Publication No. 78-e39
WA-28-1027
Segment 13-28-03

Weaver Creek – Battleground Sewage Treatment Plant Impact Study

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December 1978

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Project Report PR-4

CONCLUSIONS

1. Weaver Creek is adversely affected by the Battleground STP. The major concern is the drastic depression of dissolved oxygen concentrations. The average values of 3.7 mg/l at Station 3 and 4.1 mg/l at Station 4 were well below the state Class A standard of 8 mg/l. D.O. levels were below the state standard for about 2.6 kilometers (1.6 miles) downstream of the outfall.

2. The major factor in the effluent causing the dissolved oxygen depression appeared to be the high concentration of total ammonia (NH_3+NH_4^+).

3. If the size of the STP is increased, permitting greater effluent flows with the same characteristics, dissolved oxygen values will probably decline further and the zone of adverse impact increase.

4. Even slightly lower dissolved oxygen values could decimate Weaver Creek's biological community which consists of a variety of aquatic invertebrates and fish.

INTRODUCTION

The Battleground sewage treatment plant (STP) discharges to Weaver Creek, a small stream which originates about 3 km. northeast of Battleground, Washington (Figure 1). The STP discharges to the creek about 4 km. below its headwaters. Below this discharge, the stream flows south by southwest for 3.6 km. and empties into Salmon Creek, a tributary of Vancouver Lake. Flows in Weaver Creek are quite low during late summer. The September 12, 1978 flow was 1.88 cubic feet per second (cfs) just above the STP outfall, 2.63 cfs just below the outfall, and 3.31 cfs just above the confluence with Salmon Creek.

Battleground STP operates within its design flow of .4 million gallons per day (mgd) during dry weather. However, during wet weather it reaches and exceeds its NPDES limit of .98 mgd. A number of housing developments are being constructed and planned, necessitating an enlargement of the STP. The proposed enlargement of the STP will double the discharge rate and the BOD (biochemical oxygen demand) loading to Weaver Creek.

During September 1978, water quality and biological surveys were conducted on Weaver Creek. The purpose was to determine the present impact of the STP on the stream and to predict what would happen to the stream environment if STP flow and BOD loading were doubled.

