JOHN SPELLMAN
Governor

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
7272 Cleanwater Lane, LU-11 • Olympia, Washington 98504

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MEMORANDUM
May 25, 1982

To: Files

From: Lynn Singleton and Joseph Joy

Subject: Spokane River Data

This memo documents work completed on the Spokane River during 1980 and 1981. The surveys and information presented here represent efforts of Art Johnson, Shirley Prescott, Tim Determan, Dale Norton, John Bernhardt, and ourselves.

The five surveys included are a response to information and/or data needs of the Spokane River Wasteload Allocation Study (URS, 1981). Their compilation at this time is to ensure the data are not lost. The surveys are as follows: (1) Spokane River Point Sources; (2) Spokane River Dissolved Oxygen Levels Below Long Lake; (3) Groundwater Samples Around Long Lake; (4) Spokane River Time of Travel; and (5) Water Quality of Long Lake Embayments.

Spokane River Point Sources

The study was a cooperative effort by the Environmental Protection Agency (EPA) and the Washington Department of Ecology (WDOE). The purpose of the study, as it was originally designed by EPA, was to identify sources and sinks for nutrients and metals between Post Falls and Hangman Creek. Data collection occurred during four different flows. The first survey was solely conducted by EPA. WDOE then became involved in the project and expanded the sampling to include all Spokane River point sources within the state. WDOE was responsible for the quantification and qualification of these sources, whereas EPA monitored river discharge and water quality. The original project by EPA has been completed and a report drafted (Yearsley, 1981). The point source data collected by WDOE is presented here. Point source locations are presented in Figure 1.

Materials and Methods

Acid-washed, 24-hour compositors were set up at the final discharge of each point source. Samples were drawn at 30-minute intervals

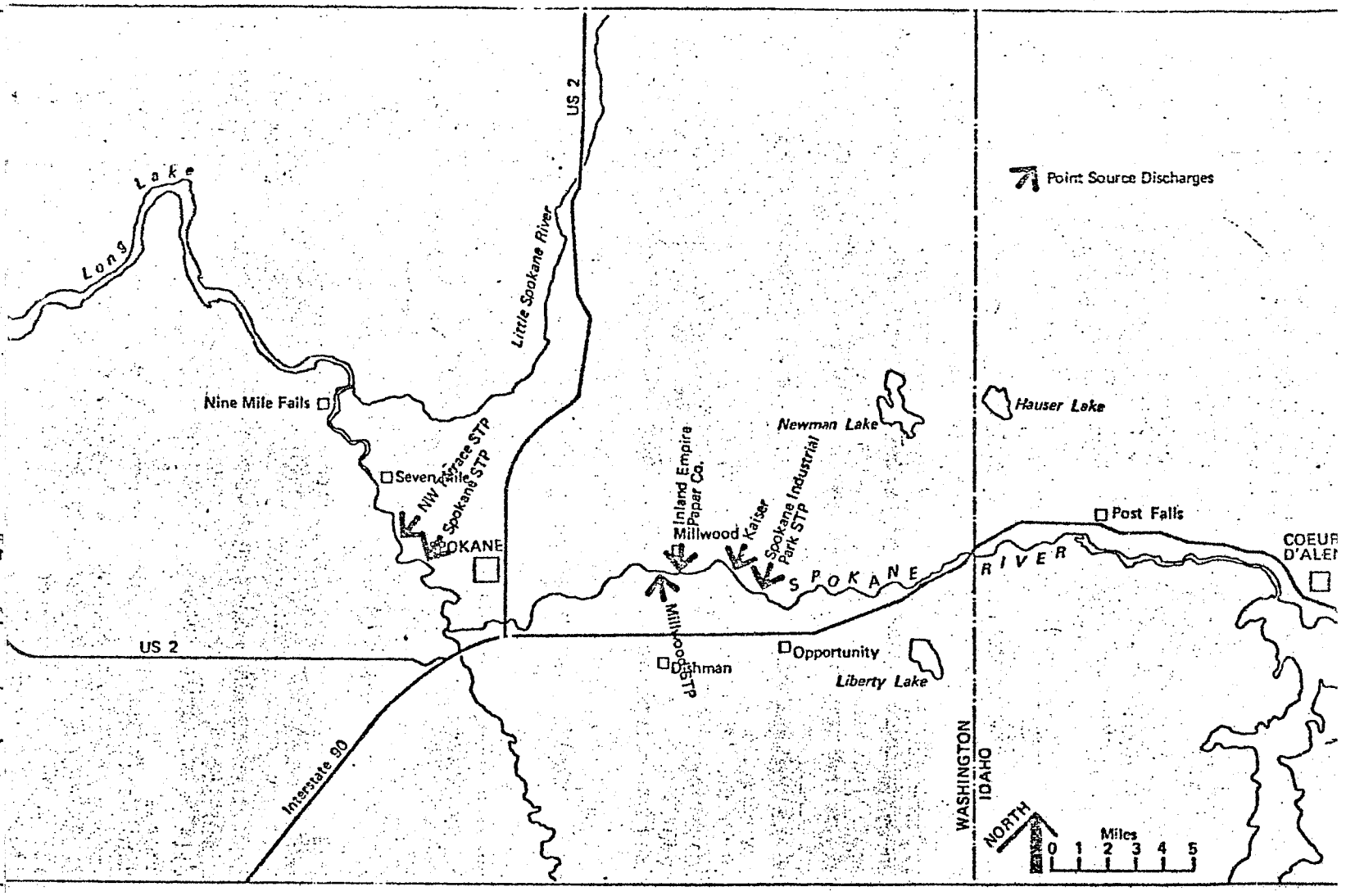

Figure 1. Spokane River point sources. After URS (1981).

and composited in the iced carboy of the compositor. After 24 hours, subsamples were taken from the composite, kept at 4°C, and delivered to the Olympia environmental laboratory within 24 hours. These samples were analyzed as per APHA.AWWA.WPCF (1980) for conductivity, pH, total phosphate-phosphorus, orthophosphate-phosphorus, nitrate-nitrogen, nitrite-nitrogen, ammonia-nitrogen, total solids, total nonvolatile solids, total suspended solids, total nonvolatile suspended solids, turbidity, chemical oxygen demand, biochemical oxygen demand, chloride, chromium, copper, iron, nickel, lead, zinc, and mercury. Grab samples were collected for fecal coliform, oil and grease, phenolics, and cyanide and shipped as per composited samples. Temperature, dissolved oxygen (Winkler method), pH, specific conductance, chromium +VI, and total residual chlorine were determined in the field. Flows were determined from either: (1) plant discharge records; (2) Manning Dipper flow meter; or (3) calculations using weir and instantaneous head height.

Results

Table 1 contains data collected from the point sources. Loadings have been calculated from the 24-hour composite samples and grab samples where appropriate (Table 2).

Spokane River Dissolved Oxygen Levels Below Long Lake Dam

A dissolved oxygen survey was made in the Spokane River between Long Lake and Little Falls dams on September 26, 1980. Profiles were made at mid-stream with an IBC D.O. meter at five stations. The meter was calibrated against a sample analyzed using the Winkler method just prior to the field work. *In situ* measurements were made at two-meter intervals from surface to the bottom.

Temperatures and D.O. concentration at each site indicated the river waters were homogeneous. Mean values have therefore been reported where appropriate (Table 3). The mean D.O. was below the Class A criterion at all stations; however, the increase in D.O. concentration between stations 4 and 5 possibly indicates the standard of 8.0 mg/L would be met before Little Falls Dam was reached, approximately 1.7 miles down stream. Turbulence caused by Little Falls Dam would also increase aeration. The data appear to indicate that the low D.O. is confined to the 4.8-mile reach between Long Lake Dam and Little Falls Dam.

