INLAND EMPIRE PAPER COMPANY
MIXING ZONE SURVEY, SEPTEMBER 1990

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(Segment No. 24-57-04)

ABSTRACT

A survey was conducted in September 1990, on the Spokane River to evaluate compliance of the Inland Empire Paper Co. (IEP) wastewater discharge with water quality and dimensional mixing zone criteria. IEP effluent was meeting recently expired NPDES permit limits. Dye and water quality samples indicated IEP effluent aluminum, copper, lead, and mercury concentrations were adequately diluted, and met chronic toxicity criteria within the mixing zone. CORMIX2 and UDKHDEN mixing zone model simulations compared well to field dye study results. Field data and model simulation results indicated the IEP discharge system was complying with the mixing zone standards set under a settlement agreement. CORMIX2 simulations predicted poorer mixing with a lower effluent temperature, or a greater effluent volume. A possible problem with far-field D.O. concentrations in the Upriver Dam pool was also explored with a QUAL2E model simulation. Several recommendations were made.

INTRODUCTION

At the request of the Ecology Eastern Regional Office (ERO), the Inland Empire Paper Company (IEP) wastewater mixing zone in the Spokane River was evaluated in September 1990. The evaluation was conducted concurrently with an Ecology Environmental Investigations and Laboratory Services (EILS) Class II Inspection, results of which are reported in a separate document (Das and Zinner, 1991). Mike Huffman of ERO provided field assistance for the mixing zone survey.

Three objectives were outlined in the project proposal (Joy, 1990) to meet the needs of ERO staff. These were:

1. Provide a spatial description of the mixing of IEP effluent with the Spokane River below the diffuser.
2. If a multi-port numerical model is available for river systems:
   a. compare field results to model output, and
   b. simulate various discharge scenarios.
3. Provide background water column and sediment quality data.

The survey was timed to coincide with low flow conditions in the Spokane River and normal IEP production volumes. After initial field data were reviewed, an additional modeling task was requested by the ERO. This was to model the effect of various IEP effluent biochemical oxygen demand loads on dissolved oxygen concentrations on the Spokane River. Preliminary results of the model output were given to ERO staff in May 1991 (Joy, 1991). They are also briefly presented in this memorandum.

SITE DESCRIPTION

The Inland Empire Paper Company mill is located in Millwood, east of Spokane at river mile (RM) 82.6 of the Spokane River (Figure 1). The mill produces pulp and newsprint using groundwood coarse molded news and groundwood chemi-mechanical processes (Esvelt, 1990).

The mill has recently installed an old newspaper recycling line with de-inking facilities (Hallinan, 1991).

Wastewater from the manufacturing processes are treated at the mill. The treatment system consists of: a bar screen; wastewater pump station; primary clarifier; three stage aeration basin; secondary clarifier; an outfall diffuser; and sludge dewatering equipment. The IEP effluent must comply with limits on loads of BOD and TSS, and pH range as specified in the NPDES permit (Table 1). The permit expired in 1989, was extended, and is under review for renewal by the ERO. Effluent is discharged to the Spokane River through an 18" diameter, 70' outfall line with a 32' diffuser attached (Figure 2). The line and diffuser have been shifted approximately 10° downstream perpendicular to the shoreline (Hallinan, 1991). The diffuser has eight ports, four feet apart, on 90° risers facing downstream and an open end. Port sizes are:

Port Number(s)	Diameter (inches)
1	4
2 & 3	6
4 & 5	8
6, 7, 8 & End	10

The Spokane River in the vicinity of the outfall is heavily influenced by operation of Upriver Dam (also called Spokane Dam), located downstream at RM 80.2 (Figure 1). Under normal storage and release operations during the low flow period, the river in the vicinity of the outfall is a slow-moving reservoir. The channel is fairly deep (>20 feet) and flat bottomed in the

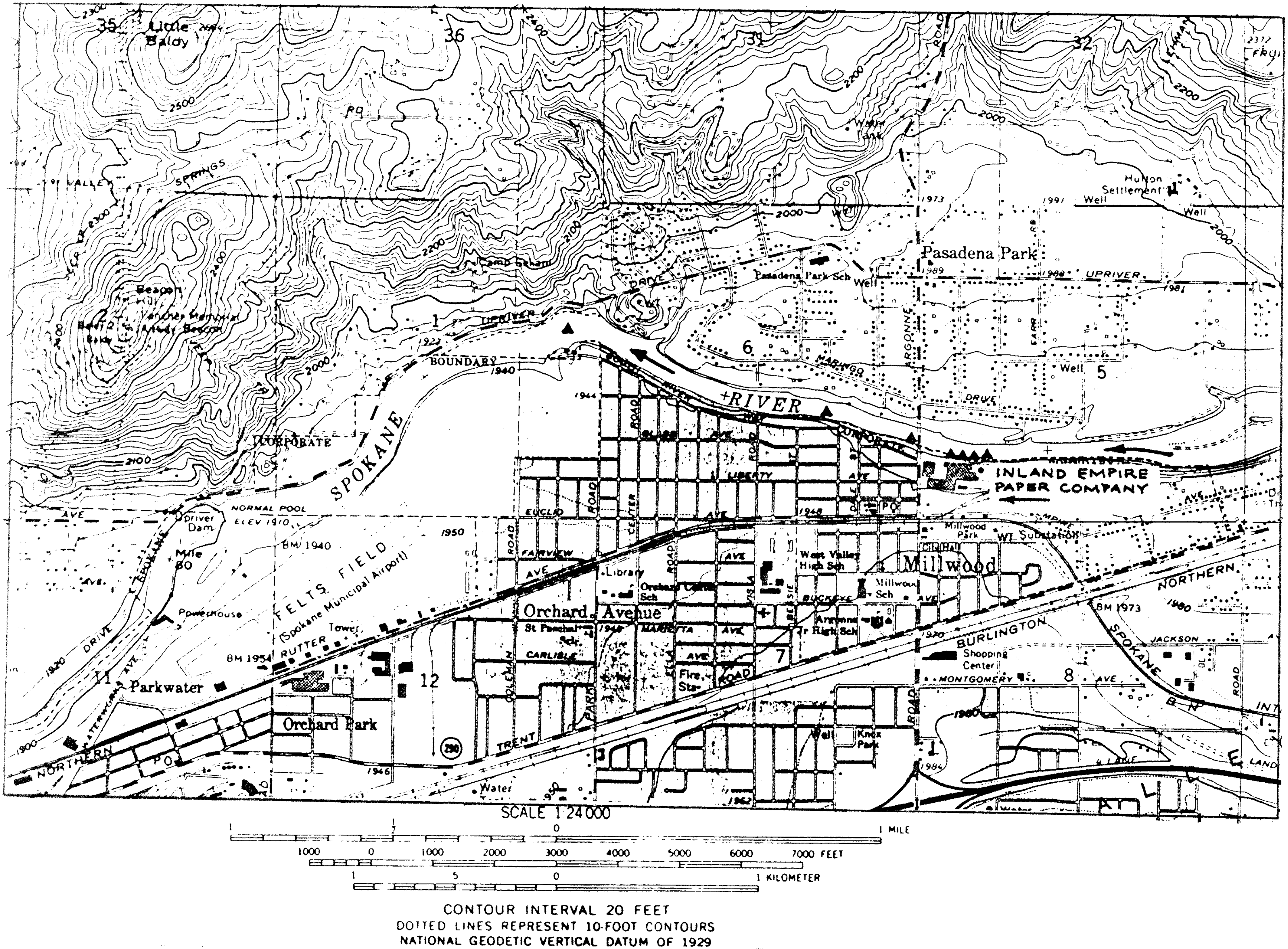


Figure 1. Location of water quality sampling stations along the Spokane River (▲) for the Inland Empire Paper Company mixing zone survey, September, 1990.

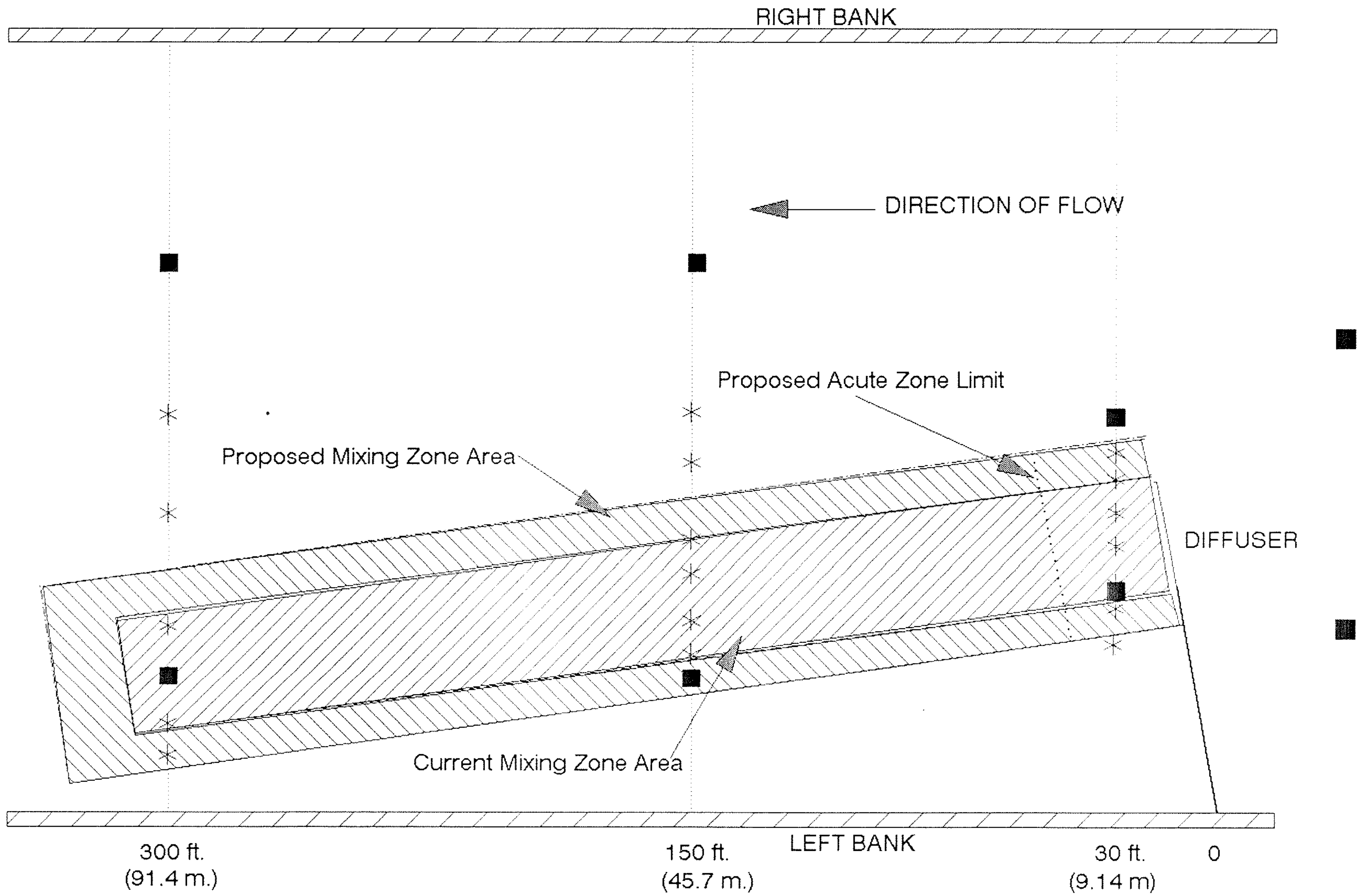


Figure 2. Inland Empire mixing zone boundaries and station locations on the Spokane River, September 11-12, 1990.

