ST. CROIX RIVER

UNITED STATES
ENVIRONMENTAL PROTECTION AGENCY
REGION I
BOSTON, MASSACHUSETTS

a study of water quality and benthic conditions in the st. croix river, grand falls to milltown, maine and new brunswick

ST. CROIX RIVER STUDY
AUGUST 1972

A STUDY OF WATER QUALITY AND BENTHIC CONDITIONS IN THE ST. CROIX RIVER GRAND FALLS TO MILLTOWN, MAINE & NEW BRUNSWICK

U. S. ENVIRONMENTAL PROTECTION AGENCY
REGION I
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ACKNOWLEDGEMENT

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LIST OF ABBREVIATIONS

TERM	DEFINITION
BOD_5	5-day biochemical oxygen demand
^oC	degrees centigrade
Cent.	degrees centigrade
cfs	cubic feet per second
DO	dissolved oxygen
Diss.	dissolved
EPA	United States Environmental Protection Agency
EPS	Canadian Environmental Protection Service
Flt.	filterable
Fix.	fixed
gm O_2/m^2/day	grams per square meter per day
G-P	Georgia-Pacific Corporation, Woodland, Maine
GSS	Geophysical Survey Systems, North Billerica, MA.
IJC	International Joint Commission (Canada-United States)
Jksn	Jackson
JTU	Jackson Turbidity Units
LT_{50}	lethal time for 50% of bioassay test organisms, the time in which 50% of the test organisms die.
mg/l	milligrams per liter
mgd	million gallons per day
ml/l	milliliters per liter

LIST OF ABBREVIATIONS CONTINUED

TERM	DEFINITION
Nflt.	nonfilterable
pH	the negative logarithm of the hydrogen ion concentration
ppd	pounds per day
#/day	pounds per day
Pt-Co. Units	Platinum-Cobalt Units
SOD	sediment oxygen demand
SU	Standard Units
Temp.	temperature
Tot.	total
ug/l	micrograms per liter

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Conclusions

1. During the study the average river flow was approximately 500 cfs higher than the 1968-1972 mean for August and five times higher than the 1-in-10 year, 7-day low flow (480 cfs).
2. Because of high flows, water quality was much better than could normally be expected.
3. The practice of log floating and storage increases oxygen demands in Woodland Lake and Mill Pond.
4. Very little lateral mixing occurs in the St. Croix River from Woodland to Baring, Maine, and wastes from Georgia-Pacific Corporation's mill which hug the U. S. bank have caused numerous sludge banks and bacterial slimes to develop.
5. Sludges in the river exert a substantial sediment oxygen demand, emit gases, rise and float on the river's surface. Left in place these wastes continue to exert a demand which is not expected to decrease to less than 2.0 gm O_2/m^2/day.
6. Dilute solutions of mill effluent are chemically toxic to fish and toxicity is present many miles downstream from the point of discharge.
7. The number and kinds of bottom organisms confirm the polluted environment in the St. Croix River as a result of the Georgia-Pacific discharge.

8. Georgia-Pacific's effluent causes the temperatures in the St. Croix River to exceed the Federally-approved Maine Water Quality Standards. Immediately downstream from the outfall, the average increase to ambient river temperature is 8.5 ^{o}C and steam was observed rising from the U. S. side of the river for approximately two miles downstream.

9. Considering that the mill was operating at reduced capacity, the characteristics of Georgia-Pacific's waste have changed relatively little from the 1970 survey.

10. Georgia-Pacific's effluent increases the color of the St. Croix River.

11. To meet water quality standards for dissolved oxygen, Georgia-Pacific should eliminate log floating and log storage in the St. Croix River, maintain an instantaneous low flow above 750 cfs at Baring, Maine and maintain a maximum daily BOD loading of 10,000 pounds per day during the four warmest months.

WATER QUALITY STUDY

ST. CROIX RIVER

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INTRODUCTION

Background

During August 1972, the U. S. Environmental Protection Agency (EPA) and the Canadian Environmental Protection Service (EPS) conducted a comprehensive study of the water quality in the St. Croix River and its effect on aquatic life. The purpose of the study was to examine the effects of log rafting, log storage, and pulp and paper making wastes on the aquatic environment. The study area was from Spednik Falls to the international bridge at Milltown, Maine - New Brunswick (See Figure 1).

On August 4 and 5, EPA conducted dye studies and aerial photography work on the river to determine the time of travel from Woodland to Milltown. From August 8 to 16, EPA studied the river water quality, benthos and sediments and examined the effluent discharging from the Georgia-Pacific Corporation's (G-P) mill at Woodland. During the same period, EPS studied the toxicity of both the mill effluent and the diluted mill effluent in the river. From August 16 to 19, EPA visually examined the bottom conditions, counted sunken logs, and measured the depth of accumulated debris in Mill Pond and Woodland Lake.

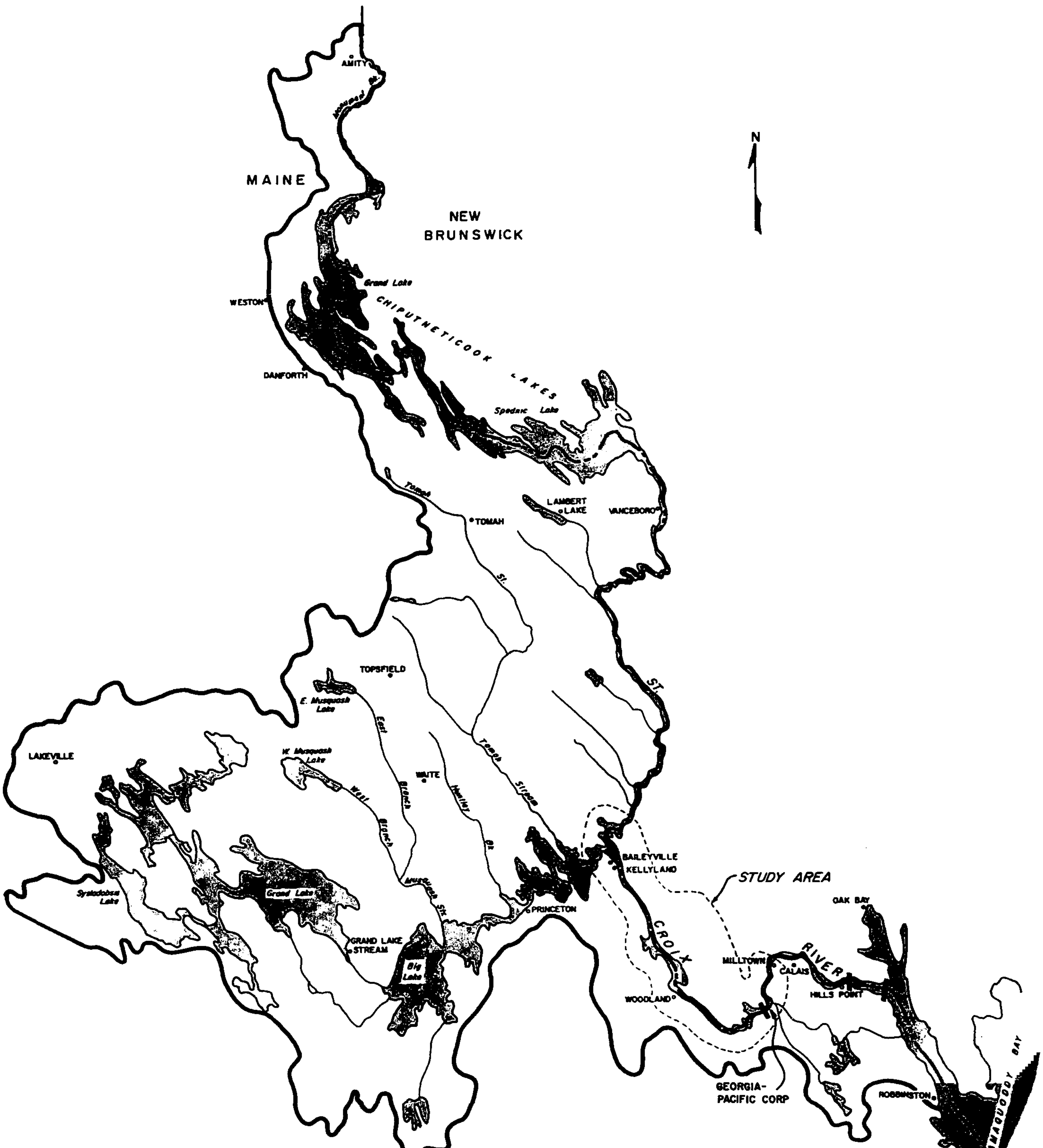
During the study period, river flows were approximately 500 cfs higher than the mean August flow based on five years of record; the Georgia-Pacific mill was on reduced production; and a construction project for repair of the Woodland Dam was discharging sediment into the Canadian side of the river.

Hydrology

According to the Water Resources Division, U. S. Geological Survey (USGS), above normal precipitation fell during the spring and summer of 1972. Nine inches of rainfall were recorded at Woodland in the three month period preceding the August study (See Figure 2). On August 9, showers which covered nearly all of the state moderately increased flow in most streams. However, because of extensive stream flow regulation, the St. Croix River was virtually unaffected. Excessive runoff occurred in May, June, and July. In August runoff returned to normal. The groundwater table followed a similar pattern.

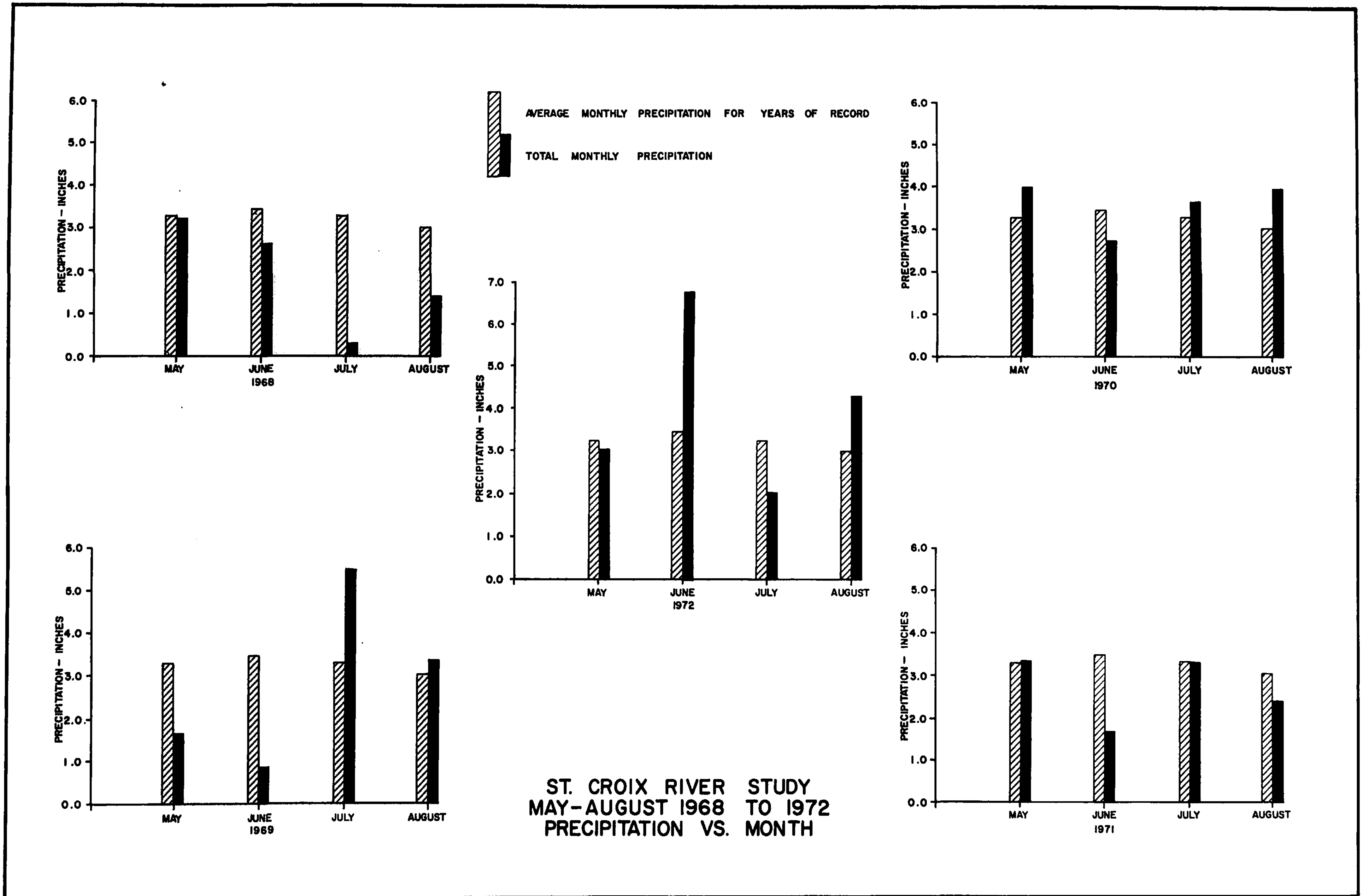
The usable water storage capacity in the St. Croix River Basin's reservoir system is approximately 24 billion cubic feet.[1] During the three months preceding the survey, the water in storage averaged 91% of capacity. The norm for the three months is 71% of capacity. At the end of July, the basin storage capacity was 84% full and during August it dropped to 62%. The mean percentage for the end of August, based on five years of record, is 51%. Table 1 is a comparision of month's end water in storage from May to September 1970-1972.

Georgia-Pacific Corporation and its subsidiary, the St. Croix River Company, controls most of the storage in the St. Croix River Basin, particularly Spednik Lake and East Grand Lake. Georgia-Pacific Corporation's Grand Falls Dam controls the storage in Grand Falls Flowage and regulated the flow in the study area at all times, except during freshets when the flowage is filled to capacity. During the study period, the Georgia-Pacific



ST. CROIX RIVER BASIN

FIGURE I



ST. CROIX RIVER STUDY
MAY-AUGUST 1968 TO 1972
PRECIPITATION VS. MONTH

FIGURE 2

TABLE 1

ST. CROIX RIVER STUDY

AUGUST 1972

ST. CROIX RIVER RESERVOIR SYSTEM*
Percent of Full Water Storage Capacity at Month's End
May to September 1970 - 1972
100% = 23. 579 billion cubic feet

	AVERAGE FOR YEARS OF RECORD	1970	1971	1972
MAY	78	89	86	94
JUNE	71	83	67	93
JULY	62	79	47	84
AUGUST	51	74	35	62
SEPTEMBER	43	62	28	48

* Based on "Current Water Resources in Maine". Water Resources Division, U. S. Geological Survey in Cooperation with Maine Public Utilities Commission.

Corporation could regulate the flow in the study area.

The International Joint Commission (IJC) regulates the operation of the dams at East Grand Lake and Spednik Lake using broad guidelines based on pool elevations and minimum discharges. The dam at East Grand Lake must discharge water at a rate of at least 75 cubic feet per second (cfs) and Spednik dam must maintain a flow of 200 cfs. No regulatory requirements have been established at the downstream dams. The lack of strict regulatory guides means that the operation of the dam can randomly effect large flow fluctuations in the St. Croix River in a very short time. Gage records show that dam operation, not rainfall, is the most significant factor affecting flow within the study area. Taking into account that historical flow records are biased by dam regulation, the IJC established the minimum 1-in-10 year, 7-day low flow at 480 cfs.[2]

During the past five years the daily flow rates in August ranged from 868 cfs to 3810 cfs at Baring. The 1968 - 1972 mean daily flow rate for August is 1720 cfs. Because of a wet spring and summer the Spednik and Grand Falls Dams were releasing more water than usual for August. During August 4 - 16 the average daily flow rates measured at the USGS Gage, Baring, Maine varied from 2290 - 2580 cfs with the arithmetic mean being 2410 cfs. These flows represent a 39% increase over the same period in 1971 and 35% more than that of 1970. Tables showing the average daily flow rates at the Baring gage for May to September 1968 - 1972 are in Appendix A.

Dye studies showed that at a river flow of approximately 2600 cfs, wastes discharged by G-P's mill required approximately four hours to reach the railroad bridge at Baring and a total of 11 hours to reach the Milltown bridge. Coastal Research Corporation's report[3] showed that little or no lateral mixing occurs until the rapids at Baring, Maine. Turbulent mixing occurs at the Baring rapids and at the Milltown bridge, the dye is well mixed across the river. Further time of travel information is available in Appendix B.

WASTE SOURCES

Pollutional loadings in the St. Croix River within the study area may be attributed primarily to three sources: log floating and storage, G-P's mill and municipal waste from Baileyville, Maine.

Log Floating and Storage

The log floating and storage problem results from the dumping of pulpwood into the St. Croix River. The logs are introduced from the Canadian bank several hundred yards downstream from the Grand Falls Dam. The floating logs are driven by current and wind approximately five miles downstream to river storage sites near G-P's mill at Woodland. In addition to the logs floated to wet storage, logs delivered to the mill site by truck are transferred to river storage.

During water transport and storage the collision of logs abrades bark and wood fiber. Debris is removed when the logs hit the water, and some bark which may have been loosened before the logs entered the river, breaks free as it absorbs moisture. As these bark particles and some logs become water saturated, "water logged", they settle to the bottom, coat the natural substrata, and decay. The degradation of these sunken logs and particulates creates an oxygen demand on the overlying waters.

The Woodland mill uses deciduous and conifer pulpwood for its paper production. From 1968 - 1971, 257,777 cords were floated from the log landings near Grand Falls Dam to the mill. The floated logs represent 13% of the wood used by the mill in the four year period. Table 2 gives a yearly breakdown of the mill's total log consumption and floated logs.

Research has shown that during the log floating process sugars, tannins, lignin precursors, degradation products, and cellulose like materials are

TABLE 2
ST. CROIX RIVER STUDY
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Quantities of Logs Consumed and Floated
by Georgia-Pacific Corporation, Woodland, Maine

YEAR	CORDS PROCESSED	CORDS FLOATED	% FLOATED
1968	514,540	77,559	15.1
1969	490,511	65,731	13.4
1970	515,187	61,254	11.9
1971	452,584	53,234	11.8

leached to the carrying media.[4,5] The leached materials increase color and cause an oxygen demand during degradation. The degree to which this occurs is dependent upon multiple factors: wood type, quantity, length of time in storage, etc. The length of time the logs remain in wet storage varies with the production needs of the mill and the number of logs supplied from dry storage, truck and rail haul. During the study period, 44,000 cords were estimated to be in wet storage at Woodland Lake and Mill Pond.

The Georgia-Pacific Mill

G-P's mill, which is located on the west bank of the St. Croix River at Woodland, Maine, produces kraft pulp, groundwood pulp, and paper. The mill uses deciduous and conifer wood in its production processes. The mill is reported[6] to be capable of processing 1400 cords of peeled pulpwood and 1200 cords of wood chips and produce 200 tons of unbleached groundwood pulp, 600 tons of bleached softwood kraft pulp, and 550 tons of paper daily.

During most of the sampling period, the mill was on reduced production. At the start of the sampling period, reportedly the mill was operating at 60-65 percent capacity and by the end of the period was at full production. Table 3 lists production figures during the study period.

The mill discharges wastes at two locations. Waste water from the log flume discharges near the base of Woodland Dam. The main effluent, however, is through a defoaming lagoon located about 500 yards downstream.

Georgia-Pacific's main effluent contains sanitary wastes and process wastes from pulp and paper production. The sanitary wastes receive secondary treatment in an activated sludge "package" plant. The process wastes

TABLE 3

ST. CROIX RIVER STUDY

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PRODUCTION AT THE GEORGIA-PACIFIC CORPORATION MILL
WOODLAND, MAINE

DATE AUGUST	GROUNDWOOD	TONS KRAFT PULP	NEWSPRINT	PRINTING PAPER
	151	561	217	124
9	158	328	251	---
10	198	536	286	18
11	164	553	311	112
12	225	652	286	99
13	229	496	290	118
14	251	488	222	121
15	195	500	297	122
16	156	419	309	90

receive primary clarification and portions of the Kraft mill wastes are treated for color removal. Figure 3 is a schematic of effluent development. The wastes combine in a catchbasin and are discharged through a defoaming lagoon to the St. Croix River.

As noted in the schematic, wastes from the Kraft mill's first stage caustic extraction is returned to the wood mill and then discharged to a color clarifier utilizing lime coagulation. The effluent is discharged to the defoaming lagoon except for a relatively small amount which may be returned to a caustic sump. The sludge from this unit is sent to a lime mud washer for lime recovery. The remaining liquid process wastes are sent to a primary clarifier before discharge to the defoaming lagoon. The sludge from the clarifier is vacuum filtered and burned in a bark incinerator. For pH control the effluent from the color clarifier and main clarifier are joined by an acid waste stream prior to entering the defoaming lagoon.

The term "defoaming lagoon" is a misnomer. The defoaming lagoon is a diked section of the river. Its purpose is to retain the foam which develops as the waste tumbles down to the river elevation. Waste retention time in the lagoon is estimated as fourteen minutes and no treatment is provided to remove or neutralize foaming agents. The lagoon's sole purpose is to retain floating foam and present a more aesthetically acceptable waste stream. Waste leaves the lagoon via two submerged 24" pipes. Although very little foam is visible immediately downstream from the mill, large masses of floating foam attributable to the mill are evident after the rapids downstream from Milltown bridge and following the rapids at Baring.

During the sampling period the mill's waste flow ranged between 30.7 and 32.4 million gallons per day (mgd). The average daily rate was

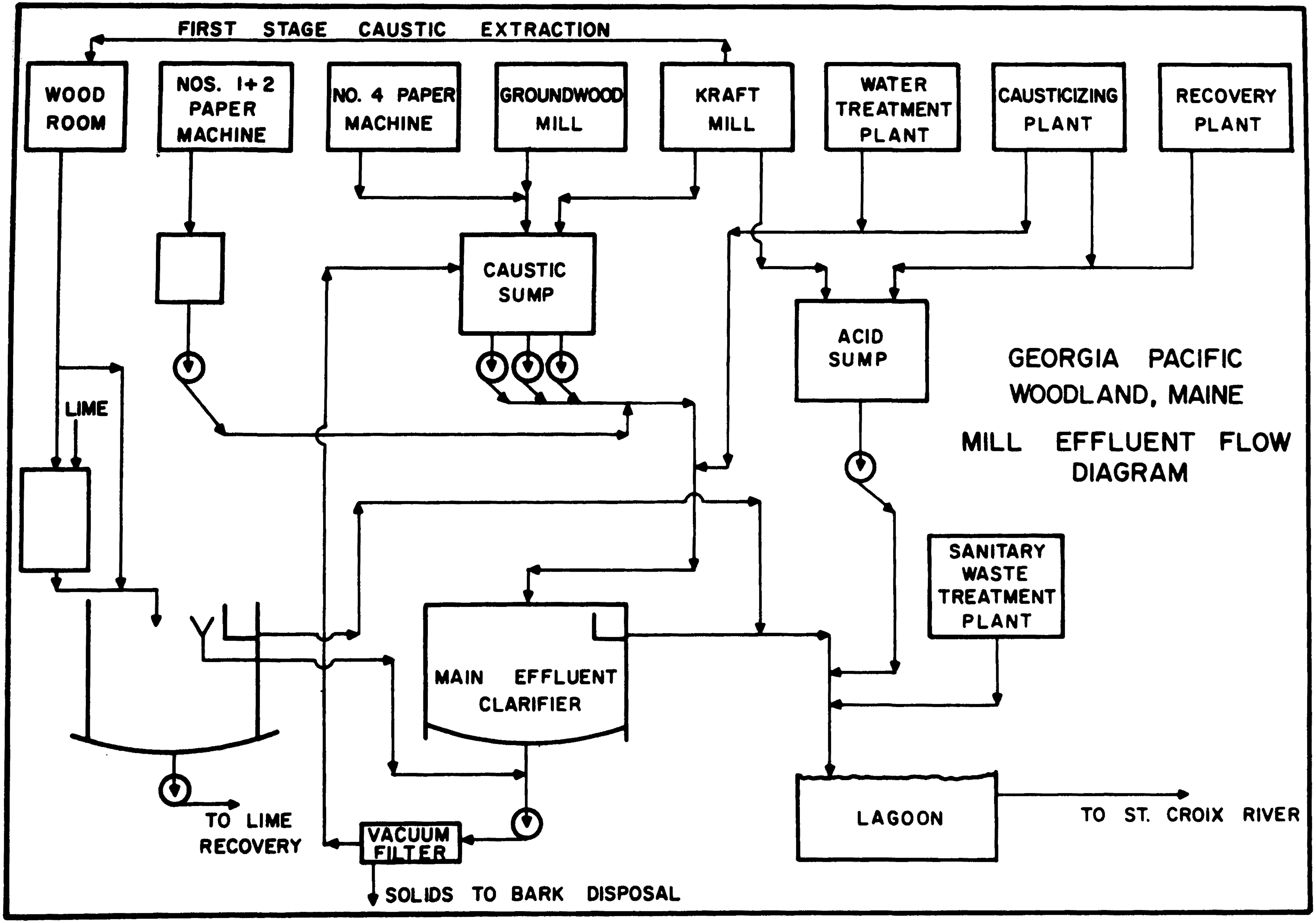
FIRST STAGE CAUSTIC EXTRACTION
WOOD ROOM
NOS. 1+2 PAPER MACHINE
NO. 4 PAPER MACHINE
GROUNDWOOD MILL
KRAFT MILL
WATER TREATMENT PLANT
CAUSTICIZING PLANT
RECOVERY PLANT
CAUSTIC SUMP
ACID SUMP
GEORGIA PACIFIC
WOODLAND, MAINE
MILL EFFLUENT FLOW DIAGRAM
LIME
SANITARY WASTE TREATMENT PLANT
MAIN EFFLUENT CLARIFIER
LAGOON
TO ST. CROIX RIVER
TO LIME RECOVERY
VACUUM FILTER
SOLIDS TO BARK DISPOSAL

FIGURE 3

31.6 mgd. This represents approximately 2.0% of the average flow in the river. Table 4 shows the daily flows as determined by three methods--integrator, planimeter, and Parshall flume.

Initially flows were being measured at a Parshall flume prior to the defoaming lagoon but foam entrainment caused the liquid level recorders to malfunction. Subsequently daily flow readings were based on the amount of water entering the plant at G-P's Degremont building and North Filter. From flow charts for these intakes, G-P personnel calculated the daily flow using an integrator and a planimeter. The planimeter usually gave the more conservative flows. The flow values above are based on planimeter determinations. Although some water is lost to evaporation and paper moisture content, the amount is negligible when compared to variations in flow measurements. The daily waste loadings from the mill were calculated using the conservative flows.

To determine the strength of the wastes being discharged, EPA personnel sampled the main effluent on a continuous twenty-four hour basis from August 8 - 16. Sampling crews collected eight, twenty-four hour composite samples. The sample increments were composited proportional to the flow recorded by the Parshall flume. Although these flows were incorrect, the changes in flow volume remained proportional to the actual flow. Thus, the volumes composited were proportional to the actual flow. (A procedure agreed upon with mill officials.) The composite samples were analyzed for 5-day biochemical oxygen demand (BOD_5), k-rate BOD (1-5 days), true color, and residues: total nonfilterable, fixed nonfilterable, total filterable and fixed filterable. Dissolved oxygen, temperature, pH, and settleable solids were determined regularly through the day. In addition one grab sample per

TABLE 4

ST. CROIX RIVER STUDY

AUGUST 1972

Estimated Waste Flows From Defoaming Lagoon
at Georgia-Pacific Corporation, Woodland, Maine

DATE AUGUST	FLOWS (MGD) INTAKE WATER[1] CACULATED BY PLANIMETER	INTEGRATOR	EFFLUENT RECORDED AT PARSHALL FLUME
8	30.8	32.2	48.4
9	30.7	32.1	41.9
10	30.8	32.0	51.2
11	31.7[2]	31.3	57.3
12	32.4[3]	36.5	75.2
13	31.4	33.0	58.3
14	32.1	33.9	50.0
15	32.5	33.2	48.8
MEAN	31.6	33.0	53.9

1 Sum of intake water at G-P's Degremont Bldg. and North Filter.

2 Includes 4.6 million gallons at North Filter calculated by integrator.

3 Includes 4.7 million gallons at North Filter calculated by integrator.

day was collected and analyzed for total and fecal coliforms and *Klebsiella*. A summary of these analyses is presented in Table 5 and complete analytical results are in Appendix C. Appendix D contains *Klebsiella* data.

Based upon the recorded daily flows and analytical results, the G-P mill discharges an average calculated BOD load of 54,000 pounds per day (ppd) and 20,000 ppd suspended solids. The pH was highly variable ranging from a high of 11.3 to a low of 5.7 with the median being 7.5. The waste stream averaged 1350 color units and 33 Jackson turbidity units (JTU). It also had a strong odor and the volume of foam in the lagoon increased markedly as the study progressed.

Municipal Wastes

During 1972 the town of Baileyville (Woodland village) was constructing a municipal waste treatment plant and installing new sewers which will separate storm water runoff from domestic wastes. At the time of the study, the treatment plant was approximately 85% complete and not accepting any wastes. Many new sewers were completed but were not in use. Formerly, Baileyville discharged untreated municipal wastes to the St. Croix River at three locations. In August the sewers discharging to one of these locations had been diverted, thus two outfalls accounted for the entire untreated municipal combined flow. The flow from the major portion of the town was directed through an existing 18" combined sewer to the outfall located approximately 500' downstream from the defoaming lagoon discharge at Georgia-Pacific Corporation and downstream from sampling station SC2U (See fold-out map at back of report). The remaining untreated wastes were discharged through a 12" combined sewer which terminated at an untreated point farther downstream.

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TABLE 5

SUMMARY OF ANALYTICAL RESULTS FOR
DEFOAMING LAGOON EFFLUENT TO THE ST. CROIX RIVER
WOODLAND, MAINE
AUGUST 8 - 16

PARAMETER	MAXIMUM	MINIMUM	MEAN
Temperature (°C)	43.0	32.0	35.7
Dissolved Oxygen (mg/l)	6.7	1.6	5.5
pH (std. units)	11.3	5.7	7.8
Settleable solids (ml/l)	3.0	<0.1	1.1
Color (plat. cobalt units)	1500	1000	1375
Turbidity (JTU)	73	2	36
BOD (mg/l)	240	150	205
Residues (mg/l)			
Total filterable	1249	680	912
Fixed filterable	845	431	601
Total nonfilterable	102	57	76
Fixed nonfilterable	56	8	30
Coliforms (#/100 ml)			
Total	59,000	1200	6,100*
Fecal	16,000	100	200*

* Median value

Since no known industries contribute to the municipal sewers, the 18" sewer was considered representative of both discharges. Each day, August 8-11, samplers collected eight, hourly grab samples between 0600 and 1500 hours. The sampling crew then combined increments of the grab samples to get a representative composite sample which was analyzed for BOD_5, color, turbitity, and residues: total nonfilterable, fixed non-filterable, total filterable, and fixed filterable. The results of these analyses are found in Table 6. In addition, each grab sample was tested for settleable solids and one daily for total and fecal coliforms and *Klebsiella*.

The flow in each pipe was measured in catchbasins near the discharge points. A 90° V-notch weir was constructed for each sewer. Flow in the 18" sewer was measured around the clock using an automatic liquid level recorder. The flow in the 12" sewer was measured hourly during the sampling period. Because these are combined sewers, the weirs became surcharged following periods of intense rainfall, and in one instance, debris fouled the float of the liquid level recorder. The average combined waste flow rate from both pipes approximated 0.25 mgd.

Assuming that the concentrations in the 18" sewer was representative of both sewers, the average BOD_5 loading was 185 ppd and total nonfilterable residue averaged 164 ppd. Both are negligible when compared to the 54,000 ppd BOD_5 and 20,000 ppd nonfilterable residue from the mill. The pH ranged from 6.3-8.8. The median total and fecal coliform densities were 1,300,000/100 ml and 50,000/100 ml, respectively.

ST. CROIX RIVER STUDY
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TABLE 6

SUMMARY OF ANALYTICAL RESULTS
FOR BAILEYVILLE'S MUNICIPAL WASTES

PARAMETER	MEAN VALUE
Temperature (^oC)	15.4
BOD_5 (mg/l)	104
pH (standard units)	6.6
Turbidity (JTU)	47
Residues (mg/l)	
Total filterable	261.5
Fixed filterable	195.5
Total nonfilterable	59
Fixed nonfilterable	31
Coliforms per 100 ml	
Total	1,000,000
Fecal	50,000

WATER QUALITY STUDY

Coincident with the sampling at Georgia-Pacific and Baileyville, EPA personnel conducted a water quality sampling program in the St. Croix River from Kellyland to Milltown, Maine. Nine stations were selected which would duplicate as nearly as possible the locations sampled in 1970 plus a station on the U. S. side of the river downstream from Woodland Dam and upstream from Georgia-Pacific's main outfall. Fold-out 1 at the rear of the report locates the stations and Table 7 describes all stations sampled. Each station was sampled at least once every morning during August 8-15. Samples collected were analyzed for total and fecal coliforms, DO, temperature, pH, BOD_5, color, turbidity, residue: total nonfilterable, fixed nonfilterable, total filterable, and fixed filterable. A second sampling run for DO, temperature, and pH was made at most stations downstream from Woodland Lake. Table 8 summarizes the results of those analyses. Complete tables of results are in Appendix C.

When discussing water quality, no parameter should be discussed independently of the others. The interaction of one parameter with another determines the quality or health of the water body, therefore, parameters will be grouped and discussed in three categories: physical, chemical, and biological.

Physical Parameters

Nonfilterable Residue

Although the terms nonfilterable residue and settleable matter are often used synonomously, Standard Methods for the Examination of Water and Wastewater, Thirteenth Edition, differentiates between the two. For

TABLE 7
STATION LOCATIONS
ST. CROIX RIVER STUDY
AUGUST 1972

WATER QUALITY STATIONS

STATION	LATITUDE ° ' "	LONGITUDE ° ' "	DESCRIPTION
SCKU	45 16 00	67 28 29	Downstream from dam at Kellyland, Maine near USGS gage.
SC01	45 10 02	67 24 18	Railroad bridge at Woodland Junction, Maine.
SC2C	45 09 20	67 23 42	500' downstream from defoaming lagoon outfall at Georgia-Pacific Corp., one-quarter way from Canadian bank opposite Woodland, Maine.
SC02	45 09 20	67 23 43	500' downstream from defoaming lagoon outfall at Georgia-Pacific Corp., midpoint in river, Woodland, Maine.
SC2U	45 09 20	67 23 45	500' downstream from defoaming lagoon outfall at Georgia-Pacific Corp., 50' from U.S. bank, Woodland, Maine.
SC2D	45 09 25	67 23 56	500' upstream from defoaming lagoon outfall at Georgia-Pacific Corp., 5' from U.S. bank ("Gunite" slope protection for G-P's defoaming lagoon) Woodland, Maine.
SC4C	45 08 03	67 19 14	One-quarter way off Canadian bank at railroad bridge, Upper Mill, New Brunswick.
SC04	45 08 03	67 19 12	Midpoint in river at railroad bridge, Baring, Maine.
SC4U	45 08 04	67 19 11	One-quarter way off U.S.A. bank at railroad bridge, Baring, Maine.
SC05	45 10 12	67 17 51	Midpoint in river at bridge Milltown, Maine - Milltown, New Brunswick.

TABLE 7
STATION LOCATIONS
ST. CROIX RIVER STUDY
AUGUST 1972
BENTHOS STATIONS

STATION	LATITUDE ° ' "	LONGITUDE ° ' "	DESCRIPTION
SCB10	45 18 02	67 27 40	St. Croix River 1,000' downstream from Landmark 175, three feet from U.S.A. bank, T1R1, Maine.
SCB11	45 17 59	67 28 05	St. Croix River 2,000' southwest of Landmark 175 near downstream tip of island midpoint in river, T1R1, Maine.
SCB12*	45 16 28	67 29 49	Grand Falls Flowage midway between scow Point and point of land northwest of Kellyland, Maine.
SCB13C	45 12 35	67 25 52	St. Croix River 5,000' downstream from Landmark 188 at log boom, 10' from Canadian bank, Baileyville, Maine.
SCB13M*	45 12 33	67 25 55	St. Croix River 5,000' downstream from Landmark 188, at log boom midpoint in the river, Baileyville, Maine.
SCB13U	45 12 32	67 25 58	St. Croix River 5,000' downstream from Landmark 188, at log boom, 15' from U.S.A. bank, Baileyville, Maine.
SCB14C	45 11 01	67 24 32	Woodland Pond 3,000' downstream from Landmark 191 one-quarter way from Canadian bank.
SCB14M	45 10 56	67 24 39	Woodland Pond 3,000' downstream from Landmark 191 midpoint in river, Baileyville, Maine.
SCB14U	45 10 51	67 24 44	Woodland Pond 3,000' downstream from Landmark 191 one-quarter way from U.S.A. bank, Baileyville, Maine.
SCB15C	45 10 41	67 23 54	Woodland Pond 6,000' downstream from Landmark 191 one-quarter way from Canadian bank.

* Benthic respirometer station

TABLE 7
STATION LOCATIONS
ST. CROIX RIVER STUDY
AUGUST 1972
BENTHOS STATIONS

STATION	LATITUDE ° ' "	LONGITUDE ° ' "	DESCRIPTION
SCB15M	45 10 36	67 24 07	Woodland Pond 6,000' downstream from Landmark 191, midpoint in river, Baileyville, Maine.
SCB15U	45 10 32	67 24 22	Woodland Pond 6,000' downstream from Landmark 191, one-quarter way from U.S.A. bank, Baileyville, Maine.
SCB16C	45 09 21	67 23 40	500' downstream from defoaming lagoon outfall at Georgia-Pacific Corp., 5' from Canadian bank opposite Woodland, Maine.
SCB16M	45 09 21	67 23 38	500' downstream from defoaming lagoon outfall at Georgia-Pacific Corp., midpoint in river Woodland, Maine.
SCB16U	45 09 19	67 23 38	700' downstream from defoaming lagoon outfall at Georgia-Pacific Corp., 5' from U.S.A. bank Woodland, Maine.
SCB17C*	45 08 53	67 22 36	1,000' downstream from Landmark 197, 5' from Canadian bank opposite Baileyville, Maine.
SCB17M*	45 08 52	67 22 38	1,000 downstream from Landmark 197, 500' downstream from Landmark 198, midpoint in river near downstream tip of island, Baileyville, Maine.
SCB17U	45 08 52	67 22 43	5' from U.S.A. bank opposite Landmark 198, Baileyville, Maine.
SCB18C*	45 07 57	67 19 23	700' downstream from Landmarks 205 & 206, 20' from Canadian bank opposite Baring, Maine.
SCB18M	45 07 55	67 19 16	800' downstream from Landmarks 205 & 206, midpoint in river at Baring, Maine.

* Benthic respirometer station

TABLE 7
STATION LOCATIONS
ST. CROIX RIVER STUDY
AUGUST 1972
BENTHOS STATIONS

STATION	LATITUDE ° ' "	LONGITUDE ° ' "	DESCRIPTION
SCB18U	45 07 51	67 19 08	1,400' east of Landmark 206, 5' from U.S.A. bank, Baring, Maine.
SCB19C	45 09 12	67 17 49	10' from Canadian bank opposite Magurrewock Stream, Calais, Maine.
SCB19M*	45 09 13	67 17 45	Midpoint in river opposite Magurrewock Stream, Calais, Maine.
SCB20C*	45 10 12	67 17 59	200' upstream from bridge at Milltown, Maine - Milltown, New Brunswick, 5' from Canadian bank.
SCB20U*	45 10 09	67 17 53	200' upstream from bridge at Milltown, Maine - Milltown, New Brunswick, 5' from U.S.A. bank.
SCB21M*	45 08 46	67 18 11	1700' downstream from Landmark 211 5' from Canadian bank opposite large island in Baring Basin, Baring, Maine.
MC10*	45 09 13	67 19 52	Midpoint in Mohannas Stream at "oxbow" in stream.
GF01*	45 14 52	67 31 57	Grand Falls Flowage near southerly tip of island west of Lamb's Place, Baileyville, Maine.
			POINT SOURCES
SCGP	45 08 18	67 23 53	River side of outfall from defoaming lagoon Georgia-Pacific Corp., Woodland, Maine.
SCB2	45 08 12	67 23 53	18" municipal combined sewer for Baileyville, Maine.

* Benthic respirometer station

TABLE 8

SUMMARY OF WATER QUALITY DATA
ST. CROIX RIVER
AUGUST 8 - 15, 1972

Station		Temp. °C	DO mg/l	BOD_5 mg/l	pH standard units	Color Pt-Co units	Turbidity Jackson Candle	Residue mg/l Total Diss.	Residue mg/l Fixed Diss.	Residue mg/l Total Nflt.	Residue mg/l Fixed Nflt.	Coliforms per 100 ml Total	Coliforms per 100 ml Fecal
SCKU	MAX.	22.0	8.4	K 1.2	6.8	50	1.0	45	27	3	3	2500	6
	MIN.	19.0	6.2	K 1.2	6.3	45	0.7	21	2	0	0	560	K 2
	MEAN	20.3	7.9	K 1.2	6.5	45	0.9	31	17	2	1	1600*	2*
SC01	MAX.	22.0	7.5	K 1.2	6.9	50	1.1	52	38	8	3	2500	K 10
	MIN.	19.5	5.1	K 1.2	6.3	45	0.6	19	4	0	0	420	K 2
	MEAN	20.4	6.7	K 1.2	6.6	45	0.7	35	20	3	1	900*	K 2*
SC2D	MAX.	21.5	7.7	2.0	6.8	50	6.5	55	52	10	10	4900	56
	MIN.	20.5	6.8	K 1.2	6.8	30	0.9	6	1	1	0	490	2
	MEAN	21.0	7.2	1.4		45	2.6	30	19	4	3	2200*	14*
SC2C	MAX.	21.5	7.7	1.2	6.9	50	14.0	68	30	17	16	10,000	10
	MIN.	19.5	6.8	K 1.2	6.1	40	0.8	8	1	1	0	800	K 2
	MEAN	20.2	7.0	1.2	6.5	45	5.1	33	16	7	6	1300*	4*
SC02	MAX.	21.5	6.8	1.3	6.9	50	19.0	50	32	16	16	3100	800
	MIN.	19.5	5.5	K 1.2	6.0	45	0.8	11	9	2	1	920	K 2
	MEAN	20.3	6.0	1.2	6.5	50	4.1	34	19	5	4	2800*	2*

Note: "K" denotes "less than"
* Median value

TABLE 8 CONTINUED

SUMMARY OF WATER QUALITY DATA
ST. CROIX RIVER
AUGUST 8 - 15, 1972

Station		Temp. °C	DO mg/l	BOD_5 mg/l	pH standard units	Color Pt-Co units	Turbidity Jackson Candle	Residue mg/l Total Diss.	Fixed Diss.	Total Nflt.	Fixed Nflt.	Coliforms per 100 ml Total	Fecal
SC2U	MAX.	32.0	7.1	190	9.6	500	72.5	820	570	64	25	29,000	6,900
	MIN.	24.0	4.1	40	5.9	1250	1.4	400	280	18	6	4,000	20
	MEAN	28.4	5.9	104	7.8	890	21.1	540	380	41	17	8,000*	440*
SC4C	MAX.	22.0	7.0	3.5	6.9	70	4.6	75	58	5	5	6,900	1,000
	MIN.	19.0	5.6	1.4	6.3	60	2.0	14	12	2	0	900	K 10
	MEAN	20.4	6.4	2.3	6.6	60	3.0	45	30	4	2	32,000*	30*
SC04	MAX.	22.5	7.3	3.5	6.9	100	3.8	71	36	6	3	5,000	220
	MIN.	19.0	5.8	2.0	6.3	60	2.1	23	12	1	0	1,800	22
	MEAN	20.5	6.3	2.8	6.6	70	2.9	53	28	4	2	3,000*	70*
SC40	MAX.	23.0	6.2	9.0	7.2	150	4.9	94	67	8	6	7,900	2,400
	MIN.	19.5	5.1	4.6	6.4	100	2.8	53	25	2	0	3,100	80
	MEAN	21.0	5.7	6.7	6.7	110	3.3	76	49	6	2	5,000*	190*
SC05	MAX.	22.0	6.2	5.2	6.8	100	7.8	80	53	7	6	12,000	1,210
	MIN.	18.5	4.9	2.8	6.0	70	2.3	26	1	4	1	250	60
	MEAN	19.9	5.8	3.9	6.4	85	4.4	57	36	5	3	3,300*	200*

* Median value

the purpose of this discussion, nonfilterable residues include all matter in suspension which will not pass a Gelman type A filter or equivalent, and settleable matter are those nonfilterable residues which will settle in a quiescent body of water within one hour.[7]

Nonfilterable residues have a deleterious effect upon aquatic life. Although their chemical constituents may in themselves be harmful, the more universal danger lies in the deposition of residues on the bottom. When materials are deposited in sufficient quanitites, as in the St. Croix River, the bottom is blanketed. The settling materials clog interstices in gravel or rubble, ruin spawning beds, smother bottom organisms (benthos), and choke plant life and fauna. These effects interrupt the food chain and directly eliminate energy sources for fish and higher life forms.

High concentrations of nonfilterable residues have an abrasive action upon the gill and respiratory passages of fish. When fish have sustained damage to their respiratory systems, low concentrations of dissolved oxygen and/or toxic substances can destroy fish life.

Wood fibers and other nonfilterable residues abrade and clog the gills of fish. They interfere with its life processes. They are also harmful to the extent that they blanket the bottom and decay. Ellis[8] has recommended that all cellulose pulps and sawdust be excluded from streams and that the stream bottom not be blanketed to a depth exceeding 0.25 inches. Other studies have shown fish egg mortalities ranging from 36% - 75% in areas covered with fibers from mechanical pulping operations as compared to 3% - 15% mortality in control areas.[9]

Nonfilterable residues destroy aesthetic values and upon settling create sludge beds which can hinder navigation. Since these residues contain organic material, the sludge settling to the bottom putrefies and emits methane and hydrogen sulfide gases. During the degradation process, bacterial oxidation exerts a high oxygen demand on the overlying waters.

It is significant to note that dissolved or colloidal sized materials may be synthesized by bacteria to form suspended or settleable sludges in the form of biological or bacteriological slimes such as Sphaerotilus.

EPA's 1972 study showed that the total nonfilterable residue in the river ranged from 0.4-63.9 mg/l. The average values gradually increased from Kellyland to Woodland, Maine (See Figure 4). The average concentration in the U. S. side of the river increased 900% (4.1 mg/l at station SC2D to 38.5 mg/l at SC2U) immediately following G-P's defoaming lagoon discharge, and then declines in the downstream study area. EPA's biologists noted that sludge from paper wastes created a toxic environment at a point 700 feet downstream from the mill discharge and observed Sphaerotilus approximately 1.0 mile downstream (See Appendix E). Coastal Research Corporation's report[3] provides no specific reference to sludge deposits downstream from the mill because "the majority of the Maine side of the river has sludge deposits in it." The sludge was apparently putrefying because sludge mats had broken from the bottom and were floating on the surface. Divers from EPA's Cincinnati Field Investigation Center observed gas bubbles rising to the water surface in Baring Basin.

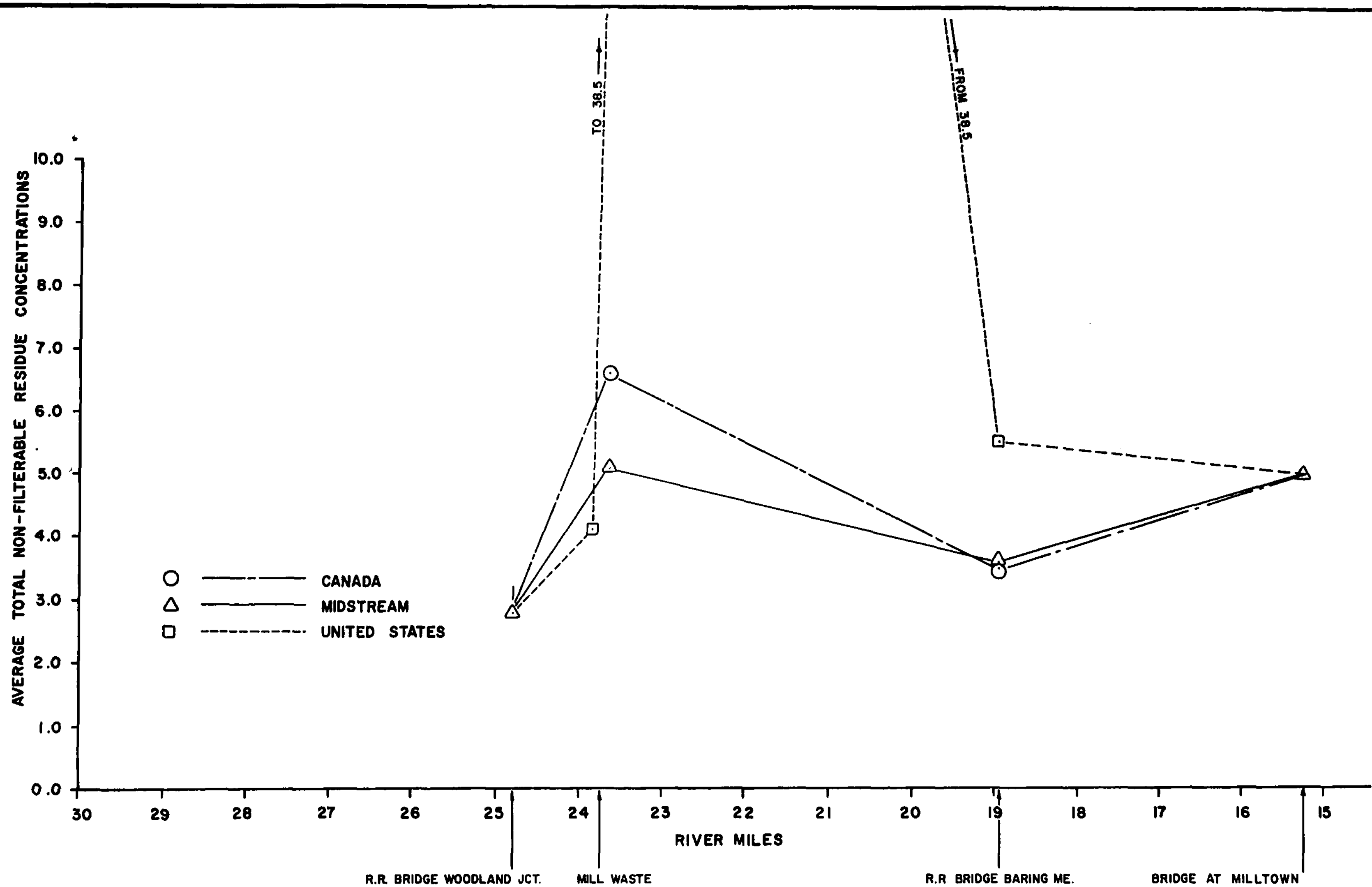
Scuba divers and biologists reported that the river bottom from Spednik Falls to Milltown bridge contained wood fibers and bark which had been abraded from logs. Upstream from Kellyland, the bottom appeared to be covered with a thin layer of floc and marl but did not contain any logging debris.

In Woodland Lake and Mill Pond, logs, wood fiber, bark, and a floc material littered the bottom. Gas bubbles rose from the sediments. A study by Geophysical Survey Systems, Inc. (GSS) determined the depth of logs and debris in the log storage areas (See Appendix F). GSS reported logs layered one to three feet thick over 80% of the areas examined. Some log deposits were four to five feet thick. Appendix G is a diving report which estimates log layerings and confirms the GSS findings.

Turbidity

Turbidity is an expression of the optical property of a water to absorb and disperse light. It is caused by emulsions and/or suspended matter such as clays, silt, bacteria, plankton, and finely divided organic matter which interrupt the light path and reduce light penetration.

Turbidity levels in the St. Croix River parallel the nonfilterable residue concentrations. Average turbidities upstream from the dam at Woodland remained less than 1.0 JTU. The analysis of stations downstream from the dam not affected by G-P's main effluent (SC2D, SC02, and SC2C) showed increases in turbidity. The increases at SC02 and SC2C can be attributed to silt washing into the river from dam reconstruction activities on the Canadian side. At SC2D the increase is attributable to the log flume and the wet storage area at the mill. Downstream from G-P's discharge



ST. CROIX RIVER STUDY
AUGUST 1972
AVERAGE TOTAL NON-FILTERABLE RESIDUE CONCENTRATION VS. RIVER MILES

FIGURE 4

(station SC2U), the average turbidity on the U. S. side of the river increased ten-fold. This is directly attributable to the nonfilterable residues discharged by the mill. From the mill downstream to Milltown bridge, turbidity averaged more than 2.9 JTU at all stations sampled.

Color

Color in water may be of organic or mineral origin. True color is defined as color caused by dissolved matter and is measured after suspended materials have been removed. For purposes of comparison, one standard color unit has been defined as the color imparted to distilled water by a 1.0 mg/l dissolved platinum concentration.

Color affects the ability of certain wave lengths of light to penetrate water. Unlike turibidity which also disperses the light rays, colors, especially browns and grays, absorb the light energy. In so doing, the light intensity diminshes and the absorbed energy increases the temperature of the water. Color retards photosynthesis and may have a deleterious effect upon aquatic life, particularly phytoplankton, and the benthos.[10]

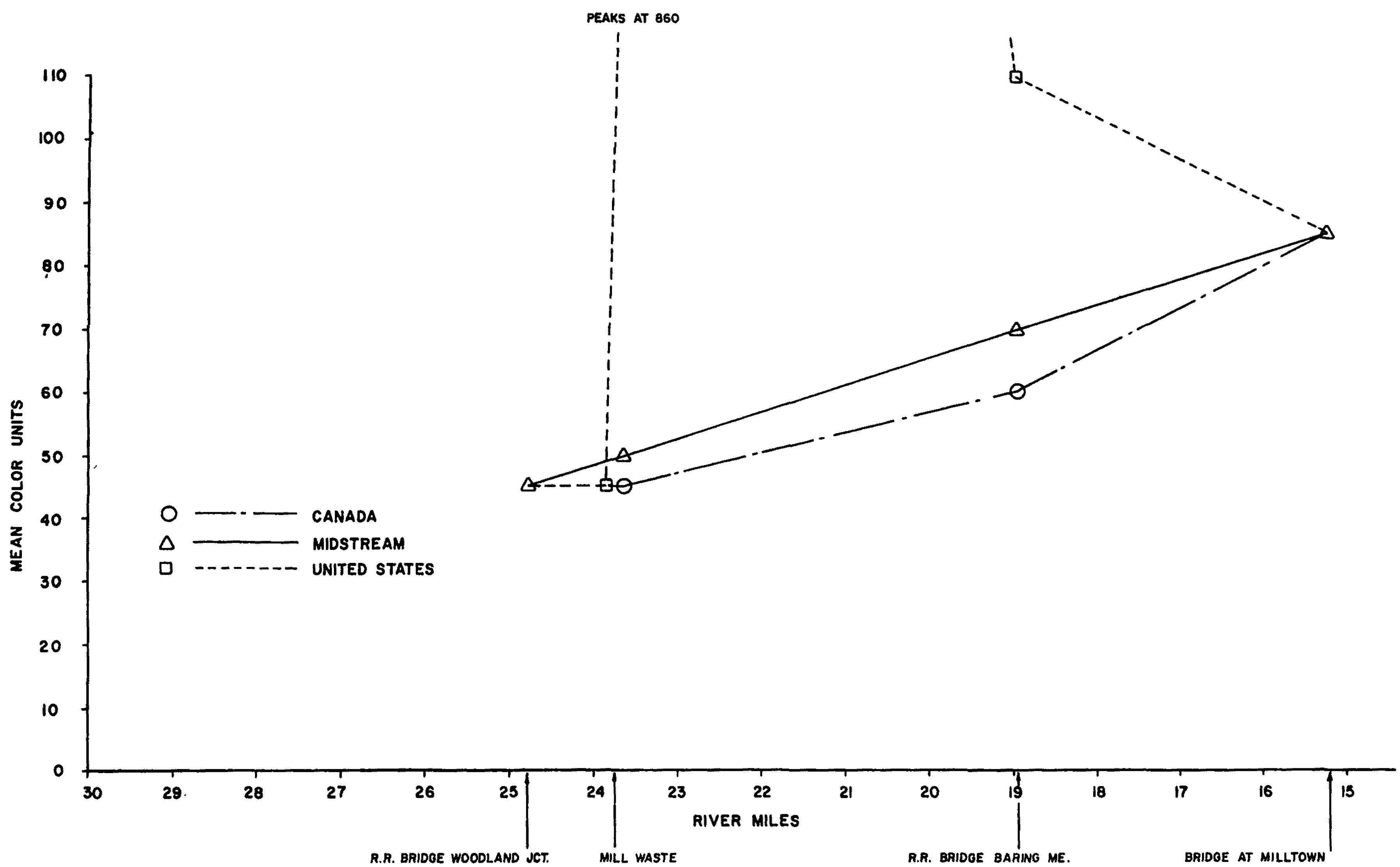
The St. Croix River, even in the control areas, is highly colored, averaging nearly 50 color units. The high color can be attributed to drainage from swamps and forested areas. Starting upstream at Kellyland and coming downstream, the color of the water remained uniform until the water passed the G-P mill. The pulp and paper industry has long been recognized as a major contributor of color to the nation's waterways, and Georgia-Pacific Corporation is no exception. Downstream from the mill (station SC2U) the color averaged 850 units. Continuing downstream the highest color values occurred on the U. S. side of the river. At Milltown bridge the color averaged 85 units. Figure 5 is a representation of mean color units in the study area.

Temperature

Temperature is an important regulator of natural processes in aquatic ecosystems. Changes in temperature control, the physiological functions within the biosystem, both by altering the physical and chemical character of the environment and by directly affecting the life organs of aquatic animals and plants. Each species has its own unique thermal requirements, so that a given change in water temperature will have a broad range of effects upon the organisms within the water body. Therefore, the thermal regime of a water ecosystem controls the community structure and food chain relationships.[11,12]

Elevated temperature has the following significant observable effects: (1) decreased solubility of oxygen; (2) increased metabolism and respiration, resulting in an increased demand for the diminished dissolved oxygen; (3) increased ability for enteric, including pathogenic, bacteria to survive in the water; (4) increased toxicity of certain substances; (5) inability of certain species' organs to function properly resulting in failure to reproduce or death; (6) increased growth of sewage fungus and putrefaction of sludge deposits and (7) a shift (rejuvenation) of the ecological composition of sludge deposits in favor of "pollution-tolerant" organisms which are better able to compete for a given niche in the aquatic environment.

Because increased temperatures have such a profound influence on the biological support system, considerable research has been done to determine acceptable temperature limits. Maine has established a maximum temperature limit of 28.5°C in waters designated to support a warm water fishery (bass, pickerel, perch) and 20.0°C to support a cold water fishery (trout and



ST. CROIX RIVER STUDY
AUGUST 1972
MEAN COLOR UNITS VS. RIVER MILES

FIGURE 5

salmon).[13] Historically, the St. Croix River is a cold water fishery and the intent is to continue to operate the river as one.

Except for the U. S. side of the river immediately downstream from the defoaming lagoon outfall, average river temperatures remained near 20°C. Immediately downstream from the outfall, the average temperature jumped to 28°C and ranged from 23°C to 32°C. Fish studies performed by the Canadian Environmental Protection Service showed that fish placed in the river immediately downstream from the mill died in seconds apparently from thermal shock. During reconnaissance studies, boat crews observed steam rising from the U. S. side of the river nearly 2.0 miles downstream from the mill.

Chemical Parameters

Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), and Sediment Oxygen Demand (SOD)

Dissolved oxygen, BOD, and SOD are so interrelated that all must be treated within the same discussion.

Biochemical oxygen demand is a laboratory test which measures the quantity of oxygen consumed by bacteria and interim chemical reactions for the degradation of organic matter in water under controlled conditions for a specified time. Sediment oxygen demand is a measure of the dissolved oxygen being utilized for the stabilization of organic matter in sediment deposits. The numerical values of BOD and SOD are not significant per se, rather, they are indices of the degradability or "strength" and are only important insofar as they relate to oxygen balances in a stream.

Dissolved oxygen may be introduced into a stream by the tumbling of water over rocks, dams, and riffles, the molecular diffusion of oxygen from air at the water-air interface, and photosynthesis by plant life.

Oxygen is important in maintaining a healthy fish population. It is also important for the degradation of wastes because aerobic bacteria more quickly stabilize wastes than anaerobic bacteria. Also, aerobic digestion does not produce foul odors. The amount of oxygen necessary to maintain fish life varies with the fish species to be maintained. The recommended limits may be specified as a percent of the saturation value (which is temperature dependent) and/or a minimum concentration. The Federally-approved Maine Water Quality Standards specify, "The dissolved oxygen content of such waters (St. Croix River) shall not be less than 5 parts per million for trout and salmon waters."[13]

The amount of organic wastes a stream can safely assimilate is dependent upon maintaining an oxygen balance in the stream. The amount of oxygen consumed to satisfy chemical and/or biological demands must not exceed the reaeration necessary to maintain favorable conditions. A way to control the rate at which oxygen is consumed is to reduce the concentration of the waste in the stream. This may be done by accelerating the degradation process in a controlled system (waste water treatment) prior to discharging the waste.