Table 1. Effluent concentrations of selected parameters from Spokane River point sources. All values are expressed in mg/L unless otherwise noted; N.D. means none detected.

Date	Dissolved Oxygen	Temp. (°C)	pH (S.U.)	Specific Cond. (µmhos/cm)	Residual Chlorine	T-PO_4-P	O-PO_4-P	NO_2-N	NO_3-N	NH_3-N	Total Solids	TNVS	Total Susp. Solids	TNVSS	Turbidity (NTU)	COD
SPOKANE INDUSTRIAL PARK - RM 87.1																
3/31/80	8.7	10.8	7.9	350	N.D.											
4/01/80	7.9	12.2	7.7	315	N.D.											
24-hr. comp.			7.6	373		1.6	1.2	<0.01	1.4	2.4	270	170	22	9	24	52
6/10/80	7.9	17.3	7.3	420	0.02											
6/11/80	7.6	18.0	7.7	413	0.01											
24-hr. comp.			7.6	411		2.9	1.5	0.04	4.1	1.8	320	220	29	15	32	43
2/10/81	9.3	5.6	8.3	390	0.0											
2/11/81	9.2	6.5	8.0	340	0.3											
24-hr. comp.			8.1	488		3.7	3.7	<0.01	2.0	2.9	340	210	81	36	63	61
KAISER ALUMINUM AT TRENTWOOD - RM 86.0																
Sanitary Effluent																
3/31/80	5.4	12.6	7.0	290	1.0											
4/01/80	0.0	13.5	7.5	480	1.0											
24-hr. comp.			7.4	364		0.9	1.5	0.04	1.3	6.2	210	140	4	<1	24	83
6/10/80	6.2	16.9	7.3	375	0.6											
6/11/80	5.5	18.6	7.0	580	0.8	2.3	2.0	0.38	3.0	7.0						
24-hr. comp.			7.7	492		3.1	1.5	0.38	3.3	5.3	290	200	10	2	10	54
2/10/81	9.0	5.8	7.4	488	2.0											
2/11/81	8.0	5.6	7.7	490	1.5											
24-hr. comp.			7.5	474		1.6	1.1	<0.01	4.4	6.8	270	150	4	1	6	45
Industrial Effluent																
3/31/80	0.0	26.6	6.7	2360	N.D.											
3/31/80	0.0	28.9	8.2		N.D.											
4/01/80	0.0	28.0	11.9		N.D.											
24-hr. comp.			10.3	2120		<0.1	0.04	0.12	2.5	0.7	2400	2100	170	110	62	890
6/10/80	0.0	31.6	10.6	>1000	N.D.											
6/11/80	0.0	<40.0	10.8	>1000	N.D.											
24-hr. comp.			12.1	3890		1.3	0.30	0.20	<0.05	2.9	4200	3400	71	47	31	660
2/10/81	N.D.	28.4	7.3	>1000												
2/11/81		20.8	11.8	>1000												
24-hr. comp.			11.0	2010		2.3	1.6	<0.05	<0.05	2.1	2300	1700	51	39	23	1300
Combined Effluent																
3/31/80	10.3	11.9	7.2	145	N.D.											
4/01/80	10.5	12.3	8.7	135	<0.1	0.46	0.01	0.01	0.15	0.08						
24-hr. comp.			7.4	127		0.08	0.05	<0.01	0.13	0.09	99	60	<1.0	<1.0	5	14
6/10/80	8.6	19.4	6.4	100	0.2											
6/11/80	8.3	21.1	6.4	131	<0.1											
24-hr. comp.				126		0.06	0.03	<0.01	0.06	0.11	87	71	<1.0	<1.0	3	7
2/10/81	11.8	7.4	9.2	103	0.0											
2/11/81	11.2	7.4	7.8	98	0.0											
24-hr. comp.			8.4	142		0.09	0.08	<0.01	0.14	0.05	98	70	2	2	4	24

Table 1. Effluent concentrations of selected parameters from Spokane River point sources - continued. All values are expressed in mg/L unless otherwise noted; N.D. means done detected.

Date	Oil and Grease	Phenolics	BOD_5	Fecal Coliform (org/100 ml)	*Klebsiella* (Percent)	Chloride	CN	Total Cd	Total Cr	Total Cr+6	Total Cu	Total Fe	Total Ni	Total Pb	Total Zn	Hg (µg/L)	Flow (MGD)
SPOKANE INDUSTRIAL PARK - RM 87.1																	
3/31/80	5	0.020		96						N.D.							
4/01/80	6	0.001		<2						N.D.							
24-hr. comp.			9					<0.01	<0.01		2.2	0.15	<0.05	0.20	0.14	0.33	0.61
6/10/80	N.D.	0.011		1 1/	0		0.02			N.D.							
6/11/80	N.D.	0.008		1 1/	0					N.D.							
24-hr. comp.			6			8.5		<0.01	<0.02		3.1	0.98	0.42	0.17	0.20		0.69
2/10/81				220													
2/11/81				4 1/													
24-hr. comp.			14			13		<0.01	<0.02		2.7	0.46	0.31	1.0	0.82	0.72	0.78
KAISER ALUMINUM AT TRENTWOOD - RM 86.0																	
Sanitary Effluent																	
3/31/80	8	0.022		23						N.D.							
4/01/80	11	0.046		2 1/						N.D.							
24-hr. comp.			14					<0.01	<0.01		0.01	0.12	0.30	<0.05	0.14	0.25	
6/10/80	N.D.	0.018		2 1/	0												
6/11/80	9	0.030		49	22												
24-hr. comp.			7			45		<0.01	<0.02		0.01	0.17	<0.05	<0.05	0.12		0.16
2/10/81				0													
2/11/81				4 1/													
24-hr. comp.			<4			54		<0.01	0.03		<0.01	0.02	<0.03	<0.07	0.13	<0.20	0.19
Industrial Effluent																	
3/31/80	16	0.079		<2						N.D.							
4/01/80	22	0.203		<1						N.D.							
24-hr. comp.			130					0.01	2.4		0.03	3.5	0.1	0.1	0.09	0.25	0.07
6/10/80	N.D.	0.60		<1													
6/11/80	16	0.56		2 1/	0												
24-hr. comp.			120			13		0.01	0.73		0.02	1.7	0.17	0.10	0.03		0.07
2/10/81																	
2/11/81																	
24-hr. comp.			110			12		0.01	2.9		0.07	1.4	0.11	0.19	0.05	0.24	0.05
Combined Effluent																	
3/31/80	N.D.	0.011		6 1/													
4/01/80	<1.0	0.012	5							N.D.							
24-hr. comp.			8					<0.01	<0.01		<0.01	0.6	<0.05	0.05	0.16	0.25	26.6
6/10/80	N.D.	0.025		125	8					N.D.							
6/11/80	N.D.	0.018		62 1/	0												
24-hr. comp.						1.4		<0.01	<0.02		<0.01	0.10	<0.05	<0.05	0.11		27.3
2/10/81				11 1/													
2/11/81				1 1/													
24-hr. comp.			4			2		<0.01	0.05		0.01	0.13	<0.03	0.10	0.19	<0.20	26.3

1/ Estimated population based on nonideal plate counts.

Table 1. Effluent concentrations of selected parameters from Spokane River point sources - continued. All values are expressed in mg/L unless otherwise noted.

