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MEMORANDUM
May 7, 1984

To: Roger Ray, WDOE Eastern Regional Office

From: Gary Bailey and Lynn Singleton, Water Quality Investigations Section

Subject: Spokane Industrial Park Receiving Water Survey

INTRODUCTION

At the request of the WDOE Eastern Regional Office, a receiving water survey was conducted on August 29 and 30, 1983 by the Water Quality Investigations Section in conjunction with a Class II inspection (Yake, 1984) of the Spokane Industrial Park (SIP) wastewater treatment plant. The general objective of the receiving water survey was to determine the impact of the SIP discharge on the water quality of the Spokane River.

The SIP treatment plant discharges to the Spokane River at river kilometer (r.k.) 139.4, approximately 0.8 kilometer downstream from the Sullivan Road Bridge (Figure 1). The Spokane River is a Class A river, and the reach of river which receives the SIP effluent is heavily used for rafting, swimming, and fishing (URS Co., 1981). This reach is also notable because of the very high trout density when compared to other sections of the river (Bailey and Saltes, 1982).

The sampled area, between the Sullivan Road Bridge and the Walk in the Wild Park, is an area where a large amount of groundwater flows to the river. This inflow can be observed as small springs along the banks at low river flow.

METHODS

On August 29, 200 mLs of Rhodamine WT dye were added to the effluent at the end of the chlorine contact chamber to: determine the in-pipe travel time (discussed in Yake, 1984); locate the outfall; and examine the dispersion of the effluent in the river.

Water samples were collected from the north bank as subsurface grabs at three stations on August 29. Station 1a, a control station above the effluent discharge, was located about 50 meters downstream from the Sullivan Road Bridge (r.k. 140.2); Station 2 was located about 10 meters below the discharge point (r.k. 139.2); and Station 3 was located about 300 meters below the discharge point. On August 30, the upstream control station was moved about 100 meters above the Sullivan Road Bridge (Station 1b) to an area above substantial groundwater inflow. Sample stations 2 and 3 were the same as on August 29. Additional samples were collected from the groundwater inflow just below the Sullivan Road Bridge and at the Walk in the Wild Park (Station 4) on the south bank, 1 kilometer below the SIP discharge.

Parameters measured in the field included temperature (mercury-filled thermometer), dissolved oxygen (Winkler method), and pH (Beckman meter). Other water samples were placed on ice and returned to the WDOE Environmental Laboratory in Olympia for analysis. These samples were analyzed for specific conductance, total hardness, chloride, turbidity, chemical oxygen demand, fecal coliform, total phosphorus, orthophosphate-phosphorus, nitrate-nitrogen, nitrite-nitrogen, ammonia-nitrogen, oils and greases, phenol, cyanide, total solids, total non-volatile solids, total suspended solids, total non-volatile suspended solids, copper (total and soluble), zinc (total and soluble), nickel (total and soluble), lead (total and soluble), arsenic (total and soluble), and total mercury. Samples for priority pollutants from Station 2 were forwarded to the U.S. Environmental Protection Agency (EPA) laboratory at Manchester, WA, for analysis. A portion of the metal samples was also analyzed at the Manchester laboratory at lower detection limits than possible at the Olympia laboratory.

Fish samples were collected from above and below the effluent discharge by electroshocking during the night of September 1, and frozen within 3 hours after collection. Whole-fish samples were analyzed by the EPA Manchester laboratory for priority pollutants (organics) and metals.

Fish distribution was observed by skindivers swimming from the Sullivan Road Bridge to about 100 meters below the discharge. One diver swam down the north bank, and one swam down the south bank to the point where the railroad bridge crosses the river 200 meters upstream of the SIP discharge. Both divers then swam down the northern bank and into the discharge and dilution zone.

The toxicity of the effluent was assessed by standard 96-hour acute bioassays (WDOE, 1980) using rainbow trout. The tests were run with 0.0 percent, 0.6 percent, and 4.2 percent effluent in Spokane River water and well water. The 0.6-percent dilution corresponds to a theoretical concentration if the effluent is completely mixed with 100 percent of the 7-day, 10-year low river flow (170 cfs). The 4.2-percent dilution corresponds to effluent mixed with 15 percent of the river discharge. The SIP discharge was assumed to be 0.7 MGD. The river dilution water was collected at Harvard Road (r.k. 148.3), and the well water was collected from a tap at the Liberty Lake WTP. Water was transported to the Olympia Environmental Laboratory in acid-cleaned plastic drums.

RESULTS AND DISCUSSION

The dyed effluent plume traveled along the north bank through a small riffle about 120 meters below the discharge and then appeared to move toward the center of the river. The last faintly visible dye was observed at the head of a set of rapids about 300 meters below the discharge. This area was our #3 sampling station. River flow on both days of sampling was 365 cfs (USGS, 1984). This equates to a dilution ratio of 330:1. The ratio during the 7-day, 10-year low flow event of 170 cfs would be 240:1.

The SIP discharge pipe terminated near the shoreline during this survey (365 cfs, USGS, 1984), and would probably be within a meter of the shore during 7-day, 10-year low flow design conditions (170 cfs). The pipe is not equipped with a diffuser. It is doubtful that the location and the type of outfall facilitates mixing with either 15 percent of the river width or volume as recommended in the dilution zone guidelines (WDOE, 1978).

To further complicate the dilution, the effluent discharge rate was highly variable. Yake (1984) discussed the hydraulic surges and determined they were caused by the sludge return pumps in the SIP. The effluent flow doubled for a period of 27 minutes per hour and decreased to about 1/2 the normal flow for the remainder.

