Publication No. 84-e24

WA-23-1020

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
7272 Cleanwater Lane, LU-11 • Olympia, Washington 98504 • (206) 753-2353

MEMORANDUM
October 29, 1984

To: Jon Neel, Southwest Regional Office

From: Joe Joy, Water Quality Investigations Section

Subject: Evaluation of Conditions Contributing to the Dissolved Oxygen Problem in the Chehalis River between Chehalis and Centralia

INTRODUCTION

The Chehalis River in the vicinity of Centralia and Chehalis has long been an area of concern to the Southwest Regional Office (SWRO) and the Water Quality Investigations Section (WQIS). Depressed oxygen concentrations have chronically occurred in the late summer and early fall during low-flow periods. These episodes have been investigated by SWRO and WQIS staff at different times over the past decade (McCall, 1970; Devitt, 1972; Houck, 1980; Yake, 1980; Clark, 1981; and Johnson and Prescott, 1982). The most serious oxygen-depletion events in the past have been attributed to inadequate sewage treatment facilities at Chehalis and accidental discharge of food-processing wastes into Salzer Creek (Devitt, 1972; Houck, 1980). The SWRO has taken steps to mitigate these problems; e.g., arranging for a series of upgrades of the Chehalis sewage treatment plant (STP), and requiring an automatic alarm system on the National Fruit Canning Company waste system adnacent to Salzer Creek (Morhous, 1983).

The purpose of the 1982 survey was to further investigate the relative contribution of possible causes of dissolved oxygen (D.O.) depletion between Chehalis and Centralia and compare results to past low-flow surveys. Present and past data are evaluated in consideration of the following subjects:

- seasonal and spatial changes in in-stream temperatures and D.O. concentrations
- physical reaeration processes
- stratification formation
- benthic oxygen-demanding processes
- point and non-point sources of biochemical oxygen demand (BOD) and nitrogenous oxygen demand (NOD)
- algal oxygen production
- nutrients loads and their effects on algal production
- nitrification processes
- bacterial growths

In addition, many of the processes mentioned above are incorporated into a D.O. model. The model, which was verified in a 1983 survey, is used to simulate both a past D.O. depletion incident and some theoretical waste loading situations in the study area.

STUDY AREA

The major study area included approximately 8.5 miles of the Chehalis River, from the Highway 12 bridge at river mile (r.m.) 74.8 to the Washington State Department of Game (WDG) boat launch below the confluence with the Skookumchuck River at r.m. 66.5 (Figure 1). However, on one occasion (September 25, 1982), the study area was expanded to r.m. 54, another 12.5 miles below the major study area (Figure 1). The lower boundary of the major study area represents runoff from approximately 830 square miles of forest and agricultural lands.

As the Chehalis River enters the study area, it is relatively shallow and swift. At about r.m. 74.3, the river channel becomes deep and velocities are much slower. At r.m. 67, just above the confluence with the Skookumchuck River, velocities increase and the river becomes wide and shallow once more.

The historical range of discharges passing through the major part of the study area can be estimated by difference using gaging records of nearby stations. The average daily river discharge recorded from mid-July through October at the U.S. Geological Survey (USGS) station number 12027500 at Grand Mound (r.m. 59.9, Figure 1) ranges from 180 to 300 cubic feet per second (cfs) (WDOE, 1972). According to records from USGS station 12026600, about 100 cfs of this comes from the Skookumchuck River (WDOE, 1972). This leaves about 100 to 200 cfs average discharge for the study area. The 7-day, 10-year (7Q10) low flow for Grand Mound is 104 cfs, and 19.5 cfs for the Skookumchuck (base period 1945-1966), leaving about 85 cfs for the 7Q10 above the Skookumchuck if the low flows presented above occur simultaneously.

The slow-moving characteristics of the area between r.m. 67 and 74.3, coupled with holes up to 25 to 30 feet deep (8-9 m), create phenomena typically associated with lakes and impoundments rather than rivers. Previous surveys have shown mid-summer thermal stratification often occurs from about r.m. 70 to r.m. 67 in areas deeper than 12 feet (4 m). A metalimnion, defined as a layer of water exhibiting decrease in temperature greater than 1°C per meter, is formed and may grow for at least a couple of weeks before being broken by wind-generated currents, increased river discharge, or cooler temperatures. Oxygen concentrations in the metalimnion decrease during the stratofoed period. Also, at times the slow-moving, warm water is able to support a substantial bloom of algae. The blooms cause oxygen supersaturation, nutrient depletion, and reduced light penetration in the upper layer of water--phenomena more typically associated with impoundments.

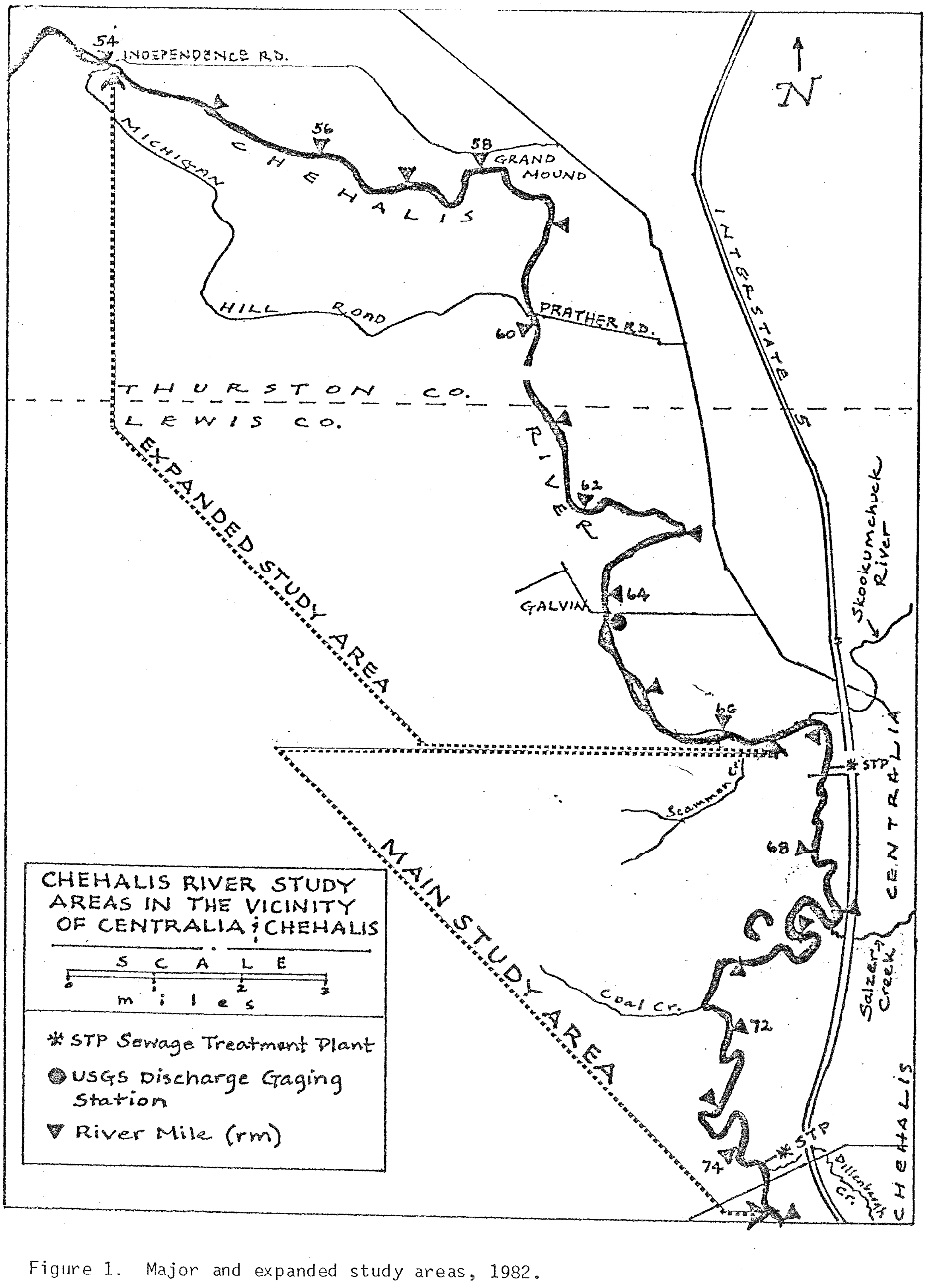


Figure 1. Major and expanded study areas, 1982.

Several point- and non-point dischargers have the potential to contribute nutrients and oxygen-demanding effluent to the study area. The major National Pollutant Discharge Elimination System (NPDES) permitted point dischargers are:

- Chehalis STP and Centralia STP

  These are the STPs serving Chehalis (estimated population 6,000) and Centralia (estimated population 11,190). Both discharge secondary effluent into the study area at r.m. 74.3 and r.m. 67.3, respectively (Figures 1 and 2). The Centralia STP was upgraded and expanded in 1971. The Chehalis STP was undergoing upgrade and expansion construction during the 1982 surveys.

- National Fruit Canning Company

  National Fruit Canning Company also discharges to the Chehalis STP. In addition, they maintain a spray-irrigation waste disposal system on lands adjoining Salzer Creek. Malfunction of the spray system has been implicated in past water quality pollution incidents (Houck, 1980).

- Consolidated Dairy Products (Darigold)

  Darigold was discharging into the Chehalis sewer system during the 1982 survey period. Effluent has periodically bypassed the Chehalis STP and directly entered the Chehalis River. This occurred during winter and spring storm events (Neel, 1983). Darigold brought a pretreatment plant on-line in 1983. The plant is designed to discharge secondary effluent directly into the Chehalis River most of the year. During June 15 to October 15 of each year, however, it is required to route its treated effluent to the Chehalis STP for further treatment and chlorination.

The major potential non-point sources are:

- croplands and livestock areas
- recreational facilities
- various upstream sources; e.g., septic tanks, forest and agricultural land uses.

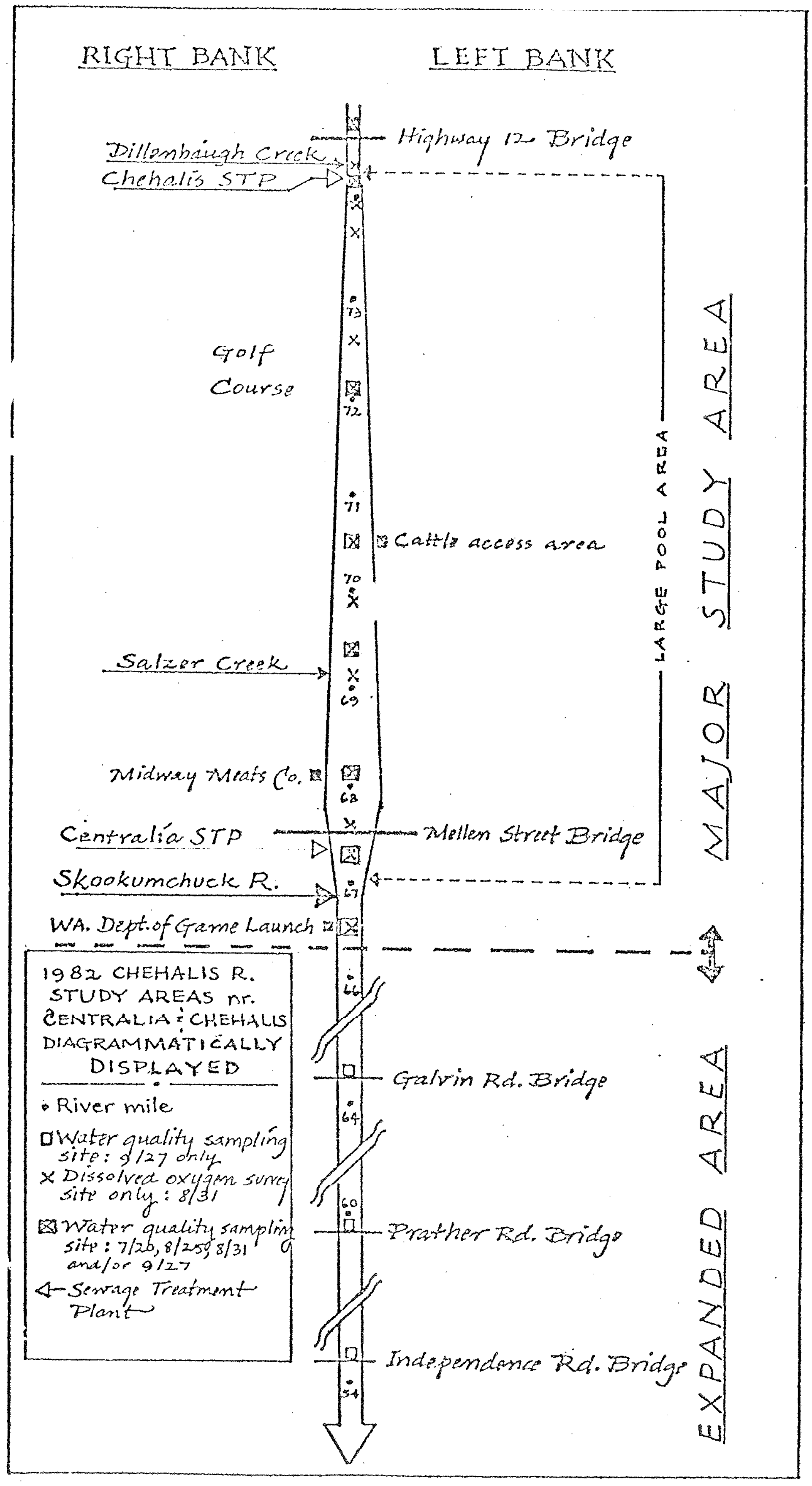


Figure 2. Water quality sampling stations, 1982.

> Non-point sources have been suspected of contributing to water quality deterioration in the Chehalis River basin (Singleton and Joy, 1981). In areas similar to the Chehalis basin (Yakima and Nooksack basins), intensive agricultural, silvicultural, and recreational land uses have been shown to contribute to water quality degradation (Johnson & Prescott, 1979; U.S. Corps of Engineers, 1978; USDA, 1978).

The water quality in the study area must meet Class A standards (Table 1). However, a special provision which applies to the Chehalis River from r.m. 65.8 to 75.2 allows the D.O. to reach 5.0 mg/L from June 1 to September 15 (WAC 173-201-080[8]). Class A standards without any special D.O. provision apply to the Chehalis River above and below this section.

METHODS

Site locations and sample collection information for all surveys are presented in Table 2. Coal Creek (r.m. 71.5) and China Creek (r.m. 67.1) were not sampled during any survey because they were dry. Samples were taken on four occasions in 1982 and once in 1983. The primary objective of the 1982 surveys was to obtain in-stream and point-source water quality information. Six to fifteen sites were sampled for this (Figure 2). The objective of the 1983 survey was to verify the accuracy of the dissolved oxygen computer model.

Water samples collected for laboratory analyses were kept in the dark, on ice, and transported to the WDOE environmental laboratory, Tumwater, within twenty-four hours. Samples were analyzed using approved procedures (EPA, 1979; AWWA, 1981).

Discharge was measured in the Chehalis River at r.m. 74.8, in Dillenbaugh Creek, and in Salzer Creek using the magnetic flow meter. Discharge at r.m. 67.5 (Mellen Street Bridge) was measured using the wire-weight gage and provisional rating curve (Poole, 1983). Discharge measurements from the Chehalis and Centralia STPs were obtained from in-plant meters. USGS telemetric stations on the Chehalis River at Grand Mound (station 12026400) and on the Skookumchuck River at Bucoda (station 12027500) provided data for estimating discharge from the survey area at r.m. 66.9.

Main-channel mean velocities were estimated at most points in the river using occupied channel volume calculations (Velz, 1970). At r.m. 74.8, velocity measurements were made in the field as described for discharge measurements. The estimated velocities were verified during the October 1983 survey with direct measurements.

Three cross-sectional profiles were obtained during the August 25 survey using a Sitex-Honda 4-inch strip-chart depth recorder. Profiles were made at river miles 74.2, 72.6, and 68.1.

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 reproducing, migrating, rearing, and harvesting.
<u>Water Quality Criteria</u>	
Fecal Coliform:	Median 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.

Table 2. 1982-83 Chehalis-Centralia survey sampling information.

A. July 20, 1982 river and point-source survey

Field and Grab Samples

Sample Location	Depth	Time	Field/Laboratory Analyses†
r.m. 74.8 - above Hwy. 12 bridge	Surface	1150	Discharge, Hydrolab 8000, dissolved oxygen/nutrients (5), chlorophyll a, pheophytin a, fecal coliform.
r.m. 74.4 - Dillenbaugh Cr. at mouth	Surface	1210	Discharge, dissolved oxygen/nutrients (5), chlorophyll a, pheophytin a.
r.m. 74.3 - 200' below Chehalis STP outfall	Surface	1230	Hydrolab 8000/nutrients (5), chlorophyll a, fecal coliform
	2.5 m	1235	Hydrolab 8000, dissolved oxygen, Secchi/ nutrients (5)
r.m. 72.1 - golf course	Surface	1300	Hydrolab 8000/nutrients (5), chlorophyll a, pheophytin a
r.m. 68.1 - behind Midway Meats	Surface	1350	Hydrolab 8000/nutrients (5), chlorophyll a, pheophytin a
	2.0 m		Hydrolab 8000
	4.0 m		Hydrolab 8000
	6.0 m	1400	Hydrolab 8000, dissolved oxygen, Secchi/ nutrients, chlorides, chlorophyll a, pheophytin a
r.m. 67.3 - 300' below Centralia STP	Surface	1425	Hydrolab 8000/nutrients, fecal coliform
	2.0 m		Hydrolab 8000
	3.5 m		Hydrolab 8000, dissolved oxygen, Secchi/ nutrients (5), chloride, chlorophyll a, pheophytin a
r.m. 6.5 - WDG boat launch	Surface	1455	Hydrolab 8000, dissolved oxygen/nutrients (5), chlorophyll a, pheophytin a
	1 m		Hydrolab 8000, dissolved oxygen/nutrients (5)
Chehalis STP from chlorine contact chamber			/nutrients (5), BOD_5 with and without nitrification inhibition. Discharge recorded from plant meter.
Centralia STP from secondary clarifier			Same as above.
Salzer Creek at freeway bridge	Surface		Dissolved oxygen, temperature, discharge/ pH, nutrients (5), BOD_5 with and without nitrification inhibition

†Field analyses and laboratory analyses are separated by the slash mark.

Hydrolab 8000R system includes: dissolved oxygen, pH, conductivity, temperature, and oxygen-reduction potential.

Dissolved oxygen performed using Winkler method with azide modification.

Nutrients (5): NO_3-N, NO_2-N, NH_3-N, orthophosphate-P, total phosphorus-P.

Solids (4): Total solids, total non-volatile solids, total suspended solids, total non-volatile suspended solids.

Table 2. Continued.

B. August 25, 1982 river and point-source survey

Field and Grab Samples

Sample Location	Depth	Time	Field/Laboratory Analyses
r.m. 74.8 - above Hwy. 12 bridge	Surface	0945	Discharge, dissolved oxygen, temperature/pH, conductivity, chlorides, nutrients (5), chlorophyll a, pheophytin a
r.m. 74.3 - Chehalis STP at outfall pipe		1035	Temperature, dissolved oxygen/pH, conductivity, chlorides, BOD_5, nutrients (5)
r.m. 74.3 - 200' below Chehalis STP outfall	Surface	1100	Same as at r.m. 74.8 except no discharge taken.
	2.5 m		Temperature, Secchi
r.m. 72.1 - golf course	Surface	1115	Same as surface at R.M. 74.3 plus BOD_5
	3.0 m		Temperature, Secchi
r.m. 69.2 - Salzer Creek at mouth	Surface	1200	Discharge, dissolved oxygen, temperature/pH, conductivity, chloride, nutrients (5), chlorophyll a, pheophytin a, BOD_5
r.m. 68.1 - behind Midway Meats	Surface	1230	Same as surface at r.m. 72.1.
	4.0 m,		Temperature, dissolved oxygen
	7.5 m	1400	Temperature, dissolved oxygen, Secchi/ nutrients (5), chloride, pH, conductivity, BOD_5
r.m. 67.3 - Centralia STP at secondary clarifier			Dissolved oxygen/pH, conductivity, chlorides, nutrients (5), BOD_5
r.m. 67.3 - 300' below Centralia STP	Surface	1350	Temperature, dissolved oxygen/pH, conductivity, chlorides, nutrients (5), chlorophyll a, pheophytin a
	4 m		Temperature, dissolved oxygen, Secchi
r.m. 66.9 - Skookumchuck River at mouth	Surface	1330	Same as surface at r.m. 67.3.
r.m. 66.5 - at WDG boat launch	Surface	1400	Same as surface at r.m. 67.3

Table 2. Continued.

C. August 31, 1982 river and point-source survey

Field Monitoring

Sample Location	Depth	Time	Field Analyses
r.m. 74.8 - above Hwy. 12 bridge	Surface	1200	Hydrolab 8000, dissolved oxygen
r.m. 74.4 - Dillenbaugh Creek at mouth	Surface	1225	Same as above.
r.m. 74.3 - 50' above Chehalis STP outfall	Surface	1235	Same as above.
	3 m		Hydrolab 8000
r.m. 74.3 - Chehalis STP at outfall pipe		1250	Dissolved oxygen, temperature
r.m. 74.3 - 200' below Chehalis STP	Surface	1255	Hydrolab 8000, dissolved oxygen
	3 m		Same as above.
r.m. 74.0 - at point bar	Surface	1310	Same as above.
	2 m		Hydrolab 8000
r.m. 73.7 - near eroding banks	Surface	1335	Hydrolab 8000
	4 m		Hydrolab 8000, dissolved oxygen
r.m. 72.6 - at profile site #2	Surface	1400	Same as above.
	4 m		Same as above.
r.m. 72.1 - golf course	Surface	1410	Same as above.
	2 m		Hydrolab 8000
	5 m		Dissolved oxygen
r.m. 70.5 - cattle access area	Surface	1435	Hydrolab 8000, dissolved oxygen
	7 m		Hydrolab 8000
	9 m		Same as surface.
r.m. 69.9 - near rt. bank drainage cut	Surface	1500	Hydrolab 8000, dissolved oxygen
	7 m		Same as above.

Table 2. Continued.

C. August 31, 1982 river and point-source survey - Continued

Field Monitoring

Sample Location	Depth	Time	Field Analyses
r.m. 69.4 - above Salzer Creek	5 m	1525	Hydrolab 8000, dissolved oxygen
r.m. 69.2 - Salzer Creek at mouth	Surface	1530	Same as above.
r.m. 69.2 - below Salzer Creek	Surface	1540	Hydrolab 8000
	5 m		Hydrolab 8000
	7 m		Hydrolab 8000, dissolved oxygen
r.m. 68.1 - behind Midway Meats	Surface	1555	Hydrolab 8000
	7 m		Hydrolab 8000, dissolved oxygen
r.m. 67.5 - Mellen Street bridge	2.5 m	1605	Dissolved oxygen
r.m. 67.3 - below Centralia STP	Surface	1615	Hydrolab 8000
	3.5 m		Hydrolab 8000, dissolved oxygen
r.m. 66.5 - WDG boat launch	Surface	1630	Hydrolab 8000, dissolved oxygen

D. September 27, 1982 river and point-source survey

Field and Grab Samples

Sample Location	Depth	Time	Field/Laboratory Analyses
r.m. 74.8 - above Hwy. 12 bridge	Surface	1240	Hydrolab 8000, dissolved oxygen/pH, conductivity, chloride, nutrients (5), solids (4), chlorophyll _a_, pheophytin _a_
r.m. 74.4 - Dillenbough Cr. at mouth	Surface	1300	Same as r.m. 74.8, except no solids (4).
r.m. 74.3 - 200' below Chehalis STP	Surface	1310	Same as r.m. 74.8 + Kjeldahl-N.
	2.3 m		Hydrolab 8000, dissolved oxygen

Table 2. Continued.

D. September 27, 1982 river and point-source survey - Continued

Field and Grab Samples

Sample Location	Depth	Time	Field/Laboratory Analyses
r.m. 72.1 - golf course	Surface	1340	Same as r.m. 74.8.
	2.9 m		Hydrolab 8000, dissolved oxygen
r.m. 70.5 - cattle access area	Surface	1405	Same as r.m. 74.8.
	7 m		Hydrolab 8000, dissolved oxygen, nutrients (5)
r.m. 69.4 - above Salzer Creek	Surface	1450	Same as r.m. 74.8.
	5.5 m		Same as r.m. 74.8, except no solids (4)
r.m. 68.1 - behind Midway Meats	Surface	1520	Same as r.m. 74.8.
	6.5 m		Same as r.m. 74.8, except no solids.
r.m. 67.3 - below Chehalis STP	Surface	1540	Same as r.m. 74.3.
	3.5 m		Hydrolab 8000
r.m. 66.9 - Skokumchuck River at mouth	Surface	1550	Dissolved oxygen, temperature, pH, conductivity, chlorides, nutrients (5)
r.m. 66.5 - at WDG boat launch	Surface	1600	Same as r.m. 74.8.
r.m. 64.2 - mid-channel off Galvin bridge	Surface	0915	Same as Skookumchuck River.
r.m. 59.9 - mid-channel off Prather Road bridge	Surface	0855	Same as Skookumchuck River.
r.m. 54.2 - mid-channel off Independence Rd. bridge	Surface	0805	Same as Skookumchuck River.

24-hour Composite Samples

General Sample Location	Date Installed	Time Begin	Time End	Specific Location
Centralia STP	9/27-28/82	0955	1045	Secondary clarifier weir
Chehalis STP	9/27-28/82	1045	1115	Chlorine contact chamber
Salzer Creek	9/27-28/82	1145	1210	Mouth of creek

Table 2. Continued.

E. October 11, 1983 river monitoring for computer model verification

Field and Grab Samples

Sample Location	Depth	Time	Field/Laboratory Analyses
r.m. 74.8 - above Hwy. 12 bridge	Surface	1012	Discharge, Hydrolab 8000, dissolved oxygen pH, conductivity, nutrients (5), TSS, BOD_5
r.m. 74.4 - above Chehalis STP	Surface	1057	Hydrolab 8000, dissolved oxygen
r.m. 74.1 - below Chehalis STP	Surface	1110	Hydrolab 8000, dissolved oxygen/pH, conductivity, nutrients (5)
r.m. 72.6 - at profile site #2	Surface	1125	Hydrolab 8000, dissolved oxygen
r.m. 72.1 - golf course	Surface	1140	Same as r.m. 74.1.
r.m. 70.5 - cattle access area	Surface	1200	Same as r.m. 74.1.
	7 m		Hydrolab 8000, dissolved oxygen
r.m. 69.3 - above Salzer Creek	Surface	1233	Same as r.m. 74.8, except no discharge.
r.m. 69.2 - Salzer Creek at mouth	Surface	1245	Same as r.m. 74.8.
r.m. 68.1 - behind Midway Meats	Surface	1300	Same as r.m. 74.1.
	6 m		Hydrolab 8000, dissolved oxygen
r.m. 67.5 - at Mellen Street br.	Surface	1320	Same as r.m. 74.1.

24-hour Composite Samples

General Sampler Location	Date Installed	Time Begin	Time End	Specific Location
Chehalis STP	10/11/83	0811	0845	Chlorine contact chamber

Time of travel was estimated using the occupied channel volume method (Velz, 1970). The method uses cross-sectional channel area data, velocity, and discharge measurements.

RESULTS AND DISCUSSION

Flow and Time of Travel

The 1982 survey flows at the upper (r.m. 74.8) and lower (r.m. 66.5) ends of the major study area are presented in Tables 3 - 6. Flows at r.m. 66.5 were 50 to 70 cfs lower than the mean monthly flows established for r.m. 59.9. However, none of these flows were as low as the 7Q10 low flow of 104 cfs.