Date	Dissolved Oxygen	Temp. (°C)	pH (S.U.)	Specific Cond. (μmhos/cm)	Residual Chlorine	$T\text{-}PO_4\text{-}P$	$O\text{-}PO_4\text{-}P$	$NO_2\text{-}N$	$NO_3\text{-}N$	$NH_3\text{-}N$	Total Solids	TNVS	Total Susp. Solids	TNVSS	Turbidity (NTU)	COD
INLAND EMPIRE PAPER COMPANY - RM 82.6																
3/31/80	0.0	23.6	7.2	350												
4/01/80	0.0	23.8	6.8	530												
24-hr. comp.			6.8	376		0.43	<0.5	<0.01	<0.05	<0.01	410	180	61	<1.0	82	310
6/10/80	0.8	23.0	6.8	400												
6/11/80	0.0	23.2	6.8	450												
24-hr. comp.			7.3	439		0.80	0.2	<0.1	<0.1	0.5	430	240	57	3	73	240
2/10/81	1.9	26.4	6.5	380												
2/11/81	2.6	25.7	6.8	350												
24-hr. comp.			7.1	413		0.75	0.30	<0.10	<0.1	2.0	470	220	110	11	140	380
MILLWOOD STP - RM 82.3																
6/10/80	3.0	14.2	7.4	555	3.5											
6/11/80	0.5	14.3	7.1	450	0.1											
24-hr. comp.			7.5	490		16	9.2	2.4	1.0	9.8	2300	1300	2000	990	630	1600
2/10/81	8.4	8.2	7.4	390	0.0											
2/11/81	3.8	8.4	7.2	400	0.0											
24-hr. comp.			7.4	435		2.8	2.5	<0.01	10	0.20	390	220	100	35	35	130
CITY OF SPOKANE STP - RM 67.3																
3/31/80	9.7	12.3	7.2	630	0.8											
4/01/80	10.6	12.7	7.2	800	0.8											
24-hr. comp.			7.4	819		0.8	0.5	<0.1	2.0	12.0	460	330	2	<1.0	9	56
6/10/80	10.2	16.6	7.5	675	2.0											
6/11/80	9.1	17.6	7.5	825	1.5											
24-hr. comp.			7.9	719		3.4	2.7	0.80	4.6	11.0	470	320	45	22	28	110
2/10/81	10.4	11.0	7.3	700	0.6											
2/11/81	10.2	10.7	7.2	650	0.3											
24-hr. comp.			7.6	792		0.70	0.55	0.02	12	5.3	480	330	8	6	6	33
NORTHWEST TERRACE STP - RM 64.3																
3/31/80	1.9	13.8	7.0	700	2.0											
4/01/80	2.2	13.9	7.0	700	1.0											
24-hr. comp.			6.9	719		8.5	9.0	<0.1	9.7	2.1	450	340	2	<1.0	8	56
6/10/80	3.6	18.6	7.3	740	2.0											
6/11/80	2.9	19.6	7.3	826	1.0											
24-hr. comp.			7.7	755		8.4	8.4	<0.1	1.0	1.0	440	340	6	<1.0	6	35
2/10/81	1.3	12.0	7.2	700	0.8											
2/11/81	2.2	12.0	7.2	650	1.2											
24-hr. comp.			7.6	785		7.0		0.03	5.3	3.4	480	360	4	2	6	37

Table 1. Effluent concentrations of selected parameters from Spokane River point sources - continued. All values are given in mg/L unless otherwise noted.

Date	BOD_5	Fecal Coliform (org/100 ml)	*Klebsiella* (Percent)	Chloride	Total Cd	Total Cr	Total Cu	Total Fe	Total Ni	Total Pb	Total Zn	Hg (µg/L)	Flow (MGD)
INLAND EMPIRE PAPER COMPANY - RM 82.6													
3/31/80		3,000											
4/01/80		>60,000 1/											
24-hr. comp.	160				<0.01	<0.01	0.01	0.11	<0.05	<0.05	0.02	<0.20	2.15
6/10/80		300 1/, 200 1/	67, 25										
6/11/80		1,000 1/ 500 1/	100, 80										
24-hr. comp.	64			5	<0.01	<0.02	0.03	0.25	0.05	<0.05	0.02		2.19
2/10/81		0											
2/11/81		0											
24-hr. comp.	90			3	<0.01	<0.02	0.08	0.13	<0.03	<0.07	<0.01	0.24	2.40
MILLWOOD STP - RM 82.3													
6/10/80		2,400 1/	<1										
6/11/80		190,000 1/	0										
24-hr. comp.	520			19	<0.01	0.07	0.55	10.5	<0.05	0.10	1.2		0.02
2/10/81		>7,400 1/											
2/11/81		950											
24-hr. comp.	58			18	<0.01	<0.02	0.04	0.32	<0.03	<0.07	0.12	0.60	0.04
CITY OF SPOKANE STP - RM 67.3													
3/31/80		19 1/											
4/01/80		27											
24-hr. comp.	4				<0.01	<0.01	0.03	0.04	<0.05	<0.05	0.3	0.25	36.0
6/10/80		3 1/	0										
6/11/80		3 1/	0										
24-hr. comp.	50			72	<0.01	<0.02	<0.03	0.36	<0.05	<0.05	0.11		36.0
2/10/81		4 1/											
2/11/81		7 1/											
24-hr. comp.	<10			90	<0.01	<0.02	<0.01	0.06	0.05	<0.07	0.04	0.48	28.4
NORTHWEST TERRACE STP - RM 64.3													
3/31/80		<1 1/											
4/01/80		<1 1/											
24-hr. comp.	<10				<0.01	<0.01	0.02	<0.01	<0.05	<0.05	0.06	0.25	0.12
6/10/80		5 1/	0										
6/11/80		4 1/	0										
24-hr. comp.	4			70	<0.01	<0.02	0.01	<0.05	<0.05	<0.05	0.04		0.11
2/10/81		0											
2/11/81		0											
24-hr. comp.	<10			77	<0.01	<0.02	<0.01	<0.02	<0.03	<0.07	0.04	0.24	0.15

1/ Estimated population based on nonideal plate counts.

Table 2. Loading from the Spokane River point sources surveys. All concentrations are given in pounds per day.

Date	T-PO_4-P	O-PO_4-P	NO_2-N	NO_3-N	NH_3-N	Total Solids	TNVS	Total Susp. Solids	TNVSS	COD
SPOKANE INDUSTRIAL PARK - RM 87.1										
3/31-4/01/80 24-hr. comp.	8.1	6.1	<0.05	7.1	12.2	1374	865	112	45.8	265
6/10-11/80 24-hr. comp.	16.7	8.6	0.23	23.6	10.4	1841	1266	167	86.3	247
2/10-11/81 24-hr. comp.	24.1	24.1	<0.07	13.0	18.9	2212	1366	527	234	397
KAISER ALUMINUM AT TRENTWOOD - RM 86.0										
Sanitary Effluent										
3/31-4/01/80 24-hr. comp.	1.2	2.0	0.05	1.7	8.3	280	187	5.3	<1.3	111
6/10-11/80 24-hr. comp.	4.7	2.3	0.57	5.0	8.0	435	300	15.0	3.0	81.1
2/10-11/81 24-hr. comp.	2.5	1.7	<0.02	7.0	10.8	428	238	6.3	1.6	71.3
Industrial Effluent										
3/31-4/01/80 24-hr. comp.	<0.06	0.02	0.07	1.5	0.4	1401	1226	99.2	64.2	520
6/10-11/80 24-hr. comp.	0.8	0.2	0.12	<0.03	1.7	2452	1985	41.4	27.4	385
2/10-11/81 24-hr. comp.	1.0	0.7	<0.02	<0.02	0.9	959	709	21.3	16.3	542
Combined Effluent										
3/31-4/01/80 24-hr. comp.	17.4	11.1	<2.2	28.8	20.0	21963	13311	<222	<222	3106
6/10-11/80 24-hr. comp.	13.7	6.8	<2.3	13.7	25.0	19808	16165	<228	<228	1594
2/10-11/81 24-hr. comp.	19.7	17.5	<2.2	30.7	11.0	21496	15354	439	439	5264

Table 2. Loading from the Spokane River point sources surveys - continued. All concentrations are given in pounds per day.

