluent should meet the acute criterion at the end of the pipe.

The following steps were followed to calculate monthly ammonia discharge limits for the critical period (July - October) [Ecology (1989b) and EPA (1985)]. The example below uses data for July.

Step 1. Estimate effluent variability.

The coefficient of variation is used to estimate monthly effluent variability where CV = standard deviation/mean. Table 7 shows monthly effluent ammonia CV's for two years of data.

Table 7. Spokane AWT effluent ammonia mean, standard deviation and coefficient of variation for low flow months for 1987-88 (July-October). Values represent daily composite samples (5/week).

	Ammonia (mg/L-N)			
	July	August	September	October
Mean (u)	3.492	3.270	4.406	3.572
St Dev (σ)	1.986	1.797	3.428	1.865
CV (σ/u)	0.569	0.549	0.778	0.522

Step 2. Determine monthly acute and chronic toxicity criteria.

Monthly toxicity criteria must be chosen based on pH and temperature. Individual temperature and pH measurements for each monthly sampling date for 15 years were used to calculate ammonia acute and chronic toxicity criteria using the methods in EPA (1986). The natural logs of the criteria were then used to compensate for the non-normality of the small data sets. Ninety percent exceedence criteria values for each month were then calculated according to the following:

$$90\% \text{ exceedence} = e^{(\bar{x} - 1.28\, s)}$$

where $\bar{x}$ = the mean of the ln's of ammonia acute and chronic toxicity criteria for a given month

s = the standard deviation of ln's for ammonia acute and chronic toxicity criteria for the same month

The resulting monthly ammonia acute and chronic toxicity criteria (90% exceedence) are shown in Table 8.

Table 8. Monthly ammonia acute and chronic toxicity criteria - 90% exceedence level.

	July	August	September	October
Acute toxicity criteria (mg/L-N)	2.17	1.69	1.80	3.34
Chronic toxicity criteria (mg/L-N)	0.37	0.28	0.34	0.68

An alternative method for determining an appropriate end-of-pipe toxicity criteria for ammonia would be to use the effluent pH and temperature rather than those of the receiving water. Except for data collected during Class II surveys, effluent temperature data do not exist for the Spokane AWT. Influent temperature is measured continuously at the AWT. However, acute toxicity criteria calculated using influent and effluent temperature and pH measurements at about the same time during the September 1988 Class II survey (Hallinan, 1989) suggested that the influent conditions were not representative of the effluent and were therefore not used.

Step 3. Define the long-term average acceptable ammonia value at the point of compliance.

Long Term Average (LTA) represents an average concentration less than the acute criteria times the appropriate dilution factor. For acute criteria, the recommended point of compliance is the end of the pipe where dilution is not a factor.

The LTA requires information about the variability of the effluent and a choice of exceedence probability. The CV is used as an indication of effluent variability, and the probability of exceedence is typically set at 1% or 5%. [The probability was set at 5% for this analysis ($Z = 1.645$)]. The LTA is calculated as:

$$\text{LTA} = e^{(u + 0.5\sigma^2)}$$

where u = population mean

σ^2 = population variance

The toxicity criterion times the dilution factor is the Waste Load Allocation (WLA).

Two mean values are used to solve for LTA ammonia-N using the July Spokane AWT data:

u_4 = the distribution of average values that meet the WLA
u = uses u_4 to convert average values to a distribution of daily values
$u_4 = \ln(\mathrm{WLA}) - Z(\ln[1 + ((e\sigma^2 - 1)/4]]^{1/2}$
where: $Z = 1.645$ for the 95th percentile
$\sigma^2 = \ln(CV^2 + 1) = .280$
$\sigma = [\ln(CV^2 + 1]^{1/2} = .530$
CV = std deviation/mean for each month = 0.569 for July
WLA = (Acute toxicity criteria) X (dilution factor)
= (2.166 mg/L) X (1.0)
= 2.17 mg/L
$u = u_4 - 0.5\sigma^2 (0.5)\ln[1 + ((e\sigma^2 - 1)/4]$

The formulas to solve for u_4 and u combine to form the following formula:

$$u = \ln(\mathrm{WLA}) - Z[\ln[1 + ((e\sigma^2 - 1)/4]]^{1/2} - 0.5\sigma^2 + (0.5)\ln[1 + ((e\sigma^2 0 - 1)/4]$$
$$u = \ln(2.166) - (1.645)[1 + ((e^{0.28} - 1)/4]]^{1/2} - 0.5\,(0.28) + (0.5)\ln[1 + ((e^{0.28} - 1)/4]$$
$$u = -0.098$$

The LTA equation can then be solved:

$$\mathrm{LTA} = e^{(u - 0.5\sigma^2)}$$
$$= e^{(0.098) + (0.5)(0.28)}$$
$$= 1.04 \text{ mg/L}$$

Step 4. Determine average monthly and daily maximum discharge limits.