Dilution ratios in the river at the two STPs in the study area were well above the 20:1 WDOE guidelines (WDOE, 1980). The lowest ratio of 68:1 occurred during the August 25 survey. The dilution ratios for the Chehalis and Centralia STPs during a 7Q10 low-flow period would be approximately 45:1 and 47:1, respectively. The dilution ratios of the Chehalis River to Salzer Creek were also above 20:1.

Mean river velocities throughout most of the study area were less than 0.6 ft/sec except above r.m.74.5 and below r.m. 66.9. In-stream solids settle-out at velocities below 0.6 ft/sec (Velz, 1970). Estimated and verified velocities of 0.04 to 0.1 ft/sec were used in computer model simulations for r.m. 66.9 to r.m. 71 (see Model Simulations).

Time of travel is an important component of the D.O. computer model. Under the discharge conditions observed in the 1982 surveys, the time of travel from the Chehalis STP to the bridge, a distance of 6.8 river miles, was estimated to be greater than three days. Data from past surveys also produced similar times of travel (Figure 3). These estimated times reflect the characteristics of the large pool between r.m. 67.5 and 74.3.

Temperature

Seasonal changes in longitudinal and vertical temperature profiles are illustrated in Figure 4. The patterns observed reinforce past survey findings (Johnson and Prescott, 1982).

The main features of the collective temperature data show:

- generally warmer surface water temperatures existed between r.m. 66.9 and 70.5 than either above r.m. 70.5 or below the confluence with the Skookumchuck River (r.m. 66.9)

- only slight vertical changes in temperature were present at points above r.m. 70.5 throughout the survey season

Table 3. Chehalis River Survey - July 20, 1982, 1030-1600 hours. In situ (Hydrolab 8000) and laboratory water quality parameter analytical results in mg/L unless otherwise noted.

						Hydrolab 8000															
River Mile	Station Name	Max. Depth Ft. (M)	Sample Depth Ft. (M)	D.O. (Winkler)	% D.O. Saturation	D.O. (Hydrolab)	Temperature (°C)	pH (S.U.)	Cond. (umhos/cm)	ORP[1] mV	NO_3-N	NO_2-N	NH_3-N	O-PO_4-P	Total P	Chl. a/Pheo. a[2]	BOD_5 inh/ BOD_5 as read[3]	Cl-	F.C. (org/100 mL)	Discharge (cfs)[4]	Secchi (ft.)
74.8	Abv. Hwy. 12 Br.	3.2(1.0)	0	8.5	92.9	8.7	20.1	6.87	86	151	0.09	<0.01	0.03	0.02	0.03	0.4/3.4	--	--	48	166	--
74.4	Dillenbaugh Cr.	0.8(0.2)	0	5.4	59	--	20*	--	--	--	0.06	<0.01	0.08	0.11	0.11	1.2/2.7	--	--	--	1.6	--
74.3	Chehalis STP	--	--	--	--	--	--	--	--	--	<0.10	<0.10	12	8.2	9.3	--	52/66	--	--	2.5	--
74.3	200 feet below outfall	8.2(2.5)	0			8.9	20.2	6.7	95	236	0.09	<0.01	0.21	0.14	0.16	1.5/1.8	--	--	77	170	8
			8.2(2.5)	8.2	89.2	7.5	19.9	6.6	95	213	0.09	0.01	0.20	0.15	0.16						
72.1	Golf course	13(4.0)	0			8.6	21.7	7.1	90	259	0.16	0.01	0.19	0.17	0.18	2.8/1.4			--	172	7
			13(4.0)	7.5	82.2	8.1	20.3	6.7	91	259	0.17	0.01	0.19	0.18	0.19			9.2			
69.2	Salzer Creek	1.2(0.4)		2.8	30.5	--	20	6.7	--	--	<0.05	<0.05	1.7	0.35	0.50	--	33/36	--	--	2.1	--
68.1	Behind Midway Meats	20(6.0)	0			9.7	20.5	7.0	91	288	0.12	<0.01	0.07	0.07	0.09	5.5/1.9	--	--	23	175	7
			6.6(2.0)			11.0	20.1	6.8	91	279											
			13.1(4.0)			12.9	19.6	6.7	92	278											
			20.0(6.0)	6.9	74.4	9.3	19.4	6.5	93	267	0.12	<0.01	0.07	0.06	0.07	3.4/1.6	--	10	--	--	--
67.3	Centralia STP	--	--	--	--	--	--	--	--	--	4.7	<0.01	8.2	7.1	7.4	--	22/29	--	--	2.7	--
67.3	300 feet below STP	13(4.0)	0			9.2	21.6	6.8	94	254	0.13	<0.01	0.05	0.04	0.05		--	--	28	183	10
			6.6(2.0)			10.4	19.7	6.7	94	255											
			11.5(3.5)	7.4	79.7	11.6	19.4	6.6	106	252	0.27	0.02	0.60	0.27	0.30	5.5/1.3	--	12	--	--	
66.5	WDG Boat Launch	6(1.8)	0	9.2	98.8	8.7	19.2	6.7	81	241	0.20	0.01	0.08	0.06	0.08	3.2/1.2	--	--	--	289	
			3.3(1)	9.1	97.7	8.6	19.2	6.6	81	240	0.18	0.01	0.08	0.06	0.07						

[1]Oxidation-reduction potential

[2]Chlorophyll a/Pheophytin a in mg/m^3, or ug/L

[3]Five-day BOD with nitrification inhibition/five-day BOD without inhibitation

[4]Discharge measurements taken at r.m. 74.8, at r.m. 67.5 (Mellen Street Bride), Salzer and Dillenbaugh Creeks. STP discharge taken from Discharge Monitoring Reports (DMRs). Discharges for Skookumchuck River and r.m. 66.5 checked against mean daily discharges from USGS stations 12026400:
Skookumchuck near Bucoda, and Station 12027500: Chehalis at Grand Mound.

*Approximate value.

Table 4. Chehalis River Survey - August 23, 1982, 0945-1500 hours. In situ (temperature) and laboratory water quality parameter analytical results in mg/L unless otherwise noted.

River Mile	Station Name	Max. Depth Ft. (M)	Sample Depth Ft. (M)	Temperature (°C)	D.O. (Winkler)	% D.O. Saturation	pH (S.U.)	Cond. (umhos/cm)	Cl^-	NO_3-N	NO_2-N	NH_3-N	O-PO_4-P	Total P	Chl. a/Pheo. a[1]	BOD_5	Discharge (cfs)[2]	Secchi (ft.)
74.8	Abv. Hwy. 12 Br.	3.4(1.0)	0	20.8	8.7	96.3	7.8	113	8.5	0.06	<0.01	0.05	0.02	0.04	6.8/3.8	--	81.5	--
74.3	Chehalis STP	--	--	20.6	6.8	75.1	7.6	583	50	<0.10	<0.10	17	9.2	10	--	70	1.2	--
74.3	200 feet be-lowSTP	8.2(2.5)	0	21.2	7.3	81.5	7.1	115	8.5	0.05	<0.01	0.31	0.17	0.19	2.2/1.5	--	83	6.5
			8.2(2.5)	21.0														
72.1	Golf course	9.3(3.0)	0	21.5	7.8	87.5	7.4	113	9.2	0.08	<0.01	0.24	0.14	0.20	0.7/13	4	83	6.0
			9.8 (3.0)	20.9														
69.2	Salzer Creek	0.9(0.3)	0	18.1	1.5	15.8	6.8	542	120	<0.01	<0.01	0.29	0.05	0.16	14/6.9	42	2.1	--
68.1	Behind Midway Meats	23(7.5)	0	22.5	13.5	154.3	8.9	109	8.5	<0.01	<0.01	0.05	0.07	0.13	2.2/5.4	6	85	6.0
			13(4)	18.2	1.3	13.7												
			23(7.5)	12.1	0.5	4.6	6.5	179	7.1	0.31	0.01	0.27	0.23	0.23	--	<4		
67.3	Centralia STP	--	--	--	5.8	--	7.2	449	35	6.2	0.10	16	6.7	6.7	--	16	1.7	--
67.3	300 feet be-low STP	13(4.0)	0	21.6	10.7	120.4	8.7	111	9.2	<0.01	<0.01	0.09	0.06	0.11	2.9/2.6	--	87	5
			13(4)	12.8	1.0	129.7												
66.9	Skookumchuck R.	--	0	18.9	9.8	104.6	7.8	66	4.3	0.2	<0.01	0.06	0.01	0.03	11/4.9	--	75	--
66.5	WDG Boat Launch	3.3(1.0)	0	20.8	11.5	127.4	8.0	94	5.7	0.11	<0.01	0.04	0.05	0.08	9.8/5.3	--	162	--

[1] mg/M^3 or ug/L.

[2] Discharge measurements taken at r.m. 74.8, r.m. 67.5 (Mellen Street Bridge), and Salzer Creek; STP discharges taken from Discharge Monitoring Reports (DMRs). All other discharges estimated.

able 5. Chehalis River Survey - August 31, 1982, 1200-1630 hours. Hydrolab 8000 in situ and other water quality measurements.

							Hydrolab 8000				
River Mile	Station Description	Maximum Depth Ft.(M)	Sample Depth Ft.(M)	Temp. (°C)	(Winkler) Dissolved Oxygen (mg/L)	Percent 1/ Dissolved Oxygen Saturation	(Hydrolab) Dissolved Oxygen (mg/L)	pH (S.U.)	Spec. Cond. (umhos/cm)	ORP2/ mV	Discharge3/ (cfs)
74.8	Above Highway 12 Bridge	--	0	18.3	8.6	90.5	8.5	6.4	109	178	94
74.4	Dillenbaugh Creek	--	0	16.5	5.5	55.8	5.6	6.2	133	150	
74.3	Above Chehalis STP	9.8(3)	0	18.2	8.2	86.3	9.4	6.6	108	161	
			9.8(3)	18.1			10.8	6.6	109	165	
74.3	Chehalis STP	--	--	18.0*	7.7	80.7	--	--	--	--	1.1
74.3	200 feet below STP	9.8(3)	0	18.3	8.2	86.5	9.5	6.7	123	174	
			9.8(3)	18.2	7.8	82.1	--	6.6	123	170	
74.0	Approx. 1/4 mi. blw. STP	6.5(2)	0	18.4	7.9	83.5	7.6	6.6	121	181	
			6.5(2)	18.3			7.8	6.6	120	183	
73.7	Approx. 1/2 mi. blw. STP	13(4)	0	18.5			9.3	6.6	117	204	
			13(4)	18.4	7.5	79.3	7.1	6.6	117	213	
72.6	Profile Site #2	13(4)	0	19.1	7.0	75.0	9.0	6.5	122	195	
			13(4)	19.0	6.8	72.7	13.1	6.5	122	199	
72.1	Golf Course	6.5(2)	0	19.3	6.7	72.0	6.8	6.5	121	197	
			6.5(2)	19.0			8.5	6.5	121	204	
			16.4(5)	--	6.1	--	--				
70.5	Cattle Access Area	29.5(9)	0	20.0	6.3	68.7	5.5	6.4	121	131	
			23(7)	18.9	--		2.7	6.2	117	80	
			29.5(9)	16.8	0.0	0.0	0.2	6.0	253	-48	
69.9	Near Farm Drainage Cut	23(7)	0	20.5	5.8	74.9	9.5	6.5	119	64	
			23(7)	13.2	0.0	0.0	0.2	6.0	999	-76	
69.4	Approx. 1/4 mile above Salzer Creek	16.4(5)	16.4(5)	18.3	1.9	20.0	1.0	6.2	120	153	
69.2	Salzer Creek	--	0	17.2	0.4	4.1	2.8	5.6	387	31	
69.2	50 feet blw. Salzer Cr.	23(7)	0	21.0			9.1	6.3	123	81	
			16.4(5)	18.5			1.2	5.9	261	-7	
			23(7)	15.6	0.0	0.0	0.5	6.3	574	-89	
68.1	Behind Midway Meats	23(7)	0	20.9			9.9	7.0	125	94	
			23(7)	14.3	0.5	4.9	5.2	6.0	173	89	
67.5	Mellen Street Bridge	8.2(2.5)	8.2(2.5)	21*	4.6	51.2	--				100
67.3	Below Centralia STP	11.5(3.5)	0	21.5			7.1	6.8	130	133	
			11.5(3.5)	17.4	0.5	5.2	6.8	6.1	171	116	
66.5	At WDG Boat Launch	--	0	19.1	10.2	109.3	9.6	6.9	111	217	178

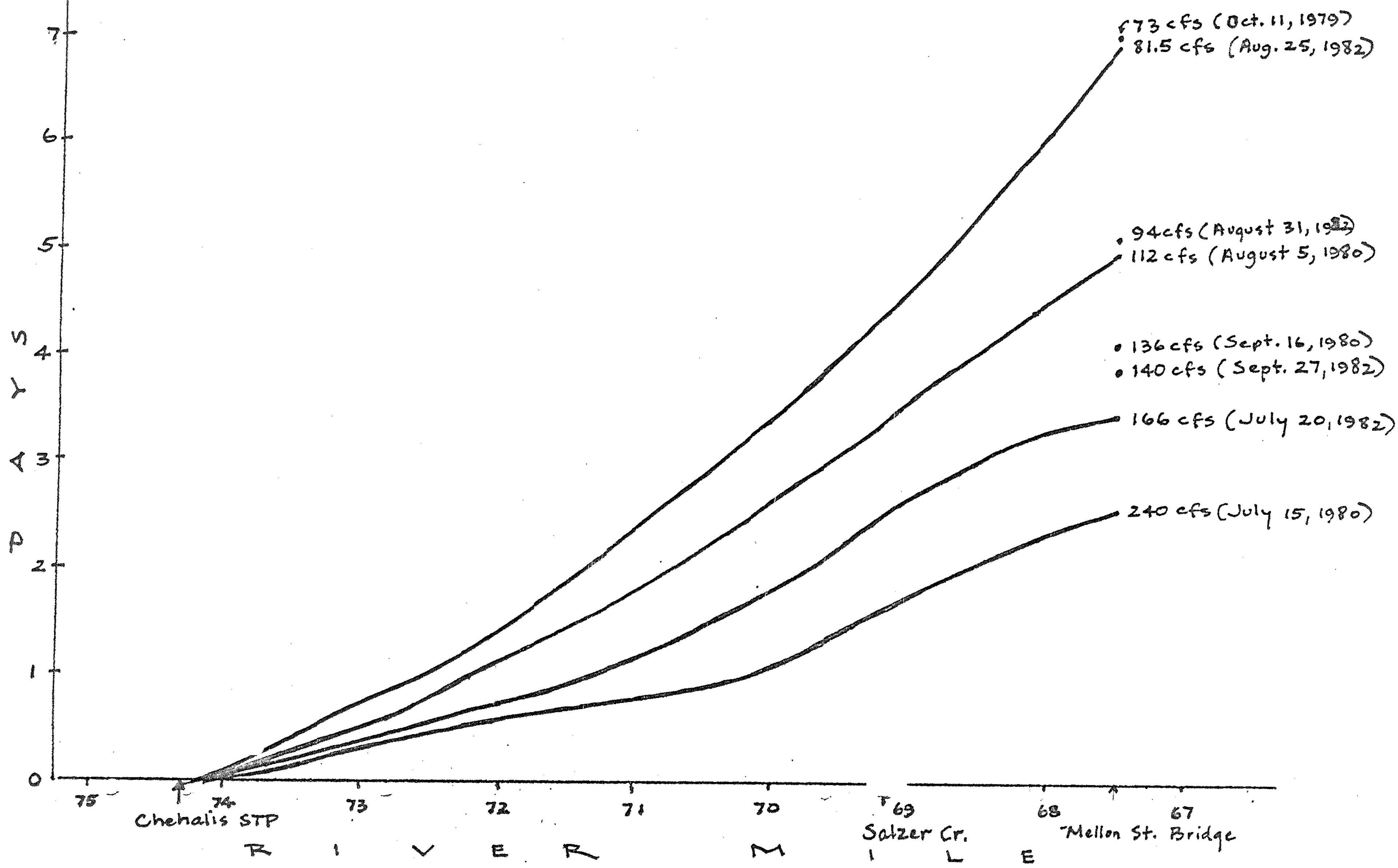
1Percent dissolved oxygen saturation based on Winkler method dissolved oxygen results only.
2Oxidation-reduction potential.
3Discharge measurements taken at r.m. 74.8, at r.m. 67.5 (Mellen Street Bridge), Salzer and Dillenbaugh Creeks. STP discharge taken from Discharge Monitoring Reports (DMRs). Other discharges interpolated.
*Approximate value.

Table 6. Chehalis River Survey - September 27, 1982, 0805-1600 hours. In situ (Hydrolab 8000) and laboratory water quality parameter analytical results in mg/L unless otherwise noted.

River Mile	Station Description	Maximum Depth Ft.(M)	Sample Depth Ft.(M)	D.O. (Winkler)	% D.O. Saturation	Hydrolab 8000: D.O. (Hydrolab)	Hydrolab 8000: Temperature (°C)	Hydrolab 8000: Cond. (umhos/cm)	Hydrolab 8000: pH (S.U.)	Hydrolab 8000: ORP[1] mV	pH (S.U.)	Cl^-	Sp. Cond. (umhos/cm)	NO_3-N	NO_2-N	NH_3-N	T. Kjeld. N (Organic N)	O-PO_4-P	T. Phos.-P	Chl a/pheo a[2]	F.C. (org/100 mL)	BOD_5	COD	Total Solids	TNVS	TSS	TNVSS	Discharge (cfs)[3]
74.8	Above Hwy. 12 Bridge		0	9.7	96.3	9.8	15.4	102	6.9	161	7.5	8.5	99	0.08	<0.01	0.02	--	0.02	0.04	1.1/1.3	53	--	--	100	72	2	1	140
74.4	Dillenbaugh Creek	--	0	6.4	61.7	7.2	14.0	130	6.5	153	7.0	8.5	124	0.02	<0.01	0.09	--	--	0.05	--	--	--	--	--	--	--	--	
74.3	Chehalis STP*	--	--	--		--	--	--	--	--	7.4	72	689	0.15	0.10	23		7.4	8.9			40	180	470	320	32	1	1.0
74.3	Below Chehalis STP	8.3(2.5)	0 8.3(2.5)	9.4 9.9	93.2 98.1	9.4 9.2	15.3 15.3	108 106	7.0 7.0	148 148	7.4	9.9	103	0.07	<0.01	0.25	0.66 (0.41)	0.12	0.16	1.3/2.9	52			120	82	5	3	143
72.1	Golf Course	9.8(3)	0 9.8(3)	8.6 8.5	86.1 85.1	10.1 --	15.8 15.8	109 109	6.9 6.9	192 192	7.4	8.5	103	0.10	<0.01	0.16	--	0.09	0.12	5.4/6.2	25			110	76	4	3	143
70.5	Cattle Access Area	25(7.5)	0 27(7.5)	7.7 7.7	77.4 76.9	9.0 --	16.0 15.7	110 110	6.8 6.7	203 193	7.2	8.5	104	0.11 0.11	<0.01 <0.01	0.16 0.15	--	0.11 0.09	0.12 0.12	0.5/0.9	33			110	70	3	2	144
69.4	Above Salzer Creek	18(5.5)	0 18(5.5)	7.1 6.9	71.8 69.5	-- 7.1	16.3 16.1	111 111	6.7 6.7	201 215	7.2 7.1	8.5 8.5	106 107	0.13 0.13	<0.01 <0.01	0.17 0.19	--	0.11 0.09	0.13 0.12	1.4/1.7 0.8/1.0				110	69	4	2	145
69.2	Salzer Creek*		0	0.4	3.8	1.3	13.7	273	5.7	74	6.7	43	268	<0.01	<0.01	0.01		--	0.07	--		110	150	270	140	16	<1	2
68.1	Behind Midway Meats	21(6.5)	0 21(6.5)	5.6 6.4	56.9 64.3	9.3 --	16.5 16.0	112 113	6.6 6.5	175 175	7.1 7.0	8.5 9.2	104 105	0.14 0.11	<0.01 0.01	0.11 0.04		0.07 --	0.11 0.04	1.1/1.6	140			100	72	6	4	147
67.3	Centralia STP*		--								7.5	36	413	3.7	0.10	16	--	5.3	9.4			30	130	300	190	33	1	1.81
67.3	300 feet below Centralia STP	11.5(3.5)	0 11.5(3.5)	6.9 --	70.1	10.1 12.8	16.5 16.0	116 116	6.7 6.6	202 197	7.1 --	9.2 --	107 --	0.15 --	<0.01 --	0.15 --	0.69 (0.54)	0.07 --	0.10 --	2.4/1.8	17			91	64	2	1	149
66.9	Skookumchuck River		0	10.9	106.2		14.5				7.8	3.5	71	0.17	<0.01	0.01	--	0.02	0.03									111
66.5	WDG Boat Launch		0	8.6	84.7	9.4	15.0	101	6.8	230	7.3	6.4	94	0.21	0.01	0.18	--	0.09	0.14	1.4/1.8	24			91	64	3	2	280
64.2	Galvin Bridge		0	8.1	79.1		14.6				7.2	7.1	93	0.22	0.01	0.14		0.09	0.09	1.0/2.4								
59.9	Prather Road Bridge		0	8.2	79.8		14.4				7.2	6.4	95	0.28	0.02	0.07		0.09	0.10	1.0/2.2								284
54.2	Independence Rd. Br.		0	8.5	82.3		14.2				7.2	7.1	98	0.46	0.02	0.05		0.07	0.11	1.[illegible]/2.4								

[1]Oxidation-reduction potential
[2]Chlorophyll a/pheophytin a in mg/m^3 (ug/L
[3]Discharge measurement taken at r.m. 67.5 (Meller Street Bridge); STP discharge taken from Discharge Monitoring Report (DMR); all others estimated or interpolated.
*24-hour composite sampler

Figure 3. Estimated times for a volume of water to travel from the Chehalis STP (r.m. 74.3) to the Mellen Street Bridge (r.m. 67.5). Discharges are those measured at r.m. 74.8 during various Chehalis River low-flow surveys. Data: 1979 - Houck 1980; 1980 - Johnson & Prescott, 1982; 1982 - present study.



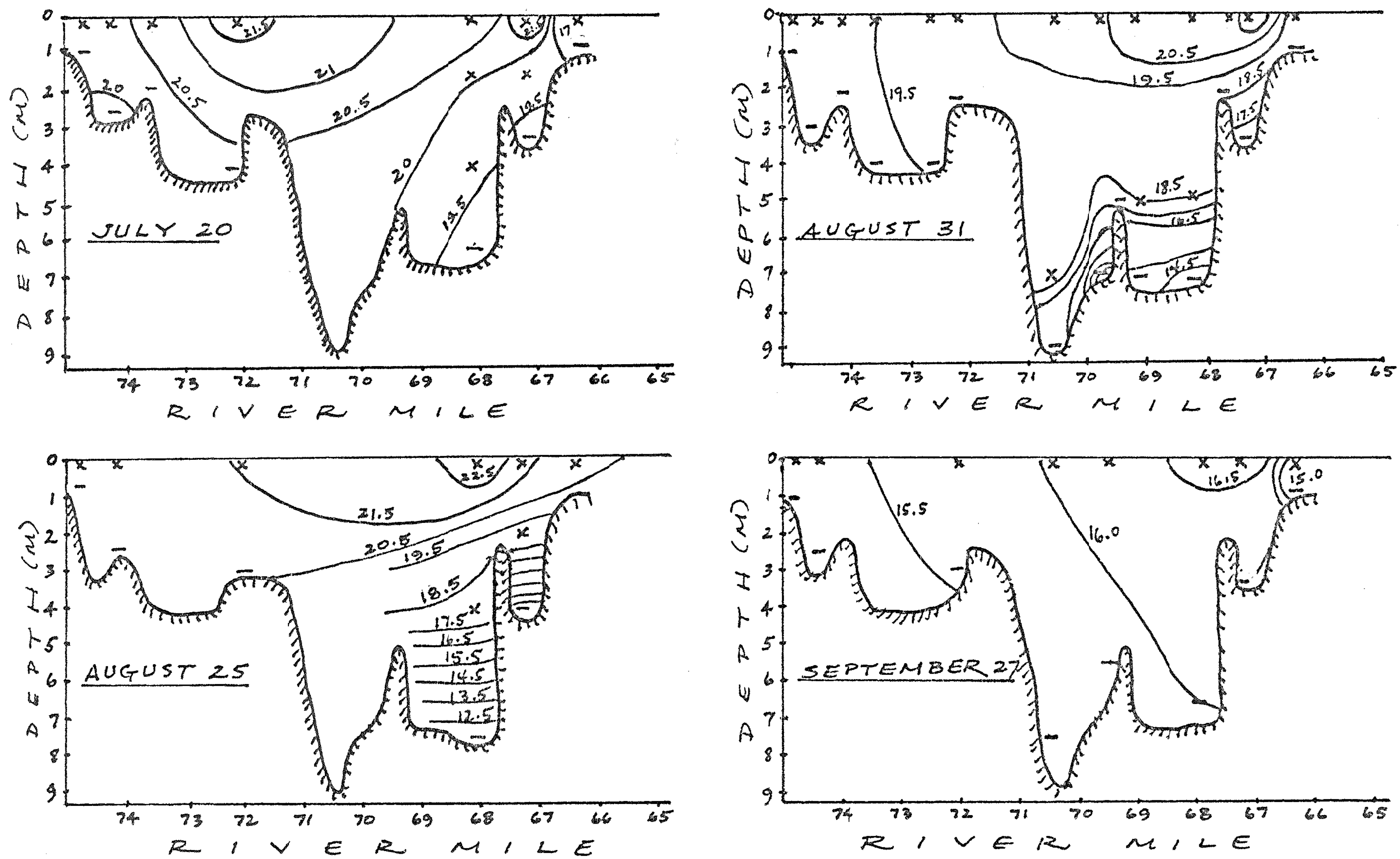


Figure 4. 1982 survey temperature results conformed to isotherms and placed on a generalized bottom contour of the Chehalis River study area. Temperature isotherms are in degrees centigrade.

x: surface or mid-water field temperature measurement.

-: bottom sounding and field temperature measurement.

- slight vertical gradient throughout the study area was present in mid-July
- deeper holes from r.m. 67 to 70.5 stratified in August to the extent that a metalimnion was formed
- stratification deteriorated by mid-September, but a strong temperature gradient remained at r.m. 68 to 69
- homogeneous vertical temperature profiles returned by late September

The importance of temperature to in-stream D.O. concentrations and development of the D.O. model will be discussed in following sections.

Dissolved Oxygen

The following observations were made concerning D.O. concentrations found during the 1982 surveys (Figure 5):

- Surface concentrations at both ends of the major study area (r.m. 74.8 and 66.5) remained relatively stable; concentrations were always greater than 8.0 mg/L.
- Surface concentrations in much of the large pool area (r.m. 66.9 to 70.5) after September 15 were below 8.0 mg/L. This violated the Class A standard.
- No surface concentrations violated the 5 mg/L D.O. special provision in effect from June 1 to September 15.
- Subsurface concentrations were often below 8.0 mg/L. In August, subsurface concentrations at some sites dropped below 5 mg/L(in violation of water quality standards)--sometimes dropping to zero. Between r.m. 67.5 and r.m. 71, holes deeper than 4 meters were especially affected.
- Surface and depth concentrations at individual sites were similar in mid-July and late September, but differed greatly in August.
- Supersaturation was evident at the surface at the lower end of the large pool area (r.m. 67 to 68).
- A slight D.O. sag was observed in the expanded study area on September 27. D.O. was slightly depressed at r.m. 64.2 compared to D.O. at r.m. 66.5 and r.m. 54.2 (Table 6).