Examination of BOD and SOD and their affect upon DO in a stream should be made during low flow conditions. During low flow conditions, the dilution factor is minimized, reaeration rates are usually minimized and the residence time in a reach maximized. Also, low flow conditions usually occur in the late summer months when water temperatures are at their maximum. Maine's criteria[13] specifies that the 1-in-10-year, 7-day low flow should be used for determining the assimilative capacity of a stream.

As stated previously, during the study period flows in the river averaged 2410 cfs which was approximately 500 cfs higher than that experienced in 1970 and nearly 2000 cfs more than the 1-in-10-year, 7-day low flow of 480 cfs.

The BOD_5 at the stations upstream from Woodland Dam never exceeded 1.2 mg/l. On the Canadian side of the river and midstream downstream from the dam at Woodland, Maine the average BOD_5 remained at less than 1.2 mg/l. However, at station SC2D a slight increase was observed. Downstream from the main outfall, the average was 92 mg/l. Further downstream at the railroad bridge at Baring, Maine the BOD_5 on the U. S. side of the river ranged from 4-6 - 9.0 mg/l. Figure 6 presents the average BOD5 values in the river.

The SOD data collected (Appendix H) show an average oxygen demand of 2.3 grams per square meter per day (gm O_2/m^2/day) in the control areas of the St. Croix River and Grand Falls Flowage. As a result of photosynthesis supplying more oxygen than bacteria were consuming a negative demand was observed in Mohannas Stream. In the log storage areas, the SOD increased from 2.3 gm O_2/m^2/day in the control areas to approximately 2.7 gm O_2/m^2/day in Woodland Lake. Associated with this increase was an average DO reduction of 1.5 mg/l from Kellyland to the railroad bridge at Woodland junction. Approximately 1.25 miles downstream from the mill (transect SCB17) the sediment oxygen demand jumped from an average of 2.7 gm O_2/m^2/day in

Woodland Lake (station SCB15M) to an average of 6.7 gm O_2/m^2/day. Near Milltown bridge the average SOD dropped to 2.6 gm O_2/m^2/day or nearly the same as that which occurs at SCB15M.

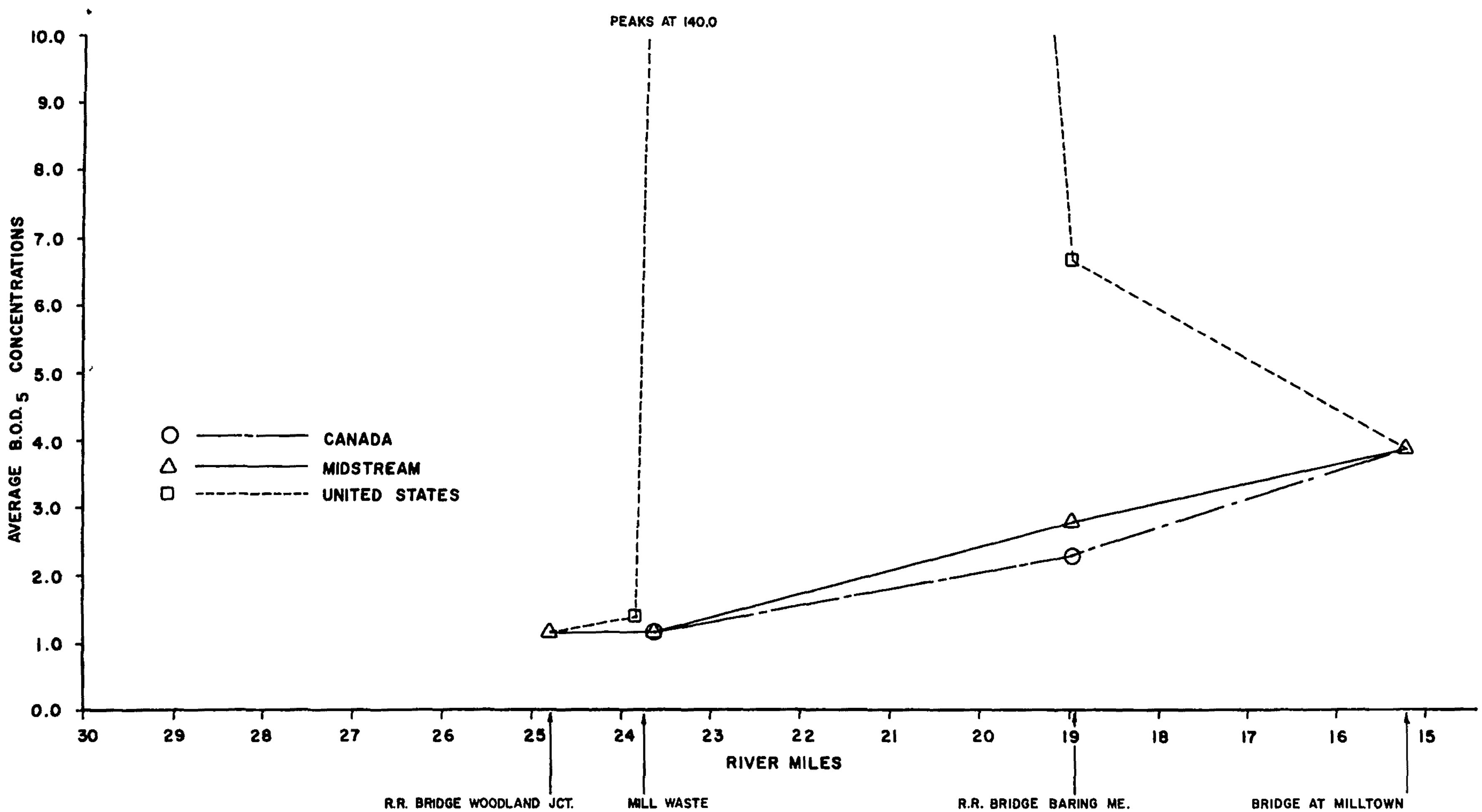
The sunken debris caused by log storage in Woodland Lake and Mill Pond represents a substantial pollution load. The 0.4 gm O_2/m^2/day increase in SOD when distributed over the downstream portion of Woodland Lake and Mill Pond removes 2400 pounds of dissolved oxygen from the overlying water daily. If the overlying water is not reaerated or exchanged, severe oxygen depeletions can occur. Such depletions occur during low stream flow conditions. For instance, in August 1970, when the average flow was approximately 1900 cfs, the mean DO under the railroad bridge at Woodland junction (SC01) was 4.5 mg/l[2], 0.5 mg/l less than the 5.0 mg/l established by the Federally approved Maine Water Quality Standards.

Analysis of the 1972 data shows that a slight, but significant depression occurs in Woodland Lake. The mean DO decreases from 7.9 mg/l downstream from Grand Falls Dam (SCKU) to 6.7 mg/l at SC01. Comparing DO's at SCKU and SC01 on a day-to-day basis, the DO in Woodland Lake was consistently lower although the temperatures at the two stations never varied more than 0.5°C.

The most severe DO depression occurred immediately downstream from Georgia-Pacific's outfall (SC2U). At this station, the DO's ranged from 4.1 - 7.1 mg/l, and averaged 5.9 mg/l. The mean DO values at SC4U and SC05 were 5.7 mg/l and 5.8 mg/l respectively. Figure 7 represents the mean DO concentrations reported during the study.

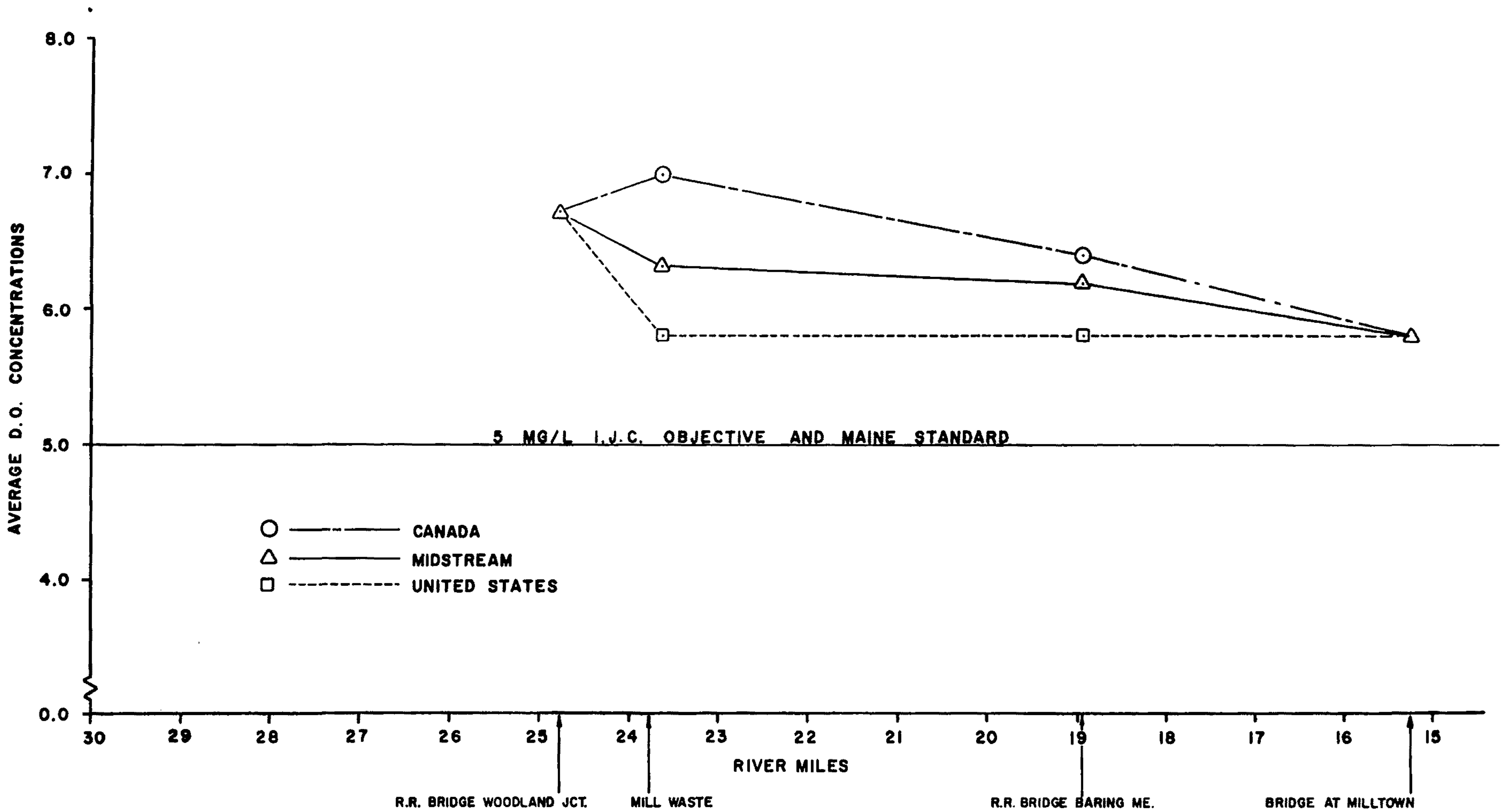
<u>Toxicity</u>

To determine the toxicity of G-P's wastes, the Canadian Environmental



ST. CROIX RIVER STUDY
AUGUST 1972
AVERAGE B.O.D_5 CONCENTRATIONS VS. RIVER MILES

FIGURE 6



ST. CROIX RIVER STUDY
AUGUST 1972
AVERAGE D.O. CONCENTRATIONS VS. RIVER MILES

FIGURE 7

Protection Service (EPS) conducted three kinds of live fish bioassays: 1. semi-static, 2. continuous flow, and 3. in-situ. All bioassays showed that G-P's wastes were highly toxic.

EPS personnel conducted the semi-static and continuous flow bioassays using effluent from G-P's defoaming lagoon diluted with water taken from Grand Falls Flowage at Grand Falls Dam. In the semi-static tests, fish were placed in tanks containing 100, 56, 32 and 17 percent effluent. Fish were also placed in control tanks which contained no effluent. Every twenty-four hours, 50 percent of the solution in each tank was removed and replaced with fresh solution of like concentration. In this test, all fish subjected to waters containing 17 percent effluent died in less than eighty-five hours, while those in higher effluent concentrations died even sooner. All fish in the control tanks, zero percent effluent, survived more than the 96 hours alloted for the test. Table 9 shows the results of the semi-static bioassay and Appendix I is a detailed report of the bioassays.

Sets of continuous flow bioassays were run on August 12, 13 and 15. Fresh river water from Grand Falls Flowage and fresh effluent were continually pumped into various tanks to make up test solutions containing 75, 65, 50, 35 and 25 percent effluent. In addition, control tanks were run which received only river water.

All fish placed in control tanks survived longer than the 96-hours specified for the tests. Only in one other tank did any fish survive more than 96 hours. In one of two 25% effluent tanks tested, 80% of the fish survived the test. In the remaining tanks, 100% mortality occurred in less than 40 hours. Table 10 summarizes the test results and Appendix I details the bioassays and results.

Table 9

THE CONCENTRATION, PERCENT SURVIVAL AND LT50 VALUES FOR THE GEORGIA-PACIFIC EFFLUENT USING FINGERLING ATLANTIC SALMON

CONCENTRATION (%)	% SURVIVAL	LT50 (HOURS)
100	0	12
100	0	9.7
56	0	22
56	0	17
56	0	23
56	0	34
32	0	34
32	0	40
32	0	62 [1]
17	0	76
17	0	37 [2]
Control	100	96
Control	100	96
Control	100	96

1 No explanation has been presented for the anomolous LT50 in the 32% concentration. Since the pH agrees with those of the other two 32% tests, it must be assumed that the initial concentration was 32%. The recorded pH at 48 hours, however, was lower than that of the other two.

2 In the case of the 17% effluent bioassay, the operator found that an air valve was working improperly, thus creating an artifact in the toxicity.

TABLE 10

CONCENTRATIONS, PERCENT SURVIVAL AND LT50 VALUES OF THE CONTINUOUS FLOW BIOASSAYS CONDUCTED WITH GEORGIA-PACIFIC MILL EFFLUENT ON AUGUST 12, 13 and 15, 1972 USING ATLANTIC SALMON

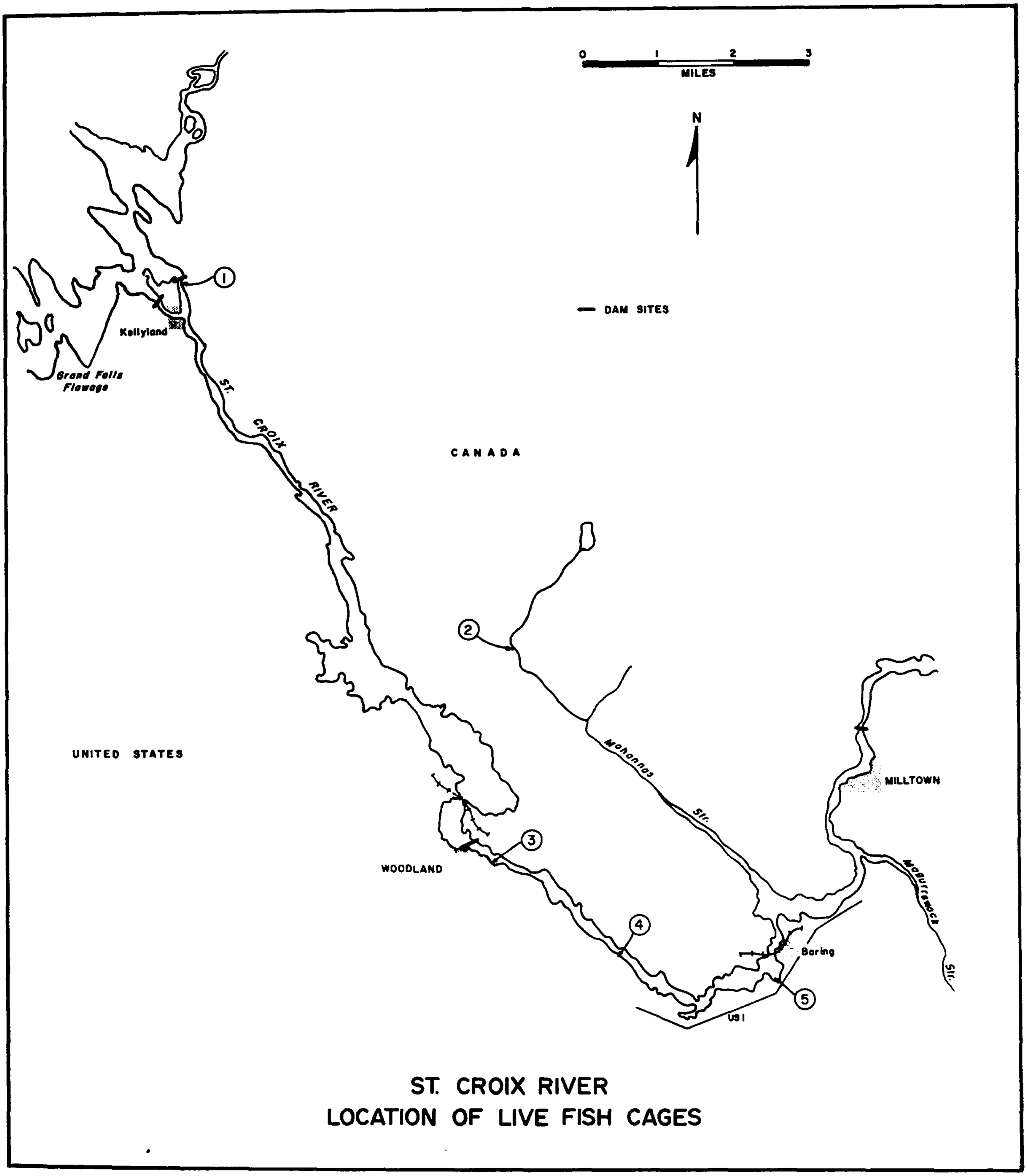
CONCENTRATION %	% SURVIVAL	LT50 (HOURS)
75	0	8.2
50	0	12
25	0	18
75	0	20
50	0	27
25	80	--
65	0	17
35	0	27

In addition to the bioassays performed on the mill's effluent, live fish cages were placed at five locations in the river basin (See Figure 8). All fish placed in cages downstream from the mill died in less than 80.5 hours while all those upstream survived more than 96.0 hours. An exception to this was a group of caged fish which was left without water when the gates at the Kellyland Dam were closed. Fish placed in the St. Croix River on the U. S. side 400 yards downstream from the effluent discharge died in seconds probably from thermal shock. At Bailey Rips 1.5 miles downstream from the mill, severe toxicity was indicated. One-hundred percent mortality occurred in 80.5 hours at Milltown bridge. Temperature was not termed a limiting factor at Bailey Rips nor Milltown bridge. Appendix J is a more descriptive presentation of the insitu fish cage studies.

The fish which died during the bioassay studies were preserved and transported to EPA's National Marine Water Quality Laboratory at West Kingston, Rhode Island for histopathological examinations.

The examinations showed that the olfactory organs (smell) had lesions present. Salmon exposed for more than twenty hours were usually severely affected. Rapid death of an organism does not allow enzymatic changes to occur in cells which will allor recognition of cause of death by microscopy. This may explain the absence of lesions in some groups. As stated in Appendix K:

> The prime function of the chemoreceptive organs are to convey information concerning changes in the chemical composition of the internal and external environment to the higher centers of the central nervous system for correlation. These sensory imputs allow the organism to alter behavioral patterns by adjusting their internal physiological or biochemical mechanisms to cope with a changing environment. Chemoreception in the salmon is vital to their orientation and migration into "home streams", and therefore, is vital to successful reproduction and propagation of the species.



ST. CROIX RIVER
LOCATION OF LIVE FISH CAGES

FIGURE 8

Biology

EPA's biologists examined portions of the St. Croix River for benthic invertebrates. Benthic invertebrates (benthos) are those organisms living in and crawling on the bottom. The log covered substratum in the running water at the upstream end of the log storage area (transect SCB13) did not exhibit a deterioration of benthic populations when compared to the upstream control stations. SCB13U and SCB13C have 9 and 14 kinds of benthos respectively compared to 12-19 kinds at river control stations. However, decreased benthos diversities at treansects SCB14 and SCB15 in Woodland Lake indicate degradation. Four to seven kinds of organisms were present compared to seventeen kinds at the Grand Falls Flowage control station. Organisms found in Woodland Lake are typified as moderately pollution tolerant.

The U. S. side of the St. Croix River 700 feet downstream from Georgia-Pacific's outfall was devoid of benthos, but on the Canadian side bottom organisms flourished. This two natured aspect of the river continued for at least one mile downstream.

On the U. S. side of the river offensive smelling bacteriological slime, filamentous bacterium, was accumulating on the bottom (station SCB17U) approximately 1.0 miles downstream from the mill. This gray slime thrives in organically enriched waters and is toxic to clean water organisms. Only the pollution tolerant sludgeworm Tubificidae was found at SCB17U.

Fast water, rapids, and island cause lateral mixing downstream, resulting in degradation of benthos midstream and on the Canadian side. Although the river begins to recover, degradation still remains present approximately six miles downstream from the mill. A more complete presentation of the biological examinations can be found in Appendix E.

Bacteriology

Water polluted by wastes from warm-blooded animals and humans frequently contains pathogenic (disease causing) organisms. Because of the difficulty in identifying pathogens, coliform bacteria are used as indicator organisms. Their presence indicates that pathogenic organisms are probably present. The presence of coliforms in sufficient numbers excludes the use of a water for drinking, water contact recreation, and, in the case of an estuary, the harvesting of shellfish. Because of this, the State of Maine in their Federally approved Water Quality Standards[12] established a maximum limit of 5,000 total coliform per 100 milliliters and 1,000 fecal coliforms per 100 milliliters for the St. Croix River downstream from Woodland.

Coliform bacteria are generally analyzed in two categories: total coliforms and fecal coliforms. Total coliforms may originate in soils as well as from warm-blooded animals. Fecal coliforms on the other hand usually originate in the intestinal tract of warm-blooded animals. Therefore, the presence of fecal coliforms is indicative of fecal contamination. During the August study, fecal coliforms exceeded the established criteria on one day, August 10. On this day, 6,900 and 2,400 fecal coliforms were recorded at stations SC2U and SC4U respectively. Station SC2U is downstream from the defoaming lagoon outfall and upstream from the municipal outfalls. Station SC4U is at Baring. The total coliform standard was generally exceeded at station SC2U and occasionally exceeded at stations farther downstream. At stations upstream from SC2U coliform criteria were not exceeded.

In addition to analyzing for total and fecal coliforms, analyses were conducted at selected stations to isolate the coliform genus Klebsiella. Research by EPA's Corvallis and Duluth laboratories isolated members of the genus *Klebsiella* in pulp and paper mill effluents. *Klebsiella* are not only an indicator of pathogens but some members of the genus are themselves pathogenic. *Klebsiella* are present in human fecal matter and were used as indicators of fecal pollution before being replaced by fecal coliforms. *Klebsiella* are often the cause of septicemia, pneumonia and post-operative infections. They rank second to *Escherichia coli*, as fecal coliform, as causative agents in urinary tract infections. In view of these fects, the presence of *Klebsiella pneumoniae* in water has as great a significance as the presence of *Escherichia coli*.

Klebsiella pneumoniae was isolated from the mill effluent in all effluent samples collected. Samples from the Baileyville municipal wastes also contained *Klebsiella pneumoniae* and *Klebsiella* were isolated from the river at Baring and Milltown (stations SC04 and SC05). Because all samples collected from the river upstream from the G-P mill failed to isolate this organism, the river was discounted as a background source of *Klebsiella*.

Further testing showed that Baileyville's wastes were not responsible for the presence of *Klebsiella* at Baring and Milltown. Capsular types isolated at SC04 and SC05 matched capsular types isolated from the mill effluent and not those from the municipal wastes. Although the source of *Klebsiella* within the mill complex is impossible to determine, their presence in the river downstream from the mill discharge is attributable to the mill effluent.

Appendix D is a more thorough presentation of *Klebsiella*'s significance and test results.

MATHEMATICAL MODELING

The data from any sampling program are specific. That is, the information compiled pertains only to the time, flow, waste strengths, temperature and all other interrelated factors at the time of collection. Being an active and vital environment, a water body and its constituents are constantly changing. Continually sampling a water body to compile information for every possible condition is impossible, but duplicating environmental conditions with matematical equations, which represent known conditions, can be run on a computer to provide good approximations of what conditions would be as factors are varied.

Because the formulation of the model is somewhat complex, only a brief summary will be presented here and a more complete presentation is in Appendix L.

Based on information collected during the August 1972 study, EPA's Systems Analysis Branch developed a model for approximating dissolved oxygen concentrations in the portion of the St. Croix River from Woodland Dam to the Milltown bridge.

Dissolved oxygen deficits in the stream, waste loadings, sediment oxygen demand (SOD), stream flow, and dissolved oxygen concentration at saturated conditions (a function of temperature) are fed to the computer which projects oxygen deficits at points downstream.

Most oxygen deficits in streams are attributable to biological activity which increases at warmer temperatures (summer conditions). Conversely, water's ability to retain oxygen decreases with increasing temperature i.e. the DO saturation value decreases. Also, streamflow declines in the late summer months and incident sunlight increases water temperatures. Thus at a time when oxygen demands increase, the ability of the water to meet those demands diminishes. For this reason models are usually run to depict critical conditions which might normally occur in the later summer months.

Data collected have shown the following: 1. The DO downstream from Woodland Dam can drop to less than 5.0 mg/l during warm weather and low flow conditions, 2. Over the past five years the average daily flow has been less than 1000 cfs on seventy days, 3. Sediment oxygen demands in the river reach between Woodland Dam and Milltown bridge average between 3.0 and 4.0 gm O_2/m^2/day and 4. The calculated oxygen uptake rate (k-rate) necessary to satisfy the 5-day BOD is 0.3 per day.

Using the foregoing information and the two dimensional model developed from the data collected in August 1972, the model was run on a matrix of conditions while holding the river water temperature constant at 25°C. The river flow was varied from 480 cfs to 1000 cfs, G-P's waste load from 5000 ppd to 19,200 ppd BOD_5, SOD from 1.0 - 5.0 gm O_2/m^2/day, initial DO between 5.0 and 6.0 mg/l, uptake rate (k-rate) between 0.2/day and 0.3/day.

The matrix studied showed that the DO will exceed the 5.0 mg/l DO minimum specified in the Maine Water Quality Standards if the mill discharge is 5000 ppd BOD_5. If the BOD_5 is increased to 10,000 ppd, the SOD must be less than 2.0 gm O_2/m^2/day and the k-rate less than 0.3 per day to maintain a satisfactory DO level. Based upon an SOD of 2.0 gm O_2/m^2/day and a k-rate of 0.3 per day, the calculated allowable BOD_5 load from the mill is 7,500 ppd. This BOD_5 loading precludes the introduction of any new waste sources to the St. Croix River between Woodland and Milltown.

Increasing the river flow to 750 cfs, greatly improves the river's assimilative capacity. At an SOD of 2.0 gm O /m /day and a k-rate of 0.2/day, a calculated BOD of 11,800 ppd will not violate water quality standards.

DISCUSSION

Because of the high streamflow, a direct comparison of the August 1972 water quality data and past water quality data is not possible. The increased flow by diluting the waste concentrations, presents a biased representation of improved water quality conditions. The higher flows also increase the potential for reaeration, lateral mixing, and cooling, all of which will create more favorable oxygen balances in the stream. Thus, comparison of past and present data will be limited to the data least influenced by changing river conditions, namely the waste loadings.

Loadings to the river are attributable to three sources: the Baileyville municipal wastes, Georgia-Pacific Corporation mill complex, and log floating and storage. The Baileyville wastes may be discounted because they are negligible when compared to those from the mill.

Preceding a water quality study in August 1970[2], Georgia-Pacific Coporation had installed a color removal and primary treatment system for its process wastes, but these were not fully operational at the time of that study. With this in mind and the fact that the mill was operating on reduced capacity during part of the August 1972 study, a comparison of changes in effluent characteristics can proceed.

In 1970 the average daily discharge from the defoaming lagoon was 34.75 million gallons of waste which contained 69,000 pounds of BOD_5. In 1972 the respective values were 31.6 million gallons and 54,000 pounds of BOD_5. A twenty percent decrease was noted in total suspended matter which declined from 25,400 pounds in 1970 to 20,000 pounds in 1972. The color of the effluent averaged 1350 platinum-cobalt units. Although a very high value, it appears to be an improvement. This judgment is based on a comparison of water quality data immediately downstream from the effluent (station SC2U) where dilution is minimized. In 1970 the color at SC2U averaged 1264 color units and in 1972 890 units. Other notable waste characteristics were a strong odor and increasing amounts of foam in the lagoon and river as the study progressed. Both characteristics were also noted in the 1971 IJC report.

Bioassays performed using the mill's effluent indicated severe toxicity. In semi-static tests all fish subjected to waters containing 17 percent effluent were dead in less than eighty-five hours and those in higher effluent concentrations died even sooner. With the exception of the fish in the control tanks and one tank having a 25 percent effluent concentration, all fish subjected to continuous flow bioassays died in less than the 40 hours. Eighty percent of the fish in one 25 percent effluent tank and all the fish in the control tanks survived longer than the 96 hours specified for the tests. The Canadian government has established toxicity standards for effluents from pulp and paper mills. The Canadian standard stipulates that 100 percent of the test organisms must survive 96 hours in a test dilution containing 65 percent effluent. The mill effluent did not approach compliance with this standard.

Live caged fish placed in the river showed that the effluent is toxic four miles downstream and probably causes death by thermal shock immediately downstream from the mill. Histopathology showed that the toxicants damage the olfactory (smell) organs in fish. Both facts will prevent the re-establishment of a salmon fishery in the St. Croix River.

Log floating and storage practices have not changed appreciably since 1970. Georgia-Pacific Corporation through its subsidiary the St. Croix

Pulpwood Ltd. of Canada continues to float logs from the Canadian log landing near Grand Falls Dam to Woodland Lake. In so doing, G-P perpetuates the deposition and leaching of oxygen demanding wastes in Woodland Lake. The 1972 study showed that the deposition of these waters increased the sediment oxygen demand from approximately 2 gm O_2/m^2/day in Grand Falls Flowage to more than 3 gm O_2/m^2/day in Woodland Lake. Conversely, dissolved oxygen concentrations in Woodland Lake were 1.5 mg/l less than those in the river at Kellyland.

The 1972 data shows sediment ocygen demand exceeding 6.0 gm O_2/m^2/day approximately 1.25 miles downstream from the mill. Farther downstream at Baring the average demand was more than 3.5 gm O_2/m^2/day. Comparison of nonfilterable residue values at Baring and Milltown bridge indicates that little material is settling out. Therefore, the demand is being exerted primarily by historical sludge deposits and will exist for several years. The SOD is not expected to decrease to less than 2.0 gm O_2/m^2/day, the approximate value of SOD in upstream control areas.

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APPENDIX A

01021000 SUMMARY FOR JAN - SEPT 1972 TOTAL: 753907.00, MAX: 12100.00, MIN: 726.00

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION

ST. CROIX RIVER AT BARING, MAINE. NUMBER 01021000

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1971 TO SEPTEMBER 1972

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	900	812	1,340	1,070	1,740	726	2,850	7,210	2,840	3,640	2,470	2,090
2	912	750	1,330	1,450	1,720	1,010	2,860	8,840	4,130	3,440	2,040	2,090
3	903	690	1,390	1,330	1,530	1,040	2,890	8,890	4,500	2,830	1,700	2,100
4	891	730	1,360	1,040	1,280	1,210	2,880	10,200	5,060	1,440	2,290	2,040
5	849	999	1,500	1,030	1,130	1,260	2,920	11,800	4,810	1,280	2,580	1,760
6	738	742	1,230	1,080	1,120	1,170	2,920	12,100	4,290	1,960	2,470	2,390
7	747	889	1,250	1,030	1,140	1,200	2,860	11,300	3,510	2,510	2,460	2,340
8	761	844	937	997	1,270	1,430	2,800	10,500	3,470	2,360	2,500	2,410
9	759	736	1,550	1,010	1,540	1,440	2,790	9,830	3,380	2,390	2,410	2,550
10	785	738	1,630	1,140	1,110	1,510	2,490	8,360	4,100	2,320	2,400	2,300
11	920	770	1,090	1,270	904	1,560	2,100	7,310	4,520	2,480	2,370	2,510
12	1,570	792	995	1,150	923	1,550	2,340	6,650	4,860	2,650	2,360	2,520
13	1,560	950	648	1,320	917	1,540	2,460	5,560	5,550	2,630	2,370	2,470
14	1,460	730	639	1,380	833	1,770	2,590	5,270	4,880	2,460	2,360	2,230
15	1,150	593	678	1,090	792	2,010	2,490	4,820	3,830	2,480	2,460	2,000
16	935	551	741	1,270	924	1,940	2,520	5,600	3,900	2,530	2,490	2,080
17	786	615	793	1,540	913	1,960	2,690	5,960	3,970	2,150	2,410	2,110
18	765	550	771	1,670	892	2,510	2,950	5,760	3,880	2,100	2,490	2,110
19	770	734	763	1,620	890	2,860	3,190	5,080	3,640	1,950	2,370	2,080
20	762	724	762	1,590	903	2,900	3,100	4,300	3,280	1,910	2,330	1,790
21	770	566	760	1,590	875	2,890	3,080	4,350	2,900	1,570	2,390	1,560
22	1,460	495	724	1,500	846	2,960	3,090	4,310	2,860	1,320	2,300	1,530
23	1,710	510	725	1,620	828	3,780	3,150	4,120	2,920	1,320	2,350	1,780
24	1,410	593	787	1,660	952	4,130	3,190	3,610	3,050	1,380	2,420	1,870
25	1,320	679	912	1,540	730	3,070	3,550	2,860	5,130	1,890	2,330	1,690
26	1,490	935	1,000	1,710	836	2,620	3,860	3,020	6,210	1,610	2,190	1,460
27	1,160	994	835	1,810	865	2,970	4,380	3,060	6,100	1,570	2,040	1,390
28	862	940	911	1,510	812	2,940	5,310	3,020	5,890	1,750	2,170	1,680
29	778	910	1,070	1,480	757	2,940	5,850	2,620	5,370	1,970	2,260	1,380
30	792	945	1,040	1,540	------	2,840	5,990	2,550	4,430	2,450	2,250	1,380
31	803	------	1,040	1,760	------	2,830	------	2,630	------	2,490	2,150	------
TOTAL	31,527	22,475	31,446	42,997	30,164	56,166	97,130	191,490	127,260	66,830	72,180	59,690
MEAN	1,017	749	1,014	1,387	1,040	2,134	3,238	6,177	4,242	2,156	2,328	1,990
MAX	1,710	999	1,630	1,810	1,740	4,130	5,990	12,100	6,210	3,640	2,580	2,550
MIN	747	495	678	997	757	726	2,100	2,550	2,840	1,280	1,700	1,380

CAL YR 1971 TOTAL 956,610 MEAN 2,347 MAX 11,300 MIN 495
WTR YR 1972 TOTAL 839,355 MEAN 2,293 MAX 12,100 MIN 495

Note.--Not for publication.

01021000 SUMMARY FOR JAN - SEPT 1971 TOTAL: 771162.00, MAX: 11300.00, MIN: 721.00

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION

ST. CROIX RIVER AT BARING, MAINE NUMBER 01021000

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1970 TO SEPTEMBER 1971

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	1,890	2,990	2,550	1,560	1,790	2,270	2,350	7,460	2,910	2,720	1,300	1,070
2	1,570	2,980	2,640	1,450	2,010	2,220	2,530	7,440	2,820	2,450	1,310	983
3	1,740	2,930	2,520	1,800	1,870	2,180	2,830	7,570	2,550	2,490	1,190	990
4	1,870	2,900	2,650	1,860	1,740	2,180	3,150	8,040	2,010	2,460	1,100	968
5	1,940	2,470	2,650	1,850	2,000	2,210	3,950	9,890	2,920	1,490	868	951
6	2,060	2,360	2,520	1,900	1,990	2,160	5,600	11,000	2,740	1,510	934	897
7	2,050	1,910	2,310	2,210	1,590	2,170	6,000	11,300	2,500	2,360	1,060	768
8	2,040	2,530	2,590	2,390	1,860	2,220	5,950	10,800	2,500	2,230	982	816
9	1,360	2,180	2,500	2,400	1,940	2,030	5,850	10,200	2,320	2,300	982	980
10	2,010	1,710	2,430	1,960	2,140	2,190	5,650	9,120	2,620	2,520	982	987
11	1,860	2,100	2,410	1,830	2,270	2,030	5,600	8,540	2,740	2,560	950	928
12	1,650	2,030	2,490	2,060	2,290	2,140	5,600	7,000	2,540	2,180	974	919
13	1,450	1,970	2,300	1,920	2,230	2,190	5,800	5,380	2,490	1,890	1,080	900
14	1,320	2,050	2,380	1,920	2,930	2,070	6,800	4,970	2,510	1,890	1,060	737
15	1,200	1,950	2,560	1,340	3,220	2,220	7,700	5,220	2,550	1,680	1,060	979
16	1,560	2,020	2,300	1,850	3,060	2,290	7,650	5,230	2,530	1,630	1,040	895
17	1,780	1,850	1,760	1,810	3,140	2,380	7,450	5,050	2,450	2,150	1,010	816
18	1,770	2,130	1,710	1,810	3,110	2,390	7,150	4,020	2,320	1,970	1,030	864
19	1,710	2,370	1,530	2,320	3,200	2,370	7,000	3,090	2,620	1,450	1,120	1,020
20	1,280	2,360	1,660	2,110	3,320	2,390	7,300	2,810	2,670	1,920	987	998
21	2,260	2,600	1,960	2,150	3,220	2,350	8,380	2,840	2,410	1,700	976	957
22	2,470	2,350	2,650	1,780	3,150	2,310	8,860	2,760	2,410	1,920	1,120	825
23	2,270	2,360	1,470	1,670	3,160	2,290	9,000	2,840	2,410	2,070	1,060	721
24	2,550	2,760	682	1,880	3,140	2,280	8,820	2,900	2,290	2,030	1,090	780
25	3,270	2,810	763	1,730	3,080	2,270	8,710	2,810	2,590	1,980	1,080	1,070
26	3,090	2,680	1,170	1,750	3,030	2,270	8,580	2,740	2,740	1,980	1,070	1,290
27	2,910	2,700	2,190	1,460	3,010	2,150	8,340	2,980	2,380	2,100	1,040	1,280
28	2,860	2,640	1,810	1,980	3,010	2,390	8,080	2,740	2,230	2,290	1,120	1,180
29	3,050	2,600	1,670	1,690	------	2,270	7,760	2,690	2,300	2,170	1,180	1,040
30	2,820	2,520	1,620	1,790	------	2,280	7,540	2,820	2,480	1,660	1,020	992
31	2,990	------	1,710	1,790	------	2,250	------	3,010	------	1,350	966	------
TOTAL	64,650	71,810	64,145	58,020	72,500	69,410	195,980	175,260	75,550	63,100	32,741	28,601
MEAN	2,085	2,394	2,069	1,872	2,589	2,239	6,533	5,654	2,518	2,035	1,056	953
MAX	3,270	2,990	2,650	2,400	3,320	2,390	9,000	11,300	2,920	2,720	1,310	1,290
MIN	1,200	1,710	682	1,340	1,590	2,030	2,350	2,690	2,010	1,350	868	721

CAL YR 1970 TOTAL 1,122,425 MEAN 3,075 MAX 13,000 MIN 682
WTR YR 1971 TOTAL 971,767 MEAN 2,662 MAX 11,300 MIN 682

Note.--Not for publication.

ST. CROIX RIVER AT BARING, MAINE

NO. 01021000
DRAINAGE AREA 1370.000 SQ MI

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1969 TO SEPTEMBER 1970

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	2,120	1,920	1,790	5,800	2,560	2,740	3,130	5,010	3,130	1,740	1,430	2,530
2	2,630	1,910	1,870	4,700	2,360	2,810	2,980	4,950	3,030	1,740	1,270	2,660
3	2,350	1,900	1,640	4,000	3,320	2,890	4,110	5,030	3,150	1,740	1,720	2,660
4	2,620	2,090	1,870	3,500	9,900	2,890	5,210	5,070	2,320	1,280	1,850	2,610
5	2,330	2,490	1,950	3,000	13,000	2,490	4,480	5,610	2,380	1,100	1,840	2,510
6	2,110	3,990	1,960	2,700	11,000	2,860	4,300	6,070	2,640	1,770	1,670	2,620
7	2,260	5,040	1,960	2,630	8,400	2,460	4,220	6,010	2,710	1,690	1,870	4,440
8	2,400	5,160	1,650	2,660	7,400	2,430	4,230	6,300	2,260	1,700	1,870	5,210
9	2,560	4,690	1,910	2,770	7,000	2,580	3,680	6,840	2,240	1,690	1,850	3,460
10	2,480	4,710	2,730	2,750	5,500	2,970	2,900	6,910	2,420	1,680	1,590	3,720
11	2,510	4,090	3,770	2,550	4,100	2,740	2,900	5,870	2,450	1,720	1,830	3,110
12	2,430	3,540	6,270	2,430	5,700	2,730	3,030	5,490	2,550	1,790	1,820	2,260
13	2,090	3,810	6,240	2,540	7,600	2,810	3,090	4,740	7,060	2,040	1,790	2,520
14	2,390	3,220	5,810	2,590	7,600	2,850	3,420	5,060	6,050	2,690	1,830	1,990
15	2,400	3,020	4,100	2,710	7,400	2,960	4,450	5,560	4,810	2,820	1,740	2,210
16	2,440	3,370	4,090	2,170	6,500	2,900	4,970	5,430	2,560	2,260	1,830	2,510
17	2,180	3,250	3,750	2,860	5,400	2,950	5,640	5,410	1,910	1,790	1,760	2,030
18	2,510	3,180	2,430	2,540	3,500	2,990	5,850	6,720	2,050	2,130	1,650	2,170
19	2,380	2,660	2,890	2,420	2,460	2,360	4,910	9,440	2,250	2,150	1,850	2,210
20	2,250	2,730	2,690	2,390	2,520	2,710	3,730	10,600	2,130	2,190	1,860	2,390
21	2,340	2,560	2,970	2,470	2,600	2,990	4,340	10,800	2,260	1,910	1,890	2,290
22	2,510	2,790	3,160	2,360	2,540	2,560	4,890	10,200	2,190	1,760	1,930	2,350
23	2,130	2,690	3,310	2,560	2,970	2,370	4,910	10,100	1,680	1,780	2,070	1,410
24	2,520	2,650	3,350	2,340	3,160	2,350	4,920	8,970	1,920	1,720	1,290	1,780
25	2,500	2,630	4,190	2,200	2,540	2,520	7,100	7,640	1,750	1,620	1,290	2,360
26	2,500	2,290	4,160	2,410	2,500	2,440	8,700	6,190	1,630	1,580	1,620	2,060
27	2,480	2,490	4,890	2,310	2,740	3,450	6,060	4,360	1,670	1,600	1,550	2,060
28	2,400	1,910	9,060	2,110	2,740	4,180	6,850	3,070	1,780	1,620	2,530	1,950
29	1,910	1,900	9,390	2,230	------	3,760	6,680	2,900	1,730	1,600	2,410	1,800
30	1,970	1,900	8,890	2,280	------	3,410	5,580	2,950	1,760	1,600	2,260	1,740
31	1,960	------	7,000	2,780	------	3,220	------	3,050	------	1,570	2,340	------
TOTAL	72,660	90,580	125,740	85,760	144,910	88,640	143,240	192,220	78,970	56,070	56,300	75,640
MEAN	2,344	3,019	4,056	2,766	5,175	2,861	4,775	6,201	2,632	1,809	1,816	2,522
MAX	2,630	5,160	9,390	5,800	13,000	4,180	8,700	10,800	7,060	2,820	2,530	5,210
MIN	1,910	1,900	1,640	2,110	2,360	2,360	2,900	2,900	1,630	1,100	1,270	1,410

CAL YR 1969 TOTAL 987,246 MEAN 2,705 MAX 10,500 MIN 698
WTR YR 1970 TOTAL 1,210,800 MEAN 3,317 MAX 13,000 MIN 1,100

ST. CROIX RIVER AT BARING, MAINE

NO. 1-0210.00
DRAINAGE AREA 1390.000 SQ MI

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1968 TO SEPTEMBER 1969

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	1,130	887	1,660	2,460	1,790	1,740	3,610	4,090	1,990	1,430	1,780	1,460
2	1,110	887	1,490	2,580	1,880	1,950	4,370	3,730	1,930	1,860	1,930	1,360
3	1,100	937	1,290	2,480	1,660	1,890	3,540	3,520	1,540	1,250	2,030	2,170
4	1,080	732	1,320	2,200	1,810	2,090	3,920	3,180	1,810	698	2,140	2,230
5	1,100	808	2,340	2,360	1,920	2,030	3,830	3,150	1,650	778	2,760	1,970
6	933	985	2,630	2,470	1,780	1,850	3,810	3,100	1,610	1,490	3,810	1,990
7	1,040	617	2,900	2,650	1,670	1,980	3,770	2,970	1,330	1,420	2,750	2,230
8	1,000	1,020	3,240	2,680	1,660	1,990	3,730	2,830	1,730	1,440	2,420	2,090
9	832	843	2,880	2,300	1,720	2,040	3,380	2,760	1,250	1,620	1,840	2,300
10	787	855	2,680	2,440	1,660	2,110	4,300	2,690	1,650	1,510	2,070	4,640
11	863	780	2,460	2,630	1,990	1,790	5,310	2,860	1,730	1,080	1,980	5,780
12	1,100	822	1,820	2,630	2,160	1,960	6,250	1,760	1,640	1,250	2,040	5,030
13	851	974	2,000	2,480	1,820	2,010	6,410	2,550	1,480	1,410	1,780	4,550
14	1,030	2,170	2,130	2,470	1,960	1,830	6,630	2,740	1,690	2,210	1,870	3,460
15	962	1,950	3,150	2,520	1,980	1,880	7,090	2,580	1,630	2,360	2,120	2,360
16	738	2,050	5,180	2,390	1,910	1,890	7,850	2,070	1,510	1,940	2,070	2,400
17	660	1,770	6,410	2,410	1,930	2,080	8,250	2,230	1,460	1,970	2,090	2,460
18	791	1,640	4,920	1,840	1,990	2,130	9,500	1,720	1,620	1,960	1,900	2,370
19	1,220	2,120	4,320	1,920	2,010	1,830	10,500	1,920	1,610	1,930	1,940	2,530
20	1,200	2,090	3,560	1,870	1,930	2,080	9,830	2,060	1,460	1,270	1,870	2,560
21	1,300	2,050	3,030	1,850	2,040	1,850	8,080	2,360	1,400	1,280	1,940	2,610
22	1,150	1,800	2,960	1,540	2,120	2,060	6,910	2,160	1,340	1,230	2,050	2,460
23	1,010	1,960	2,960	1,790	1,890	1,720	7,180	2,270	1,530	1,310	1,920	2,520
24	1,010	1,970	2,440	1,740	1,900	2,110	8,410	2,170	1,570	1,500	2,050	2,760
25	936	2,030	2,500	1,940	1,930	2,200	8,740	2,280	1,610	1,470	1,850	2,480
26	1,030	1,650	2,770	1,550	2,120	2,690	8,580	2,080	1,640	1,740	1,790	2,060
27	989	1,990	2,690	1,740	1,930	3,120	7,530	1,930	1,480	1,980	1,970	2,420
28	905	1,760	2,870	2,040	2,030	3,190	6,300	2,070	1,750	2,010	2,340	2,580
29	882	1,940	2,810	1,780	------	3,430	5,730	1,800	1,760	1,830	1,800	2,360
30	1,000	1,720	2,640	1,570	------	4,270	4,860	1,820	1,510	1,900	1,960	2,480
31	844	------	2,310	1,680	------	4,010	------	1,830	------	1,960	2,230	------
TOTAL	30,583	43,807	88,360	67,000	53,190	69,820	188,200	77,300	47,910	49,086	65,090	80,670
MEAN	987	1,460	2,850	2,161	1,900	2,252	6,273	2,494	1,597	1,583	2,100	2,689
MAX	1,300	2,170	6,410	2,690	2,160	4,270	10,500	4,090	1,990	2,360	3,810	5,780
MIN	660	617	1,290	1,540	1,660	1,720	3,380	1,720	1,250	698	1,780	1,360

CAL YR 1968 TOTAL 898,440 MEAN 2,455 MAX 8,170 MIN 617
WTR YR 1969 TOTAL 861,016 MEAN 2,359 MAX 10,500 MIN 617

Not for publication

ST. CROIX RIVER AT BARING, MAINE

NO. 1-0210.00
DRAINAGE AREA 1390.000 SQ MI

DISCHARGE, IN CFS, WATER YEAR OCTOBER 1967 TO SEPTEMBER 1968

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	4,950	1,410	2,410	2,300	3,010	2,260	5,750	3,490	2,680	2,070	1,460	1,170
2	5,330	1,380	2,330	2,280	2,840	2,690	6,200	3,000	2,710	1,890	1,500	818
3	4,220	1,420	1,850	2,710	4,300	2,920	5,770	2,690	2,710	2,030	1,630	743
4	3,820	1,540	2,520	2,710	6,180	2,780	5,400	2,950	2,580	1,120	1,620	1,120
5	3,380	1,810	3,030	2,780	5,850	2,780	4,950	2,670	2,530	1,630	1,500	919
6	3,220	2,140	2,840	2,940	5,610	2,910	5,430	2,940	2,530	2,160	1,680	1,100
7	2,320	1,730	2,690	3,070	5,380	2,770	5,160	2,830	2,580	2,060	1,360	1,060
8	2,320	1,490	2,830	2,130	4,950	2,580	5,080	2,890	2,610	1,560	1,360	1,080
9	2,050	1,340	2,610	2,820	4,030	2,430	5,100	2,770	2,610	1,490	1,610	1,130
10	1,800	1,380	2,800	2,980	4,110	2,210	4,770	2,750	2,540	1,490	1,610	1,120
11	1,910	1,410	2,420	2,750	4,050	2,130	5,260	2,680	2,510	1,450	1,450	915
12	2,080	1,220	3,000	2,740	3,530	2,370	5,370	2,200	2,370	1,300	1,320	1,100
13	1,940	1,290	3,950	2,650	2,700	2,380	5,380	2,490	2,060	1,480	1,410	1,080
14	2,090	1,380	3,890	3,000	3,090	2,390	5,330	2,350	2,240	1,660	1,370	1,250
15	1,620	1,010	5,030	2,820	2,980	2,430	5,280	2,560	1,970	1,450	1,280	1,260
16	1,860	1,220	6,170	2,820	2,890	2,430	5,970	2,590	1,910	1,350	1,270	1,080
17	1,600	1,250	5,860	2,750	2,990	2,680	7,320	2,490	1,860	1,330	1,290	1,110
18	1,560	1,330	5,190	3,120	3,110	3,000	8,170	2,690	1,900	1,260	1,280	1,190
19	1,650	1,370	4,840	3,040	2,780	2,930	7,620	2,760	1,730	1,240	1,320	1,160
20	1,210	1,390	4,300	3,170	2,610	3,080	6,290	2,890	1,740	1,230	1,340	1,180
21	1,290	1,280	4,280	2,890	3,220	3,480	5,760	3,250	1,930	1,250	1,380	1,210
22	1,330	1,260	4,000	3,060	3,010	3,990	5,670	3,120	2,250	1,220	1,480	1,090
23	1,250	1,440	3,750	3,030	2,880	4,550	5,810	2,890	2,180	1,320	910	1,090
24	1,060	2,750	2,760	3,150	2,960	4,750	5,280	2,770	1,870	1,240	1,010	1,050
25	1,300	2,430	2,730	3,050	2,780	4,310	5,560	2,650	1,710	1,640	1,080	1,050
26	1,480	2,730	3,190	2,990	2,650	4,790	7,400	2,640	2,040	1,500	960	1,040
27	1,410	2,580	3,500	3,080	2,790	4,660	6,620	2,640	1,930	1,240	1,050	1,110
28	1,600	2,680	2,950	2,940	2,700	4,680	6,480	2,110	1,790	1,300	1,110	1,090
29	1,550	2,630	2,800	2,560	2,680	4,710	5,490	2,440	2,060	1,210	974	1,050
30	1,510	2,840	2,450	3,000	------	4,530	4,240	2,630	1,990	1,210	1,110	996
31	1,530	------	2,210	2,970	------	5,260	------	2,450	------	1,190	935	------
TOTAL	66,240	51,130	105,180	88,300	102,660	101,860	173,890	84,270	66,120	45,570	40,659	32,361
MEAN	2,137	1,704	3,393	2,848	3,540	3,286	5,796	2,718	2,204	1,470	1,312	1,079
MAX	5,330	2,840	6,170	3,170	6,180	5,260	9,170	3,490	2,710	2,160	1,680	1,260
MIN	1,060	1,010	1,850	2,130	2,610	2,130	4,240	2,110	1,710	1,120	910	743

CAL YR 1967: TOTAL 819,616 MEAN 2,246 MAX 9,350 MIN 788
WTR YR 1968: TOTAL 958,240 MEAN 2,618 MAX 8,170 MIN 743

APPENDIX B

ST. CROIX RIVER
AUGUST 1972

TIME OF TRAVEL STUDY

WOODLAND TO MILLTOWN, MAINE

On August 5, 1972 EPA Region I personnel and Coastal Research Coporation, Lincoln, Massachusetts, conducted a time of travel study on the St. Croix River. The study area was from the Georgia-Pacific Coporation mill in Woodland, Maine to the International Bridge at Milltown, Maine-New Brunswick. Using fluorometric techniques, EPA personnel measured dye concentrations at the railroad bridge in Baring, Maine and Milltown Bridge. In conjunction with this, Coastal Research Coporation, Lincoln, Massachusetts, traced the dye path using multispectral aerial photographic techniques.

During the study river flows as measured at the Baring gage ranged from 2480 cubic feet per second (cfs) to 2700 cfs (See Table B-1). These flows are approximately 43% higher than the flows encountered during the 1970 study, and 52% higher than the monthly mean August flow based on five years of record including 1972, and 5.4 times higher than the established 1-in-10-year, 7-day low flow of 480 cfs.

Also during this time, the dam at Woodland, Maine was being repaired. The construction activities created a continual sediment discharge into the Canadian side of the St. Croix River which could be traced many miles downstream.

At 0740, hours, the EPA crew injected a ten gallon slug of Rhodamine B dye 20 feet downstream fro the defoaming lagoon outfall at Georgia-

[1]Coastal Research Corporation, "Interpretation Report - Aerial Photography of Dye Dispersion and Characteristics of the St. Croix River, Lincoln, Mass.: Coastal Research Corp., 1972 (Xeroxed).

TABLE B-1

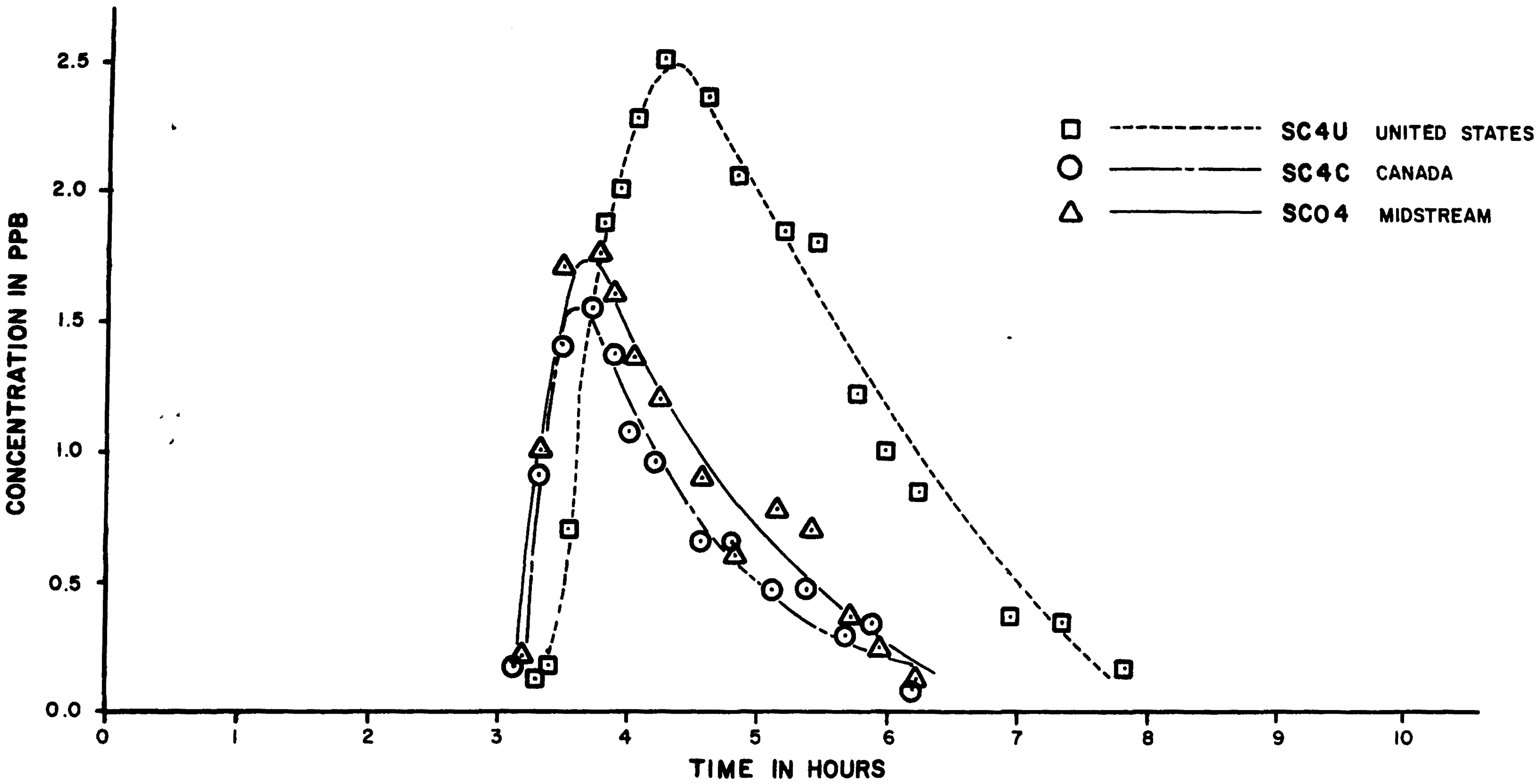
ST. CROIX RIVER STUDY
AUGUST 1972

BI-HOURLY FLOWS AT BARING DURING DYE STUDY

Time (Hours)	Flow (cfs)
0600	2470
0800	2480
1000	2480
1200	2620
1400	2700
1600	2700
1800	2700
2000	2690
2200	2700

Pacific Corporation. Approximately 1.25 hours later, aerial reconnaissance showed that the leading edge and major concentration of dye was at Bailey Rips. Approximately 4.5 hours after the dye was introduced, the peak concentration passed the railroad bridge at Baring, Maine. Aerial photographs showed that at 1400 hours, the leading edge was leaving Baring Basin. At 1720 hours, the leading edge arrived at Milltown Bridge. The peak arrived at Milltown at 1840 hours. Figures B-1 and B-2 are representations of the dye patterns.

The dye and sediment confirmed previous assumptions that the St. Croix River from Woodland to Baring could be considered three distinct and separate streams for modeling purposes. Aerial photographs showed that the dye hugged the U. S. bank and sediment lay along the Canadian bank while midstream was relatively unaffected. These conditions persisted until Baring Rapids. At the Baring railroad bridge, the dye was mixing across the entire river. Following the rips at Baring, visual observations indicated rapid lateral mixing. By the time the dye passed Milltown Bridge, lateral diffusion was nearly uniform.

