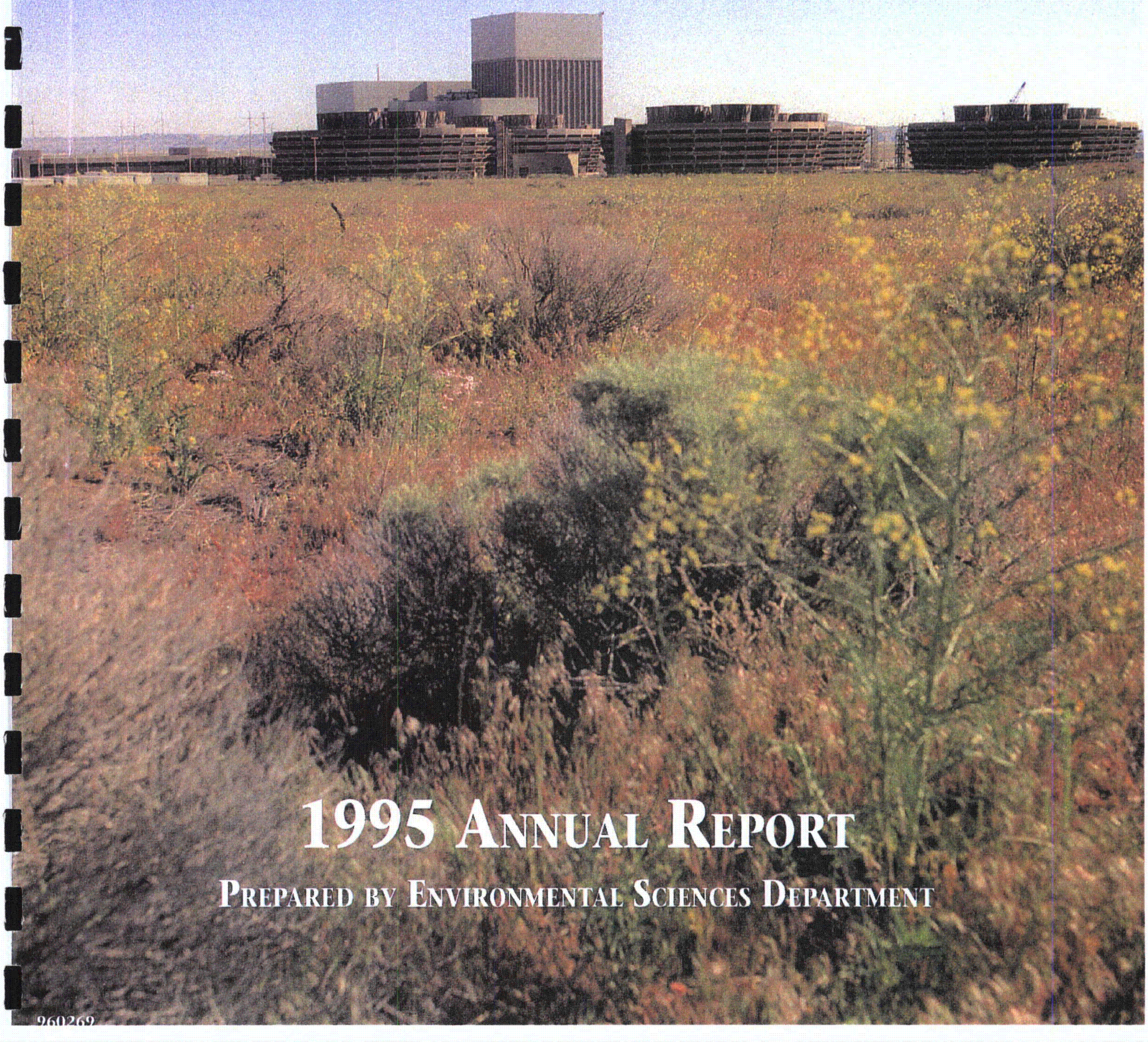
Operational Ecological Monitoring Program for Nuclear Plant 2

Washington Public Power Supply System



1995 Annual Report

Prepared by Environmental Sciences Department

960269

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EXECUTIVE SUMMARY

The Ecological Monitoring Program is comprised of several elements which are intended to determine the effects of the operation of the Supply System's Nuclear Plant No. 2 on the environment. These program elements include: plant effluent and Columbia River water quality; vegetation cover and phytomass in selected plots; and soil chemistry at established sampling locations. The results of the 1995 monitoring efforts may be summarized as follows:

- Plant cooling water discharges had no discernible effect on Columbia River water quality.

- No measurable effects of plant cooling tower drift were observed on vegetation cover, phytomass, or soil chemistry. A dramatic increase in cover and phytomass was observed at most stations. This is in direct correlation with the record precipitation recorded during the growing season.

ACKNOWLEDGEMENTS

This report, prepared by the Washington Public Power Supply System, describes the soil and vegetation studies, and water quality programs for WNP-2.

Project Team

Terry E. Northstrom	Supervisor, Environmental Sciences
Deborah C. Singleton	Environmental Scientist
Richard E. Welch	Environmental Scientist

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1.0 INTRODUCTION

1.0 INTRODUCTION

1.1 BACKGROUND

The Site Certification Agreement (SCA) for WNP-2 was approved on May 17, 1972, by the State of Washington and the Washington Public Power Supply System (Supply System). The SCA requires that environmental monitoring be conducted during the preoperational and operational phases of site development and use. The objective of the monitoring program is to provide an environmental measurement history for evaluation by the Supply System and the Washington State Energy Facility Site Evaluation Council (EFSEC) and to identify significant effects of plant operation on the environment. Since 1972, several revisions of the monitoring program have been approved by EFSEC in the form of SCA attachments and EFSEC resolutions Nos. 193, 194, 214, 239, and 266.

Most of the studies, analyses, and reports for the preoperational (1973-1984) environmental program of the SCA were performed by outside laboratories for the Supply System. The aquatic studies were in reports by Battelle Pacific Northwest Laboratories for the period of September 1974 through August 1978 (Battelle 1976, 1977, 1978, 1979a, 1979b) and by Beak Consultants, Inc. for the period of August 1978 through March 1980 (Beak 1980). The terrestrial program was performed and reports were prepared by Battelle from 1974 until 1979 (Rickard 1976, 1977, 1979a, 1979b) and then by Beak from 1980 to 1982 (Beak 1981, 1982a, 1982b).

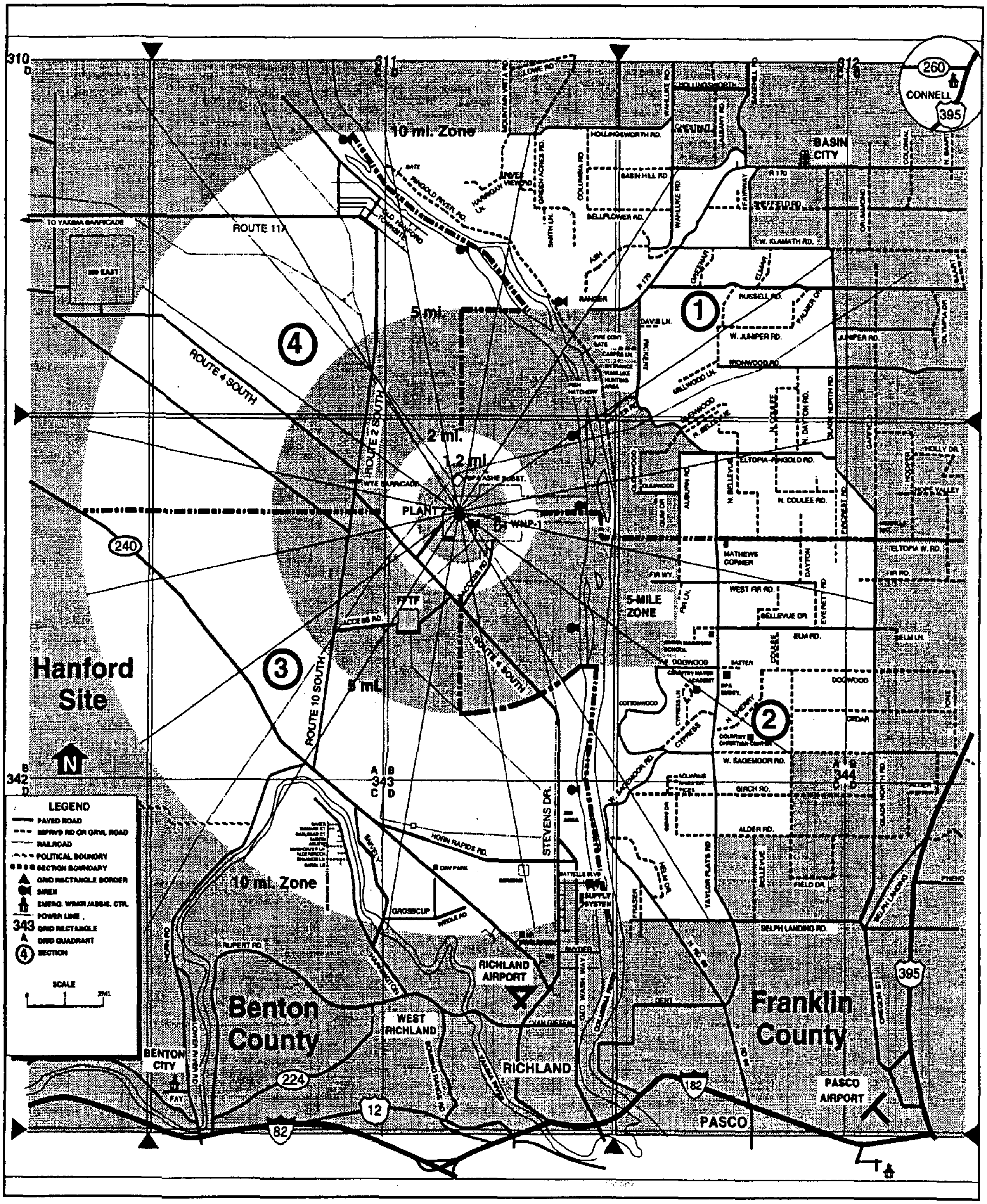
Since 1983, Supply System scientists have been responsible for the entire operational environmental monitoring program. Using the data acquired during 1984, the first comprehensive operational environmental annual report was prepared by Supply System scientists (Supply System 1985) and has since continued annually (Supply System 1986 through 1994). A few studies and reports were completed by Supply System personnel prior to the annual reports, including animal studies (Schleder 1982, 1983, 1984) and terrestrial monitoring (Northstrom 1984).

This report presents the results of the Ecological Monitoring Program for the period of January through December 1995.

1.2 THE SITE

The Supply System leases the WNP-2 site (441 hectares or 1089 acres) from the U. S. Department of Energy. WNP-2 lies within the boundaries of the Columbia Basin between the Cascade Range in Washington and Blue Mountains in Oregon and comprises approximately two-thirds of the area lying east of the Cascades. Approximately 5 km (3.25 miles) to the east, the site is bounded by the Columbia River. The plant communities within the region are described as shrub-steppe communities consisting of various layers of perennial grasses overlaid by a discontinuous layer of shrubs. In general, moisture relations do not support arborescent species, except along streambanks. In August 1984, a range fire destroyed much of the shrub cover on the Hanford site and temporarily modified the shrub-steppe associations which were formerly present.

Figure 1-1 WNP-2 Location Map



2.0 WATER QUALITY

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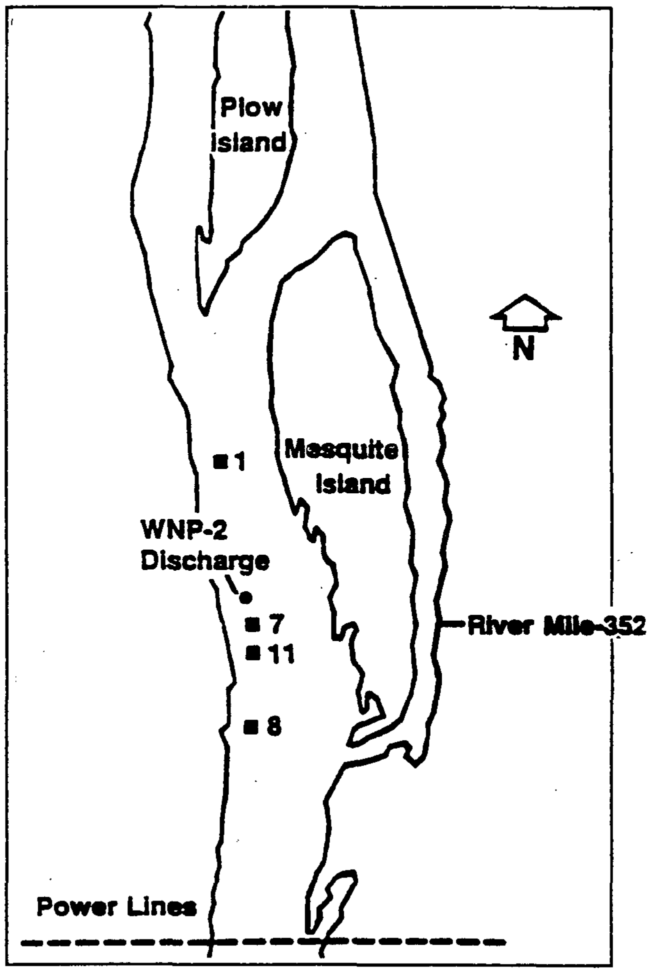
2.1 INTRODUCTION

The water quality sampling stations are located near the west bank of the Columbia River at river mile 352. Sampling was limited to the main channel on the Benton County side. Near the site, the river averages 370 meters (1200 feet) wide with a water surface elevation of 105 meters (345 feet) above sea level and ranges to 7.3 meters (24 feet) deep. Sampling stations have been established in the river both upstream and downstream from the plant intake and discharge structures. The river level in this area fluctuates considerably during a 24-hour period and from day to day in response to release patterns at the Priest Rapids Dam (river mile 397).

2.2 MATERIALS AND METHODS

Figure 2-1. Location of Sampling Stations



Columbia River Surface water was sampled monthly from January through December 1995. Samples were collected near river mile 352 from four stations numbered 1, 7, 11, and 8 (Figures 2-1 and 2-2). Station 1 is upstream of the WNP-2 intake and discharge and represents the control. Station 7 is in the center of the mixing zone approximately 45 meters (150 feet) downstream of the discharge and provides a measure of near field blowdown effects. Station 11, at 91 meters (300 feet) downstream from the discharge, represents the extremity of the mixing zone. Substations 11M and 11B sample water from middle and bottom depths, respectively. Station 8 is approximately 568 meters (1870 feet) downstream from the discharge and represents a location where the blowdown is well mixed in the Columbia River. With the exception of Substations 11M and 11B, Columbia River samples were analyzed for temperature, dissolved oxygen (DO), pH, conductivity, turbidity, total alkalinity, total hardness, total phosphorus, inorganic phosphate, sulfate, total copper, total iron, total zinc, total nickel, total lead, total cadmium and total chromium. The samples from substations (11M and 11B) were analyzed for total copper only.

Plant blowdown was sampled monthly during 1995. Blowdown samples were analyzed for temperature, pH, conductivity, turbidity, total phosphorus, inorganic phosphate, sulfate, oil and grease, total copper, total iron, total zinc, total nickel, total lead, total cadmium, and total chromium. Volatile organic compounds (VOCs) and semi-volatile organic compounds were analyzed on a quarterly basis.

The evaporation/percolation pond (storm drain pond) is located approximately 1500 feet northeast of the plant. The pond is a collection point for water from various locations within the controlled area. Water and sediment were sampled monthly and semiannually, respectively. Monthly water samples were analyzed for pH, conductivity, total iron, total copper, total nickel, total zinc, total lead, total cadmium, total chromium, and oil and grease. In addition, quarterly water samples were analyzed for total dissolved solids and VOCs and semi-VOCs. Semiannual sediment samples were analyzed for the same total metals as the monthly water samples, excluding iron. A summary of water quality parameters, stations and sampling frequencies is presented in Table 2-1.

Table 2-1. Summary of Water Quality Parameters, Stations, and Sampling Frequencies , 1995

Parameter	1	7**	11**	11M &11B**	8**	Plant Blowdown	Pond
Temperature	M	M	M	—	M	M	—
Dissolved Oxygen	M	M	M	—	M	—	—
pH	M	M	M	—	M	M	M
Turbidity	M	M	M	—	M	M	—
Total Alkalinity	M	M	M	—	M	—	—
Filerable Residue (TDS)	—	—	—	—	—	—	Q
Conductivity	M	M	M	—	—	M	M
Iron (Total)	M	M	M	—	M	M	M
Copper (Total)	M	M	M	M	M	M	M
Nickel (Total)	M	M	M	—	M	M	M
Zinc (Total)	M	M	M	—	M	M	M
Lead (Total)	M	M	M	—	M	M	M
Cadmium (Total)	M	M	M	—	M	M	M
Chromium (Total)	M	M	M	—	M	M	M
Sulfate	M	M	M	—	M	M	—
Orthophosphorus	M	M	M	—	M	M	—
Total Phosphorus	M	M	M	—	M	M	—
Oil and Grease	—	—	—	—	M	M	M
Hardness	M	M	M	—	M	—	—
Organics (VOCs and semi-Vocs)	—	—	—	—	—	Q	Q

Symbols Key

Q= Quarterly
M= Monthly
**= Samples collected only if the plant is operating

2.2.1 Sample Collection

Columbia River water samples were collected by boat approximately 300 feet from the Benton County shore. Temperature was determined in situ with portable instruments. Water for total metal, conductivity, pH, sulfate, total phosphorus, inorganic phosphate, turbidity, total alkalinity and total hardness analyses was collected in 2.8 liter polypropylene cubitainers and stored in a cooler until delivered to the Supply System's Environmental and Analytical Support Laboratory (EASL). Water for total copper analysis from substations 11M and 11B was collected in one-liter polypropylene cubitainers with an all-Teflon pump and Tygon tubing. Water for dissolved oxygen measurements was collected in 300 ml (Biological Oxygen Demand) bottles.

Blowdown temperature was determined in situ. Water for pH, conductivity, turbidity, total phophorus, inorganic phosphate and total metals analysis was collected in 2.8 liter polypropylene cubitainers. Water for oil and grease and semivolatile organics anlsysis was collected in one-liter clear and amber glass bottles, respectively. Water for volatile organics analysis was collected in 40 ml glass bottles.

Evaporation/percolation pond water for pH, conductivity and total metals was collected in 2.8 liter polypropylene cubitainers. Water for total dissolved solids analysis was collected in 500 ml plastic bottles. Water for oil and grease, VOCs and semi-VOCs was collected as described under blowdown sampling. All samples were stored in a cooler until delivered to the laboratory for analysis.

River water quality samples collected during the annual plant maintenance outage (April through June) consisted of station 1 (control) samples only.

2.2.2 Analysis Methods

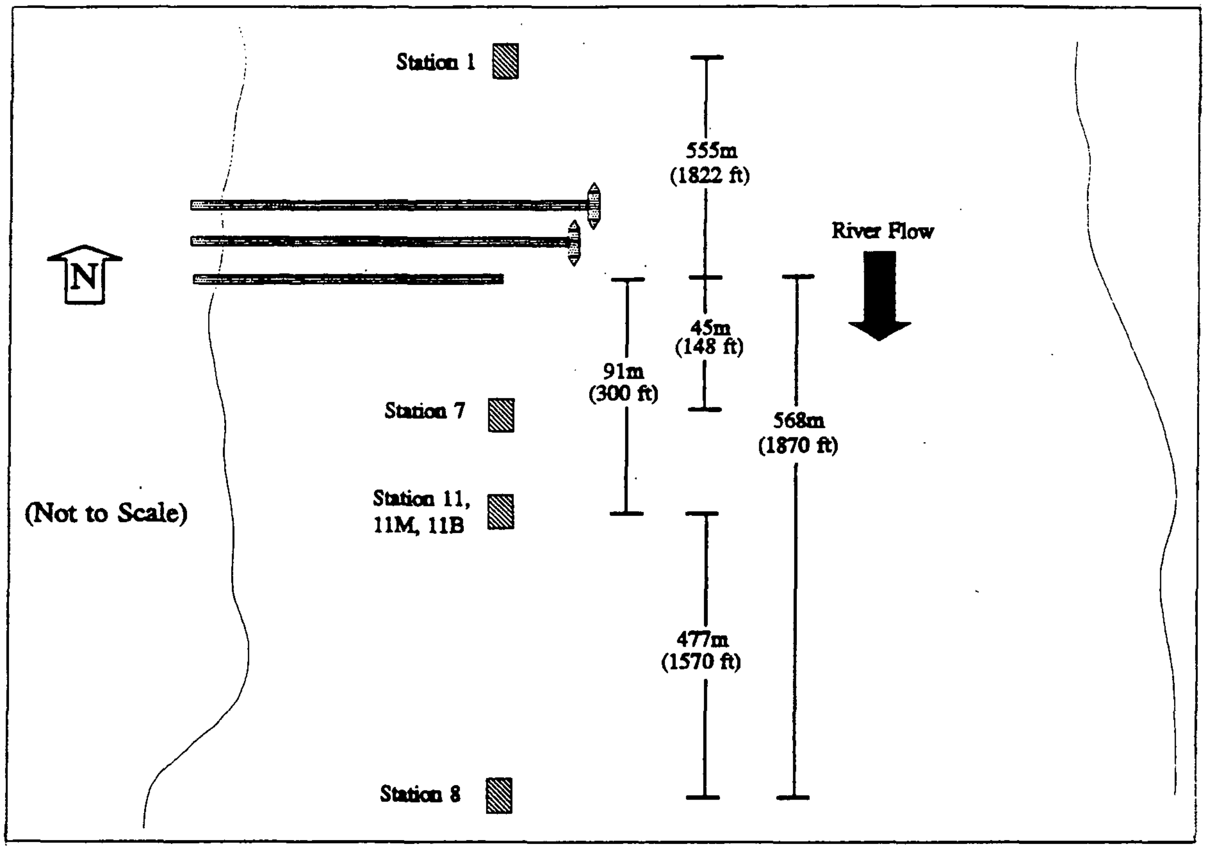
Field temperature measurements were made using a Fisher NIST-traceable thermometer. Temperature was recorded to within 0.1 °C after the probe had been allowed to equilibrate for a minimum of one minute.

Total metals, sulfate, conductivity, pH, dissolved oxygen, inorganic phosphate, turbidity, total alkalinity, total hardness, VOCs and semi-VOCs, total phosphorus, and oil and grease, were determined by Supply System laboratory personnel. Analyses for total dissolved solids and some total metals were performed by an offsite laboratory. Sample holding times followed those recommended by the U.S. Environmental Protection Agency (EPA 1983). Table 2-2 lists the approved EPA and Standard Methods used.

Table 2-2. Summary of Water Quality Parameters, EPA and Standard Method Method Numbers

Parameter	EPA Method Number	Standard Methods Method Number
Water Temperature (°C)	170.1	
Turbidity (NTU)	180.1	
Conductivity (μS/cm) at 25°C	120.1	
Disssolved Oxygen (mg/L) Probe	360.1	
Dissolved Oxygen (mg/L) Modified Winkler	360.2	
pH (Standard Unit)	150.1	
Total Alkalinity (mg/L as $CaCO_3$)	310.1	
Total Hardness (mg/L as $CaCO_3$)	130.2, 6010	2340B
Oil and Grease (mg/L)	412.2	
Total Phosphorus (mg/L as P)	365.2	4500-P
Inorganic Phosphate (mg/L as P)	300, 365.2	
Sulfate (mg/L as SO_4)	300, 375.4	
Total Copper (μg/L as Cu)	200.7, 220.1, 220.2	
Total Iron (μg/L as Fe)	200.7, 236.1, 236.2	
Total Nickel (μg/L asNi)	200.7, 249.1, 249.2	
Total Zinc (μg/L as Zn)	200.7, 289.1, 289.2	
Total Lead (μg/L as Pb)	200.7, 239.1, 239.2	
Total Cadmium (μg/L as Cd)	200.7, 212.1, 212.2	
Total Chromium (μg/L as Cr)	200.7, 218.1, 218.2	
Filterable Residue: TDS (mg/L)	160.1	
Volatile Organics (μg/L)	8240	
Semivolatile Organics (μg/L)	8270	

Figure 2-2. Schematic of River Sample Locations for Water Quality



2.3 RESULTS AND DISCUSSION

The evaporation/percolation pond is a discharge to ground and is not related to potential effects of the blowdown on the Columbia River. There was no plant blowdown during the February sampling event. For all sampling periods, significant interstation differences could not be detected for any of the measured parameters. The water quality monitoring results for both the river and the pond are presented in the following subsections.

2.3.1 Temperature

Columbia River surface temperatures varied seasonally with a temperature of 3.2°C at all stations on January 30 and a maximum of 19.8°C at station 1 on September 19 (Table 2-3). Blowdown temperatures ranged from 19.8°C in January to 41.7°C in July.

Table 2-3. Summary of Temperature (°C) Measurements for 1995

Sample Date	1	7	11	8	Plant Blowdown
01/30/95	3.2	3.2	3.2	3.2	19.8
02/28/95	3.5	3.5	3.5	3.5	--
03/30/95	5.5	5.5	5.5	5.5	37.1*
04/26/95	8.6	--	--	--	--
05/30/95	13.1	--	--	--	--
06/29/95	16.0	--	--	--	--
07/25/95	18.5	18.5	18.5	18.5	41.7*
08/31/95	19.0	19.0	19.0	19.0	40.6*
09/19/95	19.8	19.7	19.7	19.7	39.1*
10/24/95	13.8	13.8	13.8	13.8	35.5*
11/09/95	11.7	11.7	11.6	11.7	34.0*
12/20/95	6.8	6.8	6.8	6.8	24.2*

*Measurements taken from cooling tower 2B- top deck.

2.3.2 Dissolved Oxygen (DO)

DO measurements for each sample station are presented in Table 2-4. Columbia River DO concentrations ranged from 9.4 mg/L at Stations 1, 7 and 11 in September to 14.0 mg/L at Station 1 in February.

Table 2-4. Summary of Dissolved Oxygen (mg/L) Measurements

Sample Date	1	7	11	8
01/30/95	13.6	13.6	13.5	13.5
02/28/95	14.0	13.9	13.9	13.9
03/30/95	13.4	13.4	13.5	13.4
04/26/95	13.5	--	--	--
05/30/95	11.9	--	--	--
06/29/95	10.8	--	--	--
07/25/95	10.1	10.2	10.2	10.2
08/31/95	10.0	10.0	9.9	10.0
09/19/95	9.4	9.4	9.4	9.5
10/24/95	10.2	10.5	10.1	10.3
11/09/95	11.0	10.8	10.9	10.8
12/20/95	12.1	12.1	12.0	12.2

DO concentrations were inversely related to river temperature as would be expected from solubility laws. DO levels were never below the water quality standard for Class A waters (WDOE 1992) indicating good water quality with respect to dissolved oxygen throughout the year.

2.3.3 pH and Alkalinity

Columbia River pH values ranged from 7.47 at Station 1 in January to 8.12 at Station 1 in May. The pH water quality standard for Class A waters is from 6.5 to 8.5 (WDOE 1992). Blowdown pH values ranged from 7.86 in December, to 8.47 in September. Pond pH values ranged from 7.09 in January to 9.19 in April. Columbia River alkalinities ranged from 49 to 62 mg/L as calcium carbonate. Results for pH and alkalinity are listed in Tables 2-5 and 2-6.

Table 2-5. Summary of pH Measurements

Sample Date	1	7	11	8	Plant Blowdown	Pond
01/30/95	7.47	7.51	7.48	7.48	8.11	7.09
02/28/95	7.57	7.53	7.59	7.65	--	7.92
03/30/95	7.48	7.52	7.54	7.53	8.15	8.12
04/26/95	8.01	--	--	--	--	9.19
05/30/95	8.12	--	--	--	--	7.81
06/29/95	7.94	--	--	--	--	8.09
07/25/95	7.83	7.76	7.81	7.82	8.32	7.92
08/31/95	7.94	7.78	8.07	7.91	8.46	8.09
09/19/95	7.87	7.92	7.97	7.85	8.47	8.07
10/24/95	7.62	7.71	7.63	7.73	8.21	8.16
11/09/95	7.64	7.64	7.65	7.64	8.37	8.04
12/20/95	7.71	7.65	7.87	7.62	7.86	8.13

Table 2-6. Summary of Alkalinity Measurements

Sample Date	1	7	11	8
01/30/95	61	62	62	62
02/28/95	57	60	58	57
03/30/95	55	55	56	55
04/26/95	57	--	--	--
05/30/95	57	--	--	--
06/29/95	49	--	--	--
07/25/95	54	55	55	55
08/31/95	57	58	58	58
09/19/95	57	57	56	57
10/24/95	54	54	54	54
11/09/95	56	56	55	56
12/20/95	61	60	61	61

2.3.4 Hardness

Hardness ranged from 55 to 85 mg/L as calcium carbonate. This data is presented in Table 2-7.

Table 2-7. Summary of Total Hardness Mesurements

Sample Date	1	7	11	8
01/30/95	72	74	72	73
02/28/95	72	73	73	72
03/30/95	71	72	71	71
04/26/95	85	--	--	--
05/30/95	58	--	--	--
06/29/95	55	--	--	--
07/25/95	59	60	61	60
08/31/95	66	65	66	67
09/19/95	65	64	63	65
10/24/95	63	64	63	63
11/09/95	67	69	67	66
12/20/95	71	70	69	71

2.3.5 Conductivity

Columbia River conductivity measurements ranged from 112 μS/cm at 25°C at station 1 in June to 153 μS/cm at 25°C at station 7 in January and February. Blowdown measurements ranged from 1060 μS/cm at 25°C to 1570 μS/cm at 25°C. Storm drain pond values ranged from 68 to 575 μS/cm at 25°C. Conductivity measurements are listed in Table 2-8.

Table 2-8. Summary of Conductivity Measurements

Sample Date	1	7	11	8	Plant Blowdown	Pond
01/30/95	151	153	151	152	1140	68
02/28/95	150	153	148	148	--	575
03/30/95	149	150	149	149	1270	431
04/26/95	146	--	--	--	--	326
05/30/95	148	--	--	--	--	273
06/29/95	112	--	--	--	--	198
07/25/95	128	127	127	130	1480	223
08/31/95	138	140	140	140	1550	226
09/19/95	138	138	138	139	1570	305
10/24/95	125	124	131	133	1340	455
11/09/95	127	129	128	129	1320	433
12/20/95	146	147	147	147	1060	421

2.2.7 Turbidity

In the Columbia River, measured turbidities were low and ranged from 1.0 nephlometric turbidity units (NTU) to 4.5 NTU. Blowdown values ranged from 9 to 40 NTU. Turbidity results are listed in Table 2-9.

Table 2-9. Summary of Turbidity Measurements

Sample Date	1	7	11	8	Plant Blowdown
01/30/95	1.5	1.1	1.4	1.0	10
02/28/95	4.0	4.3	4.3	4.2	–
03/30/95	3.6	3.8	3.5	3.6	40
04/26/95	4.5	–	–	–	–
05/30/95	4.5	–	–	–	–
06/29/95	1.0	–	–	–	–
07/25/95	2.0	2.0	1.9	1.8	9
08/31/95	1.3	1.5	1.4	1.6	12
09/19/95	1.6	1.6	1.7	1.5	16
10/24/95	2.0	1.9	1.9	2.1	15
11/09/95	1.4	1.5	1.5	1.3	25
12/20/95	2.3	2.4	2.2	2.4	38

2.3.7 Metals (Total)

Columbia River cadmium concentrations were below the respective method detection limit (1.4μg/L) at all stations during all periods. River copper concentrations ranged from <1.9 μg/L to 4.6 μg/L. Zinc concentrations ranged from <5.0 μg/L to 14.4 μg/L and iron concentrations ranged from 33 μg/L to 218 μg/L. Nickel concentrations were generally below the detection limit of 2.0 μg/L. The highest nickel reading of 2.6 μg/L was recorded at station 7 in January.

Blowdown cadmium concentrations were below the detection limit for all stations and periods, except October (5.1 μg/L). Nickel and lead concentrations were fairly low, ranging from <2.0 μg/L to 7.0 μg/L and < 1.0 μg/L to 4.7 μg/L, respectively. Blowdown copper, zinc and iron concentrations were substantially higher than river concentrations and ranged from 45 μg/L to 110 μg/L, 47 μg/L to 108 μg/L, and 360 μg/L to 2010 μg/L, respectively. Chromium concentrations ranged from <0.5 μg/L to 5.0 μg/L.

Evaporation/percolation pond water cadmium and nickel concentrations were below their respective detection limits for all periods. Lead concentrations ranged from <1.0 μg/L to 19.0 μg/L. Chromium concentrations ranged from <0.5 μg/L to 1.6 μg/L. Copper concentrations ranged from <1.9 μg/L to 35 μg/L and zinc concentrations ranged from 27 μg/L to 774 μg/L. Iron concentrations ranged from a low of 20 μg/L in November to a high of 196 μg/L in January. With the exception of lead and nickel, measurable levels for all other metal constituents were observed in the storm drain pond sediment samples.

Total metal results are listed in Tables 2-10 through 2-16.

Table 2-10. Summary of Copper (μg/L) Measurements

Sample Date	1	7	11	11M	11B	8	Plant Blowdown	Pond	Pond Sediment (μg/g)
01/30/95	<1.9	2.1	<1.9	<1.9	<1.9	<1.9	54	8.5	--
02/28/95	<1.9	2.4	2.4	<1.9	<1.9	2.1	--	2.4	--
03/30/95	<1.9	2.0	<1.9	<1.9	<1.9	<1.9	51	<1.9	--
04/26/95	<1.9	--	--	--	--	--	--	35	--
05/30/95	2.6	--	--	--	--	--	--	17	--
06/29/95	2.9	--	--	--	--	--	--	13	71.4
07/25/95	2.0	3.0	2.0	4.6	2.4	2.0	110	6.0	--
08/31/95	<1.9	2.0	2.0	<1.9	<1.9	2.0	58	5.0	--
09/19/95	2.0	<1.9	<1.9	<1.9	<1.9	<1.9	45	8.0	--
10/24/95	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	54	<1.9	--
11/09/95	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	69	3.0	--
12/20/95	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	57	2.0	101

Table 2-11. Summary of Nickel (μg/L) Measurements

Sample Date	1	7	11	8	Plant Blowdown	Pond	Pond Sediment (μg/g)
01/30/95	<2.0	2.6	<2.0	<2.0	4.2	<2.0	—
02/28/95	<2.0	<2.0	<2.0	<2.0	—	<2.0	—
03/30/95	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	—
04/26/95	<2.0	—	—	—	—	<2.0	—
05/30/95	<2.0	—	—	—	—	<2.0	—
06/29/95	<2.0	—	—	—	—	<2.0	<0.4
07/25/95	<2.0	<2.0	<2.0	<2.0	3.0	<2.0	—
08/31/95	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	—
09/19/95	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	—
10/24/95	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	—
11/09/95	<2.0	<2.0	<2.0	<2.0	5.0	<2.0	—
12/20/95	<2.0	<2.0	<2.0	<2.0	7.0	<2.0	<0.4

Table 2-12. Summary of Zinc (μg/L) Measurements

Sample Date	1	7	11	8	Plant Blowdown	Pond	Pond Sediment (μg/g)
01/30/95	6.9	7.5	<5.0	8.7	54	124	--
02/28/95	6.2	7.8	9.4	8.4	--	27	--
03/30/95	<5.0	<5.0	<5.0	<5.0	47	53	--
04/26/95	14.1	--	--	--	--	67	--
05/30/95	7.7	--	--	--	--	262	--
06/29/95	6.8	--	--	--	--	75	258
07/25/95	6.0	6.9	7.4	7.0	108	134	--
08/31/95	5.9	6.0	8.4	5.7	68	435	--
09/19/95	<5.0	8.6	<5.0	<5.0	53	774	--
10/24/95	5.4	5.4	6.0	5.4	65	41	--
11/09/95	<5.0	<5.0	<5.0	<5.0	57	44	--
12/20/95	6.6	7.2	5.4	5.0	68	62	740

Table 2-13. Summary of Iron ($\mu g/L$) Measurements

Sample Date	1	7	11	8	Plant Blowdown	Pond
01/30/95	41	44	46	49	906	196
02/28/95	207	206	216	218	–	29
03/30/95	35	33	37	33	360	67
04/26/95	241	–	–	–	–	186
05/30/95	149	–	–	–	–	70
06/29/95	196	–	–	–	–	144
07/25/95	103	101	107	100	435	–
08/31/95	70	73	72	71	603	38
09/19/95	56	70	69	61	589	71
10/24/95	83	87	69	75	624	24
11/09/95	74	87	83	75	1250	20
12/20/95	135	134	131	124	2010	28

Table 2-14. Summary of Lead ($\mu g/L$) Measurements

Sample Date	1	7	11	8	Plant Blowdown	Pond	Pond Sediment ($\mu g/g$)
01/30/95	2.7	<1.0	<1.0	<1.0	<.9	<1.0	–
02/28/95	<1.0	3.3	<1.0	<1.0	–	<1.0	–
03/30/95	<1.0	<1.0	<1.0	<1.0	4.7	<1.0	–
04/26/95	<1.0	–	–	–	–	<1.0	–
05/30/95	<1.0	–	–	–	–	19	–
06/29/95	<1.0	–	–	–	–	14	<0.14*
07/25/95	2.0	8.0	2.0	4.0	1.0	2.0	–
08/31/95	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	–
09/19/95	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	–
10/24/95	<1.0	<1.0	<1.0	<1.0	1.0	<1.0	–
11/09/95	1.0	<1.0	<1.0	<1.0	2.0	<1.0	–
12/20/95	<1.0	<1.0	<1.0	<1.0	2.0	<1.0	14.2

*Detection limit for solid sample.