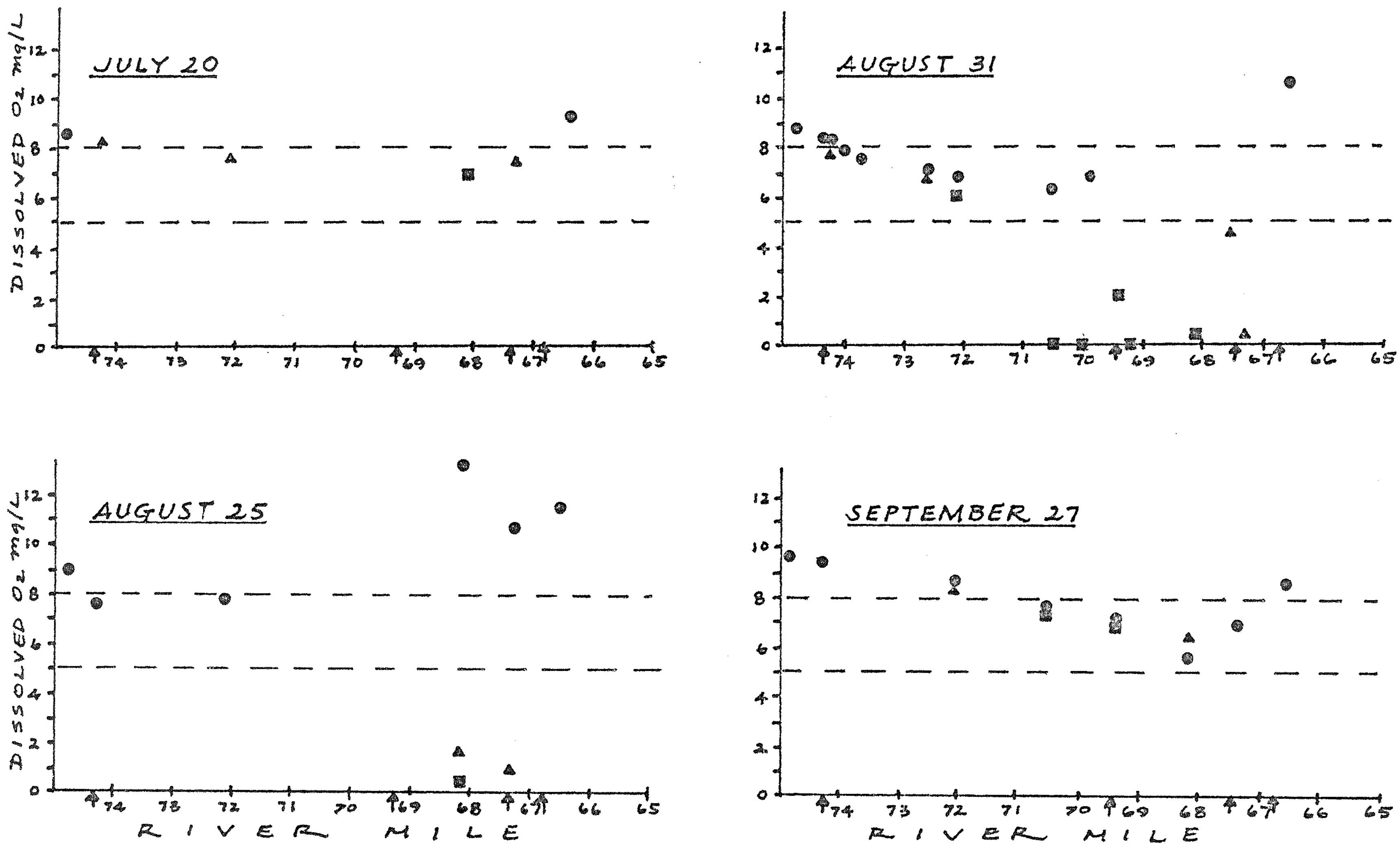


Figure 5. Dissolved oxygen concentrations observed during 1982 Chehalis River surveys.
● surface; ▲ 2-4 m; ■ below 4m
point sources: r.m. 74.3 Chehalis STP; r.m. 69.2 Salzer Creek;
r.m. 67.3 Centralia STP; r.m. 66.9 Skookumchuck River

The data suggest recurrent seasonal and longitudinal D.O. patterns along the river. Historical data from past surveys support the concept of recurrent patterns (Figure 6). However, some specific historical incidents also show how these patterns can be disrupted (see Model Simulations).

The data from present and past surveys also suggest that there are many interacting factors affecting D.O. in this portion of the Chehalis River. Among the most prominent are:

- physical reaeration
- stratification
- benthic oxygen demand
- point-source biochemical and nitrogenous oxygen demand
- algal oxygen production
- nutrients: limiting, loads, and nitrification
- bacterial populations in the river

The interaction of these factors are somewhat complicated. The available data only suggest the true nature of their interactions. A basic interpretation of the interactions has been used for constructing the computer model. These basic interpretations are discussed below.

Physical Reaeration

Physical reaeration in a river is generally mediated by temperature, velocity, and depth. Shallow, swift reaches such as those above r.m. 74.3 and below r.m. 67 have high reaeration rate (k_2) constants. The k_2 constants used in the model were calculated to be 5-10 day^{-1} (log base e). However, between these points, the river is relatively slow and deep. Reaeration rates were calculated from O'Connor's formula designed for deep, slow-moving rivers (Zison et al., 1978). Rates of 0.04 to 0.1 day^{-1} were obtained and used in the model for the large pool area.

Reaeration processes in the large pool area can be approached another way. In lake environments, physical reaeration is more dependent on winds than internal water movement. Winds around Chehalis are generally less than 15 mph in the summer (WDOE, 1972). Calculated reaeration rates using wind speeds of 3 to 15 mph would produce k_2 constants of 0.19 to 0.65 day^{-1} (Zison, et al., 1978). However, the high banks and protective vegetation along the top of the banks would reduce the maximum potential reaeration available from wind; therefore, the 0.04 to 0.1 day^{-1} k_2 constants by O'Connor's formula seem reasonable for use in the D.O. model.

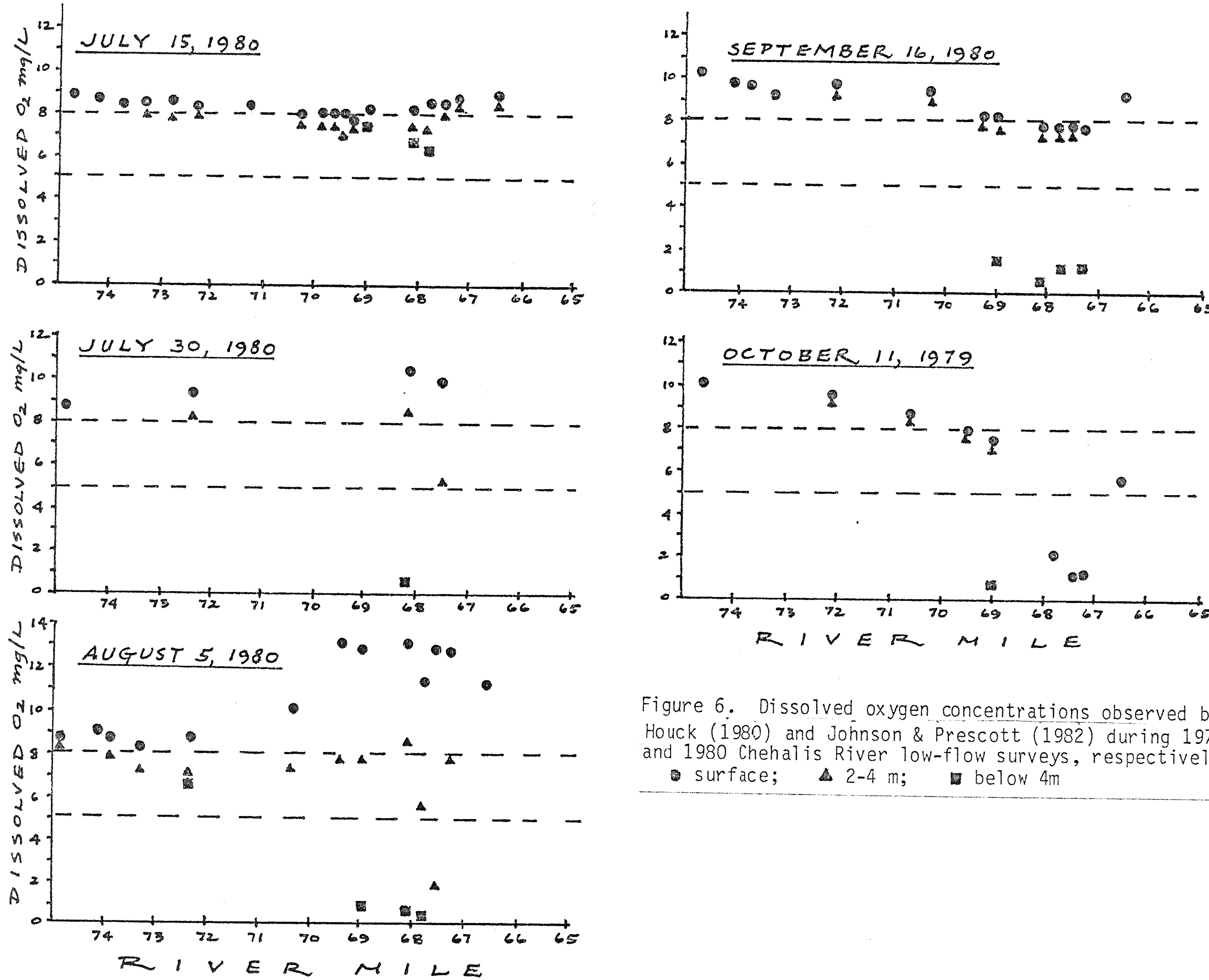


Figure 6. Dissolved oxygen concentrations observed by Houck (1980) and Johnson & Prescott (1982) during 1979 and 1980 Chehalis River low-flow surveys, respectively. ● surface; ▲ 2-4 m; ■ below 4m

Stratification

Temperature-induced stratification influence oxygen exchange between surface and deeper water layers. In August, surface and deeper water layers became isolated from one another as the metalimnion formed throughout much of the large pool (r.m. 67 to 70.5). The greater divergence between surface and deep-water concentrations of D.O. in the August surveys was partially caused by this lack of circulation of oxygenated surface waters into deeper layers. With no oxygen entering the metalimnic layer, oxygen-demanding processes created a rapid depletion of D.O. As stratification broke up in September, D.O. concentations returned to the more vertically homogeneous pattern present in mid-July (Figure 5). As discussed earlier, historical data confirm stratification as a seasonal phenomenon in the Chehalis River. Severe D.O. deficits in the metalimnion have also been found in the past (Johnson and Prescott, 1982)

Additional data and a more detailed analysis would be necessary to model stratification formation and metalimnion oxygen depletion. However, factors contributing to the rapid depletion of oxygen in the metalimnion will be discussed below.

Benthic Oxygen Demand

Organic materials from allochthonous and autochthonous sources accumulate in benthic regions as water velocities decrease. These materials are chemically or biochemically converted into basic constituents through oxygen-demanding processes. Without adequate mixing or reaeration, oxygen can become totally depleted in the subsurface water.

Low in-stream velocities throughout most of the study area may create a situation that enhances the influence of benthic oxygen demand. Two major types of material were thought to settle-out and create benthic oxygen demand in the study area:

- algal materials
- point-source effluent solids

Although no sediment oxygen demand measurements were made, depressed subsurface D.O. values were observed at sites possibly influenced by these materials. The primary sites were behind Midway Meats (r.m. 68.1) within much of the large pool (r.m. 69.2 to 70.5), and below the Chehalis STP (r.m. 74.3).

The rapid depletion of oxygen in the metalimnion behind the Midway Meats Company (r.m. 68.1) observed in the August surveys may be partially caused by algal decay and/or accumulated materials from Salzer Creek. Algae, produced in the upper end of the large pool (r.m. 74 to 72) and sinking at a rate of 1 m/day (a rate taken from Zison et al, 1978), could be deposited in the deep holes r.m. 69.2 to 68.1. Decomposition agents can potentially use 160 mg oxygen for each milligram phosphorus created from algal detritus (Welch, 1980). These processes create an oxygen depletion, especially in subsurface waters during stratification. Calculations in Table 7 illustrate the theoretical situation for the August 5, 1980 survey.

Salzer Creek could have contributed solids and other materials of high BOD concentration to this area of the river. Colder, denser water from Salzer Creek would tend to flow into the deeper areas of the Chehalis River. Of course, the BOD load during spills from the National Fruit Canning Company irrigation system certainly made an immediate impact as far as r.m. 68.1. However, the somewhat "normal" load of solids and BOD also may have had an accumulative effect after deposition. Data obtained in 1982 and 1980 surveys suggest suspended solids loads from Salzer Creek of approximately 110 pounds per day, and BOD from 90 to 370 pounds per day.

Approximately 0.4 mg/L difference in D.O. was observed below the Chehalis STP (r.m. 74.3) between surface and subsurface during the August 31 survey (Figure 5). No stratification was apparent, so that the oxygenated surface water should have circulated within the entire water column. Therefore, benthic oxygen demand was considered a possible source of depletion. The Chehalis STP effluent and upstream sources of organic materials could easily accumulate in the area. Poorer-than-normal STP effluent quality could have further aggravated the situation (see Biochemical and Nitrogenous Demand).

Benthic oxygen demand is a computer model option (see Model Simulations). The value chosen for benthic demand is based on professional judgment. The calculation uses an equation based on the oxygen demand from various depths of sludge beds found below STPs (Zison et al., 1978). For example, a 0.5-inch benthic deposit below the Chehalis STP would translate into a 3.15 gm/m^2 oxygen demand.

Point Source Biochemical and Nitrogenous Oxygen Demand

The primary point sources of BOD have been the Centralia and Chehalis STPs and Salzer Creek. Long-term nitrification-inhibited and uninhibited BOD analyses were run on both STP effluents and Salzer Creek water taken as composite samples on July 20-21, 1982 (Figure 7). Nitrogenous oxygen demand (NOD) was a large component of the Chehalis and Centralia STP effluents, but not of Salzer Creek water. Ultimate demand concentrations were 115 mg/L, 25 mg/L, and 38 mg/L, respectively. The high concentration from the Chehalis STP was because of construction-related problems at the plant.

Table 7. Calculation of O_2 demand exerted by algal decay in metalimnion between R.M. 67.6 and 69.2 on August 5, 1980. Phosphorus and D.O. data from Johnson and Prescott, 1982.

Assumptions

Volumes from R.M. 69.2 to 67.6:	Total	: 4.36×10^8 liters
	3.5 m metalimnion	: 1.32×10^8 liters
	4.5 m epilimnion	: 3.04×10^8 liters

Concentrations: 0.06 mg/L organic phosphorus in epilimnion
7.5 mg/L dissolved oxygen in metalimnion initially
160 mg O_2 demand/mg organic phosphorus decomposed

Calculations

Initial metalimnic D.O. (July 15): 7.5 mg/L x 1.32×10^8 L = 1.0×10^9 mg D.O.

Organic phosphorus concentration: 0.06 mg/L x 3.04×10^8 L = 1.82×10^7 mg

Ultimate demand by organic P: 1.82×10^7 mg P x 160 mg O_2/mg P = 2.9×10^9 mg O_2

Conclusions

The 2.9×10^9 mg O_2 demand is greater than 1.0×10^9 mg O_2 initial concentration. The actual daily rate of depletion would depend upon rate and efficiency of decomposition, and stability of metalimnion.

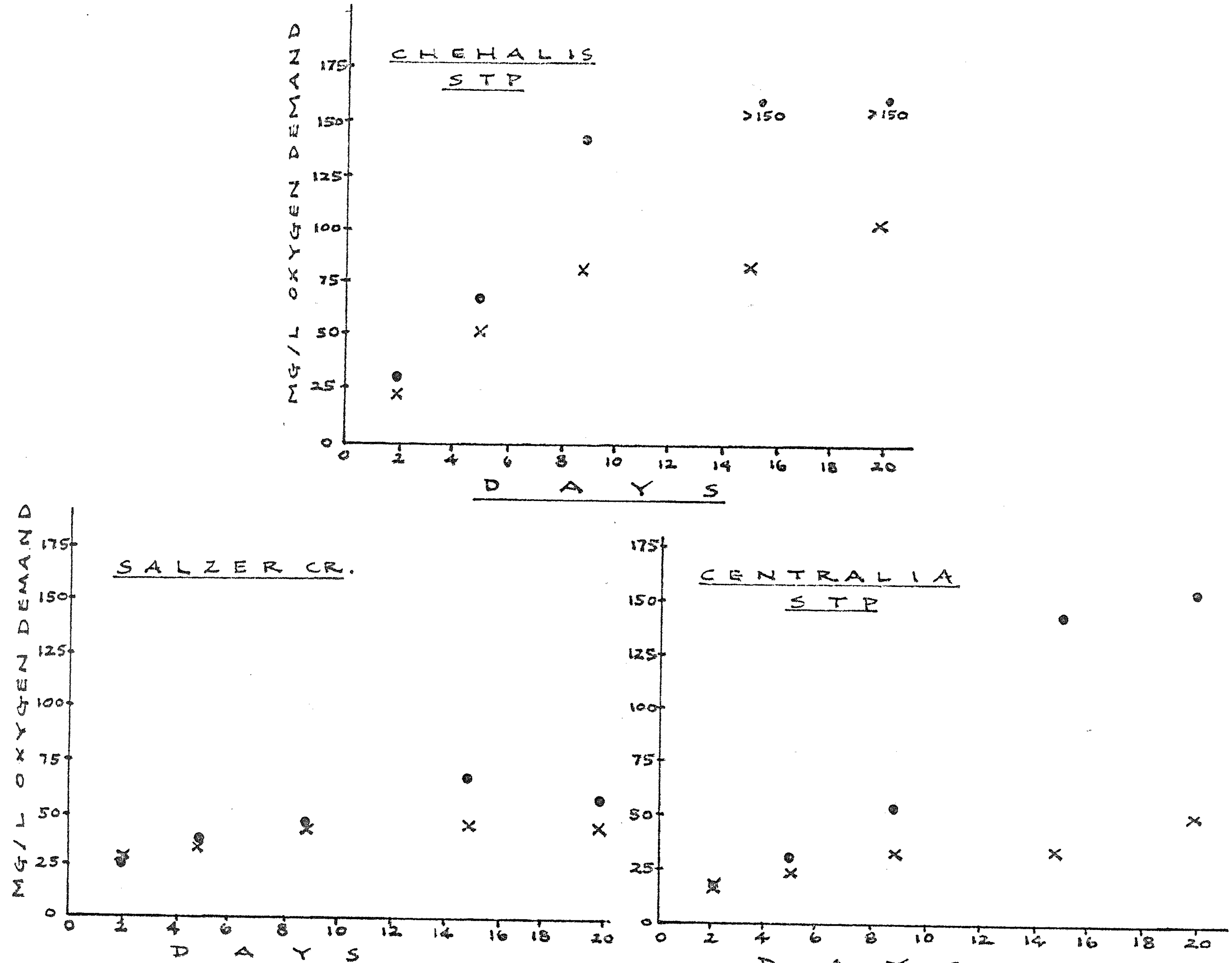


Figure 7. Long-term BOD results on Chehalis and Centralia STPs effluents and on Salzer Creek water sampled July 20-21, 1982.
x: nitrification inhibited; ●: uninhibited

Data from the 1982 and past surveys indicate BOD contributions from Centralia STP have been fairly constant, whereas the Chehalis STP and Salzer Creek contributions of BOD have been sporadic (Houck, 1980; Johnson and Prescott, 1982; WDOE 1979, 1980, 1982). Chehalis and Centralia STP effluent 5-day BOD mean values over the period of these surveys were 50 ± 33 mg/L (mean ± S.D., n = 46), and 21 ± 7 mg/L (n = 41), respectively. The wider variability in Chehalis STP effluent values occurred because of higher BODs in 1982 during STP upgrade construction.

Salzer Creek 1982 5-day BODs were never below 33 mg/L (Tables 3-6). However, in-stream 5-day BOD concentrations in 1980 ranged from <2 to 18 mg/L (Johnson and Prescott, 1982). And, Houck (1980) found a spill of vegetable canning process waste into Salzer Creek from spray irrigation fields had driven creek 5-day BOD concentrations up to 640 mg/L (Houck, 1980). BOD loads from these sources were important factors in modeling Chehalis River D.O. concentrations.

The July 20, 1982 survey data were used to obtain BOD decay rates for the computer simulations. These rates were also applied to 5-day BOD concentrations to gain ultimate demand concentration (Hammer and MacKichan, 1981). BOD decay rates calculated for Salzer Creek, Chehalis STP, and Centralia STP wastewaters at 20°C were 0.115 day^{-1}, 0.279 day^{-1}, and 0.163 day^{-1} (log base e), respectively.

Algal Oxygen Production

The data show algal oxygen production greatly influences D.O. concentrations in the epilimnic layer, especially in late July and throughout August. Oxygen supersaturation was observed in the surface during the August 25 survey (Table 4). Elevated pH levels (8.7 to 8.9) and low inorganic nitrogen concentrations further indicated algal production. However, the concentrations of chlorophyll a were lower than would be expected during a bloom.

In 1980, elevated chlorophyll a concentrations and low Secchi readings accompanied D.O. supersaturation occurring in areas with suspected algal blooms (Johnson and Prescott, 1982). D.O. supersaturation in 1980 occurred over a wider portion of the study area than in 1982 (Figures 5 and 6).

No large diel changes in D.O. resulting from algal respiration and photosynthesis were detected during a 24-hour D.O. survey performed in 1980 (Johnson and Prescott, 1982). The survey monitored various sites in the study area and the usual night D.O. depression and day D.O. peak in concentrations were not observed.

Algal oxygen production rates were calculated for use in the D.O. computer model. Maximum potential rates were estimated to be 4.5 to 5.5 mg/L/day, with average rates of 0.2 to 2.3 mg/L/day. All were based on chlorophyll a levels (Zison et al., 1978).

Nutrients

Nutrients are important to the D.O. problem in two major respects; (1) nutrients are essential for algal, bacterial, and macrophyte growth--sources of D.O. production and demand; and (2) nutrients in the form of organic nitrogen and ammonia exert an oxygen demand if conditions are favorable for decay and/or nitrification. Therefore, identifying primary sources of nutrients and their relative contribution may help to better understand this aspect of the D.O. problem.

Nutrient Limitation

Welch (1980) has presented ratios of "soluble usable" nitrogen and phosphorus concentrations determined by various researchers. He states, these data suggest nitrogen is the limiting nutrient for algal growth when nitrogen-to-phosphorus ratios are below 7:1 (by weight). The ratios above Chehalis STP did not conclusively indicate a limiting nutrient. Ratios averaged 5:1 with a range of 0.7:1 to 9:1 over the period covered by the 1979, 1980, and 1982 surveys. Below the STP ratios definitely indicated a nitrogen-limited system. Nitrogen limitation from r.m. 66.9 to 74.3 has been pointed out in past reports (Yake, 1980; Johnson and Prescott, 1982). Below the STP ratios in the epilimnion averaged 2.3 with a range of 0.3 to 4.5. Also, the limited data from the September 1982 expanded study area survey indicated that in-stream ratios may not increase to 7:1 until r.m. 54.2.

Inorganic nitrogen in the epilimnic region was not as completely depleted during 1982 surveys as during some 1980 surveys. During the August 25, 1982 survey, some NH_3-N remained in the epilimnic region of the lower large pool area (r.m. 66.9 to 69.2) (Table 4). However, on August 5, 1980, Johnson and Prescott (1982) found total inorganic nitrogen depletion in the same area. In both surveys, at least 0.05 mg/L O-PO_4-P remained in the epilimnic region.

Nitrogen-limited algal systems are uncommon in freshwater except rivers and lakes receiving a large portion of their nutrient input from domestic effluent (Welch, 1980). This is because domestic effluent, fertilizers, and agricultural runoff contain more phosphorus relative to nitrogen than is normally available by natural sources; e.g., atmospheric, geologic, and biotic.

Often, enriched freshwater systems are nitrogen-limited in the short term and phosphorus-limited in the long term (Welch, 1980). Nitrogen-fixing blue-green algae play a crucial role in this switch. However, no evidence of this situation was observed for the study area during these surveys. The presence of blue-green algae and the probability of a significant bloom occurring in this portion of Chehalis River is unknown.

Nutrient Loads

Loading calculations for various point sources and selected in-stream sites were made from 1979, 1980, and 1982 survey data (Table 8). Organic nitrogen (Org.N) and total nitrogen (TN) data were calculated for many sites and point sources using a method described in Appendix I.

Four major sources of nutrient loading were identified in the study area:

- upstream sources
- Chehalis STP
- Centralia STP
- Skookumchuck River

Nutrient contributions from Salzer Creek and non-point sources within the study area seemed to be of minor importance. No obvious increases in nutrient loads could be detected downstream of livestock access areas, farm lands, and the golf course. Salzer Creek NH_3-N concentrations were often elevated, but calculated loads remained small in comparison to the major sources listed above (Table 8). Nutrient contributions from non-point sources could become more important during a summer storm event.

The upstream sources of nutrients were not investigated. However, agricultural runoff, silvaculture practices, and septic system failures are potential sources of nutrients in the watershed.

The relative contribution of nitrogen to the study area from upstream sources would be important if basin-wide nutrient control were considered in the future. Theoretical loading calculations indicate upstream nitrogen loads, especially Org.N may be significant (Table 9). The contribution of upstream Org.N over the low-flow season may substantially modify the precentage of nitrogen entering the study area and attributed to the Chehalis STP.

Table 8. In-stream nutrient loads and point-source loads calculated along the Chehalis River between the WDG boat launch and the Chehalis STP (r.m. 66.5 and 74.3) from data taken during seven surveys performed between 1979 and 1982 (Houck, 1980; Johnson & Prescott, 1982; this report). All values are pounds/day.

Date	Nutrient	r.m. 74.3†	r.m. 72	r.m. 69.4	Salzer Cr. r.m. 59.2	r.m. 68.1	r.m. 67.5	Centralia STP r.m. 67.3	Skookumchuck River r.m. 66.9	r.m. 66.5
07/20/82	NH_3	189	176		19	66		119		125
	$NO_2 + NO_3$	<84	162		<1	113		70		296
	TIN	<273	338		<20	179		189		421
	Org. N.*	96	73			110		41		175
	TN*	369	411			289		230		596
	$O\text{-}PO_4\text{-}P$	128	162		4	61		103		93
	TP	152	172		6	76		108		117
07/30/80	NH_3	148	6		14	27				
	$NO_2 + NO_3$	35	20		1	0				
	TIN	184	26		15	27				
	Org. N.*	257	234			250				
	TN*	441	260			277				
	$O\text{-}PO_4\text{-}P$	117	85		0.4	67				
	TP	158	117		0.6	101				
08/05/80	NH_3	50	26	0	6	0	44	97	5	51
	$NO_2 + NO_3$	47	75	0	<0.2	0	44	65	165	279
	TIN	97	101	0	6	0	88	162	170	330
	Org. N.	398*	209	299		265	264	30	231	277
	TN	495*	310	299		265	352	180	401	607
	$O\text{-}PO_4\text{-}P$	88	58	41	0.7	35	57	61	5	114
	TP	142	84	82	0.7	77	107	70	37	152
08/25/82	NH_3	130	107		3	32		147	24	38
	$NO_2 + NO_3$	26	36		<0.1	14		58	81	106
	TIN	156	143		3	46	209	205	105	144
	Org. N.*	86	197			180		37	58	210
	TN*	242	340			266		242	163	354
	$O\text{-}PO_4\text{-}P$	68	62		0.6	39		61	4	48
	TP	82	80		2	64	61	61	12	77
09/16/80	NH_3	21	15	39	1	42	47			
	$NO_2 + NO_3$	151	218	202	3	226	205			
	TIN	172	233	241	4	268	252			
	Org. N.	130	184			142	165			
	TN	302	417			410	418			
	$O\text{-}PO_4\text{-}P$	70	69	85	1	71	63			
	TP	74	92	85	1	79	86			
09/27/82	NH_3	139	123	141	0.1	87		155	7	272
	$NO_2 + NO_3$	61	77	102	0.2	103		37	118	332
	TIN	200	200	243	0.3	190		192	125	604
	Org. N.*	104	168	146		230		35	58	542
	TN*	304	368	389		420		227	183	1146
	$O\text{-}PO_4\text{-}P$	55	69	78		55		51	14	136
	TP	78	92	98	1	87		91	22	211
10/11/79	NH_3	146	30		0.3	0	14			71
	$NO_2 + NO_3$	86	38		0.1	0	0			95
	TIN	232	68		0.4	0	14			166
	Org. N.	115	77		17	206	275			
	TN	347	145		17	206	289			
	$O\text{-}PO_4\text{-}P$	150	55		14	52	38			95
	TP	162	64		15	80	71			142

*Denotes organic nitrogen values back-calculated from phosphorus data as described in Appendix I.
†Denotes estimated combined load of Chehalis STP and Chehalis River above STP -- values taken from Table 9.