■ Water Chemistry Station ✳ Dye Station vicinity of the diffuser. There is a net loss of water from the river to the Spokane aquifer in this reach (Patmont, *et al.*, 1985). The river in the reach holds a Class A water quality classification with a special condition for temperature (Table 2).

Under current Ecology (1985) guidelines, the IEP mixing zone is defined as (Figure 2):

- 15% of the river width (35 feet);
- 300 feet downstream of the diffuser; and
- one foot from the water surface and from the bottom.

In the mixing zone section of the proposed state water quality standards (Ecology, 1991), the defined area is slightly different (Figure 2):

- 300 feet downstream plus the depth of the water over the diffuser, i.e. 300 + 20 = 320 feet; and
- 25% of the river width (55.8 feet) or 25% of the river flow at critical stage (205 cfs)

In addition, the proposed mixing zone section (Ecology, 1991) also defines an acute toxicity zone as the most restrictive of the following:

- 10% of the mixing zone length (32 feet);
- 50 times the discharge length scale (15-37 feet for the port diameter range of 4 to 10 inches); and
- Five times the local water depth (5x20 = 100 feet).

The Ecology water quality standards have not been adopted as of November 1991. However, a settlement agreement was reached between Ecology and a group of dischargers that included IEP. In that agreement, the newer mixing zone standards are applicable.

METHODS

Station locations are shown in Figures 1 and 2. Analyses performed at each station during the September 11-12, 1990, survey are listed in Table 3. Field analyses were conducted using a Hydrolab® multi-probe meter with temperature, dissolved oxygen (D.O.), pH, and conductivity probes. The multi-probe meter was calibrated before and after a day of use. The D.O. probe was air calibrated; pH buffers and conductivity standards were used to calibrate these probes. Grab samples for D.O. Winkler-azide modified titration were collected to check the D.O. probe performance at 10% of the sites.

River discharge was measured following USGS methods (Buchanan and Somers, 1969) using a metered, fixed cable, and a boat-mounted "A-reel" with a propeller velocity meter. The river discharge was measured once, approximately 100 feet above the IEP diffuser location.

Table 1. National Pollution Discharge Elimination System (NPDES) permit WA-000082-5 for Inland Empire Paper Company, Issued June 25, 1984 and expiring June 25, 1989.

Parameter	Effluent Limitations Daily Average	 Daily Maximum
Flow	3.5 MGD	4.5 MGD
BOD_5	10.1 lb./ton; not to exceed 2374 lb./day	19.2 lb./ton; not to exceed 4536 lb./day
TSS	16.4 lb./ton; not to exceed 3854 lb./day	30.6 lb./ton; not to exceed 7191 lb./day
pH	not outside the range of 5.0-9.0	

The daily average is the average values for 30 consecutive days. The daily maximum is the maximum for any one day.

The BOD_5 and TSS effluent limitations pounds/day, are based on an annual production rate of 235 tons per day. Production is defined as the off-the-machine production measured at off-the-machine moisture content. When Best Conventional Technology (BCT) limitations are promulgated by the EPA, the department may reopen this permit to include such new limitations, if BCT limits are more stringent than the BPT limits.

Table 2. Class A (excellent) freshwater quality standards and characteristic uses (WAC 173-201-045) for the Spokane River from Nine Mile Dam to the Idaho Border (WAC 173-201-080(107).

CLASS A

General Characteristic:

Shall meet or exceed the requirements for all, or substantially all uses.

Characteristic uses:

Shall include, but not be limited to, the following:
domestic, industrial, and agricultural water supply; stock watering; salmonid and other fish migration, rearing, spawning, and harvesting; wildlife habitat; primary contact recreation, sport fishing, boating, and aesthetic enjoyment; and commerce and navigation.

Water Quality Criteria

Fecal Coliform:	Shall not exceed a geometric mean value of 100 organisms/100 mL, with not more than 10% of samples exceeding 200 organisms/100 mL.
Dissolved Oxygen:	Shall exceed 8.0 mg/L.
Total Dissolved Gas:	Shall not exceed 110% saturation.
Temperature:	*Shall not exceed 20.0°C due to human activities. When natural conditions exceed 20°C, no temperature increase will be allowed which will raise the receiving water temperature 0.3°C; nor shall such temperature increases at any time exceed $t=34/(T+9)$. Increases from non-point sources shall not exceed 2.8°C with a maximum of 18.3°C.
pH:	Shall be within the range of 6.5 to 8.5 with a man-caused variation within a range of less than 0.5 units.
Turbidity:	Shall not exceed 5 NTU over background turbidity when the background turbidity is 50 NTU or less, or have more than a 10% increase in turbidity when the background turbidity is more than 50 NTU.
Toxic, Radioactive, or Deleterious material:	Shall be below concentrations which may adversely affect characteristic water uses, cause acute or chronic conditions to aquatic biota, or adversely affect public health.
Aesthetic Values:	Shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch, or taste.

* WAC 173-201-080(107) temperature exception to Class A criteria.

Table 3. Analyses performed by the Washington State Department of Ecology on the Spokane River during the September 11-12, 1990, Inland Empire Paper Company mixing zone survey. An X represents each day's sampling.

Site Name	Profile Depths* (m)	Depth of Sample** (m)	Hard.	Color	NH3	TP	F.C.	Bact†	BOD_5	Metals‡	QA SET
Up rt. 50 ft	1,2,3,4	2.0	XX	X	XX	XX	XX	XX		XX	
Up left 50 ft	1,2,3,4,5	2.5	XX	X	XX	XX	XX		XX	XX	
Down rt. 30 ft	1,2,3,4,5,6,7	4.0	XX	X	XX	XX	XX			XX	
Down left 30 ft	1,2,3,4,5,6	4.0	XX	X	XX	XX	XX	X		XX	
Down rt. 150 ft	1,2,3,4,5,6	4.0	X	X	X	X	X			X	
Down left 150 ft	1,2,3,4,5,6	4.0	XX	X	XX	XX	XX			X	
Down rt. 300 ft	1,2,3,4,5,6	4.0	XX	X	XX	XX	XX	X		XX	
Down left 300 ft	1,2,3,4,5	3.0	XX	X	XX	XX	XX	XX	XX	XX	X
Down rt. 0.2 mi	1,2,3,4,5,6,7	4.0	X	X	X	X	X				
Down left 0.2 mi	1,2,3,4,5,6,7	4.0	X	X	X	X	X	X		X	
Down center 0.2 mi	1,3	3.0	X		X	X	X	X	X	X	X
Down center 0.5 mi	1,2,3,4,5,6	3.0	X	X	XX	XX	XX	XX	XX		
Down center 1 mi	1,2,3,4,5,6	3.0	X		XX	XX	XX	XX	X		

* Profiles measurements included: temperature, D.O., conductivity, and pH.
† Bacteria analyzed were enterococcus and E. coli. and % Klebsiella.
** Fecal Coliform and bacteria samples were taken from the surface only.
‡ Metals analyzed were: cadmium, chromium, copper, lead, nickel, and zinc.

Surface samples were collected by hand-dipping sample bottles at a depth of approximately one foot; a Kemmerer sampler was used to collect samples deeper than a foot below the surface of the water. Subsurface sampling required multiple casts of the sampler to fill all necessary bottles for a particular station. Water from the first cast at each station was used to rinse the sampler, and then discarded. Pre-cleaned sample bottles provided by the Ecology/USEPA Manchester Environmental Laboratory were used (Huntamer and Smith, 1988). Samples collected for laboratory analysis were stored in the dark on ice, and received via air freight by the Ecology/USEPA Manchester Environmental Laboratory within 24 hours. All analyses were performed by the Manchester Lab or a contract laboratory using approved procedures within specified holding times (Huntamer and Smith, 1988). The USEPA (1988) aluminum criteria document recommends using acid soluble results for comparison to criteria; the same method used in this survey for dissolved metals (Huntamer and Smith, 1988).

One set of samples from a randomly selected station was replicated each day for quality assurance (QA), and quality control (QC). Laboratory samples underwent normal QA/QC procedures (Huntamer and Smith, 1988).

Sediment samples were not collected. Collection was attempted with a Ponar grab sampler at several locations as far as 1000 feet downstream of the outfall. However, the river substrate appeared to be cobbles and boulders in all areas, and not amenable to the sampling technique.

Rhodamine WT dye was used to evaluate dispersion of the effluent within the mixing zone. Diluted dye was mixed with IEP effluent at the surge tank outlet to the discharge line at a rate of 130 to 190 mL/minute. Dye was allowed to discharge with effluent for 90 minutes before river sampling commenced. Samples were collected from the river water column above the outfall, and at transects 30', 150', and 300' below the outfall line (as measured from the outfall intersection with the left shore edge). Surface, mid-depth, and near-bottom samples were taken from six or seven points along each transect. A metered cable attached to each shore allowed sample points to be accurately located. Fluorometer difficulties prevented on-site analysis of the samples. Samples were collected into clean glass jars by filling from a Kemmerer sampler, or hand-dipping at the surface. Jars were kept in a cool, dark ice chest until they were read twelve days later at the EILS lab, using a Turner® Model 111 fluorometer. Water collected upstream of the discharge was used as a blank for the readings, and the standard curve. Stock and standard solutions were made using dye mixed with tap water.

RESULTS AND DISCUSSION

General Water Quality Results

Field and laboratory river water sample analysis results are shown in Table 4 and 5. Inland Empire Paper Company effluent analysis results are shown in Table 6. For the duration of this report: 1) the stations upstream of the diffuser were considered background; 2) left and right station labels denote position of the station as the observer faces downstream; 3) mixing zone

Table 4. Receiving water field data for Inland Empire Paper, September 11, 1990.