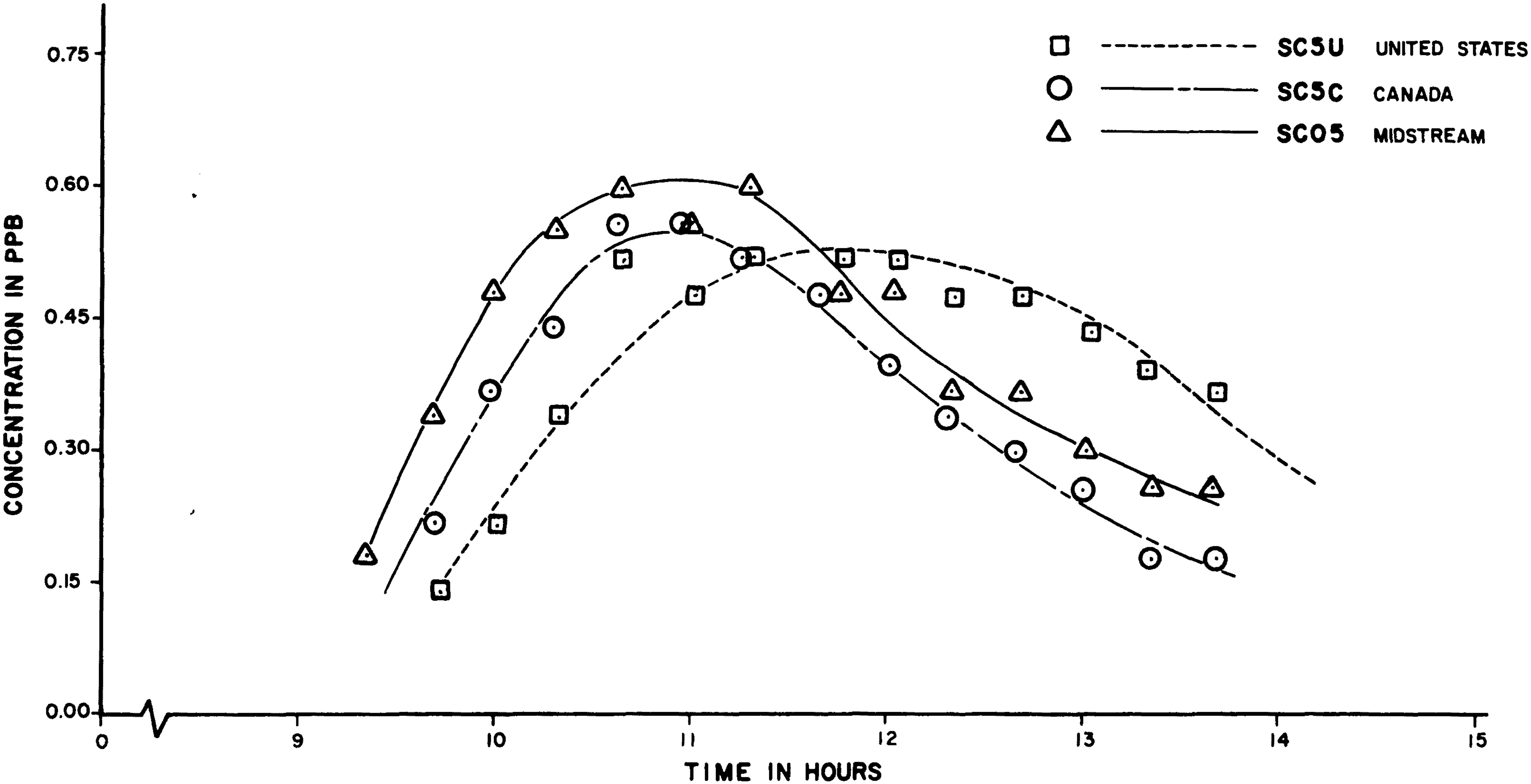


TIME OF TRAVEL STUDY

GEORGIA-PACIFIC CORP. TO BARING (TRANSECT SC04)

DYE CONCENTRATION VS. ELAPSED TIME

FIGURE B1



TIME OF TRAVEL STUDY

GEORGIA-PACIFIC CORP. TO MILLTOWN (TRANSECT SC05)
DYE CONCENTRATION VS. ELAPSED TIME

FIGURE B2

APPENDIX C

NOTE:

"J" denotes approximate value

"K" actual value known to be less than value shown

"L" actual value known to be more than value shown

STORET RETRIEVAL DATE 73/05/15

SCKU
45 16 00.0 067 28 29.0

23 MAINE
NORTHEAST
ST CROIX
1111REG1 2111204
2 0999 FEET DEPTH

	RIVER SYSTEM	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
INDEX	0119001											
MILES	0033.72	.	.	.	.	.	.	.	.	.	.	.

DESCRIPTION

DOWNSTREAM FROM DAM AT KELLYLAND, MAINE NEAR USGS GAGE.

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00070 TURB JKSN JTU	00080 COLOR PT-CO UNITS	00299 DO PROBE MG/L	00310 BOD 5 DAY MG/L	00400 PH SU	31501 TOT COLI MFIMENDO /100ML	31616 FEC COLI MFM-FCBR /100ML
72/08/08	11 25	0002	22.0	0.7	50	6.2	1.2K	6.80		
72/08/09	11 35	0001	21.5	0.7	45	7.2	1.2K	6.50		
72/08/10	10 45	0001	20.0	0.7	45	8.4	1.2K	6.80	2500	2
72/08/11	11 05	0001	20.0	0.9	50	8.2	1.2K	6.30	1600	2K
72/08/13	11 15	0001	20.0	1.0	45	8.2	1.2K	6.30	2200	2K
72/09/14	11 40	0001	20.0	0.9	45	8.3	1.2K	6.60	1600	6
72/09/15	10 35	0002	19.0	1.0	50	8.4	1.2K	6.40	1200	2

DATE FROM TO	TIME OF DAY	DEPTH FEET	00515 RESIDUE DISS-105 C MG/L	00525 RESIDUE FIX FLT MG/L	00530 RESIDUE TOT NFLT MG/L	00540 RESIDUE FIX NFLT MG/L	00545 RESIDUE SETTLBLE ML/L	01027 CADMIUM CD,TOT UG/L	01042 COPPER CU,TOT UG/L	01067 NICKEL NI,TOTAL UG/L	01092 ZINC ZN,TOT UG/L	01050 LEAD PB,SUSP UG/L
72/08/08	11 25	0002	32J	14J	1J	1J						
72/08/09	11 35	0001	21	2	2	0.4						
72/08/10	10 45	0001	27	27	2	1						
72/08/11	11 05	0001	29	24	3	3						
72/08/13	11 15	0001	23	15	2	0.4						
72/08/14	11 45	0001	30	18	3	1						
72/08/15	10 35	0002	39	11	2	1						

[redacted]

SC01
45 10 02.0 067 24 18.0

23 MAINE
NORTHEAST
ST CROIX
1111REG1 2111204
2 0999 FEET DEPTH

	RIVER SYSTEM	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
INDEX	0119001											
MILES	0024.77	.	.	.	.	.	.	.	.	.	.	.

DESCRIPTION

RAILROAD BRIDGE AT WOODLAND JUNCTION, MAINE.

ST.CROIX RIVER SURVEY.

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00070 TURB JKSN JTU	00080 COLOR PT-CO UNITS	00299 DO PROBE MG/L	00310 BOD 5 DAY MG/L	00400 PH SU	31501 TOT COLI MFIMENDO /100ML	31616 FEC COLI MFM-FCBR /100ML
72/08/08	10 40	0002	22.0	0.6	45	5.1	1.2K	6.70	420	10K
72/08/09	10 45	0002	21.5	0.6		6.8		6.30		
	16 10	0002	21.5			6.7		6.30		
72/08/10	10 05	0002	20.0	0.6	45	7.0	1.2K	6.60	1400	8
	14 25	0002	20.0			6.9		6.60		
72/08/11	10 20	0002	20.0	0.9	45	7.4	1.2K	6.50	440	2K
	14 50	0002	20.0			7.5		6.80		
72/08/12	10 25	0002	19.5	1.1	50	6.8	1.2K	6.60	900	2K
	14 50	0002	20.0			6.6		6.80		
72/08/13	10 35	0002	20.0	0.6	45	6.4	1.2K	6.50	2500	2K
72/08/14	11 00	0002	20.0	0.7	45		1.2K	6.80	750	2K
72/08/15	10 00	0002			5		1.2K		1400	2K
	14 35	0002	20.5			6.6		6.90		

DATE FROM TO	TIME OF DAY	DEPTH FEET	00515 RESIDUE DISS-105 C MG/L	00525 RESIDUE FIX FLT MG/L	00530 RESIDUE TOT NFLT MG/L	00540 RESIDUE FIX NFLT MG/L	00545 RESIDUE SETTLBLE ML/L	01027 CADMIUM CD,TOT UG/L	01042 COPPER CU,TOT UG/L	01067 NICKEL NI,TOTAL UG/L	01092 ZINC ZN,TOT UG/L	01050 LEAD PB,SUSP UG/L
72/08/08	10 40	0002	36J	11J	1J	1J						
72/08/09	10 45	0002	19	5	8	0						
72/08/10	10 05	0002	41	39	1	0.2						
72/08/11	10 20	0002	39	26	3	3						
72/08/12	10 25	0002	52	30	1	0.5						
72/08/13	10 35	0002	43	9	0.4	0						
72/08/14	11 00	0002	20	18	1	0.1						

STORET RETRIEVAL DATE 73/05/15

SC20
45 09 25.0 067 23 56.0

23 MAINE
NORTHEAST
ST CROIX
1111REG1 2111204
2 0999 FEET DEPTH

RIVER SYSTEM	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
INDEX 0113001											
MILES 0023.94	.	.	.	.	.	.	.	.	.	.	.

DESCRIPTION

500 FT UPSTREAM FROM THE DEFOAMING LAGOON OUTFALL AT GEORGIA-PACIFIC
CORP.. 5 FT FROM U.S.A. BANK NEAR DOWNSTREAM EDGE OF "GUNITE" SLOPE
PROTECTION FOR DEFOAMING LAGOON. WOODLAND. MAINE.

LAGOON. U.S.A. BANK. WOODLAN.MAINE.

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00070 TURB JKSN JTU	00080 COLOR PT-CO UNITS	00299 DO PROBE MG/L	00310 BOD 5 DAY MG/L	00400 PH SU	31501 TOT COLI MFIMENDO /100ML	31616 FEC COLI MFM-FCBR /100ML
72/08/08	09 43		20.5	6.5	50	7.7	1.2	6.80	2200	20
72/08/09	10 21	0001	21.5	1.8	50	7.2			490	2
72/08/10	10 25	0001	21.0	3.2	45	6.9			2200	56
72/08/11	09 40	0001	21.0	2.0	50	6.8	2.0		1000	4
72/08/12	11 10	0001	21.5	1.5	45				2000	2
72/08/13	10 00	0001	20.5	0.9	30					
72/08/14	09 30	0001	21.0	2.1	50					
72/08/15	10 50	0001	21.0		45		1.2K			

DATE FROM TO	TIME OF DAY	DEPTH FEET	00515 RESIDUE DISS-105 C MG/L	00525 RESIDUE FIX FLT MG/L	00530 RESIDUE TOT NFLT MG/L	00540 RESIDUE FIX NFLT MG/L	00545 RESIDUE SETTLBLE ML/L	01027 CADMIUM CD.TOT UG/L	01042 COPPER CU.TOT UG/L	01067 NICKEL NI.TOTAL UG/L	01092 ZINC ZN.TOT UG/L	01050 LEAD PB.SUSP UG/L
72/08/08	09 43		7	1	11	10						
72/08/09	10 21	0001	7	3	3	1						
72/08/10	10 25	0001	55	52	5	3						
72/08/12	11 10	0001	32	12	2	1						
72/08/13	10 00	0001	36	15	1	0.2						
72/08/14	09 30	0001	37	22	2	1						

SC2C
45 09 21.0 067 23 42.0

23 MAINE
(01)NORTHEAST
(19)ST.CROIX RIVER
1111REG1 2111204
2 0000 FEET DEPTH

DESCRIPTION

STATION LOCATED 500 YARDS BELOW DISCHARGE 1/4 WAY OFF CANADIAN BANK.

ESTABLISHED IN 1970 AS PART OF THE UNITED STATES CANADA JOINT ST. CROIX

RIVER SURVEY.

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00070 TURB JKSN JTU	00080 COLOR PT-CO UNITS	00299 DO PROBE MG/L	00310 BOD 5 DAY MG/L	00400 PH SU	31501 TOT COLI MFIMENDO /100ML	31616 FEC COLI MFM-FCBR /100ML
72/08/08	09 45	0001	21.5	14.0	50	7.7	1.2	6.60	1100	10K
72/08/09	09 10	0001	21.0	3.4	50		1.2K	6.10		
72/08/10	09 00	0001	20.0	9.6	50	6.8	1.2K	6.10	10000	2K
72/08/11	09 15	0001	20.0	4.1	50	7.0	1.2K	6.90	1000	2
72/08/12	09 35	0001	19.5	6.6	45	6.8	1.2K	6.20	1600	4
	14 15	0001	20.0			6.6J		6.80		
72/08/13	09 40	0001	20.0	0.6	40	6.9	1.2K	6.70	2100	4
72/08/14	10 05	0001	20.5	1.3	45		1.2K	6.50	1300	10
72/08/15	09 05	0001	20.0	0.9	45	7.0	1.2K	6.40	940	10
	14 05	0001	20.0			6.8J		6.60		

DATE FROM TO	TIME OF DAY	DEPTH FEET	00515 RESIDUE DISS-105 C MG/L	00525 RESIDUE FIX FLT MG/L	00[illegible]30 RESIDUE TOT NFLT MG/L	00540 RESIDUE FIX NFLT MG/L	00545 RESIDUE SETTLBLE ML/L	01027 CADMIUM CD,TOT UG/L	01042 COPPER CU,TOT UG/L	01067 NICKEL NI,TOTAL UG/L	01092 ZINC ZN,TOT UG/L	01050 LEAD PB,SUSP UG/L
72/08/08	09 45	0001	8	5	17	16						
72/08/09	09 10	0001	20	1	3	1						
72/08/10	09 00	0001	25	24	10	9						
72/08/11	09 15	0001	37	23	8	8						
72/08/12	09 35	0001	63	30	9	9						
72/08/13	09 40	0001	26	6	1	0						
72/08/14	10 05	0001	33	19	3	2						
72/08/15	09 05	0001	47	23	2	1						

STORET RETRIEVAL DATE 73/05/15

SC02
45 09 21.0 067 23 43.0

23 MAINE
(01)NORTHEAST
(19)ST.CROIX RIVER
1111REG1 2111204
2 0000 FEET DEPTH

DESCRIPTION

STATION LOCATED 500 YARDS BELOW DISCHARGE MIDPOINT IN RIVER.

ESTABLISHED IN 1970 AS PART OF THE UNITED STATES CANADA JOINT ST. CROIX RIVER SURVEY.

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00070 TURB JKSN JTU	00080 COLOR PT-CO UNITS	00299 DO PROBE MG/L	00310 BOD 5 DAY MG/L	00400 PH SU	31501 TOT COLI MFIMENDO /100ML	31616 FEC COLI MFM-FCBR /100ML
72/08/08	09 20	0001	21.5	19.0	50	5.5	1.2K	6.50	1600	10K
72/08/09	09 15	0001	21.0	2.0	50		1.2K	6.20	1800	2K
72/08/10	09 05	0001	20.0	3.0	50	6.6	1.2K	6.00	2900	800
72/08/11	09 17	0001	20.0	3.3	50	6.9J	1.2K	6.90	1000	2
72/08/12	09 40		19.5	2.6	45	6.5J	1.2K	6.30	1000	2
	14 17	0001	20.0			6.1J		6.60		
72/08/13	09 44	0001	20.0	0.8	45	7.1J	1.2K	6.40	3100	2K
72/08/14	10 10	0001	21.0	1.3	50		1.3	6.60	2800	2K
72/08/15	09 08	0001	20.0	1.1	45	6.8	1.2K	6.50	920	12
	14 07	0001	20.0			6.7J		6.70		

DATE FROM TO	TIME OF DAY	DEPTH FEET	00515 RESIDUE DISS-105 C MG/L	00525 RESIDUE FIX FLT MG/L	00530 RESIDUE TOT NFLT MG/L	00540 RESIDUE FIX NFLT MG/L	00545 RESIDUE SETTLBLE ML/L	01027 CADMIUM CD,TOT UG/L	01042 COPPER CU,TOT UG/L	01067 NICKEL NI,TOTAL UG/L	01092 ZINC ZN,TOT UG/L	01050 LEAD PB,SUSP UG/L
72/08/08	09 20	0001	11	9	16	16						
72/08/09	09 15	0001	23	11	2	1						
72/08/10	09 05	0001	33	32	4	3						
72/08/11	09 17	0001	28	25	7	6						
72/08/12	09 40		44	15	4	4						
72/08/13	09 44	0001	34	13	2	1						
72/08/14	10 10	0001	50	24	3	2						
72/08/15	09 08	0001	46	22	3	2						

STORET RETRIEVAL DATE 73/05/15

SC2U
45 09 20.0 067 23 45.0

23 MAINE
NORTHEAST
ST CROIX RIVER
1111REG1 2111204
2 0999 FEET DEPTH

	RIVER SYSTEM	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
INDEX	0119001											
MILES	0023.64	.	.	.	.	.	.	.	.	.	.	.

DESCRIPTION

500 FT DOWNSTREAM FROM THE DEFOAMING LAGOON OUTFALL AT GEORGIA-PACIFIC

CORP.,AND 50 FT. FROM THE U.S.A. BANK, WOODLAND, MAINE.

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00070 TURB JKSN JTU	00080 COLOR PT-CO UNITS	00299 DO PROBE MG/L	00310 BOD 5 DAY MG/L	00400 PH SU	31501 TOT COLI MFIMENDO /100ML	31616 FEC COLI MFM-FCBR /100ML
72/08/08	09 30	0001	27.0	35.0	500	6.0	40.0	5.90	5400	440
	15 30	0001				5.2J		7.90		
72/08/10	09 07	0001	26.0	25.0	750	6.6	50.0	6.30	13000	6900
72/08/11	09 20	0001	23.5	3.4	1250	6.0	80.0	12.30	8000	20
	14 20	0001	31.0			4.2J		9.20		
72/08/12	09 45	0001	30.0	6.6	750	7.1	128.0	9.10	27000	90
	14 20	0001	31.5			5.3J		8.80		
72/08/13	09 46	0001	32.0	1.4	1250	4.1	190.0	9.60	29000	50
72/08/14	10 15	0001	28.0	42.0	750		130.0	7.10	4200	240
72/08/15										
	09 10	0001	32.0	72.5	1000	5.7	110.0	7.20	4000	520
	14 10	0001	28.0			6.2J		6.70		

DATE FROM TO	TIME OF DAY	DEPTH FEET	00515 RESIDUE DISS-105 C MG/L	00525 RESIDUE FIX FLT MG/L	00530 RESIDUE TOT NFLT MG/L	00540 RESIDUE FIX NFLT MG/L	00545 RESIDUE SETTLBLE ML/L	01027 CADMIUM CD,TOT UG/L	01042 COPPER CU,TOT UG/L	01067 NICKEL NI,TOTAL UG/L	01092 ZINC ZN,TOT UG/L	01050 LEAD PB,SUSP UG/L
72/08/10	09 07	0001	569	436	14	7						
72/08/11	09 20	0001	449	325	34	22						
72/08/12	09 45	0001	461	278	42	19						
72/08/13	09 46	0001	821	570	44	17						
72/08/14	10 15	0001	399	298	42	15						
72/08/15	09 10	0001	526	350	64	25						

SC4C
45 08 03.0 067 19 14.0

23 MAINE
101 NORTHEAST
119 ST. CROIX RIVER
111 REG1 2111204
2 0009 FEET DEPTH

DESCRIPTION

STATION LOCATED AT BARING MAINE, RR BRIDGE, 1/4 WAY OFF CANADIAN BANK.

ESTABLISHED IN 1970 AS PART OF THE UNITED STATES CANADA JOINT ST. CROIX

RIVER SURVEY.

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00070 TURB JKSN JTU	00080 COLOR PT-CO UNITS	00299 DO PROBE MG/L	00310 BOD 5 DAY MG/L	00400 PH SU	31501 TOT COLI MFIMENDO /100ML	31616 FEC COLI MFM-FCBR /100ML
72/08/08	07 45	0002	21.0	2.8	60	5.6	2.2	6.30		
72/08/09	08 10	0002	20.5	3.2	60	5.9	1.4	6.30	6900	30
	14 26	0002	22.0			5.1J		6.50		
72/08/10	07 55	0002	20.0	4.6	60	6.2	2.1	6.50	2100	1000
	13 40	0002	21.0			6.5J		6.60		
72/08/11	08 10	0002	19.0	3.1	70	6.4	2.2	6.70		
	13 55	0002	21.5			5.7J		6.60		
72/08/12	08 10	0002	19.0	2.3	60	6.6	2.1	6.90	900	30
	12 55	0002	21.0					6.80		
72/08/13	08 45	0002	20.0	2.0	60	6.9	2.7	6.90	3600	50
72/08/14	08 55	0002	20.0	2.9	60		3.5	6.60	9000	20
72/08/15	08 10	0002	19.0	2.8	60	7.0	2.0	6.80	1100	10
	13 15	0002	21.0			7.3J		6.60		

DATE FROM TO	TIME OF DAY	DEPTH FEET	00515 RESIDUE DISS-105 C MG/L	00525 RESIDUE FIX FLT MG/L	00530 RESIDUE TOT NFLT MG/L	00540 RESIDUE FIX NFLT MG/L	00545 RESIDUE SETTLBLE ML/L	01027 CADMIUM CD,TOT UG/L	01042 COPPER CU,TOT UG/L	01067 NICKEL NI,TOTAL UG/L	01092 ZINC ZN,TOT UG/L	01050 LEAD PB,SUSP UG/L
72/08/08	07 45	0002	14	14	2	0.1						
72/08/09	08 10	0002	24	13	4	2						
72/08/10	07 55	0002	75	58	4	2						
72/08/11	08 10	0002	55	40	5	5						
72/08/12	08 10	0002	69	30	3	2						
72/08/13	08 45	0002	43	17	2	1						
72/08/14	08 55	0002	41	36	4	2						
72/08/15	08 10	0002	60	34	4	2						

SC04
45 08 03.0 067 19 12.0

23 MAINE
(01)NORTHEAST
(19)ST.CROIX RIVER
1111REG1 2111204
2 0000 FEET DEPTH

DESCRIPTION

STATION LOCATED AT BARING MAINE, AT RR BRIDGE MIDPOINT IN RIVER.

ESTABLISHED IN 1970 AS PART OF THE UNITED STATES CANADA JOINT ST.CROIX RIVER SURVEY.

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00070 TURB JKSN JTU	00080 COLOR PT-CO UNITS	00299 DO PROBE MG/L	00310 BOD 5 DAY MG/L	00400 PH SU	31501 TOT COLI MFIMENDO /100ML	31616 FEC COLI MFM-FCBR /100ML
72/08/08	08 05	0002	21.0	2.6	70	5.8	2.6	6.30	3000	60
72/08/09	07 55	0002	21.0	3.0	70	5.8	2.0	6.40	1800	70
	14 22	0002	22.5			5.2J		6.60		
72/08/10	07 40	0002	20.0	3.8	70	6.1	2.8	6.60	3400	170
	13 35	0002	21.0			6.5J		6.60		
72/08/11	07 45	0002	19.0	3.2	100	6.7	3.4	6.50	2600	220
	13 50	0002	21.0			6.0J		6.80		
72/08/12	08 05	0002	19.0	2.7	60	6.2	2.8	6.90	2000	66
	11 05	0002	20.0	1.0				6.70		
72/08/13	08 40	0002	20.0	2.1	70	7.3	3.5	6.60	2700	100
72/08/14	08 45	0002	20.0	2.8	60	6.5J	2.6	6.60	5000	24
72/08/15	08 05	0002	19.0	3.0	60	5.9	2.7	6.90	4100	22
	13 13	0002	22.0			6.0J		6.60		

DATE FROM TO	TIME OF DAY	DEPTH FEET	00515 RESIDUE DISS-105 C MG/L	00525 RESIDUE FIX FLT MG/L	00530 RESIDUE TOT NFLT MG/L	00540 RESIDUE FIX NFLT MG/L	00545 RESIDUE SETTLBLE ML/L	01027 CADMIUM CD,TOT UG/L	01042 COPPER CU,TOT UG/L	01067 NICKEL NI,TOTAL UG/L	01092 ZINC ZN,TOT UG/L	01050 LEAD PB,SUSP UG/L
72/08/08	08 05	0002	50J	15J	4J	42						
72/08/09	07 55	0002	23	12	4	2						
72/08/10	07 40	0002	45	27	4	3						
72/08/11	07 45	0002	66	35	6	4						
72/08/12	08 05	0002	71	36	0.5	0.3						
	11 05	0002	45	21	0.5	0.4						
72/08/13	08 40	0002	39	21	3	1						
72/08/14	08 45	0002	66	31	3	1						
72/08/15	08 05	0002	62	33	5	3						

STORET RETRIEVAL DATE 73/05/15

SC40
45 DH 04.0 067 19 11.0

23 MAINE
(01)NORTHEAST
(19)ST.CROIX RIVER
1111REG1 2111204
2 0000 FEET DEPTH

DESCRIPTION

STATION LOCATED AT BARING MAINE, AT RR BRIDGE, 1/4 WAY OFF USA BANK.

ESTABLISHED IN 1970 AS PART OF THE UNITED STATES CANADA JOINT ST.CROIX

RIVER SURVEY.

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00070 TURB JKSN JTU	00080 COLOR PT-CO UNITS	00299 DO PROBE MG/L	00310 BOD 5 DAY MG/L	00400 PH SU	31501 TOT COLI MFIMENDO /100ML	31616 FEC COLI MFM-FCBR /100ML
72/08/08	08 15	0002	21.0	2.9	100	5.6	5.8	6.80	7900	190
72/08/09	07 40	0002	21.0	3.3	100	5.3	4.6	6.40	4300	80
	14 15	0002	23.0			5.1J		6.60		
72/08/10	07 35	0002	20.5	4.9	100	5.4	6.3	6.50	6400	2400
	13 30	0002	22.0			5.4J		6.60		
72/08/11	07 35	0002	19.5	2.8	150	6.2	6.1	6.70	4600	210
	13 45	0002	22.0			5.4J		7.20		
72/08/12	07 55	0002	19.5	3.3	150	5.8	8.0	6.80	3100	180
	12 45	0002	22.0					6.60		
72/08/13	08 35	0002	20.0	2.8	100	5.9	9.0	6.70	5000	700
72/08/14	08 30	0002	20.0	3.2	100	5.8	8.5	6.60	7400	170
72/08/15	07 55	0002	20.0	3.4	100	6.1	5.4	6.80	3400	110
	13 10	0002	22.0			6.0J		6.90		

DATE FROM TO	TIME OF DAY	DEPTH FEET	00515 RESIDUE DISS-105 C MG/L	00525 RESIDUE FIX FLT MG/L	00530 RESIDUE TOT NFLT MG/L	00540 RESIDUE FIX NFLT MG/L	00545 RESIDUE SETTLBLE ML/L	01027 CADMIUM CD,TOT UG/L	01042 COPPER CU,TOT UG/L	01067 NICKEL NI,TOTAL UG/L	01092 ZINC ZN,TOT UG/L	01050 LEAD PB,SUSP UG/L
72/08/08	08 15	0002	75J	33J	7J	4J						
72/08/09	07 40	0002	53	26	4	1						
72/08/10	07 35	0002	77	51	8	4						
72/08/11	07 35	0002	85	67	8	6						
72/08/12	07 55	0002	94	53	2	0.1						
72/08/13	08 35	0002	67	43	6	2						
72/08/14	08 30	0002	50	62	6	2						
72/08/15	07 55	0002	76	45	5	2						

SC05
45 10 12.0 067 17 51.0

23 MAINE
NORTHEAST
ST CROIX RIVER
1111REG1 2111204
2 0999 FEET DEPTH

	RIVER SYSTEM	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
INDEX	0119001											
MILES	0016.27	.	.	.	.	.	.	.	.	.	.	.

DESCRIPTION

MIDPOINT IN RIVER AT BRIDGE MILLTOWN, MAINE - MILLTOWN, NEW BRUNSWICK

RIVER SURVEY.

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00070 TURB JKSN JTU	00080 COLOR PT-CO UNITS	00299 DO PROBE MG/L	00310 BOD 5 DAY MG/L	00400 PH SU	31501 TOT COLI MFIMENDO /100ML	31616 FEC COLI MFM-FCBR /100ML
72/08/08	07 15	0002	20.5	7.8	90	4.9	3.4	6.40	900	10K
72/08/09	07 15	0002	20.5	6.2	75	5.1	2.8	6.00	250	60
	13 55	0002	22.0			5.7		6.30		
72/08/10	07 05	0002	20.0	5.3	100	6.2	3.3	6.30	4000	630
	13 00	0002	20.5			5.8		6.30		
72/08/11	07 10	0002	18.5	5.4	70	6.2	2.8	6.50	2300	200
	13 15	0002	20.0			6.2		6.40		
72/08/12	07 35	0002	19.5	3.3	75	6.0	4.3	6.80	3300	190
	12 20	0002	19.5					6.60		
72/08/13	08 00	0002	19.5	2.3	100	5.8	5.2	6.60	2100	350
72/08/14	08 10	0002	20.0	2.4	100	5.7	5.2	6.30	5900	320
72/08/15	07 25	0002	18.5	2.6	70	6.2	4.0	6.70	12000	130
	12 40	0002	20.0			6.1		6.60		

DATE FROM TO	TIME OF DAY	DEPTH FEET	00515 RESIDUE DISS-105 C MG/L	00525 RESIDUE FIX FLT MG/L	00530 RESIDUE TOT NFLT MG/L	00540 RESIDUE FIX NFLT MG/L	00545 RESIDUE SETTLBLE ML/L	01027 CADMIUM CD,TOT UG/L	01042 COPPER CU,TOT UG/L	01067 NICKEL NI,TOTAL UG/L	01092 ZINC ZN,TOT UG/L	01050 LEAD PB,SUSP UG/L
72/08/08	07 15	0002	35	1	6	2						
72/08/09	07 15	0002	302	244	104	38						
72/08/10	07 05	0002	69	50	7	5						
72/08/11	07 10	0002	53	47	7	6						
72/08/12	07 35	0002	81	43	5	3						
72/08/13	08 00	0002	63	27	4	1						
72/08/14	08 10	0002	65	53	4	2						
72/08/15	07 25	0002	65	39	4	3						

STORET RETRIEVAL DATE 73/05/15

SC02 BAILEYVILLE2
45 04 12.0 067 23 53.0

23 MAINE
NORTHEAST
ST CROIX
1111REGI 2111204
2 0999 FEET DEPTH

DESCRIPTION

18 INCH MUNICIPAL COMBINED SEWER, BAILEYVILLE, MAINE.

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00070 TURB JKSN JTU	00080 COLOR PT-CO UNITS	00299 DO PROBE MG/L	00310 BOD 5 DAY MG/L	00400 PH SU	31501 TOT COLI MFIMENDO /100ML	31616 FEC COLI MFM-FCBR /100ML	00545 RESIDUE SETTLBLE ML/L
72/08/08	07 40		15.0								0.5
	08 40		15.0								2
	09 40		15.0								
	10 40		16.0								0.5
	11 40		16.0					6.60			9
	12 45		16.0								4
	13 40		15.0								3
	14 40		16.0								
72/08/09				59.0	60		118.0				
72/08/09	07 08		15.0								4
	07 55		14.0								6
	08 55		15.0					6.60			19
	09 55		15.0						1000000	50000	7
	10 55		15.0								6
	11 55		16.0					6.40			
	12 55		16.0								
	13 55		16.0								
72/08/09							90.0				
72/08/10	06 35		16.0								
	07 30		15.0								
	08 30		15.0					7.00			
	09 30		17.0								
72/08/10	10 30		16.0								
	11 30		17.0					6.70			
	12 30		16.0								
72/08/10			15.0								
72/08/10				52.0							
72/08/11	06 30		14.0								
	07 30		14.0								
	08 30		15.0								
	09 30		15.0								
	10 30		15.0					6.40			
	11 30		16.0								
	12 30		15.0					6.30			
	13 30		16.0								
72/08/11				30.0							
72/08/14	08 45		15.0								
	09 45		15.0								

DATE FROM TO	TIME OF DAY	DEPTH FEET	00515 RESIDUE DISS-105 C MG/L	00525 RESIDUE FIX FLT MG/L	00530 RESIDUE TOT NFLT MG/L	00540 RESIDUE FIX NFLT MG/L	01027 CADMIUM CD,TOT UG/L	01042 COPPER CU,TOT UG/L	01067 NICKEL NI,TOTAL UG/L	01092 ZINC ZN,TOT UG/L	01050 LEAD PB,SUSP UG/L
72/08/08			302	244	104	38					
72/08/09			306	265	109	48					
72/08/10			247	191	74	48					
72/08/11			276	200	44	13					

STORET RETRIEVAL DATE 73/05/15

SCGP G-P LAGOON
45 08 18.0 067 23 53.0

23 MAINE
NORTHEAST
ST CROIX
1111REG1 2111204
2 0999 FEET DEPTH

	RIVER SYSTEM	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
INDEX	0119001											
MILES	0023.74	.	.	.	.	.	.	.	.	.	.	.

DESCRIPTION

RIVER SIDE OF OUTFALL FROM DEFOAMING LAGOON, GEORGIA-PACIFIC CORP.,

WOODLAND, MAINE.

STORET RETRIEVAL DATE 73/05/15

SCGP G-P LAGOON
45 08 18.0 067 23 53.0

23 MAINE
NORTHEAST
ST CROIX
1111REGI 2111204
2 0999 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00070 TURB JKSN JTU	00080 COLOR PT-CO UNITS	00299 DO PROBE MG/L	00310 BOD 5 DAY MG/L	00400 PH SU	31501 TOT COLI MFIMENDO /100ML	31616 FEC COLI MFM-FCBR /100ML	00545 RESIDUE SETTLBLE ML/L
72/08/08	09 00	0001	36.0			6.7		6.50			1.5
	10 54	0001	36.0			6.1		6.30			0.1
	11 57	0001							59000	2100	1.5
	13 17	0001	37.0			5.9		10.60			1.2
	13 54	0001	36.5			5.7		6.20			1.0
	15 01	0001	37.0			5.3		7.70			1.2
	16 00	0001	37.0			5.9		6.80			0.5
	17 12	0001	36.0			5.7		7.50			0.3
	18 10	0001	39.0			4.5		9.20			0.6
	19 05	0001	36.5			5.9		7.20			0.3
	20 05	0001	35.0			6.0		7.00			0.4
	21 10	0001	38.0			6.0		6.30			0.1K
	22 05	0001	35.0			6.5		7.00			1.2
	23 05	0001	36.0			6.6		6.00			1.2
72/08/08		0001		65.0	1000		140.0				
72/08/09	00 05	0001	32.0			6.5		6.50			1.0
	01 00	0001	34.0			6.3		6.90			0.1
	02 00	0001	34.0			6.3		6.00			0.5
	03 00	0001	33.0			5.9		6.00			0.5
	04 00	0001	34.0			6.5		5.70			0.2
	05 00	0001	36.0			6.4		6.20			0.1
	06 00	0001	36.0			6.4		6.20			0.1K
	07 00	0001	35.0			6.2		5.90			0.3
	08 00	0001	38.0			5.5		6.30			
	09 05	0001	36.0			6.1		6.30			0.1
	10 00	0001	36.0			6.6					0.3
	11 05	0001	36.0					7.20			0.1
	12 42	0001	35.5			5.8		7.50			0.1
	13 05	0001	35.0			4.8		9.20			0.3
	14 06	0001	34.5			5.1		8.80			0.2
	15 05	0001	34.5			5.3		8.90			0.4
	16 00	0001	35.0			5.0		8.70			0.1
	17 10	0001	35.0			6.0		7.50			0.4
	18 05	0001	35.0			5.8		6.50			0.4
	19 10	0001	35.0			6.0		6.60			0.4
	20 15	0001	35.0			5.8		7.50			0.6
	21 05	0001	35.5			5.7		7.20			0.7
	22 15	0001	35.5					6.50			0.5
	23 40	0001	34.0					6.80			1.0

STORET RETRIEVAL DATE 73/05/15

SCGP G-P LAGOON
45 08 18.0 067 23 53.0

23 MAINE
NORTHEAST
ST CROIX
1111REG1 2111204
2 0999 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00070 TURB JKSN JTU	00080 COLOR PT-CO UNITS	00299 DO PROBE MG/L	00310 BOD 5 DAY MG/L	00400 PH SU	31501 TOT COLI MFIMENDO /100ML	31616 FEC COLI MFM-FCBR /100ML	00545 RESIDUE SETTLBLE ML/L
72/08/09		0001		72.5	1500		190.0				
72/08/10	01 00	0001	34.0					6.40			0.1
	02 00	0001	34.5					8.90			0.1K
	03 00	0001	34.0					8.90			1.0
	04 00	0001	34.0					6.80			0.5
	05 00	0001	34.5					6.90			0.1K
	06 00	0001	36.0					7.00			1.0
	07 00	0001	35.0					7.00			0.2
	08 00	0001	35.0					6.50			
	09 04	0001	36.5			5.9		6.70			0.2
	10 02	0001	36.0			6.1		6.70	48000	16000	0.3
	11 06	0001	35.5			5.9		6.70			0.5
	12 27	0001	35.5			6.1		6.60			1.5
	13 00	0001	35.5			6.0					0.3
	14 22	0001	36.0			5.8		7.30			2.0
	15 00	0001	36.5			4.2		10.70			0.4
	15 57	0001	38.0			4.3		10.70			1.4
	17 10	0001	37.5			4.7		10.60			1.0
	18 10	0001	36.0			4.5		11.30			1.0
	19 10	0001	35.0			4.7		11.30			0.7
	20 05	0001	35.0			5.7		6.10			1.0
	21 10	0001	34.5			5.8		7.40			1.0
	22 05	0001	34.0			4.6		8.80			0.5
	23 15	0001	36.5			1.6		9.70			1.3
72/08/10		0001		44.0	1500		220.0				
72/08/11	00 05	0001	36.0			2.6		9.20			2.1
	01 00	0001	34.0			5.1		7.50			1.9
	02 00	0001	34.0			6.0		7.00			2.0
	03 00	0001	36.0			6.2		7.00			2.1
	04 00	0001	37.5			5.7		8.90			2.0
	05 00	0001	37.0			4.4		9.50			2.5
	06 00	0001	37.0			4.5		9.40			1.8
	07 04	0001	36.0			4.8		9.80			2.5
	07 45	0001	37.0			4.9		9.10			2.6
	09 07	0001	34.5			5.0		8.60	3200	200	1.5
	10 25	0001	36.0			5.2					0.5
	12 00	0001	36.0			4.2		9.50			1.5
	13 31	0001	38.1			4.3		9.60			1.0
	15 00	0001	38.5			4.5		9.20			

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23 MAINE
NORTHEAST
ST CROIX
1111REG1 2111204
2 0999 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00070 TURB JKSN JTU	00080 COLOR PT-CO UNITS	00299 DO PROBE MG/L	00310 BOD 5 DAY MG/L	00400 PH SU	31501 TOT COLI MFIMENDO /100ML	31616 FEC COLI MFM-FCBR /100ML	00545 RESIDUE SETTLBLE ML/L
72/08/11	16 40	0001	35.0			4.7		9.90			0.9
	18 10	0001	35.5			5.6		7.50			1.0
	19 35	0001	36.0			5.6		7.50			1.1
	21 10	0001	36.0			5.6		8.40			1.3
	22 35	0001	35.0			5.5		9.00			1.0
	24 00	0001	35.0			6.2		6.90			
72/08/11		0001		3.4	1250		210.0				
72/08/12	01 30	0001	33.0			5.5		8.50			0.1
	03 00	0001	34.0			5.5		8.50			2.0
	04 30	0001	35.0			5.3		10.00			1.0
	06 00	0001	36.0			4.6		8.40			0.8
	07 30	0001	36.0			6.0		8.80			2.0
	09 12	0001	36.0			5.6		9.70			1.2
	10 35	0001	36.5					9.90			2.4
	11 30	0001	36.0					9.70			
	12 15	0001	36.5								2.1
	13 39	0001	35.5								1.0
	15 05	0001	36.0					9.60			2.0
	18 10	0001	36.5								1.0
	19 30	0001	36.5								1.0
	21 10	0001	36.5								1.2
	22 30	0001	36.5					9.70			0.8
	24 00	0001	37.5					7.20			0.5
72/08/12		0001		2.4	1500		240.0				
72/08/13	01 30	0001	37.0					6.90			
	03 20	0001	41.0					8.60			
	04 30	0001	43.0					7.40			
	06 00	0001	38.0					7.80			
	07 30	0001	37.0					8.70			
	09 00	0001	36.0					9.20	9800	100K	0.7
	10 37	0001	36.0					9.90			2.0
	12 05	0001	36.5					9.80			2.5
	13 23	0001	36.0					9.10			1.7
	15 05	0001	36.5					8.80			1.0
	16 35	0001	37.5					9.60			
	19 00	0001	37.0					9.60			1.8
	19 30	0001	36.5					9.10			
	21 10	0001	37.0					7.50			2.0
	22 30	0001	36.5					8.50			1.5

STORET RETRIEVAL DATE 73/05/15

SCGP G-P LAGOON
45 08 18.0 067 23 53.0

23 MAINE
NORTHEAST
ST CROIX
1111REG1 2111204
2 0999 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00070 TURB JKSN JTU	00080 COLOR PT-CO UNITS	00299 DO PROBE MG/L	00310 BOD 5 DAY MG/L	00400 PH SU	31501 TOT COLI MFIMENDO /100ML	31616 FEC COLI MFM-FCBR /100ML	00545 RESIDUE SETTLBLE ML/L
72/08/13	24 00	0001	36.5					7.70			1.5
72/08/13		0001		2.8	1500		220.0				
72/08/14	01 30	0001	35.0					7.40			1.7
	03 00	0001	35.0					6.60			1.0
72/08/14	04 30	0001	35.0					8.00			0.9
	06 00	0001	35.0					7.50			2.0
72/08/14	07 30	0001	34.0					6.80			1.0
	09 05	0001	36.0					7.10	6100	200	1.0
	10 32	0001	36.5					7.90			1.5
	12 00	0001	36.5					6.40			0.5
	13 30	0001	36.5					8.00			1.5
	15 01	0001	36.5					9.40			2.0
	16 30	0001	36.5					9.20			1.5
	18 15	0001	36.0					9.10			1.2
	19 30	0001	36.5					6.80			0.8
	21 00	0001	36.5					7.30			1.0
	22 30	0001	36.0					7.40			0.8
	24 00	0001	36.5					7.40			1.0
72/08/14		0001		63.0			150.0				
72/08/15	01 30	0001	34.0					7.70			1.1
	03 00	0001	34.0					6.40			0.6
	04 30	0001	33.0					6.40			1.0
	06 00	0001	33.0					6.50			0.9
	07 30	0001	33.0					6.60			1.0
	09 03	0001	35.5					6.50			1.0
	10 33	0001	35.5								1.0
	12 07	0001	35.5					6.90			0.5
	13 30	0001	35.0					6.50			0.5
	15 05	0001	35.5					7.00			1.5
	16 30	0001	36.5					9.50			2.5
	18 00	0001	36.5					8.20			3.0
	19 30	0001	36.0					7.00			2.5
	21 05	0001	35.5					6.90			2.0
	22 30	0001	35.0					6.80			1.0
	23 50	0001	36.5					6.60			0.8
72/08/16	01 30	0001	33.0					6.40			0.7
	03 00	0001	32.0					6.50			2.1
	04 30	0001	34.0					7.30			1.5
	06 00	0001	34.0					6.60			1.8
	07 30	0001	34.0					6.40			

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23 MAINE
NORTHEAST
ST CROIX
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2 0999 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00515 RESIDUE DISS-105 C MG/L	00525 RESIDUE FIX FLT MG/L	00530 RESIDUE TOT NFLT MG/L	00540 RESIDUE FIX NFLT MG/L	01027 CADMIUM CD,TOT UG/L	01042 COPPER CU,TOT UG/L	01067 NICKEL NI,TOTAL UG/L	01092 ZINC ZN,TOT UG/L	01050 LEAD PB,SUSP UG/L
72/08/08		0001	681	437	57	9					
72/08/09		0001	1013	750	61	25	20K	76	40K	200	
72/08/10		0001	1249	845	102	56	20K	64	40K	170	
72/08/11		0001	933	592	73	35	20K	76	40K	150	
72/08/12		0001	895	549	97	41	20K	68	40K	100	
72/08/13		0001	944	672	74	33	20K	70	40K	120	
72/08/14		0001	680	431	71	31	20K	44	40K	130	
72/08/15		0001	909	534	64	8	20K	36	40K	110	

APPENDIX D

ST. CROIX RIVER STUDY
AUGUST 1972
ISOLATION OF KLEBSIELLA PNEUMONIAE

As a result of research conducted by EPA's Duluth and Corvallis Laboratories, members of the genus Klebsiella had been isolated from the effluent of paper mills. Consequently the isolation of this organism from the effluent of the Georgia Pacific Corporation at Woodland, Maine and in samples taken from stations along the St. Croix was undertaken.

Members of the genus Klebsiella are included in the family Enterobacteriaceae (1,3,8,13) and comprise one of the group of bacteria commonly referred to as the "coliform" group. Coliform bacteria are defined as Gram-negative, rod-shaped, non-sporeforming bacteria capable of fermenting lactose with the production of gas within 48 hours of incubation at 35°C. Moreover, Klebsiella has the same appearance as Type I coliforms on both m-Endo and m-FC media and can be distinguished from them only on the basis of a series of biochemical tests referred to as the IM ViC series. Furthermore, this group possesses the same reactions for the IM ViC series as Enterobacter aerogenes (Aerobacter-aerogenes), and until recently it was difficult to differentiate the majority of Klebsiella pneumoniae cultures from Aerobacter aerogenes. The source from which the organism was isolated generally dictated the classification given to it. As a result of studies concerned with the relationships of these two genera, differentiation between these groups is made on motility, presence of a capsule, and a series of biochemical tests (3,7,12,19,21,29,30). In contrast to the innocuous Enterobacter, members of Klebsiella were reportedly found in the fecal matter of 5%

of humans (2,6,8,9,15,17,28) but in smaller numbers than the fecal coliform (Type I) and was used as an indicator of fecal pollution in the past but was replaced by Escherichia coli. It can, therefore, be considered as "normal flora".

While there is no question concerning the significance of the presence of E. Coli in water, the same is not true for the presence Kl. pneumoniae. Its significance in an environment has yet to be reconciled, and has resulted in research to assess whether any significance exists.

Because this organism was isolated from pulp mill effluents, the National Council for Air and Stream Improvement, Inc. (NCASI), the environmental voice of the pulp and paper industry, engaged in a program aimed at assessing the sanitary significance of this organism in receiving waters. The program included a review of public health literature on the epidemiology of Klebsiella as they may be related to water borne incidence and a field investigation of the prevalence of Kl. pneumoniae in common environmental situations (10,11,14).

In the former review, confined almost exclusively to the occurrence of klebsiella infection in the hospital environment, the inference is that hospital admission with klebsiella infections is meager and that there is, at present, no evidence that the presence of Klebsiella in waters has been a factor in the epidemiology of Kl. pneumoniae infections in humans (14).

In the latter instance the field investigations were concerned with the isolation of Klebsiella from a conifer forest. Samples of

Water, soil, needles and bark from three different forest environments and from logs at a paper and pulp mill were examined. Of 123 isolates, 71% were classified as Klebsiella (11).

The occurrence of Klebsiella in this forest environment prompted an investigation of the occurrence of these organisms on fruits and vegetables, especially those consumed raw in salads. (10) Radishes, lettuce, tomatoes, celery, beets, carrots and green onions were purchased from a supermarket and examined. Klebsiella were isolated from all samples.

As a result of these findings, the NCASI feels that the source should be considered before any significance is attributed to the isolation of these organisms. No significance would be attributed to those organisms isolated from a common environment while those isolated from a clinical environment would be significant. In addition, they would further like serological typing of isolates performed and these types compared with those that have a clinical history. If the organism has no clinical history, then it would be considered innocuous.

However, other investigations tend to classify Klebsiella as a pathogen (disease producer) and consider its presence a potential hazard. The organism was first isolated by Friedlander in 1882 and has been recognized as the occasional cause of severe pulmonary pneumonia. (6, 8) While the incidence of Klebsiella pneumonia is small, the mortality rate is generally higher than is seen is pneumococcal pneumonia. (12)

A wide variety of other types of infections caused by *Klebsiella pneumoniae* have been observed. The second most common cause of urinary tract infections is *Klebsiella pneumoniae* (5). Other infections caused by this organism such as post-operative infections, lesion infections and intra-abdominal sepsis have been observed in hospitalized patients. In addition *Klebsiella* bacteremia has been reported in Boston City Hospital (4, 16, 17) and other hospital-acquired *Klebsiella pneumoniae* has been reported at Johns Hopkins Hospital (27).

The mortality rate resulting from *Klebsiella pneumoniae* infection was high until the advent of antibiotics. While treatment with antibiotic has reduced the mortality, it has also created another problem. *Klebsiella pneumoniae* has the propensity to become antibiotic resistant. Variable resistance to tetracycline, chloramphenicol, streptomycin, Kanamycin, neomycin, and the cephalosporin drugs have been reported (Eickhoff). The penicillins have no useful activity against *Klebsiella*. Furthermore, it was shown that hospital acquired infections of *Klebsiella* tend to be more drug resistant than those acquired outside the hospital. The epidemiology of *Klebsiella* infections has not been established, but studies conducted in regard to this problem tend to incriminate colonization by this organism as the cause. This colonization may occur in the patient, staff, equipment or food of the hospital (18, 22, 23). Because *Klebsiella* is responsible for many types of infections, and colonization with this organism seems to be the foremost incriminating factor associated with infection, then it seems imperative that this organism should be restricted in our environment. In view of this information, the presence of *Kl. pneumoniae* in water signifies the presence of a pathogenic organism.

Because this organism is associated with pulp mill wastes and is considered to be of sanitary significance, the isolation of this organism from the Georgia-Pacific effluent was undertaken. Samples were collected at each of the stations listed on the map (Foldout 1) of the survey area. The frequency with which each station was tested varied, but samples from the clear-water station and from the mill effluent were tested for six consecutive days. The presence of Klebsiella pneumoniae was determined by randomly selecting at least 10% of the typical colonies on 24-hour m-Endo and m-FC plates and running as many of the tests listed in Table I as were necessary for positive identification. At least one positive culture from each of the stations where Klebsiella pneumoniae was isolated was sent to the Center for Disease Control, Atlanta, Georgia, for confirmation and serological typing. The results of the Klebsiella pneumoniae isolation are given in Tables II and III and those obtained from CDC in Table IV.

To briefly summarize the findings, Klebsiella pneumoniae was not isolated from the stations located above the effluent from the mill, but was isolated from the mill effluent and the stations located downstream of the effluent. While other investigators successfully isolated Kl. pneumoniae from natural environments, which included fresh water (24, 25, 26), all attempts during this survey were unsuccessful. Therefore, the conclusion can be drawn that the river is not the source of this organism in the mill effluent. Since this organism was isolated from the mill effluent every time it was tested, it appears

TABLE I

*CHARACTERISTICS OF KLEBSIELLA PNEUMONIAE

Test	Reaction
Gram Stain	Negative
Capsule (India Ink)	Positive
TSI Slant	Acid
TSI Butt	Acid and Gas
Indol	Negative
Methyl Red	Negative
Voges - Proskauer (Acetylmethyl Carbinol)	Positive
Citrate Utilization	Positive
Hydrogen Sulfide Production (TSI and SIM)	Negative
Urease	Positive
Motility (SIM and Hanging Drop)	Negative
Gelatin	Negative
Lysine Decarboxylase	Positive
Arginine Dihydrolase	Negative
Ornithine Decarboxylase	Negative
Phenylalanine Deaminase	Negative
Malonate	Positive
Glucose Fermentation	Positive
Lactose Fermentation	Positive
Sucrose Fermentation	Positive

TABLE II

FREQUENCY OF TESTING SAMPLE STATIONS FOR

ISOLATION OF KL. PNEUMONIAE

Station No.	No. of Times Tested	No. of Times Klebsiella Isolated	% of Time Klebsiella Isolated
SC-KU	7	0	0%
SC-01	1	0	0%
SC-02	6	0	0%
SC-2C	7	2	28.5%
SC-2D	6	1	16.7%
SC-2U	5	2	40%
SC-04	4	1	25%
SC-4C	4	1	25%
SC-4U	3	1	33%
SC-05	4	3	75%
SCB-1	1	1	100%
SCB-2	4	1	25%
SCG-P	6	6	100%

TABLE III

KLEBSIELLA PNEUMONIAE DATA AS RELATED TO OTHER COLIFORM DATA

Station Number	Date Collected	Total Coli Count/100ml	Fecal Coli Count/100ml	No. of Kl. pneumoniae/100ml	% of Coli Identified as Kl. pneumonae
SC-2C	8/10/72	10,000	< 2	10	<1%
	8/12/72	1,600	4	100	6.25
SC-2D	8/8/72	2,200	20	100	4.5
SC-2U	8/9/72	5,400	440	400	7.2
	8/11/72	8,000	20	1,000	12.5
SC-04	8/11/72	2,600	220	500	19.2
SC-4C	8/8/72	3,200	90	200	6.25
SC-4U	8/9/72	4,300	80	100	2.3
SC-05	8/9/72	2,500	60	100	4
	8/13/72	2,100	350	100	4.8
	8/14/72	5,900	320	100	1.6
SCB-1	8/8/72	13,000,000	420,000	100,000	0.8
SCB-2	8/11/72	7,500,000	90,000	100,000	1.3
SCG-P	8/8/72	59,000	2,100	800	38
	8/10/72	48,000	16,000	8,000	16.7
	8/11/72	3,200	200	300	9.4
	8/12/72	1,200	100	200	6.25
	8/13/72	9,800	100	200	2
	8/14/72	6,100	200	300	5

TABLE IV

Results of *Serological Typing of Klebsiella pneumoniae Isolated from the St. Croix River

Identification Number of Culture	Station Number of Isolation	Serological Type
EPA-1	SC-4C	Type-24
EPA-2	SC-2D	Type-31
EPA-3	SCB-1	Type-6
EPA-4	SCG-P	Type-66
EPA-5	SC-05	Insufficient Capsule
EPA-6	SC-4U	Type-44
EPA-7	SC-2U	Type-10
EPA-8	SC-04	Type-66
EPA-9	SCG-P	Type-9
EPA-10	SCG-P	Type-6

*Performed by Center for Disease Control, Atlanta, Georgia.

then that the source must be the Georgia-Pacific complex. The persistence of what was identified as A. aerobacter in wood and wood products was reported in 1931 and the presence and growth of capsulated bacteria, identified as coliforms, was considered to be responsible for pulp slime. (20) Conceivably, these organisms could have been Kl. pneumoniae. The source of the organism could possibly be the logs used in the pulping process since Kl. pneumoniae was successfully isolated from bark and logs at pulp mills (11).

Another source of the organism downstream from the effluent could also be from the municipal sewage. Samples of this waste were positive for Kl. pneumoniae. However, it is interesting to note that the capsular types isolated further downstream did not match the capsular type isolated from the sewage outfall. The mill effluent, however, contained the type isolated downstream.

Regardless of what the ultimate source of these organisms might be, the significant aspect is that they were isolated from the mill effluent. While no evidence exists that incriminates the presence of Klebsiella pneumoniae in water with Klebsiella infections, there should be concern with the potential hazard presented by them. Since "colonization" by this organism is related to its infectivity, every opportunity to prevent this should be taken. In the past, this organism was overlooked because of the lack of methodology for identification. Today, however, a higher degree of precision in taxonomy is evident, and for this reason the isolation of this organism from a water environment is significant.

*Characteristics compiled from:

Diagnostic Microbiology

Bailey, W. R. and Scott, E. G.

3rd Edition, C. F. Mosby Co., St. Louis, 1970

Begey's Manual of Determinative Bacteriology

The Williams and Wilkins Co.

Baltimore, Md., 1957

Bacterial and Mycotic Infections of Man

Dubos, R. J. and Hirsch, J. C., 4th Ed.

J. B. Lippincott, Co., 1965

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APPENDIX E

ST. CROIX RIVER STUDY
AUGUST 1972
QUALITATIVE BIOLOGICAL SURVEY

During Agusut 1972 personnel from the Environmental Protection Agency Region I conducted a qualitative biological survey of benthic invertebrates in the St. Croix River. Benthic invertebrates are those organisms living in and crawling on the bottom sediments. Twenty-four stations were selected for biological examination. Three control stations were selected upstream from Kellyland, Maine and one in Mohannas Stream, a clean water tributary to the St. Croix River downstream from the Georgia-Pacific mill at Woodland, Maine. Eight stations were selected in the wood wet storage area to show the effects of log ponding, and 12 more were selected downstream from the Georgia-Pacific mill. These stations are shown in Foldout 2 at the rear of the report and described in Table E-1.

Respectively stations SCB10, SCB11 and SCB12 are representative of fast flowing, slow flowing and ponded water reaches which have been free from logging operations for several years. Station MC10 provides information about benthic invertebrates which are naturally indigenous to the area around Baring Basin. Three transects comprising eight stations were selected in the wet storage area, and four transects comprising 12 stations downstream from the mill were selected to obtain an adequate biological assessment of water quality in the St. Croix River.

TABLE E-1
STATION LOCATIONS
ST. CROIX RIVER STUDY
AUGUST 1972
BENTHOS STATIONS

STATION	LATITUDE ° ' "	LONGITUDE ° ' "	DESCRIPTION
SCB10	45 18 02	67 27 40	St. Croix River 1,000' downstream from Landmark 175, three feet from U.S.A. bank, T1R1, Maine.
SCB11	45 17 59	67 28 05	St. Croix River 2,000' southwest of Landmark 175 near downstream tip of island midpoint in river, T1R1, Maine.
SCB12*	45 16 28	67 29 49	Grand Falls Flowage midway between scow Point and point of land northwest of Kellyland, Maine.
SCB13C	45 12 35	67 25 52	St. Croix River 5,000' downstream from Landmark 188 at log boom, 10' from Canadian bank, Baileyville, Maine.
SCB13M*	45 12 33	67 25 55	St. Croix River 5,000' downstream from Landmark 188, at log boom midpoint in the river, Baileyville, Maine.
SCB13U	45 12 32	67 25 58	St. Croix River 5,000' downstream from Landmark 188, at log boom, 15' from U.S.A. bank, Baileyville, Maine.
SCB14C	45 11 01	67 24 32	Woodland Pond 3,000' downstream from Landmark 191 one-quarter way from Canadian bank.
SCB14M	45 10 56	67 24 39	Woodland Pond 3,000' downstream from Landmark 191 midpoint in river, Baileyville, Maine.
SCB14U	45 10 51	67 24 44	Woodland Pond 3,000' downstream from Landmark 191 one-quarter way from U.S.A. bank, Baileyville, Maine.
SCB15C	45 10 41	67 23 54	Woodland Pond 6,000' downstream from Landmark 191 one-quarter way from Canadian bank.

* Benthic respirometer station

TABLE E-1 continued
STATION LOCATIONS
ST. CROIX RIVER STUDY
AUGUST 1972
BENTHOS STATIONS

STATION	LATITUDE ° ' "	LONGITUDE ° ' "	DESCRIPTION
SCB15M	45 10 36	67 24 07	Woodland Pond 6,000' downstream from Landmark 191, midpoint in river, Baileyville, Maine.
SCB15U	45 10 32	67 24 22	Woodland Pond 6,000' downstream from Landmark 191, one-quarter way from U.S.A. bank, Baileyville, Maine.
SCB16C	45 09 21	67 23 40	500' downstream from defoaming lagoon outfall at Georgia-Pacific Corp., 5' from Canadian bank opposite Woodland, Maine.
SCB16M	45 09 21	67 23 38	500' downstream from defoaming lagoon outfall at Georgia-Pacific Corp., midpoint in river Woodland, Maine.
SCB16U	45 09 19	67 23 38	700' downstream from defoaming lagoon outfall at Georgia-Pacific Corp., 5' from U.S.A. bank Woodland, Maine.
SCB17C*	45 08 53	67 22 36	1,000' downstream from Landmark 197, 5' from Canadian bank opposite Baileyville, Maine.
SCB17M*	45 08 52	67 22 38	1,000 downstream from Landmark 197, 500' downstream from Landmark 198, midpoint in river near downstream tip of island, Baileyville, Maine.
SCB17U	45 08 52	67 22 43	5' from U.S.A. bank opposite Landmark 198, Baileyville, Maine.
SCB18C*	45 07 57	67 19 23	700' downstream from Landmarks 205 & 206, 20' from Canadian bank opposite Baring, Maine.
SCB18M	45 07 55	67 19 16	800' downstream from Landmarks 205 & 206, midpoint in river at Baring, Maine.

* Benthic respirometer station

TABLE E-1 continued
STATION LOCATIONS
ST. CROIX RIVER STUDY
AUGUST 1972
BENTHOS STATIONS

STATION	LATITUDE ° ' "	LONGITUDE ° ' "	DESCRIPTION
SCB18U	45 07 51	67 19 08	1,400' east of Landmark 206, 5' from U.S.A. bank, Baring, Maine.
SCB19C	45 09 12	67 17 49	10' from Canadian bank opposite Magurrewock Stream, Calais, Maine.
SCB19M*	45 09 13	67 17 45	Midpoint in river opposite Magurrewock Stream, Calais, Maine.
SCB20C*	45 10 12	67 17 59	200' upstream from bridge at Milltown, Maine - Milltown, New Brunswick, 5' from Canadian bank.
SCB20U*	45 10 09	67 17 53	200' upstream from bridge at Milltown, Maine - Milltown, New Brunswick, 5' from U.S.A. bank.
SCB21M*	45 08 46	67 18 11	1700' downstream from Landmark 211 5' from Canadian bank opposite large island in Baring Basin, Baring, Maine.
MC10*	45 09 13	67 19 52	Midpoint in Mohannas Stream at "oxbow" in stream.
GF01*	45 14 52	67 31 57	Grand Falls Flowage near southerly tip of island west of Lamb's Place, Baileyville, Maine.