Table 9. A comparison of nutrient loads from the Chehalis STP and from the river upstream with the percentage of the combined loads attributed to the STP. Also, the seasonal average contribution of individual nutrient loads based on these data. Loads in units of pounds/day.

Date	7/20/82*	7/30/80*	8/5/80*	8/25/82*	9/16/80	9/27/80*	10/11/79	Seasonal Average (mean ± S.D.)
Total Inorganic Nitrogen								
Upstream load	108	50	54	48	74	75	8	
Chehalis STP load	<155	134	43	108	98	125	224	
Combined load	<273	184	97	156	172	200	232	
% attributed to STP	50.4	72.8	44.3	69.2	57.0	62.5	96.6	66 ± 16
Organic Nitrogen								
Upstream load	65	231	390	65	110	79	63	
Chehalis STP load	31	26	8	21	20	25	52	
Combined load	96	257	398	86	130	104	115	
% attributed to STP	32.3	10.1	2.0	24.4	15.4	24.0	45.2	22 ± 15
Total Nitrogen								
Upstream load	173	281	444	113	184	154	71	
Chehalis STP load	196	160	51	129	118	150	276	
Combined load	369	441	495	242	302	304	347	
% attributed to STP	53.1	36.3	10.3	53.3	39.1	49.3	79.5	46 ± 21
Orthophosphate-Phosphorus								
Upstream load	18	12	6	9	22	15	12	
Chehalis STP load	110	105	82	59	48	40	138	
Combined load	128	117	88	68	70	55	150	
% attributed to STP	85.9	89.7	93.2	86.8	68.6	72.7	92.0	84 ± 10
Total Phosphorus								
Upstream load	27	44	60	18	22	30	24	
Chehalis STP load	125	114	82	64	52	48	138	
Combined load	152	158	142	82	74	78	162	
% attributed to STP	82.2	72.2	57.7	78.0	70.3	61.5	85.2	72 ± 11

*Organic nitrogen data for these dates back-calculated from phosphorus data as described in Appendix I.

The Chehalis STP was a very significant source of nutrients to the study area during the low-flow season. Values taken from Table 9 show that when compared to upstream loads, the Chehalis STP contributed an estimated seasonal average at r.m. 74.3 of:

- 66 percent total inorganic nitrogen
- 22 percent organic nitrogen
- 46 percent total nitrogen
- 84 percent orthophosphate-phosphorus
- 72 percent total phosphorus

These estimated percentages contain a moderate degree of variability (S.D. = 10 to 21 percent). Much of the variablity is tied to treatment processes and influent character. For example, Yake (1980) compared total inorganic nitrogen (TIN) effluent data from the July 30 and August 5, 1980 survey. He showed the variability in the nitrogen loads from the Chehalis STP when the plant was under normal operation and when experiencing uncontrolled denitrification. Also, sudden discharges from Consolidated Dairy Products and National Fruit Canning Company have upset plant treating efficiency in the past (Neel, 1983). This could, in turn, influence nutrient effluent concentrations.

In-stream nutrient loads at below the Chehalis STP (r.m. 74.3) from mid-July through August were usually greater than the in-stream load at the lower end of the large pool (r.m. 68.1) and above the Centralia STP outfall (Table 8). However, throughout September, loads leaving the large pool area were greater than those entering. Possible mechanisms for this apparent seasonal nutrient pattern include:

- detrital sedimentation
- algal nutrient uptake
- algal settling and decay
- macrophyte nutrient uptake
- macrophyte decay
- nutrient sediment or metalimnic release

These are all common factors for nutrient cycles in lakes (Wetzel, 1975; Welch, 1980). Also, the conversion of inorganic nutrients into organic forms such as algal biomass was especially evident in this portion of the river. For example, the limited data suggest that during the August 5, 1980 survey, approximately 100 pounds of TIN was converted into organic nitrogen between r.m. 72 and r.m. 69.4 (Table 8).

Below r.m. 67.5, the river received substantial nutrient loads from the Centralia STP and the Skookumchuck River. The Chehalis River nutrient load carried from upstream was also usually quite substantial (Table 8). In terms of inorganic, organic, and total nitrogen, the relationship between the Centralia STP and in-stream loads appeared to be similar to the situation discussed for the Chehalis STP.

The Skookumchuck River contributed a substantial nitrogen load to the Chehalis River, but only a minor load of phosphorus (Table 8). Nitrogen from the Skookumchuck River was primarily in the nitrate (NO_3-N) form.

Nitrification

Habitat throughout most of the study area was not conducive for nitrifying organisms. Nitrifiers prefer shallow, stable rock substrate and a good supply of oxygen with a pH between 7.5 - 8.0 (Hammer and MacKichan, 1981). However, nitrifiers can populate deeper, less stable habitats and continue to perform nitrification at reduced rates until oxygen levels approach 0.3 mg/L (Wetzel, 1975).

The best nitrifier habitats in the study area were located below the confluence of the Skookumchuck River and at a submerged point bar about 1/4 mile below the Chehalis STP. Nitrifying bacteria would be only a part of the rich assemblage of macrophytes, aquatic mosses, attached algae, and periphyton observed below the Skookumchuck. Although the data suggest that nitrification processes probably proceeded below the Skookumchuck, interference from other processes such as biomass growth and decay made calculations of nitrification rates (k_n) highly speculative.

The inorganic nitrogen data also suggest that nitrification occurred in deeper, slow-moving reaches of the study area (Tables 3-6). Nitrification rates (k_3) for use in the computer model were calculated to be in the range of 0.07 to 0.19 day^{-1} in those areas. These are relatively slow rates when compared to many river systems (Zison *et al.*, 1978; Hines *et al.*, 1977).

Bacterial Growths

During the September 1982 survey, between Salzer Creek (r.m. 69.4) and r.m. 68.1, TIN in the Chehalis was rapidly converted to organic nitrogen without the usual indications of algal growth; e.g., increased O_2 production and elevated chlorophyll *a* values (Table 6). Observing similar conditions, Houck (1980) postulated a heavy bacterial growth in the entire water column below Salzer Creek in October 1979. It may be that various bacterial populations in the Chehalis River below Salzer Creek utilize the nitrogen in the Chehalis as an energy source and nutrient to assimilate the high carbonaceous, but low nitrogenous, waste from Salzer Creek in the early fall. Researchers have also found bacterial populations often peak in freshwater systems during the fall (Silvey and Wyatt, 1969; Wetzel, 1979).

The presence of nitrate and changes in nitrate-to-ammonia ratios may suggest various bacterial-mediated processes of denitrification in deeper waters and nitrification in upper water (Wetzel, 1975; Hutchinson, 1975). However, the exact mechanisms for the Chehalis system are not clear.

Fishery

The upper Chehalis River basin has received recent interest as an area for fishery enhancement projects (Hiss et al., 1982; Morhous, 1982). The area supports some salmonid spawning and rearing habitat, but currently these are below potential. Many researchers believe that general environmental degradation in the upper basin has depleted natural fish populations (Hiss et al., 1982). Poor water quality caused by poor agricultural practices and by the Chehalis and Centralia STPs have been specifically cited.

The data from the 1982 and past surveys suggest that water quality in the study area may be detrimental to fish. For example, upstream salmonid migration occurs between August and November (Hiss et al., 1982). The migration could be seriously hampered by the combination of high surface temperatures and depressed D.O. concentrations in the metalimnic region observed at the lower end of the large pool (r.m. 69.2 and r.m. 67.5).

Model and Simulations

CHEHALIZ

A dissolved oxygen computer model, "CHEHALIZ" (Appendix I) was prepared to help illustrate factors influencing longitudinal changes in D.O. and to be used as a predictive tool. CHEHALIZ is a modified version of the one-dimensional, steady-state D.O. stream model used in previous studies by the WQIS (Singleton and Joy, 1982; Joy, 1983). It incorporates the following rates and parameters to calculate in-stream D.O. concentrations:

- stream reaeration (k_2) rate
- BOD decay (k_1) rate
- nitrification (k_3) rate
- temperature
- initial in-stream oxygen concentration

- carbonaceous and nitrogeneous oxygen demands from point-source and in-stream loads
- benthic oxygen demand
- algal respiration and photosynthetic oxygen production

The algal respiration and photosynthetic oxygen production modifications to the model program are very approximate and simplistic in form and are included only to estimate algal influences on the system. The respiration value is calculated from chlorophyll a concentrations as suggested by Zison et al. (1978). Photosynthetic oxygen production is calculated from an areal value supplied by the user based on professional judgment.

Model calculations are made on a reach-by-reach basis. A river reach is defined as a stretch of river that is hydrologically uniform. Where hydrologic characteristics change or where point sources enter, a new reach is defined. The Chehalis River from r.m. 74.3 to r.m. 67.8 was divided into four reaches (Figure 8). Some simulations contained two additional reaches, r.m. 67.8 to r.m. 66.5, to include Centralia STP and the Skookumchuck River.

The model was calibrated; then this calibration was verified during the October 1983 survey (Appendix III). The predicted in-stream D.O. values fit actual field data very well (Figure 9). Other past surveys were simulated for model component testing. Simulations made of data collected during periods of vertically homogeneous temperature and D.O. river conditions fit fairly well; e.g., mid-July, September, and October surveys. However, since stratification was not built into the model, those simulations of late-July and August surveys did not fit well.

The D.O. model can be used to estimate the effects of various point-source wastes and in-stream factors on D.O. concentrations. Simulations can be performed to analyze past events or to predict D.O. concentrations under various hypothetical situations.

Two simulations will be used to demonstrate the utility of the model. The first is the October 11, 1979 cannery waste spill from irrigation lines via Salzer Creek into the Chehalis River. The second is the theoretical overloading of the Chehalis STP by vegetable and dairy food processing wastes while water quality in the river has been degraded by upstream sources. Both simulations occur during the Chehalis River 7-day, 10-year low flow at r.m. 74.8 of approximately 73 cfs, and while the river downstream is not stratified.

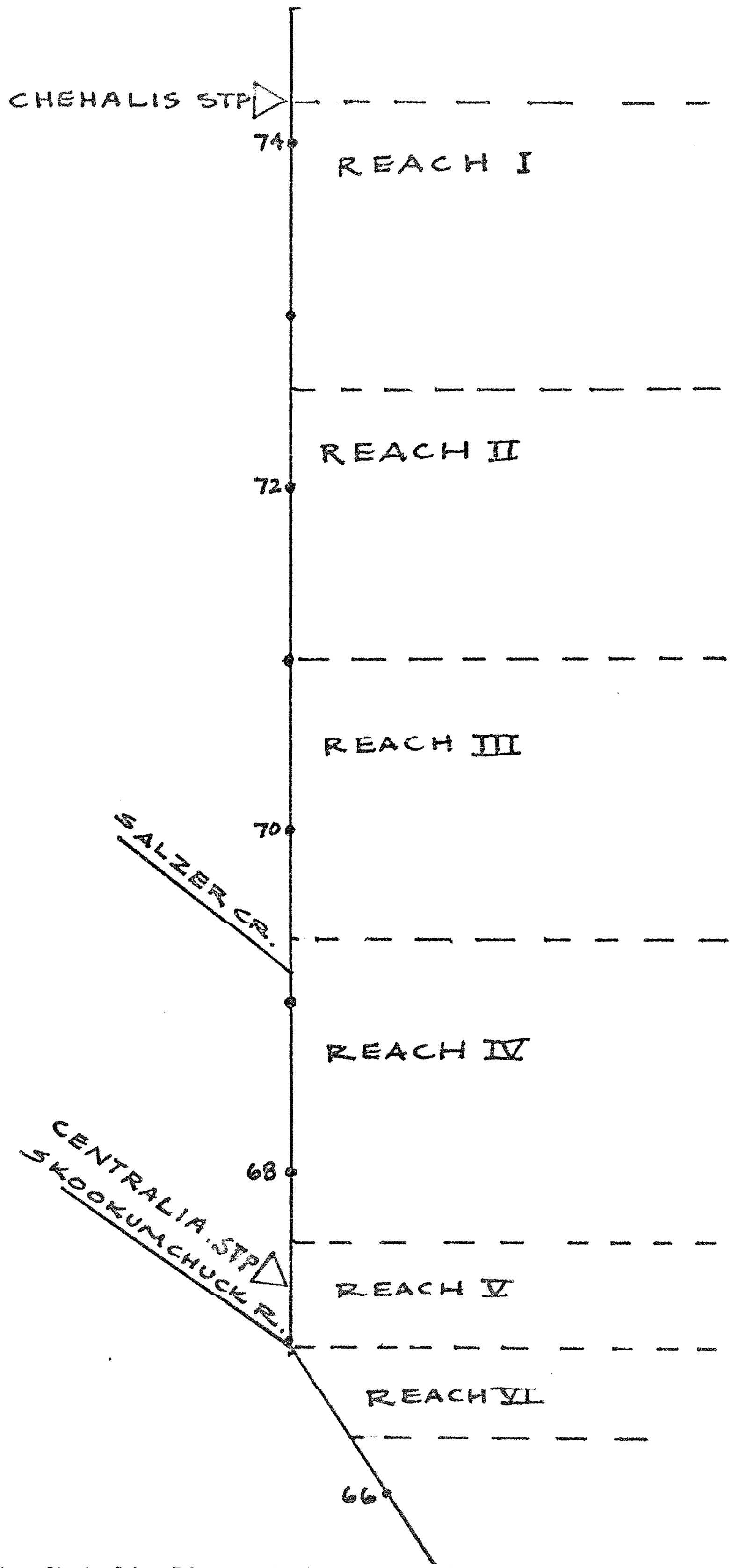
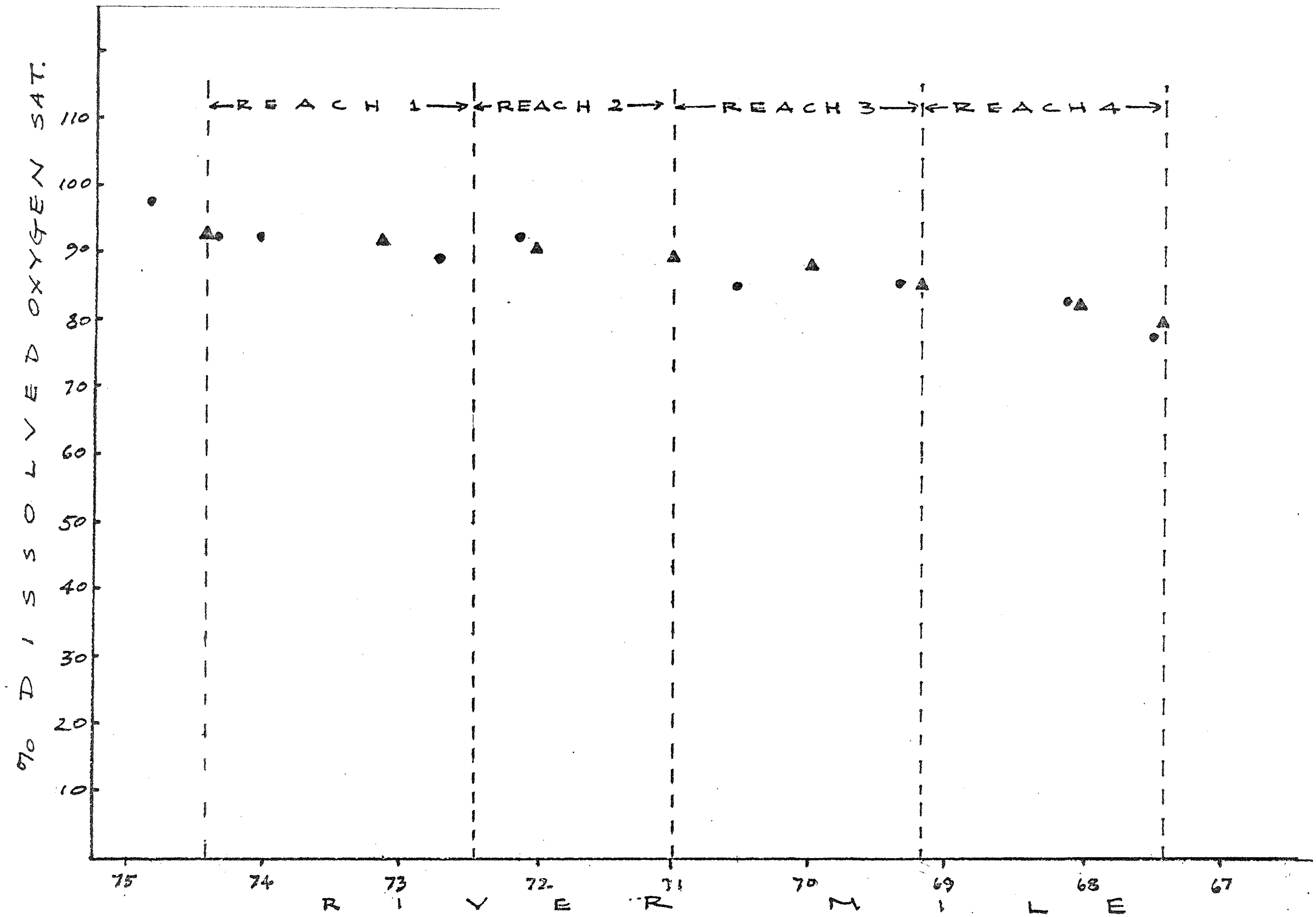


Figure 8. Diagram of the Chehalis River study area. Computer model reaches are indicated. ● river mile; ▷ sewage treatment plant

Figure 9. Computer model prediction (▲) and field data (●) of dissolved oxygen concentrations (as percent saturation) in the Chehalis River on October 11, 1983.



October 11, 1979 Spill

The October 1979 Salzer Creek spill incident will be used to demonstrate the following on D.O.:

- the effects of high-strength canning wastes from Salzer Creek
- the effects of Chehalis STP effluent when the effluent has a relatively high 5-day BOD
- the effects of natural channel characteristics

Variables and rates used in the model simulations are listed by reach in Appendix IV. The following component simulations of the October 1979 incident are presented in Figures 10 and 11:

- a total simulation of the spill incident (Figure 10)
- a simulation without the spill but with Chehalis STP effluent (Figure 11)
- a simulation without either Salzer Creek or Chehalis STP effluent (Figure 11)

Houck's (1980) field data are superimposed on Figure 10. The field data and total spill incident simulation match very well. The poor-quality Chehalis STP effluent caused some decline in D.O. concentrations between the outfall and Salzer Creek. However, Salzer Creek water with a 5-day BOD of 650 mg/L clearly drove D.O. concentrations in the Chehalis River near zero. Dilution by the Skookumchuck River and increased reaeration below the Skookumchuck returned D.O. concentrations to normal. Estimated time of travel from Salzer Creek at r.m. 69.2 to the Mellen Street Bridge at r.m. 67.5 (a WDOE water quality monitoring station) was about two days (Appendix IV). The Chehalis River to Salzer Creek dilution ratio was 37:1.

The simulation points out the importance of controlling the irrigated waste system on Salzer Creek. Wastes are of high strength and can severely affect Chehalis River D.O. A September 27, 1982 survey simulation of a similar but less severe incident confirmed this. In addition, if by chance a spill is detected during the monthly monitoring at Mellen Street Bridge, because of the slow travel time in the river, the incident would be at least two days old. The October 1979 incident was detected in just this way (Houck, 1980).

The two additional component simulations of the survey area in October 1979 were compared. The observed decline from 10 mg/L at r.m. 74.3 to 7.7 mg/L at r.m. 69.2 was apparently caused by:

- an estimated 1.1 mg/L loss from natural channel conditions
- another 1.1 mg/L loss from Chehalis STP effluent

Figure 10. Computer model simulated data and field data of in-stream dissolved oxygen concertrations (as percent saturation) in the Chehalis River on October 11, 1979.

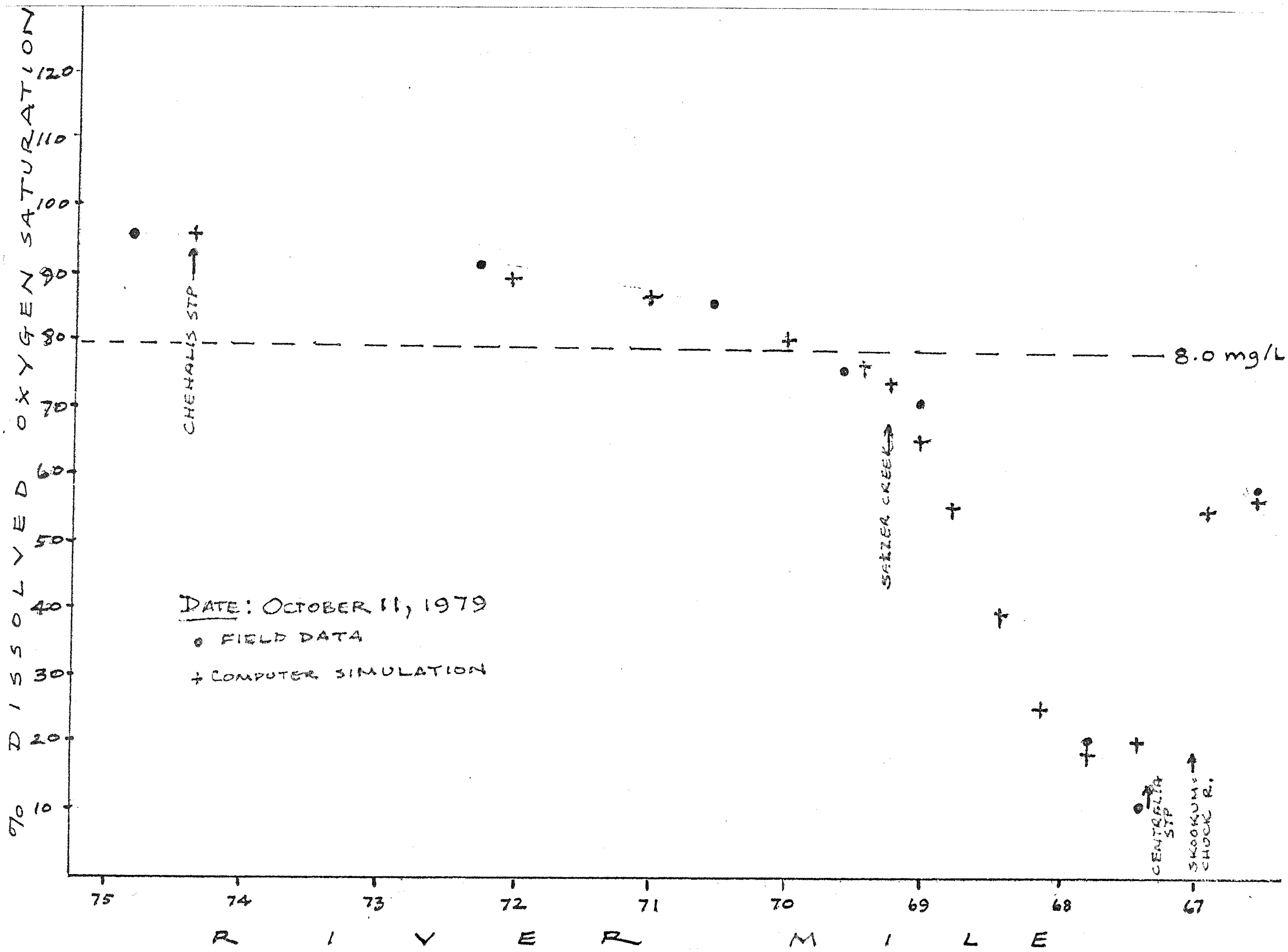
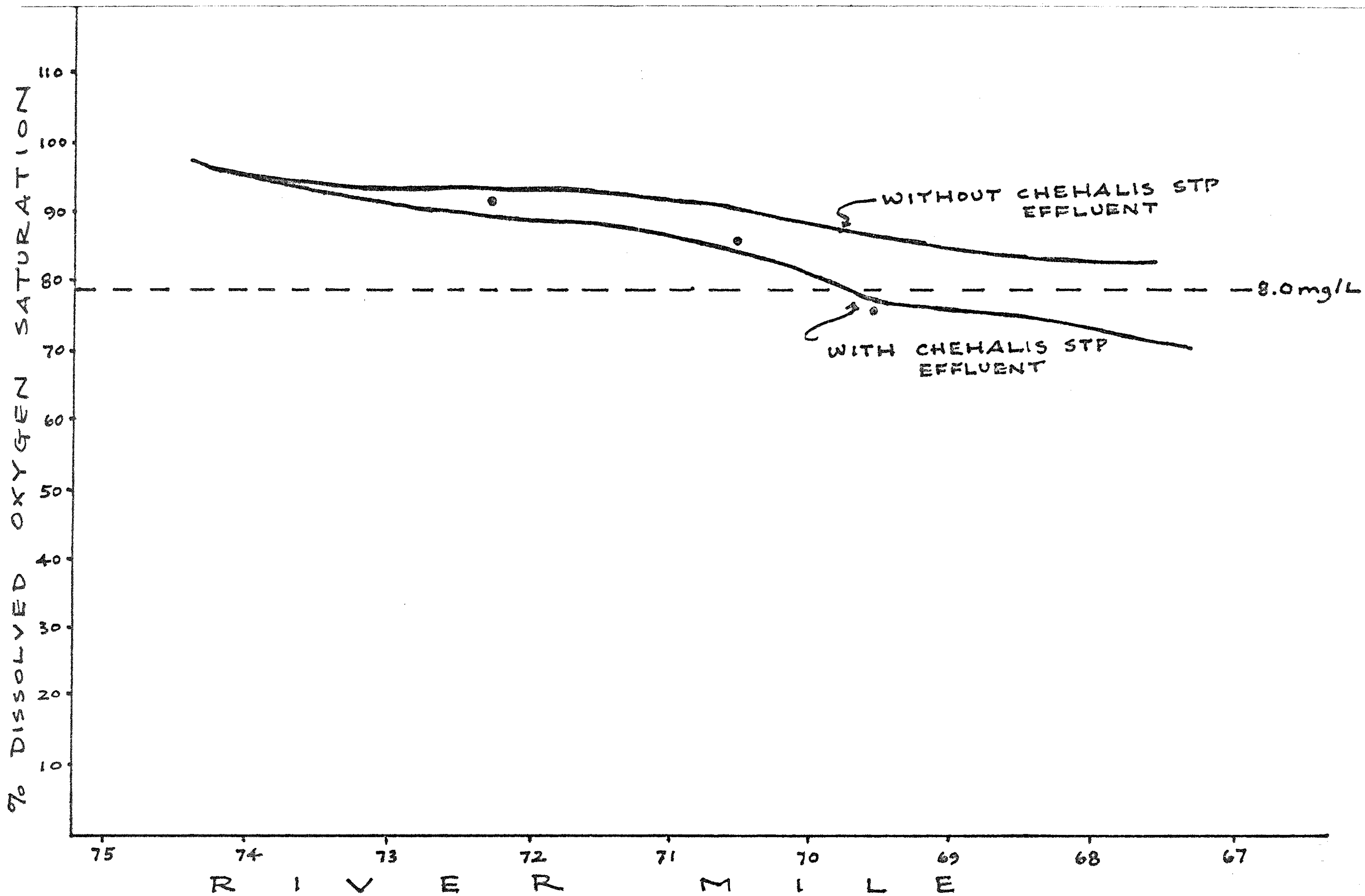


Figure 11. Computer model simulated data and field data of in-stream dissolved oxygen concentrations (as percent saturation) in the Chehalis River without the Salzer Creek spill incident on October 11, 1979. D.O. corcentrations with and without the influence of Chehalis STP effluent are predicted. ●: October 11, 1979 field data



The combined loss resulted in a violation of the Class A 8.0 mg/L D.O. water quality criterion before Salzer Creek wastes were added. These findings are significant considering the 45:1 dilution ratio of Chehalis River water to effluent was at the approximate 7-day, 10-year low-flow value.