Station	Side	Distance meters	Depth meters	Temp °C	pH s.u.	Cond. µmhos/cm	D.O. mg/L	D.O.Sat. %
Upstream	right	-15.2	1	19.3	7.8	110	9.5	103
		-15.2	2	19.2	7.8	112	9.6	104
		-15.2	3	19.1	7.8	116	9.6	104
		-15.2	4	19.1	7.8	118	9.6	104
Upstream	left	-15.2	1	19.2	7.8	111	9.6	104
		-15.2	2	19.1	7.7	112	9.5	103
		-15.2	3	19.1	7.7	115	9.5	103
		-15.2	4	19.1	7.7	117	9.5	103
		-15.2	5	19.0	7.7	119	9.5	102
30' down	right	9.1	1	19.2	7.9	108	9.7	105
		9.1	2	19.2	7.9	111	9.7	105
		9.1	3	19.1	7.8	114	9.8	106
		9.1	4	19.1	7.8	115	9.7	105
		9.1	5	19.1	7.8	117	9.7	105
		9.1	6	19.1	7.8	118	9.7	105
		9.1	7	19.1	7.8	119	9.7	105
30' down	left	9.1	1	19.2	7.8	110	9.7	105
		9.1	2	19.1	7.8	111	9.7	105
		9.1	3	19.1	7.8	114	9.6	104
		9.1	4	19.1	7.7	116	9.6	104
		9.1	5	19.1	7.7	120	9.5	103
		9.1	6	19.1	7.7	120	9.5	103
150' down	right	45.7	1	19.4	7.9	108	9.9	108
		45.7	2	19.3	7.9	114	9.9	107
		45.7	3	19.3	7.9	116	9.8	106
		45.7	4	19.2	7.9	115	9.9	107
		45.7	5	19.2	7.9	118	9.8	106
		45.7	6	19.2	7.9	118	9.9	107
150' down	left	45.7	1	19.4	7.9	108	9.8	106
		45.7	2	19.3	7.9	111	9.8	106
		45.7	3	19.3	7.8	117	9.7	105
		45.7	4	19.2	7.8	116	9.7	105
		45.7	5	19.3	7.8	117	9.7	105
		45.7	6	19.2	7.8	118	9.7	105
150' down	left	45.7	0	19.6	7.8	116	9.6	105
		45.7	1	19.6	7.8	119	9.5	104
		45.7	2	19.5	7.8	121	9.8	107
		45.7	4	19.3	7.8	120	9.8	106
		45.7	6	19.2	7.9	118	9.8	106
300' down	right	91.4	1	19.7	8.0	107	9.9	108
		91.4	2	19.6	8.0	109	9.9	108
		91.4	3	19.6	8.0	112	9.9	108
		91.4	4	19.6	8.0	115	9.9	108
		91.4	5	19.5	8.0	116	9.9	108
		91.4	6	19.5	8.0	116	9.9	108
300' down	left	91.4	1	19.7	7.9	112	9.8	107
		91.4	2	19.6	8.0	115	9.8	107
		91.4	3	19.6	8.0	116	9.8	107
		91.4	4	19.6	8.0	119	9.8	107
		91.4	5	19.6	8.0	119	9.9	108

Table 4 (cont). Receiving water field data for Inland Empire Paper, September 11 and 12, 1990.

Station	Side	Distance meters	Depth meters	Temp °C	pH s.u.	Cond. umhos/cm	D.O. mg/L	D.O.Sat. %
1000' down	right	304.8	1	19.6	8.0	109	9.9	108
		304.8	2	19.5	8.0	110	10	109
		304.8	3	19.5	8.0	114	9.9	108
		304.8	4	19.5	8.0	115	10	109
		304.8	5	19.5	8.0	116	10	109
		304.8	6	19.5	8.0	117	10	109
		304.8	7	19.5	8.0	118	10	109
1000' down	left	304.8	1	19.6	8.0	110	9.8	107
		304.8	2	19.6	8.0	111	9.8	107
		304.8	3	19.6	7.9	114	9.8	107
		304.8	4	19.5	7.9	115	9.8	107
		304.8	5	19.5	7.9	118	9.8	107
		304.8	6	19.5	7.9	118	9.9	108
		304.8	7	19.5	8.0	118	9.9	108
2500' down	center	762	1	19.5	8.0	109	9.9	108
		762	2	19.4	7.9	110	9.9	108
		762	3	19.4	7.9	114	9.8	106
		762	4	19.4	7.9	116	9.8	106
		762	5	19.3	7.9	117	9.8	106
		762	6	19.3	7.9	118	9.8	106
5000' down	center	1524	1	19.3	7.8	109	9.7	105
		1524	2	19.3	7.8	111	9.6	104
		1524	3	19.2	7.8	114	9.5	103
		1524	4	19.1	7.7	115	9.3	100
		1524	5	19.0	7.7	117	9.3	100
		1524	6	19.0	7.6	118	9.2	99.2
September 12								
Upstream	right	-15.2	0	18.5	7.3	107	8	85.3
		-15.2	2	18.4	7.2	110	7.9	84.2
		-15.2	4	18.4	7.2	114	7.9	84.1
		-15.2	6	18.4	7.2	118	7.9	84.1
Upstream	left	-15.2	0	18.5	7.3	108	7.9	84.4
		-15.2	2	18.4	7.2	112	7.9	84.2
		-15.2	4	18.4	7.2	115	7.9	84.1
		-15.2	6	18.4	7.2	118	7.9	84.1
30' down	right	9.1	0	18.5	7.3	108	8	85.4
		9.1	1	18.5	7.3	109	8.1	86.4
		9.1	3	18.4	7.2	113	8.1	86.3
		9.1	5	18.4	7.2	117	8	85.2
		9.1	7	18.4	7.2	121	7.9	84.1
30' down	left	9.1	0	18.5	7.2	106	8.1	86.5
		9.1	1	18.5	7.2	108	8.1	86.4
		9.1	3	18.4	7.2	112	8	85.2
		9.1	5	18.5	7.2	151	7.7	82.2
		9.1	6	18.9	7.1	133	7.9	85.0
150' down	right	45.7	0	18.5	7.3	106	8.2	87.5
		45.7	1	18.5	7.3	108	8.3	88.5
		45.7	3	18.4	7.3	113	8.3	88.4
		45.7	5	18.4	7.3	116	8.3	88.4

Table 4 (cont). Receiving water field data for Inland Empire Paper, September 12, 1990.

Station	Side	Distance meters	Depth meters	Temp °C	pH s.u.	Cond. umhos/cm	D.O. mg/L	D.O.Sat. %
150' down	left	45.7	0	18.6	7.3	109	8.2	87.7
		45.7	1	18.7	7.3	118	8.1	86.7
		45.7	3	18.5	7.3	119	8.1	86.5
		45.7	5	18.5	7.2	118	8.1	86.4
300' down	right	91.4	0	18.6	7.3	107	8.3	88.7
		91.4	1	18.5	7.3	107	8.4	89.7
		91.4	3	18.5	7.3	112	8.4	89.5
		91.4	5	18.4	7.3	118	8.4	89.5
300' down	left	91.4	0	18.6	7.3	110	8.3	88.7
		91.4	1	18.6	7.3	111	8.3	88.7
		91.4	3	18.6	7.3	116	8.3	88.7
		91.4	5	18.5	7.3	118	8.3	88.6
1000' down	center	304.8	0	18.7	7.3	110	8.2	87.8
		304.8	3	18.6	7.3	114	8.2	87.6
2500' down	center	762	0	18.8	7.3	108	8.1	87.0
		762	3	18.6	7.3	115	8.1	86.6
5000' down	center	1524	0	19.3	7.3	107	7.7	83.6
		1524	3	18.9	7.3	113	7.8	83.9

Table 5. Receiving water laboratory data for Inland Empire Paper survey, September 11-12, 1990. A river discharge of 880 cfs was measured at the upstream transect on September 12.

September 11

Station	Side	Dist. m	Depth m	BOD 5 mg/L	Color c.u.	NH3 mg/L	Hard. mg/L	Total P mg/L	F. coli CFU/100mL	Klebsiella %	E.coli CFU/100mL	Enteroc CFU/100mL	Cu µg/L	Zn* µg/L
Upstream	rt	-15.2	1						10	100	1.3	5		
			2	<2.0	15	<0.005	54	0.024						55.5 B
Upstream	left	-15.2	1						18					
			2		15	0.01	50	0.025						
30' down	rt	9.1	1						10					
			2		20									
			4		5	0.005	48	0.018						50.5 B
			6		20									
30' down	left	9.1	1						15	100	1.3	10		
			2		20									
			4		15	<0.005	43	0.015						50.8 B
			6		30									
			2		10									
			4		15									
			6		15									
150' down	left	45.7	1						95					
			2		20									
			4		25	<0.005	48	0.023						
			6		15									
300' down	rt	91.4	1						10					
			2		10									
			4		15	<0.005	50	0.018					4.9 J	46.0 B
			6		20									
300' down	left	91.4	1						460	14	397.0	60		
			2		10									
			3	<2.0	15	<0.005	54	0.021					2.4 J	54.7 B
Duplicate			3		25	0.005	51	0.022	760				2.4 J	52.3 B
			5		15									
0.2 mi	rt	304.8	1						30					
			4		15	<0.005		0.020						
0.2 mi	left	304.8	1						93	52	45.0	7.5		
			4		20	0.005	46	0.021						45.9 B
0.5 mi	center	762	1						20	100	1.3	12		
			3	<2.0	15	0.007	41	0.019						
1.0 mi	center	1524	1						10	100	1.3	10		
			3	<2.0		0.006	45	0.018						

Table 5. Continued.

September 12

Station	Side	Dist. m	Depth m	BOD5 mg/L	NH3 mg/L	Hardness mg/L	Total P mg/L	F. coli CFU/100mL	Klebsiella %	E.coli CFU/100mL	Enteroc CFU/100mL	Cu µg/L	Zn µg/L
Upstream	rt	-15.2	0					23					
			2		<0.005	49	0.014						59.4 B
Upstream	left	-15.2	0					25	100	1.3	7.5		
			2	3	<0.005	46	0.013						52.3 B
30' down		9.1	0					13					
			3		<0.005	45	0.017						55.8 B
30' down	left	9.1	0					33	100	1.3	2.5		
			3		<0.005	47	0.016						55.5 B
150' down	rt	45.7	0					28					
			3		<0.005	55	0.015						57.7
150' down	left	45.7	0					23					
			3		<0.005	44	0.017						56.6 B
300' down	rt	91.4	0					10	100	1.3	2.5		
			3		<0.005	55	0.017					2.1 J	56.6 B
300' down	left	91.4	0					40					
			3	5	<0.005	44	0.021						53.6 B
0.2 mi	center	304.8	0					13	100	1.3	7.5		
			3	105	<0.005	55	0.017						
Duplicate			3		<0.005	44	0.018	320					
0.5 mi	center	762	0					30	100	1.3	13.0		
			3	62	<0.005		0.016						
1.0 mi	center	1524	0					5	100	1.3	7.5		
			3		<0.005		0.019						

Qualifiers

B = element also detected in blank sample.

J = element is estimate, above detection limit but below quantification limit.

* = The following metals were analyzed but all samples analyzed were below detection limits:

Cadmium < 2.0 µg/L   Lead < 20 µg/L

Chromium < 5.0 µg/L   Nickel < 10 µg/L

The detection limit for copper and zinc was 2.0 µg/L.

Table 6. Inland Empire Paper Company effluent data collected during the Ecology Class II Inspection: September 11 - 12, 1990. Data from Das and Zinner, 1991.