* Benthic respirometer station

Samples were collected with a Petersen dredge. The dredge was placed on the bottom at wading locations and lowered from a boat in deeper water. However, in certain areas large debris, i.e., bark and pulp wood, necessitated the use of scuba divers to place the Petersen dredge on the bottom of the wet storage area.

A clean water environment is characterized by a diversity of bottom dwelling organisms (benthos). Conversely, degraded or polluted areas are characterized by less benthos diversity and/or a predominance of pollution tolerant species. Areas subjected to extreme pollution or toxicity are devoid of benthos.

The substrate of the control stations supported 12 to 19 kinds of invertebrates associated with clean water environments. Clean water organisms such as mayfly and caddis larvae were found at all control stations. Other clean water forms, found at some but not all control stations, were stonefly, alderfly and dobsonfly larvae, waterpennies, seedshrimp, waterflea, sponge and copepod. Identifications of all organisms found are listed in Table E-2 and population counts at selected stations are in Table E-3.

At stations SCB13U and SCB13C respectively, nine and 14 kinds of benthos were present. These stations compare favorably with the control station SCB11 which had 19 kinds of invertebrates. Although the substrata was overlain with pulp logs, a deterioration benthic population was not observed. (See Table E-4.)

Moving downstream to the two other transects in the wet storage area SCB14 and SCB15; diversities declined to four and seven kinds of life. Clean water organisms such as mayfly and caddis larvae, seedshrimp and waterfleas were not present. The extent and density of

TABLE E-2

ST. CROIX RIVER STUDY - AUGUST 1972
IDENTIFICATION OF BOTTOM ORGANISMS (QUALITATIVE)

ORGANISMS	STATIONS																				
	CONTROL				WET STORAGE								DOWNSTREAM FROM THE GEORGIA - PACIFIC MILL								
	MC10	SCB10	SCB11	SCB12	SCB13		SCB14			SCB15			SCB16			SCB17			SCB18		
					U	C	U	M	C	U	M	C	U	M	C	U	M	C	U	M	C
PLECOPTERA (STONEFLIES)		X																			
EPHEMEROPTERA (MAYFLIES)	X	X	X	X	X	X									X			X			
TRICHOPTERA (CADDISFLIES)	X	X	X	X										X	X			X	X		
NEUROPTERA																					
SIALIDAE (ALDERFLIES)		X	X	X		X					X										
CORYDALIDAE (DOBSONFLIES)		X	X								X										
ODONATA																					
ANISOPTERA (DRAGONFLY)	X	X	X	X		X						X									
ZYGOPTERA (DAMSELFLY)		X																			
DIPTERA (FLIES, MIDGES)																					
TENDIPEDIDAE	X	X	X	X	X	X	X	X	X	X	X	X		X	X		X	X	X	X	X
CULICIDAE							X														
SIMULIDAE		X													X			X			
TABANIDAE	X		X																		
COLEOPTERA (BEETLES)																					
PSEPHENIDAE		X																			
HALIPLIDAE			X																		

ORGANISMS	SCB19		
	U	M	C
PLECOPTERA (STONEFLIES)			
EPHEMEROPTERA (MAYFLIES)			
TRICHOPTERA (CADDISFLIES)			
NEUROPTERA			
SIALIDAE (ALDERFLIES)			
CORYDALIDAE (DOBSONFLIES)			
ODONATA			
ANISOPTERA (DRAGONFLY)			
ZYGOPTERA (DAMSELFLY)	X		
DIPTERA (FLIES, MIDGES)			
TENDIPEDIDAE	X	X	X
CULICIDAE			
SIMULIDAE			
TABANIDAE			
COLEOPTERA (BEETLES)			
PSEPHENIDAE			
HALIPLIDAE			

TABLE E-2 continued

ORGANISMS	STATIONS: CONTROL MC10	SCB10	SCB11	SCB12	WET STORAGE SCB13 U	SCB13 C	SCB14 U	SCB14 M	SCB14 C	SCB15 U	SCB15 M	SCB15 C	DOWNSTREAM FROM THE GEORGIA - PACIFIC MILL SCB16 U	SCB16 M	SCB16 C	SCB17 U	SCB17 M	SCB17 C	SCB18 U	SCB18 M	SCB18 C	SCB19 U	SCB19 M	SCB19 C
ELMIDAE	X																	X						
CHRYSOMELIDAE		X	X																X					
GASTROPODA (SNAILS)																								
HYDROBIIDAE	X	X	X			X		X							X		X	X				X		
PLANORBIDAE			X	X		X									X				X					
ANCYLIDAE			X												X									
VIVIPARIDAE			X		X	X	X																	
PHYSIDAE			X																					
LYMNAEDIAE					X														X			X	X	X
PELECYPODA (CLAM)	X	X	X	X	X	X		X	X	X	X			X	X		X					X		
O LIGOCHAETA (WORM)																								
TUBIFICIDAE							X	X	X	X	X	X				X	X	X	X	X	X	X	X	X
UNIDENTIFIED	X	X	X	X	X	X																		
HIRUDINEA (LEECH)	X		X	X	X	X				X				X	X		X	X		X		X		X
NEMATODA (ROUNDWORM)				X		X		X	X									X			X			
TRICLADIDA (PLANARIAN)				X	X	X			X	X		X			X									
AMPHIPODA (SCUD)	X	X	X	X	X	X		X	X	X	X	X		X	X			X	X			X		

TABLE E-2 continued

ORGANISMS	STATIONS																							
	CONTROL				WET STORAGE								DOWNSTREAM FROM THE GEORGIA - PACIFIC MILL											
	MC10	SCB10	SCB11	SCB12	SCB13		SCB14			SCB15			SCB16			SCB17			SCB18			SCB19		
					U	C	U	M	C	U	M	C	U	M	C	U	M	C	U	M	C	U	M	C
ISOPODA (SOWBUG)				X		X		X	X	X	X	X		X	X		X	X				X	X	X
HYDRACARINA (WATER MITE)												X												
OSTRACODA (SEED SHRIMP)	X		X	X													X							
CLADOCERA (WATER FLEA)				X														X						
PORIFERA (SPONGE)				X											X									
HYDROZOA (HYDRA)															X									
COREPODA				X																				
TOTAL KINDS	12	15	19	17	9	14	4	7	7	7	7	7	0	6	14	1	7	12	7	3	3	9	4	5

TABLE E-3
ST. CROIX RIVER STUDY
BENTHIC POPULATION PER SQUARE METER

	STATIONS					
	CONTROL	WET STORAGE	DOWNSTREAM FROM GEORGIA-PACIFIC MILL			
ORGANISMS	SCB11	SCB15M	SCB16C	SCB16U	SCB18C	SCB19U
EPHEMEROPTER (MAYFLIES)	56		168			
TRICHOPTERA (CADDISFLIES)	364		2,744			
NEUROPTERA (ALDERFLY)	28	28				
ODONATA (DRAGONFLY)	252					
(DAMSELFLY)						14
DIPTERA						
TENDIPEDIDAE (MIDGE FLY)	8988	448	168		1008	560
SIMULIDAE (BLACK FLY)			84			
COLEOPTERA (BEETLES)						
ELMIDAE	56					
HALIPLIDAE	56					
GASTROPODA (SNAILS)						
HYDROBIIDAE			70			490
PLANORBIDAE			42			
LYMNAEIDAE						518
VIVIPARIDAE	448					
ANCYLIDAE			28			
PELECYPODA (CLAM)	980	112	154			420
OLIGOCHAETA (WORM)	364	112			2,380	560
NEMATODA (ROUNDWORM)	112				140	
TRICLADIDA (PLANARIAN)	84		70			
ISOPODA (SOWBUG)		420	70			56
AMPHIPODA (SCUD)	1,876	168	84			126
HIRUDINEA (LEECH)			42			14
PORIFERA (SPONGE)			14			
HYDROZOA (HYDRA)			14			
TOTAL NUMBER	13,664	1,288	3,752	0	3,528	2,758
TOTAL KINDS	13	6	14	0	3	9

TABLE E-4

ST. CROIX RIVER
BOTTOM ORGANISMS (BENTHOS)
August 1972

Control Stations	No. of Kinds of Bottom Organisms	Benthos Biological Assessment of Water Quality
River		
SCB10	15	Clean
SCB11	19	Clean
MC10	12	Clean
Wet Storage Stations		
River		
SCB13U	9	Clean
SCB13C	14	Clean

pulp logs covering the bottom necessitated the use of a scuba diver to guide the dredge to soft bottom areas comparable to those found at SCB12. Based on the reduction in benthos diversity, the wet storage area is considered moderately degraded. (See Table E-5.)

Downstream from the Georgia-Pacific Corporation's mill, three kinds of water quality can be observed as one moves laterally across the river. The U. S. side is toxic and grossly polluted, midstream exhibits moderate degradation, and the Canadian side compares to the control stations. These conditions exist at transects SCB16 and persist down to transect SCB17. Apparently lateral mixing occurs between transects SCB17 and SCB18 because the river exhibits a paucity of organisms on the Canadian side and mid-stream. The U. S. side shows signs of recovery, but the entire area may be defined as moderately polluted. (See Table E-6.)

At transect SCB19, the river is still moderately polluted, but showing a recovery in water quality from transect SCB18. Station SCB19U indicates a better quality of water on the U. S. side of the river, but this improvement may be attributed to dilution waters from U. S. tributaries--Stoney Brook, Conic Stream and Magurrewock Stream.

The most adverse benthic conditions occurred on the U. S. side of the river. At station SCB16U which is approximately 700 feet downstream from Georgia-Pacific Corporation's main discharge, gray colored biological slimes which included the filamentous bacterium <u>Sphaerotilus</u> covered the bottom. Paper waste sludge dredged at this station was devoid of benthos.

At station SCB17U sludge worms, pollution tolerant organisms, were the only invertebrates dwelling in the gray sludge covering the bottom.

TABLE E-5

ST. CROIX RIVER
BOTTOM ORGANISMS (BENTHOS)
August 1972

Control Station	No. of Kinds of Bottom Organisms	Benthos Biological Assessment of Water Quality
Ponded		
SCB12	17	Clean
Wet Storage Stations		
Ponded		
SCB14U	4	Moderate Pollution
SCB14M	7	" "
SCB14C	7	" "
SCB15U	7	" "
SCB15M	6	" "
SCB15C	7	" "

TABLE E-6

ST. CROIX RIVER
BOTTOM ORGANISMS (BENTHOS)
August 1972

Control Stations	No. of Kinds of Bottom Organisms	Benthos Biological Assessment of Water Quality
River		
SCB10	15	Clean
SCB11	19	Clean
MCB10	12	Clean
Downstream of Georgia-Pacific Mill		
River		
SCB16U	0	Toxic
SCB16M	6	Moderate Pollution
SCB16C	14	Clean
SCB17U	1	Polluted
SCB17M	7	Moderate Pollution
SCB17C	12	Clean
SCB18U	7	Moderate Pollution
SCB18M	3	Polluted
SCB18C	3	Polluted
SCB19U	9	Moderate Pollution
SCB19M	4	Moderate Pollution
SCB19C	5	Moderate Pollution

Long strands of Sphaerotilus and other slimes were attached to a fallen tree at this station and streaming in the current. Living in these smelly masses of slime were sludge worms (tubificidae) and the pollution tolerant specie of midge larvae (Tendipedidae) commonly known as the bloodworm (Tendipes sp).

Strands of gray colored slimes were found clinging to aquatic vegetation at SCB18U.

Clean water invertebrates were found on the Canadian side of the river at station SCB16C and SCB17C. Twelve and 14 kinds of bottom organisms, including caddisfly and mayfly larvae were found at the respective stations. The substratum did not contain any sludge from the paper making processes. The diversity of benthos at these stations was typical of that at the control stations.

APPENDIX F

REPORT OF SUBSURFACE INVESTIGATION
ST. CROIX RIVER, WOODLAND, ME.

For
Environmental Protection Agency
Division Surveillance & Analysis
New England Regional Lab
Needham, Mass.

By
Geophysical Survey Systems, Inc.
16 Republic Road
North Billerica, Massachusetts 01862

File No. 0107
September 1972

REPORT OF SUBSURFACE INVESTIGATION
ST. CROIX RIVER, WOODLAND, ME.

For
Environmental Protection Agency
Division Surveillance & Analysis
New England Regional Lab
Needham, Mass.

SCOPE

This report covers electromagnetic subsurface investigations performed by Geophysical Survey Systems, Inc. to determine characterization of the log ponding area of the St. Croix River at Woodland, Maine. The general purpose is to locate the areas of pulp wood log deposits on the lake bottom and to determine the quantities of logs where possible.

Field Work

The field work on this project was performed on September 17, 18 and 19, 1972 on the Woodland Pond Section of the St. Croix River, Woodland, Maine. The maps of the survey lines are shown in Figures 1 and 2. The survey lines (transects) are lettered alphabetically from point to point as run in the field. The ground truth marks are numbered consecutively, also, as run in

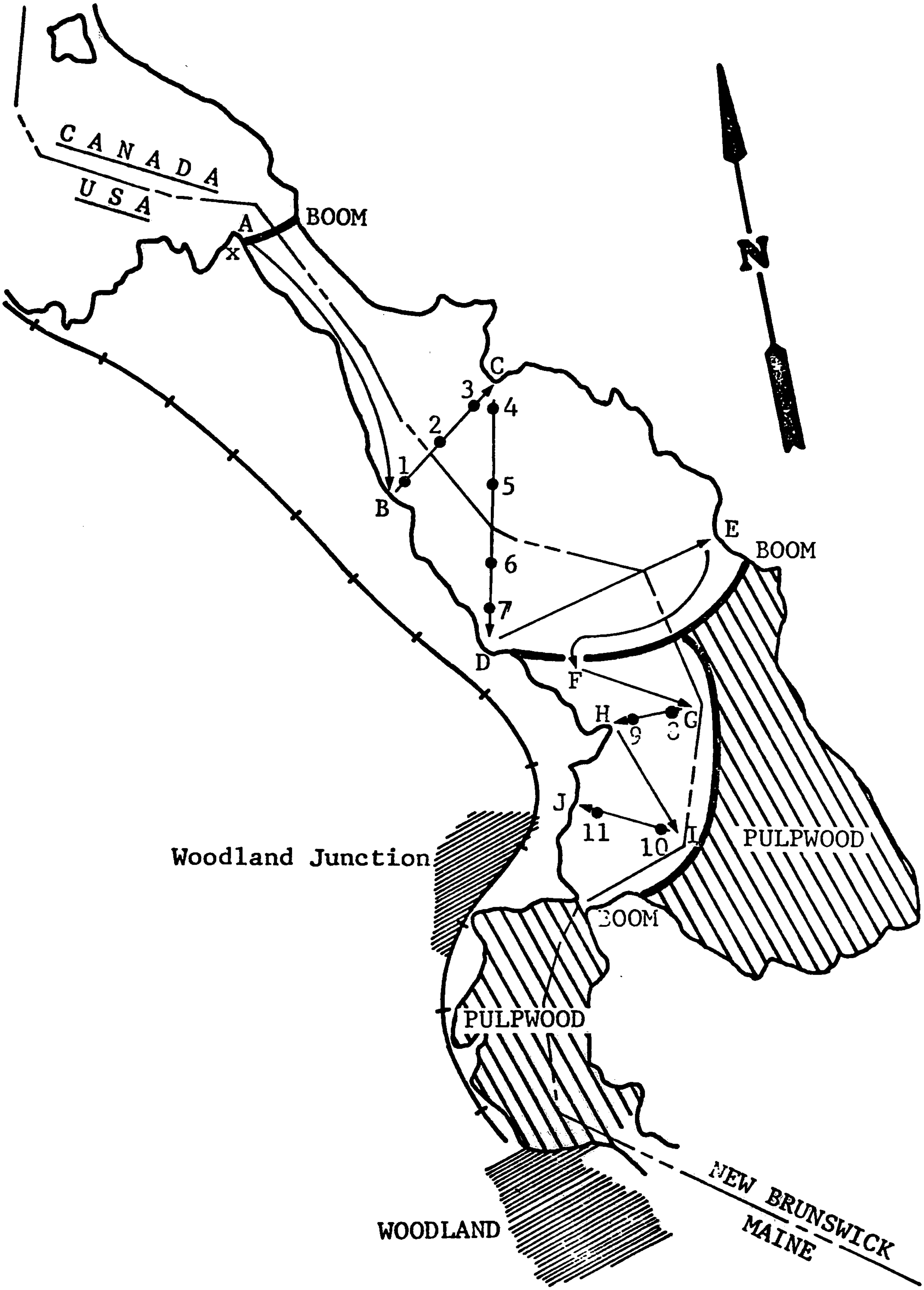

CANADA
USA
A
x
BOOM
N
C
3
4
2
1
5
B
E
BOOM
6
7
D
F
H
G
9
J
11
10
I
PULPWOOD
Woodland Junction
BOOM
PULPWOOD
NEW BRUNSWICK
MAINE
WOODLAND

FIGURE F1

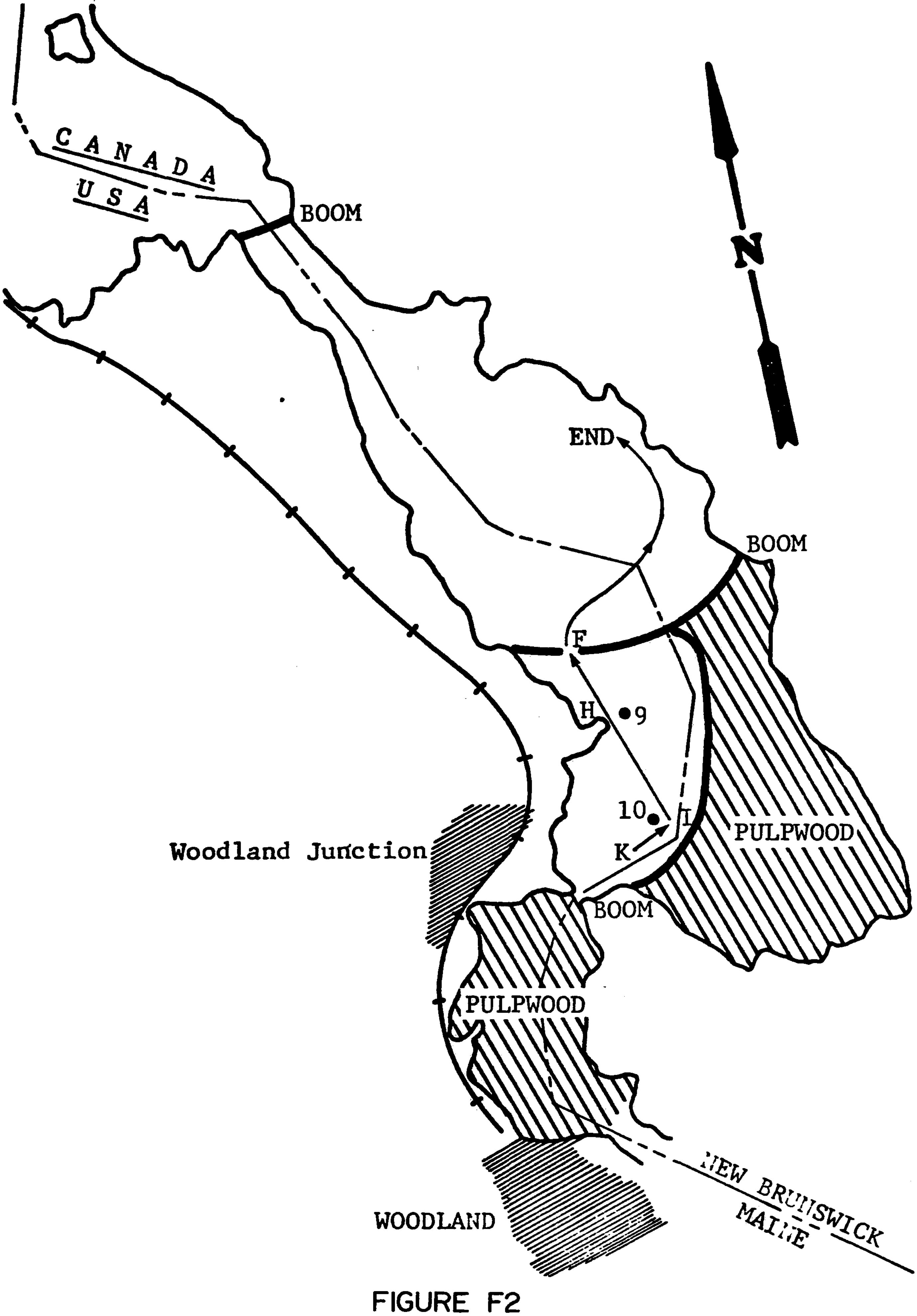

CANADA
USA
BOOM
N
END
BOOM
F
H
9
10
I
K
PULPWOOD
Woodland Junction
BOOM
PULPWOOD
WOODLAND
NEW BRUNSWICK
MAINE

FIGURE F2

the field. The ground truth locations are also plotted on the maps in Figures 1 and 2.

All the data on this survey was collected utilizing the Geophysical Survey System's Electromagnetic Subsurface Profiling (ESP) System. A brief description of this system is contained in Appendix A.

The first day of operation in the field was utilized in setting up the equipment and making experimental scans. The data collected from these scans was played back at the site and was used to direct a diver in bottom investigations. This information was used to determine the characteristic signature of various bottom conditions.

The field operations on the second day were cancelled due to heavy rain and high wind conditions.

All the transect lines shown in Figures 1 and 2 were surveyed on the third day of field operations. The transects were run between the lettered points shown in Figures 1 and 2. These were marked on the site by anchored floats. As the survey lines were being scanned, additional marker floats were layed out at 100 ft. intervals. These 100 ft. interval points were recorded in the data as the antenna passed each marker float. At various points along the transect lines visual observations of the bottom were made by divers. These points were marked with anchored buoys and their locations were recorded in the data as the antenna passed these points. The complete logs of these diver observations are contained in Appendix B.

A core sample was collected from the pond bottom and returned to the GSS laboratory for electromagnetic analysis. This sample was tagged and identified as Number 30124.

RESULTS

General Background

As noted in the report of diver observations enclosed in Appendix B, wherever EPA divers conducted operations on Woodland Pond, sunken logs lying on the bottom were encountered. The logs varied in diameter from approximately 3 inches to 24 inches. There was no uniformity in character of the logs layered on the bottom. The logs lay in an assorted jumble from the phase of upright through horizontal. The spaces between the logs varied from a few inches to large gaps of up to 8 ft. The gaps or spaces between the logs were laden with bark and woody debris interspersed with silt. Overlying this logging debris was a fine floc which was easily disturbed and resuspended. The deposit thicknesses discussed in the survey results do not differentiate the logs from the logging debris. Rather, the deposits are treated as a composite material.

Laboratory Tests

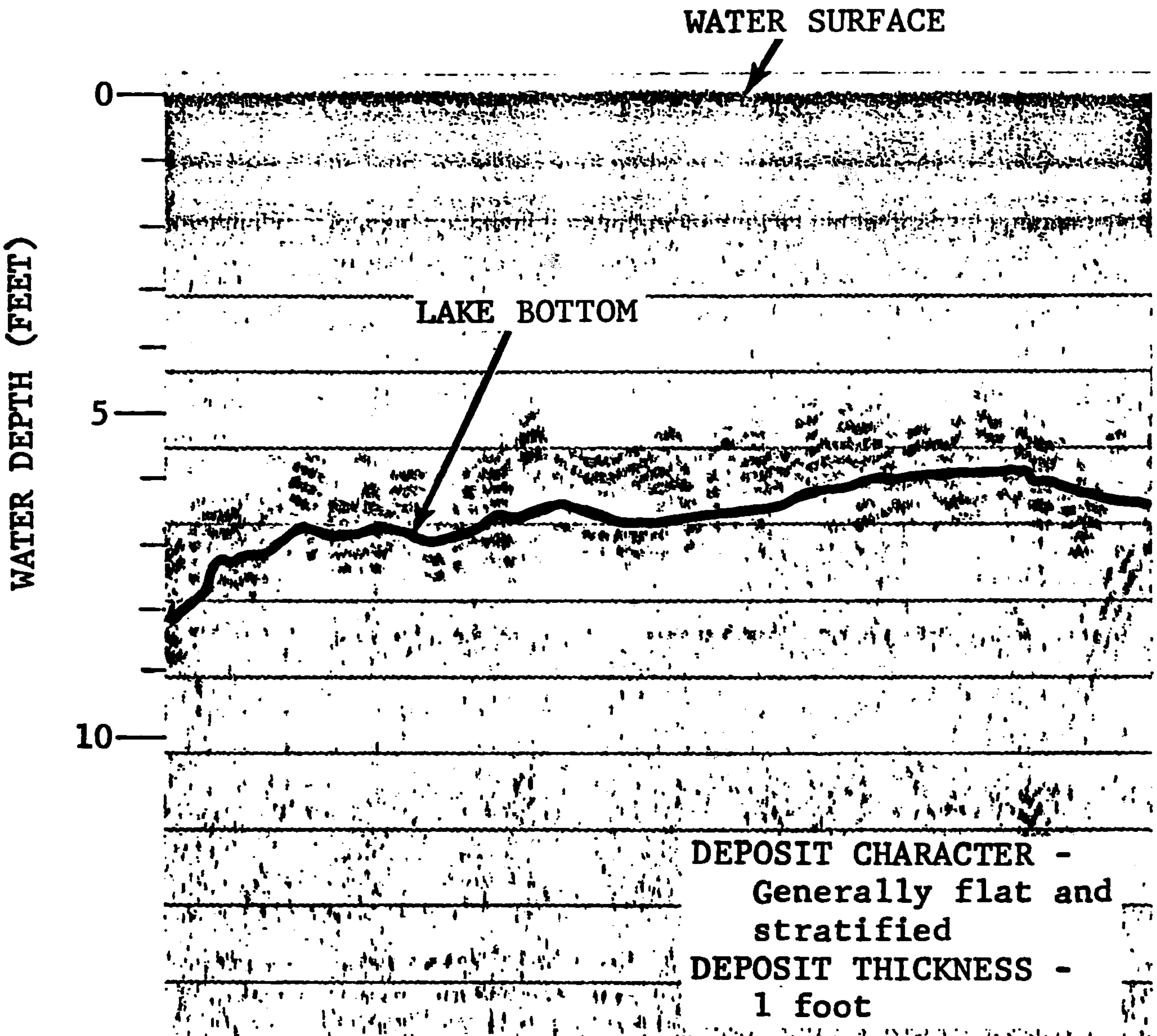
The core sample taken from the lake bottom was tested in the laboratory in the standard coaxial tube test used by GSS to classify materials. Insertion loss measurements show this material to have an attenuation characteristic of 55.9db per meter, which is extremely high. System penetration into this material will be negligible. Based on the results of this test it is safe to say that the multiple interfaces shown in the ESP data all occur above this material in the lake bottom and show the thickness of logs and silt deposits. The data recorded in the insertion loss test is included in Appendix C.

Field Data

The response of the ESP system to the conditions in Woodland Pond was very good. Strong reflections from the bottom were recorded throughout this site. The maximum depth of operation was 29 ft. This was limited only by the time base setting of the equipment. The only problem experienced with the equipment was an instrumentation noise band recorded at a depth of 20 feet. This is only a problem when the depth to the bottom is coincident with this noise band. In some cases information can be seen within this noise band but it is extremely difficult to make a meaningful analysis of this data.

The ESP system performed well in distinguishing between various characteristics of bottom conditions. Figures 3 through 8 are examples of the data collected from different areas. Note the difference in bottom signature between areas where the logs are flat and stratified and those where the logs are upright and jumbled. Also note the difference in the data caused by the thickness of the log deposits.

Interpretation of the data for each line was performed to determine the thickness of the log deposits and the general character of the deposits. The deposits were generally classified into two categories: flat and upright. For the most part, the deposits



WATER SURFACE
0
5
10
WATER DEPTH (FEET)
LAKE BOTTOM
DEPOSIT CHARACTER -
Generally flat and
stratified
DEPOSIT THICKNESS -
1 foot

FIGURE F3

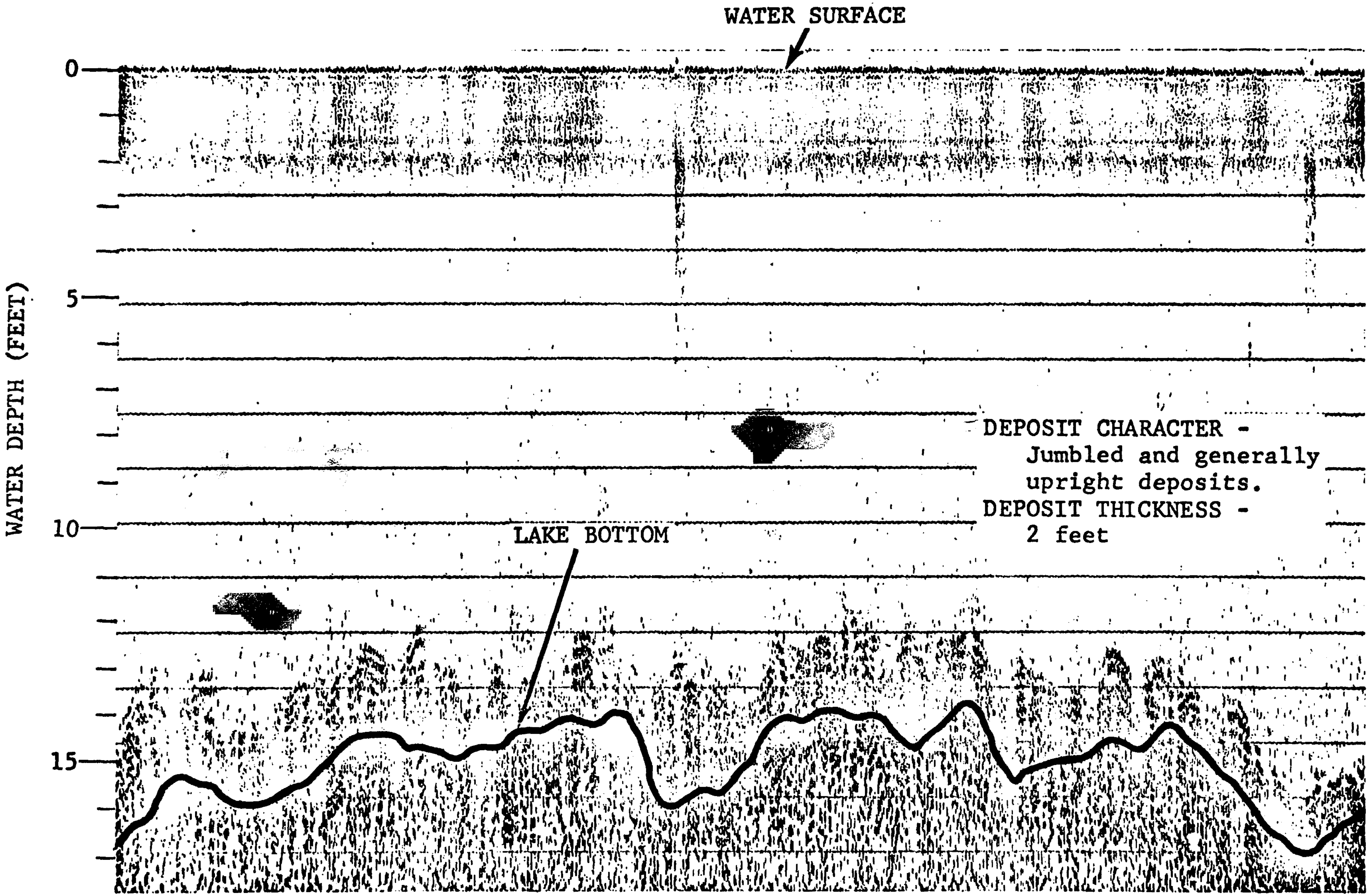

WATER SURFACE
0
5
10
15
WATER DEPTH (FEET)
DEPOSIT CHARACTER -
Jumbled and generally
upright deposits.
DEPOSIT THICKNESS -
2 feet
LAKE BOTTOM

FIGURE F4

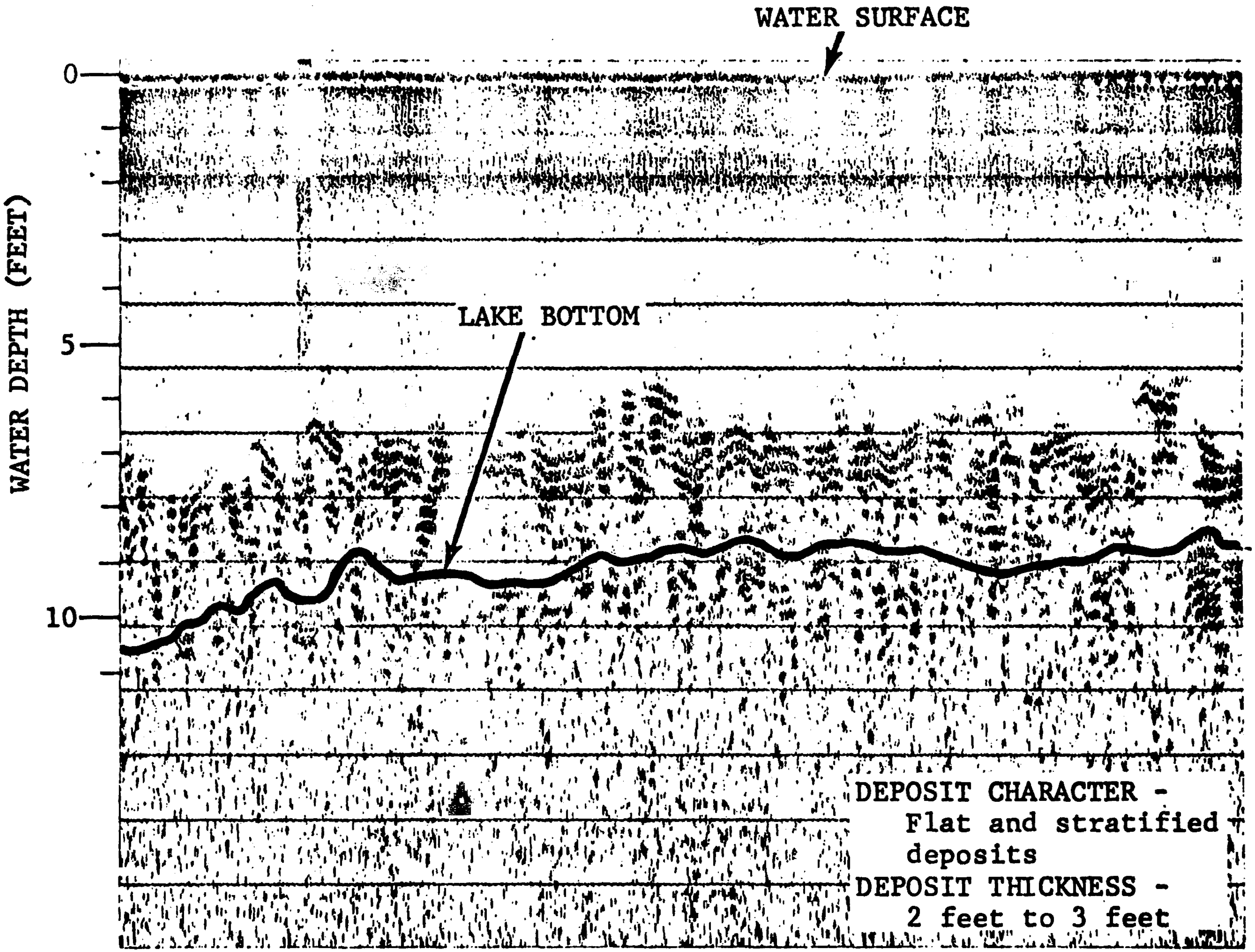

WATER SURFACE
0
5
10
WATER DEPTH (FEET)
LAKE BOTTOM
DEPOSIT CHARACTER - Flat and stratified deposits
DEPOSIT THICKNESS - 2 feet to 3 feet

FIGURE F5

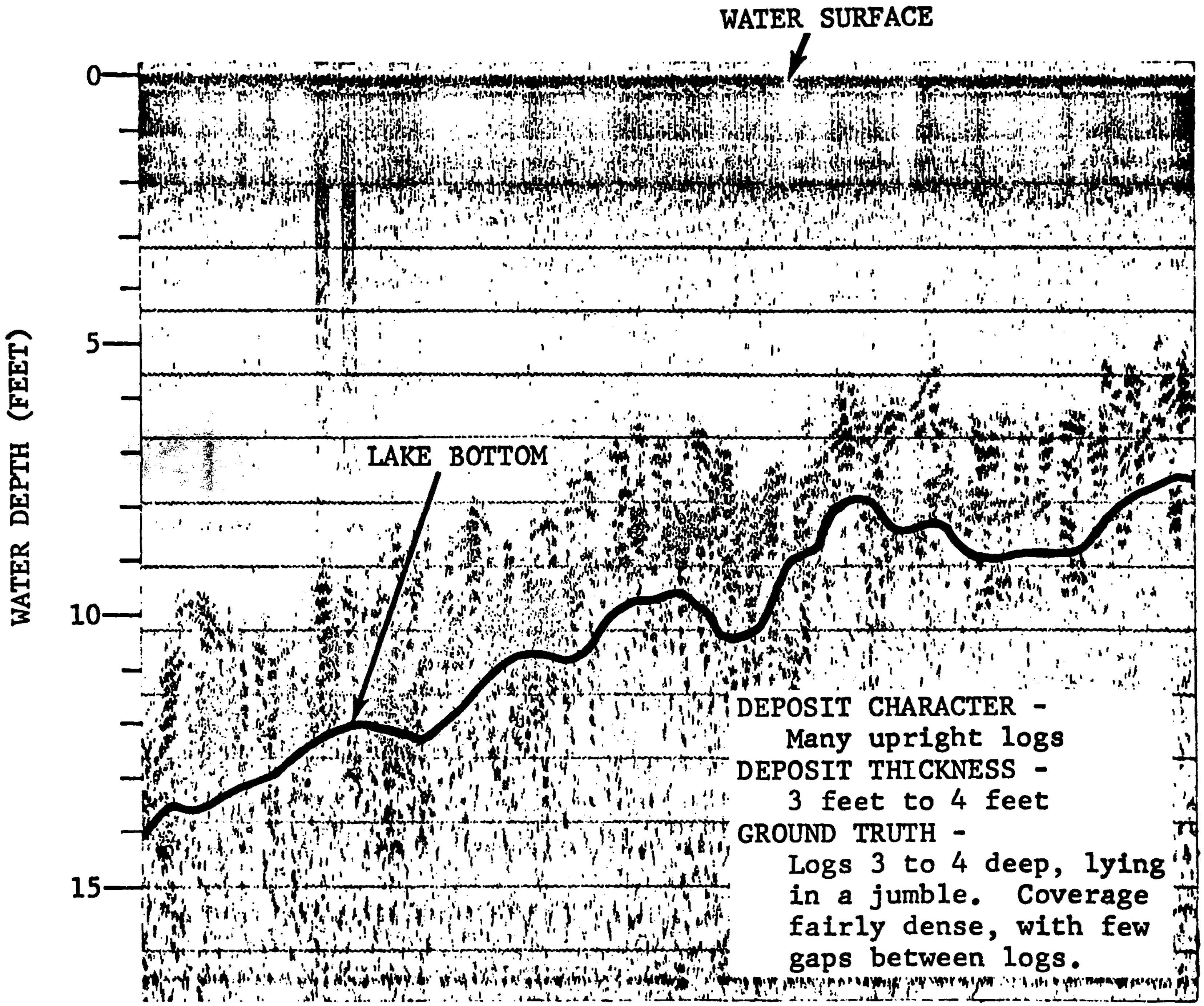

WATER SURFACE
0
5
10
15
WATER DEPTH (FEET)
LAKE BOTTOM
DEPOSIT CHARACTER -
Many upright logs
DEPOSIT THICKNESS -
3 feet to 4 feet
GROUND TRUTH -
Logs 3 to 4 deep, lying
in a jumble. Coverage
fairly dense, with few
gaps between logs.

FIGURE F6

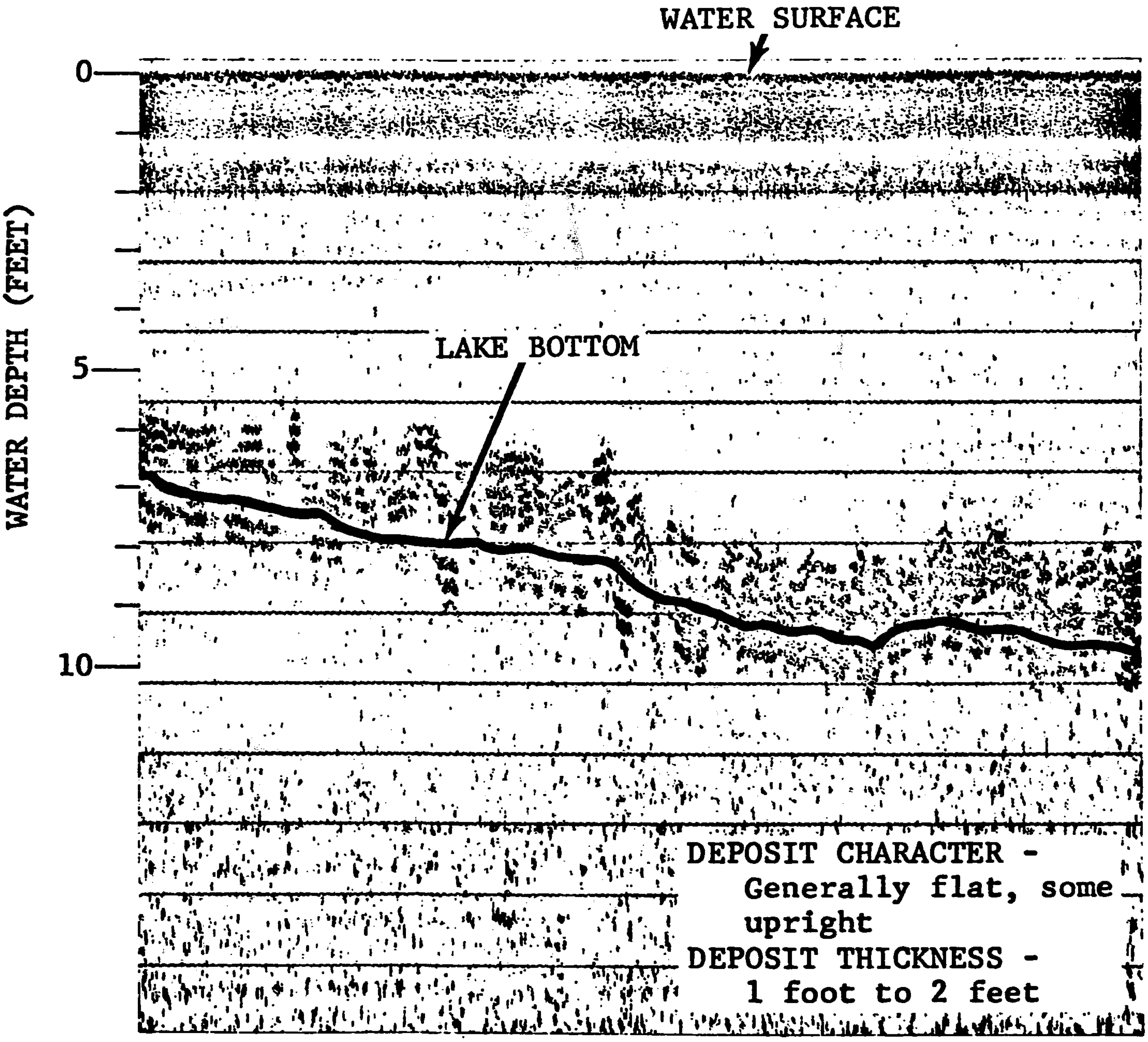

WATER SURFACE
0
5
10
WATER DEPTH (FEET)
LAKE BOTTOM
DEPOSIT CHARACTER -
Generally flat, some
upright
DEPOSIT THICKNESS -
1 foot to 2 feet

FIGURE F7

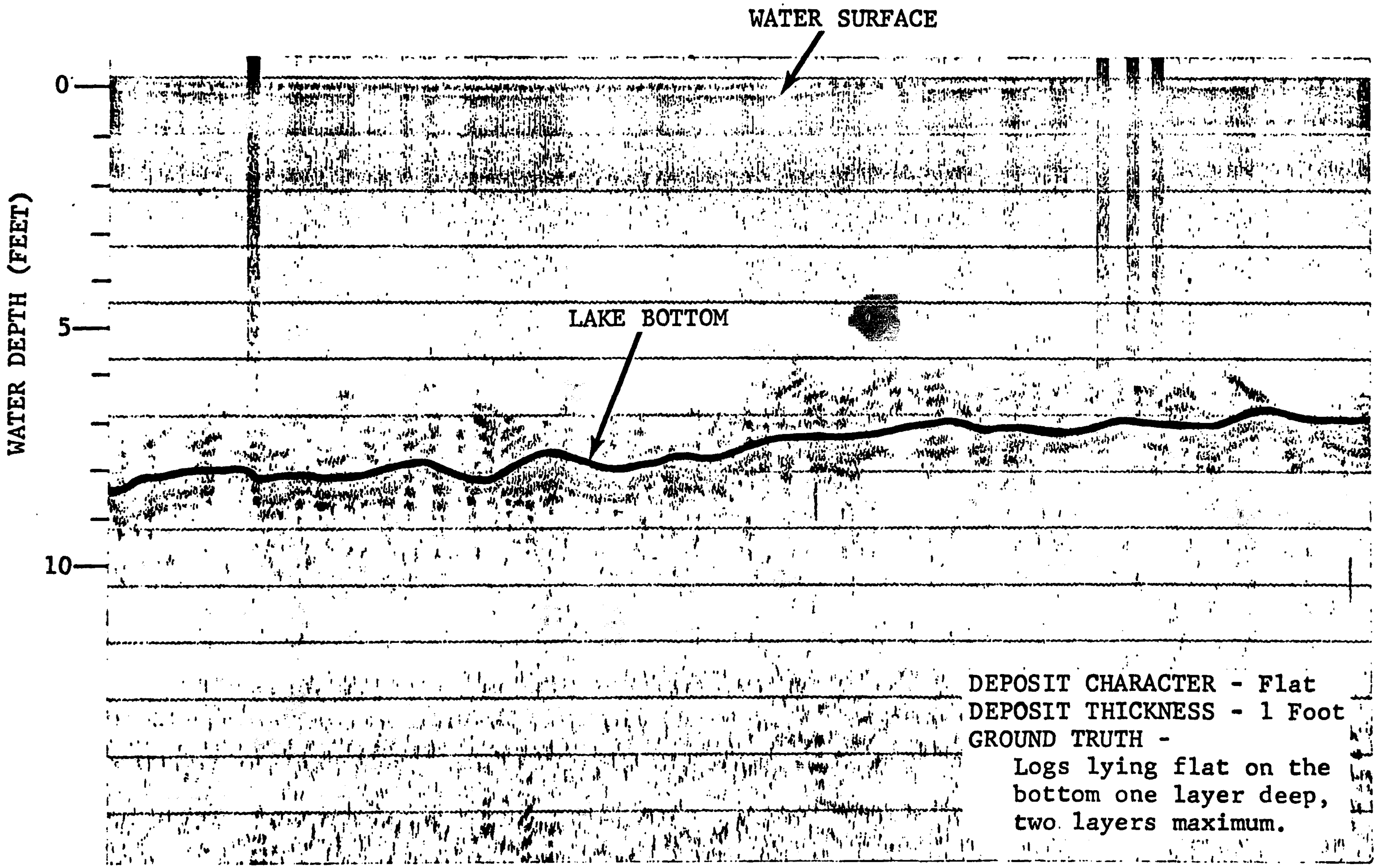

WATER SURFACE
LAKE BOTTOM
WATER DEPTH (FEET)
0
5
10
DEPOSIT CHARACTER - Flat
DEPOSIT THICKNESS - 1 Foot
GROUND TRUTH -
Logs lying flat on the bottom one layer deep, two layers maximum.

FIGURE F8

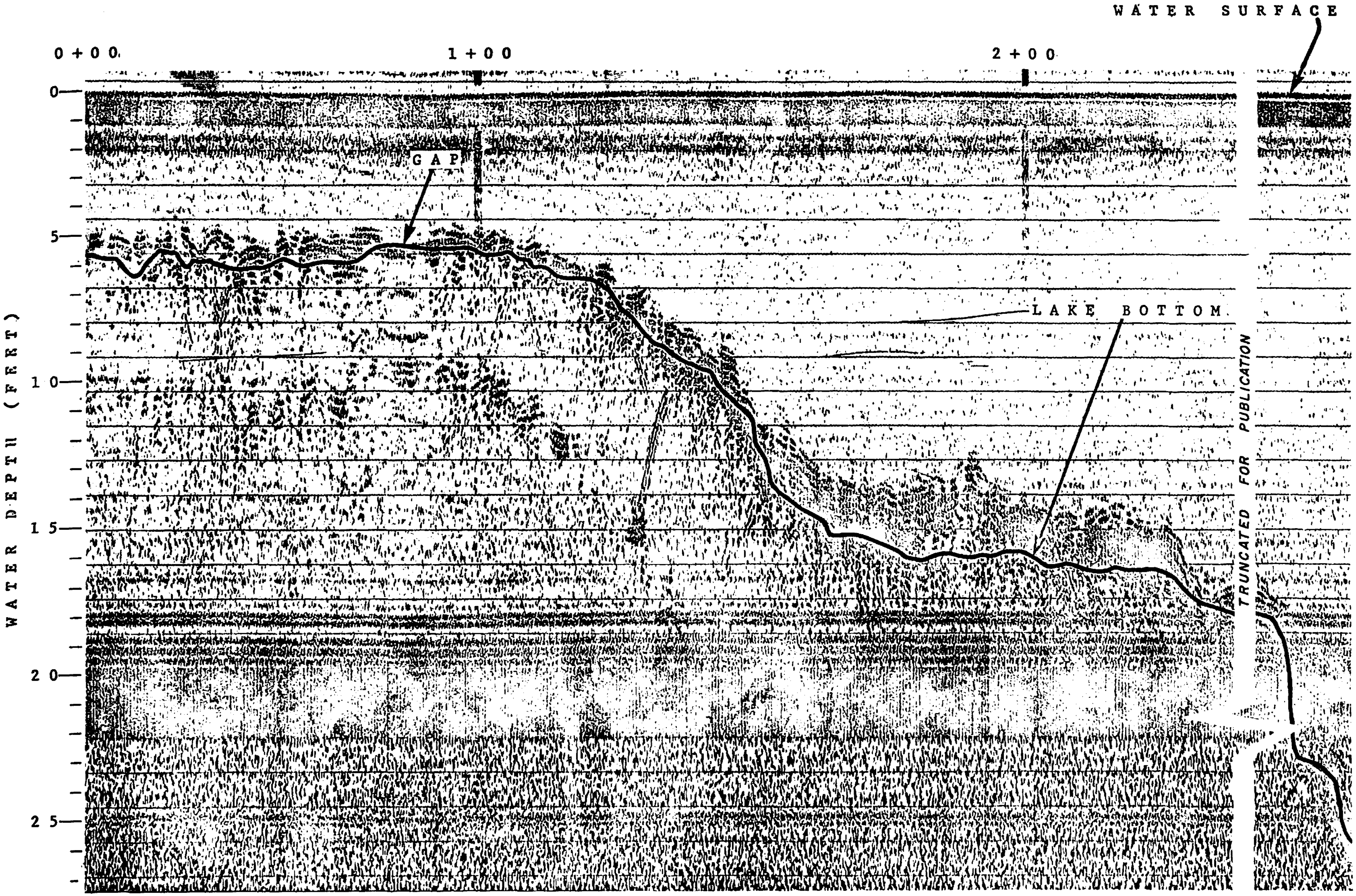

WATER SURFACE
0+00
1+00
2+00
GAP
LAKE BOTTOM
TRUNCATED FOR PUBLICATION
WATER DEPTH (FEET)
0
5
10
15
20
25

FIGURE F9

appeared to be generally flat. For this reason, notations will be made only for areas where the logs appear to be upright and jumbled and all other areas should be considered generally flat. The following is a summary of the conditions recorded for each of the scan lines. A complete point to point tabulation of the interpretation for the scan lines is contained in Appendix D.

TRANSECT A - B

Data on this line was recorded while enroute to Point B. The line was run along the channel and the depths in this area are in the order of 30 feet. The bottom reflection appears too close to the end of the equipment time base to show all the sub-bottom information.

TRANSECT B - C

Data was taken on this line for 1100 linear feet. Some of the thickest log deposits were observed on this line. The general character of the deposits was flat except that some indication of upright logs was observed between Station 7+80 and 8+60.

The summary of deposit thicknesses is:

Thicknesses less than 1 ft. - None

Thicknesses 1 ft. to 2 ft. - 37%

Thicknesses 2 ft. to 3 ft. - 34%

Thicknesses 3 ft. to 4 ft. - 25%

Thicknesses 4 ft. to 5 ft. - 4%

The ESP data from this line is enclosed in this report as Figure 9.

TRANSECT C - D

The length of this line is 2100 linear feet including approximately a 500 foot width of channel which was beyond the depth range of the system. The deposits in this line can be generally characterized as flat. Evidence of upright and jumbled deposits appear between stations 7+60 and 9+00, and stations 15+00 and 18+50. What appears to be a log pile about 5 ft. high is observed at Station 3+95. A summary of the observed bottom conditions is:

Deposits less than 1 ft. - 7%

Deposit thicknesses 1 ft. to 2 ft. - 20%

Deposit thicknesses 2 ft. to 3 ft. - 44%

Deposit thicknesses 3 ft. to 4 ft. - None

Deposit thicknesses 4 ft. to 5 ft. - 1%

TRANSECT D - E

This line is 2300 linear feet long. The character of the log deposits in this line is generally flat except that evidence of upright logs was noted between Stations 4+00 and 5+00. What could be logs trapped by stumps is observed at Station 2+90. A log filled depression is observed between station 20+00 and 21+00. A summary of the deposits in this line is:

Deposits less than 1 ft. thick - 36%

Deposit thicknesses 1 ft. to 2 ft. - 59%

Deposit thicknesses 2 ft. to 3 ft. - 5%

Deposit thicknesses 3 ft. to 4 ft. - None

Deposit thicknesses 4 ft. to 5 ft. - None

TRANSECT E - F

The length of this line is 1600 linear feet. It was run approximately parallel to Transect D-E except closer to the logging boom.

The same general characterization comments apply. A summary of the deposits is:

Deposit thicknesses less than 1 ft. - 23%

Deposit thicknesses 1 ft. to 2 ft. - 54%

Deposit thicknesses 2 ft. to 3 ft. - 23%

Deposit thicknesses 3 ft. to 4 ft. - None

Deposit thicknesses 4 ft. to 5 ft. - None

TRANSECT F - G

This is a survey line 670 linear feet long which runs from the opening in the logging boom to point G. The general characteristics of the deposits in this line were flat. No differences from this character were observed. A summary of the deposits is:

Deposits less than 1 ft. thick - None

Deposit thicknesses 1 ft. to 2 ft. - 66%

Deposit thicknesses 2 ft. to 3 ft. - 24%

Deposit thicknesses 3 ft. to 4 ft. - 10%

Deposit thicknesses 4 ft. to 5 ft. - None

TRANSECT G - H

The length of this line was 400 linear feet. The general character of the deposit was flat. Approximately 70% of this line was in the noise band and no meaningful information could be extracted. Deposits of two to three feet in thickness make up 17% of this line.

TRANSECT H - I

This line length is 950 linear feet. The general character of the deposits is flat except that upright indications are shown from station 6+90 to 9+55. A summary of the deposits is:

Deposit thicknesses less than 1 ft. - None

Deposit thicknesses 1 ft. to 2 ft. - 68%

Deposit thicknesses 2 ft. to 3 ft. - 32% - Estimated

It should be noted that approximately 310 feet of this line was within the instrumentation noise band. The thickness here appears to be 2 to 3 ft. but was hard to define. It makes up the 32% estimated quantity in the summary.

TRANSECT I - J

The length of this line is 780 linear feet. The same general comments as in the H-I transect apply. A summary of the deposit thickness is:

Deposits less than 1 ft. thick - 17%

Deposits 1 to 2 ft. thick - 38%

Deposits 2 to 3 ft. thick - 45%

Deposits 3 to 4 ft. thick - None

Deposits 4 to 5 ft. thick - None

Figure 9 is a reproduction of the data from the complete scan line of B to C. General points of interest are noted such as the 100 ft. station marks, locations of diver ground truth information, diver ground truth reports, and the interpreted location of the actual lake bottom.

CONCLUSIONS

The ESP data collected supports the diver observations of the extensive deposits of logs on the bottom of Woodland Pond. The interpretations of the data collected from Point B through to Point J indicates that log deposits ranging in thickness from 1 to 3 ft. make up 80% of the lake bottom along these lines.

APPENDIX F-A

APPENDIX F-A

INTRODUCTION

Geophysical Survey Systems, Inc., has developed an impulse radar system that makes shallow subsurface investigations. The technique is known as Electromagnetic Subsurface Profiling (ESP), and is the electrical analog of seismic sub-bottom profiling techniques used in marine geology. The system is capable of detecting and graphically displaying subsurface interfaces to depths of as much as 50 feet.

Broadband, time-limited pulses of electromagnetic energy are continuously radiated into the earth from a special antenna moving along the surface. The system receives reflections of these pulses from interfaces between materials that have different electrical properties. This data is stored on magnetic tape and is printed out graphically after an area has been scanned. The printout displays a close approximation to the interfaces one would see in the vertical wall of a trench dug along the corresponding scan line. The printout is produced by printing high signal levels as black and no signal as white. Intermediate signals are in the gray range.

In practice, scans are made by slowly driving a small truck or boat containing the impulse radar system over the area of interest. A block diagram of the system is shown in Figure A1. A sled-mounted antenna is towed behind the survey vehicle. The antenna can also be handpulled over an area as much as 100 feet from the vehicle or towed behind an all-terrain vehicle in areas where the standard vehicle is unsuitable. Data may be printed out in the field for immediate interpretation or sent back to the laboratory for computer processing and data enhancement.

The impulse radar system has been used successfully to locate ice wedges in permafrost, determine the geologic structure of several deposits of unconsolidated material, map bottom topography through ice on fresh-water lakes, measure fresh-water and sea-ice thickness, locate buried objects such as pipes, tunnels, barrels, and synthetic foam, and profile the bedrock surface buried beneath unconsolidated materials.

EXPLANATION OF IMPULSE RADAR THEORY

Impulse propagation through naturally-occurring media is a complicated phenomenon. Physical and chemical properties of a medium affect the dielectric constant and conductivity. These parameters in turn influence impulse shape and propagation. The dielectric constant determines the velocity at which the impulse travels through the medium. If the velocity and time of travel are known, the thickness of the material can be determined.

The impulse radar system emits a pulse that is approximately Gaussian in shape (see Figure A2). It is possible to express this time domain impulse through its fourier transform as a frequency spectrum of components (Ref. 1, 2 and 3). The reflection of each of the spectral components and hence the impulse is determined by the dielectric constant and conductivity of the medium from which it is reflected. This is because the reflected pulse must satisfy the boundary conditions at each interface. These boundary conditions are derived from Maxwell's equations (Ref. 4). If the impulse passes through multiple media it is partially reflected and partially transmitted at each interface (see Figure A3). It is the reflected pulse that the radar system developed by Geophysical Survey Systems, Inc. will detect, analyze and record.

