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KITTITAS WASTEWATER TREATMENT PLANT RECEIVING WATER SURVEY AND ABBREVIATED CLASS II INSPECTION: AUGUST 1987

by
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ABSTRACT

An abbreviated Class II inspection of the Kittitas wastewater treatment plant (WTP) was concurrently conducted with a three-day, low-flow, receiving water survey of Cooke Creek in August 1987. The purpose was to: (1) determine the efficiency of the WTP during the irrigation season when infiltration problem are greatest, (2) determine the impact of the effluent on Cooke Creek, and (3) compare 1987 receiving water quality to that in 1978-79. The WTP was hydraulically overloaded. Both influent and effluent were very weak; e.g., 43 mg/L and 8 mg/L BOD, respectively. The BOD removal was less than 70 percent. Effluent impacts observed on creek water quality were primarily a result of poor dilution and mixing. Residual chlorine was detected, and dissolved oxygen (D.O.) was depressed just below the outfall. Water quality, benthic macroinvertebrate, and fish population data suggested the WTP, non-point sources, or poor irrigation management practices continue to degrade creek water quality. The total maximum daily load analysis used a typical creek low-flow condition and reduced infiltration with resultant increases in WTP effluent strength. Predicted were: D.O. depression, ammonia toxicity, chlorine toxicity, and nutrient enrichment for at least 0.5 mile downstream. Several recommendations were made.

INTRODUCTION

On August 18-20, 1987, Joe Joy and Joy Michaud from the Water Quality Investigations Section (WQIS) of the Department of Ecology conducted a receiving water survey of Cooke Creek and an abbreviated Class II inspection of the Kittitas wastewater treatment plant (WTP). Dean Johnston, the Kittitas WTP operator, provided assistance. The study was requested by John Hodgson and Harold Porath of the Ecology Central Regional Office (CRO) to document any improvements in treatment efficiency and collection system operation since its upgrade in 1980, and to obtain receiving water quality data. The information will be used to evaluate the sewage treatment needs of Kittitas.

BACKGROUND

Site Description

The town of Kittitas (population 950) lies in the Kittitas Valley approximately 10 miles northeast of the Yakima River and 10 miles east of Ellensburg (Figure 1). It is primarily a residential community surrounded by irrigated farmland and pasture. The town has a small commercial district, but no industrial development. In the near future, Kittitas would like to extend services to a proposed motel and gas station complex at the Interstate 90 interchange.

The Cascade irrigation canal runs west to east across the north end of the town; Cooke and Caribou Creeks flow north to south through town. From April through October, the creeks flow into the canal and canal water is diverted into the creek channels downstream. Approximately two miles south of Kittitas, Cooke Creek enters the Town Canal and canal water is diverted into the creek channel downstream; Caribou Creek flows under the Town Canal (Figure 1). Outside the irrigation season the creeks flow in their own channels.

The town of Kittitas is served by an aerated lagoon secondary sewage treatment plant built in 1980. The facility includes: a headworks with comminutor, two lined 3.5-million-gallon aeration basins, two lined 0.49-million-gallon settling basins, two lined rock filters, a chlorine contact chamber, and a control house with some laboratory facilities (Figure 2). Flow is measured only in-line at the head of the chlorine contact chamber. The WTP effluent is discharged into Cooke Creek one mile above the confluence with the Town Canal (Figure 1). The NPDES permit limits for the discharge are listed in Table 1.

Although the water in Cooke Creek downstream of the Cascade Canal is essentially canal water six months of the year, the creek is designated a Class A waterbody and should meet the water quality criteria and provide the beneficial uses listed in Table 2.

Historical Water Quality Data

Irrigation of the surrounding farmlands have historically caused problems with the Kittitas sewage collection and treatment facilities. The local groundwater table typically is raised within 18 inches of the surface during the April-through-October irrigation season. This has caused severe infiltration to the sewage collection system. It was noted during the 1978 WTP upgrade design process that the collection system required reconstruction to decrease the average influent flow from 0.6 MGD to the design flow of 0.28 MGD (CRO, 1980). Despite several attempts to eliminate the infiltration, the influent still exceeds the design flow during the irrigation season (CRO, 1987). In turn, hydraulic overload of the treatment system reduces BOD and TSS removal efficiencies. The effluent often cannot meet its NPDES permit limits for either average monthly BOD load or BOD removal efficiency.

Irrigation management practices directly affect the quantity and quality of the receiving water, Cooke Creek, as well. In-stream flows of Cooke Creek in the vicinity of the WTP outfall are controlled by the ditch rider who regulates the amount of canal water released into the downstream channel. The irrigation district performs an annual de-mossing of the canal using xylene as a biocide. From 1981 to 1984, inadvertent leaks of the xylene-contaminated water into Cooke Creek resulted in fish kills (Kittle, 1981; Porath, 1985; Kittle, 1986). In 1985, attempts to totally prevent xylene-treated canal water from entering Cooke Creek caused a fish kill because the stream dried up (Kittle, 1986). In 1986, water was siphoned over the canal from the upstream to the downstream channel using flexible PVC pipe during the de-mossing procedure. This alleviated the drying and prevented another fish kill (Kittle, 1986).

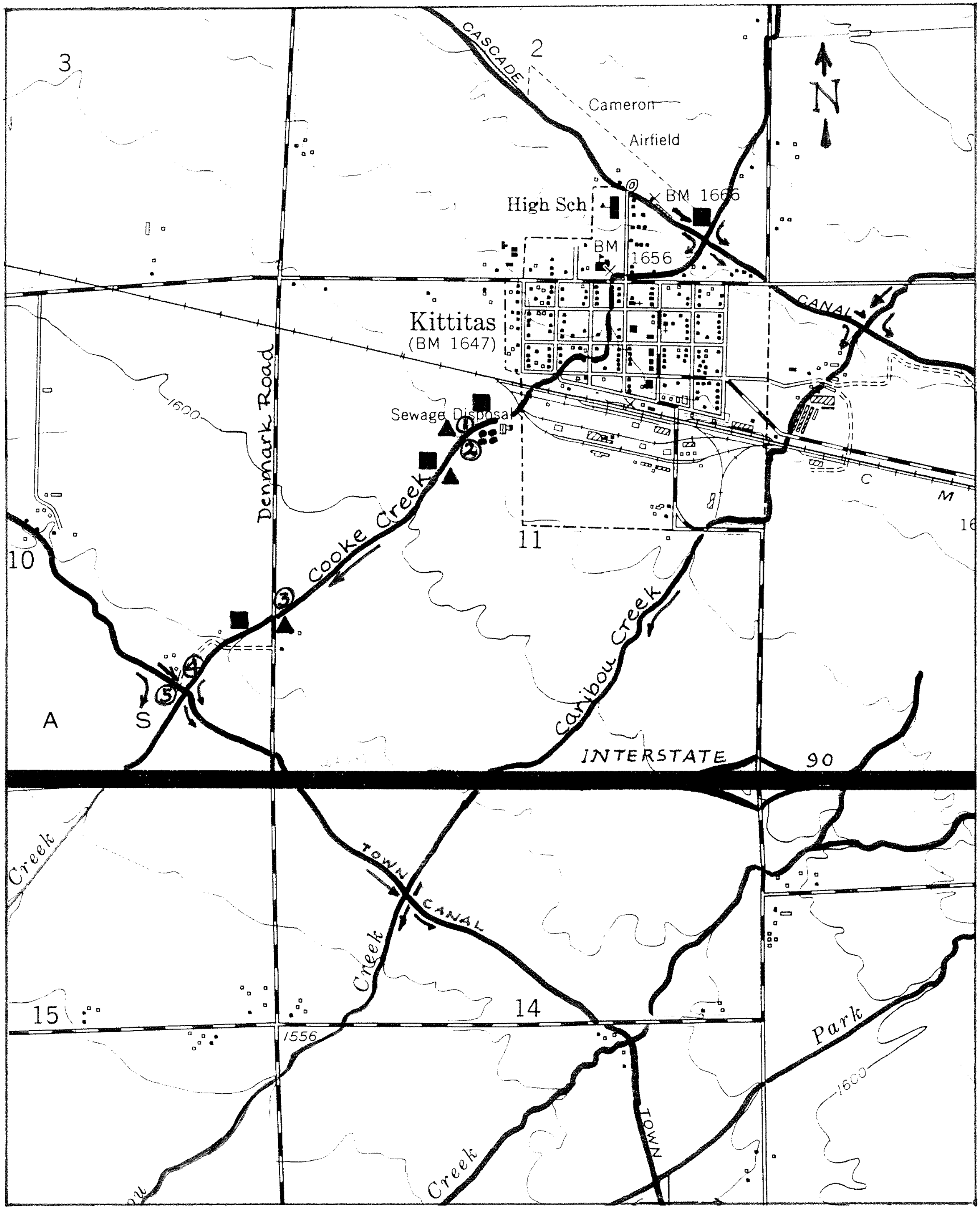

Figure 1. Kittitas and Cooke Creek study area, August 1987. Station location denoted: (1) ▲ benthic invertebrate station, ■ fish population site; ⟶ indicates direction of water flow during irrigation season.

