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MEMORANDUM

October 21, 1985

To: Chris Haynes and Harold Porath

From: Joe Joy

Subject: Roslyn Wastewater Lagoons and Crystal Creek Receiving Water Study - Findings

ABSTRACT

A receiving water survey was performed on Crystal Creek (Segment 18-39-05) in the vicinity of Roslyn. Water quality impacts from the Roslyn wastewater treatment lagoons' (WTL) effluent, raw wastewater from within the town of Roslyn, and Fanhouse No. 5 mine drainage were evaluated. The WTL effluent caused Class A water quality standard violations by elevating in-stream pH and chlorine levels; it also elevated nutrient loads and created a minor dissolved oxygen sag in Crystal Creek. The receiving water-to-effluent ratio was only 5:1, far below the recommended 20:1 ratio. An analysis of calculated seasonal flows indicated the 20:1 ratio is rarely met. Direct discharges within the town of Roslyn contributed fecal wastes and caused Class A fecal coliform standard violations. The mine discharge was high in alkalinity and ammonia. Further data are necessary to evaluate if metal toxicity problems are present.

INTRODUCTION

As requested, the Water Quality Investigations Section (WQIS) performed a dry-weather receiving water survey of Crystal Creek in the vicinity of Roslyn on June 11 and 12, 1985. Will Kendra and I of WQIS were assisted by Mr. Joe Peck, the Roslyn WTL operator.

The primary purposes of our study were to evaluate the receiving environment for the Central Regional Office and Municipal Grants Office, and to provide data to consultants hired by Roslyn so they can perform a cost-benefit analyses for wastewater collection, treatment, and disposal improvements. The following survey objectives were developed:

1. Characterize the water quality effects of effluent from the Roslyn lagoons on Crystal Creek.

2. Evaluate the current receiving water-to-effluent dilution ratios and estimate low-flow and seasonal ratios.

3. Determine if infiltration and inflow (I&I) and other collection system correction measures have greatly affected wastewater quality or overall treatment efficiency at the Roslyn lagoons.

4. Determine if the I&I and collection system work have alleviated the fecal contamination problem in Crystal Creek above the Roslyn lagoon outfall.

5. Determine if water flowing from abandoned coal-mining shafts and across spoils near the lagoon are adversely affecting water quality in Crystal Creek.

Site Description and Background

The town of Roslyn (population estimate 980) is located in the upper Yakima River valley between Ellensburg and Snoqualmie Pass (Kittitas County). Crystal Creek (segment 18-39-05) drains 7.7 mi^2 of forested foothills around Roslyn and Cle Elum (Figure 1). Various tributaries to Crystal Creek enter the Roslyn stormwater collection system along the western and northern edges of the town. The sources of the large western tributary are springs in the foothills and overflow from the Roslyn water reservoir. Springs are also the source of a primary northern (middle) tributary. The tributaries emerge as a single channel at river mile (r.m.) 3.0. A small eastern tributary enters the creek at r.m. 2.6 as the creek flows through pastures below Roslyn. Effluent from the Roslyn WTL and mine drainage from Fanhouse No. 5 enter the creek at r.m. 1.6 as the creek meanders to its confluence with the Yakima River at Cle Elum.

Water quality in the creek should meet Class A standards (WAC 173-201-070 [60]) (Table 1). However, in the past, water quality was probably very poor. Prior to the 1970s, domestic wastes generated in Roslyn were disposed of on-site, processed through a small treatment plant at r.m. 3.0, or discharged directly into Crystal Creek. Conversion of an old coal-washing pond into the Roslyn sewage treatment lagoons in 1973 allowed much of this waste to be diverted for treatment.

The 10.5-acre lagoon system consists of a headworks, two equally sized clay-lined cells, and a chlorine contact chamber (Figure 1 inset). A record of influent flow is continuously monitored from a 12-inch Parshall flume at the headworks. Effluent from the first cell moves to the second cell through two eight-inch culverts, and then enters a contact chamber where chlorine is mechanically fed at a constant rate. The chamber was constructed with an "over-under" baffle system that has been modified by the plant operator. Effluent in the modified chamber now flows over the tops of all baffles. Chlorinated effluent is discharged out of the contact chamber, through a pipe, and into an open ditch on the opposite side of a raised railroad grade from

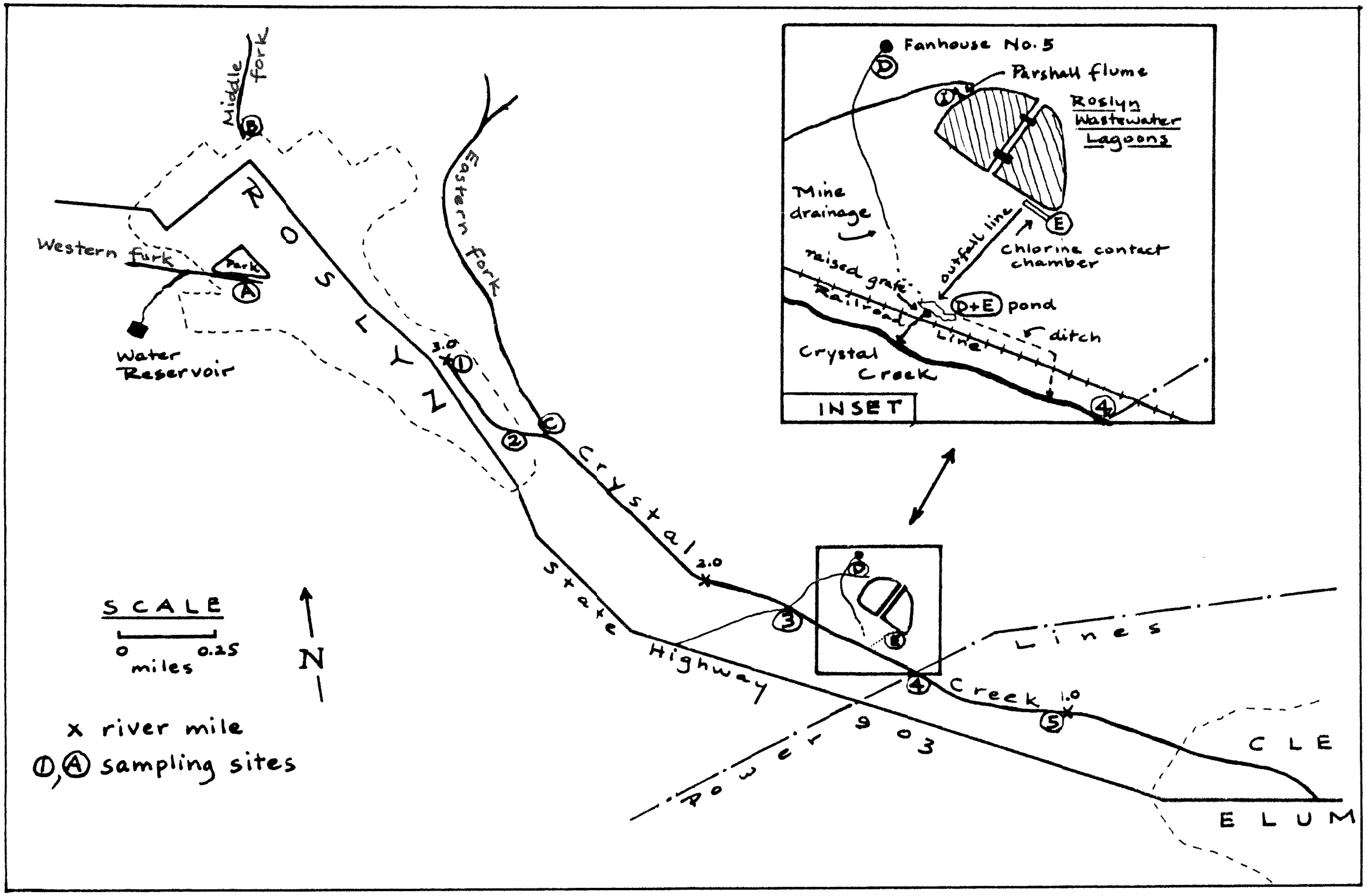


Figure 1. The location of water quality monitoring sites along Crystal Creek in the vicinity of Roslyn and the Roslyn wastewater treatment lagoon on June 11 and 12, 1985.