Date	Oil and Grease	Phenolics	BOD_5	Chloride	CN	Cd	Cr	Cr+6	Cu	Fe	Ni	Pb	Zn	Hg
SPOKANE INDUSTRIAL PARK - RM 87.1														
3/31/80	25.4	0.10						N.D.						
4/01/80	30.5	0.005						N.D.						
24-hr. comp.			45.8			<0.05	<0.05		11.2	0.76	<0.25	1.02	0.71	0.002
6/10/80	N.D.	0.06			0.11			N.D.						
6/11/80	N.D.	0.05						N.D.						
24-hr. comp.			34.5	48.9		<0.06	<0.12		17.8	5.6	2.4	0.98	1.15	
2/10-11/81														
24-hr. comp.			91.1	84.6		<0.07	<0.13		17.6	3.0	2.0	6.5	5.3	0.005
KAISER ALUMINUM AT TRENTWOOD - RM 86.0														
Sanitary Effluent														
3/31/80	12.0	0.03						.D.						
4/01/80	16.5	0.07						N.D.						
24-hr. comp.			21.0			<0.02	<0.02		0.02	0.18	0.30	<0.08	0.21	0.0004
6/10/80	N.D.	0.02												
6/11/80	12.0	0.04												
24-hr. comp.			9.3	60.0		<0.01	<0.03		0.01	0.23	<0.07	0.07	0.16	
2/10-11/81														
24-hr. comp.			<6.3	85.6		<0.02	0.05		<0.02	0.03	<0.05	<0.11	0.21	<0.0003
Industrial Effluent														
3/31/80	9.3	0.05						N.D.						
4/01/80	12.8	0.12						N.D.						
24-hr. comp.			75.9			0.01	1.40		0.02	2.04	0.06	0.06	0.055	0.0001
6/10/80	N.D.	0.35												
6/11/80	9.3	0.33												
24-hr. comp.			70.1	7.6		0.01	0.43		0.01	0.99	0.10	0.06	0.02	
2/10-11/81														
24-hr. comp.			45.9	5.0		0.004	1.21		0.03	0.6	0.05	0.08	0.02	0.0001
Combined Effluent														
3/31/80	N.D.	2.4												
4/01/80	<222	2.7	1109					N.D.						
24-hr. comp.			1775			<2.2	<2.2		<2.2	133	<11.1	11.1	35.5	0.06
6/10/80	N.D.	5.7						N.D.						
6/11/80	N.D.	4.1												
24-hr. comp.				319		<2.3	<4.6		<2.3	22.8	<11.4	<11.4	25.0	
2/10-11/81														
24-hr. comp.			877	439		<2.2	11.0		2.2	28.5	<6.6	21.9	41.7	<0.04

Table 2. Loading from the Spokane River point sources surveys - continued. All concentrations are given in pounds per day.

Date	T-PO_4-P	O-PO_4-P	NO_2-N	NO_3-N	NH_3-N	Total Solids	TNVS	Total Susp. Solids	TNVSS	COD
INLAND EMPIRE PAPER COMPANY - RM 82.6										
3/31-4/01/80 24-hr. comp.	7.7	<9.0	<0.2	<0.9	<0.2	7352	3228	1094	<18	5559
6/10-11/80 24-hr. comp.	14.6	3.7	<1.8	<1.8	9.1	7854	4384	1041	55	4384
2/10-11/81 24-hr. comp.	15.0	6.0	<2.0	<2.0	40.0	9408	4404	2202	220	7606
MILLWOOD STP - RM 82.3										
6/10-11/80 24-hr. comp.	2.7	1.5	0.4	0.2	1.6	384	217	334	165	267
2/10-11/81 24-hr. comp.	0.9	0.8	<0.003	3.3	0.07	130	73	33	12	43
CITY OF SPOKANE STP - RM 67.3										
3/31-4/01/80 24-hr. comp.	240	150	<30	600	3600	138110	99080	600	<300	16810
6/10-11/80* 24-hr. comp.	1021	811	240	1381	3303	147120	96077	13510	6605	33026
2/10-11/81 24-hr. comp.	166	130	4.7	2842	1255	113690	78162	1895	1421	7816
NORTHWEST TERRACE STP - RM 64.3										
3/31-4/01/80 24-hr. comp.	8.5	9.0	<0.1	9.7	2.1	450	340	2.0	<1.0	56
6/10-11/80 24-hr. comp.	7.7	7.7	<0.09	0.9	0.9	404	312	5.5	<0.9	32
2/10-11/81 24-hr. comp.	8.8		0.04	6.6	4.3	600	450	5.0	2.5	46

*Impacted by May 18, 1980 Mount St. Helens eruption.

Table 2. Loadings from the Spokane River point source surveys - continued. All concentrations are given in pounds per day.

Date	BOD_5	Chloride	Cd	Cr	Cu	Fe	Ni	Pb	Zn	Hg
INLAND EMPIRE PAPER COMPANY - RM 82.6										
3/31-4/01/80 24-hr. comp.	2869		<0.18	<0.18	0.18	2.0	<0.9	<0.9	0.4	<0.004
6/10-11/80 24-hr. comp.	1169	91.3	<0.18	<0.37	0.5	4.6	0.9	<0.9	0.37	
2/10-11/81 24-hr. comp.	1801	60.0	<0.2	<0.4	1.6	2.6	<0.6	<1.4	<0.2	0.005
MILLWOOD STP - RM 82.3										
6/10-11/80 24-hr. comp.	86.7	3.2	<0.002	0.01	0.09	1.8	<0.01	0.02	0.2	
2/10-11/81 24-hr. comp.	19.3	6.0	<0.003	<0.007	0.01	0.1	<0.01	<0.02	0.04	0.0002
CITY OF SPOKANE STP - RM 67.3										
3/31-4/01/80 24-hr. comp.	1201		<3.0	9.0	12.0	<15.0	<15.0	90.1	33.0	0.08
6/10-11/80 24-hr. comp.	1512	21617	<3.0	<6.0	<12.0	108.0	<15.0	<15.0	33.0	
2/10-11/81 24-hr. comp.	<2369	21317	<2.4	<4.7	<2.4	14.2	11.8	<16.6	9.5	0.11
NORTHWEST TERRACE STP - RM 64.3										
3/31-4/01/80 24-hr. comp.	<10		<0.01	<0.01	0.02	<0.01	<0.05	<0.05	0.06	0.0003
6/10-11/80 24-hr. comp.	3.7	64.2	<0.01	<0.02	0.01	<0.05	<0.05	<0.05	0.04	
2/10-11/81 24-hr. comp.	<12.5	96.3	<0.01	<0.03	<0.01	<0.03	<0.04	<0.09	0.05	0.0003

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Table 3. Results of dissolved oxygen survey on the Spokane River, September 26, 1980.