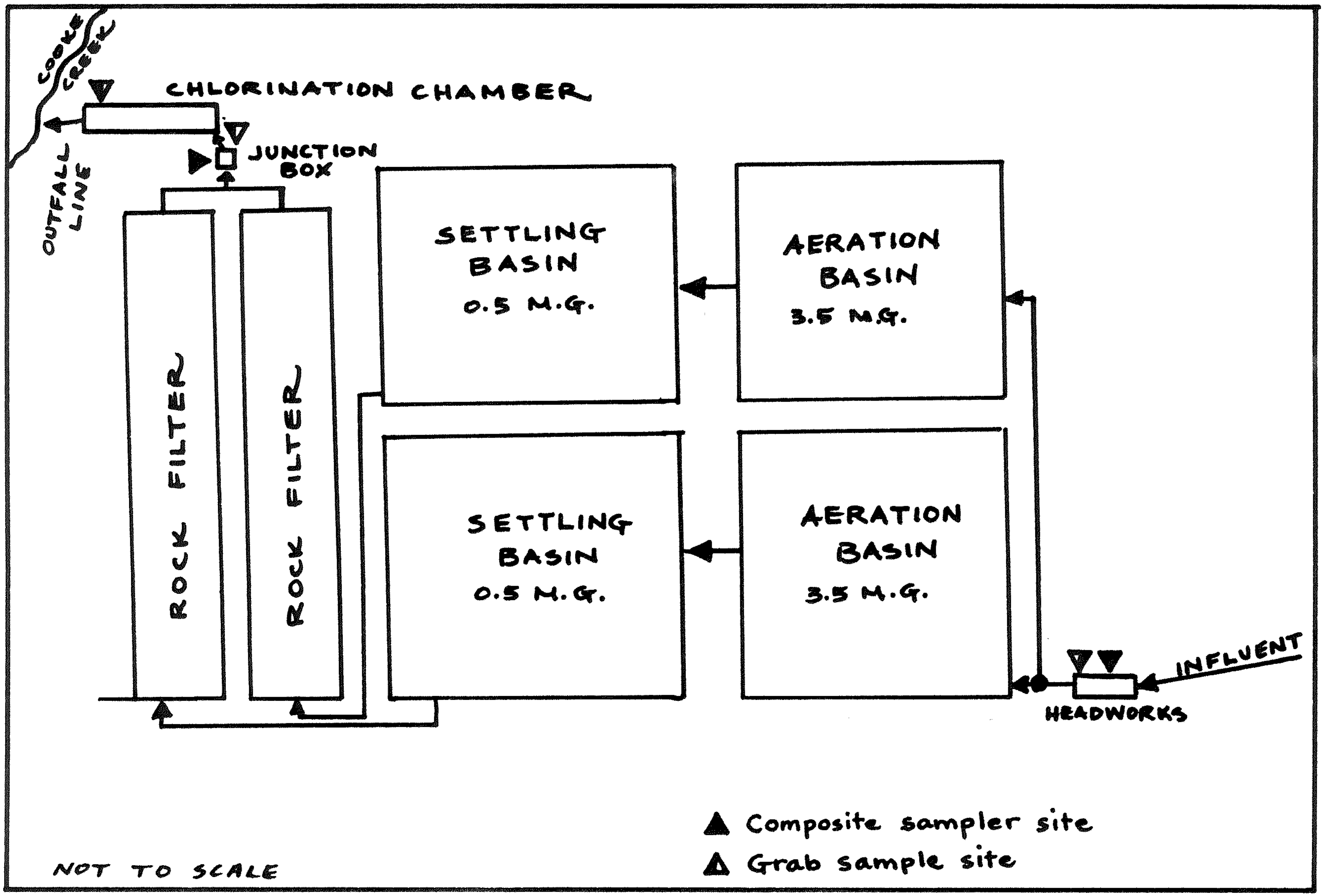

Figure 2. Schematic diagram of the Kittitas wastewater treatment plant showing flow path and sampling locations during the August 1987 survey.

Table 1. National Pollutant Discharge Elminiation System (NPDES) permit limits and sampling schedule for the Kittitas wastewater treatment plant. Permit number WA-002125-3, expiring June 30, 1987.

S1. FINAL EFFLUENT LIMITATIONS

Beginning on the date of permit issuance, the permittee is authorized to discharge subject to meeting the following limitations for secondary treatment:

The monthly average quantity of effluent discharge shall not exceed 0.28 mgd.

Parameter	EFFLUENT LIMITATIONS Monthly Average	Weekly Average
Biochemical oxygen demand* (5 day)	30 mg/1, 31 lb/day	45 mg/1, 47 lb/day
Suspended solids	75 mg/1, 175 lb/day	110 mg/1, 263 lb/day
Fecal coliform bacteria	200/100 ml	400/100 ml
pH	Shall not be outside the range of 6.0 to 9.0.	

The monthly and weekly averages for BOD_5 and Suspended Solids are based on the arithmetic mean of the samples taken. The averages for fecal coliform are based on the geometric mean of the samples taken.

*The monthly average effluent concentration limitations for BOD_5 shall not exceed 30 mg/l or 15 percent of the respective influent concentrations, whichever is more stringent.

Total available (residual) chlorine shall be maintained which is sufficient to attain the Fecal Coliform limits specified above. Chlorine concentrations in excess of that necessary to reliably achieve these limits shall be avoided.

S2. FINAL TESTING SCHEDULE

The permittee shall monitor the wastewater according to the following schedule:

Tests	Sample Point	Sampling Frequency	Sample Type
Temperature	raw sewage	daily	grab
pH	raw sewage	weekly	grab
	final effluent	weekly	grab
Flow	influent and effluent	daily	grab
D.O.	raw sewage	weekly	grab
	final effluent	weekly	grab
BOD	raw sewage	2/month	8 hr. composite
	final effluent	2/month	8 hr. composite
Settleable Solids	raw sewage	weekly	grab
	final effluent	weekly	grab
Suspended Solids	raw sewage	2/month	8 hr. composite
	final effluent	2/month	8 hr. composite
Lagoon depth	each cell	weekly	grab
Fecal Coliform	final effluent	2/month	grab

Table 2. Class A (excellent) freshwater quality standards (WAC 173-201-045) and characteristic uses

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CLASS A

Characteristics shall meet exceed requirements for all or substantially all uses:	Domestic, industrial, and agricultural or water supply, wildlife habitat; livestock watering; general recreation and aesthetic enjoyment; commerce and navigation; salmonid and other fish reproduction, migration, rearing, and harvesting.

Water Quality Criteria

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^{o}C due to human activity. Increases shall not, at any time, exceed $t = 28(T+7)$; or where temperature exceeds 18^{o}C naturally, no increase greater than 0.3^{o}C. t = allowable temperature increase across dilution zone, and T = highest temperature outside the dilution zone. Increases from non-point sources shall not exceed 2.8^{o}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.
Turbidity:	Shall not exceed 5 NTU over background when background is 50 NTU or less, or cause 10 percent increase in turbidity over background when background is greater than 50 NTU.
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.

Cooke Creek was included in a Wilson Creek drainage area water quality study in 1978-79 conducted by WQIS staff (WQIS, 1980a). Two stations were located on the creek, bracketing the Kittitas WTP outfall. At that time, the treatment plant was:

> "...an antiquated secondary treatment facility whose secondary clarifier has been bypassed for a number of years."

Fifteen sets of samples were collected at each station between July 1978 and July 1979. The following conclusions were reached concerning the water quality in Cooke Creek (WQIS, 1980a):

- Water quality in Cooke Creek upstream of the WTP outfall was poor; e.g., high levels of fecal coliform, turbidity and nutrients.

- The Kittitas WTP effluent further degraded water quality; e.g., increasing fecal coliform levels, causing periodic Class A dissolved oxygen violations, increasing nutrients, promoting growths of *Sphaerotilus*, and creating a chlorine toxicity problem.

These data will be further discussed later in this report.

METHODS

Descriptions and field/laboratory activities for individual stations are listed in Table 3. Station locations are shown in Figure 1.

Field analyses included temperature by mercury thermometer, D.O. by Winkler-azide modified titration, pH and conductivity by field meters, and total residual chlorine by DPD colorimetry (APHA,AWWA,WPCF, 1985). Stream discharges were calculated for selected sites using cross-sectional stream areas and velocity measurements. Flow measurements in the Kittitas WTP were calculated using the in-plant flowmeter and totalizer.

Grab samples collected for laboratory analysis were stored in the dark on ice and received via bus freight by the Ecology/USEPA Manchester Environmental Laboratory within 24 hours. Composite samplers were set to collect 250 mL aliquots of influent and unchlorinated effluent at 30-minute intervals for 24 hours. The compositor jugs were adequately iced over that period and analyzed within 24 hours at the Manchester Laboratory. All analyses were performed using approved procedures (Huntamer, 1986). Additional nitrogen analyses were performed by a contract laboratory; their data provided a quality assurance check on nitrate/nitrite data. Benthic invertebrate samples were collected at or near selected chemical sampling stations in the middle of riffle areas. Specific collection sites were chosen because of similarities in water velocity and depth, and ambient lighting. At each site a rock of four to six inches in diameter was randomly selected from mid-channel, right-channel, and left-channel. The organisms were picked, scraped, and rinsed clean from the three rocks into a No.

30 standard screen bucket and transferred into a shallow white tray. All organisms obtained within 15 minutes were placed in jars with a 70 percent alcohol solution. Organisms were enumerated and identified to at least family level using standard texts: Merritt and Cummins (1976), Pennak (1953), and Usinger (1973).

Fish population surveys were conducted at or near Stations 1, 2, and 3, and on Cooke Creek (Figure 1). An additional survey was conducted out of the study area above the Cascade Canal. Approximately 50 feet of mixed riffle and run area with an average depth of one foot was selected at each site, and covered once using a backpack electroshocking unit. Block nets were not used, but fish moving ahead of the shocking field could be easily seen.

RESULTS AND DISCUSSION

Kittitas WTP Efficiency

Several difficulties were encountered while attempting to evaluate the efficiency of the WTP. The headworks area was too turbulent to measure flow. Access ports along the main collection line into the headworks were either in the middle of narrow roads or at changes of line direction which also prevented suitable flow measurement. In addition:

- The vertical discharge pipe from the chlorine contact chamber to the creek was not plumb and therefore was inappropriate as a weir; so continuous, independent flow measurements of the effluent were not made.