PARAMETER	UNITS	9/11 Grab	9/12 Grab	24-hr. Composite		
FIELD						
Temperature	°C	30.7	31.4	----		
pH	s.u.	7.2	7	7.4		
Conductivity	µmhos/cm	571	625	563		
LABORATORY						
Turbidity	NTU	34	34	32.5		
Conductivity	umhos/cm	510	595	580		
Alkalinity	mg/L as CaCO3	58	62	58		
Hardness	mg/L as CaCO3	65	58	100		
Color	c.u.	250	400	280		
TS	mg/L			530		
TNVS	mg/L			87		
TSS	mg/L	23	25	27		
TNVSS	mg/L			66.7		
BOD5	mg/L			23		
COD	mg/L	260	240	250		
TOC	mg/L			59.5		
NH3-N	mg/L	0.012	0.0025	<0.005		
NO2+NO3-N	mg/L	0.113	0.111	<0.01		
Total P	mg/L	0.425	0.42	0.41		
Ortho P (auto)	mg/L	0.126	0.138	0.182		
Ortho P (manual)	mg/L			0.16		
Fecal Coliform	CFU/100mL	310	240			
E.Coli	CFU/100mL	6	<2.5			
Enterococci	CFU/100mL	30	120			
% Klebsiella	percent	81	100			
METALS				Dissolved	Total	Blank
Cyanide	mg/L			<0.005	<0.005	
Aluminum	µg/L			442	1010	
Antimony	µg/L			1.6 J	< 2.5	< 2.5
Arsenic	µg/L			3.5 J	3.6 J	< 1.5
Cadmium	µg/L			< 0.1	0.11 J	< 0.1
Chromium +6	µg/L	202	23			<0.005
Copper	µg/L			17.4 J	17 B	3 J
Lead	µg/L			3.8 J	1.8 JB	< 1
Mercury	µg/L			0.052 J	< 0.04	0.1 J
Zinc	µg/L			46.2	21.1 B	4.2 J

J = Estimated value

B = Analyte was detected in blank as well as in sample samples were those taken downstream within 300 feet (91 m) of the diffuser; and 4) far-field samples were those taken at 1000 feet (305 m), 2500 feet (762 m), and 5000 feet (1524 m) downstream.

Color, hardness, and fecal coliform replicate analyses exhibited high variability; total phosphorus and ammonia duplicates were less variable. Since samples were not always collected during the same Kemmerer cast, some of the variability may reflect error in sampler placement and the dynamics of the effluent plume mixing in the river.

Laboratory calibration, blanks, and spikes for most analyses were within acceptable QC ranges (Twiss, 1990). However, most zinc analyses were qualified values because the blank sample contained 3.3 and 5.7 parts per billion (ppb or μg/L) zinc (Table 5).

The seven-day, ten-year, low flow (7Q10) and one-day, ten year events for the Spokane River at IEP were calculated to compare the 880 cubic feet per second (cfs) flow observed during the survey to the critical design conditions for the discharge. Data from USGS Station 12422500 at RM 72.9 were analyzed and the water balance portion of the Spokane River/Long Lake phosphorus model (Patmont *et al.*, 1987) were used to estimate the 7Q10 at RM 82.6.

Inspecting the USGS 7Q10 events for the period of record showed an obvious step trend in the 1930s (Figure 3). The date coincides with the construction and completion of the Upriver (Spokane) Dam in 1935 (USGS, 1991: Figure 21, pg. 242). Therefore, only the data collected since 1935 was used. The Log-Pearson distribution in the statistical program WQHYDRO (Aroner, 1990) was used to generate frequency duration values (Table 7). The 7Q10 discharge of 757 cfs for the past 55 years is 131 cfs lower than the 7Q10 for the 87 year record (1892-1979) published by USGS (1985). The water balance model simulated aquifer and river water exchanges, and resulted in a 7Q10 discharge of approximately 820 cfs at RM 83 with the 760 cfs at RM 72.9 (Table 8). The 1Q10 discharge was estimated to be 700 cfs at RM 83. The discharges are general estimates since the Patmont *et al.* (1987) model has not been calibrated at a range of low flows.

The 880 cfs discharge observed during the survey was only slightly higher than the calculated 7Q10 low flow value, and probably not significantly different considering the errors in the method. The estimated river/effluent dilution factor during the sampling period averaged approximately 185, i.e., 4.76 cfs discharge into a Spokane River volume of 880 cfs. Dilution factors within the dilution zone will be discussed in detail (see-Dye and Mixing Zone Field Results section). Effluent was meeting the NPDES requirements for BOD, TSS, pH, discharge volume, and bioassay (Das and Zinner, 1991).

Few of the mixing zone area samples contained effluent contaminants exceeding water quality criteria. A fecal coliform (FC) concentration of 460 colony forming units/100mL (cfu/100mL) was detected 300' below the diffuser from the left half of the river (Table 5). The FC density

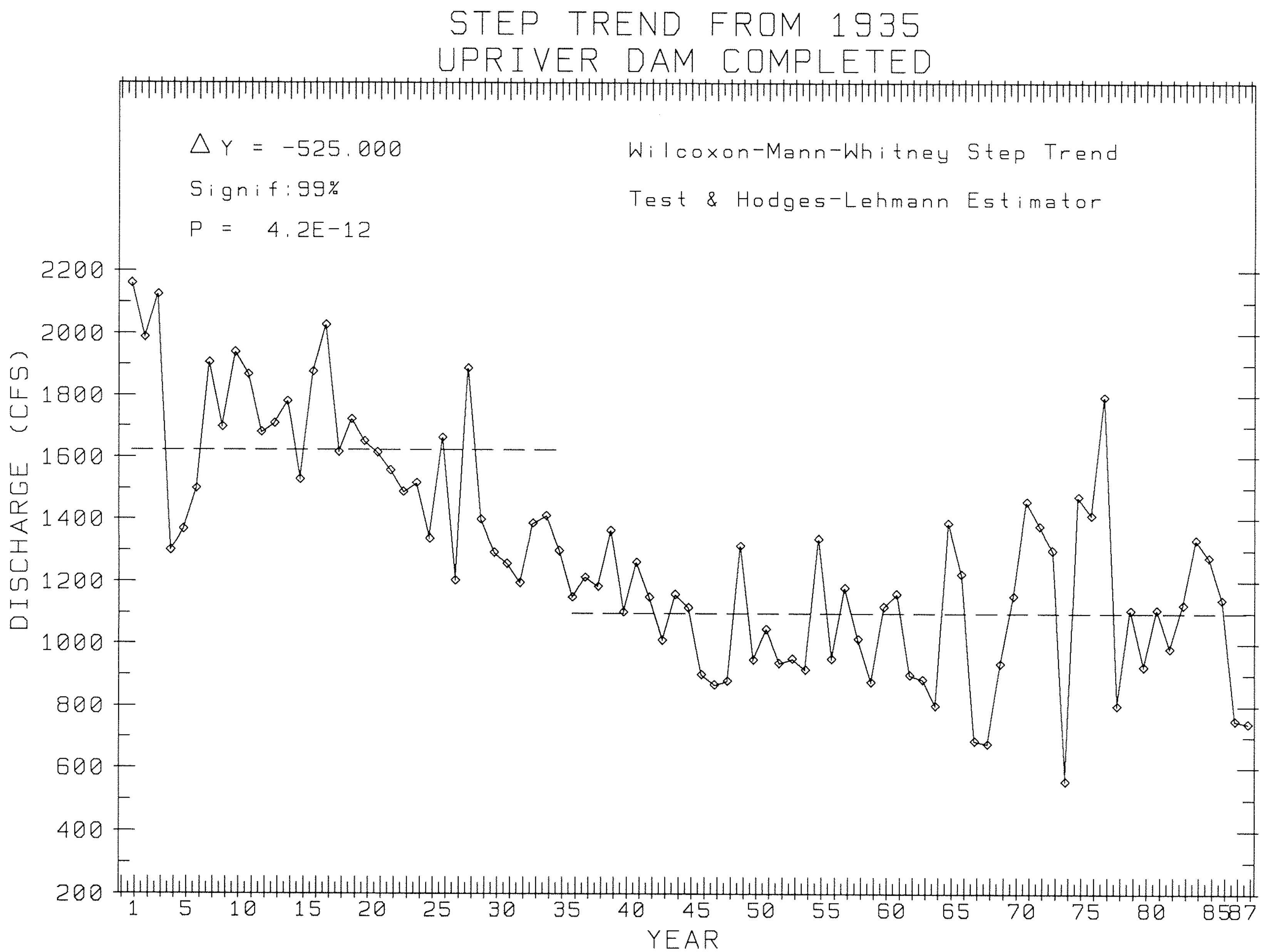


Figure 3. Record of annual 7-day low flow events at USGS Station No. 12422500 at river mile 72.9 of the Spokane River. Upriver Dam was completed in 1935 (see text). Data were analyzed and presented using WQHYDRO (Aroner, 1990) software.

Table 7. Frequency duration statistics generated for low flow data from the USGS discharge record on the Spokane River (12422500) for 1935 to 1987.

Spokane River Frequency Duration Table: 1 to 30 Days; 1.1 to 50 years.

		DAYS					
		1	3	5	7	15	30
YEAR	1.1	1248.8	1304.2	1355.5	1402.3	1540.4	1716.6
	2	952.79	1017.6	1049.9	1072.2	1132	1246.3
	3	854.88	917.77	947.06	964.19	1011	1107.5
	4	799.92	860.84	888.96	903.69	945.22	1032.4
	5	762.64	821.88	849.39	862.69	901.42	982.38
	6	734.86	792.68	819.82	832.16	869.16	945.61
	7	712.95	769.54	796.44	808.08	843.93	916.88
	8	694.99	750.51	777.25	788.34	823.38	893.5
	9	679.85	734.42	761.04	771.71	806.15	873.92
	10	666.82	720.55	747.08	757.4	791.38	857.14
	15	620.61	671.11	697.43	706.64	739.44	798.23
	20	591.04	639.31	665.55	674.15	706.53	760.99
	25	569.66	616.22	642.44	650.64	682.87	734.26
	30	553.08	598.28	624.49	632.42	664.6	713.64
	35	539.64	583.7	609.91	617.63	649.83	696.99
	40	528.4	571.49	597.7	605.26	637.51	683.1
	45	518.77	561.01	587.24	594.66	626.97	671.24
	50	510.37	551.87	578.1	585.42	617.8	660.92

Climatic Year, Log–Pearson 3, by WQHYDRO Program, Aroner (1990).

Table 8. Water balance output from the Spokane River model by Patmont et al., 1987 using a 7-day, 10-year low flow at river mile 72.9 of 760 cfs.

Summary of Water Balance by Reach				
Upstream River Mile	Downstream River Mile	Surface Water In/Out (cfs)	Ground Water In/Out (cfs)	River Flow (cfs)
111.7	106.6	3.4	0.0	503.4
106.6	101.7	-32.1	0.0	471.3
101.7	96.0	0.2	21.8	493.3
96.0	93.0	0.0	9.2	502.4
93.0	90.4	0.4	0.0	502.8
90.4	87.8	0.0	0.0	502.8
87.8	85.3	1.1	313.1	817.0
85.3	82.6	1.6	0.0	818.6
82.6	79.8	3.7	-256.2	566.1
79.8	78.0	0.0	366.8	932.9
78.0	74.1	0.0	-179.7	753.2
74.1	69.8	6.9	141.8	901.9
69.8	67.6	0.0	42.8	944.6
67.6	64.6	53.6	58.3	1,056.5
64.6	62.0	0.3	50.5	1,107.3
62.0	58.1	0.0	0.0	1,107.3
58.1	33.9	328.3	23.3	1,458.9

Long Lake Outflow = 1458.893 $\pm$ 247.9901 cfs is greater than the Class A criteria. However, the other FC densities within the mixing zone were far lower than this with a higher percentage of *Klebsiella*. The source of the high fecal density remains uncertain.

Field conductivity and temperature profile results at various stations indicated some effluent mixing zone characteristics (Table 4). In general, the effluent appeared to be more concentrated near the bottom at 30' below the diffuser, and near the surface at 150' and 300'. There also appeared to be a tendency for the effluent to be heading toward the left shore. Samples analyzed for color also exhibited a similar tendency (Table 5).