Table 1. Class A (excellent) water quality standards (WAC 173-201-045) and characteristic uses.

Characteristic Uses:	Water supply, wildlife habitat; livestock watering; general recreation and aesthetic enjoyment; commerce and navigation; fish reproduction, migration, rearing, and harvesting.
<u>Water Quality Criteria</u>	
Fecal Coliform:	Geometric mean not to exceed 100 organisms/100 mLs with not more than 10 percent of samples exceeding 200 organisms/100 mLs.
Dissolved Oxygen:	Shall exceed 8 mg/L.
Total Dissolved Gas:	Shall not exceed 110 percent saturation.
Temperature:	Shall not exceed 18°C due to human activity. Increases shall not, at any time, exceed $t = 28/(T+7)$; or where temperature exceeds 18°C naturally, no increase greater than 0.3°C. t = temperature in dilution zone, and T = highest temperature outside the dilution zone increases from non-point sources shall not exceed 2.8°C.
pH:	Shall be within the range of 6.5 to 8.5, with man-caused variation within a range of less than 0.5 unit.
Toxic, Radioactive, or Deleterious Materials:	Shall be below concentrations of public health significance, or which may cause acute or chronic toxic conditions to the aquatic biota, or which may adversely affect any water use.
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.

Crystal Creek. The wastewater creates a pond in the ditch and has two possible routes to the creek. Either it (1) follows natural contours of the ditch approximately 100 feet to a culvert passing through the railroad grade, or (2) it is discharged at the pond into the creek via a raised grate and drain pipe (Figure 1-inset). The wastewater route seems to depend upon discharge volumes and the amount of trash blocking the grate. Also, mine drainage from Fanhouse No. 5 combines with the WTL effluent at the pond before entering the creek (Figure 1-inset).

Although most of Roslyn's wastewaters were directed to the lagoons in 1973, some problems remained. Some of the collection system received large volumes of surface and sub-surface drainage. This diluted the influent and created episodes of hydraulic overloading in the collection system. In addition, some direct discharges into the creek evidently remained from the old collection system. These problems were documented when Anderson and Egbers (1978) inspected the Roslyn lagoons and Crystal Creek in 1978 and found:

- Although the Roslyn WTL effluent to Crystal Creek dilution ratio was approximately 1:1.5, only minor impacts on receiving water quality were observed.
- Influent and effluent wastewaters at the Roslyn lagoons had lower-than-expected waste strengths, believed to be caused by substantial collection system I&I of surface- and ground-waters.
- High fecal coliform counts were detected in the creek from unidentified sources in the town of Roslyn.

Since the 1978 investigation, Roslyn has received WDOE grant money to correct I&I and general collection system problems. Roslyn is now ready to proceed with the second phase of grant-funded improvements; i.e., evaluation and improvement of treatment and disposal systems.

METHODS

We established five water quality stations on Crystal Creek below Roslyn. In addition, we sampled four tributaries to the creek (two located above Roslyn), and monitored the Roslyn WTL influent and effluent. The station location, description, and sample collection information are available in Figure 1 and Table 2. Grab samples were collected on two occasions along the course of the creek for field and laboratory analysis. We also made a third collection of dissolved oxygen samples and flow measurements. Composite samples were taken over a 24-hour period from the Roslyn WTL influent and effluent. Compositors were set to sample 250 mL every 30 minutes.

Water samples collected for laboratory analyses were kept in the dark, on ice, and transported to the WDOE/USEPA Environmental Laboratory in Manchester within 24 hours. Samples were analyzed using approved procedures (USEPA, 1979; APHA-AWWA-WPCF, 1981).

Table 2. Station description and sampling information for the June 11 and 12, 1985, receiving water survey of Crystal Creek near Roslyn, Kittitas County.

Site Number	River Mile	Location	Field/Laboratory Analyses
A	0.6	West fork of Crystal Creek at S.E. corner of Pioneer park, 100' upstream from grating to storm drain.	Discharge, dissolved oxygen, pH, temperature, conductivity/nutrients (5), hardness, alkalinity, pH, conductivity, turbidity, fecal coliform, total suspended solids
B	0.8	North fork of Crystal Creek above grating to storm drain at Nevada Avenue alleyway between North First Street and North "A" Street.	Same as above
1	3.0	Crystal Creek storm drain in auto junk yard with old chlorination building off South "A" Street.	Discharge, dissolved oxygen, temperature/ fecal coliform, nutrients (5)
2	2.7	Crystal Creek 20' below culvert through South "A" Street at Hoffmanville Avenue.	Same as Sites A and B
C	2.6	East fork of Crystal Creek at confluence with main channel.	Discharge, pH, conductivity, temperature
3	1.8	Crystal Creek 50' below dirt road leading to Roslyn wastewater treatment lagoon (WTL)	Discharge, dissolved oxygen, temperature, pH, conductivity/BOD_5, nutrients (5), hardness, alkalinity, turbidity, pH, conductivity, fecal coliform, total suspended solids, total residual chlorine, copper, zinc, nickel, chromium, lead, cadmium
4	1.4	Crystal Creek approximately 900' below WTL outfall and beneath power lines.	Same as above
5	1.0	Crystal Creek in brushy area approximately 1/4 mile N.W. of Cle Elum at Mile 3 marker on Highway 903.	Same as Sites A, B, and 2, with addition of total residual chlorine
D	--	Mine drainage from Fanhouse No. 5 as it seeped from concrete base approximately 500' N.W. of Roslyn WTL.	Same as Sites A, B, and 2, with the addition of copper, zinc, nickel, chromium, lead and cadmium
I	--	Influent to Roslyn WTL at headworks Parshall flume	Discharge/nutrients(5), pH, conductivity, turbidity, hardness, alkalinity, BOD_5, total suspended solids - all 24-hr. composite sample
E	--	Effluent from Roslyn WTL: field samples taken from far end of chlorine contact chamber; laboratory samples (24-hr. composite) from wet well before chlorination.	Same as Sites 3 and 4.

Table 3. Field data and laboratory analytical results for samples taken from Crystal Creek and tributaries including the Roslyn wastewater treatment lagoon (WTL) (Station E) on June 11 and 12, 1985. See Table 1 for station descriptions.