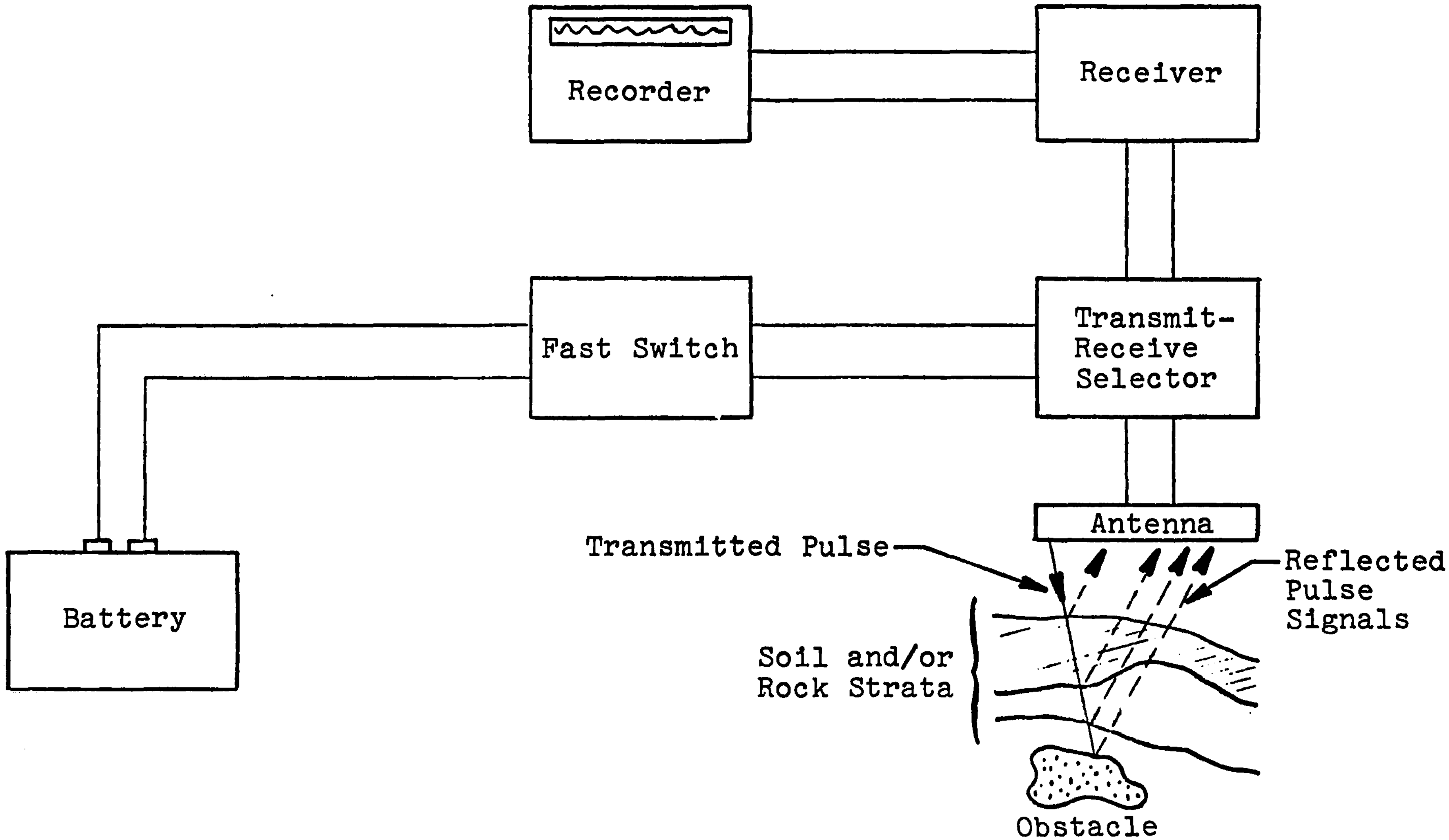


FIGURE FA1 Block Diagram of Impulse Radar System

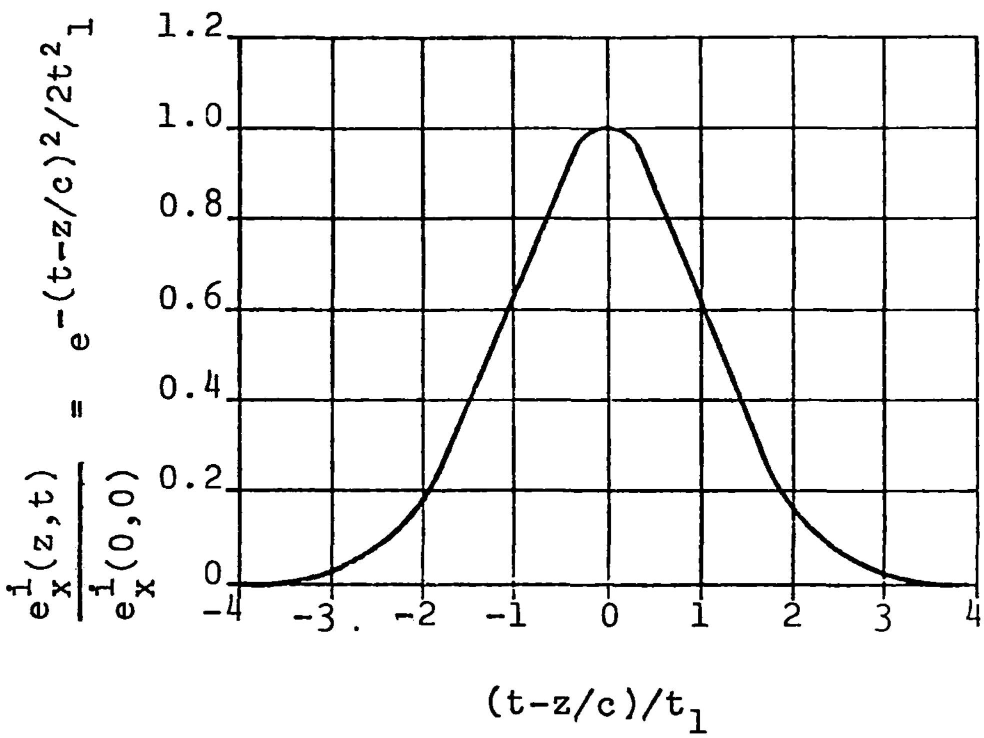
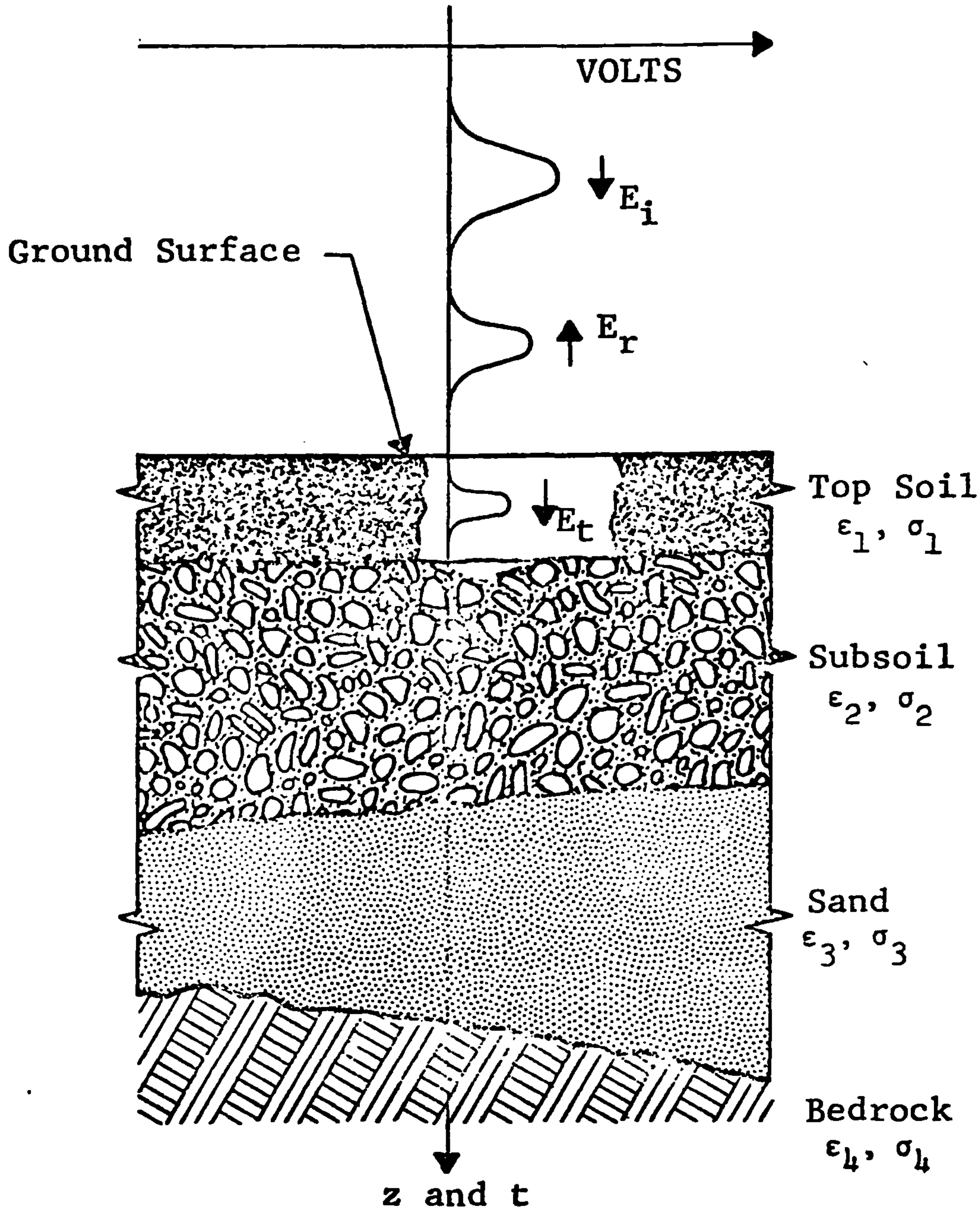


FIGURE FA2 A Gaussian Pulse



LEGEND

E_i = Incident Pulse (Pulse Transmitted by Radar)
E_r = Reflected Pulse From Interface (Ground Surface)
E_t = Transmitted Pulse Into Ground
z = Distance
t = Time
ε = Dielectric Constant
σ = Conductivity

FIGURE FA3 Multiple Media

REFERENCES CITED

1. Redheffer, R.M.; Sokolnikoff, I.S.; Mathematics of Physics and Modern Engineering, pp 175 - 195, McGraw-Hill, Inc. 1958

2. IBID; Redheffer, R.M.; pp 482 - 488.

3. Adler, Richard B.; Chu, LanJen; Fano, Robert M.; Electromagnetic Energy Transmission and Radiation, pp 6 - 24, John Wiley & Sons, Inc. 1960.

4. IBID; Adler, Richard B.; pp 189 - 194.

APPENDIX F-B

ENVIRONMENTAL PROTECTION AGENCY
Division of Surveillance and Analysis
240 Highland Avenue
Needham Heights, Massachusetts 02194

September 22, 1972

Geophysical Survey Systems, Inc.
16 Republic Road
North Billerica, Massachusetts 01862

Attention: Mr. Walter Harrington

Gentlemen:

Enclosed is the ground truth information requested by GSS for the interpretation of ESP data recorded for the Woodland Pond section of the St. Croix River, Woodland, Maine. The maps of the survey lines I (the run from north to south) and II (the return run from south to north) are fairly good representations of those run in the field. These will have to serve as temporary lines until such time as an aerial composite map can be put together and the survey lines more accurately mapped.

Included are blank maps of the study area. Suggestions and changes relative to identifying transects and their locations are welcome. If any problems or discrepancies arise or if I can be of further assistance, do not hesitate to contact me.

FOR THE REGIONAL ADMINISTRATOR:

Sincerely yours,

Peter M. Nolan

Peter M. Nolan
Aquatic Biologist

Enclosure(s)

GROUND TRUTHS

General Information

Wherever EPA divers conducted operations on Woodland Pond, sunken logs lying on the bottom were encountered. The logs varied in diameter from approximately 3 to 24 inches. A stick of pulpwood averages 4 feet in length. Generally, the pond from the channel east was more densely laden with logs. There was no uniformity in character of the logs layered on the bottom. The logs lay in an assorted jumble from upright to horizontal. The spaces between the logs varied from a few inches to large gaps of up to eight feet. The gaps or spaces between the logs were laden with bark and woody debris interspersed with silt. Depending on location, this could be as much as 24 inches or as little as 1 inch. This debris was observed to be heaviest in the downstream end of the study area. Overlying this logging debris was a fine floc which was easily disturbed and resuspended.

The observations stated for ground truth points are considered by us to be a fair representation of the area in the general vicinity of the point.

The layering of logs referred to in this report indicates the numbers of logs piled on one another re(2 to 3 layers). Estimates of depths in feet of log related deposits was not considered reliable. For example, depending on the size of the logs and configuration on the bottom, 2 layers of logs could be 4 to 5 feet deep and conversely 4 layers could be only 2 to 3 feet deep, etc.

The survey lines (transects) are lettered alphabetically from point to point as run in the field. The ground truth marks are numbered consecutively also as run in the field.

Transect A to B

Although no diving was done along this transect, we were sufficiently close to shore to observe at visible depths the presence of sunken logs. My estimate is that the logs were layered from 1 to 3 deep for most of this survey line. The logs were positioned on the bottom in various configurations from upright to horizontal.

Transect B to C

Ground Truth Point 1 - Logs layered 1 to 2 deep, some laying horizontal and others layered or were leaning against these. There were some gaps between the logs of approximately 4 to 5 feet. The gaps are filled in with bark, wood fragments, a light floc and silt to a depth of approximately 2 to 6 inches.

Ground Truth Point 2 - Logs generally layered from 1 to 2 deep with some logs layered up to 4 deep. Logs were fairly uniformly distributed on the bottom. The substrate was composed of bark, wood fragments, silt, etc. to depths of 6 to 12 inches.

Ground Truth Point 3 - Logs layered 2 to 3 thick with bark, wood fragments and silt comprising the substrate. Other observations are similar to the above.

Transect C to D

Ground Truth Point 4 - Considerable logs sunk at visible depths near the shore with logs layered 3 to 4 deep, lying in a jumble on the bottom. Coverage is fairly dense with few gaps between logs.

Ground Truth Points 5 and 6 - Bottom visibility was 6 inches or less at these points due to log recovery operations being conducted by GP. However, diver verification of the presence of logs was made faced rocks up to 8 feet across. Logs were piled on top of the rocks usually not exceeding 2 layers.

East side $\frac{1}{4}$ of line distance from the Canadian shore, logs covered the bottom in every direction with fewer in the vicinity of the channel. Bottom coverage by logs was fairly dense with logs layered from 1 to 5 deep. The logs of largest diameter were observed to be on the bottom of the piles with the smaller sticks on top. The logs on the bottom varied from upright to flat on the bottom. Bark, wood fragments and debris covered the bottom to depths up to 18 inches deep. Some logs were buried beneath the substrate. Near the shore in some locations more stumps were noticed and the logs were 1 deep. One pile of logs was observed to be about 6 to 8 feet high.

Relative numbers of logs for 100 feet in 3 different directions for this area are:

From point O to northeast 330 logs and 279 logs

From point O due south 150 logs

From point O west to channel 78 logs

<u>Transect E to F</u>

Ground truth from point E to the intersection of the two large logging booms.

This line was surveyed on August 17, 1972, for verification of the presence of logs. 3 to 4 layers of logs were observed to be fairly uniformly covering the bottom along this line. The bark, wood debris, etc. was noted to be 6 to 12 inches deep.

<u>Transect F to G</u>

No truth.

by feeling on the bottom. At these points, logs are estimated to be layered 2 to 3 deep with variable gaps up to 5 feet separating some of the logs. Bottom materials, such as bark, wood fragments, floc and silt are estimated to be about 2 to 12 inches. Some of this area is channel.

Ground Truth 7 - Logs are less dense, 1 to 2 layers with some lying horizontal and others laying or leaning against these. Some logs protruding out of the water closer to shore.

Transect D to E

Although ground truth marks per se are not given along this transect, we conducted a good deal of diving activity along this line and have a good deal of ground truth available for it.

On the west side ¼ of line distance from the American shore, the bottom was observed to have a good deal of stumps and trees lopped off at 6 feet. Many of these stumps were trapping logs and causing piles to be created, accumulations of which reached 5 layers. The logs are not as dense as on the east side with gaps with no logs extending for up to 8 feet. Typically, the logs are layered 2 to 4 deep. The substrate encountered typically was comprised of bark, wood fragments interspersed with silt and floc.

Lines which divers swam on compass bearings for 100 feet indicate relative numbers of logs over which the diver passed.

From point zero due east 183 logs and 178 logs were counted.

From point zero due west 220 logs were counted.

At mid-stream the water was up to 25 to 30 feet deep. Exposed portions of the channel indicated the presence of ledge and broad faced rocks up to 8 feet across. Logs were piled on top of the rocks usually not exceeding 2 layers.

East side $\frac{1}{4}$ of line distance from the Canadian shore, 4 logs covered the bottom in every direction with fewer in the vicinity of the channel. Bottom coverage by logs was fairly dense with logs layered from 1 to 5 deep. The logs of largest diameter were observed to be on the bottom of the piles with the smaller sticks on top. The logs on the bottom varied from upright to flat on the bottom. Bark, wood fragments and debris covered the bottom to depths up to 18 inches deep. Some logs were buried beneath the substrate. Near shore in some locations more stumps were noticed and the logs were 1 deep. One pile of logs was observed to be about 6 to 8 feet high.

Relative numbers of logs for 100 feet in 3 different directions for this area are:

From point 0 to northeast 330 logs and 279 logs.

From point 0 due south 150 logs.

From point 0 west to channel 78 logs.

Transect E to F

Ground truth from point E to the intersection of the two large logging booms.

This line was surveyed on August 17, 1972, for verification of the presence of logs. 3 to 4 layers of logs were observed to be fairly uniformly covering the bottom along this line. The bark, wood debris, etc. was noted to be 6 to 12 inches deep.

Transect F to G

No truth.

Transect G to H

Truth Point 8 - Logs are present on the pond bottom in densities similar to those for areas on the east side of Woodland Pond. These vary from approximately 2 to 4 layers with fairly uniform bottom coverage. Bark, wood fragments and woody debris are present to depths of 18 inches.

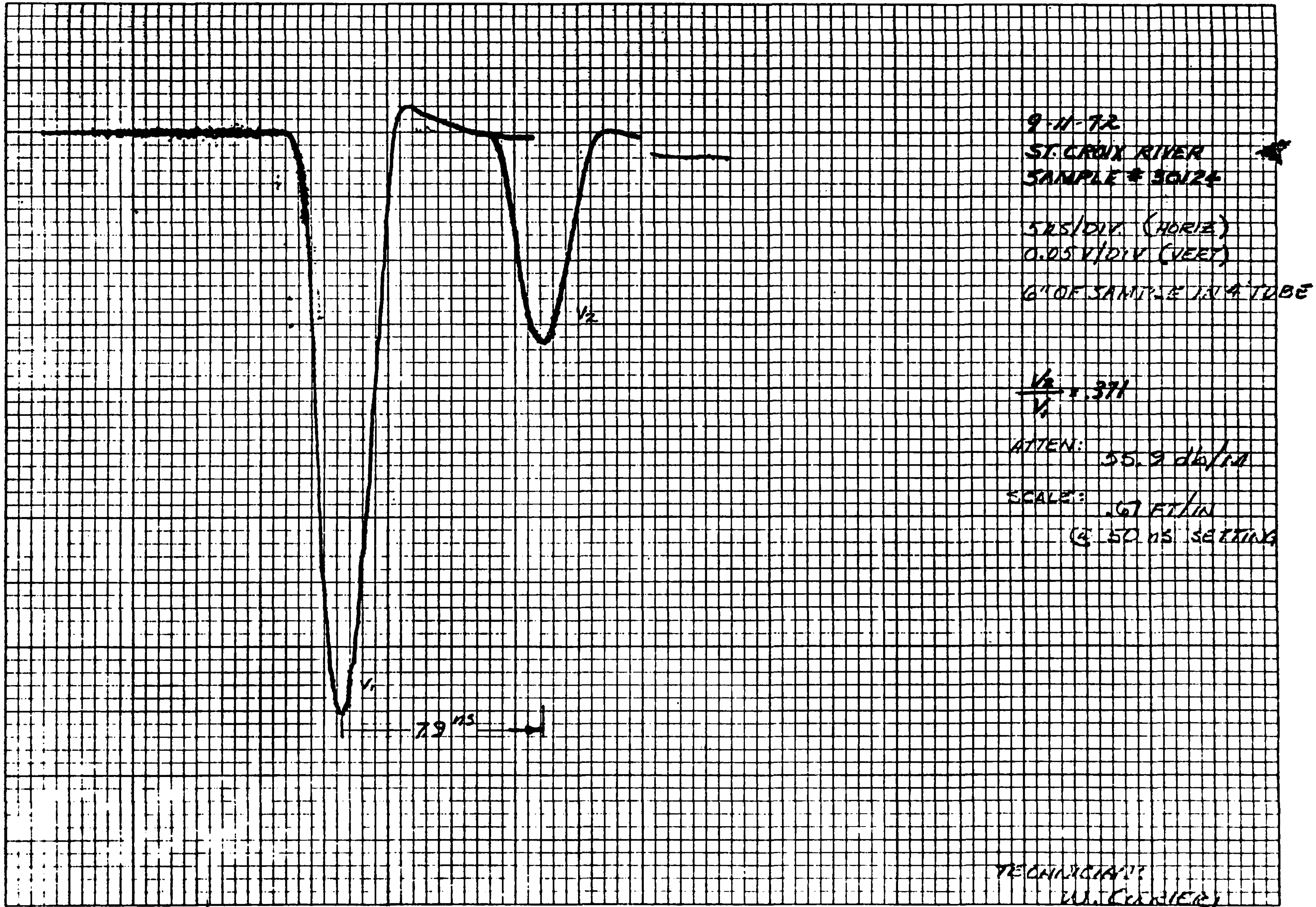
Truth Point 9 - Similar to above.

Truth Point 10 - Presence of logs verified average 2 to 4 layers with some spots having logs 5 to 6 layers deep. Logs are lying on the bottom in a jumble upright to horizontal. Typical coverage for 100 feet (the number of logs over which the diver passes) was approximately 150 logs. A divers count for an area estimated to be 10 square feet was 25 logs. These logs would be wholly or partially in this area.

Bark, woody debris and floc was deeper here than in areas previously noted. A diver could put his arm to shoulder depth (24 or more inches) in this area and not feel hard bottom. Groping beneath this debris revealed the presence of buried logs.

Truth Point 11 - The logs were less dense, approximately 1 layer deep with 2 layers the maximum depth. The logs were lying flat on the bottom. Submerged vegetation was noted to be more abundant.

APPENDIX F-C



9-11-72
ST. CROIX RIVER
SAMPLE # 30124
5ns/DIV. (HORIZ)
0.05 V/DIV (VERT)
6" OF SAMPLE IN 4' TUBE
V2/V1 = .371
ATTEN: 55.9 db/in
SCALE: .67 FT/IN
@ 50 ns SETTING
V2
V1
7.9 ns
TECHNICIAN:

APPENDIX F-D

TRANSECT B - C

Station	Deposit Thickness	Water Depth	Comments
0+00 to 1+60	1'	5'-14'	Gap at 0+80
1+60 to 2+40	2'-3'	14'-15'	
2+40 to 4+90	1'-2'	17'-29+	2+90 to 4+50 Ground Truth #1 Steep Channel
4+90 to 5+40	2'-3'	14'-15'	
5+40 to 7+40	3'-4'	12'-15'	Ground Truth #2
7+40 to 7+80	4'-5'	12'	Some Upright
7+80 to 8+60	3'-4'	12'-15'	9+00 to 9+50 log filled depression
8+60 to 11+00	2'-3'	15'-17'	After 11+00 bottom is difficult to define. Ground Truth #3

TRANSECT C - D

Station	Deposit Thickness	Water Depth	Comments
0+00 to 0+70	2'-3'	5-9	
0+70 to 1+00	1'-2'	5-8	
1+00 to 1+20	2'-3'	5-7	Ground Truth Pt. #4
1+20 to 2+15	1'-2'	5-7	
2+15 to 2+90	<1	5	
2+90 to 3+75	1'-2'	5-17	
3+75 to 5+00	2'-3'	16-17	Small 5' pile at 3+95 Generally Flat
5+00 to 7+60	2'	17	Ground Truth Pt. #5
7+60 to 9+00	2'-3'	17	Jumbled-Some Upright
9+00 to 15+00	-	16-29+	
15+00 to 16+20	1'-2'	19-20	Some Upright
16+20 to 18+50	2'-3'	20	Some Upright Ground Truth Pt. #6
18+50 to 19+20	<1	9-15	
19+20 to 21+00	1'-2'	6-8	Mostly 1' Exactly Ground Truth Pt. #7

TRANSECT D - E

Station	Deposit Thickness	Water Depth	Comments
0+00 to 1+00	<1'	5'	Some Flat
1+00 to 1+50	1'-2'	5'-7'	
1+50 to 2+00	<1'	7'-8'	
2+00 to 5+00	1'-2'	8'-17'	2+90 logs trapped by stumps. 4+00 to 5+00 upright logs
5+00 to 7+70	<1'	17'-29'	
7+70 to 13+00	1'-2'	18'-28'	
13+00 to 17+00	<1'	17'-29'	
17+00 to 19+70	1'-2'	17'-20'	Data in Noise Band
19+70 to 21+00	2'-3'	20'-23'	
21+00 to 23+00	1'	5'-22'	20+00 - 21+00 log filled depression

TRANSECT E - F

Station	Deposit Thickness	Water Depth	Comments
0+00 to 1+60	1'-2'	6-20	
1+60 to 4+60	2'-3'	18-23	1+70 to 3+20 log filled depression
4+60 to 5+40	1'-2'	18-20	
5+40 to 9+00	<1	17-29+	Channel/Tree 8+25
9+00 to 13+20	1'-2'	14-18	Some Upright Logs
13+20 to 14+00	2'-3'	17-18	
14+00 to 16+00	1'-2'	16-19	

TRANSECT F - G

0+00 to 1+60	2'-3'	15'-19'
1+60 to 4+50	1'-2'	19'-21'
4+50 to 5+20	3'-4'	16'-20'
5+20 to 6+70	1'-2'	20'

TRANSECT G - H

Station	Deposit Thickness	Water Depth	Comments
0+00 to 1+30	-	18'-23'	
1+30 to 3+30	1'-2'	19'-21'	Ground Truth #8 Data in Noise Band
3+30 to 4+00	2'-3'	16'-20'	Ground Truth #9

TRANSECT H - I

0+00 to 3+10	2'-3'	21'	Data in Noise Band
3+10 to 6+90	1'-2'	13'-21'	
6+90 to 9+55	1'	15'-18'	Upright Logs

TRANSECT I - J

0+00 to 3+55	2'-3'	15'-18'	Ground Truth #10
3+55 to 6+45	1'-2'	6'-14'	Many flat - Mostly about 2'
6+45 to 7+75	<1'	6'-9'	Some Flat Ground Truth #11

APPENDIX G

ST. CROIX RIVER STUDY
AUGUST 1972
DIVING REPORT
WOODLAND LAKE & MILL POND
WOODLAND, MAINE

During the period of August 16 - 19, 1972 an underwater investigation was performed by EPA Region I divers in the Log Storage Pond on the St. Croix River, Woodland, Maine. The diving operation was to determine the areal extent of bottom coverage due to sunken pulp logs, bark and related debris. Divers mapped, photographed, and counted sunken logs. Also, the divers provided assistance and ground truth data to Geological Survey Systems, North Billerica, Massachusetts for its use in conducting subsurface investigations. (See Appendix F).

Diving activities were conducted in impounded portions of the St. Croix River known as Mill Pond and a two mile reach of Woodland Lake. Mill Pond is a small body of water extending from the Woodland Dam north to the railroad bridge at Woodland Junction. The two mile reach of Woodland Lake extended from the railroad bridge in Woodland Junction upstream. These two sections have a combined surface area of approximately 666 acrea (1.04 square miles).

Woodland Lake and Mill Pond are used by the Georgia-Pacific Corporation Woodland, for the wet storage of pulp logs. During the time of this investigation the southeastern portion of Woodland Lake (locally known as Hanson Cove) and the entire Mill Pond were being used for log storage. Large booms adjacently rigged from north to south for approximately 0.6 mile and east to west for approximately 0.5 mile are used to keep the logs in position (see Figure G-1). Of the 666 acres previously mentioned, about 266 acres were actively being used for the wet storage of logs.

A huge bark pile in Woodland Junction boarded the shore line of the Woodland Lake for about 0.5 mile (Figure G-1). Several small man-made boom rigging islands dot the lake surface.

DIVING LOCATIONS

Diving locations were randomly selected in the field by the EPA diving coordinator. The locations were chosen to include as much of the study area as possible to get representative impressions of bottom conditions.

Diving in the southeastern portion of the lake was precluded due to the logs in storage. Peripheral areas were investigated by swimming under the logs from open water. Mill Pond, which was tightly packed with logs, was examined by diving from shore using life lines.

Figure G-1 shows the diving locations in consecutive numbers from south to north. The solid circles indicate the general areas which were extensively surveyed by divers and the open circles represent areas which were spot checked for bottom conditions.

GENERAL REMARKS - BOTTOM CONDITIONS

Wherever EPA divers conducted diving operations in Woodland Lake and in the adjacent Mill Pond, sunken logs, lying in various configurations on the bottom were encountered. The logs lay in an assorted jumble of non uniform layers on the bottom.

The sunken logs were approximately four feet long and varied in diameter from three inches to 24 inches.

Generally, the lake bottom from the channel east to the Canadian shore was more densely laden with logs than was the west side. This is probably due to prevailing winds from a westerly direction or the

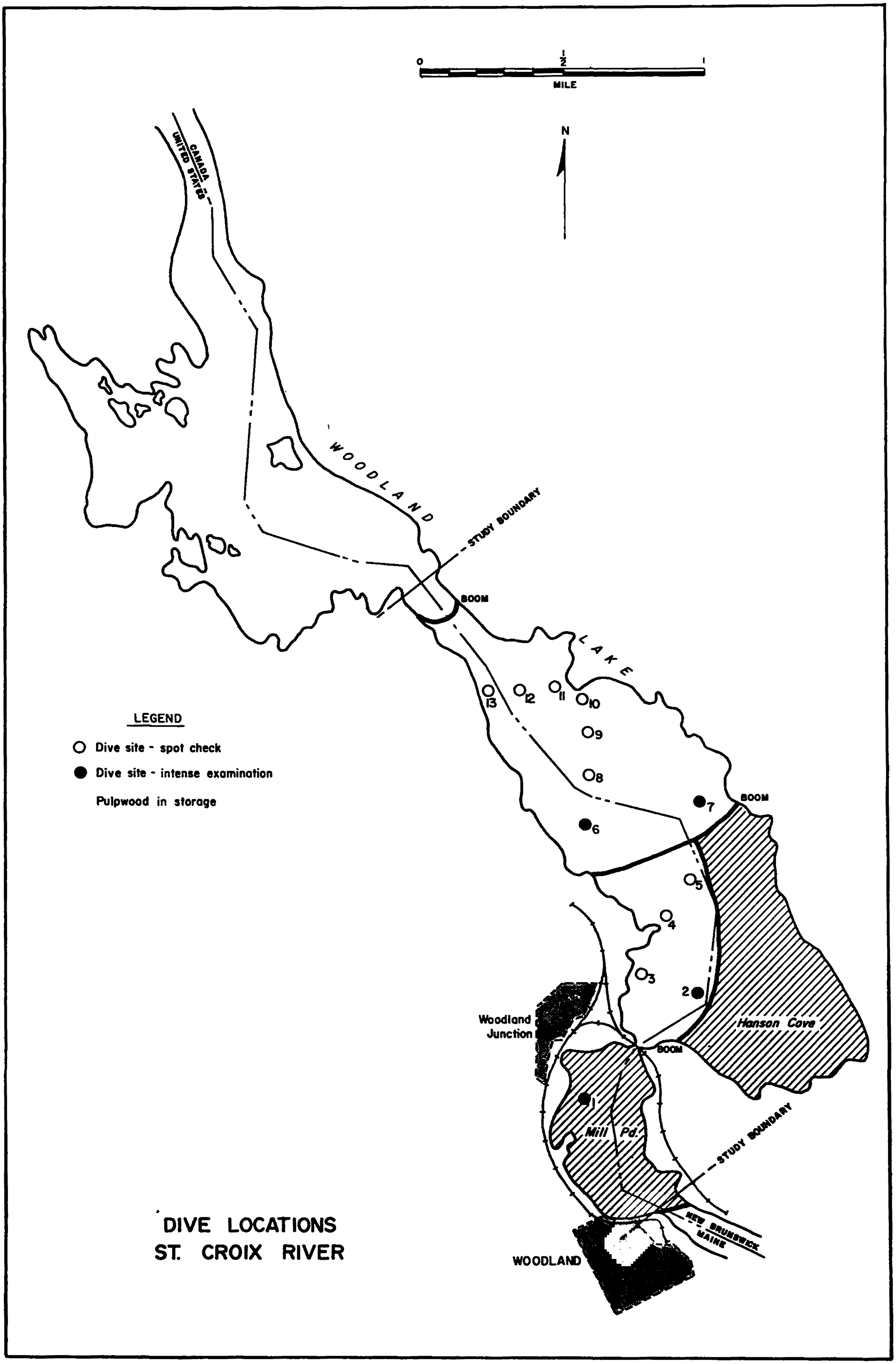

0
1/2
1
MILE
N
CANADA
UNITED STATES
WOODLAND
STUDY BOUNDARY
BOOM
LAKE
LEGEND
Dive site - spot check
Dive site - intense examination
Pulpwood in storage
13
12
11
10
9
8
7
6
5
4
3
2
1
BOOM
Woodland Junction
BOOM
Hanson Cove
Mill Pd.
STUDY BOUNDARY
NEW BRUNSWICK
MAINE
WOODLAND
DIVE LOCATIONS
ST. CROIX RIVER

FIGURE G-1

dredging of logs from the pond bottom on the west side of the lake. The Mill Pond had the greatest abundance of sunken logs.

Spaces and gaps did exist between logs lying on the bottom. The gaps varied from a few inches up to eight feet across. The gaps were heavily laden with bark mixtures, wood fragments and woody debris interspersed with a fine silt. Depending on location the debris ranged from one inch to more than two feet deep. The amount of debris increased in the downstream portions of the Woodland Lake study area, and Mill Pond had the heaviest concentrations.

Overlying the logs and other related matter was a fine flocculent substance which was easily disturbed and resuspended. This floc, when subjected to microscopic examination, resembled a colloidal humus or humoid substance.

Core samples taken by the EPA divers showed that a light gray clay type material underlies the log and debris deposits. This clay is found throughout Woodland Lake and Mill Pond. Exposed areas of the natural river bed are found in the channel. These areas contain a high percentage of rocks, stones and coarse gravel.

Depths of logs laying on the bottom are made in terms of layers (the count of logs piled or leaning against one another i.e. 2-3 layers).

Depths of the bark, woody debris and floc deposits were estimated in linear measure. For example, by penetrating the deposit with his hand and arm a diver can determine relative depth (i.e. penetration to the wrist = approximately eight inches, elbow = 18 inches and shoulder 24 or more inches).

Log counts were performed on compass bearings from a selected bottom point for a distance of about 100 feet. The divers counted logs and portions of logs over which their bodies passed. The width of the path normally would not be greater than six feet, thus the area of coverage on any compass bearing from the point selected was approximately equal to 600 square feet. Occasionally, the logs lying wholly or partially within an area estimated to be 100 square feet were counted.

The following observations and results regarding the bottom conditions are considered to be a fair representation of the general dive locations. These results are compendiums of the individual divers' impressions of bottom conditions.

OBSERVATION AND RESULTS

Dive Location 1 August 16

The surface of the Mill Pond was tightly packed with floating pulp wood. Much of the pulpwood was partially or totally debarked. In many cases the remaining bark was in the process of sloughing off. Access to Mill Pond was from the U.S.A. shore. Logs partially and totally sunken along shore impeded entry into the water. The divers had to crawl and push their way from shore until they reached a water depth which enabled them to dive under the floating pulpwood.

The bottom was densely covered with logs. The sunken logs are conservatively estimated to be four times more plentiful on the bottom.

Between the sunken logs were deposits of bark, woody debris, wood fragments and silt. Overlying the logs and related deposits was a fine light floc which was easily disturbed and resuspended. While obtaining a core sample of the bottom material, the corer penetrated the deposits its entire length (30 inches) plus the length of the divers arm to the elbow.

By fanning away the debris, the end of the corer was exposed and retrieved. These deposits are estimated to exceed three feet. Logs were encountered beneath these deposits.

The bottom of the pond was investigated for a distance of 100 yards from shore. Log coverage was fairly uniform with typical coverage of three to five layers of logs.

The log density is characterized as: Very heavy.

Dive Location 2 August 17

The range of this dive extended from areas under the floating pulpwood to areas of channel. Logs were present lying flat on the bottom and in a jumble from upright to horizontal. Bottom coverage was fairly uniform with the logs layered approximately two to four deep. Gaps between logs of up to six feet were observed.

Bark, woody debris, silt and floc deposits were deep here. A diver pushed his arm to shoulder level into these deposits.

A diver, swimming on a north compass bearing for 100 feet from Point 2, counted the logs over which he passed.

1. 140 logs
2. 161 logs

A diver counted 25 logs in two, 100 square feet areas adjacent to Point 2.

The log density in this area is characterized as: Light - Moderate.

Dive Location 3 August 18

Logs generally one layer deep with two layers the maximum depth. The logs were usually lying flat on the bottom. Depositions of bark, wood fragments etc. was not as extensive as noted at locations one and two.

Submerged vegetation was notably more abundant.

The log density in this area is characterized as: Light.

Dive Location 4 August 18

Bottom fairly uniformly covered with logs. Logs are layered 2-4 deep with some gaps existing between them. Sunken bark, wood, fragments and debris have accumulated to depths up to 18 inches. Overlying the logs and debris was the fine flocculent substance previously noted.

The log density is characterized as: Moderate.

Dive Location 5 August 18

Observations similar to location 4 above with variable gaps up to five feet between logs.

The log density is characterized as: Moderate.

Dive Location 6 August 17-18

This location is situated approximately 1/8 mile off the U.S.A. shore. The bottom had a good deal of stumps and some trees lopped off at six feet. Many of the stumps were trapping sunken logs and submerged dead heads causing piles to be created, accumulations of which reached five layers. The logs otherwise are uniformly layered 1-2 deep with some four layered areas. Gaps up to eight feet across contained no logs. The substrate comprised bark, wood fragments and woody debris interspersed with silt and floc. Depth of this debris laden substrate was highly variable. Eighteen inches was the maximum observed.

Logs counted by divers on compass bearings for 100 feet indicate relative numbers of logs over which the diver passed.

From Point 6 due east, two counts.

1. 183 logs

2. 178 logs

From Point 6 due west, one count

1. 220 logs

Log density is characterized as: Moderate.

Dive Location 7 August 16, 17

Diving activities in this area extended from a location 1/8 mile from the Canadian shore southward into shallow water (3-5 feet deep). westward to river channel and northerly about 100 yards.

Logs covered the bottom in every direction with fewer in the vicinity of the channel.

Layering of the logs was variable with 1-2 layers commonly seen and 3 to 4 layers less frequently observed. The logs of the largest diameter were on the bottom of the log piles.

Bark, wood fragments and debris covered the bottom to depths of up to 18 inches. Some logs were totally or partially buried beneath the substrate.

Near shore, stumps of trees and larger tree trunks were seen. Sunken pulpwood was normally lying flat on the bottom generally one layer deep. The logging debris was estimated to be 1"-6" deep nearer shore.

In the river channel (30 feet deep water) exposed portions of the river bed indicated the presence of ledge and broadfaced rocks, etc. one to two layers deep with large gaps between logs.

Approximately 20 feet north from the intersection of the two large logging booms was a pile of logs about six or eight feet high. Divers could not determine if the pile was a natural outcropping of the bottom covered with logs or an acutal pile of logs.

Logs counted by divers swimming on different compass bearings for 100 feet are:

From Point 7 northeast, two counts

1. 330 logs
2. 279 logs

From Point 7 due south, one count

1. 150 logs

From Point 7 due west toward channel, one count

1. 78 logs

Log densities are characterized as: Moderate - Heavy.

Dive Location 8 August 18

Bottom visibility at this location was hindered due to log recovery operations being conducted by the Georgia-Pacific Corporation Verification for the presence of logs was made by feeling and groping on the bottom. The logs were estimated to be layered 2-3 deep with variable gaps up to five feet separating the logs. Bottom materials, bark, wood fragments etc. are estimated to be no deeper than 12 inches. Some of this area is channel.

Log densities are characterized as: Light - Moderate.

Dive Location 9 August 18

Observations similar to those above with improved visibility. Logs were either lying flat on the bottom or in assorted jumbles from upright to horizontal. Logging debris was present. Some of the area is in the channel.

Log density characterized as: Light - Moderate.

Dive Location 10 August 18

Considerable logs were sunken at visible depths near shore with layers as great as four deep. Some logs protruded from the water surface. Proceeding westerly from shore the logs were fairly uniformly layered at one to two deep. The substrate comprised bark, wood fragments interspersed with silt overlain by a layer of floc.

Log density characterized as: Moderate.

Dive Location 11 August 18

Logs were layered two to three deep. The substrate comprised silted bark and wood fragments ranging from four to eight inches deep. Logs nearly covered the bottom however some gaps three to four feet existed.

Log density characterized as: Moderate.

Dive Location 12 August 18

Logs observed on bottom one to two layers deep with accumulations of four layers frequently encountered. Logs were tightly packed with few gaps exceeding one foot. The logs were situated on the bottom in a jumble from horizontal to upright.

The bottom material was composed of bark, wood fragments and woody debris interspersed with silt. The depths of these woody materials were six to twelve inches.

Log density characterized as: Heavy.

Dive Location 13 August 18

Logs were layered one to two deep. Some logs lay flat on the bottom with others lying on or leaning against these. Some four to five feet gaps existed between logs.

Gaps were overlain with bark, woody material, silt, etc. to six inches in depth. A light flocculent substance was overlying the benthic materials.

Log density characterized as: Light - Moderate.

Sunken log counts and estimates of total logs sunken

By utilizing the count data generated in the field and applying logical assumptions a reasonable estimate of sunken logs in Woodland Lake can be obtained.

Previously reported were counts of sunken logs given for 100' x 6' areas in different parts of Woodland Lake. These were:

183, 179, 140, 161, 150, 279, 330, and 78.

The average of these counts is 187 logs/600 square feet.

1. Let count equal 185 logs/600 square feet.
2. The study area as previously described is 666 acres.

   At 4.3560X104 square feet/acre

   Total area square feet = 4.3560X104 square feet/acre

   X 666 acre

   29,010,960 square feet

3. Estimate total logs - $\frac{185 \text{ logs}}{600 \text{ square feet}}$ X 29,010,960 square feet

   = 8,945,120 or approximately 9.0 million logs.

   To estimate cords of wood.

   1 cord = 128 cubic feet or 4'X4'X8'

   A stick of pulpwood averages 4'X8" diameter

   By mathematics 72 logs/cord

   but say --- 80 logs/cord

   $\frac{9.0 \text{ million logs}}{80 \text{ logs/cord}}$ = approximately 110,000 cords of wood

Allow for 50% error and the possible range is

55,000 cords to 165,000 cords.

These estimates are intended to be conservative. Note that the figures are for only part of the pulpwood storage and log driving areas.

APPENDIX H

SEDIMENT OXYGEN DEMAND STUDIES

ST. CROIX RIVER, MAINE - AUGUST 1972

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Water Sciences Branch
National Field Investigations Center - Cincinnati
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At the request of the Director, Division of Surveillance and Analysis, Region I, EPA, oxygen demand rates of bottom sediments were measured in a 20-mile long reach of the St. Croix River in the vicinity of Woodland, Maine (Figure H-1). The study was conducted by the National Field Investigations Center - Cincinnati during the period of August 8-14, 1972, in support of an overall investigation by EPA, Region I to determine the effects on the river of pulp and paper making activities of the Georgia-Pacific Corporation, Woodland, Maine.

Sediment oxygen demand (SOD) rates were obtained by measuring the changes in the dissolved oxygen content of water sealed and circulated in plexiglas chambers (Figure H-2) embedded in the river sediments. Measurements were made only in areas where the bottom was soft enough to permit the chamber cutting edge to penetrate and effect a seal. The chambers covered 0.186 square meter of river bottom and held 14.5 liters of river water. Water was circulated with a 12-volt submersible pump. Changes in the dissolved oxygen content of the entrapped water were measured with portable DO meters. Dissolved oxygen changes were sufficient within 15 to 90 minutes to estimate the oxygen demand of the sediments.

The effectiveness of the chamber to river-bottom seal was measured by adding a concentrated salt (NaCl) solution to the chamber water to increase its specific conductivity above the conductivity of the river water. The increased conductivity was then monitored during the test run. Logs and large wood chips on the river bottom at some locations made it necessary that SCUBA divers place the chambers on the river bottom to ensure a maximum chamber-to-sediment seal. Nevertheless, effective seals were difficult to obtain at several locations. In these cases estimates of the oxygen demand rates, based on changes in specific conductivity of the chamber water, were calculated.

To determine if bottom sediments within the chambers were disturbed during the test runs, water trapped in the chamber plumbing after each test run was visually inspected.

The SOD rates were calculated on an areal basis using the following formula:

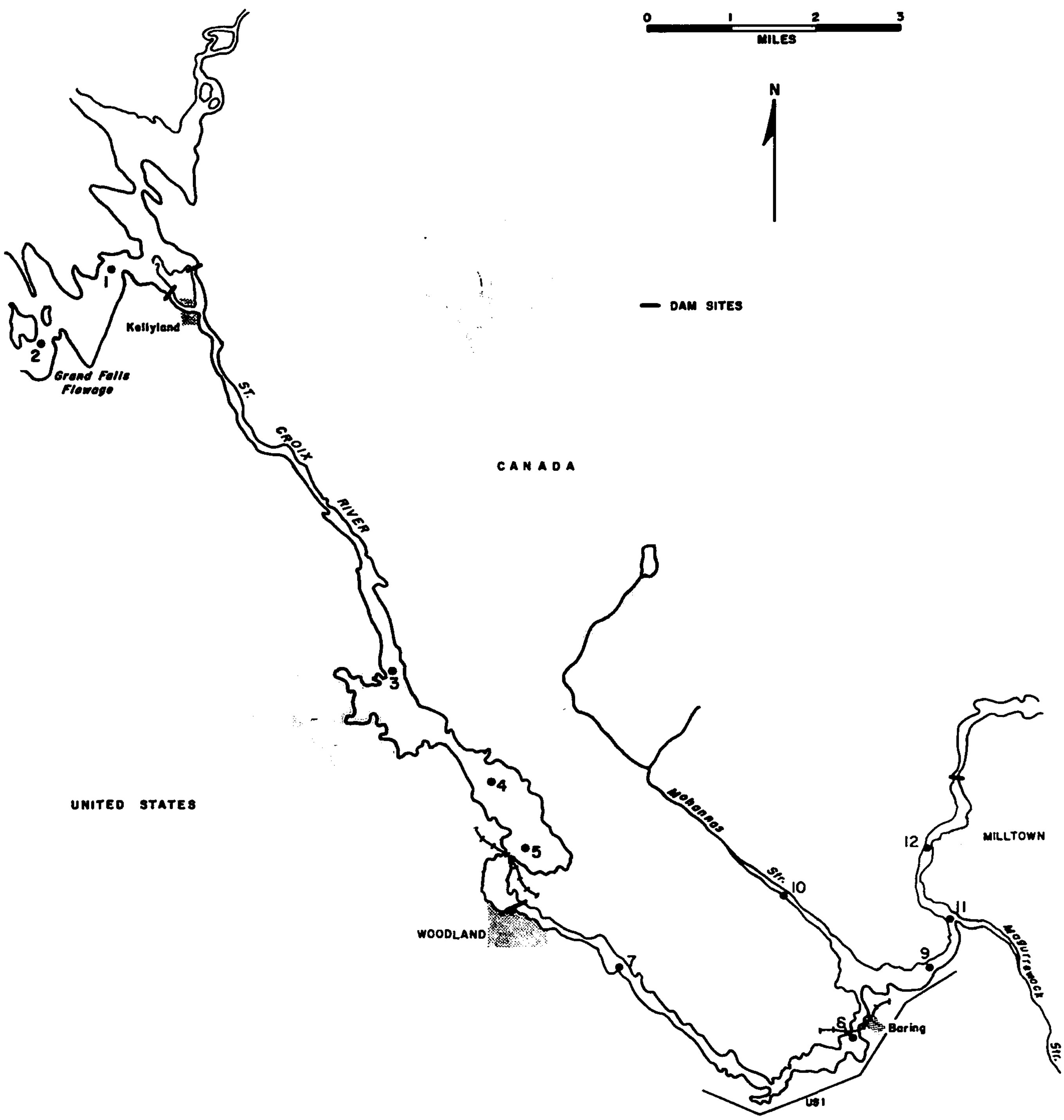
$$SOD = \frac{(Ci - Cf)\ V}{tA}$$

where :
- SOD = sediment uptake rate in gm O_2/m^2/day
- V = volume of confined water in m^3 (0.0145)
- A = bottom area within chamber in m^2 (.186)
- t = test period in days
- Ci = initial measured DO of chamber water in mg/l
- Cf = final measured DO of chamber water in mg/l

RESULTS AND DISCUSSION

SOD rates measured in the St. Croix River in areas unaffected by active logging or pulp and paper making operations (Stations 1c, 2 and 10) ranged from 0.9 to 2.4 gm O_2/m^2/day* (Table H-1). Bottom substrate in these areas were primarily mud and silt.

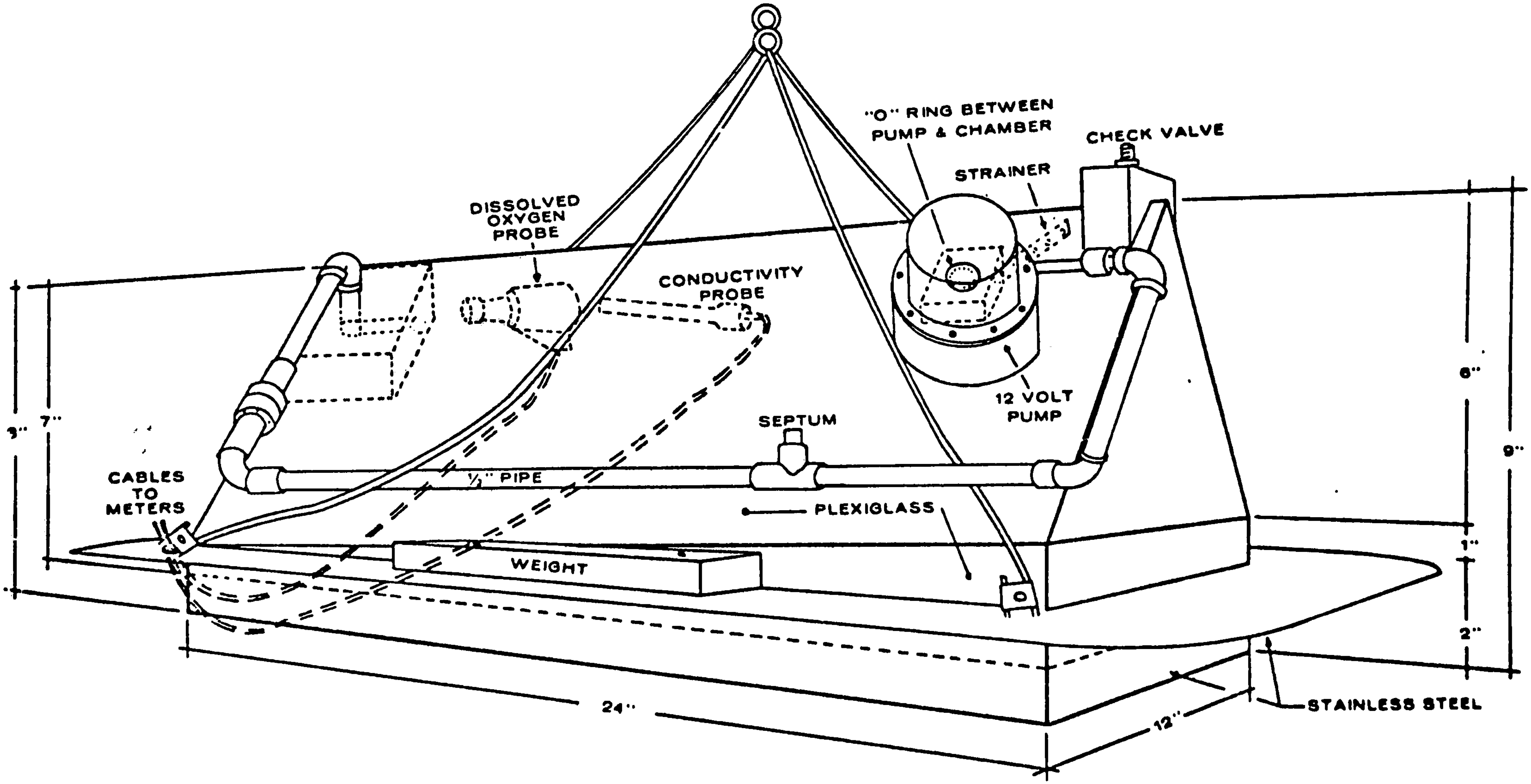
* A measurement made with a clear chamber indicated that benthic algae present at Station 10 produced 0.3 gm O_2/m^2/day in excess of the sediment oxygen demand during at least part of the daylight hours.



ST. CROIX RIVER
LOCATIONS USED TO MEASURE SEDIMENT OXYGEN DEMAND

FIGURE H-1

FIGURE H-2



Sediment oxygen demand chamber.

TABLE H-1
SEDIMENT OXYGEN DEMAND RATES
ST. CROIX RIVER, MAINE
AUGUST 8 - 14, 1972

STATION		DATE	TIME	BOTTOM TYPE	DO OF BOTTOM WATER mg/l	SEDIMENT OXYGEN DEMAND MEASURED RATE gm $O_2/m^2/day$	SEDIMENT OXYGEN DEMAND CORRECTION FOR LEAKAGE AMBIENT DO gm $O_2/m^2/day$	BOTTOM CONDITIONS IN CHAMBER **	CHAMBER
1C	Midchannel	8/14/72	1140-1235	Mud-silt	8.0	2.3	2.3		Black
	Midchannel		1155-1240	Mud-silt	8.0	2.4	*		Clear
2	Midchannel	8/8/72	1820-1905	Silt-bark	7.8	1.3	2.2		Clear
3	Midchannel			Bark		No rate			
4	Midchannel	8/13/72	1550-1605	Bark-silt	-	4.1	*	Slightly roiled	Black
	Midchannel		1510-1605	Bark-silt	-	2.5	*		Clear
5	Midchannel	8/13/72	1740-1815	Bark-silt	7.6	2.4	2.7		Clear
	Midchannel		1750-1820	Bark-silt	7.6	2.8	2.9		Black
7	Midchannel	8/12/72	1235-1250	Wood fibers & chips	7.8	7.1	*	Slightly roiled	Black
	Midchannel		1335-1350	Wood fibers - plant detritus	7.8	6.0	6.3		Clear
	Canadian Side		1445-1500	Wood fibers & sawdust	7.3	6.7	*		Clear
8	Canadian Side	8/11/72	1610-1700	Wood fibers & silt over sludge	6.0	3.7	4.0		Black
	Canadian Side		1656-1700	Wood fibers & silt over sludge	6.0	12.6	*	Moderately roiled	Clear
	Canadian Side		1750-1755	Wood fibers & silt over sludge	6.0	6.7	*	Slightly roiled	Black

TABLE H-1 continued
SEDIMENT OXYGEN DEMAND RATES
ST. CROIX RIVER, MAINE
AUGUST 8 - 14, 1972

STATION		DATE	TIME	BOTTOM TYPE	DO OF BOTTOM WATER mg/l	SEDIMENT OXYGEN DEMAND MEASURED RATE	SEDIMENT OXYGEN DEMAND CORRECTION FOR LEAKAGE AMBIENT DO	BOTTOM CONDITIONS IN CHAMBER **	CHAMBER
						gm O_2/m^2/day	gm O_2/m^2/day		
	Canadian Side		1730-1815	Wood fibers & silt over sludge	6.0	3.4	*		Clear
9	Midchannel	8/10/72	1625-1705	Wood chips	6.4	1.3	4.7		Clear
10	Midchannel	8/11/72	1055-1220	Mud-clay-algae	7.3	0.9	*		Black
	Midchannel		1105-1220	Mud-clay-algae	7.3	- 0.3	*		Clear
11	Midchannel	8/10/72	1415-1440	Wood chips & bark	6.1	4.0	5.6		Black
	Midchannel	8/10/72	1325-1400	Wood chips & bark	6.1	3.7	4.5		Clear
12	U.S. Side	8/14/72	1535-1550	Wood fiber & sawdust	5.3	2.2	*		Black
	U.S. Side		1515-1555	Wood fiber & sawdust	5.3	2.8	3.0		Clear
	Canadian Side		1640-1705	Wood fiber & sawdust	5.3	2.5	*		Black
	Canadian Side		1640-1705	Wood fiber & sawdust	5.3	2.7	2.8		Clear

* No leakage

** Based on visual examination of water trapped in chamber plumbing at end of test run; unroiled unless noted.

Stations 4 and 5, upstream from Georgia-Pacific Corporation, are areas where active logging operations occur. Logs destined for the pulp mill are floated down river to the wood storage area at Woodland. The river bottom in this reach of the river was strewn with sunken logs. The SOD chambers were placed by SCUBA divers in pockets among the logs. The substrate in these pockets, primarily bark fragments with some silt, had oxygen demand rates of 2.7 to 4.1 gm O_2/m^2/day. These rates are similar to rates measured on bark sediments in the Klamath River, Oregon (Table H-2).

Downstream from Georgia-Pacific Corporation and the city of Woodland the bottom sediments contained waste products associated with pulp and paper making operations. Bark, wood chips, dust, and fibers were found on the river bottom. Depositions of the lighter materials, such as sawdust and wood fibers, occurred in the more slack water areas.

SOD rates measured on sediments that contained large amounts of coarse wood chips and bark (Stations 9 and 11) ranged from 4.5 to 4.7 gm O_2/m^2/day. Chamber seals were least effective at these locations.

Highest oxygen demands by sediments were measured approximately one mile downstream from the Georgia-Pacific mill (Station 7). Sediments composed primarily of wood fibers and chips had oxygen demand rates of 6.3 to 7.1 gm O_2/m^2/day.

Oxygen demand rates measured on wood fiber - silt deposits (Station 8) and on wood fiber and sawdust banks (Station 12) were similar and ranged from 2.8 to 4.0 gm O_2/m^2/day. Sawdust deposits in the Klamath River, Oregon,.had an oxygen demand of 3.0 gm O_2/m^2/day (Table H-2). Silt-sludge deposits located downstream from pulp and paper mill discharges

TABLE H-2

SEDIMENT OXYGEN DEMAND OF VARIOUS RIVERS AND ASSOCIATED POLLUTANTS

RIVER	POLLUTANT OR BOTTOM TYPE	SEDIMENT OXYGEN DEMAND **
Hoston River, Tenn. (Thomas & Lucas, 1969)	Incinerator ash	2.3
	Paper mill wastes) Chemical production waste) Sewage treatment plant discharge)	16.0
	Vegetation	3.7
Klamath River, Oregon (Thomas, 1968)	Algae	6.7
	Bark	2.1
	Sawdust	3.0
	Agricultural runoff	4.4*
Licking River, Kentucky (Personal Data)	Silt	1.2
Mill Creek, Ohio (Personal Data)	Sewage	4.8
Ohio River, Kentucky (Ballentine, Thomas & Mathur, 1970)	Sand	0.75
	Sewage sludge	6.1
	Sphaerotilus natans	12.1
Reservoirs--North Carolina (Warner, Ballentine, & Keup, 1969)	Undisturbed lake bed bottom	1.2
	Cleared lake bed bottom	0.9
Willamette River, Oregon (Thomas, 1970)	Natural substrate (primarily sand)	0.8-3.7
	Pulp and paper mill wastes (silt-sludge deposits)	5.1-19.5

*DO very low

** gm O_2/m^2/day

on the Willamete River, Oregon, were characterized by SOD rates greater than 5.1 gm $O_2/m^2/day$.

Thomas (1970) found that the oxygen demand of Willamete River sediments associated with pulp and paper making wastes were greatest during early summer when water temperatures were increasing and the amount of oxidizable materials in the sediments was greatest. During the cooler periods of the year, low temperatures inhibited oxygen consuming processes in the sediments and permitted waste materials to accumulate. In late summer, although water temperatures were maximal, the oxygen demand of the sediments had decreased because oxidizable materials in the sediments had been partially utilized.

The effect of sediment resuspension in the St. Croix River caused by high flow conditions are reflected by rates measured at Stations 4, 7, and 8. Oxygen demand rates of roiled sediments within the chambers were approximately 50 to 425 percent greater than rates on undisturbed sediments.

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APPENDIX I

A STUDY OF THE TOXICITY OF THE GEORGIA-PACIFIC PULP AND PAPER MILL EFFLUENT, IN WOODLAND, MAINE

R. P. COTE

WATER SURVEILLANCE UNIT
ENVIRONMENTAL PROTECTION SERVICE
DEPARTMENT OF ENVIRONMENT
HALIFAX, NOVA SCOTIA

AUGUST, 1972

INTRODUCTION

At the request of the International Joint Commission and the U.S. Environmental Protection Agency, the Water Surveillance Unit of EPS participated in a comprehensive survey of the St. Croix River in August, 1972.

The involvement of the Physiological Testing Laboratory was requested for two primary purposes:

1. to conduct semi-static (bioassay test solution replaced every 24 hours) 96 hr. TLm dilution type bioassays according to the APHA Standard Methods manual (13th edition) in the mobile laboratory.

