March 30, 1990

TO: Kim Anderson

FROM: Pat Hallinan

SUBJECT: British Petroleum Oil Refinery Class II Inspection,
Water Body No. WA-01-0010, (Segment No. 01-01-07)

INTRODUCTION

Ecology conducted a Class II inspection at the British Petroleum (BP) Oil Refinery in Ferndale on May 8-10, 1989. Pat Hallinan and Keith Seiders from the Ecology Compliance Monitoring Section and Kim Anderson from the Ecology Industrial Section conducted the inspection. John Webb from BP Oil assisted during the inspection.

The refinery processes about 75,000 barrels a day of crude oil to produce various petroleum products. Process wastewater generated at the site is treated by a system consisting of several equalization basins, API oil/water separators, a pH neutralization basin, a DAF oil/water separator, a trickling filter, solid/wastewater contact units (aero-accelerators), and a series of holding ponds (see Figure 1). Sanitary wastes generated on site are also treated by this system (also Figure 1). Treated wastewater discharges into the Strait of Georgia as regulated by National Pollutant Discharge Elimination System (NPDES) permit WA-000298-4.

Objectives of this inspection included:

1. Verify effluent compliance with NPDES permit limits.

2. Chemically characterize refinery effluent for toxic pollutants.

3. Evaluate refinery effluent for toxicity using a series of marine and freshwater bioassays.

4. Chemically characterize sediments surrounding the wastewater outfall for toxic pollutants.

5. Evaluate sediment toxicity using sediment amphipod and Microtox bioassays.

6. Review laboratory procedures at the refinery for conformance to standard techniques. Samples were split with the permittee to determine the accuracy of laboratory results.

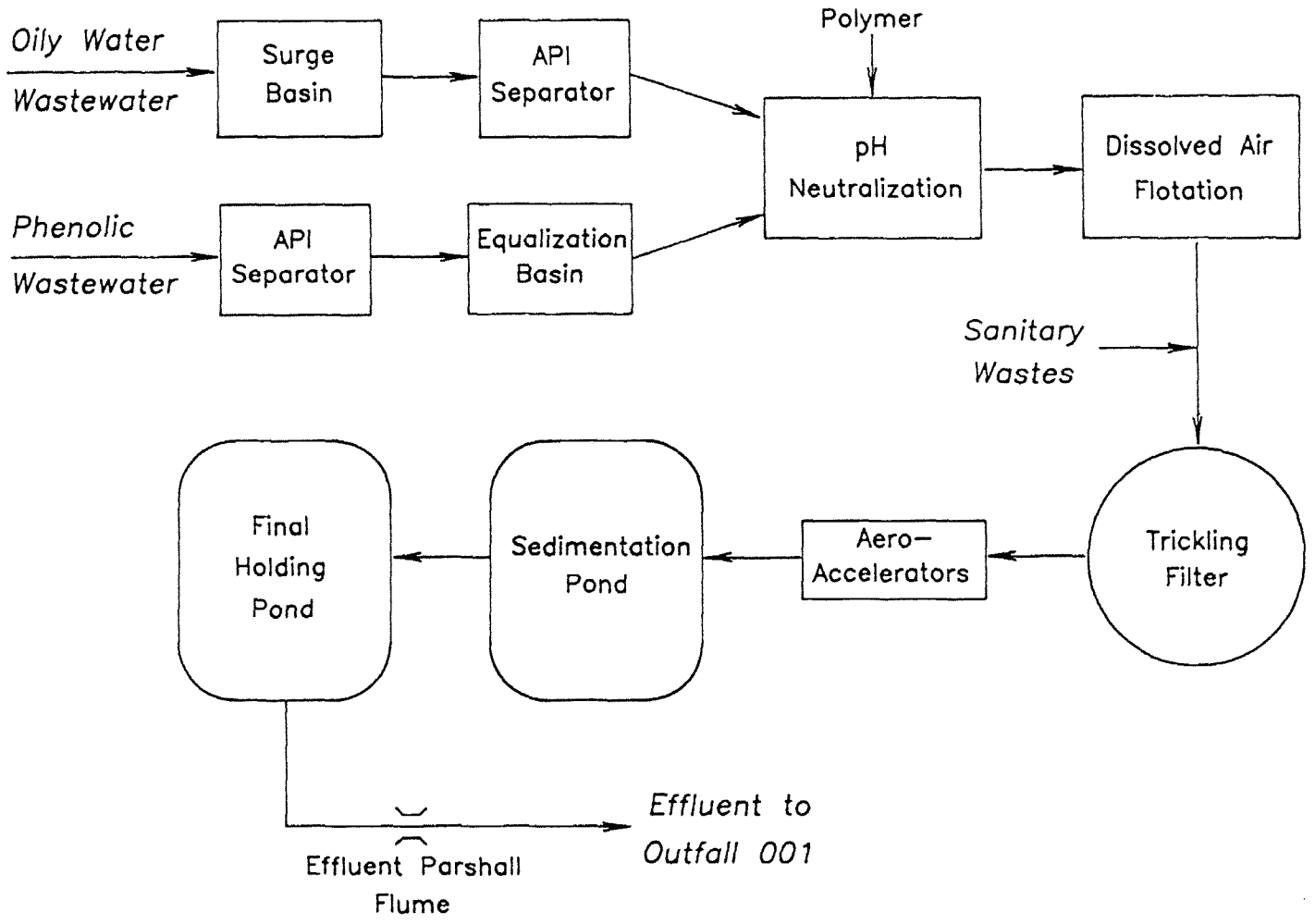

Figure 1 – Wastewater Treatment System Schematic – BP Oil, 5/89

PROCEDURES

Ecology collected a 24-hour composite sample of refinery effluent. The sample was collected at the effluent Parshall flume by an ISCO automatic sampler, sampling about 330 mLs of wastewater every 30 minutes for 24 hours. Grab samples of treated effluent were also collected for field and laboratory analyses. Table 1 lists effluent sampling times and parameters analyzed. An instantaneous check of the effluent Parshall flume was also made.

The wastewater sampler was fitted with teflon tubing and glass sampling bottles. This equipment was cleaned before use by washing with non-phosphate detergent and then rinsing three times with deionized water, dilute nitric acid, methylene chloride, and acetone. Collection apparatus was air-dried then wrapped in aluminum foil until used.

Three sites were sampled for bottom sediment in the vicinity of the wastewater discharge (see Figure 2): at the outfall ("at outfall"), at the edge of the NPDES permitted dilution zone ("near outfall"), and at a reference site approximately one mile northwest of the outfall ("field control").

Sediment samples were collected with a 0.1 meter square van Veen sampler following recommended Puget Sound protocols (Tetra Tech, 1986). Samples consisted of three to four individual grabs in which the top 2 cm of sediment from each grab was removed, then composited. Composites were thoroughly mixed, then divided for separate analysis, except for sediment analyzed for volatile organics (VOAs). These samples were taken directly from the van Veen. Stainless steel utensils were used in the collection of the sediment samples and were cleaned by the same procedures as the wastewater composite samplers. Table 1 also includes sediment sampling times and parameters analyzed.

The Ecology Manchester Laboratory analyzed conventional pollutant samples collected during the inspection. Analytical Resources Incorporated of Seattle completed the volatile, semi-volatile and pesticide/PCB organic and metal analyses. For the bioassay samples, Ecova performed the water and sediment (saline extract) Microtox tests, while E.V.S. Consultants completed the echinoderm (Sand dollar; *Dendraster excentricus*) sperm fertilization and sediment amphipod bioassays. Weyerhaueser Labs performed the rainbow trout bioassay. Through money provided by the Environmental Protection Agency (EPA), a seven day growth and survival fathead minnow test, a duplicate echinoderm (purple sea urchin; *Strongylocentrotus purpuratas*) fertilization bioassay, and a pacific oyster embryo development test was performed by ERCE Bioassay Laboratory of San Diego, California. Appendix 1 lists all chemical and biological test methods used.

Ecology was not able to split the 24-hour effluent composite sample collected by BP Oil; the BP Oil composite sample collected was not large enough to allow for a split. Sediment samples and wastewater 24-hour composite and grab samples collected by Ecology were split for analyses between Ecology and BP Oil. BP duplicated all chemical tests and bioassays performed by Ecology, except for the field control sediment semi-volatile analyses. For the BP samples, AMTEST Inc. of Redmond performed the sediment organic and metal analyses. The fathead minnow, echinoderm fertilization, sediment amphipod, sediment and effluent Microtox, and rainbow trout bioassays were completed by Beak Laboratories of Toronto, Canada. E.V.S. Consultants of Vancouver, British Columbia, performed the pacific oyster bioassay. Eagle-Picher Environmental Services of Miami, Oklahoma completed the effluent organic and metal analyses.

Table 1 - Sampling Times and Parameters Analyzed - BP Oil, 5/89.

						Sediments		
	Station:	Effluent				Field Control	@ Outfall	Near Outfall
	Type:	Grab			Composite	Grab	Grab	Grab
	Date:	5/9	5/9	5/10	5/9-10	5/8	5/8	5/8
Parameters	Time:	1050	1635	1020	1030-1030	1625	1310	1500
GENERAL CHEMISTRY								
Turbidity (NTU)					X			
pH (S.U.)					X			
Conductivity (umhos/cm)					X			
Alkalinity (mg/L as $CaCO_3$)					X			
Hardness (mg/L as $CaCO_3$)					X			
Cyanide (mg/L)					X			
Solids (mg/L)								
TS					X			
TNVS					X			
TSS		X	X	X	X			
TNVSS					X			
BOD_5 (mg/L)					X			
COD (mg/L)		X	X	X	X			
Nutrients (mg/L)								
NH_3-N		X	X	X	X			
NO_3+NO_2-N		X	X	X	X			
T-Phosphate		X	X	X	X			
Fecal Coliform (#/100mL)					X			
Oil & Grease (mg/L)		X	X	X				
% Solids						X	X	X
Grain Size						X	X	X
ORGANICS + METALS								
pp Metals					X	X	X	X
Hexa-chromium					X			
Semi-Volatiles					X	X	X	X
Volatiles				X		X	X	X
Pesticides/PCBs					X	X	X	X
Phenols (ug/L)					X			
TOC (mg/L)					X	X	X	X
BIOASSAYS								
Trout					X			
Microtox (water)					X			
Echinoderm					X			
Pacific Oyster								
Fathead minnow					X			
Rhepoxynius abronius						X	X	X
Microtox (sediment)						X	X	X
FIELD ANALYSES								
Temperature (C)		X	X	X	X			
pH (S.U.)		X	X	X	X			
Conductivity (umhos/cm)		X	X	X	X			
Sulfide		X	X	X				