			FIELD DATA								LABORATORY DATA																	
River Mile	Station Number	Day	Flow (cfs)	Temp. (°C)	pH (S.U.)	Sp. Cond. (umhos/cm)	D.O. (mg/L)	D.O. (% Sat.)	TRC (mg/L)	F. Coli. (#/100 mL)	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)	pH (S.U.)	Sp. Cond. (umhos/cm)	Alk. (mg/L as $CaCO_3$)	Hard. (mg/L as $CaCO_3$)	Turb. (NTU)	TSS (mg/L)	BOD_5 (mg/L)	Total Metals (ug/L) Cu	Zn	Ni	Cr	Cd	Pb
0.6	A	11	0.3	11.7	6.95	75	9.8	89.9	--	20	0.02	<0.01	0.01	0.02	0.04	7.5	65	52	††	2	<1	--						
		12	0.6	10.2	6.65	70	10.4	92.6	--	3*	<0.01	<0.01	<0.01	0.02	0.03	7.7	62	53	††	1	1	--						
0.8	B	11	0.4	10.4	7.80	200	9.8	87.3	--	<1	0.02	<0.01	<0.01	0.02	0.04	8.0	164	100	††	2	7	--						
		12	0.3	8.9	7.60	195	10.4	89.9	--	1*	0.01	<0.01	<0.01	0.01	0.02	8.0	162	110	††	1	<1	--						
3.0	1	11	--	10.7	--	--	--	--	--	TNTC	0.16	<0.01	0.02	0.04	0.04	--	--	--	--	--	--	--						
		12	1.3	9.5	--	--	--	--	--	400*	0.13	<0.01	0.03	0.03	0.03	--	--	--	††	--	--	--						
2.7	2	11	1.3	11.6	7.50	155	9.3	85.1	--	2400	0.20	<0.01	0.02	0.04	0.06	7.6	120	77	††	3	10	--						
		12	1.3	9.7	6.65	120	10.1	88.5	--	1300*	0.16	<0.01	0.01	0.04	0.06	7.6	116	73	††	2	6	--						
2.6	C	11	0.1	15.7	7.65	460	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--						
1.8	3	11	1.2	14.6	7.50	175	9.1	88.9	<0.1	59	0.22	0.01	0.03	0.04	0.06	7.8	132	85	††	3	5	<4	7	125	7	<1	0.1	11
		12	1.1	10.6	7.05	130	10.0	89.4	<0.1	160	0.19	<0.01	0.02	0.05	0.06	7.8	131	81	††	2	5	<4						
	D	11	0.03	17.0	7.20	>1000	0.2	2.1	--	--	<0.01	<0.01	1.35	0.02	0.04	7.4	2540	1700	97	1	9	--	23	273	<1	22	0.4	<1
	E1/	11	0.21	18.8	9.70	280	8.0	85.2	0.6-1.3	<1,1*,2*	0.08	0.01	0.08	1.5	1.7	9.8	243	120	††	7	8	9	22	124	<1	<1	0.2	22
		12	0.27	19.5	9.70	280	11.5	124.2	0.5-0.9																			
1.6	D+E2/	11	0.24	18.6	8.09	--	--	--	0.5-1.1	--	0.07	<0.01	0.24	1.3	1.5	8.3	530	318	††	7	8	--	22	143	<1	3	0.2	22
		12	0.30	19.2	8.19	--	--	--	0.4-0.8	--	0.07	0.01	0.21	1.4	1.5	8.4	473	278	††	6	8	--						
1.4	4	11	1.4	16.2	8.4	300	8.4	84.8	<0.1	28	0.22	<0.01	0.05	0.46	0.46	8.6	221	130	††	4	8	<4	75	127	<1	<1	0.4	<1
		12	1.4	12.1	8.05	260	9.6	88.3	0.1	180	0.20	<0.01	0.03	0.29	0.32	8.2	219	130	††	4	--	<4						
1.0	5	11	--	15.7	8.0	300	8.3	82.9	<0.1	25	0.22	0.02	0.04	0.44	0.44	8.2	245	150	††	4	2	--						
		12	--	12.2	7.8	285	9.4	87.2	<0.1	170	0.22	<0.01	0.02	0.28	0.30	8.1	253	140	††	4	2	--						

1/Most laboratory effluent data are from a 24-hour composite sample.
2/Theoretical values based on flow-weighted mixing of mine drainage and effluent.
*Estimated bacterial concentration based on non-ideal plate counts.
††Laboratory analysis error - data not reported.
TNTC = too numerous to count.
< = less than
> = greater than

We used a magnetic flow meter, top-setting rod, and a tape measure to determine discharge in the creek and tributaries. This method was also used to measure Roslyn WTL influent flows through the 12-inch Parshall flume.

We calculated WTL effluent flow by applying head height measurements from the chlorine contact chamber broad-crested weir to the equation from King, Wisler and Woodburn (1980, pg. 165):

$$Q = 2.7 \times L \times H^{3/2}$$

where, Q = flow in cfs
L = length of weir in feet
H = head height in feet

RESULTS AND DISCUSSION

Discharge

The discharge measurements made along Crystal Creek, its tributaries, and at the Roslyn WTL are presented in Table 3. The average sum of the discharges measured above Roslyn (Stations A + B) was significantly lower than the average discharge measured below Roslyn (Station 1) (Table 3). The 0.5 cfs difference in discharge above and below Roslyn was probably due to other minor tributaries we had been unable to locate and gage. However, water quality data suggest some portion of the addition may be due to sanitary wastes (see Crystal Creek below). A more intensive sewage and stormwater collection system survey would be necessary to ascertain the amount of raw wastewater reaching the creek within Roslyn.

There was a slight, but insignificant, drop in water volume between Stations 1 and 3. The eastern fork (Station C) that entered Crystal Creek in that reach had only a minimal contribution (Table 3). A water withdrawal line within the culvert at Station 2 was evidently not operating at the time of the survey, since measured flows above and below the culvert were the same. No significant changes in discharge were noted until r.m. 1.6 where the WTL effluent and mine drainage entered the creek. The dilution ratio of mine drainage and Crystal Creek flow to WTL effluent averaged 5:1. Discharge was not monitored below Station 4 at r.m. 1.45. However, since Anderson and Egbers (1978) detected only a minor increase of 0.2 cfs between r.m. 1.45 and r.m. 0.4 during their survey, no appreciable changes in discharge were expected below the outfall in our study area.

There are no year-round records of Crystal Creek discharge. However, since February 1985, Joe Peck has measured stage height at two points along the creek (our sites 2 and 3) almost daily. Also, discharge data from an unregulated watershed nearby, and climatological data can be used to estimate flow patterns in Crystal Creek.

The quantity of water in Crystal Creek during our survey was probably close to normal. Snow cover and precipitation in the area had been average or close to average in the four months prior to our survey (USDA, 1985a-d). Air temperatures had been colder than average during February through April, and had delayed snowmelt runoff, but temperatures were normal in June (USDA, 1985a-d).

Climatological data from Lake Cle Elum (elevation 2,255 feet; Roslyn 2,218 feet) are shown in Table 4. The periods of greatest discharge in unregulated streams in the area should usually be March through May as warm rains and warmer air temperatures melt snow accumulations. Discharge volumes would be expected to increase for short periods after warming periods during the winter months. Flows would decrease steadily from June through September as snowmelt was depleted and precipitation was at an annual minimum. Increased precipitation in October and November would increase discharges in the creeks until temperatures turned rain into snow.

Although a much larger watershed than Crystal Creek, the unregulated Teanaway River shows a discharge pattern similar to the one just described (USGS, 1970-1975). Crystal Creek should be similar, but with a greater degree of day-to-day variation and a shorter period of spring runoff because of the watershed's small size.

I used Joe Peck's (1985) stage height measurements from Crystal Creek to calculate a winter-spring seasonal flow pattern in the creek. Stage heights from Station 3 were converted to discharge volumes from a rating curve developed using the Manning equation (Figure 2). The equation states:

$$V = (1.49/n)\ R^{0.66} S^{0.5}$$ where,

V = velocity
n = roughness coefficient
R = hydraulic radius
S = slope

then, $Q = AV$ where,

Q = discharge
A = area

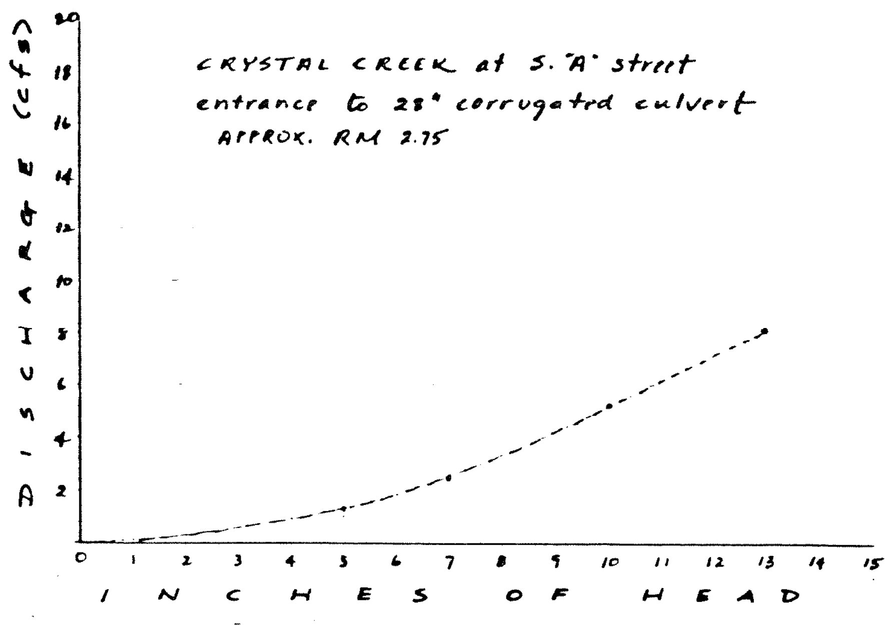
Two roughness coefficients, 0.013 and 0.017, were used to provide a range of flows to match stage heights. This was necessary since we had obtained only one stage measurement with a field-verified discharge measurement. (More discharge measurements at various stage heights should be made if a more precise rating curve is needed in the future.) A slope of 0.019 was used, based on topographic lines from Washington State Department of Transportation and USGS maps. Hydraulic radii were calculated for several head heights within the 24-inch culvert.