Table 2-15. Summary of Cadmium (μg/L) Measurements

Sample Date	1	7	11	8	Plant Blowdown	Pond	Pond Sediment (μg/g)
01/30/95	<1.4	<1.4	<1.4	<1.4	<1.4	<1.4	--
02/28/95	<1.4	<1.4	<1.4	<1.4	--	<1.4	--
03/30/95	<1.4	<1.4	<1.4	<1.4	<1.4	<1.4	--
04/26/95	<1.4	--	--	--	--	<1.4	--
05/30/95	<1.4	--	--	--	--	<1.4	--
06/29/95	<1.4	--	--	--	--	<1.4	3.6
07/25/95	<1.4	<1.4	<1.4	<1.4	<1.4	<1.4	--
08/31/95	<1.4	<1.4	<1.4	<1.4	<1.4	<1.4	--
09/19/95	<1.4	<1.4	<1.4	<1.4	<1.4	<1.4	--
10/24/95	<1.4	<1.4	<1.4	<1.4	5.1	<1.4	--
11/09/95	<1.4	<1.4	<1.4	<1.4	<1.4	<1.4	--
12/20/95	<1.4	<1.4	<1.4	<1.4	<1.4	<1.4	10.4

Table 2-16. Summary of Chromium (μg/L) Measurements

Sample Date	1	7	11	8	Plant Blowdown	Pond	Pond Sediment (μg/g)
01/30/95	<0.5	<0.5	<0.5	<0.5	1.1	<0.5	--
02/28/95	<0.5	<0.5	<0.5	<0.5	--	<0.5	--
03/30/95	<0.5	<0.5	<0.5	<0.5	5.0	<0.5	--
04/26/95	<0.5	--	--	--	--	<0.5	--
05/30/95	<0.5	--	--	--	--	<0.5	--
06/29/95	<0.5	--	--	--	--	<0.5	8.8
07/25/95	0.8	0.9	0.8	0.9	2.5	0.8	--
08/31/95	<0.5	<0.5	<0.5	<0.5	<0.5	1.6	--
09/19/95	<0.5	<0.5	<0.5	<0.5	2.1	<0.5	--
10/24/95	<0.5	<0.5	<0.5	<0.5	1.5	<0.5	--
11/09/95	0.8	0.8	0.7	0.9	2.8	0.9	--
12/20/95	0.9	1.0	1.0	0.9	5.0	0.9	11.2

2.3.8 Oil and Grease

Blowdown and pond oil and grease values were below the detection limit of 1.0 mg/L for all periods sampled. Oil and grease measurements are summarized in the following table.

Table 2-17. Summary of Oil and Grease (mg/L) Measurements

Sample Date	Plant Blowdown	Pond
01/30/95	<1.0	<1.0
02/28/95	--	<1.0
03/30/95	<1.0	<1.0
04/26/95	--	<1.0
05/30/95	--	<1.0
06/29/95	--	<1.0
07/29/95	<1.0	<1.0
08/31/95	<1.0	<1.0
09/19/95	<1.0	<1.0
10/24/95	<1.0	<1.0
11/09/95	<1.0	<1.0
12/20/95	<1.0	<1.0

2.3.9 Total Phosphorus and Inorganic Phosphate

Columbia River total phosphorus concentrations ranged from <0.01 to 0.02 mg/L as P. Blowdown values ranged from 2.4 to 4.7 mg/L as P. Columbia River inorganic phosphate concentrations were at or below 0.1 mg/L for all stations and periods, except Station II in March (0.2 mg/L).. Blowdown inorganic phosphate measurements ranged from 0.8 to 1.6 mg/L as P. Total phosphorus and inorganic phosphate measurements are summarized in Tables 2-18 and 2-19.

Table 2-18. Summary of Total Phosphorus (mg/L as P) Measurements

Sample Date	1	7	11	8	Plant Blowdown
01/30/95	0.02	0.02	0.02	0.01	2.4
02/28/95	0.02	0.02	0.02	0.02	--
03/30/95	0.03	0.02	0.02	0.02	4.1
04/26/95	0.02	--	--	--	--
05/30/95	0.01	--	--	--	--
06/29/95	<0.01	--	--	--	--
07/25/95	0.01	0.01	0.01	0.01	4.4
08/31/95	0.01	0.01	0.01	0.01	4.4
09/19/95	0.01	0.02	0.02	0.02	4.4
10/24/95	0.01	0.02	0.02	0.02	4.1
11/09/95	0.01	0.02	0.01	0.01	4.7
12/20/95	0.03	0.02	0.02	0.02	3.3

Table 2-19. Summary of Inorganic Phosphate (mg/L as P) Measurements

Sample Date	1	7	11	8	Plant Blowdown
01/30/95	<0.1	<0.1	<0.1	<0.1	1.0
02/28/95	<0.1	<0.1	0.1	<0.1	--
03/30/95	<0.1	<0.1	0.2	<0.1	1.0
04/26/95	<0.1	--	--	--	--
05/30/95	<0.1	--	--	--	--
06/29/95	<0.1	--	--	--	--
07/25/95	<0.1	<0.1	<0.1	<0.1	0.8
08/31/95	<0.1	<0.1	<0.1	<0.1	0.9
09/19/95	<0.1	<0.1	<0.1	<0.1	0.8
10/24/95	<0.1	<0.1	<0.1	<0.1	1.3
11/09/95	<0.1	<0.1	<0.1	<0.1	1.2
12/20/95	<0.1	<0.1	<0.1	<0.1	1.6

2.3.10 Sulfate

Individual Columbia River sulfate measurements ranged from 9.3 to 10.8 mg/L. Blowdown measurements ranged from 419 to 775 mg/L. The results are presented in Table 2-20.

Table 2-20. Summary of Sulfate (mg/L) Measurements

Sample Date	1	7	11	8	Plant Blowdown
01/30/95	10.1	10.8	10.2	10.1	471
02/28/95	10.2	10.2	10.2	10.2	—
03/30/95	10.5	10.6	10.6	10.5	443
04/26/95	10.3	—	—	—	—
05/30/95	8.6	—	—	—	—
06/29/95	7.3	—	—	—	—
07/25/95	9.0	9.0	9.2	9.0	660
08/31/95	8.9	8.9	8.8	8.8	700
09/19/95	9.1	9.1	9.1	9.1	775
10/24/95	9.2	9.4	9.2	9.2	595
11/09/95	9.3	10.5	10.1	9.3	525
12/20/95	9.2	9.2	9.2	9.2	419

2.3.11 Total Dissolved Solids

The quarterly total dissolved solids (TDS) measurements of the pond ranged from 130 mg/L to 260 mg/L. This data is presented in Table 2-21.

Table 2-21. Summary of Quarterly Total Dissolved Solid (mg/L) Measurements

Sample Date	Conc.
03/30/95	250
06/29/95	130
09/19/95	230
12/20/95	260

2.3.12 VOCs and Semi-VOCs

Blowdown volatile and semivolatile concentrations were below their respective detection limits for all compounds during all periods.

Evaporation/percolation pond semivolatile organic compound concentrations were below their respective detection limits for all compounds during all periods, except bis (2-ethylhexyl) phthalate in March (480 μg/L) and September (24 μg/L). Limit of detection for bis(2-ethylhexyl) phthalate is 10 μg/L. Volatile organic concentrations were below their respective detection limits for all compounds during all periods, except freon 113 in September (24 μg/L) and December (88 μg/L) and chloroform in December (11 μg/L). Limits of detection for freon 113 and chloroform are 10 μg/L and 5 μg/L, respectively. A list of the volatile and semivolatile organic compounds analyzed are presented in Tables 2-22 and 2-23, respectively.

Table 2-22. Summary of Volatile Organic Compounds

Chloromethane	Vinyl chloride	trans-1,3-Dichloropropene
Trichlorofluoromethane	Bromomethane	Dibromochloromethane
Freon 113	Chloroethane	Toluene
1,1-Dichloroethene	Carbon disulfide	2-Hexanone
Acetone	Methylene chloride	Ethylbenzene
cis-1,2-Dichloroethene	trans-1,2-Dichloroethene	Styrene
1,1-Dichloroethane	Chloroform	1,4-Dichlorobenzene
1,2-Dichloroethane	2-Butanone	1,1,2,2-Tetrachloroethane
1,1,1-Trichloroethane	Carbon tetrachloride	Bromoform
Benzene	Trichloroethene	4-Methyl-2-pentanone
1,2-Dichloropropane	Vinyl acetate	Tetrachloroethene
Bromodichloromethane	2-Chloroethylvinylether	Chlorobenzene
cis 1,3-Dichloropropene	1,1,2-Trichloroethane	Total Xylenes
1,3-Dichlorobenzene	1,2-Dichlorobenzene	

Table 2-23. Summary of Semivolatile Organic Compounds

Acids	Base Neutrals	
Phenol	2-Chloronaphthalene	2,4-Dinitrotoluene
2-Chlorophenol	2-Nitroaniline	Diethylphthalate
2-Methylphenol	Dimethylphthalate	Fluorene
4-Methylphenol	Acenaphthalene	4-Chlorophenyl-phenylether
2-Nitrophenol	2,6-Dinitrotoluene	4-Nitroaniline
2,4-Dimethylphenol	3-Nitroaniline	n-Nitrosodiphenylamine
2,4-Dichlorophenol	Acenaphthene	4-Bromophenyl-phenylether
Benzoic Acid	Dibenzofuran	Hexachlorobenzene
4-Chloro-3-methylphenol	Phenanthrene	bis (2-Chloroethyl)ether
2,4,6-Trichlorophenol	1,3-Dichlorobenzene	Anthracene
2,4,5-Trichlorophenol	1,4-Dichlorobenzene	Di-n-butylphthalate
2,4-Dinitrophenol	Benzyl Alcohol	Fluoranthene
4-Nitrophenol	1,2-Dichlorobenzene	Pyrene

Table 3-23. Summary of Semivolatile Organic Compounds

Acids	Base Neutrals	
Pentachlorophenol	n-Nitroso-di-n-propylamine	Benzo[a]anthracene
	Hexachloroethane	Nitrobenzene
	Isophorone	bis (2-Chloroethoxy)methane
	1,2,4-Trichlorobenzene	Naphthalene
	4-Chloroaniline	Dibenzo[a,h]anthracene
	Benzo[g,h,i]perylene	Hexachlorobutadiene
	2-Methylnaphthalene	Hexachlorocyclopentadiene
	Benzo[b]fluoranthene	3,3-Dichlorobenzidine
	Benzo[k]fluoranthene	Chrysene
	Benzo[a]pyrene	bis (2-Ethylhexyl)phthalate
	Indeno[1,2,3-cd]pyrene	

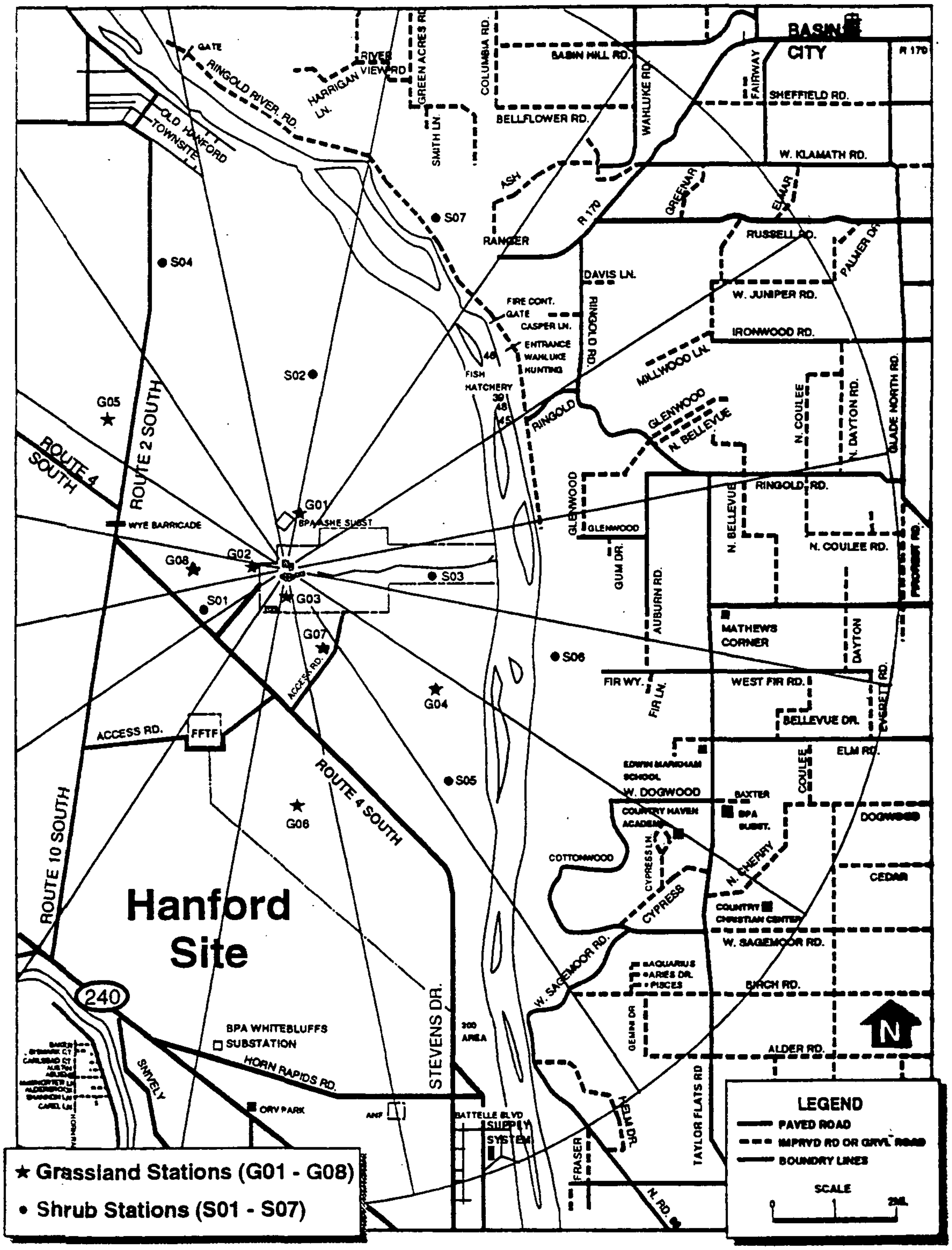
3.0 SOIL AND VEGETATION STUDIES

3.0 SOIL AND VEGETATION STUDIES

3.1 INTRODUCTION

The objective of the soil and vegetation studies is to identify any significant effects or impacts of plant cooling tower operation upon the plant communities surrounding WNP-2. Vegetation and soil sampling is conducted at the peak of the cheatgrass growth cycle known as the purple stage (Klemmedson 1964). Cheatgrass *(Bromus tectorum)* is the predominant species within all fifteen of the sampling plots with a mean frequency >98% and cover often approaching 50%. Cheatgrass fruits turn purple shortly after reaching viability and then brown when mature. The purple stage of development correlates well with the peak productivity of many associated species and serves as a marker for initiation of annual sampling and comparison of phytomass productivity between years. The program includes the measurement of herbaceous canopy cover, herbaceous phytomass and soil chemistry. Soil chemical parameters measured include pH, carbonate, bicarbonate, sulfate, chloride, sodium, copper, zinc and conductivity. Fifteen sampling stations are located within a five mile radius of the plant. The stations consist of eight grassland (G01-G08) and seven shrub sites (S01-S07). The location of each station is illustrated in Figure 3-1.

Figure 3-1. Soil and Vegetation Sampling Location Map



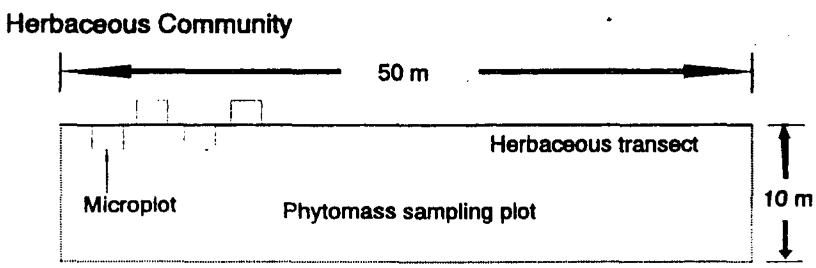
880334.19 Map
July 1993

3.2 MATERIALS AND METHODS

3.2.1 Herbaceous Canopy Cover

At each of the fifteen stations fifty microplots (20 cm x 50 cm) were placed at 1-meter intervals on alternate sides of the herbaceous transect (fig. 3-2). Canopy cover was estimated for each species occurring within a microplot using Daubenmire's (1968) cover classes. Data were recorded on standard data sheets. To assure the quality of the sampling, three randomly selected microplots were sampled twice. The entire transect was resampled if cover estimates for any major species (>50% frequency) differed by more than one cover class.

Figure 3-2. Layout of Vegetation and Soil Sampling Plots



3.2.2 Herbaceous Phytomass

Phytomass sampling was conducted concurrently with cover sampling. Phytomass sampling plots were randomly located within an area adjacent to the permanent transects or plots (Figure 3-2). At each station, all live herbaceous vegetation rooted in the designated microplot (20 x 50 cm) was clipped to ground level and placed in paper bags. Each bag was stapled shut and labeled with station code, plot number, date and personnel initials.

Sampling bags were transported to the laboratory, opened, and placed in a drying oven until a consistent weight was obtained. Following drying, the bags were removed singularly from the oven and their contents immediately weighed to the nearest 0.1 g. Laboratory quality assurance consisted of independently reworking 10 percent of the phytomass samples to assess data validity and reliability.

3.2.3 Soil Chemistry

At each of the fifteen grassland and shrub stations, two soil samples were collected from the top 15 cm of soil with a clean stainless steel trowel. The soil samples are randomly selected and taken from the phytomass sampling plot. The samples were placed in 250 ml sterile plastic cups with lids, labeled and refrigerated at 4°C. Nine parameters were analyzed in each sample, including pH, bicarbonate, carbonate, conductivity, sulfate, chloride, copper, zinc, and sodium. Aliquots of soil for trace metal analysis were microwave digested according to Gilman (1989). Preservation times and conditions, when applicable, followed EPA procedures (1983).

Laboratory quality control comprised 10-20% of the sample analysis load. Routine quality control samples included internal laboratory check standards, reagent blanks, and prepared EPA or NIST controls.

3.3 RESULTS AND DISCUSSION

During the 1995 season, 62 plant taxa were observed in the study areas. Table 3-1 lists the vascular plants observed during 1995 field studies.

Table 3-1. Vascular Plants Observed During 1995

Scientific Name	Common Name
APIACEAE	Pasley Family
Cymopterus terebinthinus (Hook.) T.&G. var. *terebinthinus*	Turpentine cymopterus
ASTERACEAE	Aster Family
Achillea millefolium L.	Yarrow
Antennaria dimorpha (Nutt.) T.& G.	Low pussy-toes
Artemisia tridentata Nutt.	Big Sagebrush
Balsamorhiza careyana Gray	Carey's balsamroot
Chrysothamnus nauseosus (Pall.) Britt	Gray rabbitbrush
Chrysothamnus viscidiflorus (Hook.) Nutt	Green rabbitbrush
Crepis atrabarba Heller	Slender hawksbeard
Franseria acanthicarpa Hook.	Bur ragweed
Layia glandulosa (Hook.) H & A	White daisy tidytips
Tragopogon dubius Scop.	Yellow salsify
Aster canescens Pursh	Hoary aster
BORAGINACEAE	Borage Family
Amsinckia lycopsoides Lehm.	Tarweed fiddleneck
Cryptantha circumscissa (H&A) Johnst.	Matted cryptantha
Cryptantha leucophaea (Dougl.) Pays	NA
Cryptantha pterocarya (Torr.) Greene	Winged cryptantha
BRASSICAEAE	Mustard Family
Descurainia pinnata (Walt.) Britt.	Western tansymustard
Draba verna L.	Spring draba
Erysimum asperum (Nutt.) DC.	Prairie rocket
Sisymbrium altissimum L.	Tumblemustard
CACTACEAE	Cactus Family
Opuntia polycantha Haw.	Starvation cactus

Table 3-1. Vascular Plants Observed During 1995 (Continued)

Scientific Name	Common Name
CARYOPHYLLACEAE	Pink Family
Arenaria franklinii Dougl. var *franklinii*	Franklin's sandwort
Holosteum umbellatum L.	Jagged chickweed
CHENOPODIACEAE	Chenopod Family
Chenopodium leptophyllum (MOQ.) Wats.	Slimleaf goosefoot
Grayia spinosa (Hook.) MOQ.	
Salsola kali L.	Russian thistle
FABACEAE	Pea Family
Astragalus purshii Dougl.	Wooly-pod milk-vetch
Astragalus sclerocarpus Gray	Stalked-pod milk-vetch
Psoralea lanceolata Pursh	Lance-leaf scurf-pea
GERANIACEAE	Geranium Family
Erodium cicutarium (L.) L'Her.	Filaree, storks-bill
HYDROPHYLLACEAE	Waterleaf Family
Phacelia hastata Dougl.	Whiteleaf phacelia
Phacelia linearis (Pursh) Holz.	Threadleaf phacelia
LILIACEAE	Lily Family
Brodiaea douglasii Wats.	Douglas' brodiaea
Calochortus macrocarpus Dougl.	Sego lily
Fritillaria pudica (Pursh) Spreng.	Chocolate lily
LOASACEAE	Blasing-star Family
Mentzelia albicaulis Dougl. Ex Hook.	White-stemmed mentzelia
MALVACEAE	Mallow Family
Sphaeralcea munroana (Dougl.) Spach Ex Gray	White-stemmed globe-mallow
ONAGRACEAE	Evening-primrose Family
Oenothera pallida Lindl. var. *pallida*	White-stemmed evening-primrose
PLANTAGINACEAE	Plantain Family
Plantago patagonica Jacq.	Indian-wheat

Table 3-1. Vascular Plants Observed During 1995 (Continued)

Scientific Name	Common Name
POACEAE	Grass Family
Agropyron cristatum (L.) Gaertn.	Crested wheatgrass
Agropyron dasystachyum (Hook.) Scribn.	Thick-spiked wheatgrass
Agropyron spicatum (Pursh) Scribn. & Smith	Bluebunch wheatgrass
Bromus tectorum L.	Cheatgrass
Festuca octoflora Walt.	Six-weeks fescue
Koeleria cristata Pers.	Prairie Junegrass
Oryzopsis hymenoides (R&S) Ricker	Indian ricegrass
Poa sandbergii Vasey	Sandberg's bluegrass
Sitanion hystrix (Nutt.) Smith	Bottlebrush squirreltail
Stipa comata Trin. & Rupr.	Needle-and-thread
POLEMONIACEAE	Phlox Family
Gilia minutiflora Benth.	Gilia
Gilia sinuata Dougl.	Shy gilia
Leptodactylon pungens (Torr.) Nutt.	Granite gilia
Microsteris gracilis (Hook.) Greene var. *humilior* (Hook.) Cronq.	Pink microsteris
Phlox longifolia Nutt.	Long-leaf phlox
POLYGONACEAE	Buckwheat Family
Eriogonuum niveum Dougl.	Snow buckwheat
Rumex venosus Pursh	Wild begonia
RANUNCULACEAE	Buttercup Family
Delphinium nuttallianum Pritz. ex Walpers	Larkspur
ROSACEAE	Rose Family
Purshia tridentata (Pursh) DC	Antelope Bitterbrush
SANTALACEAE	Sandalwood Family
Comandra umbellata (L.) Nutt.	Bastard toad-flax
SAXIFRAGACEAE	Saxifrage Family
Ribes aureum Pursh	Golden current
SCROPHULARIACEAE	Figwort Family
Penstemon acuminatus Dougl.	Sand-dune penstemon

Table 3-1. Vascular Plants Observed During 1995 (Continued)

Scientific Name	Common Name
VALERIANACEAE	Valerian Family
Plectritis macrocera T&G	Longhorn plectritis

3.3.1 Herbaceous Cover

Total herbaceous cover averaged 92.39% in 1995 which represents an increase of 105% from 1994 (45.05). With the exception of station GO6, all other stations showed an increase of 45% or greater in total herbaceous cover. *Bromus tectorum* continues to be the dominant annual grass with an average cover of 34.42%, an increase of 35.25%. Total perennial grass cover was 27.60%, an increase of 212%. As in previous years, the dominant perennial grass was *Poa sandbergii* with an average cover of 19.69%. The most significant change in cover occurred in the annual forbs. Total annual forb cover increased 395% from last year. *Sisymbrium altissimum* had an average cover of 7.44% compared to 0.54 % last year. *Draba verna* with a previous cover of 0.88% increased 509% with an average cover of 5.36% for 1995. The total perennial forb cover was 3.5%.

Frequency values (%) increased at eight of the fifteen stations. The most significant increase in frequency values was seen in annual forbs. Only two stations (SO2 and SO4) showed a decrease in the number of annual forb species per site. Station GO5 had an increase of six annual forb species. The total species per site for station GO5 increased from 14 to 21. Station SO6 increased from 7 to 14 in total species per site. Table 3-3 shows mean frequency values (%) by species for each sampling station.

Table 3-2. Herbaceous Cover for Fifteen Sampling Stations (%)

	GO1	GO2	GO3	GO4	GO5	GO6	GO7	GO8	SO1	SO2	SO3	SO4	SO5	SO6	S07	AVG. GO1-SO7
ual Grasses																
Bromus tectorum	78.65	70.60	55.50	4.80	10.50	27.60	53.65	60.20	31.80	9.25	25.80	36.15	46.75	4.00	1.10	34.42
Festuca octoflora	0.00	0.00	0.00	0.00	0.60	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
al Annual Grass Cover	**78.65**	**70.60**	**55.50**	**4.80**	**11.10**	**27.65**	**53.65**	**60.20**	**31.80**	**9.25**	**25.80**	**36.15**	**46.25**	**4.00**	**1.10**	**34.47**
Perennial Grasses																
Agropyron spicatum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.02
Oryzopis hymenoides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.60	0.00	0.00	0.00	2.30	0.00	0.33
Poa sandbergii	10.15	18.00	4.00	38.25	47.45	1.95	16.75	16.25	17.60	21.80	30.00	8.64	0.00	51.85	12.65	19.69
Stipa comata	0.00	0.00	0.00	26.60	0.00	2.45	0.00	6.65	0.00	14.40	0.00	0.00	2.00	0.40	0.00	7.50
Total Perennial Grass Cover	**10.15**	**18.00**	**4.00**	**64.85**	**47.45**	**4.40**	**16.75**	**22.90**	**17.60**	**98.80**	**30.00**	**8.64**	**2.30**	**55.55**	**12.65**	**27.60**
ual Forbs																
Amsinckia lycopsoides	0.05	0.10	9.50	0.05	0.50	0.05	11.20	0.05	4.15	0.35	0.00	0.00	3.30	0.10	2.35	2.12
Brodiaea douglasii	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Cryptantha cirmumscissa	0.00	0.00	0.00	0.05	0.05	0.15	0.00	0.00	0.15	0.00	0.00	0.00	0.15	0.00	0.00	0.04
Descurainia pinnata	0.00	0.10	0.10	0.00	0.05	0.00	1.70	0.00	0.55	0.00	0.00	0.00	0.00	1.85	57.80	4.14
Draba verna	16.55	15.15	3.65	3.30	14.00	0.05	5.55	8.15	4.45	0.00	4.60	2.00	2.00	0.90	0.10	5.36
Erodium cicutarium	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.85	0.00	0.00	0.06
Franseria acanthicarpa	0.00	0.00	3.15	0.10	0.10	0.40	1.40	0.05	0.95	0.00	0.00	0.00	0.30	0.05	0.00	0.43
Gilia minutiflora	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00
Holosteum umbellatum	2.30	8.65	2.75	3.70	9.30	0.35	4.60	9.10	7.10	5.70	6.55	2.60	2.90	0.00	0.60	4.41
Mentzelia albicaulis	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.05	0.00	0.10	0.00	0.00	0.00	0.01
Microsteris gracilis	0.15	0.00	3.80	0.15	0.60	2.30	2.45	0.20	7.60	0.00	9.50	0.00	1.20	0.00	0.00	1.29
Phacelia linearia	0.00	0.00	0.05	0.05	0.10	0.10	0.00	0.00	0.10	0.00	0.00	0.00	0.20	0.00	0.00	0.04
Plantago pategonica	0.40	1.15	0.00	1.70	0.00	0.00	0.00	0.40	0.00	0.00	5.00	0.00	1.45	0.00	0.50	0.71
Salsola kali	1.35	0.15	0.15	0.10	1.45	0.20	0.05	0.05	5.40	0.45	0.00	0.45	0.65	0.05	0.00	0.70
Sisymbrium altissimum	2.95	1.90	0.30	0.00	0.10	0.15	3.85	2.60	1.00	1.10	0.65	44.47	1.70	11.15	40.75	7.44
Total Annual Forb Cover	**23.75**	**27.50**	**23.35**	**9.65**	**26.25**	**3.75**	**30.85**	**20.65**	**31.45**	**6.65**	**17.75**	**49.62**	**14.75**	**14.30**	**102.1**	**26.82**
rrenial Forbs																
Achillea millefolium	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	1.30	0.00	0.10
Aster canescens	0.00	0.00	0.10	0.00	0.00	0.00	0.05	0.00	1.75	0.00	0.00	0.30	0.00	0.00	0.00	0.88
Astragalus sclerocarpus	0.00	0.00	0.00	0.00	0.00	1.30	0.00	0.00	0.00	0.00	0.00	1.05	0.30	0.00	0.00	0.09
Balsamorhiza careyana	0.00	0.00	0.00	0.00	3.40	0.05	0.00	0.00	0.00	0.00	0.00	2.30	1.70	0.00	0.00	0.43
Comandra umbellata	0.00	0.00	0.00	0.00	0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
Crepis atrabarba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.40	0.00	0.00	0.00	0.00	0.16
Cymopterus terebinthinus	0.00	0.60	0.00	0.00	0.00	0.00	4.15	0.05	0.00	0.00	6.95	0.00	0.00	0.00	6.45	1.51
Eriogonum niveum	0.00	0.00	0.00	0.00	1.40	0.00	0.00	0.00	0.05	0.00	0.00	0.00	6.75	0.00	0.00	0.55
Oenothera pallida	0.00	0.00	0.20	0.20	0.85	0.15	0..00	0.00	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.12
Phlox longifolia	0.10	0.05	0.05	0.50	0.90	0.00	0.05	2.80	0.30	0.35	0.00	0.00	0.00	3.00	0.00	0.42
Rumex venosus	0.05	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.01
tal Perennial Forb Cover	**0.15**	**0.65**	**0.45**	**0.25**	**7.15**	**5.65**	**0.15**	**2.80**	**2.25**	**7.40**	**2.40**	**3.65**	**8.48**	**4.60**	**6.45**	**3.50**
tal Herbaceous Cover	**112.7**	**116.8**	**85.30**	**79.55**	**91.95**	**41.45**	**101.4**	**106.6**	**83.10**	**122.1**	**75.95**	**98.06**	**72.28**	**78.45**	**122.3**	**92.39**

Table 3-3.. Mean Frequency Values (%) by Species for Each Sampling Station

	GO1	GO2	GO3	GO4	GO5	GO6	GO7	GO8	SO1	SO2	SO3	SO4	SO5	SO6	SO7
Annual Grasses															
Bromus tectorum	100	100	100	76	96	98	96	96	100	52	90	100	100	34	34
Festuca octoflora					14	2						4			
Perennial Grasses															
Agropyron spicatum													2		
Oryzopis hymenoides										10				14	
Poa sandbergii	86	82	8	96	94	10	48	56	38	52	100	30		86	80
Stipa comata				74		4		12		50			4	6	
Annual Forbs															
Amsinckia lycopsoides	2	4	44	2	10	2	56	2	40	4			26	4	16
Chenopodium leptophyllum													6		
Cryptantha circumscissa				2	2	4			6						
Cryptantha pterocarya									6						
Descurainia pinnata		4	4		2		2		12					36	96
Draba verna	94	98	98	82	98	2	92	98	88		94	60	70	26	4
Erodium cicutarium													2		
Franseria acanthacarpa			66	4	4	16	36	2	18				12	2	
Gilia sinuata					2					2					
Holosteum umbellatum	62	98	90	52	98	4	74	96	94	58	94	54	76		14
Layia glandulosa					2										
Mentzelia albicaulis							2			2		4			
Microsteris gracilis	6		72	6	14	62	20	8	68		28		28		
Phacelia linearis			2	2	4				4	4	22		8		
Plantago pategonica	16	26		48				6			74		28		10
Salsola kali	54	6	6	4	38	8	2	2	62	18		18	26	2	
Sisymbrium altissimum	30	26	12		4	6	20	16	20	4	26	86	20	52	78
Tragopogon dubius												2			
Perennial Forbs															
Achillea millifolium														4	
Aster canescens			4				2						2		
Astragalus purshii															
Astragalus sclerocarpus						4						4		2	
Balsamorhiza careyana					4	2						6	2		
Brodiaea douglasii					2			2	2						
Comandra umbellata					4										
Crepis atrabarba															
Cymopterus terebinthinus		4				22									
Eriogonum niveum					6				8				20		
Oenothera pallida			8	8	14	6			2	2		4	40		
Phlox longifolia	4	2	2	10	8		2	32	2	4			6	6	
Rumex venosus	2		4						4						
Total Species per Site	11	11	15	14	21	16	13	13	18	11	9	10	19	14	8