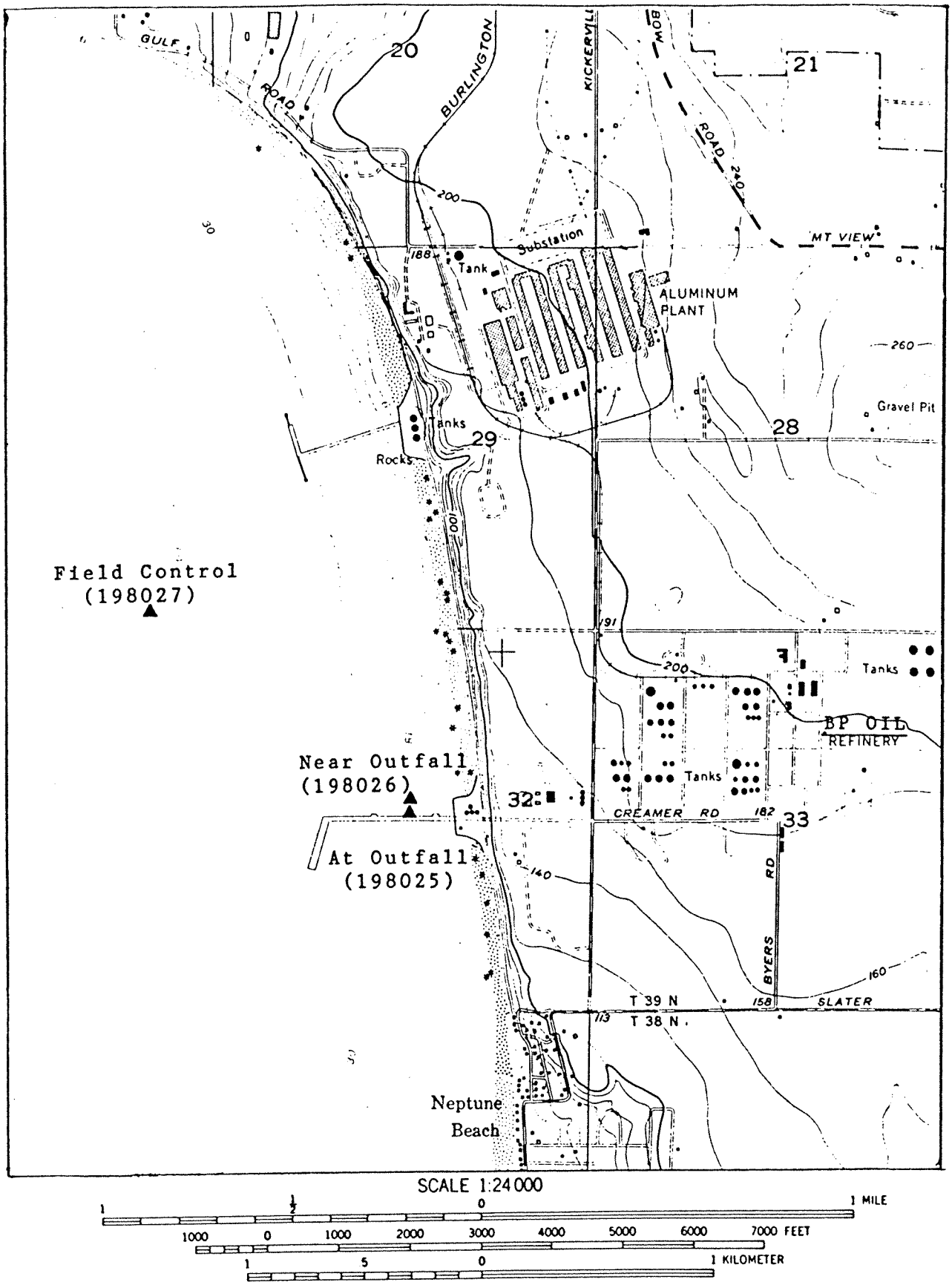

Figure 2 - Sediment Sampling Stations
- BP Oil, 5/89.

RESULTS AND DISCUSSION

Comparison of Effluent Parameters to NPDES Permit Limits

Conventional pollutant data collected during the inspection is summarized in Table 2. The effluent met permit limits for biochemical oxygen demand (BOD), total suspended solids (TSS), oil and grease, ammonia (as nitrogen), hexavalent chromium, total phenolics, fecal coliform, chemical oxygen demand (COD), sulfide and pH (Table 3). The effluent also passed the rainbow trout bioassay with a 100 percent survival in 65 percent effluent. For chromium, Ecology used the total recoverable analytical method (the permit specifies total chromium). However, the total recoverable amount (in pounds per day discharged) was still an order of magnitude below the permit limit.

Flow readings made during the inspection are given on Table 4. An instantaneous check showed that the meter was accurate at the inspection flow rate (about 0.84 MGD). However, the Parshall flume was 1/2" to 1-1/2" too narrow at the throat section. At higher flows, the flume may overestimate the actual flow rate.

Other Effluent Bioassay Results

Effluent bioassay results are given in Table 5. In the fathead minnow test, significant mortalities occurred at the 50 and 100 percent effluent concentrations (46.7 and 30 percent respectively). Larval growth results were inconclusive at these concentrations due to the excessive mortalities. For effluent concentrations of 25, 12.5 and 6.25 percent, fish survival and mean weight were not statistically different than the laboratory control. For larval growth, an NOEC (no observable effect concentration) of 25 percent effluent and an LOEC (lowest observable effect concentration) of 50 percent effluent were measured. The seven day LC_{50} (lethal concentration to 50 percent of the test organisms) was 55 percent effluent. In the effluent Microtox test, an EC_{50} of 69.4 percent effluent was measured which represents a moderate level of toxicity (EPA, 1980).

For the pacific oyster embryo development bioassay, significant embryo mortalities also occurred at the two highest effluent concentrations tested (38.5 and 76.9 percent with mortalities of 73.3 and 100 percent, respectively). Embryo abnormalities at 38.5 percent effluent (9.4 percent) were statistically different than the laboratory control. At the lower effluent concentrations tested (19.2, 9.6 and 4.8 percent), survival and the number of abnormal embryos were similar to the laboratory control. For abnormality, an NOEC of 19.2 and an LOEC of 38.5 percent effluent were measured.

The purple sea urchin (performed by ERCE) and sand dollar (performed by EVS) fertilization bioassay results varied significantly. For the sea urchin test, an NOEC and LOEC 38.5 and 76.9 percent were measured, respectively. The sand dollar was more sensitive to the effluent. This test yielded an NOEC, LOEC, and EC_{50} (effluent concentration resulting in a 50% reduction in fertilization compared to the laboratory control) as <0.1, 0.1, and 2.2 percent effluent, respectively.

Two different test procedures were used in these bioassays which may account for the varying results. For the sea urchin bioassay, the salinity of the effluent was adjusted before the test was started. For the sand dollar test, the salinity of the sample was not adjusted prior to testing. Instead, sample dilutions were made with seawater. Because echinoderm fertilization is inhibited by lack of salinity, the maximum effluent concentration tested was only 18 percent. To account for reduced fertilization due to decreased sample salinity, a salinity control was used (seawater diluted with deionized water).

Table 2 - Ecology Analytical Results - BP Oil, 5/89.

Station:	Effluent			
Type:	Grab			Composite
Date:	5/9	5/9	5/10	5/9-10
Time:	1050	1635	1020	1030-1030
Parameters / Laboratory ID #:	198022	198023	198024	198020
GENERAL CHEMISTRY				
Turbidity (NTU)				4
pH (S.U.)				8.02
Conductivity (umhos/cm)				1,750
Alkalinity (mg/L as $CaCO_3$)				200
Hardness (mg/L as $CaCO_3$)				107
Cyanide (mg/L)				0.012
Solids (mg/L)				
TS				1,042
TNVS				875
TSS	12	13	13	13
TNVSS				2
BOD_5 (mg/L)				10
COD (mg/L)	75	76	81	78
Nutrients (mg/L)				
NH_3-N	1.3	1.2	1.4	1.2
NO_3+NO_2-N	2.6	2.6	3.3	3.0
T-Phosphate	3.38	3.29	3.26	3.38
Fecal Coliform (#/100mL)			2	
Oil & Grease (mg/L)	<1	<1	<1	
Hexa-chromium (ug/L)				6.17
Phenols (ug/L)				20
TOC (mg/L)				32
FIELD ANALYSES				
Temperature (C)	21.1	21.4	20.0	8.4
pH (S.U.)	8.05	8.24	7.98	7.96
Conductivity (umhos/cm)	1,660	1,750	1,915	1,720
Sulfide (mg/L)	<1	<1	<1	

Table 3 - NPDES Permit Limits Compared to Inspection Data - BP Oil, 5/89.

Parameter	NPDES Permit Limits		Inspection Data		
	Daily Average	Daily Maximum	Ecology Composite	BP Oil Composite	Ecology Grab Samples
BOD_5					
(mg/L)			10	29	
(lbs/D)	310	560	70	203	
Chemical Oxygen Demand					
(mg/L)			78	88	75,76,81
(lbs/D)	2,200	4,200	546	616	
TSS					
(mg/L)			13	12	
(lbs/D)	250	390	91	84	
Oil & Grease					
(mg/L)	10	15			<1,<1,<1
(lbs/D)	90	170	<6.9		
Phenolic Compounds					
(ug/L)			20	20	
(lbs/D)	2.0	4.2	0.14	0.14	
Ammonia as N					
(mg/L)			1.2	1.1	1.3,1.2,1.4
(lbs/D)	170	370	8.4	7.7	
Sulfide					
(mg/L)					<1,<1,<1
(lbs/D)	1.6	3.7	<6.9		
Chromium*					
(ug/L)			17	NA	
(lbs/D)	2.2	6.3	0.12		
Hexavalent Chromium					
(ug/L)			6.17	0.0	
(lbs/D)	0.18	0.41	0.04	0.00	
Fecal coliform (#/100 mL)	200	400			2
pH (S.U.)	6.0 - 9.0				8.05,8.24, 7.98
Flow (MGD)				0.84	

* - Measured as total recoverable chromium; permit specifies total.

Table 4 - Flow Data - BP Oil, 5/89.

Date	Time	Instantaneous (MGD)	Ecology Instantaneous Flow Check (MGD)	Totalizer Reading	Flow for Time Increment (MGD)
5/9	11:05	0.86		961243	
					0.88
5/9	16:35	0.92		961445	
					0.83
5/10	9:06	0.79	0.84	962018	

Total flow during inspection = 0.84

Table 5 - Effluent Bioassay Results - BP Oil, 5/89.