Table 4. Climatological data for Lake Cle Elum (elevation 2,255 feet) as reported in USCOAE, 1978.

	Precipitation[1] (inches)	Temperature (°C)[2]		
		Avg. Max.	Avg. Min.	Mean
January	5.87	33.4	19.0	26.0
February	4.31	38.6	21.6	29.9
March	3.67	45.4	26.7	35.7
April	1.57	54.7	32.3	43.6
May	1.31	62.3	39.0	51.2
June	1.09	68.2	45.8	57.1
July	0.36	77.4	50.7	64.3
August	0.42	78.1	49.7	63.4
September	1.32	70.8	42.3	56.9
October	3.61	58.5	35.2	46.8
November	6.00	43.7	28.3	35.5
December	6.96	36.5	23.8	30.3
Annual	36.48	55.6	34.5	45.1

[1]Database 1931 - 1960.

[2]Database 1930 - 1959.



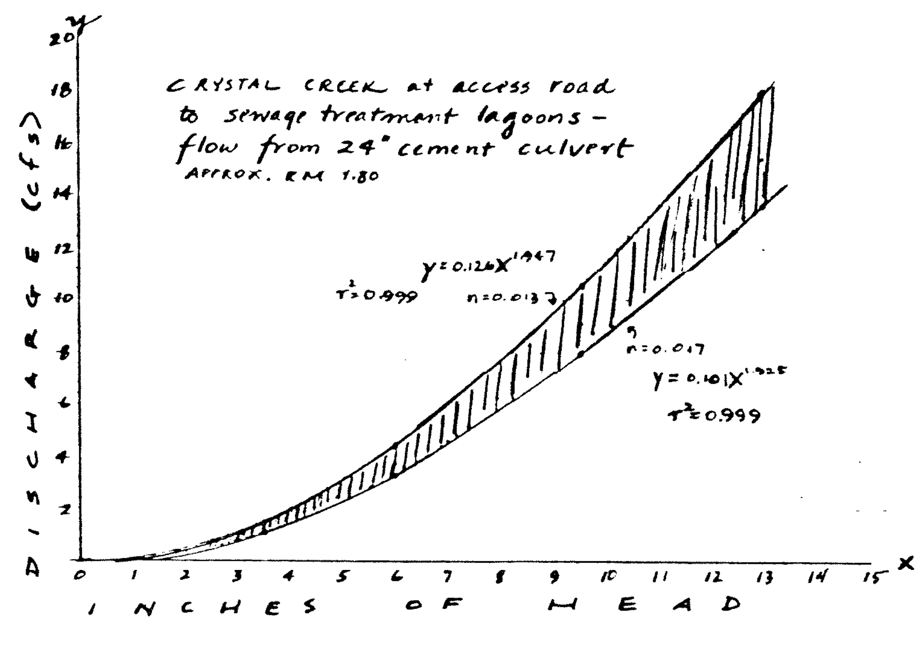


Figure 2. Crystal Creek stage height curves at two sites generated from the Manning equation.

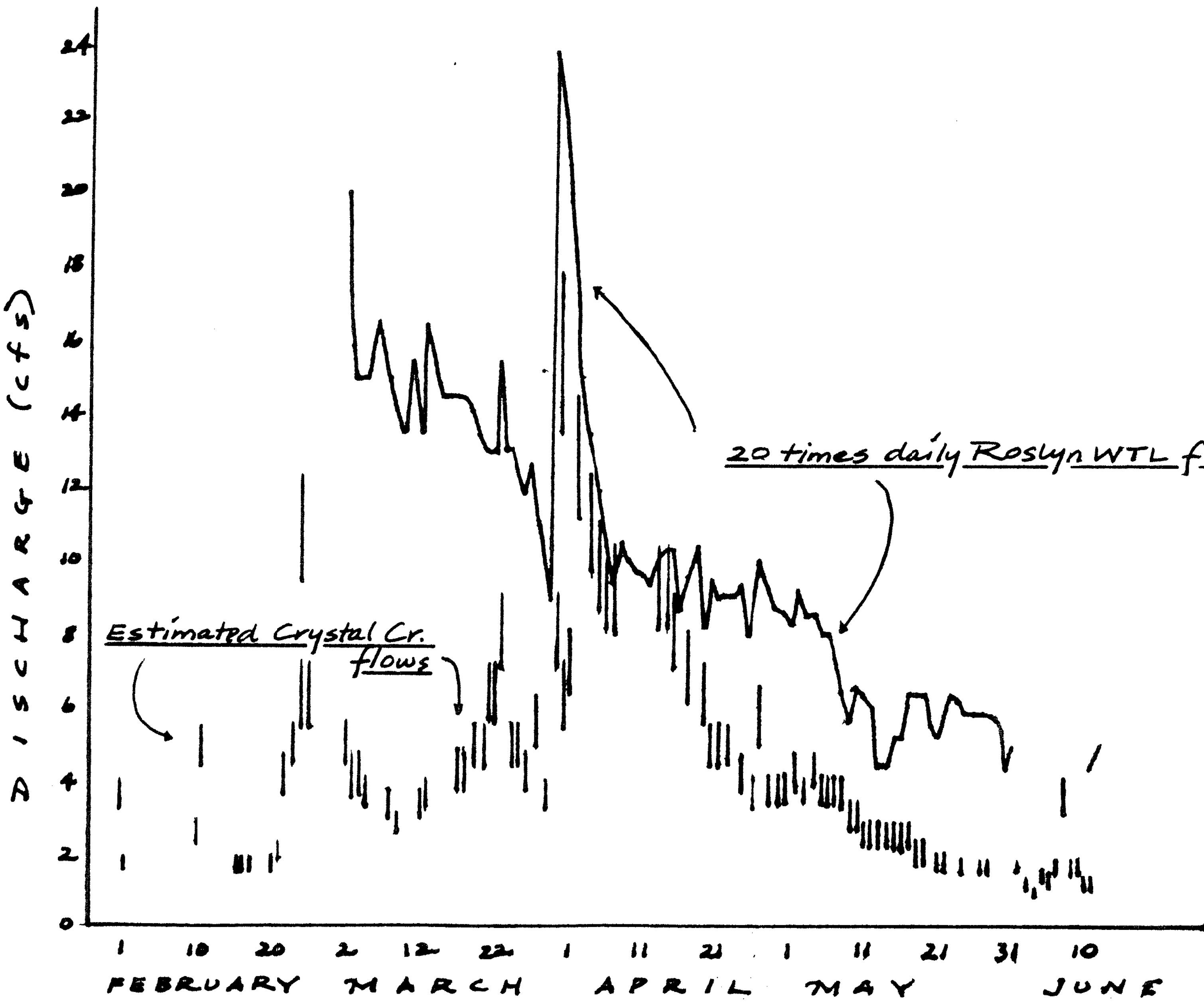


Figure 3. A comparison of estimated Crystal Creek flows to theoretical flows necessary for 20:1 dilution of Roslyn wastewater treatment lagoon (WTL) effluent. Crystal Creek flow range estimated from 1985 head height measurements at R.M. 1.8 interpreted using Figure 2 graph. Roslyn WTL discharge monitoring reports supplied flow data to calculate level of 20 times daily effluent flow.