- The stream channel in the vicinity of the outfall was overgrown with grass and brush, so instantaneous stream flow measurements above and below the outfall probably contained a high degree of error.

- The influent composite sampler experienced an overnight power failure two nights in succession, so only a 19-hour influent composite sample was obtained.

Despite these difficulties, the data collected at the WTP provide some assessment of the plant's treatment efficiency. For example, it is apparent from the influent sample results that groundwater is still heavily infiltrating the collection system:

- BOD and TSS concentrations were far below the 100-200 mg/L normally encountered for municipal treatment plants (Mills *et al.*, 1985).

- Nitrate concentrations were higher than most municipal influents, and ammonia concentrations were low (Mills, *et al.*, 1985).

- Specific conductivity was lower than expected.

Influent flows were not measured, so a very rough estimate was calculated assuming that influent flow was equal to the sum of effluent discharge and evaporation. Leakage from the lagoons was considered to be insignificant, and the 20-day retention time was ignored. Appendix I provides details of the formula and local climatological data used in estimating evaporation. Conservatively, evaporation may have accounted for a 10 percent loss of the flow through the WTP during the survey period. The figure is conservative because agitation by the aerators and evapotranspiration effects from the mats of duckweed were unaccounted.

The collection system construction projects undertaken by Kittitas over the past couple of years may be alleviating some of the infiltration problem. A comparison of DMR mean monthly effluent flow data from 1983 to 1987 indicates apparently decreased flows in 1987 during the irrigation season (Figure 3). A seasonal Kendall trend analysis (Gilbert, 1987) was performed on the data. No significant trend was indicated, probably because the decrease in flow occurred more as a step, between 1986 and 1987, rather than a gradual decline. Water table data in the area are not available, so we cannot determine if some of the improvement in 1987 may be a result of the drought conditions and a depressed water table rather than from structural improvements in the collection system. The flows are still higher than the 0.28 MGD plant design flow, and further improvements are necessary.

Operator and Ecology sample splits compared poorly, especially for influent BOD concentrations (Table 4a). The ratio of BOD to TSS and total nitrogen appeared to be more reasonable for the Ecology set of influent results. The Ecology influent concentrations are far less than those obtained by the Kittitas operator, and indicate BOD and TSS efficiency may be poorer than reported in the monthly DMRs. Even if the influent flow values are increased 10 percent over the reported effluent flows to account for evaporation, the efficiencies are often below the 85 percent removal secondary treatment requirement. The 10 percent increase generally resulted in only a 1 percent increase in removal efficiency. The CRO should arrange for further sample splits or for help from Ecology's roving operator to verify or alleviate the analytical problems.

During the survey the operator grabbed a single influent and effluent sample during the morning hours as his sample to split with us, although the NPDES permit states eight-hour composite samples are necessary for BOD and TSS (Table 1). This was his normal sampling procedure since he has several duties in addition to WTP maintenance. However, the three influent samples collected during the survey exhibited a very wide range of BOD and TSS concentrations, indicating that a single grab sample can be very misleading for evaluating the WTP's performance. The operator now collects three influent grab samples on one day and a single effluent grab the day before (personal conversation, T. Gaurn, 1988). The CRO should come to an agreement on sampling times and frequency. Ideally, both influent and effluent should be sampled over the same time period as frequently as possible.

Table 3. Station descriptions and activities performed during the Kittitas WTP abbreviated Class II and receiving water survey, August 18-20, 1987.

Station	River Mile	Station Description	Field / Laboratory Activities	Benthic Invertebrate Sample
0	0.83	Cooke Creek, approximately 60 feet above the Kittitas WTP outfall, mid-channel	Temperature, pH, conductivity / ammonia, NO_2+NO_3, COD, total phosphorous, fecal coliform	No
CUL	0.82	Culvert from left bank, approximately 50 feet above the WTP outfall	Same as Station 0 / Same as Station 0	No
1	0.81	Cooke Creek, 30 feet above the WTP outfall, mid-channel	Discharge, temperature, conductivity, pH, dissolved oxygen, total residual chlorine / pH, turbidity, solids(4), COD, BOD, ammonia, NO_2+NO_3, Kjeldahl N, organic N, total P, fecal coliform, alkalinity, chlorides	Yes, upstream near Station 0
2	0.80	Cooke Creek, approximately 70 feet below WTP outfall, mid-channel	Same as Station 1 / Same as Station 1 except no BOD	Yes, 125 feet downstream
3	0.25	Upstream side of Denmark Road bridge, mid-channel	Same as Station 1 / Same as Station 1 but TSS for solids (4)	Yes, same site
4	0.06	Cooke Creek approximately 100 feet upstream from confluence with Town Canal, right channel	Same as Station 1 / Same as Station 1 except TSS for solids(4), and no BOD	No
5	--	Town Canal, 50 feet above Cooke Creek confluence mid-channel from wooden bridge	Same as Station 4 / Same as Station 4	No
INF	--	Influent grab sample at Kittitas WTP at headworks	Temperature, pH, conductivity / pH, COD, solids (4), turbidity, BOD, ammonia, NO_2+NO_3, organic N, Kjeldahl N, total P, chloride	--
INC	--	Influent composite sample taken for about 19 hours - 0910 to 2240, 0530 to 0945	Same as INF / Same as INF	--
INO	--	Influent grab sample collected by the WTP operator at headworks and split w/Ecology	None / Conductivity, pH, BOD, TSS	--
EFF	--	Effluent grab sample taken at outlet from chlorine contact chamber to outfall	Temperature, pH, conductivity, D.O., total residual chlorine / Same as INF plus oil and grease, fecal coliform, alkalinity	--
EFC	--	Effluent composite sample collected over 24 hours at junction box prior to chlorination	Same as INF / Same as INF	--

Figure 3. Mean monthly effluent discharge from the Kittitas WTP, April-Oct, 1983-87

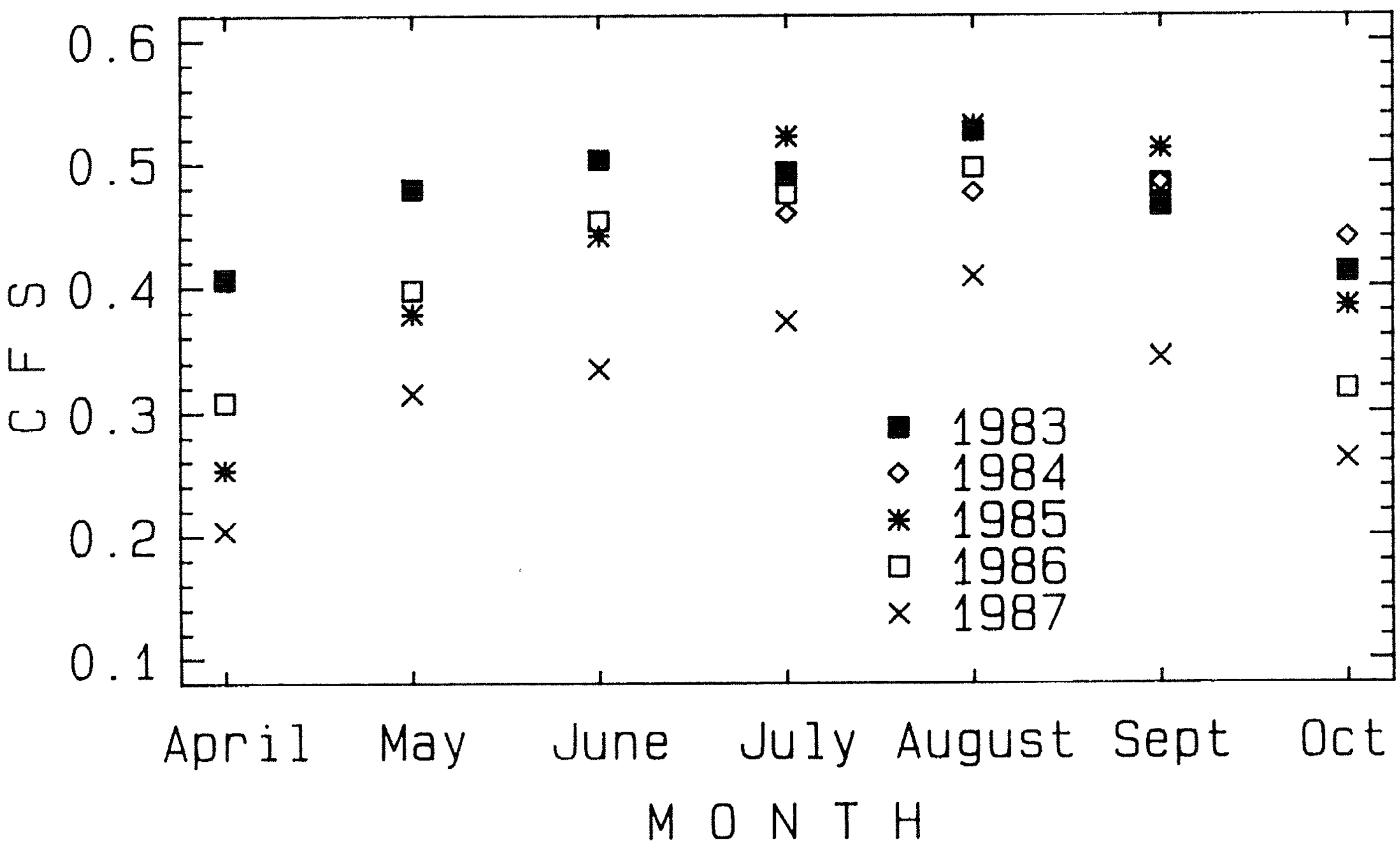

Table 4a. Analytical results for influent and effluent samples collected at the Kittits WTP by Ecology and Kittitas personnel during the August 18-20, 1987, abbreviated Class II inspection and receiving water survey. All values are mg/L unless otherwise noted.

