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MEMORANDUM

July 6, 1981

To: John Bernhardt

From: Bill Yake

Subject: Interpretation of June 3, 1981 Budd Inlet Data with Particular Respect to Oxygen Depletion

Immediately after learning of a fish kill in Budd Inlet on June 3, 1981, personnel from the Water Quality Investigations Section of the Department of Ecology (DOE) conducted a study in the vicinity of the kill. Figure 1 shows the sampling locations, Table 1 the field and laboratory analytical results of the receiving water study, and Table 2 the results of analysis of an Olympia Wastewater Treatment Plant (WTP) effluent sample collected the same day.

As can be noted in Table 1, surface water dissolved oxygen concentrations were very low at locations both north and south of the treatment plant discharge (near Station 14) along the east side of the western lobe of Budd Inlet. Severely depressed oxygen concentrations were apparently limited to surface waters. Based on the data in Table 1, Budd Inlet displayed vertical oxygen, temperature, and salinity gradients indicating strong vertical stratification. This stratification probably was enhanced by the lack of significant winds during the period of the fish kill and subsequent survey.

It is probable that several adverse factors coincided to result in the severe oxygen depletion noted during the survey. Among these are:

1. The high biochemical oxygen demand of the Olympia WTP effluent;

2. The lack of winds which minimized physical reaeration and vertical mixing;

3. The cutoff of freshwater flow from Capitol Lake which minimized the dilution of effluent in the surface waters of Budd Inlet; and

4. The depression of photosynthetic activity during the night and subsequent overcast day coupled with algal and dinoflaggelate respiration.

14	0	1100/1120	14/15.5	8.9/9.3	–/6.17	–/6.18	0.4	26	52	220	<0.10	<0.10	4.0	0.8	1.8	21.8	7.0	6.7	9.2	1.3
15	0	1110	15	8.3																
16	0	1415	15.5	1.3	0.17	7.20	–	5	26	210	0.01	<0.01	0.03	0.09	0.25	24.8	6.9	–	–	–
	5																			
17	0	1320	14.0	1.8	1.09	7.32	0.8	4	22	190	0.01	<0.01	0.04	0.09	0.29	25.1	6.9	0.5	2.6	1.1
	5		12.8	8.7																
	10																			
18	0	1345	13.5	6.1			1.0													
	5		12.5	6.7																
19	0	1355	13.8	5.3			2.0													
	5		13.5	9.9																
20	0	1420	15.2	7.8			2.0	2	15	10(est)	0.04	<0.01	0.17	0.08	0.13	19.5	7.6	–	–	–
	5		13.0	7.9																

1 Preliminary values; approximately 20% higher than actual values due to salinity effect on electrode

2 Winkler values lower than actual values when sulfide is present (APHA, 1976).

3 High Tide – 4:54 AM, 14.9 feet; Low tide = 12:15 PM, -2.8 feet

State of Washington Department of Ecology

TABLE 2

OLYMPIA ENVIRONMENTAL LABORATORY

DATA SUMMARY

ORIGINAL TO: Lab Files

COPIES TO: Jim Krull, Rick Pierce, John Bernhardt

LAB FILES Bill Yake

SOURCE Budd Inlet / Olympia STP

DATE COLLECTED 6-3-81

COLLECTED BY J. Oberlander

Sample (Log) Number 81-	2300	2301	2302	2304
Station:	Fiddlehead	Marina	Plant Effluent to Temporary Discharge	Plant Effluent to Temporary Outfall
pH (units)	6.3	Sample sent to Wenatchee Pesticides lab for pesticides analysis	6.6	Sample sent to EPA Manchester lab for toxics analysis
Turbidity (NTU)	14		180	
Sp. Conductivity (umhos/cm)	30,300		802	
COD	870		1,700	
BOD (5 day)	140		1200	Note: Sample No 2300 sent to EPA Manchester lab for priority pollutants analysis
Fecal Coliform (Col./100 ml)				
NO3-N	<0.10		<0.05	
NO2-N	<0.10		<0.05	
NH3-N	1.2		14	
T. Kjeldahl-N				
O-P04-P	0.40		4.7	
Total Phos.-P	0.85		6.7	
Total Solids				
Total Non Vol. Solids				
Total Suspended Solids	27		210	
Total Non Vol. Sus. Solids				
Total Sulfide as S	<0.1		<0.1	
Salinity, 22.5°C, parts/thousand	23.3		0.6	

Dissolved oxygen under BOD test conditions, 1% sample dilution, ppm. Sample No 2302

Time	DO	BOD*	Time	DO	BOD*	Time	DO	BOD*	Time	DO
0 minutes	9.1	—	2 hours	8.1	100	5 hours	7.4	170	30 hours	3.1
15 minutes	9.0	10 est	3 hours	7.7	140	6 hours	7.2	190		BOD 600
1 hour	8.6	50 est	4 hours	7.4	170	7 hours	7.1	200		

* Does not include blank and seed corrections.