The LTA is used to calculate discharge limits. The average monthly limit is the mean of the sampling distribution which ensures that the LTA is maintained.

$$\text{Average monthly limit} = e(^{u_n + Z\sigma_n})$$
$$= u_n - u + [\sigma^2 - \sigma^2 n/2]$$
$$\sigma_n{}^2 = \ln[1 + ((e\sigma^2 - 1/n)]$$
$$\text{where } n = \text{the number of ammonia samples/month} = 20$$
$$\sigma^2 = 0.28 \text{ from above}$$
$$\sigma_n{}^2 = \ln[1 + ((e^{(0.28)^2} - 1/20]$$
$$= 0.016$$
$$\sigma_n = 0.127$$
$$\text{from above equation } u_{20} = (-0.098) + [(0.280 - 0.127)/2]$$
$$= 0.034$$
$$\text{The average monthly limit} = e^{(0.034) + (1.645)(0.127)}$$
$$= 1.27 \text{ mg/L } NH_3\text{-N}$$
$$\text{The daily maximum limit} = e^{(u + Z\sigma)}$$
$$= e^{(-0.098) + (1.645)(0.530)}$$
$$= 2.17 \text{ mg/L } NH_3\text{-N}$$

Recommended acute toxicity-based limits for each of the critical months are shown in Table 9.

Table 9. Effluent discharge limits for ammonia calculated using acute toxicity criteria and 90% exceedence level for pH and temperature.

Month	Jul	Aug	Sep	Oct
Acute Criteria				
Monthly average total NH_3-N (mg/L)	1.3	1.0	1.0	2.0
Daily maximum total NH_3-N (mg/L)	2.2	1.7	1.8	3.3

Ammonia limits were also calculated using chronic toxicity criteria for each of the critical months. Dilution factors of 5.0 and 5.9:1 were used to ensure that chronic criteria are met at the recommended point of compliance 300 feet below the discharge. Table 10 shows the daily and monthly maximum discharge limits using chronic criteria for ammonia.

Table 10. Effluent discharge limits for ammonia calculated using chronic toxicity criteria and 90% exceedence levels for pH and temperature.

Month	July		August		September		October	
Chronic Criteria								
Dilution Factor	5:1	5.9:1	5:1	5.9:1	5:1	5.9:1	5:1	5.9:1
Monthly average total NH_3-N (mg/L)	1.5	1.8	1.2	1.4	1.3	1.5	2.8	3.3
Daily maximum total NH_3-N (mg/L)	2.6	3.0	1.9	2.3	2.4	2.8	4.6	5.4

Since ammonia limits using the acute toxicity criteria were somewhat lower than those based on chronic criteria, permit requirements should use the acute-based limits.

Total Residual Chlorine (TRC)

Estimated TRC concentrations toward the right bank of the river exceeded the chronic toxicity criterion during the survey based on effluent grab samples and mixing characteristics (Table 11). All total residual values were below acute limits. Total residual chlorine values measured after dechlorination and using the plant chlorine meter are shown in Table 12.

Table 11. Estimated TRC concentrations downstream of the Spokane AWT on September 21, 1988, using mean effluent TRC values and effluent TRC at the permit limit (0.1 mg/L).

Distance Downstream of Discharge (ft)*	% Effluent (mean of conductance and chloride-derived values)	Estimated TRC using mean % effluent and permit TRC limit at 0.1 mg/L**	Estimated TRC based on 9/21/88 mean effluent TRC (0.08 mg/L) (mg/L)
300-RB	14.0 ± 0.6	0.014	0.011
300-MID (surface)	7.0 ± 0.5	0.007	0.006
300-MID (bottom)	5.6 ± 0.1	0.006	0.004
300-LB	2.3 ± 0.6	0.003	0.002
1,000-RB	10.6 ± 0.4	0.011	0.002
1,000-MID	6.7 ± 0.3	0.007	0.008
1,000-LB	4.0 ± 0.1	0.004	0.005
2,600-RB	6.2 ± 1.0	0.006	0.003
2,600-MID	6.8 ± 0.1	0.007	0.005
2,600-LB	7.4 ± 0.4	0.008	0.006

(Underlined values exceed chronic toxicity criteria: 4-day average not to be exceeded more than once in three years. EPA, 1986)

* RB = Right Bank; MID = Midstream; LB = Left Bank

** Estimated TRC (mg/L) = (0.1 mg/L TRC) X (Mean % effluent using conductance and chloride)

Table 12. Effluent TRC data for the Spokane AWT on September 20-21, 1988. Effluent values were measured following dechlorination.