The flows estimated from applying the head height to the rating curve are shown in Figure 3. Discharge in Crystal Creek may have ranged from 1.1 to 17.8 cfs over the period of record. Lowest flows occurred in mid-February and early June. Highest flows were in early March and April. The pattern is similar to unregulated watersheds in the area. The steady low flow of 1.5 to 2 cfs in late May and June suggest a spring-fed base flow. Conversations with Joe Peck in August 1985 confirmed that stage had remained constant at 3 1/2 inches (1.0 to 1.5 cfs) during the 1985 summer, indicating a ground water source or perhaps the impact from constant water reservoir spillage.

The 20:1 receiving-water-to-effluent dilution ratio has been adopted as design criteria for all new wastewater treatment facilities (WDOE, 1980). The 7-day, 10-year, low-flow volume is generally used to design wastewater treatment plant discharge systems to meet this 20:1 requirement. Unfortunately, a rough analysis of Crystal Creek discharge volumes suggests that the current receiving-water-to-effluent ratio is rarely up to 20:1. The flows estimated from the March through May stage measurements are compared to the flow required to meet a 20:1, receiving water: effluent ratio at the Roslyn WTL outfall (Figure 3). The 20:1 flows were calculated by multiplying the daily influent flows reported in the Roslyn discharge monitoring reports (DMRs) by 20. The figure illustrates that an adequate dilution ratio was probably rarely met. Crystal Creek would have required 2.5 to 4 times more discharge volume to adequately meet the guideline in months not usually considered critical in terms of low flow (February-June).

The pattern of influent flows in the DMRs during spring melt, April through May, also resemble the creek flow pattern (Figure 3). This suggests that the influent may still contain large quantities of stormwater at times. We were told that stormwater probably still enters the collection system from the southwest portion of Roslyn where separation work was not completed during the 1984 grant program (Brozovich and Peck, personal communication, 1985). Roslyn influent flows are further discussed below (Roslyn WTP Influent and Effluent).

As the final note on Crystal Creek discharge, Joe Peck stated that the Roslyn water system could possibly be used to influence Crystal Creek volumes. The Roslyn reservoir, on the west side of the town, is supplied via a five-mile pipeline from Demerie Creek. Excess water in the reservoir is intentionally spilled into two outflows. One outflow spills into the western tributary of Crystal Creek; the other spills into another watershed. If significant quantities of spill water could be generated, perhaps all spillage could be diverted into Crystal Creek and help to increase flows for the receiving water. Of course, water-rights issues, base flow guidelines, and other impacts would need proper evaluation before such a diversion was made.

Roslyn WTP Influent and Effluent

Sample results and other monitoring data for the Roslyn WTL stations are presented in Table 5. The influent compositor was only two-thirds full after 24 hours. We do not know if the problem arose from a clogged compositor intake hose malfunction or from reduced nighttime flows.

While monitoring flows in the lagoons, we observed problems with the plant flow-monitoring system that require attention. The 12-inch Parshall flume located at the headworks is oversized and in disrepair. For example, the minimum free flow capacity for a 12-inch flume is 0.4 cfs (USBR, 1967). A six- or nine-inch Parshall flume, with minimum free flow capacities of 0.05 and 0.1 cfs, respectively, would be better suited to the range of flows recorded in the DMRs (0.2 - 1.2 cfs) (USBR, 1967). Also we noted the bottom of the flume has been scoured. Head heights across the throat of the flume varied by more than one-half inch. Flow-monitoring sensors record flow with the shallower head height and probably underestimate flows. Also, debris was being deposited in various portions of the flume because of low influent volumes and velocities. The operator cleaned the flume of debris prior to our arrival, but debris was building up at a rapid rate. The significance of the debris build-up on recorded flows may be minor considering the existing error from the oversized flume and the minimum flow capacities.

The DMRs we obtained for March through May of 1985 had flow recorded to three decimal places. Comparison of our measured instantaneous flow to those recorded on the in-plant meter agreed to one significant digit. The practice of recording flows on the DMRs to three decimal places is highly questionable and should be discontinued until a more accurate flow-monitoring system is devised.

Data from Anderson and Egbers' (1978) study are summarized in Table 6 for comparison to data from our study (Table 5). Noteworthy observations when the two efforts are compared include:

- Influent flow levels were lower in the current study.
- Current concentrations of influent biochemical oxygen demand (BOD), total suspended solids (TSS), and nutrients were higher.
- Effluent pH levels and concentrations of BOD, TSS, nutrients, chlorine residual, and fecal coliform were similar in both studies.

The changes in influent quantity and quality compared to the 1978 data reflect recent improvements in the wastewater collection system. However, probably not all I&I has yet been removed. The 980 people served by the system would be expected to contribute approximately 100 gallons/person/day (0.15 cfs) and 0.17 pounds BOD/person/day (166 pounds BOD). The measured average influent flow was 70 percent greater than the estimate; the measured influent BOD was only 66 percent of the estimate.

The lagoons were effective in removing BOD, nutrients, and TSS (Table 5). Evidently the "dead spot" in the second cell created by the plugged culvert was not having an impact on wastewater treatment effectiveness at the time of the survey. Retention times were estimated to be 44 days for the full 10.5-acre lagoon with an estimated mean depth of 2.5 feet, and 34 days for the lagoon with the "dead spot." Under the wasteload and flow conditions observed during the survey, these retention times were adequate for BOD removal according to lagoon design formula (Gloyna, 1976; USEPA, 1983).

Table 5. Influent and effluent data taken at the Roslyn WTL on June 11 and 12, 1985.

	Influent		Effluent[1]	
	Grab	24-hour Composite	Grab	24-hour Composite
Flow (cfs)	0.21, 0.3†		0.21-0.28††	0.24*
BOD_5 (mg/L)		80		9
(lbs/day)		110		12
% Reduction				89
TSS (mg/L)		53		8
(lbs/day)		73		10
% Reduction				86
F. Coli. (col/100 mL)		--	<1, 1**, 2**, 2**	
T. Res. Chlorine (mg/L)		--	0.5 - 1.25	
D.O. (mg/L)		--	8.0, 11.5	
Temp. (°C)		--	18.6 - 23.2	
pH (S.U.)		7.5	9.65 - 9.7	9.8
Turbidity (NTU)		26		7
Sp. Cond. (umhos/cm)		276	265 - 280	243
NO_3-N (mg/L)		1.0		0.08
NO_2-N (mg/L)		<0.1		0.01
NH_3-N (mg/L)		6.6		0.08
O-PO_4-P (mg/L)		2.3		1.5
T. Phos.-P (mg/L)		3.7		1.7
T. Hardness (mg/L as $CaCO_3$)		15		14
Alkalinity (mg/L as $CaCO_3$)		140		120

[1] Grab samples were taken from chlorinated effluent. The 24-hour composite sample was unchlorinated effluent.

*Approximate flow - average of five instantaneous measurements.

**Estimated bacterial concentration.

< = Less than

† = Instantaneous influent flows obtained at 1930 on June 11 and 0946 on June 12.

†† = Instantaneous effluent flows obtained at 1135, 1850, and 1950 on June 11; 1035 and 1415 on June 12.

Table 6. Water quality data collected by WDOE during Roslyn survey, May 22 to May 24, 1978 (Anderson and Egbers, 1978).