The remainder of the results are presented and discussed in categories of: (1) Conventional Parameters, (2) Metals, (3) Priority Pollutants, (4) Toxicity Testing, (5) Design Flow Analysis, and (6) General Observations.

1. Conventional Parameters

The groundwater inflow noticeably affects physical and chemical parameters in the sampled river reach and masks the effect of the SIP discharge for some parameters. For example, the temperature data for August 29 (Table 1) appear to indicate the SIP discharge raised the river temperature substantially when compared with the upriver station (#1a), but we noticed the following day that our upstream station was below several large springs. Consequently, the #1 station was moved upriver and above some of the groundwater inflow. The temperature data for August 30 indicate the groundwater inflow reduces the river temperature about 1 degree Centigrade between Stations #1b and #4 with no observable effect of the SIP discharge.

The dissolved oxygen was near saturation (89 to 95 percent) at all river stations on both days. The groundwater was relatively well-aerated at 73 percent saturation.

The river pH was circumneutral (range 7.0 to 7.3 units) at all stations on both days. The SIP effluent pH (Yake, 1984) was similar to river conditions.

Specific conductance, total hardness, and chloride increased at the discharge site. Chloride concentrations returned to background concentration at Stations #3 and #4. Total hardness and specific conductance remained elevated at downstream stations, probably because of groundwater inflow. Both constituents were higher in the groundwater. The downstream increases also appear in the summer low-flow data collected at r.k. 140.6 and r.k. 137.3 by Gibbons, et al. (1984). Their data show that chloride, hardness, and conductivity values routinely double between the two sites.

Turbidity increased from 1 NTU to a mean of 5 NTUs at the discharge site, but returned to background units at the downstream stations.

No increase in COD or fecal coliform counts was attributed to the discharge. The present and historic loads for COD and other parameters are presented in Table 2.

Total phosphorus and orthophosphate-P concentrations increased at the discharge site. The increased concentrations at the downstream stations may be due to both the effluent discharge and the groundwater additions. Phosphorus loading to the river is of concern because of the eutrophication potential in Long Lake reservoir, but the loading from the SIP is included in the current wasteload allocation strategy (Singleton, 1981). Yake (1984) reported the SIP total phosphorus load as 9.5 #P/day, a value within the range of previous data (Singleton and Joy, 1982).

Nitrate-nitrogen and ammonia-nitrogen concentrations increased at the discharge site (Station 2) and at Station 3 downstream. Increases in nitrate-nitrogen cannot be attributed solely to the SIP effluent because of the high groundwater concentration (0.78 mg/L). The SIP ammonia load was 35.8 #N/day during this survey. It did appear to increase the concentrations at Station 3. The calculated un-ionized ammonia concentrations (EPA, 1976) at the time of sampling were 0.006 mg/L un-ionized NH_3-N, well below the 0.057 mg/L NH_3-N acute and 0.012 mg/L NH_3-N chronic criteria (EPA, 1984). A 7-day, 10-year low flow scenario can be projected by: using the highest observed SIP NH_3-N load (range 10.4 to 35.8 # N/day); the highest river pH (8.1) and temperature (20°C) observed during the summer months at a site located slightly downstream of Station 4 (Gibbons, et al., 1984); and 15 percent river volume dilution zone. The projected un-ionized ammonia concentration is 0.009 mg/L. Under these conditions, the chronic criterion is 0.025 mg/L NH_3-N and the acute criterion is 0.103 mg/L NH_3-N.

2. Metals

The metals data collected during the receiving water survey are presented in Table 3 and compared with criteria concentrations (either total recoverable metals or the metals which pass through a 0.45 um filter after acidification to a pH of 4.0 with nitric acid) and acute toxicity data for trout (Table 4). Toxicity is a function of hardness, and a value of 50 mg/L (as $CaCO_3$) was used for criteria calculations. This hardness was observed during the survey and appears to best represent conditions during summer low flow in the reach in question.

Upstream lead and mercury concentrations both exceeded the average concentration criteria. Copper, zinc, nickel, cadmium, and lead levels were substantially increased at the SIP discharge. Copper, the most notable of the group, was 170 times greater than the upstream concentration at the discharge site. At Station 4, 1 kilometer downstream, copper still exceeded the maximum allowable criterion, and was 6 times greater than upstream levels. Soluble copper concentrations at the discharge substantially exceeded the range of experimentally determined toxicity values for trout. All of the other metals were at or near background levels at Station 3, 300 meters below the discharge.

The copper load from the SIP discharge appears to be somewhat variable. Singleton and Joy (1982) reported a range of 11.2 to 17.8 # Cu/day. The load during this survey was 44 # Cu/day (Yake, 1984). If the historic SIP loads are compared to historic loads from other Spokane River, Washington, discharges (Singleton and Joy, 1982), the SIP has been the greatest contributor. The load observed during this survey suggests that it probably remains the largest source.

To determine if these metal concentrations are typical, the data of Gibbons, et al. (1984) was examined for the low-flow period (August-September) at stations comparable to our above Station 1, and 1 kilometer below Station 4. This comparison (Table 5) indicates the increase in total copper was also detected in 1980 and 1981, although the magnitude of increase was considerably smaller than in our data. This difference in magnitude may, in part, be due to differences in river flows and the SIP load at times of sampling and to the difference in downstream sampling locations.