Date	Time	TRC (mg/L)
9/20	15:20	0.065
9/21	08:35	0.085
9/21	13:50	0.075

Toxicity criteria state that the 4-day average TRC concentration may not exceed 0.011 mg/L more than once every three years (EPA, 1986). Although only slightly higher, the acute TRC level (0.019 mg/L) may not be exceeded for more than one hour on the average every three years.

The mean effluent TRC for the AWT (not including CSO discharge) was 0.08 mg/L +/- 0.1. Based on percent effluent during the survey, the estimated TRC concentration 300 feet downstream near the right bank was at the chronic toxicity level (0.011 mg/L).

In order to project effects of design conditions on the receiving water at various distances downstream, TRC estimates were made for the nine field sites using the permitted effluent TRC concentration for the Spokane AWT (0.1 mg/L) and 7Q10 design flows (Table 3).

It was assumed that TRC is conservative over the stretch of interest (0-2,600 feet downstream of the AWT), since the decay rate for monochloramine, the major form of chlorine expected under these conditions is usually low (EPA, 1984). The travel time through the stretch is less than 1/2-hour for flows as low as those during the survey (Singleton and Joy, 1982). Little time is therefore allowed for TRC loss. TRC was also assumed to mix similarly to conductivity and chloride tracers in the stretch below the discharge.

The chronic toxicity criterion for TRC would be exceeded on the right bank 300 feet downstream (to at least 20 feet from the right bank). Violations would also occur 1,000 feet downstream on the right bank (to at least 45 feet from the right bank).

Since chronic and acute TRC criteria are so close (0.008 mg/L difference), estimated TRC values at 300 feet (right bank) also approach acute levels (57-80% of acute values). At the design discharge level, 44 MGD, percent effluent and TRC concentrations in the mixing area would likely be higher than those predicted using the September 21, 1988, discharge of 41.3 MGD.

The same procedure was used estimating TRC permit limits as was used for ammonia. The Coefficient of Variation (CV) for the three TRC measurements recorded during the survey was 0.125. The probability of exceedence was again set at 5%.

Under the conditions where acute criteria are to be met at the end of the pipe, the estimated daily maximum TRC limit would be 0.021 mg/L. The average monthly limit would be 0.018 mg/L. On the other hand, if meeting TRC chronic criteria at 300 feet is sufficient (5:1 dilution) then the maximum daily limit would be 0.061 mg/L; the average monthly limit 0.052 mg/L.

The option of either acute end of pipe or chronic 300 foot points of compliance rather than the lower criteria is presented because disinfection is required. Since chlorine addition is currently the most commonly used method for bacterial disinfection at wastewater treatment plants, it can be treated differently than other toxics (Bailey, 1989).

An additional TRC toxicity problem was caused by chlorinated stormwater discharged at the AWT. Chlorine used to disinfect CSO water is not removed after treatment. A single TRC measurement of the CSO discharge was 2.5 mg/L on September 20. TRC from the plant's CSO effluent (CSO sewage separate from other treated sewage) likely exceeded the acute toxicity criterion on September 19 and 20. The estimated mixed concentration in the river (0.015 mg/L at 5 MGD on September 20) exceeded the chronic toxicity criterion. Violation of the acute toxicity criterion also probably occurred in the 2,600-foot stretch where mixing is incomplete. Higher stormwater discharge from the plant the previous day (7.1 MGD on September 19) likely violated the acute toxicity criterion, not only in the mixing area but for an unknown distance downstream.

Fecal coliform bacteria (FC)

Both receiving water FC samples collected on September 20, 1988, far exceeded the water quality standard: at 1,000 feet downstream of the discharge (mid-channel) and upstream close to the right bank within the area affected by the discharge (Table 4). The high upstream value may indicate FC loading from runoff, although conductivity measurements the following day also indicated effluent flow upstream along the right bank.

A high effluent FC sample collected on September 20, 1988, provides additional evidence of water quality violations (>2,400 FC/100 mL). If downstream concentrations are estimated by the tracer technique, then the 10-11% effluent at the 300-foot downstream right bank site translates to a minimum of 250 FC/100 mL. This result is one of the highest summer effluent FC concentrations observed in daily samples (five/week) over the past two years (Ecology 1988b).

Under typical summer conditions effluent FC levels should not cause water quality violations assuming that upstream loading is negligible (Ecology, 1988b). However, at the design weekly average limit of 400 FC/100 mL, violations may occur at the 300-foot right bank area if the percent effluent is in the 17-20% range. A maximum weekly average of 300 FC/100 mL would reduce the possibility of water quality standard violations at and below the 300-foot area during low flow.