	ECOLOGY LABORATORY RESULTS								KITTITAS RESULTS			
Station	INF.	EFF.	EFF.	EFF.	EFF.	INC.	EFC.	INO.	INO.	EFF.	INC.	EFC.
Date	8/18	8/18	8/19	8/19	8/20	8/20	8/20	8/20	8/20	8/20	8/20	8/20
Time	1325	1345	0923	1400	0540	24-hr.	24-hr.	0950	0950	1000	24-hr.	24-hr.
Discharge (cfs)	0.670	0.670	0.680	0.680	0.690	0.690	0.690	0.690	0.688	0.688	0.713 est.	0.690
Temperature (°C)	18.7	19.8	19	20.6	17.8	5.5	6.5					
pH (S.U.)	7.3	7.6	8	7.7		7.8	7.8					
Sp. Cond. (umhos/cm)	400	460	480	450		410	455					
Dissolved oxygen		3.9			3.7							
Diss. oxygen % sat.												
T. Residual Chlorine		0.60	0.30	0.60						0.3		
Lab Conduct. (umhos/cm)		451				425	450	451				
Lab pH (S.U.)	7.2	7.5				7.7	7.9	7		7		
Turbidity (NTU)	4	4				9	5					
Alkalinity		220					214					
Total Solids	300	310				330	300					
T. Non-Vol. Solids	190	190				210	190					
Total Suspended Solids	13	11				50	8	35	42	6		
T. Non-Vol. Susp. Sol.	2	3				18	3					
COD		36				79	40					
BOD, 5-day	16	7		8		28	9	43	84	13	123	10
NO_2 + NO_3-N	0.77	0.15				0.76	0.03					
NH_3 + NH_4-N	0.63	2.00				1.20	2.20					
Total Inorganic N	1.40	2.15				1.96	2.23					
Kjeldahl Nitrogen*	2.8	3.7				4.5	4.1					
NO_2 + NO_3-N*	0.65	0.17				0.69	0.05					
Organic Nitrogen-N**	2.2	1.7				3.3	1.9					
Total Nitrogen*	3.45	3.87				5.19	4.15					
Total Nitrogen	3.60	3.85				5.26	4.13					
Total P	1.40	1.50				1.30	1.50					
Chloride	6.9	10.0				7.8	8.9					
Fecal coliform (#/100 mL)		12	14	28						50		
Oil and grease		0.5		1								

*Analysis performed by contract laboratory.
**Organic nitrogen calculated by difference, Kjeldahl - NH_3 = Organic

Table 4b. Treatment plant BOD and TSS loading and removal efficiency data.

	ECOLOGY LAB RESULTS							KITTITAS RESULTS			
Sample	Inf.	Eff.	Eff.	Inc.	Efc.	Ino.	NPDES Permit	Ino.	Eff.	Ino.	Eff.
Date	8/18	8/18	8/19	8/20	8/20	8/20	Monthly Avg.	8/20	8/20	8/20	8/20
Flow	0.670	0.670	0.680	0.688	0.688	0.688	0.433 cfs	0.688	0.688	0.713	0.690
TSS	13	11		50	8	35	75 mg/L	42	6		
BOD	16	7	8	28	9	43	30 mg/L	84	13	123	10
TSS load	47	40		185	30	130	175 lbs./day	156	22		
BOD load	58	25	29	104	33	159	31 lbs./day	311	48	473	37
TSS % removal		15			84	77			86		
BOD % removal		56			68	79	85 % removal		85		92

Most NPDES requirements for the Kittitas discharge were met during the survey (Table 4b):

- The TSS and BOD effluent concentrations and loads were within permit limits.
- Fecal coliform level were low.
- Effluent pH was within limits.

Manual chlorination control led to periodic over-chlorination. Effluent residual chlorine concentrations were adequate in the morning, but rose to excessive levels in the afternoon (Table 4a). The automated chlorination equipment should be repaired or replaced to pace dosing to discharge volumes.

Infiltration and dilute influent led to some permit difficulties. The permit states that effluent BOD must not exceed 30 mg/L, or 15 percent of the influent concentration, whichever is more stringent (Table 1). During the survey, the 85 percent removal requirement was far more stringent; i.e., the effluent should not have exceed 2 to 6 mg/L. It is not possible for the lagoons to perform this degree of treatment under the current influent conditions. The lagoons were removing approximately 84 percent of the TSS and 68 percent of the BOD based on the Ecology composite sample results (Table 4b). Kittitas should continue to alleviate its infiltration problem, but the CRO now has the option to use the recent change in WAC 173-221-050 (2)(a) allowing the BOD removal requirement for lagoon under 0.5 MGD to be relaxed to 65 percent (Ecology, 1987).

Effluent Impacts on Cooke Creek

Water quality of Cooke Creek at Station 1, upstream of the WTP outfall, met Class A pH, turbidity, temperature, and daytime dissolved oxygen (D.O.) criteria (Table 2; Table 5). Fecal coliform levels and early-morning D.O. concentrations did not meet the criteria (Table 5; Figure 4). Ammonia concentrations were low, but other nutrients at Station 1 were somewhat elevated. Total nitrogen, mainly as nitrate and nitrite, and phosphorous concentrations exceeded levels likely to cause eutrophication problems (Mills, *et al.*, 1985). We discovered on the second day of the survey that most of the upstream nitrate and nitrite nitrogen (NO_2+NO_3) load came from a culvert just 50 feet upstream of the WTP outfall (Table 5). The culvert diverts subsurface water around the WTP lagoons (personal conversation T. Gaurn, 1988), and supplied approximately one-fifth of the upstream flow. Its high NO_2+NO_3 and low COD indicate the water is probably from adjacent irrigated fields rather than leakage from the lagoons.

The Kittitas WTP effluent to Cooke Creek dilution ratio was approximately 1:5 over the three days. This is far lower than the 1:100 recommended ratio (Ecology, 1985), or the former 1:20 guideline (Ecology, 1982), but the CRO is aware of the problem. Cooke Creek was probably experiencing a low-flow event at the time of the survey although the annual range of flows is difficult to determine since the creek is regulated by the irrigation district. The seven-day, ten-year, low-flow (7Q10) statistic for the creek has not been determined. The 1978-79 flows during the irrigation season (April through October) were generally less than 10 cfs, and one-fourth were less than 1 cfs (WQIS, 1980b). It is improbable that the plant effluent could achieve a 1:100 dilution ratio even at its design flow (0.28 MGD or 0.43 cfs) since at least 43 cfs would be required in the creek.

The WTP effluent was dilute for a secondary plant, and appeared to have some impact on Cooke Creek, but less than might have been expected considering the low dilution ratio. The lack of dilution water seriously compromises the ability of creek to assimilate the WTP effluent. The following effluent characteristics and impacts were noted:

- Effluent loads of BOD and COD were approximately the same as upstream; effluent TSS loads were one third upstream loads.

- Low effluent D.O. and the BOD and ammonia loads contributed to an immediate D.O. depression downstream.

- The effluent increased loads of ammonia and phosphorus in the creek. However, there did not appear to be ammonia toxicity at Station 2, downstream, because of low ammonia effluent concentrations and depressed pH levels relative to other station's pH.

- The WTP effluent appeared to have little effect on in-stream fecal coliform levels.

- Trace chlorine residuals were occasionally detected at Station 2, suggesting that toxic conditions may have been present.

- D.O. concentrations at Station 2, below the outfall, never met the 8 mg/L Class A criterion.

The channel characteristics at the outfall site created an inadequate dilution zone and led to poor assimilation of the effluent ammonia, BOD, COD, and low effluent D.O. An irrigation diversion structure 100 feet below the outfall had created a pool, so that in-stream reaeration was deficient. The D.O. depression at Station 2 may have been somewhat alleviated had the area been a riffle. The pool's impact is quite apparent from the model simulation performed in the total maximum daily load evaluation (see below). A riffle would have also more rapidly dissipated residual chlorine.

<u>Cooke Creek Water Quality</u>

The irrigation structure just below Station 2 diverted about one-third of the flow from the creek toward adjacent crop land. Velocities increased below the structure as the stream returned to a riffle and run character. Flows at Station 3, the Denmark Road bridge, indicated groundwater and/or irrigation returns feed the creek between the diversion and Station 3. The water quality characteristics at Station 3, and at Station 4, just before the confluence with Town Canal, showed very few changes from those at Station 2 (Table 5). Ammonia loads had declined, and daytime D.O. concentrations were greater than 8 mg/L. However, D.O. concentrations showed wider diurnal swings than Station 1 concentrations, and early-morning D.O.s were below 8 mg/L, but above 5 mg/L (Figure 4). These swings were probably directly related to the phosphorous and nitrogen concentrations that continued to exceed nuisance eutrophication levels (Mills, *et al.*, 1985). Periphyton was luxuriant, and mats of *Potamogeton* sp. and *Elodea* sp. were quite common. Class A criteria were not met for fecal coliform. Other nutrient, COD, and solids loads remained the same as Station 2.

Non-point sources may have sustained the fecal and nutrient loads downstream of the outfall. About 30 horses and cattle were observed in the area between Station 2 and Station 3. The livestock had free access to the creek or irrigation return channels. Riparian vegetation had been removed from much of the bank, and several areas of heavy grazing and bank erosion were apparent. The nutrient concentrations of the irrigation return flows has already been noted above. Non-point source controls should be integrated with the WTP improvements if the creek is to meet "fishable-swimmable" goals.