2. to conduct flow-through fish bioassays using the effluent of the Georgia-Pacific pulp and paper mill.

The purpose of our work was to demonstrate the effect of the discharge from the mill on Atlantic salmon, *Salmo salar* L., a species which once frequented the St. Croix River.

After the initial contacts were made by Mr. J. A. Dalziel, A/Regional Director of EPS Atlantic Region, with E.P.A. officials, correspondence by mail and telephone led to a meeting in St. Stephen on August 1 between EPA and EPS representatives to set down the logistics of our part of the survey in greater detail.

The work of the Physiological Testing Laboratory began on August 7 with the arrival of the Bioassay Trailer and three lab assistants. Mr. R. P. Cote, EPS toxicologist, arrived at Woodland on August 9 and personally supervised the mobile toxicity laboratory operations.

PROCEDURES:

1. General

The bioassay trailer was delivered to the Woodland, Maine high school site on August 7 and power was connected. The EPS pickup truck transported river water to the trailer several times daily to be used as the dilution water for the bioassays; our vehicle was manned by EPA personnel who had agreed to provide us with water as well as effluent. Their deliveries proceeded smoothly throughout the study period. Reasonable precautions were taken to ensure that neither the dilution water, nor the effluent was tampered with.

The lab assistants worked 8 hour shifts to cover the 24 hours and thus all tests were well monitored, and any problems which arose could be handled immediately.

The Atlantic salmon used in the bioassays were collected from the St. John Fish Culture Station in St. John, N.B. and taken to the trailer. The fish were placed in aerated holding tanks equiped with filters; the temperature of the water in these tanks was maintained at 15.0°+1.0°C by regulating the air temperature in an insulated portion of the trailer which serves as the bioassay lab. No mortalities occurred in the holding tanks during the 10 day period. The transfer from hatchery water to St. Croix River water was done with a dilution series.

2. Semi-static bioassays with fingerling salmon:

In these tests, the test-solution is replaced every 24 hours by transferring the fish into fresh solutions. The procedures described in the 13th edition of the APHA Standard Methods were generally followed for the semi-static tests. This applied to the following points:

a) Selection of test fish
b) Preparation of the test fish
c) Selection of the diluent
d) Temperature
e) Dissolved oxygen
f) Concentrations of toxicants
g) Controls
h) Number of test fish
i) Transfer of test fish
j) Feeding of fish
k) Calculation and reporting of results.

Samples were collected hourly by EPA personnel and composited in 25 gallon containers. Before the required volumes were removed for preparation of the semi-static tests, the effluent was thoroughly mixed. Plastic tanks were then filled with required 20 liter mixtures of effluent and dilution water. Slight aeration was applied to each test tank and the water was allowed to equilibrate to 15.0°C. When the dissolved oxygen level reached 6.0 ppm as determined by a YSI oxygen meter and the temperature reached 15.0°C, the pH was recorded and ten *Salmo salar* fingerlings were introduced to each bioassay tank. The pH recordings were made with a Fisher Accumet pH meter. Screen covers were installed on the tanks to prevent the escape of fish.

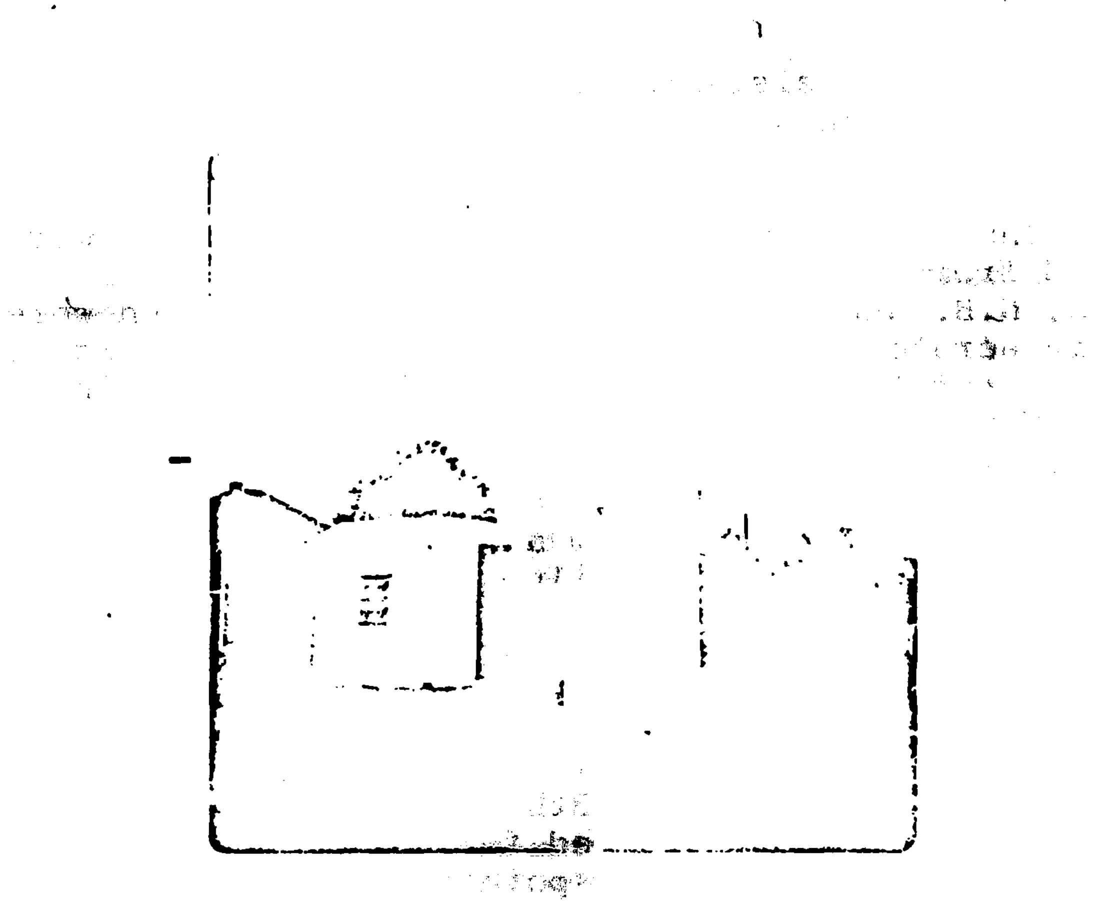


Plate 1. The mobile bioassay laboratory of the Environmental Protection Service at Woodland, Maine.

Temperature, D.O. and pH measurements were made every 8 hours during the test period as well as after the death of the last fish in each tank. Dead fish removed from the tanks, were frozen immediately in dry ice for histological examination at a later date. At the end of the study, salmon from the semi-static and continuous-flow bioassays were placed in a fixative (Dietrich's solution) and taken to the EPA National Marine Water Quality Laboratory in Rhode Island.

Table I lists the mean temperatures, dissolved oxygen, pH and lengths of fish for all semi-static bioassays.

Table I. Mean temperatures dissolved oxygen levels, pH and fish lengths values of all tests conducted with Georgia-Pacific mill effluent.

Type of Test	Conc. (%)	Temperature (°C)	D.O. (ppm)	pH	Fish Length (cm)
Semi static	100	14.5	6.2	7.2	4.2
	100	14.7	6.4	7.2	4.6
	56	14.6	6.3	6.9	4.0
	56	14.5	6.3	6.9	4.0
	56	14.6	6.4	6.9	4.1
	32	14.7	6.4	6.7	3.9
	32	14.6	6.4	6.7	4.2
	17	14.6	6.3	6.7	4.1
	17	14.7	6.5	6.5	4.3
			6.4	6.5	4.2
Semi-static Control	-	14.5	6.0	6.1	-
	-	14.3	6.5	6.6	-
	-	14.4	6.7	6.2	-

The mean temperatures listed in Table I demonstrate that the bioassay trailer temperature control system is able to maintain a set level within a degree Centigrade. Dissolved oxygen levels were maintained at or above 6.0 ppm (70% saturation) in all tanks, except in one control tank where the D.O. concentration dropped to 5.9 for a few hours. The mean pH readings were well within the acceptible range for salmon.

3. Semi-static bioassays with yearling salmon:

In an attempt to determine the effect of the G-P mill effluent on another life stage of Salmo salar, yearling salmon were obtained from the St. John Fish Culture Station and used in bioassays.

For this set of tests, one tank was prepared with 56% effluent, a second one was set up with 32% effluent and a third, as a control. Five salmon only, were introduced to each tank, creating a ratio of 2 gms of fish per liter of solution. This ratio is twice that of the bioassays with the fingerling salmon.

Table II. Mean temperatures, dissolved oxygen, pH and lengths of yearling *Salmo salar* in semi-static bioassays.

Concentration (%)	Temperature (°C)	D.O. (ppm)	pH	Fish length (cm)
56	14.6	6.2	6.7	10.2
32	14.5	6.5	6.4	10.1
Control	14.5	6.6	6.0	-

4. Continuous-flow bioassays:

These tests were conducted according to a procedure and dilution unit developed at the Physiological Testing Laboratory. A proportional diluter was designed (Cote and Parker, 1972) for use in continuous monitoring of industrial effluents. The diluter is based on the principle that in a tank with a constant head of water, the rate of flow through open valves is directly proportional to the area of the valve opening. Thus valves with holes having areas in a set ratio, will produce concentrations in test tanks receiving the flowage from the diluter in the same ratio. The proportional diluter used, is able to provide these concentrations of effluent and a control. The concentrations which can be studied at present are 100%, 75%, 65%, 50%, 35% and 25%.

The effluent solutions flow into the bioassay tanks at 400 ml/min and continuously overflow through stand-pipes into a drain. In this way, a 90% molecular replacement of the test solution occurs in approximately 6 hours.

The main purpose of a continuous-flow bioassay system is to replenish the toxicants (if they are present in the effluent) which might be degraded or oxidized in the test tank during static conditions. This situation, then, more closely approaches that of an outfall continuously pouring effluent into a body of water such as a river. Previous studies have led us to expect that the LT50 values in continuous-flow bioassays would be lower than those in static or semi-static tests.

Average temperature, dissolved oxygen, pH and lengths were calculated and are listed in Table III.

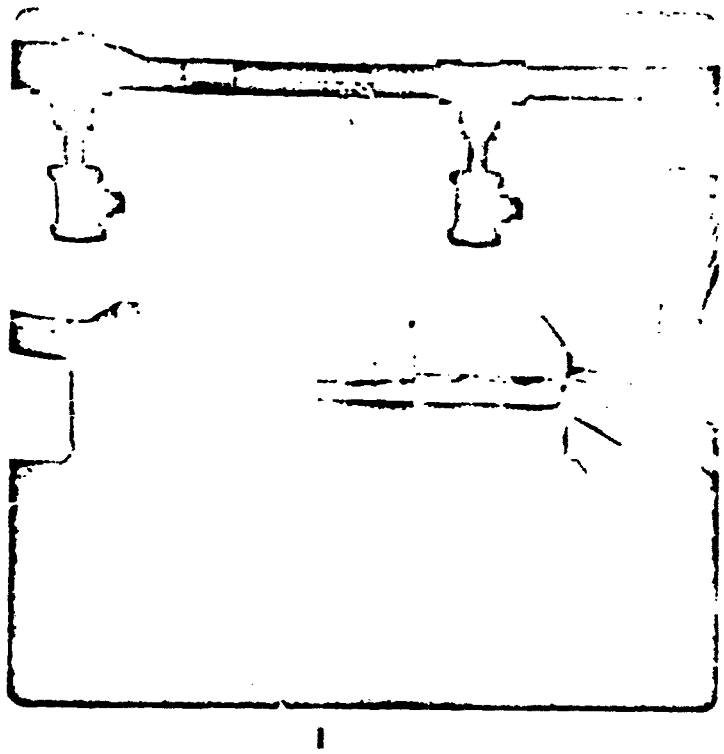


Plate 2. The proportional diluter utilized for the continuous-flow bioassays.

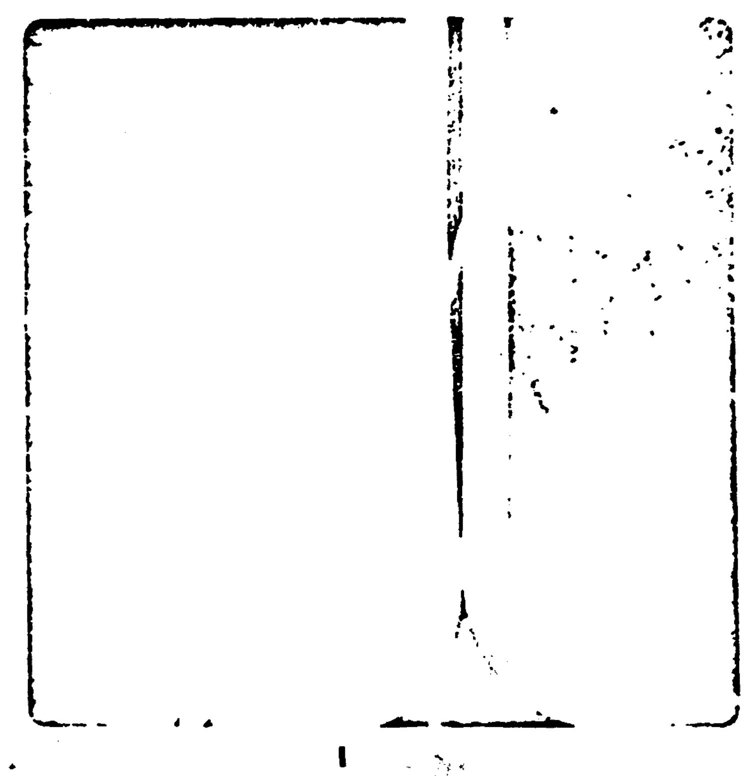


Plate 3. The test tanks used during the Georgia-Pacific study. (Note the difference in color between the clean river water and Georgia-Pacific mill effluent.

Table III. Mean temperatures, dissolved oxygen, pH and lengths of fish from the continuous-flow bioassays with G-D mill effluent.

Concentration (%)	Temperature (°C)	D.O. (ppm)	pH	Fish Length (cm)
75	15.4	5.6	8.2	4.5
75	14.1	5.9	7.3	4.2
65	14.4	6.2	6.5	3.9
50	15.6	6.0	8.0	4.0
50	14.3	6.4	6.7	4.3
35	14.7	6.2	6.5	4.4
25	15.2	5.9	7.5	4.2
25	14.6	6.1	6.4	3.5
Control	14.5	6.1	6.1	-
Control	14.5	6.2	6.2	-

5. Static bioassays with foam condensates:

Foam was collected from the effluent cooling tank in the bioassay trailer and allowed to liquefy. Anticipating a more toxic condition, two tanks containing 10% and 5% foam condensate respectively, were prepared; a control tank was also set up. Ten fingerling salmon were introduced into each bioassay tank.

Table IV. Mean temperatures, dissolved oxygen, pH and lengths of fish from the foam condensate bioassays.

Concentration (%)	Temperature (°C)	D.O. (ppm)	pH	Fish Length (cm)
5	14.4	6.7	6.1	-
10	14.3	6.7	5.9	4.2
Control	14.3	6.7	6.0	-

6. Samples for Chemical Analysis:

Frozen samples of the foam, control river water, 100% effluent, river water taken beneath logs above the mill, and river water taken downstream from the mill were frozen in dry ice and returned to the EPS Pollution Laboratories in Halifax for resin acid and lignin analyses. These samples were placed in a locked freezer and handled by the staff of the EPS Chemistry Laboratory.

Results and Discussion:

The results of the semi static bioassay tests using fingerling Atlantic salmon are presented in Table V. The graphs used to derive the LT50 values are presented in Figures 1 to 5.

Table V. The concentrations, percent survival and LT50 values for the Georgia-Pacific effluent.

Test	Concentration (%)	% Survival	LT50 (hours)
A	100	0	12
B	100	0	9.7
C	56	0	22
D	56	0	17
E	56	0	23
F	32	0	34
G	32	0	40
H	32	0	62 *
I	17	0	76
J	17	0	37 *
	Control	100	>96
	Control	100	>96
	Control	100	>96

* In the case of the 17% effluent bioassay, the operator found that an air valve was working improperly, thus creating an artifact in the toxicity.

No explanation has been presented for the anomolous LT50 in the 32% concentration. Since the pH agrees with those of the other two 32% tests, it must be assumed that the initial concentration was 32%. The recorded pH at 48 hours, however, was lower than that of the other two.

Because of these variations, these results have not been used in the preparation of the toxicity curve.

Figure 1. The lethal time (LT50) for fingerling salmon exposed to 100% Georgia-Pacific mill effluent as derived by semi static bioassay testing. (Tests A, B).

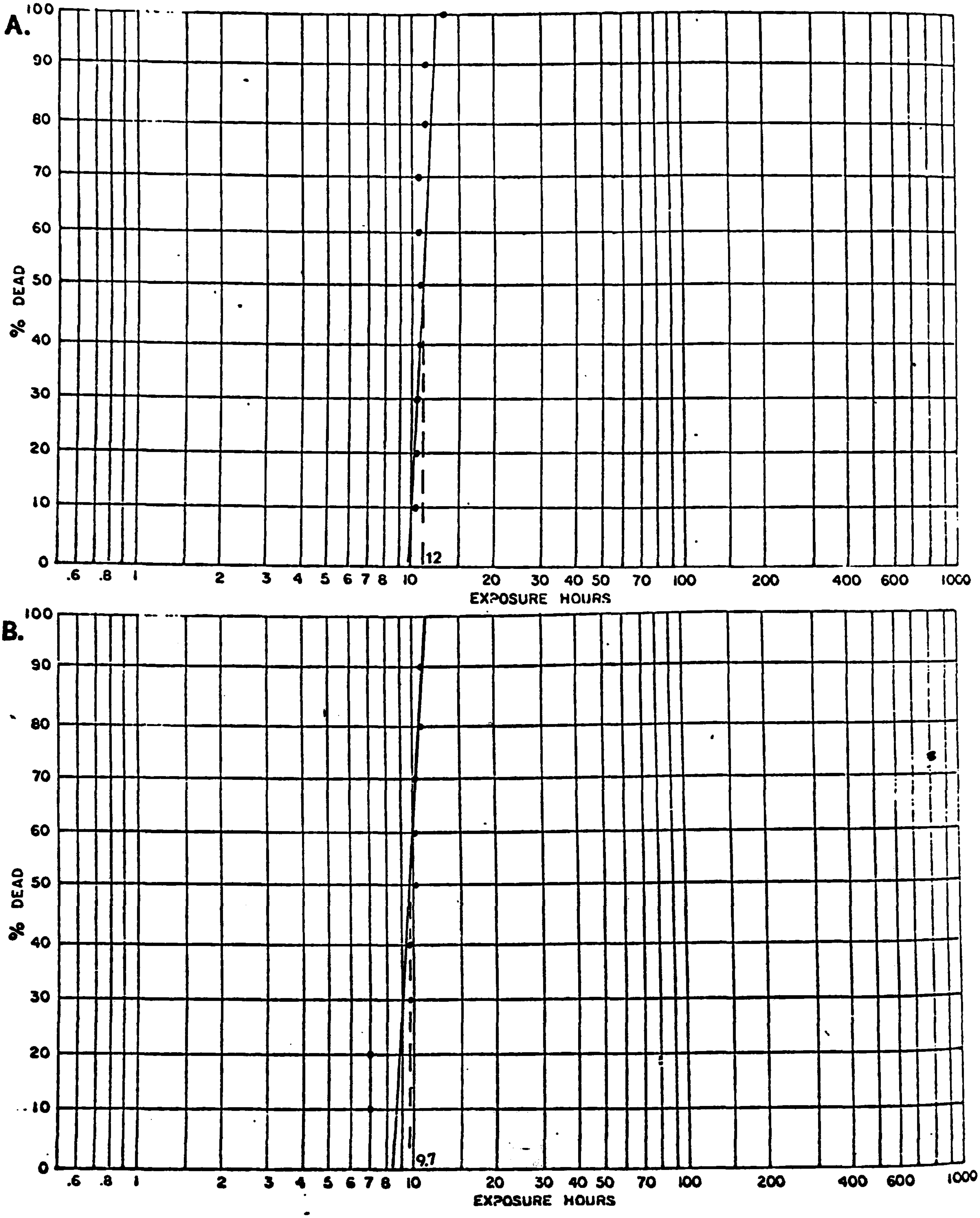


Figure 2. The lethal time (LT50) for fingerling salmon exposed to 56% Georgia Pacific mill effluent as derived by semi static bioassays (Tests C, D).

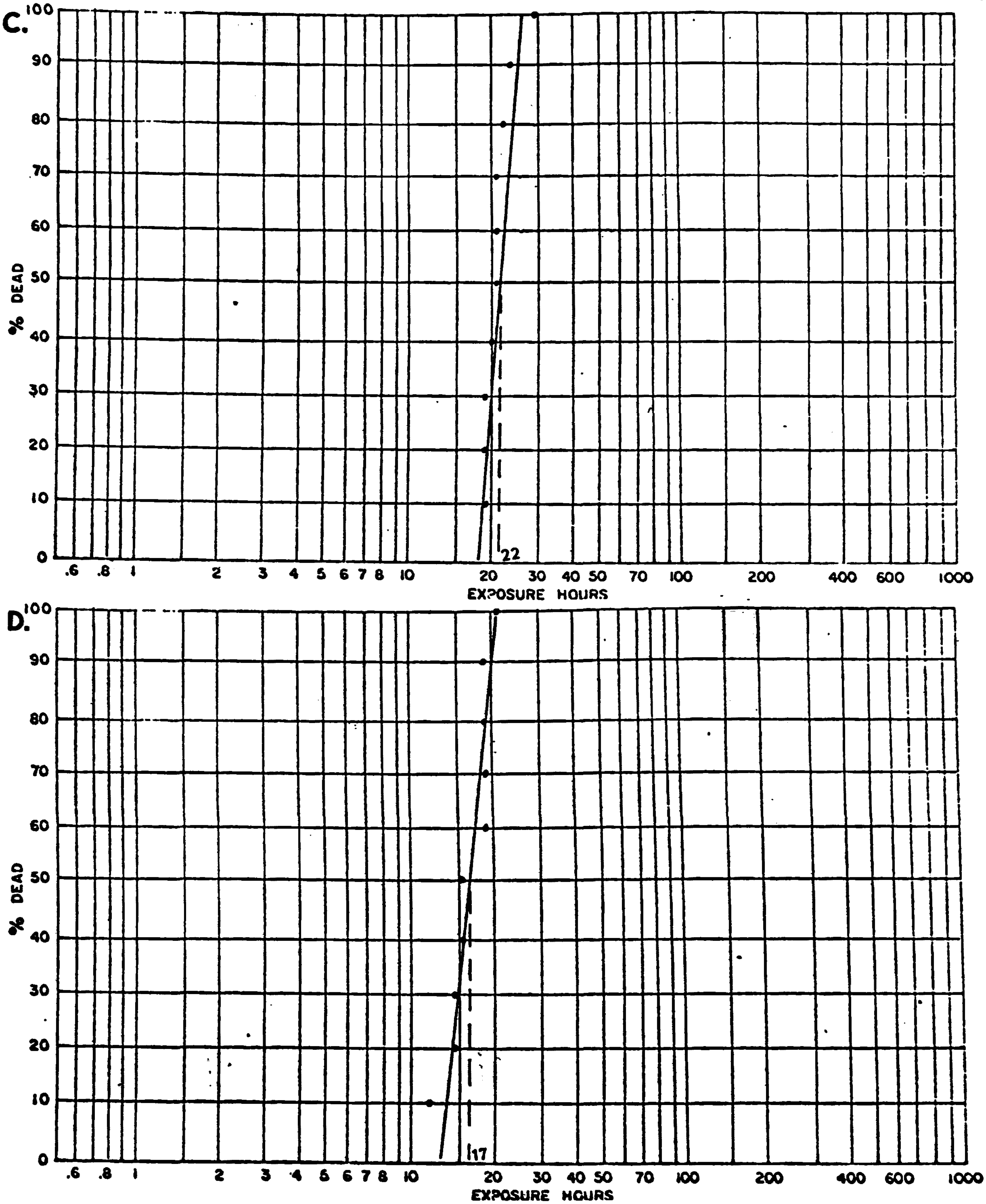


Figure 3. The lethal time (LT50) for fingerling salmon exposed to 56% (Test E) and 32% (Test F) Georgia Pacific mill effluent.

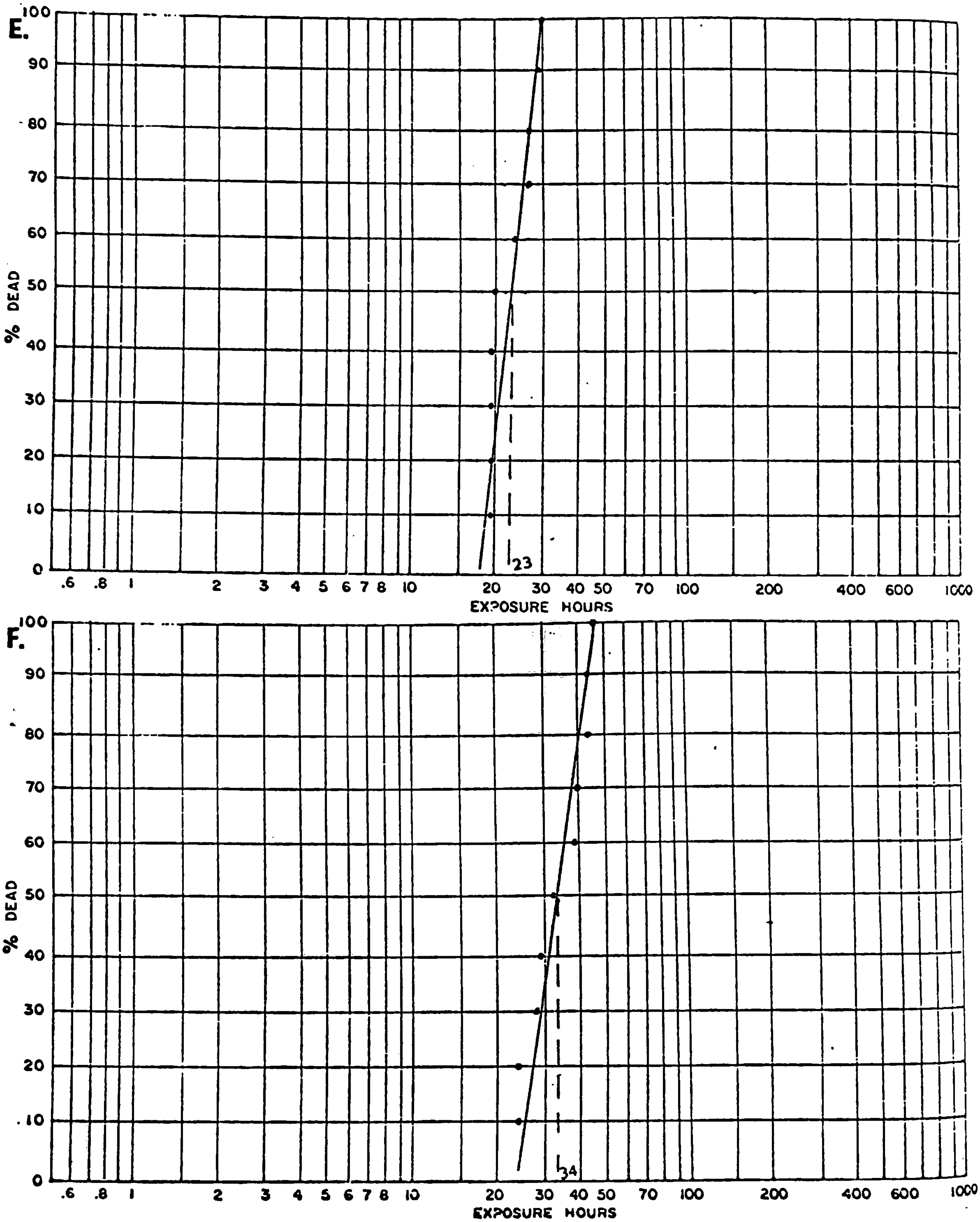
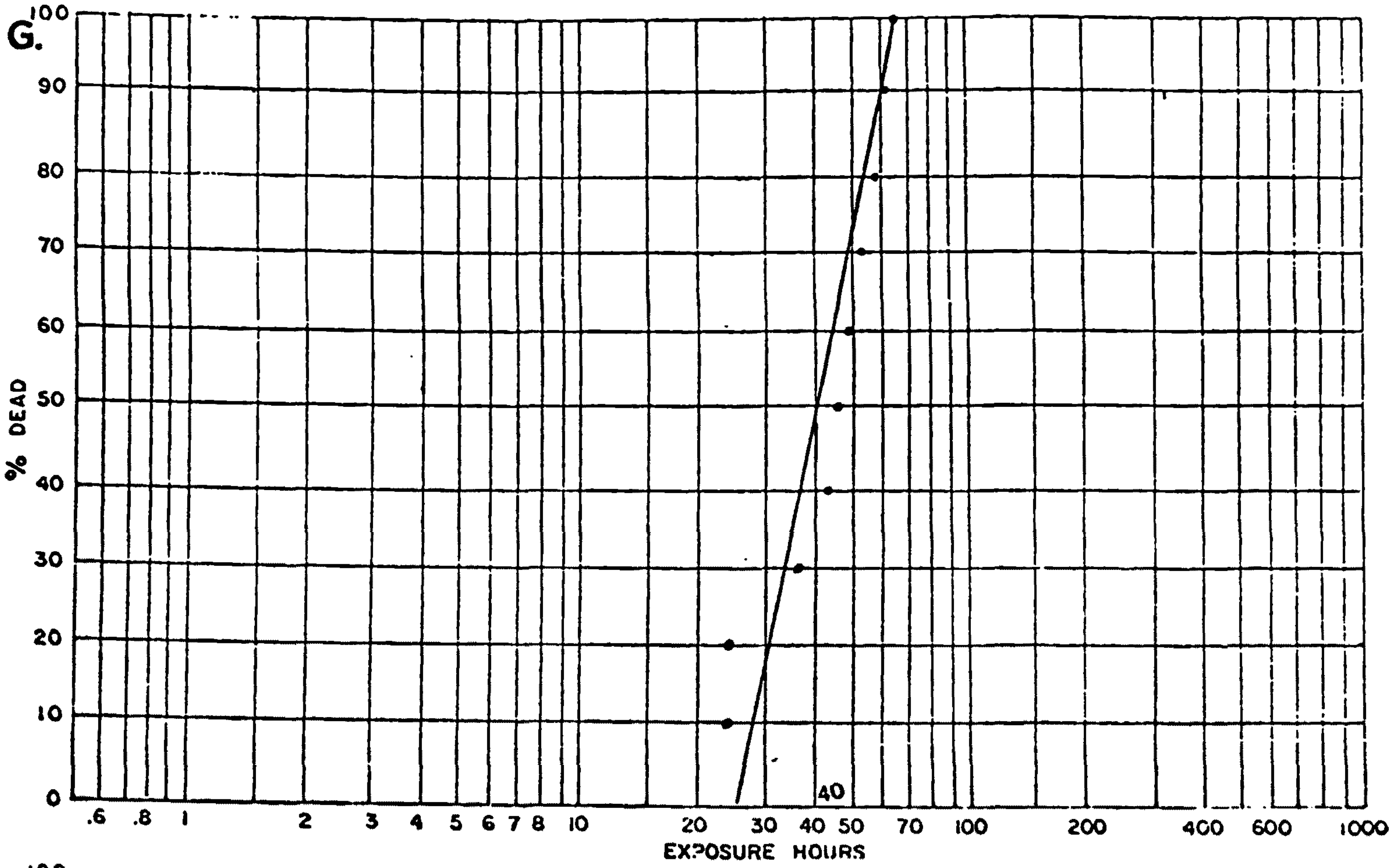


Figure 4. The lethal time (LT50) for fingerling salmon exposed to 56% Georgia Pacific mill effluent as derived by semi static bioassays (Tests G, H).

G.



H.

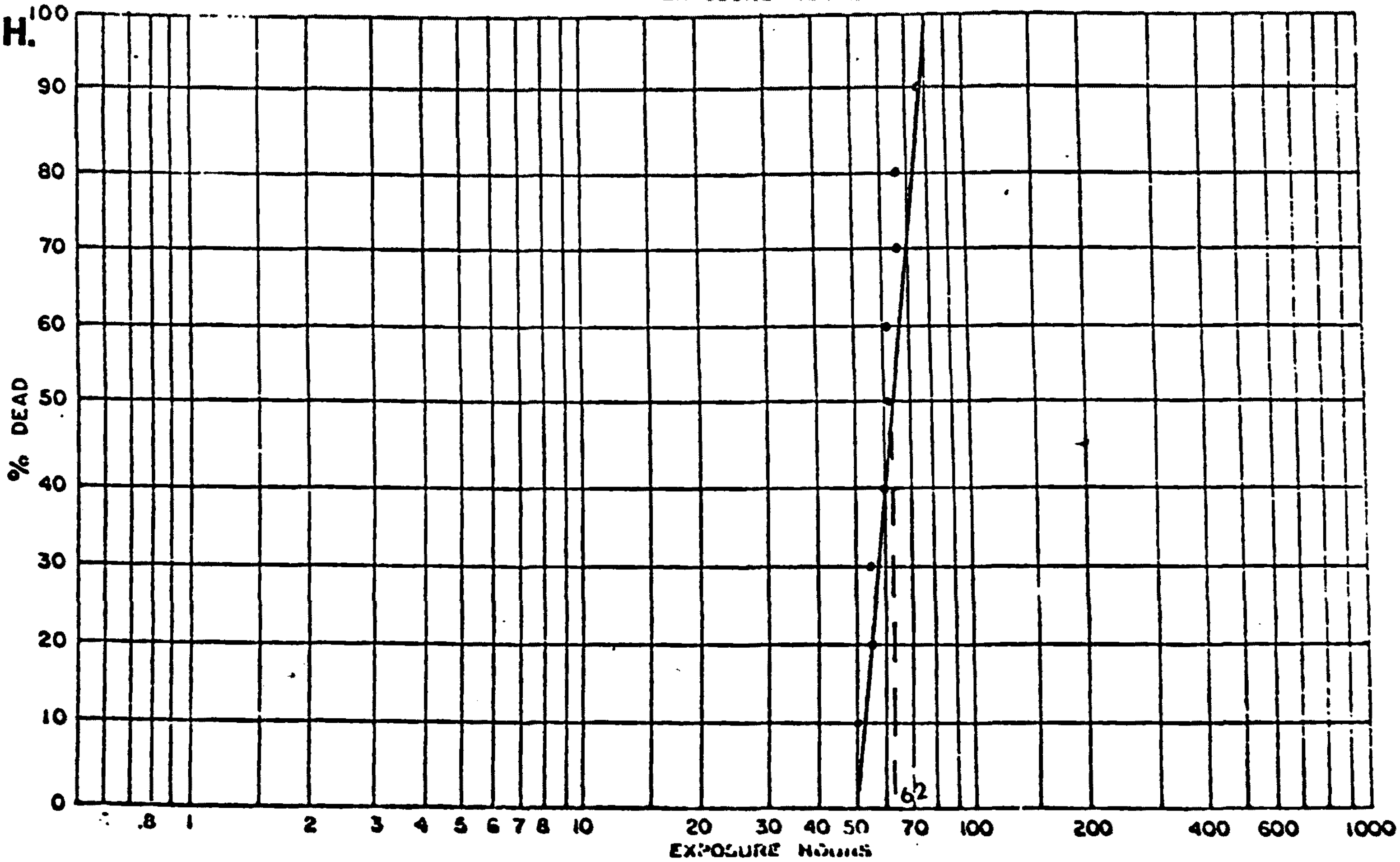
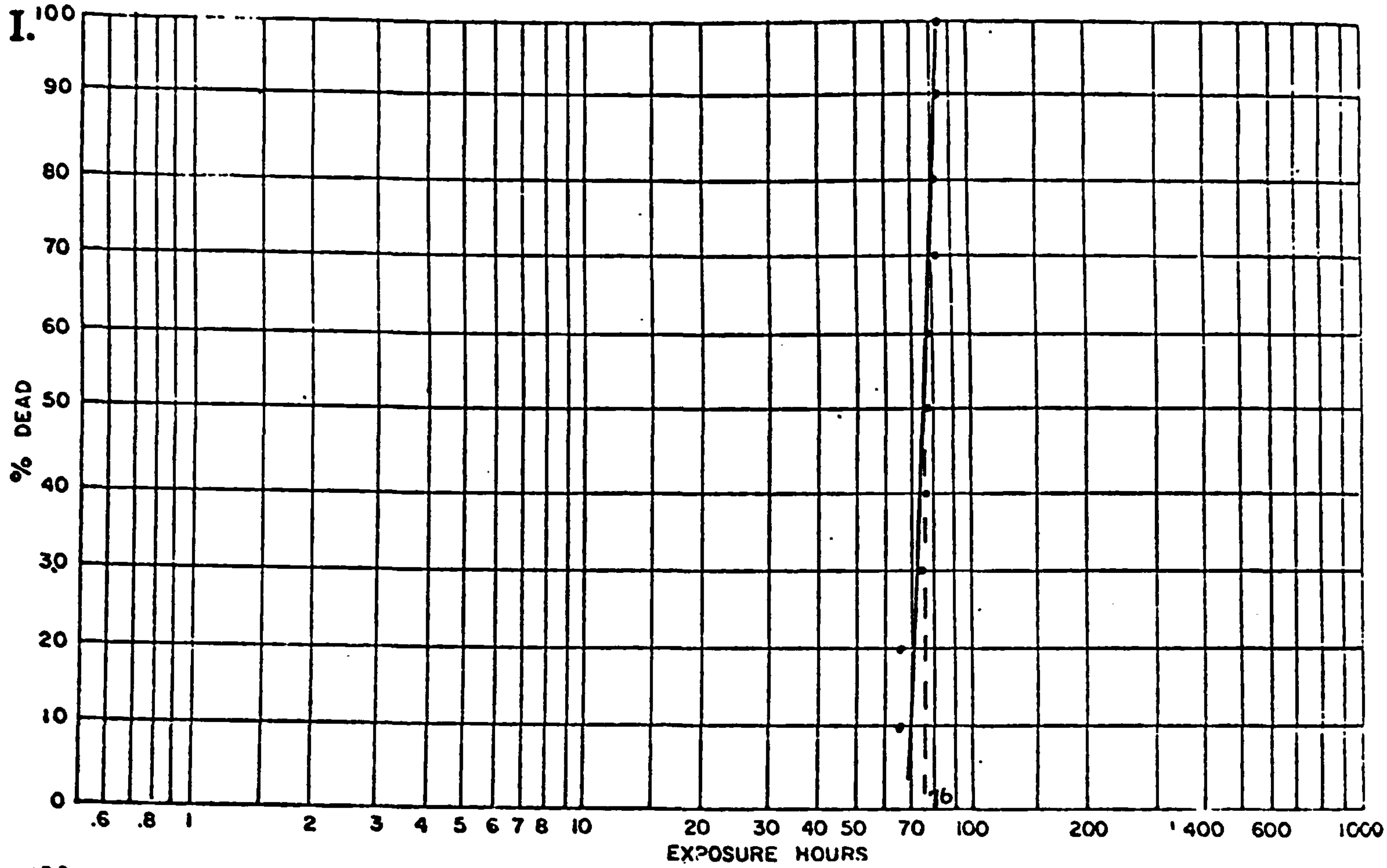


Figure 5. The lethal time (LT50) for fingerling salmon exposed to 56% Georgia Pacific mill effluent as derived by semi static bioassays (Tests I, J).



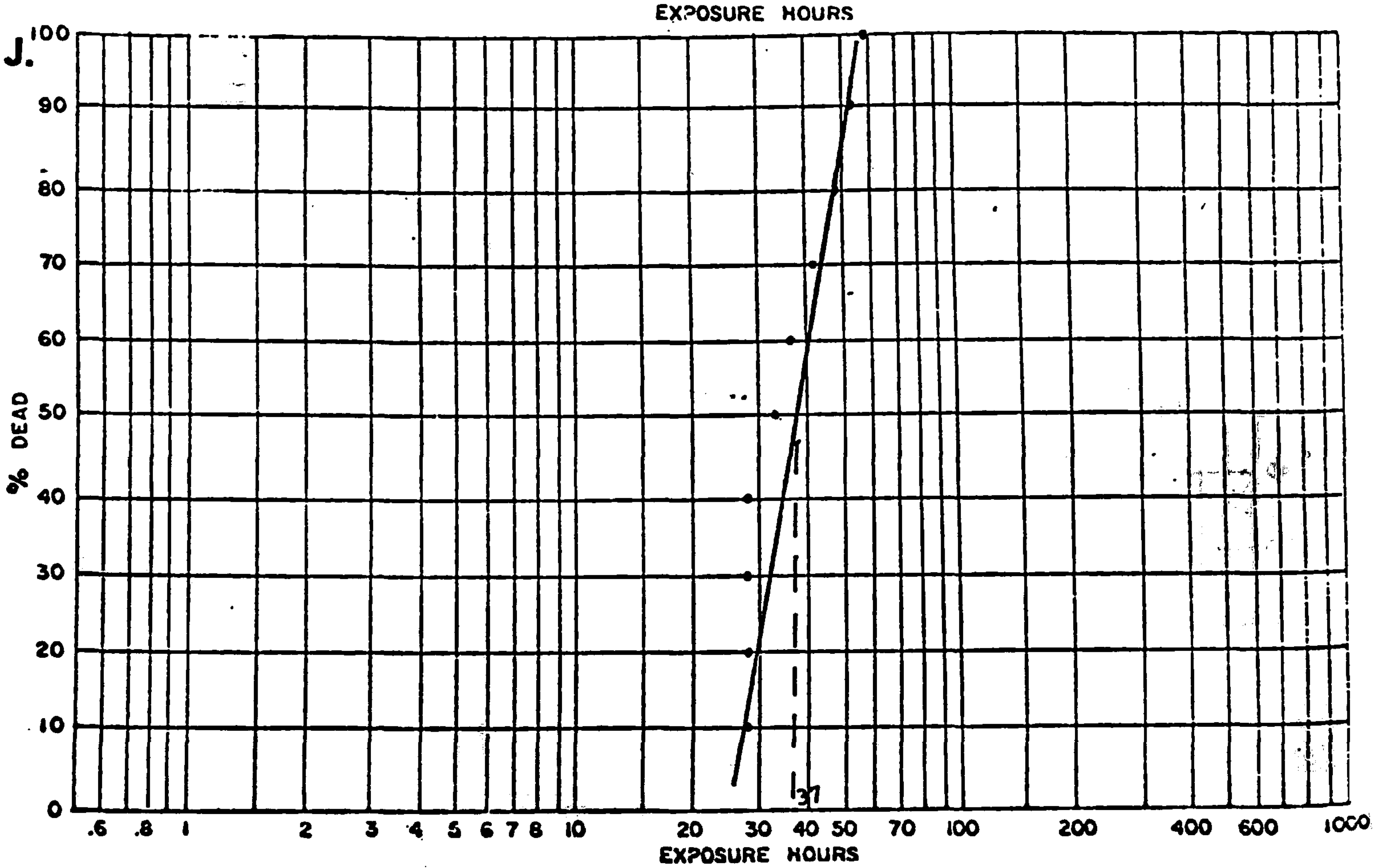
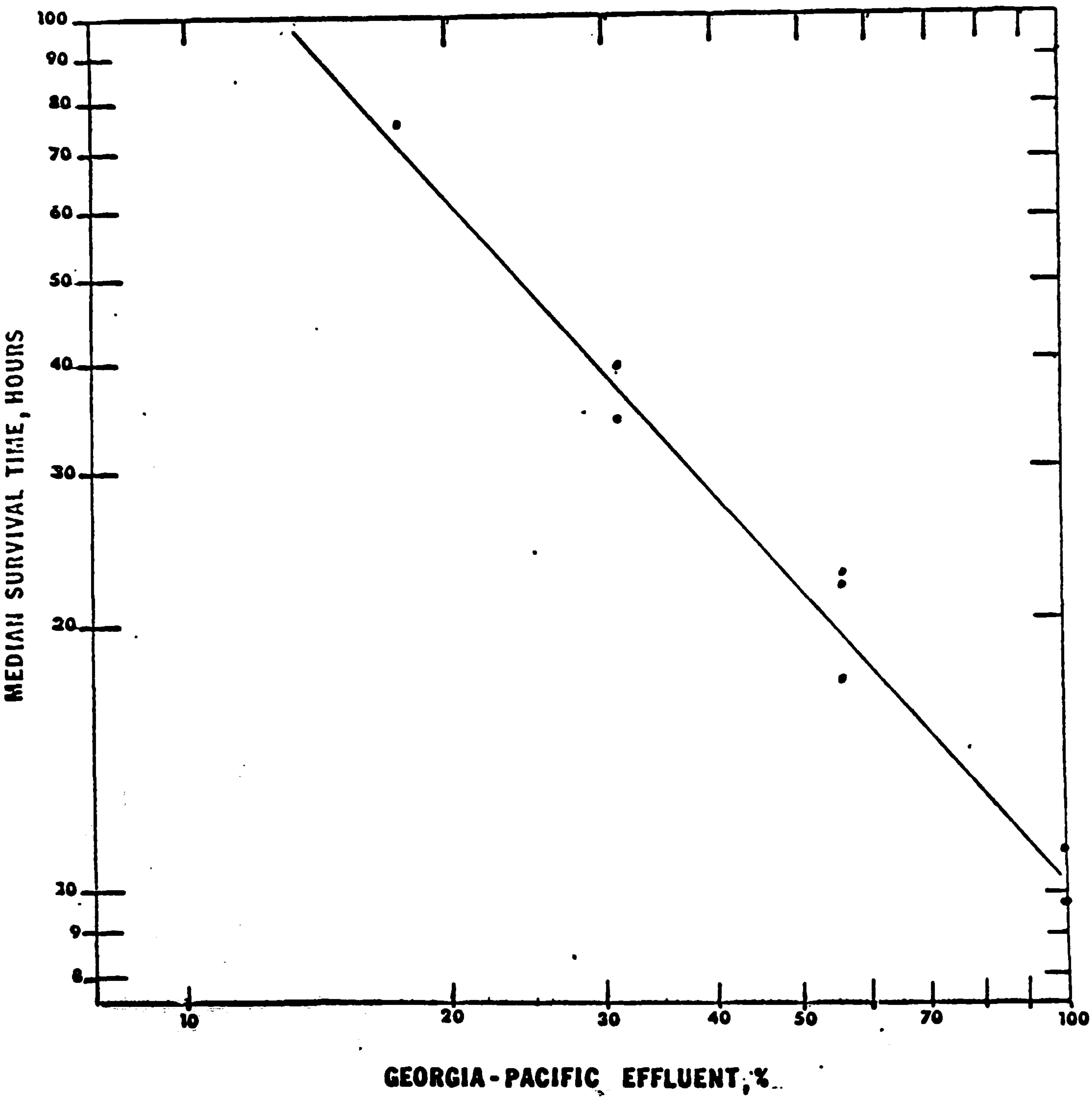


Figure 6. A toxicity curve representing the median survival time of Atlantic salmon fingerlings at any concentration of G-P mill effluent in a 96 hour bioassay at 14.5°C.



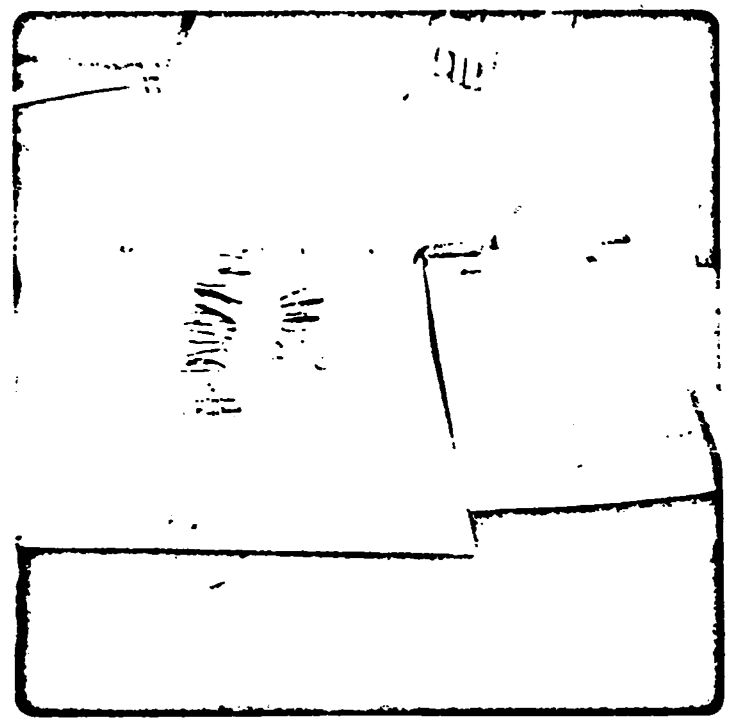


Plate 4. Fingerling Salmo salar as removed from 100% and 56% Georgia-Pacific mill effluent during semi-static bioassays.

The LT50 values demonstrate the classical inverse toxicity relationship between fish survival and pulp mill effluent concentration i.e. as the effluent concentration is halved, the median survival time of the Salmo salar fingerlings is doubled.

Figure 6 demonstrates the response pattern of Atlantic salmon to concentrations of Georgia-Pacific mill effluent. This graph demonstrates that the G-P effluent is not acutely toxic at 14% concentration or less. This concentration is referred to as the 96 hour LC50, and represents that concentration of effluent which allows 50% of the fish to survive 96 hours.

In the case of certain toxicants, the incipient lethal, which is used to distinguish acute toxicity from chronic responses, is essentially the same as the 96 hour LC50. There is no evidence to suggest that this is the case for the G-P effluent.

It should be pointed out that the Georgia-Pacific pulp and paper mill was reported to be at 60% production while EPA personnel collected samples for the semi-static bioassays.

The classical nature of the results is also demonstrated by the increase in slope of the LT50 lines as concentrations go from high to lower levels. The assumption in this case is that in a sample of 10 fish, the variability in sensitivity of the individual fish to lower toxicant concentrations will create a greater range of survival times. This is generally shown in the LT50 graphs. There are two possible modifying factors however; one is that the lines drawn are only the best fit by eye, the other is that in a hatchery stock such as the one used, the size differences between the salmon is very small. In nature, due to a variety of stresses, one would expect size differences of a sample of fish to be greater.

When the continuous-flow tests were started, the Georgia-Pacific mill was returning to 100% production. The pulp mill personnel indicated that as the various mill processes reached optimum operation losses would be reduced with an expected reduction in toxicity.

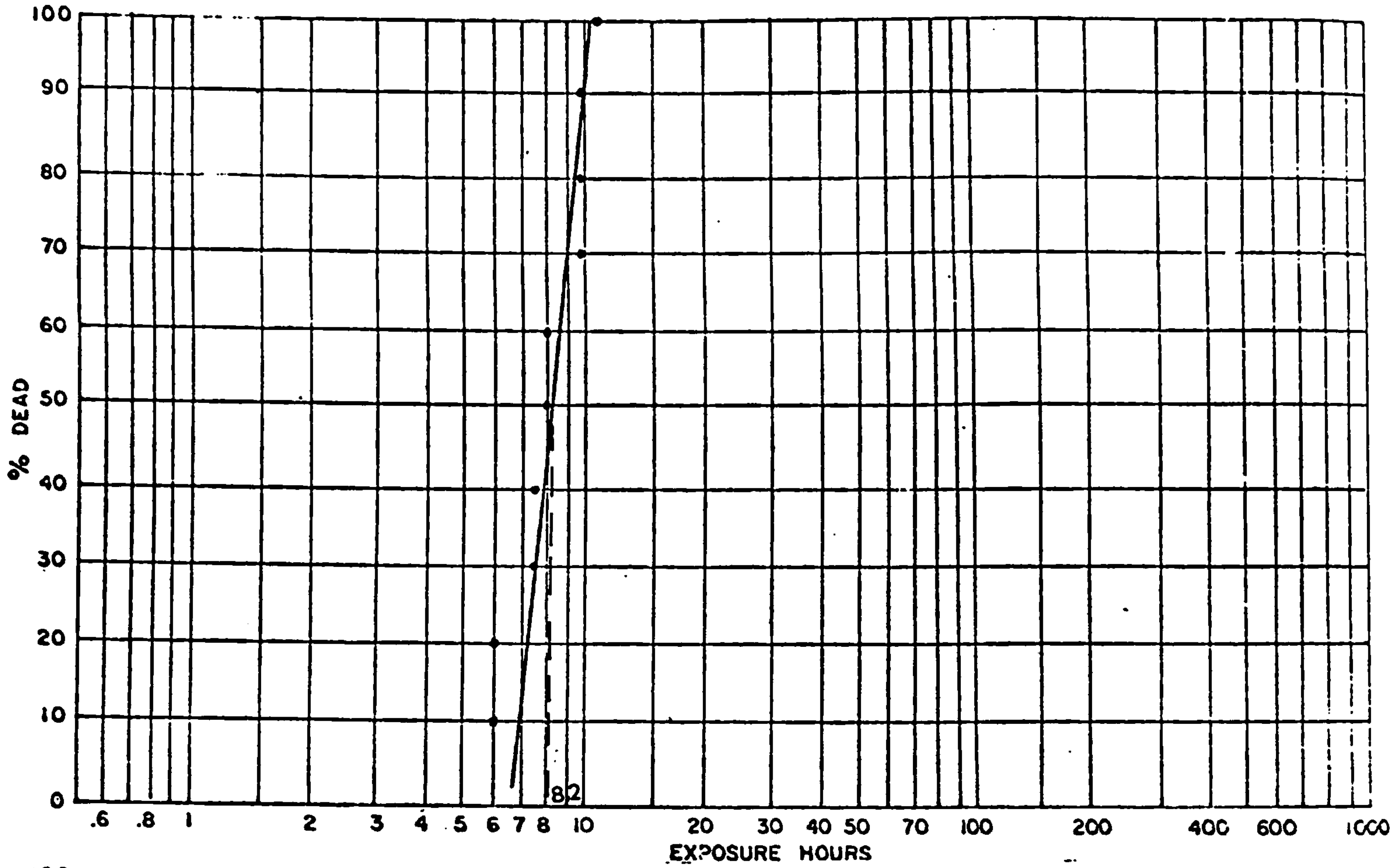
Table VI. Concentrations, percent survival and LT50 values of the continuous flow bioassays conducted with Georgia-Pacific mill effluent on August 12, 13 and 15, 1972.

Concentration %	% Survival	LT50 (hours)
75	0	8.2
50	0	12
25	0	18
75	0	20
50	0	27
25	80	-
65	0	17
35	0	27

Figures 7 to 10 provide the graphical interpolations of the LT50 values.

The first series, as expected, produced significantly lower LT50 values than those obtained in semi-static bioassays. It is not known, however, whether the start-up of the extra 40% production contributed to the increase in toxicity of samples collected on the night of August 11 and morning of August 12 (see Figure 11).

Figure 7. The lethal time (LT50) for fingerling salmon exposed to 75% Georgia Pacific mill effluent in continuous flow bioassays on August 12 and 13, 1972 respectively.



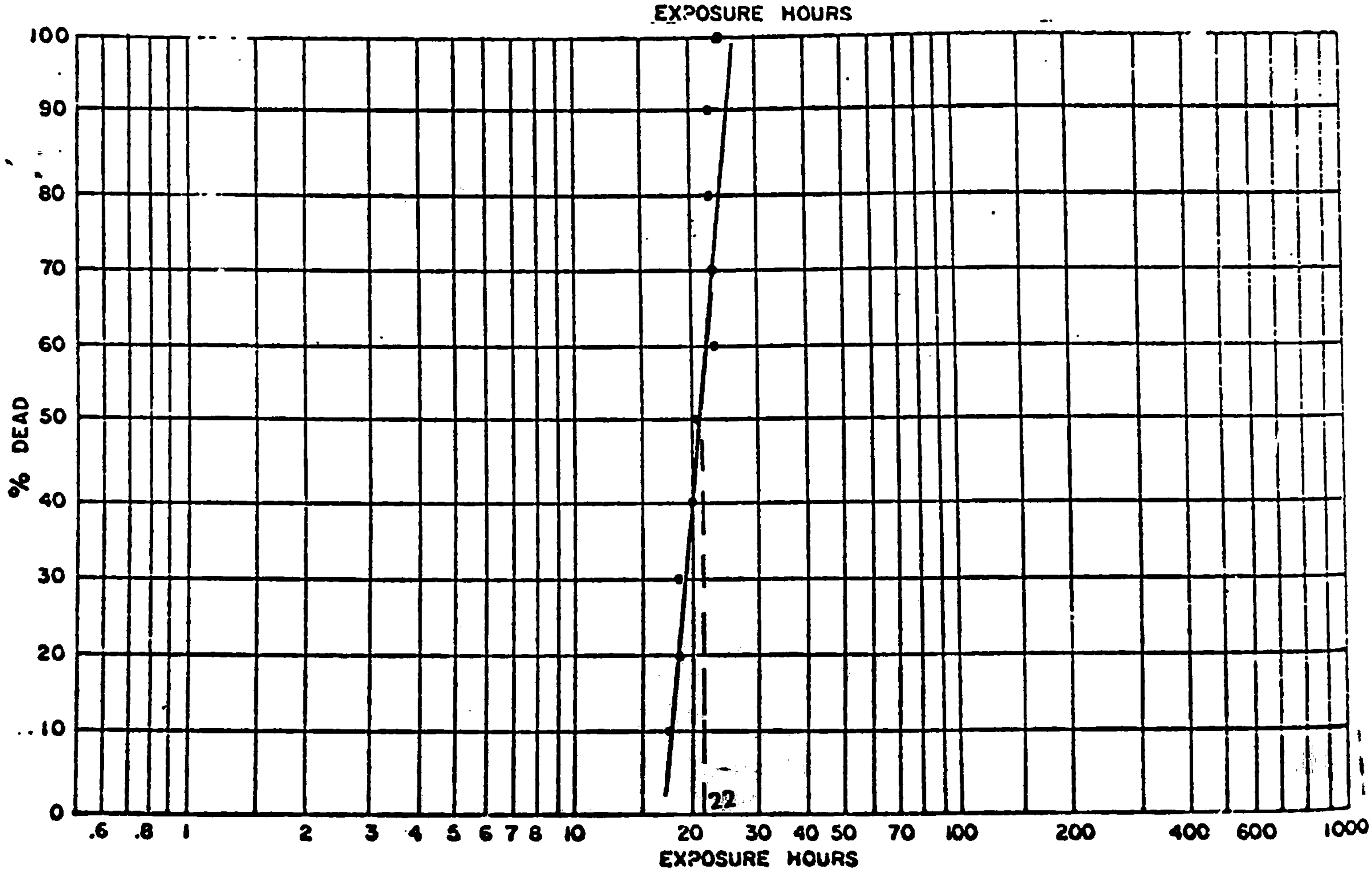


Figure 8. The lethal time (LT50) for fingerling salmon exposed to 50% Georgia-Pacific mill effluent in continuous flow bioassays on August 12 and 13, 1972 respectively.