96-hour rainbow trout bioassay:

	# of test organisms		Percent
	Initial	Final	Mortality
65% Effluent	30	30	0
Control	10	10	0

Microtox:
EC_{50} (15 mins) = 69.5% (95 percent confidence limits 54.8 - 88.2%)

7-day growth and survival fathead minnow bioassay:

% Effluent	Total # Exposed	Total # Survived	Percent Survival	Mean Weight per fish (mg)
Control	30	30	100	0.46
6.25	30	29	96.7	0.45
12.5	30	28	93.3	0.42
25.0	30	25	83.3	0.55
50.0	30	14	46.7	0.73
100.0	30	9	30.0	0.96

NOEC (No Observable Effects Concentration) = 25.0%
LOEC (Lowest Observable Effects Concentration) = 50.0%
7-day LC_{50} = 55%

Echinoderm (*Strongylocentrotus purpuratas*) fertilization bioassay:

Average % Effluent	% Unfertilized
Control	10.8
4.8	8.8
9.6	12.8
19.2	11.8
38.5	12.5
76.9	88.8

NOEC (No Observable Effects Concentration) = 38.5%
LOEC (Lowest Observable Effects Concentration) = 76.9%

Pacific oyster (*Crassostrea gigas*) embryo development bioassay:

% Effluent	Mean % survival/Mean% abnormal
Control	96.7/0.0
4.8	96.7/0.9
9.6	85.9/0.0
19.2	85.8/0.0
38.5	26.7/9.4
76.9	0.0/0.0

NOEC (No Observable Effects Concentration) = 19.2%
LOEC (Lowest Observable Effects Concentration) = 38.5%

Effluent Chemistry

No volatile organics or pesticide/PCB compounds were detected in the effluent sample. Two phthalates (butylbenzyl and bis-2-ethylhexyl) were detected in the semi-volatile analysis at 2 and 3 ppb (parts per billion; ug/L), respectively. Bis-2-ethylhexylphthalate was also detected in the field transfer blank at 1 ppb. Phthalates are used in the manufacture of plastics and are commonly found in wastewaters. Metals detected in the effluent samples are compared to Washington State water quality criteria in Table 6. Chromium, selenium and zinc were found at levels below both fresh and saltwater chronic criteria. However, mercury exceeded both fresh and saltwater chronic criteria by factors of 17 and 8 times, respectively. Cyanide also exceeded freshwater chronic criteria and saltwater acute criteria. These levels may account for the responses seen in the pacific oyster, echinoderm, and fathead minnow bioassays. It should be noted that the mercury and cyanide results are total results, which may overestimate actual toxic threshold concentrations. EPA recommends the use of the total recoverable analytical method when comparing results to water quality criteria. Further testing of effluent for mercury and cyanide using the total recoverable analytical method is recommended.

Sediment Bioassays

Sediment amphipod and Microtox (saline extract) bioassay results are given in Table 7. In the amphipod bioassay, survival was similar for the outfall (87 percent), near outfall (86 percent) and field control (85 percent) sediments. All three stations exhibited a slight decrease in survival compared to the laboratory control (92 percent) sediments. However, there was no statistical difference at a 95 percent confidence level. In the Microtox test, all three stations showed no toxic effects (e.g. no reduction in bacterial luminescence was observed after the 15 minute exposure time).

In proposed Washington State sediment quality standards (Ecology, 1989), criteria for the amphipod bioassay are exceeded when a test sample has a higher mean mortality than the reference sample (statistically significant, t test, $p<0.05$) and the test mortality exceeds 25 percent (absolute). Both the outfall and near outfall sediments passed this criteria.

Sediment Chemistry

Various polyaromatic hydrocarbons (PAHs), dibenzofuran and a PCB were detected in the outfall and near outfall sediments (Table 8). The PAHs generally were more concentrated in the outfall sediments (total low molecular weight PAHs (LPAHs) of 1,082 ppb dry weight; total high molecular weight PAHs (HPAHs) of 2,500 ppb dry) than in the near outfall sediments (total LPAHs of 835 ppb dry; total HPAHs of 1,325 ppb dry). These levels were well above the field control PAH sediment concentrations (estimated total LPAHs of 42 ppb dry; total HPAHs of 213 ppb dry). Dibenzofuran was found at 78 and 46 ppb dry weight in the near outfall and outfall sediments, respectively. For the PCB detected (at estimated concentrations of 16 and 24 ppb dry in the near outfall and outfall sediments, respectively) the analyses failed to distinguish between the 1016 and 1242 isomers. However, isomer 1242 is generally more common. All organics detected were below Washington State draft sediment quality standards (Table 8). Concentrations of the individual PAHs ranged from 2 to 70 percent of the draft criteria. Dibenzofuran levels near the outfall were within 62 percent of the criteria.

Metals detected in the sediment samples are listed in Table 9. Lead and nickel near the outfall, and arsenic at the outfall were slightly elevated compared to the field control. All other metals appeared to be similar for the three stations. All concentrations were far below the proposed sediment quality standards (Table 9).

Table 6 - Effluent Metals and Cyanide Compared to Water Quality Criteria - BP Oil, 5/89.

		Water Qualtity Criteria			
		Freshwater		Saltwater	
Metal	Effluent* (ug/L)	Acute (ug/L)	Chronic (ug/L)	Acute (ug/L)	Chronic (ug/L)
Chromium	17	1,835	219	-	-
Mercury	0.2	2.40	0.012	2.10	0.025
Selenium	17	260	35	410	54
Zinc	16	124	112	95	86
Cyanide	12	22	5.2	1.0	-
Hardness	107				

* - Total recoverable results, except for mercury and cyanide which are totals.

Table 7 - Sediment Bioassay Results - BP Oil, 5/89.

Sample	Lab ID #	*Amphipod (Rhepoxynius abronius)* Mean value +/- S.D. Survival*	Avoidance**	Percent Reburial+	*Microtox* EC50++ (%Effluent)
At Outfall	198025	17.4 +/- 1.8	0.5 +/- 0.6	100	>100
Near Outfall	198026	17.2 +/- 1.6	1.0 +/- 1.6	100	>100
Field Control	198027	17.0 +/- 3.0	1.1 +/- 2.5	100	>100
Lab Control		18.4 +/- 1.5	0.8 +/- 0.3		

* - Value of 20.0 = 100%
** - # of amphipods on the surface of jar per day
\+ - At end of ten-day exposure, surviving amphipods were transfered to clean sediment. % Reburial indicates the number able to rebury after one hour
++ - For all samples, Microtox data was not suitable for reduction indicating a non-toxic sample. EC_{50} was assumed to be greater than 100% effluent.

Table 8 - Organics in Sediments Compared to Sediment Quality Standards - BP Oil, 5/89.

	Sediments - ug/kg dry*			Draft Sediment Quality Standard (mg/kg organic carbon)
Lab ID #:	Field Control 198027	At Outfall 198025	Near Outfall 198026	
% Fines**	43.0	46.8	39.2	
% Sand	57.0	43.2	60.8	
% Gravel	<2.0	10.0	<2.0	
% TOC	0.71	1.10	0.84	
% Dry Weight	54.9	50.2	65.6	
Low Molecular Weight PAHs:				
Naphthalene	74 U	74 U	130 (15.5)	99
2-Methylnaphthalene	74 U	74 U	31 (3.7)J	64
Acenaphthene	74 U	67 (6.1)J	25 (3.0)J	16
Fluorene	74 U	85 (7.7)	31 (3.7)J	23
Phenanthrene	42 (5.9)J	800 (72.7)	580 (69.1)	100
Anthracene	74 U	130 (11.8)	38 (4.5)J	220
Total LPAHs	42 (5.9)J	1,082 (98.4)J	835 (99.4)J	370
High Molecular Weight PAHs:				
Fluoranthene	61 (8.6)J	930 (84.5)	570 (67.9)	160
Pyrene	45 (6.3)J	560 (50.9)	240 (28.6)	1,000
Benzo(a)Anthracene	74 U	160 (14.6)	69 (8.2)	110
Chrysene	74 U	300 (27.3)	140 (16.7)	110
Benzo(b)Fluoranthene+ Benzo(k)Fluoranthene	84 (11.8)	430 (39.1)	240 (28.6)	230
Benzo(a)Pyrene	23 (3.2)M	120 (10.9)	66 (7.9)	99
Total HPAHs	213 (30.0)J	2,500 (227.3)	1,325 (157.7)	960
Miscellaneous:				
Dibenzofuran	74 U	46 (4.2)J	78 (9.3)	15
PCBs:				
Aroclor-1242/1016	40 U	16 (1.5)J	24 (2.9)J	
Total PCBs	40 U	16 (1.5)J	24 (2.9)J	12

* - Value in parenthesis is concentration in mg/kg organic carbon.
** - Silt + Clay (<4um-62um).
U - Not detected at the detection limit shown.
J - Estimated result, value is less than the method detection limit.
M - Estimated value, analyte found and confirmed with low spectral match parameters.

Table 9 - Sediment Metals Compared to Sediment Quality Standards - BP Oil, 5/89.

	Sediments - ug/kg dry*			Draft Sediment Quality Standard (mg/kg organic carbon)
Lab ID #:	Field Control 198027	At Outfall 198025	Near Outfall 198026	
% Fines*	43.0	46.8	39.2	
% Sand	57.0	43.2	60.8	
% Gravel	<2.0	10.0	<2.0	
% TOC	0.71	1.10	0.84	
% Dry Weight	54.9	50.2	65.6	
Arsenic	2.31	3.62	2.23	57
Beryllium	0.36	0.27	0.27	-
Chromium	34.0	40.7	33.5	260
Copper	17.6	18.4	16.9	390
Lead	9.0	6.7	16.0	450
Mercury	0.09 U	0.07 U	0.09	0.41
Nickel	35.4	38.7	46.8	-
Zinc	65.0	69.0	55.8	410

* - Silt + Clay (<4um-62 um)
U - Not detected at detection limit shown.

COMPARISON OF LABORATORY RESULTS

Comparison of Effluent Results

A comparison of effluent conventional parameters between the Ecology and BP laboratories is given in Table 10. TSS, ammonia (as nitrogen), and total phenolics between the two labs compare well. Discrepancies for lab results are as follows: oil and grease measured by BP ranged from 2 to 3 mg/L; and Ecology did not detect any at a detection limit of 1 mg/L. Ecology measured 6.2 ug/L of hexavalent chromium, whereas the BP result was 0.0 (no detection limit available). COD measured by BP was about 5 to 20 percent higher than the Ecology results. Lastly, the BOD of the BP composite sample (29 mg/L as measured by BP) was higher compared to the Ecology composite sample (Ecology result of 10 mg/L, BP result of 8 mg/L). Further splits for these parameters are recommended during the next Class II inspection.