Chehalis STP Overload

Simulations were made of individual and combinations of theoretical worst-case events involving the Chehalis STP and receiving water quality. In some, the river water quality is seriously degraded from upstream wastes. These elevated in-stream BOD and ammonia levels. In others, the Chehalis STP receives a load of food-processing wastes it cannot adequately treat. Therefore, wastes with high BOD and ammonia levels are discharged into the river. And as a final problem, a demand from benthic deposits is exerted in the first river reach--below the Chehalis STP.

Five simulations were made during a worst-case in-stream water temperature of 20°C (Figure 12):

1. Upstream water quality normal, STP effluent normal (baseline)
2. Upstream water quality normal, STP effluent poor
3. Upstream water quality poor, STP effluent normal
4. Upstream water quality poor, STP effluent poor
5. Upstream water quality poor, STP effluent poor, benthic demand present

The simulation variables are presented in Appendix V. In addition, the influence of in-stream temperature was assessed with simulations made at 20°C and 15°C while upstream water and STP effluent quality were both poor (Figure 13).

The set of six simulations shows how vulnerable the study area can be under low-flow conditions. Data from the simulations indicate:

- Under "normal" STP and in-stream conditions (curve 1), a 2.5 mg/L D.O. loss is shown between r.m. 74.3 and r.m. 67.6 (Table 10).

- Except under benthic demand conditions (curve 5), the most rapid decline in D.O. occurs in Reach 3, where the very slow section of the study area begins.

- Neither the overloaded STP (curve 2) nor the poor upstream water quality (curve 3) simulation shows D.O. concentrations declining below 5.0 mg/L. However, the model is not accurate enough to be certain of this prediction.

Figure 12. Chehalis River dissolved oxygen (as percent saturation) predicted by computer simulation under theoretical conditions of Chehalis STP overload and poor upstream water quality during low-flow conditions. Curve numbers pertain to individual conditions described in text.

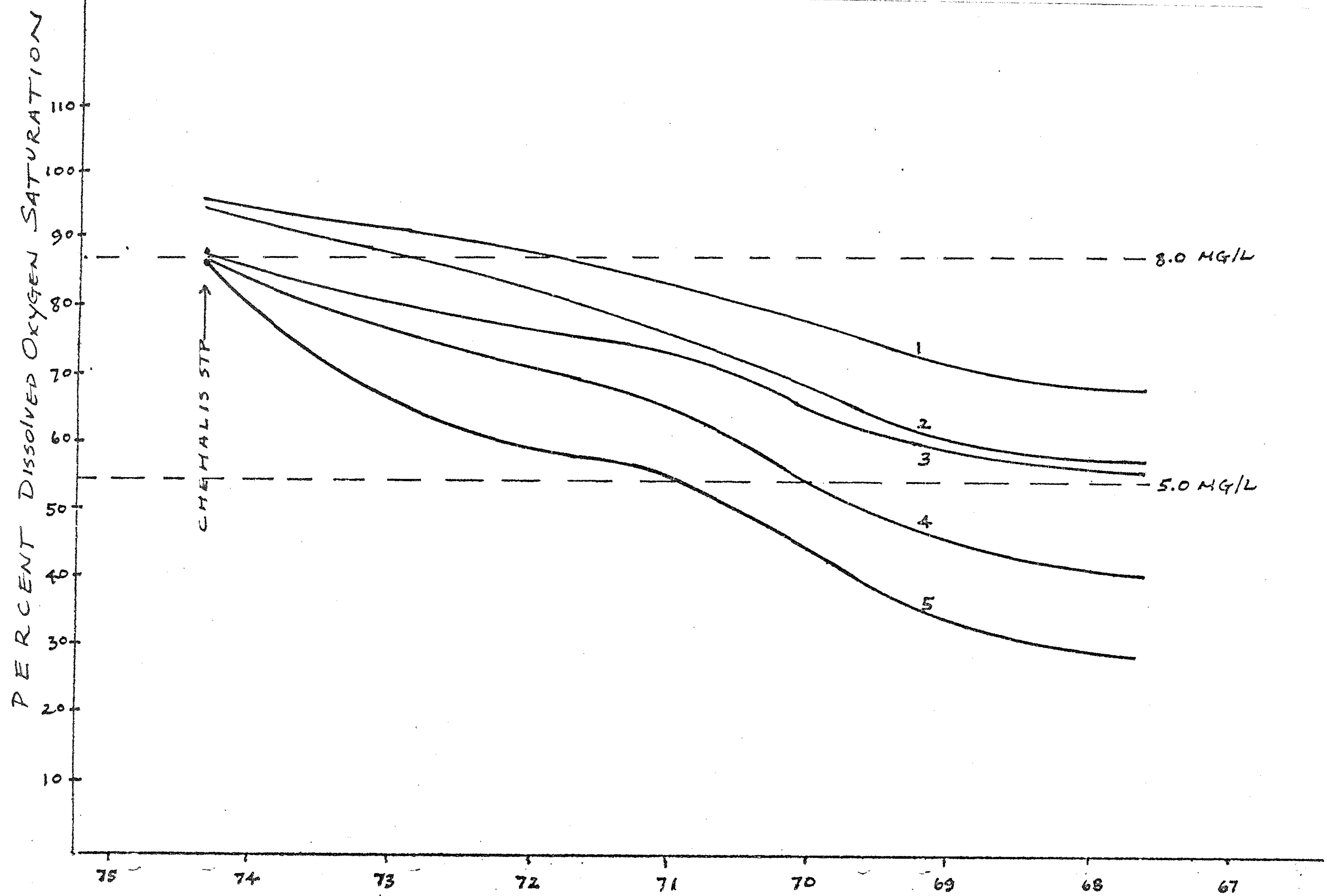
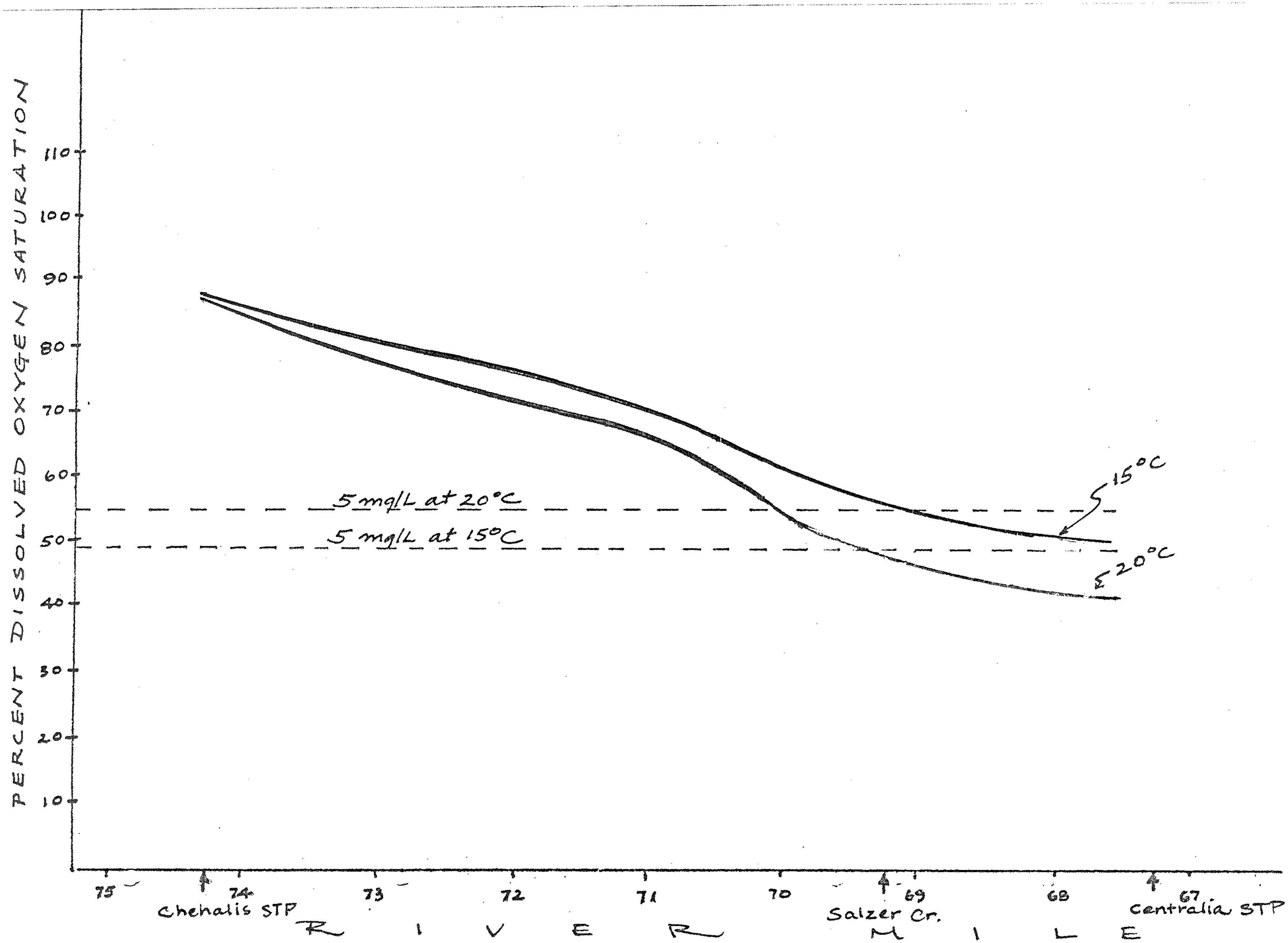


Figure 13. Chehalis River dissolved oxygen (as percent saturation) simulated for 20°C and 15°C with poor Chehalis STP effluent quality and poor upstream water quality (see text: CHEHALIS STP OVERLOAD).



- The STP overload (curve 2) and the poor upstream quality (curve 3) simulations result in similar D.O. concentrations at r.m. 67.6 and similar percentage of D.O. loss over the study area (Table 10). However, the two curves look slightly different. Curve 2 is a more gradual decline while curve 3 has a step downward between r.m. 70 and 71. Again, the area is the head of reach 3 where the river is slowest and D.O. deficits easily overcome reaeration processes.

- The combination of an STP overload and poor upstream water quality yields a 52 percent loss of D.O. between r.m. 74.3 and r.m. 67.6 (Table 10). D.O. concentrations drop to 3.8 mg/L at r.m. 67.6. In comparison, the simulation at 15°C shows a 42 percent loss of D.O. over the same area with a final D.O. concentration of 5.1 mg/L (Figure 13). Lower decay rates and higher initial in-stream oxygen values at 15°C account for much of the difference from the 20°C simulation.

Table 10. Comparison of D.O. values obtained from computer model simulations for beginning (r.m. 74.3) and end (r.m. 67.5) of the Chehalis River study area.

Model Simulation Conditions	D.O. (mg/L) r.m. 75.3	D.O. (mg/L) r.m. 67.5	mg/L Loss	Percent D.O. Loss
1: 20°C, Upstream normal, STP normal	8.8	6.3	2.5	28.4
2: 20°C, Upstream normal, STP poor	8.7	5.2	3.5	40.2
3: 20°C, Upstream poor, STP normal	8.0	5.1	2.9	36.2
4: 20°C, Upstream poor, STP poor	8.0	3.8	4.2	52.5
5: 20°C, same as #4 + benthic demand	8.0	2.7	5.3	66.2
6: 15°C, Upstream poor, STP poor	8.8	5.1	3.7	42.0

- The addition of benthic demand (curve 5) to the worst-case condition (curve 4) results in an additional 1.1 mg/L D.O. loss at r.m. 67.6, and an overall 66 percent loss in D.O. over the study area. The benthic demand in reach 1 produces an initial steep D.O. decline similar to the decline found between r.m. 70 and 71.

CONCLUSIONS

The 1982 water quality surveys showed continued problems with point-source BOD loading. The 1982 and past surveys have shown conditions in the study area gave rise to accelerated algal growth, benthic deposition, high temperatures, slow mixing, low reaeration, and stratification. These conditions impaired or complicated the waste assimilative capacity of this section of the river and resulted in chronic violations of dissolved oxygen standards.

As a point source, Salzer Creek has had the greatest impact on dissolved oxygen levels. The most serious episodes of oxygen depletion can be traced to spills of food-processing wastes with a high BOD from irrigation fields or lines into the Chehalis River via Salzer Creek. Even when an obvious spill of waste was not reported, Salzer Creek BODs in 1982 were greater than 30 mg/L and probably contributed to a metalimnic oxygen depletion in the Chehalis River.

The SWRO has recently directed the National Fruit Canning Company, owner of the irrigation operation, to install an alarm system to warn of line breaks; this should prevent large spills in the future (Morhous, 1983). However, the "background" BOD concentrations in Salzer Creek of 18 to 42 mg/L warrant further investigation.

The surveys suggest that BOD and NOD loads from the Chehalis and Centralia STPs now have only a small direct impact on dissolved oxygen depletion in this section of the Chehalis River. However, the STPs may also be indirectly affecting D.O. through sludge deposits and nutrient loading. Sludge deposits may account for slightly depressed subsurface D.O. values a short distance below the Chehalis STP. The Chehalis STP contributed an average of 65 percent of the total inorganic nitrogen and an estmiated average of 46 percent of the total nitrogen load to the upper end of the study area. A similar contribution of nutrients was made by the Centralia STP. The surveys suggest that the algal population in the study area was nitrogen-limited. This being the case, the STPs, as major sources of nitrogen, affect oxygen concentrations through algal production, respiration, and decay.

The contribution of algal decay to metalimnic D.O. depletion could not be quantified from these data. If D.O. violations persist while Salzer Creek is under control, a closer look at the impacts of algal growth and decay would be warranted.

This would be especially important if a salmonid enhancement program commenced for the upper Chehalis. It would be important to ensure that the combination of high epilimnic temperatures and low metalimnic D.O. concentrations in the study area do not impede salmonid migration and rearing.

Water quality in the Chehalis River below the confluence with the Skookumchuck River was very good compared to the study area above this point. The rapid reaeration rate and rich benthic community in the river below the confluence seemed to diminish the impacts of the Centralia STP wastes and Chehalis River water. However, one late-September survey suggested that a minor D.O. sag occurs in the twelve-mile stretch of river below the confluence with the Skookumchuck.

In summary, the data from these surveys and from ambient monitoring data in 1983 suggest that the major impediments to improving water quality in this section of the Chehalis River have been removed (Appendix VI; WDOE 1977-1983). The actions taken by the SWRO to improve controls over wastes from the Chehalis STP and the National Fruit Canning Company irrigation system have achieved this end. Further improvement might be made by controlling algal growth through nutrient source elimination, but the impacts of algal growth on metalimnic oxygen depletion have not been quantified.

Metalimnic oxygen depletion by organic wastes or nutrient-stimulated algal growth would need to be addressed before any additional wastewater outfalls could be located in the study area.

The computer model may be of assistance for determining the general impact of an additional source with oxygen-demanding wastes. However, the effects of nutrients upon algal growth and the effects of wastes upon metalimnic oxygen depletion would not be adequately covered by the model.

JJ:cp

Attachments

cc: Dick Cunningham
Files

REFERENCES

AWWA, 1981. Standard Methods for the Examination of Water and Wastewater, 15th Edition, Washington, D.C.

Clark, D., 1981. "Chehalis River Survey" Memorandum to Howard Steeley, September 30, 1981, Washington State Dept. of Ecology, 2 pp.

Devitt, R., 1972. "Water Quality of Chehalis River in the Chehalis-Centralia Area" Memorandum to Nelson Graham, October 30, 1972, Washington State Dept. of Ecology, 4 pp.

EPA, 1979. Methods for Chemical Analysis of Water and Wastewater, EPA 600/4-79-020. Env. Support Lab., Cincinnati, OH. 460 pp.

Graham, N., 1972. "Efficiency Studies and Survey Requests," Memorandum to Ron Pine, July 26, 1972, Washinton State Dept. of Ecology, 4 pp.

Hammer, M. and K. MacKichan, 1981. Hydrology and Quality of Water Resources, John Wiley and Sons, New York, NY. 450 pp.

Hines, W.G., S.W. McKenzie, D.A. Rickert, and F.A. Rinella, 1977. Dissolved Oxygen Regimen of the Willamette River. U.S. Geological Survey Circular 715-I, Arlington, VA. 52 pp.

Hiss. J., J. Meyer, and R. Boomer, 1982. Status of Chehalis River Salmon and Steelhead Fisheries and Problems Affecting the Chehalis Tribe. Report by the Fisheries Assistance Office, U.S. Fish and Wildlife Service, Olympia, WA. 57 pp.

Houck, D., 1980. "Low D.O. Values in the Chehalis River", Memorandum to Water Quality Investigations Sectin File: 10-23-13. January 22, 1980, Washington State Dept. of Ecology, Olympia, WA. 3 pp.

Hutchinson, G.E., 1975. A Treatise on Limnology, Vol. I. Part 2. Chemistry of Lakes, John Wiley and Sons, New York, NY. 574 pp.

Johnson, A. and S. Prescott, 1979. "Lower Nooksack River Waer Quality Survey, August 27-28, 1979". Memorandum to John Glynn, Northwest Regional Office, November 21, 1979, Washington State Dept. of Ecology, 5 pp.

Johnson A. and S. Prescott, 1982. "Chehalis River Water Quality Data Collected July-September, 1980," Memorandum to oward Steeley, S.W. Regional Office, November 16, 1982, Washington State Dept. of Ecology, 2 pp.

Joy, J., 1983. "Little Klickitat River Receiving Water Survey in the Vicinity of Goldendale STP," Memorandum to Alan Newman, Central Regional Office, April 30, 1983, Washington State Dept. of Ecology, 24 pp.

McCall, M., 1970. "Chehalis River Study," Memorandum to Gene Asselstine and Nelson Graham, November 19, 1970, Washington State Dept. of Ecology, 1 pp.

Metcalf and Eddy, Inc., 1972. Wastewater Engineering, McGraw-Hill Book Co., San Francisco, CA.

Morehous, M., 1982. Personal communication with WDOE Southwest Regional Office Environmental Inspector, November 1982.

Neel, J., 1983. Personal conversation with WDOE Southwest Regional Office District Supervisor, March 1983.

Poole, J.E., 1983. Correspondence to Joe Joy from U.S. Geological Survey Supervisory Hydrologic Technician, April 12, 1983.

Singleton, L. and J. Joy, 1981. "Modification of 1980 WQI Analysis using 1981 Criteria," Memorandum to J. Bernhardt, May 22, 1981, Washington State Dept. of Ecology, 1 pp.

Singleton, L., and J. Joy, 1982. "Mill Creek Receiving Water Survey," Memorandum to Carl Nuechterline, May 5, 1982, Washington State Dept. of Ecology, 22 pp.

Silvey, J.K.G., and J.T. Wyatt, 1969. "The Interrelationship between Freshwater Bacteria, Algae, and Actinomycetes in Southwestern Reservoirs," pg. 249-275 in: The Structure and Function of Freshwater Microbial Communities, edited by John Cairns, American Microscopial Society Symposium Research Div. Monograph 3, Blacksburg, VA. 301 pp.

Stumm, W. and J. Morgan, 1970. Aquatic Chemistry, Wiley Interscience, New York, NY, 563 pp.

U.S. Corps of Engineers, 1978. Yakima Valley Regional Water Management Study, Vol. 2 Water Quality. U.S. Army Corps of Engineers, Seattle District. 105 pp.

USDA, 1978. Yakima Cooperative River Basin Study, Draft, U.S. Dept. of Agriculture, Soil Conservation Service, Forest Service. 171 pp.

USGS, 1981-2. Surface Water Records, Pt. 1 Water Resources of Washington.

Velz, C.J., 1970. Applied Stream Sanitation, Wiley-Interscience, New York, NY. 619 pp.

WDOE, 1972. Water Resources of Southwestern Washington, review draft, June 1972. Cooperative study with the U.S. Department of Agriculture, Olympia, WA. 206 pp.

WDOE, 1980. Criteria for Sewage Works Design, Washigntón State Dept. of Ecology, Olympia WA. 365 pp.

WDOE 1977-1983. Ambient monitoring data for water quality station 23A120, Chehalis River at Centralia, Washington State Dept. of Ecology, Water Quality Investigations Section.

Welch, E., 1980. Ecological Effects of Wastewater, Cambridge University Press, New York, NY. 337 pp.

Wetzel, R.G., 1975. Limnology, W.B. Saunders Co., Philadelphia, PA. 743 pp.

Yake, W.E., 1980. "Chehalis Wastewater Treatment Plant-Class II Inspection," Memorandum to Doug Houck, September 25, 1980, Washington State Dept. of Ecology, 19 pp.

Zison, S.W., W.B. Mills, D. Deimer, and C.W. Chen, 1978. Rates, Constants and Kinetics Formulations in Surface Water Quality Modelling, EPA-600/3-78-105, December 1978, Environmental Research Laboratory, Athens, GA. 317 pp.

APPENDIX I

ORGANIC AND TOTAL NITROGEN ESTIMATES

Organic and Total Nitrogen Estimates

In order to establish the in-stream nitrogen loads and those from various sources for samples without adequate data, organic nitrogen concentrations were derived from other available field data. In-stream OrgN concentrations were derived assuming that the difference between the total phosphorus and orthophosphate-phosphorus concentrations in samples was roughly equivalent to the organic phosphorus concentration. Since the ratio of organic nitrogen to organic phosphorus in algae is typically about 7.1:1 by weight (Stumm and Morgan, 1978), the organic phosphorus value was multiplied by 7.1 to obtain an estimated organic nitrogen value.

For example, given the following analytical results from the September 16, 1980 survey at r.m. 70.3 (Johnson and Prescott, 1982):

Total phospohrus	Ortho-phosphorus
0.12 mg/L	0.09 mg/L

The organic phosphorus should be: 0.12 - 0.09 = 0.03 mg/L.

The organic nitrogen concentration would then be:

$$0.03 \times 7.1 = 0.21 \text{ mg/L}$$

The organic nitrogen value derived from total Kjeldahl and NH_3 results reported by Johnson and Prescott (1982) was 0.22 mg/L.

The 7:1 ratio of organic nitrogen to organic phosphorus was tested using 13 ratios from the field data (Johnson & Prescott, 1982; Houck, 1980). The mean value was found to be 7.6:1 with a 95 percent probability of the mean value being between 6.7 and 8.5.

The STP organic nitrogen concentrations were estimated based on ratios calculated from the sample results of the October 1979 and September 1980 surveys. Organic nitrogen accounted for approximately 17 percent of the total nitrogen concentration. Total inorganic nitrogen accounted for approximately 83 percent of the total nitrogen concentration in the effluent. This is 20 percent higher than normal domestic influents (Metcalf and Eddy, 1972).