Metals

Although metals were not sampled in the receiving water, results of the AWT inspection indicate likely violations of toxicity criteria near the discharge under low flow conditions (Hallinan, 1989). Both cadmium and silver were near the acute toxicity criteria in the one effluent metals sample collected during the inspection (Table 13). Similar to ammonia toxicity, acute toxicity criteria for metals should be met at the end of the pipe due to the bank discharge and incomplete mixing for over 1,000 feet under nearly 7Q10 flow conditions.

Table 13. Metals detected in Spokane AWT effluent - Spokane, September 1988, (Hallinan, 1989).

		Washington State Water Quality Criteria	
	Effluent* (μg/L)	Acute (μg/L)	Chronic (μg/L)
Arsenic	0.6	360	190
Lead	3.5	144	5.6
Silver	0.6	0.77	--
Mercury	0.08 U	2.4	0.012
Cadmium	5	6.5	1.6
Copper	13	27	17.3
Zinc	42	171	154

* = Effluent hardness = 156 mg/L as $CaCO_3$
U = Not detected at detection limit shown

CONCLUSIONS

A receiving water study of dilution and water quality below the Spokane AWT on September 20-22, 1988, indicated the following:

- Effluent is mixed below the large downstream riffle area (about 2,600 feet below the discharge) as indicated by tracer analysis using specific conductance and chloride.
- Under nearly 7Q10 flow, effluent mixing violates several mixing zone guidelines such as:
    - Effluent should not contact the shoreline.
    - Effluent should not occupy more than 15% of the stream width nor the top one foot of the receiving stream.

  - Effluent should be mixed within 300 feet of the center line of the diffuser (if present).
  - Only 15% of the receiving water volume should be used for mixing.

- No violation of ammonia toxicity criteria was observed during the survey when ammonia loading from the plant was relatively low (34% of the weekly permit limit for September). However, under design conditions (7Q10 flow and maximum permitted weekly average ammonia loading), chronic toxicity would likely occur from the discharge point to at least 2,600 feet downstream.

- A violation of the chronic TRC toxicity criterion likely occurred on September 21, 1988, in the area 300 feet downstream of the discharge toward the right bank. Under design flow conditions (7Q10 flow and maximum allowable effluent TRC concentration), acute toxicity is likely at the 300-foot right bank area and chronic toxicity in the 2,600-foot study area and beyond.

- TRC discharge from the combined sewer overflows treated at the plant on September 20, 1988, likely caused chronic toxicity violations for at least the first 2,600 feet downstream. Acute toxicity may have occurred within the 2,600-foot unmixed area on September 20 and further downstream on September 19, 1988.

- FC bacteria violations occurred below the AWT on September 20 and upstream in the area affected by the discharge. This may be due to upstream flow of effluent and/or other stormwater runoff sources, including other CSO's. Downstream FC violations probably also occurred on September 21, 1988, as indicated by elevated effluent FC concentrations.

- Under design conditions, FC violations are likely in the right bank area 300 feet downstream of the discharge.

- Under low flow conditions, metals acute toxicity criteria are likely exceeded at times in the Zone of Initial Dilution, especially cadmium and silver.

RECOMMENDATIONS

Because dilution and mixing are inadequate for the Spokane AWT effluent, a mixing zone will likely be required. It is important to note that if a mixing zone is established, water quality standards as well as toxicity criteria may not be violated beyond that boundary due to the plant discharge.

Whether or not a mixing zone is specified in the Spokane AWT permit, discharge limits for ammonia, TRC, and FC should be reduced to minimize the area where water quality standards and toxicity criteria are likely to be exceeded under low flow conditions.

The suggested changes are designed to protect beneficial uses below the discharge and prevent unnecessary degradation. These recommendations also account for the high concentration of effluent on the right bank above the mixed zone.

The following changes and activities are recommended:

- If a diffuser is not added, lower the monthly and daily average ammonia discharge limits during the low flow season to protect the receiving water below 300 feet of the discharge. Based on critical low flow conditions and 90% exceedence for ammonia acute toxicity criteria, ammonia discharge limits are recommended at this time; however, because design conditions and criteria are subject to change, proposed permit limits should be repeated prior to permit issuance. The following limits are suggested given the present design and data considerations.

Month	NH_3-N Monthly Ave. Limit (mg/L)	NH_3-N Daily Ave. Limit (mg/L)
July	1.3	2.2
August	1.0	1.7
September	1.0	1.8
October	2.0	3.3

  (If a diffuser is installed that provides more rapid dilution, the permit writer could allow a small pass-through zone (i.e., within 30 feet of the diffuser) resulting in higher ammonia limits. The size of the pass-through zone and increased ammonia limits would depend on mixing characteristics close to the diffuser (Ecology, 1989b)(EPA, 1985).

- If a diffuser is added, projected mixing characteristics and discharge limits for toxic substances should be carefully analyzed for conformance with Ecology mixing zone guidelines.