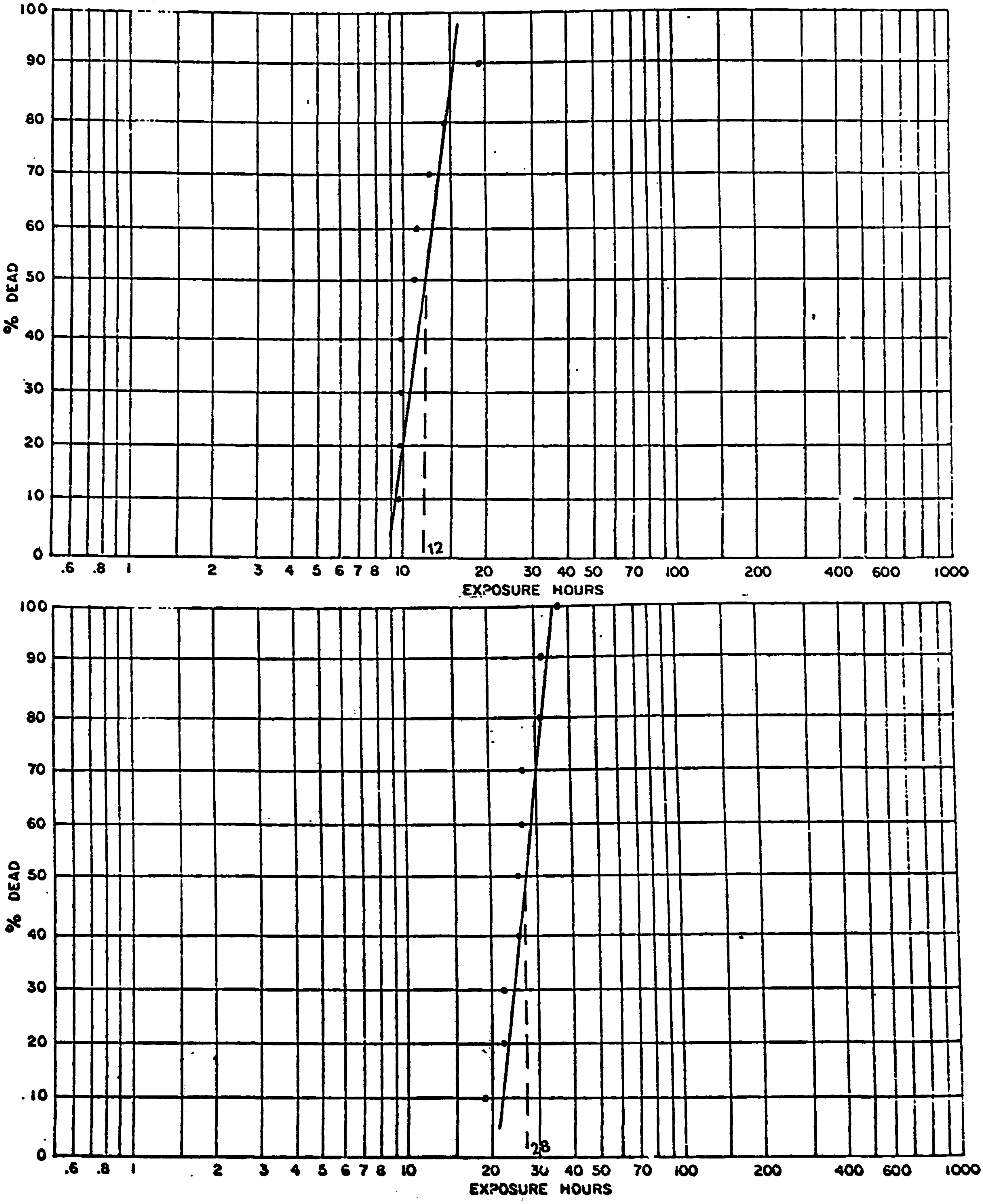
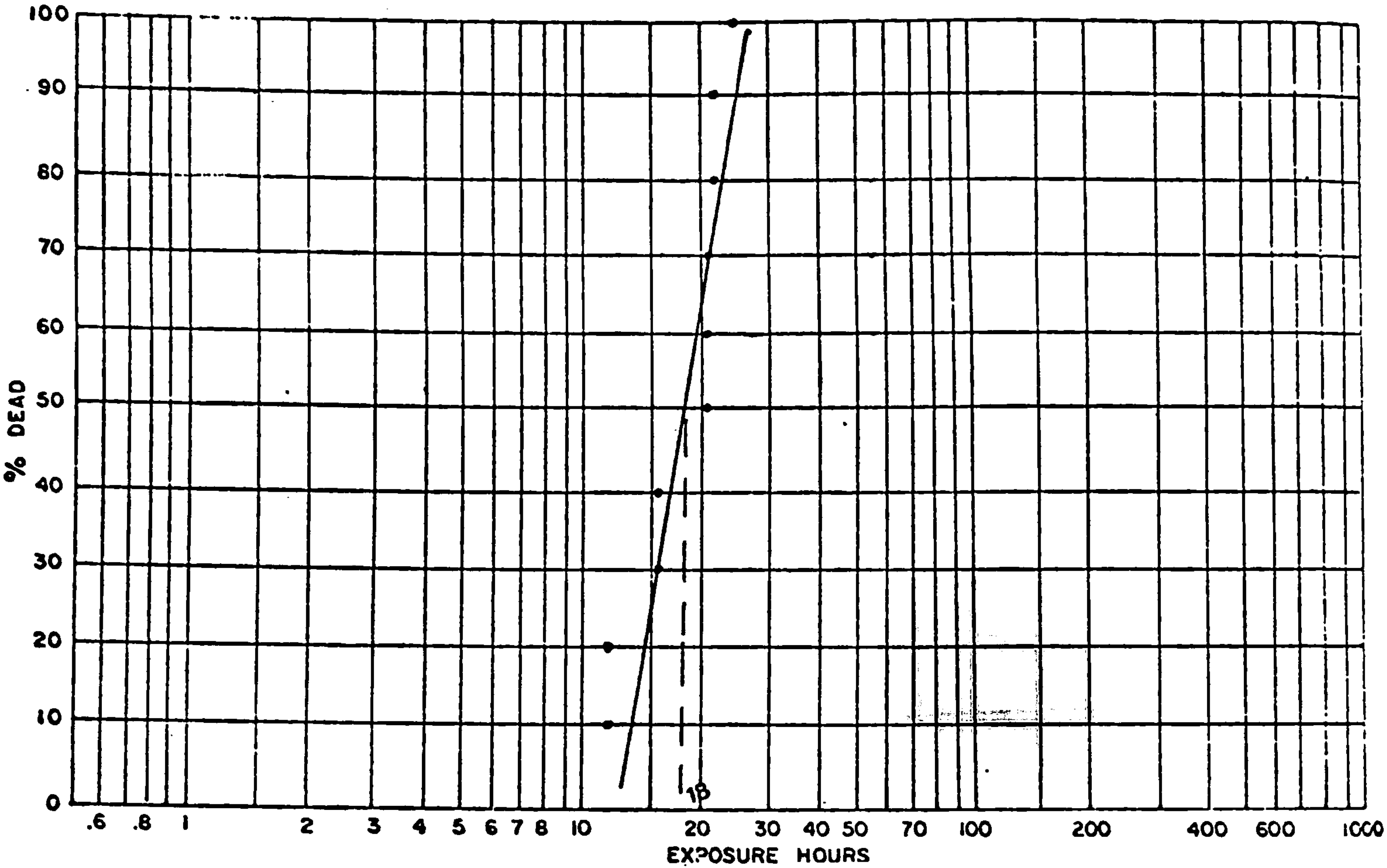


Figure 9. The lethal time (LT50) for fingerling salmon exposed to 25% Georgia-Pacific mill effluent in continuous flow bioassays on August 12 and 13, 1972 respectively.



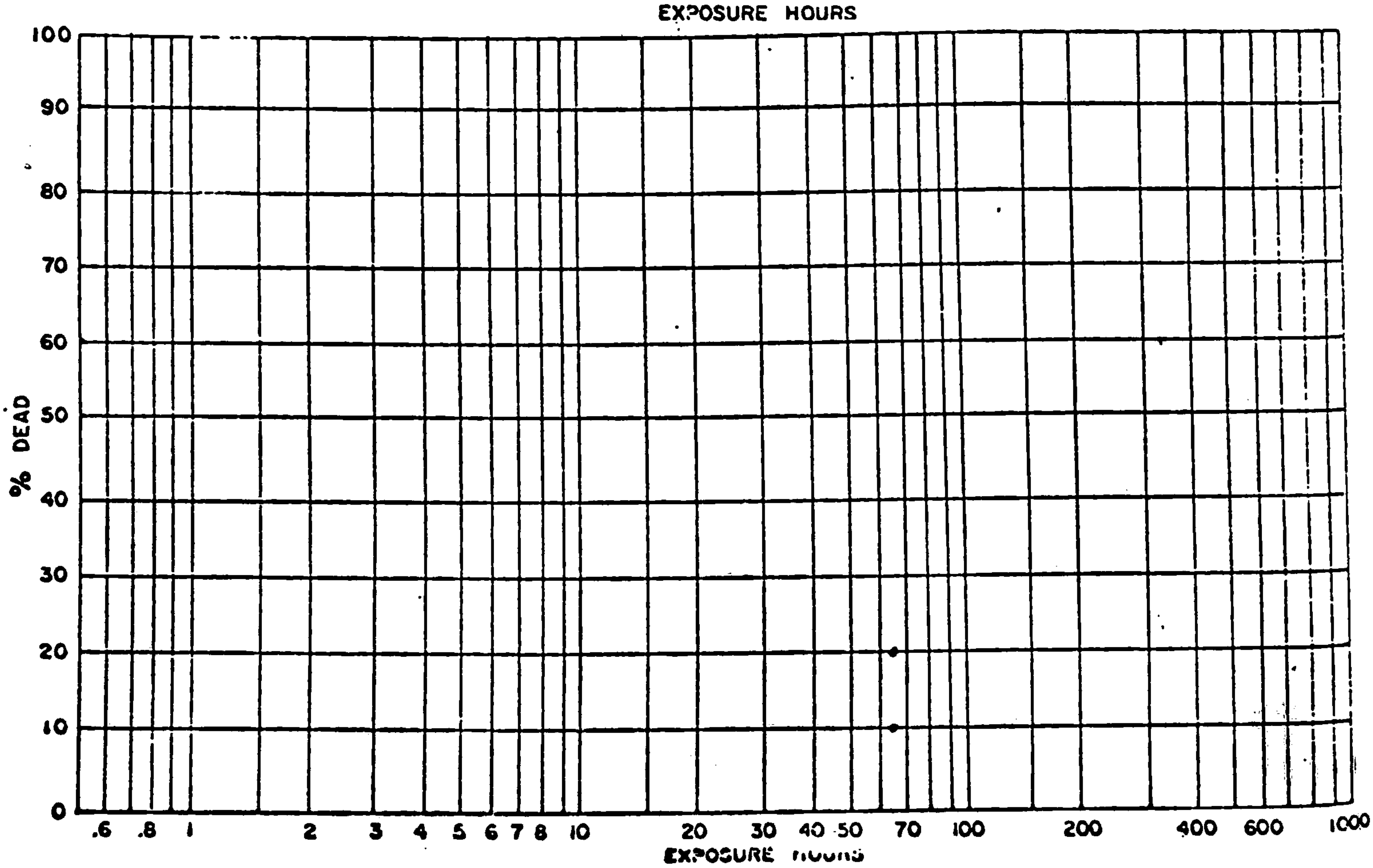
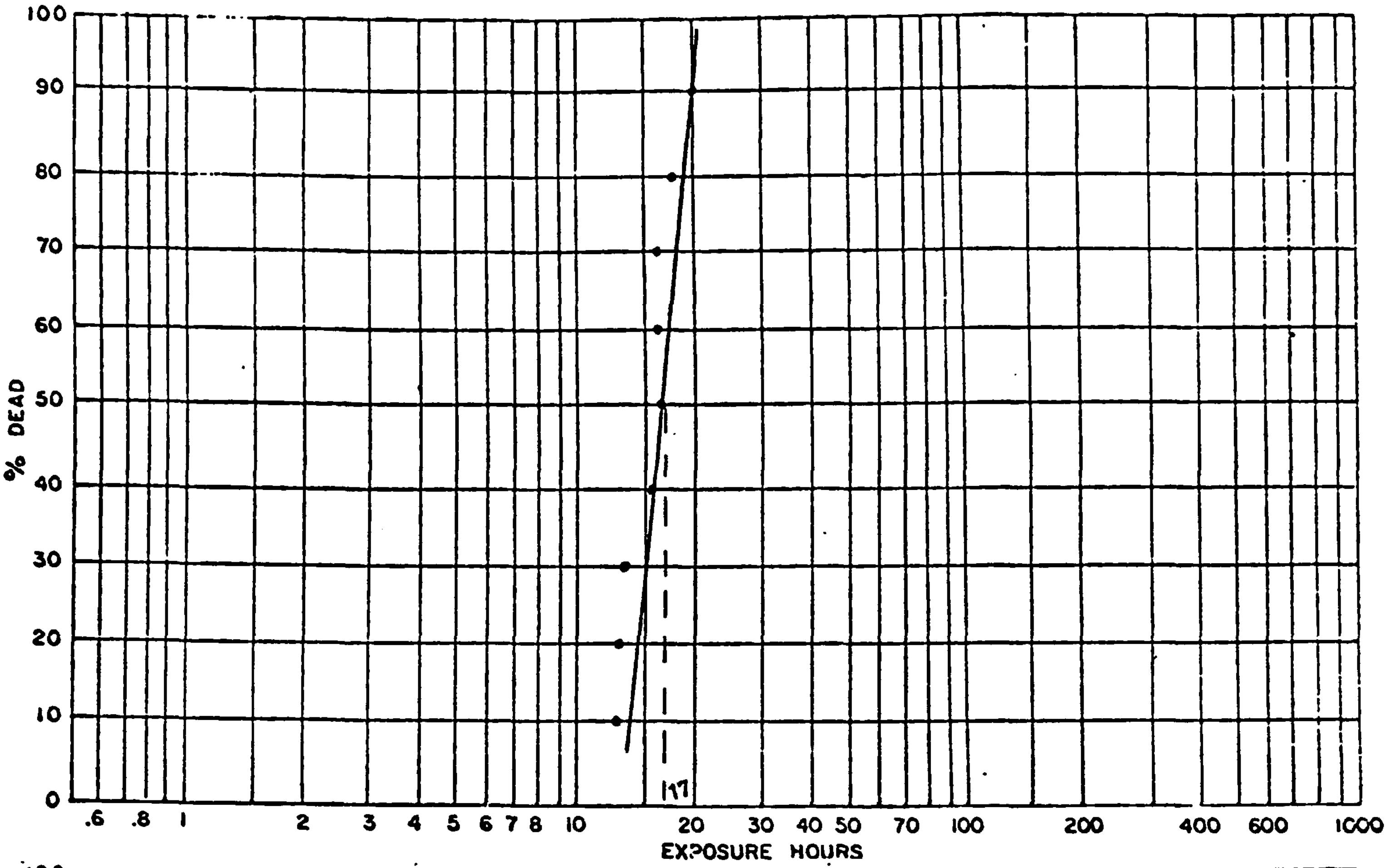


Figure 10. The lethal time (LT50) for fingerling salmon exposed to 65% and 35% G-P mill effluent in continuous flow bioassays on August 15, 1972.



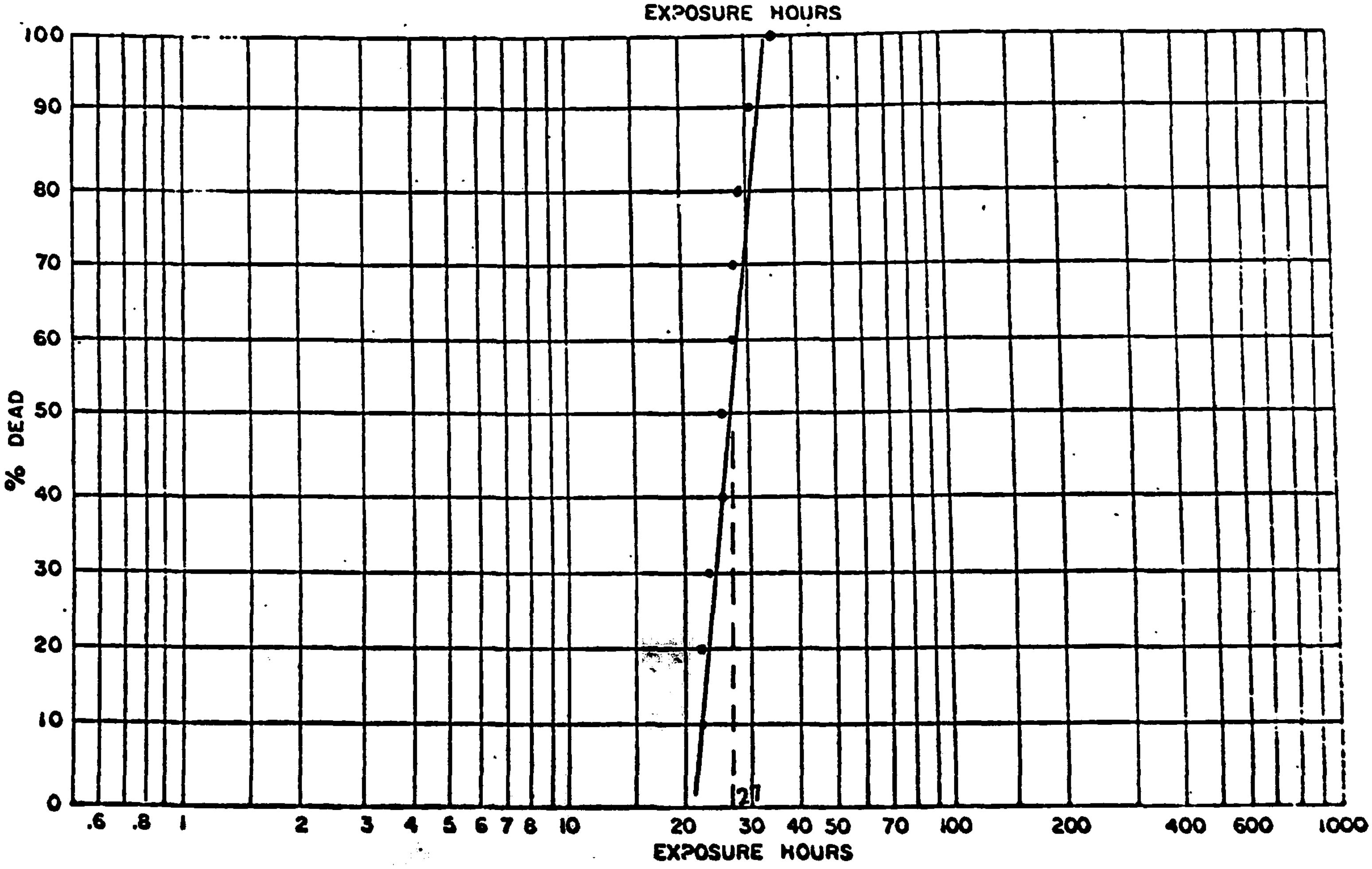


Figure 11. A toxicity curve representing the median survival time of Atlantic Salmon fingerlings a a number of concentrations of G-P mill effluen in a continuous-flow bioassay at 14.5°C.

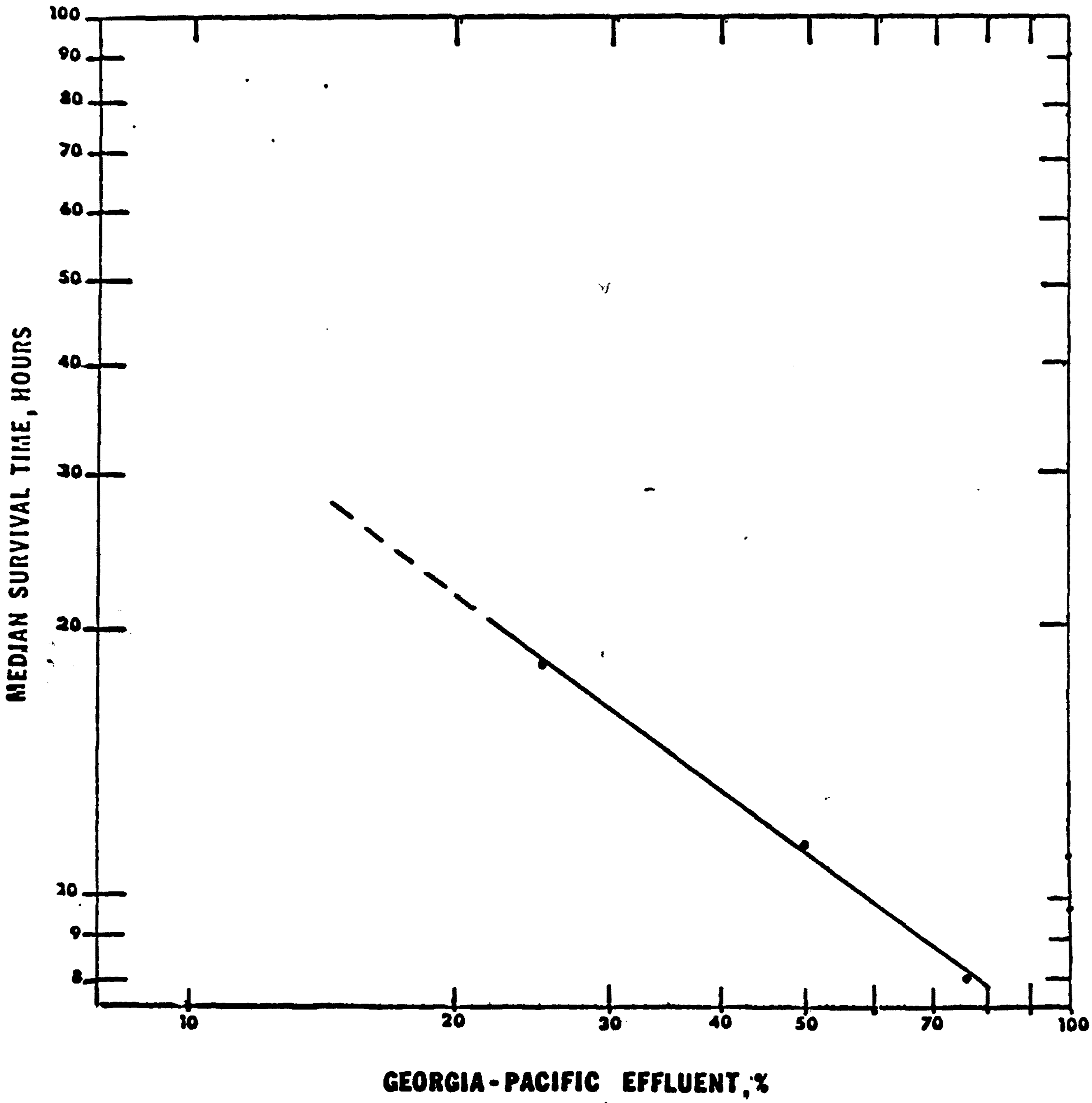
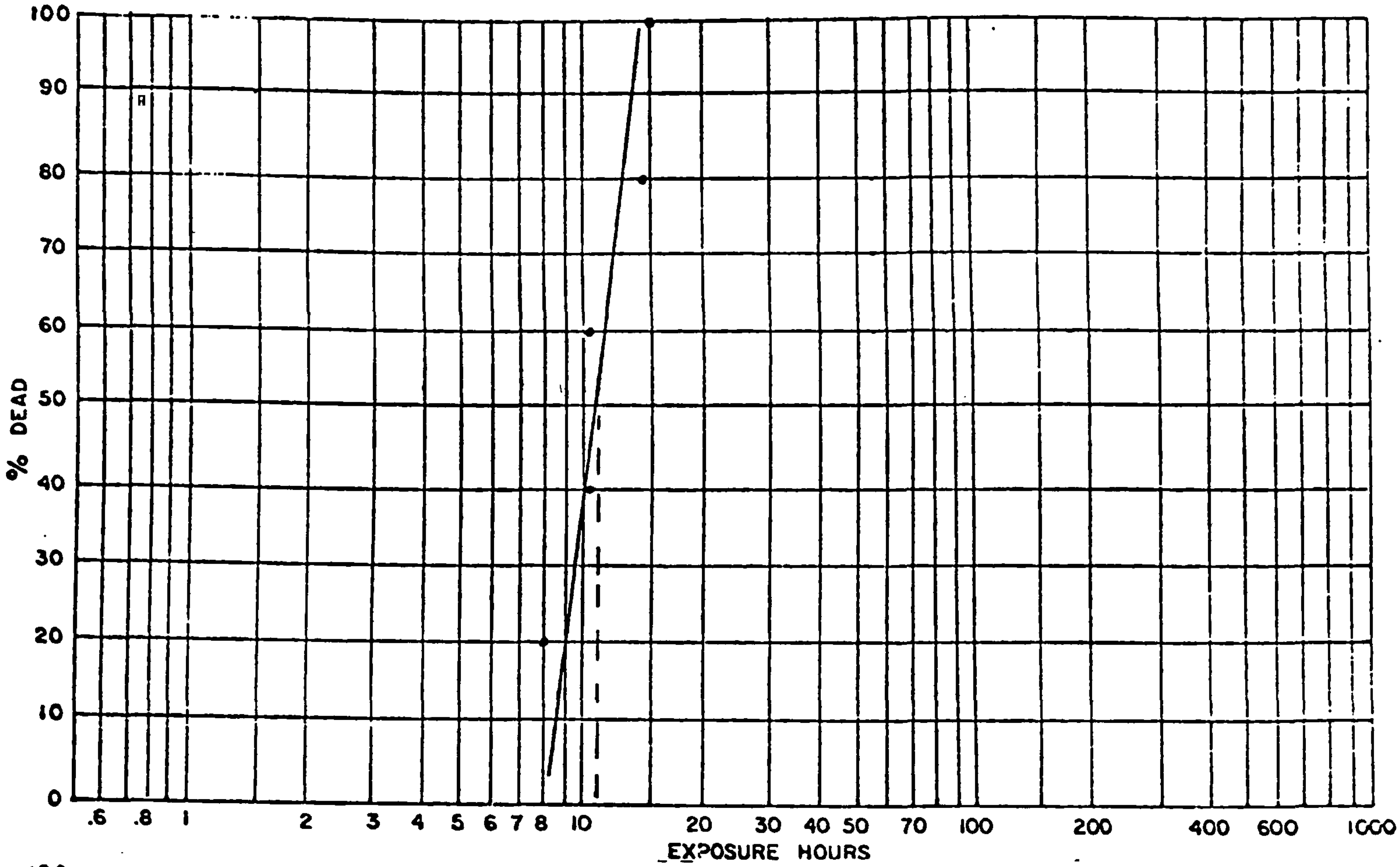
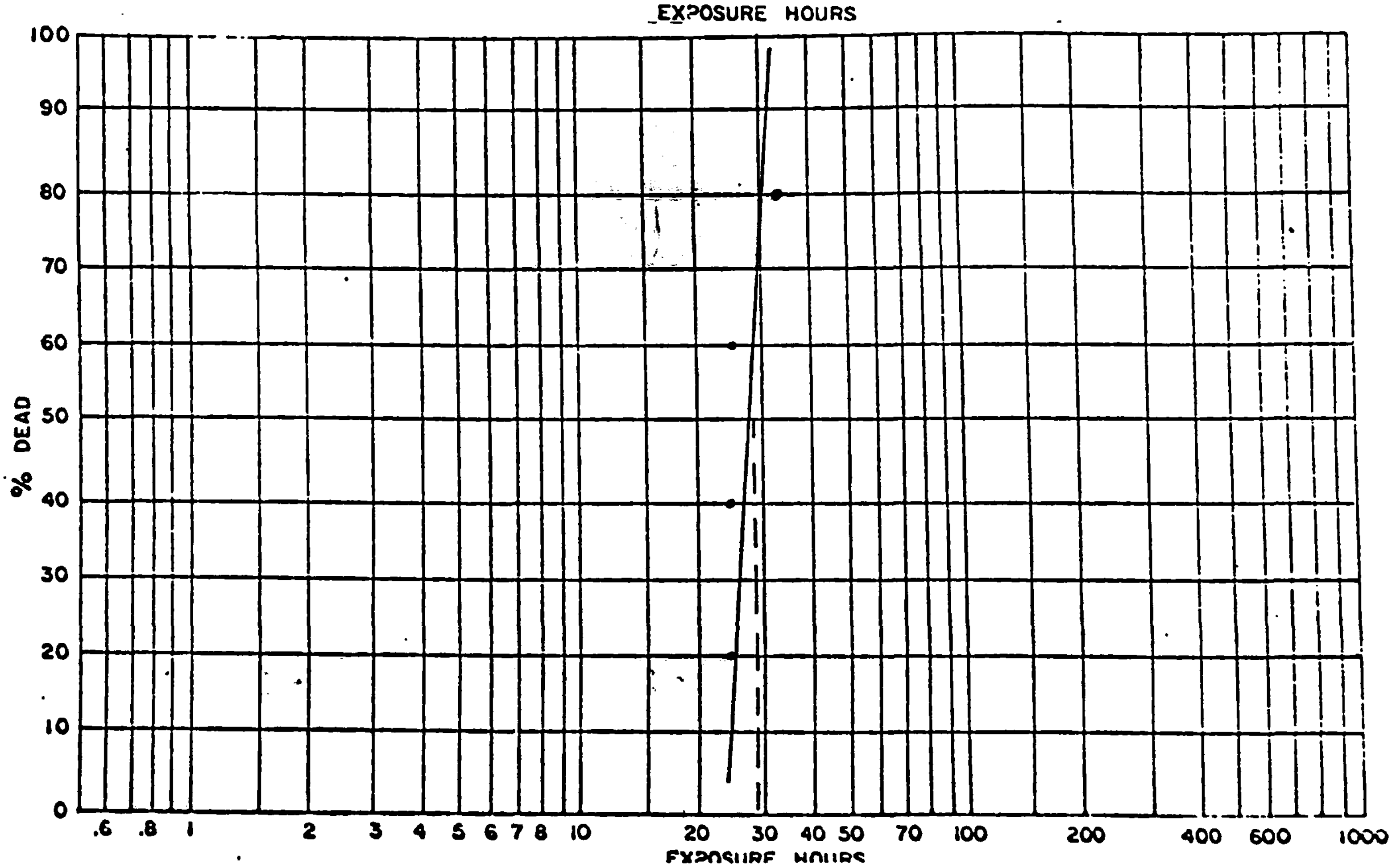


Figure 12. Graphical interpolation of the LT50 values for the semi-static bioassays conducted with yearling salmon at 56% and 32% effluent concentrations respectively.





As suggested by G.P. mill personnel, a reduction in toxicity did occur when the mill reached 100% production but the toxic level was probably not raised many percentage points beyond 25% effluent. The basis for this conclusion is three-fold:

1) 50% effluent kills 50% of the salmon in 28 hours and 100% in 36 hours;

2) yearling Salmo salar in 32% effluent died in 29 hours;

3) preliminary static tests conducted in May, 1972 on Georgia-Pacific mill effluent indicated an LC50 between 56% and 32%;

Figure 12 demonstrates the LT50 values obtained with yearling Salmo salar. At 56% effluent 100% mortality occurred within 15 hours while at a 32% concentration 100% mortality required 33 hours. This demonstrates a similar relationship to that obtained in earlier semi-static bioassays with fingerlings, i.e. an inverse relation between concentration and survival time.

Studies by Courtright and Bond (1969) have shown that foam produced by pulp and paper mill effluents concentrates resin acid by a factor of 5. Since a recent continuous-flow bioassay series run at the Physiological Testing Laboratory demonstrated an LC50 of 0.6 mg/liter (ppm) of abietic acid for Atlantic trout, I felt it would be worthwhile to study the toxicity of the foam condensates.

Fingerling Atlantic salmon placed in tanks containing 10% foam condensate survived only 66 hours while fish in 5% condensate survived 96 hours.

One 5% foam condensate bioassay was conducted at the Physiological Testing Laboratory with shrimp, Crangon septemspinosa, in sea water to obtain some information on the effect of the foam in the estuary. Though there was 20% mortality in the test tank versus no mortality in the control, no definitive statement can be made, though Courtright and Bond demonstrated the inhibition of normal development in mussel embryos at 0.1% foam.

Table VII. Analytical results for lignin and resin acid for some samples from the Georgia-Pacific survey.

SOURCE	LIGNIN* (ppm)	RESIN ACID (ppm)
1. Holding tank-100% effluent	312	5.6
2. Continuous flow-50% effluent	567	4.6
3. St. Croix River 120 yds upstream RR Bridge		<1
4. St. Croix River 120 yds upstream RR Bridge		<1
5. St. Croix River 500 yds below mill		5.9
6. St. Croix River 500 yds below mill		6.2
7. Continuous flow-75% effluent	637	5.0
8. Holding tank-100% effluent	329	4.8
9. Continuous flow-75% effluent	274	4.8
10. St. Croix River water (control)		<1
11. St. Croix River water (control)		<1
12. Continuous flow-50% effluent	194	2.1
13. Foam (Baring, Maine)		19.9

* Lignin results are the means of three readings.

Lignin and resin acid analyses were requested by the Physiological Testing Laboratory in an attempt to label some of the toxic constituents of the G-P effluent.

A recent study by our laboratory had lowered the LC50 of Lignosulfonates for rainbow trout from 1000 ppm to 225 ppm in continuous-flow situations. Previous work by other biologists in EPS Atlantic Region had shown that 1000 ppm was also the lethal threshold for salmon in static tests as had been reported for rainbow trout. It is expected that continuous-flow bioassays with lignin and salmon would lower the LC50 to a similar level. The lignin concentrations in 100% and 75% G-P effluent are sufficient to kill juvenile rainbow trout and probably young salmon. In any event, they would contribute to the toxicity.

The abnormally high lignin readings of 637 ppm and 567 ppm probably resulted from a slug of effluent with a concentrated lignin content running through the system as the samples were taken from different tanks within seconds of each other.

The effluent from the mill and the foam produced contains toxic concentrations of resin acid.

The toxic components of kraft mill wastes are very complex and variable. Consequently, tests conducted with the same concentrations of different mill samples may result in different LC50 values. This applies even when the same species is used as test organism (Betts and Wilson, 1966; Courtright and Bond, 1969). This variability is important not only in considering differences in mortality, as demonstrated in our continuous-flow bioassays, but also with the possibility that low kraft effluent levels in pools may create lethal conditions whereas higher concentrations of the waste discharge with different compounds may be non-toxic.

Servizi et al, (1966) reported an average 4 day LC50 of bleached kraft mill effluent for fingerling sockeye salmon of 22% with a range of lethal concentrations from 12-43% effluent.

Furthermore, Alderdice and Brett (1957) concluded that neutralized bleached kraft mill effluent had a toxicity for sockeye salmon (Oncorhynchus nerka) similar to that reported by Sprague and McLeese (1968) for Atlantic salmon.

These results are consistent with those reported by the Physiological Testing Laboratory for effluent from the Georgia-Pacific mill.

Avoidance studies are presently underway and suggest that yearling Atlantic salmon would avoid effluent concentrations in the range of 10-25%. These levels are similar to those found by Sprague and Drury (1969) with bleached kraft mill effluent.

Conclusions

1. In semi-static 96 hour bioassays with fingerling Atlantic salmon, the LC50 is 14% mill effluent (60% production).

2. In continuous flow bioassays with fingerling Atlantic salmon at 60% production, it does not appear that a non-toxic effluent can be reached.

3. In continuous flow bioassays with fingerling Salmo salar at 100% production, a reasonable estimate of the LC50 is 30% effluent.

4. The LC50 for the foam condensate derived from the foaming of the efflunet as it mixes in river water lies between 5 and 10%.

5. Similar LT50 values are obtained with yearling Atlantic salmon as with fingerlings.

6. Lignin and resin acid are two of the toxic compounds present in Georgia-Pacific effluent.

Some of the people directly and indirectly involved are listed by way of acknowledgements for their able assistance and advice.

Environmental Protection Service

Dr. R. H. Cook - A/Head, Environmental Assessments
R. P. Cote - Project Leader, Physiological Testing
W. R. Parker - Senior Technician
Ron Duggan - Toxicity Lab Assistant
Gerald Myatt - Toxicity Lab Assistant
Kenneth Doe - Toxicity Lab Assistant
R. Crocker - Chemistry Technician

Environmental Protection Agency

R. Thompson - Program Coordinator
H. Davis - Microbiologist
C. Corkin - Attorney
G. Gardner - Histologist
as well as many other members of their field staff.

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Sprague, J.B. and D.E. Drury. 1969. Avoidance reactions of salmonid fish to representative pollutants. Adv. in Water Pollut. Res. 4th Int. Conf. Prague.

APPENDIX J

Your file Votre référence

CONFIDENTIAL

Our file Notre référence

MEMORANDUM NOTE DE SERVICE

TO:
A: Dr. R. H. Cook, Head
Water Surveillance Unit

FROM:
DE: Hugh A. Hall, Project Leader
Special Studies

SUBJECT:
SUJET: Caged-fish tests on St. Croix River August, 1972

In an attempt to evaluate the present condition of the water in the St. Croix River and the influence of waste discharge from the Georgia-Pacific Mill at Woodland, Maine on the river condition, a series of caged-fish tests were run in several locations in the river from August 7 to August 16, 1972.

Test Series No. 1

Wooden cages were constructed following the design descripted in the Environmental Protection Service Methods Manual. The cage dimensions were 18" x 18" x 42".

Finglering Atlantic Salmon were supplied by the Fish Culture Station in Saint John, N. B. The fish were transported by truck, with continuous aeration, to Woodland, Maine where they were acclimated to river water for approximately 12 hours.

Test locations were as follows (see map):

1. St. Croix River below Grand Falls Dam, Canadian side. A control location.
2. Mohannas Stream. A control location.
3. 400 yds. below Georgia-Pacific Mill, above Baileyville sewage plant, on U. S. side.
4. 1.5 miles downstream from Baileyville sewage plant on U. S. side.
5. Railway bridge at Baring, Maine, (U. S. side).

Fine mesh screen was installed inside the cages when it was discovered fingerlings could escape through the normal cage mesh.

August 29, 1972

Results of Run #1 were as follows:

Station #1

- 10 salmon fingerlings placed in cage at 1700, Aug. 9, 1972.
- all fish survived 96 hrs. in excellent condition.
- water temperature 20°C. 68°F

Station #2

- 10 salmon fingerlings placed in cage at 1745, Aug. 9, 1972.
- all fish in excellent condition after 43 hrs. Site eliminated.
- water temperature 17°C. 62.6°F

Station #3

a. - 10 salmon fingerlings placed in cage at 2000, Aug. 9, 1972.
   - 100% mortality in less than 5 minutes.
   - water temperature 35°C. 95°F

b. - 10 more salmon fingerlings added at 2010, Aug. 9, 1972.
   - 100% mortality in 30 seconds.
   - water temperature 35°C. 95°F

c. - 10 more salmon fingerlings added at 2025, Aug. 9, 1972.
   - 100% mortality in 40 seconds.

d. - 10 more salmon fingerlings added at 0010, Aug. 10, 1972.
   - 100% mortality in 40 seconds.

Temperatures above and below the pulp mill on the U. S. side were then checked.

0730, 10/8/72.	Above Mill	20.5°C	Station #3	35.0°C
0830, 10/8/72.	Above Mill	20.0°C	Station #3	35.0°C
0630, 11/8/72.	Above Mill	20.0°C	Station #3	34.0°C

Station #4

- 10 salmon fingerlings placed in cages in the river at 1400, 10/8/72.
- 40% mortality 10 hr. 20 min.
  100% mortality 16 hr. 30 min.
- water temperature 21°C.

Station #5

- 10 salmon fingerlings placed in river at 1930, 9/8/72.

Mortality (%)	Exposure Time (hrs.)
10	30.5
20	40.25
30	41.75
40	48.0
60	53.0
70	62.0
80	65.0
90	69.5
100	76.0

A new series of caged-fish tests were run during August 14-18, 1972. For these tests Atlantic Salmon yearlings were used. They were supplied by the Saint John Fish Culture Station. These fish were treated in a similar manner to the fingerlings of the week previous. For these tests Station #2 was not used.

Station #1

This test had been in operation for 51.5 hours when at 1230, 17/8/72 the cage was found out of the water. It had been left high and dry when the gates at the dam were closed thereby decreasing the volume of water below the dam. It is estimated that the fish had been out of the water 1 to 2 hours. All fish were in excellent condition prior to the decrease of flow.

Water temperature average 22.0°C.

Station #3

- 10 salmon yearlings added to the cage at 0920, 15/8/72.
- 100% mortality in 40 seconds.
- water temperature that day averaged 37.0°C.

Station #5

- 10 salmon yearlings added to the cage at 2400, 14/8/72 (0000, 15/8/72)

Station #5 (cont'd)

Mortality (%)	Exposure time (hrs.)
10	45.5
40	48.0
50	70.5
100	80.5

Station #4

a. - 10 salmon yearlings placed in the cage at 1130, 15/8/72.
   - 100% mortality in 12.0 hrs.

b. - 10 salmon yearlings placed in cage at 0030, 16/8/72
   - 100% mortality in 11.5 hrs.

   - water temperature in a. and b. 24°C. ≈ 76°F

From the tests conducted in the St. Croix River at Station #1 (control station) it can be seen that water at this location is non-toxic. Tests at the second control location (Station #2), although of limited duration, confirmed the suspicion that this stream continues to be suitable for fish. Mohannas Stream has been used several times in previous years as a control location when testing the St. Croix River toxicity.

Station #3 showed rapid and total mortality. However, it is not possible to distinguish between toxicity resulting from chemical pulp mill effluent and death due to heat shock. Brett (1956) suggests that Salmonidae have a low thermal tolerance with maximum upper lethal temperatures barely exceeding 25.0°C. Alabaster (1967) testing salmon (*Salmo solar L.*) and trout (*Salmo trutta L.*) in the River Axe established the lethal temperature of smolts and parr at between 23.9 and 26.0°C. while Bishai (1960) established that *Salmo solar* alevins die if subjected to temperatures above 25°C. Since the water temperature at Station #3 was between 34°C and 37°C during the tests, heat death could mask any effluent chemical toxicity.

Station #4, although 1.5 miles downstream of the pulp mill indicated severe toxicity. Yearling salmon lived no more than 12.0 hours. Temperature was not a limiting factor at this station downstream of the pulpmill.

Station #5, which is some 8 miles downstream of the pulp mill produced mortalities of 100% in 76 hours with fingerling salmon and in 80.5 hours with the larger (yearling) salmon. Again, temperature was not a limiting factor here.

References Cited

1. Alabaster, J. S. 1967. The survival of salmon *(Salmo solar L.)* and sea trout *(Salmo trutta L.)* in fresh and saline water at high temperature. Water Research 1(10), 717-730.

2. Bishai, H. M. 1960. Upper lethal temperatures for larval salmonids. J. Cons. perm. int. Explor. Mer. 25(2), 129-133.

3. Brett, J. R. 1956. Some principles in the thermal requirements of fishes. Rev. Biol. 31(2), 75-87.

Hugh A. Hall
Project Leader
Special Studies

HAH:jy

ST. CROIX RIVER

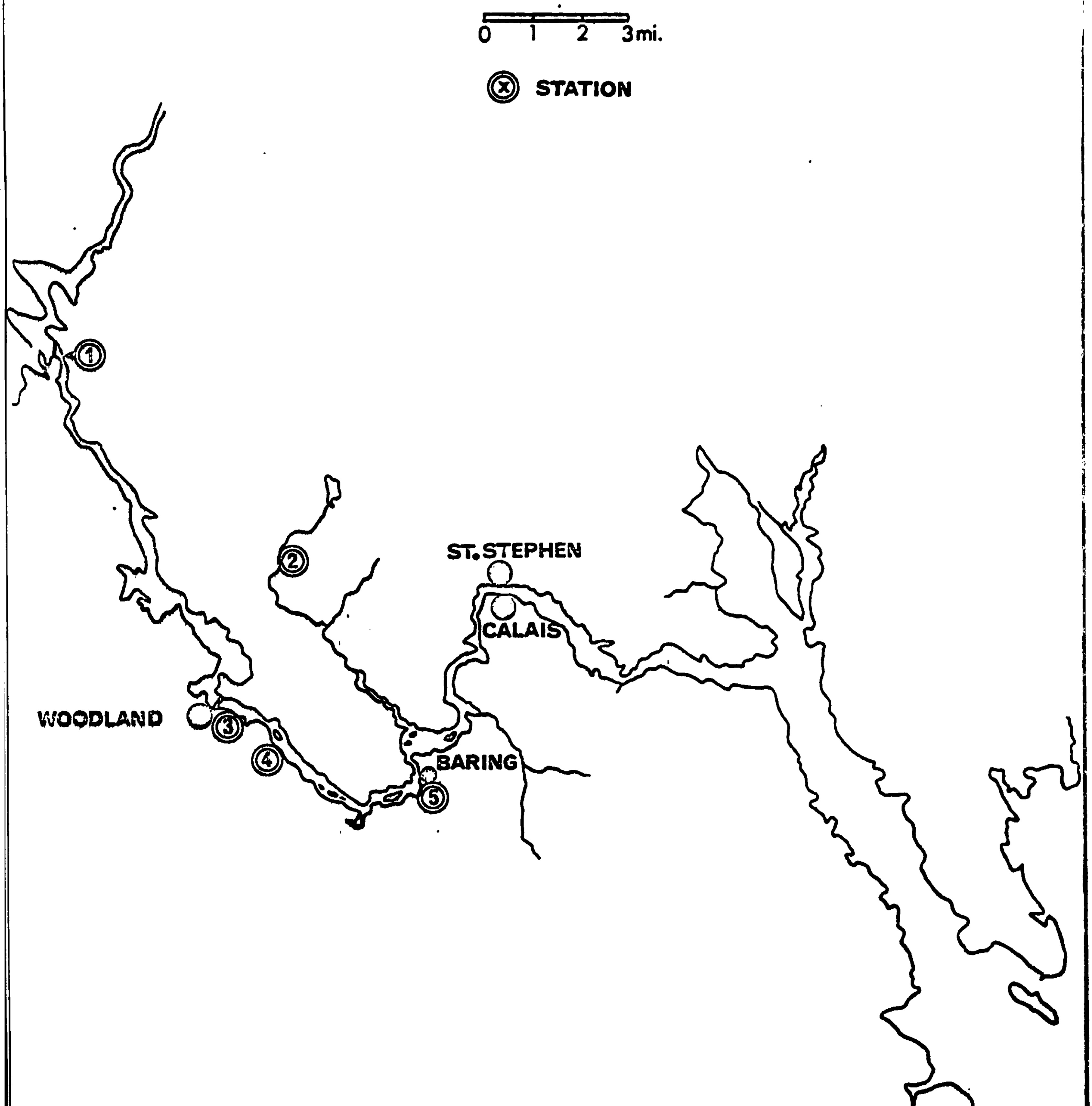


FIGURE J1

APPENDIX K

ENVIRONMENTAL PROTECTION AGENCY

REPLY TO ATTN OF: George R. Gardner
Research Aquatic Biologist, NMWQL

DATE: October 20, 1972

SUBJECT: Environmental Protection Agency vs Georgia Pacific

TO: Director, NMWQL

One hundred seventy eight Atlantic Salmon (Salmo salar) submitted to the National Marine Water Quality Laboratory, Technical Operations Branch, by Dr. Raymond Coté representing the Canadian Environmental Protection Service were recieved and recorded on the 16th of August, 1972. The specimens consisted of previously frozen and fresh yearling and fingerling salmon. These fishes were immediately fixed in Dietrich's Fixative upon receipt; the yearlings were trimmed of excess tissues at the time to insure proper fixation.

All specimens were processed in accordance with routine clinical methods adopted by the NMWQL, and stained with Harris' Hematoxylin and Eosin for histopathological examination. The results of the examination are as follows:

Gross Anatomy:

No gross lesions were evident at autopsy.

Microscopic Anatomy:

Lesions were present in the olfactory organs of both fingerling and yearling salmon. Morphological alterations were associated with the basal, neurosensory, and sustentacular cells of the chemoreceptive sites; in some instances the epithelium comprising the lining of the olfactory pits was affected. Cytolysis of the above cellular elements was indicated by various degrees of nuclear and cytoplasmic degeneration. Due to the nature of the alteration, the lesions appeared to have origin near the basement membrane. The nuclei of altered cells had increased basophilia, chromatin condensed near the nuclear membrane, were pyknotic, and finally karyorrhexsis (rupture of the nuclear membrane and fragmentation of the chromatin) had occured. The cytoplasmic ratio was generally reduced and was either clear or lacking in severly afflicted cells.

Migration of sensory cell nuclei from their usual basal to an apical position followed the initial cellular changes near the basement membrane. Normally the apical portions of sensory cells are free of nuclei and form a marginal "zone of cytoplasm". The marginal zone of cytoplasm was reduced or eliminated in exposed fishes having severe lesions, due to migration of the nuclei into the apical area of the cells. Mucous cells usually present in the marginal zone of cytoplasm were lacking.

Lesions were found in the intestine of some fishes; they were reminescent of cadmium poisoning in the estuarine teleost *Fundulus heteroclitus*. However, the lesion was inconsistant. There were no lesions associated with other major tissues, including the respiratory epithelium.

Conclusions:

A table is included in the report to represent the NMWQL pathology numbers as recorded, the treatments, and the exposure groups having the lesion. Salmon exposed for periods of 20 hr or more were usually severly affected (ex- 32% G.P. effluent; 26.5 hr) (Figures). Cellular alterations would not be expected to occur after exposures to high concentrations that were rapidly lethal (ex- 40 second survival at station #4). Rapid death of an organism does not permit enzymatic changes to occur in cells that will allow recognition of their death by the light microscope. This may explain the absence of lesions in some groups. Approximately 49% of the specimens were of no value in the evaluation due to autolytic or post mortem change. These changes occured as the result of improper preservation prior to procurement by the NMWQL.

The prime function of the chemoreceptive organs are to convey information concerning changes in the chemical composition of the internal and external environment to the higher centers of the central nervous system for correlation. These sensory imputs allow the organism to alter behavioral patterns by adjusting their internal physiological or biochemical mechanisms to cope with a changing environment. Chemoreception in the salmon is vital to their orientation and migration into "home streams", and therefore, is vital to successful reproduction and propagation of the species.

Recent investigations have reported the occurence of lesions in the olfactory organs of other marine teleosts of both an experimental and a spontaneous character (Gardner and LaRoche, 1973 a, b). The experimentally induced lesions in the above instances were caused by certain heavy metals, a pesticide, and a whole crude oil and the soluble and insoluble fractions of the crude oil. These preliminary investigations have indicated the characteristics of lesions in the olfactory organs to vary dependant upon the type of toxicant exposure. Plausibly, these changes in the olfactory organ may in time lend themselves to categorization. Research to date has shown the sensory system of the teleost to be very vulnerable to a variety of water pollutants, a fact which has been further substantiated by the effects of pulp mill effluents in the present case.

a) Gardner, G.R. and G. LaRoche. 1973. Copper induced lesions in estuarine teleosts. J. Fish. Res. Bd. Canada (In Press).
b) Gardner, G.R. and G. LaRoche. 1973. Chemically induced lesions in estuarine or marine teleosts. Presented at Armed Forces Institute of Pathology, Fish Pathology Symposium, Aug. 6-8, 1972. (In Press).

George R. Gardner

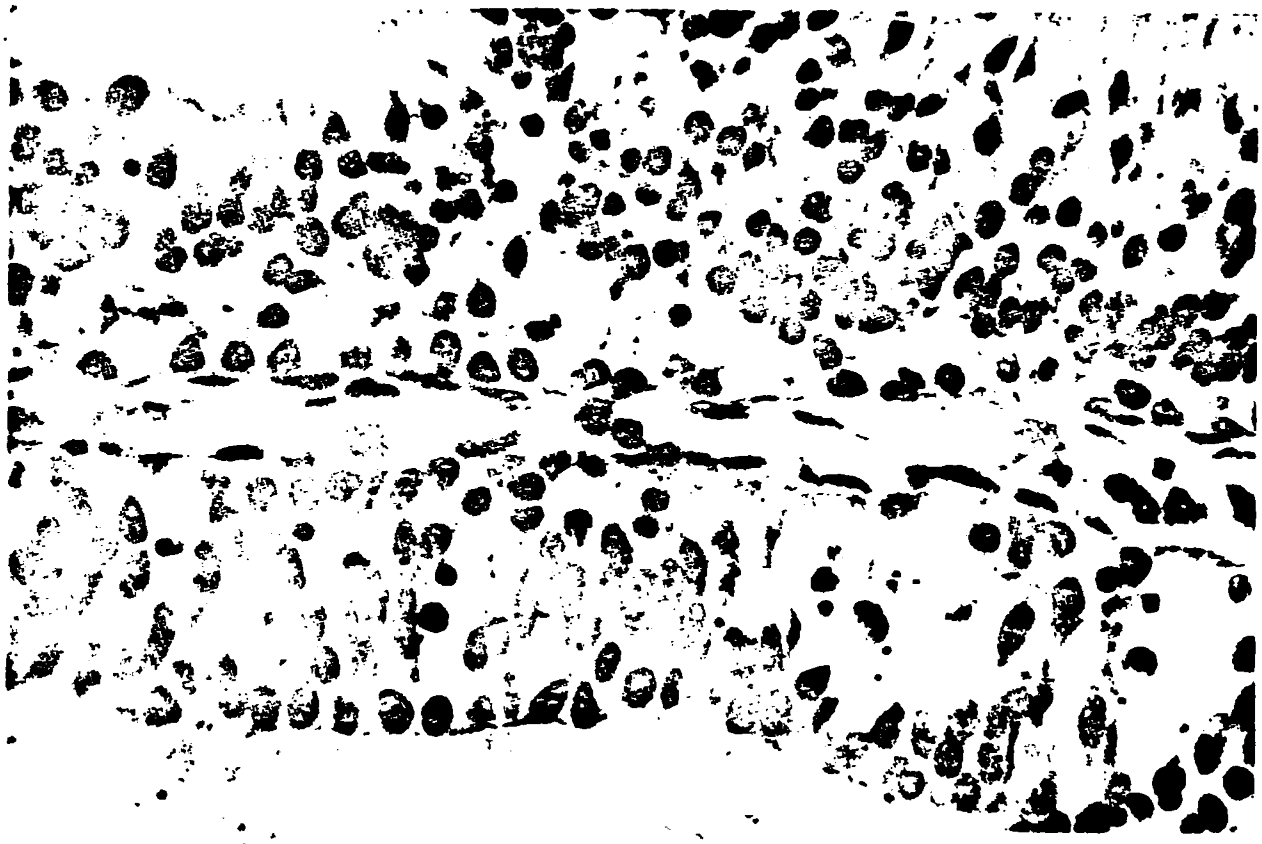
TECHNICAL OPERATIONS BRANCH
NATIONAL MARINE WATER QUALITY LABORATORY

NMWQL 1972 Pathology Numbers	Fingerling (f) Yearling (y)	Exposure Data: Tank # or Station #	Exposure Data: Treatment	Number Animals	PM Post Mortem Change	L Lesion Present
3838-3844	y	Cont flow (1760 hr)	Control	7	PM	-
3845-3854	y	Tank #9	Control - river H_2O	10	-	-
3855-3858	f	Tank #2	75% G.P. eff.	4	PM	-
3859-3862	y	Tank #2	32% G.P. eff. 26.5 hr	4	-	L
3863	y	Tank #3	56% G.P. eff.	1	PM	-
3864-3871	f	Tank #10	25% eff.	8	-	-
3872-3878	f	Tank #10	25% eff.	7	PM	-
3879-3884	f	Tank #11	35% eff.	6	-	L
3885-3890	f	Tank #11	50%	6	PM	-
3891-3892	f	Tank #11	32% 25 hrs	2	-	L
3893-3894	f	Tank #11	50%	2	PM	-
3895-3912	f	Tank #12	75%	18	PM	-
3913-3916	f	--------	50%	4	PM	-
3917	f	--------	25% eff. 75 hrs	1	-	L
3918	f	--------	35% eff. 29 hrs	1	-	L
3919	f	--------	62% eff. 20 hrs	1	-	L
3920-3928	f	--------	5% foam conc.	9	-	-
3929-3937	f	--------	10% foam 66 hrs	9	-	-
3938-3953	y	--------	Control	16	-	-
3954-3963	f	Sta. #1	Control	10	PM	-
3964-3966	f	Sta. #1	Control	3	-	-
3967	y	Sta. #3	70 hrs	1	-	-
3968	y	Tank #3	56% eff.	1	PM	-
3969-3976	f	Sta. #3	Baring	8	PM	-
3977-3980	y	Sta. #3	Baring	4	-	-
3981-3985	y	Sta. #3	Dead or moribund	5	-	1+(L)
3986-3995	y	Sta. #4	40 sec.	10	PM	-
3996-4000	y	Sta. #5	12 hr dead	5	PM	-
4001-4008	y	Sta. #5	7.5 hr dead	8	PM	-
4009-4013	y	Sta. #5	12 hr dead	5	PM	-
4014-4015	y	Sta. #5	11.5 hr moribund	2	-	L
TOTAL				178		

CONTROL
(X 156)

32% G.P.
Effluent
26.5 hr
(X 156)

CONTROL (X 625)
M=mucosa
SM=submucosa
BM=basement membrane
NS=neurosensory cells
ZC=zone of cytoplasm
MC=mucous cell



32% G.P. Effluent 26.5 hr (X 625)

APPENDIX L

ST. CROIX RIVER STUDY
AUGUST 1972

DEVELOPMENT OF A DO DEFICIT MODEL FOR THE ST. CROIX RIVER WOODLAND - MILLTOWN, MAINE

The St. Croix River between the Georgia-Pacific effluent and Milltown Bridge was modeled for biochemical oxygen demand (BOD) and dissolved oxygen (DO) response under specified sets of conditions.

Modeling a river may be a physical or analytical process. EPA chose to employ the analytical approach. This is based on mathematical formulations of the physical, chemical and biological phenomena occurring in the system and may be summarized simply as:

1. The quantity of material entering a system is equal to the amount leaving plus the amount lost by various processes, plus the buildup of the material in that system.
2. Organic pollution, measured in terms of BOD, is oxidized at a rate proportional to its quantity.
3. Dissolved oxygen is added to a system by natural processes of reaeration in proportion to its deficit from saturation.

As a result of the modeling program, we can expect the response of the St. Croix River to be as shown in Figure 1 for all combinations of input variables. This shows the maximum deficit in the river as a function of the various environmental and imposed conditions.

One of the runs has been extracted and illustrated fully for DO and BOD as a function of river distance. This was done for a flow of 1000 cfs, a load of 8680 pounds per day, a benthic demand of 3 gm $O_2/m^2/day$, and a deoxygenation rate of 0.3/day (see Figure 2).

A detailed description of the model, calibration and application will now be discussed.

The reliability of the results are subject to some question in terms of data available and modeling techniques, but the analysis was undertaken with the intention of obtaining meaningful results and filling in data gaps with the best engineering analysis we could employ. The problems inherent in any modeling endeavor arise from the following:

1. Range of values for dissolved oxygen and BOD were recorded at high flow. Ranges of parameters must be selected to represent the system at all flows.
2. Some parameters have more significant economic impact than others in terms of treatment requirements. These significant parameters have been analyzed and their values narrowed to a small range of probable and representative values.
3. The BOD - DO interaction model used has historically been accepted as the basis for economic decisions, although analysts realize the actual system is more complex.
4. A closed form solution of the system is not available, so we rely on discrete segmentation.

Formalizing the equations to make the concepts compatible with a computing scheme we obtain:

$$V_k \frac{dC_k}{dt} = \sum_j [Q_{kj} (\alpha_{kj} C_k + \beta_{kj} C_j) + E'_{kj} (C_j - C_k)] - V_k C_k K_k + W_k$$

where k is an element under consideration

j is any contiguous element

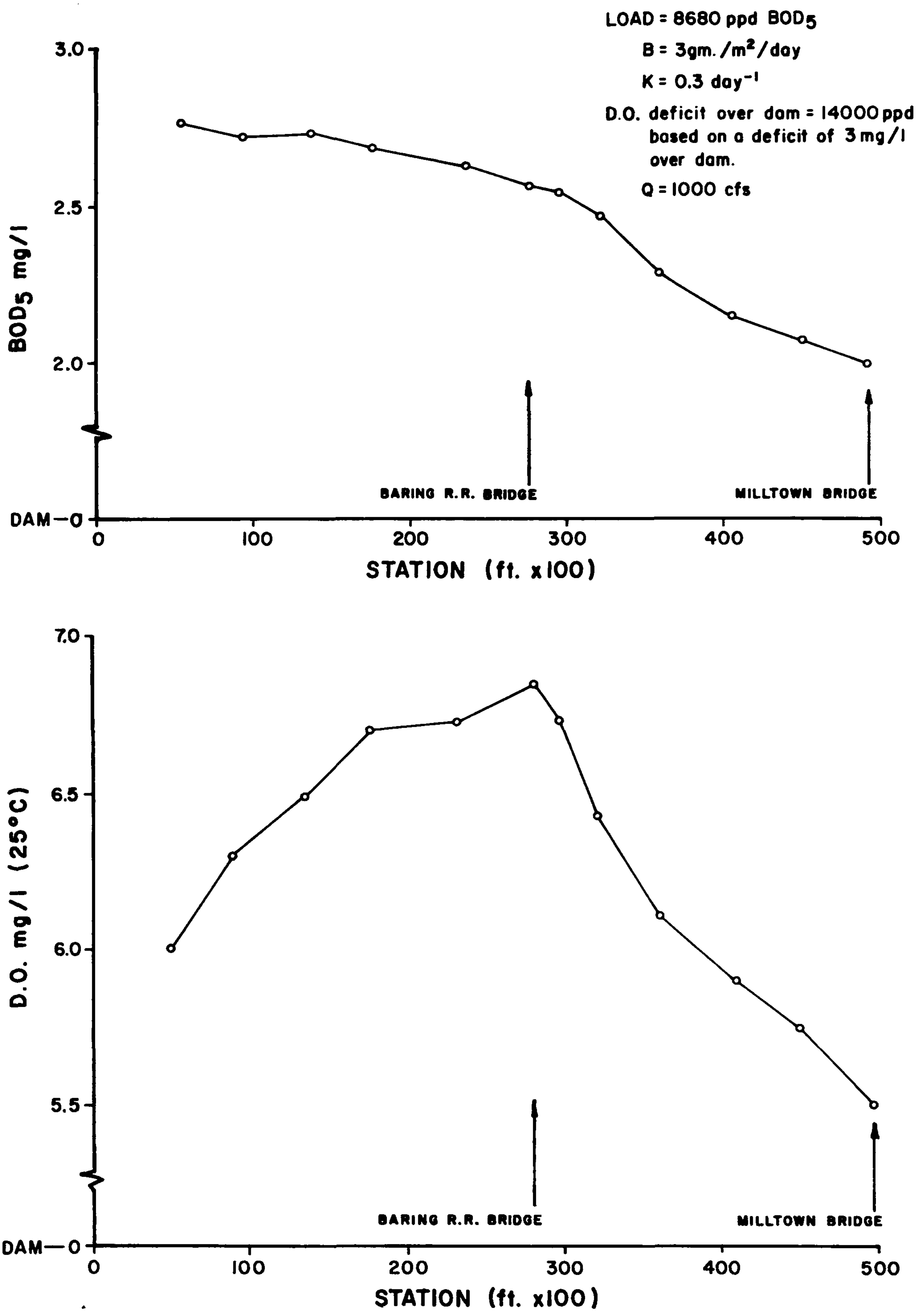
ST. CROIX RIVER STUDY
AUGUST 1972

PROJECTED DISSOLVED OXYGEN CONCENTRATIONS
AT MILLTOWN BRIDGE

(Water Temperature = 25 C)

River Flow cfs	Plant Load ppd BOD_5	Benthic Load gm O_2/m^2/day	DO at Woodland Dam, mg/l	Reaction Rate $days^{-1}$	DO at Milltown Bridge, mg/l
480	5,000	2	5.0	0.3	5.2
		3	5.0	0.2	5.1
	10,000	1	5.0	0.3	5.4
		2	5.0	0.3	4.5
		3	5.0	0.2	4.1
	15,000	1	5.0	0.3	4.8
		3	5.0	0.2	3.5
750	10,000	2	5.0	0.2	6.1
				0.3	5.1
		3	5.0	0.3	4.4
			6.0	0.3	4.5
		4	5.0	0.3	3.7
			6.0	0.3	3.8
	19,200	2	5.0	0.2	4.7
				0.3	4.1
		3	5.0	0.3	3.3
			6.0	0.3	3.1
		4	5.0	0.3	2.7
			6.0	0.3	2.8
				0.3	
1,000	8,680	1	5.0	0.2	5.7
				0.3	5.7
			6.0	0.2	6.5
				0.3	6.5
		3	5.0	0.2	5.5
				0.3	5.5
			6.0	0.2	5.9
				0.3	5.7
		5	5.0	0.2	4.6
				0.3	4.4
			6.0	0.2	4.8
				0.3	4.6
	10,000	3	5.0	0.3	5.5
			6.0	0.3	5.3
		4	5.0	0.3	4.8
			6.0	0.3	5.0
	19,200	3	5.0	0.3	4.9
			6.0	0.3	5.1
		4	5.0	0.3	4.3
			6.0	0.3	4.5

FIGURE L-1



TYPICAL RESULT OF A MODEL RUN

FIGURE L2

V is the volume of the element

C is BOD concentration (or any other substance subject to first order kinetics)

E' is the effective diffusion coefficient

k is the first order decay rate of the material under consideration

W is the input (or release of waste matter)

α, β are weighting terms, such that $\alpha + \beta = 1$

Q_{kj} is flow from j to k

The equation says, in words, "the change in the amount of material in section k $[V_k \partial C_k / \partial t]$ is equal to the sum of all the material entering by advection $[\sum_j Q_{kj} (\alpha_{kj} C_k + \beta_{kj} C_j)]$ where α and β define the relative weight each section contributes, plus the sum of the the material entering by diffusion $[\sum_j E'_{kj} (C_j - C_k)]$ plus the input waste $[W_k]$, minus the mass destroyed by decay or utilization $[V_k K_k C_k]$.