NOTE: All results ... unless otherwise specified. ND is "None Detected"

SUMMARIZED BY G. Freeman DATE 6-17-81

Table [illegible] ... DO ... [illegible]

Stn No.	Z	Time	Temp (°C)	DO (mg l⁻¹)[1]	DO (mg l⁻¹)[2]	Ph (units)	Secchi (m)	Turb NTU	TSS (mg l⁻¹)	FC (per 100 ml)	NO_3-N (mg l⁻¹)	NO_2-N (mg l⁻¹)	NH_3-N (mg l⁻¹)	O-PO_4-P (mg l⁻¹)	T-PO_4-P (mg l⁻¹)	Sal (‰)	Ph (units)	Chl-a (mg l⁻¹)	Phaeo (mg l⁻¹)	Pigment Ratio
1	0	1450	14.2	11.3	9.40	7.95	2.5	7	16	2 (est.)	0.01	<0.01	0.08	0.08	0.11	27.3	7.9			
	5		12.9	13.1																
	10		11.8	12.8																
2	0	1222	14.2	6.3	5.10		2													
	5		13.2	10.5																
	10		12.8	12.5																
3	0	1230	14.2	6.8	4.34															
4	0	1215	14.5	1.6	0.48	6.75	>1.5	3	30	540	<0.01	<0.01	0.04	0.07	0.21	24.8	7.0			
	5		12.8	9.0																
5	0	1238	13.8	9.2			1.5													
	5		—	—																
6	0	1245	13.8	7.2			1.5													
	5		12.7	11.9																
7	0	1250	13.5	8.1			1.5													
	5		12.3	12.2																
8	0	1255	13.5	1.8																
9	0	1200	13.0	1.1	0.11	6.8	1.3	5	20	1200	<0.01	<0.01	0.08	0.09	0.28	26.4	7.0	1.8	5.7	1.2
	5		12.5	6.1																
	10		11.5	7.6																
	15		7.7	11.5																
10	0	1125/1135	13.5/13.5	5.6/7.8	– /.44	– /6.72	1	5	32	3200	<0.01	<0.01	0.09	0.12	0.37	22.7	6.9	—	—	—
	5		13.0/12.0	8.4/7.4																
	10		12.0/12.0	8.9/7.5																
	15		11.0/11.0	5.5/7.0																
11	0	1130/1305	13/13.5	7.8/7.5	6.12/5.20	– /7.24	—	19	27	120	<0.05	<0.05	1.6	0.50	0.84	24.6	6.8	0.0	6.4	1.0
	5		12.5/12.0	6.1/10.1																
	10		11.5/11.3	7.6/7.4																
	15		11.5/11.0	7.7/3.6																
12	0	1300	14.0	5.9			—													
1[illegible]	0	1120	13	8.7			—													
	5		13	9.5																
13	0	1115/1430	13/13.8	8.4/8.5	– /5.89	– /7.28	1.0	9	17	320	0.01	<0.01	0.5	0.22	0.52	24.9	6.8	—	—	—
	5		13/12.5	10.1/7.6																

In an attempt to isolate the probable magnitude of oxygen depression attributable to the treatment plant effluent, this memo examines (1) the apparent concentration of effluent in samples taken from the surface of Budd Inlet, (2) the results of effluent BOD tests to determine the rate at which oxygen is consumed by these wastes, and (3) the degree to which the observed effluent fractions could depress oxygen concentrations over various time periods.