Table 3-3. Mean Herbaceous Cover for 1975 through 1995

CLASS	YEAR	S01	S02	S03	S04	S05	X S01-5	S06	S07	XS	G01	G02	G03	G04	X G01-4	G05	G06	G07	G08	XG	XSG	G01-4, S01-5
AG	1975	49.90	35.30	43.80						43.00	43.90	43.00								43.45	43.18	43.18
PG	1975	0.60	2.00	4.50						2.37	3.70	5.50								4.60	3.26	3.26
AF	1975	14.60	11.70	11.70						12.67	29.50	13.00								21.25	16.10	16.10
PF	1975	4.30	0.90	1.80						2.33	1.50	2.10								1.80	2.12	2.12
ALL	1975	69.40	49.90	61.80						60.37	78.60	63.60								71.10	64.66	64.66
AG	1976	50.70	40.90	34.30						41.97	71.20	51.60								61.40	49.74	49.74
PG	1976	0.40	10.50	10.30						7.07	4.40	3.10								3.75	5.74	5.74
AF	1976	5.50	5.30	7.20						6.00	11.90	8.50								10.20	7.68	7.68
PF	1976	0.00	0.50	0.20						0.23	0.00	0.20								0.10	0.18	0.18
ALL	1976	56.60	57.20	52.00						55.27	87.50	63.40								75.45	63.34	63.34
AG	1977	1.35	0.65	1.90						1.30	5.20	1.45								3.33	2.11	2.11
PG	1977	0.35	11.30	8.28						6.64	3.25	2.90								3.08	5.22	5.22
AF	1977	0.25	0.05	0.90						0.40	2.40	9.35								5.88	2.59	2.59
PF	1977	0.55	0.60	1.42						0.86	0.05	6.30								3.18	1.78	1.78
ALL	1977	2.50	12.60	12.50						9.20	10.90	20.00								15.45	11.70	11.70
AG	1978	51.00	67.00	51.00						56.33	68.00	42.00								55.00	55.80	55.80
PG	1978	3.00	18.00	11.00						10.67	8.00	7.00								7.50	9.40	9.40
AF	1978	38.00	10.00	33.00						27.00	23.00	25.00								24.00	25.80	25.80
PF	1978	8.00	0.00	5.00						4.33	2.00	3.00								2.50	3.60	3.60
ALL	1978	100.00	95.00	100.00						98.33	101.00	77.00								89.00	97.60	94.60
AG	1979	25.00	29.00	9.00						21.00	31.00	10.00								20.50	20.80	20.80
PG	1979	1.00	18.00	11.00						10.00	7.00	5.00								6.00	8.40	8.40
AF	1979	2.00	4.00	10.00						5.33	43.00	33.00								38.00	18.40	18.40
PF	1979	11.00	0.00	3.00						4.67	0.00	7.00								3.50	4.20	4.20
ALL	1979	39.00	51.00	33.00						41.00	81.00	55.00								68.00	51.80	51.80
AG	1980	50.40	51.80	24.30	56.20	56.40	47.82			47.82	64.30	77.80	73.80	12.30	57.05					57.05	51.92	51.92
PG	1980	1.00	7.20	23.30	10.90	0.10	8.50			8.50	28.30	64.00	0.10	26.60	29.75					29.75	17.94	17.94
AF	1980	7.60	4.20	22.50	3.40	14.10	10.36			10.36	7.30	5.00	28.70	4.90	11.48					11.48	10.86	10.86
PF	1980	2.20	2.20	4.70	4.60	1.80	3.10			3.10	0.40	0.00	0.00	4.60	1.25					1.25	2.28	2.28
ALL	1980	61.20	65.40	74.80	75.10	72.40	69.78			69.78	100.30	146.80	102.60	48.40	99.53					99.53	83.00	83.00
AG	1981	74.80	54.60	66.50	49.80	76.20	64.38			64.38	77.40	84.00	88.40	48.90	74.68					74.68	68.96	68.96
PG	1981	0.10	4.70	14.30	5.80	0.00	4.98			4.98	19.60	25.90	0.00	36.70	20.55					20.55	11.90	11.90
AF	1981	5.30	3.50	18.20	1.20	12.50	8.14			8.14	15.90	11.90	17.50	5.90	12.80					12.80	10.21	10.21
PF	1981	0.00	3.20	0.70	4.90	0.50	1.86			1.86	0.20	0.00	0.00	1.90	0.53					0.53	1.27	1.27
ALL	1981	80.20	66.00	99.70	61.70	89.20	79.36			79.36	113.10	121.80	105.90	93.40	108.55					108.55	92.33	92.33
AG	1982	51.50	25.80	36.60	32.70	20.00	33.32			33.32	42.20	45.50	51.00	22.90	40.40					40.40	36.47	36.47
PG	1982	0.40	6.40	17.90	4.30	0.80	5.96			5.96	11.20	11.60	0.10	31.30	13.55					13.55	9.33	9.33
AF	1982	4.60	4.20	7.50	1.60	17.30	7.04			7.04	9.70	4.60	4.60	4.10	5.75					5.75	6.47	6.47
PF	1982	0.20	4.30	0.70	6.20	1.00	2.48			2.48	0.30	0.00	1.30	3.80	1.35					1.35	1.98	1.98
ALL	1982	56.70	40.70	62.70	44.80	39.10	48.80			48.80	63.40	61.70	57.00	62.10	61.05					61.05	54.24	54.24

Table 3-3. Mean Herbaceous Cover for 1975 through 1995 (continued)

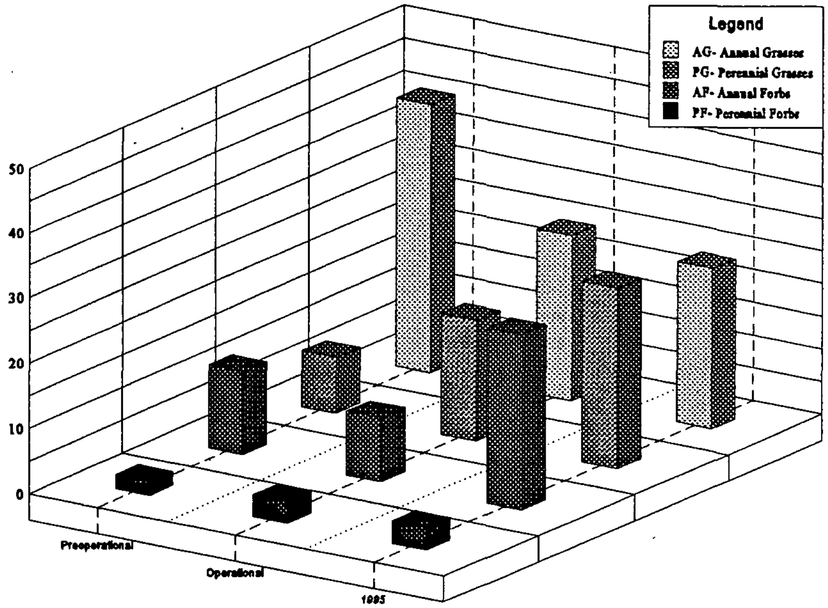
CLASS	YEAR	S01	S02	S03	S04	S05	X S01-5	S06	S07	XS	G01	G02	G03	G04	X G01-4	G05	G06	G07	G08	XG	XSG	G01-4, S01-5
AG	1983	53.80	37.60	33.65	36.75	31.85	38.73			38.73	49.50	39.55	62.75	17.55	42.35					42.34	40.33	40.33
PG	1983	2.15	7.70	14.45	6.40	1.29	6.40			6.40	2.10	15.75	0.00	25.50	10.84					10.84	8.37	8.37
AF	1983	8.20	7.85	12.55	3.45	22.35	10.88			10.88	18.70	8.85	8.65	6.65	10.71					10.71	10.81	10.81
PF	1983	0.70	3.10	1.05	4.40	1.95	2.24			2.24	0.65	0.05	2.10	4.00	1.70					1.70	2.00	2.00
ALL	1983	64.85	56.25	61.70	51.00	57.44	58.25			58.25	70.95	64.20	73.50	53.70	65.59					65.59	61.51	61.51
AG	1984	41.50	32.75	39.35	36.30	36.50	37.28			37.28	60.85	71.30	60.85	9.60	50.65					50.65	43.22	43.22
PG	1984	1.85	8.80	11.55	8.55	0.40	6.23			6.23	1.20	4.45		25.00	10.22					10.22	6.87	7.73
AF	1984	12.35	8.10	11.10	4.00	13.40	9.79			9.79	20.65	9.70	19.45	7.95	14.44					14.44	11.86	11.86
PF	1984	0.30	4.00	0.75	6.55	0.65	2.45			2.45	0.70	0.20	1.10	1.25	0.81					0.81	1.72	1.72
ALL	1984	56.00	53.65	62.75	55.40	50.95	55.75			55.75	83.40	85.65	81.40	43.80	73.56					73.56	63.67	63.67
AG	1985	2.10	2.15	14.60	4.95	27.05	10.17			10.17	8.00	8.10	18.30	7.25	10.41					10.41	10.28	10.28
PG	1985	1.05	4.70	17.85	2.40	1.85	5.57			5.57	9.20	17.95	0.00	13.90	10.26					10.26	7.66	7.66
AF	1985	0.70	1.35	9.40	2.30	4.75	3.70			3.70	18.20	8.15	7.55	3.05	9.24					9.24	6.16	6.16
PF	1985	0.00	1.35	1.15	3.00	0.25	1.15			1.15	0.80	0.10	2.35	0.90	1.04					1.04	1.10	1.10
ALL	1985	3.85	9.55	43.00	12.65	33.90	20.59			20.59	36.20	34.30	28.20	25.10	30.95					30.95	25.19	25.19
AG	1986	17.45	1.95	7.20	11.45	13.05	10.22			10.22	9.40	4.65	13.25	7.35	8.66					8.66	9.53	9.53
PG	1986	2.20	10.75	17.25	9.85	1.30	8.27			8.27	19.85	38.65	0.00	26.00	21.13					21.13	13.98	13.98
AF	1986	25.40	16.65	38.10	10.25	16.70	21.42			21.42	27.65	34.15	25.45	8.70	23.99					23.99	22.56	22.56
PF	1986	1.15	5.35	2.30	9.15	1.25	3.84			3.84	1.80	1.95	0.05	2.55	1.59					1.59	2.84	2.84
ALL	1986	46.20	34.70	64.85	40.70	32.30	43.75			43.75	58.70	79.40	38.75	44.60	55.36					55.36	48.91	48.91
AG	1987	28.90	9.95	7.80	19.05	33.40	19.82			19.82	23.85	9.45	51.65	4.65	22.40					22.40	20.97	20.97
PG	1987	3.60	21.90	42.65	19.55	2.30	18.00			18.00	32.45	58.79	0.05	45.95	34.31					34.31	25.25	25.25
AF	1987	12.56	8.50	10.80	6.55	11.40	9.96			9.96	10.30	11.32	14.00	3.25	9.72					9.72	9.85	9.85
PF	1987	5.00	6.00	2.00	10.40	1.75	5.03			5.03	0.90	1.90	0.15	1.55	1.13					1.13	3.29	3.29
ALL	1987	50.06	46.35	63.25	55.55	48.85	52.81			52.81	67.50	81.46	65.85	55.40	67.55					67.55	59.36	59.36
AG	1988	13.80	5.05	8.10	13.80	10.15	10.18	10.40	12.24	10.51	22.95	10.10	16.75	4.80	13.65	11.95	19.20	15.85	10.40	14.00	12.32	11.72
PG	1988	1.75	8.40	11.95	9.40	3.35	6.97	16.85	17.50	9.89	17.85	21.70	0.05	30.20	17.45	9.50	12.05	10.45	14.30	14.51	12.34	11.63
AF	1988	6.08	5.25	3.60	3.10	4.00	4.41	0.00	0.35	3.20	6.30	16.15	7.55	1.80	7.95	1.20	1.45	12.35	6.12	6.61	5.16	5.98
PF	1988	11.55	15.75	2.10	4.85	3.25	7.50	0.10	0.00	5.37	0.20	2.00	0.00	4.40	1.65	15.25	8.70	2.45	4.34	4.34	4.79	4.90
ALL	1988	33.18	34.45	25.75	31.15	20.75	29.06	27.35	30.09	28.96	47.30	49.95	24.35	41.20	40.70	37.90	41.40	41.10	32.52	39.47	34.60	34.23
AG	1989	21.85	12.50	12.45	10.25	32.90	17.99	15.00	47.65	21.80	22.50	13.20	65.85	3.05	26.15	22.35	35.10	38.05	12.05	26.52	24.05	21.62
PG	1989	8.30	29.55	64.00	13.00	1.25	23.22	30.35	37.50	26.28	60.40	59.60	0.05	49.55	42.40	36.75	16.20	32.05	48.95	37.94	32.54	31.74
AF	1989	12.50	6.95	13.05	6.45	11.10	10.01	0.85	5.15	8.01	12.85	5.90	42.20	2.85	15.95	8.85	13.55	13.05	13.95	14.15	11.48	12.65
PF	1989	4.45	14.50	4.40	8.20	0.55	6.42	0.10	0.00	4.60	3.85	1.10	0.05	3.00	2.00	6.45	10.40	12.90	10.60	6.04	5.23	4.46
ALL	1989	47.10	63.50	93.90	37.90	45.80	57.64	46.30	90.30	60.69	99.60	79.80	108.15	58.45	86.50	74.40	75.25	96.05	85.55	84.66	73.31	70.47
AG	1990	36.80	16.80	17.50	32.40	53.35	31.37	12.90	5.45	25.03	18.60	7.75	61.55	13.65	25.39	23.80	35.45	36.55	19.75	27.01	26.06	28.71
PG	1990	3.30	12.85	18.35	12.70	0.05	9.45	18.40	17.55	11.89	18.70	0.00	0.00	30.00	12.18	11.90	10.70	9.30	12.10	11.59	11.73	10.66
AF	1990	7.95	2.60	8.15	4.55	8.90	6.43	0.10	0.00	4.61	7.75	2.35	15.70	3.35	7.290.3	2.75	6.90	8.95	7.00	6.84	5.80	6.81
PF	1990	0.40	9.55	1.75	3.90	0.05	3.313	0.00	0.00	2.24	0.00	0.05	0.05	1.20	3	3.95	8.55	0.05	0.20	1.76	1.98	1.88
ALL	1990	48.45	41.80	45.30	53.55	62.35	50.29	31.40	23.00	43.69	45.05	10.15	77.30	48.20	45.18	42.40	61.60	53.85	39.05	47.20	45.56	48.02
AG	1991	40.25	15.25	40.05	38.55	48.15	35.85	17.85	5.90	25.14	26.15	20.80	65.55	18.90	32.85	36.95	37.25	48.30	38.25	36.52	33.81	34.52
PG	1991	7.60	32.05	26.35	14.45	2.30	11.14	38.40	60.60	25.96	41.75	50.55	1.35	38.70	29.09	23.55	12.80	0.00	22.85	23.94	26.14	11.12
AF	1991	36.25	15.00	16.75	37.30	21.60	24.29	4.85	7.30	19.86	0.25	4.20	13.35	1.85	4.92	4.75	6.30	35.13	16.65	10.31	14.77	16.26
PF	1991	4.45	6.35	1.95	2.35	0.30	3.08	0.30	0.00	2.24	0.00	0.10	0.60	0.90	0.25	3.35	12.20	0.05	1.70	2.29	2.25	1.88
ALL	1991	88.55	63.65	85.10	89.65	72.35	74.36	61.40	73.80	76.36	61.15	75.65	80.25	60.35	66.11	68.60	68.55	83.48	79.45	72.19	76.97	63.78
AG	1992	30.30	30.20	42.60	55.95	51.60	42.13	23.90	15.20	35.67	48.70	64.25	53.15	34.24	50.09	46.00	41.80	66.15	55.15	51.18	43.95	45.67
PG	1992	3.25	15.65	11.40	5.40	2.39	7.62	31.30	33.80	14.74	25.60	20.00	0.00	32.20	19.45	18.60	10.20	5.95	8.80	15.17	14.97	12.88
AF	1992	9.85	5.55	11.95	16.40	8.95	10.54	4.65	23.05	11 48	13.15	8.15	15.05	7.15	10.87	7.65	10.20	8.80	17.25	10 93	11.19	10 693
PF	1992	9.15	10.70	2.25	4.25	1.05	5.48	0.65	6.00	4.01	0.10	0.25	0.30	0.75	0.35	1.95	12.55	1.35	3 85	2.64	3.28	20
ALL	1992	52.55	62 10	68.20	82.00	63.99	65.77	60.50	72.70	65.90	87.55	92.65	68.50	74.34	80.76	74.20	74.75	82.25	85.05	79.92	73.39	72.44

Table 3-3. Mean Herbaceous Cover for 1975 through 1995 (continued)

CLASS	YEAR	S01	S02	S03	S04	S05	X S01-5	S06	S07	XS	G01	G02	G03	G04	X G01-4	G05	G06	G07	G08	XG	XSG	G01-4, S01-5
AG	1993	27.70	34.65	53.45	58.25	48.20	44.45	23.65	57.95	43.41	46.90	68.65	43.40	29.20	47.04	38.35	28.90	68.85	59.60	47.98	45.85	45.74
PG	1993	7.15	22.14	16.25	12.85	4.00	12.48	46.10	23.15	18.81	48.25	23.35	2.00	46.10	29.93	31.40	15.40	12.25	16.35	24.39	21.78	21.2
AF	1993	12.95	8.70	12.90	14.80	13.25	12.52	2.15	9.85	10.66	13.45	5.95	22.60	10.20	13,05	10.90	16.45	13.45	9.02	12.75	11.77	12.79
PF	1993	13.70	12.70	2.690	8.65	7.40	9.01	0.05	0.05	6.45	1.45	0.00	0.75	2.15	1.09	5.85	8.85	1.55	4.50	3.14	4.68	5.05
ALL	1993	58.10	77.49	85.20	94.55	71.35	77.34	71.95	88.90	78.22	110.00	97.95	66.25	87.55	90.44	86.00	69.60	94.40	89.27	87.63	84.08	83.89
AG	1994	23.30	11.00	28.40	21.20	35.50	23.88	5.35	9.70	19.21	47.50	61.85	27.50	9.05	36.48	6.35	16.70	42.40	51.20	32.88	26.50	30.18
PG	1994	2.65	16.95	5.70	3.75	2.15	6.24	11.20	9.55	7.42	5.50	4.30	0.60	34.30	11.18	9.55	16.65	2.20	7.20	10.04	8.82	8.71
AF	1994	8.10	2.70	7.40	3.30	7.65	5.83	0.15	2.90	4.60	4.10	1.90	18.15	2.50	6.66	2.20	6.65	11.35	2.25	6.14	5.42	6.25
PF	1994	2.25	7.15	3.60	4.50	7.50	5.00	1.30	6.45	4.68	0.15	0.05	11.25	0.60	3.01	5.30	11.10	0.75	2.80	4.00	4.32	4.01
ALL	1994	36.30	37.80	45.10	32.75	52.80	40.95	18.00	28.60	35.91	57.25	68.10	57.50	46.45	57.33	23.40	51.60	56.70	63.45	53.06	45.05	49.14
AG	1995	31.80	9.25	25.8	36.15	46.75	29.95	4.0	1.1	22.12	78.65	70.60	55.50	4.80	52.39	11.10	27.65	53.65	60.20	45.21	34.47	39.92
PG	1995	17.60	98.80	30.0	8.64	2.3	31.47	55.55	12.65	32.22	10.15	18.0	4.00	64.85	24.25	47.45	4.40	16.75	22.90	26.59	27.60	28.26
AF	1995	31 45	6.65	17.75	49.62	14.75	24.04	14.30	102.1	33.81	23.75	27.5	23.35	9.65	21.06	26.25	3.75	30.85	20.65	20.72	26.96	22.72
PF	1995	2 25	7.4	2.4	3.65	8.48	4.84	4.6	6.45	5.03	0.15	0.65	0.45	0.25	0.38	7.15	5.65	0.15	2.80	2.16	3.50	2.86
ALL	1995	83.10	122.1	75.95	98.06	72.28	90.30	78.45	122.30	93.18	112.70	116.75	83.30	79.55	98.08	91.95	41.45	101.40	106.55	91.71	92.39	93.76

Figure 3-3 shows a comparison of the current data with previous data. Growing season (October 94 - April 95) precipitation (21.06 cm) increased 465% from the previous season (3.73 cm). According to Battelle Northwest Laboratories, the months of January through April were recorded as the wettest four months of the year on record. The mean temperature during the growing season was 6.43 °C compared with 6.161 °C for 1994. A comparison of mean cover and precipitation for 1982 through 1995 can be seen in Figure 3-4.

Fig. 3-3. Mean Herbaceous Cover for 1975-1995



3.3.2 Herbaceous Phytomass

The increase (260%) in herbaceous phytomass is in direct correlation to the increase in herbaceous cover. At grassland and shrub stations, the herbaceous phytomass production averaged 107g/m² and 123g/m² respectively. Mean herbaceous phytomass production at grassland and shrub stations is shown graphically in Figure 3-5 and summarized in Table 3-6.

Fig. 3-4. Mean Herbaceous Cover and Total Precipitation

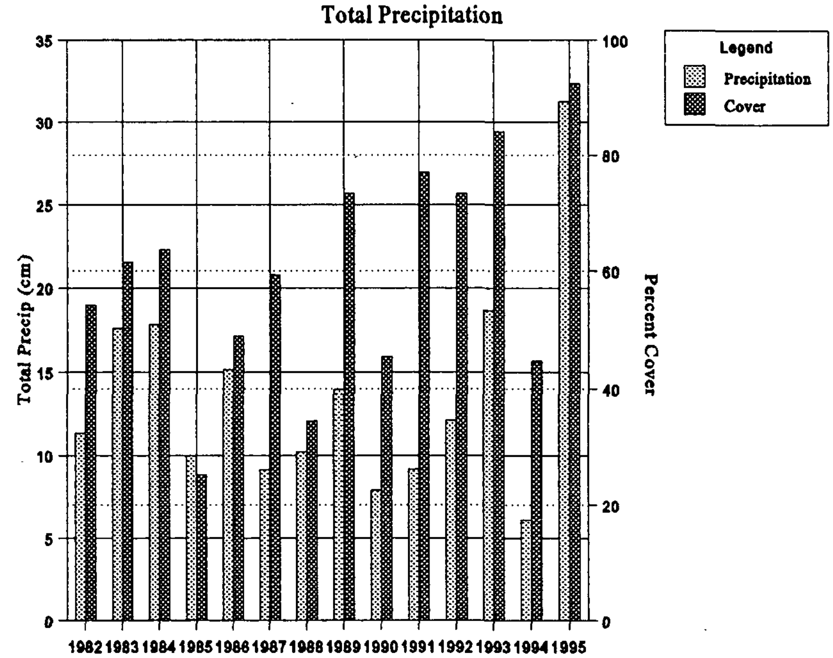


Table 3-5. Herbaceous Phytomass for 1995

DATE	SITE	PLOT	WT.(g)	WT./m²
05/25	GO1	35-3	32.0	319.8
05/25	GO1	2-6	17.5	175.2
05/25	GO1	31-7	16.7	167.1
05/25	GO1	45-7	29.1	291.4
05/25	GO1	29-4	8.9	89.1
		AVG	20.9	208.5
		STD	8.5	85.3

DATE	SITE	PLOT	WT.(g)	WT./m²
05/25	GO2	45-9	29.3	293.3
05/25	GO2	29-4	15.1	151.4
05/25	GO2	2-6	17.2	171.6
05/25	GO2	31-7	12.9	129.1
05/25	GO2	35-3	12.7	127.0
		AVG	17.4	174.5
		STD	6.2	61.6

DATE	SITE	PLOT	WT.(g)	WT./m²
05/18	GO3	31-7	0.4	3.9
05/18	GO3	2-6	1.1	11.4
05/18	GO3	29-4	2.5	24.9
05/18	GO3	45-9	4.7	46.9
05/18	GO3	35-3	8.0	80.2
		AVG	3.3	33.5
		STD	2.8	27.6

DATE	SITE	PLOT	WT(g)	WT./m²
05/15	GO4	29-4	2.6	26.0
05/15	GO4	2-6	8.7	86.6
05/15	GO4	25-3	7.9	78.8
05/15	GO4	31-7	11.1	111.2
05/15	GO4	45-9	2.5	24.9
		AVG	6.6	65.5
		STD	3.4	34.4

DATE	SITE	PLOT	WT.(g)	WT./m²
05/16	GO5	29-4	1.4	13.6
05/16	GO5	45-9	2.4	23.9
05/16	GO5	2-6	7.1	70.9
05/16	GO5	35-6	4.7	47.3
05/16	GO5	31-7	2.2	21.9
		AVG	3.6	35.5
		STD	2.1	20.9

DATE	SITE	PLOT	WT.(g)	WT./m²
05/17	GO6	31-7	7.2	71.5
05/17	GO6	29-4	13.4	134.0
05/17	GO6	35-3	8.6	86.1
05/17	GO6	45-9	3.1	30.6
05/17	GO6	2-6	14.0	139.7
		AVG	9.2	92.4
		STD	4.1	40.7

DATE	SITE	PLOT	TE.(g)	WT./m²
05/18	GO7	35-3	9.3	16.3
05/18	GO7	31-7	5.7	27.9
05/18	GO7	29-4	2.4	50.9
05/18	GO7	45-9	26.0	46.1
05/18	GO7	2-6	10.1	66.4
		AVG	10.7	41.5
		STD	.1	17.6

DATE	SITE	PLOT	WT.(g)	WT./m²
05/25	GO8	45-9	22.4	224.4
05/25	GO8	29-4	10.2	102.2
05/25	GO8	35-3	16.8	168.2
05/25	GO8	2-6	8.6	85.9
05/25	GO8	31-7	11.6	115.6
		AVG	13.9	139.3
		STD	5.1	50.7

DATE	SITE	PLOT	WT.(g)	WT./m²
05/25	SO1	2-6	12.3	123.0
05/25	SO1	35-3	5.2	51.9
05/25	SO1	45-9	2.6	26.0
05/25	SO1	31-7	5.0	49.7
05/25	SO1	29-4	13.2	131.9
		AVG	7.7	76.5
		STD	4.3	42.7

DATE	SITE	PLOT	WT.(g)	WT./m²
05/26	SO2	2-6	6.5	65.2
05/26	SO2	29-4	6.4	63.8
05/26	SO2	31-7	14.9	149.3
05/26	SO2	35-3	6.8	68.4
05/26	SO2	45-9	7.7	76.5
		AVG	8.5	84.6
		STD	3.3	32.6

DATE	SITE	PLOT	WT.(g)	WT./m²
05/12	SO3	2-6	4.8	47.5
05/12	SO3	31-3	4.7	47.0
05/12	SO3	47-4	2.4	24.4
05/12	SO3	41-5	2.0	20.3
05/12	SO3	19-7	13.0	130.0
		AVG	5.4	53.8
		STD	4.0	39.7

DATE	SITE	PLOT	WT.(g)	WT./m²
05/26	SO4	35-3	59.9	599.4
05/26	SO4	31-7	15.3	153.1
05/26	SO4	29-2	22.4	224.0
05/26	SO5	45-9	13.2	132.1
05/26	SO4	2-6	11.2	111.8
		AVG	24.4	244.1
		STD	18.2	181.6

DATE	SITE	PLOT	WT.(g)	WT./m²
05/16	SO5	2-6	8.7	87.1
05/16	SO5	29-4	6.1	61.3
05/16	SO5	35-3	2.7	27.0
05/16	SO5	31-7	31.3	312.6
05/16	SO5	45-9	8.2	81.5
		AVG	11.4	113.9
		STD	10.4	101.6

DATE	SITE	PLOT	WT.(g)	WT./m²
05/17	SO6	31-7	7.7	77.0
05/17	SO6	29-4	6.9	69.2
05/17	SO6	35-3	5.6	56.4
05/17	SO6	45-9	6.3	63.2
05/17	SO6	2-6	10.2	101.7
		AVG	7.4	73.5
		STD	1.6	15.6

DATE	SITE	PLOT	WT.(g)	WT./m²
05/08	SO7	45-9	18.0	180.1
05/08	SO7	35-3	2.5	25.2
05/08	SO7	2-6	24.5	245.1
05/08	SO7	29-4	29.4	294.3
05/08	SO7	31-7	32.8	327.9
		AVG	21.5	214.5
		STD	10.7	106.9

Phytomass Summary

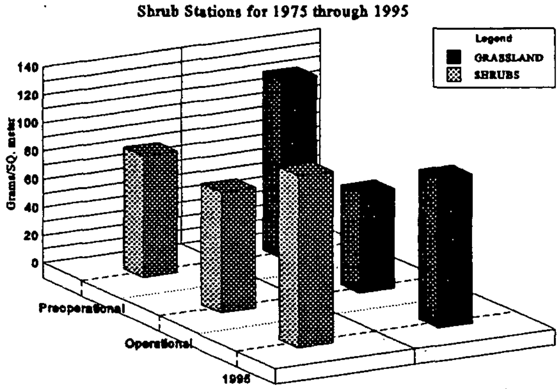
MEAN GO1-GO8	107.0 Grams/sq. meter
MEAN SO1-SO7	123.0 Grams/sq. meter

Table 3-6 presents mean phytomass values for each station in each year since 1975.

Table 3-6. Comparison of Herbaceous Phytomass (g/m²) for 1975 through 1995

YEAR	GO1	GO2	GO3	GO4	GO5	GO6	GO7	GO8	SO1	SO2	SO3	SO4	SO5	SO6	SO7
1975	359	302	–	–	–	–	–	–	126	144	88	–	–	–	–
1976	108	258	–	–	–	–	–	–	137	98	177	–	–	–	–
1977	21	11	–	–	–	–	–	–	4	7	7	–	–	–	–
1978	166	162	–	–	–	–	–	–	173	128	115	–	–	–	–
1979	64	37	–	–	–	–	–	–	21	28	16	–	–	–	–
1980	160	68	53	79	–	–	–	–	36	63	43	78	71	–	–
1981	200	255	261	159	–	–	–	–	180	115	31	52	81	–	–
1982	90	60	62	113	–	–	–	–	98	24	22	39	184	–	–
1983	77	137	64	82	–	–	–	–	171	232	54	68	136	–	–
1984	94	116	133	67	–	–	–	–	104	57	95	93	43	–	–
1985	70	27	12	37	–	–	–	–	5	1	27	11	61	–	–
1986	50	61	32	35	–	–	–	–	35	112	25	176	42	–	–
1987	83	77	134	90	–	–	–	–	62	144	48	108	145	–	–
1988	34	14	16	61	–	–	–	–	59	73	15	24	19	–	–
1989	173.3	65.7	105.1	49.5	43.2	61	113.1	112.3	53.9	72.8	67	39.8	103.7	72.7	149.5
1990	13.6	4.1	64	73.2	36.8	39.8	29.1	10	32.8	78.3	28.2	30.9	43.4	34	6.1
1991	87.7	97.2	161.6	67.6	171.8	101.4	168.4	137.3	225.1	58.2	87.6	185.2	111.3	225.1	226
1992	142.4	109.4	82.7	60	54.4	49.4	101.4	74.3	49.2	147.5	90.7	80.3	110.3	101.3	187.3
1993	146	156.6	70.3	109.8	75.3	162	150.7	100.3	80.2	84.1	91.7	261.4	173.1	93.5	330.3
1994	45.7	48.8	49.2	15.6	13.2	60.1	41.5	44.1	27.3	13.4	20.5	19.8	60.8	7	19.1
1995	208.5	174.5	33.5	65.5	35.5	92.4	106.9	139.3	76.5	84.6	53.8	244.1	113.9	73.5	214.5

Fig. 3-5. Phytomass at Grassland and Shrub Stations for 1975 through 1995



3.3.3 Soil Chemistry

In comparison to previous years data, their has been no significant change in soil chemistry for the fifteen sampling stations. The following Table (3-8) is a summation of soil chemistry for 1995.

Table 3-8 Summary of Soil Chemistry for 1995

	pH	Conductivity μS/cm	Sulfate μg/gm	Chloride μg/gm	Copper μg/gm	Zinc μg/gm	Sodium μg/gm	Bicarbonate (meq/HCO_3/gm)
GO1	6.91	29.9	1.01	0.205	8.9	46.7	0.047	0.0011
GO2	7.21	36.3	0.94	0.330	10.9	53.7	0.053	0.0010
GO3	7.13	71.8	6.43	0.606	9.0	46.4	0.046	0.0018
GO4	6.84	15.4	1.34	0.160	8.1	46.4	0.053	0.0005
GO5	6.94	19.2	0.86	0.215	7.8	38.3	0.043	0.0007
GO6	6.85	16.6	0.63	0.163	8.1	43.1	0.054	0.0005
GO7	7.08	61.1	0.83	0.205	12.7	47.6	0.056	0.0014
GO8	7.11	28.1	0.85	0.247	12.8	42.8	0.047	0.0009
SO1	7.14	33.7	1.15	0.277	9.9	33.5	0.049	0.0010
SO2	7.62	19.1	0.33	0.196	3.1	15.2	0.032	0.0010
SO3	6.22	131	2.01	0.528	10.0	53.9	0.057	0.0006
SO4	7.166	18.6	0.32	0.209	9.0	43.4	0.051	0.0008
SO5	7.03	23.9	0.37	0.143	7.8	42.6	0.051	0.0007
SO6	7.91	43.7	0.39	0.205	8.7	41.3	0.042	0.0030
SO7	8.50	212	5.85	2.51	13.1	59.2	0.056	0.0054

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4.0 REFERENCES

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ENERGY NORTHWEST COLUMBIA GENERATING STATION EFFLUENT MIXING STUDY

prepared by

R.E. Welch, Environmental Services

in accordance with

NPDES Permit No. WA-002515-1
Special Condition S8

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Energy Northwest
P.O. Box 968
Richland, WA 99352-0968

ENERGY NORTHWEST COLUMBIA GENERATING STATION EFFLUENT MIXING STUDY

INTRODUCTION

This report summarizes the results of an effluent mixing study for the Energy Northwest Columbia Generating Station's circulating cooling water discharge to the Columbia River.

BACKGROUND

The Columbia Generating Station (CGS) National Pollutant Discharge Elimination System (NPDES) Waste Discharge Permit No. WA-002515-1 establishes effluent limitations for discharges to the Columbia River (Outfall 001). These limitations are presented in Special Condition S1.B of the current permit (effective July 1, 2006).[1] Limitations for copper are based on dilution factors obtained from modeling performed on the discharge in 1995 during the permit application and review process for the 1996 to 2001 permit cycle. The results of a water effect ratio (WER) study performed in 1997 - 1998 was used to establish the copper limits that have been in effect for the last two permit cycles, including the present.[2]

The fact sheet associated with the current permit identified an area of concern to the Energy Facility Site Evaluation Council (Council) related to the methodologies used in developing the dilution factors that established the effluent limits in use today.[3] These methodologies are now considered outdated and Section S.8 of the current permit required an effluent mixing study to determine new dilution factors using newer methodologies.

OBJECTIVES

The primary objective of this study was to establish new dilution factors using updated modeling methodologies. The revised dilution factors were used to calculate new effluent limits for copper and to assess other components of the effluent for compliance with the water quality standards. In addition, the new dilution factors determined in this study will be used to re-characterize the discharge for whole effluent toxicity.

APPROACH

The primary focus of this study was to implement state of the art modeling to predict mixing (dilution) of the effluent within the authorized regulatory mixing zone (RMZ) under critical ambient flow conditions. The "Critical Condition" is defined in WAC 173-201A-020 as being equal to the 7Q10 flow event.[4] The fact sheet specifies the critical condition for this outfall to be applicable to the warm weather months of July through September.

The RMZ for this outfall has defined boundaries for chronic and acute compliance and meets the requirements for mixing zones established in WAC 173-201A. The chronic mixing zone extends from 100 feet upstream, to 306 feet downstream, of the discharge. In addition, the chronic mixing zone extends 175 feet to either side of the center-point of the discharge port. The acute mixing zone, also referred to as the zone of initial dilution (ZID), is 10 percent of the distance of the chronic zone and thus extends 31 feet downstream of the outfall.

The study was comprised of two major components including application of a steady-state mixing zone model to determine new dilution factors (Energy Northwest Dilution Modeling Analysis, Attachment 1) and performance of an in-situ tracer study for model validation (Field Monitoring Dilution Study, Appendix A of Attachment 1).

The approach to this study was outlined in the Effluent Mixing Study – Plan of Study.[5] The modeling cases (scenarios) evaluated in this study are summarized below and were selected to address the objectives presented in the plan of study.