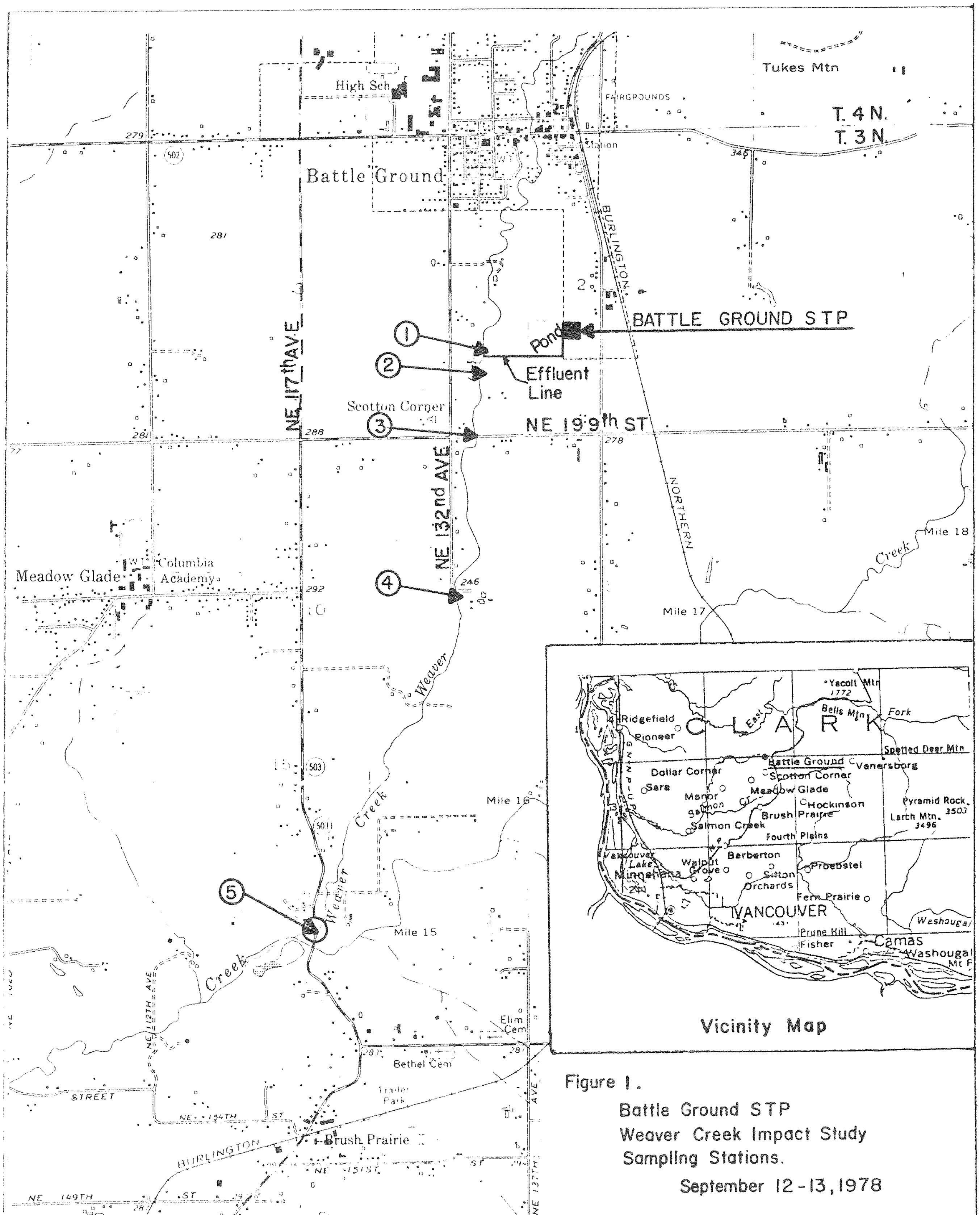

Figure 1.
Battle Ground STP
Weaver Creek Impact Study
Sampling Stations.
September 12-13, 1978

MATERIALS AND METHODS

The sampling period covered 24 hours beginning at noon September 12 and ending about noon September 13, 1978.

For the facility (STP) sampling, a Manning S-4040 sequential sampler was installed to sample the effluent before chlorination. A 500 ml sample was taken every hour. At the end of 6 hours, the six samples were composited and a sample was drawn off and set in ice, making a total of four composited effluent samples for the 24-hour period. These samples were analyzed in the DOE Tumwater laboratory for ortho-phosphate-phosphorus ($O\text{-}PO_4\text{-}P$), total phosphate-phosphorus ($T\text{-}PO_4\text{-}P$), ammonia-nitrogen ($NH_3\text{-}N$), nitrate-nitrogen ($NO_3\text{-}N$), nitrite-nitrogen ($NO_2\text{-}N$), total kjeldahl-nitrogen (TKN), 5-day biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), and pH.

The effluent flow was measured at the composite sampling point using a Manning Dipper Flowmeter. Total flow was recorded every 6 hours.

Five stations were established for the Weaver Creek receiving water survey as described below and shown in Figure 1.

Station Name	Station Description
#1	5 meters above outfall
#2	35 meters below outfall
#3	400 meters below outfall - N.E. 199th St. (Culvert)
#4	1500 meters below outfall - N.E. 132nd Ave. Bridge (Private)
#5	3635 meters below outfall - N.E. 117th Ave. Bridge (Immediately upstream from mouth)

Field chemical and physical observations were made every 2 hours during the 24-hour sampling period. Parameters included dissolved oxygen (mg/l), temperature (°C), and pH. Dissolved oxygen and temperature were measured with an IBC Dissolved Oxygen Meter. The pH values were determined with an Analytical Measurements Portable pH Meter.

Stream samples were collected every 6 hours and analyzed for the following: $O\text{-}PO_4\text{-}P$, $T\text{-}PO_4\text{-}P$, $NH_3\text{-}N$, $NO_3\text{-}N$, $NO_2\text{-}N$, and TKN. Fecal coliform samples were collected only once at 0400 hours, September 13. All samples were preserved in ice before shipping to the DOE laboratory.

The diversity of macro-invertebrates inhabiting the receiving waters was also determined. At each station, three stones were collected from a riffle area. The macro-invertebrates then were removed and preserved in methanol, counted, and keyed to species or lowest identifiable taxa. Species diversity indexes were computed using the Margalef formula:

$$d = \frac{S-1}{\ln N}, \qquad \text{Formula (1)}$$

where d = diversity index,

S = number of species,

N = total number of individuals [6]

RESULTS AND DISCUSSION

The most significant finding was substantial depression of dissolved oxygen concentrations in Weaver Creek downstream of the STP discharge point. The average dissolved oxygen levels at each station for the 24-hour survey period are listed below:

Station Number	Dissolved Oxygen (mg/l)
1	9.0
2	7.3
3	3.7
4	4.1
5	9.3

Dissolved oxygen concentrations at Stations 2, 3, and 4 were consistently below the state standard of 8 mg/l for Class A water in Washington State [9] (Table 1). These data indicate that D.O. levels were below the state standard for about 2.6 kilometers (1.6 miles) below Battleground STP's outfall.

Figure 2 illustrates the dissolved oxygen depression for the survey period for each station. Figure 3 shows the downstream progression of dissolved oxygen for three separate time periods (1200 hours September 12, 0600 hours September 13, and 1000 hours September 13).