APPENDIX II

PRINTOUT OF "CHEHALIZ" DISSOLVED OXYGEN PROGRAM

```
10  DEFFN'14"SELECTLIST005(80)";HEX(0D)
20  DEFFN'15"SELECTLIST215(132)";HEX(0D)
30 DEFFN'0"SELECTPRINT215(132)";HEX(0D)
40 DEFFN'1"SELECTPRINT005(80)";HEX(0D)
50  DEFFN'30 "Q$=";HEX(22);"CHEHALIZ";HEX(223A);"SCRATCH F Q$";HEX(0D)
60  DEFFN'31 "SAVE DC F$(Q$)Q$";HEX(0D)
70 REM PROGRAM NAME-- CHEHALIZ
80 REM THIS MODELS THE DO CONCENTRATION IN THE CHEHALIS RIVER AT CHEHALIS
90 REM PROGRAMMER JOE JOY
100 REM JULY, 1982,1983
110 REM SOURCES; HAMMER AND MACKICHAN, 1980 AND YAKE, 1981; SINGLETON, 1981
120 P1=760
130 REM ********** INPUT MODULE **********
140 DIM A$60
150 INPUT "ENTER TITLE:CONDITIONS OR DATE(USE QUOTATION MARKS)",A$
160 INPUT "TOTAL NUMBER OF REACHES TO MODEL",A
170 FOR A0=1 TO A
180 INPUT "ARE THERE POINT SOURCES IN THIS REACH (1=Y,2=N)",Y1
190 IF Y1=2 THEN 260
200 INPUT "UP FLOW, PT. SOURCE FLOW (CFS)",F1,F2
210 INPUT  "TEMP UP,PT.SOURCE TEMP",T1,T2
220 INPUT "D.O. UP,PT. SOURCE D.O.",D1,D2
230 INPUT "NH3-N UP, PT. SOURCE NH3-N",N1,N2
240 INPUT "IS BOD FIVE DAY (1) OR ULTIMATE (2)",C
250 INPUT "ENTER BOD UP, PT.SOURCE BOD",C1,C2 : GOTO 300
260 INPUT "ENTER TOP OF REACH FLOW(CFS), D.O., TEMP., & NH3", F,C0,T0,N0
270 N0=N0*4.33
280 INPUT "IS BOD FIVE DAY (1) OR ULTIMATE (2)",C
290 INPUT "ENTER BOD",C1
300 INPUT "DO YOU WISH TO CALCULATE SED. OXY.DEMAND,1=Y,2=N",Y
310 IF Y=2 THEN 330
320 INPUT "DEPTH OF SEDIMENT?",G
330 INPUT "DOES THE BOD RATE NEED TEMP. ADJUSTMENT (Y=1,N=2)",Y2
340 INPUT "ENTER BOD & NOD RATES",K1,K3
350 INPUT "HAVE YOU A REAERATION RATE (Y=1,N=2)",Y3
360 IF Y3=2 THEN 380
370 INPUT "ENTER REAERATION RATE @20 DEG. C",K2
380 INPUT "HAVE YOU A CHLOROPHYLL A VALUE FOR RESPIRATION(Y=1,N=2)",Y9
390 IF Y9=2 THEN 410
400 INPUT "CHLOROPHYLL A IN UG/L",A9
410 INPUT "HAVE YOU AN ALGAL PRODUCTION RATE(Y=1,N=2)",Y8
420 IF Y8=2 THEN 440
430 INPUT "ENTER RATE IN GMS/SQ.METER",R3
440 INPUT "HAVE YOU A NON-NOD AMMONIA DEPLETION RATE(Y=1,N=2)",Y5
450 IF Y5=2 THEN 470
460 INPUT "ENTER NH3 DEPLETION RATE",R2
470 INPUT "DO YOU HAVE SINGLE VALUES (1), OR PARTIAL VALUES (2) FOR DEPTH,WIDTH,AND VELOCITY",E
480 IF E=1 THEN 520
490 INPUT "ENTER PARTIAL MEAN DEPTHS AND WIDTHS",Z1,Z2,X2,X3
500 INPUT "ENTER PARTIAL DISCHARGES",F3,F4
510 INPUT "ENTER PARTIAL VELOCITIES",V1,V2: GOTO 540
520 INPUT "ENTER MEAN DEPTH AND WIDTH",Z5,X5
530 INPUT "ENTER VELOCITY",V5
540 INPUT "ENTER RIVER MILE AT TOP OF REACH",I9
550 INPUT "ENTER CALCULATION INTERVAL (MILES)",I5
560 INPUT "ENTER LENGTH OF REACH IN MILES",I6
570 IF A0>1 THEN 580: PRINT HEX(0C)
580 PRINT HEX(0A0A): REM ****************************************************
590 GOSUB 740
600 D6=8: IF D5/2>5 THEN D6=D5/2
610 GOSUB 1090
620 FOR T5 =0 TO I6 STEP I5
630 GOSUB 1490
640 IF X=1 THEN 670
```

```
660 X=1
670 PRINT ROUND(R,3),ROUND(T,3),ROUND(L9,2),ROUND(N9,2),ROUND(D,2),ROUND(D9,2),ROUND(D/D5*100,1)
680 NEXT T5
690 PRINT : PRINT "NH3=";ROUND(N9/4.33,2)
700 PRINT "----------------------------------------------------------------------"
710 X,F,F1,F2,T1,T2,D1,D2,N1,N2,C,C1,C2,N0,G,K2,Z1,Z2,Z5,X2,X3,X5,F3,F4,V1,V2,R2,A9,Y9,R3,P2=0
720 NEXT A0
730 END
740 REM ** INITIAL CALCULATIONS SUBROUTINE **
750 IF Y1=2 THEN 800
760 R1=F1/F2
770 C0=(F1*D1+F2*D2)/(F1+F2)
780 T0=(F1*T1+F2*T2)/(F1+F2)
790 N0=((F1*N1+F2*N2)/(F1+F2))*4.33
800 IF Y=2 THEN 850
810 IF E=1 THEN 840
820 Z3=((Z1+Z2)/2)*.3048
830 S2=((T0*.15)+(.3*G))/Z3: GOTO 850
840 S2=((T0*.15)+(.3*G))/(Z5*.3048)
850 IF Y8=2 THEN 900
860 IF E=1 THEN 890
870 Z3=((Z1+Z2)/2)*.3048
880 P2=R3/Z3: GOTO 900
890 P2=R3/(Z5*0.3048)
900 REM ********* D.O. % SAT *********
910 P=(P1-4.87922*EXP(.06378*T0))/(760-4.87922*EXP(.06378*T0))
920 D5=(14.6214-.4026*T0+6.8516E-03*T0^2+2.2619E-04*T0^3-2.4998E-05*T0^4+8.5254E-07*T0^5-1.0513E-08*T0^6)*P
930 IF Y3=1 THEN 970
940 IF E=2 THEN 960
950 K2=(12.9*V5^0.5)/(Z5^1.50): GOTO 970
960 K2=((F3/(F3+F4))*(21.6*V1^.67/Z1^1.85))+((F4/(F3+F4))*(21.6*V2^.67/Z2^1.85))
970 K2=K2*1.016^(T0-20)
980 IF C=2 THEN 1020
990 B1=C1/(1-10^(-5*(K1/2.303))): IF Y1=2 THEN 1040
1000 B2=C2/(1-10^(-5*(K1/2.303)))
1010 GOTO 1030
1020 B1=C1: IF Y1=2 THEN 1040: B2=C2
1030 L0=(F1*B1+F2*B2)/(F1+F2): GOTO 1050
1040 L0=B1
1050 IF Y2=2 THEN 1070
1060 K1=K1*1.047^(T0-20)
1070 D0=D5-C0
1080 RETURN
1090 REM ***** PRINT SUBROUTINE *****
1100 IF A0>1 THEN 1130
1110 PRINT HEX(0E);TAB(4);"CHEHALIS RIVER D.O. MODEL"; HEX(0F)
1120 PRINT HEX(0E);TAB(4);A$
1130 PRINT : IF Y1=2 THEN 1310
1140 PRINT "********************** INPUT ECHO **********************"
1150 IF E=1THEN 1200
1160 PRINT  "UPSTREAM FLOW,PT.SOURCE FLOW (CFS)";F1;F2,"PARTIAL DEPTHS AND WIDTHS";Z1;Z2;X2;X3
1170 PRINT  "TEMP UP,PT.SOURCE TEMP              ";T1;T2, "PARTIAL DISCHARGES";F3;F4
1180 PRINT "D.O. UP,PT.SOURCE D.O.              ";D1;D2,"PARTIAL VELOCITIES ";V1;V2
1190 GOTO 1230
1200 PRINT "UPSTREAM FLOW,PT.SOURCE FLOW (CFS)";F1;F2," DEPTH AND WIDTH   ";Z5;X5
1210 PRINT  "TEMP UP,PT.SOURCE TEMP              ";T1;T2
1220 PRINT "D.O. UP,PT.SOURCE D.O.              ";D1;D2,"VELOCITY";V5
1230 PRINT "NH3-N UP, PT.SOURCE NH3-N           ";N1;N2
1240 IF C=2 THEN 1270
1250 PRINT "FIVE DAY BOD UP, PT.SOURCE BOD     ";C1;C2
1260 GOTO 1290
1270 PRINT "ULTIMATE BOD UP, PT.SOURCE UBOD    ";C1;C2
1280 B1=C1: B2=C2: GOTO 1290
1290 PRINT "********************************************************"
```

```
... PARTIAL DISCHARGES & VELOCITIES ";F3;F4;V1;V2: GOTO 1330
1330 PRINT "DOWNSTREAM FLOW (CFS)    ";F1+F2
1340 PRINT "DILUTION RATIO           ";ROUND(R1,2)
1350 PRINT "MIXED ULT. BOD (MG/L)    ";ROUND(L0,2)
1360 PRINT "MIXED ULT. NOD (MG/L)    ";ROUND(N0,2)
1370 PRINT "MIXED TEMPERATURE (C)    ";ROUND(T0,2)
1380 PRINT "MIXED D.O. (MG/L)       ";ROUND(C0,2)
1390 PRINT "D.O. 100% SAT =         ";ROUND(D5,2)
1400 PRINT "K1=                     ";ROUND(K1,2)
1410 PRINT "K2=                     ";ROUND(K2,2)
1420 PRINT "K3=                     ";ROUND(K3,2)
1430 PRINT "SEDIMENT DEPTH IN INCHES";G: PRINT "NON-NOD AMMONIA DEPLETION RATE";R2
1440 PRINT "CHLOROPHYLL A CONCENTRATION (UG/L)";A9
1450 PRINT "ALGAL PRODUCTION RATE (GMS./SQ.M.)"; R3,P2
1460 PRINT : PRINT "          R  E  A  C  H     ";A0
1470 PRINT HEX(0A0A)
1480 RETURN
1490 REM **** STREAM MODEL SUBROUTINE ****
1500 R=I9-T5
1510 IF E=1 THEN 1530
1520 T=(((T5*5280*X2*Z1)/(F3)+(T5*5280*X3*Z2)/(F4))/(F3+F4))/86400: GOTO 1560
1530 IF Y1=2 THEN 1550
1540 T=((T5*5280*X5*Z5)/(F1+F2))/86400: GOTO 1560
1550 T=((T5*5280*X5*Z5)/F)/86400
1560 IF T5=0 THEN T=.00001
1570 D9=((K1*L0)/(K2-K1))*(EXP(-K1*T)-EXP(-K2*T))+((K3*N0)/(K2-K3))*(EXP(-K3*T)-EXP(-K2*T))+(D0*EXP(-K2*T))+(((S2+(A9*.024)-P2)/K2)*
(1-EXP(-K2*T)))
1580 L9=L0*EXP(-K1*T): N9=N0*EXP(-K3*T)
1590 IF Y5=1 THEN N9=N0*((EXP(-K3*T)+EXP(-R2*T))-1)
1600 D=D5-D9
1610 RETURN
```

APPENDIX III

PRINTOUT OF VERIFICATION OF "CHEHALIZ" PROGRAM
USING OCTOBER 11, 1983, FIELD DATA

CHEHALIS RIVER D.O. MODEL
OCT. 11, 1983

```
********************* INPUT ECHO *********************
UPSTREAM FLOW,PT.SOURCE FLOW (CFS) 150  1.7      DEPTH AND WIDTH    9.8  100
TEMP UP,PT.SOURCE TEMP            10.7  16
D.O. UP,PT.SOURCE D.O.             10.3  9.8    VELOCITY .17
NH3-N UP, PT.SOURCE NH3-N          .02  11
ULTIMATE BOD UP, PT.SOURCE UBOD    4  30
******************************************************
```

DOWNSTREAM FLOW (CFS) 151.7
DILUTION RATIO 88.24
MIXED ULT. BOD (MG/L) 4.29
MIXED ULT. NOD (MG/L) .62
MIXED TEMPERATURE (C) 10.76
MIXED D.O. (MG/L) 10.29
D.O. 100% SAT = 11.14
K1= .08
K2= .15
K3= .12
SEDIMENT DEPTH IN INCHES 0
NON-NOD AMMONIA DEPLETION RATE 0
CHLOROPHYLL A CONCENTRATION (UG/L) 0
ALGAL PRODUCTION RATE (GMS./SQ.M.) 0 0

R E A C H 1

RIVER MILE	DAYS	BOD	NOD	D.O.	DEFICIT	% SAT.
74.3	0	4.29	.62	10.29	.84	92.4
74.1	.079	4.26	.61	10.27	.86	92.2
73.9	.158	4.24	.61	10.25	.89	92
73.7	.237	4.21	.6	10.23	.91	91.9
73.5	.316	4.19	.6	10.21	.93	91.7
73.3	.395	4.16	.59	10.19	.95	91.5
73.1	.474	4.13	.59	10.17	.97	91.3
72.9	.553	4.11	.58	10.15	.99	91.1
72.7	.632	4.08	.57	10.13	1.01	91

NH3= .13

DOWNSTREAM FLOW (CFS) 152 DEPTH & WIDTH 10.25 100 VELOCITY .15
MIXED ULT. BOD (MG/L) 4.08
MIXED ULT. NOD (MG/L) .56
MIXED TEMPERATURE (C) 10.7
MIXED D.O. (MG/L) 10.13
D.O. 100% SAT = 11.15
K1= .08
K2= .13
K3= .12
SEDIMENT DEPTH IN INCHES 0
NON-NOD AMMONIA DEPLETION RATE 0
CHLOROPHYLL A CONCENTRATION (UG/L) 0
ALGAL PRODUCTION RATE (GMS./SQ.M.) 0

RIVER MILE	DAYS	BOD	NOD	D.O.	DEFICIT	% SAT.
72.6	0	4.08	.56	10.13	1.02	90.8
72.4	.082	4.05	.56	10.11	1.04	90.7
72.2	.165	4.03	.55	10.09	1.06	90.5
72	.247	4	.55	10.07	1.08	90.3
71.8	.33	3.98	.54	10.05	1.1	90.1
71.6	.412	3.95	.54	10.03	1.12	90
71.4	.495	3.93	.53	10.01	1.14	89.8
71.2	.577	3.9	.53	9.99	1.16	89.6
71	.659	3.87	.52	9.98	1.17	89.5

NH3= .12

DOWNSTREAM FLOW (CFS) 154 DEPTH & WIDTH 16.7 120 VELOCITY .08
MIXED ULT. BOD (MG/L) 4
MIXED ULT. NOD (MG/L) .52
MIXED TEMPERATURE (C) 11.4
MIXED D.O. (MG/L) 9.98
D.O. 100% SAT = 10.98
K1= .08
K2= .05
K3= .12
SEDIMENT DEPTH IN INCHES 0
NON-NOD AMMONIA DEPLETION RATE 0
CHLOROPHYLL A CONCENTRATION (UG/L) 0
ALGAL PRODUCTION RATE (GMS./SQ.M.) 0

R E A C H 3

RIVER MILE	DAYS	BOD	NOD	D.O.	DEFICIT	% SAT.
71	0	4	.52	9.98	1	90.9
70.8	.159	3.95	.51	9.93	1.05	90.4
70.6	.318	3.9	.5	9.87	1.1	90
70.4	.477	3.85	.49	9.82	1.15	89.5
70.2	.636	3.8	.48	9.77	1.2	89
70	.795	3.75	.47	9.73	1.25	88.6
69.8	.954	3.7	.46	9.68	1.3	88.2
69.6	1.113	3.66	.45	9.63	1.34	87.8
69.4	1.272	3.61	.45	9.59	1.39	87.3
69.2	1.431	3.56	.44	9.54	1.43	86.9

NH3= .1

********************** INPUT ECHO *********************
UPSTREAM FLOW,PT.SOURCE FLOW (CFS) 155 4.2 DEPTH AND WIDTH 16.7 120
TEMP UP,PT.SOURCE TEMP 11.6 10.3
D.O. UP,PT.SOURCE D.O. 9.54 4.85 VELOCITY .08
NH3-N UP, PT.SOURCE NH3-N .1 .01
ULTIMATE BOD UP, PT.SOURCE UBOD 4 22
****

DOWNSTREAM FLOW (CFS) 159.2
DILUTION RATIO 36.9
MIXED ULT. BOD (MG/L) 4.47
MIXED ULT. NOD (MG/L) .42
MIXED TEMPERATURE (C) 11.57
MIXED D.O. (MG/L) 9.42
D.O. 100% SAT = 10.94
K1= .11
K2= .05
K3= .08
SEDIMENT DEPTH IN INCHES 0
NON-NOD AMMONIA DEPLETION RATE 0
CHLOROPHYLL A CONCENTRATION (UG/L) 0
ALGAL PRODUCTION RATE (GMS./SQ.M.) 0

R E A C H 4

RIVER MILE	DAYS	BOD	NOD	D.O.	DEFICIT	% SAT.
69.2	0	4.47	.42	9.42	1.52	86.1
69	.154	4.4	.42	9.35	1.59	85.5
68.8	.308	4.33	.41	9.28	1.65	84.9
68.6	.462	4.26	.41	9.22	1.72	84.3
68.4	.615	4.19	.4	9.15	1.78	83.7
68.2	.769	4.12	.4	9.09	1.84	83.2
68	.923	4.05	.39	9.03	1.9	82.6
67.8	1.077	3.98	.39	8.98	1.96	82.1
67.6	1.231	3.91	.38	8.92	2.02	81.6
67.4	1.385	3.85	.38	8.86	2.07	81.1

NH3= .09

APPENDIX IV

"CHEHALIZ" PROGRAM SIMULATIONS OF THE OCTOBER 11, 1979, SPILL

CHEHALIS RIVER D.O. MODEL
OCT. 11, 1979: BASIC DATA

********************** INPUT ECHO **********************

UPSTREAM FLOW,PT.SOURCE FLOW (CFS) 73 1.6 DEPTH AND WIDTH 8.8 95
TEMP UP,PT.SOURCE TEMP 14 15
D.O. UP,PT.SOURCE D.O. 10 4.9 VELOCITY .09
NH3-N UP, PT.SOURCE NH3-N .02 16
ULTIMATE BOD UP, PT.SOURCE UBOD 4 160

****

DOWNSTREAM FLOW (CFS) 74.6
DILUTION RATIO 45.63
MIXED ULT. BOD (MG/L) 7.35
MIXED ULT. NOD (MG/L) 1.57
MIXED TEMPERATURE (C) 14.02
MIXED D.O. (MG/L) 9.89
D.O. 100% SAT = 10.36
K1= .07
K2= .13
K3= .12
SEDIMENT DEPTH IN INCHES 0
NON-NOD AMMONIA DEPLETION RATE 0
CHLOROPHYLL A CONCENTRATION (UG/L) 0
ALGAL PRODUCTION RATE (GMS./SQ.M.) 0 0

R E A C H 1

RIVER MILE	DAYS	BOD	NOD	D.O.	DEFICIT	% SAT.
74.3	0	7.35	1.57	9.89	.47	95.4
74.1	.137	7.28	1.55	9.81	.56	94.6
73.9	.274	7.21	1.52	9.72	.64	93.8
73.7	.411	7.14	1.5	9.64	.72	93.1
73.5	.548	7.08	1.47	9.57	.8	92.3
73.3	.685	7.01	1.45	9.49	.87	91.6
73.1	.822	6.94	1.42	9.42	.94	90.9
72.9	.959	6.88	1.4	9.35	1.01	90.2
72.7	1.096	6.82	1.38	9.28	1.08	89.6

NH3= .32

DOWNSTREAM FLOW (CFS) 78 DEPTH & WIDTH 9.25 95 VELOCITY .09
MIXED ULT. BOD (MG/L) 6.82
MIXED ULT. NOD (MG/L) .3
MIXED TEMPERATURE (C) 15
MIXED D.O. (MG/L) 9.28
D.O. 100% SAT = 10.15
K1= .07
K2= .13
K3= .12
SEDIMENT DEPTH IN INCHES 0
NON-NOD AMMONIA DEPLETION RATE 0
CHLOROPHYLL A CONCENTRATION (UG/L) 0
ALGAL PRODUCTION RATE (GMS./SQ.M.) 0

RIVER MILE	DAYS	BOD	NOD	D.O.	DEFICIT	% SAT.
72.6	0	6.82	.3	9.28	.87	91.4
72.4	.138	6.75	.3	9.22	.93	90.9
72.2	.275	6.69	.29	9.17	.98	90.3
72	.413	6.62	.29	9.12	1.03	89.8
71.8	.551	6.56	.28	9.07	1.08	89.3
71.6	.688	6.49	.28	9.02	1.13	88.8
71.4	.826	6.43	.27	8.97	1.18	88.4
71.2	.964	6.37	.27	8.92	1.23	87.9
71	1.102	6.3	.27	8.88	1.27	87.5

NH3= .06

DOWNSTREAM FLOW (CFS) 82 DEPTH & WIDTH 16 120 VELOCITY .04
MIXED ULT. BOD (MG/L) 6.3
MIXED ULT. NOD (MG/L) .74
MIXED TEMPERATURE (C) 15
MIXED D.O. (MG/L) 8.88
D.O. 100% SAT = 10.15
K1= .07
K2= .04
K3= .12
SEDIMENT DEPTH IN INCHES 0
NON-NOD AMMONIA DEPLETION RATE 0
CHLOROPHYLL A CONCENTRATION (UG/L) 0
ALGAL PRODUCTION RATE (GMS./SQ.M.) 0 0

R E A C H 3

RIVER MILE	DAYS	BOD	NOD	D.O.	DEFICIT	% SAT.
71	0	6.3	.74	8.88	1.27	87.5
70.8	.286	6.17	.71	8.74	1.41	86.1
70.6	.572	6.05	.69	8.61	1.54	84.8
70.4	.859	5.92	.66	8.48	1.67	83.5
70.2	1.145	5.8	.64	8.36	1.79	82.3
70	1.431	5.69	.62	8.24	1.91	81.1
69.8	1.717	5.57	.6	8.12	2.03	80
69.6	2.003	5.46	.58	8.01	2.14	78.9
69.4	2.289	5.35	.56	7.9	2.25	77.9
69.2	2.576	5.24	.54	7.8	2.35	76.9

NH3= .12

********************** INPUT ECHO **********************
UPSTREAM FLOW,PT.SOURCE FLOW (CFS) 84 2.3 DEPTH AND WIDTH 16 120
TEMP UP,PT.SOURCE TEMP 15 15
D.O. UP,PT.SOURCE D.O. 7.8 .8 VELOCITY .04
NH3-N UP, PT.SOURCE NH3-N .1 .03
ULTIMATE BOD UP, PT.SOURCE UBOD 5.28 860
****

DOWNSTREAM FLOW (CFS) 86.3
DILUTION RATIO 36.52
MIXED ULT. BOD (MG/L) 28.06
MIXED ULT. NOD (MG/L) .42
MIXED TEMPERATURE (C) 15
MIXED D.O. (MG/L) 7.61
D.O. 100% SAT = 10.15
K1= .13
K2= .04
K3= .08
SEDIMENT DEPTH IN INCHES 0
NON-NOD AMMONIA DEPLETION RATE 0
CHLOROPHYLL A CONCENTRATION (UG/L) 0
ALGAL PRODUCTION RATE (GMS./SQ.M.) 0 0

R E A C H 4

RIVER MILE	DAYS	BOD	NOD	D.O.	DEFICIT	% SAT.
69.2	0	28.06	.42	7.61	2.54	75
69	.272	27.11	.42	6.68	3.47	65.8
68.8	.544	26.18	.41	5.79	4.36	57.1
68.6	.816	25.29	.4	4.94	5.21	48.7
68.4	1.088	24.43	.39	4.13	6.02	40.7
68.2	1.36	23.6	.38	3.35	6.79	33.1
68	1.632	22.8	.37	2.62	7.53	25.8
67.8	1.903	22.03	.36	1.91	8.24	18.9

NH3= .08

********************* INPUT ECHO *********************
UPSTREAM FLOW,PT.SOURCE FLOW (CFS) 88 2.75 DEPTH AND WIDTH 5.5 95
TEMP UP,PT.SOURCE TEMP 15 16
D.O. UP,PT.SOURCE D.O. 1.91 6 VELOCITY .19
NH3-N UP, PT.SOURCE NH3-N .08 16
ULTIMATE BOD UP, PT.SOURCE UBOD 22 20
****

DOWNSTREAM FLOW (CFS) 90.75
DILUTION RATIO 32
MIXED ULT. BOD (MG/L) 21.94
MIXED ULT. NOD (MG/L) 2.44
MIXED TEMPERATURE (C) 15.03
MIXED D.O. (MG/L) 2.03
D.O. 100% SAT = 10.14
K1= .13
K2= .4
K3= .08
SEDIMENT DEPTH IN INCHES 0
NON-NOD AMMONIA DEPLETION RATE 0
CHLOROPHYLL A CONCENTRATION (UG/L) 0
ALGAL PRODUCTION RATE (GMS./SQ.M.) 0 0

R E A C H 5

RIVER MILE	DAYS	BOD	NOD	D.O.	DEFICIT	% SAT.
67.8	0	21.94	2.44	2.03	8.11	20.1
67.6	.07	21.74	2.42	2.05	8.09	20.3
67.4	.141	21.55	2.41	2.08	8.07	20.5
67.2	.211	21.36	2.39	2.1	8.04	20.7
67	.281	21.17	2.38	2.12	8.02	20.9

NH3= .55

********************** INPUT ECHO *********************

UPSTREAM FLOW,PT.SOURCE FLOW (CFS) 91 132 DEPTH AND WIDTH 4 100

TEMP UP,PT.SOURCE TEMP 15 13

D.O. UP,PT.SOURCE D.O. 2.1 8.4 VELOCITY .56

NH3-N UP, PT.SOURCE NH3-N .55 .03

ULTIMATE BOD UP, PT.SOURCE UBOD 21.2 4

****

DOWNSTREAM FLOW (CFS)	223
DILUTION RATIO	.69
MIXED ULT. BOD (MG/L)	11.02
MIXED ULT. NOD (MG/L)	1.05
MIXED TEMPERATURE (C)	13.82
MIXED D.O. (MG/L)	5.83
D.O. 100% SAT =	10.41
K1=	.12
K2=	1.09
K3=	.08

SEDIMENT DEPTH IN INCHES 0

NON-NOD AMMONIA DEPLETION RATE 0

CHLOROPHYLL A CONCENTRATION (UG/L) 0

ALGAL PRODUCTION RATE (GMS./SQ.M.) 0 0

R E A C H 6

RIVER MILE	DAYS	BOD	NOD	D.O.	DEFICIT	% SAT.
67	0	11.02	1.05	5.83	4.58	56
66.8	.022	10.99	1.05	5.91	4.5	56.8
66.6	.044	10.96	1.05	5.98	4.43	57.5
66.4	.066	10.93	1.04	6.06	4.35	58.2
66.2	.088	10.9	1.04	6.13	4.28	58.9
66	.11	10.87	1.04	6.2	4.21	59.6

NH3= .24

CHEHALIS RIVER D.O. MODEL
OCT. 11, 1979: NO STP, W-W/O SALZER UPSE

DOWNSTREAM FLOW (CFS) 73 DEPTH & WIDTH 8.8 95 VELOCITY .09
MIXED ULT. BOD (MG/L) 4
MIXED ULT. NOD (MG/L) .09
MIXED TEMPERATURE (C) 14
MIXED D.O. (MG/L) 10
D.O. 100% SAT = 10.37
K1= .09
K2= .13
K3= 0
SEDIMENT DEPTH IN INCHES 0
NON-NOD AMMONIA DEPLETION RATE 0
CHLOROPHYLL A CONCENTRATION (UG/L) 0
ALGAL PRODUCTION RATE (GMS./SQ.M.) 0 0

R E A C H 1

RIVER MILE	DAYS	BOD	NOD	D.O.	DEFICIT	% SAT.
74.3	0	4	.09	10	.37	96.5
74.1	.14	3.95	.09	9.96	.41	96
73.9	.28	3.9	.09	9.91	.45	95.6
73.7	.42	3.85	.09	9.87	.49	95.2
73.5	.56	3.8	.09	9.84	.53	94.9
73.3	.7	3.75	.09	9.8	.57	94.5
73.1	.84	3.71	.09	9.76	.61	94.1
72.9	.98	3.66	.09	9.73	.64	93.8
72.7	1.12	3.61	.09	9.69	.68	93.5

NH3= .02

DOWNSTREAM FLOW (CFS) 76 DEPTH & WIDTH 9.25 95 VELOCITY .09
MIXED ULT. BOD (MG/L) 3.6
MIXED ULT. NOD (MG/L) .09
MIXED TEMPERATURE (C) 15
MIXED D.O. (MG/L) 9.69
D.O. 100% SAT = 10.15
K1= .09
K2= .13
K3= 0
SEDIMENT DEPTH IN INCHES 0
NON-NOD AMMONIA DEPLETION RATE 0
CHLOROPHYLL A CONCENTRATION (UG/L) 0
ALGAL PRODUCTION RATE (GMS./SQ.M.) 0 0

R E A C H 2

RIVER MILE	DAYS	BOD	NOD	D.O.	DEFICIT	% SAT.
72.6	0	3.6	.09	9.69	.46	95.5
72.4	.141	3.55	.09	9.65	.5	95.1
72.2	.283	3.51	.09	9.62	.53	94.7
72	.424	3.46	.09	9.58	.57	94.4
71.8	.565	3.42	.09	9.55	.6	94.1
71.6	.707	3.37	.09	9.51	.64	93.7
71.4	.848	3.33	.09	9.48	.67	93.4
71.2	.989	3.29	.09	9.45	.7	93.1
71	1.131	3.25	.09	9.42	.73	92.8

DOWNSTREAM FLOW (CFS) 80 DEPTH & WIDTH 16 120 VELOCITY .04
MIXED ULT. BOD (MG/L) 3.25
MIXED ULT. NOD (MG/L) .09
MIXED TEMPERATURE (C) 15
MIXED D.O. (MG/L) 9.42
D.O. 100% SAT = 10.15
K1= .09
K2= .04
K3= 0
SEDIMENT DEPTH IN INCHES 0
NON-NOD AMMONIA DEPLETION RATE 0
CHLOROPHYLL A CONCENTRATION (UG/L) 0
ALGAL PRODUCTION RATE (GMS./SQ.M.) 0 0

R E A C H 3

RIVER MILE	DAYS	BOD	NOD	D.O.	DEFICIT	% SAT.
71	0	3.25	.09	9.42	.73	92.8
70.8	.293	3.16	.09	9.34	.81	92
70.6	.587	3.08	.09	9.27	.88	91.3
70.4	.88	3	.09	9.2	.95	90.6
70.2	1.173	2.92	.09	9.13	1.02	89.9
70	1.467	2.84	.09	9.06	1.09	89.3
69.8	1.76	2.77	.09	9	1.15	88.7
69.6	2.053	2.69	.09	8.94	1.21	88.1
69.4	2.347	2.62	.09	8.88	1.27	87.5
69.2	2.64	2.55	.09	8.83	1.32	87

NH3= .02

SALIER CREEK UPSET

********************* INPUT ECHO *********************
UPSTREAM FLOW,PT.SOURCE FLOW (CFS) 82 2.3 DEPTH AND WIDTH 16 120
TEMP UP,PT.SOURCE TEMP 15 16
D.O. UP,PT.SOURCE D.O. 8.83 .8 VELOCITY .04
NH3-N UP, PT.SOURCE NH3-N .02 .03
ULTIMATE BOD UP, PT.SOURCE UBOD 3 860
****