Case 1: 7Q10 low summer ambient flow, highest monthly average effluent flow
Case 2: 7Q10 low summer ambient flow, highest daily maximum effluent flow
Case 3: WAC 173-563 minimum ambient flow, highest monthly average effluent flow
Case 4: WAC 173-563 minimum ambient flow, highest daily maximum effluent flow
Case 5: WAC 173-563 minimum ambient flow, permit maximum daily allowable effluent flow
Case 6: 7Q10 low ambient flow winter condition, highest monthly average effluent flow
Case 7: 7Q10 low ambient flow winter condition, highest daily maximum effluent flow
Case 8: 7Q10 high ambient flow, highest monthly average effluent flow
Case 9: 7Q10 high ambient flow, highest daily maximum effluent flow

MODELING PARAMETERS

The location and configuration of the discharge structure, geometry of the river in the vicinity of the discharge, and effluent and receiving water characteristics including flowrate, velocity, and temperature are of primary importance in modeling applications related to mixing zone assessments. The input parameters used in this study are described as follows:

Discharge Structure

An evaluation to determine the current status of the discharge structure was a required pre-requisite for using a mixing model and was performed in October, 2006.[6] The results of the integrity inspection determined that the discharge structure was in its original configuration and functioning as designed.

The CGS discharge is a single port structure located on the river bottom at approximately Columbia River mile 351.75. Global Positioning System (GPS) coordinates place the discharge at 46° 28' 274" N and 119° 15' 812" W. The outfall is aligned perpendicular to the river flow, is 8 inches in height, 32 inches wide and extends upward from the river bed at a 15° angle. At minimum regulated river flow (36,000 cfs) the outfall opening is approximately 175 feet from the west bank. Modeling/dye studies performed in the late 1970's and early 1980's estimated the water depth of the outfall at minimum regulated flow to be approximately 4 feet.[7,8,9,10]

Bathymetry work performed in association with the outfall evaluation study (Attachment 2) and depth measurements obtained during the in-situ tracer study, both using updated technologies, determined river depth at the discharge structure to be 6.9 feet (2.1 meters) at minimum regulated flow and approximately 22 feet at 7Q10 high flow.

Effluent Parameters

Discharge Flowrate - The highest daily maximum flow and the highest monthly average flow for the past three years during the critical condition period was used for critical condition scenarios at the acute and chronic boundaries, respectively. The effluent flow values used in the modeling was obtained from the CGS NPDES Discharge Monitoring Report (DMR) analysis for the period 2005 through 2007. Flow values of 5.9 MGD (4097 gpm) and 4.3 MGD (2986 gpm) were used for acute and chronic dilution calculations, respectively. A flow value of 9.4 MGD (6528 gpm), which is the maximum daily discharge flow allowable by the permit, was used to assess the worst case scenario. Average annual design flow for the three year period, per DMR analysis, was 2.8 MGD (1944 gpm). Average annual design flow is used for human health-based assessments.

Discharge Velocity - Velocity was calculated by the modeling program via input data related to flowrate and the cross-sectional area of the discharge structure.

Discharge Temperature -Circulating cooling water (discharge) temperature data from May 1, 2006 through November 30, 2007 was used to calculate the 95th percentile value of 29.6 ° C for this parameter. Temperature of the discharge is monitored on a continuous basis at the circulating water pump-house, immediately after the effluent is released to the buried discharge pipe for the approximate three mile journey to the river. The temperature data from the evaluated period did not exhibit seasonal variation and thus no yearly partitioning was required.

Receiving Water Parameters

River (channel) geometry, including depth, distance from shore, and cross-sectional characteristics, and ambient velocity data were obtained during performance of the in-situ tracer study. Conditions observed during the study included a river flow of 40.9 kcfs, depth of the outfall of 2.25 m, and a velocity of 1.47 m/s. As described in the modeling report (Attachment 1), the aforementioned conditions were used to adjust ambient velocity and depth at discharge for all of the modeling scenarios, and are based on the Manning equation for open channel flow. A detailed description of river bathymetry and velocity in the area of the discharge using Acoustic Doppler Current Profiler (ADCP) and Global Positioning System (GPS) technologies is included in the tracer study report (appendix B, Attachment 1).

Ambient Flowrate –The United States Geological Survey (USGS) gaging station located below Priest Rapids Dam on the Columbia River (USGS gage No. 12472800) was used as the primary source to calculate the 7Q10 flow. Both 7Q10 low and high flow conditions were determined. USGS staff at the Washington Water Science Center located in Tacoma, Washington performed the calculations. A monitoring period of 1975 to 2006 was selected to assess flow characteristics of the Columbia River following completion of main stem dam construction. The 7Q10 low flow and high flow conditions were calculated to be 52.7 kcfs and 261 kcfs, respectively (Attachment 3).

Ambient Temperature – The maximum temperature of the receiving water recorded during critical condition periods, based on recently available data, was used to evaluate the discharge for compliance with the water quality standards. Minimum receiving water temperature was used to evaluate the discharge during winter periods. The Grant County PUD Fixed Site Water Quality Monitoring Program was used as the data source for this parameter. Temperature recordings from the Priest Rapids Dam forebay and tailrace produced a maximum temperature nearing 22°C in August of 2006 and a minimum temperature of 1.5°C in early February of 2008.

MODEL SELECTION/MODELING RESULTS

The CORMIX Hydrodynamic Mixing Zone Model, specifically CORMIX1 – Version 5.0, was selected for use in this study based on the following reasons: is applicable to submerged single port discharges; produces centerline plume concentration values; is supported by the United States Environmental Protection Agency (USEPA); and is included as one of the recommended models in the Ecology guidance.[11]

Results of dilution modeling performed on the case studies outlined previously are presented in Table 1 of the Dilution Modeling Analysis report. The prediction files for each of the cases appear in Appendix B of the same report.

Case 1 and 2 represent the critical condition: 7Q10 low ambient summer flow of 52.7 kcfs, maximum ambient temperature, 95th percentile discharge temperature, highest daily maximum discharge flow (acute), and highest monthly average discharge flow (chronic). Per Ecology guidance [4], dilution results for cases 1 and 2 were evaluated for use in assessing the discharge during critical condition periods for compliance with the water quality standards and to develop new discharge limits. Dilution factors derived for Case 2 are more conservative and thus were selected for use in performing reasonable potential calculations and in determining effluent limits. Dilution factors of 9 and 93 were applied to the acute and chronic boundaries, respectively.

Case 3 and 4 represent the minimum instantaneous flow allowed from Priest Rapids Dam as designated in WAC 173-563 [12] of 36.0 kcfs and the ambient and discharge conditions identified in case studies 1 and 2. Case 5 represents the worst case and is characterized by the critical ambient conditions but a discharge flow of 9.4 MGD (6528 gpm), which is the maximum daily permit limit. It should be noted that discharge flows rarely exceed 4000 gpm and typically the higher discharges are associated with special plant operation/maintenance activities. Case 6 and 7 represent the thermal effects of the discharge during minimum winter ambient temperatures. Case 8 and 9 indicate dilutions for the two discharge flow rates at the 7Q10 high flow condition of 261 kcfs.

RESULTS/DISCUSSION

Ambient Water Quality – Field studies were performed to establish an adequate database for modeling. Sampling was conducted immediately upstream of the discharge structure and mixing zone. The monitoring period extended from December, 2006 to March, 2008 and included increased sampling frequency during the low ambient flows experienced in September and October. The 90th percentile value and the geometric mean were used to establish background concentrations of constituents in the receiving water for use in aquatic life-based and human health-based assessments. Concentrations are low and near the detection limit for a majority of the parameters. Sampling results for the Columbia River are presented in Table 1.0.

Effluent Pollutants – Effluent data used to assess the discharge for compliance with water quality standards is presented in Table 2.0. This data was used in conjunction with the ambient "background" data to calculate the maximum expected effluent concentration and reasonable potential determinations for certain parameters. Sampling of the effluent was performed from July, 2006 to June, 2008. The coefficient of variation (CV) and the 95th percentile effluent value are included in the table and were used for aquatic life-based analyses. The 50th percentile concentration was also calculated and was used in determining concentrations in the effluent for human health-based analyses.[13] In addition, volatile organic (VOC) and semi-volatile organic (SVOC) analyses performed on effluent samples collected in December, 2006 and 2007 are presented in Attachment 4.0.

Results of effluent monitoring indicate that a majority of the constituents in the discharge have concentrations below the water quality standards applicable to this outfall. Several parameters are in compliance in 100 percent discharge water. All of the listed parameters are in compliance with the human health based criteria when applying the 50^{th} percentile and chronic dilution factor (93). Human health based criteria is applicable at the edge of the chronic mixing zone.

Zinc, chromium, and total residual halogen are in compliance with the Best Available Technology (BAT) effluent limitations.[(14)] A majority of the effluent is a non-detect for the priority pollutants listed in Appendix A of the BAT guidance. Arsenic, lead, nickel, selenium, and Bis(2-ethylhexyl)phthalate were found in detectable amounts in the discharge. Bis(2-ethylhexyl)phthalate is discussed later in this section. Arsenic, lead, nickel, and selenium were also found in detectable amounts during previous monitoring conducted for this discharge and are compiled in Table 2 (Outfall 001 Monitoring Results) of the fact sheet for the current permit. The current levels are below those identified for these metals in the fact sheet. The fact sheet does not list these parameters as being of concern nor was any reasonable potential determinations performed previously.

VOC and SVOC results are non-detect for all compounds tested with the exception of Bis(2-ethylhexyl)phthalate, which recorded a concentration of 0.8 μg/L during the 2006 collection period. This is just slightly above the practical quantitation limit (PQL) of 0.5 μg/L but is below the human health carcinogen criteria. The December, 2007 sampling period resulted in a non-detect for this compound.

The concentration of chromium in the effluent remained consistently low throughout the monitoring period, producing 95^{th} percentile and average values of 3.1μg/L and 1.7 μg/L, respectively. The permit specifically required differentiation of chromium into trivalent and hexavalent species. The analytical method used for determining hexavalent chromium (SM 3500-Cr) has a detection limit (as PQL) above the total chromium value typically found in the effluent. The method also experienced interference problems related to the composition of the effluent that resulted in several sampling events producing hexavalent concentrations considerably higher than the total chromium value. As a result, two sets of discharge samples were submitted to an outside laboratory specializing in chromium speciation analysis using IC-ICP-DRC-MS technology. Since the chemical composition of the effluent remains fairly constant during normal plant operation evolutions, two sampling events to determine chromium speciation information was deemed adequate. Results indicate that trivalent and hexavalent concentrations are well below water quality standards. Even the maximum total chromium concentration in the effluent, when applied to the trivalent and hexavalent criteria levels, produced results well below the water quality standards.

Total phosphorus concentrations in the effluent produced 95^{th} percentile values of approximately 2.9 mg/L. There is no surface water quality standard for this parameter as pertaining to stream discharges. The concentration at the edge of the chronic mixing zone is estimated to be approximately 0.03 mg/L.

Turbidity was measured directly in the mixing zone during low ambient flow conditions (approximately 40.0 kcfs) on October 9, 2007. Upstream, middle of the RMZ, and edge of the RMZ turbidity measurements were 0.537 NTU, 0.380 NTU, and 0.386 NTU, respectively. Discharge flow at the time of the sampling event was approximately 1400 gpm. These results are in agreement with previous studies performed from 1984 through 1996[15] that indicated no discernable effects of the discharge on the receiving water with respect to turbidity.

The effect of the discharge on the temperature of the receiving water in the mixing zone was directly assessed in the in-situ tracer study. Mixing characteristics and temperature data in the mixing zone was observed by aerial remote infrared imagery sensing in conjunction with ADCP measurements. Conditions observed at the site during the study include a river flow of 40.9 kcfs, river temperature of 19.2 °C, average discharge flow rate of 3807 gpm, and a discharge temperature of 26.0 °C. Both the infrared detector and the ADCP unit display temperature sensitivity to 0.1 °C. The discharge plume could not be detected by either the infrared sensor or the ADCP unit which indicated a dilution of greater than 68 at surface contact. Cormix modeling predicted a plume surface temperature increase of $\Delta T = 0.108$ °C at plume surface contact which occurs at 86 meters downstream. Additional modeling performed using the regulated minimum river flow of 36 kcfs predicted a temperature increase of $\Delta T = 0.11$ °C at the edge of the RMZ. This is well below the 0.3 °C increase allowed by the water quality standards during warm ambient (critical) condition periods. Using the maximum effluent temperature listed in the fact Sheet of 31.56 °C and the "worst case" conditions identified in case study 5 resulted in a predicted temperature increase of $\Delta T = 0.27$ °C at the edge of the RMZ, which is below the water quality standard. Specific details of the study are presented in the Field Monitoring Dilution Study report.

Copper and zinc concentrations in the effluent warranted reasonable potential determination calculations for these parameters to assess compliance with the surface water quality standards. The single result for selenium, after application of the acute and chronic dilution factors, was removed from the reasonable potential determination process. Other parameters applicable to the surface water quality standards recorded concentrations below the reasonable concern level.

Reasonable potential determination calculations for the aforementioned parameters were performed per Ecology guidance[16] and are presented in Table 3.0. The process includes calculation of background water quality using 90th percentile data, calculation of ambient water quality criteria for acute and chronic values, determination of the maximum expected concentration in the effluent, and calculation to predict the concentration at the edge of the applicable (acute or chronic) mixing zone. Results for zinc indicate that the concentration at the edge of the acute and chronic mixing zones is substantially below the water quality criteria. For copper, the concentration at the edge of the acute and chronic mixing zones is also below the criteria, with the acute prediction being just slightly under the water quality limit. This represents the first time since effluent limits have been imposed that copper has not been classified into the reasonable potential category. It's highly likely that the lower dilution factors representing extreme low flow conditions, such as described in case studies 3, 4, and 5, would result in copper concentrations sliding back above the criteria.

MODEL VALIDATION

The CORMIX1 model was validated by performance of the in-situ tracer study (Field Monitoring Dilution Study). MixZon, Inc. performed an assessment of the mixing zone using a remote sensing water quality monitoring platform. The platform utilizes forward looking infrared (FLIR) technology and measures outfall performance focusing on temperature as a dilution tracer. This methodology was selected based on the following: directly assess temperature in the mixing zone, which is a requirement of the permit; provides real time, geo-referenced mixing zone data; is USEPA supported (USEPA SBIR Phase II); can be used to evaluate other water quality parameters within the mixing zone; and can be combined with the CORMIX modeling program to validate modeling predictions.

Results of the in-situ tracer study, including field observations and associated modeling, are in good agreement with the results of the modeling performed for the various case studies. Field monitoring results indicated a dilution of greater than 68 at the edge of the RMZ while modeling predicted a dilution of approximately 66 for an ambient flow of 40.9 kcfs. This result lines up well with the results for the case studies with ambient flows bracketing the field study conditions. 7Q10 low flow (52.7 kcfs) modeling at effluent discharge rates and conditions similar to the effluent flows observed in the field study (Case 2, acute) predicted a dilution at the RMZ of 93. The predicted dilution for an ambient flow of 36 kcfs and conditions similar to those observed in the field study (Case 4, acute) was 58. Modeling used to produce the dilution factors utilized in the development of the effluent limits proposed for copper in this study appears to be appropriate for this task.

EFFLUENT LIMIT CALCULATIONS

Final effluent limits are established using a wasteload allocation (WLA) process that includes acute and chronic dilution factors from critical condition modeling, water quality criteria, receiving water chemical characteristics, and effluent chemical characteristics.

Effluent limits for copper were calculated per ecology guidance [16,17] using the input values utilized in the reasonable potential determination calculation. The acute long term average (LTA_a) value is the most limiting and was therefore used to develop the maximum daily effluent limit and the monthly average effluent limit. The proposed effluent limits for copper are 89 μg/L maximum daily and 67 μg/L average monthly.

WATER EFFECT RATIO STUDY

The use of a water effect ratio (WER) study to modify water quality-based limits for copper was not utilized in this study to adjust the proposed effluent limits for copper. The current limits for copper in effect today were modified based on results of a WER study performed in 1997 and 1998 using EPA guidance[18] that is still applicable today. Ratios ranged from 1.3 to 3.3 for combined Columbia River/effluent samples and 1.9 to 7.1 for 100 percent Columbia River water. Ratios displayed seasonal variation, being lowest in the winter and highest in the summer/fall period. The critical ambient condition for this outfall occurs during periods demonstrated in the past to have higher WER's. The results of the WER study basically showed that the Columbia River was capable of complexing or binding copper in excess of ambient total concentrations.

CONCLUSION

The previous discussion concerning WER's lends credence to the use of the 7Q10 low flow condition in developing the proposed effluent limits for copper. Although ambient flows occasionally fall below the 7Q10 low value, these excursions generally occur during periods having higher ambient metal complexing capability. Applying limits based on extreme low flow conditions coupled with the exclusion of complexing factors (WER) would be unnecessarily overly conservative. Use of the 7Q10 low flow condition in the absence of a WER is also a conservative approach which will continue to be protective of the aquatic environment in the Columbia River.

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2. Supply System Nuclear Plant No. 2, Alternative Copper Effluent Limit Demonstration, February 3, 1999

3. Fact Sheet for NPDES Permit No. WA-002515-1, issued by the Energy Facility Site Evaluation Council (EFSEC), 2006

4. Water Quality Standards for Surface Waters of the State of Washington, WAC 173-201A

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6. *Columbia Generating Station, NPDES Outfall Evaluation Report,* Energy Northwest, June 2007

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11. *Guidance for Conducting Mixing Zone Analyses,* Washington State Department of Ecology, Permit Writers Manual (Appendix 6.1), Revised July 2002

12. Instream Resources Protection Program for the Main Stem Columbia River in Washington State, WAC 173-563

13. Environmental Protection Agency, Water Quality Standards; Establishment of Numeric Criteria for Priority Toxic Pollutants, 40 CFR Part 131 November 9, 1999

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15. *Operational Ecological Monitoring Program for Nuclear Plant 2 1985 Annual Reports for 1984 through 1996,* Washington Public Power Supply System

16. *Permit Writers Manual,* Water Quality Program, Washington State Department of Ecology, July, 2006

17. *Applying Metals Criteria to Water Quality-Based Discharge Limits,* Washington State Department of Ecology, September, 1996

18. *Interim Guidance on Determination and Use of Water-Effect Ratios for Metals,* EPA/823B/94/001, U.S. EPA, 1994

Table 1 Columbia River Ambient Data

Columbia River																				
Date	COD (mg/L)	TOC (mg/L)	TSS (mg/L)	Ammonia (mg/L)	Br (mg/L)	Cond (uS/cm)	pH	Turb. (NTU)	MZ Turb.Upstr (NTU)	MZ Turb.Mid. (NTU)	MZ Turb.RMZ (NTU)	Alk (mg/L)	F (mg/L)	Cl (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	T-P (mg/L)	SO4 (mg/L)	Al (mg/L)	Ba (mg/L)
12/20/2006	<10	1.7	<5	<0.03	<0.06	130	8.00	0.603					0.07	1.2	0.15	<0.03	<0.1	10	0.023	0.02
1/3/2007			2.3	<0.03		130	7.94	0.494				66	0.06	1.3	0.16	<0.03	<0.1	9.8		
2/5/2007			<2.0	<0.03		130	7.85	0.549				68	0.068	1.3	0.17	<0.03	<0.1	11		
3/5/2007			<2.0	<0.03		130	7.96	0.48				70	0.069	1.2	0.14	<0.03	<0.1	11		
4/2/2007			2.5	<0.03		130	7.96	1.3				68	0.07	1.3	0.18	<0.03	<0.1	11		
5/3/2007			2.8	0.037		130	8.18	1.3				66	0.07	1.3	0.091	<0.03	<0.1	8.9		
6/7/2007			3.3	0.095		130	8.11	1.28				55	0.065	0.89	0.08	<0.03	<0.1	7.3		
7/2/2007			<2.0	0.034		100	8.12	1.22				58	0.062	1	0.059	<0.03	<0.1	8.6		
8/1/2007			4	<0.03		100	8.00	2.56				61	0.059	0.97	0.049	<0.03	<0.1	9.1		
9/5/2007			<2.0	<0.03			7.91	0.694				56	0.061	0.89	0.1	<0.03	<0.1	9.9		
9/11/2007			<2.0			140	7.82	0.521				60	0.073	0.96	0.063	<0.03	<0.1	10		
9/17/2007			<2.0	0.066		100	7.87	1.12				61	0.061	1	0.1	<0.03	<0.1	10		
9/26/2007			<2.0	<0.03		130	7.73	0.415				63	0.063	0.98	0.081	<0.03	<0.1	10		
10/1/2007			<2.0	0.036		110	8.07	0.39				62	0.06	1	0.1	<0.03	<0.1	11		
10/9/2007			2.2	0.032		140	7.87	0.527	0.537	0.380	0.386	62	0.062	1	0.11	<0.03	<0.1	11		
10/18/2007			<2.0	0.036		130	7.67	0.534				57	0.06	0.87	0.089	<0.03	<0.1	9.9		
10/25/2007			<2.0	0.033		130	7.92	0.47				62	0.059	0.9	0.094	<0.03	<0.1	10		
10/31/2007			<2.0	<0.03		110	7.87	0.323				55	0.06	0.9	0.098	<0.03	<0.1	10		
11/14/2007			2.0	<0.03		130	7.86	0.928				62	0.065	0.81	0.099	<0.03	<0.1	9.5		
12/3/2007			<2.0	<0.03		130	7.87	0.543				65	0.065	0.9	0.13	<0.03	<0.1	9.5		
1/2/2008			<2.0	<0.03		140	7.76	0.497				62	0.065	1	0.15	<0.03	<0.1	10		
2/6/2008			<2.0	<0.03		130	7.91	1.16				65	0.052	1.1	0.14	<0.03	<0.1	10		
3/5/2008			<2.0	<0.03		150	8.14	0.598				68	0.055	1.2	0.15	<0.03	<0.1	10		
5th %tile																				
10th %tile																				
90th %tile						140	8.1	1.296				68	0.070	1.3	0.158			11.0		
geo mean						126	7.9	0.698				62	0.063	1.0	0.104			9.9		
max						150	8.2	2.560				70	0.073	1.3	0.180			11.0		
entries in red indicate 1/2 the PQL																				

Table 1 Columbia River Ambient Data

Col River																			
	Fe	Mg	Mn	Ca	Hard(Ca/Mg)	Sn	Sb	As	Be	Cd	Cr	Cu	Pb	Hg	Ni	Se	Ag	Tl	Zn
Date	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
12/20/2006	0.14	5.5	0.0029	20		<0.001	<0.0006	<0.0005	<0.002	0.0002	0.0001	0.0001	0.0001	<0.0002	<0.0002	<0.0006	<0.0002	<0.0002	0.0001
1/3/2007	0.12	5.4	0.0023	25	85						0.0006	0.0003	0.0001						0.0009
2/5/2007	0.086	5	0.0023	23	78						0.0003	0.0001	0.0001						<0.0002
3/5/2007	<0.0002	4.9	0.0012	24	80						0.0001	0.0001	0.0001						0.0002
4/2/2007	0.14	4.8	0.0050	20	70						0.0002	0.0001	0.0001						0.0023
5/3/2007	0.025	4.7	0.0049	18	64						0.0002	0.0005	0.0001						0.0042
6/7/2007	0.18	4	0.0094	15	54						0.0001	0.0005	0.0001						0.0023
7/2/2007	0.11	4.6	0.0056	18	64						0.0006	0.0003	0.0001						0.0007
8/1/2007	0.11	4.2	0.0043	19	65						0.0005	0.0001	0.0001						0.0004
9/5/2007	0.078	4.7	0.0030	18	64						0.0004	0.0010	0.0001						0.0013
9/11/2007	0.077	5	0.0035	18	66						0.0001	0.0006	0.0001						
9/17/2007	0.074	4.6	0.0037	17	61						0.0004	0.0009	0.0001						0.0015
9/26/2007	0.098	4.9	0.004	18	65						0.0001	0.0001	0.0001						0.0003
10/1/2007	0.086	5.3	0.0025	18	67						0.0001	0.0001	0.0001						0.0001
10/9/2007	0.11	4.2	0.0029	18	62						0.0015	0.0006	0.0001						0.0018
10/18/2007	0.021	4.6	0.0031	18	64						0.0056	0.0009	0.0008						0.0022
10/25/2007	0.094	4.1	0.0020	17	59						0.0001	0.0005	0.0001						0.0014
10/31/2007	0.022	4.6	0.0026	17	61						0.0050	0.0009	0.0014						0.0015
11/14/2007	0.11	4.5	0.0031	17	61						0.0010	0.0009	0.0001						0.0009
12/3/2007	0.1	4.6	0.0025	18	64						0.0004	0.0009	0.0001						0.0008
1/2/2008	<0.007	5	0.0023	18	66						0.0001	0.0004	0.0001						0.0013
2/6/2008	0.016	5.8	0.0027	21	76						0.0002	0.0001	0.0001						0.0019
3/5/2008	0.1	5.1	0.0024	18	66						0.0001	0.0002	0.0001						0.0026
5th %tile					59														
10th %tile					61														
90th %tile		5.4	0.0050								0.0014	0.0009	0.0001						0.0023
geo mean		4.8	0.0031								0.0003	0.0003	0.0001						0.0009
max		5.8	0.0094								0.0056	0.0010	0.0014						0.0042

Table 2 Outfall 001 Effluent Data

Outfall 001																					
	BOD	COD	TOC	TSS	Ammonia	Br	Fecal	Cond	pH	Turb.	Alk	F	Cl	Nitrate	Nitrite	N, T.Org	O&G	T-P	SO4	Al	Ba
Date	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)		(uS/cm)		(NTU)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
7/6/2006				18	0.015			940	8.14	10.6		0.44	29	0.44	0.036			2.2	400		
8/3/2006										5.59											
9/14/2006				7.2	0.042			750	8.32	4.68	130	0.37	17	0.43	0.04			2.2	230		
10/12/2006				5.4	0.015			680	8.32	3.85	120	0.32	12	0.56	0.04			2.3	210		
11/9/2006				9	0.015			360	8.19	5.92	98	0.21	6.3	0.4	<0.03			2.3	60		
12/7/2006				15	0.015			1200	7.98	12.6	96	0.5	23	1.9	0.03			2.5	500		
12/20/2006		25	13	16	0.043	7.7		1200	8.55	9.51		0.53	0.12	2.1	0.03		1.1	2.2	580	0.38	0.3
1/3/2007				11	0.015			1300	8.31	5.92	120	0.53	21	2.3	0.03			2.1	560		
2/5/2007				7	0.015			1300	8.28	5.53	130	0.54	18	2.4	0.037			2.2	550		
3/5/2007				6.9	0.015			1200	8.39	3.56	130	0.55	19	1.8	<0.03			2	570		
4/2/2007				4.5	0.039			1300	8.46	3.2	110	0.52	23	1.50	0.04			2.5	560		
5/3/2007				20	0.12			1400	8.18	11.3	110	0.54	46	1.1	0.037			2.4	630		
7/2/2007				7	0.071			400	8.15	3.6	85	0.24	5.9	0.22	0.031			1.8	110		
8/1/2007				11	0.031			1200	8.35	4.76	120	0.51	37	0.40	<0.03			2.7	640		
9/5/2007				7	0.035			1200	8.22	4.91	100	0.50	23	0.69	<0.03			2	590		
10/1/2007				6.6	0.048			1200	8.23	4.81	96	0.55	27	0.94	<0.03			2.4	590		
11/7/2007				7.8	0.046			1200	8.11	4.53	98	0.59	18	1.3	<0.03			2.4	540		
12/12/2007				11	0.015			1100	8.18	7.46	130	0.55	16	1.8	<0.03			1.8	460		
1/2/2008				6.2	0.015			770	7.93	4.68	110	0.3	7.2	0.78	<0.03			2.4	210		
2/4/2008				6.2	0.032			1100	7.78	3.89	120	0.41	14	1.5	<0.03			2.9	490		
3/5/2008				8.6	0.052			1300	8.44	4.28	150	0.460	19	1.8	<0.03			3.2	550		
4/17/2008				6.8	0.049			1500	8.01	4.97	120	0.39	24	1.3				2.5	530		
5/6/2008				13	0.058			1500	8.22	6.35	90	0.48	27	1.9	0.72			2.7	690		
5/27/2008																					
6/3/2008																					
6/10/2008				30	0.11			1300	8.61	23.5	120	0.45	41	0.9	1.0			2.6	460		
avg				10.5	0.040			1104	8.23	6.67	113	0.46	20.6	1.24				2			
95th %tile				19.8	0.106			1490	8.54	12.4	130	0.55	40.6	2.28				2.88			
stnd dev				5.98	0.029			312.7	0.20	4.40	16.4	0.1	11.1	0.68				0.3			
cv				0.570	0.736			0.283	0.024	0.660	0.144	0.232	0.538	0.548				0.140			
50th %tile				7.8	0.035			1200	8.22	4.94	120	0.5	19	1.3				2.4			
max				30	0.120						150	0.59	46	2.40				3.20			
* ammonia entries of 0.015 indicate 1/2 the PQL of 0.03 mg/L																					

Table 2 Outfall 001 Effluent Data

Outfall 001																					
Date	Fe (mg/L)	Mg (mg/L)	Mn (mg/L)	Ca (mg/L)	Hard(Ca/Mg) (mg/L)	Sn (mg/L)	Sb (mg/L)	As (mg/L)	Be (mg/L)	Cd (mg/L)	Cr (mg/L)	Cr (VI) (mg/L)	Cr (III) (mg/L)	Cu (mg/L)	Pb (mg/L)	Hg (mg/L)	Ni (mg/L)	Se (mg/L)	Ag (mg/L)	Tl (mg/L)	Zn (mg/L)
7/6/2006	0.26	28	0.026	130							0.0010			0.070	<0.0002						0.034
8/3/2006											0.0019			0.055							0.025
9/14/2006	0.24	27	0.022	100							0.0009			0.046	<0.0002						0.022
10/12/2006	0.19	23	0.019	90							0.0015			0.033	<0.0002						0.020
11/9/2006	0.32	11	0.022	48							0.0011			0.028	<0.0002						0.014
12/7/2006	0.6	42	0.038	160							0.0025			0.049	<0.0002						0.026
12/20/2006	0.64	52	0.031	190		<0.001	0.0015	0.013	<0.002	<0.0002	0.0019			0.054	0.0002	<0.0002	0.0043	0.028	<0.0002	<0.0002	0.030
1/3/2007	0.29	46	0.025	190							0.0032			0.046	0.0003						0.026
2/5/2007	0.33	49	0.019	200							0.0024			0.021	<0.0002						0.025
3/5/2007	0.11	42	0.012	170							0.0009			0.023	<0.0002						0.018
4/2/2007	0.29	48	0.014	190							0.0018			0.028	0.0003						0.022
5/3/2007	0.35	47	0.039	190							0.0020			0.052	0.0003						0.049
7/2/2007	0.26	14	0.029	59							0.0011			0.038	<0.0002						0.012
8/1/2007	0.27	48	0.032	190							0.0039			0.052	<0.0002						0.028
9/5/2007	0.96	48	0.025	190							0.0014			0.028	<0.0002						0.018
10/1/2007	0.2	45	0.029	200							0.0013			0.030	<0.0002						0.021
11/7/2007	0.28	46	0.025	180							0.0020			0.021	0.0005						0.018
12/12/2007	0.4	40	0.028	170							0.0018			0.023	0.0005						0.019
1/2/2008	0.094	23	0.014	94							0.0008			0.012	<0.0002						0.014
2/4/2008	0.24	51	0.016	180							0.0020			0.047	0.0003						0.028
3/5/2008	0.23	54	0.018	210							0.0007			0.020	0.0006						0.024
4/17/2008	0.21	51	0.028	220							0.0014			0.021	<0.0002						0.022
5/6/2008	0.26	57	0.029	250							0.0022			0.022	0.0006						0.027
5/27/2008												0.0004	0.00031								
6/3/2008												<0.00023									
6/10/2008	0.63	45	0.051	190							0.0010			0.025	<0.0002						0.027
avg	0.33	41	0.026	165							0.0017			0.035							0.024
95th %tile	0.64	53.8	0.039	219							0.0031			0.055							0.033
stnd dev	0.198	13.0	0.009	52.5							0.0008			0.015							0.008
cv	0.596	0.319	0.353	0.319							0.4602			0.429							0.321
50th %tile	0.27	46	0.025	190							0.00165			0.029							0.023
max	0.96	57	0.051	250							0.0039			0.070							0.049

Table 3 Reasonable Potential Determination

Ambient Water Quality Criteria

	Copper	Zinc
*Acute Criteria Values	10.7	75.3
*Chronic Criteria Values	7.4	68.7

* Water quality criteria as total recoverable metal (µg/L) at a hardness of 61 mg/L

Maximum Expected Concentration

	CV	ND	Multiplier	HV (µg/L)	MEC (µg/L)
Copper	0.429	24	1.2	70	84
Zinc	0.321	24	1.2	49	58.8

ND = number of data points
HV = highest value from Table 2

Reasonable Potential Calculation

	MEC (µg/L)	MECB (µg/L)	DF	CP	WQC	RP?
Copper - Acute	84	0.9	9	10.13	10.7	No
Copper - Chronic	84	0.9	93	1.79	7.4	No
Zinc - Acute	58.8	2.3	9	8.58	75.3	No
Zinc - Chronic	58.8	2.3	93	8.60	68.7	No

MEC = maximum expected concentration
MECB = maximum expected background concentration
DF = dilution factor (acute or chronic)
CP = concentration of the metal at the edge of RMZ

CP = ((MEC*translator) + (MECB*(DF-1))) / DF
translator = 1.0 per Table 8 of Ecology guidance, Applying Metals Criteria to Water Quality-Based Discharge Limits, pages 19-21

Attachment 1

Energy Northwest Dilution Modeling Analysis

Submitted By
Robert L. Doneker, Ph.D., P.E.
MixZon Inc.
1033 SW Yamhill, Suite 301
Portland, OR 97205-2539 USA
Ph: 503-222-1022 Fax: 503-296-2354
Thursday, September 27, 2007
http://www.mixzon.com
support@mixzon.com
June 5, 2008

Introduction

MixZon was contracted by Energy Northwest to conduct a mixing zone modeling analysis of a cooling water condensate (CGS) outfall into the Hanford Reach of the Columbia River near Richland Washington. The primary purpose of the mixing zone study is to determine new dilution factors from which new effluent limits will be established.

MixZon had previously conducted a mixing zone field study at the site collecting Acoustic Doppler Current Profile (ADCP) data and balloon infrared remote sensing analysis of plume mixing, as well as CORMIX model validation. The data from this report was used to characterize the velocity field in the vicinity of the discharge. The previous field study report appears in Appendix A.

Approach

Typically, mixing zone studies use the 7Q10 low flow for critical condition evaluations. WAC guidance (Chapter 173-563) establishes minimum flows for the Columbia River. It states that 36,000 cfs is the minimum instantaneous flow allowed during the September through mid-October period, but also sets 36,000 cfs as the minimum flow for all months should a low water year occur. Both flow conditions were addressed in the modeling scenarios.

The nine scenarios modeled appear in Table 1. Dilution values in Table 1 are computed based on linear interpolation from CORMIX output files, using NSTEP=800 to create a small step size in the downstream direction. Dilution S is defined as $S = C_o/C$ where C_o is the discharge concentration and C is the maximum downstream centerline concentration. Dilution values presented are rounded to the nearest integer value.

Case 1 and 2 represent 7Q10 low ambient summer flow. Appendix B has output files with NSTEP = 10 to limit prediction file length for display. Case 3 and 4 represent the minimum flow designated in WAC 173-563. The worst case scenario is the critical ambient conditions but higher discharge rate (Q_0 = 6528 gpm) for flow. The winter scenarios (Cases 6 and 7) are primarily for thermal effects of the discharge should a 7Q10 low flow condition occur during a period of low ambient river temperature. The high flow scenarios (Cases 8 and 9) show dilution behavior during the 7Q10 high flow event as an "off design" condition.