The first step is to estimate effluent concentrations in various surface water samples. Three constituents were chosen for examination as possible tracers: total phosphorus; salinity; and ammonia-nitrogen. Each of these constituents has very different concentrations in unaffected surface waters (i.e., Station 1) and the effluent. The basic equation used was:

Equation 1: $C_b\,(1-f) + C_e\,(f) = C_s$

where:
C_b = tracer concentrations at background station
f = decimal fraction of effluent in sample
C_e = tracer concentrations in effluent
C_s = tracer concentration in a given surface sample

The results of these calculations are given in Table 3. As can be noted, total phosphorus appeared to be the best tracer. Ammonia-N works well at stations near the effluent discharge, but appeared to give low results at outlying stations. This may be due to rapid NH_3-N encorporation by algae. In general, salinity appeared to give high f results, probably indicating some additional source of freshwater in the area. This may have been partially due to freshwater leakage around the Capitol Lake tide gate. Taking into account these considerations, a representative f (i.e., decimal fraction of effluent in the surface samples) was chosen and used in subsequent calculations. The results of these calculations is displayed graphically in Figure 1. Lines of equal effluent concentrations are displayed based on the calculations in Table 3. As can be seen, it appears that the effluent is distributed over the same area where depressed oxygen concentrations were observed. However, in general, the areas of lowest dissolved oxygen concentration also contain the lowest fraction of effluent. To explain the apparent contradition, one must consider the "age" of the effluent: the consumption of oxygen is time-dependent, the "older" the effluent parcel, the more oxygen will have been consumed. To quantify this effect, the rate of biochemical oxygen demand (BOD) satisfaction must be examined.

Figure 2 displays the results of interval BOD tests conducted in DOE's Tumwater labroatory at 20°C. The results are unusual in that there appears to be a two-stage curve with a very rapid initial phase lasting through about the 12th hour followed by a more typical rate through the remainder of the test. The best fit curves for these stages are:

Equation 2: $BOD_t = 340\,(1-10^{-1.55t})$, through 12th hour

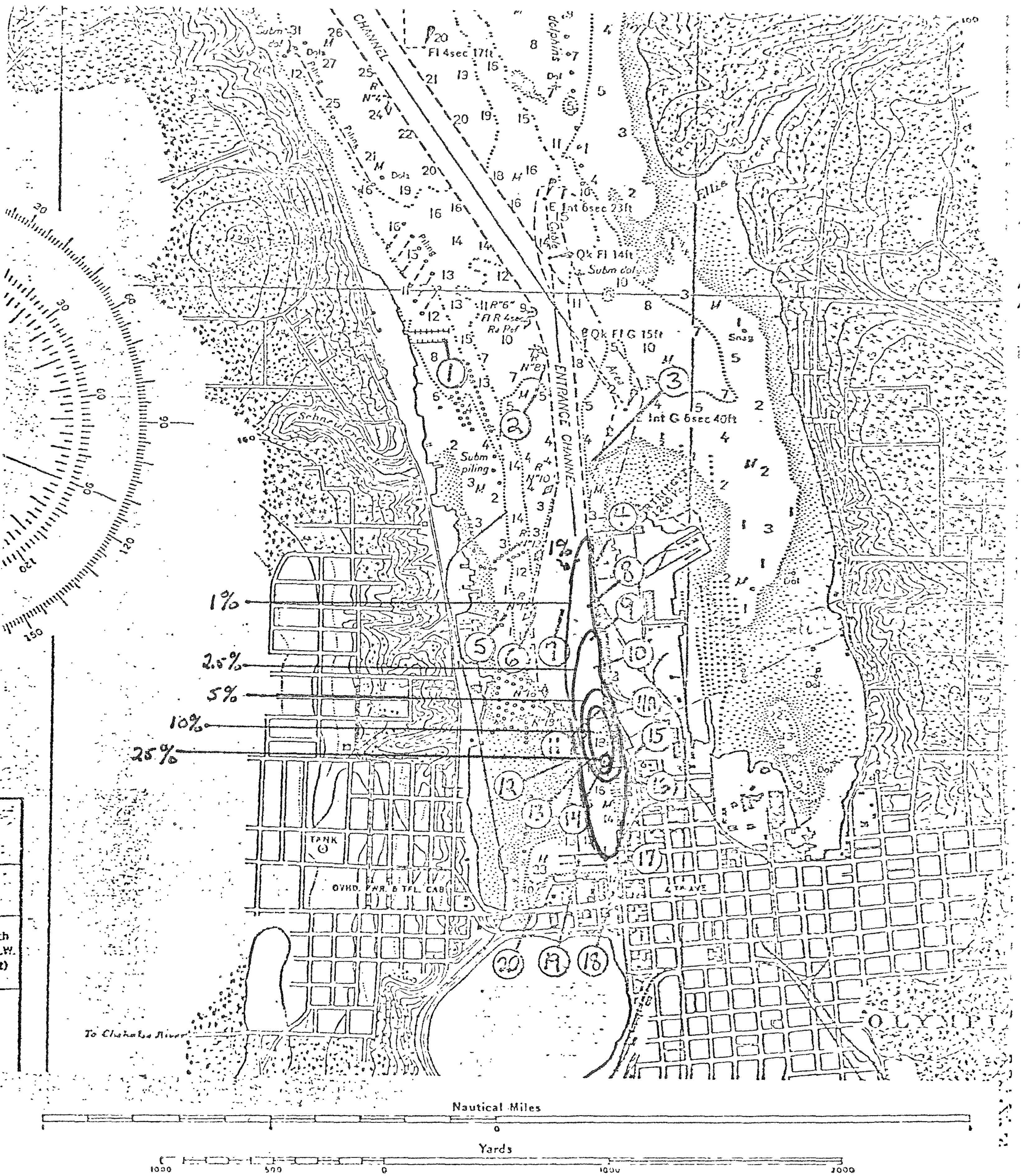

FIGURE 1 - OLYMPIA STP EFFLUENT DISTRIBUTION - 6/3/81
IN SURFACE WATERS OF BUDD INLET

Equation 3: $BOD_t = 1350\ (1-10^{-.19t})$, through 5th Day

where BOD_t = BOD exerted by time t
t = time in days

Because these tests were run at 20°C, the reaction rates must be modified for field conditions where temperatures were about 14°C. Rates were modified using equation 4.

Equation 4: $K_T = K_{20}\ (1.056)^{T-20}$

where K_{20} = the reaction rate at 20°C
K_T = the reaction rate at temperature T
T = temperature in degrees centigrade

Thus modified, equations 2 and 3 change to equations 2a and 3a.

Equation 2a: $BOD_t = 340\ (1-10^{-1.12t})$

Equation 3a: $BOD_t = 1350\ (1-10^{-.14t})$

With the dynamics of oxygen depletion and the fraction effluent in surface water samples established, it is possible to analyze the oxygen depletion attributable to Olympia WTP effluent. For this analysis, Equation 2a was used through the 12th hour, equation 3a from the 12th through the 24th hour.

Table 4 shows the results of these calculations. The fraction effluent (f) and the asympotote of equation 2a (340 mg/L) were used to calculate BOD_{ui} in Table 4. This value was then used to calculate the oxygen demand at each station through the 12th hour. The ultimate BOD (1350 mg/L) in equation 3a was used similarly for analyses from the 12th to the 24th hour. Thus the oxygen depletion attributable to Olympia WTP effluent was then calculated for various time periods from 15 minutes to 24 hours. One can compare these depletions with "actual" depletions shown in the last column of Table 4. These "actual" depletions are calculated assuming an initial dissolved oxygen concentration of 8 mg/L.

This entire analysis assumes that the effluent sample obtained early during the afternoon of June 3 was representative of effluent being discharged during the night of June 2-3. If, in fact, the effluent contained a higher BOD concentration, then a larger percentage of the observed oxygen depletion would be attributable to the treatment plant.

At present, the average age of effluent in samples collected at each of the stations is not known. Further studies should result in better definitions of this question. Nonetheless, it appears reasonable to assume that samples with lower effluent fractions (1% to 2.5%) contained effluent at least 4 to 6 hours old. Based on Table 4 then, 25% to 100% of the observed oxygen depletion appears to be attributable to Olympia WTP effluent oxygen demand.

BY:cp

Attachments

Table 3. Estimation of fraction Olympia STP effluent in Budd Inlet surface water samples.

Station	$T\text{-}PO_4\text{-}P$ (mg/L)	Salinity (o/oo)	$NH_3\text{-}N$ (mg/L)	fp	f sal.	f $NH_3\text{-}N$	f Chosen
1	.11	27.3	.08	0	0	.003	0
4	.21	24.8	.04	.015	.094	0	.015
9	.28	26.4	.08	.026	.034	.003	.030
10	.37	22.7	.09	.039	.172	.004	.040
13	.52	24.9	0.5	.062	.090	.033	.060
11	.84	24.6	1.6	.111	.099	.111	.110
14	1.8	21.8	4.0	.256	.206	.283	.250
16	.28	24.8	.03	.026	.094	--	.025
17	.29	25.1	.04	.027	.083	--	.025
STP Eff.	6.7	0.6	14	1.0	1.0	1.0	1.0

Table 4. Calculation of estimated dissolved oxygen depletion due to Olympia STP effluent.