Parameter	Lagoon Influent	Unchlorinated Effluent	Chlorinated Effluent 5/22	Chlorinated Effluent 5/23	Chlorinated Effluent 5/24
Field					
Flow (cfs)	0.77				9.5
pH (S.U.)	7.3	9.7	--	--	9.5
Spec. Cond. (umhos/cm)	320	265	--	--	230
Temperature (°C)	9.5	14.0	--	--	14.0
Chlorine Residual (mg/L)	--	--	0	1.0	1.5
Laboratory					
pH (S.U.)	7.4	9.1		9.9	
Turbidity (NTU)	15	3		3	
Spec. Cond. (umhos/cm)	291	243		237	
COD (mg/L)	55	40		44	
BOD5 (mg/L)	22	<4		<4	
(lbs/day)	91	<17		<17	
Fecal Coliform (col/100 mL)	--	--	<10	<5	<10
O-PO4-P (mg/L)	0.95	1.05		1.05	
Total Phos.-P (mg/L)	1.4	1.3		1.2	
Nitrate-N (mg/L)	0.5	0.2		0.25	
Nitrite-N (mg/L)	<0.2	<0.2		<0.2	
Ammonia-N (mg/L)	1.35	0.25		0.2	
Un-ionized Ammonia (mg/L)	0.003	0.05		0.09	
Total Solids (mg/L)	178	169		164	
T. Non-Vol. Solids (mg/L)	131	123		108	
Total Susp. Solids (mg/L)	26	3		6	
(lbs/day)	108	12		25	
Total Non-Vol. Susp. Sol. (mg/L)	<1	<1		<1	
Color (units)	38	67		46	
Copper (mg/L)	--	--		<0.01*	
Lead (mg/L)	--	--		<0.05	
Zinc (mg/L)	--	--		0.01	
Cadmium & Chromium (mg/L)	--	--		<0.01	

*Grab sample.

Table 7. Dissolved oxygen and pH effluent data from Roslyn discharge monitoring reports.

Year	Month	Time	pH (S.U.)	Dissolved Oxygen (mg/L)
1981	January	--	7.5	11.4
	January	--	7.5	10.6
	January	--	7.5	11.0
1983	January	--	7.5	9.6
	January	--	7.5	10.0
	January	--	7.5	11.0
1983	February	--	8.0	10.2
	February	--	8.0	9.6
	February	--	8.0	--
1985	March	--	9.0	13.8
	March	--	9.0	14.2
	March	--	9.0	15.0
1985	April	--	9.5	15.3
	April	--	10.0	16.6
	April	--	9.0	9.5
	April	--	9.0	10.5
1985	May	--	9.0	10.8
	May	--	9.0	11.6
	May	--	9.0	8.5
	May	--	9.5	12.4
	May	--	9.0	10.0
1985	August	0930	9.0	2.2
	August	1400	10.0	14.4
	August	1430	9.5	3.8
	August	0930	9.5	3.6
	August	1430	10.0	13.2
1985	Septemter	1400	10.0	14.2
	September	1130	9.0	1.8
1983	November	--	8.0	11.0
	November	--	7.5	10.2
	November	--	7.5	9.6
	November	--	7.5	9.6
	November	--	7.5	9.2

A properly operating lagoon system also may remove nutrients. The removal of some phosphorus and the depletion of inorganic nitrogen in the effluent suggest anaerobic denitrification processes in the near benthic water of the lagoon and/or conversion of nitrogen into algal and bacterial biomass with loss to the sediment were occurring.

Elevated pH levels and oxygen supersaturation in the effluent indicated high algal productivity. Algal growth can cause these parameters to fluctuate widely both daily and seasonally. Some lagoons experience daily changes as much as 2 pH units and 40 mg/L D.O. (King, 1976). Roslyn DMR effluent data have demonstrated some seasonal and daily differences in pH and D.O. (Table 7). The anoxic effluent discharged in late summer/early fall is something of a concern under current discharge practices at Roslyn. Effluent D.O. should be monitored as long as the current mode of discharge continues since Crystal Creek D.O. could be severely impaired during low-flow conditions.

The TSS concentration in lagoon effluent is also usually elevated during times of algal growth. However, the Roslyn effluent TSS concentration was low during the survey, and had been very low, only 1 to 4 mg/L, in March through May of 1985 (DMRs, 1985). The reason for the low concentration may be related to how the effluent was drawn off the lagoon into the chlorine contact chamber, or it may be poor testing methods. The situation requires further investigation.

During the survey, effluent pH levels and chlorine residuals were elevated. The pH exceeded the NPDES permitted level of 9 (Table 5). These concentrations also created potentially toxic conditions in the creek (see Crystal Creek, below), and violated Class A water quality standards.

Anderson and Egbers (1978) noted that effluent flows into the open ditch north of the railroad grade. The situation continues today and poses a health hazard, especially to unwary all-terrain vehicle riders who frequent the area.

Mine Drainage

At the open ditch north of the railroad grade, mine water from Fanhouse No. 5 combines with the WTL effluent before entering Crystal Creek (Figure 1). According to the WTL operator, there is a wide seasonal variation in the quantity of water from the mine drainage that mixes with the WTL effluent (Brozovich and Peck, 1985). The mine-drainage-to-effluent ratio was about 1:8 during this survey.

The mine water (Station D) had a high alkalinity, alkaline pH, and ammonia concentration. These concentrations were very similar to those in a sample taken from the same mine system in 1976 (Packard, 1981). Packard (1981) explained the lack of "acid mine drainage" as a result of low sulfur concentrations in Roslyn area coal. However, he goes on to state that there is enough sulfur for certain anaerobic bacteria to convert sulfates to sulfides and carbon to bicarbonate in the flooded mines. A hydrogen sulfide smell was noticed where the mine water flowed from the fanhouse.

The elevated ammonia concentration was also probably the result of anaerobic bacterial activity. The un-ionized ammonia concentration was approximately 0.009 mg/L, based on calculations using the temperature and pH of the drainage. It is likely that most of the ammonia in the drainage was converted to nitrate by the time it combined with the WTL effluent (Stations D and E). The mine drainage channel contained a heavy growth of algae and periphyton for approximately 1,000 feet. The habitat was ideal for nitrifying bacteria--rocky with water velocities about 1 ft/sec, alkaline pH, and good reaeration activity.

Total metal concentrations, especially zinc, copper, and chromium, in the Station D sample (Table 3) were higher than Packard's (1981) dissolved metal data: 10 ug/L zinc, <1 ug/L chromium, <1 ug/L copper. The metals present in the Station D sample were probably in a complexed state rather than a free, ionic state because of the pH, alkalinity, and hardness of the water. Complexed metals are generally less toxic to aquatic organisms.

The cadmium, copper, and zinc concentrations present in the mine drainage would have exceeded the 1980 USEPA aquatic life chronic toxicity criteria for total metal concentrations in ambient waters (Federal Register, 1980). The copper concentration would have exceeded the acute toxicity criterion as well. The 1984 USEPA criteria for copper and cadmium are based on acidified, filtered samples and cannot be compared to these data (Federal Register, 1984). Comparison of these metal concentrations to those in the creek will be discussed further (see Crystal Creek, below).

Crystal Creek

Water quality monitoring data taken along the course of Crystal Creek during each survey day are presented in Table 3. Station locations are shown in Figure 1 and described in Table 2.

These data indicate that the same basic problems determined by Anderson and Egbers (1978) are still present; i.e., Crystal Creek water quality is degraded as it flows through Roslyn and as Roslyn WTL effluent enters the creek. Various Class A water quality standards (Table 1) were violated at stations below these sources of wastewater.

Water quality in the tributaries (Stations A and B) to Crystal Creek above Roslyn was excellent. All parameters measured exceeded Class A water quality standards. Nutrient concentrations were low as well.

The water quality changed dramatically in the reach of Crystal Creek lying between Roslyn and the Roslyn WTP outfall (r.m. 3.0 to 1.6). Survey observations and the water quality data at Station 1 indicate Roslyn was the primary source of water quality degradation. We observed raw fecal wastes in the creek at Station 1. The effect of these wastes was shown in the water quality data: high fecal coliform populations, elevated nutrient loads, and falling dissolved oxygen concentrations.

The Class A fecal coliform standard was violated. The geometric mean coliform concentration of six samples taken at the three stations (1, 2, and 3) in the reach was approximately 550 organisms/100 mL; 4 samples (40 percent) contained greater than 200 organisms/100 mL.

The highest coliform concentrations were detected at Station 1 where the creek comes out of Roslyn. The degree of coliform contamination varied between the first and second day, suggesting an intermittent fecal loading from some source(s) within the town. Horses and other livestock pastured along the creek between Stations 1 and 3 could have been additional sources of coliform loading.