All depth and velocity conditions modeled in Table 1 were adjusted to conditions observed during the field monitoring study. The river flow during the study was Q_a = 40.9 kcfs and the depth at the outfall location was HD= 2.25 m. Observed velocity at the outfall was u_a1.47 m/s. The following relations were used to adjust ambient velocity and depth at discharge for the modeling scenarios and is based on the Manning equation for open channel flow.

$$HD_2 = HD_1\ (Q_{a2}/Q_{a1})^{3/5}$$

$$u_{a2} = u_{a1}\ (HD_2/HD_1)^{2/3}$$

Table 1 Energy Northwest Mixing Zone Dilutions

Case	Description	Ambient				Discharge		Dilution S = C_0/C	
		Q_A (kcfs)	T_A (°C)	HD (m)	u_a (m/s)	Q_0 (gpm)	T_0 (°C)	@ 31 (ft)	@ 306 (ft)
1	7Q10 Low - Chronic	52.7	22	2.6	1.63	2986	29.6	13	127
2	7Q10 Low - Acute	52.7	22	2.6	1.63	4097	29.6	9	93
3	WAC 173-563 Chronic	36	22	2.1	1.40	2986	29.6	10	80
4	WAC 173-563 Acute	36	22	2.1	1.40	4097	29.6	6	58
5	Worst Case	36	22	2.1	1.40	6528	29.6	4	36
6	Winter - Chronic	52.7	1.5	2.6	1.63	2986	29.6	11	128
7	Winter - Acute	52.7	1.5	2.6	1.63	4097	29.6	7	93
8	7Q10 High - Chronic	261	10	6.8	3.08	2986	29.6	34	590
9	7Q10 High - Acute	261	10	6.8	3.08	4097	29.6	22	420

Results

All conditions were modeled using CORMIX v5.0. CORMIX indicates a stable near-field with a H2A2 and H1A2 flow classes. These flow classes indicate a near-field wake attachment of the discharge plume to the bottom with local recirculation and no lift off.

Results appear in Table 1. Physical dilution ranges from S= 4 to 34 at 31-ft downstream of the outfall to S=36-590 at 306-ft downstream of the outfall.

Lowest dilutions occur for the "worst case" scenario Case 5. Highest dilutions occur for the high flow "off-design" conditions represented by Cases 8 and 9.

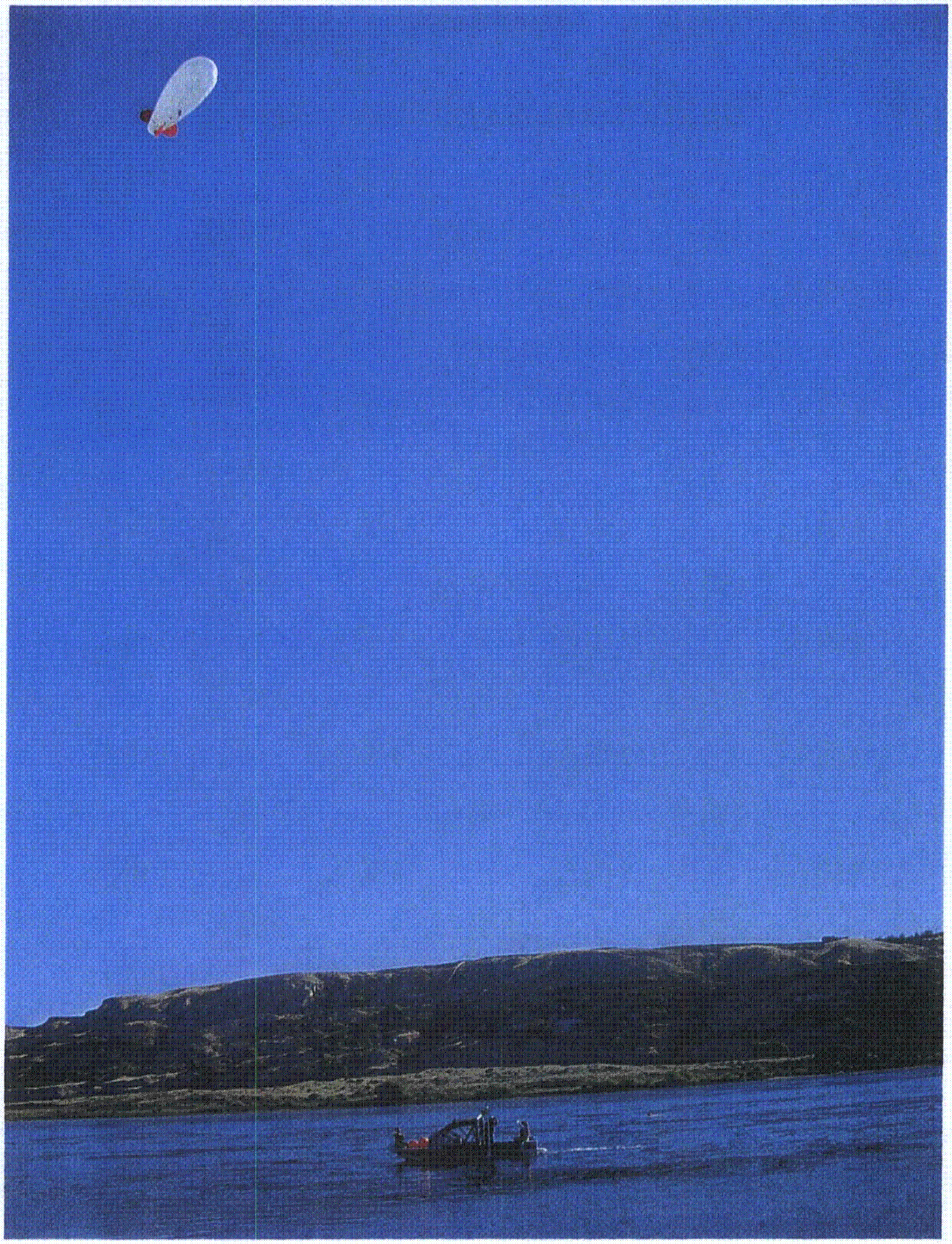
The CORMIX prediction files for the cases appear in Appendix B.

Appendix A

Field Monitoring Dilution Study

10/23/07

Energy Northwest Mixing Zone Study



Submitted By

MixZon Inc.
1033 SW Yamhill, Suite 301
Portland, OR 97205-2539 USA
Ph: 503-222-1022 Fax: 503-296-2354
Thursday, September 27, 2007

http://www.mixzon.com
support@mixzon.com
October 30, 2007

1. Introduction

This report details a mixing zone study performed for Energy Northwest by MixZon in September 2007. MixZon was contracted by Energy Northwest to conduct a mixing zone study of a cooling water discharge into the Columbia River. MixZon conducted a field data collection campaign to collect data during a low flow fall event. MixZon collected aerial infrared imagery survey of the mixing zone along with an ambient velocity and depth survey in the outfall vicinity conducted by a boat mounted Acoustic Doppler Current Profiler (ADCP).

Energy Northwest operates a submerged single port discharge of cooling water into the Columbia River into the Hanford Reach. The Columbia River flow at the discharge location is influenced by upstream releases from the Priest Rapids Dam. Ambient flow at the location varies depending upon regulatory requirements and power generation demand. The river is free flowing in the discharge reach, is relatively shallow (< 3 m depth) and does not have any ambient density stratification.

A submerged single port diffuser discharges 2000-4000 gpm of process cooling water. The discharge port is an 8" x 32" rectangle (port area = 2 ft^2) discharging perpendicular to the west shoreline (pointing east). The discharge is angled approximately 15^{o} above vertical. The discharge is located approximately 175 ft from the west bank when the river flow is 36,000 cfs. The low river flow observed at the site during the field data collection campaign corresponds to a river flow of about 40,900 cfs release from the Priest Rapids dam, based on an assumed 10 hour travel time from the dam site to the discharge location.

The discharge operates at approximately ΔT= 4 to 7 °C above ambient. During the field data collection campaign from 7AM to 11AM on September 5, 2007, the discharge averaged 3807 gpm at 26.0 °C. Ambient temperature upstream of the outfall was 19.2 °C as determined by the ADCP unit.

State mixing zone regulations require a minimum dilution S = 50 at 306 feet (100 m) downstream of the outfall or 100 ft upstream of the outfall. Maximum plume centerline half-width is 175 ft at 306 ft downstream.

MixZon conducted a field campaign to collect bathymetry on September 5, 2007. MixZon operates a 20 ft Motion Marine Jet Sled to collect ADCP, depth, and DGPS data. ADCP river velocity data was collected in conjunction with the aerial infrared imagery. Aerial infrared imagery is collected by MixZon's patent-pending tethered balloon remote sensing platform. This platform is supported by USEPA SBIR Phase II grant EP-D-07-086 "Balloon Platforms for Remote Sensing of Water Quality in Mixing Zones at Site Scales".

2. Site Survey Data

MixZon deployed boat and balloon platforms at the discharge site on the Columbia River to collect relevant data. Site bathymetry data and ambient velocity data was collected by the boat ADCP platform in conjunction with the aerial infrared balloon survey.

2.1. Ambient Bathymetry Data

MixZon conducted a river bathymetry survey in the outfall vicinity using a boat-mounted Teledyne RDI 1200kHz Workhorse Rio Grande ADCP. Position information on the ADCP data is accomplished by tagging data ensembles with Global Positioning System (GPS) position information from a Trimble AgGPS 114 operating at 5 Hz.

Collection of position-dependent data for referencing and verification of imagery and collection of water current data are subject to a number of quality control and quality assurance settings. Positional accuracy is a function of the GPS and the data acquisition conditional settings. For best accuracy MixZon uses a system with a satellite-based, real-time differential correction subscription (referred to as *Differential GPS* or DGPS). Real-time accuracy is better than 1 meter (3.2 feet).

MixZon also collects water velocity data using the same boat-mounted Teledyne/RDI Workhorse Rio Grande 1200 kHz Acoustic Doppler Current Profiler (ADCP). Accurate measurement depends on experience with the study area and using proper conditional settings. We expect velocity and depth measurement errors to be less than 10%.

2.2. DGPS Quality Assurance

Changeable Positional DGPS conditional settings are:

- Number of satellites used, (MixZon requires five or more satellites be used)
- Positional Dilution of Precision (PDOP), (MixZon uses a PDOP mask < 4)
- Signal to Noise Ratio (SNR), (MixZon uses a SNR mask > 6) and
- Satellite Elevation Mask (MixZon uses an elevation mask > 20°).

The number of satellites used by the DGPS is important for both accuracy and precision, which is measured by the unitless Positional Dilution of Precision (PDOP). Receiving signal from four satellites is the minimum requirement for accurate DGPS position, five is optimal. Five satellites, in a hexagonal geometry surrounding the GPS receiver give the lowest PDOP. This geometry, however, is seldom realized. To achieve the best possible accuracy with the minimum PDOP, we require that the DGPS receive five or more satellites with a PDOP less than four. We also require that all satellites provide a signal that improves accuracy. To assure improved signal, a SNR greater than six (> 6) and that each satellite be a minimum 20° elevation above the horizon (elevation mask) is required.

Number of Satellites, the number of satellites above 20°, PDOP and SNR are conditional settings that vary with time. To assure we will meet these conditions on the day of the field survey, we use Trimble Pre-planning GPS software. Figure 1 shows an example for the study area on Wednesday, September 5, 2007 from 0500-1000 local time, the number of satellites above the 20° elevation mask ranges from a minimum of eight to a maximum of 14. Figure 2 example shows that the PDOP during the study period, mostly remains well within the MixZon requirement of a maximum of 4 PDOP.

2.3. Site Bathymetry Results

Site bathymetry data was collected by the ADCP unit at cross sections just upstream and downstream of the outfall. The cross section just upstream of the outfall is shown in Figure 3.

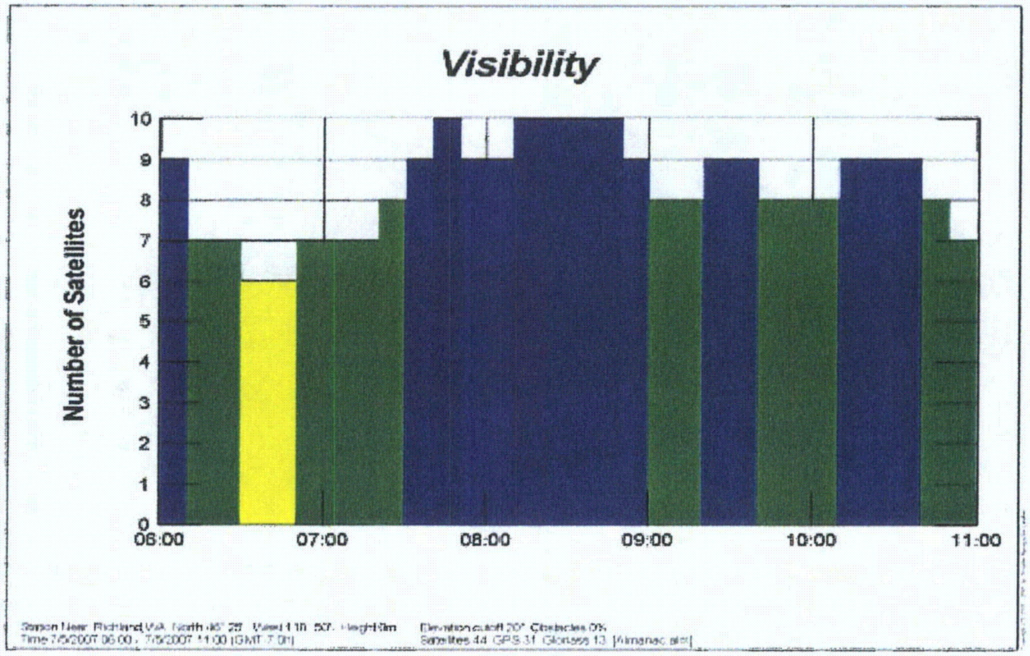


Figure 1: Number of satellites available, above the 20° elevation mask, for 9/5/2007.

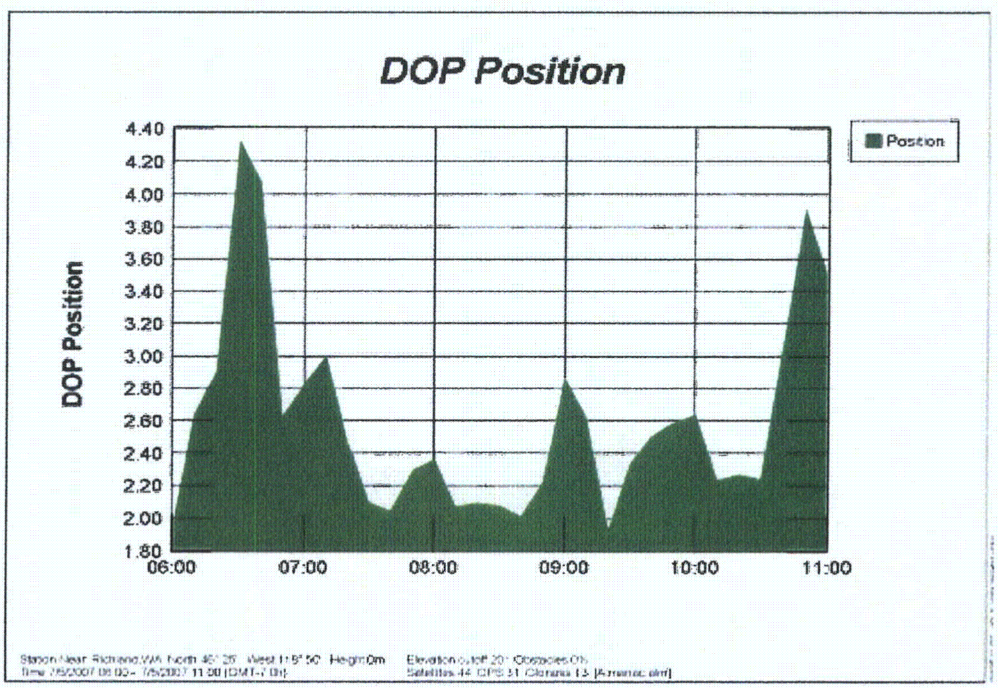


Figure 2: PDOP for available satellites, above the 20° elevation mask, for 9/5/07.

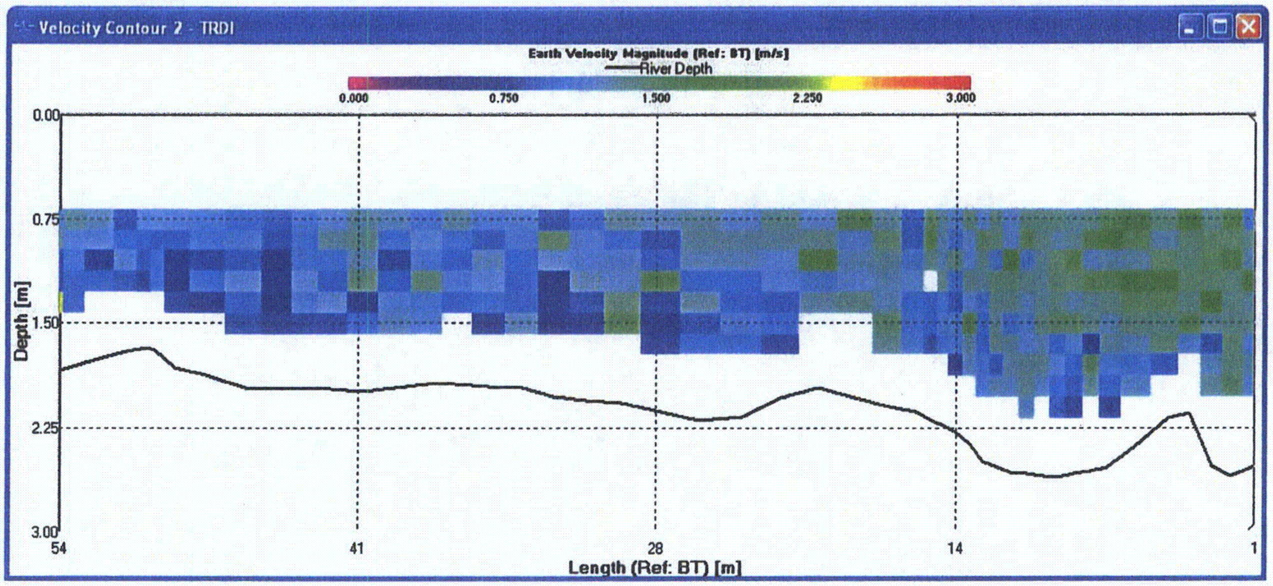


Figure 3: Bathymetry and ambient velocity profile upstream of discharge.

Figure 3 shows the site bathymetry and ambient velocity just upstream of the outfall location. The outfall is located on the right side of the Figure 3 at a depth of approximately 2.25 m.

2.4. Ambient Velocity Quality Assurance

MixZon deploys a 1200 kHz Rio Grande ADCP manufactured by Teledyne RDI to collect ambient velocity data. When coupled with the DGPS system vertical and horizontal current fields are realized. Conditional settings for the ADPC are:

- Magnetic Declination
- ADCP water mode
- Bottom Tracking mode
- Moving Bed test

The magnetic declination as determined from the National Geodetic Survey website: http://www.ngdc.noaa.gov/seg/geomag/declination.shtml is 16.6° east of north. The ADCP water mode, bottom tracking mode and moving bed test are functions of the bathymetry and bottom sediment type at the channel area. MixZon conducted an analysis of the area bathymetry and completed a moving bed test on September 5 2007. The study area river bed is stationary allowing bottom tracking mode to be used with the ADCP.

Bathymetry, which effects with ADCP water mode conditional setting, is characterized by alluvial river cross sections. This bathymetric profile allows the ADCP to be set to "Water Mode 11" which produces near surface measurements and high-resolution horizontal currents over the vertical water column.

Water Mode 11 is also a good conditional setting in shallow water (< 12 feet) and slow water (< 3.5 ft/s) settings. Current measurements over the vertical water column tend to have less error and higher correlation. MixZon requires that the error velocities associated with current measurements be less than 10% of the horizontal current at any given depth.

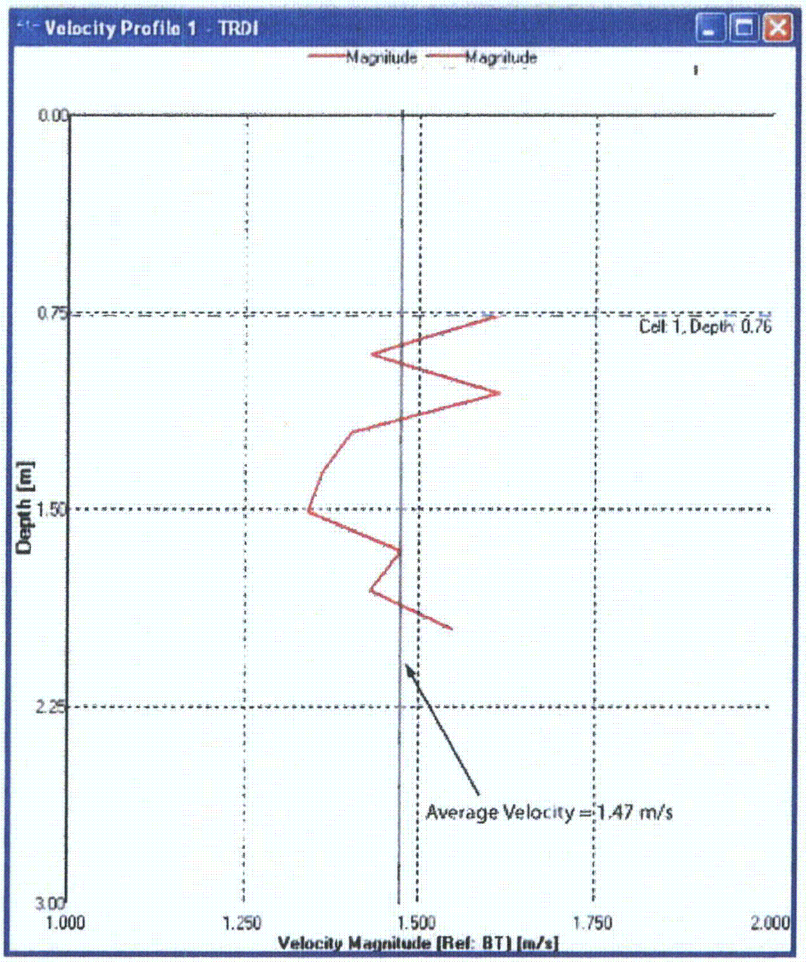


Figure 4: Average ambient velocity upstream from outfall location on the Hanford reach.

2.5. ADCP Ambient Velocity Data

Ambient velocity cross-section profiles were obtained immediately upstream of the discharge during the field campaign. Aerial infrared imagery was taken simultaneously to ensure the velocity data was taken outside the thermal plume just upstream from the plume. The cross section velocity profile (and bathymetry) is shown in Figure 3, while Figure 4 presents the vertical velocity profile just upstream from the discharge location. Characteristic values for depth averaged ambient velocity during the campaign is $u_a = 1.47$ m/s. The low flow observed at the site corresponds to a river flow of about 40,900 cfs release from the Priest Rapids dam, based on an assumed 10 hour travel time from the dam site to the discharge location.

2.6. Aerial Infrared Imagery and Quality Assurance

MixZon deploys a remote sensing platform for mixing zone water quality monitoring that it is developing with USEPA SBIR program support. Our platform uses a FLIR model A20M infrared camera bore-sighted with an IQEye Model 703 3.0 megapixel video camera mounted on an 8 m tethered helium balloon. Platform specifications for the infrared detector and lenses measure a 91-m x 69-m area at an altitude of 152-m (500-ft) with a minimum a 0.4-m x 0.4-m pixel resolution within 0.1°C temperature sensitivity.

Mixing zone water quality data are georeferenced to high-resolution aerial photography. Aerial photography is available for purchase for the project area obtained from Energy Northwest. The digital orthorectified images has high resolution of one foot (0.3048-m), which is coarser than the data returned from our remote sensing platform IR and video cameras. At the maximum flight elevation, the IR and video cameras return Instantaneous Field of View (IFOV) spot sizes closer to 0.5 m.

Two steps are necessary prior to rectifying the IR and video data to aerial photography. First, in the field, the cameras are focused such that the video camera's field of view encompasses the IR camera's field of view. This assures that the IR data fall within the spatial extent of the video imagery. Second, both cameras' data are converted to JPEG format using the MixZon ZoneView post-processor.

Georeferencing the JPEG-format data to the aerial photographs is done using a commercial off-the-shelf (COTS) mapping tool; ESRI's ARCVIEW GIS along with the Spatial Analyst Extension and a basic ArcScript. The process starts with inputting the aerial photography and declaring the projection information. In our cases all the aerial photographs were referenced to the Oregon State Plane coordinate system using the North American Datum (NAD) 83/91 (HARN) in units of International feet). Next, the user imports the video captures into the GIS software. The video captures are essential for accurate referencing because they clearly show many features coincident between the aerial photograph and the study data.

Once the JPEG format video capture is imported to the GIS package, the Spatial Analyst's Georeferencing tool rectifies the JPEG to the aerial photo. Spatial statistics are tabulated via the Spatial Analyst to assure an accurate fit between the video capture and the aerial photograph. Then, if the mixing zone extends beyond a single video image, an ArcScript will mosaic remaining images.

After the referencing of the video captures is complete the associated IR data are imported to the GIS software and referenced to the video captures. Again, spatial statistics are computed to assure an accurate rectification. In addition, GPS coordinates for several prominent locations on the shoreline visible from the infrared and video images were recorded for additional position verification.

Two methods of validation are then used to verify the accuracy of the rectification process. While in the field, we measure the dimensions of several objects that will appear in the video captures. Examples include: downed logs, widths of stream channels or walking paths. These dimensions are measured against the dimensions of the objects in the video captures, and if possible, against the dimensions of the objects in the IR data. Second, we collect GPS information at specific locations easily recognizable in the video and IR data (such as a topographic break along the shore/coastline) and compare it to the resulting rectified images.

2.7. Aerial Infrared Survey Results

Our aerial remote sensing platform was successfully deployed on September 5, 2007. Aerial imagery was collected in real-time in conjunction with the ADCP current profiling data as discussed above. Data from the aerial imaging was used to position the boat survey crew to collect ambient velocity profiles just upstream of the plume. The deployment lasted for several hours, and several sets of data were collected from 7:30 AM PDT to 9:55 AM PDT. During this period, the ambient flowrate slowly decreased to a minimum stage.

Figure 5 shows the stereo side-by-side images taken from the balloon platform. The left image is visual and the right image is infrared. The results of the infrared imagery are shown in overlaid georectified format for the survey appears in Figure 6. There is no detectable surface temperature signal from the discharge site.

2.8. Boat Survey Temperature Profiles

The ADCP unit also has a temperature sensor. During the site bathymetry survey, synoptic temperatures were also recorded at a depth of 0.10 m below the water surface. The results of the temperature data from the boat ADCP survey are shown as 0.1 °C temperature concentration profiles in Figure 7 for a survey conducted on September 5. Ambient background temperature was 19.2 °C and discharge temperature was 26 °C, giving a discharge $\Delta T= 6.8$ °C. No surface temperature signal from the discharge was detected by ADCP survey.

3. <u>CORMIX Modeling of the Mixing Zone</u>

The outfall was simulated with CORMIX v5.0 to compare modeling results and data schematization with observed bathymetry and plume behavior and dilution at the site. The discharge was simulated within CORMIX as a heated effluent type with a submerged single port discharge configuration (CORMIX1). Surface heat transfer coefficient was set to 25 W/ m^2 /°C and the manning's N was set to 0.02 to account for bottom roughness.

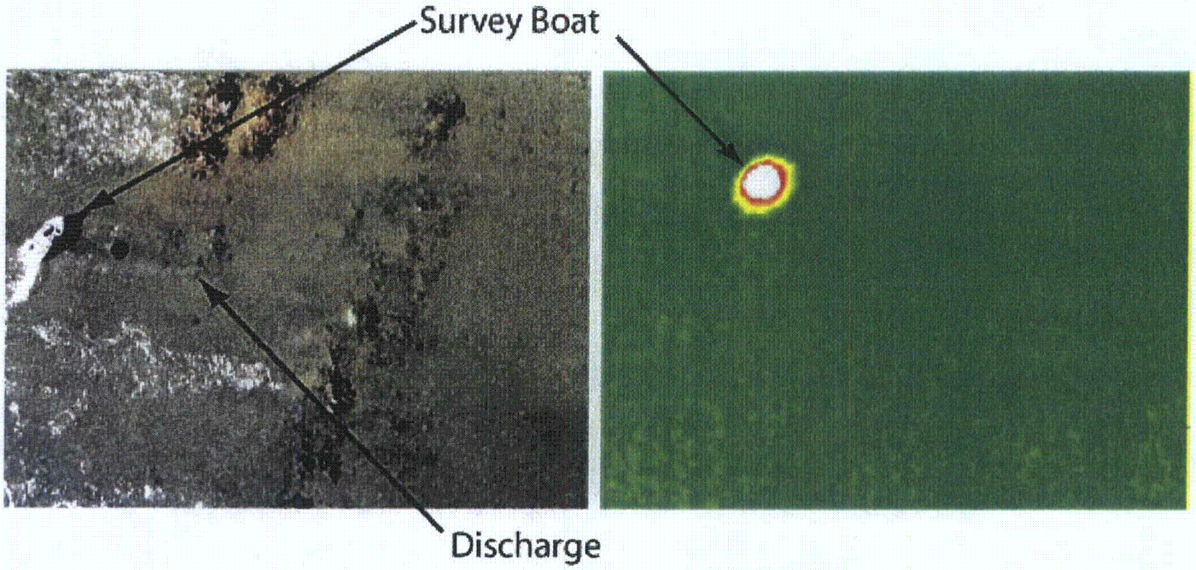


Figure 5: Visual and infrared imagery Sept. 5, 2007. Ambient flow is from left to right.

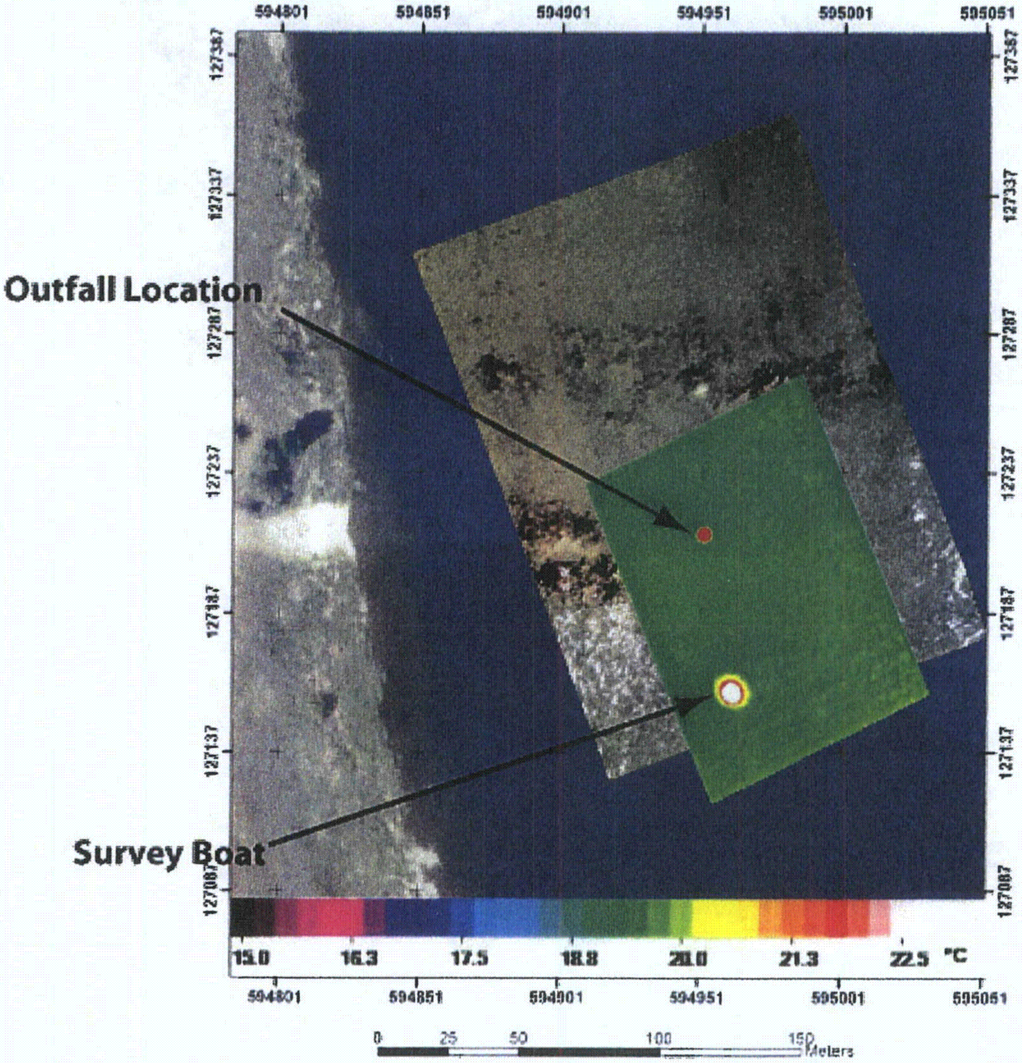


Figure 6: Geo-rectified infrared imagery Sept. 5, 2007 at approximately 9 AM.

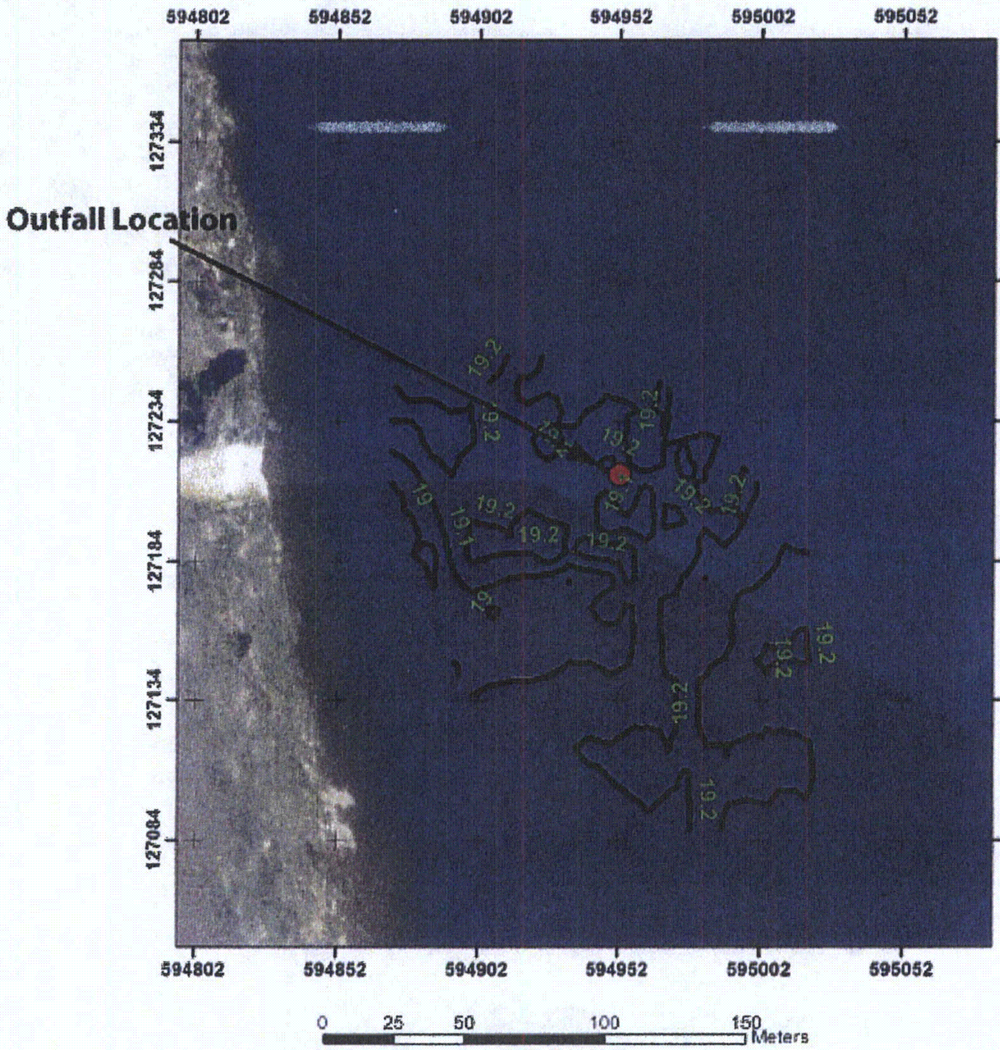


Figure 7: ADCP Temperature contours September 5, 2007 (u_a = 1.48 m/s).