Average water column temperatures were highest 300' below the diffuser on the first day of the survey. The average water column temperature increases did not exceed the 1.2° allowed using the criterion formula [WAC 173-201-080(107)], with an ambient upstream temperature of 19.1°. On the second day, temperatures appeared to generally increase downstream with only a slight effect from the effluent.

None of the copper, chromium, lead, nickel, or zinc concentrations in the IEP effluent or river exceeded aquatic life acute toxicity criteria (Table 5). IEP effluent concentrations of copper and lead needed a dilution factor of two or three to bring concentrations into compliance with chronic aquatic toxicity criteria at a river hardness of 50 mg/L as $CaCO_3$ (Table 6). Detection limits were too high to determine if cadmium in the river exceeded acute and chronic toxicity criteria. However, cadmium in the IEP effluent was below both state and USEPA aquatic toxicity criteria. Although zinc was detected in the blank, the river concentrations were near the chronic criterion both upstream and downstream of the IEP outfall (Table 5). Zinc concentrations were lower in the IEP effluent than in the river upstream of the outfall (Table 5 & 6). Zinc criteria violations in the Spokane River from the Coeur d'Alene mining district have been documented by others (Yake, 1979; Yearsley, 1982).

Hexavalent chromium, aluminum, and mercury were not analyzed in the receiving water samples, but were elevated in the IEP effluent (Table 6). The hexavalent chromium (Cr^{+6}) concentrations exceeded both acute and chronic criteria, but they are highly suspect results since total chromium concentrations were below detection limits. Neither aluminum nor mercury effluent concentrations exceeded acute aquatic toxicity criteria. The IEP effluent dissolved aluminum concentration required a dilution factor of five to meet the aquatic toxicity chronic criterion of 87 μg/L. The mercury effluent concentration required a dilution factor of four to meet the aquatic toxicity chronic criterion of 0.012μg/L; the maximum Cr^{+6} concentration observed needed a dilution factor of 18 to meet chronic toxicity criteria of 11μg/L.

Since metals appear to be the near-field contaminants of concern for this plant, additional metals effluent data would be useful to establish realistic coefficients of variation. Data should be representative of seasonal, product line, effluent volume, and treatment plant influences on metals concentrations. Once the coefficients are established, a statistically valid evaluation of the dilution factors needed and adequacy of the mixing zone can be made. Future receiving water surveys should include metals as well.

The D.O. concentrations and saturations increased in the mixing zone area over upstream values, but then dropped at the last two far-field stations (Table 4). The D.O. concentrations on the second day of the survey were 7.9 mg/L, just below the 8 mg/L criterion, upstream of the outfall, and dropped to 7.7 and 7.8 mg/L at the station farthest downstream. Five day BOD samples collected at 1000 feet and 2500 feet downstream had extremely high concentrations; much higher than the IEP effluent composite sample concentration (Tables 5 & 6).

Past surveys of the Spokane River have recorded D.O. depressions and high algal productivity in this reach (Yearsley, 1982; Gibbons *et al.*, 1984; Patmont *et al.*, 1985). Slow current velocities (low reaeration rates), elevated temperatures (low D.O. saturations), and high algal activity (high respiration) in the pool behind the Upriver Dam, probably contribute to the D.O. problem. Wastewater from IEP and other point and nonpoint dischargers could also be aggravating the problem.

A QUAL2E model of this reach of the Spokane River was constructed to simulate D.O. response to IEP effluent volumes. QUAL2E is a one-dimensional, steady-state, numerical model applicable to well-mixed river system and supported by the USEPA (Brown and Barnwell, 1987). The model structure and simulations are presented in Appendix A. The model was based on few data, but the simulations (Appendix A, Figure 1) indicate the D.O. problem and BOD loading into the Upriver Dam pool deserve further study because of the sensitivity of the reach. Future field monitoring should focus on wastewater effects on this and other pool reaches of the Spokane River during the low flow season.

Dye and Mixing Zone Field Results

The current dilution zone was not fully characterized during the survey. We attempted to dye the river at levels below human visibility, but within the range of fluorometer detection. Dye was detected in 34 (60%) of the 57 samples collected. However, the readings were all at the lowest end of the scale; only 19 samples (33%) had readings of 1 unit or greater. The fluorometer could not be run off the van battery as planned, so the low dye concentration problem was not discovered until the samples were run 12 days later.

Transect and dilution zone boundaries were not quite aligned (Figure 2). Samples along the 30 foot transect were collected approximately 12 to 20 feet away from the outfall line. The 300 foot transect line was approximately 280 feet from the center of the diffuser.

The estimated dilution factor of effluent in the Spokane River during the dye survey was 175 to 185 based on a river discharge of 880 cfs, and an effluent discharge rate of 2148 to 2275 gallons per minute. A fluorometer reading of 1 unit was calculated to be approximately equivalent to a dilution factor of 155 (Appendix B).

Field samples yielded dye concentrations with dilution factors of 22 to >155 (Figure 4). Dye concentrations generally followed the same pattern as the water quality results discussed earlier (i.e., effluent was detected near the bottom at 30 feet, and then on the surface and to the left

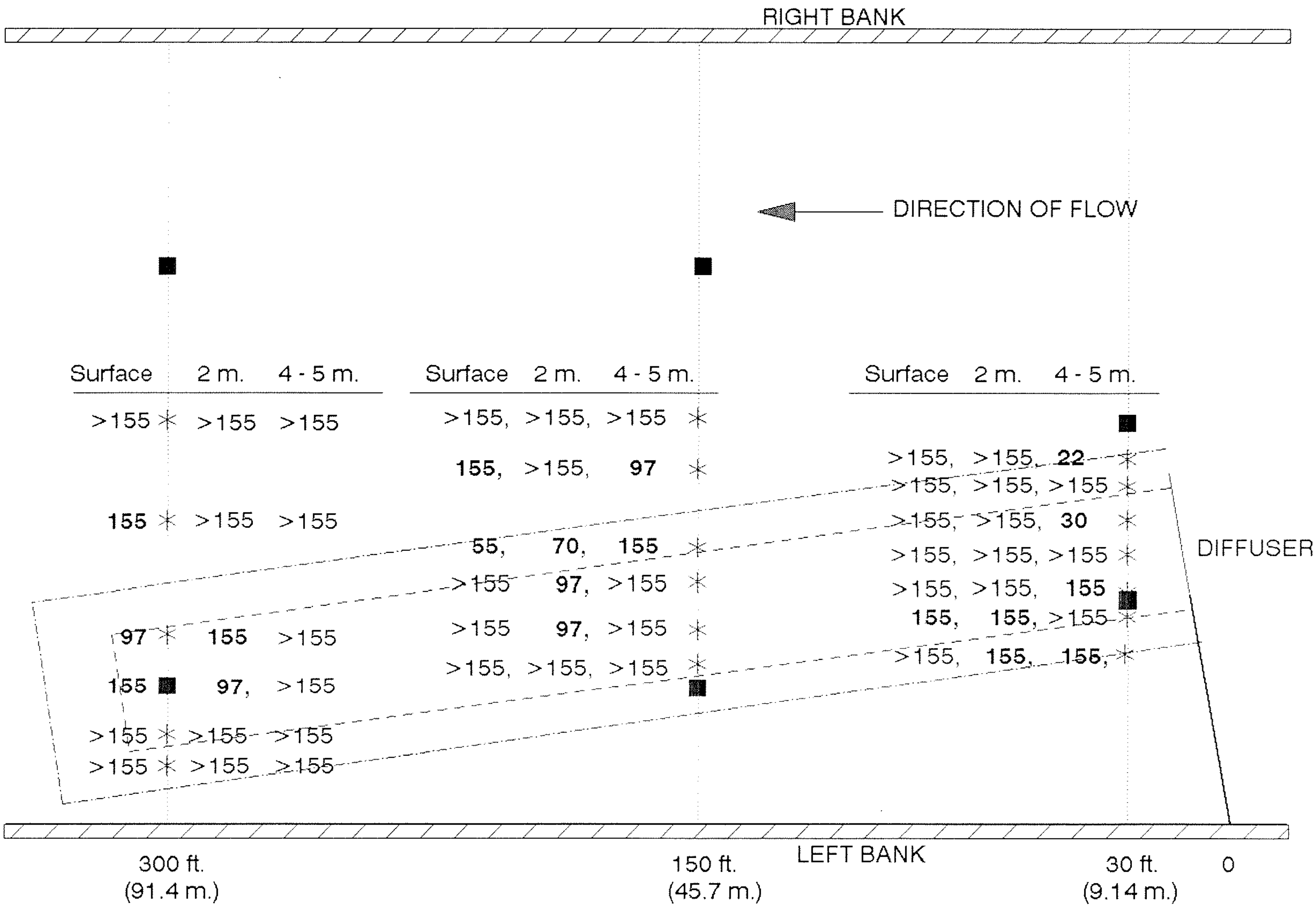


Figure 4. Dye study estimated dilution factors along three transects at three depths in the Spokane River below the Inland Empire Paper Company diffuser, 9/12/90.

side of the river at 150 foot and 300 foot transects). The centerline of the dye plume appeared to move from 90 feet off the left bank at the 150 foot transect to 30 feet at the 300 foot transect.

Dilution factors exceeded 100 at most points sampled at the 300 foot transect, 280 feet downstream of the diffuser (Figure 4). The greatest width observed with dilution factors less than 100 was 45 feet at the 150 foot transect. This is wider than acceptable under current guidelines (35 feet), but within the proposed mixing zone standards (56 feet).

CORMIX 2 and UDKHDEN Model Results

The multiple diffuser models, CORMIX2 and UDKHDEN, were used to evaluate the diffuser and to compare the model output to field chemical and dye survey results. CORMIX2 is an expert software system for the analysis, prediction, and design of multiport submerged discharges into flowing waters (Akar and Jirka, 1990). UDKHDEN is a multiport mathematical model that considers variable ambient density/temperature and velocity profile effects on individual and merging discharge plumes in unbounded systems (Muellenhoff *et al.*, 1985). Both models are recommended by the U.S. Environmental Protection Agency for analysis of diffusers and mixing zones (USEPA, 1991).

Initial model input data were based on field values and are listed in Table 9. Both models require generalization of the diffuser structure and ambient conditions, so the model outputs are not expected to be an identical match with field results. If more detail is desired, both model manuals suggest separate simulations on portions of the diffuser (i.e., running a simulation on all six inch diameter ports, then all ten inch ports, and the open end of the diffuser because of its different orientation). This level of analysis was not performed for this report.

Both models predicted surfacing of effluent within the mixing zone. CORMIX2 predicted immediate surfacing and a centerline dilution factor of 31. UDKHDEN predicted surfacing within 45 feet downstream and a average flux dilution factor of 61 (centerline dilution factor of 44). The UDKHDEN model simulations end when the plume surfaces.

Mean centerline dilution factors for the plume are shown for the CORMIX2 output in Figure 5. When divided by a factor of 1.4 to convert flux average dilution to centerline dilution, the UDKHDEN dilution output matches CORMIX2 results fairly well.

CORMIX2 predicted interaction between the plume and the left shore within 115 feet of the diffuser. Interaction with the right shore was predicted to occur 240 feet downstream. The estimated centerline dilution factors at these distances were 45 and 49, respectively (Figure 5). The simulated buoyant plume spread laterally, stratified near the surface, and then dispersed back down through the water column at distances between 16 feet (4.8 m), and 830 feet (252.5 m) downstream. The centerline of the simulated plume stayed parallel to the shore and just slightly left of the midpoint of the diffuser.