- Lower the TRC effluent limit from 0.1 mg/L to the acute end of the pipe limits: an average monthly limit of 0.018 mg/L and daily maximum of 0.021 mg/L. If these limits are not feasible, then the chronic criteria allowing 5:1 dilution may be acceptable: 0.052 mg/L monthly average and 0.061 mg/L daily maximum. A minimum limit for dissolved oxygen is also needed, since chemical oxygen demand can increase significantly if overdosing by the dechlorinating agent (sulfur dioxide) occurs (O'Brien, 1989). Additional reaeration may be necessary to meet the dissolved oxygen limit.

- Provide chlorine removal for the treated CSO discharge.

- Lower the weekly FC discharge limit from 400 to 300 FC/100 mL.

- Discharge limits should be established for metals in conjunction with ammonia toxicity limits (EPA, 1987 and 1985). Additional effluent sampling for metals and hardness is needed to determine effluent metal variability in order to calculate discharge limits. Both effluent and receiving water samples should be collected under various flow conditions to determine the critical time of year for metals toxicity in the river. Under the current bank discharge design, additive acute toxicity limits should be met at the end of the pipe.

- Any plans for expansion of plant capacity should address cumulative toxicity potential and take into account Ecology's final mixing zone guidelines scheduled for completion in 1990.

- Add effluent temperature monitoring to the discharge permit.

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APPENDICES

Appendix A. Conductivity values for four transects on September 21, 1988.

Control, RM 67.43

Distance downstream of control (ft)	Distance from Right Bank (ft)	Depth (m)	Temp (°C)	Conductivity Measured (umhos/cm)	Conductivity @ 25 degrees (umhos/cm)
0	10	0.0	12.80	162	211
0	10	0.5	11.90	159	212
0	20	0.0	12.50	137	180
0	20	0.5	12.60	137	179
0	30	0.0	12.40	135	177
0	30	0.5	12.50	136	178
0	30	0.7	12.50	136	178
0	40	0.0	12.40	136	179
0	40	0.5	12.40	135	177
0	40	0.7	12.50	135	177
0	50	0.0	12.50	137	180
0	50	0.5	12.50	135	177
0	65	0.0	12.50	136	178
0	65	0.5	12.50	135	177
0	65	0.8	12.50	135	177
0	80	0.0	12.70	136	177
0	80	0.5	12.70	136	177
0	80	1.0	12.50	137	180
0	95	0.0	12.50	137	180
0	95	0.5	12.50	135	177
0	95	1.0	12.50	136	178
0	110	0.0	12.50	135	177
0	110	0.5	12.50	135	177
0	110	0.9	12.60	137	179
0	125	0.0	12.60	136	178
0	125	0.5	12.60	135	177
0	125	0.9	12.60	136	178
0	135	0.0	12.70	136	177
0	135	0.5	12.60	135	177
0	135	1.0	12.50	136	178

Appendix A. (Continued)

300 feet downstream of discharge, RM 67.34

Distance downstream of control (ft)	Distance from Right Bank (ft)	Depth (m)	Temp (°C)	Conductivity Measured (umhos/cm)	Conductivity @ 25 degrees before adjust (umhos/cm)	Conductivity @25 deg after adjust (umhos/cm)
300	10	0.0	14.5	184	230	230
300	10	0.5	14.2	184	232	232
300	10	0.8	14.1	185	233	233
300	20	0.0	14.0	183	231	231
300	20	0.5	14.0	182	230	230
300	20	1.0	14.0	185	234	234
300	20	1.3	14.0	185	234	234
300	35	0.0	14.0	180	228	228
300	35	0.5	14.0	180	228	228
300	35	1.0	14.0	182	230	230
300	35	1.5	14.0	175	221	221
300	35	1.9	14.0	185	234	234
300	50	0.0	13.9	165	209	209
300	50	0.5	13.8	170	216	216
300	50	1.0	13.9	173	219	219
300	50	1.5	14.0	182	230	230
300	50	2.0	14.0	175	221	221
300	50	2.3	14.0	180	228	228
300	65	0.0	13.6	163	208	204
300	65	0.5	13.9	168	213	209
300	65	1.0	13.8	175	222	218
300	65	1.5	13.8	165	210	206
300	65	2.0	13.7	164	209	205
300	65	2.5	13.7	165	210	200
300	80	0.0	14.0	162	205	195
300	80	0.5	13.8	152	193	183
300	80	1.0	14.0	163	206	196
300	80	1.5	13.9	165	209	199
300	80	2.0	13.8	161	205	195
300	80	2.5	13.8	161	205	195
300	80	2.8	13.9	164	208	198
300	95	0.0	14.0	150	190	178
300	95	0.5	14.0	150	190	178
300	95	1.0	14.5	150	187	175
300	95	1.5	13.8	150	191	179
300	95	2.0	13.8	150	191	179
300	95	2.5	13.8	158	201	189
300	95	3.0	13.8	162	206	184
300	110	0.0	13.8	160	203	189
300	110	0.5	13.8	159	202	188
300	110	1.0	13.8	159	202	188
300	110	1.5	14.0	156	197	183
300	110	2.0	14.0	159	201	187
300	110	2.5	14.0	159	201	187
300	110	2.7	14.0	159	201	187
300	125	0.0	14.0	157	198	184
300	125	0.5	14.0	158	200	186
300	125	1.0	14.0	157	198	184
300	125	1.5	14.0	157	198	184
300	125	2.0	14.0	157	198	184
300	125	2.5	14.0	158	200	186
300	135	0.0	14.0	156	197	183
300	135	0.5	14.0	156	197	183
300	135	1.0	14.0	157	198	184
300	135	1.5	14.0	157	198	184
300	135	1.9	14.0	157	198	184