Table 1. CORMIX Prediction File for September 5, 2007 $Q_a \approx$ 40,900 cfs.

```
CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111111
                        CORMIX MIXING ZONE EXPERT SYSTEM
             Subsystem CORMIX1:  Single Port Discharges
                          CORMIX Version 5.0GTR
                       HYDRO1 Version 5.0.1.0 August 2007
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:
 Design case:        Low Flow
 FILE NAME:          C:\...MyFiles\EnergyNorthwest\Energy NW Sept 5 2007.prd
 Time stamp:         Tue Oct 23 15:58:07 2007

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS     =     304.80  AS     =     685.80  QA     =    1008.13  ICHREG= 1
 HA     =       2.25  HD     =       2.25
 UA     =      1.470  F      =      0.024  USTAR =0.8044E-01
 UW     =      2.000  UWSTAR=0.2198E-02
 Uniform density environment
 STRCND=  U           RHOAM =  998.3669

DISCHARGE PARAMETERS (metric units)
 BANK   =  RIGHT      DISTB =     53.34
 D0     =      0.486  A0     =      0.186  H0     =       0.03  SUB0   =       2.22
 THETA  =      20.00  SIGMA =      90.00
 U0     =      1.293  Q0     =      0.240         =0.2402E+00
 RHO0   =  996.7843   DRHO0 =0.1583E+01  GP0    =0.1555E-01
 C0     =0.6800E+01   CUNITS=  deg.C
 IPOLL  =  1          KS     =0.0000E+00  KD     =0.0000E+00

FLUX VARIABLES (metric units)
 Q0     =0.2402E+00   M0     =0.3106E+00  J0     =0.3734E-02  SIGNJ0=       1.0
 Associated length scales (meters)
 LQ     =       0.43  LM     =       6.81  Lm     =       0.38  Lb     =       0.00
                                           Lmp    =   99999.00  Lbp    =   99999.00

NON-DIMENSIONAL PARAMETERS
 FR0    =      14.87  R      =       0.88

FLOW CLASSIFICATION
 111111111111111111111111111111111111111111
 1  Flow class (CORMIX1)       =    H2A2   1
 1  Applicable layer depth HS =     2.25   1
 111111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0     =0.6800E+01   CUNITS=  deg.C
 NTOX   =  0
 NSTD   =  1          CSTD   =0.3000E+00
 REGMZ  =  1
 REGSPC=   1          XREG   =      93.27  WREG   =       0.00  AREG   =       0.00
 XINT   =   3500.00   XMAX   =    3500.00
```

Table 1 (contd). CORMIX Prediction File for September 5, 2007 Q_a ~ 40,900 cfs.

```
X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        53.34 m  from the RIGHT bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 400 display intervals per module
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

 WAKE ATTACHMENT immediately following the discharge.

       X        Y        Z         S        C        B
      0.00     0.00     0.00      1.0 0.680E+01    0.57

END OF MOD101: DISCHARGE MODULE
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
BEGIN MOD151: WAKE RECIRCULATION

  Control volume inflow:
       X        Y        Z         S        C        B
      0.00     0.00     0.00      1.0 0.680E+01    0.57

 Profile definitions:
   BV = top-hat thickness, measured vertically
   BH = top-hat half-width, measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
   S  = hydrodynamic average (bulk) dilution
   C  = average (bulk) concentration (includes reaction effects, if any)

       X        Y        Z         S        C       BV        BH       ZU       ZL
      0.00     0.38     0.00      1.0 0.680E+01   0.57      0.57     0.57     0.00
      0.22     0.38     0.00      1.1 0.608E+01   0.60      0.60     0.60     0.00
      0.43     0.38     0.00      1.4 0.470E+01   0.61      0.61     0.61     0.00
      0.65     0.38     0.00      1.9 0.356E+01   0.61      0.61     0.61     0.00
      0.86     0.38     0.00      2.4 0.280E+01   0.62      0.62     0.62     0.00
      1.08     0.38     0.00      2.9 0.234E+01   0.62      0.62     0.62     0.00
      1.29     0.38     0.00      3.3 0.206E+01   0.63      0.63     0.63     0.00
      1.51     0.38     0.00      3.6 0.189E+01   0.63      0.63     0.63     0.00
      1.72     0.38     0.00      3.8 0.180E+01   0.64      0.64     0.64     0.00
      1.94     0.38     0.00      3.9 0.174E+01   0.64      0.64     0.64     0.00
      2.16     0.38     0.00      4.0 0.169E+01   0.65      0.65     0.65     0.00
 Cumulative travel time =          1.4662 sec

END OF MOD151: WAKE RECIRCULATION
-----------------------------------------------------------------------------
** End of NEAR-FIELD REGION (NFR) **
```

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

Vertical diffusivity (initial value) = 0.362E-01 m^2/s
Horizontal diffusivity (initial value) = 0.453E-01 m^2/s

Table 1 (contd). CORMIX Prediction File for September 5, 2007 Q_a ~ 40,900 cfs.

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
2.16	0.38	0.00	4.0	0.169E+01	0.65	0.65	0.65	0.00
10.90	0.38	0.00	8.4	0.809E+00	0.78	1.12	0.78	0.00
19.64	0.38	0.00	13.3	0.510E+00	0.96	1.45	0.96	0.00
28.39	0.38	0.00	19.0	0.357E+00	1.15	1.72	1.15	0.00

WATER QUALITY STANDARD OR CCC HAS BEEN FOUND
The pollutant concentration in the plume falls below water quality standard or CCC value of 0.300E+00 in the current prediction interval.
This is the spatial extent of concentrations exceeding the water quality standard or CCC value.

37.13	0.38	0.00	25.3	0.269E+00	1.35	1.95	1.35	0.00
45.88	0.38	0.00	31.9	0.213E+00	1.54	2.16	1.54	0.00
54.62	0.38	0.00	38.6	0.176E+00	1.72	2.34	1.72	0.00
72.11	0.38	0.00	52.5	0.130E+00	2.04	2.68	2.04	0.00
80.86	0.38	0.00	59.5	0.114E+00	2.19	2.83	2.19	0.00

Plume interacts with SURFACE.
The passive diffusion plume becomes VERTICALLY FULLY MIXED within this prediction interval.

89.60	0.38	0.00	64.4	0.106E+00	2.25	2.98	2.25	0.00

** REGULATORY MIXING ZONE BOUNDARY **
In this prediction interval the plume DOWNSTREAM distance meets or exceeds the regulatory value = 93.27 m.
This is the extent of the REGULATORY MIXING ZONE.

98.35	0.38	0.00	67.4	0.101E+00	2.25	3.12	2.25	0.00
107.09	0.38	0.00	70.3	0.967E-01	2.25	3.25	2.25	0.00
115.84	0.38	0.00	73.1	0.931E-01	2.25	3.38	2.25	0.00
177.05	0.38	0.00	90.0	0.755E-01	2.25	4.16	2.25	0.00
185.79	0.38	0.00	92.2	0.737E-01	2.25	4.26	2.25	0.00
194.54	0.38	0.00	94.3	0.721E-01	2.25	4.36	2.25	0.00

220.77	0.38	0.00	100.4	0.677E-01	2.25	4.64	2.25	0.00
229.52	0.38	0.00	102.4	0.664E-01	2.25	4.73	2.25	0.00
238.26	0.38	0.00	104.3	0.652E-01	2.25	4.82	2.25	0.00
247.00	0.38	0.00	106.2	0.641E-01	2.25	4.91	2.25	0.00
500.60	0.38	0.00	150.8	0.451E-01	2.25	6.97	2.25	0.00
509.34	0.38	0.00	152.1	0.447E-01	2.25	7.03	2.25	0.00
623.02	0.38	0.00	168.2	0.404E-01	2.25	7.78	2.25	0.00
692.98	0.38	0.00	177.3	0.383E-01	2.25	8.20	2.25	0.00
701.72	0.38	0.00	178.4	0.381E-01	2.25	8.25	2.25	0.00
745.45	0.38	0.00	183.9	0.370E-01	2.25	8.50	2.25	0.00
902.85	0.38	0.00	202.3	0.336E-01	2.25	9.36	2.25	0.00
990.30	0.38	0.00	211.9	0.321E-01	2.25	9.80	2.25	0.00
999.04	0.38	0.00	212.8	0.320E-01	2.25	9.84	2.25	0.00

Table 1 (contd). CORMIX Prediction File for September 5, 2007 Q_a ~ 40,900 cfs.

1007.79	0.38	0.00	213.7	0.318E-01	2.25	9.88	2.25	0.00
1191.42	0.38	0.00	232.4	0.293E-01	2.25	10.74	2.25	0.00
1200.17	0.38	0.00	233.2	0.292E-01	2.25	10.78	2.25	0.00
1305.10	0.38	0.00	243.2	0.280E-01	2.25	11.24	2.25	0.00
1401.29	0.38	0.00	252.0	0.270E-01	2.25	11.65	2.25	0.00
1707.36	0.38	0.00	278.1	0.245E-01	2.25	12.86	2.25	0.00
1716.10	0.38	0.00	278.8	0.244E-01	2.25	12.89	2.25	0.00
1724.85	0.38	0.00	279.5	0.243E-01	2.25	12.92	2.25	0.00
1733.59	0.38	0.00	280.2	0.243E-01	2.25	12.96	2.25	0.00
1742.34	0.38	0.00	280.9	0.242E-01	2.25	12.99	2.25	0.00
1751.08	0.38	0.00	281.6	0.241E-01	2.25	13.02	2.25	0.00
1759.82	0.38	0.00	282.3	0.241E-01	2.25	13.05	2.25	0.00
1768.57	0.38	0.00	283.0	0.240E-01	2.25	13.09	2.25	0.00
1777.31	0.38	0.00	283.7	0.240E-01	2.25	13.12	2.25	0.00
1786.06	0.38	0.00	284.4	0.239E-01	2.25	13.15	2.25	0.00
1794.80	0.38	0.00	285.1	0.239E-01	2.25	13.18	2.25	0.00
1803.55	0.38	0.00	285.8	0.238E-01	2.25	13.21	2.25	0.00
1812.29	0.38	0.00	286.5	0.237E-01	2.25	13.25	2.25	0.00
1821.04	0.38	0.00	287.2	0.237E-01	2.25	13.28	2.25	0.00
1829.78	0.38	0.00	287.9	0.236E-01	2.25	13.31	2.25	0.00
1908.48	0.38	0.00	294.0	0.231E-01	2.25	13.59	2.25	0.00
2004.67	0.38	0.00	301.3	0.226E-01	2.25	13.93	2.25	0.00
2503.12	0.38	0.00	336.6	0.202E-01	2.25	15.56	2.25	0.00
3001.56	0.38	0.00	368.6	0.184E-01	2.25	17.04	2.25	0.00
3500.01	0.38	0.00	398.0	0.171E-01	2.25	18.40	2.25	0.00

```
Cumulative travel time =        2380.3855 sec

Simulation limit based on maximum specified distance =    3500.00 m.
  This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
```

Table 2. CORMIX Prediction File for Ambient Low Flow Condition $Q_a \approx 36{,}000$ cfs.

```
CORMIX1: Single Port Discharges              End of Prediction File
11111111111111111111111111111111111111111111111111111111111111111111111111111

CORMIX1 PREDICTION FILE:
11111111111111111111111111111111111111111111111111111111111111111111111111111
                       CORMIX MIXING ZONE EXPERT SYSTEM
             Subsystem CORMIX1:  Single Port Discharges
                         CORMIX Version 5.0GTR
                      HYDRO1 Version 5.0.1.0 August 2007
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:
 Design case:        Low Flow
 FILE NAME:          C:\...Northwest\Energy NW  Ambient Low Flow 36 Kcfs.prd
 Time stamp:         Wed Oct 24 14:05:27 2007

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS     =    152.40  AS     =     316.99  QA     =     465.98  ICHREG= 1
 HA     =      2.08  HD     =       2.08
 UA     =     1.470  F      =      0.025  USTAR =0.8150E-01
 UW     =     2.000  UWSTAR=0.2198E-02
 Uniform density environment
 STRCND=  U          RHOAM =  998.3669
```

```
DISCHARGE PARAMETERS (metric units)
 BANK  =  RIGHT      DISTB =      53.34
 D0    =       0.486 A0    =       0.186 H0     =       0.30  SUB0   =       1.78
 THETA =     20.00   SIGMA =     90.00
 U0    =       1.293 Q0    =       0.240        =0.2402E+00
 RHO0  =  996.7843   DRHO0 =0.1583E+01   GP0    =0.1555E-01
 C0    =0.6800E+01   CUNITS=  deg.C
 IPOLL =  1          KS    =0.0000E+00   KD     =0.0000E+00

FLUX VARIABLES (metric units)
 Q0    =0.2402E+00   M0    =0.3106E+00   J0     =0.3734E-02  SIGNJ0=       1.0
 Associated length scales (meters)
 LQ    =       0.43  LM    =       6.81  Lm     =       0.38  Lb     =       0.00
                                         Lmp    =   99999.00  Lbp    =   99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =     14.87   R     =      0.88

FLOW CLASSIFICATION
 111111111111111111111111111111111111111111
 1  Flow class (CORMIX1)      =    H2A2    1
 1  Applicable layer depth HS =     2.08   1
 111111111111111111111111111111111111111111
```

Table 2 (contd). CORMIX Prediction File for Ambient Low Flow Condition $Q_a \approx 36{,}000$ cfs.

```
MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    =0.6800E+01   CUNITS=  deg.C
 NTOX  =  0
 NSTD  =  1          CSTD  =0.3000E+00
 REGMZ =  1
 REGSPC=  1          XREG  =      93.27  WREG   =      0.00   AREG   =      0.00
 XINT  =    3500.00  XMAX  =    3500.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        53.34 m  from the RIGHT bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 400 display intervals per module
-----------------------------------------------------------------------------
```

```
-----------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

 WAKE ATTACHMENT immediately following the discharge.

      X         Y        Z         S        C        B
     0.00      0.00     0.00      1.0 0.680E+01    0.57

END OF MOD101: DISCHARGE MODULE
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
BEGIN MOD151: WAKE RECIRCULATION

  Control volume inflow:
      X         Y        Z         S        C        B
     0.00      0.00     0.00      1.0 0.680E+01    0.57

 Profile definitions:
   BV = top-hat thickness, measured vertically
   BH = top-hat half-width, measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
   S  = hydrodynamic average (bulk) dilution
   C  = average (bulk) concentration (includes reaction effects, if any)

      X         Y        Z         S        C        BV        BH       ZU       ZL
     0.00      0.38     0.00      1.0 0.680E+01    0.57      0.57     0.57     0.00
     0.22      0.38     0.00      1.1 0.608E+01    0.60      0.60     0.60     0.00
     0.43      0.38     0.00      1.4 0.470E+01    0.61      0.61     0.61     0.00
     0.65      0.38     0.00      1.9 0.356E+01    0.61      0.61     0.61     0.00
     0.86      0.38     0.00      2.4 0.280E+01    0.62      0.62     0.62     0.00
     1.08      0.38     0.00      2.9 0.234E+01    0.62      0.62     0.62     0.00
     1.29      0.38     0.00      3.3 0.206E+01    0.63      0.63     0.63     0.00
     1.51      0.38     0.00      3.6 0.189E+01    0.63      0.63     0.63     0.00
     1.72      0.38     0.00      3.8 0.180E+01    0.64      0.64     0.64     0.00
     1.94      0.38     0.00      3.9 0.174E+01    0.64      0.64     0.64     0.00
     2.16      0.38     0.00      4.0 0.169E+01    0.65      0.65     0.65     0.00
```

Table 2 (contd). CORMIX Prediction File for Ambient Low Flow Condition $Q_a \approx$ 36,000 cfs.

```
Cumulative travel time =            1.4662 sec

END OF MOD151: WAKE RECIRCULATION
-----------------------------------------------------------------------------
** End of NEAR-FIELD REGION (NFR) **
-----------------------------------------------------------------------------
BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

  Vertical diffusivity (initial value)   = 0.339E-01 m^2/s
  Horizontal diffusivity (initial value) = 0.424E-01 m^2/s

 Profile definitions:
```

```
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
   = or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
     measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S  = hydrodynamic centerline dilution
C  = centerline concentration (includes reaction effects, if any)
```

```
Plume Stage 1 (not bank attached):
      X          Y         Z          S        C        BV        BH        ZU        ZL
     2.16      0.38      0.00       4.0 0.169E+01    0.65      0.65      0.65      0.00
    10.90      0.38      0.00       8.3 0.818E+00    0.79      1.10      0.79      0.00
    19.64      0.38      0.00      13.2 0.516E+00    0.97      1.41      0.97      0.00
    28.39      0.38      0.00      18.7 0.364E+00    1.16      1.67      1.16      0.00
**WATER QUALITY STANDARD OR CCC HAS BEEN FOUND**
 The pollutant concentration in the plume falls below water quality standard
   or CCC value of 0.300E+00 in the current prediction interval.
 This is the spatial extent of concentrations exceeding the water quality
   standard or CCC value.
    37.13      0.38      0.00      24.7 0.276E+00    1.36      1.89      1.36      0.00
    45.88      0.38      0.00      30.9 0.220E+00    1.54      2.09      1.54      0.00
    54.62      0.38      0.00      37.3 0.182E+00    1.71      2.27      1.71      0.00
    63.37      0.38      0.00      43.8 0.155E+00    1.87      2.44      1.87      0.00
    72.11      0.38      0.00      50.3 0.135E+00    2.02      2.60      2.02      0.00
 Plume interacts with SURFACE.
 The passive diffusion plume becomes VERTICALLY FULLY MIXED within this
   prediction interval.
    80.86      0.38      0.00      54.9 0.124E+00    2.08      2.75      2.08      0.00
    89.60      0.38      0.00      57.7 0.118E+00    2.08      2.89      2.08      0.00
 ** REGULATORY MIXING ZONE BOUNDARY **
 In this prediction interval the plume DOWNSTREAM  distance meets or exceeds
 the regulatory value =     93.27 m.
 This is the extent of the REGULATORY MIXING ZONE.
    98.35      0.38      0.00      60.4 0.113E+00    2.08      3.02      2.08      0.00
   107.09      0.38      0.00      63.0 0.108E+00    2.08      3.15      2.08      0.00
   203.28      0.38      0.00      86.3 0.788E-01    2.08      4.32      2.08      0.00
   299.47      0.38      0.00     104.5 0.650E-01    2.08      5.23      2.08      0.00
```

Table 2 (contd). CORMIX Prediction File for Ambient Low Flow Condition $Q_a \approx 36,000$ cfs.

```
   404.41      0.38      0.00     121.4 0.560E-01    2.08      6.07      2.08      0.00
   500.60      0.38      0.00     134.9 0.504E-01    2.08      6.75      2.08      0.00
   605.53      0.38      0.00     148.3 0.458E-01    2.08      7.42      2.08      0.00
   701.72      0.38      0.00     159.6 0.426E-01    2.08      7.99      2.08      0.00
   710.47      0.38      0.00     160.6 0.423E-01    2.08      8.03      2.08      0.00
```

```
  806.66      0.38     0.00    171.1 0.397E-01   2.08        8.56     2.08     0.00
  902.85      0.38     0.00    181.0 0.376E-01   2.08        9.05     2.08     0.00
  999.04      0.38     0.00    190.4 0.357E-01   2.08        9.52     2.08     0.00
 1103.98      0.38     0.00    200.1 0.340E-01   2.08       10.01     2.08     0.00
 1200.17      0.38     0.00    208.6 0.326E-01   2.08       10.44     2.08     0.00
 1305.10      0.38     0.00    217.5 0.313E-01   2.08       10.88     2.08     0.00
 1401.29      0.38     0.00    225.4 0.302E-01   2.08       11.27     2.08     0.00
 1506.23      0.38     0.00    233.7 0.291E-01   2.08       11.69     2.08     0.00
 1602.42      0.38     0.00    241.0 0.282E-01   2.08       12.05     2.08     0.00
 1794.80      0.38     0.00    255.1 0.267E-01   2.08       12.76     2.08     0.00
 1890.99      0.38     0.00    261.8 0.260E-01   2.08       13.09     2.08     0.00
 1899.74      0.38     0.00    262.4 0.259E-01   2.08       13.12     2.08     0.00
 2450.65      0.38     0.00    298.0 0.228E-01   2.08       14.90     2.08     0.00
 3001.56      0.38     0.00    329.7 0.206E-01   2.08       16.49     2.08     0.00
 3500.01      0.38     0.00    356.0 0.191E-01   2.08       17.81     2.08     0.00
Cumulative travel time =         2379.7263 sec

Simulation limit based on maximum specified distance =    3500.00 m.
  This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
CORMIX1: Single Port Discharges              End of Prediction File
11111111111111111111111111111111111111111111111111111111111111111111111111111
```

Table 1 presents CORMIX results for conditions observed during the field study with an ambient flowrate of approximately 40,900 cfs. Table 2 presents CORMIX results for the likely low flow regulatory condition of 36,000 cfs. Keeping ambient velocity constant, the stage of the river at low flow can be related to the observed values by the Manning relation:

$$HA_2 = HA_1 \, (Q_{a2}/Q_{a1})^{3/5} = 2.25 \, (36 \text{ kcfs}/40.9\text{kcfs}) \,)^{3/5} = 2.08 \text{ m}$$

CORMIX assigned a H2A2 flow class for the discharge for both ambient flow rates. This is a stable flow and is dynamically attached to bottom at exit. The flow creates a long, thin, "pencil plume" in the river. The pencil plume can be seen in Figure 5. The plume does not lift-off from the bottom attachment downstream due to buoyancy. The discharge flow becomes quickly deflected by the ambient flow and attaches to the bottom. A recirculation eddy exists in the lee of the discharge structure. Eventually, the plume will mix vertically in the water column 30 to 80 m downstream of the discharge.

Table 3 presents predicted and observed dilution at the site. Our FLIR A20M camera has a thermal sensitivity of 0.1 °C. Based on a discharge ΔT = 6.8 °C above ambient, the camera would not detect the plume if the dilution S at surface contact for S > 68. We did not detect any thermal signal at the surface, which would indicate a minimum dilution of at least S = 68 at plume surface contact. The CORMIX model predicts a plume surface temperature rise of ΔT = 0.108 °C at surface contact which occurs at 86 m downstream, as indicated in Table 1.

Table 3. Predicted vs. Observed Plume Excess Temperatures and Dilutions for September 5, 2007 $Q_a \approx$ 40,900 cfs.

Distance Downstream (m)	Excess Temperature ΔT °C (Dilution S)	
	Predicted	Measured
9.5	0.86 (6.5)	n/a (submerged)
93	0.10 (65.6)	< 0.10 (> 68)
1000	0.03 (213)	n/a

4. Results/Discussion

A field study was conducted to gather data on mixing characteristics of the Energy Northwest cooling water outfall into the Hanford reach. Site bathymetry, ambient velocity, and surface temperature data were collected by ADCP measurement. Mixing characteristics and temperature data near the outfall were observed by aerial remote sensing in conjunction with ADCP measurements. Modeling of the discharge using CORMIX v5.0 was conducted based on the collected ADCP site data

Table 4 shows CORMIX predictions for the regulatory mixing zone at the low ambient flow rate of 36,000 cfs. Table 4 shows the discharge will easily meet dilution requirements at the Regulatory Mixing Zone distance of 306 ft (93m) downstream. Predicted temperature rise at the RMZ is ΔT = 0.11 °C, less than the maximum temperature rise ΔT = 0.3 °C. CORMIX predicts the plume half-width at the RMZ of BH = 3.0 m, much less than the maximum half-width of 175 ft.

However it is not clear if the discharge as configured will meet Toxic Dilution Zone (TDZ) requirements at 31 ft (9.5 m) downstream if the required TDZ dilution is S = 11. The CORMIX model predicts TDZ S = 7.8. The discharge attaches to the bottom soon after exit, which limits initial dilution. TDZ dilution may be improved with an alternate discharge port design.

Table 4. Predicted vs. Required Mixing Zone Dilutions $Q_a \approx 36,000$ cfs.		
Distance Downstream (m)	Dilution S	
	Predicted	Required
9.5 (TDZ)	7.8	11
93 (RMZ)	59	50
1000	190	n/a

Both observational data and modeling indicated pencil plume that is quickly advected downstream by the ambient crossflow. Because of the "pencil plume" nature of the discharge and large river width at the site, the plume does not appear likely to cause fish passage problems for migrating species.

Since no surface signal was observed, we conclude that the CORMIX predictions for this case in the RMZ are conservative, i.e. CORMIX tends to slightly under predict dilution at surface contact for this discharge. We observed no visual or thermal signals indicating a plume with an upstream intrusion, and modeling results confirmed this discharge will not have an upstream intrusion.

CORMIX modeling of the mixing zone appears to be in overall general agreement with observed data, especially for larger distances away from the source. CORMIX generally will reasonably predict plume trajectory, dilution, and dimension.

Appendix B

CORMIX Prediction Files

B.1 Case 1

```
CORMIX1 PREDICTION FILE:
111111111111111111111111111111111111111111111111111111111111111111111111111111
                       CORMIX MIXING ZONE EXPERT SYSTEM
             Subsystem CORMIX1:  Single Port Discharges
                         CORMIX Version 5.0GTR
                      HYDRO1 Version 5.0.1.0 December 2007
------------------------------------------------------------------------------
------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:   Case 1 Chronic
 Design case:       7Q10 Low Flow -Revised
 FILE NAME:         C:\...cal 7Q10 Low Chronic Q0 2986 gpm QA 52.7 kcfs.prd
 Time stamp:        Tue Jun  3 12:55:40 2008

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS     =     152.40 AS     =     399.29 QA     =     650.84  ICHREG= 1
 HA     =       2.62 HD     =       2.62
 UA     =      1.630 F      =      0.036 USTAR =0.1087E+00
 UW     =      2.000 UWSTAR=0.2198E-02
 Uniform density environment
 STRCND=  U          RHOAM =  997.7714

DISCHARGE PARAMETERS (metric units)
 BANK  =  RIGHT      DISTB =      53.34
 D0    =      0.459 A0    =      0.165 H0    =       0.15  SUB0  =       2.47
 THETA =      20.00 SIGMA =      90.00
 U0    =      1.139 Q0    =      0.188        =0.1884E+00
 RHO0  =  995.7672  DRHO0 =0.2004E+01  GP0   =0.1970E-01
 C0    =0.7600E+01  CUNITS=  deg.C
 IPOLL =  1         KS    =0.0000E+00  KD    =0.0000E+00

FLUX VARIABLES (metric units)
 Q0    =0.1884E+00  M0    =0.2147E+00  J0    =0.3712E-02  SIGNJ0=       1.0
 Associated length scales (meters)
 LQ    =      0.41  LM    =      5.18  Lm    =       0.28  Lb    =      0.00
                                       Lmp   =   99999.00  Lbp   =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =     11.98  R     =      0.70

FLOW CLASSIFICATION
 111111111111111111111111111111111111111111
 1  Flow class (CORMIX1)      =   H2A2   1
 1  Applicable layer depth HS =    2.62  1
 111111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    =0.7600E+01  CUNITS=  deg.C
 NTOX  =  0
 NSTD  =  0
 REGMZ =  1
 REGSPC=  1         XREG  =     93.27  WREG  =      0.00  AREG  =      0.00
 XINT  =   1600.00  XMAX  =   1600.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        53.34 m  from the RIGHT bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP =  10 display intervals per module
```

```
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

 WAKE ATTACHMENT immediately following the discharge.

       X        Y        Z         S        C        B
      0.00     0.00     0.00      1.0 0.760E+01    0.48

END OF MOD101: DISCHARGE MODULE
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
BEGIN MOD151: WAKE RECIRCULATION

  Control volume inflow:
       X        Y        Z         S        C        B
      0.00     0.00     0.00      1.0 0.760E+01    0.48

 Profile definitions:
   BV = top-hat thickness, measured vertically
   BH = top-hat half-width, measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
   S  = hydrodynamic average (bulk) dilution
   C  = average (bulk) concentration (includes reaction effects, if any)

       X        Y        Z         S        C       BV        BH       ZU       ZL
      0.00     0.28     0.00      1.0 0.760E+01    0.48      0.48     0.48     0.00
      0.20     0.28     0.00      1.2 0.656E+01    0.52      0.52     0.52     0.00
      0.41     0.28     0.00      1.6 0.475E+01    0.54      0.54     0.54     0.00
      0.61     0.28     0.00      2.2 0.341E+01    0.55      0.55     0.55     0.00
      0.81     0.28     0.00      2.9 0.261E+01    0.56      0.56     0.56     0.00
      1.02     0.28     0.00      3.6 0.213E+01    0.57      0.57     0.57     0.00
      1.22     0.28     0.00      4.1 0.186E+01    0.58      0.58     0.58     0.00
      1.42     0.28     0.00      4.5 0.169E+01    0.59      0.59     0.59     0.00
      1.63     0.28     0.00      4.7 0.160E+01    0.60      0.60     0.60     0.00
      1.83     0.28     0.00      4.9 0.155E+01    0.60      0.60     0.60     0.00
      2.03     0.28     0.00      5.1 0.150E+01    0.61      0.61     0.61     0.00
 Cumulative travel time =          1.2474 sec

END OF MOD151: WAKE RECIRCULATION
-----------------------------------------------------------------------------
** End of NEAR-FIELD REGION (NFR) **
-----------------------------------------------------------------------------
BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

  Vertical diffusivity (initial value)   = 0.570E-01 m^2/s
  Horizontal diffusivity (initial value) = 0.712E-01 m^2/s

 Profile definitions:
   BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
      = or equal to layer depth, if fully mixed
   BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
        measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
   S  = hydrodynamic centerline dilution
   C  = centerline concentration (includes reaction effects, if any)

 Plume Stage 1 (not bank attached):
       X        Y        Z         S        C       BV        BH       ZU       ZL
      2.03     0.28     0.00      5.1 0.150E+01    0.61      0.61     0.61     0.00
 ** REGULATORY MIXING ZONE BOUNDARY **
```

```
In this prediction interval the plume DOWNSTREAM  distance meets or exceeds
the regulatory value =     93.27 m.
This is the extent of the REGULATORY MIXING ZONE.
   161.83      0.28      0.00     94.8 0.802E-01   1.48      4.72     1.48     0.00
   321.63      0.28      0.00    159.9 0.475E-01   1.77      6.65     1.77     0.00
   481.42      0.28      0.00    255.3 0.298E-01   2.31      8.13     2.31     0.00
Plume interacts with SURFACE.
The passive diffusion plume becomes VERTICALLY FULLY MIXED within this
  prediction interval.
   641.22      0.28      0.00    334.1 0.227E-01   2.62      9.39     2.62     0.00
   801.02      0.28      0.00    373.4 0.204E-01   2.62     10.49     2.62     0.00
   960.81      0.28      0.00    408.9 0.186E-01   2.62     11.49     2.62     0.00
  1120.61      0.28      0.00    441.6 0.172E-01   2.62     12.40     2.62     0.00
  1280.41      0.28      0.00    472.0 0.161E-01   2.62     13.26     2.62     0.00
  1440.20      0.28      0.00    500.6 0.152E-01   2.62     14.06     2.62     0.00
  1600.00      0.28      0.00    527.7 0.144E-01   2.62     14.82     2.62     0.00
Cumulative travel time =         981.3114 sec

Simulation limit based on maximum specified distance =   1600.00 m.
  This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
CORMIX1: Single Port Discharges              End of Prediction File
11111111111111111111111111111111111111111111111111111111111111111111111111111
```

B.2 Case 2

```
CORMIX1 PREDICTION FILE:
11111111111111111111111111111111111111111111111111111111111111111111111111111
                       CORMIX MIXING ZONE EXPERT SYSTEM
             Subsystem CORMIX1:  Single Port Discharges
                         CORMIX Version 5.0GTR
                      HYDRO1 Version 5.0.1.0 December 2007
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:    Case 2 Acute
 Design case:        7Q10 Low Flow -Revised
 FILE NAME:          C:\...tical 7Q10 Low Acute Q0 4097 gpm QA 52.7 kcfs.prd
 Time stamp:         Tue Jun  3 12:55:57 2008

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS     =     152.40 AS     =     399.29 QA     =     650.84  ICHREG= 1
 HA     =       2.62 HD     =       2.62
 UA     =      1.630 F      =      0.036 USTAR =0.1087E+00
 UW     =      2.000 UWSTAR=0.2198E-02
 Uniform density environment
 STRCND=  U          RHOAM =  997.7714

DISCHARGE PARAMETERS (metric units)
 BANK   =  RIGHT     DISTB =      53.34
 D0     =      0.459 A0     =      0.165 H0     =       0.15  SUB0   =       2.47
 THETA =      20.00 SIGMA =      90.00
 U0     =      1.563 Q0     =      0.259        =0.2585E+00
 RHO0   =  995.7672  DRHO0 =0.2004E+01  GP0    =0.1970E-01
 C0     =0.7600E+01  CUNITS=  deg.C
 IPOLL =  1          KS     =0.0000E+00  KD     =0.0000E+00

FLUX VARIABLES (metric units)
 Q0     =0.2585E+00  M0     =0.4041E+00  J0     =0.5092E-02  SIGNJ0=       1.0
 Associated length scales (meters)
 LQ     =       0.41 LM     =       7.10 Lm     =       0.39  Lb     =       0.00
                                         Lmp    =   99999.00  Lbp    =   99999.00

NON-DIMENSIONAL PARAMETERS
 FR0    =      16.44 R      =       0.96

FLOW CLASSIFICATION
 111111111111111111111111111111111111111111
 1  Flow class (CORMIX1)       =    H2A2   1
 1  Applicable layer depth HS =     2.62   1
 111111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0     =0.7600E+01  CUNITS=  deg.C
 NTOX   =  0
 NSTD   =  0
 REGMZ =  1
 REGSPC=  1          XREG   =      93.27  WREG   =       0.00  AREG   =       0.00
 XINT   =    1600.00 XMAX   =    1600.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        53.34 m  from the RIGHT bank/shore.
```

```
   X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP =  10 display intervals per module
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

 WAKE ATTACHMENT immediately following the discharge.

       X         Y        Z         S        C        B
      0.00      0.00     0.00      1.0 0.760E+01   0.56

END OF MOD101: DISCHARGE MODULE
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
BEGIN MOD151: WAKE RECIRCULATION

  Control volume inflow:
       X         Y        Z         S        C        B
      0.00      0.00     0.00      1.0 0.760E+01   0.56

 Profile definitions:
   BV = top-hat thickness, measured vertically
   BH = top-hat half-width, measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
   S  = hydrodynamic average (bulk) dilution
   C  = average (bulk) concentration (includes reaction effects, if any)

       X         Y        Z         S        C        BV        BH       ZU       ZL
      0.00      0.39     0.00      1.0 0.760E+01   0.56      0.56     0.56     0.00
      0.20      0.39     0.00      1.1 0.688E+01   0.58      0.58     0.58     0.00
      0.41      0.39     0.00      1.4 0.544E+01   0.58      0.58     0.58     0.00
      0.61      0.39     0.00      1.8 0.419E+01   0.59      0.59     0.59     0.00
      0.81      0.39     0.00      2.3 0.335E+01   0.59      0.59     0.59     0.00
      1.02      0.39     0.00      2.7 0.282E+01   0.60      0.60     0.60     0.00
      1.22      0.39     0.00      3.0 0.249E+01   0.60      0.60     0.60     0.00
      1.42      0.39     0.00      3.3 0.230E+01   0.60      0.60     0.60     0.00
      1.63      0.39     0.00      3.5 0.219E+01   0.61      0.61     0.61     0.00
      1.83      0.39     0.00      3.6 0.212E+01   0.61      0.61     0.61     0.00
      2.03      0.39     0.00      3.7 0.206E+01   0.61      0.61     0.61     0.00
 Cumulative travel time =          1.2474 sec

END OF MOD151: WAKE RECIRCULATION
-----------------------------------------------------------------------------
** End of NEAR-FIELD REGION (NFR) **
-----------------------------------------------------------------------------
BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

  Vertical diffusivity (initial value)   = 0.570E-01 m^2/s
  Horizontal diffusivity (initial value) = 0.712E-01 m^2/s

 Profile definitions:
   BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
      = or equal to layer depth, if fully mixed
   BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
        measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
   S  = hydrodynamic centerline dilution
   C  = centerline concentration (includes reaction effects, if any)

 Plume Stage 1 (not bank attached):
       X         Y        Z         S        C        BV        BH       ZU       ZL
```

```
    2.03      0.39    0.00      3.7 0.206E+01   0.61      0.61     0.61     0.00
** REGULATORY MIXING ZONE BOUNDARY **
In this prediction interval the plume DOWNSTREAM  distance meets or exceeds
the regulatory value =     93.27 m.
This is the extent of the REGULATORY MIXING ZONE.
   161.83     0.39    0.00     57.6 0.132E+00   1.23      4.72     1.23     0.00
   321.63     0.39    0.00     94.1 0.808E-01   1.43      6.65     1.43     0.00
   481.42     0.39    0.00    144.6 0.526E-01   1.80      8.13     1.80     0.00
   641.22     0.39    0.00    225.9 0.336E-01   2.43      9.38     2.43     0.00
Plume interacts with SURFACE.
The passive diffusion plume becomes VERTICALLY FULLY MIXED within this
  prediction interval.
   801.02     0.39    0.00    272.1 0.279E-01   2.62     10.49     2.62     0.00
   960.81     0.39    0.00    298.0 0.255E-01   2.62     11.49     2.62     0.00
  1120.61     0.39    0.00    321.9 0.236E-01   2.62     12.40     2.62     0.00
  1280.41     0.39    0.00    344.0 0.221E-01   2.62     13.26     2.62     0.00
  1440.20     0.39    0.00    364.8 0.208E-01   2.62     14.06     2.62     0.00
  1600.00     0.39    0.00    384.5 0.198E-01   2.62     14.82     2.62     0.00
Cumulative travel time =          981.2059 sec

Simulation limit based on maximum specified distance =    1600.00 m.
  This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
CORMIX1: Single Port Discharges              End of Prediction File
11111111111111111111111111111111111111111111111111111111111111111111111111111
```