The Town Canal appeared to have somewhat similar water quality to Cooke Creek. Both water bodies were enriched with nutrients, had fecal coliform levels greater than the Class A criteria, and had similar pH levels (Table 5). Cooke Creek nutrient concentrations were greater than the canal's, but nitrogen and phosphorus loads from the creek were approximately one-half and one-third the respective canal loads. Cooke Creek fecal coliform and COD loads averaged less than 15 percent of the canal's loads. The dilution ratio of Town Canal to Cooke Creek was approximately 11:1. Based on these data, the additional input of nutrients, fecal coliform, and COD from the creek does not appear to substantially change the water quality of the canal.

Biological Quality

The benthic macroinvertebrate and fish population sampling were performed for verification of, and comparison to, the chemical water quality data. Biological indicators are used to indicate water quality over a longer period, when chemical data are not available, and are often better measures of whether "fishable-swimmable" goals are being met.

The macroinvertebrate assemblages on Cooke Creek were dominated by three orders: Tricoptera, Ephemeroptera, and Diptera (Table 6). None of the assemblages had the high diversity of organisms indicative of exceptional water quality; e.g., a Brillouin index score above 3.0 (Wilhm, 1970). Station 1 was lowest in diversity, but had the highest percentage of Ephemeroptera, Plecoptera, and Tricoptera (EPT), or "clean water" organisms. Station 2 diversity increased over Station 1, but the percentage of EPT dropped while Diptera increased. Large numbers of Diptera in lotic

Table 5. Water quality data collected at various stations along Cooke Creek in the vicinity of the Kittitas wastewater treatment plant - August 1987. All values are mg/L unless otherwise specified.

River Mile	0.83	0.82	0.81	0.81	0.80	0.80	0.25	0.25	0.06	0.06	--	--
Station	0	CUL	1	1	2	2	3	3	4	4	5	5
Date	8/19	8/19	8/18	8/19	8/18	8/19	8/18	8/19	8/18	8/19	8/18	8/19
Time	1135	1140	1435	1105	1412	1054	1300	1030	1230	1002	1245	1010
Discharge (cfs)	2.4 est.	0.6 est.	3.3	3.0	4.0 est.	3.7 est.	4.0	4.4	4.2 est.	4.6 est.	50 est.	50 est.
Temperature (°C)	16.9	16.0	17.0	15.5	17.1	16.0	17.1	15.6	16.6	15.2	17.0	16.2
pH (S.U.)	7.9	7.6	7.4	7.8	7.2	7.7	7.6	7.9	8.0	8.0	7.9	7.8
Sp. Cond. (umhos/cm)	270	390	310	292	320	325	330	300	325	325	140	132
Dissolved oxygen			8.0	8.3	7.2	7.4	8.4	8.3	9.1	8.5	9.1	8.4
Diss. oxygen % sat.			82.1	82.6	74.1	74.4	86.4	82.8	92.7	84.1	93.4	84.3
T. Residual Chlorine			<0.1	<0.1	T	T						
Lab Conduct. (umhos/cm)					324	331						
Lab pH (S.U.)			7.4		7.4		7.7		7.8		7.5	
Turbidity (NTU)			2	2	2	3	2	2	2	2	3	4
Alkalinity			140	150	160	150		160		160		62
Total Solids			280	270	230	230						
T. Non-Vol. Solids			130	120	140	150						
Total Suspended Sol.			6	6	5	7	5	4	2	2	20	15
T. Non-Vol. Susp. Sol.			4	4	3	4						
COD	15	4	12	6	20	15	20	19	21	17	13	9
BOD, 5-day			2	2			2	2				
$NO_2 + NO_3$-N	0.29	6.00	1.20	1.50	1.20	1.10	0.97	0.85	0.92	0.89	0.13	0.14
$NH_3 + NH_4$-N	0.02	0.01	0.01	0.01	0.34	0.36	0.08	0.09	0.06	0.05	0.01	0.01
Total Inorganic N	0.31	6.01	1.21	1.51	1.54	1.46	1.05	0.94	0.98	0.94	0.14	0.15
Kjeldahl Nitrogen*			0.7	0.7	1.3	1.2	1.2	1.0	1.3	0.1	1.0	0.6
$NO_2 + NO_3$-N*			1.20	1.30	1.20	1.00	0.94	0.86	0.90	0.86	0.24	0.14
Organic Nitrogen-N**			0.7	0.7	1.0	0.8	1.1	0.9	1.2	1.2	1.0	0.6
Total Nitrogen*			1.90	2.00	2.50	2.20	2.14	1.86	2.20	2.06	1.24	0.74
Total Nitrogen	0.31	6.01	1.91	2.21	2.54	2.26	2.15	1.84	2.18	2.14	1.14	0.75
Total P	0.11	0.10	0.11	0.10	0.38	0.38	0.29	0.35	0.27	0.31	0.09	0.09
Chloride			3.1	3.0	4.2	4.6	3.9	4.1	3.7	4.0	1.3	1.3
Fecal coli. (#/100 mL)	400	14	230	150	170	170	530	800	580	420	230	460

* = Analysis performed by contract laboratory.
** = Organic nitrogen calculated by difference, Kjeldahl - NH_3 = Organic
T = Trace amount detected, but not quantifiable.
est. = Estimated discharge
< = Less than

Figure 4. Dissolved oxygen concentration along Cooke Cr. at the Kittitas WTP, August 18–20, 1987.

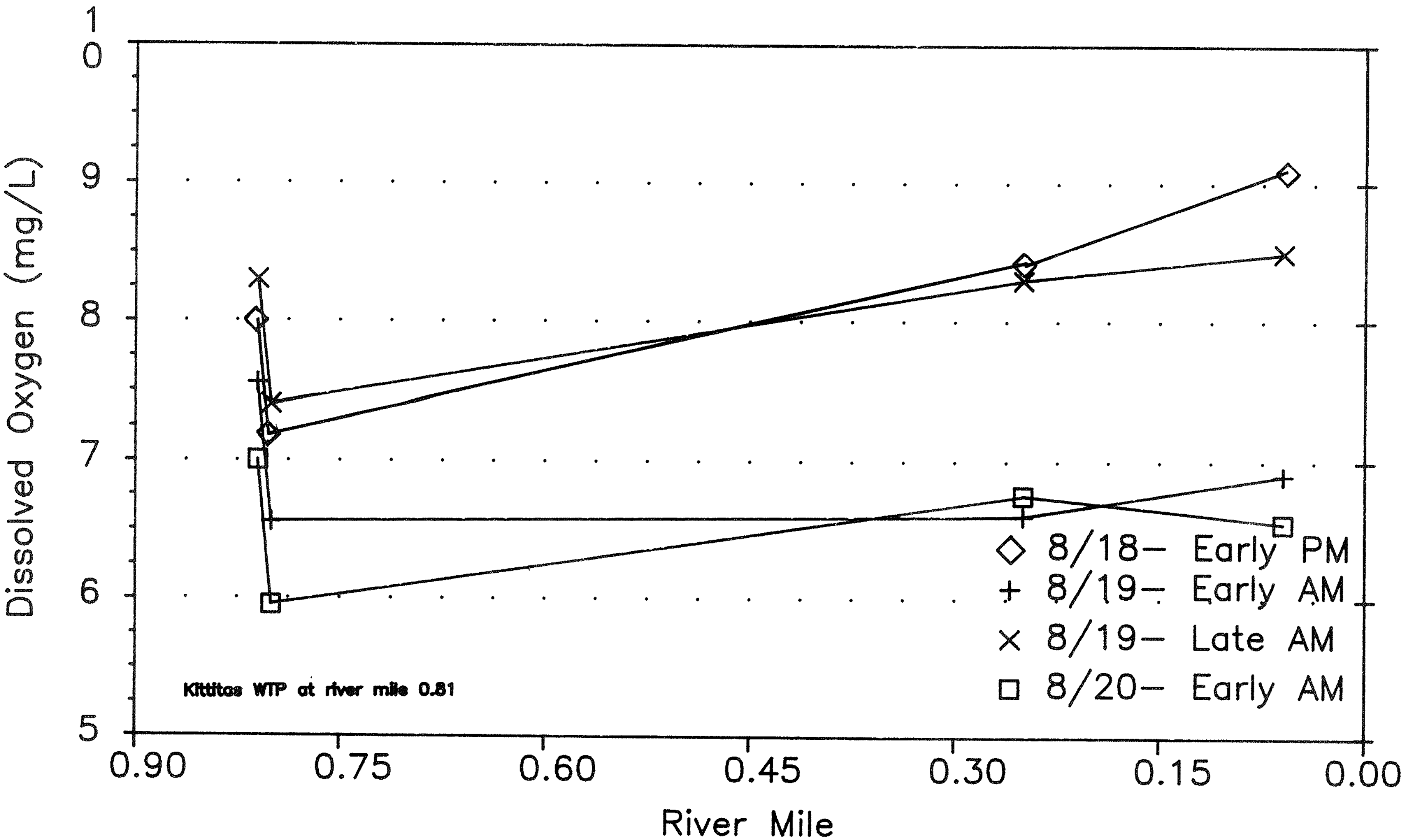

Table 6. Benthic macroinvertebrate and diversity index data collected from Cooke Creek in the vicinity of the Kittitas wastewater treatment plant discharge - August, 1987.