The effects of wastes from Roslyn on dissolved oxygen saturation levels and nutrient loads in Crystal Creek were also evident. Although all dissolved oxygen concentrations exceeded the minimum 8 mg/L Class A standard, a minor D.O. sag was evident below town at Station 2 (r.m. 2.75) (Figure 4). D.O. depletion may have been minimized by the shallow, turbulent characteristics of the creek. Nitrogen and phosphorus loads increased dramatically between Stations A and B and Station 1 (Figure 5). Within the town, the nitrogen-to-phosphorus loading was in the ratio of roughly 4:1. This ratio is common for raw sewage (Table III-29 in Mills, et al., 1982). The total loads of nutrients stayed stable throughout the reach.

Because of the low flow (0.1 cfs), the eastern tributary to Crystal Creek entering at r.m. 2.6 (Station C) was not intensively sampled (Table 3). Anderson and Egbers (1978) sampled this tributary higher in its drainage. They reported a high nitrate concentration (0.83 mg/L), some nitrite (0.02 mg/L), high conductivity (349 umhos/cm), and an alkaline pH (8.2). Maps of the area show the tributary drains an abandoned mining site. The water quality characteristics of their sample suggest that the water may be from the mines. They are similar to what one would expect if the mine drainage (Station D) collected in our survey had undergone some biochemical conversions (see Mine Drainage).

In the reach of Crystal Creek below r.m. 1.6, some water quality impacts from the Roslyn WTL effluent were evident. The effluent directly caused Class A standard violations for pH and deleterious materials (chlorine) in the creek. Effluent pH levels elevated pH in the creek 0.4 to 1.0 unit (Table 3). As discussed earlier, the elevated effluent pH was probably the result of biomass productivity in the treatment lagoons. The pH change should not have directly impacted resident or migrant aquatic organisms. However, the higher pH level would increase the chances of ammonia toxicity if the effluent ammonia level increased.

The ammonia concentrations, pH levels, and temperatures in the combined discharge mixing zone were not sampled. Therefore, the un-ionized ammonia concentration in that area could not be calculated. Ammonia concentrations at Stations 4 and 5 were not high enough at the in-stream pH and temperature to have created an un-ionized ammonia toxicity problem for aquatic organisms. However, the ammonia toxicity problems could occur during other seasons. For

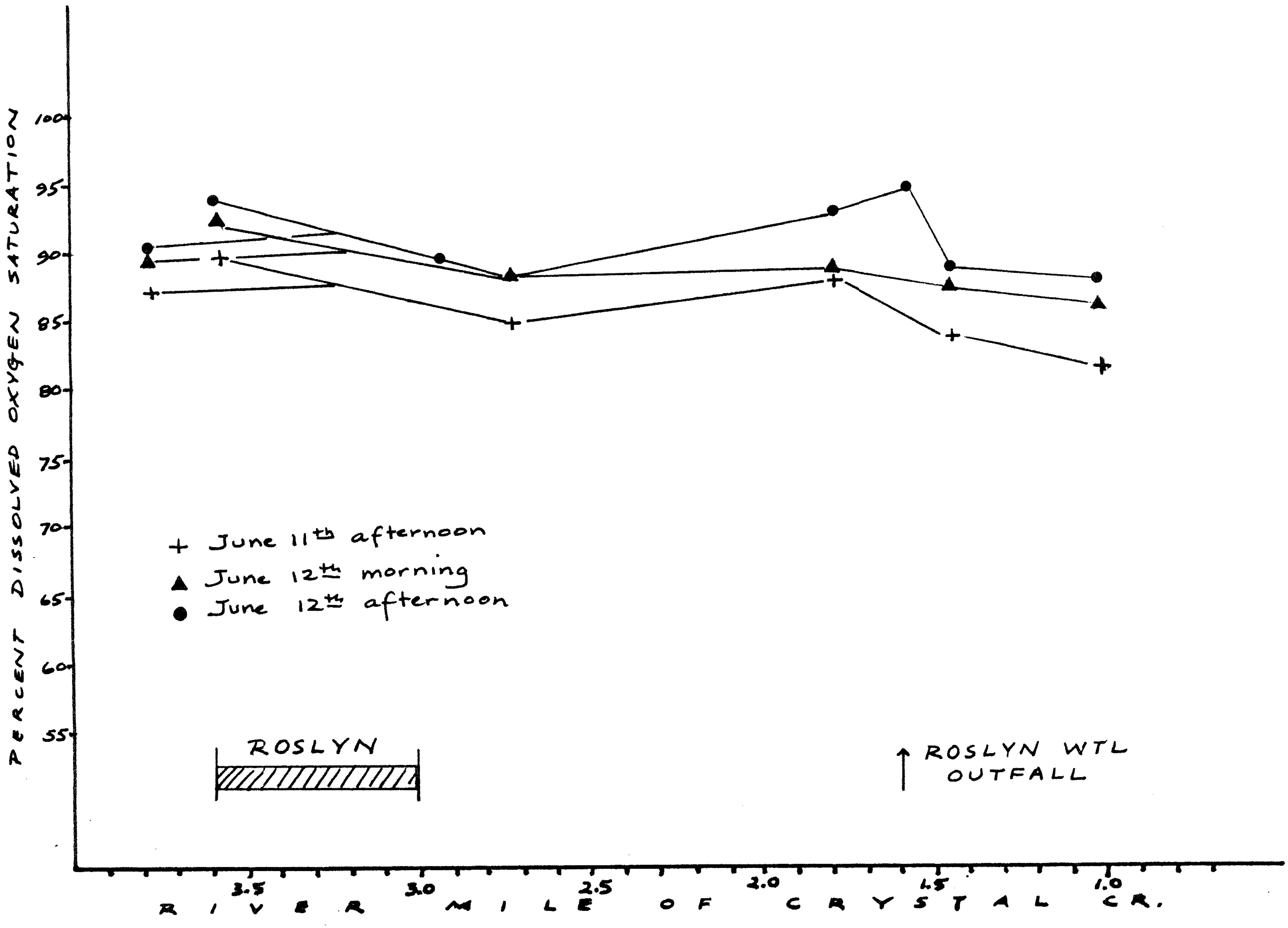


Figure 4. Changes in dissolved oxygen saturation along Crystal Creek during three sampling runs on June 11 and 12, 1985.