B.3 Case 3

```
CORMIX1 PREDICTION FILE:
11111111111111111111111111111111111111111111111111111111111111111111111111111
                       CORMIX MIXING ZONE EXPERT SYSTEM
             Subsystem CORMIX1:  Single Port Discharges
                         CORMIX Version 5.0GTR
                      HYDRO1 Version 5.0.1.0 December 2007
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:    Case 3 Chronic
 Design case:        WAC-173-563 Low Flow -Revised
 FILE NAME:          C:\...C-173-563 Case Chronic Q0 2986 gpm QA 36 kcfs.prd
 Time stamp:         Tue Jun  3 14:08:42 2008

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS     =    152.40  AS     =    320.04  QA     =    448.06  ICHREG= 1
 HA     =      2.10  HD     =      2.10
 UA     =     1.400  F      =     0.038  USTAR =0.9687E-01
 UW     =     2.000  UWSTAR=0.2198E-02
 Uniform density environment
 STRCND=  U          RHOAM =  997.7714

DISCHARGE PARAMETERS (metric units)
 BANK  =  RIGHT      DISTB =     53.34
 D0    =      0.459  A0    =     0.165  H0     =      0.15  SUB0   =      1.95
 THETA =     20.00   SIGMA =     90.00
 U0    =      1.139  Q0    =     0.188        =0.1884E+00
 RHO0  =  995.7672   DRHO0 =0.2004E+01  GP0    =0.1970E-01
 C0    =0.7600E+01   CUNITS=  deg.C
 IPOLL =  1          KS    =0.0000E+00  KD     =0.0000E+00

FLUX VARIABLES (metric units)
 Q0    =0.1884E+00   M0    =0.2147E+00  J0     =0.3712E-02  SIGNJ0=      1.0
 Associated length scales (meters)
 LQ    =      0.41   LM    =      5.18  Lm     =      0.33  Lb     =     0.00
                                        Lmp    =  99999.00  Lbp    = 99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =     11.98   R     =      0.81

FLOW CLASSIFICATION
 111111111111111111111111111111111111111111
 1  Flow class (CORMIX1)        =     H2A2   1
 1  Applicable layer depth HS =     2.10   1
 111111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    =0.7600E+01   CUNITS=  deg.C
 NTOX  =  0
 NSTD  =  0
 REGMZ =  1
 REGSPC=  1          XREG  =     93.27  WREG   =      0.00  AREG   =     0.00
 XINT  =    1600.00  XMAX  =   1600.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        53.34 m  from the RIGHT bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP =  10 display intervals per module
```

```
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

 WAKE ATTACHMENT immediately following the discharge.

       X         Y        Z         S        C         B
      0.00      0.00     0.00      1.0 0.760E+01   0.52

END OF MOD101: DISCHARGE MODULE
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
BEGIN MOD151: WAKE RECIRCULATION

  Control volume inflow:
       X         Y        Z         S        C         B
      0.00      0.00     0.00      1.0 0.760E+01   0.52

 Profile definitions:
   BV = top-hat thickness, measured vertically
   BH = top-hat half-width, measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
   S  = hydrodynamic average (bulk) dilution
   C  = average (bulk) concentration (includes reaction effects, if any)

       X         Y        Z         S        C         BV        BH       ZU       ZL
      0.00      0.33     0.00      1.0 0.760E+01   0.52      0.52     0.52     0.00
      0.20      0.33     0.00      1.1 0.672E+01   0.55      0.55     0.55     0.00
      0.41      0.33     0.00      1.5 0.509E+01   0.56      0.56     0.56     0.00
      0.61      0.33     0.00      2.0 0.378E+01   0.57      0.57     0.57     0.00
      0.81      0.33     0.00      2.6 0.295E+01   0.58      0.58     0.58     0.00
      1.02      0.33     0.00      3.1 0.244E+01   0.58      0.58     0.58     0.00
      1.22      0.33     0.00      3.6 0.214E+01   0.59      0.59     0.59     0.00
      1.42      0.33     0.00      3.9 0.196E+01   0.60      0.60     0.60     0.00
      1.63      0.33     0.00      4.1 0.186E+01   0.60      0.60     0.60     0.00
      1.83      0.33     0.00      4.2 0.180E+01   0.61      0.61     0.61     0.00
      2.03      0.33     0.00      4.3 0.175E+01   0.61      0.61     0.61     0.00
 Cumulative travel time =          1.4523 sec

END OF MOD151: WAKE RECIRCULATION
--------------------------------------------------------------------------------
** End of NEAR-FIELD REGION (NFR) **
--------------------------------------------------------------------------------
BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

  Vertical diffusivity (initial value)    = 0.407E-01 m^2/s
  Horizontal diffusivity (initial value) = 0.509E-01 m^2/s

 Profile definitions:
   BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
      = or equal to layer depth, if fully mixed
   BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
        measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
   S  = hydrodynamic centerline dilution
   C  = centerline concentration (includes reaction effects, if any)

 Plume Stage 1 (not bank attached):
       X         Y        Z         S        C         BV        BH       ZU       ZL
      2.03      0.33     0.00      4.3 0.175E+01   0.61      0.61     0.61     0.00
 ** REGULATORY MIXING ZONE BOUNDARY **
```

```
In this prediction interval the plume DOWNSTREAM  distance meets or exceeds
the regulatory value =     93.27 m.
This is the extent of the REGULATORY MIXING ZONE.
   161.83      0.33      0.00      70.3 0.108E+00   1.40      4.31     1.40      0.00
   321.63      0.33      0.00     123.6 0.615E-01   1.75      6.07     1.75·     0.00
Plume interacts with SURFACE.
The passive diffusion plume becomes VERTICALLY FULLY MIXED within this
  prediction interval.
   481.42      0.33      0.00     181.9 0.418E-01   2.10      7.42     2.10      0.00
   641.22      0.33      0.00     209.8 0.362E-01   2.10      8.56     2.10      0.00
   801.02      0.33      0.00     234.5 0.324E-01   2.10      9.57     2.10      0.00
   960.81      0.33      0.00     256.8 0.296E-01   2.10     10.48     2.10      0.00
  1120.61      0.33      0.00     277.3 0.274E-01   2.10     11.31     2.10      0.00
  1280.41      0.33      0.00     296.4 0.256E-01   2.10     12.09     2.10      0.00
  1440.20      0.33      0.00     314.3 0.242E-01   2.10     12.82     2.10      0.00
  1600.00      0.33      0.00     331.3 0.229E-01   2.10     13.52     2.10      0.00
Cumulative travel time =        1142.3773 sec

Simulation limit based on maximum specified distance =    1600.00 m.
  This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
CORMIX1: Single Port Discharges              End of Prediction File
11111111111111111111111111111111111111111111111111111111111111111111111111111
```

B.4 Case 4

```
CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111
                       CORMIX MIXING ZONE EXPERT SYSTEM
             Subsystem CORMIX1:  Single Port Discharges
                         CORMIX Version 5.0GTR
                      HYDRO1 Version 5.0.1.0 December 2007
----------------------------------------------------------------------------
----------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:    Case 4 Acute
 Design case:        WAC-173-563 Low Flow -Revised
 FILE NAME:          C:\...AC-173-563 Case Acute  Q0 4097 gpm QA 36 kcfs.prd
 Time stamp:         Tue Jun  3 13:23:54 2008

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =    152.40  AS     =     320.04  QA     =    448.06  ICHREG= 1
 HA    =      2.10  HD     =       2.10
 UA    =     1.400  F      =      0.038  USTAR =0.9687E-01
 UW    =     2.000  UWSTAR=0.2198E-02
 Uniform density environment
 STRCND=  U         RHOAM =   997.7714

DISCHARGE PARAMETERS (metric units)
 BANK  =  RIGHT     DISTB =      53.34
 D0    =     0.459  A0     =      0.165  H0     =      0.15  SUB0   =      1.95
 THETA =     20.00  SIGMA  =      90.00
 U0    =     1.563  Q0     =      0.259         =0.2585E+00
 RHO0  =  995.7672  DRHO0 =0.2004E+01  GP0    =0.1970E-01
 C0    =0.7600E+01  CUNITS=  deg.C
 IPOLL =  1         KS     =0.0000E+00  KD     =0.0000E+00

FLUX VARIABLES (metric units)
 Q0    =0.2585E+00  M0     =0.4041E+00  J0     =0.5092E-02  SIGNJ0=      1.0
 Associated length scales (meters)
 LQ    =      0.41  LM     =       7.10  Lm     =      0.45  Lb     =      0.00
                                         Lmp    =  99999.00  Lbp    =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =     16.44  R      =       1.12

FLOW CLASSIFICATION
 111111111111111111111111111111111111111111
 1  Flow class (CORMIX1)       =    H2A2   1
 1  Applicable layer depth HS =     2.10   1
 111111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    =0.7600E+01  CUNITS=  deg.C
 NTOX  =  0
 NSTD  =  0
 REGMZ =  1
 REGSPC=  1         XREG   =      93.27  WREG   =      0.00  AREG   =      0.00
 XINT  =   1600.00  XMAX   =    1600.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        53.34 m  from the RIGHT bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP =  10 display intervals per module
```

```
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

 WAKE ATTACHMENT immediately following the discharge.

       X         Y        Z         S        C        B
      0.00      0.00     0.00      1.0 0.760E+01   0.61

END OF MOD101: DISCHARGE MODULE
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
BEGIN MOD151: WAKE RECIRCULATION

  Control volume inflow:
       X         Y        Z         S        C        B
      0.00      0.00     0.00      1.0 0.760E+01   0.61

 Profile definitions:
   BV = top-hat thickness, measured vertically
   BH = top-hat half-width, measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
   S  = hydrodynamic average (bulk) dilution
   C  = average (bulk) concentration (includes reaction effects, if any)

       X         Y        Z         S        C        BV       BH       ZU       ZL
      0.00      0.45     0.00      1.0 0.760E+01   0.61     0.61     0.61     0.00
      0.20      0.45     0.00      1.1 0.701E+01   0.61     0.61     0.61     0.00
      0.41      0.45     0.00      1.3 0.576E+01   0.61     0.61     0.61     0.00
      0.61      0.45     0.00      1.7 0.459E+01   0.61     0.61     0.61     0.00
      0.81      0.45     0.00      2.0 0.376E+01   0.61     0.61     0.61     0.00
      1.02      0.45     0.00      2.4 0.321E+01   0.61     0.61     0.61     0.00
      1.22      0.45     0.00      2.7 0.287E+01   0.61     0.61     0.61     0.00
      1.42      0.45     0.00      2.9 0.266E+01   0.61     0.61     0.61     0.00
      1.63      0.45     0.00      3.0 0.254E+01   0.61     0.61     0.61     0.00
      1.83      0.45     0.00      3.1 0.247E+01   0.61     0.61     0.61     0.00
      2.03      0.45     0.00      3.2 0.240E+01   0.61     0.61     0.61     0.00
 Cumulative travel time =          1.4523 sec

END OF MOD151: WAKE RECIRCULATION
-----------------------------------------------------------------------------
** End of NEAR-FIELD REGION (NFR) **
-----------------------------------------------------------------------------
BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

  Vertical diffusivity (initial value)   = 0.407E-01 m^2/s
  Horizontal diffusivity (initial value) = 0.509E-01 m^2/s

 Profile definitions:
   BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
      = or equal to layer depth, if fully mixed
   BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
        measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
   S  = hydrodynamic centerline dilution
   C  = centerline concentration (includes reaction effects, if any)

 Plume Stage 1 (not bank attached):
       X         Y        Z         S        C        BV       BH       ZU       ZL
      2.03      0.45     0.00      3.2 0.240E+01   0.61     0.61     0.61     0.00
 ** REGULATORY MIXING ZONE BOUNDARY **
```

```
 In this prediction interval the plume DOWNSTREAM  distance meets or exceeds
 the regulatory value =     93.27 m.
 This is the extent of the REGULATORY MIXING ZONE.
    161.83       0.45      0.00      43.2 0.176E+00   1.18       4.31      1.18      0.00
    321.63       0.45      0.00      73.1 0.104E+00   1.42       6.07      1.42      0.00
    481.42       0.45      0.00     118.6 0.641E-01   1.88       7.42      1.88      0.00
 Plume interacts with SURFACE.
 The passive diffusion plume becomes VERTICALLY FULLY MIXED within this
   prediction interval.
    641.22       0.45      0.00     152.9 0.497E-01   2.10       8.56      2.10      0.00
    801.02       0.45      0.00     170.9 0.445E-01   2.10       9.57      2.10      0.00
    960.81       0.45      0.00     187.1 0.406E-01   2.10      10.48      2.10      0.00
   1120.61       0.45      0.00     202.1 0.376E-01   2.10      11.31      2.10      0.00
   1280.41       0.45      0.00     216.0 0.352E-01   2.10      12.09      2.10      0.00
   1440.20       0.45      0.00     229.1 0.332E-01   2.10      12.82      2.10      0.00
   1600.00       0.45      0.00     241.4 0.315E-01   2.10      13.52      2.10      0.00
 Cumulative travel time =        1142.1990 sec

 Simulation limit based on maximum specified distance =    1600.00 m.
   This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
CORMIX1: Single Port Discharges              End of Prediction File
11111111111111111111111111111111111111111111111111111111111111111111111111111
```

B.5 Case 5

```
CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111
                       CORMIX MIXING ZONE EXPERT SYSTEM
             Subsystem CORMIX1:  Single Port Discharges
                         CORMIX Version 5.0GTR
                      HYDRO1 Version 5.0.1.0 December 2007
----------------------------------------------------------------------------
----------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:   Case 5
 Design case:       Worst Case Low Flow -Revised
 FILE NAME:         C:\...e 5 Worst Case Chronic Q0 6528 gpm QA 36 kcfs.prd
 Time stamp:        Tue Jun  3 14:12:47 2008

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS     =      152.40  AS     =      320.04  QA     =      448.06  ICHREG= 1
 HA     =        2.10  HD     =        2.10
 UA     =       1.400  F      =       0.038  USTAR =0.9687E-01
 UW     =       2.000  UWSTAR=0.2198E-02
 Uniform density environment
 STRCND=  U            RHOAM =  997.7714

DISCHARGE PARAMETERS (metric units)
 BANK  =  RIGHT        DISTB =      53.34
 D0     =       0.459  A0     =       0.165  H0     =       0.15  SUB0   =       1.95
 THETA =       20.00  SIGMA =       90.00
 U0     =       2.491  Q0     =       0.412         =0.4119E+00
 RHO0  =  995.7672  DRHO0 =0.2004E+01  GP0    =0.1970E-01
 C0     =0.7600E+01  CUNITS=  deg.C
 IPOLL =  1            KS     =0.0000E+00  KD     =0.0000E+00

FLUX VARIABLES (metric units)
 Q0     =0.4119E+00  M0     =0.1026E+01  J0     =0.8114E-02  SIGNJ0=       1.0
 Associated length scales (meters)
 LQ     =        0.41  LM     =       11.32  Lm     =       0.72  Lb     =       0.00
                                             Lmp    =   99999.00  Lbp    =   99999.00

NON-DIMENSIONAL PARAMETERS
 FR0    =       26.20  R      =        1.78

FLOW CLASSIFICATION
 111111111111111111111111111111111111111111
 1  Flow class (CORMIX1)       =     H2A2   1
 1  Applicable layer depth HS =     2.10   1
 111111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0     =0.7600E+01  CUNITS=  deg.C
 NTOX   =  0
 NSTD   =  0
 REGMZ =  1
 REGSPC=  1            XREG   =       93.27  WREG   =       0.00  AREG   =       0.00
 XINT   =    1600.00  XMAX   =    1600.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        53.34 m  from the RIGHT bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP =  10 display intervals per module
```

```
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

 WAKE ATTACHMENT immediately following the discharge.

       X         Y        Z         S        C        B
     0.00      0.00     0.00      1.0 0.760E+01    0.77

END OF MOD101: DISCHARGE MODULE
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
BEGIN MOD151: WAKE RECIRCULATION

  Control volume inflow:
       X         Y        Z         S        C        B
     0.00      0.00     0.00      1.0 0.760E+01    0.77

 Profile definitions:
   BV = top-hat thickness, measured vertically
   BH = top-hat half-width, measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
   S  = hydrodynamic average (bulk) dilution
   C  = average (bulk) concentration (includes reaction effects, if any)

       X         Y        Z         S        C        BV        BH       ZU       ZL
     0.00      0.72     0.00      1.0 0.760E+01    0.77      0.77     0.77     0.00
     0.20      0.72     0.00      1.0 0.732E+01    0.72      0.72     0.72     0.00
     0.41      0.72     0.00      1.1 0.663E+01    0.70      0.70     0.70     0.00
     0.61      0.72     0.00      1.3 0.585E+01    0.68      0.68     0.68     0.00
     0.81      0.72     0.00      1.5 0.518E+01    0.67      0.67     0.67     0.00
     1.02      0.72     0.00      1.6 0.468E+01    0.66      0.66     0.66     0.00
     1.22      0.72     0.00      1.8 0.434E+01    0.65      0.65     0.65     0.00
     1.42      0.72     0.00      1.8 0.411E+01    0.64      0.64     0.64     0.00
     1.63      0.72     0.00      1.9 0.398E+01    0.63      0.63     0.63     0.00
     1.83      0.72     0.00      1.9 0.390E+01    0.62      0.62     0.62     0.00
     2.03      0.72     0.00      2.0 0.383E+01    0.61      0.61     0.61     0.00
 Cumulative travel time =         1.4523 sec

END OF MOD151: WAKE RECIRCULATION
-----------------------------------------------------------------------------
** End of NEAR-FIELD REGION (NFR) **
-----------------------------------------------------------------------------
BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

  Vertical diffusivity (initial value)   = 0.407E-01 m^2/s
  Horizontal diffusivity (initial value) = 0.509E-01 m^2/s

 Profile definitions:
   BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
      = or equal to layer depth, if fully mixed
   BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
        measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
   S  = hydrodynamic centerline dilution
   C  = centerline concentration (includes reaction effects, if any)

 Plume Stage 1 (not bank attached):
       X         Y        Z         S        C        BV        BH       ZU       ZL
     2.03      0.72     0.00      2.0 0.383E+01    0.61      0.61     0.61     0.00
 ** REGULATORY MIXING ZONE BOUNDARY **
```

```
 In this prediction interval the plume DOWNSTREAM  distance meets or exceeds
 the regulatory value =    93.27 m.
 This is the extent of the REGULATORY MIXING ZONE.
    161.83      0.72     0.00     21.7 0.350E+00   0.94      4.31     0.94     0.00
    321.63      0.72     0.00     34.7 0.219E+00   1.07      6.07     1.07     0.00
    481.42      0.72     0.00     51.8 0.147E+00   1.31      7.42     1.31     0.00
    641.22      0.72     0.00     79.1 0.961E-01   1.73      8.56     1.73     0.00
 Plume interacts with SURFACE.
 The passive diffusion plume becomes VERTICALLY FULLY MIXED within this
   prediction interval.
    801.02      0.72     0.00    107.2 0.709E-01   2.10      9.57     2.10     0.00
    960.81      0.72     0.00    117.4 0.647E-01   2.10     10.47     2.10     0.00
   1120.61      0.72     0.00    126.8 0.599E-01   2.10     11.31     2.10     0.00
   1280.41      0.72     0.00    135.5 0.561E-01   2.10     12.09     2.10     0.00
   1440.20      0.72     0.00    143.7 0.529E-01   2.10     12.82     2.10     0.00
   1600.00      0.72     0.00    151.5 0.502E-01   2.10     13.51     2.10     0.00
 Cumulative travel time =        1141.8087 sec

 Simulation limit based on maximum specified distance =   1600.00 m.
   This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
CORMIX1: Single Port Discharges                End of Prediction File
11111111111111111111111111111111111111111111111111111111111111111111111111111
```

B.6 Case 6

```
CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111
                       CORMIX MIXING ZONE EXPERT SYSTEM
             Subsystem CORMIX1:  Single Port Discharges
                         CORMIX Version 5.0GTR
                      HYDRO1 Version 5.0.1.0 December 2007
----------------------------------------------------------------------------
----------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:    Case 6 Chronic
 Design case:        Winter - Revised
 FILE NAME:          C:\...ter 7Q10 Low Chronic Q0 2986 gpm QA 52.7 kcfs.prd
 Time stamp:         Thu Jun  5 10:24:23 2008

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS     =     152.40  AS     =     399.29  QA     =     650.84  ICHREG= 1
 HA     =       2.62  HD     =       2.62
 UA     =      1.630  F      =      0.036  USTAR =0.1087E+00
 UW     =      2.000  UWSTAR=0.2198E-02
 Uniform density environment
 STRCND=  U           RHOAM =  999.9230

DISCHARGE PARAMETERS (metric units)
 BANK  =  RIGHT      DISTB =     53.34
 D0    =      0.459  A0     =     0.165  H0     =       0.15  SUB0   =      2.47
 THETA =      20.00  SIGMA =     90.00
 U0    =      1.139  Q0     =     0.188         =0.1884E+00
 RHO0  =  995.7672   DRHO0 =0.4156E+01  GP0    =0.4076E-01
 C0    =0.2810E+02   CUNITS=  deg.C
 IPOLL =  1          KS     =0.0000E+00  KD     =0.0000E+00

FLUX VARIABLES (metric units)
 Q0    =0.1884E+00   M0     =0.2147E+00  J0     =0.7679E-02  SIGNJ0=      1.0
 Associated length scales (meters)
 LQ    =       0.41  LM     =      3.60  Lm     =       0.28  Lb     =      0.00
                                         Lmp    =   99999.00  Lbp    =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =       8.33  R      =      0.70

FLOW CLASSIFICATION
 111111111111111111111111111111111111111111
 1  Flow class (CORMIX1)      =    H2A2   1
 1  Applicable layer depth HS =     2.62  1
 111111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    =0.2810E+02   CUNITS=  deg.C
 NTOX  =  0
 NSTD  =  0
 REGMZ =  1
 REGSPC=  1          XREG   =     93.27  WREG   =       0.00  AREG   =      0.00
 XINT  =    1600.00  XMAX   =   1600.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        53.34 m  from the RIGHT bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP =  10 display intervals per module
```

BEGIN MOD101: DISCHARGE MODULE

WAKE ATTACHMENT immediately following the discharge.

X	Y	Z	S	C	B
0.00	0.00	0.00	1.0	0.281E+02	0.48

END OF MOD101: DISCHARGE MODULE

BEGIN MOD151: WAKE RECIRCULATION

Control volume inflow:

X	Y	Z	S	C	B
0.00	0.00	0.00	1.0	0.281E+02	0.48

Profile definitions:
BV = top-hat thickness, measured vertically
BH = top-hat half-width, measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
0.00	0.28	0.00	1.0	0.281E+02	0.48	0.48	0.48	0.00
0.20	0.28	0.00	1.2	0.242E+02	0.52	0.52	0.52	0.00
0.41	0.28	0.00	1.6	0.176E+02	0.54	0.54	0.54	0.00
0.61	0.28	0.00	2.2	0.126E+02	0.55	0.55	0.55	0.00
0.81	0.28	0.00	2.9	0.963E+01	0.56	0.56	0.56	0.00
1.02	0.28	0.00	3.6	0.788E+01	0.57	0.57	0.57	0.00
1.22	0.28	0.00	4.1	0.686E+01	0.58	0.58	0.58	0.00
1.42	0.28	0.00	4.5	0.627E+01	0.59	0.59	0.59	0.00
1.63	0.28	0.00	4.7	0.593E+01	0.60	0.60	0.60	0.00
1.83	0.28	0.00	4.9	0.574E+01	0.60	0.60	0.60	0.00
2.03	0.28	0.00	5.1	0.556E+01	0.61	0.61	0.61	0.00

Cumulative travel time = 1.2474 sec

END OF MOD151: WAKE RECIRCULATION

** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

Vertical diffusivity (initial value) = 0.570E-01 m^2/s
Horizontal diffusivity (initial value) = 0.712E-01 m^2/s

Profile definitions:
BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
= or equal to layer depth, if fully mixed
BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
measured horizontally in Y-direction
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
2.03	0.28	0.00	5.1	0.556E+01	0.61	0.61	0.61	0.00

** REGULATORY MIXING ZONE BOUNDARY **

```
In this prediction interval the plume DOWNSTREAM  distance meets or exceeds
the regulatory value =     93.27 m.
This is the extent of the REGULATORY MIXING ZONE.
   161.83      0.28     0.00     64.1 0.439E+00   1.00      4.72     1.00     0.00
   321.63      0.28     0.00    100.2 0.280E+00   1.11      6.65     1.11     0.00
   481.42      0.28     0.00    144.4 0.195E+00   1.31      8.13     1.31     0.00
   641.22      0.28     0.00    210.4 0.134E+00   1.65      9.39     1.65     0.00
   801.02      0.28     0.00    317.6 0.885E-01   2.23     10.49     2.23     0.00
Plume interacts with SURFACE.
The passive diffusion plume becomes VERTICALLY FULLY MIXED within this
  prediction interval.
  960.81       0.28     0.00    408.9 0.687E-01   2.62     11.49     2.62     0.00
  1120.61      0.28     0.00    441.6 0.636E-01   2.62     12.40     2.62     0.00
  1280.41      0.28     0.00    472.0 0.595E-01   2.62     13.26     2.62     0.00
  1440.20      0.28     0.00    500.6 0.561E-01   2.62     14.06     2.62     0.00
  1600.00      0.28     0.00    527.7 0.533E-01   2.62     14.82     2.62     0.00
Cumulative travel time =          981.3114 sec

Simulation limit based on maximum specified distance =    1600.00 m.
  This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
CORMIX1: Single Port Discharges              End of Prediction File
11111111111111111111111111111111111111111111111111111111111111111111111111111
1
```

B.7 Case 7

```
CORMIX1 PREDICTION FILE:
11111111111111111111111111111111111111111111111111111111111111111111111111111
                       CORMIX MIXING ZONE EXPERT SYSTEM
             Subsystem CORMIX1:  Single Port Discharges
                         CORMIX Version 5.0GTR
                      HYDRO1 Version 5.0.1.0 December 2007
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:    Case 7 Acute
 Design case:        Winter - Revised
 FILE NAME:          C:\...inter 7Q10 Low Acute Q0 4097 gpm QA 52.7 kcfs.prd
 Time stamp:         Tue Jun  3 13:28:57 2008

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS     =     152.40  AS     =     399.29  QA     =     650.84  ICHREG= 1
 HA     =       2.62  HD     =       2.62
 UA     =      1.630  F      =      0.036  USTAR =0.1087E+00
 UW     =      2.000  UWSTAR=0.2198E-02
 Uniform density environment
 STRCND=  U           RHOAM =  999.9230

DISCHARGE PARAMETERS (metric units)
 BANK  =  RIGHT       DISTB =      53.34
 D0    =      0.459  A0     =      0.165  H0     =       0.15  SUB0   =       2.47
 THETA =      20.00  SIGMA =      90.00
 U0    =      1.563  Q0     =      0.259         =0.2585E+00
 RHO0  =  995.7672   DRHO0 =0.4156E+01  GP0    =0.4076E-01
 C0    =0.2810E+02  CUNITS=  deg.C
 IPOLL =  1          KS     =0.0000E+00  KD     =0.0000E+00

FLUX VARIABLES (metric units)
 Q0    =0.2585E+00  M0     =0.4041E+00  J0     =0.1054E-01  SIGNJ0=       1.0
 Associated length scales (meters)
 LQ    =       0.41  LM     =       4.94  Lm     =       0.39  Lb     =       0.00
                                          Lmp    =   99999.00  Lbp    =   99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =      11.43  R      =       0.96

FLOW CLASSIFICATION
 111111111111111111111111111111111111111111
 1  Flow class (CORMIX1)       =    H2A2   1
 1  Applicable layer depth HS =     2.62  1
 111111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    =0.2810E+02  CUNITS=  deg.C
 NTOX  =  0
 NSTD  =  0
 REGMZ =  1
 REGSPC=  1          XREG   =      93.27  WREG   =       0.00  AREG   =       0.00
 XINT  =    1600.00  XMAX   =    1600.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        53.34 m  from the RIGHT bank/shore.
```

```
   X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP =  10 display intervals per module
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

 WAKE ATTACHMENT immediately following the discharge.

      X         Y        Z         S        C        B
     0.00      0.00     0.00      1.0 0.281E+02    0.56

END OF MOD101: DISCHARGE MODULE
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
BEGIN MOD151: WAKE RECIRCULATION

  Control volume inflow:
      X         Y        Z         S        C        B
     0.00      0.00     0.00      1.0 0.281E+02    0.56

 Profile definitions:
   BV = top-hat thickness, measured vertically
   BH = top-hat half-width, measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
   S  = hydrodynamic average (bulk) dilution
   C  = average (bulk) concentration (includes reaction effects, if any)

      X         Y        Z         S        C        BV        BH       ZU       ZL
     0.00      0.39     0.00      1.0 0.281E+02    0.56      0.56     0.56     0.00
     0.20      0.39     0.00      1.1 0.254E+02    0.58      0.58     0.58     0.00
     0.41      0.39     0.00      1.4 0.201E+02    0.58      0.58     0.58     0.00
     0.61      0.39     0.00      1.8 0.155E+02    0.59      0.59     0.59     0.00
     0.81      0.39     0.00      2.3 0.124E+02    0.59      0.59     0.59     0.00
     1.02      0.39     0.00      2.7 0.104E+02    0.60      0.60     0.60     0.00
     1.22      0.39     0.00      3.0 0.922E+01    0.60      0.60     0.60     0.00
     1.42      0.39     0.00      3.3 0.850E+01    0.60      0.60     0.60     0.00
     1.63      0.39     0.00      3.5 0.808E+01    0.61      0.61     0.61     0.00
     1.83      0.39     0.00      3.6 0.785E+01    0.61      0.61     0.61     0.00
     2.03      0.39     0.00      3.7 0.763E+01    0.61      0.61     0.61     0.00
 Cumulative travel time =          1.2474 sec

END OF MOD151: WAKE RECIRCULATION
-----------------------------------------------------------------------------
** End of NEAR-FIELD REGION (NFR) **
-----------------------------------------------------------------------------
BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

  Vertical diffusivity (initial value)   = 0.570E-01 m^2/s
  Horizontal diffusivity (initial value) = 0.712E-01 m^2/s

 Profile definitions:
   BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
      = or equal to layer depth, if fully mixed
   BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
        measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
   S  = hydrodynamic centerline dilution
   C  = centerline concentration (includes reaction effects, if any)

 Plume Stage 1 (not bank attached):
      X         Y        Z         S        C        BV        BH       ZU       ZL
```

```
    2.03      0.39     0.00      3.7 0.763E+01   0.61      0.61     0.61     0.00
** REGULATORY MIXING ZONE BOUNDARY **
In this prediction interval the plume DOWNSTREAM  distance meets or exceeds
the regulatory value =     93.27 m.
This is the extent of the REGULATORY MIXING ZONE.
   161.83     0.39     0.00     40.8 0.688E+00   0.87      4.72     0.87     0.00
   321.63     0.39     0.00     62.1 0.453E+00   0.94      6.65     0.94     0.00
   481.42     0.39     0.00     85.4 0.329E+00   1.06      8.13     1.06     0.00
   641.22     0.39     0.00    116.4 0.241E+00   1.25      9.38     1.25     0.00
   801.02     0.39     0.00    162.8 0.173E+00   1.57     10.49     1.57     0.00
   960.81     0.39     0.00    237.0 0.119E+00   2.08     11.49     2.08     0.00
Plume interacts with SURFACE.
The passive diffusion plume becomes VERTICALLY FULLY MIXED within this
  prediction interval.
  1120.61     0.39     0.00    321.9 0.873E-01   2.62     12.40     2.62     0.00
  1280.41     0.39     0.00    344.0 0.817E-01   2.62     13.26     2.62     0.00
  1440.20     0.39     0.00    364.8 0.770E-01   2.62     14.06     2.62     0.00
  1600.00     0.39     0.00    384.5 0.731E-01   2.62     14.82     2.62     0.00
Cumulative travel time =          981.2059 sec

Simulation limit based on maximum specified distance =   1600.00 m.
  This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
CORMIX1: Single Port Discharges              End of Prediction File
11111111111111111111111111111111111111111111111111111111111111111111111111111
```