Samples of Spokane River fish (whole composite) taken above and below the discharge for metals analyses showed extremely high concentrations of cadmium, copper, lead, and zinc, and were the highest recorded when compared with results from other drainages in Basic Water Monitoring Program (BWMP) sampling (Table 6). In comparing fish metal concentrations from above and below the discharge, copper and zinc appear to be substantially higher in the downstream fish. When comparing results from above and below a discharge, it is difficult to determine how much of an increase is significant without an estimate of the variation in concentration among fish from a single site. However, for both copper and zinc, the concentrations in upstream fish were within the range for other BWMP results while the concentrations in the downstream fish were the highest observed. This increase indicates a real difference between sites. The concentrations measured are for whole-body analyses (including gut contents). How much was actually in edible and nonedible tissue is not known.

3. Priority Pollutants (organics)

Acid and base/neutral organics; volatile organics; and pesticides and PCBs analyses were all performed on water samples from Station 2, the outfall site. One compound, 1,1,1-trichloroethane (22 ug/L), was identified in the river. This concentration is below the ambient criterion for the protection of aquatic life (EPA, 1980a). A substantial concentration (5300 ug/L) was also found in the SIP discharge (Yake, 1984).

The pesticide, PCB, and volatile organics analyses of fish tissue (Table 7) indicate the presence of measurable concentrations of DDT, DDT metabolites, PCBs, and one volatile organic compound. The concentrations of DDT compounds are within the range of concentrations for the BWMP station Spokane River at Riverside State Park. The presence of measurable concentrations in fish tissue indicates the fish have been exposed to low or intermittent concentrations in the water. The Spokane River has also been identified as an area of concern because of the consistent and high concentrations of PCB in fish tissue (Joy, 1984). The presence of pesticides and PCBs does not appear to be related to the SIP discharge as none was observed in their wastewater. The volatile organic, 1,1,1-trichloroethane, was found below quantifiable levels in the fish collected below the discharge. This compound was also found in the effluent and receiving water.

4. Toxicity Tests

The effluent dilutions (0.6 percent and 4.2 percent) for the static bioassays were calculated using a 7-day, 10-year low flow in the river (Post Falls) of 170 cfs and an effluent flow of 1.07 cfs. The dilutions were based on complete mixing (1.07/170 = 0.6%) and on the 15 percent river volume limitations (WDOE, 1978) suggested for dilution zones (170 x .15 = 25.5 cfs for dilution; 1.07/25.5 = 4.2%).

The well water was intended to be a dilution water with chemical characteristics similar to the Spokane River, but without the high metal concentrations. We had planned on obtaining the water from a well near r.m. 86, but that particular well was inoperative. As an alternative, the water was collected from a tap at the Liberty Lake WTP. This water, upon analysis, was high in zinc, much harder than anticipated, and not suitable for a comparable control water. Tests with this water did, however, provide some useful comparative information.

The river water for the assays was collected at Harvard Road, the first accessible point above the SIP discharge. The results of the bioassay tests in Spokane River water indicate that the effluent is very toxic to hatchery rainbow trout. The effluent caused 100 percent mortality at a 4.2 percent dilution in Spokane River water and a 3 percent mortality at 0.6 percent dilution (Table 8).

In order to determine if the 3 percent mortality was a toxicant effect and to compare the theoretical mortality with observed mortality, the number of toxic units was estimated for each test dilution. A toxic unit is equivalent to the amount of toxicant which causes 50 percent mortality in 96 hours. The information needed to calculate toxic units is: (1) amount of each toxicant in the test solution, (2) the hardness of the test water (especially for metal toxicity which is strongly influenced by hardness), and (3) LC_{50} data for the test organism.

In our assays, the metals were measured on component waters (Table 9), but not in the actual test dilutions. Total hardness was measured at 0 and 96 hours in the actual test solutions.

The LC_{50} for individual metals (Table 10) were calculated from data presented in EPA documents (EPA, 1980b, c, d, e, f, g) and in Bailey and Saltes (1983) for comparable hardness. In some cases where no data for rainbow trout at comparable hardness were presented, the LC_{50} was calculated by regression of LC_{50} (ln transformed) and hardness (ln transformed). Chromium had only one LC_{50} for trout.

The summation of toxic units (Table 11) assumes that toxic effects are additive. For metals, that is generally a valid assumption although there are some reports that zinc and copper are antagonistic (see Bailey and Saltes, 1983 for a review of data). The observed mortality in our bioassays was much less than predicted by the summation of toxic units (Table 8). There is no clear explanation for this, but there is some uncertainty about actual concentrations in the test solutions.

The discrepancy between theoretical or expected and actual mortality is illustrated by a plot of percent mortality and toxic units (Figure 2). This plot also indicates, although somewhat tenuously, that the 3 percent mortality at 1.4 toxic units (0.6 percent SIP effluent in Spokane River water) is a toxicant-caused mortality and not a random mortality. The absence of mortality in the controls is another indication that this is a toxicant-caused mortality.

The tests indicate that even if the effluent were instantly mixed in the Spokane River, the effluent would cause some mortality of hatchery rainbow trout at 170 cfs river flow. The application factors (acute/chronic ratio) for zinc, copper, and cadmium range from 0.87 to 7.8 which indicates the discharge would cause some chronic toxic effects at dilutions much lower than those examined in the acute assays.