For the BP Oil organic results (Webb, 1990), only two compounds were detected in the priority pollutant organic scan: n-nitrosodiphenylamine and bis(2-ethylhexyl)phthalate. However, these two compounds were also detected in the method blank, indicating probable laboratory contamination. Effluent metals, cyanide and total phenols for the Ecology and BP analyses are compared in Table 11. The results for chromium, mercury and selenium compare favorably. Arsenic and beryllium were detected in the BP analyses at 5 and 8 ug/L, respectively. The Ecology analyses did not detect either arsenic or beryllium at a detection limit of 1 ug/L. Cyanide and total phenols measured by BP were about 4 and 2 times higher, respectively, than the Ecology results.

Effluent Bioassay Comparison

Both the Ecology and BP rainbow trout bioassays showed no mortalities at a 65 percent effluent concentration. Remaining effluent bioassay results are compared in Table 12. In the BP fathead minnow test, survival in the control was lower than the 80 percent required. However, survival at test concentrations of 5, 20, and 30 percent met the 80 percent limit. If survival in any test concentration exceeds 80 percent, the test results can still be considered acceptable (EPA, 1985). Results for the BP and Ecology fathead bioassays showed similar trends. Increased mortalities occurred at the highest effluent concentrations tested. The Ecology mean survival was lower than the BP results: At the 100 and 50 percent effluent concentrations, the Ecology mean survival was 30 and 46.7 percent, respectively. This compares to the BP mean survivals of 40 and 75 percent, respectively. There was more variability in the Ecology test: The maximum coefficient of variation between replicates (standard deviation/mean X 100) in the Ecology test was 67 percent and compared to 25 percent in BP test.

Larval growth results for the Ecology test were inconclusive at the highest concentrations due to the excessive mortalities. The mean weight per fish was significantly higher at these concentrations than in the controls. However, for the BP test, larval growth was more consistent at the higher concentrations. The BP test yielded an NOEC and LOEC of 50, and 65 percent, respectively, compared to the Ecology results of 25 and 50 percent, respectively.

For the Echinoderm test, results between Ecology and BP varied. The BP test results (using sea urchin; *Lytechinus anamesus*) showed no statistically different number of unfertilized eggs compared to the laboratory control at all effluent concentrations tested (3, 6, 12.5, 25, 50 and 100 percent). The salinity of the sample was adjusted before the test was initiated. The Ecology salinity adjusted echinoderm test resulted in a 38.5 percent NOEC and a 76.9 percent LOEC. In the BP test, fertilization in the control was 100 percent. Target control fertilization rates less than 100 percent are desired in the test since any toxic effect on the sperm can be observed relative to the control (Dinnel *et al.*, 1987). Therefore, the BP result probably underestimates any effects the effluent had on echinoderm fertilization.

Table 10 - Comparison of Effluent Permit Parameter Results - BP Oil, 5/89.

	Station:	Effluent								
	Type:	Grab		Grab		Grab		Composite		
	Date:	5/9		5/9		5/10		5/9-10		5/9-10
	Time:	1050		1635		1020		1030-1030		
	Sampler:	Ecology		Ecology		Ecology		Ecology		BP Oil
Parameters	Laboratory:	Ecology	BP Oil	Ecology	BP Oil	Ecology	BP Oil	Ecology	BP Oil	BP Oil
TSS (mg/L)		12	14	13	13	13	10	13	9	12
BOD5 (mg/L)								10	8	29
COD (mg/L)		75	90	76	86	81	86	78	100	88
NH3-N (mg/L)		1.3	1.2	1.2	1.6	1.4	1.4	1.2	1.4	1.1
Fecal Coliform (#/100mL)						2	0			
Oil & Grease (mg/L)		<1	2	<1	3	<1	3			
Hexa-chromium (ug/L)								6.17	0	
Phenols (ug/L)								20	40	20
Sulfide (mg/L)		<1		<1		<1			0	

Table 11 - Comparison of Effluent Priority Pollutant Metal Results - BP Oil, 5/89.

	Station:	Effluent	
	Type:	Composite	
	Date:	5/9-10	
	Time:	1030-1030	
Parameter	Sampler:	Ecology	
(ug/L)	Laboratory:	Ecology*	BP Oil**
Arsenic		1 U	5
Beryllium		1 U	8
Chromium		17	14
Mercury		0.2	0.2 U
Selenium		17	18
Zinc		16	40
Cyanide		12	43
Phenols		20	37

Qualifier:

U - Not detected at detection limit shown.
* - Total recoverable results except for Mercury and Cyanide.
** - Analyses performed by Eagle Picher, all results are totals.

Table 12 - Comparison of Effluent Bioassay Results - BP Oil, 5/89.

Fathead minnow (Pimephales promelas) 7 day larval growth and survival:

Ecology:

% Effluent	% Survival A	% Survival B	% Survival C	Mean % Survival	CV* (%)	Average Larval Dry Weight (mg) A	Average Larval Dry Weight (mg) B	Average Larval Dry Weight (mg) C	Mean Dry Weight (mg)	CV* (%)
Control	100	100	100	100	0.0	0.49	0.42	0.48	0.46	8.2
6.25	100	100	90	96.7	6.0	0.46	0.47	0.43	0.45	4.6
12.5	100	90	90	93.3	6.2	0.45	0.32	0.50	0.42	21.9
25.0	50	100	100	83.3	34.6	0.62	0.50	0.52	0.55	11.8
50.0	40	80	20	46.7	65.5	0.62	0.26	1.30	0.73	72.7
100.0	30	50	10	30.0	66.7	0.85	0.52	1.50	0.96	52.1

NOEC (No Observable Effects Concentration) = 25.0 %
LOEC (Lowest Observable Effects Concentration) = 50.0 %
7 day LC50 = 55.0 %

BP Oil:

% Effluent	% Survival A	% Survival B	Mean % Survival	CV* (%)	Average Larval Dry Weight (mg) A	Average Larval Dry Weight (mg) B	Mean Dry Weight (mg)	CV* (%)
Control	60	80	70	20.2	0.483	0.388	0.436	15.4
3	80	80	80	0.0	0.450	0.488	0.469	5.7
5	70	100	85	25.0	0.400	0.360	0.380	7.4
10	70	70	70	0.0	0.443	0.386	0.415	9.7
20	90	100	95	7.4	0.378	0.390	0.384	2.2
30	80	80	80	0.0	0.363	0.400	0.382	6.9
50	70	80	75	9.4	0.357	0.325	0.341	6.6
65	30	40	35	20.2	0.333	0.275	0.304	13.5
100	40	40	40	0.0	0.250	0.350	0.325	10.9

Echinoderm fertilization bioassay:

Ecology:

% Effluent	Average % Unfertilized
Control	10.8
4.8	8.8
9.6	12.8
19.2	11.8
38.5	12.5
76.9	88.8

NOEC = 38.5%
LOEC = 76.9%

BP Oil:

% Effluent	Average % Unfertilized
Control	1.0
3.0	1.3
6.0	2.3
12.5	1.8
25.0	1.5
50.0	2.0
100.0	5.3

Table 12 - (Continued)

Pacific oyster (Crassostrea gigas) embryo development bioassay:

Ecology: % Effluent	Mean % survival / Mean% abnormal	BP Oil: % Effluent	Mean % survival / Mean % weighted abnormal	Salinity Check Mean % survival / Mean % weighted abnormal
Control	96.7 / 0.0	Control	41.1 / 3.4	41.1 / 3.4
4.8	96.7 / 0.9	0.1	22.1 / 1.7	0.0 / 0.6
9.6	85.9 / 0.0	0.5	14.8 / 1.9	7.8 / 1.2
19.2	85.8 / 0.0	1.0	18.3 / 6.4	16.4 / 2.3
38.5	26.7 / 9.4	1.8	31.5 / 3.0	15.5 / 1.1
76.9	0.0 / 0.0	3.2	46.8 / 3.3	1.1 / 3.2
		5.6	47.9 / 7.8	35.1 / 4.4

NOEC = 19.2%
LOEC = 38.5%

Microtox bioassay:

Ecology: EC_{50} = 69.5% (95% confidence limits 54.8-88.2%)
BP Oil: EC_{50} = 77.3% (95% confidence limits 51.2-116.5%)

Sediment bioassays:

Sample	Laboratory	Amphipod** Mean survival +/- S.D.	Microtox EC_{50} (% Effluent)
At Outfall	Ecology	17.4 +/- 1.8	>100
	BP Oil	18.2 +/- 1.5	0.10
Near Outfall	Ecology	17.2 +/- 1.6	>100
	BP Oil	17.6 +/- 0.6	0.28
Field Control	Ecology	17.0 +/- 3.0	>100
	BP Oil	16.2 +/- 0.8	0.19
Lab Control	Ecology	18.4 +/- 1.5	NA
	BP Oil	18.6 +/- 0.6	0.50
Ethanol	BP Oil	-	3.03

* - Coefficient of variation (standard deviation/mean X 100).
** - Value of 20.0 = 100%

For the BP pacific oyster bioassay, the highest effluent concentration tested was 5.6 percent due to insufficient sample. There were no statistically different number of abnormal larval at 5.6 percent effluent when compared to the laboratory control. This is consistent with the Ecology test where an NOEC of 19.2 percent was determined. Microtox results also compare favorably for the Ecology and BP analyses. EC_{50}s for the Ecology and BP tests were measured at 69.5 and 77.3% effluent, respectively.

Comparison of Sediment Results

A comparison of sediment organic results is given in Table 13. Generally, the Ecology analyses found more compounds at higher concentrations than did the BP Oil analyses. The BP Oil semi-volatile results for the outfall sediments are suspect: The surrogate spike recovery for phenol-d6 (23 percent) was outside the Quality Assurance/Quality Control (QA/QC) limit of 24 to 113 percent (EPA, 1986). Other spike recoveries were within limits; however, all were at the low end of the range. Additionally, the analytical detection limits for the outfall sediments were about four times greater than the Ecology detection limits and over five times greater than the BP detection limits at the other stations.

For sediment at the outfall, Ecology detected 1400 ppb dry weight of total PAHs, while BP results did not identify any at detection limits of 306 ppb dry. For the near outfall sediments, Ecology detected 2400 ppb dry of total PAHs, while the BP identified 950 ppb dry. The BP analyses also detected 4-methylphenol at 54.9 ppb dry in the near outfall sediments. No PCBs (detection limits of 94 ppb dry) or dibenzofuran were detected at or near the outfall in the BP analyses.