DOWNSTREAM FLOW (CFS) 84.3
DILUTION RATIO 35.65
MIXED ULT. BOD (MG/L) 26.38
MIXED ULT. NOD (MG/L) .09
MIXED TEMPERATURE (C) 15.03
MIXED D.O. (MG/L) 8.61
D.O. 100% SAT = 10.14
K1= .13
K2= .04
K3= .08
SEDIMENT DEPTH IN INCHES 0
NON-NOD AMMONIA DEPLETION RATE 0
CHLOROPHYLL A CONCENTRATION (UG/L) 0
ALGAL PRODUCTION RATE (GMS./SQ.M.) 0 0

RIVER MILE	DAYS	BOD	NOD	D.O.	DEFICIT	% SAT.
69.2	0	26.38	.09	8.61	1.53	84.9
69	.278	25.46	.09	7.71	2.43	76
68.8	.557	24.58	.08	6.85	3.29	67.5
68.6	.835	23.72	.08	6.03	4.11	59.5
68.4	1.113	22.89	.08	5.25	4.89	51.8
68.2	1.392	22.1	.08	4.51	5.64	44.4
68	1.67	21.33	.08	3.8	6.35	37.4
67.8	1.949	20.59	.08	3.12	7.02	30.8
67.6	2.227	19.87	.07	2.48	7.66	24.5

NH3= .02

SALZER CR. OKAY

********************** INPUT ECHO **********************
UPSTREAM FLOW,PT.SOURCE FLOW (CFS) 82 2.3 DEPTH AND WIDTH 16 120
TEMP UP,PT.SOURCE TEMP 15 16
D.O. UP,PT.SOURCE D.O. 8.83 8 VELOCITY .04
NH3-N UP, PT.SOURCE NH3-N .02 .03
ULTIMATE BOD UP, PT.SOURCE UBOD 3 4
****

DOWNSTREAM FLOW (CFS) 84.3
DILUTION RATIO 35.65
MIXED ULT. BOD (MG/L) 3.03
MIXED ULT. NOD (MG/L) .09
MIXED TEMPERATURE (C) 15.03
MIXED D.O. (MG/L) 8.81
D.O. 100% SAT = 10.14
K1= .09
K2= .04
K3= 0
SEDIMENT DEPTH IN INCHES 0
NON-NOD AMMONIA DEPLETION RATE 0
CHLOROPHYLL A CONCENTRATION (UG/L) 0
ALGAL PRODUCTION RATE (GMS./SQ.M.) 0 0

R E A C H 4

RIVER MILE	DAYS	BOD	NOD	D.O.	DEFICIT	% SAT.
69.2	0	3.03	.09	8.81	1.34	86.8
69	.278	2.95	.09	8.75	1.4	86.2
68.8	.557	2.88	.09	8.69	1.46	85.6
68.6	.835	2.8	.09	8.63	1.51	85.1
68.4	1.113	2.73	.09	8.57	1.57	84.5
68.2	1.392	2.67	.09	8.52	1.62	84
68	1.67	2.6	.09	8.47	1.67	83.5
67.8	1.949	2.53	.09	8.42	1.72	83
67.6	2.227	2.47	.09	8.38	1.77	82.6

NH3= .02

CHEHALIS RIVER D.O. MODEL
OCT. 1979: CHEHALIS STP + SALZER CR. OKAY

********************* INPUT ECHO *********************
UPSTREAM FLOW,PT.SOURCE FLOW (CFS) 84 2.3   DEPTH AND WIDTH 16 120
TEMP UP,PT.SOURCE TEMP 15 16
D.O. UP,PT.SOURCE D.O. 7.8 8   VELOCITY .04
NH3-N UP, PT.SOURCE NH3-N .1 .03
ULTIMATE BOD UP, PT.SOURCE UBOD 5.24 4
****

DOWNSTREAM FLOW (CFS) 86.3
DILUTION RATIO 36.52
MIXED ULT. BOD (MG/L) 5.21
MIXED ULT. NOD (MG/L) .42
MIXED TEMPERATURE (C) 15.03
MIXED D.O. (MG/L) 7.81
D.O. 100% SAT = 10.14
K1= .06
K2= .04
K3= 0
SEDIMENT DEPTH IN INCHES 0
NON-NOD AMMONIA DEPLETION RATE 0
CHLOROPHYLL A CONCENTRATION (UG/L) 0
ALGAL PRODUCTION RATE (GMS./SQ.M.) 0 0

R E A C H 4

RIVER MILE	DAYS	BOD	NOD	D.O.	DEFICIT	% SAT.
69.2	0	5.21	.42	7.81	2.34	76.9
69	.272	5.12	.42	7.74	2.4	76.3
68.8	.544	5.03	.42	7.68	2.47	75.7
68.6	.816	4.94	.42	7.62	2.53	75.1
68.4	1.088	4.86	.42	7.56	2.59	74.5
68.2	1.36	4.78	.42	7.5	2.64	73.9
68	1.632	4.69	.42	7.44	2.7	73.4
67.8	1.903	4.61	.42	7.39	2.75	72.9
67.6	2.175	4.53	.42	7.34	2.8	72.4

NH3= .1

DOWNSTREAM FLOW (CFS) 88 DEPTH & WIDTH 5.5 95 VELOCITY .19
MIXED ULT. BOD (MG/L) 4.5
MIXED ULT. NOD (MG/L) .43
MIXED TEMPERATURE (C) 15
MIXED D.O. (MG/L) 7.3
D.O. 100% SAT = 10.15
K1= .07
K2= .4
K3= 0
SEDIMENT DEPTH IN INCHES 0
NON-NOD AMMONIA DEPLETION RATE 0
CHLOROPHYLL A CONCENTRATION (UG/L) 0
ALGAL PRODUCTION RATE (GMS./SQ.M.) 0 0

R E A C H 5

RIVER MILE	DAYS	BOD	NOD	D.O.	DEFICIT	% SAT.
67.6	0	4.5	.43	7.3	2.85	71.9
67.4	.073	4.48	.43	7.36	2.79	72.5
67.2	.145	4.45	.43	7.42	2.73	73.1
67	.218	4.43	.43	7.47	2.68	73.6

NH_3= .1

APPENDIX V

PRINTOUTS FOR CHEHALIS STP OVERLOAD SIMULATIONS

CURVE NUMBERS CORRESPOND TO FIGURES 12, 13,
AND ASSOCIATED SIMULATION CONDITIONS

CHEHALIS RIVER D.O. MODEL
OVERLOAD/20/O.K./NO BENTHIC DEMAND

********************* INPUT ECHO *********************
UPSTREAM FLOW,PT.SOURCE FLOW (CFS) 73 2.3 DEPTH AND WIDTH 8.9 95
TEMP UP,PT.SOURCE TEMP 20 20
D.O. UP,PT.SOURCE D.O. 8.8 9.03 VELOCITY .09
NH3-N UP, PT.SOURCE NH3-N .02 11
ULTIMATE BOD UP, PT.SOURCE UBOD 4 30
****

DOWNSTREAM FLOW (CFS) 75.3
DILUTION RATIO 31.74
MIXED ULT. BOD (MG/L) 4.79
MIXED ULT. NOD (MG/L) 1.54
MIXED TEMPERATURE (C) 20
MIXED D.O. (MG/L) 8.81
D.O. 100% SAT = 9.18
K1= .1
K2= .15
K3= .12
SEDIMENT DEPTH IN INCHES 0
NON-NOD AMMONIA DEPLETION RATE 0
CHLOROPHYLL A CONCENTRATION (UG/L) 0
ALGAL PRODUCTION RATE (GMS./SQ.M.) 0 0

R E A C H 1

RIVER MILE	DAYS	BOD	NOD	D.O.	DEFICIT	% SAT.
74.3	0	4.79	1.54	8.81	.37	96
74.1	.137	4.73	1.51	8.72	.45	95.1
73.9	.274	4.66	1.49	8.65	.53	94.2
73.7	.412	4.6	1.46	8.57	.61	93.4
73.5	.549	4.54	1.44	8.5	.68	92.6
73.3	.686	4.48	1.42	8.42	.75	91.8
73.1	.823	4.42	1.39	8.36	.82	91.1
72.9	.961	4.36	1.37	8.29	.89	90.3
72.7	1.098	4.3	1.35	8.23	.95	89.7

NH3= .31

DOWNSTREAM FLOW (CFS) 79 DEPTH & WIDTH 9.25 95 VELOCITY .09
MIXED ULT. BOD (MG/L) 4.3
MIXED ULT. NOD (MG/L) 1.34
MIXED TEMPERATURE (C) 20
MIXED D.O. (MG/L) 8.23
D.O. 100% SAT = 9.18
K1= .1
K2= .14
K3= .12
SEDIMENT DEPTH IN INCHES 0
NON-NOD AMMONIA DEPLETION RATE 0
CHLOROPHYLL A CONCENTRATION (UG/L) 0
ALGAL PRODUCTION RATE (GMS./SQ.M.) 0 0

R E A C H 2

RIVER MILE	DAYS	BOD	NOD	D.O.	DEFICIT	% SAT.
72.6	0	4.3	1.34	8.23	.95	89.7
72.4	.136	4.24	1.32	8.17	1.01	89
72.2	.272	4.18	1.3	8.11	1.07	88.4
72	.408	4.13	1.28	8.05	1.12	87.8
71.8	.544	4.07	1.26	8	1.18	87.2
71.6	.68	4.02	1.24	7.94	1.23	86.6
71.4	.816	3.96	1.22	7.89	1.28	86
71.2	.952	3.91	1.2	7.84	1.33	85.5
71	1.088	3.86	1.18	7.8	1.38	85

NH3= .27

DOWNSTREAM FLOW (CFS) 83 DEPTH & WIDTH 16 120 VELOCITY .04
MIXED ULT. BOD (MG/L) 4
MIXED ULT. NOD (MG/L) 1.17
MIXED TEMPERATURE (C) 20
MIXED D.O. (MG/L) 7.8
D.O. 100% SAT = 9.18
K1= .1
K2= .04
K3= .09
SEDIMENT DEPTH IN INCHES 0
NON NOD AMMONIA DEPLETION RATE 0
CHLOROPHYLL A CONCENTRATION (UG/L) 0
ALGAL PRODUCTION RATE (GMS./SQ.M.) 0 0

R E A C H 3

RIVER MILE	DAYS	BOD	NOD	D.O.	DEFICIT	% SAT.
71	0	4	1.17	7.8	1.38	85
70.8	.283	3.89	1.14	7.68	1.5	83.7
70.6	.565	3.78	1.11	7.56	1.62	82.4
70.4	.848	3.67	1.08	7.44	1.73	81.1
70.2	1.131	3.57	1.06	7.33	1.84	79.9
70	1.414	3.47	1.03	7.23	1.95	78.8
69.8	1.696	3.38	1	7.13	2.05	77.7
69.6	1.979	3.28	.98	7.03	2.14	76.7
69.4	2.262	3.19	.95	6.94	2.23	75.7
69.2	2.545	3.1	.93	6.85	2.32	74.7

NH3= .21

********************** INPUT ECHO *********************
UPSTREAM FLOW,PT.SOURCE FLOW (CFS) 83 2.3 DEPTH AND WIDTH 16 120
TEMP UP,PT.SOURCE TEMP 20 20
D.O. UP,PT.SOURCE D.O. 6.85 8 VELOCITY .04
NH3-N UP, PT.SOURCE NH3-N .21 .03
ULTIMATE BOD UP, PT.SOURCE UBOD 4 4
****

DOWNSTREAM FLOW (CFS) 85.3
DILUTION RATIO 36.09
MIXED ULT. BOD (MG/L) 4
MIXED ULT. NOD (MG/L) .89
MIXED TEMPERATURE (C) 20
MIXED D.O. (MG/L) 6.88
D.O. 100% SAT = 9.18
K1= .1
K2= .04
K3= .01
SEDIMENT DEPTH IN INCHES 0
NON-NOD AMMONIA DEPLETION RATE 0
CHLOROPHYLL A CONCENTRATION (UG/L) 0
ALGAL PRODUCTION RATE (GMS./SQ.M.) 0 0

R E A C H 4

RIVER MILE	DAYS	BOD	NOD	D.O.	DEFICIT	% SAT.
69.2	0	4	.89	6.88	2.29	75
69	.275	3.89	.89	6.8	2.38	74.1
68.8	.55	3.79	.88	6.72	2.46	73.2
68.6	.825	3.68	.88	6.64	2.54	72.3
68.4	1.1	3.58	.88	6.56	2.61	71.5
68.2	1.376	3.49	.88	6.49	2.68	70.8
68	1.651	3.39	.88	6.43	2.75	70.1
67.8	1.926	3.3	.87	6.36	2.81	69.4
67.6	2.201	3.21	.87	6.3	2.87	68.7

NH3= .2

CHEHALIS RIVER D.O. MODEL
OVERLOAD/N.B/20/UPSTM. OK

********************* INPUT ECHO *********************

UPSTREAM FLOW,PT.SOURCE FLOW (CFS) 73 2.3 DEPTH AND WIDTH 8.9 95
TEMP UP,PT.SOURCE TEMP 20 20
D.O. UP,PT.SOURCE D.O. 8.8 6.5 VELOCITY .09
NH3-N UP, PT.SOURCE NH3-N .02 20
ULTIMATE BOD UP, PT.SOURCE UBOD 4 105

****

DOWNSTREAM FLOW (CFS) 75.3
DILUTION RATIO 31.74
MIXED ULT. BOD (MG/L) 7.08
MIXED ULT. NOD (MG/L) 2.73
MIXED TEMPERATURE (C) 20
MIXED D.O. (MG/L) 8.73
D.O. 100% SAT = 9.18
K1= .1
K2= .15
K3= .12
SEDIMENT DEPTH IN INCHES 0
NON-NOD AMMONIA DEPLETION RATE 0
CHLOROPHYLL A CONCENTRATION (UG/L) 0
ALGAL PRODUCTION RATE (GMS./SQ.M.) 0 0

R E A C H 1

RIVER MILE	DAYS	BOD	NOD	D.O.	DEFICIT	% SAT.
74.3	0	7.08	2.73	8.73	.45	95.1
74.1	.137	6.99	2.68	8.6	.58	93.7
73.9	.274	6.89	2.64	8.47	.7	92.3
73.7	.412	6.8	2.6	8.35	.82	91
73.5	.549	6.71	2.56	8.23	.94	89.7
73.3	.686	6.62	2.51	8.12	1.06	88.5
73.1	.823	6.52	2.47	8.01	1.16	87.3
72.9	.961	6.44	2.43	7.91	1.27	86.2
72.7	1.098	6.35	2.39	7.81	1.37	85.1

NH3= .55

DOWNSTREAM FLOW (CFS) 79 DEPTH & WIDTH 9.25 95 VELOCITY .09
MIXED ULT. BOD (MG/L) 6.35
MIXED ULT. NOD (MG/L) 2.38
MIXED TEMPERATURE (C) 20
MIXED D.O. (MG/L) 7.81
D.O. 100% SAT = 9.18
K1= .1
K2= .14
K3= .12
SEDIMENT DEPTH IN INCHES 0
NON-NOD AMMONIA DEPLETION RATE 0
CHLOROPHYLL A CONCENTRATION (UG/L) 0
ALGAL PRODUCTION RATE (GMS./SQ.M.) 0 0

RIVER MILE	DAYS	BOD	NOD	D.O.	DEFICIT	% SAT.
72.6	0	6.35	2.38	7.81	1.37	85.1
72.4	.136	6.26	2.34	7.71	1.46	84.1
72.2	.272	6.18	2.31	7.62	1.56	83
72	.408	6.1	2.27	7.53	1.65	82
71.8	.544	6.01	2.23	7.44	1.74	81.1
71.6	.68	5.93	2.19	7.36	1.82	80.2
71.4	.816	5.85	2.16	7.27	1.9	79.3
71.2	.952	5.77	2.12	7.2	1.98	78.4
71	1.088	5.7	2.09	7.12	2.05	77.6

NH3= .48

DOWNSTREAM FLOW (CFS) 83 DEPTH & WIDTH 16 120 VELOCITY .04
MIXED ULT. BOD (MG/L) 5.7
MIXED ULT. NOD (MG/L) 2.08
MIXED TEMPERATURE (C) 20
MIXED D.O. (MG/L) 7.12
D.O. 100% SAT = 9.18
K1= .1
K2= .04
K3= .09
SEDIMENT DEPTH IN INCHES 0
NON-NOD AMMONIA DEPLETION RATE 0
CHLOROPHYLL A CONCENTRATION (UG/L) 0
ALGAL PRODUCTION RATE (GMS./SQ.M.) 0 0

R E A C H 3

RIVER MILE	DAYS	BOD	NOD	D.O.	DEFICIT	% SAT.
71	0	5.7	2.08	7.12	2.06	77.6
70.8	.283	5.54	2.03	6.93	2.24	75.6
70.6	.565	5.39	1.98	6.75	2.42	73.6
70.4	.848	5.24	1.93	6.58	2.59	71.8
70.2	1.131	5.09	1.88	6.42	2.76	70
70	1.414	4.95	1.83	6.26	2.91	68.3
69.8	1.696	4.81	1.78	6.11	3.06	66.6
69.6	1.979	4.68	1.74	5.97	3.21	65.1
69.4	2.262	4.55	1.7	5.83	3.34	63.6
69.2	2.545	4.42	1.65	5.7	3.47	62.2

NH3= .38

********************** INPUT ECHO **********************
UPSTREAM FLOW,PT.SOURCE FLOW (CFS) 83 2.3 DEPTH AND WIDTH 16 120
TEMP UP,PT.SOURCE TEMP 20 20
D.O. UP,PT.SOURCE D.O. 5.7 8 VELOCITY .04
NH3-N UP. PT.SOURCE NH3-N .38 .03
ULTIMATE BOD UP. PT.SOURCE UBOD 4.4 4
****

DILUTION RATIO 36.09
MIXED ULT. BOD (MG/L) 4.39
MIXED ULT. NOD (MG/L) 1.6
MIXED TEMPERATURE (C) 20
MIXED D.O. (MG/L) 5.76
D.O. 100% SAT = 9.18
K1= .1
K2= .04
K3= .01
SEDIMENT DEPTH IN INCHES 0
NON-NOD AMMONIA DEPLETION RATE 0
CHLOROPHYLL A CONCENTRATION (UG/L) 0
ALGAL PRODUCTION RATE (GMS./SQ.M.) 0 0

R E A C H 1

RIVER MILE	DAYS	BOD	NOD	D.O.	DEFICIT	% SAT.
69.2	0	4.39	1.6	5.76	3.41	62.8
69	.275	4.27	1.6	5.68	3.5	61.9
68.8	.55	4.15	1.6	5.6	3.58	61
68.6	.825	4.04	1.59	5.52	3.66	60.2
68.4	1.1	3.93	1.59	5.45	3.73	59.4
68.2	1.376	3.83	1.58	5.38	3.8	58.6
68	1.651	3.72	1.58	5.31	3.86	57.9
67.8	1.926	3.62	1.58	5.25	3.92	57.2
67.6	2.201	3.52	1.57	5.19	3.98	56.6

NH3= .36

CHEHALIS RIVER D.O. MODEL
OVERLOAD/N.B./20/STP OK

********************** INPUT ECHO **********************
UPSTREAM FLOW,PT.SOURCE FLOW (CFS) 73 2.3 DEPTH AND WIDTH 8.9 95
TEMP UP,PT.SOURCE TEMP 20 20
D.O. UP,PT.SOURCE D.O. 8 9.03 VELOCITY .09
NH3-N UP, PT.SOURCE NH3-N .15 11
ULTIMATE BOD UP, PT.SOURCE UBOD 6 30
****

DOWNSTREAM FLOW (CFS) 75.3
DILUTION RATIO 31.74
MIXED ULT. BOD (MG/L) 6.73
MIXED ULT. NOD (MG/L) 2.08
MIXED TEMPERATURE (C) 20
MIXED D.O. (MG/L) 8.03
D.O. 100% SAT = 9.18
K1= .1
K2= .15
K3= .12
SEDIMENT DEPTH IN INCHES 0
NON-NOD AMMONIA DEPLETION RATE 0
CHLOROPHYLL A CONCENTRATION (UG/L) 0
ALGAL PRODUCTION RATE (GMS./SQ.M.) 0 0

R E A C H 1

RIVER MILE	DAYS	BOD	NOD	D.O.	DEFICIT	% SAT.
74.3	0	6.73	2.08	8.03	1.14	87.5
74.1	.137	6.64	2.05	7.93	1.25	86.4
73.9	.274	6.55	2.02	7.83	1.34	85.4
73.7	.412	6.46	1.98	7.74	1.44	84.3
73.5	.549	6.37	1.95	7.65	1.53	83.3
73.3	.686	6.29	1.92	7.56	1.62	82.4
73.1	.823	6.2	1.89	7.48	1.7	81.5
72.9	.961	6.12	1.86	7.39	1.78	80.6
72.7	1.098	6.03	1.83	7.32	1.86	79.8

NH3= .42

DOWNSTREAM FLOW (CFS) 79 DEPTH & WIDTH 9.25 95 VELOCITY .09
MIXED ULT. BOD (MG/L) 6.03
MIXED ULT. NOD (MG/L) 1.82
MIXED TEMPERATURE (C) 20
MIXED D.O. (MG/L) 7.32
D.O. 100% SAT = 9.18
K1= .1
K2= .14
K3= .12
SEDIMENT DEPTH IN INCHES 0
NON-NOD AMMONIA DEPLETION RATE 0
CHLOROPHYLL A CONCENTRATION (UG/L) 0
ALGAL PRODUCTION RATE (GMS./SQ.M.) 0 0

RIVER MILE	DAYS	BOD	NOD	D.O.	DEFICIT	% SAT.
72.6	0	6.03	1.82	7.32	1.86	79.8
72.4	.136	5.95	1.79	7.24	1.93	79
72.2	.272	5.87	1.76	7.17	2	78.2
72	.408	5.79	1.73	7.1	2.07	77.4
71.8	.544	5.71	1.7	7.04	2.14	76.7
71.6	.68	5.63	1.68	6.97	2.2	76
71.4	.816	5.56	1.65	6.91	2.26	75.3
71.2	.952	5.48	1.62	6.85	2.32	74.7
71	1.088	5.41	1.6	6.8	2.38	74.1

NH3= .37

DOWNSTREAM FLOW (CFS) 83 DEPTH & WIDTH 16 120 VELOCITY .04
MIXED ULT. BOD (MG/L) 5.4
MIXED ULT. NOD (MG/L) 1.6
MIXED TEMPERATURE (C) 20
MIXED D.O. (MG/L) 6.8
D.O. 100% SAT = 9.18
K1= .1
K2= .04
K3= .09
SEDIMENT DEPTH IN INCHES 0
NON-NOD AMMONIA DEPLETION RATE 0
CHLOROPHYLL A CONCENTRATION (UG/L) 0
ALGAL PRODUCTION RATE (GMS./SQ.M.) 0 0

R E A C H 3

RIVER MILE	DAYS	BOD	NOD	D.O.	DEFICIT	% SAT.
71	0	5.4	1.6	6.8	2.38	74.1
70.8	.283	5.25	1.56	6.64	2.54	72.3
70.6	.565	5.1	1.52	6.48	2.69	70.6
70.4	.848	4.96	1.48	6.33	2.84	69
70.2	1.131	4.82	1.45	6.19	2.99	67.5
70	1.414	4.69	1.41	6.05	3.12	66
69.8	1.696	4.56	1.38	5.92	3.25	64.6
69.6	1.979	4.43	1.34	5.8	3.37	63.2
69.4	2.262	4.31	1.31	5.68	3.49	61.9
69.2	2.545	4.19	1.27	5.57	3.61	60.7

NH3= .29

********************** INPUT ECHO *********************
UPSTREAM FLOW,PT.SOURCE FLOW (CFS) 83 2.3 DEPTH AND WIDTH 16 120
TEMP UP,PT.SOURCE TEMP 20 20
D.O. UP,PT.SOURCE D.O. 5.57 8 VELOCITY .04
NH3-N UP, PT.SOURCE NH3-N .29 .03
ULTIMATE BOD UP, PT.SOURCE UBOD 4.2 4
****

DILUTION RATIO 36.09
MIXED ULT. BOD (MG/L) 4.19
MIXED ULT. NOD (MG/L) 1.23
MIXED TEMPERATURE (C) 20
MIXED D.O. (MG/L) 5.64
D.O. 100% SAT = 9.18
K1= .1
K2= .04
K3= .01
SEDIMENT DEPTH IN INCHES 0
NON-NOD AMMONIA DEPLETION RATE 0
CHLOROPHYLL A CONCENTRATION (UG/L) 0
ALGAL PRODUCTION RATE (GMS./SQ.M.) 0 0

R E A C H 1

RIVER MILE	DAYS	BOD	NOD	D.O.	DEFICIT	% SAT.
69.2	0	4.19	1.23	5.64	3.54	61.4
69	.275	4.08	1.22	5.56	3.62	60.6
68.8	.55	3.97	1.22	5.49	3.69	59.8
68.6	.825	3.86	1.22	5.42	3.76	59
68.4	1.1	3.76	1.21	5.35	3.83	58.3
68.2	1.376	3.66	1.21	5.29	3.89	57.6
68	1.651	3.56	1.21	5.23	3.95	57
67.8	1.926	3.46	1.2	5.17	4	56.4
67.6	2.201	3.37	1.2	5.12	4.05	55.8

NH3= .28

CURVE 4

CHEHALIS RIVER D.O. MODEL
OVERLOAD/N.D./20

********************* INPUT ECHO *********************
UPSTREAM FLOW,PT.SOURCE FLOW (CFS) 73 2.3 DEPTH AND WIDTH 8.9 95
TEMP UP,PT.SOURCE TEMP 20 20
D.O. UP,PT.SOURCE D.O. 8 6.5 VELOCITY .09
NH3-N UP, PT.SOURCE NH3-N .15 20
ULTIMATE BOD UP, PT.SOURCE UBOD 6 105
****

DOWNSTREAM FLOW (CFS) 75.3
DILUTION RATIO 31.74
MIXED ULT. BOD (MG/L) 9.02
MIXED ULT. NOD (MG/L) 3.27
MIXED TEMPERATURE (C) 20
MIXED D.O. (MG/L) 7.95
D.O. 100% SAT = 9.18
K1= .1
K2= .15
K3= .12
SEDIMENT DEPTH IN INCHES 0
NON-NOD AMMONIA DEPLETION RATE 0
CHLOROPHYLL A CONCENTRATION (UG/L) 0
ALGAL PRODUCTION RATE (GMS./SQ.M.) 0 0

R E A C H 1

RIVER MILE	DAYS	BOD	NOD	D.O.	DEFICIT	% SAT.
74.3	0	9.02	3.27	7.95	1.22	86.7
74.1	.137	8.9	3.22	7.8	1.37	85.1
73.9	.274	8.78	3.17	7.66	1.52	83.5
73.7	.412	8.66	3.12	7.52	1.66	81.9
73.5	.549	8.54	3.07	7.38	1.79	80.5
73.3	.686	8.43	3.02	7.26	1.92	79.1
73.1	.823	8.31	2.97	7.13	2.04	77.7
72.9	.961	8.2	2.92	7.01	2.16	76.4
72.7	1.098	8.09	2.87	6.9	2.28	75.2

NH3= .66

DOWNSTREAM FLOW (CFS) 79 DEPTH & WIDTH 9.25 95 VELOCITY .09
MIXED ULT. BOD (MG/L) 8.1
MIXED ULT. NOD (MG/L) 2.86
MIXED TEMPERATURE (C) 20
MIXED D.O. (MG/L) 6.9
D.O. 100% SAT = 9.18
K1= .1
K2= .14
K3= .12
SEDIMENT DEPTH IN INCHES 0
NON-NOD AMMONIA DEPLETION RATE 0
CHLOROPHYLL A CONCENTRATION (UG/L) 0
ALGAL PRODUCTION RATE (GMS./SQ.M.) 0 0