Several factors were causing the dissolved oxygen depression. The main reason for the depressed D.O. levels in Weaver Creek below Battleground STP appears to be the high concentrations of ammonia in the effluent (average 13.5 mg/l). Ammonia can use up 4.57 times its weight of dissolved oxygen during nitrification. [8]

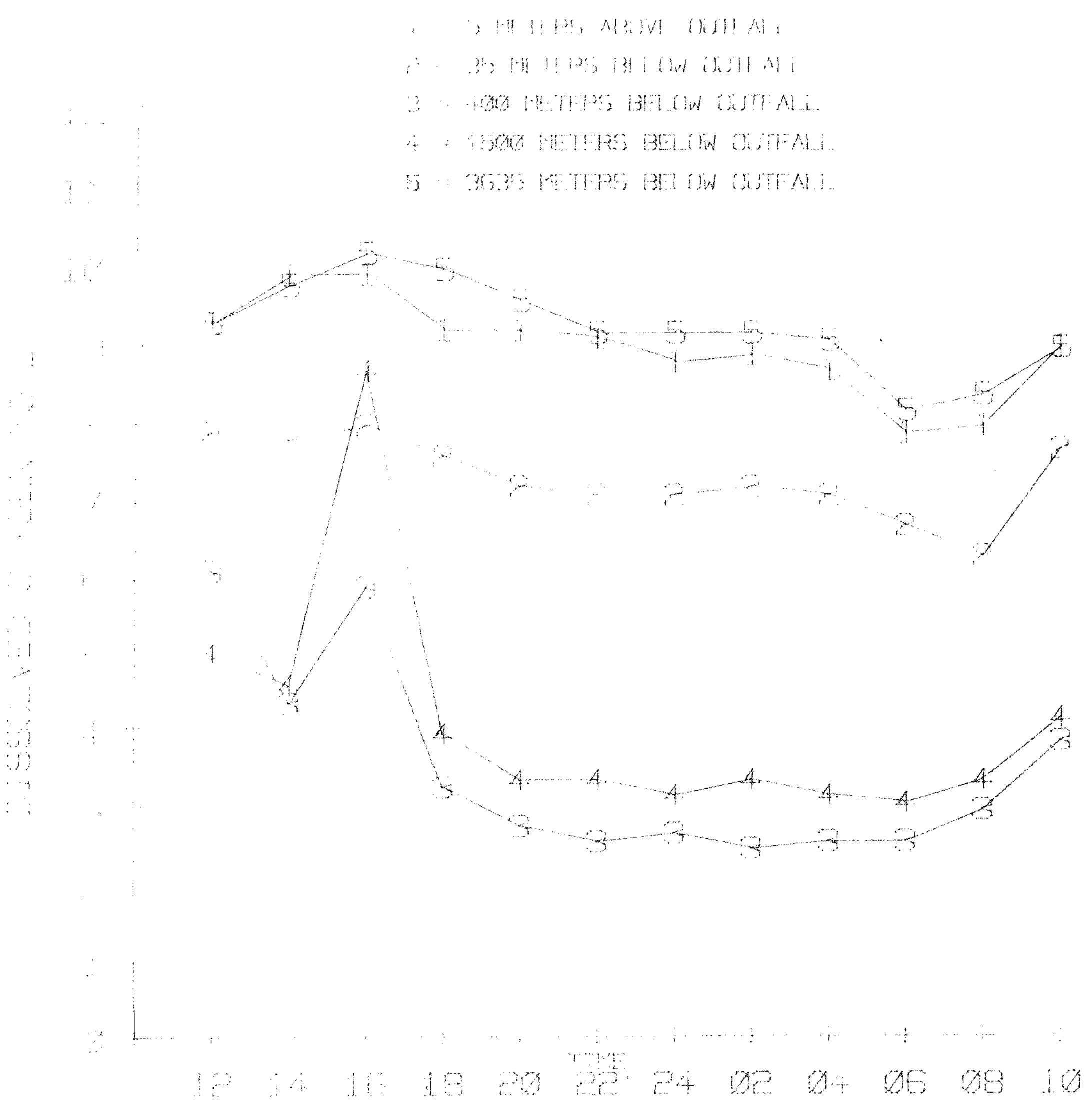

FIGURE 2 - WEAVER CREEK - 24 HOUR
DISS. OXYGEN VALUES SEPT 12-13 1978

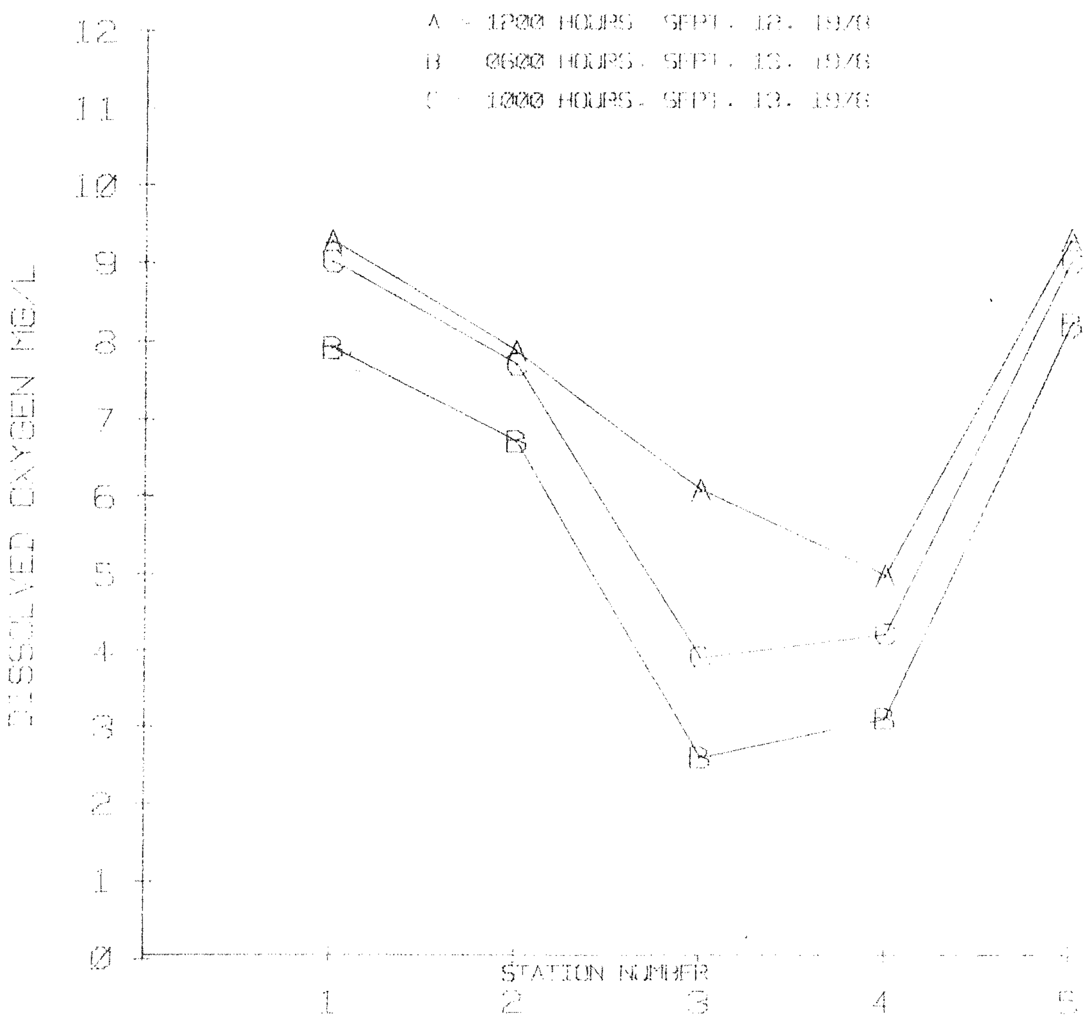

FIGURE 3. WEAVER CREEK-BATTLEGROUND STP IMPACT STUDY. DOWNSTREAM DISSOLVED OXYGEN DEPRESSION. SEPT 1978

Weaver Creek's low velocity, shallow depth, and relatively high surface area to flow volume ratio favor nitrification.

The equations expressing the process by which *Nitrosomonas* and *Nitrobacter* bacteria convert ammonia to nitrates are:

Nitrosomonas	lb. O_2 required per lb. N oxidized	
$NH_3 + 3/2\ O_2 \rightarrow NO_2^- + H_2O + H^+$	3.43	Formula (2)
and		
Nitrobacter		
$NO_2^- + 1/2\ O_2 \rightarrow NO_3^-$	1.14	Formula (3)
Total reaction		
$NH_3 + 2O_2 \rightarrow NO_3^- + H_2O + H^+$	4.57	Formula (4)

These bacteria, or nitrifers, grow best in biological slimes such as those present on the substrate of Weaver Creek. According to Tuffey *et al* (7), shallow streams will be affected by nitrifying slimes and experience rapid rates of nitrification.