Table 9. Variables input to CORMIX2 and UDKHDEN mixing zone models for the Inland Empire Paper, receiving water survey simulation of field conditions: September 12, 1990.

		CORMIX2	UDKHDEN
RIVER CONDITIONS:			
Depth of channel	(meters)	7.25	7.25
Width of channel	(meters)	70.1	---
Surface velocity	(m/sec)	---	0.073
Velocity at bed	(m/sec)	---	0.073
Mean velocity	(m/sec)	0.073	0.073
Surface temp.	(°C)	---	19.1
Depth temp.	(°C)	---	19.1
Mean temp.	(°C)	19.1	---
Manning "n"		0.03	---
DIFFUSER DESCRIPTION:			
Diffuser length	(meters)	9.75	9.75
Number of ports		9	9
Port spacing	(meters)	1.22	1.22
Mean port diameter	(m2)	0.2032	0.2032
Diffuser depth	(meters)	---	6.33
Port height	(meters)	0.9144	---
Distance to 1st port	(meters)	20.41	---
Distance to Last	(meters)	30.02	---
Port angle relative to horizontal		0	0
Angle of current relative to diffuser		---	100
Orientation angle (ß)		90	---
Horizontal discharge offset angle (sigma)		10	---
Alignment angle (y)		100	---
EFFLUENT DESCRIPTION:			
Discharge volume	(m3/sec)	0.14	0.14
Temperature	(°C)	30.5	30.5

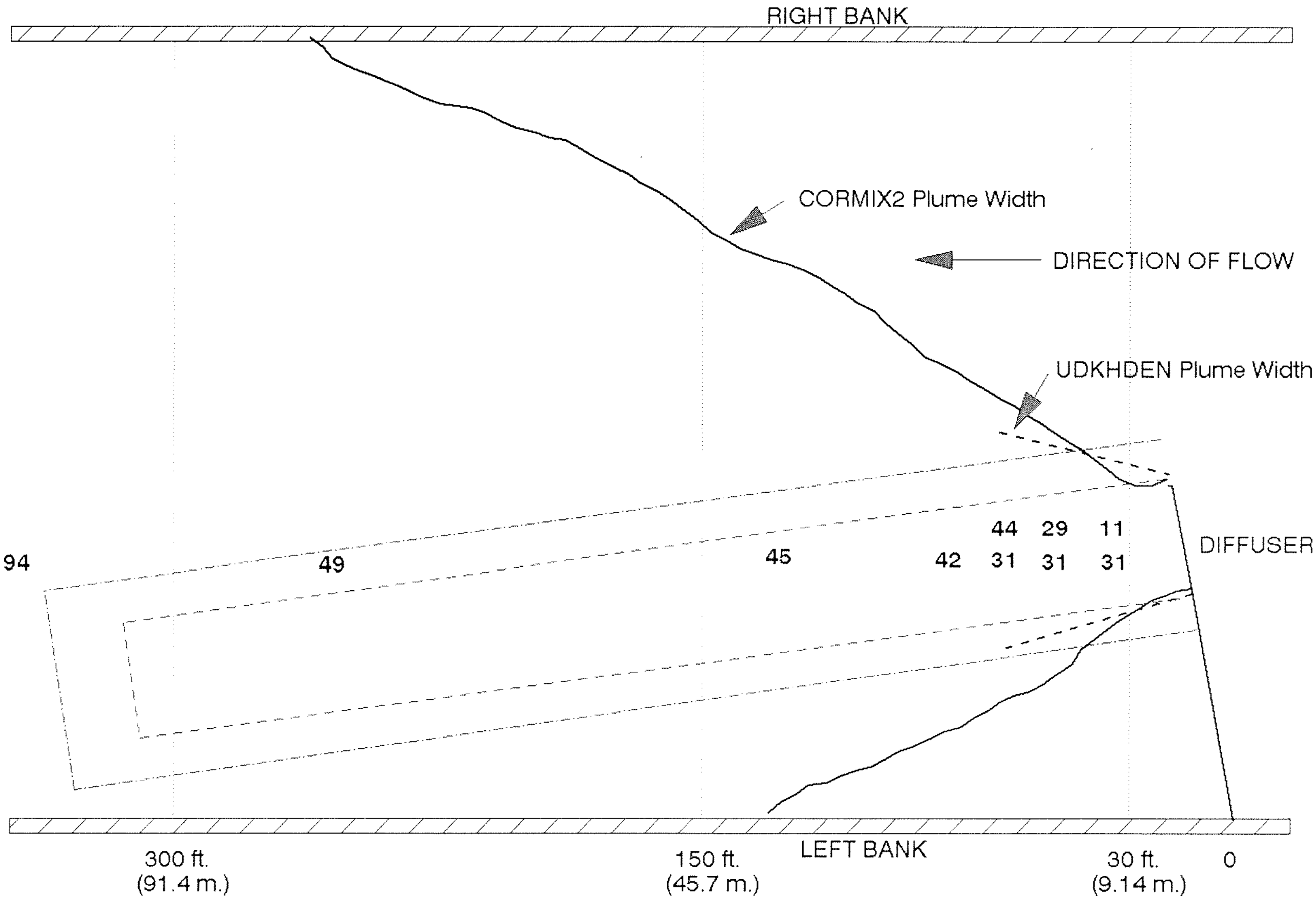


Figure 5. CORMIX2 and UDKHDEN mixing model plume widths and centerline dilution factors for field and discharge conditions: 9/12/91. Upper row are UDKHDEN model flux average dilution factors divided by 1.4.

The model simulations were also fairly similar to the field data collected, and are shown in Figure 4. CORMIX2 and UDKHDEN dilution factors are within the range observed at the 30 foot and 150 foot transect stations. The initial behavior of the UDKHDEN plume appeared to be more similar to the dye data than the CORMIX2 plume. However, the final dilution factor of 94 predicted by CORMIX2 at 300 feet was only slightly less than the 97 observed at 280 feet. The water quality and dye data also appeared to follow the CORMIX2 simulation which suggested stratification of the effluent to the surface of the water column at 300 feet. The drift of the plume centerline toward the left shore was not as apparent in the simulations as in the field data. However, field data dilution factors nearest the left shore never dropped below 155 which suggested the simulated plume interaction with the shore was inconsequential.

Three additional simulations were performed to observe mixing zone sensitivity to single variable input changes:

1. The temperature of the effluent was reduced by 10.5°, from 30.5° to 20° C;

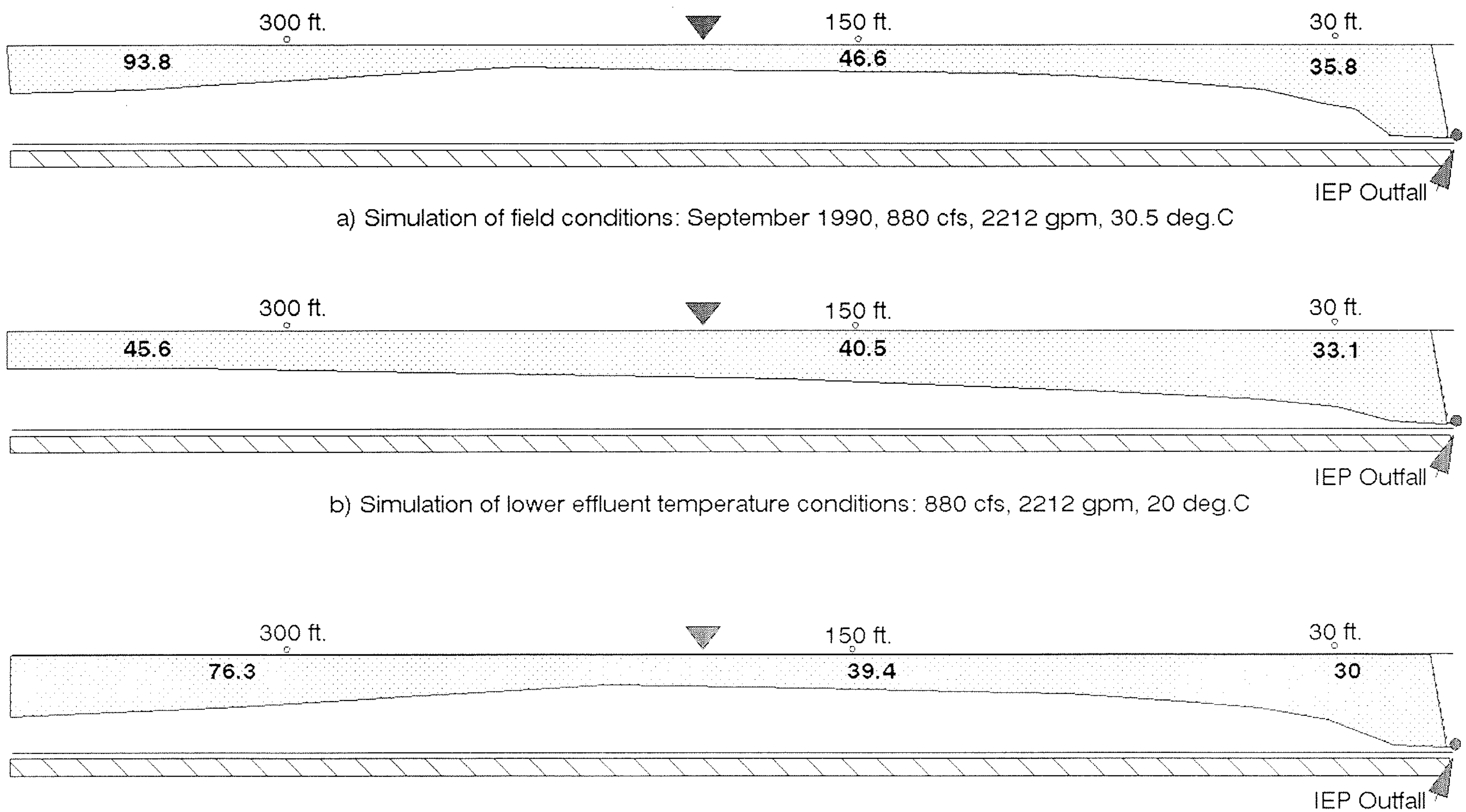
2. The effluent volume was increased to 4.0 mgd (2778 gpm), the maximum daily discharge anticipated for the mill with the de-inking units (Esvelt, 1990); and

3. The ambient river temperature was increased to 20°C to observe whether the 0.3° temperature increase criterion could be met.

The first two simulations indicated near-field dilution and dispersion rates similar to the field survey simulation results (Figure 6). However, dilution and dispersion at the edge of the mixing zone (300-320 feet) was lower. Lower effluent temperatures allowed more of the water column to be used for mixing, but the buoyant spreading processes were reduced. This resulted in effluent dilution half of what was shown under the field conditions, i.e., a dilution factor of 45.6, compared to 93.8 at 328 feet (100 m). Increasing the effluent volume did not change the plume behavior, so the reduction in the dilution factor was roughly proportional to the increase in effluent volume.