Rewriting for a steady state case, where no temporal concentrations change exists we obtain:

$$W_k = C_k \left[\sum_j (\alpha_{kj} Q_{kj} + E'_{kj}) + V_k k_k\right] + \sum_j (Q_{kj} \beta_{kj} E'_{kj}) C_j$$

Allowing a_{kk} to be the coefficient of C_k, and a_{kj} the coefficient of C_j, we can simplify by writing $W_k = a_{kk} C_k + \sum_j a_{kj} C_j$.

Note that the equations in this form lend themselves to a matrix formulation, namely: $(W) = [A] (C)$

where (W) represents the known vector of waste inputs, $[A]$ represents the known matrix of coefficients as shown above, and (C) represents the vector of concentrations for each segment.

The resulting systems can be solved as $(C) = [A]^{-1} (W)$, however cumbersome the matrix inversion happens to be.

There are, however, methods available which ease this computation. The model[1] uses a relaxation technique which converges quite rapidly.

At a boundary the equation takes the form

$$W_k = \sum_j [Q_{kj} (\alpha_{kj} C_j + \beta_{kj} C_k) + E'_{kj} (C_k - C_j)] + V_k K_k C_k + E'_{kk} (C_k - C_b) + Q_{kk} (\alpha_{kk} C_k + \beta_{kk} C_b)$$

where C_b represents the concentration of material at the boundary.

In order to retain the standard form, we must redefine the following terms at boundary segments:

New $W_k = W_k + C_b (E'_{kk} - Q_{kk}\beta_{kk})$

New $a_{kk} = a_{kk} + E'_{kk} + \alpha_{kk} Q_{kk}$

New $a_{kj} = a_{kj}$

so that

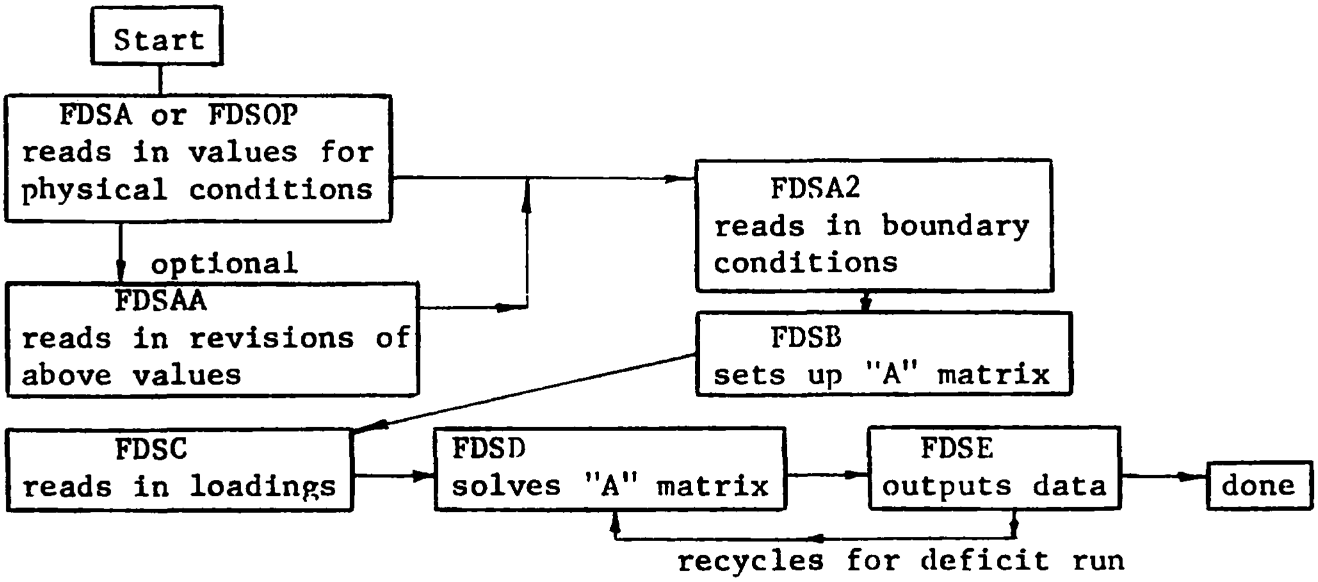
$$W_k = a_{kk} C_k + \sum_j a_{kj} C_j$$

Note: the boundary conditions were incorporated in such a way as to be made a part of the source load vector.

The deficit solution takes on the same form as the above, except a deficit coefficient (k_d) is substituted for "k", (assuming both BOD and DO deficit decay by a first order reaction), and the term $V_k K_{dk} L_k$ is added to the deficit loadings to account for the oxygen uptake of the BOD removal process. Also considered are benthic uptakes $S_k V_k / H_k$ where S is the rate in gm O_2/m^2/day and V_k/H_k represents the area under consideration, and (V_k) (P_k) the deficit (positive or negative) arising from photosynthetic effects.

$$W_k = a_{kk} D_k + {}_j\, a_{kj} D_j - V_k k_k C_k + V_k P_k - \frac{V_k}{H_k} S_k$$

Because the BOD and deficit solutions have similar formulations, there is one main program to solve both. The flow chart of this program is illustrated below.



More specifically the following data is needed for each subroutine:

<u>FDSA</u>:

TITLE, any 80 characters

N, number of segments

SCALE, scaling factors for area, dispersion, flow and length, respectively.

ICOL: contiguous segment number, (up to six per segment including a_{kk}, e_{kk}, Q_{kk} at end points of model)

A: area in ft^2

E: dispersion in mi^2/day ($E' = \frac{AE}{L}$)

Q: flow in cfs

L: length in feet

VOL: volume in million cubic feet for each segment.

Note: lengths need not be a representative side of the polygonal segment, as its only application is in computation of the E' values.

FDSA2:

NUMB: number of segments having boundary conditions

BC, ICOL: the boundary value and corresponding segment.

FDSC:

LOAD, ISEC: the waste or deficit load in pounds per day and corresponding segment number.

k: the array of reaction coefficients for segments, (values in $days^{-1}$).

ϵ: the degree of accuracy of the numerical solution desired

OMEGA: ω, the relaxation factor for the iteration scheme of matrix solution. $1 \leq \omega < 2$, with one value in particular giving an optimal convergence pattern.

FL: the ratio of BOD to BOD_5. This should be $(1-e^{-5k_1})^{-1}$ according to our assumption of first order kinetics, but since k varies throughout, and only one FL is desired, a reasonable value must be selected.

Note: Although ultimate BOD decays at a constant rate k, it can be shown that the 5-day BOD decays at the same rate. By definition, the oxygen utilized in stabilizing the organic matter per day must be $(k)(BOD_5)(FL)(VOL)$

H, depth of segment, (feet) used in calculating bottom areas only, so need not be accurate physically, as long as

$$Hi=VOLi/AREAi$$

Note: area of bottom not input directly

FDSE:

k: reaction coefficients, $days^{-1}$, for deficit kinetics.

P: net oxygen transfer to water from phytoplankton, mg/l/day.

S: benthic oxygen uptake, gm O_2/m^2/day.

MAIN PROGRAM

A set of data switch settings which determine the formats and presentation of output data will not be discussed here.

A sample, annotated input and output is illustrated:

Schematically, this represents the system of four sections as shown along with the results for BOD and deficit concentrations (See Figure 3).

The analyst must be aware of the time span and frequency over which the field data was collected and how these data fit into the concept of the steady-state. Long tern records can sometimes reflect seasonal trends. Their use will often average out irregular conditions and provide good results when compared to mathematical formulae. Short term records require a higher intensity survey at many points such as that run on the St. Croix River in August 1972. The analyst must be aware of these data and be able to make appropriate adjustments when calibrating and analyzing the system under various conditions.

Another (purely academic) consideration when modeling is to be aware of the "black box" concept. Once the model is assembled and ready, the user must not forget the physical realities of the system. He simply inputs a source load vector and obtains a concentration vector output in a matter of seconds and, perhaps, feels that the computer has done the simulation. It is imperative to keep in mind that the sole reason a computer is used at all is because the user does not like to invert large matrices by hand.

Application of Model to the St. Croix River

The sampling survey conducted by the Environmental Protection Agency in August 1972 was the main source of the initial data used in the model. Along with aerial photographs[2], USGS maps, Corps of Engineers cross-sections and former reports[3,4], the maximum amount of data was compiled.

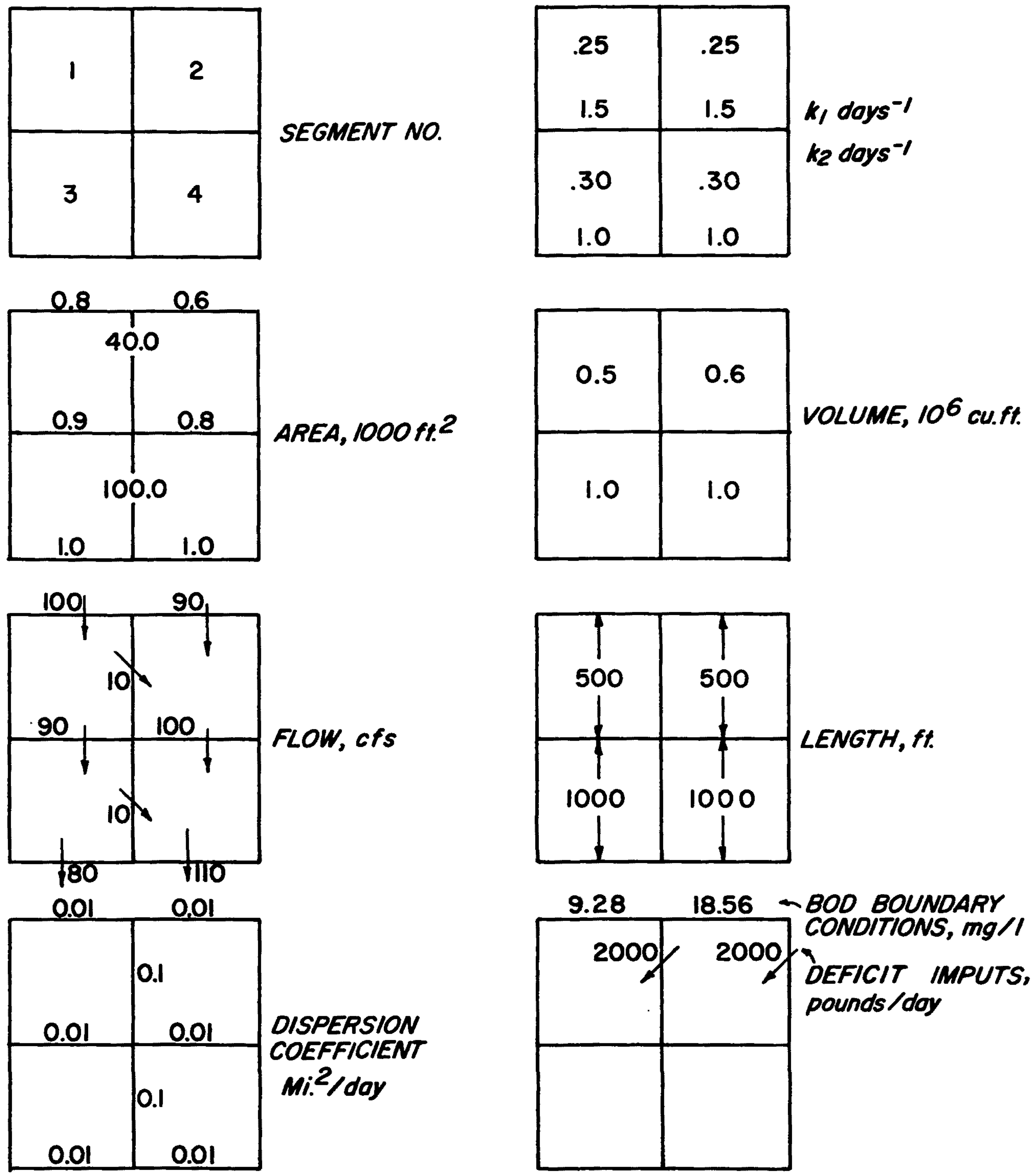
Because the Corps of Engineers cross-section study was conducted at flows lower than those of the survey, a backwater analysis was performed to determine water depths at the time of the survey. The river was divided in two separate reaches: the pooled reach from the rapids below Baring Bridge to the rapids below Milltown Bridge, and the faster flowing, more turbulent reach from the Georgia-Pacific effluent discharge downstream to the rapids downstream from the railroad bridge at Baring.

In order to compute river depths at low flows, approximations to Manning's (n) were computed based on energy loss considerations. Elevations in the lower reach did not change significantly, but those in the upper reach exhibited typical backwater profile characteristics.

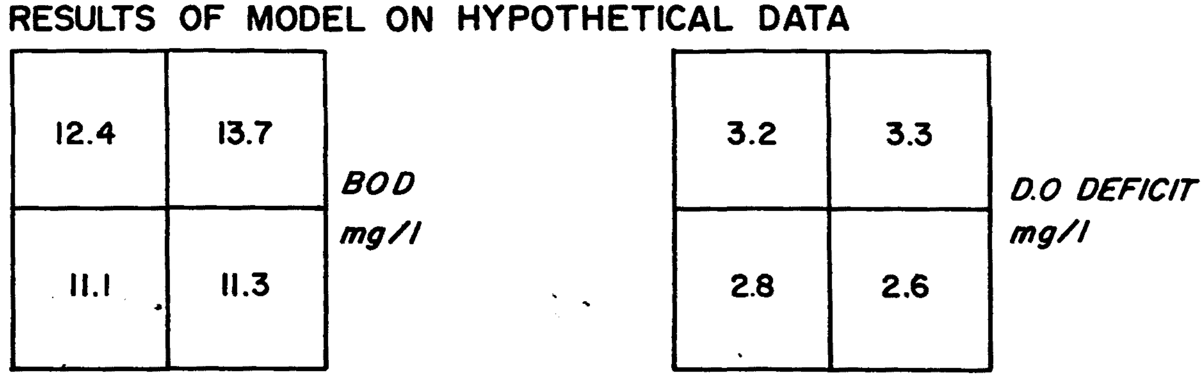
The assumptions relied upon in the backwater analysis were:

1. Manning's Equation $\left(Q = \frac{1.49}{n} R^{2/3} S^{1/2} A\right)$ is valid for the steady-state conditions where S is the slope of the total energy line, R is hydraulic radius, A is cross-sectional area; 2. Total energy was the elevation of the water surface (the velocity head $V^2/2g$ was found to be negligible in comparison); 3. Control points exist at the rapids defining the downstream end of each major reach. R, the hydraulic radius, was taken as cross-sectional area divided by top width, except in deep narrow sections below Baring Bridge.

SCHEMATICALLY THIS REPRESENTS A SYSTEM AS SHOWN:



RESULTS OF MODEL ON HYPOTHETICAL DATA



TYPICAL SCHEMATIC REPRESENTATION
of a
TWO DEMENTIONAL RIVER MODEL

FIGURE L3

A calculated water-surface elevation profile is shown in Figure 4. The station used are the same as in the Corps of Engineers report.

Figures 5 - 10 are schematics of the river which represents the physical conditions observed on the survey. Although the numbering sequence is out of order, this raises no problem in our computing scheme. The two segments (29 & 30) were appended at a later stage of this development to facilitate input loadings of waste and deficit.

The hydraulics of the river represent a highly complicated system which can not be expressed exactly. Lacking a large number of available cross-sections and velocity profiles, the flow distribution at any given station was approximated. For this reason, no islands are shown in the schematic. Where they do exist, they have been "placed" on the interface of two adjoining segments, and flows, cross-sectional areas and dispersion coefficients have been adjusted accordingly.

The more difficult problem at this point arose in the assignment of the interfacial dispersion factors and flows. There is no way to know whether a particular phenomena is the result of a flow (net transfer of water) or a dispersive process (random turbulent mixing), and moreover, it is not required to be known in such an analysis. Values were assigned such that a reasonable representation of the system was simulated. This was accomplished in the following manner:

1. Volume, area, depth were assigned to each section.

2. Flow rates were assigned and distributed.

3. Dispersion rates were assigned similarly.

4. An "artificial dye" was injected at the upstream sections of the model, and an arbitrarily high and uniform decay rate

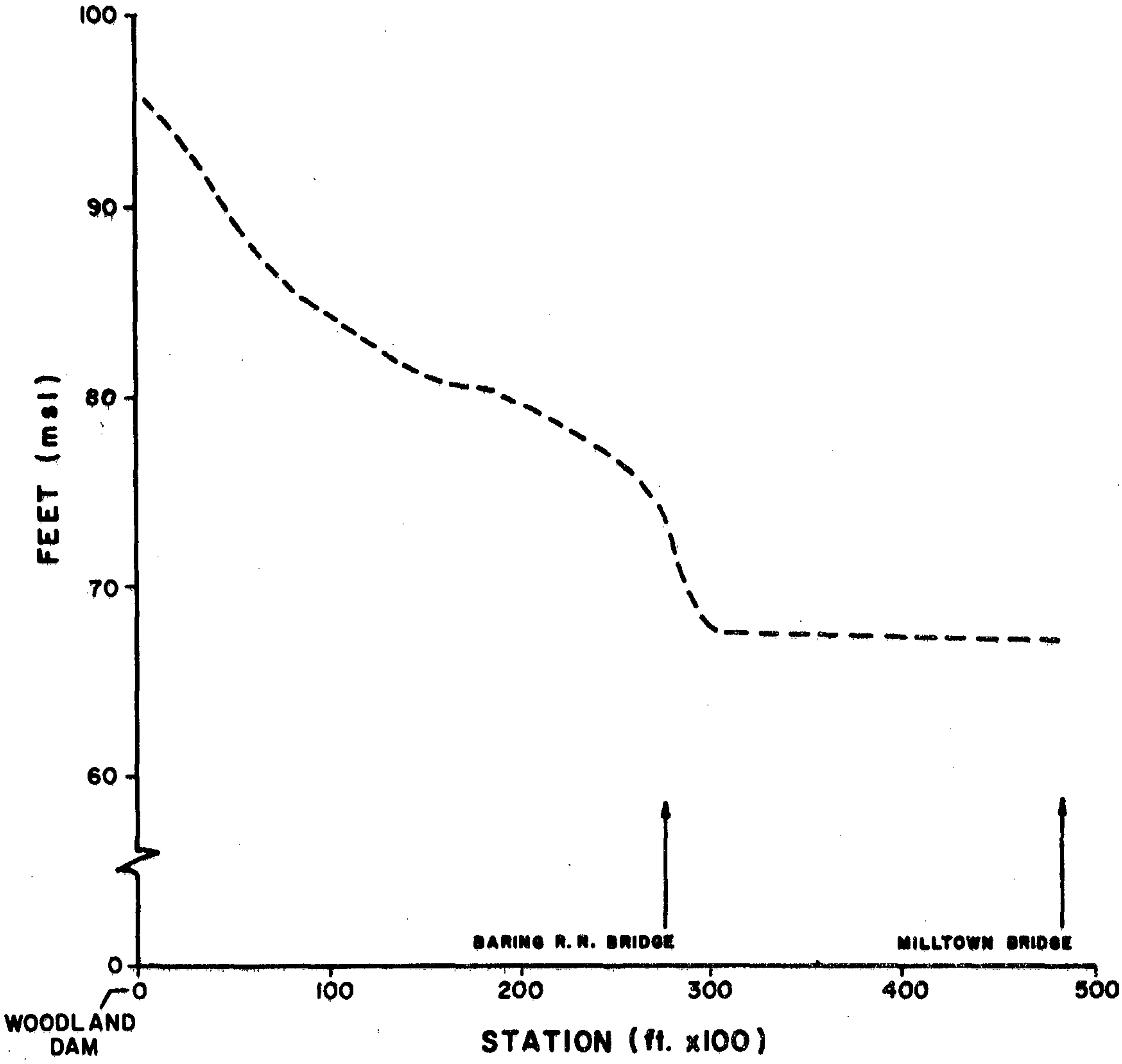
was attributed to each section. The ratio of mass rate (lbs/day) at selected points was used to verify for time of travel accuracy ($W_a/W_b \approx e^{-kt}$, where "k" was the decay rate, and "T" the time of travel, and "W" the mass rate at "a" or "b").

5. From another independent, one-dimensional program, values of k-rates for various points in the river were used to verify the first order decay model. The input data were taken from the survey records, and data from the latter part of the week were used to give a better insight into the processes. A background input BOD of 1.2 mg/l and a waste load of 54,000 pounds per day in the effluent, along with the above-computed K,A,E,Q values gave results compatable with survey-time data.

6. Verification of the deficit model involved the use of the Dobbins-O'Conner formula for the reaeration coefficient which states "k_2" is proportional to $(\text{velocity})^{1/2}$ and $(\text{depth})^{-3/2}$. Net oxygen transfer by photosynthesis was taken as zero, and bottom demand as a uniform 4 gm O_2/m^2/day. With an input dissolved oxygen deficit of 37,000 lbs/day (2.7 mg/l) in the main region of the stream (section 29) and 350 lbs/day in the effluent stream (section 30), we felt that a reasonable model of deficits had been established.

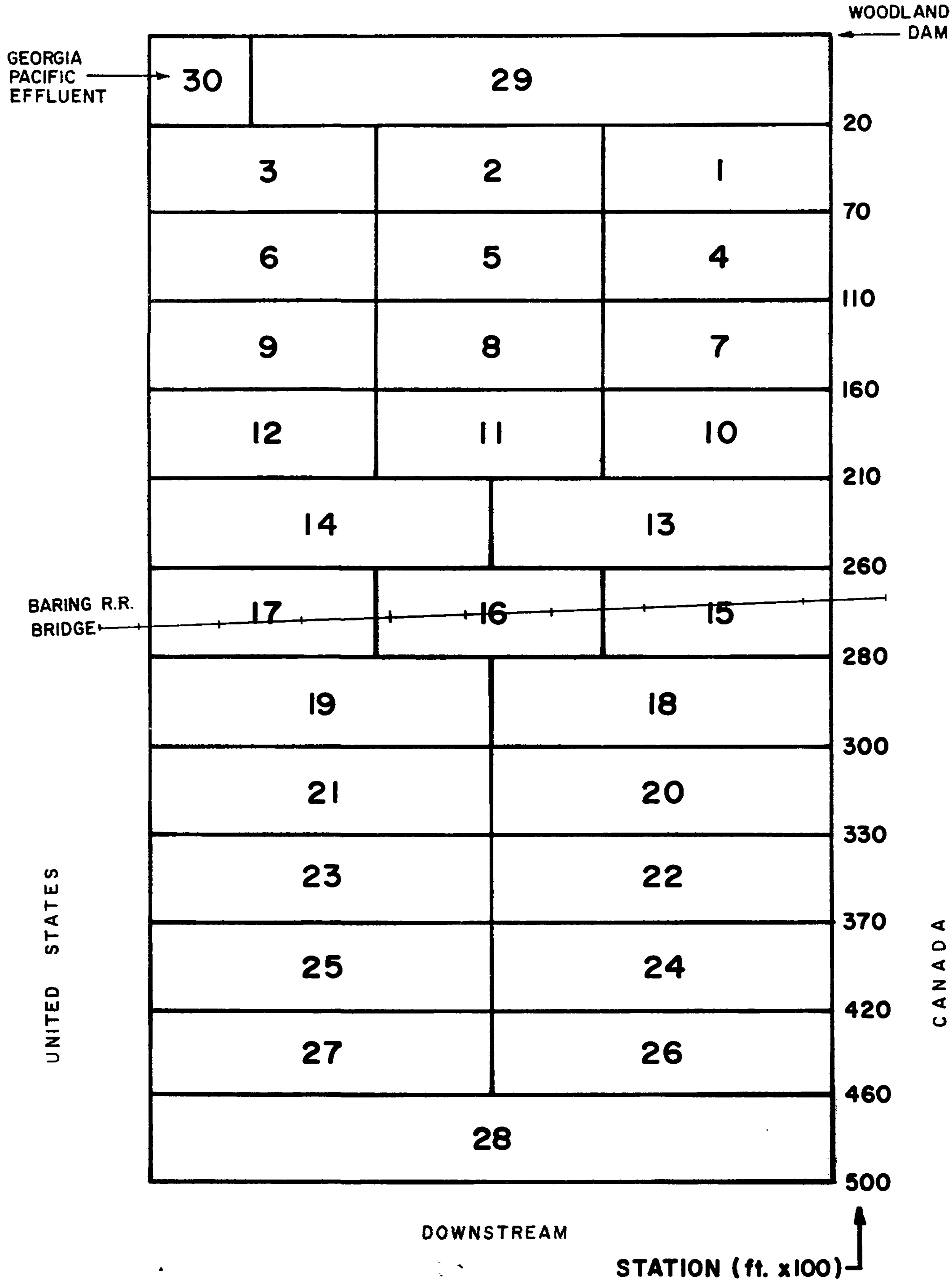
These results are summarized in Figure 10.

At this point we have assembled the "A" matrices such that at survey time they represent the observed conditions for our "n" segments. Examining this more closely, we note that we have "n " terms to be found but only "n" equations. This leaves us n(n-1) degrees of freedom, or possible combinations of parameters which satisfy the system. For this reason



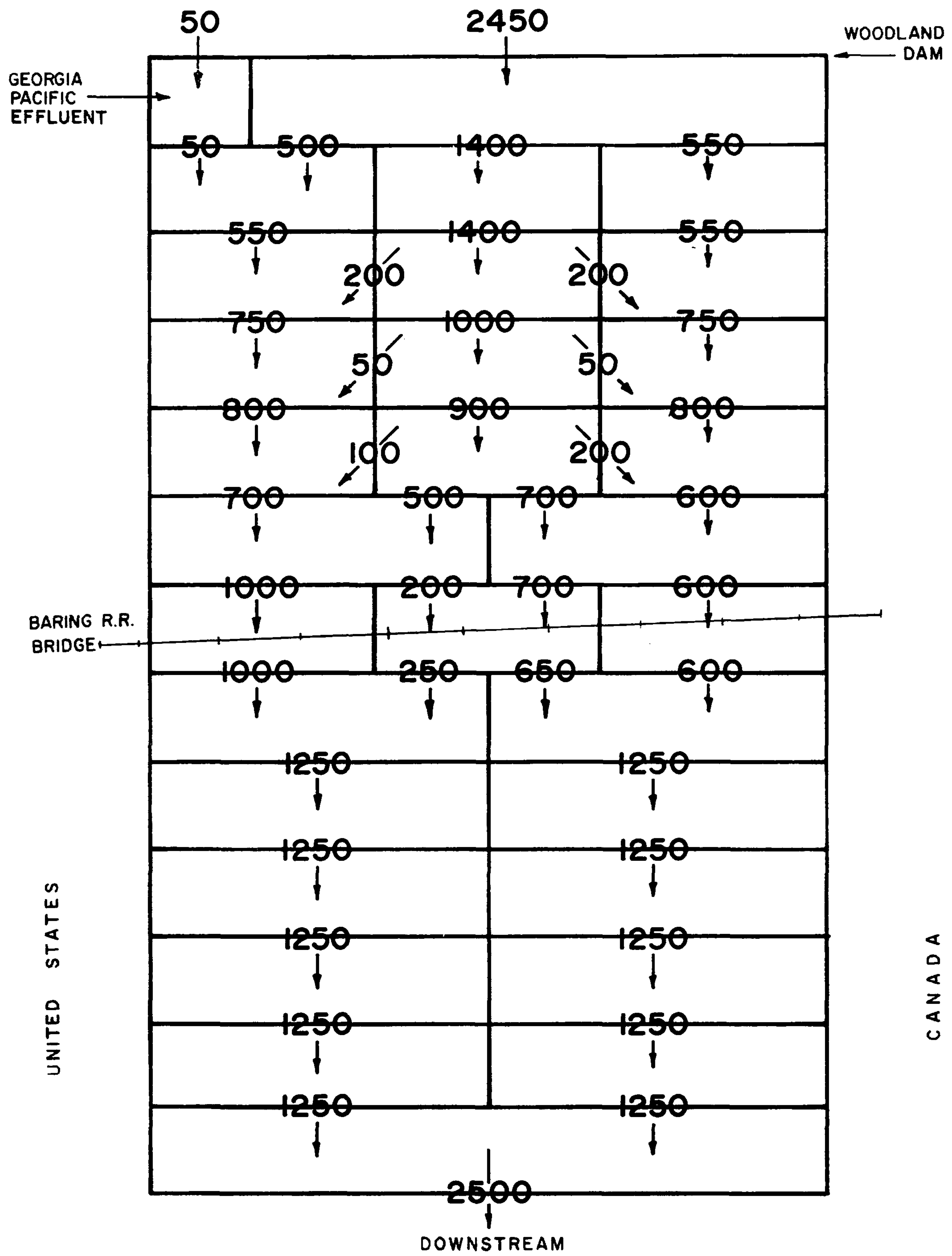
CALCULATED WATER SURFACE ELEVATION PROFILE AT 2500 CFS

FIGURE L4



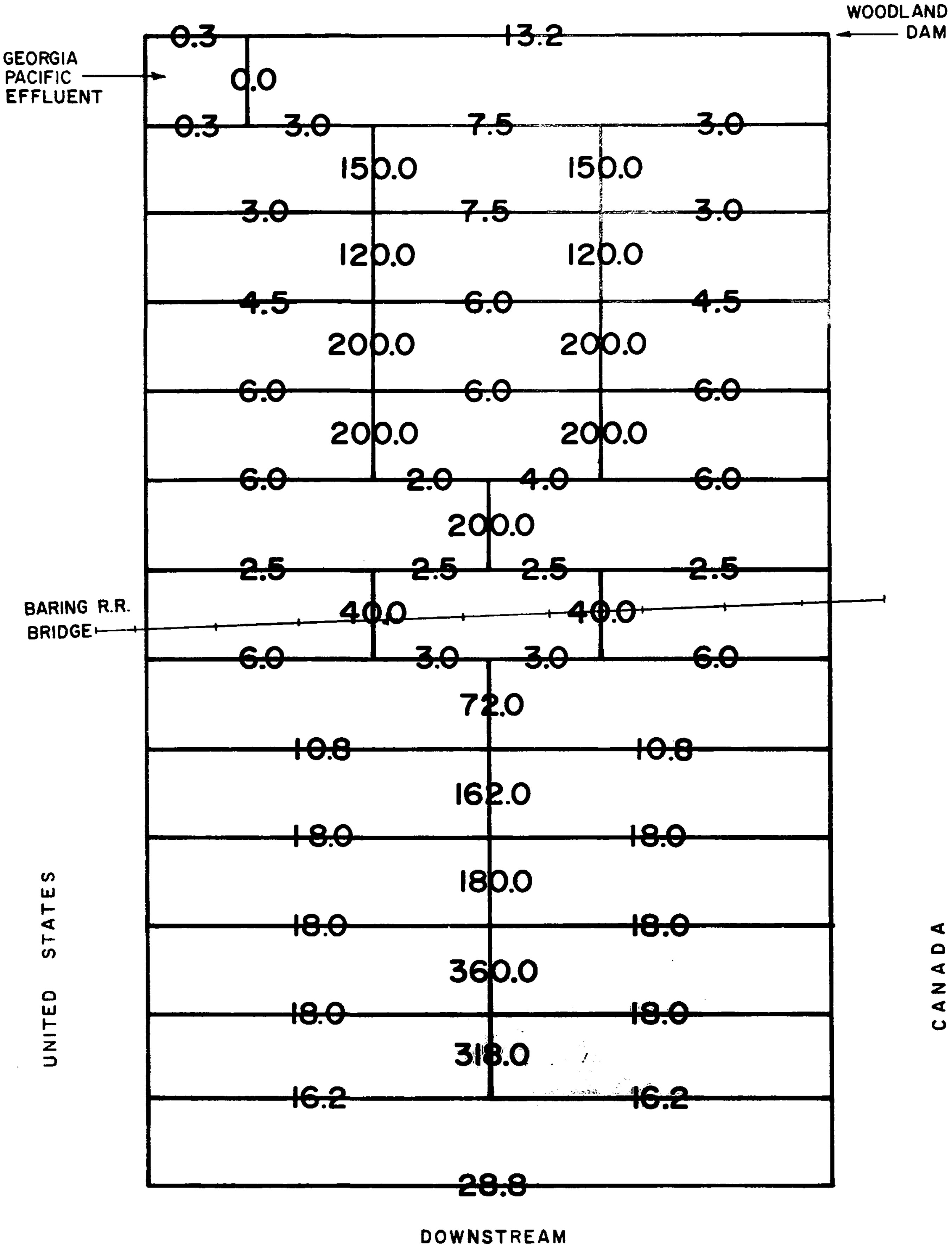
SECTION AND STATION NUMBERS

FIGURE L5



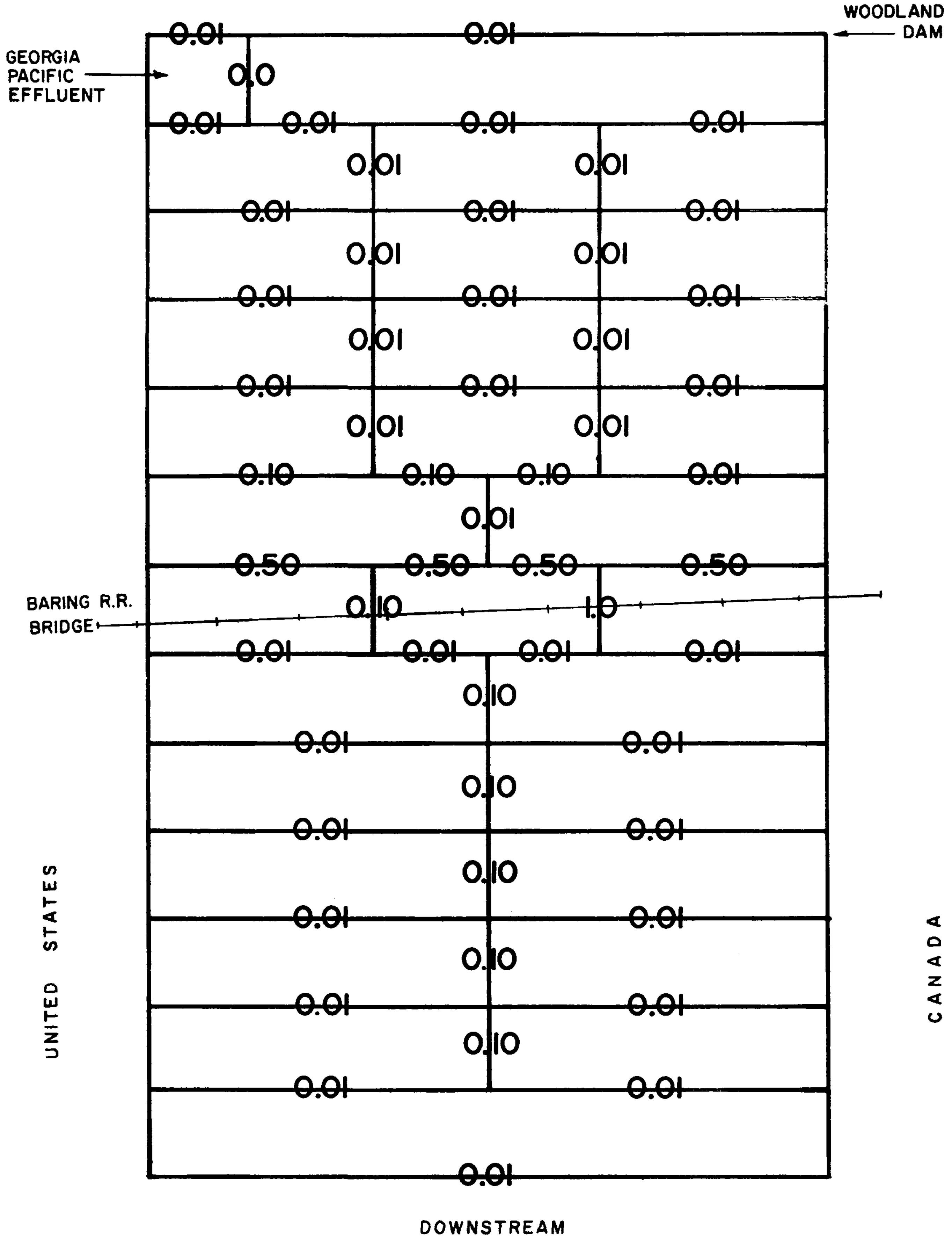
INTERFACIAL FLOWS, CFS

FIGURE L6



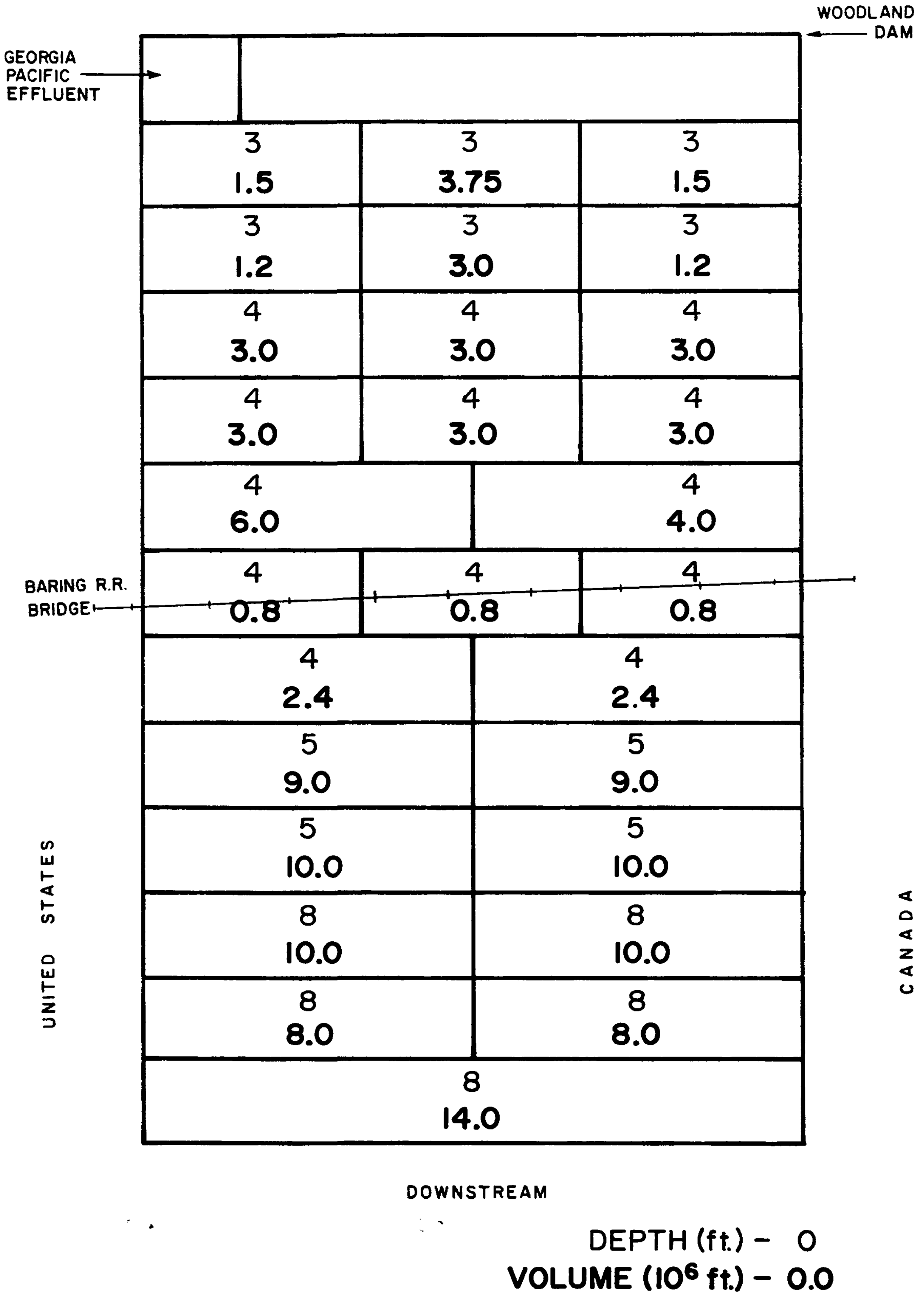
VERTICAL CROSS SECTIONAL AREAS, 100 FT.^{2}

FIGURE L7



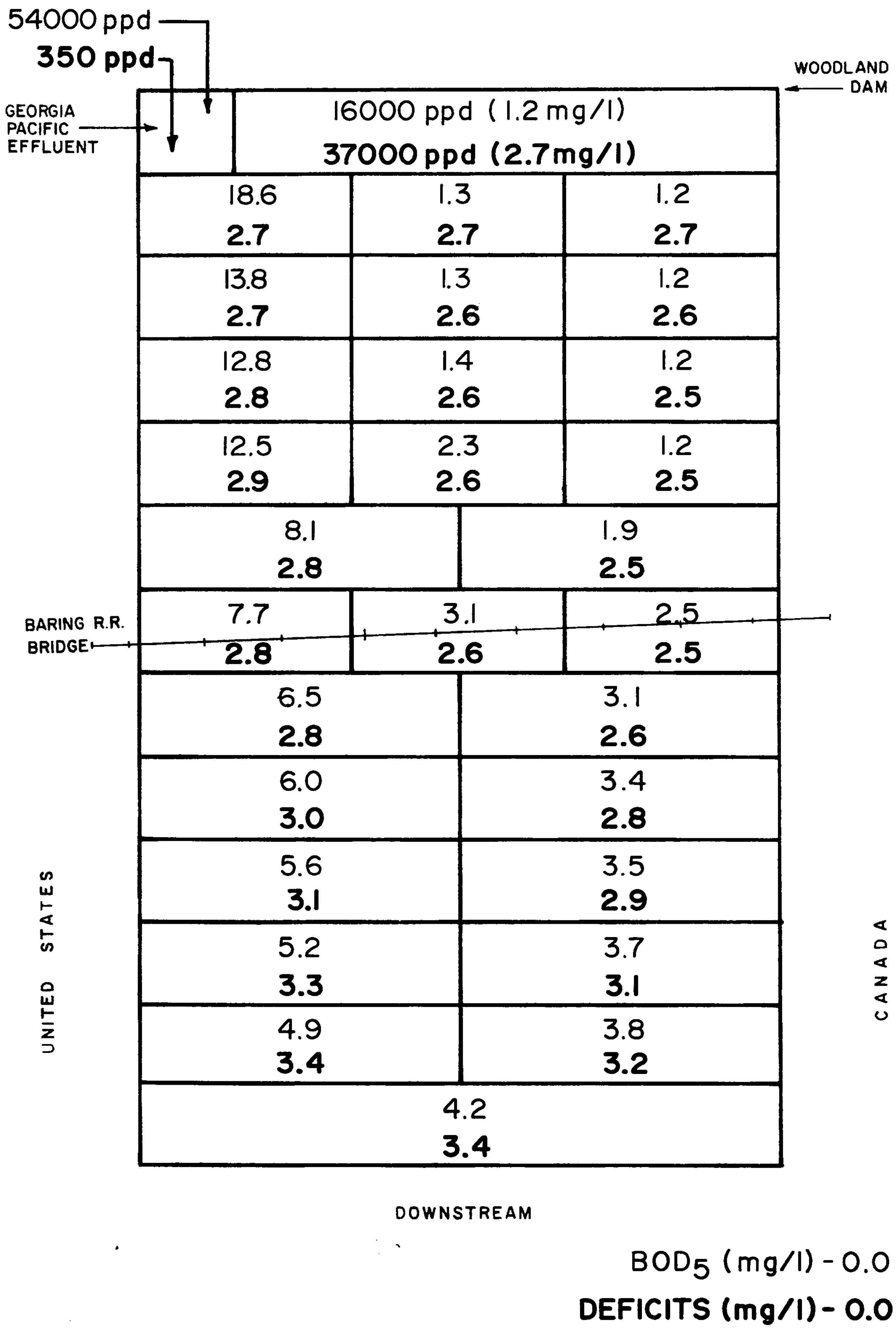
DISPERSION COEFFICIENTS, MI^2/ DAY

FIGURE L8



SECTIONAL DEPTHS AND VOLUMES

FIGURE L9



RIVER CONDITIONS AT HIGH FLOW

FIGURE L10

the predicted results may vary from future observed values, although the selection of values for "A" closely represent physical reality.

For the given flow conditions of 480; 750 and 1,000 cfs in the river, and waste loading of 8,680 lbs/day BOD in the plant's effluent, the above model was used for predicting downstream BOD and dissolved oxygen deficit concentrations.

First, new backwater curves were calculated based on the same assumptions as previously mentioned for high flow. Depth vs. station and accumulative time of travel vs. station for various flows are shown in Figure 11.

Appropriate modifications were made in cross-sectional areas, volumes, depths, and flows of each section either by directly altering the values, by altering the scale factors, or by a combination of the two.

Deficit reaction coefficients were kept constant, but reaeration coefficients were adjusted according to the formula of Dobbins-O'Connor. Table 1 shows the range of k_2's used. Background values of 1.2 mg/1 BOD were used in the main body of the river. Trials were run for oxygen deficits in the main body of the river upstream of the effluent using loading values of 1.4-3.2 mg/1 BOD.

Conclusions

Because of the uncertainties in the values of several parameters, many runs were tried. A schematic tree of the various inputs and values of the parameters is given in Figure 1.

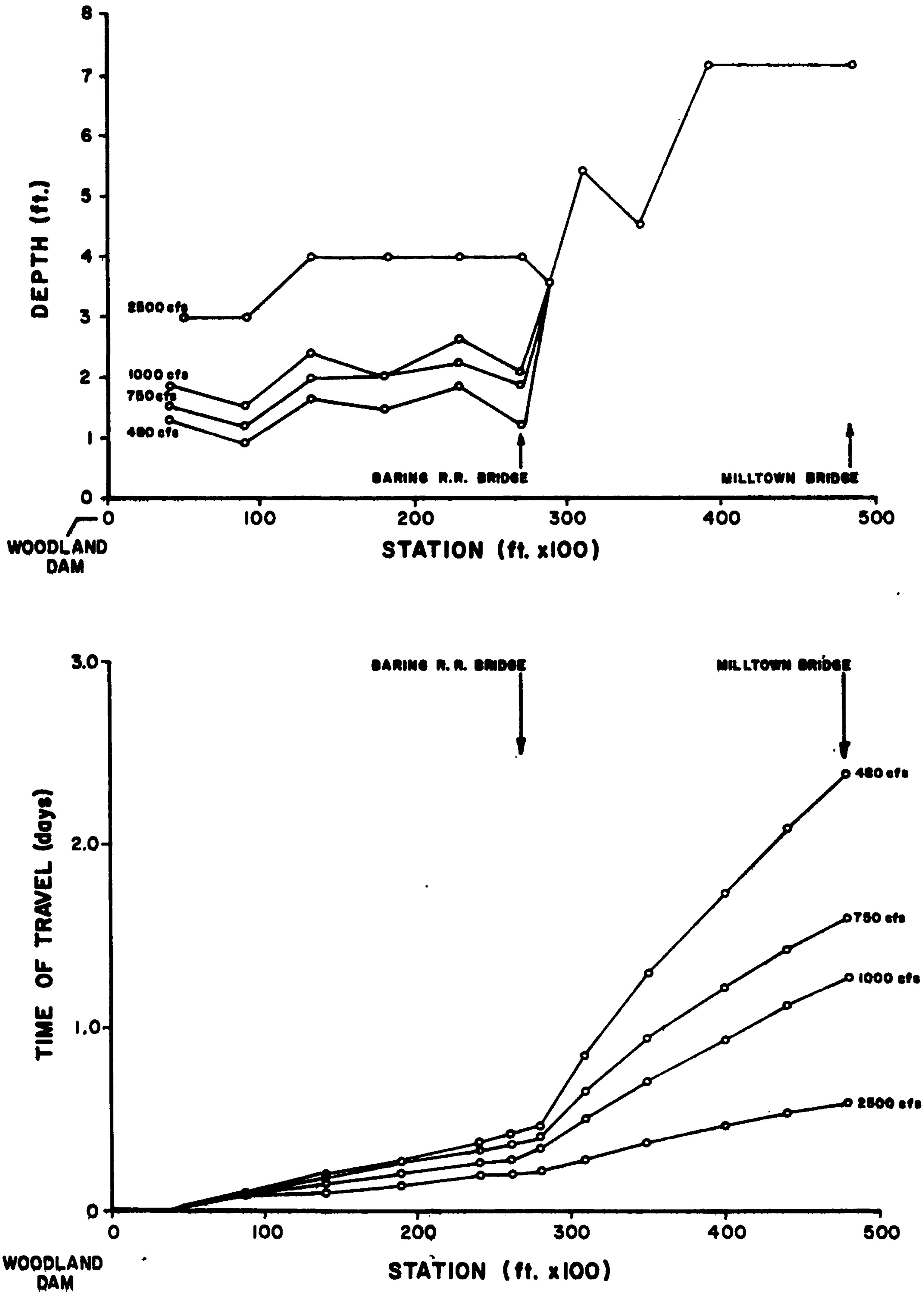
The structure of the tree is such that the more important variables are situated above those of lesser value. It can be seen from this figure that flow and plant loading (which can be controlled) have

TABLE 2

RANGE OF K_2 VALUES BASED ON
DOBBINS-O'CONNOR FORMULA

FLOW, cfs	UPPER REACH	LOWER REACH
480	4.9 - 16.3	0.26 - 0.73
750	4.1 - 10.1	0.32 - 0.91
1000	3.4 - 8.6	0.37 - 1.05
2500	1.6 - 3.4	0.59 - 1.19

ALL VALUES IN $DAYS^{-1}$



DEPTH AND TIME OF TRAVEL FLOW STUDY

FIGURE LII

significant impacts on the downstream deficits. Benthic demand has a large impact also, but is not a variable of the system.

Based on the analysis to date, at a flow of 1000 cfs and a high benthic demand of 4 gm O_2/m^2/day, a BOD load of 19,200 ppd would not be acceptable. However, with a demand of 3 gm O_2/m^2/day, it would.

At a lower flow of 750 cfs, a BOD load of 19,000 ppd is not acceptable even if the benthic demand is reduced to 2 gm O_2/m^2/day. A BOD load of 10,000 ppd, however, would be acceptable if the benthic demand is indeed 2 gm O_2/m^2/day.

At a flow of 480 cfs, it is very doubtful that even a BOD load of 10,000 ppd would achieve stream standards.

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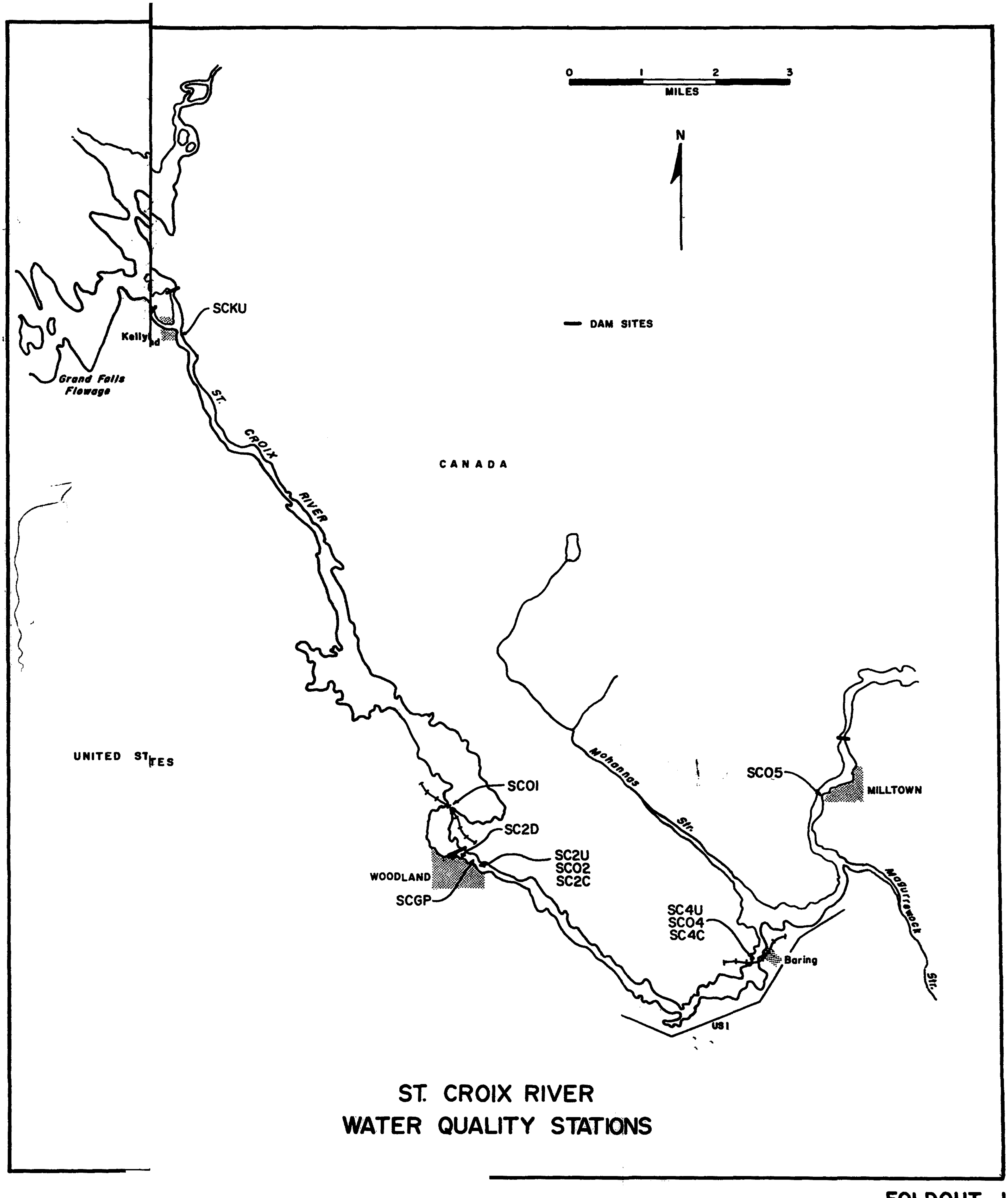
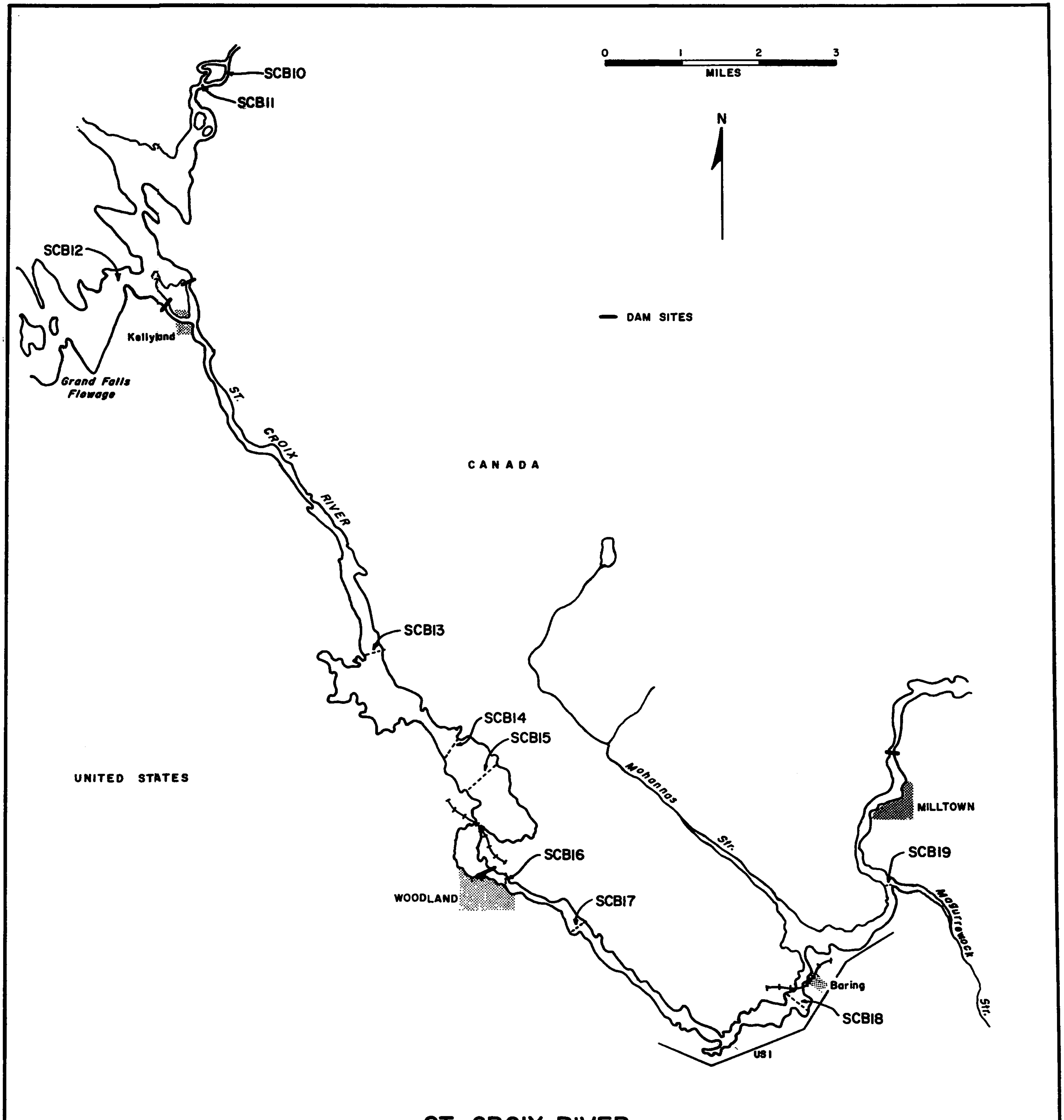


ST. CROIX RIVER
WATER QUALITY STATIONS

FOLDOUT 1



ST. CROIX RIVER
BIOLOGY STATIONS AND TRANSECTS

FOLDOUT 2