Approximately 63 pounds of ammonia was discharged to the stream during the 24-hour survey. If all of this ammonia were converted to nitrates at the discharge point, 290 pounds of dissolved oxygen would have been needed (8). The stream, however, transported only 91 pounds of dissolved oxygen past Station 1, suggesting a potential severe oxygen deficit. Figure 4 shows that after the ammonia was introduced below Station 1, it gradually decreased from an average of 3.10 mg/1, NH_4-N at Station 2 to

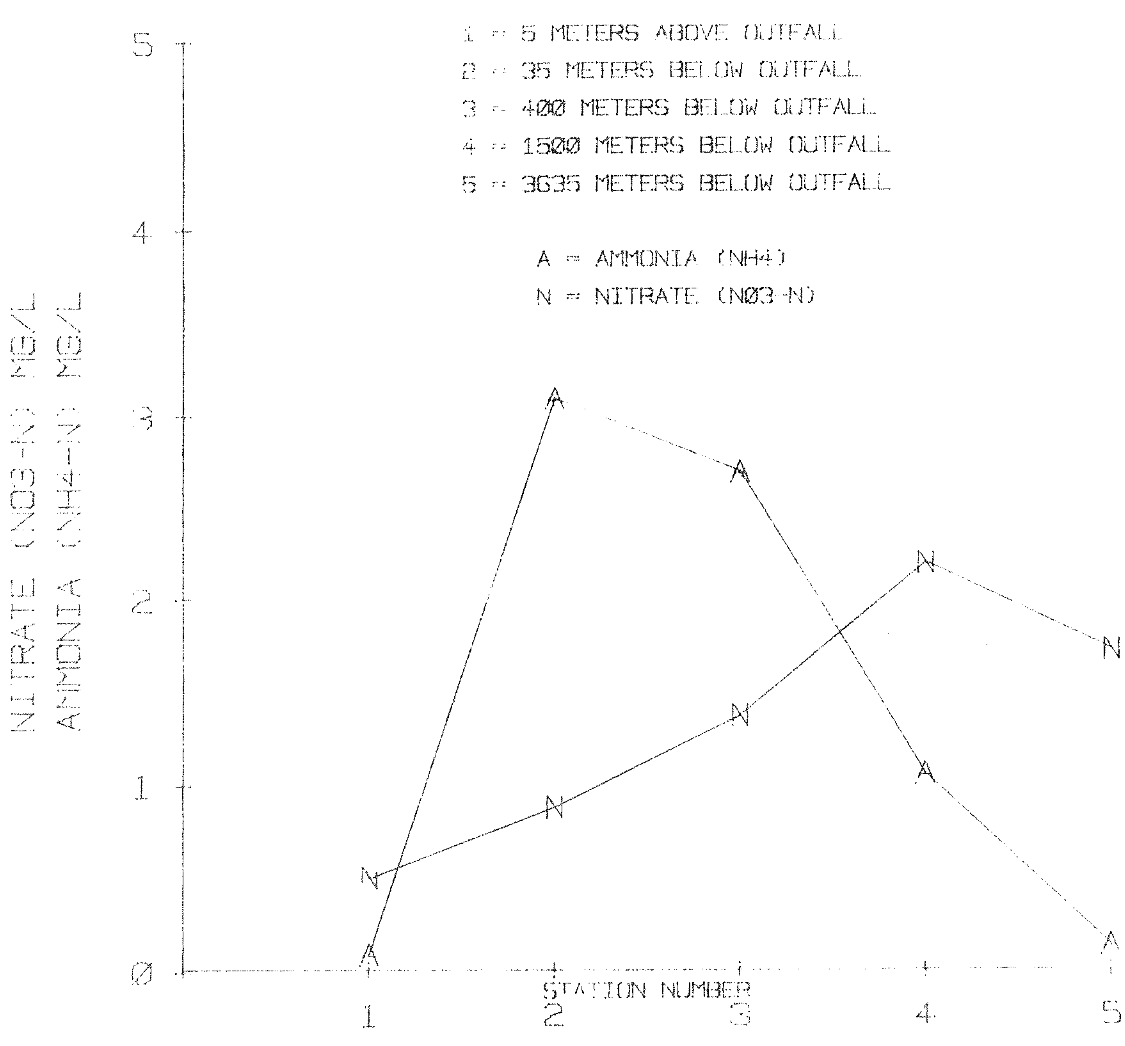

FIGURE 4. WEAVER CREEK-BATTLEGROUND STP IMPACT STUDY. AVERAGE STREAM AMMONIA (NH4-N) AND NITRATE (NO3-N) CONCENTRATIONS. SEPT. 12-13, 1978

an average of .15 mg/l, NH_4-N at Station 5, 3.6 km. downstream. Figure 4 also shows that as the ammonia concentration dropped, the nitrate concentration increased as suggested by formulas 2, 3, and 4. The discharge of ammonia obviously is one of the factors causing the reduction of oxygen.

The possibility of oxygen depression due to the 5-day BOD exerted by Battleground STP was also studied.

The equation

$$y = L(1-10^{-Kt}) \qquad \text{Formula (5)}$$

was used [5].

where

y = BOD that has been exerted at any time

L = ultimate BOD

K = reaction constant

t = time in days

to figure the ultimate BOD of the STP effluent, y_5 (5-day BOD) = 23.25, K = .1 (typical value for polluted water, 20°C) and t = 5.