The ability of the effluent plume to meet the 20°C ambient temperature condition criterion (i.e., not to cause an increase over 0.3°) was simulated using design plant flow conditions and an effluent temperature of 30.5°C. The CORMIX2 temperature simulation was very similar to the second simulation (Figure 6c). A temperature increase at the centerline of the buoyant surface plume was estimated to be 1°, 30 feet downstream of the outfall; by 100 feet it was 0.8°; and at 320 feet it had decreased to 0.4° with a total plume thickness of 11.8 feet. The criterion was met 420 feet downstream.

The simulation does not give a prediction of an obvious violation of the criterion. The temperature criterion is not specific if the increase should be judged as a maximum increase in any portion of the water column, or the increase over an average of water column temperatures. The centerline concentration would be the maximum encounter and only in the top half (12 of 24 feet) of the water column. The model input also is not finely tuned to be accurate within



a) Simulation of field conditions: September 1990, 880 cfs, 2212 gpm, 30.5 deg.C

b) Simulation of lower effluent temperature conditions: 880 cfs, 2212 gpm, 20 deg.C

c) Simulation of higher effluent discharge: 880 cfs, 2778 gpm, 30.5 deg.C

Figure 6. Side view of three CORMIX2 simulations of the Inland Empire Paper Co. effluent dispersion into the Spokane River. Vertical mixing and dilution factors are shown for various simulated conditions.

0.2°C. Based on these considerations, the effluent diffuser and mixing zone appear to be adequate to protect the beneficial uses of the river against detrimental temperature increases.

Mixing Zone Results Summary

IEP effluent appeared to be meeting most aspects of the current and proposed mixing zone criteria during the survey. The field dye work, effluent characterization, and model simulation results indicated the diffuser system and mixing zone dimensions were adequately protecting water quality during the survey. The survey data suggested the plume met the proposed mixing zone length and width criteria better than the current guidelines. The proposed dimensional criteria appear to be more reasonable under these circumstances. Most of the effluent contaminants did not exceed acute aquatic toxicity criteria, or required a dilution factor less than 5 to meet chronic aquatic toxicity criteria. The suspect Cr^{+6} effluent concentration required a maximum dilution factor of 18. Such low dilution factors appeared to be easily met a few feet from the diffuser. The effluent plume surfaced, but at a dilution factor of 30 to 40. However, more metals data would be desirable to obtain coefficients of variation and evaluate the mixing zone adequacy under a valid range effluent concentrations.

Receiving water conditions during the survey were near what could be expected under 7Q10 conditions: river velocities and discharge volumes were low, ambient temperatures were high, and chronic low D.O. conditions were present. Therefore, the mixing zone would probably be as protective of water quality and aquatic life under 7Q10 conditions as it was during the survey. A dilution factor guideline of 100 is recommended to protect aquatic life against priority pollutant chronic toxicity (Ecology, 1985; USEPA, 1991); the survey data suggested effluent at the edge of the mixing zone was meeting the guideline. However, the CORMIX2 model simulation indicated far-field, buoyant plume mixing is very dependent on the difference between effluent and receiving water temperatures. Therefore, the 100:1 guideline may not be consistently achieved during some combinations of effluent and ambient critical conditions.

A CORMIX2 model simulation of an increased effluent volume at the design daily average plant capacity (4.0 mgd), suggested there would be adequate initial dilution to meet aquatic toxicity criteria at current contaminant levels in the effluent. Temperature problems outside the mixing zone were not predicted to be severe. The dilution factor guideline of 100 will less likely be met within the proposed mixing zone dimensions as effluent volumes approach the design flow. Chronic toxicity testing is recommended as dilution factors fall below 100, or effluent characteristics change (USEPA, 1991).

CONCLUSIONS

The September mixing zone survey at IEP achieved several of the objectives stated in the proposal. Although the dye work was only marginally successful, a general characterization of the mixing zone dimensions was made. The CORMIX2 and UDKHDEN simulations independently confirmed some of the field observations, and provided insights for interpretation of some of the observed plume behavior. The water quality monitoring provided basic background information at the site, but sediment monitoring was not successful. Some of the more important findings of this evaluation were:

- The 7Q10 discharge of 757 cfs, since the construction of the Upriver Dam in the 1930's is 131 cfs lower than the 7Q10 for the 87 year record (1892-1979) published by USGS for their station at RM 72.9. The water balance model resulted in a 7Q10 estimate of 820 cfs at RM 83.

- IEP effluent was meeting the NPDES requirements. Few of the mixing zone area samples contained effluent contaminants exceeding water quality criteria. Effluent concentrations of copper, lead, aluminum, mercury, and possibly hexachromium required dilution factors in the range of 2-18 to meet chronic aquatic toxicity criteria. These dilution factors were easily met a few feet from the diffuser.

- The IEP discharge system appeared to be meeting most aspects of the current and proposed mixing zone criteria during the survey. The survey data suggested the plume met the proposed mixing zone length and width dimensional criteria better than the current guideline dimensions. The dye study indicated the dilution factors were greater than 100 at most points sampled at the 300 foot transect downstream of the diffuser. The greatest width observed with dilution factors less than 100 was within the proposed mixing zone width standards.

- The field data dilution factors were similar to CORMIX2 and UDKHDEN models predictions. The final dilution factor of 94 predicted by CORMIX2 at 300 feet was only slightly less than the 97 observed in the dye study.

- A CORMIX2 simulation of effluent plume behavior with a lower effluent temperature predicted dilution factors half of the field conditions simulations. A simulation using maximum design effluent volume did not predict changes in the plume behavior, but the dilution factor prediction was roughly proportional to the increase in effluent volume. A simulation testing the 0.3° temperature increase criterion suggested the mixing zone was adequate to protect aquatic life against harmful temperature effects.

- Slow current velocities (low reaeration rates), elevated temperatures (low D.O. saturations), and high algal activity (high respiration) in the pool behind the Upriver Dam contribute to a potential D.O. problem in the Upriver Dam pool. A preliminary QUAL2E model simulation of this reach of the Spokane River was constructed, and indicated the D.O. problem and BOD loading into the pool deserve further exploration.

RECOMMENDATIONS

- The mixing zone dimensional criteria used under the discharger settlement agreement with Ecology are protective of Spokane River water quality, and appear to be more reasonable in these circumstances than the older mixing zone guidelines.

- The use of CORMIX2 and/or UDKHDEN simulations by IEP, to evaluate the diffuser and mixing zone performance, is appropriate. ERO staff should also become active users of these models to interpret results and recognize the models limitations.

- Since metals are the near-field contaminants of concern, effluent concentrations of copper, lead, aluminum, and mercury should be collected more often to establish valid coefficients of variation. Mixing zone adequacy could then be evaluated under a wider variety of conditions. Receiving waters should also be sampled for mercury and aluminum.

- Chronic toxicity monitoring of the effluent should be undertaken by IEP when new process units come on line, effluent characteristics change, or as effluent volumes approach the daily average maximum capacity. The presence of hexavalent chromium in the effluent requires confirmation.

- A portion of future field monitoring by IEP and the ERO should focus on wastewater effects on D.O. in the Upriver Dam and other pool reaches of the Spokane River during the low flow season. At a minimum, the sampling plan in this pool should include:

    1) Sampling stations located upstream of the IEP diffuser, downstream one mile, and downstream just above the dam ($\approx$RM 80.3).
    2) D.O. and temperature measurements should be taken at surface, mid-depth, and bottom levels of the water column.
    3) Sample runs should be made at least in early morning (before 7 am) and late afternoon (after 3 pm) every two weeks in August and September.
    4) BOD samples should be analyzed from the effluent, and mid-depth level of the receiving water stations.

- The 7Q10 and other statistically derived design flow criteria for sites along the Spokane River need to account for historical changes in flow routing in the system, e.g., dam construction and irrigation diversions. The period of record used should be consistent with the current hydrologic conditions and groundwater exchange at the site.

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APPENDIX A

Low flow dissolved oxygen (D.O.) conditions on the Spokane River from river mile (RM) 82.8, just above the Inland Empire Paper (IEP) discharge, to RM 58, just below the Nine Mile Dam were modeled using the water quality model QUAL2EU (Brown and Barnwell, 1987). The model was set-up as a 'first-cut' effort to evaluate possible dissolved oxygen problems. Important hydraulic and water quality data for some key reaches in the river were not available, especially those reflecting low flow conditions below RM 72.9. Most of the hydraulic and groundwater data for this model were adapted from modeling efforts by Patmont *et al.* (1985) and Yearsley (1982). Sensitivity and verification of the model were not performed, but a simulation of the August 1979 EPA study data presented by Yearsley (1982), fit within the range of values observed at RM 82.6 to RM 72.9. Simulated D.O. concentrations in the first reach, RM 82.8 to RM 79.8, also fit field data observed during this 1990 Ecology survey.

The 24.8 mile section of river was divided into eight reaches (Table A-1). Hydraulic and water quality coefficients were assigned to each reach using available data and best professional judgement. IEP, Hangman Creek, Spokane wastewater treatment plant (WWTP), and Northwest Terrace WWTP were identified as point sources in the model. Groundwater infiltration and exfiltration was handled through the incremental inflow routine. The four dams located along the modeled section were included in the model, and a 0.5 fraction of flow over each was arbitrarily assigned to account for penstock and bypass routing conditions.

The first reach of the model was of primary importance to ERO in this study. An example of the model simulations of IEP BOD loading effects on D.O. in this reach is presented in Figure A-1. The loading assumptions for the simulations are summarized in Table A-2.

Table A-1. Example of Spokane River input to QUAL2E model for Inland Empire Paper Co. evaluation, September 1990.

SPOKANE RIVER STEADY STATE MODEL: FOR BOD COMPARE AT
LOW FLOW (820 CFS); IEP AT 0.1 MG/L AND DAMS AT 50%
BIOCHEMICAL OXYGEN DEMAND & DISOLVED OXYGEN IN MG/L

5D-ULT BOD CONV K COEF = 0.23000

NUMBER OF REACHES	= 8		
NUMBER OF JUNCTIONS	= 0		
NUM OF HEADWATERS	= 1	NUMBER OF POINT LOADS	= 4
TIME STEP (HOURS)	=	LTH COMP ELEMENT (DX)=	0.2
MAXIMUM ITERATIONS	= 30		
LATITUDE OF BASIN (DEG)	= 47.4	LONGITUDE OF BASIN (DEG)=	117.3
STANDARD MERIDIAN (DEG)	= 75.0	DAY OF YEAR START TIME	= 240
EVAP. COEFF. (AE)	= 0.00068	EVAP. COEFF. (BE) =	0.00027
ELEV. OF BASIN (ELEV)	=1900	DUST ATTENUATION COEF.=	0.13

O2 UPTAKE BY NH3 OXIDATION (MG O2/MG N)= 3.43 BY NO2 = 1.14

STREAM REACH NUMBER	DESCRIPTIVE NAME	RIVER MILES FROM	TO
1	INLAND EMPIRE TO UPRIVER DAM	82.8	79.8
2	UPRIVER DAM TO GREEN ST. BRDG	79.8	78.0
3	GREEN ST. TO POST ST. DAM	78.0	74.2
4	POST ST. TO FORT WRIGHT BRDG.	74.2	70.2
5	FORT WRIGHT TO DOWNRIVER G.C.	70.2	67.6
6	DOWNRIVER G.C. TO GUN CLUB	67.6	64.6
7	GUN CLUB TO SEVENMILE BRDG.	64.6	62.0
8	SEVENMILE BR. TO NINEMILE DAM	62.0	58.0