Sediment metal results for Ecology and BP Oil compare fairly well (Table 14). Exceptions were for arsenic at the outfall (Ecology result of 3.6 ppm dry; BP result of 36 ppm dry) and for mercury near the outfall (Ecology result of 0.09 ppm dry; BP result of 0.24 ppm dry). For arsenic, Ecology and BP used different analytical methods: Inductively coupled plasma (ICP) (BP) and graphite furnace atomic adsorption (AA) (Ecology). Graphite furnace AA provides lower detection limits and therefore should be more reliable. In addition, QA/QC performed with the Ecology samples (which included a reagent blank, matrix spike, and sample duplicate) were all within control limits. Therefore, more faith can be placed in the Ecology results.

Sediment Bioassay Comparison

Sediment amphipod and Microtox bioassays are compared in Table 12. For the amphipod test, mortalities for the splits compare very well. For the Microtox test, Ecology used the saline extract procedure, while BP completed the test with the ethanol extract procedure. In the BP test, all sediment extracts showed a decreased bacterial luminescence (e.g. reduced EC_{50}s) compared to the laboratory control sediment extracts. Ethanol would be expected to extract more organics from the sediment than saline water. This may be the reason the BP analyses resulted in a high sediment toxicity; whereas the Ecology results indicated none.

LABORATORY REVIEW

A complete laboratory review sheet is included in Appendix 2 of this report. Specific recommendations were previously made (Hallinan, 1989). These recommendations included: For the effluent pH monitoring, more frequent cleaning and re-calibration of pH probe was recommended using two standards that bracket the typical effluent pH. In the BOD test procedure, the BOD of the seed should be determined. This value along with the seeding dilution should be used to determine the seed correction factor (APHA, 1985, p529, #5d). Lastly in the fecal coliform test, dilution water should be made with distilled water buffered with phosphate (APHA, 1985, p855, #1a). Further laboratory recommendations are circled items in the laboratory review sheet (Appendix 2).

Table 13 - Comparison of Sediment Organic Results - BP Oil, 5/89.

	Sediments - ug/kg dry					
	Field Control		At Outfall		Near Outfall	
Laboratory:	Ecology	BP Oil	Ecology	BP Oil	Ecology	BP Oil
Lab ID #:	198027	Control BPO16	198025	001 BPO16	198026	002 BPO16
% Fines*	43.0	51.2	46.8	45.2	39.2	51.7
% Sand	57.0	48.6	43.2	33.0	60.8	47.5
% Gravel	<2.0	0.2	10.0	21.8	<2.0	0.8
% TOC	0.71	0.61	1.10	1.90	0.84	1.38
% Dry Weight	54.9	54.2	50.2	52.2	65.6	59.2
Phenols	NA	460 U	NA	479 U	NA	422 U
Cyanide	NA	920 U	NA	958 U	NA	844 U
Oil and Grease**	NA	159	NA	649	NA	145
Low Molecular Weight PAHs:						
Naphthalene	74 U		74 U	305.8 U	130	54.9 U
2-Methylnaphthalene	74 U		74 U	305.8 U	31 J	54.9 U
Acenaphthene	74 U		67 J	305.8 U	25 J	54.9 U
Fluorene	74 U		85	305.8 U	31 J	54.9 U
Phenanthrene	42 J		800	305.8 U	580	60.4
Anthracene	74 U		130	305.8 U	38 J	54.9 U
Total LPAHs	42 J		1,082 J	-	835 J	60.4
High Molecular Weight PAHs:						
Fluoranthene	61 J		930	305.8 U	570	109.8
Pyrene	45 J		560	305.8 U	240	126.3
Benzo(a)Anthracene	74 U		160	305.8 U	69	76.9
Chrysene	74 U		300	305.8 U	140	93.4
Benzo(b)Fluoranthene+				305.8 U		87.9
Benzo(k)Fluoranthene	84		430	305.8 U	240	76.9
Benzo(a)Pyrene	23 M		120	305.8 U	66	65.9
Total HPAHs	213 J		2,500	-	1,325	637
Miscellaneous:						
Dibenzofuran	74 U		46 J	305.8 U	78	54.9 U
4-Methylphenol	74 U		74 U	305.8 U	61 U	54.9
PCBs:						
Aroclor-1242/1016	40 U		16 J	94 U	24 J	94 U

* - Silt + Clay (<4um-62um).
** - Reported in mg/kg dry weight.
U - Not detected at the detection limit shown.
J - Estimated result, value is less than the method detection limit.
M - Estimated value, analyte found and confirmed with low spectral match parameters.
NA - Not Analyzed.

Table 14 - Comparison of Sediment Metal Results - BP Oil, 5/89.

		Sediments - ug/kg dry					
		Field Control		At Outfall		Near Outfall	
	Laboratory:	Ecology	BP Oil	Ecology	BP Oil	Ecology	BP Oil
Metal	Lab ID #:	198027	Control BPO16	198025	001 BPO16	198026	002 BPO16
Arsenic		2.31	4.7	3.62	36	2.23	7.3
Beryllium		0.36	0.286 U	0.27	0.371 U	0.27	0.290 U
Chromium		34.0	35	40.7	37	33.5	39
Copper		17.6	19	18.4	20	16.9	16
Lead		9.0	2.9 U	6.7	3.7 U	16.0	26
Mercury		0.09 U	0.044	0.07 U	0.037	0.09	0.240
Nickel		35.4	35	38.7	39	46.8	47
Zinc		65.0	61	69.0	53	55.8	53

Qualifier:
U - Not detected at detection limit shown.

CONCLUSIONS AND RECOMMENDATIONS

1. The refinery met all NPDES permit limits during the inspection.

2. Effluent priority pollutant analyses identified only a few organics at very low concentrations. Chromium, selenium, and zinc were detected in the effluent at levels below both fresh-water and saltwater water quality criteria. However, mercury and cyanide were detected at concentrations above various freshwater and saltwater water quality criteria. Additional monitoring for mercury and cyanide in the effluent (using the total recoverable analytical method) is recommended.

3. No acute toxicity was noted in the 96-hour rainbow trout bioassay at a 65 percent effluent concentration. However, acute toxicity was observed in the 7-day fathead minnow bioassay (LC_{50} of 55 percent effluent). Chronic effects were noted in the pacific oyster embryo development test (NOEC of 19.2 percent effluent), sea urchin fertilization bioassay (NOEC of 38 percent effluent), and Microtox test (EC_{50} of 69.5 percent effluent). These tests should be used as both the acute and chronic bioassays requirements in the next re-issuance of the NPDES permit.

4. Sediment surrounding the wastewater outfall were contaminated with various PAHs, dibenzofuran, and a PCB. However, all were below proposed Washington State sediment quality criteria. All metals detected in the sediment surrounding the outfall were also below sediment quality standards.

5. Sediments at and near the outfall showed no statistically different amphipod mortality compared to field and laboratory control sediments. Microtox bioassays showed no sediment toxicity.

6. Laboratory procedures were generally acceptable. Sample splits showed poor agreement for oil and grease, hexavalent chromium, and COD. Further splits for these parameters during the next Class II inspection is recommended.

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Hallinan, 1989. Ecology Memorandum to Kim Anderson, May 15, 1989, Department of Ecology, EILS.

Webb, J.A., 1990. Priority Pollutant Test Results for May 9-10, 1989 Effluent Samples. Letter to Kim Anderson, Ecology Industrial Section. March 16, 1990.

APPENDIX 1

Chemical analytical methods - BP Oil, 10/89.

Analyses	Method Used	Laboratory
TOC (sediment)	APHA, 1985: #505	Analytical Resources Inc., Seattle, WA
% Solids	APHA, 1985: #209F	Laucks Testing Labs; Seattle, WA
Grain Size	Tetra Tech, 1986	Laucks Testing Labs; Seattle, WA
Volatiles (water)	EPA, 1984: #624	Analytical Resources Inc., Seattle, WA
Volatiles (sediment)	EPA, 1986: #8240	Analytical Resources Inc., Seattle, WA
Semivolatiles (water)	EPA, 1984: #625	Analytical Resources Inc., Seattle, WA
Semivolatiles (sediment)	EPA, 1986: #8270	Analytical Resources Inc., Seattle, WA
Pest/PCB (water)	EPA, 1984: #608	Analytical Resources Inc., Seattle, WA
Pest/PCB (sediment)	EPA, 1986: #8080	Analytical Resources Inc., Seattle, WA
Metals (water)	EPA, 1983: #200 series	Analytical Resources Inc., Seattle, WA
Metals (sediment)	EPA, 1983: #200 series	Analytical Resources Inc., Seattle, WA
Ammonia	EPA, 1983: #350.1	Ecology; Manchester, WA
Total Phosphorus	EPA, 1983: #353.2	Ecology; Manchester, WA
Nitrate/Nitrite	EPA, 1983: #365.1	Ecology; Manchester, WA

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Tetra Tech, 1986. Recommended Protocols for Measuring Selected Environmental Variables in Puget Sound, Prepared for Puget Sound Estuary Program.

Effluent and Sediment Bioassay Methods - WEYCO, 5/88.

Test Organism	Test Sample	Reference Method	Test Laboratory	Test Duration	Test Concen-tration	Type of Test	Endpoint Measured
Rhepoxynius abronius	Sediment	1	E.V.S. Consultants Seattle, WA	10 days	N/A	Acute and Chronic	Survival and avoidance; % reburial after 10 days
Pacific Oyster (Crassostrea gigas)	Effluent	2	ERCE Laboratories San Diega, CA	48 hrs	4.8,9.6,19.2, 38.5,76.9%	Chronic	Development of abnormal larvae
Rainbow Trout (Salmo gairdneri)	Effluent	3	Ecology	96 hrs	65%	Acute	Survival
Microtox (Photobacterium phosphoreum)	Effluent, Sediment	4	Ecova, Inc. Seattle, WA	5,10, 15 mins	11.4,22.7,45.5, 90.9%	Acute/ Chronic	Reduction in bacterial luminescence
Purple Sea Urchin (Strongylocentrotus purpuratus)	Effluent	5	ERCE Laboratories San Diega, CA	20 mins	4.8,9.6,19.2, 38.5,76.9%	Chronic	% Fertilization
Sand dollar (Dendraster excentricus)	Effluent	5	E.V.S. Consultants Seattle, WA	20 mins		Chronic	% Fertilization
Fathead minnow (Pimephales promelas)	Effluent	6	ERCE Laboratories San Diega, CA	7 days	6.25,12,25, 50,100	Acute/ Chronic	Survival and larval growth

1. Swartz, R., W. DeBen, J. Phillips, J. Lamberson, and F. Cole, 1985. Phoxocephalid Amphipod Bioassay for Marine Sediment Toxicity. Cardwell, Purdy, and Bahner (eds), Aquatic Toxicology and Hazard Assessment: Proceeding of the Seventh Annual Symposium ASTM STP 854. As ammended by Chapman, P.M. and S. Becker, 1986. Recommended Protocols for Conducting Laboratory Bioassays on Puget Sound Sediments. Puget Sound Estuary Program, U.S. EPA, Seattle, WA.