Station	River Mile	Maximum Depth Sampled (meters)	Diss. Oxygen (mg/L)	Dissolved Oxygen (percent saturation)	Mean Temperature (°C)
Long Lk. Dam	33.9				
1	33.6	8	4.9	49.2	16.0
2	33.3	8	5.7	57.2	16.0
3	32.9	5	5.8	58.2	16.0
4	32.6	8	5.9	59.2	16.0
5	31.0	9	7.1	71.0	16.0
Little Falls Dam	29.1				

Cause of Low D.O.

The dissolved oxygen concentrations in the river below Long Lake Dam have fallen below the state D.O. criterion of 8.0 mg/L regularly each year. Historically, this problem has appeared as early as July and may extend through November (Figure 2) (unpublished WDOE data). The lowest level observed below Long Lake Dam was 1.5 mg/L in 1977 (Soltero, *et al.*, 1978).

Long Lake's anoxia was first described by Cunningham and Pine (1969). The impoundment stratifies and then the lower waters become anaerobic due to detrital decomposition. As the season progresses, the volume of anoxic water increases. The elevation of the anoxic water strata behind Long Lake Dam can extend up to the levels of the power penstocks (Soltero, *et al.*, 1978). It appears that the withdrawal of this anaerobic or low D.O. water occurs and causes the D.O. criterion to be violated downstream. The D.O. concentration in the water column behind the dam at the power penstock level does not always correspond to the D.O. concentration observed on the same date and similar time below the dam (Soltero, *et al.*, 1973; 1978, unpublished data). A linear regression of the mean water column D.O. behind the dam at station 0 versus the downstream D.O. gave correlation coefficients of .91 and .82 for 1972 and 1977, respectively, for the periods July through November. These relationships suggest that the mean D.O. concentration behind the dam is the predominent factor influencing D.O. concentration downstream. The density gradients behind the dam influence the strata from which water is drawn. Other factors influence the downstream D.O. levels by effecting the reaeration rate; e.g., temperature of mixed water below the dam, and turbulence downstream

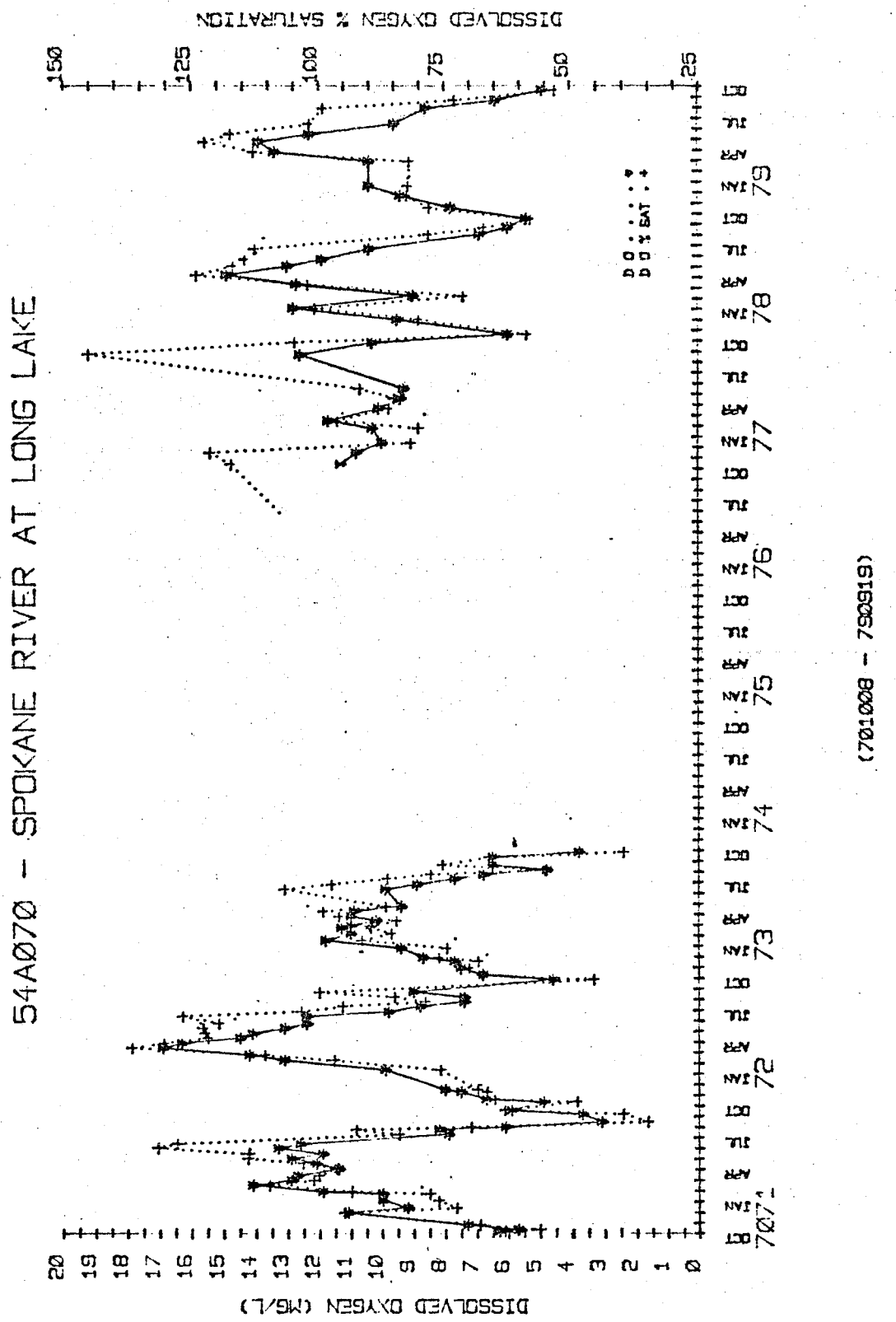

Figure 2. Dissolved oxygen concentration and percent saturation for Spokane River at Long Lake (station 54A070); water years 1971, 1972, 1973, 1977, 1978, and 1979.

is a function of the amount of water discharged by the dam. All of these effects influence the D.O. levels below Long Lake Dam.

Long Lake still experiences summer stratification and D.O. depletion in the hypolimnion behind Long Lake Dam (Soltero, Nichols, and Mires, 1981). This has persisted in spite of efforts to decrease productivity by limiting phosphorus inputs to the reservoir. As long as stratification and subsequent D.O. depletion of the hypolimnion waters behind Long Lake Dam continues, the Spokane River will experience seasonal D.O. criterion violations below the dam.

Groundwater Samples Around Long Lake

Nutrient samples were collected and analyzed as per other samples from two private wells located on the north bank of Long Lake at approximately r.m. 46.1. Both wells are in sand. Well #1 is about three years old and well #2 is over ten years old. The wells are about 300 feet apart. The data are presented in Table 4. The higher nitrate-nitrogen and orthophosphorus concentrations in well #2 may indicate it is influenced by septic drainage.

Table 4. Nutrient concentrations of wells adjacent to Long Lake.

Well						
No.	Depth (ft)	Distance from Shore	NO_3-N (mg/L)	NO_2-N (mg/L)	NO_3-N (mg/L)	O-PO_4-P (mg/L)
1	32	300	0.85	<0.01	0.02	<0.01
2	60	100	1.6	<0.01	0.04	0.04

Spokane River Time of Travel

The time-of-travel data were needed by URS Company for their modeling work on the Spokane River. Data were needed for the reach between the Idaho/Washington state line (r.m. 96.0) and Nine Mile Falls Dam (r.m. 58.1). The survey was conducted during September and October, 1980.