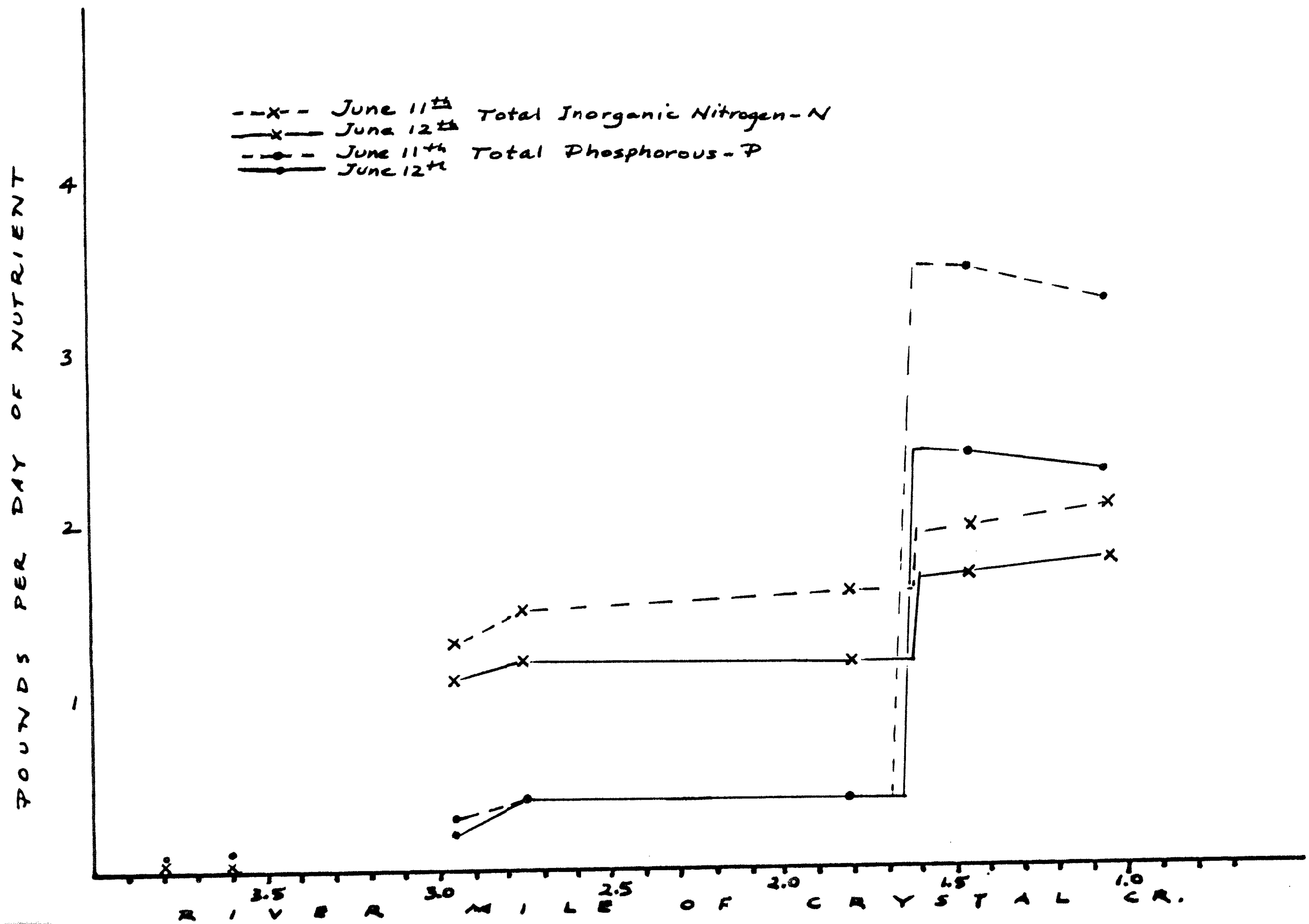


Figure 5. Changes in total inorganic nitrogen and total phosphorus loads in Crystal Creek after passing through Roslyn (river mile 3.5 - 2.95) and by the Roslyn WTL outfall (river mile 1.6).

example, winter icing and snow cover over the lagoons could create anaerobic conditions where increased ammonia concentrations are present in the effluent. Further monitoring of ammonia, pH, and temperature may be warranted if effluent continues to be discharged into the creek. This monitoring should be done before and after the WTL effluent and mine are mixed--if the present discharge configuration continues.

The effluent chlorine residuals of 0.5 to 1.3 mg/L caused an in-stream chlorine residual of 0.1 mg/L at Station 4, 0.15 mile downstream of the outfall on June 12. A balance between low chlorine residuals and adequate disinfection of the effluent is needed. Effluent chlorine residuals need to be below 0.1 mg/L under current discharge practices to be within the recommended USEPA standard of 0.002 to 0.010 mg/L.

As with the wastewater source within Roslyn, the combined Roslyn WTL effluent and Fanhouse No. 5 drainage also increased nutrient loads and decreased D.O. saturation levels slightly in Crystal Creek (Figures 4 and 5). The mine discharge contributed as much inorganic nitrogen as the WTL effluent. However, most of the phosphorus was from the latter. The nutrient loads had not significantly diminished 0.5 mile below the outfall. In-stream nitrification may have been responsible for the slight loss of D.O. at downstream stations compared to upstream stations. Nitrite, an indicator of nitrification activity, was present at Station 5.

Total metal concentrations in the vicinity of the combined outfall did not follow a distinct pattern. Increases or decreases in lead, nickel, copper, and cadmium concentrations between Stations 3 and 4 appeared to have no relation to inputs from the combined mine water/effluent discharge (Table 3). Only the slight increase in zinc between Stations 3 and 4 could be accounted as being from the combined discharge. Hardness values were not available due to laboratory analytical errors. However, the zinc chronic toxicity criterion for aquatic life (not based on hardness) was exceeded at both stations. Active metal concentrations and hardness values would be necessary to evaluate copper, cadmium, lead, and chromium concentrations in Crystal Creek to current USEPA criteria (Federal Register, 1984). The discussion concerning complexed metals in the mine drainage may be applicable to Crystal Creek metal concentrations (see Mine Drainage) in terms of aquatic toxicity.

Despite the presence of residual chlorine and zinc, we observed juvenile salmonids and numerous caddis fly larvae at Station 4. Although we did not quantitatively compare biota in different areas of the creek, the appearance of these relatively pollution-intolerant aquatic organisms suggests that the impacts from the WTL effluent were not severe during the survey.

Memo to Chris Haynes and Harold Porath
Roslyn Wastewater Lagoons and Crystal Creek Receiving Water Study - Findings
October 21, 1985

Conclusions

In general, Crystal Creek seemed able to accept the wasteload from the Roslyn WTL during our survey without severely degrading water quality. However, some Class A water quality standards were violated and problems observed in 1978 were still present. In addition, the chronic low dilution ratio and high probabilty of lagoon upset (e.g., low D.O.; high NH_3-N) create a high-risk situation for Crystal Creek water quality. The following findings were made from our survey in response to the stated objectives:

1. Effluent quality was generally good; i.e., low BOD, TSS, and ammonia concentrations. However, effluent pH and chlorine residual levels resulted in Class A water quality standard violations in Crystal Creek. Un-ionized ammonia and low dissolved oxygen during other times of the year could create toxic conditinos or Class A water quality violations in Crystal Creek.

2. The receiving-water-to-WTL-effluent ratio was 5:1, far below the 20:1 ratio recommended by WDOE. A rough comparison of estimated streamflows in February through May of 1985 to influent flows reported in the DMRs indicated that the 20:1 ratio was rarely met during those months.

3. The 1984 I&I program had probably strengthened the chemical characteristics of the influent compared to 1978 influent. However, DMR flow data indicated stormwater still enters the collection system at times. Treatment efficiency of the lagoon was not impaired during the survey period.

4. Raw wastes still enter Crystal Creek within Roslyn. The Class A fecal coliform standard was violated as a result of this unhealthy situation. Nutrient enrichment and a slight D.O. sag in Crystal Creek were also attributed to this waste source.

5. The mine drainage from Fanhouse No. 5 had high alkalinity and ammonia concentrations. Much of the ammonia may have been converted to nitrate before reaching Crystal Creek. Metals concentrations were considered low compared to acid mine drain situations. The alkaline pH and high alklinity may have reduced the toxicity of the metals present to aquatic organisms, although more data are needed.

Some additional findings were:

- Influent flow-monitoring system in the WTL was inadequate. The Parshall flume was oversized and in disrepair.

- One of the culverts connecting the two lagoons cells was plugged. This created a "dead spot" and may impair lagoon efficiency.

- Effluent still flows through an open ditch before reaching Crystal Creek. This posed a health hazard.

- Zinc concentrations in Crystal Creek above and below the Roslyn WTL/mine drainage discharge exceeded the USEPA chronic toxicity criterion for aquatic life.

Recommendations

- Eliminate raw waste discharges within Roslyn.
- Work toward eliminating the current WTL discharge from Crystal Creek.
- Reduce chlorine residual in effluent to avoid toxicity problems in the creek. A concentration less than 0.1 mg/L is recommended at a 5:1 creek to effluent ratio.
- Improve flow monitoring in the Roslyn WTL. Also, continue to monitor Crystal Creek flows and establish a discharge rating curve for better evaluation of wastewater discharge management.
- Clear plugged culvert connecting the two lagoon cells.
- Split samples to check total suspended solids testing accuracy.
- Monitor effluent ammonia, pH, and temperature, especially when the lagoons are iced over or anaerobic, to determine un-ionized ammonia levels. Monitor concentrations before and after WTL effluent and mine drainage are mixed if the current discharge configuration continues.
- Monitor effluent dissolved oxygen levels at a greater frequency while anaerobic conditions are suspected in the lagoons and while Crystal Creek flows are low.
- Determine if all spillage from the Roslyn water reservoir could be diverted into Crystal Creek to increase flows for effluent dilution.

JJ:cp

cc: Lynn Singleton

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