2. ASTM Method E 724-80, "Standard Practice for Conducting Static Acute Tests with Larvae of Four Species of Bivalve Mollusks."

3. Department of Ecology procedure "Static Acute Fish Toxicity Test."

4. Beckman Microtox System Operating Manual. Microbics Corporation, Carlsbad, CA.

5. Dinnel, P.A., J.M. Link, and Q.J. Stober, 1987. "Improved Methology for a Sea Urchin Sperm Cell Bioassay for Marine Waters." Arch. Environ. Contam. Toxicol., 16, 23-32, 1987.

6. EPA/600/4-85/014, "Short-Term Methods for Estimating the Chronic Toxcity of Effluents to Freshwater Organisms."

Results of VOA priority pollutant scan - BP Oil, 5/89.

Compound	Field Transfer Blank (ug/L)	Effluent (ug/L)	Sediments (ug/kg dry) Control	At Outfall	Near Outfall
Chloromethane	2.9 U	2.9 U	6.1 U	6.7 U	5.9 U
Bromomethane	0.9 U	0.9 U	5.0 U	5.5 U	4.8 U
Vinyl Chloride	1.1 U	1.1 U	3.2 U	3.5 U	3.1 U
Chloroethane	0.9 U	0.9 U	5.3 U	5.8 U	5.2 U
Methylene Chloride	1.1 UJ	0.5 UJ	7.0 UJ	17.0 B	7.1 UJ
Acetone	0.6 U	0.6 U	10.0 J	18.0 U	11.0 U
Carbon Disulfide	2.0 U	2.0 U	1.9 U	2.1 U	1.9 U
1,1-Dichloroethene	1.3 U	1.3 U	1.1 U	1.2 U	1.1 U
1,1-Dichloroethane	1.1 U	1.1 U	1.0 U	1.1 U	0.9 U
Trans-1,2-Dichloroethene	1.1 U	1.1 U	-	-	-
Cis-1,2-Dichloroethene	1.2 U	1.2 U	-	-	-
1,2-Dichloroethene (total)	-	-	1.3 U	1.4 U	1.3 U
Chloroform	0.9 U	0.9 U	1.7 U	1.9 U	1.7 U
1,2-Dichloroethane	0.6 U	0.6 U	0.8 U	0.9 U	0.8 U
2-Butanone	1.0 U	1.0 U	10.0 U	11.0 U	9.7 U
1,1,1-Trichloroethane	1.0 U	1.0 U	1.0 U	1.1 U	0.9 U
Carbon Tetrachloride	0.5 U	0.5 U	1.5 U	1.6 U	1.4 U
Vinyl Acetate	1.7 U	1.7 U	5.0 U	5.5 U	4.8 U
Bromodichloromethane	0.2 U	0.2 U	0.5 U	0.5 U	0.5 U
1,2-Dichloropropane	0.6 U	0.6 U	1.1 U	1.2 U	1.1 U
Trans-1,3-Dichloropropene	0.5 U	0.5 U	2.9 U	3.2 U	2.8 U
Trichloroethene	0.8 U	0.8 U	1.0 U	1.1 U	0.9 U
Dibromochloromethane	0.9 U	0.9 U	1.1 U	1.2 U	1.1 U
1,1,2-Trichloroethane	0.3 U	0.3 U	1.1 U	1.2 U	1.1 U
Benzene	0.4 U	0.4 U	1.6 U	1.8 U	1.6 U
cis-1,3-Dichloropropene	0.6 U	0.6 U	3.1 U	3.4 U	3.0 U
2-Chloroethylvinylether	1.5 U	1.5 U	4.4 U	4.8 U	4.2 U
Bromoform	0.3 U	0.3 U	4.0 U	4.4 U	3.9 U
4-Methyl-2-Pentanone	1.8 U	1.8 U	5.7 U	6.2 U	5.5 U
2-Hexanone	1.3 U	1.3 U	5.2 U	5.7 U	5.0 U
Tetrachloroethene	0.6 U	0.6 U	0.8 U	0.9 U	0.8 U
1,1,2,2-Tetrachloroethane	0.6 U	0.6 U	4.4 U	4.8 U	4.2 U
Toluene	0.6 U	0.6 U	1.3 U	1.4 U	1.3 U
Chlorobenzene	0.6 U	0.6 U	1.5 U	1.6 U	1.4 U
Ethylbenzene	1.0 U	1.0 U	1.3 U	1.4 U	1.3 U
Styrene	0.5 U	0.5 U	1.8 U	1.9 U	1.7 U
Total Xylenes	1.5 U	1.5 U	2.9 U	3.2 U	2.8 U

Qualifiers:
U - Not detected at the detection limit shown.
J - Estimated result, value is less than the method detection limit.
UJ - Estimated method detection limit.

Results of semi-volatile priority pollutant scan - BP Oil, 5/89.

Compound	Field Transfer Blank (ug/L)	Effluent (ug/L)	Sediments (ug/kg dry) Control	At Outfall	Near Outfall
Phenol	2 U	2 U	150 U	150 U	120 U
bis(2-Chloroethyl)Ether	1 U	1 U	74 U	74 U	61 U
2-Chlorophenol	1 U	1 U	74 U	74 U	61 U
1,3-Dichlorobenzene	1 U	1 U	74 U	74 U	61 U
1,4-Dichlorobenzene	1 U	1 U	74 U	74 U	61 U
Benzyl Alcohol	5 U	5 U	370 U	370 U	310 U
1,2-Dichlorobenzene	1 U	1 U	74 U	74 U	61 U
2-Methylphenol	1 U	1 U	74 U	74 U	61 U
bis(2-chloroisopropyl)ether	1 U	1 U	74 U	74 U	61 U
4-Methylphenol	1 U	1 U	74 U	74 U	61 U
N-Nitroso-Di-n-Propylamine	1 U	1 U	74 U	74 U	61 U
Hexachloroethane	2 U	2 U	150 U	150 U	120 U
Nitrobenzene	1 U	1 U	74 U	74 U	61 U
Isophorone	1 U	1 U	74 U	74 U	61 U
2-Nitrophenol	5 U	5 U	370 U	370 U	310 U
2,4-Dimethylphenol	2 U	2 U	150 U	150 U	120 U
Benzoic Acid	10 U	10 U	740 U	740 U	610 U
bis(2-Chloroethoxy)Methane	1 U	1 U	74 U	74 U	61 U
2,4-Dichlorophenol	3 U	3 U	220 U	220 U	180 U
1,2,4-Trichlorobenzene	1 U	1 U	74 U	74 U	61 U
Naphthalene	1 U	1 U	74 U	74 U	130
4-Chloroaniline	3 U	3 U	220 U	220 U	180 U
Hexachlorobutadiene	2 U	2 U	150 U	150 U	120 U
4-Chloro-3-Methylphenol	2 U	2 U	150 U	150 U	120 U
2-Methylnaphthalene	1 U	1 U	74 U	74 U	31 J
Hexachlorocyclopentadiene	5 U	5 U	370 U	370 U	310 U
2,4,6-Trichlorophenol	5 U	5 U	370 U	370 U	310 U
2,4,5-Trichlorophenol	5 U	5 U	370 U	370 U	310 U
2-Chloronaphthalene	1 U	1 U	74 U	74 U	61 U
2-Nitroaniline	5 U	5 U	370 U	370 U	310 U
Dimethyl Phthalate	1 U	1 U	74 U	74 U	61 U
Acenaphthylene	1 U	1 U	74 U	74 U	61 U
3-Nitroaniline	5 U	5 U	370 U	370 U	310 U
Acenaphthene	1 U	1 U	74 U	67 J	25 J
2,4-Dinitrophenol	10 U	10 U	740 U	740 U	610 U
4-Nitrophenol	5 U	5 U	370 U	370 U	305 U
Dibenzofuran	1 U	1 U	74 U	46 J	78
2,4-Dinitrotoluene	5 U	5 U	370 U	370 U	310 U
2,6-Dinitrotoluene	5 U	5 U	370 U	370 U	310 U
Diethylphthalate	1 U	1 U	74 U	74 U	61 U
4-Chlorophenyl-phenylether	1 U	1 U	74 U	74 U	61 U
Fluorene	1 U	1 U	74 U	85	31 J
4-Nitroaniline	5 U	5 U	370 U	370 U	310 U
4,6-Dinitro-2-Methylphenol	10 U	10 U	740 U	740 U	610 U
N-Nitrosodiphenylamine	1 U	1 U	74 U	74 U	61 U
4-Bromophenyl-phenylether	1 U	1 U	74 U	74 U	61 U
Hexachlorobenzene	1 U	1 U	74 U	74 U	61 U

Results of semi-volatile priority pollutant scan - BP Oil, 5/89. (Continued)

Compound	Field Transfer Blank (ug/L)	Effluent (ug/L)	Sediments (ug/kg dry) Control	At Outfall	Near Outfall
Pentachlorophenol	5 U	5 U	370 U	370 U	310 U
Phenanthrene	1 U	1 U	42 J	800	580
Anthracene	1 U	1 U	74 U	130	38 J
Di-n-Butylphthalate	1 U	1 U	74 U	74 U	61 U
Fluoranthene	1 U	1 U	61 J	930	570
Pyrene	1 U	1 U	45 J	560	240
Butylbenxylphthalate	2 U	2	74 U	74 U	61 U
3,3'-Dichlorobenzidine	5 U	5 U	370 U	370 U	310 U
Benzo(a)Anthracene	1 U	1 U	74 U	160	69
bis(2-Ethylhexyl)Phthalate	3	1	74 U	74 U	61 U
Chrysene	1 U	1 U	74 U	300	140
Di-n-Octyl Phthalate	1 U	1 U	74 U	74 U	61 U
Benzo(b)Fluoranthene	1 U	1 U	-	-	-
Benzo(k)Fluoranthene	1 U	1 U	84	430	240
Benzo(a)Pyrene	1 U	1 U	23 M	120	66
Indeno(1,2,3-cd)Pyrene	1 U	1 U	74 U	74 U	61 U
Dibenz(a,h)Anthracene	1 U	1 U	74 U	74 U	61 U
Benzo(ghi)Perylene	1 U	1 U	74 U	74 U	61 U

Qualifiers:
U - Not detected at the detection limit shown.
J - Estimated result, value is less than the method detection limit.
B - Also detected in method blank.
M - Estimated value, analyte found and confirmed with low spectral match parameters.