5. Design Flow Analysis

As discussed previously, the SIP metals load is significant and a cause for real concern. The design flow analysis presented in Table 12 indicates current SIP cadmium loads are acceptable under design conditions. Zinc, lead, and mercury background concentrations are presently above the criteria and therefore additional loading from the SIP is unacceptable. A determination for nickel loads was not possible with the available data.

6. General Observations

During skin diving, no fish were seen immediately below the discharge. An attempt was made to count the number of fish above and below the discharge, but the number of fish above the discharge was very high and, therefore, difficult to count and record. As we entered the discharge area, the WTP was discharging and visibility for the observer in the effluent plume was very low. The other observer, swimming adjacent to the shore where visibility was good, did not see fish below the discharge until reaching an area of significant groundwater inflow about 30 meters below the discharge.

Another interesting observation was made in the immediate area of the discharge. Periphytic growth was observed on only the lower half of rocks near and in the waste stream. This was most noticeable in areas of groundwater inflow. The effluent is apparently toxic to algae, and algae is only able to grow where dilution from groundwaer inflow occurs.

During the electroshocking on the night of September 1, some fish were found in the area below the discharge.

CONCLUSIONS

1. Nutrient concentrations increased slightly below the discharge and groundwater inputs.

2. The discharge is located in the general area where a large population of fish exists.

3. Metals loading, especially copper, is excessive and causes in-stream water quality criteria violations. Fish tissue analyses and observed effluent plume avoidance by fish substantiate its significance. The current load will either cause or aggravate water quality criteria violations during a design flow event.

4. Bioassays indicate SIP effluent is acutely toxic to rainbow trout at dilutions in Spokane River water as low as 1:167. The dilution during the 7-day, 10-year low flow is 1:170.

5. In-plant surges effectively double the loading at frequent intervals.

6. The outfall lacks a diffusor and is in a poor location to promote mixing at low river flows.

7. The poor diffusion and dilution characteristics of the current outfall, combined with hydraulic surges, a highly toxic wastestream, and a design low flow, could significantly impact the receiving water quality and be deleterious to the resident fish populations. The effluent, as currently constituted, is unacceptable for discharge into the Spokane River.

RECOMMENDATIONS

1. SIP flows and loads should not be allowed to increase.

2. Ways to eliminate metals from the effluent should be investigated and implemented as soon as possible.

3. Interim measures should be established until metals removal can be accomplished.

4. The hydraulic surge problem identified by Yake (1983) should be corrected.

5. A diffuser should not be added to the discharge pipe until metals removal is accomplished.

6. The chlorination system may have to be improved when the wastewater toxicity is decreased.

7. Wastewater monitoring practices suggested by Yake (1983) should be implemented.

8. If possible, any future NPDES permit effluent limitations should be expressed as loads.

GB:LRS:cp

Attachments (tables)

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EPA (U.S. Environmental Protection Agency), 1980e. Ambient water quality criteria for nickel. EPA 440/5-80-060.

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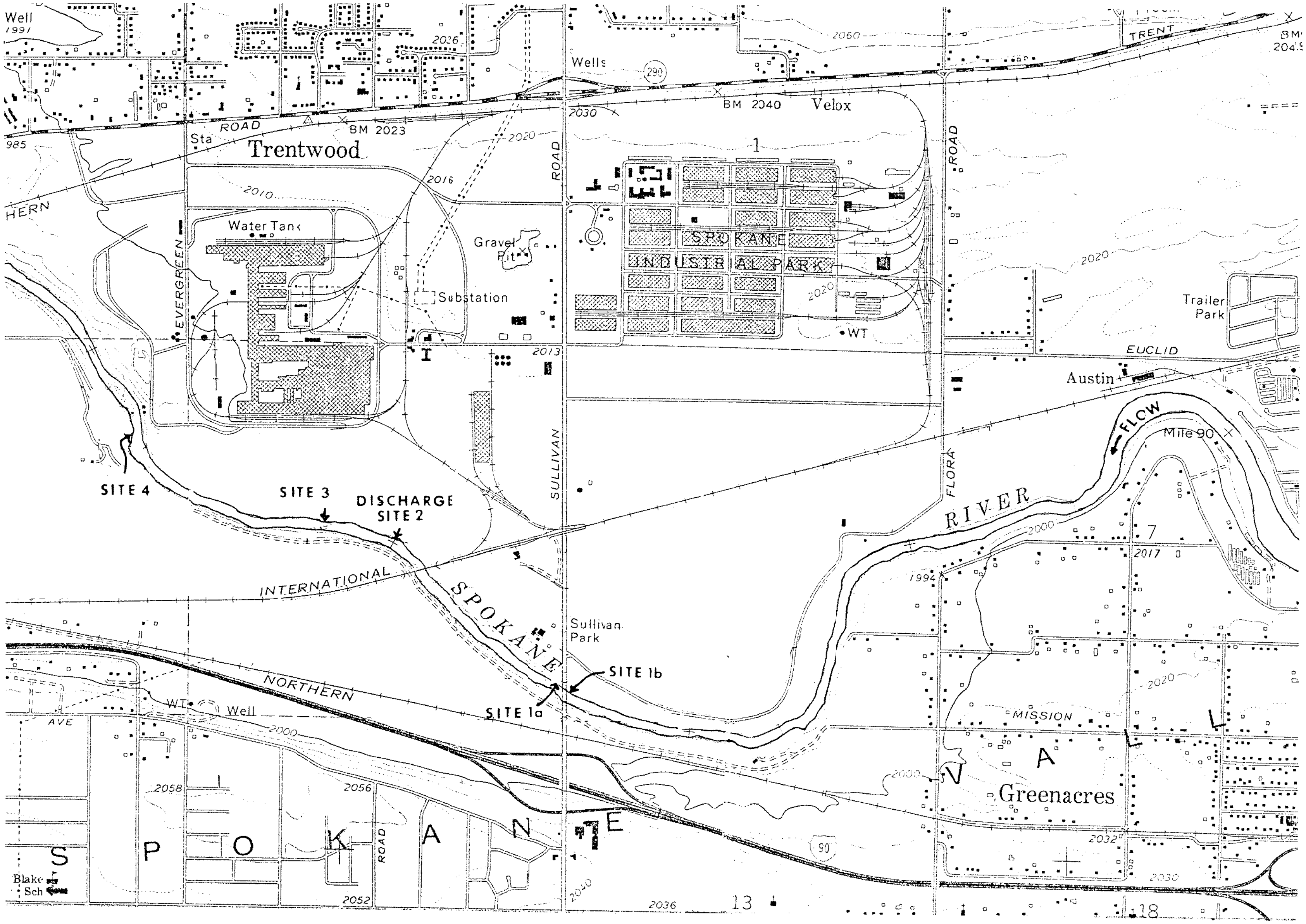