Methods

The river was divided into four reaches. Travel time for each reach was determined separately. A single slug injection of Rhodamine WT dye was made at mid-channel at the upper three reaches, whereas dye was simultaneously injected at two points at the Fort George Wright bridge. The lower end of a reach was monitored

continuously with a Turner 111 Fluorometer equipped with a submersible pump, a flow-through cell, and a strip chart recorder. The primary filter was a combination of a 1-60 and 58 with the 1-60 closest to the 110-850 lamp. The secondary filter was a 23A. This combination of filters and lamp is appropriate for Rhodamine WT dye (Turner Associates). Dye dosage requirements were determined using the methods of Kilpatrick (1970). Daily flows were obtained from the Washington Water Power dam gaging station at Post Falls. This station (USGS station 12419000) was used as the reference station for all work. Data were analyzed by methods of Kilpatrick, Martens and Wilson (1970). Additional data from an earlier study were also used.

USGS and WDOE were involved in a cooperative effort in 1968 to establish travel times on the Spokane River. This work was also confined to the area between Stateline and Nine Mile Falls Dam. The preliminary data, collected during a 7,200 cfs flow and a 3,610 cfs flow, were obtained from USGS in Tacoma. The data analysis had been completed for the first flow event; however, the second required additional analysis. A report was never issued.

The 1968 USGS/WDOE work divided the river into eight reaches during the January 23-25 survey and nine reaches during the April 24-25 survey. Their work differed from the latest WDOE effort in that one large slug of dye was injected at Stateline and monitored as it proceeded down stream. This is a preferable way to monitor time of travel; however, it requires more than one fluorometer and several teams of people.

Results and Discussion

The data from all three surveys are presented in Table 5. Data were interpolated in the 1980 survey for the reach between Fort George Wright Bridge and Nine Mile Falls Dam. The dam causes river velocities to change dramatically in the reach. The average velocity of the upriver reach was used to calculate travel time to r.m. 65.0 (location of last rapids). The remaining time was used to calculate the velocity for the lower part of the reach.

The log of flow (Q) versus the log of time (t) should be a straight line function (Kilpatrick, Martens and Wilson, 1970). Travel versus time flow from Stateline to Nine Mile Falls Dam for all three surveys was regressed and shown to follow the equation:

$$\ln t = -0.72(\ln Q) + 9.46 \quad r^2 = .999$$

As can be seen by the coefficient of determination (r^2), the fit is very good. This indicates that the results obtained during the

Table 5. Results from the Spokane River time of travel surveys 1968, 1980.
Note: Δt = change in time (hours); Δd = change in distance (miles);
$\bar{V}$ = mean velocity (ft/sec).

Date(s)	WDOE Time of Travel Sept. 23-25, 1980; October 7-9,1980	WDOE/USGS Time of Travel Jan. 23-25, 1968	WDOE/USGS Time of Travel April 24-25, 1968	Spokane River
Mean Post Falls Flow(s) (cfs)	1690; 1700	3610	7200	
				9-mile dam pool r.m. 58.1
	Δt^* = 18.74 Δd^* = 6.9 $\bar{V}^*$ = 0.54	Δt = 9.37 Δd = 3.8 $\bar{V}$ = 0.59	Δt = 5.43 Δd = 3.8 $\bar{V}$ = 1.03	
				7 mile bridge r.m. 61.9
	Δt = 23.88 Δd = 11.7 $\bar{V}$ = 0.72	Δt = 2.77 Δd = 4.3 $\bar{V}$ = 2.28	Δt = 1.63 Δd = 4.3 $\bar{V}$ = 3.87	
				Last rapids r.m. 65.0
				Bowl and pitcher r.m. 66.2
	Δt^* = 5.14 Δd^* = 4.8 $\bar{V}^*$ = 1.37	Δt = 3.58 Δd = 6.7 $\bar{V}$ = 2.74	Δt = 2.78 Δd = 6.7 $\bar{V}$ = 3.53	
				Fort Wright Bridge r.m. 69.8
	Δt = 10.70 Δd = 10.0 $\bar{V}$ = 1.37	Δt = 1.50 Δd = 2.0 $\bar{V}$ = 1.96	Δt = 0.73 Δd = 2.0 $\bar{V}$ = 4.02	Spokane gage r.m. 72.9
				Division St. Bridge r.m. 74.9
			Δt = 2.82 Δd = 4.6 $\bar{V}$ = 2.39	
				Greene St. Bridge r.m. 78.0
		Δt = 10.50 Δd = 7.7 $\bar{V}$ = 1.08		
			Δt = 3.47 Δd = 3.1 $\bar{V}$ = 1.31	Upriver dam power house r.m. 79.8
				Argonne Road r.m. 82.6
	Δt = 19.82 Δd = 7.3 $\bar{V}$ = 0.54	Δt = 2.14 Δd = 2.7 $\bar{V}$ = 1.84	Δt = 1.58 Δd = 2.7 $\bar{V}$ = 2.51	
				Trent Road Bridge r.m. 85.3
		Δt = 2.72 Δd = 5.1 $\bar{V}$ = 2.75	Δt = 1.73 Δd = 5.1 $\bar{V}$ = 4.32	
				Railroad bridge r.m. 87.1
	Δt = 8.66 Δd = 8.9 $\bar{V}$ = 1.51			
				Barker Road r.m. 90.4
		Δt = 3.10 Δd = 5.6 $\bar{V}$ = 2.65	Δt = 2.20 Δd = 5.6 $\bar{V}$ = 3.73	
				Stateline Bridge r.m. 96.0
	$\Sigma\Delta t$ = 63.06 $\Sigma\Delta d$ = 37.9 $\bar{V}$ = 0.88	$\Sigma\Delta t$ = 35.68 $\Sigma\Delta d$ = 37.9 $\bar{V}$ = 1.56	$\Sigma\Delta t$ = 22.37 $\Sigma\Delta d$ = 37.9 $\bar{V}$ = 2.48	

*Interpolated results not empirical.

three surveys are in agreement and can be used together. Such verification is fortunate as the data represent a range of flows and allows estimations of travel times outside the observed range to be extrapolated. Figure 3 shows the regression plot mentioned above for the study area (r.m. 58.1 to 96.0) extrapolated to the 1 day in 10-year low and high flows. The flow recurrence values were generated from flow data collected between 1914 and 1968 at Post Falls and provided by the USGS office in Boise, Idaho. Table 6 shows a range of travel times estimates for the study area.

Table 6. Selected travel times for the Spokane River from Stateline (r.m. 96.0) to Nine Mile Falls Dam (r.m. 58.1) using the equation $\ln t = -0.72(\ln Q) + 9.46$.

Q Post Falls (cfs)	t (hours)
300	211.3
700	114.8
1,100	82.9
1,500	66.3
1,900	55.9
2,300	48.8
2,700	43.4
3,100	39.3
5,000	27.9
10,000	16.9

It is also possible to estimate travel times for specific reaches within the study area using only the USGS/WDOE data. The equations (Table 7) represent the travel time for any Post Falls flow for reaches between Stateline and Nine Mile Falls Dam.

Table 7. Equations for Spokane River travel times (t = hours) at flows (Q = cfs) measured at Post Falls, Idaho (USGS 12419000).