Station	f	D.O. (mg/L)	BOD_{ui} (mg/L)	BOD Exerted 15 min.	1 hour	2 hrs.	4 hrs.	6 hrs.	8 hrs.	12 hrs.	BOD_u (mg/L)	16 hrs.	20 hrs.	24 hrs.	Estimated D.O. Drop (mg/L)
1	0	9.40	0	0	0	0	0	0	0	0	0	0			0
4	.015	0.98	5.1	0.14	0.52	0.99	1.78	2.23	2.94	3.70	20.3	3.93	4.78	5.59	7.0
9	.030	0.11	10.2	0.27	1.04	1.97	3.56	4.46	5.88	7.39	40.5	7.83	9.54	11.2	7.9
10	.040	0.44	13.6	0.36	1.39	2.63	4.75	5.95	7.84	9.85	54	10.4	12.7	14.9	7.6
13	.062	5.89	21	0.56	2.14	4.06	7.34	9.19	12.1	15.2	83.7	16.2	19.7	23.1	2.8
11	.110	5.20	37.4	0.99	3.81	7.23	13.1	16.4	21.6	27.1	148.5	28.7	35.0	40.9	2.1
14	.250	6.19	85	2.25	8.66	16.4	29.7	37.2	49.0	61.6	337.5	65.3	79.5	93.0	1.8
16	.025	0.17	8.5	0.23	0.87	1.64	2.97	3.72	4.90	6.16	33.8	6.54	7.96	9.31	7.2
17	.025	1.09	8.5	0.23	0.87	1.64	2.97	3.72	4.90	6.16	33.8	6.54	7.96	9.31	6.9

JOHN SPELLMAN
Governor

DONALD W. MOOS
Director

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
7272 Cleanwater Lane, LU-11 • Olympia, Washington 98504 • (206) 753-2353

M E M O R A N D U M

TO: Norm Glenn

FROM: Jim Krull

SUBJECT: Nutrients Related to Marine Discharges

DATE: February 1, 1982

Attached is a Bill Yake to Dick Cunningham Memo that may have implications with respect to existing and future grant projects.

Specifically, with respect to LOTT, it seems that the thinking has been wrong with respect to the influence of the STP discharge on nutrients and hence algal blooms and potential D.O.

The impact of secondary treatment at LOTT on nutrient loading to the inlet is unknown. The brewery is making changes to their waste stream so the nutrient loading and the form the nutrients will be in is not known. It may be that the STP will be nitrogen deficient. Let's hope not. The best thing that could happen is that the biological Nitrogen demand of the plant and the form of nutrient imput are such that significant nitrógen reduction occurs across the plant.

We will do some monitoring now to help establish a before/after data base.

I feel that this new thinking on nutrient loading to the inlet should be transmitted to the city. Let me know how you think this should be done.

JK:jk

cc: Howard Steeley
Stew Messman
Bob Monn
Dick Cunningham
Bill Yake

Available Nitrogen Data
LOTT - Budd Inlet

1) Deschutes / Capitol Lake Inorganic N Loading:

A. Kruger Rpt. = 296 lbs NO_3-N Loading / Day from Capitol Lake

B. Ambient Monitoring - Deschutes @ E Street Bridge 6/79 - 10/81

Month	Ave. Total Inorg. N Load (lbs N / day)	Range
June	510	377 - 808
July	289	241 - 346
Aug	160	138 - 182
Sept	227	133 - 295
Oct	371	153 - 762

Overall Ave. 311

2) LOTT Plant

Few Actual Data

7-7-77 - Class II Total Inorg. Load of 912 lbs/day
9-16-76 - Class II ~900 lbs Inorg. N/day; ~1900 lbs Total N/day

Based on Inorg. N - LOTT Plant may be N deficient
KCM considered including NH_3 addition but did not because of cost. Availability of Org. N unknown,
KCM believes nutrient problems can be handled by supernant recycle & controlling plant operation mode
(I assume this means extended sludge age).

3) Proposed Sampling

1) 1 day/wk. for 4 wks.
2) 24 hr Composite.
3) Obtain Concurrent Plant Flows
4) Influent, Effluent
5) Parameters: Nutrients (NH_3, NO_2, NO_3, TKN, O-PO_4-P, T-P); COD, BOD, TSS, Cond., pH, Turb.