Figure 1. Sample site locations for the Spokane Industrial Park - Spokane River receiving water survey, August 29-30, 1983.

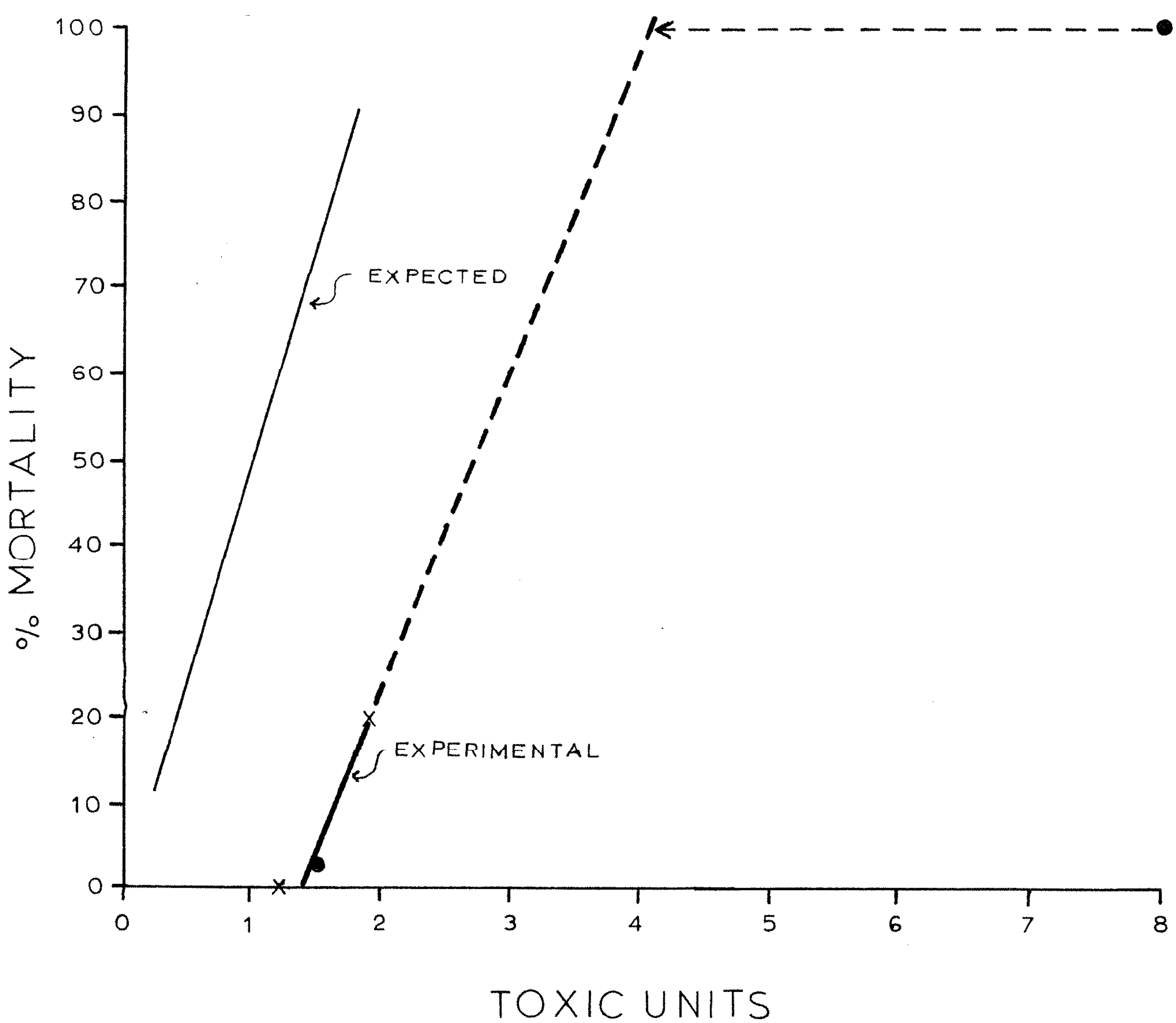

Figure 2. Experimental toxicity of Spokane Industrial Park effluent based on toxic units.

Table 1. Physical and chemical analyses of the Spokane River near the Spokane Industrial Park discharge (August 29-30, 1983). Values are in mg/L unless otherwise stated.