Appendix A. (Continued)

Natural Gas foot Bridge, RM 67.2

Distance downstream of control (ft)	Distance from Right Bank (ft)	Depth (m)	Temp (°C)	Conductivity Measured (umhos/cm)	Conductivity @ 25 degrees before adjust (umhos/cm)	Conductivity @25 deg after adjust (umhos/cm)
1,000	25	0.0	14.8	350	434	324
1,000	25	0.5	14.9	330	408	298
1,000	25	1.0	14.9	312	386	276
1,000	25	1.5	14.8	282	350	240
1,000	25	2.0	14.6	275	343	233
1,000	45	0.0	15.0	265	327	217
1,000	45	0.5	14.6	263	328	218
1,000	45	1.0	14.6	264	329	219
1,000	45	1.5	14.5	264	330	220
1,000	45	2.0	14.6	265	330	220
1,000	45	2.5	14.7	265	329	219
1,000	45	3.0	14.7	266	331	221
1,000	45	3.5	14.7	268	333	223
1,000	65	0.0	14.6	260	324	215
1,000	65	0.5	14.5	260	325	216
1,000	65	1.0	14.4	258	323	214
1,000	65	1.5	14.4	259	324	215
1,000	65	2.0	14.4	261	327	218
1,000	65	2.5	14.4	262	328	219
1,000	65	3.0	14.3	261	328	219
1,000	65	3.5	14.4	261	327	218
1,000	85	0.0	14.2	249	313	204
1,000	85	0.5	14.2	250	315	207
1,000	85	1.0	14.5	252	315	207
1,000	85	1.5	14.3	251	315	207
1,000	85	2.0	14.3	253	318	210
1,000	85	2.5	14.3	254	319	211
1,000	85	3.0	14.2	258	325	217
1,000	85	3.5	14.5	258	322	214
1,000	85	4.0	14.5	258	322	214
1,000	135	0.0	14.1	233	294	194
1,000	135	0.5	14.1	235	296	196
1,000	135	1.0	14.2	233	293	193
1,000	135	1.5	14.1	233	294	194
1,000	135	2.0	14.1	234	295	195
1,000	135	2.5	14.1	237	299	199
1,000	135	3.0	14.1	237	299	199
1,000	160	0.0	14.0	230	291	191
1,000	160	0.5	14.0	230	291	191
1,000	160	1.0	14.1	230	290	190
1,000	160	1.5	14.1	232	293	193
1,000	160	2.0	14.1	231	291	191

Appendix A. (Continued)