R E A C H 2

RIVER MILE	DAYS	BOD	NOD	D.O.	DEFICIT	% SAT.
72.6	0	8.1	2.86	6.9	2.28	75.2
72.4	.136	7.99	2.81	6.79	2.39	74
72.2	.272	7.88	2.77	6.68	2.49	72.8
72	.408	7.78	2.72	6.58	2.6	71.7
71.8	.544	7.67	2.68	6.48	2.7	70.6
71.6	.68	7.57	2.63	6.38	2.79	69.6
71.4	.816	7.47	2.59	6.29	2.89	68.6
71.2	.952	7.36	2.55	6.2	2.97	67.6
71	1.088	7.27	2.51	6.12	3.06	66.7

NH3= .58

DOWNSTREAM FLOW (CFS) 83 DEPTH & WIDTH 16 120 VELOCITY .04
MIXED ULT. BOD (MG/L) 7.27
MIXED ULT. NOD (MG/L) 2.51
MIXED TEMPERATURE (C) 20
MIXED D.O. (MG/L) 6.12
D.O. 100% SAT = 9.18
K1= .1
K2= .04
K3= .09
SEDIMENT DEPTH IN INCHES 0
NON-NOD AMMONIA DEPLETION RATE 0
CHLOROPHYLL A CONCENTRATION (UG/L) 0
ALGAL PRODUCTION RATE (GMS./SQ.M.) 0 0

R E A C H 3

RIVER MILE	DAYS	BOD	NOD	D.O.	DEFICIT	% SAT.
71	0	7.27	2.51	6.12	3.06	66.7
70.8	.283	7.07	2.45	5.89	3.28	64.2
70.6	.565	6.87	2.39	5.67	3.5	61.8
70.4	.848	6.68	2.33	5.46	3.71	59.5
70.2	1.131	6.49	2.27	5.26	3.92	57.3
70	1.414	6.31	2.21	5.07	4.11	55.2
69.8	1.696	6.14	2.16	4.88	4.29	53.2
69.6	1.979	5.96	2.1	4.71	4.47	51.3
69.4	2.262	5.8	2.05	4.54	4.63	49.5
69.2	2.545	5.64	2	4.38	4.79	47.8

NH3= .46

********************** INPUT ECHO **********************
UPSTREAM FLOW,PT.SOURCE FLOW (CFS) 83 2.3 DEPTH AND WIDTH 16 120
TEMP UP,PT.SOURCE TEMP 20 20
D.O. UP,PT.SOURCE D.O. 4.38 8 VELOCITY .04
NH3-N UP, PT.SOURCE NH3-N .46 .03
ULTIMATE BOD UP, PT.SOURCE UBOD 5.6 4
****

DOWNSTREAM FLOW (CFS) 85.3
DILUTION RATIO 36.09
MIXED ULT. BOD (MG/L) 5.56
MIXED ULT. NOD (MG/L) 1.94
MIXED TEMPERATURE (C) 20
MIXED D.O. (MG/L) 4.48
D.O. 100% SAT = 9.18
K1= .1
K2= .04
K3= .01
SEDIMENT DEPTH IN INCHES 0
NON-NOD AMMONIA DEPLETION RATE 0
CHLOROPHYLL A CONCENTRATION (UG/L) 0
ALGAL PRODUCTION RATE (GMS./SQ.M.) 0 0

R E A C H 4

RIVER MILE	DAYS	BOD	NOD	D.O.	DEFICIT	% SAT.
69.2	0	5.56	1.94	4.48	4.7	48.8
69	.275	5.41	1.94	4.37	4.8	47.7
68.8	.55	5.26	1.93	4.28	4.9	46.6
68.6	.825	5.12	1.93	4.18	4.99	45.6
68.4	1.1	4.98	1.92	4.1	5.08	44.6
68.2	1.376	4.84	1.92	4.01	5.16	43.7
68	1.651	4.71	1.91	3.94	5.24	42.9
67.8	1.926	4.58	1.91	3.86	5.31	42.1
67.6	2.201	4.46	1.9	3.79	5.38	41.3

NH3= .44

CHEHALIS RIVER D.O. MODEL
OVERLOAD/20/BENTHIC

********************* INPUT ECHO *********************
UPSTREAM FLOW,PT.SOURCE FLOW (CFS) 73 2.3 DEPTH AND WIDTH 8.9 95
TEMP UP,PT.SOURCE TEMP 20 20
D.O. UP,PT.SOURCE D.O. 8 6.5 VELOCITY .09
NH3-N UP, PT.SOURCE NH3-N .15 20
ULTIMATE BOD UP, PT.SOURCE UBOD 6 105
****

DOWNSTREAM FLOW (CFS) 75.3
DILUTION RATIO 31.74
MIXED ULT. BOD (MG/L) 9.02
MIXED ULT. NOD (MG/L) 3.27
MIXED TEMPERATURE (C) 20
MIXED D.O. (MG/L) 7.95
D.O. 100% SAT = 9.18
K1= .1
K2= .15
K3= .12
SEDIMENT DEPTH IN INCHES .5
NON-NOD AMMONIA DEPLETION RATE 0
CHLOROPHYLL A CONCENTRATION (UG/L) 0
ALGAL PRODUCTION RATE (GMS./SQ.M.) 0 0

R E A C H 1

RIVER MILE	DAYS	BOD	NOD	D.O.	DEFICIT	% SAT.
74.3	0	9.02	3.27	7.95	1.22	86.7
74.1	.137	8.9	3.22	7.65	1.53	83.3
73.9	.274	8.78	3.17	7.35	1.83	80.1
73.7	.412	8.66	3.12	7.05	2.12	76.9
73.5	.549	8.54	3.07	6.77	2.4	73.8
73.3	.686	8.43	3.02	6.5	2.68	70.8
73.1	.823	8.31	2.97	6.23	2.95	67.9
72.9	.961	8.2	2.92	5.97	3.21	65.1
72.7	1.098	8.09	2.87	5.72	3.46	62.3

NH3= .66

DOWNSTREAM FLOW (CFS) 79 DEPTH & WIDTH 9.25 95 VELOCITY .09
MIXED ULT. BOD (MG/L) 8.1
MIXED ULT. NOD (MG/L) 2.86
MIXED TEMPERATURE (C) 20
MIXED D.O. (MG/L) 5.72
D.O. 100% SAT = 9.18
K1= .1
K2= .14
K3= .12
SEDIMENT DEPTH IN INCHES 0
NON-NOD AMMONIA DEPLETION RATE 0
CHLOROPHYLL A CONCENTRATION (UG/L) 0
ALGAL PRODUCTION RATE (GMS./SQ.M.) 0 0

RIVER MILE	DAYS	BOD	NOD	D.O.	DEFICIT	% SAT.
72.6	0	8.1	2.86	5.72	3.46	62.3
72.4	.136	7.99	2.81	5.63	3.55	61.4
72.2	.272	7.88	2.77	5.54	3.63	60.4
72	.408	7.78	2.72	5.46	3.71	59.5
71.8	.544	7.67	2.68	5.38	3.79	58.7
71.6	.68	7.57	2.63	5.31	3.87	57.8
71.4	.816	7.47	2.59	5.24	3.94	57.1
71.2	.952	7.36	2.55	5.17	4.01	56.3
71	1.088	7.27	2.51	5.1	4.07	55.6

NH3= .58

DOWNSTREAM FLOW (CFS) 83 DEPTH & WIDTH 16 120 VELOCITY .04
MIXED ULT. BOD (MG/L) 7.27
MIXED ULT. NOD (MG/L) 2.51
MIXED TEMPERATURE (C) 20
MIXED D.O. (MG/L) 5.1
D O. 100% SAT = 9.18
K1= .1
K2= .04
K3= .09
SEDIMENT DEPTH IN INCHES 0
NON-NOD AMMONIA DEPLETION RATE 0
CHLOROPHYLL A CONCENTRATION (UG/L) 0
ALGAL PRODUCTION RATE (GMS./SQ.M.) 0 0

R E A C H 3

RIVER MILE	DAYS	BOD	NOD	D.O.	DEFICIT	% SAT.
71	0	7.27	2.51	5.1	4.08	55.6
70.8	.283	7.07	2.45	4.88	4.29	53.2
70.6	.565	6.87	2.39	4.67	4.5	50.9
70.4	.848	6.68	2.33	4.47	4.7	48.8
70.2	1.131	6.49	2.27	4.28	4.89	46.7
70	1.414	6.31	2.21	4.1	5.07	44.7
69.8	1.696	6.14	2.16	3.93	5.24	42.8
69.6	1.979	5.96	2.1	3.77	5.41	41
69.4	2.262	5.8	2.05	3.61	5.57	39.3
69.2	2.545	5.64	2	3.46	5.71	37.7

NH3= .46

********************* INPUT ECHO *********************
UPSTREAM FLOW,PT.SOURCE FLOW (CFS) 83 2.3 DEPTH AND WIDTH 16 120
TEMP UP,PT.SOURCE TEMP 20 20
D.O. UP,PT.SOURCE D.O. 3.5 8 VELOCITY .04
NH3-N UP, PT.SOURCE NH3-N .46 .03
ULTIMATE BOD UP, PT.SOURCE UBOD 5.7 4
****

DILUTION RATIO 36.09
MIXED ULT. BOD (MG/L) 5.65
MIXED ULT. NOD (MG/L) 1.94
MIXED TEMPERATURE (C) 20
MIXED D.O. (MG/L) 3.62
D.O. 100% SAT = 9.18
K1= .1
K2= .04
K3= .09
SEDIMENT DEPTH IN INCHES 0
NON-NOD AMMONIA DEPLETION RATE 0
CHLOROPHYLL A CONCENTRATION (UG/L) 0
ALGAL PRODUCTION RATE (GMS./SQ.M.) 0 0

R E A C H 4

RIVER MILE	DAYS	BOD	NOD	D.O.	DEFICIT	% SAT.
69.2	0	5.65	1.94	3.62	5.55	39.5
69	.275	5.5	1.89	3.48	5.69	38
68.8	.55	5.35	1.85	3.35	5.82	36.5
68.6	.825	5.21	1.8	3.23	5.95	35.2
68.4	1.1	5.06	1.76	3.11	6.07	33.9
68.2	1.376	4.93	1.72	2.99	6.18	32.6
68	1.651	4.79	1.67	2.89	6.29	31.5
67.8	1.926	4.66	1.63	2.79	6.39	30.4
67.6	2.201	4.54	1.59	2.69	6.48	29.3

NH3= .37

CHEHALIS RIVER D.O. MODEL
CHEHALIS STP OVERLOAD W/O BENTHIC — 15°C

```
*********************** INPUT ECHO *********************
UPSTREAM FLOW,PT.SOURCE FLOW (CFS) 73  2.3      DEPTH AND WIDTH    8.9  95
TEMP UP,PT.SOURCE TEMP                15  15
D.O. UP,PT.SOURCE D.O.                8.85  7     VELOCITY .09
NH3-N UP, PT.SOURCE NH3-N             .15  20
ULTIMATE BOD UP, PT.SOURCE UBOD       6  105
**********************************************************

DOWNSTREAM FLOW (CFS)       75.3
DILUTION RATIO              31.74
MIXED ULT. BOD (MG/L)       9.02
MIXED ULT. NOD (MG/L)       3.27
MIXED TEMPERATURE (C)       15
MIXED D.O. (MG/L)           8.79
D.O. 100% SAT =             10.15
K1=                         .08
K2=                         .13
K3=                         .12
SEDIMENT DEPTH IN INCHES 0
NON-NOD AMMONIA DEPLETION RATE 0
CHLOROPHYLL A CONCENTRATION (UG/L) 0
ALGAL PRODUCTION RATE (GMS./SQ.M.) 0          0
```

R E A C H   1

RIVER MILE	DAYS	BOD	NOD	D.O.	DEFICIT	% SAT.
74.3	0	9.02	3.27	8.79	1.36	86.6
74.1	.137	8.93	3.22	8.67	1.48	85.4
73.9	.274	8.83	3.17	8.55	1.6	84.2
73.7	.412	8.73	3.12	8.43	1.72	83.1
73.5	.549	8.64	3.07	8.32	1.83	82
73.3	.686	8.54	3.02	8.21	1.94	80.9
73.1	.823	8.45	2.97	8.1	2.05	79.8
72.9	.961	8.36	2.92	8	2.15	78.8
72.7	1.098	8.27	2.87	7.9	2.25	77.9

NH3= .66

```
-----------------------------------------------------------------

DOWNSTREAM FLOW (CFS)      79 DEPTH & WIDTH 9.25  95 VELOCITY .09
MIXED ULT. BOD (MG/L)       8.27
MIXED ULT. NOD (MG/L)       2.86
MIXED TEMPERATURE (C)       15
MIXED D.O. (MG/L)           7.9
D.O. 100% SAT =             10.15
K1=                         .08
K2=                         .13
K3=                         .12
SEDIMENT DEPTH IN INCHES 0
NON-NOD AMMONIA DEPLETION RATE 0
CHLOROPHYLL A CONCENTRATION (UG/L) 0
ALGAL PRODUCTION RATE (GMS./SQ.M.) 0          0
```

RIVER MILE	DAYS	BOD	NOD	D.O.	DEFICIT	% SAT.
72.6	0	8.27	2.86	7.9	2.25	77.8
72.4	.136	8.18	2.81	7.8	2.34	76.9
72.2	.272	8.09	2.77	7.71	2.44	76
72	.408	8.01	2.72	7.62	2.53	75.1
71.8	.544	7.92	2.68	7.54	2.61	74.3
71.6	.68	7.84	2.63	7.46	2.69	73.5
71.4	.816	7.75	2.59	7.38	2.77	72.7
71.2	.952	7.67	2.55	7.3	2.85	71.9
71	1.088	7.59	2.51	7.23	2.92	71.2

NH3= .53

DOWNSTREAM FLOW (CFS) 83 DEPTH & WIDTH 16 120 VELOCITY .04
MIXED ULT. BOD (MG/L) 7.6
MIXED ULT. NOD (MG/L) 2.51
MIXED TEMPERATURE (C) 15
MIXED D.O. (MG/L) 7.23
D.O. 100% SAT = 10.15
K1= .08
K2= .04
K3= .09
SEDIMENT DEPTH IN INCHES 0
NON-NOD AMMONIA DEPLETION RATE 0
CHLOROPHYLL A CONCENTRATION (UG/L) 0
ALGAL PRODUCTION RATE (GMS./SQ.M.) 0 0

R E A C H 3

RIVER MILE	DAYS	BOD	NOD	D.O.	DEFICIT	% SAT.
71	0	7.6	2.51	7.23	2.92	71.2
70.8	.283	7.43	2.45	7.03	3.12	69.3
70.6	.565	7.27	2.39	6.84	3.31	67.4
70.4	.848	7.1	2.33	6.65	3.5	65.5
70.2	1.131	6.95	2.27	6.47	3.68	63.8
70	1.414	6.79	2.21	6.3	3.85	62.1
69.8	1.696	6.64	2.16	6.14	4.01	60.5
69.6	1.979	6.49	2.1	5.98	4.17	58.9
69.4	2.262	6.35	2.05	5.83	4.32	57.4
69.2	2.545	6.21	2	5.68	4.47	56

NH3= .46

********************** INPUT ECHO **********************
UPSTREAM FLOW,PT.SOURCE FLOW (CFS) 83 2.3 DEPTH AND WIDTH 16 120
TEMP UP,PT.SOURCE TEMP 15 15
D.O. UP,PT.SOURCE D.O. 5.68 8 VELOCITY .04
NH3-N UP, PT.SOURCE NH3-N .46 .03
ULTIMATE BOD UP, PT.SOURCE UBOD 6.2 4
****

DOWNSTREAM FLOW (CFS) 85.3
DILUTION RATIO 36.09
MIXED ULT. BOD (MG/L) 6.14
MIXED ULT. NOD (MG/L) 1.94
MIXED TEMPERATURE (C) 15
MIXED D.O. (MG/L) 5.74
D.O. 100% SAT = 10.15
K1= .08
K2= .04
K3= .01
SEDIMENT DEPTH IN INCHES 0
NON-NOD AMMONIA DEPLETION RATE 0
CHLOROPHYLL A CONCENTRATION (UG/L) 0
ALGAL PRODUCTION RATE (GMS./SQ.M.) 0 0

R E A C H 2

RIVER MILE	DAYS	BOD	NOD	D.O.	DEFICIT	% SAT.
69.2	0	6.14	1.94	5.74	4.41	56.6
69	.275	6.01	1.94	5.65	4.5	55.7
68.8	.55	5.88	1.93	5.56	4.59	54.8
68.6	.825	5.75	1.93	5.48	4.67	54
68.4	1.1	5.63	1.92	5.4	4.75	53.2
68.2	1.376	5.5	1.92	5.32	4.83	52.4
68	1.651	5.39	1.91	5.25	4.9	51.7
67.8	1.926	5.27	1.91	5.18	4.97	51
67.6	2.201	5.16	1.9	5.11	5.04	50.3

NH3= .44

APPENDIX VI

SOME WATER QUALITY DATA FROM 1977 TO 1984
FOR THE CHEHALIS RIVER AT CENTRALIA
(MELLON STREET BRIDGE STATION)

DEPARTMENT OF ECOLOGY

AGENCY 21540000 RETRIEVAL --- 30 OCTOBER 1984

OFFICE OF WATER PROGRAMS
WATER QUALITY MANAGEMENT DIVISION
WATER QUALITY INVESTIGATIONS SECTION

23A120 CHEHALIS RIVER AT CENTRALIA 12025500

STORET MINOR BASIN: COASTAL STORET SUB BASIN: UPPER CHEHALIS

LATITUDE: 46 42 45.0 ELEVATION (FEET): 170 WATER CLASS: A
LONGITUDE: 122 58 39.0 COUNTY: LEWIS SEGMENT: 10-23-13

AGENCY: 21540000 STATE: WASHINGTON STA TYPE: RAP

TERMINAL STREAM	1ST LEV MILES	2ND LEV MILES	3RD LEV MILES	4TH LEV MILES	5TH LEV MILES	6TH LEV MILES
1512099	067.50	.	.	.	.	.

DATE FROM TO	TIME	DEPTH METERS	00060 STREAM FLOW CFS-AVG	00010 WATER TEMP DEG-C	00300 DISSOLVED OXYGEN mg/l	00301 DO PERCENT SATURATN	00400 pH STANDARD UNITS	00630 NITROGEN NO2 + NO3 mg/l	00620 NITRATE T NO3-N mg/l	00615 NITRITE T NO2-N mg/l	00610 AMMONIA T NH3-N mg/l	00671 DIS-ORTHO PHOSPHRUS mg/l P
77/10/04	1345		420.0	12.2	9.9	93.0	6.5	0.19			0.06	0.02
77/11/14	1300		5600.0	8.8	11.1	96.3	6.5	0.80			0.09	0.01
77/12/05	1240		12000.0	7.3	10.5	87.8	6.5	0.98			0.12	0.01
78/01/03	1245		1410.0	2.7	13.1	97.3	6.9	0.64			0.07	0.02
78/02/02	1300		5000.0	8.8	11.7	101.5	7.2	0.56			0.16	0.02
78/03/13	1220		1400.0	7.9	12.0	101.8	6.8	0.54			0.10	0.01
78/04/17	1355		1370.0	9.6	10.6	93.7	7.0	0.35			0.07	0.02
78/05/08	1315		710.0	14.6	10.4	101.6	7.2	0.29			0.12	0.01
78/06/12	1325		580.0	16.5	8.7	89.2	7.2	0.14			0.10	0.03
78/07/24	1310		140.0	23.8	10.2	124.0	7.7	0.01			0.08	0.07
78/08/14	1320		200.0	21.0	5.7	63.6	7.1	0.10			0.16	0.06
78/09/05	1250		670.0	17.2	8.3	86.4	7.2	0.10			0.14	0.04
78/10/09	1440		420.0	13.5	8.7	83.4	7.3	0.16			0.04	0.04
78/11/06	1305		1400.0	7.4	10.6	87.4	7.1	1.20			0.02	0.01
78/12/04	1335		3900.0	6.9	11.2	91.3	7.1	1.20			0.03	0.04
79/01/29	1530		990.0	2.1	13.0	94.2	7.3	0.76			0.06	0.02
79/02/20	1350		5700.0	5.8	12.8	102.2	6.8	1.20			0.03	0.01
79/03/12	1335		2170.0	7.9	11.0	91.5	6.9	0.86			0.02	0.01
79/04/16	1355		2320.0	8.6	11.1	95.7	7.3	0.72			0.03	0.01
79/05/21	1325		470.0	17.3	9.4	96.6	7.3	0.44			0.04	0.00
79/06/18	1315		280.0	16.7	8.5	87.3	7.0	0.15			0.08	0.00
79/07/09	1345		175.0	20.7	11.1	123.3	7.9	0.02			0.01	0.04
79/08/06	1340		75.0	22.2	10.0	113.6	7.5	0.01			0.00	0.05
79/09/04	1355		660.0	17.4	7.1	73.9	7.1	0.26			0.11	0.01
79/10/08	1340		100.0	15.8	3.0	28.9	6.9	0.02			0.10	0.08
79/11/13	1300		480.0	7.9	10.8	90.7	7.6	0.63			0.05	0.01
79/12/03	1250		5800.0	7.0	10.9	89.5	6.9	1.30			0.02	0.00
80/01/14	1310		16000.0B	5.6	11.6	92.6	6.8	1.20			0.03	0.00
80/02/19	1350		5400.0	6.2	11.6	95.1	7.2	0.84			0.04	0.00
80/03/17	1300		4800.0	6.2	11.9	95.9	6.9	0.21			0.00	0.01
80/04/22	1350		2450.0	11.4	10.4	94.1	6.7	0.59			0.15	0.01
80/05/27	1245		510.0	12.2	9.6	88.5	7.2	0.22			0.10	0.03
80/06/23	1310		440.0	18.7	7.7	81.3	7.3	0.18			0.09	0.04
80/07/14	1310		230.0	18.7	9.6	100.7	7.9	0.11	0.11	0.01K	0.02	0.01
80/08/25	1320		80.0	17.2	9.6	101.7	7.4	0.01K	0.01K	0.01K	0.01	0.01K

DATE FROM TO	TIME	DEPTH METERS	STREAM FLOW CFS-AVG	WATER TEMP DEG-C	DISSOLVED OXYGEN mg/l	DO PERCENT SATURATN	pH STANDARD UNITS	NITROGEN NO2 + NO3 mg/l	NITRATE T NO3-N mg/l	NITRITE T NO2-N mg/l	AMMONIA T NH3-N mg/l	DIS-ORTHO PHOSPHRUS mg/l P
0/09/22	1345		250.0	15.4	8.5	83.0	7.0	0.26	0.26	0.01K	0.04	
/10/27	1340		145.0	9.6	9.3	79.7	7.3		0.07	0.01K	0.07	0.07
/11/17	1330		730.0	6.7	11.9	95.4	7.4		0.66	0.01K	0.03	0.01
/12/15	1330		2040.0	7.4	11.5	93.8	7.1		0.67	0.01K	0.07	0.01K
1/01/19	1350		1060.0	6.3	11.2	90.6	7.4		0.70	0.01K	0.06	0.01K
1/02/23	1600		5500.0	8.2	10.6	90.7	7.1		0.93	0.01K	0.04	0.01
1/03/23	1340		710.0	9.2	10.9	93.5	7.1		0.49	0.01K	0.04	0.01
1/04/27	1230		1180.0	11.2	10.6	95.1	6.8		0.53	0.01K	0.04	0.01
1/05/19	1245		1400.0	12.2	10.6	98.3	7.2		0.29	0.01K	0.03	0.01K
1/06/15	1345		960.0	13.8	10.2	97.0	7.2		0.31	0.01K	0.06	0.01
1/07/27	1340		330.0	20.2	7.8	85.0	6.9		0.11	0.01	0.11	0.04
1/08/17	1330		110.0	16.8	8.4	85.9	7.1		0.03	0.01K	0.04	0.01
1/09/14	1355		110.0	20.1	6.7	72.8	6.7		0.12	0.01	0.05	0.07
1/10/12	1325		1750.0	9.6	10.5	91.3	6.9		0.65	0.01	0.09	0.01
1/11/09	1330		600.0	6.0	11.3	92.7	7.0		0.37	0.01	0.05	0.01
1/12/14	1340		5800.0	6.6	11.4	92.3	6.8		0.83	0.02	0.17	0.01
2/01/11	1325		1500.0	3.7	12.6	94.5	7.0		0.77	0.01	0.22	0.02
2/02/07	1340		2150.0	3.5	12.5	92.7	6.6		0.74	0.01	0.52	0.01
2/03/15	1350		5600.0	6.3	11.8	95.8	6.9		0.58	0.01	0.12	0.01
2/04/19	1400		3650.0	7.5	11.9	96.7	7.0		0.48	0.01	0.04	0.01
2/05/10	1410		740.0	11.1	10.6	95.3	7.2		0.22	0.01	0.06	0.01
2/06/14	1530		255.0	18.6	9.0	94.4	7.5		0.04	0.01K	0.02	0.01K
2/07/19	1415		150.0	20.0	7.3	79.2	7.3		0.14	0.01K	0.16	0.01
2/08/16	1235		125.0	19.0	6.3	66.9	7.1		0.14	0.01K	0.17	0.06
2/09/20	1515		100.0	16.2	6.4	64.5	7.1		0.15	0.01K	0.16	0.05
2/10/11	1525		235.0	12.2	8.9	81.8	7.3		0.06	0.01K	0.07	0.03
2/11/08	1520		2500.0	7.4	10.9	90.8	7.1		0.58	0.01	0.06	0.01
2/12/13	1545		2500.0	5.6	11.6	92.4	6.8		0.67	0.02	0.07	0.01
3/01/10	1545		13000.0	8.0	11.9	98.9	7.0		0.65	0.01	0.03	0.01
3/02/07	1515		2100.0	5.8	12.1	97.4	7.3		0.52	0.01	0.05	0.01
3/03/14	1545		6100.0	8.7	11.0	94.1	6.7		0.53	0.01	0.04	0.01
3/04/11	1545		2000.0	8.2	11.8	99.5	6.9		0.39	0.01	0.03	0.01
3/05/09	1530		1080.0	11.4	11.4	103.1	7.6		0.14	0.01K	0.05	0.02
83/06/13	1445		400.0	17.8	8.4	87.1	7.4		0.13	0.01K	0.07	0.04
83/07/11	1605		390.0	18.5	9.1	95.9	7.3		0.11	0.01K	0.03	0.02
83/08/08	1555		290.0	22.2	7.7	86.8	7.4		0.14	0.01K	0.06	0.06
83/09/06	1610		230.0	17.6	7.7	80.3	7.2		0.17	0.01K	0.02	0.02
3/10/04	1440		162.0	13.8	8.4	79.9	7.8		0.10	0.01K	0.18	0.05
3/11/02	1530			11.0	9.2	83.4	7.1		0.10	0.01K	0.07	0.05
3/12/06	1530			5.8	12.0	95.8	7.3		0.26	0.01K	0.06	0.02
84/01/04	1430			8.5	12.7	107.1	7.1		0.94	0.01K	0.04	0.01
84/02/22	1435		4700.0	6.2	12.2	97.5	7.2		0.77	0.01K	0.02	0.01
84/03/27	1350		4000.0	8.5	11.6	97.6	7.2		0.64	0.01K	0.06	0.01K
4/04/24	1355		1300.0	9.6	7.4	64.1	7.3		0.50	0.01K	0.04	0.04
84/05/22	1435			10.8	11.1	99.5	7.4		0.42	0.01K	0.03	0.02
84/06/26	1425			18.0	8.5	88.5	7.4		0.30	0.01K	0.06	0.04
84/07/24	1515			20.7	8.1	89.5	7.3		0.22	0.01K	0.06	0.06
84/08/28	1505			19.5	6.8	72.6	7.0		0.14	0.01K	0.14	