REACH ELEMENT CODE: 1=HEADWATER, 2=STANDARD, 5= LAST, 6=PT.INPUT

REACH NUMBER	NUMBER OF ELEMENTS	INDIVIDUAL ELEMENT CODE
1	15	1 6 2 2 2 2 2 2 2 2 2 2 2 2 2
2	9	2 2 2 2 2 2 2 2 2
3	19	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
4	20	2 2 2 2 2 2 2 2 6 2 2 2 2 2 2 2 2 2 2 2
5	13	2 2 2 2 2 2 2 2 2 2 2 2 2
6	15	2 2 2 2 2 2 2 2 6 2 2 2 2 2 2
7	13	2 6 2 2 2 2 2 2 2 2 2 2 2
8	20	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 5

HYDRAULIC DATA: VELOCITY AND DEPTH COEFFICIENTS & EXPONENTS

REACH NUMBER	VELOCITY COEFF.	VELOCITY EXPONENT	DEPTH COEFFICIENT	DEPTH EXPONENT
1	0.000230	1.000	13.224	0.032
2	0.008500	0.690	0.860	0.265
3	0.002300	0.790	2.200	0.189
4	0.005100	0.740	1.630	0.196
5	0.005100	0.740	1.560	0.206
6	0.005100	0.740	3.490	0.100
7	0.000290	0.950	1.990	0.220
8	0.001700	0.800	4.610	0.107

BOD & DO REACTION RATES & REAERATION COEFFICIENT TYPES

REACH NUMBER	BOD DECAY RATE	REAERATION COEFFICIENT FORMULA
1	0.44	O'CONNER AND DOBBINS
2.	0.45	CHURCHILL
3.	0.43	O'CONNER AND DOBBINS
4.	0.42	CHURCHILL
5.	0.44	CHURCHILL

Table A-1 continued.

6.	0.44	CHURCHILL
7.	0.45	O'CONNER AND DOBBINS
8.	0.46	O'CONNER AND DOBBINS

INITIAL CONDITIONS - SURFACE WATER AND GROUNDWATER EXCHANGE

REACH NUMBER	TEMP. ° F	D.O. MG/L	BOD MG/L	GROUNDWATER CFS	TEMP. °F	D.O. MG/L	BOD MG/L
1	66.2	9.4	1.5	-256.2	66.2	10.0	1.5
2	66.2	9.4	1.5	366.8	49.5	6.0	0.5
3	66.2	9.4	1.5	-179.7	66.2	10.0	1.5
4	66.2	9.4	1.5	141.8	49.5	6.0	0.5
5	66.2	9.4	1.5	42.8	49.5	6.0	0.5
6	66.2	9.4	1.5	58.3	49.5	6.0	0.5
7	66.2	9.4	1.5	50.0	49.5	6.0	0.5
8	66.2	9.4	1.5	0	66.2	10.0	1.5

HEADWATER CONDITIONS AND POINT SOURCE INPUTS

	FLOW CFS	TEMP. ° F	D.O. MG/L	BOD MG/L
SPOKANE RIVER	820.0	66.2	8.5	1.5
INLAND EMPIRE	5.6	86.0	8.0	0.1
HANGMAN CR	6.9	68.0	8.0	3.0
SPOKANE WWTP	54.4	68.0	6.0	45.0
NWTERRACE WWTP	0.3	68.0	6.0	45.0

DAM DATA

NAME	LOCATION		ADAM	BDAM	FRACTION	HEIGHT
	REACH	ELEMENT	FACTOR	COEFF.	SPILLING	FEET
UPRIVER DAM	2	2	1.600	1.05	0.5	35.0
POST ST. DAM	3	19	1.600	1.05	0.5	64.0
MONROE ST. DAM	4	2	1.600	1.05	0.5	68.0
NINEMILE DAM	8	19	1.600	1.05	0.5	65.0

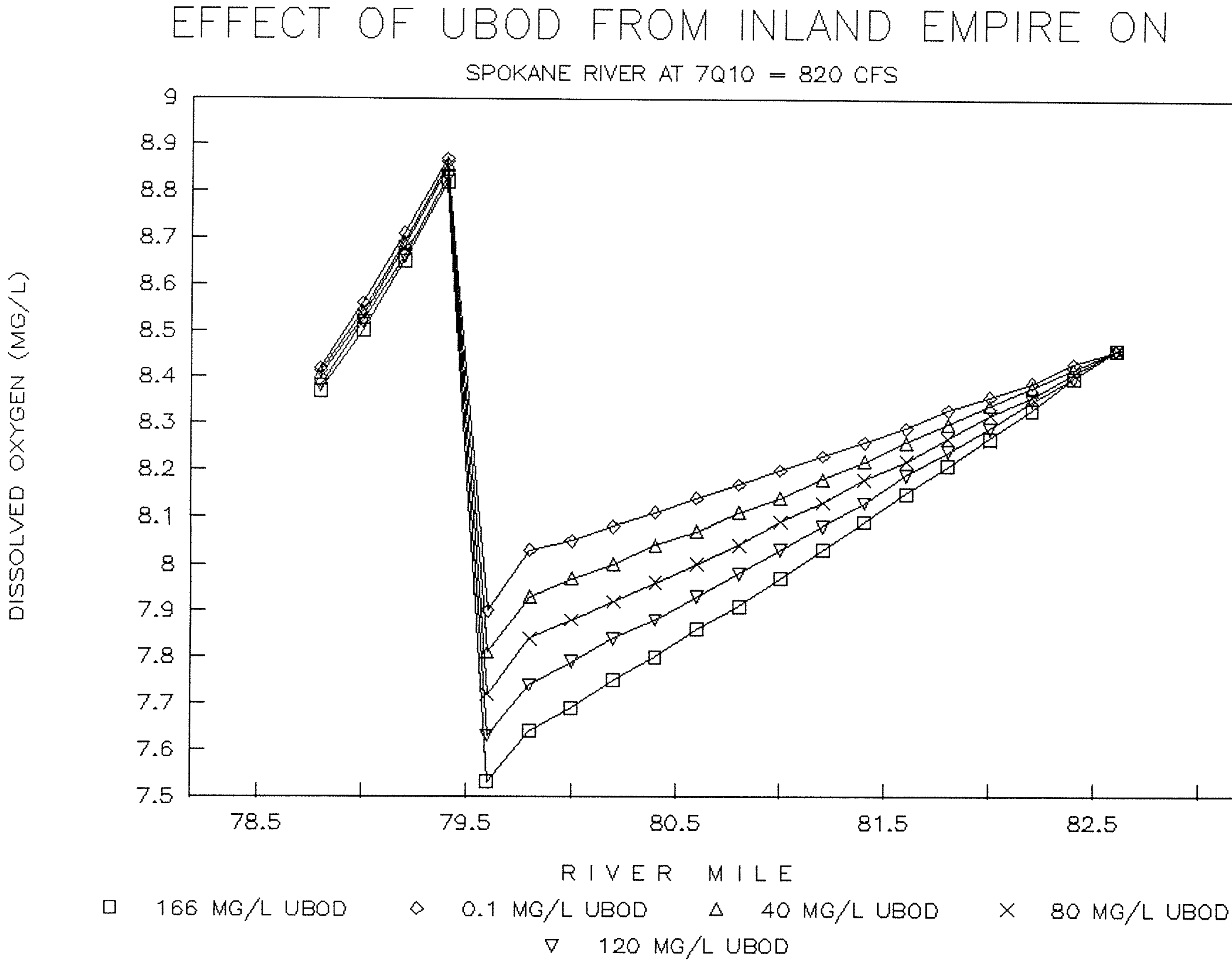

Figure A-1. QUAL2E model simulations of dissolved oxygen concentrations below the Inland Empire Paper Company wastewater discharge. Effects from various ultimate BOD (UBOD) effluent concentrations are shown.

Table A-2. Input for a set of QUAL2E simulations on the effects of Inland Empire Paper Co. effluent BOD loading on D.O. concentrations in the Spokane River. Results are illustrated in Figure A-1.

INPUT DESCRIPTION	VALUE
River discharge (cfs)	820
River temperature (°C)	19.0
River dissolved oxygen (mg/L)	8.5
River Ultimate BOD (mg/L)	1.5
IEP effluent discharge (cfs)	5.6
IEP effluent temperature (°C)	30.0
IEP effluent D.O. (mg/L)	8.0
IEP effluent NH3-N (mg/L)	0.01
IEP BOD EFFLUENT CONDITIONS	ULTIMATE BOD VALUE
Five-day BOD = 0 mg/L (mg/L)	0.1
" " 27 " "	40
" " 54 " "	80
" " 82 " "	120
" " 113 " "	166

APPENDIX B

Calculation of dilution of dye in Inland Empire Effluent and dye concentrations in the Spokane River.

Rhodamine WT dye stock solution: 210 mL into 43 L water
Injection of dye stock solution into effluent: 130 mL/min. the first 3 hrs. to 190 mL/minute the last hour with a effluent discharge rate of 2148 to 2275 gpm.
River discharge: 880 cfs upstream of the outfall

Calculation of dye in effluent:

1) Low concentration:

210 mL dye ÷ 43000 mL water = 4.88×10^{-3} mL dye/mL

4.88×10^{-3} mL dye/mL x 130 mL/minute = 0.6344 mL dye/minute

0.6344 mL dye/minute ÷ (2148 gpm x 3784.8 mL/min. / gpm) =
0.6344 mL dye/minute ÷ 8.13×10^{6} mL/min. effluent = 7.8×10^{-8} mL dye /mL effluent

2) Average concentration:

4.88×10^{-3} mL dye/mL x 130 mL/minute = 0.6344 mL dye/minute

0.6344 mL dye/minute ÷ (2212 gpm x 3784.8 mL/min. / gpm) =
0.6344 mL dye/minute ÷ 8.37×10^{6} mL/min. effluent = 7.58×10^{-8} mL dye /mL effluent

Calculation of dye standard standards:

Stock solution:
0.01 mL dye ÷ 250 mL water = 4.0×10^{-5} mL dye/mL
4.0×10^{5} mL dye/mL x 0.1 mL ÷ 50 mL = 8×10^{-8} mL dye/mL

Standards:
1. 8×10^{-8} mL dye/mL x 0.1 mL ÷ 50 mL = 1.6×10^{-10}
2. 8×10^{-8} mL dye/mL x 0.3 mL ÷ 50 mL = 4.8×10^{-10}
3. 8×10^{-8} mL dye/mL x 0.6 mL ÷ 50 mL = 9.6×10^{-10}
4. 8×10^{-8} mL dye/mL x 2.0 mL ÷ 50 mL = 3.2×10^{-9}
5. 8×10^{-8} mL dye/mL x 4.0 mL ÷ 50 mL = 6.4×10^{-9}

Readings and Dilution Factors:
Blank = 0
Standard 1 = < 1 (≈ 0.5) fluorometer unit (fu)
Standard 2 = 1 fu
Standard 3 = 2 fu
Standard 4 = 5.5 fu
Standard 5 = 11.0 fu

Beer's Law regression of standard curve:
fu = $(1.689 \times 10^{9} \times C) + 0.1809$

Example: 1 fu using regression = 4.88×10^{-10}
155 dilution factor = $7.58 \times 10^{-8} \div 4.88 \times 10^{-10}$