Mixed Zone, RM 66.9

Distance downstream of control (ft)	Distance from Right Bank (ft)	Depth (m)	Temp (°C)	Conductivity Measured (umhos/cm)	Conductivity @ 25 degrees before adjust (umhos/cm)	Conductivity @25 deg after adjust (umhos/cm)
2,600	10	0.0	14.2	241	303	202
2,600	10	0.5	14.5	240	300	199
2,600	10	1.0	14.5	241	301	200
2,600	30	0.0	14.3	240	301	200
2,600	30	0.5	14.5	240	300	199
2,600	30	1.0	14.5	240	300	199
2,600	30	1.5	14.5	240	300	199
2,600	30	2.0	14.5	241	301	200
2,600	30	2.5	14.5	242	302	201
2,600	30	3.0	14.5	242	302	201
2,600	30	3.3	14.5	243	304	203
2,600	55	0.0	14.2	239	301	205
2,600	55	0.5	14.5	239	299	203
2,600	55	1.0	14.5	239	299	203
2,600	55	1.5	14.5	239	299	203
2,600	55	2.0	14.5	240	300	204
2,600	55	2.5	14.5	240	300	204
2,600	55	3.0	14.5	241	301	205
2,600	55	3.5	14.5	241	301	205
2,600	55	4.0	14.5	242	302	206
2,600	55	4.5	14.5	241	301	205
2,600	80	0.0	14.1	238	300	208
2,600	80	0.5	14.2	239	301	209
2,600	80	1.0	14.3	239	300	208
2,600	80	1.5	14.3	240	301	209
2,600	80	2.0	14.5	240	300	208
2,600	80	2.5	14.5	240	300	208
2,600	80	3.0	14.5	240	300	208
2,600	80	3.5	14.5	241	301	209
2,600	80	4.0	14.4	241	302	210
2,600	80	4.5	14.4	241	302	210
2,600	80	5.0	14.5	242	302	210
2,600	105	0.0	14.1	238	300	212
2,600	105	0.5	14.3	238	299	211
2,600	105	1.0	14.3	239	300	212
2,600	105	1.5	14.4	239	299	211
2,600	105	2.0	14.4	239	299	211
2,600	105	2.5	14.4	240	301	212
2,600	105	3.0	14.4	240	301	212
2,600	105	3.5	14.4	240	301	212
2,600	105	4.0	14.4	240	301	212
2,600	105	4.5	14.4	240	301	212
2,600	105	5.0	14.4	242	303	214
2,600	125	0.0	14.2	233	293	208
2,600	125	0.5	14.4	232	291	206
2,600	125	1.0	14.3	232	291	206
2,600	125	1.5	14.2	235	296	211
2,600	125	2.0	14.4	235	294	209
2,600	125	2.5	14.3	235	295	210
2,600	125	3.0	14.3	235	295	210
2,600	125	3.5	14.4	236	296	211
2,600	140	0.0	14.2	230	289	204
2,600	140	0.5	14.2	230	289	204
2,600	140	1.0	14.2	229	288	203
2,600	140	1.5	14.2	228	287	202
2,600	140	2.0	14.4	227	284	199

Appendix B. Estimated percent effluent on 9/21/88 at sites downstream of the Spokane AWT using specific conductance and chloride as tracers.

Site*	Distance from right bank (feet)	% effluent using conductance	% effluent using chloride	Mean % effluent
300'-RB	20	14.4	13.6	14.0
300'-MID-surface	45	6.6	7.3	7.0
300'-MID-bottom	45	5.5	5.6	5.6
300'-LB	110	2.7	1.9	2.3
1,000'-RB	45	10.3	10.8	10.6
1,000'-MID	85	6.9	6.5	6.7
1,000'-LB	135	4.0	3.9	4.0
2,600-RB	30	5.5	6.9	6.2
2,600-MID	55	6.9	6.7	6.8
2,600-LB	125	7.7	7.1	7.4

* RB = Right Bank
Mid = Midstream
LB = Left Bank

APPENDIX C

The propagated error term was analyzed for measurements taken at mid-channel 300 feet downstream of the discharge using the following first-order uncertainty analysis technique (Bevington, 1969):

For addition and subtraction:

(1) $$z = ax +/- by$$

(2) $$s_z{}^2 = a^2 s_x{}^2 + b^2 s_y{}^2$$

where s = standard error

For division:

(3) $$z = \frac{ax}{y}$$

(4) $$s_z{}^2 = \frac{1}{y^2} s_x{}^2 + \frac{x^2}{y^4} s_y{}^2$$

For the percent effluent equation,

(5) $$\% \, E = \frac{C3 - C2}{C1 - C2} \times 100$$

where C1 = Effluent concentration of chloride or specific conductance (mean of samples collected between 9:30 and 16:30 on 9/21/88; n=3 for conductance, n=2 for chloride)

C2 = Background chloride or specific conductance (mean of samples collected 150 feet upstream of discharge)

C3 = Measured downstream chloride or specific conductance (mean of surface and bottom samples)

E = Estimated fraction of water that is effluent

The standard error for the resulting percent effluent is a combination of the addition/subtraction variance calculation described above and the division calculation. The estimated combined variance for percent effluent can be calculated in two steps using equations 2 and 4 above:

(6) $$\frac{(C_3 - C_2) \pm \sqrt{s_3{}^2 + s_2{}^2}}{(C_1 - C_2) \pm \sqrt{{}_1{}^2 + s_2{}^2}} = \frac{C_4 \pm s_4}{C_5 \pm s_5}$$

(7) $$s_E = \frac{1}{C_5{}^2} (s_4{}^2) + \frac{C_4{}^2}{C_5{}^2} (s_5{}^2)$$

The standard error (s_E) for percent effluent at 300 feet mid-channel was 1.6% using chloride and 1.5% using conductance.