B.8 Case 8

```
CORMIX1 PREDICTION FILE:
11111111111111111111111111111111111111111111111111111111111111111111111111111
                       CORMIX MIXING ZONE EXPERT SYSTEM
             Subsystem CORMIX1:  Single Port Discharges
                         CORMIX Version 5.0GTR
                     HYDRO1 Version 5.0.1.0 December 2007
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:    Case 8 Chronic
 Design case:        7Q10 Hig Flow - Revised
 FILE NAME:          C:\... 8  7Q10 High Chronic Q0 2986 gpm QA 261 kcfs.prd
 Time stamp:         Tue Jun  3 13:29:50 2008

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS     =     152.40  AS     =   1036.32  QA     =    3191.87  ICHREG= 1
 HA     =       6.80  HD     =      6.80
 UA     =      3.080  F      =     0.026  USTAR =0.1752E+00
 UW     =      2.000  UWSTAR=0.2198E-02
 Uniform density environment
 STRCND=  U           RHOAM =  999.7019

DISCHARGE PARAMETERS (metric units)
 BANK  =  RIGHT       DISTB =      53.34
 D0    =      0.459  A0     =     0.165  H0     =       0.15  SUB0   =       6.65
 THETA =      20.00  SIGMA =      90.00
 U0    =      1.139  Q0     =     0.188          =0.1884E+00
 RHO0  =  995.7672   DRHO0 =0.3935E+01  GP0    =0.3860E-01
 C0    =0.1960E+02   CUNITS=  deg.C
 IPOLL =  1          KS     =0.0000E+00  KD     =0.0000E+00

FLUX VARIABLES (metric units)
 Q0    =0.1884E+00  M0     =0.2147E+00  J0     =0.7272E-02  SIGNJ0=      1.0
 Associated length scales (meters)
 LQ    =       0.41  LM     =      3.70  Lm     =       0.15  Lb     =       0.00
                                         Lmp    =   99999.00  Lbp    =   99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =       8.56  R      =      0.37

FLOW CLASSIFICATION
 111111111111111111111111111111111111111111
 1  Flow class (CORMIX1)       =    H1A2   1
 1  Applicable layer depth HS =     6.80   1
 111111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    =0.1960E+02  CUNITS=  deg.C
 NTOX  =  0
 NSTD  =  0
 REGMZ =  1
 REGSPC=  1          XREG   =     93.27  WREG   =       0.00  AREG   =       0.00
 XINT  =    1600.00  XMAX   =   1600.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        53.34 m  from the RIGHT bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP =  10 display intervals per module
```

```
------------------------------------------------------------------------------
------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

 WAKE ATTACHMENT immediately following the discharge.

       X         Y        Z         S        C        B
      0.00      0.00     0.00      1.0 0.196E+02   0.35

END OF MOD101: DISCHARGE MODULE
------------------------------------------------------------------------------
------------------------------------------------------------------------------
BEGIN MOD151: WAKE RECIRCULATION

  Control volume inflow:
       X         Y        Z         S        C        B
      0.00      0.00     0.00      1.0 0.196E+02   0.35

 Profile definitions:
   BV = top-hat thickness, measured vertically
   BH = top-hat half-width, measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
   S  = hydrodynamic average (bulk) dilution
   C  = average (bulk) concentration (includes reaction effects, if any)

       X         Y        Z         S        C        BV        BH       ZU       ZL
      0.00      0.15     0.00      1.0 0.196E+02   0.35      0.35     0.35     0.00
      0.20      0.15     0.00      1.3 0.147E+02   0.43      0.43     0.43     0.00
      0.41      0.15     0.00      2.3 0.865E+01   0.47      0.47     0.47     0.00
      0.61      0.15     0.00      3.6 0.547E+01   0.49      0.49     0.49     0.00
      0.81      0.15     0.00      5.0 0.389E+01   0.51      0.51     0.51     0.00
      1.02      0.15     0.00      6.4 0.306E+01   0.53      0.53     0.53     0.00
      1.22      0.15     0.00      7.5 0.260E+01   0.55      0.55     0.55     0.00
      1.42      0.15     0.00      8.3 0.235E+01   0.57      0.57     0.57     0.00
      1.63      0.15     0.00      8.9 0.220E+01   0.58      0.58     0.58     0.00
      1.83      0.15     0.00      9.2 0.213E+01   0.60      0.60     0.60     0.00
      2.03      0.15     0.00      9.6 0.205E+01   0.61      0.61     0.61     0.00
 Cumulative travel time =        0.6602 sec

END OF MOD151: WAKE RECIRCULATION
------------------------------------------------------------------------------
** End of NEAR-FIELD REGION (NFR) **
------------------------------------------------------------------------------
BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

  Vertical diffusivity (initial value)   = 0.238E+00 m^2/s
  Horizontal diffusivity (initial value) = 0.298E+00 m^2/s

 Profile definitions:
   BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
      = or equal to layer depth, if fully mixed
   BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
        measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
   S  = hydrodynamic centerline dilution
   C  = centerline concentration (includes reaction effects, if any)

 Plume Stage 1 (not bank attached):
       X         Y        Z         S        C        BV        BH       ZU       ZL
      2.03      0.15     0.00      9.6 0.205E+01   0.61      0.61     0.61     0.00
 ** REGULATORY MIXING ZONE BOUNDARY **
```

```
 In this prediction interval the plume DOWNSTREAM  distance meets or exceeds
 the regulatory value =     93.27 m.
 This is the extent of the REGULATORY MIXING ZONE.
    161.83      0.15     0.00    214.4 0.914E-01    1.19      7.00      1.19     0.00
    321.63      0.15     0.00    314.8 0.623E-01    1.24      9.87      1.24     0.00
    481.42      0.15     0.00    408.7 0.480E-01    1.32     12.09      1.32     0.00
    641.22      0.15     0.00    511.0 0.384E-01    1.43     13.95      1.43     0.00
    801.02      0.15     0.00    633.6 0.309E-01    1.58     15.59      1.58     0.00
    960.81      0.15     0.00    791.3 0.248E-01    1.80     17.08      1.80     0.00
   1120.61      0.15     0.00   1007.1 0.195E-01    2.13     18.45      2.13     0.00
   1280.41      0.15     0.00   1317.6 0.149E-01    2.60     19.72      2.60     0.00
   1440.20      0.15     0.00   1777.2 0.110E-01    3.31     20.92      3.31     0.00
   1600.00      0.15     0.00   2443.1 0.802E-02    4.32     22.05      4.32     0.00
 Cumulative travel time =          519.4499 sec

 Simulation limit based on maximum specified distance =    1600.00 m.
   This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
CORMIX1: Single Port Discharges              End of Prediction File
11111111111111111111111111111111111111111111111111111111111111111111111111111
```

B.9 Case 9

```
CORMIX1 PREDICTION FILE:
111111111111111111111111111111111111111111111111111111111111111111111111111111
                         CORMIX MIXING ZONE EXPERT SYSTEM
              Subsystem CORMIX1:  Single Port Discharges
                           CORMIX Version 5.0GTR
                       HYDRO1 Version 5.0.1.0 December 2007
------------------------------------------------------------------------------
------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:    Case 9  Acute
 Design case:        7Q10 Hig Flow - Revised
 FILE NAME:          C:\...ase 9 7Q10 High Acute Q0 4097 gpm QA 261 kcfs.prd
 Time stamp:         Thu Jun  5 10:28:03 2008

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS     =     152.40  AS     =    1036.32  QA     =    3191.87  ICHREG= 1
 HA     =       6.80  HD     =       6.80
 UA     =      3.080  F      =      0.026  USTAR =0.1752E+00
 UW     =      2.000  UWSTAR=0.2198E-02
 Uniform density environment
 STRCND=  U           RHOAM =  999.7019

DISCHARGE PARAMETERS (metric units)
 BANK  =  RIGHT       DISTB =     53.34
 D0    =      0.459  A0     =      0.165  H0     =       0.15  SUB0   =       6.65
 THETA =      20.00  SIGMA =     90.00
 U0    =      1.563  Q0     =      0.259          =0.2585E+00
 RHO0  =  995.7672   DRHO0 =0.3935E+01  GP0    =0.3860E-01
 C0    =0.1960E+02  CUNITS=  deg.C
 IPOLL =  1          KS     =0.0000E+00  KD     =0.0000E+00

FLUX VARIABLES (metric units)
 Q0    =0.2585E+00  M0     =0.4041E+00  J0     =0.9978E-02  SIGNJ0=       1.0
 Associated length scales (meters)
 LQ    =       0.41  LM     =       5.07  Lm     =       0.21  Lb     =       0.00
                                          Lmp    =   99999.00  Lbp    =   99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =      11.75  R      =       0.51

FLOW CLASSIFICATION
 111111111111111111111111111111111111111111
 1  Flow class (CORMIX1)      =    H1A2   1
 1  Applicable layer depth HS =     6.80  1
 111111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    =0.1960E+02  CUNITS=  deg.C
 NTOX  =  0
 NSTD  =  0
 REGMZ =  1
 REGSPC=  1          XREG   =     93.27  WREG   =       0.00  AREG   =       0.00
 XINT  =    1600.00  XMAX   =    1600.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        53.34 m  from the RIGHT bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP =  10 display intervals per module
```

```
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

 WAKE ATTACHMENT immediately following the discharge.

       X         Y        Z         S        C        B
      0.00      0.00     0.00      1.0 0.196E+02    0.41

END OF MOD101: DISCHARGE MODULE
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
BEGIN MOD151: WAKE RECIRCULATION

  Control volume inflow:
       X         Y        Z         S        C        B
      0.00      0.00     0.00      1.0 0.196E+02    0.41

 Profile definitions:
   BV = top-hat thickness, measured vertically
   BH = top-hat half-width, measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
   S  = hydrodynamic average (bulk) dilution
   C  = average (bulk) concentration (includes reaction effects, if any)

       X         Y        Z         S        C        BV       BH       ZU       ZL
      0.00      0.21     0.00      1.0 0.196E+02    0.41     0.41     0.41     0.00
      0.20      0.21     0.00      1.2 0.159E+02    0.47     0.47     0.47     0.00
      0.41      0.21     0.00      1.9 0.104E+02    0.50     0.50     0.50     0.00
      0.61      0.21     0.00      2.8 0.699E+01    0.52     0.52     0.52     0.00
      0.81      0.21     0.00      3.8 0.513E+01    0.54     0.54     0.54     0.00
      1.02      0.21     0.00      4.8 0.411E+01    0.55     0.55     0.55     0.00
      1.22      0.21     0.00      5.6 0.353E+01    0.56     0.56     0.56     0.00
      1.42      0.21     0.00      6.1 0.320E+01    0.58     0.58     0.58     0.00
      1.63      0.21     0.00      6.5 0.301E+01    0.59     0.59     0.59     0.00
      1.83      0.21     0.00      6.7 0.291E+01    0.60     0.60     0.60     0.00
      2.03      0.21     0.00      7.0 0.281E+01    0.61     0.61     0.61     0.00
 Cumulative travel time =          0.6602 sec

END OF MOD151: WAKE RECIRCULATION
--------------------------------------------------------------------------------
** End of NEAR-FIELD REGION (NFR) **
--------------------------------------------------------------------------------
BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

  Vertical diffusivity (initial value)   = 0.238E+00 m^2/s
  Horizontal diffusivity (initial value) = 0.298E+00 m^2/s

 Profile definitions:
   BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
      = or equal to layer depth, if fully mixed
   BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
        measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
   S  = hydrodynamic centerline dilution
   C  = centerline concentration (includes reaction effects, if any)

 Plume Stage 1 (not bank attached):
       X         Y        Z         S        C        BV       BH       ZU       ZL
      2.03      0.21     0.00      7.0 0.281E+01    0.61     0.61     0.61     0.00
 ** REGULATORY MIXING ZONE BOUNDARY **
```

```
 In this prediction interval the plume DOWNSTREAM  distance meets or exceeds
 the regulatory value =      93.27 m.
 This is the extent of the REGULATORY MIXING ZONE.
    161.83       0.21      0.00     130.9 0.150E+00   1.00      7.00      1.00      0.00
    321.63       0.21      0.00     190.1 0.103E+00   1.03      9.87      1.03      0.00
    481.42       0.21      0.00     242.7 0.808E-01   1.07     12.09      1.07      0.00
    641.22       0.21      0.00     296.5 0.661E-01   1.14     13.95      1.14      0.00
    801.02       0.21      0.00     356.3 0.550E-01   1.22     15.59      1.22      0.00
    960.81       0.21      0.00     427.0 0.459E-01   1.34     17.08      1.34      0.00
   1120.61       0.21      0.00     515.1 0.380E-01   1.49     18.45      1.49      0.00
   1280.41       0.21      0.00     630.4 0.311E-01   1.71     19.72      1.71      0.00
   1440.20       0.21      0.00     788.7 0.249E-01   2.02     20.91      2.02      0.00
   1600.00       0.21      0.00    1015.7 0.193E-01   2.46     22.05      2.46      0.00
 Cumulative travel time =          519.4385 sec

 Simulation limit based on maximum specified distance =    1600.00 m.
   This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
CORMIX1: Single Port Discharges              End of Prediction File
11111111111111111111111111111111111111111111111111111111111111111111111111111
```

Table 2 Outfall 001 Effluent Data

Outfall 001																					
Date	BOD (mg/L)	COD (mg/L)	TOC (mg/L)	TSS (mg/L)	Ammonia (mg/L)	Br (mg/L)	Fecal	Cond (uS/cm)	pH	Turb. (NTU)	Alk (mg/L)	F (mg/L)	Cl (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	N, T.Org (mg/L)	O&G (mg/L)	T-P (mg/L)	SO4 (mg/L)	Al (mg/L)	Ba (mg/L)
7/6/2006				18	0.015			940	8.14	10.6		0.44	29	0.44	0.036			2.2	400		
8/3/2006										5.59											
9/14/2006				7.2	0.042			750	8.32	4.68	130	0.37	17	0.43	0.04			2.2	230		
10/12/2006				5.4	0.015			680	8.32	3.85	120	0.32	12	0.56	0.04			2.3	210		
11/9/2006				9	0.015			360	8.19	5.92	98	0.21	6.3	0.4	<0.03			2.3	60		
12/7/2006				15	0.015			1200	7.98	12.6	96	0.5	23	1.9	0.03			2.5	500		
12/20/2006		25	13	16	0.043	7.7		1200	8.55	9.51		0.53	0.12	2.1	0.03		1.1	2.2	580	0.38	0.3
1/3/2007				11	0.015			1300	8.31	5.92	120	0.53	21	2.3	0.03			2.1	560		
2/5/2007				7	0.015			1300	8.28	5.53	130	0.54	18	2.4	0.037			2.2	550		
3/5/2007				6.9	0.015			1200	8.39	3.56	130	0.55	19	1.8	<0.03			2	570		
4/2/2007				4.5	0.039			1300	8.46	3.2	110	0.52	23	1.50	0.04			2.5	560		
5/3/2007				20	0.12			1400	8.18	11.3	110	0.54	46	1.1	0.037			2.4	630		
7/2/2007				7	0.071			400	8.15	3.6	85	0.24	5.9	0.22	0.031			1.8	110		
8/1/2007				11	0.031			1200	8.35	4.76	120	0.51	37	0.40	<0.03			2.7	640		
9/5/2007				7	0.035			1200	8.22	4.91	100	0.50	23	0.69	<0.03			2	590		
10/1/2007				6.6	0.048			1200	8.23	4.81	96	0.55	27	0.94	<0.03			2.4	590		
11/7/2007				7.8	0.046			1200	8.11	4.53	98	0.59	18	1.3	<0.03			2.4	540		
12/12/2007				11	0.015			1100	8.18	7.46	130	0.55	16	1.8	<0.03			1.8	460		
1/2/2008				6.2	0.015			770	7.93	4.68	110	0.3	7.2	0.78	<0.03			2.4	210		
2/4/2008				6.2	0.032			1100	7.78	3.89	120	0.41	14	1.5	<0.03			2.9	490		
3/5/2008				8.6	0.052			1300	8.44	4.28	150	0.460	19	1.8	<0.03			3.2	550		
4/17/2008				6.8	0.049			1500	8.01	4.97	120	0.39	24	1.3				2.5	530		
5/6/2008				13	0.058			1500	8.22	6.35	90	0.48	27	1.9	0.72			2.7	690		
5/27/2008																					
6/3/2008																					
6/10/2008				30	0.11			1300	8.61	23.5	120	0.45	41	0.9	1.0			2.6	460		
avg				10.5	0.040			1104	8.23	6.67	113	0.46	20.6	1.24				2			
95th %tile				19.8	0.106			1490	8.54	12.4	130	0.55	40.6	2.28				2.88			
stnd dev				5.98	0.029			312.7	0.20	4.40	16.4	0.1	11.1	0.68				0.3			
cv				0.570	0.736			0.283	0.024	0.660	0.144	0.232	0.538	0.548				0.140			
50th %tile				7.8	0.035			1200	8.22	4.94	120	0.5	19	1.3				2.4			
max				30	0.120						150	0.59	46	2.40				3.20			

* ammonia entries of 0.015 indicate 1/2 the PQL of 0.03 mg/L

Table 2 Outfall 001 Effluent Data

Outfall 001																					
Date	Fe (mg/L)	Mg (mg/L)	Mn (mg/L)	Ca (mg/L)	Hard(Ca/Mg) (mg/L)	Sn (mg/L)	Sb (mg/L)	As (mg/L)	Be (mg/L)	Cd (mg/L)	Cr (mg/L)	Cr (VI) (mg/L)	Cr (III) (mg/L)	Cu (mg/L)	Pb (mg/L)	Hg (mg/L)	Ni (mg/L)	Se (mg/L)	Ag (mg/L)	Tl (mg/L)	Zn (mg/L)
7/6/2006	0.26	28	0.026	130							0.0010			0.070	<0.0002						0.034
8/3/2006											0.0019			0.055							0.025
9/14/2006	0.24	27	0.022	100							0.0009			0.046	<0.0002						0.022
10/12/2006	0.19	23	0.019	90							0.0015			0.033	<0.0002						0.020
11/9/2006	0.32	11	0.022	48							0.0011			0.028	<0.0002						0.014
12/7/2006	0.6	42	0.038	160							0.0025			0.049	<0.0002						0.026
12/20/2006	0.64	52	0.031	190		<0.001	0.0015	0.013	<0.002	<0.0002	0.0019			0.054	0.0002	<0.0002	0.0043	0.028	<0.0002	<0.0002	0.030
1/3/2007	0.29	46	0.025	190							0.0032			0.046	0.0003						0.026
2/5/2007	0.33	49	0.019	200							0.0024			0.021	<0.0002						0.025
3/5/2007	0.11	42	0.012	170							0.0009			0.023	<0.0002						0.018
4/2/2007	0.29	48	0.014	190							0.0018			0.028	0.0003						0.022
5/3/2007	0.35	47	0.039	190							0.0020			0.052	0.0003						0.049
7/2/2007	0.26	14	0.029	59							0.0011			0.038	<0.0002						0.012
8/1/2007	0.27	48	0.032	190							0.0039			0.052	<0.0002						0.028
9/5/2007	0.96	48	0.025	190							0.0014			0.028	<0.0002						0.018
10/1/2007	0.2	45	0.029	200							0.0013			0.030	<0.0002						0.021
11/7/2007	0.28	46	0.025	180							0.0020			0.021	0.0005						0.018
12/12/2007	0.4	40	0.028	170							0.0018			0.023	0.0005						0.019
1/2/2008	0.094	23	0.014	94							0.0008			0.012	<0.0002						0.014
2/4/2008	0.24	51	0.016	180							0.0020			0.047	0.0003						0.028
3/5/2008	0.23	54	0.018	210							0.0007			0.020	0.0006						0.024
4/17/2008	0.21	51	0.028	220							0.0014			0.021	<0.0002						0.022
5/6/2008	0.26	57	0.029	250							0.0022			0.022	0.0006						0.027
5/27/2008												0.0004	0.00031								
6/3/2008												<0.00023									
6/10/2008	0.63	45	0.051	190							0.0010			0.025	<0.0002						0.027
avg	0.33	41	0.026	165							0.0017			0.035							0.024
95th %tile	0.64	53.8	0.039	219							0.0031			0.055							0.033
stnd dev	0.198	13.0	0.009	52.5							0.0008			0.015							0.008
cv	0.596	0.319	0.353	0.319							0.4602			0.429							0.321
50th %tile	0.27	46	0.025	190							0.00165			0.029							0.023
max	0.96	57	0.051	250							0.0039			0.070							0.049

Attachment 2

BATHYMETRIC SURVEY OF THE CGS-2 INTAKE AND DISCHARGE AREA CONDUCTED OCTOBER 6, 2006

DRAFT REPORT

PREPARED FOR:
ENERGY NORTHWEST

SHUKSAN FISHERIES CONSULTING **OCTOBER 2006**

Methods & Results

A bathymetric survey of the Columbia River surrounding the CGS-2 intake and discharge structures was performed on October 6, 2006 by Shuksan Fisheries Consulting and Energy Northwest personnel.

Sampling was conducted from a 5.5 meter (18 foot) power boat equipped with a digital echo sounding system that consisted of a BioSonics DTX scientific echo sounder and transducer, a computer to control the sounder and record data, and a Garmin GPSmap 182 differential GPS to geo-code data as they were collected. The map datum used for all sampling and analysis was WGS84.

Depth measurements were made on a grid of transects approximately perpendicular and parallel to the river bank within an rectangle that encompassed the CGS-2 intake, discharge, and the discharge chronic mixing zone. This rectangle extended from approximately 10 m upstream of the intakes to 120 m downstream of the discharge, and from 25 m east of the intakes to 25 m west of the discharge (Figure 1). Transects were spaced about 10 m or less apart, with closer spacing and some overlapping coverage near the intakes and discharge. Soundings were made continuously at a density of several per meter as the boat moved along transects at about 1-2 meter per second.

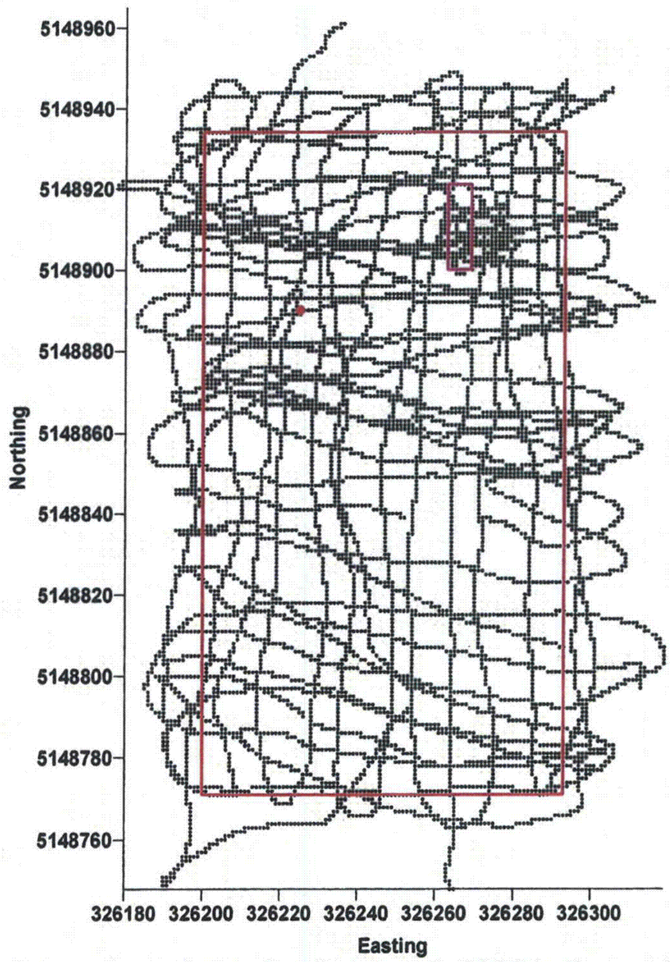


Figure 1. Locations of soundings during the October 6, 2006 bathymetric survey of the Columbia River near the CGS-2 intake and discharge. A red dot represents the discharge, a magenta box shows the location of the three intakes, and a red rectangle indicates the entire target survey area.

The nominal accuracy of GPS positions was 2-3 m during sampling (i.e., estimated positions should have been within a 2-3 m diameter circle surrounding the true position 95% of the time). The accuracy of depth measurements was verified in the field by a bar calibration (sounding on a reference target suspended a known distance beneath the water surface). Tests at a depth of 2.00 m indicated that measured and actual depths differed by an average of 2.2% (a mean of 2.04 m versus 2.00 m actual depth, n = 157, SD = 0.027).

According to engineering drawings, the top of the CGS-2 intakes are at 104.0 m (341.5 feet) above sea level. Based on repeated measurements of the intake depth, the river's surface elevation at the intakes was 105.5 m above sea level during the survey (n= 12, SD=0.09). As judged by a reference marker on shore, the river surface elevation varied no more than 6 cm during the 2.25 hours of the survey (1512-1725 hours), so no adjustment was made for changing river elevation. Discharge from Priest Rapids dam 8-10 hours prior to sampling (the estimated transit time from the dam to the study site) ranged from 66,100 to 108,900 cfs.

Digital data files were processed with SonarData Echoview ™ software to measure water depths and create ASCII format files containing depths and associate geo-coordinates. Surfer ™ software was then used to interpolate a regular grid of depths by kriging and to construct bathymetric maps (Figures 2 and 3).

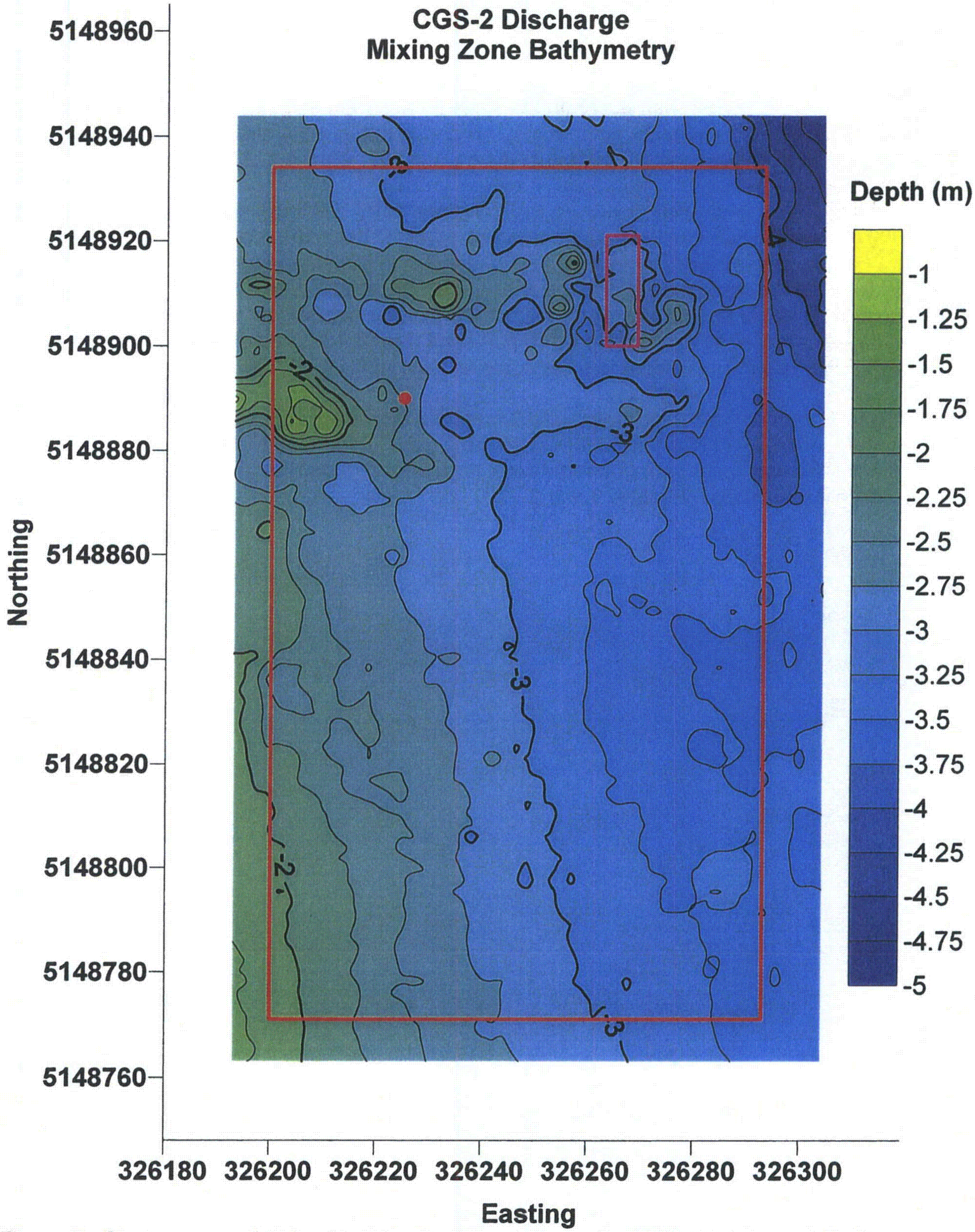


Figure 2. Contour map of Columbia River bathymetry near the CGS-2 intake and discharge on October 6, 2006. A red dot represents the discharge, a magenta box shows the location of the three intakes, and a red rectangle indicates the entire target survey area.

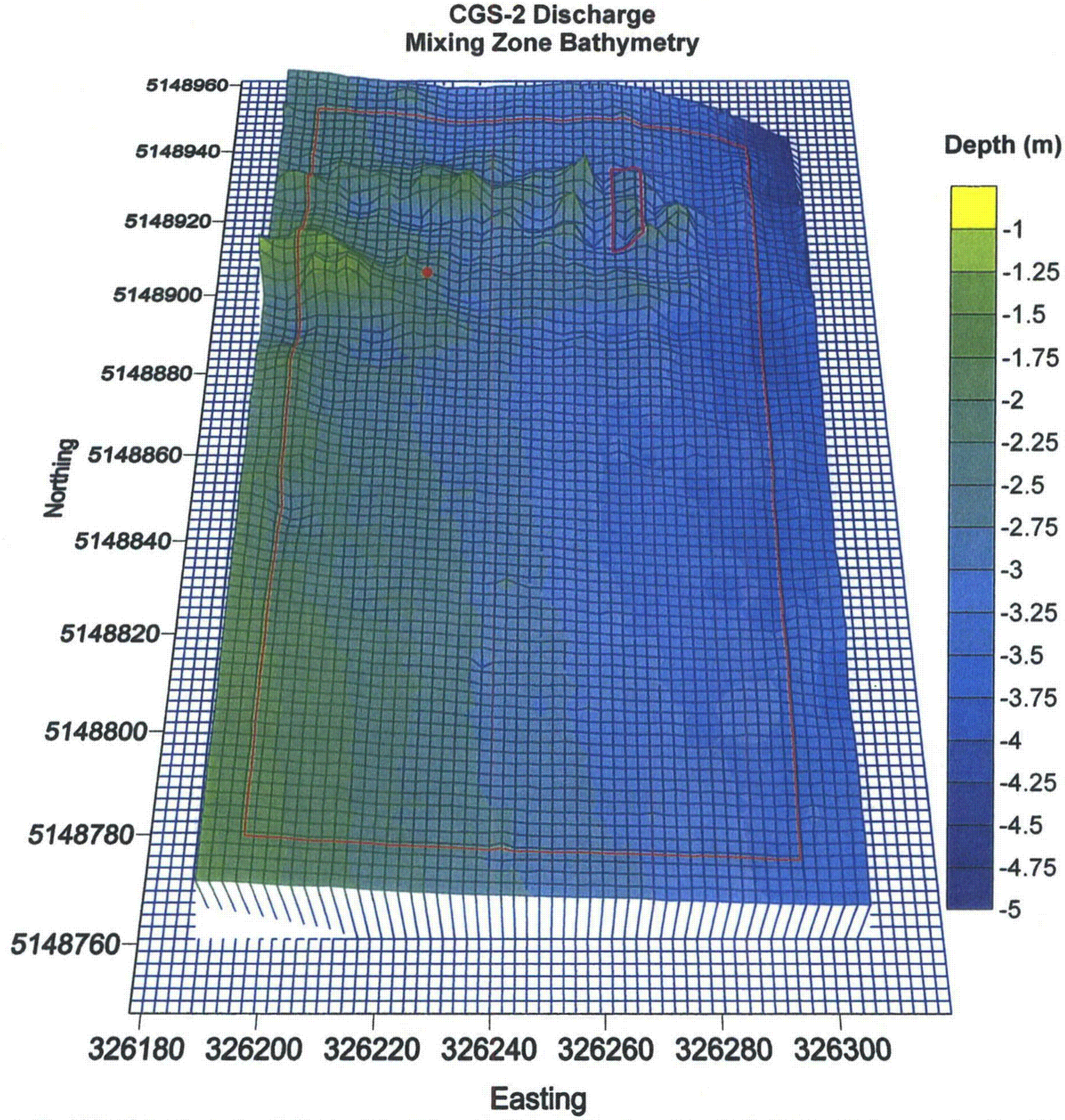


Figure 3. Wireframe map of Columbia River bathymetry near the CGS-2 intake and discharge on October 6, 2006. A red dot represents the discharge, a magenta box shows the location of the three intakes, and a red rectangle indicates the entire target survey area.

Attachment 3

Log-Pearson Type III Statistics
SWSTAT 4.1
(based on USGS Program A193)

Notice -- Use of Log-Pearson Type III or Pearson-Type III distributions are for preliminary computations. User is responsible for assessment and interpretation.

12472800 L007
April 1 - start of season
March 31 - end of season
1976 - 2006 - time period
7-day low - parameter
31 - non-zero values
0 - zero values
0 - negative values (ignored)

63771.430	84871.430	55671.430	79514.289	70614.289
63885.715	72385.711	62214.285	64000.000	64714.285
53671.430	59514.285	67300.000	68614.289	57842.855
68371.430	75971.430	56871.430	53700.000	52214.285
64185.715	81157.141	93300.000	67100.000	83300.000
66671.430	44585.715	54700.000	56142.855	62614.285
61214.285				

The following 7 statistics are based on non-zero values:

Mean (logs)	4.811
Variance (logs)	0.005
Standard Deviation (logs)	0.070
Skewness (logs)	0.197
Standard Error of Skewness (logs)	0.421
Serial Correlation Coefficient (logs)	0.234
Coefficient of Variation (logs)	0.015

Non-exceedance Probability	Recurrence Interval	Parameter Value
0.0100	100.00	45402.543
0.0200	50.00	47159.191
0.0500	20.00	49992.625
0.1000	10.00	52727.805
0.2000	5.00	56343.336
0.3333	3.00	60025.867
0.5000	2.00	64327.238
0.8000	1.25	73996.258
0.9000	1.11	79859.234
0.9600	1.04	86826.922
0.9800	1.02	91766.797
0.9900	1.01	96534.188

Log-Pearson Type III Statistics
SWSTAT 4.1
(based on USGS Program A193)

Notice -- Use of Log-Pearson Type III or Pearson-Type III distributions are for preliminary computations. User is responsible for assessment and interpretation.

12472800 H007
October 1 - start of season
September 30 - end of season
1975 - 2006 - time period
7-day high - parameter
32 - non-zero values
0 - zero values
0 - negative values (ignored)

196142.859	224857.141	131714.281	166714.281	138714.281
191142.859	257285.719	231285.719	222714.281	180857.141
162142.859	166857.141	174285.719	141285.719	175571.422
244857.141	221142.859	174857.141	195714.281	168428.578
181285.719	265142.844	372857.156	226142.859	206857.141
207714.281	122000.000	246285.719	168000.000	152571.422
156142.859	234428.578			

The following 7 statistics are based on non-zero values:

Mean (logs)	5.283
Variance (logs)	0.010
Standard Deviation (logs)	0.102
Skewness (logs)	0.452
Standard Error of Skewness (logs)	0.414
Serial Correlation Coefficient (logs)	0.237
Coefficient of Variation (logs)	0.019

Exceedance Probability	Recurrence Interval	Parameter Value
0.9900	1.01	120072.078
0.9500	1.05	134533.797
0.9000	1.11	143794.734
0.8000	1.25	156765.500
0.5000	2.00	188331.656
0.3333	3.00	209104.797
0.2000	5.00	231984.750
0.1000	10.00	261383.281
0.0400	25.00	299250.344
0.0200	50.00	328054.062
0.0100	100.00	357415.250
0.0050	200.00	387579.062