Results Pest/PCB and metal priority pollutant scans - BP Oil, 5/89.

Compound	Field Transfer Blank (ug/L)	Effluent (ug/L)	Sediments (ug/kg dry) Control	At Outfall	Near Outfall
Alpha-BHC	0.03 U	0.09 U	2 U	2 U	2 U
Beta-BHC	0.05 U	0.15 U	3 U	3 U	3 U
Delta-BHC	0.06 U	0.18 U	4 U	4 U	4 U
Gamma-BHC (Lindane)	0.03 U	0.09 U	2 U	2 U	2 U
Heptachlor	0.03 U	0.09 U	2 U	2 U	2 U
Aldrin	0.05 U	0.15 U	3 U	3 U	3 U
Heptachlor Epoxide	0.05 U	0.15 U	3 U	3 U	3 U
Endosulfan I	0.05 U	0.15 U	3 U	3 U	3 U
Dieldrin	0.06 U	0.18 U	4 U	4 U	4 U
4,4'-DDE	0.06 U	0.18 U	4 U	4 U	4 U
Endrin	0.06 U	0.18 U	4 U	4 U	4 U
Endosulfan II	0.06 U	0.18 U	4 U	4 U	4 U
4,4'-DDD	0.09 U	0.27 U	6 U	6 U	6 U
Endosulfan Sulfate	0.15 U	0.45 U	10 U	10 U	10 U
4,4'-DDT	0.09 U	0.27 U	6 U	6 U	6 U
Methoxychlor	0.12 U	0.36 U	8 U	8 U	8 U
Endrin Ketone	0.09 U	0.27 U	6 U	6 U	6 U
gamma-Chlordane	0.05 U	0.15 U	3 U	3 U	3 U
alpha-Chlordane	0.05 U	0.15 U	3 U	3 U	3 U
Toxaphene	4.50 U	14.00 U	300 U	300 U	300 U
Aroclor-1242/1016	0.60 U	1.80 U	40 U	16 J	24 J
Aroclor-1248	0.60 U	1.80 U	40 U	40 U	40 U
Aroclor-1254	0.60 U	1.80 U	40 U	40 U	40 U
Aroclor-1260	0.60 U	1.80 U	40 U	40 U	40 U

Priority pollutant metal			(mg/kg dry)		
Antimony	1 U	1 U	0.124 U	0.164 U	0.119 U
Arsenic	1.8 U	1 U	2.31	3.62	2.23
Beryllium	1 U	1 U	0.36	0.27	0.27
Cadmium	2 U	2 U	0.27 U	0.35 U	0.26 U
Chromium	5 U	17	34.0	40.7	33.5
Copper	2 U	2 U	17.6	18.4	16.9
Lead	1 U	1 U	9.0	6.7	16.0
Mercury	0.1 U	0.2	0.09 U	0.07 U	0.09
Nickel	10 U	10 U	35.4	38.7	46.8
Selenium	1 U	17	0.68 U	0.86 U	0.66 U
Silver	3 U	3 U	0.41 U	0.52 U	0.39 U
Thallium	1 U	1 U	0.136 U	0.173 U	0.131 U
Zinc	4 U	16	65.0	69.0	55.8

Qualifier:
U - Not detected at detection limit shown.

APPENDIX 2

Laboratory Procedure Review Sheet

Discharger: BP Oil

Date: 5/9/89

Discharger representative: John Webb, Bob Quinn

Ecology reviewer: Pat Hallinan, K. Seiders, Stu Lombard

Instructions

Questionnaire for use reviewing laboratory procedures. Circled numbers indicate work is needed in that area to bring procedures into compliance with approved techniques. References are sited to help give guidance for making improvements. References sited include:

Ecology = Department of Ecology Laboratory User's Manual, December 8, 1986.

SM = APHA-AWWA-WPCF, Standard Methods for the Examination of Water and Wastewater, 16th ed., 1985.

SSM = WPCF, Simplified Laboratory Procedures for Wastewater Examination, 3rd ed., 1985.

Sample Collection Review

1. Are grab, hand composite, or automatic composite samples collected for influent and effluent BOD and TSS analysis?

2. If automatic compositor, what type of compositor is used? ✓
   The compositor should have pre and post purge cycles unless it is a flow through type. Check if you are unfamiliar with the type being used.

3. Are composite samples collected based on time or flow?

4. What is the usual day(s) of sample collection?

5. What time does sample collection usually begin? 6-6

6. How long does sample collection last? 24 hrs

7. How often are subsamples that make up the composite collected? 30 min.

8. What volume is each subsample? unkn

9. What is the final volume of sample collected? ~1 gallons

10. Is the composite cooled during collection? yes

11. To what temperature?
The sample should be maintained at approximately 4 degrees C (SM p41, #5b: SSM p2).

12. How is the sample cooled?
Mechanical refrigeration or ice are acceptable. Blue ice or similar products are often inadequate.

13. How often is the temperature measured?
The temperature should be checked at least monthly to assure adequate cooling.

14. Are the sampling locations representative? yes

15. Are any return lines located upstream of the influent sampling location?
This should be avoided whenever possible.

16. How is the sample mixed prior to withdrawal of a subsample for analysis?
The sample should be thoroughly mixed.

17. How is the subsample stored prior to analysis?
The sample should be refrigerated (4 degrees C) until about 1 hour before analysis, at which time it is allowed to warm to room temperature.

18. What is the cleaning frequency of the collection jugs?
The jugs should be thoroughly rinsed after each sample is complete and occasionally be washed with a non-phospate detergent.

19. How often are the sampler lines cleaned?
Rinsing lines with a chlorine solution every three months or more often where necessary is suggested.

pH Test Review

1. How is the pH measured?
A meter should be used. Use of paper or a colorimetric test is inadequate and those procedures are not listed in Standard Methods (SM p429).
continuous meter

2. How often is the meter calibrated?
The meter should be calibrated every day it is used.

3. What buffers are used for calibration?
Two buffers bracketing the pH of the sample being tested should be used.

If the meter can only be calibrated with one buffer, the buffer closest in pH to the sample should be used. A second buffer, which brackets the pH of the sample should be used as a check. If the meter cannot accurately determine the pH of the second buffer, the meter should be repaired.

BOD Test Review

1. What reference is used for the BOD test? SM 1975
Standard Methods or the Ecology handout should be used.
should get most recent edition

2. How often are BODs run? 5x's a week
The minimum frequency is specified in the permit.

3. How long after sample collection is the test begun? 8:30 ~ 2½ hrs
The test should begin within 24 hours of composite sample completion (Ecology Lab Users Manual p42). Starting the test as soon after samples are complete is desirable.

4. Is distilled or deionized water used for preparing dilution water?
Both

5. Is the distilled water made with a copper free still? yes
Copper stills can leave a copper residual in the water which can be toxic to the test (SSM p36).

6. Are any nitrification inhibitors used in the test? No What?
2-chloro-6(trichloro methyl) pyridine or Hach Nitrification Inhibitor 2533 may be used only if carbonaceous BODs are being determined (SM p 527, #4g: SSM p 37).

7. Are the 4 nutrient buffers of powder pillows used to make dilution water?
If the nutrients are used, how much buffer per liter of dilution water are added?
1 mL per liter should be added (SM p527, #5a: SSM p37).

8. How often is the dilution water prepared? ✓
Dilution water should be made for each set of BODs run.

9. Is the dilution water aged prior to use? ✓
Dilution water with nitrification inhibitor can be aged for a week before use (SM p528, #5b).
Dilution water without inhibitor should not be aged.

10. Have any of the samples been frozen? rarely
If yes, are they seeded?
Samples that have been frozen should be seeded (SSM p38).

11. Is the pH of all samples between 6.5 and 7.5?
If no, is the sample pH adjusted?
The sample pH should be adjusted to between 6.5 and 7.5 with 1N NaOH or 1N H_2SO_4 if 6.5 > pH >7.5 if caustic alkalinity or acidity is present (SM p529, #5e1: SSM p37).
High pH from lagoons is usually not caustic. Place the sample in the dark to warm up, then check the pH to see if adjustment is necessary.

If the sample pH is adjusted, is the sample seeded?
The sample should be seeded to assure adequate microbial activity if the pH is adjusted (SM p528, #5d).

12. Have any of the samples been chlorinated or ozonated? No
If chlorinated are they checked for chlorine residual and dechlorinated as necessary?
How are they dechlorinated? —
Samples should be dechlorinated with sodium sulfite (SM p529, #5e2: SSM p38), but dechlorination with sodium thiosulfate is common practice. Sodium thiosufate dechlorination is probably acceptable if the chlorine residual is < 1-2 mg/L.
If chlorinated or ozonated, is the sample seeded?
The sample should be seeded if it was disinfected (SM p528, #5d&5e2: SSM p38).

13. Do any samples have a toxic effect on the BOD test? Sometimes
Specific modifications are probably necessary (SM p528, #5d: SSM p37).

14. How are DO concentrations measured? probe
If with a meter, how is the meter calibrated? ✓
Air calibration is adequate. Use of a barometer to determine saturation is desirable, although not manditory. Checks using the Winkler method of samples found to have a low DO are desirable to assure that the meter is accurate over the range of measurements being made.

How frequently is the meter calibrated? ✓
The meter should be calibrated before use.

15. Is a dilution water blank run? ✓
A dilution water blank should always be run for quality assurance (SM p527, #5b: SSM p40, #3).

What is the usual initial DO of the blank? ~9.0 ✓
The DO should be near saturation; 7.8 mg/L @ 4000 ft, 9.0 mg/L @ sea level (SM p528, #5b). The distilled or deionized water used to make the dilution water may be aged in the dark at ~20 degrees C for a week with a cotton plug in the opening prior to use if low DO or excess blank depletion is a problem .

What is the usual 5 day blank depletion? ✓
The depletion should be 0.2 mg/L or less. If the depletion is greater, the cause should be found (SM p527-8, #5b: SSM p41, #6).

16. How many dilutions are made for each sample? 2
At least two dilutions are recommended. The dilutions should be far enough apart to provide a good extended range (SM p530, #5f: SSM p41).

17. Are dilutions made by the liter method or in the bottle?
Either method is acceptable (SM p530, #5f).

18. How many bottles are made at each dilution?
How many bottles are incubated at each dilution? ✓
When determining the DO using a meter only one bottle is necessary. The DO is measured, then the bottle is sealed and incubated (SM p530, #5f2).
When determining the DO using the Winkler method two bottles are necessary. The initial DO is found of one bottle and the other bottle is sealed and incubated (Ibid.).

19. Is the initial DO of each dilution measured? ✓
What is the typical initial DO?
The initial DO of each dilution should be measured. It should approximate saturation (see #14).