O R G A N I S M S	Station 1	Station 2	Station 3
HIRUNDINEA			
Glossophonia	--	1	--
Dina	--	--	1
ARACHNOIDEA			
Hydracarina	1	--	1
INSECTA			
Ephemeroptera			
Baetidae	31	3	21
Tricorythidae	--	--	5
Plecoptera			
Nemouridae	5	--	--
Trichoptera			
Hydropsychidae	44	47	16
Lepidostomatidae	--	--	1
Coeloptera			
Dytiscidae	--	1	1
Elmidae	3	8	3
Diptera			
Chironomidae	4	10	2
Simuliidae	--	43	13
Tipulidae	--	2	1
GASTROPODA			
Ancylidae	--	--	3
Total "Families"	6	8	12
Total Organisms	88	115	68
Percent EPT*	90.9	43.5	63.2
Percent Diptera	4.5	47.8	23.5
Shannon Diversity Index**	1.71	1.99	2.81
Brillouin Diversity Index	1.57	1.85	2.46

*EPT = Ephemeroptera, Plecoptera, & Tricoptera
**Shannon and Brillouin indicies calculated using log base 2 (Stephens, 1978)

environments are generally indicative of degraded water quality. Station 3 showed improvement over Station 2 both in diversity and community structure. Ephemeroptera had returned and Diptera had declined, indicating a relative recovery in water quality.

The fish population survey yielded only 10 to 18 dace at each station. Dace were also captured at the pool below the outfall during some reconnaissance macroinvertebrate sampling, and were the only fish observed at the single station located outside the study area, above the Cascade Canal (Figure 1). Relatively good fish habitat was available at most sites: undercut banks, occasional deep pools, shaded areas, and adequate food organisms. The absence of other types of fish was unexpected since suckers and trout had been previously reported in Cooke Creek (Kittle, 1981).

The benthic macroinvertebrate and fish population data suggest:

- Water quality above the Kittitas outfall is generally better than below the outfall, but the impact of the effluent is not severe.

- Cooke Creek may have chronic water quality problems not necessarily related to the Kittitas outfall.

These findings are in general agreement with the chemical data. Problems with the WTP, non-point sources, and irrigation management have not been completely resolved, or their impacts mitigated, so that diverse invertebrate and fish populations are absent.

Comparison of 1978-79 to 1987 Data

Low-flow data above and below the Kittitas WTP outfall were selected from the data set collected during the 1978-79 survey (WQIS, 1980a; WQIS, 1980b). Data variability was high, and general water quality was poor both above and below the Kittitas WTP. In the low-flow data set, downstream loads of ammonia, COD, TSS, nitrate/nitrite (NO_2+NO_3), and total phosphorous were significantly higher than upstream loads based on paired t-test results; fecal coliform was not significantly different upstream to downstream.

Selected loads from the 1978-79 low-flow data set are compared to 1987 loads from Stations 1 and 2 (Table 7). A t-test was performed on each pair of data; e.g., 1978-79 upstream ammonia to 1987 upstream ammonia, etc. The only statistically significant differences between the two data sets were upstream and downstream NO_2+NO_3 loads, and downstream fecal coliform. The increased 1987 NO_2+NO_3 loads are primarily from the culvert located above the outfall (see above--Effluent Impacts on Cooke Creek). Evidently this source was not there in 1978-79, prior to the upgrade of the WTP. However, the single 1987 NO_2+NO_3 load above the culvert (Station 0) also lies above the 1978-79 median upstream load and may indicate NO_2+NO_3 upstream loads have not declined.

This is not to say that there have not been improvements in Cooke Creek water quality. For instance, *Sphaerotilus* growths observed below the WTP outfall in 1978-79 were not observed in 1987, indicating an improvement in water quality. However, the chemical water quality changes concomitant with the absence of *Sphaerotilus* are not apparent in the data set. Statistical significance is difficult to show with this data set because of the low number of samples collected in 1987 and the high variability in the 1978-79 data. A less statistically rigorous (but also less reliable evaluation) can be made by comparing the 1987 data to the historical median and quartile statistics (Table 7). On this basis some parameters appear to have improved; i.e., the 1987 loads lie below the 1978-79 median loads--some in the lowest quartile. On the other hand, some were similar or higher than their respective historical median loads, suggesting no change. All things considered, the following water quality changes may have occurred during the irrigation season in Cooke Creek between 1978-9 and 1987:

- The culverted discharge above the WTP outfall has significantly increased the NO_2+NO_3 load in Cooke Creek since 1978-79.

- Fecal coliform loads below the WTP have probably decreased since 1978-9, and upstream loads may have declined as well.

- *Sphaerotilus* no longer grows in the creek below the WTP outfall.

The data illustrate the difficulty in evaluating changes or demonstrating improved water quality conditions when both non-point and point sources are present. A longer period of stream monitoring would be necessary to present a more reliable comparison and sort the point source effects from the non-point. Also, benthic macroinvertebrate and aquatic life historical data in the vicinity of the outfall would have been helpful.

Total Maximum Daily Load Evaluation

The ability of Cooke Creek to assimilate effluent from the Kittitas WTP is examined with a total maximum daily load (TMDL) evaluation. Conditions of the TMDL assume effluent discharge and loads at the maximum permitted levels while the receiving water is at low flow. A 7Q10 low-flow statistic is usually used, but one was not available for Cooke Creek. The sum of the 25 percent quartile value (1 cfs) of the 11 low period flows measured in the two surveys, and an assumed constant culvert flow of 0.5 cfs were used instead. Background water quality conditions were taken from Station 1 data collected in 1987. The current character of the Kittitas WTP effluent is probably much different now than it would be under design conditions when infiltration is not a problem. BOD, pH, and flow are limited by permit and can be directly entered into the TMDL evaluation, but ammonia and other important effluent factors for the TMDL need to be estimated. The effluent 8 mg/L ammonia concentration was calculated using a 70 percent removal rate in the treatment system of medium strength influent; i.e., 25 mg/L NH_3-N (Mills *et al.*, 1985) at 0.28 MGD. Lagoon removal efficiencies of ammonia vary widely, and 70 percent is moderate (Middlebrooks, *et al.*, 1982).

Dissolved oxygen depletion, ammonia toxicity, excessive nutrient loading, and residual chlorine toxicity were examined in the TMDL. Simulations of downstream D.O. conditions were performed using a D.O. model (Singleton and Joy, 1982; Joy, 1983). Data used in the model simulations are summarized in Table 8. Simulation results are graphed in Figure 5. In a test of model suitability, 1987 field data were quite closely simulated. The TMDL simulations indicated a 3 mg/L D.O. loss in the pool below the outfall, with a steady return to 8 mg/L in the swifter reach of the creek. The D.O. loss appears to be a function of a low effluent D.O. concentration and ammonia and BOD loads too large for the creek at a 3.5:1 dilution. The effluent impact is aggravated, as mentioned earlier, by the poor channel configuration and dilution zone characteristics.

The effluent D.O. concentration creates an immediate and severe in-stream loss under low-flow conditions. Increasing effluent D.O. and bringing the dilution ratio to the 1982 Ecology guideline of 20:1 would eliminate the most serious water quality problems in the creek. However, bringing more water into Cooke Creek would require water rights and irrigation management decisions beyond the scope of this report. Other discharge strategies should be investigated if additional dilution water is not available during low-flow periods; e.g., seasonal discharge and retention, or land application.

Under the TMDL conditions examined, effluent ammonia could affect the creek in three ways:

- de-oxygenation during in-stream nitrification
- direct toxicity to aquatic organisms
- stimulation of excessive periphyton or benthic growths

A combination of these effects would probably occur if the WTP were discharging the concentration of ammonia predicted. Both a low and high nitrification rates were simulated and their effects on the D.O. sag are shown in Figure 5. If 70 percent of the ammonia were removed by nitrification and direct uptake by benthic biota, there could still be conditions toxic to aquatic life at pH levels above 8.25. This toxicity could affect the entire 0.8-mile reach below the outfall.

The WTP and non-point nutrient loads in the creek would generate excessive benthic growths under TMDL conditions as they did under 1987 survey conditions. Wide swings in D.O., probably dipping below 5 mg/L, could occur.

Chlorine toxicity would be a problem in the creek under TMDL conditions if effluent residuals were greater than 0.1 mg/L. Both the USEPA one-hour and four-day aquatic life criteria of 0.019 mg/L and 0.011 mg/L total residual chlorine (TRC), would have been exceeded. A 0.3 mg/L effluent TRC could be maintained with only a small risk of toxicity in the creek at a 20:1 dilution ratio, and essentially no risk at a 100:1 dilution ratio.

Table 7. A comparison of selected loading data (lbs./day) in Cooke Creek above and below the Kittitas WTP: 1978-79 low-flow data only (WQIS,1980a), and August 18-20, 1987.

	1978-79 Data Upper Quartile	Median	Lower Quartile	1987 Data (Stations 1 and 2)
Upstream Ammonia	1.7	0.4	0.2	0.18, 0.16
Downstream Ammonia	7.4	5.5	4.5	7.2, 7.3
Upstream $NO_2 + NO_3$	4.9	2.5	1.2	21, 24
Downstream $NO_2 + NO_3$	9.5	7.4	6.1	26, 22
Upstream Total P	4.4	1.0	0.6	1.6, 2.0
Downstream Total P	10.5	8.1	5.7	8.1, 7.6
Upstream COD	1141	342	122	213, 97
Downstream COD	1172	564	217	431, 299
Upstream TSS	957	119	70	107, 97
Downstream TSS	966	247	142	108, 140
Upstream fecal coliform	63600	30000	7140	4100, 2400
Downstream fecal coliform	78300	39500	4880	3700, 3400

Table 8. Model variables used to simulate dissolved oxygen concentrations in Cooke Creek below the Kittitas WTP under 1987 survey conditions and under various total maximum daily load conditions. Results are shown in Figure 4.