Date and Station	Temp. (°C)	Dissolved Oxygen Measured	Dissolved Oxygen Percent Saturation	pH (units)	Specific Conductance (umhos/cm)	Total Hardness (as $CaCO_3$)	Chloride As Cl	Turbidity (NTU)
8/29 #1A Above discharge	18.9	8.7	93	7.0	73	38	1.4	1
#2 6 m below discharge	20.0	8.7	95	7.2	128	58	3.5	4
#3 300 m below discharge	19.7	8.7	95	7.3	86	42	1.4	1
8/30 #1B Above discharge	19.7	8.3	90	7.0	63	31	1.4	1
#2	18.6	8.4	89	7.2	126	50	3.5	7
#3	18.4	8.6	91	7.3	93	50	1.4	1
#4 1 km below discharge	18.8	--	--	--	102	50	1.4	1
Groundwater	8.9	8.5	73	7.3	220	110	1.4	1

Date and Station	COD	Fecal Coliform (col/100 mL)	Total Phosphorus	Ortho-P	NO_3-N	NO_2-N	NH_3-N	Recoverable Oil & Grease
8/29 #1A	8	3 Est.	0.03	0.01	0.13	<0.01	<0.01	--
#2	4	1 Est.	0.20	0.15	0.29	<0.01	0.79	<1
#3	4	<1	0.04	0.02	0.17	<0.01	0.05	--
8/30 #1B	4	4 Est.	0.01	0.01	0.08	<0.01	<0.01	--
#2	4	1 Est.	0.22	0.19	0.30	<0.01	0.55	--
#3	4	--	0.04	0.03	0.19	<0.01	0.04	--
#4	4	--	0.02	0.01	0.18	<0.01	<0.01	--
Groundwater	4	--	0.02	<0.01	0.78	0.02	<0.01	--

Date and Station	Recoverable Phenolics as Phenol	Total Solids	Total Non-vol. Solids	Total Suspended Solids	Total Non-vol. Suspended Solids	Total Cyanide as CN
8/29 #1A	--	47	37	1	<1	--
#2	0.002	110	64	4	<1	<0.001
#3	--	75	44	1	<1	--
8/30 #1B	--	44	24	10	2	--
#2	0.008	87	53	5	<1	--
#3	--	55	31	2	<1	--
#4	--	--	--	--	--	--
Groundwater	--	--	--	--	--	--

Table 2. Compilation of selected Spokane Industrial Park effluent data collected and analyzed by WDOE (1979-1983). Concentrations in mg/L; loads in lbs/day unless otherwise stated (source: Yake, 1984).

Reference	1		2		2		2		3	
Date Collected	2/6-7/79		3/31-4/1/80		6/10-11/80		2/10-11/81		8/29-30/83	
Parameter	Conc.	Load	Conc.	Load	Conc.	Load	Conc.	Load	Conc.	Load
Flow (MGD)	0.645		0.61		0.69		0.78		0.715	
BOD_5	4 Est.	22 Est.	9	46	6	35	14	91	4	24
COD	58	312	52	265	43	247	61	397	28	167
TSS	29	156	22	112	29	167	81	527	25	149
O-PO_4-P	1.6	8.6	1.2	6.1	1.5	8.6	3.7	24.1	1.3	7.8
T-PO_4-P	2.3	12.4	1.6	8.1	2.9	16.7	3.7	24.1	1.6	9.5
Cadmium	<0.01	<0.05	<0.01	<0.05	<0.01	<0.06	<0.01	<0.07	0.008	0.048
Chromium	<0.02	<0.11	<0.01	<0.05	<0.02	<0.12	<0.02	<0.13	<0.001	<0.006
Copper	2.9	15.6	2.2	11.2	3.1	17.8	2.7	17.6	7.3	44
Iron	0.22	1.18	0.15	0.76	0.98	5.6	0.46	3.0	0.32	1.9
Mercury			0.00033	0.002			0.00072	0.005	0.0003	0.002
Molybdenum									0.012	0.072
Nickel	0.30	1.61	<0.05	<0.25	0.42	2.4	0.31	2.0	1.0	6.0
Lead	0.19	1.02	0.20	1.02	0.17	0.98	1.0	6.5	0.10	0.60
Zinc	0.15	0.81	0.14	0.71	0.20	1.15	0.82	5.3	0.305	1.8
Cyanide	0.007	0.038			0.02	0.11			0.002	0.012
Phenolics	0.002	0.011	0.011*	0.05	0.010*	0.06			0.037	0.22

*Mean of two grab samples.

References:
1. Yake, 1979
2. Singleton & Joy, 1982
3. Yake, 1984

Table 3. Metal analyses of Spokane River water near the Spokane Industrial Park discharge (August 29-30, 1983). Values are in ug/L.