River Mile Range	Time of Travel Equation
61.9 - 58.1	$\ln t = -0.79 (\ln Q) + 8.71$
66.2 - 61.9	$\ln t = -0.77 (\ln Q) + 7.31$
72.9 - 66.2	$\ln t = -0.37 (\ln Q) + 4.28$
74.9 - 72.9	$\ln t = -1.04 (\ln Q) + 8.95$
82.6 - 74.9	$\ln t = -0.74 (\ln Q) + 8.43$
85.3 - 82.6	$\ln t = -0.45 (\ln Q) + 4.42$
90.4 - 85.3	$\ln t = -0.66 (\ln Q) + 6.37$
96.0 - 90.4	$\ln t = -0.50 (\ln Q) + 5.20$

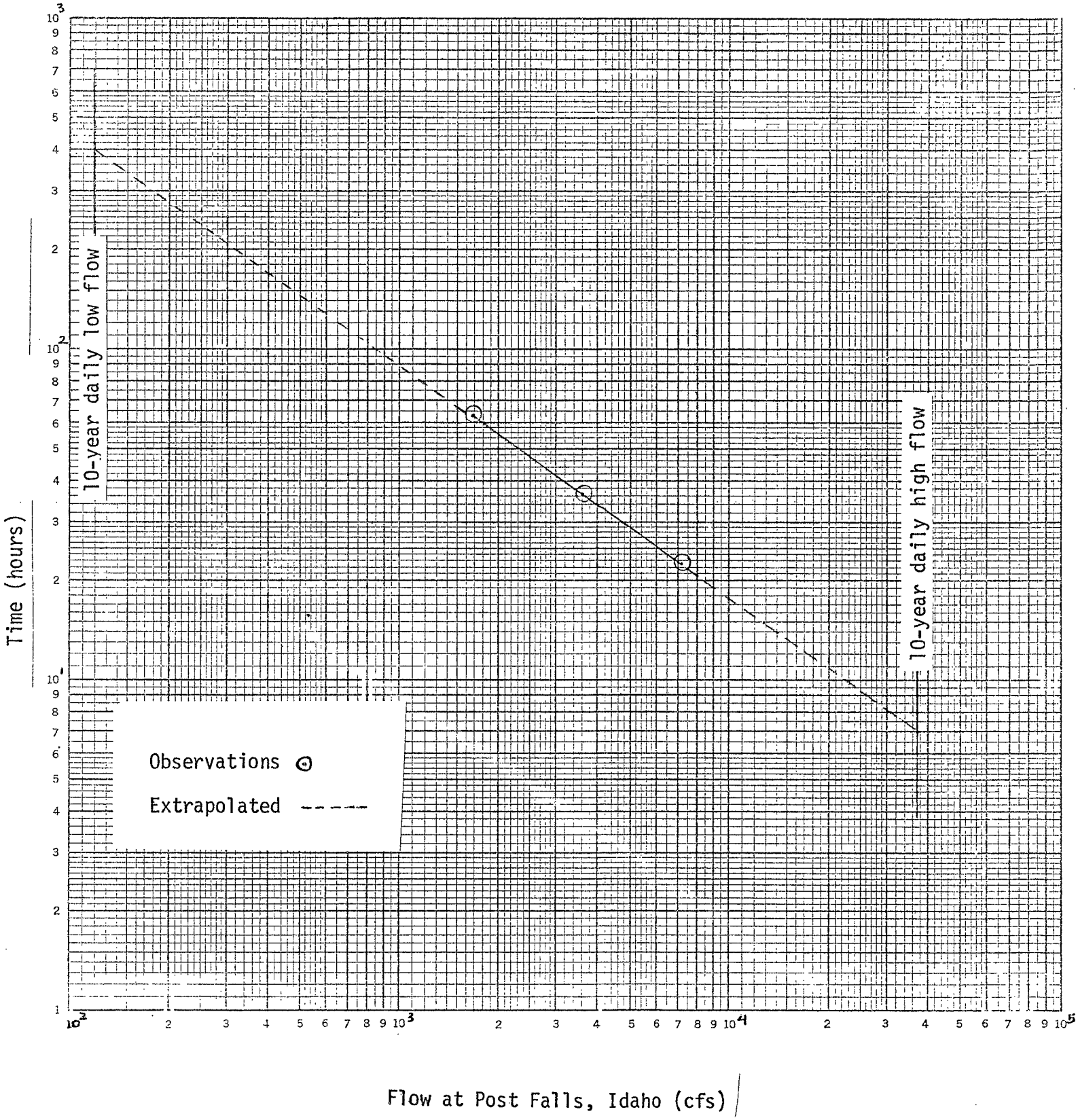

Figure 3. Flow versus time relationship determined for the reach from r.m. 96.0 to 58.1.

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Water Quality of Long Lake Embayments

One of the concerns of the Long Lake Environmental Association (Peterson, 1980) is that the water quality of Long Lake's embayments is different than the water quality of the mid-channel areas sampled by Ray Soltero (Eastern Washington University). Two synoptic surveys were conducted by WDOE to investigate this concern. The first survey was held on June 12, 1980. Four embayments and their adjacent mid-channel sites were sampled (Figure 4). Two samples were collected at each site; a surface grab, and a bottom sample via a Kemmerer water sampler. The second survey on August 27, 1980, sampled two embayments and the respective offshore areas. Depth profiles were made at each site and the extent of the euphotic zone was determined with a submarine photometer. Euphotic zone composites were made for chlorophyll a analysis. All samples in both surveys were placed on ice, shipped, and analyzed as previously noted.

Results and Discussion

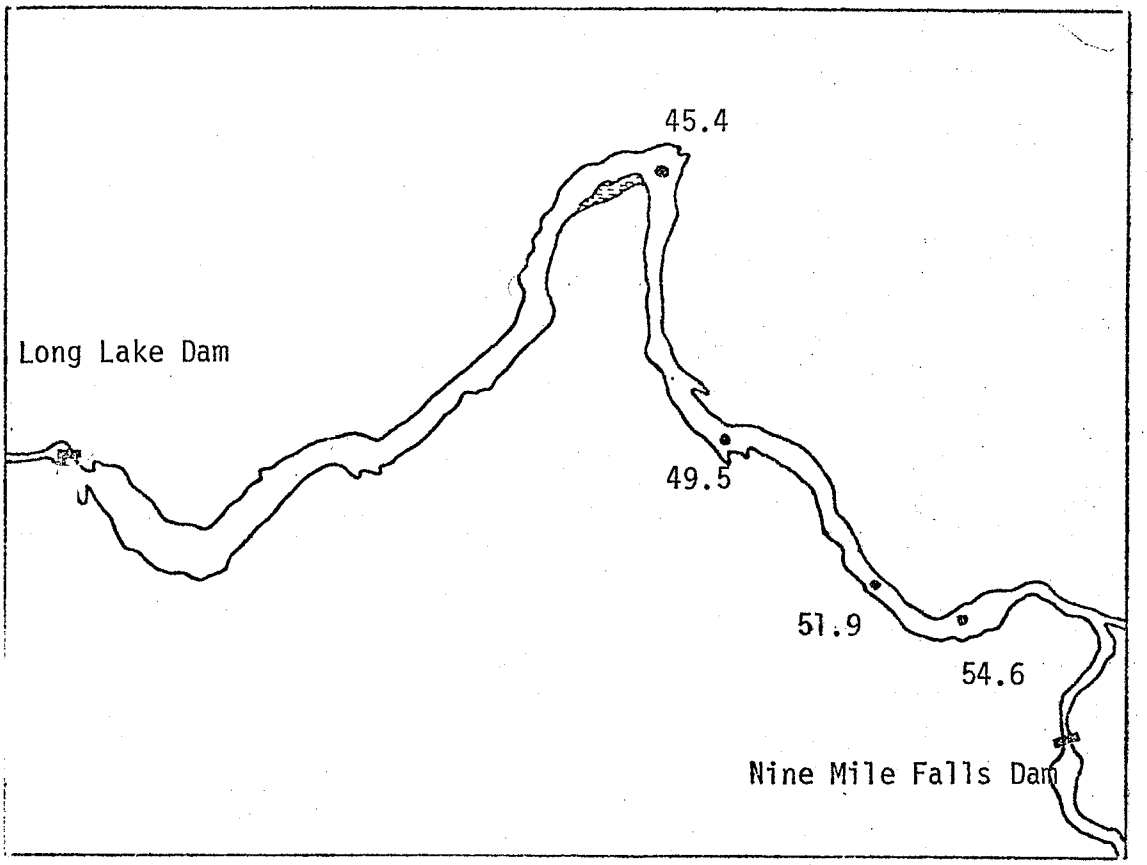
The June 12 survey occurred during spring runoff when the reservoir was obviously flowing. The data indicate (Table 8) that the water quality of the embayments was similar to the mid-channel areas. No distinct differences were noted between conditions at the upper end of the reservoir, Nine Mile Resort, and the lower reservoir site at Sunset Bay.