S I M U L A T I O N :	Aug. 1987 Survey	TMDL- 7Q10 Max. NPDES	TMDL- 7Q10 Max. NPDES Increase NH_3 Conver. Rate
Model Variable or Coefficient			
Reach 1: r.m. 0.8 to 0.7			
Flow: upstream, source (cfs)	3, 0.7	1.5, 0.43	1.5, 0.43
Temp.: upstream, source (^{o}C)	17, 20	20, 20	20, 20
D.O.: upstream, source (mg/L)	8.2, 3.8	8.0, 3.8	8.0, 3.8
Ammonia: upstream, source (mg/L)	0.01, 2.1	0.01, 8	0.01, 8
BOD: upstream, source (5-day, mg/L)	2, 8	2, 20	2, 20
BOD decay rate (log e)	1.34	1.7	1.7
Ammonia to nitrate/nitrite rate	7.0	7.0	7.0
Reaeration rate (Owen's formula)	2.3	2.55	2.55
Reach 2: r.m. 0.7 to 0.0			
Flow at top of reach (cfs)	4.2	3.0	3.0
Temp. at top of reach (deg. C)	17.6	20	20
D.O. at top of reach (mg/L)	7.1	5.3	5.3
Ammonia at top of reach (mg/L)	0.34	1.41	1.41
BOD at top of reach (ultimate, mg/L)	3.0	5.7	5.7
BOD decay rate (log e)	1.7	2.2	2.2
Ammonia to nitrate/nitrite rate	2.0	2.0	7.0
Reaeration rate (Owen's formula)	37.0	62.6	62.6

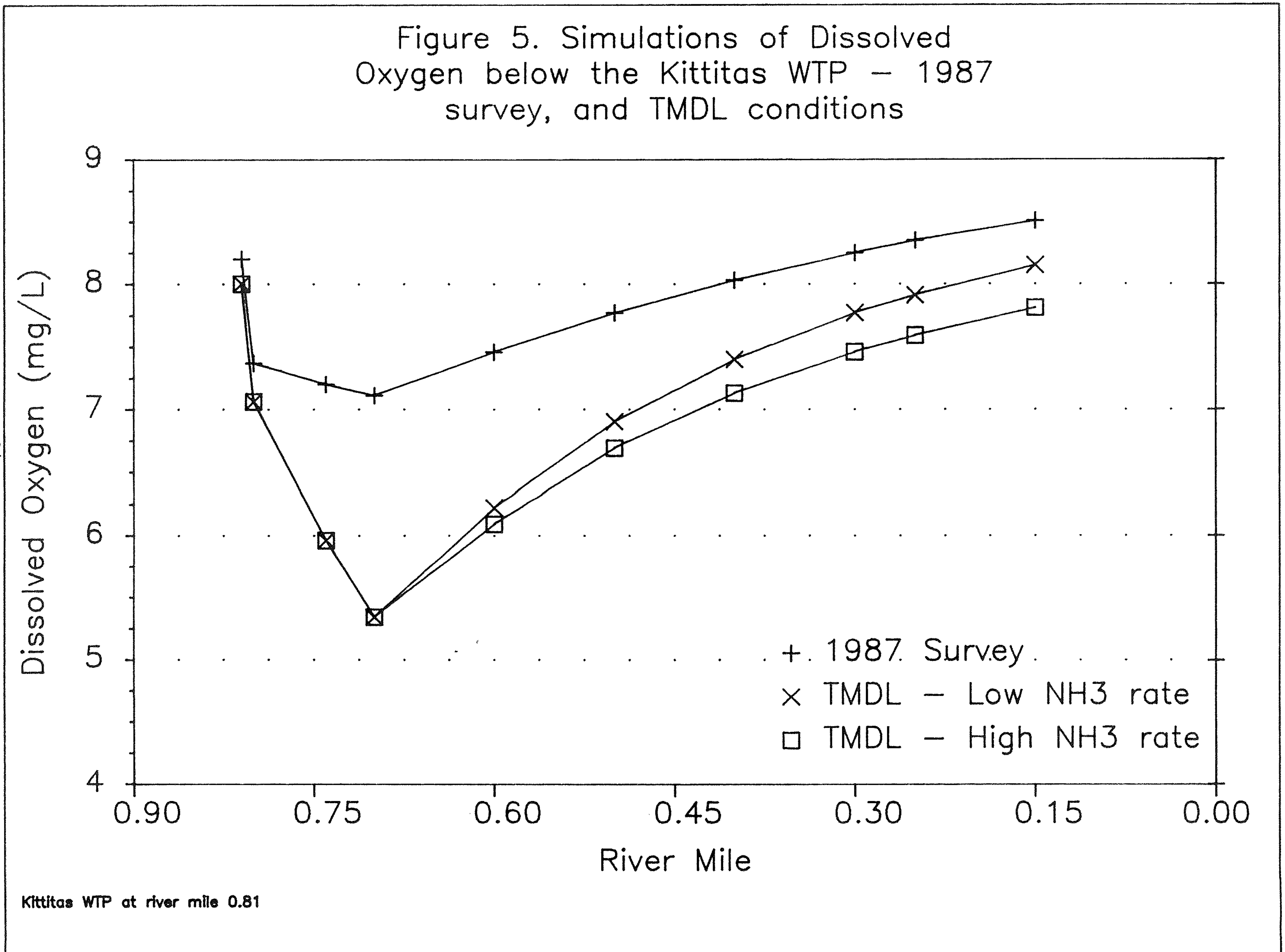
Figure 5. Simulations of Dissolved Oxygen below the Kittitas WTP - 1987 survey, and TMDL conditions
Dissolved Oxygen (mg/L)
9
8
7
6
5
4
0.90
0.75
0.60
0.45
0.30
0.15
0.00
River Mile
+ 1987 Survey
× TMDL - Low NH3 rate
□ TMDL - High NH3 rate
Kittitas WTP at river mile 0.81

CONCLUSIONS AND RECOMMENDATIONS

The following findings were made from the 1987 Kittitas WTP abbreviated Class II inspection and Cooke Creek receiving water survey:

- The Kittitas WTP collection system continues to have serious infiltration problems during the irrigation season. The 1986 discharge data indicated possible improvement, but not enough to meet the permitted flow of 0.28 MGD.

- The infiltration problem weakens influent BOD concentrations so that the WTP cannot meet 85 percent removal efficiency. The CRO may take advantage of new Ecology lagoon treatment criteria relaxing the 85 percent removal efficiency to 65 percent

- The WTP operator and Ecology split samples did not compare well. Analytical and sampling techniques require improvement, and past DMR data may be incorrect.

- Kittitas WTP effluent was weak, and met most NPDES permit limits. Manual chlorination control led to occasional over-chlorination.

- An immediate D.O. depression in the creek was caused by low effluent D.O., and BOD and ammonia loads too large for the 5:1 receiving water to effluent dilution ratio. Channel characteristics below the outfall created assimilative and dilution problems.

- The WTP effluent increased ammonia loads in the creek, but ammonia toxicity was not apparent. Effluent nutrient loads aggravated existing non-point nutrient loading problems, creating excessive benthic growths downstream. Wide swings in diurnal D.O. resulted.

- Residual chlorine was occasionally detected in the creek downstream of the outfall. TRC toxicity may have occurred.

- Fecal coliform concentrations in the creek exceeded Class A criteria above and below the WTP outfall.

- Irrigation returns and livestock were non-point sources identified along Cooke Creek and contributing to water quality degradation.

- The impact of Cooke Creek upon Town Canal water quality appeared to be minor. Increases in canal nutrient concentrations were noted.

- Benthic invertebrate and fish population data confirmed that water quality is generally better above the outfall than below, but non-point and irrigation management practices also impact the creek.

- Some apparent improvements in Cooke Creek water quality were shown after comparison with 1978-79 survey data. The decrease in fecal coliform loads below the outfall was statistically significant.

- Dissolved oxygen depletion, ammonia toxicity, excessive nutrient loading, and residual chlorine toxicity were examined in the total maximum daily load evaluation. The Kittitas WTP at design loads would probably have severe impact on the creek in all these areas, primarily because the dilution ratio in the creek would only be 3.5:1.

The following recommendations were made in this report based on the data and conclusions:

- Kittitas should continue to alleviate its infiltration problem so the lagoons can perform more efficiently.

- Further split samples should be taken and the analytical problems resolved at the WTP. The operator and the CRO need to agree upon a sampling frequency and methodology for BOD and TSS composite samples.

- An influent flow measuring device should be installed at the WTP for more accurate tracking of infiltration in the collection system and treatment efficiency through the plant.

- The automatic chlorination equipment should be repaired and TRC concentrations should be kept less than 0.1 mg/L when the creek discharge is low.

- More water should be released from Cascade Canal into Cooke Creek to meet effluent dilution requirements. This may become especially important in the future as the infiltration problem is corrected and effluent concentrations increase. If additional water is not available for dilution, alternative discharge strategies should be explored.

- Effluent D.O. concentrations should be increased and/or the channel downstream of the outfall should be modified to accommodate both irrigation and effluent dilution/assimilation needs.

- The WTP outfall and non-point problems along the creek and irrigation return drains should be addressed in a comprehensive manner so the creek can meet "fishable-swimmable" goals.

REFERENCES

AWWA, APHA, WPCF, 1985. Standard Methods for the Examination of Water and Wastewater. American Water Works Assn. 16th Edition, Washington D.C. 1268 pp.

CRO, 1980. "Kittitas WTP design criteria and fact sheet." Copied information from the files of the Central Regional Office. Dept. of Ecology, Yakima, WA. 4pp.

CRO, 1987. Kittitas WTP discharge monitoring reports, 1984-1987. Dept. of Ecology, Central Regional Office Files, Yakima, WA.

Ecology, 1982. Criteria for Sewage Works Design. State of Washington, Dept. of Ecology, Olympia, WA.