Solving:

$$y_5 = L(1-10^{(-.1)(5)})$$

$$L = \frac{23.25}{(1-10^{(-.1)(5)})}$$

$$L = 34.00$$

Using flow measurement velocities, the stream travel time from Station 1 to Station 5 was calculated at about 4 hours or .17 day. To solve the STP BOD exerted on Weaver Creek, the value of K had to be adjusted for temperature.

The equation to calculate K at the average stream temperature of 13.3°C is:

$$K_T = K_{20}\theta^{(T-20°)}$$

where

K_T = the K value at temperature

K_{20} = .1, the K value at 20°C

θ = 1.047

T = 13.3°C

Solving:

$$K_{13.3} = .1\ (1.047)^{(13.3-20)}$$

$$K_{13.3} = .07$$

Using K = .07, L = 34 and t = .17 in formula (5):

$$y_{.17} = 34\ (1-10^{-(.07)(.17)})$$

$$y_{.17} = .92\ mg/l$$

The STP effluent exerts a BOD of .92 mg/l or 4 percent of the total BOD_5 discharged to Weaver Creek by the Battleground treatment plant. This means that the effluent BOD was having very little effect upon Weaver Creek. The quick fall and rise of dissolved oxygen along the stream must be due primarily to the much quicker nitrification process described earlier.

Assuming a constant stream velocity of 1000 M/hr and the average temperature of 13.3°C at the station, and formulas 4 and 6, the NOD (nitrogenous oxygen demand) and BOD for the stretches between Stations 2-3, 3-4, and 4-5 were computed [11]. These calculations assume that decreases in total inorganic nitrogen (NH_3-N + NO_2^--N + NO_3^--N) are due to uptake by aquatic vegetation and that this uptake is distributed proportionally based on the percent abundance of the specific inorganic nitrogen forms present in these segments. Further, it is assumed that this assimilation by aquatic vegetation does not result in a nitrogenous oxygen demand in the segments. Therefore, the NOD estimations are conservative.

Stream Stretch Between Stations	NOD (lb./day)	BOD (lb./day)
2-3	96	0.4
3-4	91	0.8
4-5	47	1.1

Another factor influencing the dissolved oxygen concentrations in Weaver Creek below the STP is the natural photosynthesis-respiration process. The dissolved oxygen concentrations are highest during daylight hours due to photosynthetic production by the plant life in the stream. At night, when photosynthesis stops and respiration continues, a natural depression of oxygen concentrations occurs. Stations 1 and 5 showed a slight oxygen depression at night which is typical of a healthy stream with low nutrient loadings. However, dissolved oxygen concentrations at Stations 3 and 4 fluctuated more than the other stations, causing lower minimums as a result of the altered biological community (Figure 3).

Another process which may be affecting dissolved oxygen concentrations could be a dilution effect from low dissolved oxygen in the effluent. Station 2, immediately below the outfall, averaged 1.7 mg/l dissolved oxygen less than Station 1 which is only 40 meters upstream. This sudden dissolved oxygen drop was probably due to the combination of the purely physical process of low dissolved oxygen effluent mixing with the stream and biological processes including nitrification and BOD.

The fecal coliform counts (Table 1) show that there is a die-off occurring below the outfall until Station 5 is reached. Here the numbers exceed those of Station 1.

The diversity index (Tables 1 and 2) calculated from the macroinvertebrate samples show an impact from the STP. The lowest quality was at Station 2 just below the outfall. The large number of diptera (Table 2) at Station 2 and low species diversity of .69 indicate pollution stress. The sensitive baetidae at Station 1 disappear from Stations 2, 3, and 4 and then reappear at Station 5 where dissolved oxygen values are again high and ammonia values are low.

In addition to the list of collected invertebrates itemized in Table 2, a number of small minnows were observed in the stream. Although not seen, trout are probably present in the stream, especially when the dissolved oxygen is high, such as at Stations 1 and 5. The Washington State Department of Fisheries also reports that Weaver Creek is used for the production of Coho salmon [10]. It is very possible that the low dissolved oxygen concentrations at Stations 3 and 4 periodically stress or kill sensitive fish such as trout. Water Quality Criteria of California [4] reports that "under average stream conditions, 3.0 mg/l of dissolved oxygen, or less, should be regarded as hazardous or lethal, and that to maintain a varied fish fauna in good condition the dissolved-oxygen concentration should remain at 5.0 mg/l or higher." Davis [2] shows, for the temperatures found in Weaver Creek during the survey, that dissolved oxygen levels below 5 mg/l will produce physiological changes indicating the onset of hypoxic stresses. Any increase in the STP loading to Weaver Creek would increase possibilities of biological kills.