Appendix D. Ambient monitoring summer data collected by Ecology at the Riverside State Park station used to determine ammonia concentrations at the 10% exceedence level in the Spokane River.

STA #	DATE	TIME	FLOW (cfs)	TEMP (C)	PH	NH3-N (mg/L)
54A120	730711	1145	450	18.0	8.2	0.710
54A120	730724	1130	850	17.0	8.0	0.660
54A120	730807	1245	770	18.8	8.0	1.600
54A120	730821	1200	930	19.1	7.7	0.990
54A120	730912	1240	2100	18.4	7.8	0.750
54A120	730925	1135	2400	14.3	7.4	0.480
54A120	740710	1135	3970	14.4	7.7	0.560
54A120	740726	0930	3700	7.8	8.8	0.180
54A120	740807	0900	2700	18.2	8.8	0.200
54A120	740822	0945	1830	15.2	8.0	0.350
54A120	740910	1000	1980	14.2	7.8	0.390
54A120	740925	1100	2490	14.8	7.8	0.370
54A120	741008	0820	2160	10.5	7.8	0.330
54A120	741021	1015	2490	10.8	8.0	0.360
54A120	750710	1040	6510	18.9	7.3	0.110
54A120	750722	1000	3270	17.6	7.9	0.210
54A120	750807	0915	1980	16.4	7.2	0.300
54A120	750825	1000	2500	16.0	7.9	0.190
54A120	750908	0945	2390	15.6	7.4	0.520
54A120	750925	1000	2300	14.4	7.3	0.430
54A120	751008	1000	2670	11.7	7.1	0.500
54A120	760706	1415	4330	18.4	7.6	0.220
54A120	760802	1145	2000	18.6	7.9	0.420
54A120	760902	1430	2020	17.5	8.4	0.470
54A120	761005	1000	2270	13.0	7.3	0.250
54A120	761012	1100	2520	13.7	N/D	0.380
54A120	770714	1000	1770	16.6	8.0	0.300
54A120	770725	1150	1250	19.0	N/D	0.580
54A120	770812	1500	1020	19.8	8.2	0.940
54A120	770822	1010	946	18.4	N/D	0.430
54A120	770926	0950	1710	12.4	N/D	0.080
54A120	770929	1115	2120	12.0	7.7	0.030
54A120	771019	1200	1930	11.5	7.5	0.130
54A120	780801	1030	1400	18.6	8.0	0.060
54A120	780824	1415	2210	16.9	8.4	0.130
54A120	780912	1145	2150	15.2	7.9	0.080
54A120	781018	1200	2220	11.6	8.2	0.010
54A120	790726	1345	1070	19.0	8.0	0.030
54A120	790820	1130	784	17.4	8.3	0.000
54A120	790918	1245	1630	16.8	8.3	0.200
54A120	791011	0900	1650	12.2	7.9	0.050
54A120	800708	0900	3680	18.0	7.6	0.000
54A120	800730	1030	1870	18.8	8.0	0.100
54A120	800821	0845	1530	17.7	7.7	0.350
54A120	800922	0745	2110	13.6	7.9	0.000
54A120	801021	1230	N/D	11.5	8.1	0.100
54A120	820711	1450	3760	19.8	8.0	0.020
54A120	820817	1645	1250	17.8	8.6	0.180
54A120	820914	1435	1980	14.2	8.5	0.020
54A120	830719	1510	5210	19.0	7.8	0.030
54A120	830823	1540	495	15.0	7.9	0.020
54A120	830927	1540	2400	14.8	8.2	0.130
54A120	831025	1500	2420	10.9	7.6	0.040
54A120	840508	1335	1150	8.7	8.1	0.080
54A120	840710	1530	3420	19.0	8.4	0.300
54A120	840814	1410	1650	17.4	8.4	0.360
54A120	840911	1545	2280	14.9	8.1	0.280
54A120	841009	1350	2290	13.2	8.1	0.700
54A120	850813	1425	1050	13.5	8.5	0.280
54A120	850917	1435	2480	11.8	7.9	N/D
54A120	851022	1430	2350	9.8	7.8	N/D
54A120	860708	1500	1160	16.0	8.5	0.050
54A120	860812	1450	918	17.4	8.1	0.020
54A120	860909	1525	879	14.0	7.6	N/D
54A120	861021	1445	2640	11.7	7.7	N/D
54A120	870707	1500	1940	18.4	8.1	0.090
54A120	870804	1425	1100	17.7	8.3	0.150
54A120	870908	1505	1280	17.7	8.4	0.030
54A120	871006	1355	1490	13.4	8.5	0.050
54A120	880705	1505	1870	16.2	8.3	0.120
54A120	880802	1320	750	16.3	8.4	0.070
54A120	880913	1455	1270	16.1	8.6	0.410

N/D incicates data not available