Date and Station	Copper		Zinc		Nickel		Chromium		Cadmium		Lead		Arsenic		Mercury
	Total	Soluble	Total	Soluble	Total	Soluble	Total	Soluble	Total	Soluble	Total	Soluble	Total	Soluble	Total
8/29 #1A Above discharge	10	10	57	53	<50	<50	<10	<10	0.4	<2	1	<50	<1	<1	<0.2
#2 6 m below discharge	900	410	110	99	170	150	<10	<10	1.1	<2	11	<50	<1	<1	<0.2
#3 300 m below discharge	60	50	53	43	<50	<50	<10	<10	0.4	<2	1	<50	<1	<1	0.4
8/30 #1B Above discharge	1	2	77	71	100	100	<10	<10	0.4	0.3	1	<1	<1	<1	0.3
#2	1000	280	92	65	150	120	<10	<10	0.7	0.5	21	1	<1	<1	0.2
#3	60	40	60	56	50	<50	<10	<10	0.4	0.3	2	1	<1	<1	0.2
#4 1 km below discharge	32	9	67	58	<50	<50	<10	<10	0.8	0.5	4	1	<1	<1	0.3
Groundwater	<10	<10	6	5	<50	<50	<10	<10	0.1	<0.1	2	<1	<1	<1	0.2

Table 4. A comparison of metal concentrations (ug/L) in the Spokane River above and below the Spokane Industrial Park discharge with criteria concentrations and trout toxicity data. The criteria are based on either the metal which passes through a 0.45 um filter after acidification to a pH of 4.0 with nitric acid, or the total recoverable metals (trm). Experimental values probably best correspond with soluble metals.

Metal	Above[1]	6 m below[1]	300 m below[1]	1 km below[1]	Maximum Criteria[2]	24-hour Average Criteria[2]	30-day Average Criteria[2]	Experimental LC50 for Trout[3]
Total Copper	5.5	950	60	32	8.4		5.8	
Soluble Copper	6	345	45	9				22 to 57
Total Zinc	67	101	57	67	181(trm)	47 (trm)		
Soluble Zinc	62	82	50	58				370 to 2420
Total Nickel	<75	160	<50	<50	1100(trm)	56 (trm)		
Soluble Nickel	<75	135	<50	<50				35,500 at 100 hardness
Total Cadmium	0.4	0.9	0.4	0.8	2.0		2.0	
Soluble Cadmium[4]	0.3	0.5	0.3	0.5				1.75 at 30 hardness
Total Lead	1	16	1.5	4	25.2		1.0	
Soluble Lead[4]	<1	1	1	1				1170 to 4100
Total Mercury[4]	0.3	0.2	0.2	0.3	1.1		0.20	249 at 155 hardness

[1]Average to two days except where noted.

[2]Calculated from EPA 1980a, b, e, and 1984 for a total hardness of 50 mg/L ($CaCO_3$).

[3]Bailey and Saltes, 1983.

[4]Data from August 30 only.

Table 5. A comparison of metal concentrations in the Spokane River for 1980, 1981, and 1983. Data from 1980 and 1981 are from Gibbons, et al., 1984. All concentrations are in ug/L.

Metal	August 26, 1980		August 25, 1981		August 29-30, 1983	
	r.k. 140.6	r.k. 137.3	r.k. 140.6	r.k. 137.3	r.k. 140.6	r.k. 138.1
Total Copper	<1.0	2.0	<1.0	2.0	5.5	32
Soluble Copper	<1.0	1.7	<1.0	<1.0	6	9
Total Zinc	106	65	20	15	67	67
Soluble Zinc	65	40	5	15	62	58
Total Nickel	--	--	<5.0	<5.0	<75	<50
Soluble Nickel	--	--	<5.0	<5.0	<75	<50
Total Cadmium	--	--	<1.0	<1.0	0.4	0.8
Soluble Cadmium	--	--	<1.0	<1.0	0.3	0.5
Total Lead	<1.0	<1.0	<1.0	<1.0	1	4
Soluble Lead	<1.0	<1.0	<1.0	<1.0	<1	1
Total Mercury	<0.5	<0.5	<0.5	<0.5	0.3	0.3

Table 6. Metal concentrations in Spokane River whole-fish samples collected on August 29-30, 1983. Concentrations are ug/Kg dry weight[1].

Collection Location	Fish Sample	As	Cd	Cr	Cu	Hg	Pb	Zn
r.k. 139.8 (above discharge)	1 longnose sucker	711	2,650*	777	6,070	33.2	10,400*	36,500
r.k. 138.6 (below SIP discharge)	2 longnose suckers	616	2,030*	313	36,000*	28.4	6,260	292,000*
Statewide	Whole comp.[3]	148	<338	1,994	5,291	<146	3,431	75,333
Statewide	Whole comp.[4]	15-280	<80-1100	400-24,000	3000-8100	60-670	1300-9100	10,700-200,000

[1]Analysis reported as ug/Kg wet weight for r.k. 139.8 and r.k. 138.9 samples. Conversion to dry weight by approximation of 21.1 percent solids.

[2]1978-1982 collected as part of Basic Water Monitoring Program. Data for Spokane River-Riverside State Park are omitted.

[3]Geometric means.

[4]Range.

Table 7. Toxic organic compounds in Spokane River whole-fish samples collected on August 29-30, 1983. Concentrations are ug/Kg dry weight.

Sample Location	Sample	a-BHC	DDT	DDE	DDD	Total DDT Forms	PCB Aroclor 1254	PCB Aroclor 1260	Total PCBs	1,1,1-trichloroethane	Percent Lipids	Percent Solids
r.k. 139.8	1 longnose sucker	8.1	<5	39	<5	39	441	<47	441		2.5	21.1
	4 longnose sucker (whole)	<4.5	<4.5	49	<5	49	161	<45	161		5.8	22.3
R.M. 86.8	2 longnose sucker (whole)	23	<4.7	75	<4.7	75	986	<47	986	T	3.2	21.3
Statewide[1]	Whole fish comp.[2]					1764			459			
Statewide[1]	Whole fish comp.[3]					8.4-6800			<30-1300			

T = Trace; present but less than the quantifiable limit of 2 ug/Kg dry weight. Data for Spokane River-Riverside State Park are omitted.