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TABLE 1
Water Quality Data Collected by DOE during Weaver Creek Survey, September 12-13, 1978

Station	Description	Flow CFS / MGD	Time	°C Temp	pH	IBC-DO ppm	% DO Sat.	Ortho-P Mg/l	Total Phos-P Mg/l	Ammonia-N Mg/l	Nitrate-N Mg/l	Nitrite-N Mg/l	T-Kjeldahl-N Mg/l	Fecal Coliform Col/100ml	Macro-inverta-brate (Species Div.)
			1200	12.1	7.3	9.3	87.4	.08	.12	.06	.43	ND	.19		1.12
1	5 meters above outfall	1.88/1.21	1400	13.8	---	9.9	96.7								
			1600	14.0	7.3	9.9	97.0								
			1800	14.0	7.3	9.2	90.0	.07	.10	.11	.54	ND	.35		
			2000	13.0	7.4	9.2	88.0								
	9/12/78		2200	12.5	7.5	9.1	86.0								
			2400	12.0	6.9	8.8	82.0	.07	.11	.10	.54	ND	.26		
			0200	12.5	6.9	8.9	84.0								
	9/13/78		0400	12.0	6.9	8.7	82.0							230 est.	
			0600	12.0	6.8	7.9	74.0	.10	.14	.11	.54	ND	.43		
			0800	12.0	7.2	8.0	75.0								
			1000	12.5	---	9.0	85.0								
			1200	14.9	7.1	7.9	79.0	1.2	*	2.3	1.2	.05	2.4		0.69
2	35 meters below outfall	2.63/1.70	1400	14.9	---	7.8	78.0								
			1600	15.0	7.1	8.0	80.0								
			1800	15.9	7.2	7.6	62.0	1.6	1.6	4.3	.9	.1	4.7		
			2000	15.0	7.3	7.2	72.0								
	9/12/78		2200	14.0	7.4	7.1	70.0								
			2400	13.5	6.9	7.1	69.0	1.5	1.6	3.7	.8	.1	4.6		
			0200	13.0	6.8	7.2	69.0							140 est.	
	9/13/78		0400	13.0	6.9	7.1	68.0								
			0600	12.5	6.7	6.7	64.0	1.0	1.0	2.1	.65	.05	2.2		
			0800	13.0	7.0	6.3	60.0								
			1000	14.0	7.1	7.7	76.0								

* = Rejected by Laboratory due to Unknown Interference.

TABLE 1 (cont.)
Water Quality Data Collected by DOE during Weaver Creek Survey, September 12-13, 1978

Sta-tion	Description	Flow CFS / MGD	Time	°C Temp	pH	IBC-DO ppm	% DO Sat.	Ortho-P Mg/l	Total Phos-P Mg/l	Ammonia-N Mg/l	Nitrate-N Mg/l	Nitrite-N Mg/l	T-Kjeldahl-N Mg/l	Fecal Coliform Col/100ml	Macro-inverta-brate (Species Div.)
			1200	14.0	7.2	7.9	78.0	1.4	1.4	1.9	1.7	.2	1.9		1.84
3	400 meters	None Taken	1400	14.9	7.4	4.4	44.0								
	below outfall		1600	15.0	7.1	5.9	59.0								
	at N.E. 199th		1800	15.0	7.2	3.3	33.0	1.3	1.4	3.4	1.4	.2	*		
	St. Bridge		2000	14.5	7.1	2.8	28.0								
		9/12/78	2200	13.5	7.0	2.6	25.0								
			2400	13.0	6.7	2.7	26.0	1.5	1.6	3.7	1.2	.2	*		
			0200	12.0	6.8	2.5	23.0							48	
		9/13/78	0400	12.5	6.6	2.6	25.0								
			0600	12.5	6.0	2.6	25.0	.95	1.0	1.8	1.2	.15	*		
			0800	13.0	6.4	3.0	29.0								
			1000	13.0	6.9	3.9	37.0								
			1200	13.1	7.2	5.0	48.0	1.1	1.2	.39	1.7	.15	.73		2.36
4	1500 meters	2.99/1.93	1400	14.5	7.3	4.6	46.0								
	below outfall at		1600	15.0	7.1	8.7	87.0								
	N.E. 132nd Ave.		1800	15.0	7.3	4.0	40.0	.47	1.4	.39	1.8	.23	*		
	Bridge (Private)		2000	14.0	7.3	3.4	33.0								
		9/12/78	2200	13.0	7.2	3.4	33.0								
			2400	13.0	6.7	3.2	31.0	.65	1.5	2.2	2.8	.2	2.7		
			0200	13.0	6.6	3.4	33.0							170 est.	
		9/13/78	0400	12.5	6.8	3.2	30.0								
			0600	12.5	6.1	3.1	29.0	.5	1.2	1.3	2.5	.2	*		
			0800	13.0	7.2	3.4	33.0								
			1000	13.0	---	4.2	40.0								

* = Rejected by Laboratory due to Unknown Interference.