The August 27, 1980 (Table 9) survey occurred when flows were low and phytoplankton densities were at their seasonal high (Soltero, Nichols and Mires, 1981). The data show the embayment water quality to be very similar to the epilimnion waters at mid-channel.

Both the June and August surveys indicate that the water quality of the embayment areas is the same as the mid-channel areas. This is not to say that the floating algal mats occasionally observed on Long Lake during a bloom do not accumulate due to wind action and cause both aesthetic and water quality perturbations in the bays.

LRS:JJ:cp

cc: John Bernhardt
Carl Nuechterlein
Section Files



Scale approximately 1:161760

Figure 4. Map of Long Lake depicting river mile of sites where embayment/mid-channel transects were made. After Soltero *et al.* (1978).

Table 8. Long Lake Reservoir embayment survey, June 12, 1980.

Name	r.m.	Secchi (m)	Sample Depth (m)	Temp. (°C)	Field Cond. (μmhos/cm)	pH (S.U.)	D.O.	NO_3-N (mg/L)	NO_2-N (mg/L)	NH_3-N (mg/L)	O-PO_4-P (mg/L)	T-PO_4-P (mg/L)
Nine Mile Resort	54.6	0.76	0	16.0	96	6.18	10.1	0.13	<0.01	0.06	0.03	0.05
Near Shore			1	16.0	96	5.84	10.3	0.15	<0.01	0.04	0.02	0.03
Mid-channel	54.6	0.84	0					0.11	<0.01	0.02	0.02	0.02
			0	16.8	96	6.41	10.7	0.19	<0.01	0.06	0.01	0.03
			1.2	16.1	94	6.43	10.7	0.16	<0.01	0.04	0.02	0.04
Embayment nr. Houseboat	51.9	0.79	0	16.4	96	6.02	10.4	0.20	<0.01	0.06	--	0.01
			4	16.3	96	6.18	10.4	0.20	<0.01	0.05	0.01	0.01
Mid-channel	51.9	0.84	0	16.3	98	5.83	10.4	0.20	<0.01	0.05	0.01	0.05
			9.1	16.0	96	6.12	10.3	0.19	<0.01	0.06	0.01	0.04
Sportsman Paradise	49.5	1.2	0	16.9	100	6.01	11.3	0.19	<0.01	0.01	0.01	0.01
Mid-channel			6.4	16.0	101	6.68	11.4	0.20	<0.01	0.01	0.01	0.05
Weed Bed nr. Sportsmans Paradise	49.6	1.2	0	17.0	104	6.21	11.8	0.17	<0.01	0.01	<0.01	0.03
			3.3	16.4	101	6.47	10.6	0.18	<0.01	0.01	0.01	0.05
Sunset Bay	45.4	1.2	0	17.8	103	6.63	12.0	0.16	<0.01	0.03	0.01	0.05
Mid-channel			12.2	15.3	94	6.61	10.7	0.22	<0.01	0.08	0.01	0.05
Inner Bay	45.4	>1.2	0	18.8	108		12.4	0.12	<0.01	0.02	<0.01	0.04
			1.2	16.3	102	6.72	11.6	0.20	<0.01	<0.01	<0.01	0.04

Table 9. Long Lake Reservoir embayment survey August 27, 1980.

Name	r.m.	Secchi (m)	Sample Depth (m)	Temp. (°C)	Field Conductivity (µmhos/cm)	pH (S.U.)	D.O. (mg/L)	Conductivity (µmhos/cm)	NO_3-N (mg/L)	NO_2-N (mg/L)	NH_3-N (mg/L)	O-PO_4-P (mg/L)	T-PO_4-P (mg/L)	Chlorophyll a* (mg/m^3)	Pheophytin a* (mg/m^3)
Nine Mile Resort	54.6	1.3	0	20.0	115	8.55	12.00	188	0.14	<0.01	0.01	<0.01	0.02	12.4	1.6
Near Shore			1.0	20.0	117	8.55	11.65	221	0.12	<0.01	0.01	<0.01	0.02	--	--
			1.5	20.0	120	8.50	11.90	191	0.19	<0.01	<0.01	<0.01	0.02	--	--
Mid-lake	54.6	1.5	0	19.5	120	8.55	12.05	184	0.22	<0.01	<0.01	<0.01	0.02	14.6	1.0
			1	19.5	115	8.60	--	183	0.22	<0.01	<0.01	<0.01	0.02	--	--
			2	19.5	120	8.55	12.30	183	0.21	<0.01	<0.01	<0.01	0.02	--	--
North Bank	54.6	1.6	0	19.0	120	8.45	11.50	189	0.38	<0.01	<0.01	<0.01	0.02	--	--
			2	18.75	120	8.35	--	--	--	--	--	--	--	--	--
			4	18.25	125	8.15	--	--	--	--	--	--	--	--	--
			6	17.40	133	7.80	--	--	--	--	--	--	--	--	--
			8	17.50	135	7.72	8.95	216	0.90	0.01	0.06	0.01	0.02	--	--
Sunset Bay	45.4	2.1	0	22.2	110	8.65	11.35	179	<0.01	<0.01	<0.01	<0.01	0.02	9.0	0.5
Mid-channel			3	22.2	110	8.65	--	178	<0.01	<0.01	<0.01	<0.01	0.02	--	--
			6	22.2	112	8.65	--	182	<0.01	<0.01	<0.01	<0.01	0.02	--	--
			9	22.2	112	8.35	10.85	182	<0.01	<0.01	<0.01	<0.01	0.02	--	--
			12	19.7	125	7.45	--	204	0.49	<0.01	0.05	<0.01	0.02	--	--
			15	18.2	133	7.35	6.95	207	0.53	0.01	0.08	<0.01	0.02	--	--
			18	18.2	133	7.25	--	214	0.66	0.01	0.14	0.01	0.02	--	--
			21	17.5	138	7.20	6.60	215	0.65	0.01	0.15	0.01	0.02	--	--
Inner-bay	45.4	2.2	0	22.5	110	8.68	11.40	180	<0.01	<0.01	<0.01	<0.01	0.02	8.4	1.1
			1	22.5	110	8.70	--	178	<0.01	<0.01	<0.01	<0.01	0.02	--	--
			2	22.5	110	8.70	--	178	<0.01	<0.01	<0.01	<0.01	0.02	--	--
			3	22.5	112	8.72	--	179	<0.01	<0.01	<0.01	<0.01	0.02	--	--
			4	22.7	112	8.72	11.25	182	<0.01	<0.01	<0.01	<0.01	0.02	--	--

*Euphotic zone composite.

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