[1]1978-1982 collected as part of Basic Water Monitorng Program.

[2]Geometric means.

[3]Range.

Table 8. Results of acute bioassay test with Spokane Industrial Park effluent*.

Dilution Water	Percent SIP Effluent	96-hr. Mortality of Rainbow Trout	Estimated Toxic Units
Spokane River	0.6	1/30 = 3%	1.4
Spokane River	4.2	30/30 = 100%[1]	7.9
	0.0	0/30 = 0%	1.1
Liberty Lake Well Water	0.6	0/30 = 0%	1.2
Liberty Lake Well Water	4.2	6/30 = 20%	1.8
Liberty Lake Well Water	0.0	0/30 = 0%	.1

*See Tables 9, 10, and 11 for components of calculation.

[1]Complete mortality within 24 hours.

Table 9. Metal analyses for water and effluent used in the acute toxicity tests.

Sample Location	Zinc		Copper		Cadmium		Lead		Nickel		Chromium		Mercury	Arsenic
	Total	Soluble	Total	Soluble	Total	Soluble	Total	Soluble	Total	Soluble	Total	Soluble	Total	Total
Spokane River Water r.k. 148.3 - Harvard Road	51	48	<10	2	<2	0.5	<50	1	<50	<50	<50	<50	<0.2	<1
Liberty Lake area well water	200	170	<10	<10	<2	<2	<50	<50	<50	<50	<50	<50	<0.2	<1
Spokane Industrial Park effluent	310	89	7300	860	8	2	100	2	1000	900	<1	1	0.3	<1

Table 10. Estimated LC_{50} of individual metals to rainbow trout. (Data from EPA 1980 b, c, d, e, f, g, and Bailey and Saltes, 1983.)

Metal	Hardness 25-29 mg/L	Hardness 139-143 mg/L
Zn	396	1,614
Cu	3.2	4.6
Ni	7,200	35,500
Cd	1.5	15.7
Pb	8.3	12.4
Cr	69,000[1]	69,000[1]

[1]Only 1 LC_{50} value for salmonids in literature reviewed (Bailey and Saltes, 1983).

Table 11. Concentrations of soluble metals in test solutions, based on analysis conducted on components before mixing, and the resultant estimated toxicity (1 toxic unit = 50% mortality in 96 hours).

		Toxic Units
I.	Well water - hardness = 139 mg/L	
	Zn = 170 µg/L	.1 calculated as 170 ÷ 1614 (Table 9)
II.	0.6% SIP effluent in well water - hardness = 141 mg/L	
	Zn ≃ 170 µg/L	.1
	Cu ≃ 5.2 "	1.1
	Ni ≃ 5.4 "	<.1
	Cd ≃ .01 "	<.1
	Pb ≃ .01 "	<.1
	Cr ≃ .006 "	<.1
		Σ = 1.2
III.	4.2% SIP effluent in well water - hardness = 143	
	Zn ≃ 170 µg/L	.1
	Cu ≃ 36 "	7.8
	Ni ≃ 38 "	<.1
	Cd ≃ .08 "	<.1
	Pb ≃ .08 "	<.1
	Cr ≃ .04 "	<.1
		Σ = 7.9
IV.	Spokane River water - hardness - 25	
	Zn = 48 µg/L	.1
	Cu = 2 "	.6
	Ni = <50 "	<.1
	Cd = 0.5 "	.3
	Pb = 1.0 "	.1
	Cr = <10 "	<.1
		Σ = 1.1
V.	0.6% SIP effluent in Spokane River water - hardness = 25	
	Zn ≃ 70 µg/L	.2
	Cu ≃ 1.3 "	.4
	Ni ≃ 0.4 "	<.1
	Cd ≃ 0.4 "	.8
	Pb ≃ <.01 "	<.1
	Cr ≃ <.01 "	<.1
		Σ = 1.4
VI.	4.2% SIP in Spokane River water - hardness = 29	
	Zn ≃ 48 µg/L	.1
	Cu ≃ 4.4 "	1.4
	Ni ≃ 37.7 "	<.1
	Cd ≃ 0.4 "	.3
	Pb ≃ 0.08 "	<.1
	Cr ≃ .04 "	<.1
		Σ = 1.8

Table 12. Projected and allowable loads for the SIP effluent in consideration of in-stream water quality criteria* during the 7-day, 10-year flow evert (170 cfs). Loads are in pounds/day and concentrations are in ug/L.

Metal	Present Upriver Concentration	River Design Load**	Present SIP Load	Mixed Load	Mixed In-stream Concentration	Criteria Concentration	SIP Load Required to Equal Criteria	Maximum Effluent Concentration
Total Copper	5.5	5.04	44	49.04	53	5.8†	0.3	0.3
Total Zinc	67	61.4	1.8	63.2	69	47††	0	0
Total Nickel	<75	<68.7	6.0	<74.7	<81	56††	more information needed	
Total Cadmium	0.4	0.4	0.048	0.45	0.49	2†	1.39	1.5
Total Lead	1	0.9	0.6	1.5	1.6	1†	0	0
Total Mercury	0.3	0.3	0.002	0.302	0.3	0.2†	0	0

*Calculated from EPA 1980a, b, e, and 1984 for a total hardness of 50 mg/L ($CaCO_3$).
**Assumed concentrations observed during this survey were representative of design flow conditions.
†30-day average criterion.
††24-hour average criterion.