TABLE 1 (cont.)

Water Quality Data Collected by DOE during Weaver Creek Survey, September 12-13, 1978

Sta-tion	Description	Flow CFS / MGD	Time	°C Temp	pH	IBC-DO ppm	% DO Sat.	Ortho-P Mg/1	Total Phos-P Mg/1	Ammonia-N Mg/1	Nitrate-N Mg/1	Nitrite-N Mg/1	T-Kjeldahl-N Mg/1	Fecal Coliform Col/100ml	Macro-inverta-brate (Species Div.)
			1200	13.0	7.3	9.3	89.0	.62	1.4	.09	1.7	.06	.65		1.83
5	3635 meters	3.31/2.14	1400	15.1	7.5	9.8	98.0								
	below outfall at		1600	14.9	7.4	10.2	102.0								
	N.E. 117th Ave.		1800	15.0	7.2	10.0	100.0	.39	.73	.05	1.6	.01	.62		
	Bridge (Immed.		2000	14.0	7.5	9.6	94.0								
	upstream from		2200	13.0	7.5	9.2	88.0								
	mouth)	9/12/78	2400	12.5	6.9	9.2	87.0	.42	.88	.06	1.8	.01	.64		
			0200	12.0	6.8	9.2	86.0							320	
		9/13/78	0400	12.5	7.1	9.1	86.0								
			0600	12.0	6.4	8.2	77.0	1.1	1.6	.41	1.8	.13	.66		
			0800	13.0	6.9	8.4	81.0								
			1000	12.5	---	9.0	85.0								

Battleground STP

Auto-Composite Data

Day	Time	Flow-MG	Ortho-P Mg/1	Total-Phos-P Mg/1	Ammonia-N Mg/1	Nitrate-N Mg/1	Nitrite-N Mg/1	T-Kjeldahl-N Mg/1	BOD_5 Mg/1	COD Mg/1	pH
9/12	1200-1800	.1557	4.9	---*	13.	2.4	.2	---*	21	93	7.5
9/12	1800-2400	.1601	6.2	---*	16.	1.3	.3	---*	24	90	7.6
9/13	0000-0600	.0930	7.4	---*	14.	2.8	.4	12.	26	90	7.6
9/13	0600-1200	.1512	7.8	---*	11.	2.4	.4	6.	22	90	7.6
	MGD Total	.5600									

* = Rejected by Laboratory due to Unknown Interference.

TABLE 2

Weaver Creek Survey, Macroinvertebrate Data Sheet
September 12, 1978

STATION	ORGANISM	TOTAL NUMBER
# 1 (immediately abv. outfall)	DIPTERA	
	Tendipedidae	
	Unidentified species	17
	EPHEMEROPTERA	
	Baetidae	
	Baetinae	
	Baetis sp.	2
	Leptophlebiinae	
	Paraleptophlebia sp.	5
	SPECIES DIVERSITY	1.12
# 2 (100 ft. blw. outfall)	DIPTERA	
	Tendipedidae	
	Unidentified species	95
	CRUSTACEA	
	Isopoda	
	Asellus sp.	15
	MOLLUSCA	
	Pelecypoda	
	Pelecypoda musculium	2
	SPECIES DIVERSITY	0.69
# 3 (132nd ave. bridge)	DIPTERA	
	Tendipedidae	
	Unidentified species	5
	CRUSTACEA	
	Isopoda	
	Asellus sp.	10
	Amphipoda	
	Gammarus lacustris	11
	MOLLUSCA	
	Gastropoda	
	Ancylidae	
	Ferrissia caurina caurina	3
	SPECIES DIVERSITY	1.84

TABLE 2 (cont.)

Weaver Creek Survey, Macroinvertebrate Data Sheet
September 12, 1978

STATION	ORGANISM	TOTAL NUMBER
# 4 (0.75 mi. blw. outfall)	Diptera	
	Tendipedidae	
	Unidentified species	5
	Simuliidae	
	Unidentified species	4
	CRUSTACEA	
	Isopoda	
	Asellus sp.	1
	Amphipoda	
	Gammarus lacustris	7
	MOLLUSCA	
	Gastropoda	
	Goniobasis silicula	11
	Lymnae sp.	8
	SPECIES DIVERSITY	2.36
# 5 (immed. upstream from mouth)	DIPTERA	
	Tendipedidae	
	Unidentified species	2
	TRICOPTERA	
	Rhyacophilidae	
	Rhyacophila sp.	3
	EPHEMEROPTERA	
	Leptophlebiinae	
	Paraleptophlebia sp.	3
	Baetidae	
	Baetinae	
	Baetis sp.	19
	MOLLUSCA	
	Gastropoda	
	Goniobasis silicula	27
	Lymnae sp.	2
	SPECIES DIVERSITY	1.83