Ecology, 1985. Criteria for Sewage Works Design, Revised October 1985. State of Washington Dept. of Ecology, Olympia, WA. 276

Ecology, 1987. Discharge Standards and Effluent Limits for Domestic Wastewater Facilities, WAC 173-221-050(2)(a). State of Washington Administrative Code. November 12, 1987. Olympia, WA.

Gaurn, T., 1988. Personal conversation with Tom Gaurn, Chief operator of the Kittitas wastewater treatment plant. March, 1988.

Gilbert, R.O., 1987. Statistical Methods for Environmental Pollution Monitoring. Van Nostrand Reinhold Company, New York, NY. 320 pp.

Gray, D.M., 1973. Handbook on the Principles of Hydrology. D.M. Gray, Ed., Water Information Center, Inc., New York, NY.

Huntamer, D., 1986. Dept. of Ecology Laboratory User's Manual. Dept. of Ecology Manchester Laboratory, Manchester, WA.

Joy, J., 1983. "Little Klickitat River receiving water survey in the vicinity of the Goldendale STP." Memorandum to A. Newman, Dept. of Ecology, Central Regional Office, Yakima, WA. 26 pp.

Kittle, L., 1986. "Cascade Canal Irrigation District Herbicide Application, July 1986." Memorandum to J. Hodgson and H. Porath, Cascade Irrigation Canal Files, Central Ops., Resource Damage Assess., Olympia, WA. 6 pp.

Kittle, L., 1985. "Cascade Canal Freshwater Resource Damage Assessment." Memorandum through P. Lee to M. Horton. Cascade Irrigation Canal Files, Central Ops., Resource Damage Assess., Olympia, WA. 9 pp.

Merritt, R.W. and K.W. Cummins, 1978. An Introduction to the Aquatic Insects of North America, First Edition. Kendall/Hunt Publishing Co., Dubuque, IA. 722 pp.

Middlebrooks, J.E., C.H. Middlebrooks, J.H. Reynolds, G.Z. Watters, S.C. Reed and D. B. George, 1982. Wastewater Stabilization Lagoon Design, Performance and Upgrading. Macmillan Publishing Co., Inc., New York, NY. 356 pp.

Mills, W.B., D.B. Porcella, M.J. Ungs, S.A. Gherini, K.V. Summers, *et al.*, 1985. Water Quality Assessment: A Screening Procedure for Toxic and Conventional Pollutants, Part 1. EPA/600/6-85/002a, USEPA Office of Research and Development, Envir. Research Lab., Athens, GA. 609 pp.

NOAA, 1987. "Climatological data for Washington, August, 1987." Nat'l. Oceanographic and Atmospheric Admin., National Weather Service

Pennak, R.W., 1953. Freshwater Invertebrates of the United States. Ronald Press Company, New York, NY. 769 pp.

Porath, H. and D. Bowhay, 1981. "June 26 fish kill near Kittitas" and "Kittitas Co. fish kill investigation," Memorandum to Files--Cooke Cr. Fishkill, 6/27/81 Kittitas file, Central Operations, Resource Damage Assess., Olympia, WA. 4 pp.

Singleton, L. and J. Joy, 1982. "Mill Creek receiving water survey," Memorandum to C. Nuechterlein, Dept. of Ecology, Eastern Regional Office, Spokane, WA. 23 pp.

Stephens, D., 1978. "The application of numerical indices to biological data - A class handout 17-II-78." U.S. Geological Survey, Gulf Coast Hydroscience Center, N.S.T.L. Station, MI. 83 pp.

USEPA, 1983. Methods for Chemical Analysis of Water and Wastes. EPA 600/4-79-020 Cincinnati, OH.

Usinger, R.L., 1973. Aquatic Insects of California. University of California Press, Berkeley, CA. 508 pp.

Wihlm, J.L., 1970. "Range of diversity index in benthic macroinvertebrate populations." Journ. Water Pol. Control Fed., Vol. 42, pp 221

WQIS, 1980a. Unpubl. field notes for the Wilson Creek drainage report, DOE 80-13, Raw data files. Dept. of Ecology, Water Quality Investigations Section, Olympia, WA.

WQIS, 1980b. "Wilson Creek Drainage - Surface and Ground Water Quality" DOE 80-13. November 1980. Dept. of Ecology, Water Quality Investigations Section, Olympia, WA. 60 pp.

APPENDIX I

Data and calculations used to estimate the evaporation rate from the Kittitas WTP lagoons on August 18-20, 1987.

Kohler's evaporation formula for a shallow lake using pan evaporation data (Gray,1973):

$$E_L = 0.7 \left[E_p + 0.00051p\ A_p\ (0.37 + 0.0041\ u)\ (T_o - T_a)^{0.88} \right]$$

in which E_L = lake evaporation (in./day)
E_p = pan evaporation (in./day)
p = atmospheric pressure (in. mercury)
A_p = proportion of advected energy to the pan used for evaporation
u = wind speed (mpd)
T_o = surface water temperature (°F), and
T_a = air temperature (°F).

Ellensburg and Yakima Climate data (NOAA, 1987):

		DAY IN AUGUST 16	17	18	19	20
Ellensburg Temp. (°F)	Min.	48	42	49	49	53
	Max.	71	77	83	83	83
Yakima Temp. (°F)	Min.	48	42	41	45	49
	Max.	79	79	85	87	81
Yakima Wind Speed	(mi./day)	156	106	57	57	75
Yakima Evaporation	(in.)	0.42	0.34	0.43	0.22	0.24
Yakima Pan Water Temp. (°F)	Min.	50	45	45	53	55
	Max.	76	78	77	80	88

Elevation of Ellensburg and Kittitas is approximately 1000'.

Using data for the 18th and applying it to the nomographs in Figure A-1, at a lagoon temperature of 66°F, E_L = 0.31 inches.

The lagoons occupy an area of 153,426 ft.^{2}, so total evaporation is roughly:

153,426 ft.^{2} x 0.31 in. / 12 in./ft. = 4,000 ft.^{3}, or 0.03 MGD

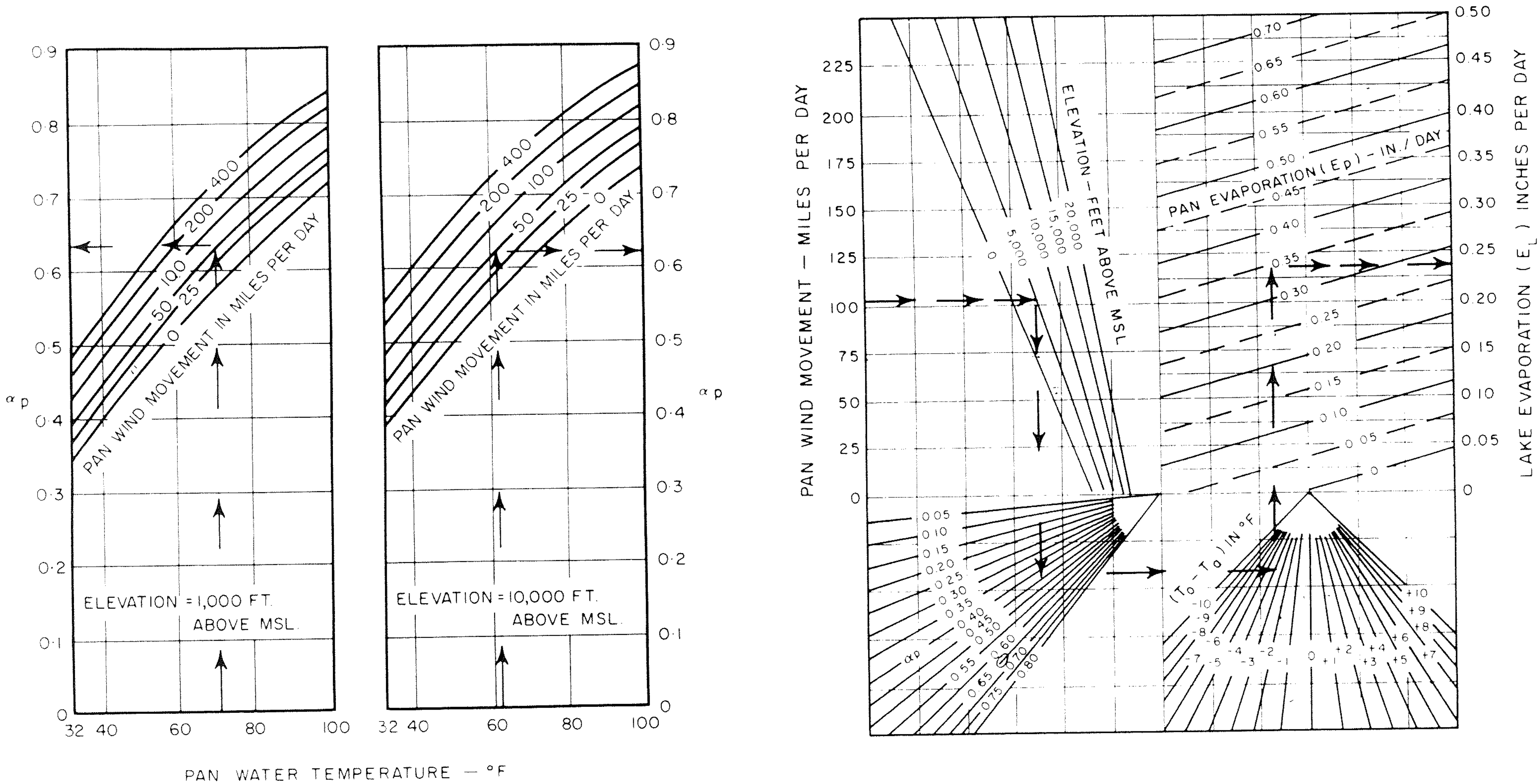

Figure A-1. Nomographs for using Kohler's evaporation formula (Gray, 1973).