20. What is considered the minimum acceptable DO depletion after 5 days?
What is the minimum DO that should be remaining after 5 days? ✓
The depletion should be at least 2.0 mg/L and at least 1.0 mg/L should be left after 5 days (SM p531, #6: SSM p41).

21. Are any samples seeded? yes
Which?
What is the seed source? Aero effluent
Primary effluent or settled raw wastewater is the preferred seed. Secondary treated sources can be used for inhibited tests (SM p528, #5d: SSM p41).

How much seed is added to each sample? 1ml
Adequate seed should be used to cause a BOD uptake of 0.6 to 1.0 mg/L due to seed in the sample (SM p529, #5d).

How is the BOD of the seed determined? No
Dilutions should be set up to allow the BOD of the seed to be determined just as the BOD of a sample is determined. This is called the seed control (SM p529, #5d: SSM p41).

22. What is the incubator temperature? 20°C
The incubator should be kept at 20 +/- 1 degree C (SM p531, #5i: SSM p40, #3).

How is incubator temperature monitored? ✓
A thermometer in a water bath should be kept in the incubator on the same shelf as the BODs are incubated.

How frequently is the temperature checked? ✓
The temperature should be checked daily during the test. A temperature log on the incubator door is recommended.

How often must the incubator temperature be adjusted? ✓
Adjustment should be infrequent. If frequent adjustments (every 2 weeks or more often) are required the incubator should be repaired.

Is the incubator dark during the test period? ✓
Assure the switch that turns off the interior light is functioning.

23. Are water seals maintained on the bottles during incubation? ✓
Water seals should be maintained to prevent leakage of air during the incubation period (SM p531, #5i: SSM p40, #4).

24. Is the method of calculation correct?
Check to assure that no correction is made for any DO depletion in the blank and that the seed correction is made using seed control data.

Standard Method calculations are (SM p531, #6):

for unseeded samples;

$$BOD\ (mg/L) = \frac{D1 - D2}{P}$$

for seeded samples;

seed correction factor

$$BOD\ (mg/L) = \frac{(D1 - D2) - (B1 - B2)f}{P}$$

Where:
D1 = DO of the diluted sample before incubation (mg/L)
D2 = DO of diluted sample after incubation period (mg/L)
P = decimal volumetric fraction of sample used
B1 = DO of seed control before incubation (mg/L)
B2 = DO of seed control after incubation (mg/L)

$$f = \frac{\text{amount of seed in bottle D1 (mL)}}{\text{amount of seed in bottle B1 (mL)}}$$

Total Suspended Solids Test Review

No review done Lab analyst that performs TSS analysis not present.

Preparation

1. What reference is used for the TSS test?

2. What type of filter paper is used?
   Std. Mthds. approved papers are: Whatman 934AH (Reeve Angel), Gelman A/E, and Millipore AP-40 (SM p95,footnote: SSM p23)

3. What is the drying oven temperature?
   The temperature should be 103-105 degrees C (SM p96, #3a: SSM p23).

4. Are any volatile suspended solids tests run?
   If yes--What is the muffle furnance temperature?
   The temperature should be 550+/- 50 degrees C (SM p98, #3: SSM p23).

5. What type of filtering apparatus is used?
   Gooch crucibles or a membrane filter apparatus should be used (SM p95, #2b: SSM p23).

6. How are the filters pre-washed prior to use?
   The filters should be rinsed 3 times with distilled water (SM p23, #2: SSM p23, #2).

   Are the rough or smooth sides of the filters up?
   The rough side should be up (SM p96, #3a: SSM p23, #1)

   How long are the filters dried?
   The filters should be dried for at least one hour in the oven. An additional 20 minutes of drying in the furnance is required if volatile solids are to be tested (Ibid).

   How are the filters stored prior to use?
   The filters should be stored in a dessicator (Ibid).

7. How is the effectiveness of the dessicant checked?
   All or a portion of the dessicant should have an indicator to assure effectiveness.

Test Procedure

8. In what is the test volume of sample measured?
   The sample should be measured with a wide tipped pipette or a graduated cylinder.

9. Is the filter seated with distilled water?
   The filter should be seated with distilled water prior to the test to avoid leakage along the filter sides (SM p97, #3c).

10. Is the entire measured volume always filtered?
The entire volume should always be filtered to allow the measuring vessel to be properly rinsed (SM p97, #3c: SSM p24, #4).

11. What are the average and minimum volumes filtered?

	Volume	
	Minimum	Average
Influent		
Effluent		

12. How long does it take to filter the samples?

	Time
Influent	
Effluent	

13. How long is filtering attempted before deciding that a filter is clogged?
Prolonged filtering can cause high results due to dissolved solids being caught in the filter (SM p96, #1b). We usually advise a five minute filtering maximum.

14. What do you do when a filter becomes clogged?
The filter should be discarded and a smaller volume of sample should be used with a new filter.

15. How are the filter funnel and measuring device rinsed onto the filter following sample addition?
Rinse 3x's with approximately 10 mLs of distilled water each time (? ?).

16. How long is the sample dried?
The sample should be dried at least one hour for the TSS test and 20 minutes for the volatile test (SM p97, #3c; p98, #3: SSM p24, #4). Excessive drying times (such as overnight) should be avoided.

17. Is the filter thoroughly cooled in a dessicator prior to weighing?
The filter must be cooled to avoid drafts due to thermal differences when weighing (SM p97, #3c: SSM p97 #3c).

18. How frequently is the drying cycle repeated to assure constant filter weight has ben reached (weight loss <0.5 mg or 4%, whichever is less: SM p97, #3c)?
We recommend that this be done at least once every 2 months.

19. Do calculations appear reasonable?
Standard Methods calculation (SM p97, #3c).

$$\text{mg/L TSS} = \frac{(A - B) \times 1000}{\text{sample volume (mL)}}$$

where: A= weight of filter + dried residue (mg)
B= weight of filter (mg)

Fecal Coliform Test Review

1. Is the Membrane Filtration (MF) or Most Probable Number (MPN) technique used?
   This review is for the MF technique.

2. Are sterile techniques used?

3. How is equipment sterilizated? flame
   Items should be either purchased sterilized or be sterilized. Steam sterilization, 121 degrees C for 15 to 30 minutes (15 psi); dry heat, 1-2 hours at 170 degrees C; or ultraviolet light for 2-3 minutes can be used. See Standard Methods for instruclions for specific items (SSM p67-68).

4. How is sterilization preserved prior to item use?
   Wrapping the items in kraft paper or foil before they are sterilized protects them from contamination (Ibid.).

5. How are the following items sterilized?

	Purchased Sterile	Sterilized at Plant
Collection bottles		✓
Phosphate buffer	✓	
Media	✓	
Media pads	✓	
Petri dishes		✓
Filter apparatus		✓
Filters		✓
Pipettes		✓
Measuring cylinder		✓
Used petri dishes		

6. How are samples dechlorinated at the time of collection? None
   Sodium thiosulfate (1 mL of 1% solution per 120 mLs (4 ounces) of sample to be collected) should be added to the collection bottle prior to sterilization (SM p856, #2: SSM p68, sampling).

7. Is phosphate buffer made specifically for this test? No
   Use phosphate buffer made specifically for this test. The phosphate buffer for the BOD test should not be used for the coliform test (SM p855, #12: SSM p66).

8. What kind of media is used?
   M-FC media should be used (SM p896, SSM p66).

9. Is the media mixed or purchased in ampoules?
   Ampoules are less expensive and more convient for under 50 tests per day (SSM p65, bottom).

10. How is the media stored? ✓
    The media should be refrigerated (SM p897, #1a: SSM p66, #5).

11. How long is the media stored? ✓
Mixed media should be stored no longer than 96 hours (SM p897, #1a: SSM p66, #5). Ampoules will usually keep from 3-6 months -- read ampoule directions for specific instructions.

12. Is the work bench disinfected before and after testing?
This is a necessary sanitazation procedure (SM p831, #1f).

13. Are forceps dipped in alcohol and flamed prior to use? yes
Dipping in alcohol and flaming are necessary to sterilize the forceps (SM p889, #1: SSM p73, #4).

14. Is sample bottle thoroughly shaken before the test volume is removed?
The sample should be mixed thoroughly (SSM p73, #5). yes

15. Are special procedures followed when less than 20 mLs of sample is to be filtered?
10-30 mLs of sterile phosphate buffer should be put on the filter. The sample should be put into the buffer water and swirled, then the vacuum should be turned on. More even organism distribution is attained using this technique (SM p890, #5a: SSM P73, #5).

16. Are special procedures followed when less than 1 mL of sample is to be filtered?
Sample dilution is necessary prior to filtration when <1 mL is to be tested (SM p864, #2c: SSM p69).

17. Is the filter apparatus rinsed with phosphate buffer after sample filtration?
Three 20-30 mL rinses of the filter apparatus are recommended (SM p891, #5b: SSM p75, #7).

18. How soon after sample filtration is incubation begun? right away
Incubation should begin within 20-30 minutes (SM p897, #2d: SSM p77, #10 note).

19. What is the incubation temperature? ✓
44.5 +/- 0.2 degrees C (SM p897, #2d: SSM p75, #9).

20. How long are the filters incubated? ✓
24 +/- 2 hours (Ibid.).

21. How soon after incubation is complete are the plate counts made?
The counts should be made within 20 minutes after incubation is complete to avoid colony color fading (SSM p77, FC).

22. What color colonies are counted? ✓
The fecal coliform colonies vary from light to dark blue (SM p897, #2e: SSM p78).

23. What magnification is used for counting? None
10-15 power magnification is recommended (SM p898, #2e: SSM p78).

24. How many colonies blue colonies are usually counted on a plate? ✓
Valid plate counts are between 20 and 60 colonies (SM p897, #2a: SSM p78).

25. How many total colonies are usually on a plate? few ✓
The plate should have <200 total colonies to avoid inhabition due to crowding (SM p893, #6a: SSM p63, top).

26. When calculating results, how are plates with <20 or >60 colonies considered when plates exist with between 20 and 60 colonies?
In this case the plates with <20 or >60 colonies should not be used for calculations (SM p898, #3: SSM p78, C&R).

27. When calculating results how are results expressed if all plates have < 20 or > 60 colonies?
Results should be identified as estimated.
The exception is when water quality is good and <20 colonies grow. In this case the lower limit can be ignored (SM p893, #6a: SSM p78, C&R).

28. How are results calculated?
Standard Methods procedure is (SM p893, #6a: SSM p79):

$$\text{Fecal coliforms/100 mL} = \frac{\text{\# of fecal coliform colonies counted}}{\text{sample size (mL)}} \times 100$$ ✓